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Note Regarding Publications

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Publication of the **Transactions** of the Academy is discontinued with the issue of Volume XVI, 1898. The matter heretofore printed in the Transactions will be incorporated in the Annals.

The **Annals** (8vo), beginning with Volume XVI, will appear with new forms of typography and arrangement of matter; many changes having been made in the endeavor to facilitate the use of the volume for reference purposes. A volume of the Annals will hereafter coincide with the calendar year and will be issued in three parts. The price per volume is three dollars.

The **Memoirs** in quarto form will be published at irregular intervals. Part I of Volume I has been issued.

ANNALS

OF THE

NEW YORK ACADEMY OF SCIENCES,

VOLUME X.

I.—*The Nature and Origin of Stipules.*

BY A. A. TYLER, A.M.

Read Feb. 8, 1897.

The investigation which has resulted in the preparation of this dissertation was undertaken with a view to determine the true nature and phylogenetic origin of those appendages of the bases of the petioles of leaves which are known as stipules and which are present in so large a number of the families of flowering plants.

The data have been collected from every available source; the evidences to be gathered from known geological facts have been taken into consideration, observations have been made upon the morphology and anatomy of the foliar organs in a large number of cases, and the gradual modification of leaf-forms in the annual growth of plants from simple scales to adult leaves has been carefully studied. In addition to the data so gathered, the literature dealing with the subject, relatively scanty though it is, has yielded much valuable material both by the record given of the observations of others and by the suggestion of lines of investigation.

With all this material in hand, I have endeavored to ground the theoretical consideration of the problem upon the broadest foundation possible in the present stage of the progress of science, and from a comparative study of the evidence gathered from all the various sources of information, have drawn the conclusions set forth at the close of my paper.

The results of my investigations are herewith given to the public with the conviction that conclusions arrived at in the manner indicated cannot fail of interest to the reader, nor, in some degree at least, of scientific value.

COLUMBIA UNIVERSITY,
NEW YORK, Feb. 8, 1897.

SYNOPSIS.

A Review of Important Literature Pertaining to Stipules.

Owing to the fact that a large part of the literature pertaining to stipules is inaccessible to the majority of botanical students, scattered as it is, for the most part, in the journals of various scientific bodies, it has seemed desirable to preface the consideration of the results of my research on the question of the Nature and Origin of Stipules with a brief summary, in chronological order, of the publications having reference to the general subject of stipules. I have, however, omitted mention of their consideration in systematic works and the general allusions and definitions as they occur in most general works on the Spermatophyta together with their special consideration in individual species and groups except in the most important cases.

Stipules have not received a very large degree of attention from botanists apart from their morphology as used in classification and the publications to be considered are not very numerous, but it is thought that a review of those following will be profitable and of general interest:

Malpighi, Marcello.—Opera omnia, 22–39. 1686.

This is one of the earliest works in which stipules are treated. A considerable number are figured and described under the name of *foliola caduca.*

Linnæus, Carolus.—Philosophica Botanica, 50. 1751.

A general definition is given of stipules as scales borne at the base of the petiole. Buds are spoken of as formed by stipules, by petioles, or by rudiments of leaves.

Linnæus, Carolus.—Prælectiones in ordines naturales plantarum, 520. 1792. (Cited by Hanstein in Abhandl. Akad. Berlin, 77. 1857.)

In speaking of the whorled leaves of the Stellatæ, Linnæus says that only two of these leaves are true leaves, the remainder are stipules which have grown to the same size as the leaves.

De Candolle, Augustin P.—Theorie de la Botanique, 364. 1819.

The stipule is defined as a foliaceous appendage or accessory leaf situated at the base of certain leaves. The stipel, first so named by De Candolle, is defined as a stipule placed on the common petiole at the base of the leaflets.

De Candolle, Augustin P.—Organographie Végétale, 1 ; 334–341. 1827.

De Candolle's views as here expressed may be outlined as follows: "Stipules do not exist in any monocotyledonous plant,* nor in any dicotyledons in which the petiole has a sheathing base; among dicotyledons with leaves not sheathing, stipules are frequently wanting, especially in plants with opposite leaves. Their existence is intimately connected with the general symmetry of plants, and they occur or are wanting in all the species of a family.

"The only essential character of stipules is their lateral position at the base of the leaves, and it is not impossible that we confound under a common name objects really distinct. Their texture is, in many plants, perfectly foliaceous and in these cases they exhibit so exactly the character of leaves that we can say that they are small accessory leaves.

"In certain verticillate leaves, such as those of *Galium*, it is noticeable that the buds and young branches are not produced in the axils of all the leaves, but only of two among them which are opposite to one another. I presume that these two leaves furnished with buds are the true leaves and that the others should be considered as foliaceous stipules.

"The natural use of stipules seems to be the protection of the leaves during their development, but we must admit that in many cases their smallness or their nature or form make them inappropriate to this use, though we cannot well assign another to them, those which are foliaceous assist in the elaboration of the sap, those which are changed into spines serve for the defense of the plant.

"The tendril in the Cucurbitaceæ is perhaps a modified stipule. The ochrea of Polygonums is a prolongation of the base of the petiole into connate stipules."

In volume 2, pages 213 and 214, De Candolle says in treating of buds, "They have received particular names according as they are formed by different parts of the foliar organs, and according to the degree of their degeneration and adnation.

"1. Buds are called foliar when, the leaves being sessile, the blade itself, reduced to the form of a scale, forms the buds, as in *Daphne mezereum* L.

"2. They are called petiolar when the bases of the petioles dila-

* See also A. Richard. Précis de Bot., 126.

ted into scales form the covering of the young shoot. This occurs in petiolate leaves without stipules, as in the walnut, ash and horse-chestnut.

"3. Buds are stipular when the scales are formed, not by the leaves, but by the stipules which are not united with the petioles. Of these there are two sorts,—those which are formed by a great number of stipules enclosing a young shoot collectively, as in oaks, willows and elms, and those in which the stipules, free or united by their exterior margins, form a peculiar envelope for each leaf, as in *Ficus* and the magnolias.

"4. When the stipules are adherent with the petiole, these two organs united into one form the bud scales, and are named fulcral. This occurs in most of the Rosaceæ, and the scales are frequently three-lobed or three-toothed, indicating the origin of the scale formed by the petiole and the two stipules united together." Plate 21, figure 9, shows the progressive change from scales to foliage-leaves in buds that are fulcral in nature.

Bischoff, G. W.—Lehrbuch der Botanik. 177–183. 1834.

The subject is here more fully outlined than in De Candolle's Organographie. Stipules are defined as peculiar leafy expansions at the base of a free middle leaf. They are recognized as belonging to the leaf on the ground of their frequent connection with the petiole, the receiving of their vascular bundles from those of the leaf and the absence of buds from their axils. Various kinds of stipules are described and the ochrea, the ligule, the stipule in the Naiadaceæ and the ochrea of palms are included with stipular formations.

Lindley, John.—Introduction to Botany, 99. 1832.

The following statement is of interest: "The exact analogy of stipules is not well made out. I am clearly of opinion that, notwithstanding the difference in their appearance, they are really accessory leaves; because they are occasionally transformed into leaves, as in *Rosa bracteata*, because they are often indistinguishable from leaves of which they obviously perform all the functions, as in *Lathyrus*, and because there are cases in which buds develop in their axilla, as in *Salix*, a property peculiar to leaves and their modifications." The character of stipules is denied to the tendril of the Cucurbitaceæ and the tendrils of *Smilax* (p. 96) are regarded as lateral branches of the petiole.

Henry, A.—Recherches sur les bourgeons. Nova Acta Acad. Nat. 18 : 525–540. 1836. (Cited by Clos in Bull. Soc. Bot. Fr. 26 : 193. 1879.)

Henry says that he recognizes in the Betulaceæ and Cupuliferæ that the bud-scales are formed by stipules in an anamorphosed condition, and that in *Platanus* they are formed by the ochrea as he terms the basal foliar appendage in this genus.

Lestiboudois, Them.—Etudes sur l'anatomie et la physiologie des vegetaux. 1840. (Cited by himself in Bull. Soc. Bot. Fr. 4 : 746–747. 1857.)

The author states that he has shown that stipules are parts of the leaf, formed by the bundles or lateral fibers of these organs, whether they arise from bundles not yet having left the stem, from anastomosing arcades which unite the leaves as in the Stellatæ, or from the fibres of the petiole, as in the adnate stipules of Rosaceæ, or whether they are in part supplied by bundles directly from the cauline cylinder, as in *Platanus*.

In relation to the tendril in the Cucurbitaceae, he states that its bundles are derived from those which pertain to the axillary bud; that it is therefore not a stipule, but the first foliar appendage of the axillary branch for its fibro-vascular bundles are not disposed like those of stems, but are analogous with those of petioles.

St. Hilaire, Aug.—Leçons de Botanique. 170, 1840. (Quoted by Colomb in Ann. Sci. Nat. (VII), 6 : 28. 1887.)

It is stated that the tendrils of *Smilax* are to be considered as lateral leaflets of a compound leaf.

Agardh, J. G.—Ueber die Nebenblätter der Pflanzen. (Reviewed by Fries and Wahlberg in Flora, 33 : 758–761. 1850.)

Agardh believes that, although stipules have been considered as degenerate appendages of the leaf or modifications of it, they are not at all a part of the leaf because they are formed before it, and must be considered as independent organs. The outer bud-scales and also the protective coverings of the earliest shoots of a plant are a kind of stipule-formation, leading to the conclusion that in the lower part of a shoot or the outer part of a bud the stipule-formation preponderates, and in the upper or inner parts, the leaf-formation, so that often at the lowest nodes the leaf does not develop and at the upper stipules are absent. In *Tussilago* there are special leafy shoots and the flowering shoots are provided with stipules only.

From these considerations Agardh concludes that there are two kinds of appendicular organs instead of one, namely stipules and leaves.

Astaix.—Essai sur la Théorie des stipules, thése de l'Ecole de pharmacie de Paris. 1–25. 1841. (Cited by Clos in Bull. Soc. Bot. Fr. 1 : 302. 1854.)

The conclusion is reached that the leaf is not a primitive appendage of the stipule and that the stipule is nothing more than an appendage of the leaf.

Regel, E.—Beobachtung über den Ursprung und Zweck der Stipeln. Linnæa, 17: 193–234. 1843.

Regel has studied the development of stipules in seedlings and in the growth of individual leaves. He believes, but does not feel ready to assert, that stipules are present in all Angiosperms in the earliest stages of growth. He therefore includes in stipular formations the ligule, ochrea, sheathing petiole and the supernumerary leaves of the Stellatæ. He concludes from his observations:

1. "That all the leafy organs of phanerogamic plants are divided into two entirely distinct formations, the stipular and leaf-formations.

2. "That the stipular formation arises from the base of the meristem tissue of the leafy axis, covering the summit, but always with a longitudinal cleft or one passing transversely across the apex.

3. "That perfect stipules are formed by the occurrence of two, four or more clefts in the original stipular sheath, giving rise to as many stipular leaflets.

4. "That the stipules receive their vascular bundles directly from the stem, and are usually parallel veined because of their forming originally a completely encircling sheath.

5. "That they serve always for the protection of the growing point and of the true leaves, when these are present, during their development.

6. "In all plants, organs adapted for protection belong not to the leaf-formation but to the stipule-formation.

7. "That stipules are to be regarded as a formation preceding the leaf-formation, since they appear before the leaves.

8. "That they belong primarily to a nodal ring distinct from that producing the leaves and situated either above or below it.

From these relations, as regards the leaf, interior and exterior stipules are distinguished.

9. "Interior stipules protect the formation of the following node and leaves. The leaf at the same node develops somewhat earlier or at about the same time.

10. "Exterior stipules develop before the leaf at the same node and therefore protect their own node with its leaf.

11. "As stipules are limited in the time during which they are functional, they lose their significance as soon as this purpose is fulfilled. They do not produce buds in their axils except in cases where true leaves are not developed."

The following statement (p. 227) should be noted. "In some species of *Thalictrum* the membrane rising above the inner margin of the base of the petiole is the analogue of the ligule."

Kirschleger, F.—Flora, 28 : 615. 1845.

The tendril of Cucurbitaceæ is regarded as a normal stipular formation.

Mercklin, C. E.—Entwicklungsgeschicte der Blattgestalten. 1846. (Translated into the French in Ann. Sci. Nat. (III), 6 : 215–246. 1846.)

The statements of Mercklin are contrary to those of Regel. He says, "In all cases the stipules of the developing leaf appear as portions of the lamina; it is only later, during the development and elongation of the petiole, that they become sufficiently separated to be considered as distinct organs. In all simple leaves the stipules never appear at the same time with the first rudiments of the lamina; they develop only with the inferior parts of the lamina including the petiole."

"From my observations of stipules I conclude that in common with the leaflets they owe their origin to the common petiole and are formed later than the leaflets."

Krause, G.—Einige Bemerke über den Blumenbau der Fumariaceæ und Cruciferæ. B. Cruciferæ. Bot. Zeit. 4 : 137–150. 1846.

Stipules in the Cruciferæ are considered (pp. 142–145) and the homology with stipules of the so-called glands at the base of the leaves is established by a careful series of observations upon their development. The glands of the bracts and floral organs are also included.*

*See also Duchartre, Rev. Bot. 2 : 208. 1845-7 and Norman, Quelques Observ. de Morph. Veg. 1857.

Jussieu, Adrien.—Cours d'Histoire Naturelle: Botanique. 108–111. 1852.

Speaking of the leaf-sheath, Jussieu says that "sometimes the vascular bundles converge little by little, and there is a gradual transition from the sheath to the petiole; sometimes the marginal bundles stop after a course varying in length, or are prolonged in another plane than that of the petiole, and then there is a clear distinction of petiole and sheath. Often, however, the parenchyma does not unite the lateral bundles to the central ones which continue in the petiole, and this is the probable origin of many stipules."

Trécul, A.—Sur la Formation des Feuilles. Ann. Sci. Nat. (III), 20: 288–299. 1853.

The usual classification of stipules is given with the addition of extra-foliar stipules to include those of *Nelumbium.* The author says, "In all adnate stipules that I have seen, they do not envelop the leaf to which they belong, but that which comes next after them, and their own leaf is protected by the stipules of the leaf preceding. Under these circumstances the stipules play the same rôle as the sheath, from which they differ very little. We see thus clearly that there is the closest analogy between the formation of adnate stipules and that of a sheath; the analogy is such that it is impossible to distinguish between them in principle." All the forms of stipules, the ochrea, the tendrils of *Smilax* and the ligule of grasses are classed together.

Among the conclusions those relating to stipules are as follows: In basifugal leaf-formation all the parts are formed from below upward, the stipules first of all. In leaves with basipetal formation, the stipules have their origin earlier than the lower parts of the blade and sometimes even before the upper.

Trécul, A.—Vegetation du Nelumbium codophyllum. Ann. Sci. Nat. (IV), 1: 291–298. 1854.

In the seedling of this plant the leaves are in two ranks on the upper and lower sides of the rhizome and each of them is provided with an axillary stipule. In its later stages the leaves of the lower rank are aborted with the exception of the stipule of every second one and in the upper rank every second leaf is represented by the stipule only. The internodes above the stipules which stand alone remain undeveloped so that three stipules are associated with each leaf, one axillary and two extra-axillary.

One of these last is on the upper side of the rhizome external to the leaf, the other on the lower side.

This paper was presented before the Botanical Society of France, May 24, 1854. M. Ad. Brongniart took part in the discussion which followed. He agreed with Trécul in his conclusions and closed with the statement that "this arrangement recalls that of certain buds in which the scales result from the stipules of leaves of which the petiole and blade are alike aborted." M. F. J. Lestiboudois remarked that "to decide whether stipules are an integral part of the leaf, it is necessary to study them anatomically. In other plants the same fibro-vascular bundles are distributed to the leaf and stipules. Stipules should therefore be regarded as appendages of the leaf."

Clos, D.—Considerations sur la Nature du prétendu Calicule ou involucre des Malvacées. Bull. Soc. Bot. Fr. 1: 289–303. 1854.

The stipular nature of the parts of the involucre or exterior calyx in the Malvaceæ is asserted contrary to the views of Aug. St. Hilaire (Leçons de Bot. 372. 1840) and the term *stipulium* is suggested as applicable to it.

Clos, D.—Du Stipulium chez les Géraniacées, les Légumeneuses et les Rosacées. Bull. Soc. Bot. Fr. 2: 4. 1855.

The term *stipulium* is applied to the exterior calyx of the Malvaceæ and the involucre of the umbel of some Geraniaceæ. In the Cistaceæ the bractlets of the calyx are wanting in exstipulate species.* In many of the Leguminosæ and Rosaceæ the bracts are evidently formed by stipules.

Clos, D.—La Vrille des Cucurbitacées, Organe de Dédoublement de la Feuille. Bull. Soc. Bot. Fr. 3: 545–548. 1856.

The different theories regarding the tendril in the Cucurbitaceæ are briefly stated. They have been considered to be roots; abortive peduncles by Tassi; stipules by De Candolle, Stoks and Aug. St. Hilaire; leaves by Gasparini, Seringe and Braun; degenerate branches by Meneghini; superfluous branches by Link; terminal branches of the axis as in Vitaceæ by Fabre; partly leaf, partly branch by Naudin. Clos concludes that the tendril arises by a division of the leaf, three fibrovascular bundles entering the leaf when there is no tendril and two when the tendril is present and receives the third bundle.

*See also Aug. St. Hilaire. Leçons de Bot. 326 and 371. 1840.

Clos, D.—Les Vrilles des Smilax ni Folioles ni Stipules. Bull. Soc. Bot. Fr. 4: 984–987. 1857.

A summary is given of the literature pertaining to the tendrils of *Smilax*. They are considered as representing two lateral leaflets of a compound leaf by von Mohl (Ueber den Bau und das Winden der Ranken und Schlingpflanzen, 41, 1827), Lindley (Introd. to Botany, Ed. 2, 118, 1835), Link (Elem. Phil. Bot. Ed. 2, 1 : 478, 1837), St. Hilaire (Leçons de Bot. 170 and 854, 1840), Le Maout (Atlas de Bot. 23, 1846) and Duchartre (Art. vrille in Dict. Univ. Hist. Nat.).

Mirbel (Élém. de Physiol. et de Bot., 2: 680, 1815), Treviranus (Physiol. der Gewachse. 2: 138, 1838), Seringe (Élém. de Bot. 175, 1841), De Candolle (Theorie Élément. Ed. 3, 321, 1844), Trècul (Ann. Sci. Nat. (III), 20: 295, 1854) and Lestiboudois (Bull. Soc. Bot. Fr. 4: 745, 1857), believe these organs to be stipular tendrils. It is the opinion of Clos that they are neither leaflets nor stipules, but a double lateral prolongation of the cellulo-vascular elements of the petiole.

Rossman, J.—Beiträge zur Kentniss der Phyllomorphose. 1857. (Cited by Clos in Bull. Soc. Bot. Fr. 26: 192. 1879.)

Rossman considers the problem of the nature of stipules, and from a study of bud-scales arrived at his conclusions. He figures the passage from bud-scales to leaves in *Ribes sanguineum* Pursh, *Prunus Padus* L., *Spiræa sorbifolia* L., etc. He notes the presence in the bud-scales of three median veins, separated at the base and joining one another at the apex, where the petiole will originate. The lateral parts of the scale outside of these three nerves he believes to represent the stipules which show themselves at the appearance of the blade in two little points at the apex.

Hanstein, J.—Ueber gürtleformige Gefässstrang-Verbindung in Stengleknoten dicotyler Gewächse. Abhandl. der Akademie der Wissenschaften zu Berlin, 1857 : 77–98. 1858.

The vascular nodal girdle of the Stellatæ is treated of at length. It is shown that from this girdle arise the bundles that supply those leaves of the whorl which are really stipules, and in some cases also the veins of the lateral parts of the true leaves. Similar nodal girdles are shown to exist in other families of plants, notably in *Sambucus*, *Valeriana*, *Verbena*, *Dipsacus*, *Scabiosa*, *Dahlia* and *Silphium*. In *Sambucus Ebulus* L. the girdle sends off vascular branches to true stipules. In the majority of other cases if branches arise they enter the margins of the petioles or the interfoliar portions of connate leaves. In *Platanus* and *Liriodendron* with alternate leaves, each of which receives seven vascular bundles, a similar girdle is shown to pass around the stem posterior to the leaf, and is there joined by another small leaf-trace bundle. From this girdle arise a part of the stipular veins, the others being branches of the sixth and seventh leaf-trace bundles.

Clos, D.—Sépales Stipulaires. Bull. Soc. Bot. Fr. 6: 580–589. 1859.

It is argued from the similarity of the sepals to the divisions of the involucre (stipulium) and also to the stipules of the fully developed foliage leaves which is frequently observed, that they represent stipules. This is held to be true in many Geraniaceæ, Malvaceæ, Begoniaceæ and Cistaceæ. In concluding Clos adds the theoretical consideration that "whether or not stipules are admitted to be organs different from the leaf, analogy seems to demand that in some cases at least they should participate in some degree in floral formation."

Cosson, E.—Note sur la Stipule et la Préfeuille dans le Genre Potamogeton. Bull. Soc. Bot. Fr. 7: 715–720. 1860.

"The stipule in *Potamogeton* is very closely like the first leaf of one of the branches. It is homologous with the ligule of the Gramineæ and Cyperaceæ and is constituted by a single organ, not by two united by their margins."

Eichler, A. W.—Zur Entwicklungsgeschichte des Blattes. 22–31, 1861 (Cited by Martin Franke in Bot. Zeit. 54 : 45, 1896.)

Stipules are said to arise without exception as a product of the leaf base of the primordial leaf. This mode of origin of the stipules is their chief characteristic. Their form, their more or less foliaceous condition and their persistence are secondary.

In individual leaf development in the Stellatæ, the whorl originates in a uniform ring about the growing point. Then arise two opposite prominences in the ring. These develop into the true leaves. After them appear two smaller prominences on each side of the stem between the first. These are the stipules. According to the species they develop separately, forming six-leaved whorls, or grow together giving origin to four-leaved whorls.*

*With this view Göbel agrees (Schenk's Handbuch der Botanik 3 : 230. 1884), except that he does not distinguish the time of appearance of the different parts of the whorl.

Where a larger number of leaves occurs, an additional prominence for each arises between the original stipular prominences.*

Cauvet, D.—Probabilité de la Presence des Stipules dans quelques Monocotyedones. Bull. Soc. Bot. Fr. 12 : 241. 1865.

A number of cases are considered and the conclusion drawn that very probably some Monocotyledones are provided with stipules, but the difference in their form and position has caused them to be considered as another kind of organ.

Meehan, Thomas.—On the Stipules of Magnolia and Liriodendron. Proc. Acad. Nat. Sci. Phila. 114–116. 1870.

Mr. Meehan argues for the origin of the stipules of *Magnolia* as lobes of the lamina similar to the auricles which occur in *M. Fraseri* Walt. by a union of the auricles with the upper surface of the petiole, and a subsequent adnation of their margins and separation from the lamina. He says, " It is scarcely possible to avoid the suspicion that the stipules of *Magnolia* are not formed like the stipules of most plants which are perhaps leaf portions which have never been well developed, but rather are the tolerably well developed side pinnules of a trifoliate or deeply auricled leaf."

Speaking of observations upon the flowers of *M. fuscata* Andr., of East India, the following interesting statement is made : " This observation confirms the views of some botanists as I have learned from Professor Asa Gray, that it is by metamorphosis of the petiolar and stipular parts, rather than by modifications of the leaf-blade, that petals are formed."

Duval-Jouve, J.—Sur quelques tissues de Joncées, etc. Bull. Soc. Bot. Fr. 18 : 231–239. 1871.

The presence of the ligule in the Juncaceæ is treated of. To quote the author, " If in certain species the ligule is so reduced that it appears to be lacking between the separated auricles at the apex of the sheath, in most others these auricles are united by a true ligule, as pronounced as that of grasses, either entire or cleft at the middle."

Dutaily, G.—Sur les variations de structure de la ligule des Graminées. Bull. de la Soc. Linnéene, 170. 1878.

*F. Pax (Allgemeine Morph. der Pflanzen, 100. 1890) says, when there are more than six parts to the whorl, the additional parts must have their origin in a division of the blades of the stipules.

It is argued from the presence of a median vein in the ligule of some of the grasses in which this organ is supplied with vascular support that it cannot be formed of two stipules grown together.

Hilburg, C.—Dissertation über den Bau und die Function der Nebenblätter. (Reviewed by F. Hildebrand in Flora, (II), 36 : 161–167. 1878.)

The general neglect of the subject of stipules and the timeliness of this dissertation is referred to by the reviewer.

The functions of stipules as protecting organs are discussed. They are considered under the heads of (1) those protecting the buds in winter, (2) those protecting the growing parts in the spring, (3) those which serve as protection against insects and other animals, (4) those which serve as well the function of assimilation.

The adaptation of most stipules in their form and manner of growth to the special function they are intended to fulfill and the apparent lack of function in others is remarked upon.

Clos, D.—Des Stipules et de leur rôle à l'infloresence et dans la Fleur. Mem. Acad. Sci. Toulouse, (VII), 10: 201–317. 1878.

This paper is the first part of an extended consideration of the subject of stipules. It deals with their occurrence in the families of plants and their importance in classification on account of the great variety of their characteristics.

Clos, D.—De la part des Stipules a l'infloresence et dans la Fleur. Comptes Rendus, 87: 305–306. 1878.

The stipular nature of the sepals in *Geranium*, *Helianthemum*, *Begonia*, *Oxalis*, *Alchimilla*, *Viola* and many other genera in different families is maintained.

Dixon, Alex.—On the stipules of *Spergularia marina*. Journal of Botany (Trimen), 7: 316. 1878.

Attention is called to the anomalous connation of the stipules of *Spergularia marina* Griseb. exterior to the petioles of the opposite leaves.

Clos, D.—Des Stipules considérées au point de vue morphologique. Bull. Soc. Bot. Fr. 26: 151–155. 1879.

Under this title a summary of the opinions of botanical authorities as to the true nature of stipules is given and the different theories are briefly discussed.

Various leaves have been considered as stipules, for example the primary leaves of *Asparagus* (Dutrochet), the first leaves of the branches of *Verbena aphylla* Gill & Hook. (Hooker, Bot. Misc. 1: 116. 1830) and of the Piperaceæ (C. DeCandolle, Mém. sur les Piper. 18–19, 1866), and the first two leaves of the axillary buds of many Solanaceæ.

The appendages sometimes accompanying the leaf in some Convolvulaceæ, as *Ipomea stipulacea* Sweet., have been considered as stipules (Jacquin. Pl. Hort. Schoenbr. Descr. et Ic. 2: 39. 1797).

Many have regarded stipules as leaflets, as for example in *Vibernum* (Baillon, Adans. 1: 372. 1860), and the lower leaflets in many plants have been taken for stipules, as in *Cobœa scandens* Cav. (Blume. Rumphia 3: 142. 1837), and *Lotus tetraphyllus* Murr. (Linnæus, Trinius, E. Meyer, Fischer.)

In 1844 Wydler declared that stipules belong to the sheath and cites examples of transition between the two kinds of organs in the Rosaceæ, Polygonaceæ, Leguminosæ, etc. Stipules, in connection with the sheath have been ascribed to *Ranunculus*, *Isopyrum* and *Thalictrum* by Lloyd (Fl. de l'Ouest de Fr. Ed. 2, 1868), to *Caltha* by Wydler, Kützing (Grundz. der phil. Bot. 684, 1851–52) and Hooker. They have been recognized in the scales of the stems of the Aroids.

The so-called " decurrences " of leaves do not differ anatomically from stipules and are to be considered as identical with them, as for example in *Crotalaria.*

The tendril of the Cucurbitaceæ has been regarded as a stipule by Seringe (Mém. Soc. Hist. Nat. Genèv. 3 : 1–31. 1825), De Candolle (Organ. Veg. 1 : 336. 1827), Kirschleger (Flora, 28 : 615. 1845), Stoks (Ann. Nat. Hist. 1846), Payer (Elém. de Bot. 53. 1857–58), Parlatore, etc. Those of *Smilax* have been so considered by Cauvet (Bull. Soc. Bot. Fr. 12: 241. 1865), but are looked on by Clos as " simple prolongations of the fibro-vascular bundles of the petiole without morphological signification."

The spines of the orange are considered as stipules by Du Petit-Thouars (Cours de Phytol. 47. 1820). Clos regards them as branches and those of *Amaranthus spinosus* L. as leaves, though they are considered stipular by Lamarck (Encyc. Meth. 2 : 118. 1786). *Ribes* shows stipular spines in some species. The spines of *Xanthium spinosum* L. mentioned by Sachs as occupying the place of stipules, Clos regards as representing pistillate flowers. He looks with disfavor on the doctrine that the glands at the base of the leaves in Resedaceæ, Cruciferæ, *Epilobium*, *Lyth-*

rum and some Euphorbiaceæ and Balsaminaceæ as well as the axillary hairs in some Portulacaceæ are stipules.

Clos, D.—Indépendance, developpement, anomalies des stipules; Bourgeons a écailles stipulaires. Bull. Soc. Bot. Fr. 26: 189–193. 1879.

Stipules have been regarded as appendages of the leaf by Du Petit-Thouars (Cours de Phytol. 46, 1820), Aug. St. Hilaire (Leçons de Bot. 189, 1840), G. St. Pierre and F. J. Lestiboudois.

Clos agrees with Agardh in considering stipules as independent organs, giving as his reason that frequently in the Rosaceæ, Leguminosæ, Malvaceæ, Geraniaceæ, etc., the stipules persist alone, the leaves having completely disappeared, whether in the inflor-esence or at the base of stems and branches.

Under the head of the development of stipules the conflicting opinions of Mercklin and Trécul as to their time of appearance in relation to that of the leaf-blade is referred to. Agreement with Trécul is indicated and the evidence is not considered sufficient as a basis for the theory of the autonomy of stipules on the ground that they appear before the leaf-blade.

In consideration of stipular bud-scales reference is made to their recognition by Linnæus (Phil. Bot. Ed. 3, 52. 1790), Adanson (Familles des Pl. 246, 1763), De Candolle (Ann. Sci. Nat. (III), 5: 321, 1846)* and Lindley (Veg. Kingdom, 283, 1846).

Göbel, K.—Beiträge zur Morphologie und Physiologie des Blattes. Pt. I. Die Niederblätter. Bot. Zeit. 38: 753, etc.—845. 1880.

This extended treatise deals with bud-scales and the scales of subterranean parts of plants and their homologies with leaves. Speaking of the primordial leaf Göbel says, "it is divided into two parts, a stationary zone which takes no farther part in the leaf-formation and a part out of which the lamina is developed." He calls these parts respectively the leaf-base and upper-leaf and states that the petiole arises after the formation of the blade and is inserted between the two parts.

Bud-scales are regarded as modified foliage-leaves and divided into those formed from the blade (*Syringa*), those formed by the leaf-base (*Æsculus*, *Prunus*), and those consisting of stipules (*Liriodendron*, *Quercus*). In *Prunus*, etc., the formation of the bud-scales by the union of petiole and stipules is denied on the ground that the continuous separate development of the petiole and stipules can be followed.

* See also Org. Veg. 2: 213. 1827.

The scales of rhizomes are divided into those formed by a development of the leaf-base (*Dentaria*, *Chrysosplenium*) and those formed by a modification of the upper-leaf (Labiatæ, Onagraceæ).

Colomb, G.—Note sur l'ochrea des Polygonées. Bull. Soc. Bot. Fr. 33: 506–507, 1886.

"The ochrea of the Polygonums is a complex organ formed of two parts: one opposite the leaf, the leaf-sheath, the other in its axil and detached from the petiole. This is a ligule." "Practically the same conditions prevail in the Gramineæ as in *Polygonum* with the difference that in the former the sheath proper is greatly developed and little prolonged beyond the insertion of the blade, while in the latter, the sheath proper remains short and is much prolonged above the petiole. By union with the ligule it forms an ochrea. So considered the ochrea is not peculiar to the Polygonaceæ. It is found also in *Ficus* and *Magnolia*, establishing the transition between the ochrea and stipules properly so called.

Vuillemin, P.—Apropos d'une recent communication de M. Colomb. Bull. Soc. Bot. Fr. 34: 141–142. 1887.

Commenting on the preceding paper, the author says that the leaf is primitively unifasciculate. The concrescence of a verticil of elementary leaves, such as occurs in the fossil *Asterophyllites*, gave a sheath analogous to that of *Equisetum;* the bundle of one of these elementary leaves becoming predominant and functioning as a midvein gave rise to an aggregate leaf, the first stage of a high differentiation. In this way the origin of the leaf-blade in *Polygonum*, *Platanus*, etc. is explained, while the ochrea, the homologue of the sheath of *Equisetum*, remains as a vestige of the primordial state.

Kronfeld, M.—Ueber die Beziehung der Nebenblätter zu ihrem Hauptblatte. Verhand. der Kais.-Konig. Zool.-Bot. Gesellschaft Wien. 37. Abhandl. 69–79. 1887.

The author has made investigations experimenting upon a large number of plants, by the removal of the lamina of the leaves at the earliest possible stage of development, in order to observe the effect upon the development of the stipules and so determine their physiological relation to the leaf-blade. Only in exceptional cases was the ultimate size of the stipules increased, and those where the stipules were normally foliaceous.

Colomb, G.—Recherches sur les stipules. Ann. Sci. Nat. (VII), 6 : 1–76. 1887.

This paper is the result of an exhaustive anatomical study of stipules and their homologues. The results obtained are of great interest and value. They are admirably summed up at the close of the paper as follows :

" When a leaf is sheathing, the sheath may be prolonged in a ligule situated above the point of insertion of the blade upon the sheath.

" In this organ three regions may be recognized :

" 1. The lateral regions into which the marginal bundles of the sheath are merely prolonged. These regions naturally do not exist if all the bundles of the sheath enter into the leaf.

" 2. The stipular regions, the bundles of which arise from a doubling of the last bundle of the sheath entering into the leaf.

" 3. The axillary region, which unites the two stipular regions, a lamina, usually of parenchyma, but which may receive bundles arising from the internal doubling of those bundles of the sheath which become petiolar.

" The sheath may be reduced even to complete disappearance without a consequent disappearance of the ligule.

" 1. If the ligule is complete with its three regions, I give it the name of an axillary ligule.

" 2. If the stipular and axillary regions only persist, the sheathing regions having disappeared, we have an axillary stipule.

" 3. If finally the axillary region divides into two halves, right and left (which would not be remarkable, considering its purely parenchymatous nature), the stipular regions exist alone at the base of the petiole, and we have then stipules properly so-called.

" Stipules and the ligule are then organs of the same nature, between which it is possible to find all forms of intergradation, the stipule being a portion of the axillary ligule.

" When, finally, the manner of origin of the bundles of the stipule is studied, we arrive at the following definition of the organ: An appendage inserted on the stem, at the base of the leaf, all the bundles of which arise exclusively from the corresponding foliar bundles."

Each of the tendrils of a leaf of *Smilax* is characterized as a demi-ligule, the " stipule " of *Potamogeton* as a ligule identical with that of grasses, the ochrea of *Polygonum* and *Platanus* as axillary stipules, the stipules of *Ficus elastica* Roxb. and *Magnolia grandiflora* L. as axillary ligules.

Ward, L. F.—The Paleontologic History of the Genus Platanus. Proc. U. S. Nat. Mus. 11: 39–42. 1888.

Professor Ward says (p. 41) in speaking of the fossil leaves of *Platanus basilobata* Ward, of the Yellowstone valley, that some of those found had "a remarkable expansion at the base of the blade, projecting backward on the leaf-stalk and having two to five lobes or points.

"These expansions are to be interpreted as evidence that the leaves all belong to *Platanus* or to some extinct ancestral type of the genus, since something quite analagous to them is found in our American plane-tree. The ordinary leaves of this tree are, it is true, destitute of basilar expansions, but those on young shoots, and sometimes those on the lower or non-fruit-bearing branches of trees exhibit this peculiarity.

"In place of this backward expansion of the blade many sycamore leaves have an appendage similar in shape at the base of the leaf-stalk, as though the once basilar appendage had been separated from the blade and crowded down the petiole to its point of insertion." This is shown in a short-petioled, wedge-shaped leaf from a young shoot of *Platanus* corresponding to the fossil form of *Platanus appendiculata* Lesq. from the auriferous gravels of California. The indication is that "the constriction seen in the fossil forms between the blade of the leaf and the appendage would seem to represent the beginning of this process of detachment."

Ward, L. F.—Origin of the Plane-Trees. Am. Nat. 24: 797–810. 1890.

The same cases as those in the preceding paper are discussed, the appendages in *Platanus appendiculata* Lesq. being described as stipular, while those of *P. nobilis* Newb. and *P. basilobata* Ward are not so considered.

Lubbock, Sir John.—On Stipules, their Form and Function. Jour. Linn. Soc. Lond. 28: 217–243. 1890.

"The primary function of stipules seems to be to protect the bud. In other species, however, they serve as accessory or deputy leaves. Their protective function is confirmed by the fact of their early fall. Some are more persistent than the leaves and protect the leaves of the following year.

"When stipules are present [in *Helianthemum*] the petiole is always very narrow, semiterete, and tapered to the base. Where they are absent the leaf is often sessile and, whether or not, its base is always dilated and concave on the inner face, completely enclosing the bud up to a certain stage of its development."

The presence of stipules in the lower imperfect leaves of *Ailanthus glandulosa* Desf. is noticed, though the family of the Simarubiaceæ has been described as exstipulate. In *Ribes sanguineum* Pursh. the bud-scales are described as consisting of the dilated base of the petiole, the lamina being represented by a small black point. "One or two succeeding leaves bear a small lamina sessile on the sheath, which is wholly adnate to the thin dilated base of the petiole and membranous, especially outside of the three vascular bundles. The next one or two have a well-developed lamina, and the sheaths partly separated from the petiole and corresponding to stipules. Farther up the stipular sheaths are shorter and wholly adnate to the petiole."

The form and function of the stipules in a large number of species are described.

Lesquereux, L.—U. S. Geol. Surv., Monog. No. 117: Geology of the Dakota Group. 1892.

Well-developed stipules of a species of *Betulites* from Kansas are described (p. 65) as having been found in their original connection with the leaf, and the discovery of leaves of a *Cratægus* with large undoubted stipules, from the Devonian of Wyoming is mentioned (p. 254). Speaking of a leaf of *Aspidiophyllum* (p. 232), Professor Lesquereux says, "the basilar appendage or pelta is like a primordial form of stipules, as in *Platanus basilobata* Ward of the Laramie group of Wyoming, *P. appendiculata* Lesq. of the auriferous gravels of California and definitively in *P. occidentalis* L. of the living flora."

Henslow, Rev. George.—On a Theoretical Origin of Endogens from Exogens. Jour. Linn. Soc. Lond. 29: 485–528. 1893.

The absence of vascular bundles in certain stipules is noted (p. 494).

Hollick, Arthur.—Wing-like Appendages on the Petioles of *Liriophyllum populoides* Lesq. and *Liriodendron alatum* Newb. Bull. Torr. Bot. Club, 21: 467–471. 1894.

These peculiar wing-like appendages are described and figured. Their similarity to the appendages in fossil species of *Platanus* as described by Professors Lesquereux and Ward is mentioned, and the probability suggested that we have here an explanation of the origin of the stipules of *Liriodendron Tulipifera* L. in the same manner as that indicated for those of *Platanus occidentalis* L. by Professor Ward. The presence of an unwinged portion of the petiole next to the blade in what is evidently the mature form of the leaves of *Liriophyllum*, and its absence in the immature ones is mentioned as tending to confirm the theory.

In commenting on this paper, the *Botanical Gazette* (19 : 515, 1894) says, "The phyllopodium is to be regarded as an axis which has a tendency to develop wing-like appendages at any portion, notably, of course, in the epipodium. If stipules are branches of the hypopodium their origin has simply to do with the branching of that part of the phyllopodium, without any reference to the method of winging found in other regions."

Lubbock, Sir John.—On Stipules, their Form and Function. Pt. II. Jour. Linn. Soc. Lond. 30 : 463–532. 1894.

This paper is a continuation of the author's former publication. The presence of stipels in *Sambucus Ebulus* L. is noticed. The membranous protective margins of the sheath in *Thalictrum aquilegifolium* L. and the "membranous stipular processes at each trifurcation of the lamina" are mentioned, the latter "appearing to differ somewhat in their origin from the primary sheath." In treating of *Ranunculus aquatilus* L., the author says, "The terminal bud is enclosed by the stipules of the two uppermost expanded leaves. The developing leaves push their way out at the apex of the stipular sheath. Similarity of conditions have therefore developed in the aquatic Ranunculaceæ, an arrangement very similar to that of the Potamogetons."

The following remarks are of particular interest: "In *Magnolia glauca* L. the winter bud is covered by a pair of connate stipules adnate to a petiole that is less than half their length. Succeeding leaves are perfect, and the stipules are two or three times as long as the petiole, the free portions being connate by both edges, like a candle extinguisher, over the bud, so that the leaf appears to spring from the back. As they are adnate to the petiole, there is some reason to assume that the stipules once formed a sheath pure and simple to the leaf of some ancestral form."

Franke, Martin.—Berträge Zur Morphologie und Entwicklungsgeschichte der Stellaten. Bot. Zeit., 54: 33–60. 1896.

In the part of this paper which treats of the development of the leaf-whorl the author agrees with Eichler that the stipules originate later than the principal leaves. But he says that in the species having four-leaved whorls never more than four prominences arise to develop into the parts of the whorl, and that if the parts number six or more, there is a distinct prominence for each. In the last case the supernumerary stipules first make their appearance in the course of development of the whorl a little later than the first pair of stipules.

Hollick, Arthur.—Appendages to the Petioles of Liriodendra. Bull. Torr. Bot. Club, 23: 249. 1896.

The author, referring to his former paper, describes and figures some abnormal leaves of *Liriodendron* collected from saplings, seedlings and new shoots from old stumps. One in particular of these leaves is of interest on account of its similarity to the fossil leaves of *Liriophyllum populoides* Lesq. both in the form of the lamina and especially in having a short petiole with broadly winged margins which extend from the base of the petiole and connect with the base of the leaf-blade.

The question is put whether in this case we have "stipules adnate to the petiole and leaf-blade, or portions of the leaf-blade which are acting the part of stipular appendages."

Such, in brief, is the import of what has been written on the subject of stipules, so far as I have been able to learn. The results of my own observations are not at variance to any very considerable degree with the opinions of most of the botanists who have studied the subject carefully, as will appear from the following exposition of my investigations and the conclusions at which I have arrived. To these I shall pass at once, deeming unnecessary farther comment on previous writings, except such as the statement of my results may imply.

The Nature and Origin of Stipules.

Though it is not part of the purpose of this paper to discuss the problem of the phylogeny of the plant world, it is nevertheless necessary in order to define our field of inquiry to make a brief statement concerning the probable relationship of the higher forms, namely of those in which foliar organs are developed, including in the widest interpretation the Characeæ, Bryophyta, Pteridophyta and Spermatophyta.

As, in the Characeæ and Bryophyta, the plant body represents the gametophyte stage of development, there can be no homology of the leaves of these plants with those of the Pteridophyta and Spermatophyta in which the plant body is the sporophyte. For this reason the so-called stipules of the Charas, together with the basal lobes or saclike and straplike appendages of the leaves of many Hepaticæ need not be taken into consideration.

Accepting the general theory of evolution in nature, we must admit that the origin of all the higher plants is algal, but just what the relationship of the Pteridophyta to the Spermatophyta may be is still an open question. The same is true in greater or less degree of the affinity of the Monocotyledones, Dicotyledones and Gymnospermæ in the latter group.

This question of relationship is of considerable importance in connection with the problem before us as determining the homology of the foliar appendages in the several groups. The evidence in support of the doctrine of the common origin of all the Angiospermæ is particularly strong and may be considered as conclusive. But the relationship of the Gymnospermæ to the Angiospermæ is more remote, and that of the Pteridophyta still more so-and, though there are many points of resemblance, the similar characters may be cases of parallel development rather than indications of a common origin. It is my present opinion, however, that the Gymnospermæ sprang from some generalized hetero, sporous Pteridophyte,* that the early Angiospermæ were differentiated from related forms, and that therefore, the foliar organs in the three groups may be considered as homologous. But this homology can apply to the leaves of Pteridophytes in a very general way only, namely, to such undifferentiated forms of leaves as the ancestors which gave rise to the early Gymnospermæ and Angiospermæ may be supposed to have had. While, therefore, the foliar organs in the three classes are to be considered homologous in their origin, they cannot be so considered in their differentiation and the evolution of leaf-forms in the Pteridophyta and Gymnospermæ, though analogous in many points to their evolution among the Angiospermæ, should be regarded as independent. We may then consider the "stipule" of the Ophio-

* See Campbell, Mosses and Ferns, 300. 1895.

glossaceæ, Marrattiaceae and Osmundaceæ and the "ligule" of *Selaginella* and *Isoetes* as special developments and as properly placed in a separate category from the appendages bearing these names among the Angiospermæ. The Gymnospermæ present nothing to represent either stipule or ligule and we have left for our special consideration the ligule, stipule and their homologues as they occur in the various groups of the Angiospermæ only.

Having thus defined our field, we should have, for the consideration of the problem before us, some conception of what sort of plant the earliest Angiosperm was. In the absence of geological evidence this conception must be purely hypothetical and, basing it on a generalization which would admit of the differentiation from it of all the varied forms of the modern group of Angiosperms, we can see that it must have been a plant of very simple organization indeed. For our present purpose we need not concern ourselves with any other organs of this primitive Angiosperm than the leaves which, from the point of view of the proposed generalization, must be conceived of as hardly more than the bare rudiments of leaves, mere sheathing scales at the nodes of the plant, serving slightly, if at all, the function of assimilation which was still subserved, as in its ancestors, by the general surface of the plant, but confined chiefly to that of protection. The primitive leaf was probably parallel-veined or approximately so, giving rise in its earlier differentiation to the parallel-veined leaves of the Monocotyledones. The geological evidence indicates that these appeared before the Dicotyledones* which must have sprung from them later at one or more unknown points, and netted-veined leaves are of a more recent evolution. Consequently the tendency of aquatic Dicotyledones to revert toward monocotyledonous structure is rather a case of atavistic degeneration than an indication of the origin of Monocotyledones from Dicotyledones in ancient times through the effects of aquatic habit.†

Now, as advance in evolution proceeded, the need of greater assimilative capacity arose and, as the foliar organ was the one best

* Professor L. F. Ward. Sketch of Paleobotany. Fifth Ann. Rep. U. S. Geol. Surv. 448, 1885. Professor A. C. Seward, on the contrary, does not believe that we have satisfactory evidence of pre-Cretaceous Monocotyledones. Notes on the Geologic History of Monocotyledones. Annals of Botany, 10: 220. 1896.

† See Rev. George Henslow. Jour. Linn. Soc. Lond. 29: 485–528. 1893.

adapted for specialization in this direction, it was the one upon which the office devolved. Every botanist knows what an endless variety of forms and special adaptations of particular foliar parts have arisen in the course of evolution which was inaugurated when this setting aside of the leaf to bear in future the weight of the assimilative function took place, or rather when this additional function was placed upon it, for the old protective function has always been retained, though it has become less noticeable as the new function has overshadowed the old.

There has been in the line of vegetable descent a progressive development of the foliar organ, and a history of this development, together with that of other organs, if it were obtainable, would give us a complete phylogeny of the flowering plants, and leave no morphological problem unsolved,* but as the geological record is very incomplete, and we have in the lower Cretaceous an already well developed and much differentiated angiospermous flora of the earlier history of which almost nothing is known, we must seek other sources of information in determining the homologies of parts. At this juncture we may safely follow the example of the zoölogists and turn to embryology for the evidence which geology, as yet, refuses to give except in fragments Among animals, as the phylogeny and ontogeny are found to parallel one another, so we may feel confident they will be found to do among plants when the geological record shall be more completely unearthed.

It has become a well established part of the theory of evolution that each individual organism epitomizes more or less fully in its development the historical steps in the evolution of the type to which it belongs.† By the application of this law of re-

* "On this same view of descent with modification most of the facts in morphology become intelligible, whether we look to the same pattern displayed by the different species of the same class in their homologous organs, to whatever purpose applied, or to the serial and lateral homologies in each individual animal and plant." *Charles Darwin*, Origin of Species, 1859. Am. Ed. 6, 2 . 264. 1889. See also p. 239, *et seq.*

† This theory, known as Von Baer's law, was promulgated by that scientist in his Ueber Entwicklungsgeschichte der Thiere, 224. 1828–37.

See also F. M. Balfour. Comparative Embryology. Ed. 2, 1: 2. 1885.

Opposed to this law is Adam Sedgewick. On the Law of Development commonly known as Von Baer's Law. Quar. Jour. Mic. Soc. (II), 36: 35. 1894.

capitulation to the development of plants we may arrive at valuable and trustworthy conclusions. The question would at once be asked, where shall the embryology of the flowering plants be studied, and the answer would naturally be, in the development of the seed in the ovary. And here indeed, we trace in outline an epitome of the course of development from the simple unicellular organism, represented by the fertilized egg-cell of the ovule to the highest thalloid form, the "embryo," with its bud (plumule) which is to develop into the full-formed plant perfect in all its parts. For a summary of the further development of the Angiosperms we must look to the growing bud which is the essential reproductive organ of the sporophyte stage and, doubtless, a more primitive one than the seed, for it is common among the more ancient Pteridophytes and these have no seed. The embryo of flowering plants does, however, correspond pretty closely to that advanced stage of development of the egg-cell of some of the higher Pteridophyta now generally spoken of as the embryo and should be regarded as a young plant in a state of arrested development. In this state it remains during a period of rest, in a highly specialized environment in the seed, awaiting favorable conditions for farther growth. Because of the highly specialized environment of the embryo, it has itself become correspondingly specialized and has been variously modified to suit the special conditions of its surroundings. The plumule cannot then be regarded as any longer representing a primitive form of bud and its development is so altered by secondary modifications that the series of phylogenetic changes is disguised and imperfectly represented. A parallel case is found among animals in the development of Echinoderms, in which the changes that have taken place through secondary modification are so great that the relationship of the group cannot be satisfactorily determined by developmental evidence.

It is not then in the seedling that we should expect to find representations of primitive leaf-forms, though later ancestral forms paralleling those of fossil leaves, of which we shall speak, are found in some seedlings, as for example in *Liriodendron.* But it is in the growth of the less specialized buds developing under more primitive conditions that we should expect to find them. Such buds are the ordinary leaf-buds of perennial plants, and especially those occurring on basal and subterranean portions which I conceive to develop under conditions somewhat more primitive than is the case with aërial buds. But in both these the recapitulation of the development of leaf-forms may be traced with a considerable degree of confidence, from the primitive sheathing protective scale to the most highly differentiated and complex of modern leaf-forms.

It is at this point that the fragmentary geological evidence sheds its strongest light on the problem under consideration. In the Cretaceous and Tertiary floras which preceded the modern, the present degree of differentiation had not as yet been attained and but few modern species made their appearance before the close of the Tertiary.* The species, however, which immediately preceded those which now exist were very closely related to them, being their immediate ancestors, and differed from them only in showing a somewhat lower degree of differentiation, and their leaf-forms are accordingly more primitive than those of the existing species which have descended from them.

Now it is a well-established fact that the lower leaves of young branches and shoots, and especially of those which spring from the stumps of felled trees, are frequently unlike the adult forms which occur higher up and bear a close resemblance to the fossil leaves of extinct species, so close indeed, as oftentimes to be indistinguishable from them. This is strong evidence in favor of the doctrine that the lower foliar organs represent not reduced leaves, as botanists have commonly supposed,† but the primitive foliar organs, and that in an ascending series from the lowest scale to the mature adult leaves of the upper part of the stem, giving a more or less perfect summary of the phylogenetic development of the foliar organ from the most primitive type upward to the most highly differentiated.‡ In other words, a single stem may represent the whole phylogeny of the foliar organs of its type. It is true that there are simple leaf-forms which have become so

* Our modern species of *Corylus* are recorded from the Eocene by Professor J. S. Newbury. Later Extinct Floras of North America. Ann. N. Y. Lyc. Nat. Hist. 9 : 59–60. 1868.

† See DeCandolle. Org. Veg. 2 : 212. 1827.

‡ "Most modern botanists now regard the varying forms of leaf seen on young shoots and near the base of trees as valuable hints at the probable stages through which the final forms have passed in the history of their development." Professor L. F. Ward. Proc. U. S. Nat. Mus. 11 : 41. 1888.

by reduction but, as an organ cannot be reduced until it has been developed, these are to be looked for above and not below the perfect leaves, and are found in bracts, involucral scales and the parts of floral envelopes, reduction taking place in inverse order to the course of development, and only the most primitive structure, the simple sheath, persists in the petals of most flowers. Reduced leaves are also common in parasites, and in the flora of desert regions as is well illustrated in some of the Leguminosæ of Australia the leaves of which are little more than spines, or are developed into bladeless phyllodia, while in the seedlings the ancestral pinnate or bipinnate forms occur.*

We thus have shown in each season's growth of a plant, though not clearly in annuals because disguised in the seedling, a more or less complete series of foliar organs which may for illustration be compared with the vertebrate series among animals, the lowest leaf-scales being comparable in degree of development to the simple structures of the fishes and the most highly developed leaves to the complicated ones of mammals. Each leaf in the series is equally perfect for the function it is intended to perform, but the lowest of a lower type of organization, as are the fishes, and representing an earlier stage in the phylogenetic series.

Now in animals we look to the developing egg of the more generalized fishes for the least abbreviated embryological recapitulation of the early development of the vertebrate branch, for in the mammals the early stages are passed through so rapidly and with so many disguises as to be of comparatively small importance in giving the history of the branch, unless viewed in the light of the embryological development of the lower types. So the lower foliar organs of a branch or shoot are embryologically of far greater importance than the upper, for in the beginning of the development of one of the upper leaves we have but the early stages of a highly organized appendage. These early stages are consequently abbreviated and more or less disguised. The formation of the stipules in the growth of the upper leaves is therefore not a salient point in the consideration of our problem though it has had much stress laid upon it, yet it is of interest to note that in general the stipules appear earlier than the leaf-blade, thus giving evidence that they are of more ancient origin. It may be added,

*See Sir John Lubbock. On Seedlings. 1: 474. 1892. See also p. 440 as to the similar case of *Lathyrus Aphaca*.

and it is a matter of common observation, that the petiole is the last portion of the leaf to develop ontogenetically and is therefore to be regarded as the most recent part to be added phylogenetically. This helps to explain the common occurrence of sessile and petiolate leaves even in different species of the same genus, as variation more readily occurs in recent than in ancient structures, while on the contrary it has been a matter of remark among even the earlier botanists that stipules when they occur usually characterize all the species of a family, an additional evidence of the antiquity of their origin.

Let us now take up, in the light of the foregoing conclusions the consideration of the destiny of the primitive foliar organ as it has been modified and developed in the course of evolution. For convenience in making our inquiry, I would divide the primitive leaf into the central-basal, axial, apical and lateral portions. Each of these figures prominently in the evolutionary history of foliar organs, for from the original condition there has been progressive development along several lines of varying degrees of relationship and the morphological result of the development of the several parts has been quite different in the divergent groups, so much so as to render the question of homology a doubtful one to many minds. We shall endeavor to establish its reality.

The lamina of the leaf, as we shall see, has been developed chiefly from the apical portion, usually from scarcely more than a mere point, though it may also include the axial and lateral portions. The true petiole, when present, is developed from the axial portion,* the sheathing petiole from the central basal together with the lateral portions, stipules and structures of the same signification from the lateral portions. It is with the lateral portions, therefore, that we are chiefly concerned.

With reference to the formation of stipules there are three principle types of leaf-development: that in which the several portions of the primitive leaf have developed together into a simple unappendaged blade, that in which a sheathing petiole is formed with or without a ligule or ochrea, and that in which stipules properly so-called are present.

In the first and simplest case the development of all the parts

* See S. H. Vines. Text-book of Botany, 1: 49. 1894.

together gives rise to such leaf-forms as are found in *Vaccinium* and *Sassafras*, the principal portion of the lamina being formed by the development of the apical portion, but including at the base the lateral, central-basal and axial portions which are contracted below into a short petiole.

If we observe the development of the leaf in *Sassafras* the relative growth of the several parts can be readily traced. The first four leaves (fig. 1) are very simple. In the fifth (fig. 2) considerable development has taken place. The apical portion, now forming about half of the organ, is provided with the three typical veins as they appear in the adult leaf, but starting out separately from the very base. The lateral portions have reached their highest development and each is furnished with a pair of veins. In the sixth leaf (fig. 3) there is a very close approach to the adult form. The upper part has expanded and the lower parts have elongated, removing the point of separation of the three principal veins of the leaf to a considerable distance from the stem. At the same time there has been a basal contraction looking toward the formation of the petiole with a considerable degeneration of the lateral portions, one of the veins having disappeared from each of them, while the other has become associated with the midvein. The seventh leaf (fig. 4) represents the unlobed adult form and differs but little from the sixth.

A similar condition is observable in *Ailanthus glandulosa* Desf. (figs. 5–10), but resulting in this case in the final separation of the lateral portions as small gland-bearing fugacious stipules, comparable to those at the base of the leaves of many of the Ranunculaceæ. The comparison of *Sassafras* and *Ailanthus* shows how small a difference in development may determine a leaf as stipulate or exstipulate.

The case of *Syringa vulgaris* L. is like that of *Sassafras*, though more difficult to trace, owing to the larger number of veins in the leaf, but the homologies of parts may be followed more or less distinctly from the second leaf up to the sixth, the first adult leaf (figs. 11–14). The lateral portions are seen to have degenerated almost entirely and, their bundles having disappeared, they remain only in the margin of the petiole.

The Compositæ furnish examples of a similar course of development but often with a closer approach to the true stipular condition, as the lateral portions are supplied with vascular tissue by small branches coming off at the base of the leaf from the main lateral bundles.

In *Erigeron annuum* (L.) Pers., for example, there are three fibro-vascular bundles in the leaf-trace which pass up through the central portion of the petiole, converging as it narrows. But almost immediately on their departure from the stem each of the lateral bundles gives off a branch in the same manner as when true stipules are present. This branch forks at once and supplies the wings of the petiole. In the cauline leaves (fig. 15) its branches can be distinctly traced into the lower lobes of the leaf. The basal leaves of *Aster undulatus* L. show a condition very closely similar to that found in *Erigeron annuum* (L.) Pers., but in the cauline leaves there is a considerable modification by which the large lobes of the base of the petiole (fig. 16) are formed. The stipular bundle curves outward through the lobe giving off branches which form a net-work supporting its parenchyma. It then passes up through the wing of the petiole and into the basal part of the leaf. In *Solidago juncea* Ait., there are eleven bundles in the leaf-trace and a stipular bundle is given off on each side, supplying the margins of the petiole. *Artemisia vulgaris* L. affords a very interesting variation. The lateral portions of the primitive leaf have branched in a very curious manner (fig. 17), forming several small leaflet-like appendages to the base of the petiole. That they belong to the lateral portions and are stipular in their character is shown by the fact that they are supported by branches of the stipular bundle which is given off a little higher up than in *Erigeron*, passes on through the wings of the petiole after giving off the branches and enters the base of the blade as in other cases. This is the nearest approach to the true stipular condition that I have observed among the Compositæ.

The embryonic development of the foliar organ among the Compositæ is in general too much abbreviated to give much evidence in the consideration of the present question, and it should be so expected from the position which the family holds at the head of the vegetable kingdom.

Petioles of the kind seen in this type of leaf-development are very often short and usually more or less margined or winged by the contracted basal parts of the lateral portions of the primitive leaf. They are evidently genetically different from the petioles of stipulate leaves which are developed by the elongation of the axial portion alone. Sessile leaves also are of this type, hence the absence of stipules, the stipular tissue being incorporated into the basal part of the blade. But even where stipules are present, the lateral basal portions of the leaves are often in the closest anatomical relation with the stipules. This may be seen in *Viola obliqua* Hill (fig. 18) in which, near the bundle which passes into the stipule, a similar one arises, takes its course up the petiole supporting its narrow wing and is distributed to a small part of the basal portion of the lamina. We shall find several cases similar to this when we come to the consideration of the Rosaceæ. There is in this a suggestion of the occasional separation of only a part of the lateral portions to form the stipules and the incorporation of the remainder into the petiole and blade.

The second case is that of the sheathing petiole as it occurs in the Graminæ, Araceæ and Umbelliferæ. In this case the central-basal portion of the primitive leaf is very largely developed and with it the lateral portions which form the margins of the sheathing petiole. The lamina and true petiole are later developments of the apical and axial tissues. We are strongly supported in this view by the fact that the sheathing petiole is interchangeable with petioles of the ordinary type accompanied by stipules. This occurs in the Umbelliferæ. In *Hydrocotyle* and a few other genera the sheathing petiole is wanting and stipules are present. The closely related *Aralia racemosa* L. also has stipules. Still more striking is the case of *Comarum palustre* L. in which the basal leaves have the sheathing petiole remarkably developed with no indication of stipules (fig. 19), while the upper leaves possess well developed stipules adnate for not more than half their length (fig. 20).

But the identity of the marginal tissue of sheathing petioles is perhaps best shown in the Ranunculaceæ. In the upper basal leaves of *Ranunculus bulbosus* L., the separation of the lateral portions is seen actually to have begun, presenting exactly the appearance of adnate stipules. The development can be clearly traced from below upward. The first leaf has a short sheathing petiole of the ordinary type (fig. 21). This is slowly modified till in the fourteenth leaf (fig. 22) the vascular bundles have drawn closer together, the sheath has grown shorter and the broad lateral portions, hyaline in texture and requiring no special support other than that of the surrounding leaves, are rounded off distinctly at the top at the point of beginning of the true petiole. In the fifteenth leaf (fig. 23) there is a further reduction in size and the tips of the lateral portions are free. Another interesting case among the Ranunculaceæ is that of *Thalictrum polygamum* Muhl. in which the sheathing petiole is of a very generalized type (fig. 24). The lateral portions are chiefly hyaline, though sometimes faintly netted-veined and their margins turn in at the apex and meet in the central dorsal channel of the petiole at its base, forming a ridge between the sheathing and true petioles. This ridge supports a very narrow hyaline membrane which appears to me as the rudiment of a ligule. It would become typical by a little further development of marginal tissue. I believe this to be the origin of the ligule wherever it occurs, though it does not appear so clearly evident in highly specialized groups, nor should we expect such to be the case. There is also present at the first and second forkings of the petiole a transverse hyaline scale very much like a ligule.

It is noteworthy that the ligule always occurs in connection with the sheathing petiole, as in the Gramineæ and Cyperaceæ, or where there is evidence that there has been a sheathing petiole which has disappeared by degeneration, leaving the ligule axillary as in some of the Naiadaceæ which we shall presently consider.

When the ligule has developed sufficiently to require special support, it is supplied by the introduction of vascular bundles. These bundles have their origin most frequently as tangential branches of the main leaf-bundles at their point of passage from the sheathing petiole into the true petiole, or, where the latter is undeveloped as in the grasses, into the blade. This mode of origin of the ligular bundles is seen in some of the tropical grasses and in the ligular portion of the stipule of the Naiadaceæ and the ochrea of the Polygonaceæ. *Richardia* shows an exceptional venation of the ligule.

The best marked examples of the sheathing petiole among the Monocotyledones are found in the Araceæ, the Cyperaceæ and the Gramineæ. If we examine a developing plant of the common hot-house calla (*Richardia Africana* Kunth.), the first leaf (fig. 25) is seen to be a short, broad sheath, the second (fig. 26) has increased to a considerable length and the apical and axial tissues have developed into a minute blade and petiole. The third leaf is of the adult form, but smaller, though all the parts have increased very much in size. This is contrary to what is observed in *Ranunculus* where the sheathing petiole degenerates while the other parts advance. The margins of the sheathing petiole of *Richardia* curve inward at their apices and meet in the middle line of the leaf as in the case of *Thalictrum polygamum* L., but they are much broader and form a distinct ligule which is supported by the incurving and union of the marginal veins of the sheath instead of by tangential branches. In *Arisæma triphyllum* (L.) Torr., the transition is not so well marked, owing to the small number of leaves the first of which is but a sheath as in *Richardia*, while the second bears a mature lamina.

Scirpus polyphyllus Vahl. (fig. 27) will serve well to illustrate the ligule in the Cyperaceæ. It is but little developed as a slight hyaline outgrowth upon the ridge at the union of the sheath and lamina, but the sheath is closed, as is typical in the family. and a little farther development of marginal tissue would produce an ochrea. Typical of the ligule in our common grasses is that of *Phalaris arundinacea* L. (fig. 28). It consists of a considerable outgrowth of hyaline tissue which is continuous laterally with the marginal hyaline tissue of the sheath. This continuity strongly supports the position taken as to the origin of the ligule. The purpose of the ligule is evidently to prevent the flow of water from the upper parts of the leaf down between the sheathing petiole and the stem which together with the axillary bud it invests and protects, and neither the ligule nor the primitive ridge which bears it are found in those cases where the sheathing petiole does not closely invest the stem, at least in the early stages of growth, and its purpose could not be in any considerable measure fulfilled.

The usually axillary position of the "stipule" in the Naiadaceæ has occasioned considerable discussion as to its real relation to the ligule of grasses and to stipules proper. That it is in reality a development of the lateral portions of the primitive leaf, and that it corresponds to the ligule together with the margins of the sheathing petiole of grasses and is rendered more or less nearly axillary by the degeneration of the central-basal portion, becomes clear from the fact that in some species of Naiadaceæ the sheathing petiole retains a considerable degree of what should be regarded as its ancestral development, and a condition approaching that which occurs in grasses is found. *Potamogeton crispus* L. is one of our species which will serve well for an illustration. The first leaves do not develop a blade, but the lateral and central-basal portions are well developed. In the adult leaves there is present a true sheathing petiole (fig. 29). The fibro-vascular bundles of the central-basal portion pass into the blade, giving off tangentially, at the point of transition from sheath to blade, the bundles of the ligular part of the stipule. The bundles of the lateral portions do not in this case curve about to join those entering the blade but are prolonged upward, remaining parallel and supplying the lateral portions of the stipule with supporting tissue directly. In *Althenia filiformis* Petit. (fig. 30), the conditions are more primitive in the larger relative development of the lateral and central-basal portions. In *Ruppia* the ligule is not developed, and the tips of the lateral portions are free as in ordinary adnate stipules.

The condition found in *Potamogeton* is almost exactly repeated in *Polygonella articulata* (L.) Meisn. (fig. 31). The ochrea is cylindrical, surrounding the stem. The central-basal portion is long and narrow, bearing at its apex the terete lamina which is deciduous before flowering. The lateral portions form the principal part of the sheath, are parallel veined with a few anastomosing bundles and are prolonged above the central-basal portion, growing in along the ridge between it and the lamina. This middle portion shows its origin by a deep median sinus and receives its bundles typically as tangential branches from those entering the lamina. We do not have then in *Polygonella* a typical ochrea as it occurs in *Rumex* and *Polygonum*, where, because of the small development of the central-basal portion, the sheathing petiole is very short or almost wholly wanting. The lamina, being of much greater importance than in *Polygonella*, receives all the bundles of the leaf-trace. They are more or less abruptly deflected into the true petiole, generally developed in these genera, according to the degree of degeneration of the central-basal portion. The lateral portions receive their supporting bundles as branches of the lateral ones of the leaf-trace. In *Polygonum sagittatum* L. (fig. 32), the marginal tissues do not extend across the petiole and we have a stipule opposite the leaf. In *Rumex crispus* L. (fig. 33) and *Polygonum Virginianum* L. (fig. 34), the ochrea is complete and the axillary parts receive the typical tangential bundles.

The ochrea of palms is doubtless of the same character, though I have not had opportunity to examine its anatomical structure. In those species which I have examined morphologically, the case is that of the ochrea associated with a remarkable development of the sheathing petiole. There is no true petiole and the ligule may be seen even a little above the base of the blade on the upper surface of the midrib. From this point the lateral portions may be traced down the margins of the sheath, though dried up and very much torn and broken by the more rapid development of the central tissues, till they unite with those parts which in their development have formed the "ochrea." The degeneration of the sheathing petiole with the probable concomitant formation of a true petiole would give the same conditions as in *Polygonum* with its typical ochrea.

The ochreate stipule of *Platanus* differs little morphologically from the typical ochrea, except in the absence of development of the central-basal portion and the possession of a horizontal limb, but there is no fibro-vascular support for the ligular part and this usually splits, leaving apparently a single stipule opposite the leaf.

The case of the tendrils of *Smilax* is one which has occasioned much discussion, but the embryological together with the anatomical characters make it sufficiently clear that in *Smilax* the tendrils are true stipules found in connection with the sheathing petiole. If a young shoot of *Smilax rotundifolia* L. be examined, the first leaf (fig. 35) is seen to be of the typical primitive form. In the second (fig. 36), the apical portion has developed into a blade of considerable size and there is a well-marked sheathing petiole. In the third (fig. 37), the true petiole has begun to develop, the central-basal portion is degenerating and at the same time the lateral portions have begun to separate, forming rudimentary tendrils which in the adult leaves come to considerable length by secondary development in adaptation to their new and unusual function of support. In cross section the bundles of the tendrils are seen to arise as branches of those of the petiole, so that anatomically, as well as embryologically, they answer to true stipules.

Pastinaca sativa L. (fig. 38) furnishes a good example of the sheathing petiole among the Umbelliferæ. The lateral portions are broad and furnished with several vascular bundles parallel with those of the central basal portion. The lateral portions remain of considerable breadth to the top where they are distinctly rounded off, and their bundles, with the exception of two or three of the exterior ones. curve around and unite with those entering the petiole. This free condition of the exterior lateral bundles with the anastomosing network between them shows a considerable degree of approach to the true stipular condition.

In the third case true stipules are developed. They are formed by a very early separation of the lateral portions from the main body of the primitive leaf, a separation which can be very clearly traced progressively in the embryological history of leaf development. The function of the lateral portions in their primitive connection with the main body of the foliar organ is, in common with the other portions, protective, and while the apical portion, having had placed upon it the special function of assimilation, goes on in its development together with the accessory axial portion in adaptation to this purpose, the lateral portions usually serve their ancient function only, sharing it with the central-basal portion when this has not disappeared by degeneration. The central-basal portion also supports the main body of the leaf, a function from which the lateral portions have been freed by separation.

It is in consequence of this separation that all the main vascular bundles of the leaf-trace in the third type of leaf-development are deflected toward the central one that they may pass up through the petiole into the lamina and give the required support to these important parts. The support of the lateral portions is left to comparatively small lateral branches from the two exterior bundles of the trace, evidently developed expressly for the purpose. This we may conclude, since vascular tissue is the most modern of plant tissues and introduced because of the necessity of support in the evolutionary development of the primitive ground tissues. It would, therefore, follow and not precede the evolution of leaf-forms, being introduced where needed and disappearing again when degeneration or other support of particular parts renders its presence unnecessary. This will appear in some of our examples. In the first and second types of leaf-development the lateral portions may retain in greater or less degree their independent venation.

As the other portions of the primitive leaf have been so wonderfully modified in the course of their development and altered from their original condition, so the freed lateral portions to which we may now apply the term *stipules* have not retained their primitive proportions in adult leaves nor the identity of all their parts. But as the central basal portion has often almost wholly degenerated, the same thing has happened to the basal parts of the lateral portions. The parallel degeneration of the two portions has brought the stipules into closer and closer apparent relation to the stem, so much so as to lead to the enquiry whether they are not accessory leaves and to suggest their origin from the reduction or lack of development of a portion of the leaves as in *Selaginella* and their subsequent association in close relation to the larger ones, but in all my investigation I have not found the slightest evidence in support of this theory. The degeneration of the stipules may continue until they become vestigial or finally disappear altogether. This is evidently the case in those families of plants a few species only of which still possess stipules, as for example the Caprifoliaceæ.

But opposed to the basal degeneration of stipules, there has very commonly been a longitudinal development corresponding to that by which the lamina has been evolved. This has resulted in the adaptation of the stipules to the peculiar requirements of each genus and species. Often in this secondary development they remain membranous, serving the protective function only, and when free are early deciduous. But in numerous cases they have acquired the assimilative function also, developing abundant chlorophyll and sometimes, as in the pea (*Pisum sativium* L.), becoming of equal assimilative importance with the lamina. In *Lathyrus Aphaca* L., they even replace it almost entirely.

Among all these varying forms we should expect to find closer similarities in those plant groups of nearer relationship as we do in floral structures, and conversely these similarities of foliar development should also point to relationship, due allowance being made for parallel development in adaptation to similar environment and for secondary functional modifications which find morphological expression. Also in types more recently evolved and more highly differentiated wide divergence from the typical mode of development may be looked for. The Caprifoliaceæ, before mentioned, are of such a type, with stipules usually wholly aborted;

another is the family of the Rubiaceæ with anomalous stipular development in the group of the Stellatæ. The oaks also, though of lower organization, are an advancing type and still actively undergoing differentiation as evinced by the close relationship and difficulty of determination of the species of any given group. In this genus all but the upper part of the primitive leaf has disappeared by degeneration even in the earliest stages represented in embryonic leaf-development, and the well developed stipules are distinct and separate from the very base of a developing shoot. Not until the fifteenth node, in *Quercus rubra* L. (fig. 39), is there any appearance of lamina. The apical portion of the protophyll must however be regarded as potentially present between the stipules at their base. It begins its development unusually late in the series and exhibits several stages, of which the twentieth leaf (fig. 40) is illustrative, before reaching adult size. The axial portion of the protophyll being aborted, the petiole, here again a short one, is formed by the contraction of the basal part of the lamina itself. The case of *Fagus* is very similar, but the lamina appears as early as the eighth node (fig. 41), indicating a less degree of specialization. In related genera a different course has been followed. The lamina develops still earlier and the stipules of the lowest nodes are united, separating only on the appearance of the first accompanying lamina.

In the family of the Juglandaceæ the genus *Hicoria* furnishes a very interesting example. The lower foliar organs are of the primitive type with an unusual development in size in some species. The transition to the adult leaf-form is commonly rather abrupt, but I have observed, in both *Hicoria alba* (L.) Britton and *H. microcarpa* (Nutt.) Britton, the frequent occurrence of intermediate forms, the lateral portions remaining as typical adnate stipules (fig. 42).

I have not seen the typical representation of embryonic leaf-development better exemplified than in the case of *Baptisia tinctoria* (L.) R. Br. where at a glance one is struck with its clearness. It is also especially full and accurate as occurring in the development of subterreanean buds. The first five leaves are extremely primitive, completely surrounding the node, though only slightly developed on one side. The fifth (fig. 43) shows at its apex a minute apical tooth, the beginning of the lamina which is farther developed in the sixth leaf. In the seventh (fig. 44) the three leaflets are plainly distinguishable, the petiole has begun its development and the separation of the stipules has made considerable advance. The ninth leaf (fig. 45) is well developed, with the large stipules still showing considerable adnation. But in the tenth (fig. 46) they are wholly free and much reduced, and higher up disappear altogether. We could hardly have a more complete series in illustration of the formation of stipules than this, giving as it does all the stages from an extremely primitive leaf-form to that very highly organized condition where the stipules have entirely disappeared. By a comparison of the venation in the seventh and ninth leaves, it will appear that the separate condition of the stipules has been attained in the manner already described, partly by the formation of an apical cleft, partly by the degeneration of the central-basal portion bringing the base of the cleft lower down. Meanwhile there has also been a considerable apical development of the stipule itself. But this increase in size is lost again in the tenth leaf and the reduction continues to final abortion. *Melilotus alba* Lam. presents very similar though somewhat less primitive conditions.

While considering leguminous plants, a few words concerning stipels, which are so characteristic of the family, would be in place. They have been denominated as "the stipules of leaflets," but I am convinced that they have no connection with stipules whatever, but that they represent rudimentary leaflets which have their origin in a tendency to increased compounding. The habit has become so fixed in the Leguminosæ that evidence of its origin is seldom met with. I have however seen, in *Lespedeza capitata* Michx., one of the earliest leaves with the terminal leaflet only developed and the two lateral ones represented by stipels.

I have found more light on the question in other families where the same tendency to increased compounding often occurs. In *Sanguisorba Canadensis* L. (fig. 47) for example, very vigorous plants sometimes show rudimentary leaflets, more developed indeed than typical stipels, but in the same position. Their character as leaflets of secondary rank is evinced by their occasional removal to a little distance from the primary petiole. A more striking case is that of *Sumbucus Canadensis* L. In this species the leaves of young shoots springing up where the bushes have been cleared away are frequently partially bicompound and there are all gradations between the ordinary pinnate form and the bipinnate condition (figs. 48–50). In this case it is remarkable that the first appearance of the secondary leaflet is in the shape of a small body with both the form and position of a stipel, with the same small supporting vein and differing only in greater thickness. These facts seem to give evidence sufficiently conclusive that stipels are in reality rudimentary leaflets. That their development is not confined to the Leguminosæ is farther shown by their characteristic occurrence in *Staphylea trifolia* L.

Another frequent foliar variation among the Leguminosæ is the development of the phyllodium, which might be thought to have some connection with stipules, but the presence of both together in some genera disproves the idea.* The stipules in the Leguminosæ often take the form of spines which serve for the general protection of the plant. We have an example in the well known *Robinia Pseudacacia* L. (fig. 51). In some of the tropical Acacias, as for example *A. spadicigera* C. & S. (fig. 52), they take the form of enormous hollow horns which are appropriated as homes by some species of ants.†

Sambucus Canadensis L. presents another remarkable character. The leaves of the vernal shoots from subterranean buds are furnished with stipules of the same form and in the same position as those of *Sambucus Ebulus* L., but smaller. There are four of them at each node, they are ovate or nearly orbicular in form, small, rather fleshy and persist but a short time. Each is supplied with a small vascular bundle, originating as a branch of the nodal girdle which connects the leaf-traces. These facts give evidence of the close relationship of these two species of *Sambucus*, and of the characteristic presence of stipules in the ancestral form. In *Sambucus Ebulus* L., they are still typically developed, but in our species have become so far vestigial as to appear only in connection with the early leaves of shoots from subterranean buds, an additional evidence of the importance of the leaf-forms successively developed from such buds, in their bearing on the evolutionary development of modern adult forms.

If now we turn to the family of the Rosaceæ we shall find many illustrative examples of the same facts as those born out in the case of *Baptisia tinctoria* (L.) R. Br. But it frequently happens that basal degeneration does not take place or is only partial, re-

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* Bentham and Mueller. Flora of Australia, 2: 304. 1864.

† Belt. Naturalist in Nicaraugua, 218. 1874.

sulting in the adnate stipules characteristic of so many genera and species of the family. *Agrimonia striata* Michx., in the development of its subterranean buds in the spring, presents an excellent series of embryonic leaf-forms. The lower ones are all simple sheathing scales completely surrounding the stem at their insertion. Not until the eleventh leaf (fig. 53), which is three-toothed at the apex, does the differentiation of parts begin. The central tooth is the beginning of the blade with its petiole; the lateral portions with their tips now free are the stipules. To say that they are "adnate" indicates only that they retain their primitive connection with the central-basal portion. In the twelfth leaf (fig. 54), there has been some basal degeneration, as shown by the lower point at which the three main bundles of the leaf converge and the lower position of the zigzag plexus of the stipular veins. The free tips, on the other hand, have increased in size and a small blade supported by a petiole is present in consequence of the development of the central tooth. The fifteenth leaf (fig. 55) shows a stronger development of all the parts, and a branch of the main stipular bundle is seen to pass up the petiole. The adult form is attained in the seventeenth leaf (fig. 56). In it some further basal degeneration has taken place, but the adnation of the stipules is still very prominent.

Prunus Cerasus L. gives a very good morphological series, but the venation is obscure. A view of the several forms can be had by an examination of the tenth, thirteenth, fifteenth, sixteenth and seventeenth leaves (figs. 57–61). They show the transition from the simple primitive scale to the mature condition in which the stipules are rendered entirely free. The series is similar in *Rubus occidentalis* L., *Pyrus Malus* L. and *Pyrus communis* L. In *Rubus villosus* Ait. (figs. 62–66), the basal degeneration is not carried quite so far and the stipules in the adult leaf-forms remain adnate for some distance from the base of the leaf. The tips of the stipules have taken a larger comparative development than in *Agrimonia*. Anatomically, however, *Rubus villosus* Ait. resembles the latter in having a vein which enters the petiole, neighboring to the main stipular bundle much as in *Viola obliqua* Hill (fig. 18). The venation in *Pyrus Malus* L. (fig. 67) is still more like that in *Agrimonia*.

The stipules of *Fragaria* and *Rosa* show the highest degree of adnation and little, if any, basal degeneration seems to have taken place, though the lateral leaf bundles curve in toward the median one at but a short distance from the stem. This arrangement of the bundles is probably secondary in these forms for the purpose of giving a firmer support to the leaf by an axial concentration of the vascular tissue in the sheath and a corresponding thickening of the surrounding tissues, a firmer support than could be given by only three bundles if they did not converge till they approached the point of their entering the petiole. The venation of the stipules is also peculiar. In *Fragaria Virginiana* Duchesne (fig. 68), there is a single strong bundle running out into the free tip of the stipule. From this are sent out one or two weak veins above, and below there is a faint vascular network confined mostly to the region of the tip and extending in a long curve toward the outer portion of the base, where it gradually fades out without forming any connection with other vascular tissue below. This condition seems to indicate a former basal connection of these stipular bundles, either with the lateral bundle of the leaf or possibly with those of the stem, forming an additional leaf-trace bundle distributed to the stipules only. The former case is far more likely. A probable explanation of this degeneration of the basal stipular bundles can be found by a consideration of the conditions of the environment. All the leaves being basal, the stipules are clustered together and are supported by one another and by the surrounding soil. They are more or less fleshy, destitute of chlorophyll, and in their moist surroundings loss of water by evaporation is comparatively slight. All these circumstances lessen the necessity of the supply of fresh sap. The rapidly conducting vascular tissue has come into disuse, and its degeneration and disappearance is the natural consequence. The same arrangement in forms with leafy stems is not so readily explainable except by the supposition that the arrangement is ancestral. This seems rather evident in the case of *Agrimonia striata* Michx. (figs. 53–56), where the same condition of the bundles occurs, for the earliest leaves representing the ancestral forms develop under the same conditions as the adult leaves of *Fragaria*. But in *Rosa* it would be by no means clear did we not have such intermediate types as *Agrimonia*. *Rosa humilis* Marsh. (fig. 69) may be taken as typical of the genus. The venation of the tip of the stipules is nearly like that in *Fragaria*, but with a little larger development above the main bundle. The vascular network below is much more extensive and is reënforced by several small branches from the lateral bundle which enters the petiole, below the main stipular branch. This additional supply of vascular tissue is evidently rendered necessary by the exposure of the stipules to the light and air and the development of chlorophyll. It seems to be of secondary introduction.

The nearest approach to the stipular conditions occurring in *Fragaria* and *Rosa* which I have observed among the Leguminosæ is found in the adnate stipules of *Trifolium pratense* L. (fig. 70). There are two sets of stipular bundles. One of these supplies the tip of the stipule and consists of three veins of which the lowest corresponds to the single large bundle of the tip of the stipules of *Fragaria* and *Rosa.* The other has its origin as branches from the lateral bundle of the leaf-trace at the base of the leaf, the usual point of origin of the veins of free stipules. This set of veins is distributed to the lateral and basal parts of the stipules and apparently corresponds to the lower network of the stipules in *Fragaria.* These stipules are mainly protective in function. Their meshes are filled with hyaline tissue, but there is some green parenchyma along the veins.

Two very interesting cases in the family of the Rosaceæ are those of *Cliffortia graminea* L. f. of South Africa (fig. 71) and *Potentilla fruticosa* L. (fig. 72). In the former the leaves very closely simulate those of grasses with the linear lamina sessile upon a sheathing petiole. They differ in having the tips of the lateral portions (stipules) free instead of turning in across the insertion of the lamina to form a ligule. In the latter the conditions are very closely similar to those of the ochrea of *Polygonum.* There is a short sheathing petiole, above the apex of which the tips of the stipules rise. Each of them is supported by a strong vein which has its origin at the base of the true petiole. But instead of being free from one another as in *Rosa*, the stipules are connected back of the petiole by a hyaline ligular tissue. The lateral portions of the sheathing petiole are also united to one another on the opposite side of the stem, at least in young leaves, to a considerable degree. Thus an ochrea is formed, not quite a typical one it is true, yet more nearly so than that of *Polygonum sagittatum* L. (fig. 32).

The fact that such forms as these can occur in the same family of plants along with typical stipules, both adnate and free, goes to show how small is the real difference between the various stipular forms. Not all stipules possess supporting tissues but, just as is the case in the ligule of most grasses, may be without any fibro-vascular bundles whatever. This is the case in *Vitis*, in *Parthenocissus* and *Hydrocotyle*. *Vitis Labrusca* L. (fig. 73) shows a somewhat thickened central streak at the base of the membranous stipule, but in *Hydrocotyle Americana* L. (fig. 74), the thickness is uniform and the stipule very thin. These facts give some authority to the supposition that the pectinate interpetiolar appendages which occur in the Composite *Willoughbya scandens* (L.) Kuntze (fig. 75) are true stipules. They are hyaline in texture, without supporting tissue, and may possibly be merely of epidermal origin. To determine this point requires opportunity to examine their development.

It is of importance to state that the tendril of the Cucurbitaceæ, regarded by many as a stipule, has been determined by anatomical examination to represent the first leaf of the axillary bud.* The spines of *Xanthium spinosum* L., simulating stipules in position, are degenerate pistillate flowers. As proof of this, they often bear a greater or less number of hooked prickles like those of the flowers, and there may be a spine on one side and a flower on the other, showing them to be of the same significance.†

The stipules of *Comptonia peregrina* (L.) Coulter (fig. 76) denied by some to be properly so-called, do not differ anatomically from other stipules notwithstanding their peculiar morphology, and are to be included under the term. One of the chief reasons for their exclusion seems to have been the absence of stipules in *Myrica*. This is doubtless a case parallel with that of *Viburnum*, of which most of the species have lost their stipules by degeneration.

While it is not a generally accepted view, there is no good reason why stipules should not sometimes be distinguishable in floral parts. They are clearly present in the sepals of *Rosa* and *Rhodotypus*, and the smaller intermediate lobes of the calyx of *Potentilla* probably represent pairs of united stipules, one from each neighboring calyx-lobe in the manner of interpetiolar stipules.‡ The teeth of the filament in *Deutzia* are very suggestive of stipules in

*See Lestiboudois, Bull. Soc. Bot. Fr. 4: 746–747. 1857. Cited on p. 6.

† See also Clos. Mem. Acad. Sci. Toulouse, (IV), 6: 66–75. 1875.

‡ See Engler and Prantl. Pflanzen Familien. 3: Abt. 3, 6. 1894.

stamens, and the corona of *Silene* may very probably represent a ligule. The glands of the leaves of Ranunculaceæ which have been homologized with stipules, as already stated, can often be traced up into the flowers and are familiar in connection with the petals of *Ranunculus*.

One of the most interesting families of plants in the development of its stipules is that of the Rubiaceæ, the development being very unusual in the group of the Stellatæ. Though the foliar anomaly in this group was early remarked upon and was anatomically explained as early as 1840,* there are considerations which make its present discussion desirable.

In the greater part of the family the leaves are opposite, or occasionally in whorls of three as in *Cephalanthus occidentalis* L., and are usually stipulate. The stipules are of variable character and often interpetiolar, the adjoining stipules on each side of the stem being connate. In the group of the Stellatæ however, comprising ten or twelve genera, the stipules usually are apparently wanting and the leaves in whorls. There is a tendency toward a verticillate arrangement of the leaves in others of the Rubiaceæ, as shown by the frequent occurrence of whorls of three in usually opposite-leaved species. Now an anatomical examination of the whorled leaves of *Mollugo verticillata* L., *Silene stellata* (L.) Ait. f., *Leptandra Virginica* (L.) Nutt. and *Cephalanthus occidentalis* L. reveals the fact that in other families, as well as in the Rubiaceæ exclusive of the Stellatæ, each leaf of any whorl receives its fibro-vascular bundles directly from the cauline cylinder. But in *Galium* the case is different. Two leaves only of the whorl receive their bundles in the manner stated, and only these two produce buds in their axils. All the others receive their vascular supply from what may be termed a nodal girdle, each half of which is formed by the union of two bundles arising, one from each of the two leaf-traces in the same manner as those supplying stipules of the ordinary form. From this girdle arise the bundles which supply the additional leaves, whether there be only one on each side, as in *Galium circæzans* Michx. and *G. lanceolatum* Torr., two, as in *G. triflorum* Michx. and *G. tinctorium* L., or even three or four, as occurs in *G. Aparine* L. The distribution of the vascular bundles may be seen in a cross section of the node of *Galium tinctorium* L. (fig. 77).

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* See page 6.

This anatomical arrangement shows that the so-called additional leaves of the whorls in *Galium* are in reality stipules and that the Stellatæ agree with the rest of the Rubiaceæ in having opposite leaves. The tendency of the family however to produce verticillate leaves has been strongly felt in this group but has taken an unusual course, the increased assimilative area having been evolved through the stipules instead of by an increase in the number of true leaves. The explanation is thus made comparatively simple except in those cases where the number of stipules at a node is more than four.

As a general rule, in plants with stipulate leaves, each leaf is provided with two stipules. But when the leaves are opposite, the two on the same side of the node often coalesce, forming a single interpetiolar stipule, as in the case of *Cephalanthus* (fig. 78). That this coalescence is secondary is shown by the fact that the distal portions only of the veins of the two stipules have united. Now in the Stellatæ also, this must have been the original condition, but the interpetiolar stipules have been greatly developed to serve assimilative purposes, the veins having meanwhile united completely to form a midrib. The increase in size has advanced until in *Galium* the stipules are of the same size and form as the leaves and morphologically indistinguishable from them, except in *G. bifolium* where the stipules are smaller. In this condition they remain in the broader-leaved species, as *G. pilosum* Ait., *G. latifolium* Michx. and *G. lanceolatum* Torr. But in the narrower-leaved species, a still greater foliar expansion being desirable, separation has been re-accomplished, proceeding probably from the tip downward, as is illustrated in *Rubia peregrina* L. with whorls of four. In this species stipules are occasionally found with two midribs (fig. 79), most widely separated at the apex or even coalescing toward the base. In *Galium Aparine* L. and other species in which the number of stipules is abnormal, we may suppose this condition to have arisen from a repetition of the process of division which has produced the six-leaved whorls. This is not improbable, since even in the four-leaved forms the stipules have already entirely lost their original morphological character and have taken on a more generalized nature, making them fit material for development along new lines of evolution. Embryological evidence is not wholly wanting, although the family stands so near the head of the plant series. In

Galium Aparine L., in common with the six-leaved species, the earlier whorls are of four leaves only, representing the ancestral condition. In *Rubia tinctorium* L., the opposite leaves of the subterranean portion of the stem are exstipulate. At the first aërial node there is a whorl of four, interpetiolar stipules being present, and in the higher whorls there are six leaves.* This is a series of long range, though lacking in intermediate steps.

Another case in which there is present a nodal girdle from which the stipular bundles arise is that of *Humulus Lupulus* (fig. 80), but there are three bundles in each leaf-trace. They are placed at about equal distances around the circumference of the stem, and the girdle-bundles proper occupy only about one-third of the periphery on each side. From them a part of the stipular bundles arise, the remainder originating directly from the lateral bundles of the leaf-traces.

It would be to small purpose that examples should be further multiplied. From those already cited we may confidently deduce the following conclusions:

1. The sheathing petiole has its origin independently of the true petiole and is formed by a concomitant development of the lateral and central-basal portions of the primitive leaf.

2. The ligule is a special development of the apical parts of the lateral portions of the primitive leaf along the ridge between the sheathing petiole and the distal parts of the leaf. It may be supplied with veins either by the marginal bundles of the sheath or by tangential branches from those entering the blade. The sheathing petiole may disappear by degeneration, rendering the ligule axillary as in many species of *Potamogeton*.

3. The ochrea is related to the ligule and is generally associated with the sheathing petiole. It consists of the apical tissues developed in those cases where the sheathing petiole completely surrounds the stem or did so in the ancestral condition. The part of the ochrea posterior to the lamina or petiole may be called its ligular portion and is usually supplied by bundles arising tangentially from the main ones.

4. The lateral portions of the primitive leaf, when separated in greater or less degree, constitute stipules in the usual acceptation of the term. They are variously modified by subsequent evolu-

*Sir John Lubbock. Jour. Lin. Soc. Lond. 30 : 504. 1894.

tionary changes, by increased development, by basal or total degeneration, by secondary adnations and various textural modifications. They receive their vascular bundles typically as branches of the lateral ones of the leaf-trace.

5. The lateral portions of the primitive leaf therefore represent in potential the ligule, the ochrea, the margins of sheathing petioles and stipules, but they are often incorporated with the other portions as the wings of petioles and as lateral basal portions of leaf-blades.

II.—*The Ascidian Half-Embryo.*

BY HENRY E. CRAMPTON, JR.

Read March 8, 1897.

The development of isolated blastomeres of the ascidian egg has afforded a subject of considerable discussion on the part of many theoretical embryologists. Chabry* approached the subject from the experimental side, and, from the results of his many detailed observations and experiments, was led to the conclusion that one of the isolated blastomeres of the two-celled stage produced a strict half-embryo. As it was well known that the first cleavage-plane divided the egg into right and left halves, this conclusion seemed altogether probable and of considerable interest.

A number of writers, however, among them Hertwig,† Driesch,‡ Weismann,§ Barfurth‖ and Roux,¶ were led, on the grounds of Chabry's results, to opinions more or less at variance with his. Barfurth considered Chabry to be in greater part correct. Roux and Weismann believed that during the later development the missing part was supplied by the other cells through "postgeneration." Hertwig states that, in his opinion, Chabry was in error; and Driesch also argued that a typical total development occurred. Finally, Driesch** in 1893 repeated Chabry's experiments, upon the eggs of *Phallusia mammillata*, and by the results wholly confirmed the theoretical conclusions of his previous paper.

* Chabry L. Contribution à l'embryologie normale et teratologique des ascidies simples. Journ. de l'anat. et de la phys. XXIII. 1887.

† Hertwig, R. Urmund und Spina bifida. Arch. f. mikr. Anat. XXXIX. 1892.

‡ Driesch, H. Der Werth der beiden ersten Furchungszellen in der Echinodermentwickelung. Zeit. f. wiss. Zool. LIII.

§ Weismann, A. Das Keimplasma. 1882.

‖ Barfurth, D. Halbbildung oder Ganzbildung von halber Grösse. Anat. Anz. VIII. 1893.

¶ Roux, W. Über des entwickelungsmechanische Vermögen jeder der beiden ersten Furchungszellen des Eies. Verhandl. d. Anat. Ges. Wien. 1892.

** Driesch, H. Von der Entwickelung einzelner Ascidienblastomeren. Archiv für Entwick. der Organismen. I. 3. 1895.

Although at that time reluctant to admit anywhere the occurrence of " partial " development, Driesch has since proved, in connection with Morgan, the existence of a partial *early* development in the ctenophore egg.* And in a recent paper by the writer † it has been shown that the isolated blastomere of the snail possesses the power of forming only a corresponding portion of an embryo. In a later paper, Driesch,‡ developing an idea suggested by Prof. E. B. Wilson and myself (loc. cit.), recognized the existence of a series among animal eggs, from the nearly isotropic eggs of the medusa, Amphioxus, fish, sea-urchin, etc., at one extreme, to forms such as the frog and ctenophore, and finally to the snail, at the other extreme, where the blastomere possesses such an organization that but a part of an embryo can be formed and postgeneration cannot occur.

The ascidian egg, however, remained unexplained by the contradictory results of Chabry and Driesch. From this consideration the author was led to an examination of the facts in another ascidian. The results will, it is hoped, clear up the confusion to some extent, and will show how far the development is a " partial " one and in what respects it is " total."

The experiments were performed during the past summer at the Marine Biological Laboratory, Wood's Holl, upon the eggs of *Molgula manhattensis*, which grows very abundantly upon the piles and wharves at New Bedford, Mass. Artificial cross-fertilization was resorted to, and the eggs at the desired stage were spurted in a watch-glass by means of a fine spiral pipette.§ Those eggs presenting isolations were placed separately in watch-glasses, and camera drawings of successive stages were made at intervals, using a Zeiss oc. 4, and obj. C.

As to nomenclature, the system proposed by Kofoid || and ap-

* Driesch, H., and Morgan T. H. Von der Entwickelung einzelner Ctenophorenblastomeren. Archiv für Entwick. der Organismen. II. 2. 1895.

† Crampton, H. E., Jr. Experimental Studies on Gasteropod Development, with an appendix on Cleavage and Mosaic Work, by E. B. Wilson. Archiv für Entwick. der Organismen. III. 1. 1896.

‡ Driesch, H. Betrachtung über die Organisation des Eies und ihre Genese. Archiv für Entwick. der Organismen. IV. 1. 1896.

§ As previously described in connection with the gasteropod experiments.

|| Kofoid, C. On some laws of Cleavage in Simax. Proc. Amer. Acad. Arts and Sciences. Vol. XXIX. 1894.

plied by Castle * to the *Ciona* egg has been used for obvious reasons. According to this system, now well known, each cell is designated by a letter referring to the particular quadrant of the four-cell stage from which it arose; in addition it receives an exponent denoting the generation to which it belongs, and a second exponent denoting its place in that generation, counting from below upward.

Detailed Description of Cleavage.

A. *Normal Cleavage.*—The cleavage of the *Molgula* egg is precisely the same as that of *Ciona* and other ascidians, as far as it has been followed. Therefore, it is unnecessary to discuss the normal phenomena further than to emphasize a few of the facts which are important in connection with the cleavage of the fragments.

The first and second cleavage-planes are meridional, while the third is equatorial. An eight-cell stage results (fig. 1) which, seen from the side, consists of two tiers of four cells each. The upper tier is shifted anteriorly upon the lower, so that the *posterior upper* cells are in contact with the *anterior ventral* cells. This relation is constant, and characteristic of probably all ascidian eggs (Castle. loc. cit., p. 228). Passing to the 16-cell stage, all the eight blastomeres divide. The spindle axes are inclined in such a manner that the *anterior* products of the *anterior* cells (fig. 2: $B^{5\cdot2}$, $b^{5\cdot4}$) lie slightly *below* the median products; while the *posterior* products of the *posterior* cells lie slightly *above* the other cells (fig. 2: $C^{5\cdot1}$, $c^{5\cdot3}$). When activity is again resumed, the dorsal cells remain quiescent, while the ventral cells segment, and a 24-cell stage results (fig. 3). After a period of rest the dorsal cells pass into the same generation (sixth) with the ventral cells, and a morula of 32-cells results. Then the ventral cells divide at about the same time, while the dorsal cells remain quiescent, giving a 48-cell stage.

Further details are unnecessary for our purpose. We emphasize the fact that, beginning with the 16-cell stage, there is a well-marked alternation of activity between the cells of the upper and those of the lower hemisphere of the embryo.

* Castle, W. E. The Early Embryology of Ciona intestinalis. Bulletin of Mus. of Comp. Zool. Harvard. Jan. 1896.

B. *Cleavage of the $\frac{1}{2}$ blastomere.*—As is well known, the isolation of an ascidian blastomere is effected by the death of its neighboring cell or cells, and not by an actual separation. The dead cell partially disintegrates and exerts upon the living cell no modifying influence, such as mechanical obstruction to rounding during division, etc.

$\frac{2}{4}$. At the normal time, viz: at the time of division of control eggs, the injured blastomere divides about equally (figs. 4 and 13). Often when the eggs are operated upon when passing into the 4-cell stage, evidence of division in the dead cell will remain. In such cases the division plane of the living cell is seen to be meridional and at right angles to the first. Therefore, it corresponds with the second cleavage-plane of the normal embryo. In all cases where it is possible to ascertain the facts this relation obtains. Driesch finds in *Phallusia* that no such constancy of relation exists.

$\frac{4}{8}$. After a normal period of rest the two cells divide at the same time. There are thus produced four cells which are arranged in a manner exactly similar to the half of a normal 8-celled embryo. Seen from the side (figs. 5, 9) the cells lie so that two are separated, while two are in contact; these latter are the posterior dorsal and the anterior ventral cells, as shown by the succession of the cleavage planes of the fragment. Precisely as in the normal 8-celled embryo, there is an anterior shifting of the dorsal cells upon the lower cells. According as this shifting is to the right or left, in lateral view, one is confronted by a right or left half-embryo. From a comparison of the figures, it is seen that the embryo in fig. 5 is the same as the half turned toward the observer of fig. 1; while that shown in fig. 9 is derived from a right $\frac{1}{2}$ blastomere. The appearance of the $\frac{4}{8}$ embryo in end view is shown in fig. 14, and a characteristic crossing of the spindle axes is exhibited, which is similar to their crossing in the complete egg (vide Castle for figures). The four-celled fragment, then, is in nowise a counterpart of the normal four-celled embryo, but, on the contrary, corresponds in *every* particular to the half of an eight-celled embryo.

From Chabry's fig. 106, it appears that a typical $\frac{4}{8}$ stage occurs also in *Ascidiella*.

$\frac{8}{16}$. At the next cleavage, all the cells divide (figs. 6, 10). Exactly as in the origin of corresponding normal cells, (fig. 2) the *anterior* products of the *anterior* cells (fig. 6 : $B^{5 \cdot 1}$, $b^{5 \cdot 3}$; figs. 10 and 16: $A^{5 \cdot 1}$, $a^{5 \cdot 3}$) lie slightly below the other cells ; and the *posterior* products of the *posterior* cells (fig. 6 : $C^{5 \cdot 2}$, $c^{5 \cdot 4}$; figs 10 and 16 : $D^{5 \cdot 2}$, $d^{5 \cdot 4}$) lie slightly above the median products. On a comparison of fig. 6 and fig. 2, it will be seen, however, that the topographical relations of the cells of the fragment are quite different from the normal. For example in fig. 6, the cell $c^{5 \cdot 4}$ is in contact with $B^{5 \cdot 1}$ and $b^{5 \cdot 3}$, while in the normal egg it lies at the other end of the embryo. A similar rearrangement is still better shown in fig. 10, that of a right $\frac{8}{16}$ embryo, where $D^{5 \cdot 2}$ is in contact with $A^{5 \cdot 1}$, while $d^{5 \cdot 4}$ is in contact with $A^{5 \cdot 1}$ and $a^{5 \cdot 3}$. This rearrangement is obviously rendered possible by the absence of the other half of the embryo, so that the cells cohere in a spherical form just as a corresponding number of soap-bubbles. It cannot be considered as a "gliding," for the spindle-axes are from the first accommodated to the changed conditions. That is (figs. 15, 16), the anterior end of the anterior spindles, and the posterior ends of the posterior mitotic figures are swung somewhat toward the original first cleavage-plane of the embryo.

Chabry's fig. 113 leaves no doubt that the $\frac{8}{16}$ embryo of *Ascidiella* is precisely the same as that described above for *Molgula.* From Driesch's fig. 5, there is no doubt that in *Phallusia* the eight cells are arranged as the normal 8 cells.

$\frac{8}{16}-\frac{12}{24}$. When activity is again resumed, only the four lower cells are affected, while the dorsal cells remain quiescent. A 12-celled fragment results (figs. 7 and 11), which is exactly equivalent to a half of the normal 24-cell stage (fig. 3). The quiescence of the dorsal cells during the division of the ventral cells is the first indication of the alternation of activity in the rhythm of cleavage, which was found to be characteristic of this type of segmentation. As in the preceding stage, when the resting condition is assumed, there is a passive rearrangement of the cells. For example, the cells $A^{6 \cdot 3}$ and $A^{6 \cdot 4}$ were segmented along an axis inclined at an angle of 45° to the axis joining their centres at the resting stage. Again the cells $D^{6 \cdot 3}$ and $D^{6 \cdot 4}$ have retreated around the posterior end of the fragment.

$\frac{16}{32}$. While the eight cells of the lower hemisphere are resting, the four dorsal cells likewise pass into the sixth generation, and a $\frac{16}{32}$ stage results (figs. 8, 12). Its resemblance to the half of a normal 32-cell stage is still less marked than that of a $\frac{12}{24}$ embryo to a half of the normal 24-celled stage. This is so, for the reason that further passive rearrangements of the cells occur, obscuring the partial character of their origin, and causing the cell complex in its solid, or "complete," condition to resemble a normal or "complete" embryo. Nevertheless, the succession of rhythmic cleavages, relation of successive cleavage-planes, etc., point to the operation of factors which are counterparts of those operating in a *half* of the normal embryo.

Later development. The embryo is now "complete," and gives rise to a complete blastula and larva. Although the process of gastrulation has not been carefully observed, enough of the later development has been ascertained to prove that a larva arises which resembles the normal larva, except as regards its smaller size and certain minor defects. My results, therefore, are entirely confirmatory of those of Driesch upon *Phallusia.*

C.—*Cleavage of the $\frac{1}{4}$ blastomeres.*—One of the isolated blastomeres of the four-cell stage, is divided at the next cleavage by a plane which is seen to be at right angles to both of the preceding planes. Therefore it corresponds to the third cleavage plane of the normal embryo. The $\frac{2}{8}$ stage is shown in fig. 17. A subsequent cleavage cuts each of the cells equally, and a $\frac{4}{16}$ stage results (figs. 18, 19), until this time, one is left in doubt as to the true nature of the fragment, that is, whether it will segment as a quarter or as an entire egg. However, from this time on, the character of cleavage is exactly that of a quadrant of a normal embryo.

When division next occurs, only the two cells toward the observer segment (fig. 20), and a stage of six cells results, which is evidently comparable to a $\frac{6}{24}$ embryo only, and not to any stage of the normal development. After a normal period, the dorsal cells (lower in the figure) pass into the sixth generation, and an $\frac{8}{32}$ embryo (fig. 21) is the result. As in the previously described fragments, passive rearrangements occur when the resting condition is assumed, and the cells flatten down upon one another (fig. 22). The cells of the ventral half segment at the next period of activity (fig. 23), while the dorsal cells remain undivided. The resulting $\frac{12}{48}$ stage, although solid, is nevertheless derived from the $\frac{1}{4}$ blastomere through a segmentation of a partial character. This partial character is expressed chiefly in the characteristic rhythm of cleavage.

Concerning the later stages, the results of Driesch are again confirmed. The young larvæ represented in Figs. 25, 26 of this paper illustrate one point further, although of minor consequence. It will be seen that the long axis of the $\frac{1}{4}$ larva in fig. 25, and the long axes of the $\frac{1}{4}$ larvæ derived from the same egg, in fig. 26, are approximately parallel to the principal dorso-ventral-axis of the original egg.

Summary and Conclusion.

An isolated blastomere of the Molgula egg segments as if still forming a corresponding part of an entire embryo. The *cleavage phenomena* are strictly *partial*, as regards the origin of cells, the inclination of cleavage-planes, and especially in respect to the rhythm of segmentation. The general appearance of the fragment differs materially from that of a half of a complete embryo, for the reason that rearrangements of the blastomeres occur, which tend progressively to mask the partial nature of development. The end result is a larva of less than normal size, and with defects in certain of its systems. These defects are undoubtedly due to the fact that but a portion of the normal amount of material is available for the formation of the larva; that, for instance, the chorda of a larva derived from a one-half blastomere, receives but one-half of the normal number of cells, and consequently a chorda of one row, and not two rows of cells, results.

In conclusion, one is constrained to adopt the view of Roux-namely, that in Molgula as in the well-known case of the echino, derms (Driesch, Wilson, and others) the development begins as a partial one, but that the missing part is gradually supplied by the cells already present. Driesch is also entirely correct, as far as the end result, a nearly complete larva, is concerned.

Explanation of Plate IV.

Magnification of figs. 1–3 about 280 diameters; of all other figures, 250 diameters. The arrows show the direction of cleavage.

Fig. 1, 8-cell stage of *Ciona* from Castle (fig. 23), from the left side.

Fig. 2, 16-cell stage of *Ciona* from Castle (fig. 24), from the left side.

Fig. 3, 24-cell stage of *Ciona* from Castle (fig. 43), from the right side.

Figs. 4–8, cleavage of the left $\frac{1}{2}$ blastomere of *Molgula*, from the side.

Fig. 4, $\frac{2}{4}$ embryo.

Fig. 5, $\frac{4}{8}$ embryo.

Fig. 6, $\frac{8}{16}$ embryo.
Fig. 7, passage to $\frac{12}{24}$ embryo.
Fig. 8, $\frac{16}{32}$ embryo.
Figs. 9–12, cleavage of the right $\frac{1}{2}$ blastomere, from the side.
Fig. 9, $\frac{4}{8}$ embryo.
Fig. 10, $\frac{8}{16}$ embryo.
Fig. 11, $\frac{12}{24}$ embryo.
Fig. 12, $\frac{16}{32}$ embryo.
Figs. 13–16, cleavage of the right $\frac{1}{2}$ blastomere, from the front.
Fig. 13, $\frac{2}{4}$ embryo.
Fig. 14, $\frac{4}{8}$ embryo.
Fig. 15, passage to $\frac{8}{16}$ embryo.
Fig. 16, complete $\frac{8}{16}$ embryo.

Explanation of Plate V.

Figs. 17–24, cleavage of the $\frac{1}{4}$ blastomere, ventral view.
Fig. 17, $\frac{2}{8}$ embryo.
Fig. 18, passage to $\frac{4}{16}$.
Fig. 19, complete $\frac{4}{16}$.
Fig. 20, $\frac{6}{24}$ embryo.
Fig. 21, $\frac{8}{32}$ embryo, immediately after division.
Fig. 22, $\frac{8}{32}$ embryo, in resting condition.
Fig. 23, passage to $\frac{12}{48}$ stage.
Fig. 24, complete $\frac{12}{48}$ embryo.
Fig. 25, $\frac{1}{4}$ larva. The arrow indicates the long axis.
Fig. 26, two $\frac{1}{4}$ larvæ, from same egg. The arrows indicate the principal axes.

III.—*The Rutherfurd Photographic Measures of Sixty-five Stars near 61 Cygni.*

BY HERMAN S. DAVIS.

Read May, 1897.

1. It was but natural that MR. RUTHERFURD, in developing the art of astronomical photography, should try his skill upon that star which has attracted the attention of so many investigators ever since BESSEL proved by it the possibility of determining stellar parallax.

Of these photographs of *61 Cygni* and its surrounding stars taken by Mr. RUTHERFURD, nineteen, exposed between 1871, Nov. 9, and 1874, June 13, were measured by Miss Ida Martin more than twenty years ago, but have remained unreduced until recently placed in my hands for that purpose by Professor J. K. REES, Director of the Observatory. The present paper contains the results of measures of position of stars surrounding *61 Cygni*, and will be followed by a second paper containing the results of an investigation of the *Parallax of* 61^1 *Cygni.* The methods of reduction used so far as measures of distance are concerned are those presented by Dr. HAROLD JACOBY in earlier *Contributions* from this Observatory.

2. In Table I are given the general data of exposure of the plates, including the computed values of the zenith-distance, parallactic angle and refraction factor.

3. Table II contains the *means* of the refractions computed for the Eastern and Western impressions from the data of Table I by the formulæ

$$\frac{\sigma - s}{s} = \kappa \left[\tan^2 \zeta \cos^2 (p - q) + 1\right]$$

$$\pi - p = -\tfrac{1}{2}\kappa \operatorname{cosec} 1'' \tan^2 \zeta \sin 2 (p - q).$$

The argument for entering this table is p.

4. Table III.—The corrections to the position-angle due to precession, nutation and aberration will be found in column two. These were computed by the formulæ

$$\alpha' = 20.''06 \sin \alpha \sec \delta \qquad \gamma' = \cos \alpha \tan \delta$$
$$\beta' = \cos \alpha \sec \delta \qquad \delta' = \sin \alpha \tan \delta$$
$$\Delta p = (T - t)\, \alpha' - A\alpha' - B\beta' - C\gamma' - D\delta'.$$

The epoch $T = 1873.0$ has been selected to which to reduce all the observations. The substitution of the coördinates of *61*[1] *Cygni* for this epoch gives:

$$\Delta p_{71} = -36'' + [1.254]\, A + [9.956_n]\, B + [9.746_n]\, C + [9.742]\, D.$$
$$\Delta p_{72} = -18 + [1.254]\, A + [9.956_n]\, B + [9.746_n]\, C + [9.742]\, D.$$
$$\Delta p_{73} = 0 + [1.254]\, A + [9.956_n]\, B + [9.746_n]\, C + [9.742]\, D.$$
$$\Delta p_{74} = +18 + [1.254]\, A + [9.956_n]\, B + [9.746_n]\, C + [9.742]\, D.$$

Where Δp_{71} denotes the correction to be applied to the position-angle for the plates made in 1871, and so on in the other years as denoted by the subscripts.

5. Precession and nutation have no effect upon the distances; but aberration does have, and its amount is given by:

$$\gamma'' = (\tan \varepsilon \sin \delta + \sin \alpha \cos \delta) \sin 1''$$
$$\delta'' = -\cos \alpha \cos \delta \sin 1''$$
$$\Delta s = (C\gamma'' + D\delta'')\, s$$

For *61*[1] *Cygni* this becomes

$$\Delta s = \{ [4.141_n]\, C + [4.433_n]\, D \}\, s \qquad \text{for all years,}$$

and is additive to the distances to reduce them to 1873.0. This factor of *s* is given in column three of Table III.

6. The logarithms of the Besselian day-numbers, taken from the *American Ephemeris*, are:

Plates.	log A.	log B.	log C.	log D.
1,	9.692	0.035_n	1.104	1.178
2, 3,	9.699	0.022_n	1.077	1.198
4,	9.774	0.583_n	0.840	1.279
5, 6,	9.816	0.580_n	0.244	1.309
7,	9.821	0.582_n	0.038	1.310
8, 9,	9.788	0.807_n	1.043	1.218
10,	9.800	0.802_n	0.985	1.244
11, 12, 13,	9.805	0.801_n	0.958	1.253
15,	9.336	0.857_n	0.776_n	1.287_n
16, 17,	9.411	0.854_n	0.418_n	1.306_n
18, 19, 20.	9.417	0.854_n	0.364_n	1.307_n

7. In the second portion of Table III. is given the mean of the

East and West zero-corrections computed for each by the formula *

$$v = \frac{1}{2} k z \tan \delta - y + x$$

in which v is the zero-correction to be added to all observed position angles of each plate.

In the next column are the special corrections † required by the position-angles of the Western impressions in consequence of using the same zero-point in measuring both Eastern and Western impressions.‡ The sum of these two columns is then given in column six, which, therefore, contains the final correction as actually applied in the reductions.

8. In Table IV. is given the tangent correction. This is always negative and its unit is .0001 divisions of the micrometer. It has been computed by the formula:

$$\text{Correction} = -\frac{1}{3} s^3 d^2 \sin^2 1'' = [1.7887_n] s^3$$

where s denotes the distance in divisions of the glass scale and d is the value of one division of the scale in seconds of arc.

Table V.—Measures of Distance.

9. The first column contains the numbers of the stars in order of right ascension and also in parentheses, for convenience of reference to the original measures and plates, are the numbers as assigned by Rutherfurd. The number of the plate is given in column two, after which follows the *observed* distances for the Eastern and Western impressions. The numbers set down are the fractional part of the measured distance expressed in divisions of the glass scale, the whole number of divisions being ordinarily the same as that given in the *final corrected distance.* Where there is a change of .8 or .9 in the observed distance, it is an indication of a change of a unit in the whole number of divisions in passing from the observed distance to the corrected mean. In columns five, six and seven are placed the corrections as applied for refraction,§ aberration‖ and scale¶ respectively; these, with addition of

* Annals N. Y. Acad. of Sci., Vol. VI., p. 272.

† Ibid., p. 278.

‡ Ibid., p. 240.

§ Table II and Paragraph 2.

‖ Table III and Paragraph 4.

¶ *Pleiades*, pp. 242–251.

the tangent correction only—which may be obtained directly from Table IV, being practically constant for each star—present all the corrections which have been applied to the observed *mean* distance of the East and West impressions to get the *corrected mean* of column eight.

10. It is noticeable that among these corrected means the distances belonging to some of the plates are always larger than the average and to other plates always smaller. To get rid of this variation of scale value, whatever may be its cause, I have selected the following four stars as standards:

No.	Distance.	sin p.	cos p.
5	77.2926	—0.998	+0.054
23	89.2118	—0.068	+0.998
32	77.0019	+0.127	—0.992
48	50.7333	+0.962	—0.274
Sums	294.2396	+0.02	—0.21

Now, if s_5, s_{23}, s_{32}, s_{48} represent the distances of stars 5, 23, 32 and 48 from *61*[1] *Cygni* on any given plate and Σs_s the sum of the standard distances, there must be added to every distance on that plate for any other star its proportional part of the difference between the mean of the sums of the distances of the standard stars and their separate sums for that particular plate, or:

$$\text{Scale variation} = \frac{\Sigma s_s - (s_5 + s_{23} + s_{32} + s_{48})}{\Sigma s_s} s$$

The following table gives the value of this coefficient of s for each plate. The individual values of *scale variation* are given in column nine of Table V.

Plate.	Scale Variation Factor × 10^3.
1	+ .1948
2	+ .2275
3	+ .1666
4	— .0027
5	+ .0439
6	+ .0894
7	+ .0928
8	— .1272
9	— .0442
10	— .0408
11	— .0714
12	— .0598
13	— .0129
15	— .1047
16	— .0670
17	— .0714
18	— .0537
19	— .0326
20	— .1241

11. The measures of distance are next to be corrected for the proper motion of the central star. For this purpose let:

$t =$ date of the plate.
$\tau = t - 1873.0$
$\rho =$ annual motion on great circle
$\chi =$ position-angle of that great circle
$S_1 = \cos(\chi - p)$
$S_2 = -\frac{1}{2s}\sin^2(\chi - p)$
$P_1 = \tau\rho$
$P_2 = \tau^2\rho^2$

The correction for proper motion, additive to observed distances, will then be:

$$\Delta s = S_1 P_1 + S_2 P_2$$

I have adopted Auwers's values of

$\mu = +0\overset{s}{.}3444,$ $\mu' = +3\overset{''}{.}230,$

as given in the *Fundamental Catalog*. Corresponding to these are:

$\rho = 5\overset{''}{.}1904 = 0\overset{d}{.}18528,$ $\chi = 51^\circ 30' 56''$

The values of p used in the above formulæ were the means after correction for "zero" and refraction, as explained in paragraph 7; and the values of s were after correction for scale variation.

12. The values of S_1 and S_2 will be found in columns two and three of Table VII. The following table gives τ, P_1, and P_2:

Plate.	τ	For Proper Motion. P_1	P_2
1	— 1.142	— 0.2116	+ 0.045
2	— 1.134	— 0.2101	+ 0.044
3	— 1.134	— 0.2101	+ 0.044
4	— 0.085	— 0.0157	+ 0.000
5	— 0.041	— 0.0076	+ 0.000
6	— 0.041	— 0.0076	+ 0.000
7	— 0.036	— 0.0067	+ 0.000
8	+ 0.876	+ 0.1623	+ 0.026
9	+ 0.876	+ 0.1623	+ 0.026
10	+ 0.890	+ 0.1649	+ 0.027
11	+ 0.895	+ 0.1658	+ 0.027
12	+ 0.895	+ 0.1658	+ 0.027
13	+ 0.895	+ 0.1658	+ 0.027
15	+ 1.418	+ 0.2627	+ 0.069
16	+ 1.448	+ 0.2683	+ 0.072
17	+ 1.448	+ 0.2683	+ 0.072
18	+ 1.451	+ 0.2688	+ 0.072
19	+ 1.451	+ 0.2688	+ 0.072
20	+ 1.451	+ 0.2688	+ 0.072

13. As the quantity which depends on the square of the time is always small for a star having even so large a proper motion as *61 Cygni*, its values may be tabulated for limiting values of S_2. Such a table as used in the present paper is:

$S_2 P_2$ \ Plates	1	2, 3	4, 5, 6, 7	8, 9	10, 11, 12, 13	15	16, 17, 18, 19, 20
	.0	.0	.0	.0	.0	.0	.0
— .0000							
	11.2	11.3	140.0	19.0	18.2	7.2	6.9
— 1							
	33.5	34.0		57.0	54.8	21.7	20.7
— 2							
	55.8	56.7		95.0	91.2	36.2	34.7
— 3							
	78.2	79.3		133.1	127.8	50.7	48.5
— 4							
	100.5	102.0			164.2	65.2	62.4
— 5							
	122.8	124.6			200.8	79.7	76.2
— 6							
	145.1	147.3				94.2	90.1
— 7							
						108.7	104.0
— 8							
						123.2	117.8
— .0009							
						137.7	131.7

The figures at the tops of the columns are the numbers of the plates to which the columns are applicable as determined by their values of P_2. Selecting, therefore, the proper column and using S_2 as the argument in the body of the table (where it is expressed in units of the fourth decimal place), one will find in the first column the desired value of $S_2 P_2$, expressed in divisions of the scale. Column ten of Table V gives the total proper motion correction.

14. A correction for parallax of the principal star was next applied. Using AUWERS's values of the coördinates of *61*[1] *Cygni* reduced to 1873.0

$$\alpha = 21^{h}\ 01^{m}\ 12^{s}.329$$

$$\delta = 38^{\circ}\ 07'\ 33''.40$$

and the almanac values of r and $\odot$, the radius vector and longitude of the sun respectively, the values of S_3, S_4, P_3 and P_4 were computed by the formulæ

$$g \sin G = \sin \delta \cos \alpha \qquad h \sin H = \sin \delta \sin \alpha$$

$$g \cos G = \sin \alpha \qquad h \cos H = -\cos \delta$$

$$f \sin F = h \sin (H + \varepsilon)$$

$$f \cos F = -\cos \alpha \cos \varepsilon$$

$$S_3 = f \sin (p + F)$$

$$S_4 = g \sin (p + G)$$

$$P_3 = -r \sin \odot$$

$$P_4 = -r \cos \odot$$

The value of p used here was the mean of the position-angles after correction for proper motion and orientation variation, as described in paragraphs 17 and 19. The values of P_3 and P_4 are:

Plates.	For Parallax.	
	P_3	P_4
1	+ 0.727	+ 0.672
2	+ 0.761	+ 0.632
3	+ 0.761	+ 0.632
4	+ 0.915	+ 0.366
5	+ 0.979	+ 0.096
6	+ 0.979	+ 0.095
7	+ 0.982	+ 0.061
8	+ 0.798	+ 0.583
9	+ 0.798	+ 0.583
10	+ 0.845	+ 0.511
11	+ 0.862	+ 0.481
12	+ 0.862	+ 0.480
13	+ 0.862	+ 0.480
15	— 0.962	— 0.322
16	— 1.006	— 0.142
17	— 1.006	— 0.142
18	— 1.008	— 0.125
19	— 1.008	— 0.125
20	— 1.008	— 0.125

In Table VIII, columns two and three, will be found S_3 and S_4. The *coefficient* of the parallax, as printed in column eleven of Table V is

$$S_3P_2 + S_4P_4$$

and the correction, additive to the distances, is

$$(S_3P_3 + S_4P_4)\,\frac{\Pi}{28.''0124}$$

where Π is the parallax expressed in seconds of arc. Table XI gives values of this quantity corresponding to limiting values of the coefficient. The method of using this table is the same as described in paragraph 13. In its construction I used*

$$\Pi = +\,0.''3597$$

15. The distances thus corrected for all known disturbances affecting the central star, *61*[1] *Cygni*, are given in column twelve of Table V. In this column are also the *means* of the distances.

Table VI.—Measures of Position-angle.

16. This table has been put on pages opposite the correspond-

* The Parallax of *61*[1] *Cygni* as deduced from Rutherfurd Photographic Measures, by Herman S. Davis. *Contribution No. 13.*

ing measures of distance in Table V. The first column is a repetition of the number of the plate. In columns two and three are given the *observed* angles for the eastern and western impressions. The number of degrees for the *west* column are the same as printed in the *east* column, except where there is an obvious change of ± 1° indicated by a difference of nearly 60′ in the minutes of the two columns.

In column four are placed the zero-corrections of paragraph 7 plus the special corrections due to the precession, etc., mentioned in the same paragraph. This quantity is taken from the last column of Table III. The correction for refraction from Table II is in column five. The mean of the east and west impressions thus corrected is placed in column six.

17. In column seven of Table VI is the correction due to proper motion of the central star. This has been computed from the following formulæ: *

Let t, τ, S_1, P_1, P_2, ρ and χ have the same meaning as in paragraph 11; also let

$$S_5 = \sin(\chi - p)$$
$$S_6 = \frac{1}{\sigma}$$
$$S_7 = S_5 S_6$$
$$P_5 = \tau \rho \operatorname{cosec} 1''$$
$$K = - \left\{ P_1 \sin\chi \tan\delta + \tfrac{1}{2} P_2 \sin 1'' \sin\chi \cos\chi \, (1 + 2\tan^2\delta) \right\}$$

Then will the correction for proper motion, additive to observed angles, be

$$\Delta p = S_7 P_5 \, (1 + S_1 P_1 \cdot S_6) + K.$$

Throughout these formulæ ρ and σ are to be expressed in divisions of the scale, whereas K and Δp are in seconds of arc. The convenience of expressing Δp in this form is more noticeable when it is remembered that $S_1 P_1$ has already been computed for use in correcting the distances; see paragraph 11. Here σ is to represent the value of s after being corrected for scale variation and proper motion.

18. As K is obviously a constant for all stars on the same plate, being only that part of the variation in $(\chi - p)$ due to the

* Handbuch der Vermessungskunde von Dr. W. Jordan, Bd. III. S. 359. Vierte Auflage.

effect of meridian-convergence upon the value of χ at different dates, we have for *61*[1] *Cygni:*

$$K = -17''.2094\ P_1$$

the term in P_2 being neglected, as its maximum value in the present research is only $\pm 0.''00015$.

The following table gives K for the various plates, and also the values of P_5; while in columns four, five and six of Table VII will be found S_5, S_6 and S_7.

Plate.	For Proper Motion.	
	K	P_5
	"	
1	+ 3.6	− 43644.
2	+ 3.6	− 43338.
3	+ 3.6	− 43338.
4	+ 0.3	− 3248.
5	+ 0.1	− 1567.
6	+ 0.1	− 1567.
7	+ 0.1	− 1376.
8	− 2.8	+ 33478.
9	− 2.8	+ 33478.
10	− 2.8	+ 34013.
11	− 2.8	+ 34204.
12	− 2.8	+ 34204.
13	− 2.8	+ 34204.
15	− 4.5	+ 54191.
16	− 4.6	+ 55338.
17	− 4.6	+ 55338.
18	− 4.6	+ 55452.
19	− 4.6	+ 55452.
20	− 4.6	+ 55452.

19. *Orientation Variation.*—When the angles have been corrected as described above, observation of the *corrected mean* plus *proper motion* in Table VI reveals a variation of measures on some of the plates from the mean of all that is erratic, and in some cases very considerable in magnitude. This is undoubtedly due to the method which Rutherfurd used for the orientation of his plates.

It was his custom in making the exposures to take two impressions of the stars on each plate. After the second, or western impression, the telescope clock was stopped, and the stars were allowed to trail across the plate for a distance of sixty to eighty scale-divisions. The clock was then again made to run long enough to permit the formation of another image of the central star. The line joining this last image with the central image was used as the origin of the position-angles. Angles so measured were made in the present paper to conform to the custom of counting from the north point towards the east by addition of 270° to the observed readings, as seen in Table VI.

Of course the position-angle of this last impression of the principal star is not exactly 270°, however, unless there has been absolutely no shifting of the telescope in declination during the formation of the trail, or when clamping in the clock for the final image. It is *a priori* probable that such shifting did occur; but with such alterations in the balance-weights of the tube, in the pointing of the telescope, and in the other conditions of exposure of many plates during the course of several years, we may fairly assume, on the other hand, that such shifting in declination is not systematically in the same direction; that, consequently, the mean of the position-angles of a given star as determined from all the plates is its most probable value. Hence, if all the stars were found on all the plates, it would be unnecessary to apply a correction for error of orientation. But such is not the case. Furthermore it is desirable to use the individual measures separately for a determination of the parallax.

This correction may be deduced from standard stars by taking from the mean of all the angles of all the plates the angle measured on each plate separately, and regarding the residual as the orientation variation of that plate. For any particular star such residuals would not, however, be the true correction; for it would contain the effect of both the proper motion and the parallax of the central star. Several stars should, therefore, be selected as standards; and they should be so distributed in distance and angle as to eliminate both parallax and proper motion from the mean of their residuals for each plate severally. Since the probable error of measures of angle vary inversely as the distance, these means should be taken by weight proportional to the square of the distance.

Expressed symbolically these conditions are:

A. $$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = 0 \quad \text{and} \quad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = 0$$

B. $$\Sigma S_7 = 0.$$

The significance of S_8 and S_9 will be found in paragraph 22, and of S_7 in paragraph 17.

20. It is easily seen that both A and B cannot be satisfied at the same time, unless the direction of proper motion of the principal star coincide with the major or the minor axis of the parallactic ellipse. This fortunately is very nearly the case with *61*^{1} *Cygni;* wherefore it would have been immaterial here whether the angles of the standard stars had been corrected for proper motion or not, though as a matter of fact they were so corrected; as would ordinarily be necessary.

21. If stars can be found on all the plates which will satisfy only very closely, but not exactly, condition A, the *residuum* of the parallactic effect may be more nearly eliminated by adding to the orientation variation deduced from such stars the quantity

$$\left\{ \frac{(P_3' - P_3)\ \Sigma\sigma^2 S_8}{\Sigma\sigma^2} + \frac{(P_4' - P_4)\ \Sigma\sigma^2 S_9}{\Sigma\sigma^2} \right\} \Pi'$$

where the primed P_3' and P_4' are the means of the values of P_3 and P_4 for all the plates, and where Π' is an approximate value of the parallax, or a value deduced from the measures of distance.

In this paper the following six stars were selected as the standards:

Star	$\sigma^2 S_8$	$\sigma^2 S_9$	S_7	σ^2
5	—423898.2	+227748.4	+0.008588	5962.
6	— 90170.0	+550938.7	— .000240	9017.
13	—611921.1	—381846.5	+ .009566	9667.
23	—459811.3	—441482.6	+ .009229	7969.
32	+418587.4	+364040.6	— .011118	5929.
48	+322758.0	— 85914.0	— .016022	2580.

These give:

$$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = -20.5 \qquad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = +5.7 \qquad \Sigma S_7 = -.000003$$

which shows that they are admirably adapted to the present purpose. From these stars, therefore, and with $\Pi' = +0.''40$ have been deduced the following corrections, additive to observed position-angles.

Plate.	Orientation Variation.
	° ′ ″
1	+ 0 13
2	+ 1 0
3	+ 0 6
4	— 0 35
5	— 0 8
6	+ 0 17
7	+ 3 21
8	— 0 12
9	— 0 30
10	— 0 21
11	— 0 31
12	+ 0 11
13	+ 0 24
15	— 0 19
16	— 0 29
17	— 2 5
18	— 0 50
19	— 0 1
20	+ 0 14

22. In column eight of Table VI are given the parallax coefficients. They have been computed by the formulæ:

$$S_8 P_3 + S_9 P_4$$

where:

$$S_8 = \frac{f \text{ cosec } 1''}{28.''0124} S_6 \cos (\pi + F)$$

$$S_9 = \frac{g \text{ cosec } 1''}{28.''0124} S_6 \cos (\pi + G)$$

$$S_6 = \frac{1}{\sigma}$$

and where f, g, F, G, P_3, and P_4 have the same meaning as in paragraph 14. The value of the position-angle used here, π, is the angle p corrected for proper motion and orientation variation. The quantities S_8, S_9, and S_6 are in columns four and five of Table VIII and five of Table VII respectively. P_3 and P_4 are tabulated in paragraph 14.

23. After adding to the observed angle the correction

$$(S_8 P_3 + S_9 P_4)\ \Pi$$

taken from Table XI with the parallax coefficient of column eight, Table VI, as the argument we have the final corrected angle given in the last column of Table VI.

24. Table IX.—Column three contains the mean of the final position-angles of Table VI, and column two the mean of the distances, converted to seconds of arc by the scale value 28.″0124. These are followed in columns four and five by the differences of right ascension and of declination derived by aid of the formulæ :

	Logarithms for Plates of 61^1 *Cygni* only.
$n = \sigma \sin \pi$	
$m = \sigma \cos \pi$	
$P = \sec \delta$	$= [0.104215]$
$Q = [4.685575\ ] \tan \delta \sec \delta$	$= [4.6846\ ]$
$R = [8.89403_n\ ] \tan^2 \delta \sec \delta$	$= [8.7878_n\ ]$
$S = [8.89403\ ] \sec \delta\ (1 + 3 \tan^2 \delta)$	$= [9.4528\ ]$
$T = [4.384545_n] \tan \delta$	$= [4.2793_n\ ]$
$U = [8.59300_n\ ]\ (1 + 3 \tan^2 \delta)$	$= [9.0475_n\ ]$
$V = [3.57960_n\ ] \sec \delta \tan \delta\ (1 + 3 \tan^2 \delta)$	
$W = [3.57960\ ] \sec \delta \tan \delta\ (2 + 3 \tan^2 \delta)$	

$$\alpha' - \alpha = Pn + Qnm + Rn^3 + Snm^2 + (Vn^3m + Wnm^3)$$
$$\delta' - \delta = m + Tn^2 + Un^2m$$

where σ and π are the final corrected mean distance and position-angle respectively of the star whose α' and δ' are desired. It was found also that the terms in V and W were not needed, since they are so nearly equal and have contrary signs.

In column six is the number of plates on which the image of the star was impressed; though it is proper to state that the given position is the result of at least twenty measures of distance and twelve of position-angle for *each* plate recorded in this column.

In columns seven and eight are the *Durchmusterung* number and magnitude for as many of the stars as could be identified. A few of those found in the *Durchmusterung* but not found on these plates, though of much brighter magnitude than many which are on the plates, no doubt are missing because of their color; as obviously light from reddish stars affects the plate but little, though optically it may appear quite bright.

25. Table X is on pages opposing Table IX and gives the right ascensions and declinations of each star. These were obtained by adding the $\alpha' - \alpha$, $\delta' - \delta$ of Table X to AUWERS's position of 61^1 *Cygni* reduced to 1873.0 with the constants given in the *Fundamental Catalog:*

$$\left.\begin{array}{l} \alpha = 21^h\ 01^m\ 12^s.329 \\ \delta = 38^\circ\ 07'\ 33''.40 \end{array}\right\}\ 1873.0$$

The other columns contain the precession constants, whereby the positions of these stars may be reduced to another epoch, T, by the formulæ:

$$\alpha_T = \alpha_{1873} + J(T - 1873) + K\frac{(T - 1873)^2}{200}.$$

$$\delta_T = \delta_{1873} + L(T - 1873) + M\frac{(T - 1873)^2}{200}.$$

TABLE I.—GENERAL DATA.—Observatory of L. M. Rutherfurd, New York.

Lat. = 40° 43′ 48″.5 Long. = 4h 55m 56s.62 W

Plate.	Date.		Sidereal Time.	Hour Angle.	Barom.	Att. Therm.	Ext. Therm.	Tel. Therm.	Focus.	Zero.	ζ	q	Log. κ
			h m s	h m s		°	°	°			°	°	
1	1871	Nov. 9	0 11 5	3 9 56	29.988	45	42	45	7.7	70.38	36.32	+70.57	6.4559
2		Nov. 12	23 58 5	2 56 56	30.460	38	35	38	7.8	77.08	33.91	+71.38	6.4690
3		Nov. 12	0 28 20	3 27 11	30.460	38	35	40	7.8	77.19	39.50	+69.38	6.4685
4	1872	Nov. 29	0 18 47	3 17 35	29.748	25	22	25	8.0	69.72	37.74	+70.04	6.4706
5		Dec. 15	0 14 47	3 13 35	30.150	35	34	35	7.9	63.56	37.01	+70.31	6.4654
6		Dec. 15	1 21 2	4 19 50	30.150	35	34	35	7.8	63.18	49.07	+65.33	6.4641
7		Dec. 17	0 45 52	3 44 40	30.328	33	32	33	7.9	69.44	42.71	+68.10	6.4695
8	1873	Nov. 15	0 28 20	3 27 7	29.716	35	35	35	8.0	70.05	39.50	+69.38	6.4581
9		Nov. 15	1 8 12	4 6 59	29.716	35	35	35	7.9	76.95	46.76	+66.40	6.4574
10		Nov. 20	23 26 2	2 24 49	30.070	32	30	32	7.9	71.01	27.88	+73.13	6.4682
11		Nov. 22	23 5 47	2 4 34	30.392	38	37	40	7.8	77.15	24.10	+73.95	6.4667
12		Nov. 22	23 47 2	2 45 48	30.392	38	37	40	7.8	84.37	31.82	+72.05	6.4663
13		Nov. 22	0 24 47	3 23 33	30.392	38	37	40	7.8	70.29	38.83	+69.67	6.4660
15	1874	June 1	18 12 47	21 11 30	29.984	60	55	60	7.7	68.32	32.33	—71.88	6.4442
16		June 12	16 49 32	19 48 15	29.950	71	69	70	7.64	(63.00)	47.64	—66.03	6.4303
17		June 12	17 19 22	20 18 5	29.950	71	69	70	7.64	63.18	42.20	—68.33	6.4312
18		June 13	16 59 2	19 57 45	30.300	59	57	60	7.7	(62.88)	45.90	—66.77	6.4461
19		June 13	17 29 32	20 28 15	30.300	59	57	60	7.7	63.67	40.34	—69.07	6.4466
20		June 13	18 3 2	21 1 45	30.300	59	57	60	7.7	70.22	34.14	—71.30	6.4472

Table II.—Corrections for Refraction.

Position Angle, p.		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$	Position Angle, p.		$\frac{\sigma-s}{s}\times 10^3$	$\pi-p$
Plate 1.				Plate 2.			
			″				″
71°	251°	+.440	0.0	71°	251°	+.427	0.0
81	261	.436	− 5.4	81	261	.423	− 4.7
91	271	.422	−10.2	91	271	.411	− 8.8
101	281	.402	−13.8	101	281	.394	−11.9
111	291	.377	−15.7	111	291	.372	−13.5
121	301	.350	−15.7	121	301	.349	−13.5
131	311	.325	−13.8	131	311	.327	−11.9
141	321	.304	−10.2	141	321	.310	− 8.8
151	331	.291	− 5.4	151	331	.298	− 4.7
161	341	.286	0 0	161	341	.294	0.0
171	351	.291	+ 5.4	171	351	.298	+ 4.7
181	1	.304	+10.2	181	1	.310	+ 8.8
191	11	.325	+13.8	191	11	.327	+11.9
201	21	.350	+15.7	201	21	.349	+13.5
211	31	.377	+15.7	211	31	.372	+13.5
221	41	.402	+13 8	221	41	.394	+11.9
231	51	.422	+10.2	231	51	.411	+ 8.8
241	61	.436	+ 5.4	241	61	.423	+ 4.7
251	71	+.440	0.0	251	71	+.427	0.0
Plate 3.				Plate 4.			
			″				″
69°	249°	+.494	0.0	70°	250°	+.473	0.0
79	259	.488	− 7.0	80	260	.468	− 6.3
89	269	.471	−13.2	90	270	.453	−11.8
99	279	.444	−17.8	100	280	.429	−15.8
109	289	.411	−20.3	110	290	.400	−18.0
119	299	.377	−20.3	120	300	.369	−18.0
129	309	.344	−17.8	130	310	.340	−15.8
139	319	.318	−13.2	140	320	.317	−11.8
149	329	.300	− 7.0	150	330	.301	− 6.3
159	339	.294	0.0	160	340	.296	0.0
169	349	.300	+ 7.0	170	350	.301	+ 6.3
179	359	.318	+13.2	180	0	.317	+11.8
189	9	.344	+17.8	190	10	.340	+15.8
199	19	.377	+20.3	200	20	.369	+18.0
209	29	.411	+20.3	210	30	.400	+18.0
219	39	.444	+17.8	220	40	.429	+15.8
229	49	.471	+13.2	230	50	.453	+11.8
239	59	.488	+ 7.0	240	60	.468	+ 6.3
249	69	+.494	0.0	250	70	+.473	0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 5.				PLATE 6.			
70°	250°	+.458	″ 0.0	65°	245°	+.678	″ 0.0
80	260	.453	— 5.8	75	255	.666	—13.6
90	270	.439	—11.0	85	265	.633	—25.7
100	280	.417	—14.8	95	275	.581	—34.6
110	290	.390	—16.8	105	285	.518	—39.3
120	300	.361	—16.8	115	295	.451	—39.3
130	310	.333	—14.8	125	305	.388	—34.6
140	320	.312	—11.0	135	315	.336	—25.7
150	330	.297	— 5.8	145	325	.303	—13.6
160	340	.292	0.0	155	335	.291	0.0
170	350	.297	+ 5.8	165	345	.303	+13.6
180	0	.312	+11.0	175	355	.336	+25.7
190	10	.333	+14.8	185	5	.388	+34.6
200	20	.361	+16.8	195	15	.451	+39.3
210	30	.390	+16 8	205	25	.518	+39.3
220	40	.417	+14.8	215	35	.581	+34.6
230	50	.439	+11.0	225	45	.633	+25 7
240	60	.453	+ 5.8	235	55	.666	+13.6
250	70	+.458	0.0	245	65	+.678	0.0
PLATE 7.				PLATE 8.			
68°	248°	+.546	″ 0.0	69°	249°	+.482	″ 0.0
78	258	.539	— 8.9	79	259	.476	— 6.9
88	268	.517	—16.7	89	269	.459	—12.9
98	278	.484	—22.4	99	279	.433	—17.4
108	288	.443	—25.5	109	289	.402	—19.8
118	298	.399	—25.5	119	299	.367	—19.8
128	308	.358	—22.4	129	309	.336	—17.4
138	318	.325	—16.7	139	319	.310	—12.9
148	328	.303	— 8.9	149	329	.293	— 6.9
158	338	.295	0.0	159	339	.287	0.0
168	348	.303	+ 8.9	169	349	.293	+ 6.9
178	358	.325	+16.7	179	359	.310	+12.9
188	8	.358	+22.4	189	9	.336	+17.4
198	18	.399	+25.5	199	19	.367	+19.8
208	28	.443	+25.5	209	29	.402	+19.8
218	38	.484	+22.4	219	39	.433	+17.4
228	48	.517	+16.7	229	49	.459	+12.9
238	58	.539	+ 8.9	239	59	.476	+ 6.9
248	68	+.546	0.0	249	69	+.482	+ 0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 9.				PLATE 10.			
			″				″
66°	246°	+.612	0.0	73°	253°	+.376	0.0
76	256	.602	—11.5	83	263	.374	— 2.9
86	266	.574	—21.5	93	273	.367	— 5.5
96	276	.531	—29.0	103	283	.356	— 7.3
106	286	.477	—33.0	113	293	.342	— 8.4
116	296	.421	—33.0	123	303	.328	— 8.4
126	306	.368	—29.0	133	313	.314	— 7.3
136	316	.325	—21.5	143	323	.304	— 5.5
146	326	.297	—11.5	153	333	.296	— 2.9
156	336	.287	0.0	163	343	.294	0.0
166	346	.297	+11.5	173	353	.296	+ 2.9
176	356	.325	+21.5	183	3	.304	+ 5.5
186	6	.368	+29.0	193	13	.314	+ 7.3
196	16	.421	+33.0	203	23	.328	+ 8.4
206	26	.477	+33.0	213	33	.342	+ 8.4
216	36	.531	+29.0	223	43	.356	+ 7.3
226	46	.574	+21.5	233	53	.367	+ 5.5
236	56	.602	+11.5	243	63	.374	+ 2.9
246	66	+.612	0.0	253	73	+.376	0.0
PLATE 11.				PLATE 12.			
			″				″
74°	254°	+.352	0.0	72°	252°	+.406	0.0
84	264	.350	— 2.1	82	262	.403	— 4.0
94	274	.345	— 3.9	92	272	.393	— 7.5
104	284	.337	— 5.2	102	282	.378	—10.0
114	294	.327	— 6.0	112	292	.359	—11.4
124	304	.317	— 6.0	122	302	.339	—11.4
134	314	.308	— 5.2	132	312	.321	—10.0
144	324	.300	— 3.9	142	322	.306	— 7.5
154	334	.295	— 2.1	152	332	.296	— 4.0
164	344	.293	0.0	162	342	.293	0.0
174	354	.295	+ 2.1	172	352	.296	+ 4.0
184	4	.300	+ 3.9	182	2	.306	+ 7.5
194	14	.308	+ 5.2	192	12	.321	+10.0
204	24	.317	+ 6.0	202	22	.339	+11.4
214	34	.327	+ 6.0	212	32	.359	+11.4
224	44	.337	+ 5.2	222	42	.378	+10.0
234	54	.345	+ 3.9	232	52	.393	+ 7.5
244	64	.350	+ 2.1	242	62	.403	+ 4.0
254	74	+.352	0.0	252	72	+.406	0.0

TABLE II. CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 13.				PLATE 14.			
			$''$				
70°	250°	+.481	0.0				
80	260	.475	— 6.7				
90	270	.459	—12.5				
100	280	.434	—16.9				
110	290	.403	—19.2				
120	300	.370	—19.2				
130	310	.339	—16.9				
140	320	.314	—12.5				
150	330	.298	— 6.7				
160	340	.292	0.0				
170	350	.298	+ 6.7				
180	0	.314	+12.5				
190	10	.339	+16.9				
200	20	.370	+19.2				
210	30	.403	+19.2				
220	40	.434	+16.9				
230	50	.459	+12.5				
240	60	.475	+ 6.7				
250	70	+.481	0.0				
PLATE 15.				PLATE 16.			
			$''$				$''$
288°	108°	+.389	0.0	294°	114	+.593	0.0
298	118	.386	— 3.9	304	124	.583	—11.4
308	128	.376	— 7.4	314	134	.555	—21.5
318	138	.362	—10.0	324	144	.512	—28.9
328	148	.343	—11.3	334	154	.459	—32.9
338	158	.324	—11.3	344	164	.403	—32.9
348	168	.306	—10.0	354	174	.350	—28.9
358	178	.291	— 7.4	4	184	.307	—21.5
8	188	.281	— 3.9	14	194	.279	—11.4
18	198	.278	0.0	24	204	.269	0.0
28	208	.281	+ 3.9	34	214	.279	+11.4
38	218	.291	+ 7.4	44	224	.307	+21.5
48	228	.306	+10.0	54	234	.350	+28.9
58	238	.324	+11.3	64	244	.403	+32.9
68	248	.343	+11.3	74	254	.459	+32.9
78	258	.362	+10.0	84	264	.512	+28.9
88	268	.376	+ 7.4	94	274	.555	+21.5
98	278	.386	+ 3.9	104	284	.583	+11.4
108	288	+.389	0.0	114	294	+.593	0.0

Table II.—Corrections for Refractions. (*Concluded.*)

Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p.		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
Plate 17.				Plate 18.			
			″				″
292°	112°	+.492	0.0	293°	113°	+.576	0.0
302	122	.485	− 7.8	303	123	.567	−10.5
312	132	.466	−14.7	313	133	.541	−19.7
322	142	.437	−19.8	323	143	.501	−26.6
332	152	.400	−22.6	333	153	.453	−30.2
342	162	.362	−22.6	343	163	.402	−30.2
352	172	.326	−19.8	353	173	.353	−26.6
2	182	.296	−14.7	3	183	.314	−19.7
12	192	.277	− 7.8	13	193	.288	−10.5
22	202	.270	0.0	23	203	.279	0.0
32	212	.277	+ 7.8	33	213	.288	+10.5
42	222	.296	+14.7	43	223	.314	+19.7
52	232	.326	+19.8	53	233	.353	+26.6
62	242	.362	+22.6	63	243	.402	+30.2
72	252	.400	+22.6	73	253	.453	+30.2
82	262	.437	+19.8	83	263	.501	+26.6
92	272	.466	+14.7	93	273	.541	+19.7
102	282	.485	+ 7.8	103	283	.567	+10.5
112	292	+.492	0.0	113	293	+.576	0.0
Plate 19.				Plate 20.			
			″				″
291°	111°	+.482	0.0	289°	109°	+.409	0.0
301	121	.476	− 7.1	299	119	.405	− 4.5
311	131	.459	−13.4	309	129	.394	− 8.6
321	141	.432	−18.0	319	139	.377	−11.5
331	151	.399	−20.5	329	149	.356	−13.1
341	161	.363	−20.5	339	159	.333	−13.1
351	171	.331	−18.0	349	169	.312	−11.5
1	181	.304	−13.4	359	179	.295	− 8.6
11	191	.286	− 7.1	9	189	.284	− 4.5
21	201	.280	0.0	19	199	.280	0.0
31	211	.286	+ 7.1	29	209	.284	+ 4.5
41	221	.304	+13.4	39	219	.295	+ 8.6
51	231	.331	+18.0	49	229	.312	+11.5
61	241	.363	+20.5	59	239	.333	+13.1
71	251	.399	+20.5	69	249	.356	+13.1
81	261	.432	+18.0	79	259	.377	+11.5
91	271	.459	+13.4	89	269	.394	+ 8.6
101	281	.476	+ 7.1	99	279	.405	+ 4.5
111	291	+.482	0.0	109	289	+.409	0.0

Table III.—Corrections for Precession, etc., to 1873 and Zero Corrections.

Plate No.	Precession, etc.		Zero Correction ½ (East + West)	Special Correction Mean.	Adopted Mean.
	Position Angle Correction.	Distance Factor × 10^3			
	″		′ ″	″	′ ″
1	—25.	—.0584	+12 29	—27	+12 2
2	—24.	—.0593	13 52	—24	13 28
3	—24.	—.0593	13 58	—24	13 34
4	+ 3.	—.0611	13 1	—22	12 39
5	+ 8.	—.0576	11 57	—19	11 38
6	+ 8.	—.0576	12 12	—34	11 38
7	+ 8.	—.0568	13 9	—17	12 52
8	+20.	—.0601	13 23	—20	13 3
9	+20.	—.0601	14 50	—20	14 30
10	+21.	—.0609	13 27	—20	13 7
11	+22.	—.0611	14 34	—21	14 13
12	+22.	—.0611	15 56	—21	15 35
13	+22.	—.0611	13 27	—19	13 8
15	+21.	+.0608	12 45	—32	12 13
16	+19.	+.0584	11 27	—29	10 58
17	+19.	+.0584	11 38	—28	11 10
18	+19.	+.0582	11 29	—26	11 3
19	+19.	+.0582	11 45	—23	11 22
20	+19.	+.0582	+13 3	—25	+12 38

Table IV.—Tangent Correction.

This correction is always *negative*, and is here expressed in terms of the *fourth* decimal place of the micrometer readings.

Distance.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
20.	— 0	— 0	— 0	— 0	— 0	— 1	— 1	— 1	— 1	— 1
30.	2	2	2	2	2	3	3	3	3	3
40.	4	4	4	5	5	6	6	6	7	7
50.	8	8	8	9	9	10	10	11	11	12
60.	13	13	14	15	16	17	17	18	19	20
70.	21	22	23	24	25	26	27	28	30	31
80.	32	34	35	36	37	38	40	41	42	43
90.	45	46	48	50	52	53	55	57	59	61
100.	62	64	65	67	69	71	73	75	77	79
110.	81	83	85	87	90	93	95	98	100	103
120.	106	109	112	114	117	120	123	126	129	132
130.	—135	—138	—141	—145	—148	—151	—155	—158	—162	—165

TABLE V.—RESULTS OF MEASURES OF DISTANCE.

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
	1	.5188	.5206	479	—79	4	.5452	+262	+.0502	+0.612	134.6295
1	2	.4992	.5242	458	—80	4	.5349	+306	+.0499	+ .582	.6229
	3	.5392	.5166	479	—80	2	.5531	+224	+.0499	+ .582	.6329
(16)	5	.5864	.6211	464	—78	12	.6285	+ 59	+.0018	+ .157	.6382
	6	.5898	.6182	513	—78	5	.6330	+120	+.0018	+ .157	.6488
	7	.6063	.6018	493	—77	10	.6316	+125	+.0016	+ .129	.6474
	10	.6539	.6502	439	—82	10	.6737	— 55	—.0394	+ .490	.6351
	15	.6880	.7412	516	+82	5	.7599	—141	—.0629	— .343	.6785
	16	.5970	.6074	774	+79	6	.6731	— 90	—.0643	— .197	.5973
	17	.6227	.6303	650	+79	6	.6851	— 96	—.0643	— .197	.6087
						Mean					134.6339
	3	.7912	.7799	532	—65	112	.8357	+181	+.2096	+0.925	109.0753
2	11	.2029	.2003	384	—67	117	.2371	— 78	—.1654	+ .970	.0764
	12	.1825	.1745	438	—67	112	.2189	— 65	—.1654	+ .970	.0595
(25)	13	.1650	.1473	517	—67	112	.2045	— 14	—.1654	+ .970	.0502
	15	.2923	.2717	355	+66	106	.3267	—114	—.2621	—1.011	.0402
	19	.3074	.3010	382	+63	112	.3519	— 36	—.2682	—0.991	.0674
						Mean					109.0615
	2	.0674	.0344	474	—68	105	.0930	+260	+.2100	+0.892	114.3405
3	11	.4735	.4343	397	—70	123	.4897	— 82	—.1658	+ .950	.3279
	13	.4314	.4084	533	—70	114	.4685	— 15	—.1658	+ .950	.3134
(26)	15	.5538	.5548	361	+70	105	.5987	—120	—.2626	—1.004	.3112
	18	.5716	.5540	395	+67	107	.6106	— 62	—.2687	—0.997	.3229
						Mean					114.3232
4	2	.5200	.5410	451	—66	114	.5722	+252	+.2094	+0.868	110.8179
	12	.8999	.9155	435	—68	114	.9475	— 66	—.1653	+ .932	.7876
(27)						Mean					110.8028
5	1	.0086	.0100	327	—45	115	.0462	+150	+.1583	+0.934	77.2315
	2	.0038	.0036	320	—46	115	.0398	+175	+.1571	+ .925	.2263
(19)	3	.0032	.0030	360	—46	115	.0432	+128	+.1571	+ .925	.2250
	4	.2026	.1564	350	—47	115	.2185	— 2	+.0117	+ .827	.2406
	5	.1722	.1676	339	—44	115	.2080	+ 34	+.0057	+ .670	.2257
	6	.1544	.1458	463	—44	117	.2009	+ 69	+.0057	+ .670	.2221
	7	.1684	.1552	397	—44	115	.2058	+ 72	+.0050	+ .646	.2263
	8	.3030	.2988	352	—46	115	.3401	— 98	—.1216	+ .912	.2204
	9	.2870	.2860	438	—46	115	.3343	— 34	—.1216	+ .912	.2210
	10	.3072	.2922	289	—47	115	.3325	— 32	—.1235	+ .889	.2172
	11	.3110	.3048	271	—47	115	.3389	— 55	—.1242	+ .877	.2205
	12	.3072	.3017	307	—47	115	.3391	— 46	—.1242	+ .877	.2216
	13	.3002	.2900	355	—47	115	.3345	— 10	—.1242	+ .877	.2206
	15	.3853	.3863	300	+47	117	.4293	— 81	—.1968	— .824	.2138
	16	.3727	.3607	432	+45	116	.4231	— 52	—.2010	— .720	.2077
	17	.3793	.3739	368	+45	116	.4266	— 55	—.2010	— .720	.2109
	18	.3771	.3737	424	+45	116	.4310	— 42	—.2014	— .709	.2163
	19	.3878	.3854	358	+45	116	.4356	— 25	—.2014	— .709	.2226
	20	.3781	.3947	313	+45	116	.4309	— 96	—.2014	— .709	.2108
						Mean					77.2211

Table VI.—Results of Measures of Angle.

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	37 37 13	38 1	12 2	—16	49 23	—5 11	—41	307 44 10
2	35 58	36 24	13 28	—13	49 26	—5 9	—43	45 2
3	36 36	37 10	13 34	—18	50 9	—5 9	—43	44 51
5	33 34	33 42	11 38	—15	45 1	—0 11	—51	44 24
6	33 2	33 30	11 38	—32	44 22	—0 11	—51	44 10
7	29 2	29 22	12 52	—23	41 41	—0 10	—52	44 33
10	27 3	27 33	13 7	— 8	40 17	+4 3	—46	43 42
15	25 8	25 34	12 13	— 7	37 27	+6 26	+52	43 53
16	26 53	27 27	10 58	—18	37 50	+6 34	+54	44 14
17	28 18	28 40	11 10	—12	39 27	+6 34	+54	44 15
				Mean				307 44 19.4
3	325 11 34	12 22	13 34	+10	25 42	—0 23	+21	235 25 33
11	10 54	11 18	14 13	+ 3	25 22	+0 18	+12	25 13
12	8 2	8 58	15 35	+ 6	24 11	+0 18	+12	24 44
13	11 20	11 12	13 8	+10	24 34	+0 19	+12	25 21
15	12 55	13 37	12 13	+11	25 40	+0 29	— 3	25 49
19	13 8	13 48	11 22	+18	25 8	+0 30	+ 9	25 40
				Mean				235 25 23.3
2	319 54 34	54 28	13 28	+ 9	8 8	+0 13	+26	230 9 30
11	54 45	55 27	14 13	+ 4	9 23	—0 10	+17	8 48
13	55 22	55 25	13 8	+13	8 45	—0 10	+17	9 5
15	57 15	58 12	12 13	+10	10 6	—0 16	— 8	9 28
18	57 48	59 32	11 3	+25	10 8	—0 16	+ 3	9 3
				Mean				230 9 10.8
2	316 42 20	43 42	13 28	+10	56 39	+0 35	+30	226 58 25
12	42 20	43 42	15 35	+ 9	58 45	—0 27	+22	58 37
				Mean				226 58 31.0
1	3 0 28	1 28	12 2	—11	12 49	—6 12	—26	273 6 41
2	2 58 36	59 32	13 28	— 9	12 25	—6 9	—30	7 5
3	59 6	59 40	13 34	—15	12 42	—6 9	—30	6 28
4	55 20	55 48	12 39	—13	8 0	—0 28	—51	6 39
5	55 50	56 35	11 38	—12	7 38	—0 13	—66	6 53
6	55 4	56 52	11 38	—33	7 3	—0 13	—66	6 43
7	50 38	51 27	12 52	—20	3 34	—0 12	—68	6 19
8	49 32	49 50	13 3	—15	2 29	+4 44	—35	6 48
9	48 3	48 53	14 30	—26	2 32	+4 44	—35	6 33
10	48 35	49 33	13 7	— 5	2 6	+4 49	—41	6 19
11	47 56	48 22	14 13	— 4	2 33	+4 50	—43	6 37
12	45 58	46 20	15 35	— 8	1 36	+4 50	—43	6 22
13	48 28	49 23	13 8	—13	1 51	+4 50	—43	6 50
15	46 7	47 10	12 13	+ 6	58 57	+7 40	+56	6 38
16	47 32	47 38	10 58	+23	58 56	+7 49	+66	6 40
17	48 15	49 23	11 10	+13	0 12	+7 49	+66	6 20
18	46 56	47 58	11 3	+20	58 50	+7 50	+67	6 14
19	46 37	47 11	11 22	+12	58 28	+7 50	+67	6 41
20	45 18	45 46	12 38	+ 7	58 17	+7 50	+67	6 45
				Mean				273 6 36.6

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Coefficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s				σ
6	1	.6858	.6818	401	—55	131	.7262	+185	+.2115	+0.871	94.9674
	2	.6928	.6910	393	—56	130	.7333	+215	+.2100	+ .892	.9763
(24)	3	.6920	.6812	455	—56	130	.7342	+158	+.2100	+ .892	.9715
	4	.8981	.8831	437	—58	134	.9365	— 3	+.0157	+ .971	.9644
	5	.9014	.8962	423	—55	138	.9441	+ 42	+.0076	+ .962	.9683
	6	.8773	.8578	626	—55	132	.9326	+ 85	+.0076	+ .962	.9611
	7	.8896	.8944	503	—54	138	.9454	+ 88	+.0067	+ .956	.9732
	8	.0688	.0660	445	—57	134	.1143	—121	—.1623	+ .916	.9517
	9	.0571	.0546	561	—57	135	.1145	— 42	—.1623	+ .916	.9598
	10	.0923	.0755	352	—58	134	.1214	— 39	—.1649	+ .942	.9647
	11	.0848	.0872	330	—58	134	.1213	— 68	—.1658	+ .950	.9609
	12	.0814	.0812	376	—58	136	.1214	— 57	—.1658	+ .950	.9621
	13	.0632	.0488	444	—58	134	.1027	— 12	—.1658	+0.950	.9479
	15	.1924	.1991	300	+58	132	.2394	—100	—.2626	—1.005	.9539
	16	.1892	.1790	322	+56	132	.2298	— 64	—.2682	—1.000	.9424
	17	.2069	.2078	323	+56	132	.2531	— 68	—.2682	—1.000	.9653
	18	.1939	.1912	328	+55	132	.2388	— 51	—.2687	—0.998	.9522
	19	.2206	.1926	319	+55	136	.2523	— 31	—.2687	— .998	.9677
	20	.2064	.2074	304	+55	132	.2506	—118	—.2687	— .998	.9573
						Mean					94.9615
7	2	.0818	.1088	341	—48	125	.1337	+185	+.2097	+0.923	81.3738
	13	.4722	.4627	244	—50	126	.4960	— 11	—.1655	+ .969	.3418
(23)						Mean					81.3578
8	2	.0438	.0356	213	—36	100	.0660	+139	+.0676	+0.650	61.1558
	3	.0383	.0341	228	—36	100	.0640	+102	+.0676	+ .650	.1501
(17)	11	.1636	.1495	196	—37	100	.1811	— 44	—.0538	+ .541	.1298
	12	.1595	.1823	209	—37	100	.1967	— 37	—.0538	+ .541	.1461
	13	.1678	.1622	214	—37	100	.1913	— 8	—.0538	+ .541	.1436
	15	.1983	.2245	237	+37	96	.2471	— 64	—.0854	— .426	.1498
						Mean					61.1459
9	2	.4752	.4860	416	—68	115	.5178	+260	+.1873	+0.631	114.7392
	3	.5146	.4676	458	—68	122	.5331	+191	+.1873	+ .631	.7476
(29)	11	.8372	.8280	371	—70	120	.8654	— 82	—.1478	+ .740	.7189
	13	.8130	.8001	449	—70	120	.8473	— 15	—.1478	+ .740	.7075
	15	.9240	.9426	327	+70	121	.9758	—120	—.2343	— .849	.7186
	18	.9489	.9477	328	+67	120	.9905	— 62	—.2398	— .912	.7328
						Mean					114.7274
10	10	.0253	.0063	300	—60	132	.0469	— 40	+.0296	+0.097	99.0737
	12	.0295	.9887	298	—60	132	.0400	— 49	+.0298	+ .069	.0648
(78)	15	.9722	.9822	337	+60	128	.0236	—104	+.0470	+ .077	.0612
	18	.9556	.9712	460	+58	132	.0223	— 53	+.0480	+ .233	.0680
	19	.9687	.9714	404	+58	132	.0233	— 32	+.0480	+ .233	.0711
	20	.9906	.9534	352	+58	132	.0201	—123	+.0480	+ .233	.0588
						Mean					99.0663

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ' "	' "	' "	"	' "	' "		° ' "
1	319 59 30	59 52	12 2	+11	11 54	+ 0 14	+ 34	230 12 33
2	57 56	57 56	13 28	+ 9	11 33	+ 0 14	+ 31	12 58
3	58 5	58 24	13 34	+13	12 1	+ 0 14	+ 31	12 32
4	59 48	0 13	12 39	+12	12 52	+ 0 1	+ 13	12 23
5	320 0 48	1 28	11 38	+11	12 57	+ 0 1	— 4	12 49
6	0 18	0 34	11 38	+20	12 24	+ 0 1	— 4	12 41
7	319 55 52	56 2	12 52	+13	9 2	+ 0 0	— 6	12 21
8	59 28	59 12	13 3	+12	12 35	— 0 11	+ 28	12 22
9	57 45	58 38	14 30	+18	12 59	— 0 11	+ 28	12 28
10	59 27	0 13	13 7	+ 6	13 3	— 0 11	+ 23	12 39
11	58 34	59 12	14 13	+ 4	13 10	— 0 11	+ 21	12 36
12	56 38	56 58	15 35	+ 8	12 31	— 0 11	+ 21	12 39
13	58 15	59 5	13 8	+13	12 1	— 0 11	+ 21	12 22
15	320 00 40	1 35	12 13	+10	13 31	— 0 18	— 10	12 50
16	1 28	2 12	10 58	+27	13 15	— 0 18	+ 1	12 28
17	2 50	3 45	11 10	+20	14 48	— 0 18	+ 1	12 25
18	1 5	1 57	11 3	+25	12 59	— 0 18	+ 2	11 52
19	1 22	1 57	11 22	+18	13 19	— 0 18	+ 2	13 1
20	319 59 30	59 55	12 38	+12	12 32	— 0 18	+ 2	12 29
				Mean				230 12 33.1
2	325 1 15	1 43	13 28	+ 6	15 3	— 0 31	+ 29	235 15 42
13	0 15	0 59	13 8	— 3	13 42	+ 0 24	+ 16	14 36
				Mean				235 15 9.0
2	32 40 22	41 24	13 28	—13	54 7	—11 8	— 89	302 43 27
3	40 16	40 45	13 34	—19	53 46	—11 8	— 89	42 12
11	20 2	21 20	14 13	— 6	34 48	+ 8 46	—100	42 27
12	18 40	18 37	15 35	—11	34 2	+ 8 46	—100	42 23
13	21 10	21 48	13 8	—17	34 20	+ 8 46	—100	42 54
15	16 8	15 24	12 13	— 5	27 54	+13 53	+101	42 4
				Mean				302 42 34.5
2	294 17 35	18 20	13 28	+14	31 40	+ 2 55	+ 48	204 35 52
3	17 33	18 48	13 34	+20	32 4	+ 2 55	+ 48	35 22
11	23 23	24 5	14 13	+ 6	38 3	— 2 18	+ 41	35 29
13	22 47	23 22	13 8	+19	36 31	— 2 18	+ 41	34 52
15	26 32	28 41	12 13	+ 2	39 51	— 3 38	— 35	35 41
18	27 52	28 53	11 3	+ 2	39 27	— 3 43	— 26	34 45
				Mean				204 35 20.2
10	61 42 56	44 10	13 7	— 3	56 37	+ 5 35	— 73	332 1 25
12	40 24	41 48	15 35	— 4	56 37	+ 5 37	— 73	1 59
15	40 38	40 37	12 13	—11	52 40	+ 8 54	+ 75	1 42
18	41 12	42 16	11 3	—30	52 17	+ 9 6	+ 72	0 59
19	39 25	41 23	11 22	—21	51 25	+ 9 6	+ 72	0 56
20	39 43	40 13	12 38	—13	52 23	+ 9 6	+ 72	2 9
				Mean				332 1 31.7

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
11	11	.1390	.1408	223	—45	124	.1675	— 53	+.0261	+0.090	74.1895
	12	.1531	.1270	225	—45	124	.1679	— 44	+.0261	+ .090	.1908
(77)	15	.1319	.1356	255	+45	123	.1736	— 78	+.0412	+ .056	.2077
						Mean					74.1960
12	11	.6700	.6604	166	—33	99	.6874	— 38	—.0056	+0.276	53 6815
	13	.6836	.6730	172	—33	99	.7011	— 7	—.0056	+ .276	.6983
(15)	15	.6732	.6743	195	+33	96	.7053	— 56	—.0090	— .138	.6889
						Mean					53.6896
13	1	.3524	.3614	285	—57	136	.3874	+192	—.0720	+0.092	98.3358
	2	.3630	.3550	293	—58	136	.3901	+224	—.0715	+ .050	.3416
(14)	3	.3642	.3513	295	—58	138	.3894	+164	—.0715	+ .050	.3349
	4	.2984	.2968	297	—60	136	.3289	— 3	—.0053	— .191	.3208
	5	.3068	.2918	293	—57	136	.3305	+ 43	—.0026	— .394	.3271
	6	.2970	.2951	299	—57	136	.3278	+ 88	—.0026	— .394	.3289
	7	.3014	.3063	298	—56	136	.3356	+ 91	—.0023	— .419	.3370
	10	.2354	.2393	294	—60	136	.2684	— 40	+.0559	— .066	.3195
	11	.2419	.2395	294	—60	136	.2716	— 70	+.0562	— .094	.3196
	12	.2335	.2293	293	—60	136	.2624	— 59	+.0562	— .094	.3115
	13	.2352	.2496	293	—60	136	.2734	— 13	+.0562	— .094	.3271
	15	.1947	.1884	317	+60	136	.2369	—103	+.0889	+ .242	.3186
	16	.1811	.1681	413	+57	136	.2293	— 66	+.0908	+ .378	.3184
	17	.1604	.1670	366	+57	136	.2137	— 70	+.0908	+ .378	.3024
	18	.1569	.1686	407	+57	136	.2169	— 53	+.0910	+ .390	.3076
	19	.1873	.1810	361	+57	136	.2336	— 32	+.0910	+ .390	.3264
	20	.1854	.1686	329	+57	136	.2233	—122	+.0910	+ .390	.3071
						Mean					98.3226
14	2	.5585	.5620	127	—21	106	.5811	+ 79	+.0881	+0.723	34.6864
	3	.5667	.5729	135	—21	105	.5914	+ 58	+.0881	+ .723	.6946
(18)	10	.7285	.7121	119	—21	104	.7402	— 14	—.0698	+ .646	.6773
	11	.7369	.7223	115	—21	105	.7492	— 25	—.0702	+ .625	.6845
	12	.7356	.7166	123	—21	105	.7465	— 21	—.0702	+ .625	.6822
	13	.7191	.6993	135	—21	104	.7307	— 4	—.0702	+ .625	.6681
	15	.7756	.7645	136	+21	102	.7956	— 36	—.1115	— .521	.6738
	16	.7510	.7642	208	+20	106	.7907	— 23	—.1140	— .384	.6695
	18	.7750	.7772	203	+20	108	.8089	— 19	—.1142	— .370	.6880
	19	.7717	.7725	169	+20	105	.8012	— 11	—.1142	— .370	.6811
	20	.7780	.7722	143	+20	108	.8019	— 43	—.1142	— .370	.6786
						Mean					34.6804
15	2	.9422	.9548	201	—31	106	.9753	+118	+.2018	+0.760	52.1987
	3	.9428	.9546	227	—31	110	.9784	+ 87	+.2018	+ .760	.1987
(22)	10	.3307	.3272	183	—32	106	.3537	— 21	—.1584	+ .835	.2039
	11	.3287	.3188	175	—32	106	.3478	— 37	—.1593	+ .850	.1957
	12	.3230	.3271	194	—32	106	.3510	— 31	—.1593	+ .850	.1995
	13	.3143	.3105	223	—32	110	.3416	— 7	—.1593	+ .850	.1925
	15	.4327	.4583	194	+32	94	.4766	— 55	—.2523	— .938	.2068
	18	.4623	.4506	163	+31	101	.4851	— 28	—.2583	— .972	.2115
						Mean					52.2009

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
11	60 27 37	27 48	14 13	— 3	41 52	+ 7 33	— 97	330 48 19
12	25 25	25 33	15 35	— 5	40 59	+ 7 33	— 97	48 8
15	23 52	23 32	12 13	—11	35 44	+11 57	+101	47 58
				Mean				330 48 8.3
11	49 29 30	30 22	14 13	— 4	44 5	+10 34	—130	319 53 21
13	30 2	30 36	13 8	—13	43 14	+10 34	—130	53 25
15	23 57	24 5	12 13	—10	36 4	+16 44	+137	53 18
				Mean				319 53 21.3
1	71 19 56	19 39	12 2	0	31 50	— 6 54	— 73	341 24 43
2	16 25	17 22	13 28	0	30 21	— 6 51	— 73	24 4
3	17 55	18 45	13 34	+ 1	31 55	— 6 51	— 73	24 44
4	13 42	14 30	12 39	+ 1	26 46	— 0 31	— 72	25 14
5	13 6	14 22	11 38	+ 1	25 23	— 0 15	— 66	24 36
6	12 30	13 43	11 38	+ 8	24 53	— 0 15	— 66	24 31
7	8 41	9 25	12 52	+ 3	21 58	— 0 13	— 65	24 43
10	7 2	7 11	13 7	— 1	20 12	+ 5 23	— 74	24 47
11	5 35	6 38	14 13	— 1	20 19	+ 5 25	— 74	24 46
12	3 48	3 50	15 35	— 1	19 23	+ 5 25	— 74	24 32
13	5 57	6 16	13 8	+ 1	19 15	+ 5 25	— 74	24 37
15	3 10	4 4	12 13	—11	15 39	+ 8 34	+ 74	24 21
16	4 43	6 21	10 58	—33	15 57	+ 8 45	+ 69	24 38
17	6 8	7 37	11 10	—23	17 39	+ 8 45	+ 69	24 44
18	4 58	5 50	11 3	—30	16 51	+ 8 46	+ 69	25 12
19	3 38	4 32	11 22	—20	15 7	+ 8 46	+ 69	24 17
20	2 5	3 3	12 38	—13	14 59	+ 8 46	+ 69	24 24
				Mean				341 24 38.4
2	26 54 6	55 10	13 28	—14	7 52	—18 53	—140	296 49 9
3	54 0	56 16	13 34	—20	8 22	—18 53	—140	48 45
10	19 37	21 27	13 7	— 8	33 31	+14 45	—158	46 58
11	19 26	19 38	14 13	— 6	33 39	+14 50	—162	47 0
12	17 28	17 46	15 35	—11	33 1	+14 50	—162	47 4
13	20 3	20 21	13 8	—19	33 1	+14 50	—162	47 17
15	12 35	11 37	12 13	— 3	24 16	+23 28	+185	48 32
16	10 30	12 42	10 58	— 3	22 31	+23 58	+196	47 10
18	11 42	11 58	11 3	— 3	22 50	+24 1	+197	47 12
19	10 10	12 35	11 22	— 4	22 40	+24 1	+197	47 51
20	10 2	9 56	12 38	— 3	22 34	+24 1	+197	48 0
				Mean				296 47 43.5
2	305 0 0	1 40	13 28	+13	14 31	+ 3 55	+ 87	215 19 57
3	1 54	2 42	13 34	+19	16 11	+ 3 55	+ 87	20 43
10	10 13	11 25	13 7	+ 8	24 4	— 3 3	+ 74	21 7
11	9 37	9 55	14 13	+ 6	24 5	— 3 4	+ 71	20 56
12	6 58	8 16	15 35	+11	23 23	— 3 4	+ 71	20 56
13	9 44	10 6	13 8	+19	23 22	— 3 5	+ 71	21 7
15	14 53	16 10	12 13	— 9	27 36	— 4 52	— 54	22 6
18	15 43	15 5	11 3	+18	26 45	— 4 59	— 32	20 44
				Mean				215 20 57.0

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
16	2	.0451	.0651	131	—18	107	.0769	+ 68	+.1978	+0.976	30.2940
	3	.0509	.0502	151	—18	107	.0743	+ 50	+.1978	+ .976	.2896
(20)	10	.4275	.4128	116	—19	108	.4405	— 12	—.1554	+ .984	.2965
	11	.4162	.4188	108	—19	108	.4369	— 22	—.1563	+ .982	.2910
	13	.4499	.4011	148	—19	108	.4490	— 4	—.1563	+ .982	.3049
	15	.5196	.5287	108	+19	136	.5503	— 32	—.2475	— .984	.2870
	16	.5260	.5298	137	+18	104	.5536	— 21	—.2528	— .926	.2868
	18	.5404	.5371	137	+18	106	.5647	— 16	—.2533	— .920	.2980
						Mean					30.2935
17	2	.4646	.4644	246	—49	135	.4942	+188	—.0712	+0.052	82.4425
	10	.3210	.3434	246	—50	136	.3618	— 34	+.0555	— .064	.4131
(13)	11	.3304	.3316	246	—50	136	.3607	— 59	+.0558	— .092	.4094
	13	.3578	.3466	246	—50	136	.3818	— 11	+.0558	— .092	.4353
	15	.2947	.2895	266	+50	136	.3338	— 86	+.0884	+ .240	.4167
	20	.2928	.2669	276	+48	135	.3223	—102	+.0904	+ .388	.4075
						Mean					82.4207
18	2	.9388	.9421	230	—41	128	.9701	+159	—.0607	+0.103	69.9266
	10	.8614	.8647	210	—43	127	.8903	— 29	+.0472	— .013	.9344
(12)	11	.8696	.8500	209	—43	127	.8870	— 50	+.0475	— .040	.9290
	12	.8637	.8578	209	—43	128	.8881	— 42	+.0475	— .040	.9309
	13	.8604	.8524	209	—43	127	.8836	— 9	+.0475	— .040	.9297
	15	.8128	.8102	230	+42	128	.8494	— 73	+.0752	+ .188	.9197
	18	.8071	.8033	304	+41	128	.8504	— 37	+.0769	+ .339	.9280
	19	.8118	.8030	251	+41	127	.8472	— 23	+.0769	+ .339	.9262
	20	.8181	.8011	237	+41	127	.8480	— 87	+.0769	+ .339	.9206
						Mean					69.9272
19	11	.9849	.9861	397	—79	23	.0064	— 92	—.1211	+0.529	128.8829
	12	.9814	.9767	410	—79	23	.0013	— 77	—.1211	+ .529	.8793
(62)	15	.0476	.0500	366	+78	23	.0823	—135	—.1917	— .662	.8686
	19	.0705	.0634	381	+75	23	.1016	— 42	—.1962	— .763	.8914
						Mean					128.8806
20	2	.8045	.8214	223	—44	120	.8403	+168	—.0985	—0.087	73.7575
	3	.8395	.8172	226	—44	120	.8561	+123	—.0985	— .087	.7688
(11)	9	.6494	.6636	228	—44	120	.6844	— 33	+.0758	— .136	.7552
	10	.6614	.6699	221	—45	120	.6927	— 30	+.0770	— .203	.7641
	11	.6725	.6640	220	—45	115	.6948	— 53	+.0774	— .230	.7639
	12	.6730	.6656	221	—45	120	.6964	— 44	+.0774	— .230	.7664
	13	.6560	.6576	223	—45	120	.6841	— 10	+.0774	— .230	.7575
	15	.6016	.5942	228	+45	120	.6347	— 77	+.1225	+ .377	.7543
	16	.5856	.5666	282	+43	118	.6179	— 49	+.1251	+ .502	.7445
	18	.5646	.5910	278	+43	118	.6192	— 40	+.1253	+ .514	.7471
	19	.5870	.5912	252	+43	118	.6279	— 24	+.1253	+ .514	.7574
	20	.6028	.5880	233	+43	118	.6323	— 91	+.1253	+ .514	.7551
						Mean					73.7576

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	341 7 47	3 50	13 28	0	19 16	− 8 0	+ 13	251 12 21
3	7 48	6 20	13 34	− 2	20 36	− 8 0	+ 13	12 47
10	340 53 52	54 38	13 7	+ 1	7 23	+ 6 12	− 15	13 9
11	51 57	52 45	14 13	+ 1	6 35	+ 6 15	− 22	12 11
13	55 44	55 50	13 8	− 1	8 54	+ 6 15	− 22	15 25
15	49 42	51 33	12 13	+11	3 1	+ 9 52	+ 59	12 55
16	51 14	49 54	10 58	+33	2 5	+10 4	+ 92	12 13
18	51 43	51 24	11 3	+30	3 7	+10 5	+ 94	12 56
				Mean				251 12 59.6
2	71 15 34	15 8	13 28	0	28 49	− 8 11	− 87	341 21 7
10	2 41	2 43	13 7	− 1	15 48	+ 6 26	− 88	21 21
11	1 3	0 38	14 13	− 1	15 2	+ 6 28	− 88	20 27
13	1 15	2 23	13 8	+ 1	14 58	+ 6 28	− 88	21 18
15	70 58 12	59 25	12 13	−11	10 50	+10 14	+ 88	20 13
20	57 58	57 30	12 38	−13	10 9	+10 29	+ 82	20 22
				Mean				341 20 48.0
2	68 17 43	17 50	13 28	− 1	31 13	− 9 49	−103	338 21 47
10	1 25	3 22	13 7	− 2	15 28	+ 7 43	−103	22 13
11	1 3	0 58	14 13	− 1	15 13	+ 7 46	−104	21 51
12	67 58 2	58 56	15 35	− 3	14 1	+ 7 46	−104	21 21
13	68 0 20	2 15	13 8	− 2	14 23	+ 7 46	−104	21 56
15	67 57 33	57 45	12 13	−11	9 41	+12 18	+105	22 18
18	58 53	59 22	11 3	−30	10 34	+12 36	+ 98	22 55
19	57 8	58 34	11 22	−20	8 53	+12 36	+ 98	22 3
20	56 12	57 7	12 38	−13	9 4	+12 36	+ 98	22 29
				Mean				338 22 5.9
11	278 5 48	7 0	14 13	+ 4	20 41	− 3 4	+ 48	188 17 23
12	4 0	4 20	15 35	+ 9	19 54	− 3 4	+ 48	17 18
15	10 45	11 25	12 13	− 4	23 14	− 4 52	− 44	17 47
19	11 47	11 52	11 22	− 9	23 2	− 4 58	− 36	17 50
				Mean				188 17 34.5
2	79 23 48	24 47	13 28	+ 4	37 50	− 8 35	− 98	349 29 40
3	23 40	25 59	13 34	+ 7	38 31	− 8 35	− 98	29 27
9	8 30	9 58	14 30	+15	23 59	+ 6 39	− 97	29 33
10	10 40	10 56	13 7	+ 2	23 57	+ 6 45	− 96	29 46
11	10 7	10 20	14 13	+ 1	24 28	+ 6 48	− 95	30 11
12	6 45	7 52	15 35	+ 3	22 56	+ 6 48	− 95	29 21
13	10 12	11 0	13 8	+ 7	23 51	+ 6 48	− 95	30 29
15	6 4	7 24	12 13	−10	18 47	+10 46	+ 94	29 48
16	8 53	9 40	10 58	−31	19 43	+11 0	+ 86	30 45
18	8 12	8 35	11 3	−28	19 48	+11 1	+ 86	30 30
19	6 40	7 37	11 22	−19	18 11	+11 1	+ 86	29 42
20	5 42	7 2	12 38	−11	18 49	+11 1	+ 86	30 35
				Mean				349 29 58.9

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean. *s*	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
21	2	.0277	.0658	82	—13	100	.0636	+ 50	+.1945	+0.692	22.2720
	10	.4069	.4061	77	—14	100	.4227	— 9	—.1529	+ .775	.2789
(21)	11	.4056	.3932	73	—14	100	.4152	— 16	—.1537	+ .792	.2701
	12	.3958	.3944	80	—14	100	.4116	— 13	—.1537	+ .792	.2668
	13	.3989	.3947	91	—14	100	.4144	— 3	—.1537	+ .792	.2706
	15	.5047	.5059	64	+14	101	.5231	— 24	—.2436	— .892	.2656
	20	.5184	.5169	65	+13	102	.5355	— 28	—.2492	— .943	.2714
						Mean					22.2708
22	2	.7426	.7498	340	—66	123	.7777	+252	—.1171	—0.187	110.6834
	3	.7438	.7714	350	—66	123	.7901	+185	—.1171	— .187	.6891
(9)	13	.5671	.5651	345	—68	128	.5983	— 14	+.0922	— .327	.6849
	15	.4800	.4844	331	+67	128	.5266	—116	+.1461	+ .472	.6672
	16	.4590	.4456	386	+64	128	.5018	— 74	+.1492	+ .590	.6512
	19	.4759	.4712	358	+64	128	.5204	— 36	+.1495	+ .599	.6740
	20	.4736	.4740	340	+65	132	.5193	—137	+.1495	+ .599	.6628
						Mean					110.6732
23	1	.3538	.3482	271	—52	134	.3820	+174	—.1201	—0.156	89.2773
	2	.3584	.3390	276	—53	134	.3801	+203	—.1192	— .199	.2786
(10)	3	.3613	.3465	284	—53	134	.3860	+149	—.1192	— .199	.2791
	4	.2602	.2464	280	—55	135	.2849	— 2	—.0089	— .430	.2703
	5	.2526	.2460	277	—51	135	.2810	+ 39	—.0043	— .604	.2728
	6	.2462	.2428	309	—51	134	.2793	+ 80	—.0043	— .604	.2752
	7	.2490	.2478	290	—51	135	.2814	+ 83	—.0038	— .623	.2779
	8	.1524	.1357	432	—54	135	.1910	—113	+.0919	— .248	.2684
	9	.1444	.1497	293	—54	135	.1801	— 39	+.0919	— .248	.2649
	10	.1484	.1524	270	—54	135	.1812	— 36	+.0933	— .314	.2669
	11	.1523	.1553	268	—55	135	.1843	— 64	+.0938	— .339	.2673
	12	.1550	.1485	272	—55	135	.1826	— 53	+.0938	— .339	.2667
	13	.1528	.1490	278	—55	135	.1824	— 12	+.0938	— .339	.2706
	15	.0830	.0692	267	+54	135	.1173	— 93	+.1485	+ .484	.2627
	16	.0650	.0636	310	+52	135	.1096	— 60	+.1517	+ .600	.2630
	17	.0568	.0660	284	+52	135	.1042	— 64	+.1517	+ .600	.2572
	18	.0544	.0614	307	+52	135	.1030	— 48	+.1520	+ .609	.2580
	19	.0596	.0628	288	+52	135	.1044	— 29	+.1520	+ .609	.2613
	20	.0694	.0656	274	+52	135	.1093	—111	+.1520	+ .609	.2580
						Mean					89.2683
24	11	.4972	.4884	25	— 5	29	.4977	— 6	+.0292	+0.064	8.5271
	13	.4776	.4791	26	— 5	32	.4837	— 1	+.0292	+ .064	.5136
(75)						Mean					8.5204
25											
26											

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	298 44 53	50 40	13 28	+14	1 28	+12 23	+229	209 16 13
10	299 12 10	13 43	13 7	+ 8	26 11	− 9 34	+202	17 29
11	11 45	10 38	14 13	+ 6	25 30	− 9 38	+195	16 31
12	8 36	5 25	15 35	+11	22 47	− 9 38	+195	14 30
13	10 50	9 6	13 8	+19	23 25	− 9 38	+195	15 21
15	21 38	21 3	12 13	+ 4	33 38	−15 11	−158	17 11
20	20 40	20 32	12 38	+ 5	33 19	−15 32	−108	17 22
				Mean				209 16 22.4
2	85 15 2	16 8	13 28	+ 6	29 9	− 5 22	− 64	355 24 24
3	16 17	17 35	13 34	+11	30 41	− 5 22	− 64	25 2
13	7 0	7 5	13 8	+10	20 20	+ 4 14	− 62	24 36
15	5 40	5 50	12 13	− 8	17 50	+ 6 43	+ 59	24 35
16	6 55	8 10	10 58	−28	18 2	+ 6 52	+ 53	24 44
19	5 53	6 13	11 22	−16	17 9	+ 6 52	+ 53	24 19
20	5 15	5 17	12 38	− 9	17 45	+ 6 52	+ 53	25 10
				Mean				355 24 41.4
1	85 58 25	59 45	12 2	+ 8	11 15	− 6 39	− 79	356 4 21
2	56 44	57 45	13 28	+ 6	10 48	− 6 36	− 79	4 44
3	57 6	58 2	13 34	+11	11 19	− 6 36	− 79	4 21
4	53 18	53 55	12 39	+ 9	6 25	− 0 30	− 73	4 54
5	52 30	53 10	11 38	+ 8	4 36	− 0 14	− 62	3 52
6	51 37	53 26	11 38	+27	4 37	− 0 14	− 62	4 18
7	48 48	48 42	12 52	+15	1 52	− 0 6	− 60	4 45
8	46 12	47 43	13 3	− 5	59 56	+ 5 6	− 78	4 22
9	45 25	45 34	14 30	+21	0 21	+ 5 6	− 78	4 29
10	46 30	47 30	13 7	+ 3	0 10	+ 5 11	− 77	4 32
11	45 10	46 20	14 13	+ 2	0 0	+ 5 13	− 76	4 15
12	43 18	44 27	15 35	+ 6	59 34	+ 5 13	− 76	4 31
13	45 52	46 40	13 8	+10	59 34	+ 5 13	− 76	4 44
15	43 43	44 12	12 13	− 8	56 3	+ 8 17	+ 73	4 27
16	45 27	46 0	10 58	−27	56 15	+ 8 27	+ 66	4 37
17	45 43	47 46	11 10	−18	57 37	+ 8 27	+ 66	4 23
18	45 18	45 28	11 3	−25	56 46	+ 8 28	+ 65	4 47
19	44 5	44 6	11 22	−15	55 13	+ 8 28	+ 65	4 3
20	43 15	43 37	12 38	− 9	55 57	+ 8 28	+ 65	5 2
				Mean				356 4 29.8
11	61 51 28	55 42	14 13	− 3	7 46	+ 6 2	−852	333 8 11
13	62 5 29	1 51	13 8	− 5	16 43	+ 6 3	−852	18 4
				Mean				333 13 7.5

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s				σ
27	2	.2265	.2096	118	—23	109	.2380	+ 87	+.1228	+0.222	38.3724
	3	.2274	.1914	122	—23	109	.2298	+ 64	+.1228	+ .222	.3619
(30)	10	.4421	.4243	141	—23	108	.4554	— 16	—.0969	+ .335	.3612
	11	.4299	.4405	116	—23	108	.4549	— 27	—.0974	+ .361	.3594
	12	.4387	.4402	118	—23	108	.4593	— 23	—.0974	+ .361	.3642
	13	.4381	.4337	121	—23	108	.4561	— 5	—.0974	+ .361	.3628
	15	.4898	.4942	114	+23	108	.5161	— 40	—.1546	— .504	.3510
	16	.4972	.5186	129	+22	108	.5334	— 26	—.1579	— .618	.3650
	18	.5107	.4993	130	+22	108	.5306	— 21	—.1582	— .627	.3622
	20	.4933	.5113	117	+22	108	.5266	— 48	—.1582	— .627	.3555
						Mean					38.3616
28	11	.8154	.8118	338	—68	112	.8433	— 80	—.1002	+0.381	111.7400
	12	.8212	.8102	343	—68	112	.8459	— 67	—.1002	+ .381	.7439
(60)	13	.8050	.8032	351	—68	112	.8351	— 14	—.1002	+ .381	.7384
	15	.8830	.8616	329	+68	112	.9147	—117	—.1588	— .523	.7375
	18	.8925	.8660	374	+65	112	.9258	— 60	—.1625	— .645	.7490
	19	.8712	.8688	353	+65	112	.9145	— 36	—.1625	— .645	.7401
						Mean					111.7415
29	3	.1795	.1523	129	—21	112	.1876	+ 60	—.1601	—0.440	36.0279
	11	.8741	.8697	111	—22	112	.8917	— 26	+.1259	+ .567	.0077
(5)	13	.8725	.8763	125	—22	112	.8956	— 5	+.1259	+ .567	.0137
						Mean					36.0164
30 (69)	11	.2444	.2182	60	—11	78	.2440	— 13	+.1536	—0.793	18.3861
31 (64)	11	.9278	.9310	179	—37	102	.9525	— 43	—.0820	+0.258	59.8695
32	1	.8124	.7994	227	—45	130	.8343	+150	+.1095	+0.100	76.9601
	2	.8056	.7947	235	—46	130	.8293	+175	+.1087	+ .142	.9573
(31)	3	.7998	.8035	238	—46	130	.8311	+128	+.1087	+ .142	.9544
	4	.9032	.9052	238	—47	124	.9329	— 2	+.0081	+ .378	.9457
	5	.9166	.9137	235	—44	124	.9439	+ 34	+.0039	+ .560	.9584
	6	.9144	.8940	256	—44	130	.9356	+ 69	+.0039	+ .560	.9536
	7	.9134	.9000	245	—44	124	.9364	+ 71	+.0035	+ .580	.9544
	8	.0047	.0115	235	—46	124	.0366	— 98	—.0842	+ .191	.9451
	9	.0119	.0014	246	—46	124	.0363	— 34	—.0842	+ .191	.9512
	10	.0117	.9983	232	—47	124	.0331	— 31	—.0856	+ .258	.9477
	11	.0044	.0053	231	—47	124	.0328	— 55	—.0860	+ .284	.9449
	12	.0090	.0010	233	—47	124	.0332	— 46	—.0860	+ .284	.9462
	13	.9911	.0017	236	—47	124	.0249	— 10	—.0860	+ .284	.9415
	15	.0522	.0566	235	+47	124	.0922	— 81	—.1365	— .430	.9421
	16	.0533	.0692	270	+45	125	.1025	— 52	—.1394	— .552	.9508
	17	.0687	.0591	253	+45	124	.1033	— 55	—.1394	— .552	.9513
	18	.0672	.0500	276	+45	124	.1003	— 41	—.1396	— .562	.9494
	19	.0698	.0420	254	+45	124	.0954	— 25	—.1395	— .562	.9461
	20	.0621	.0665	240	+45	121	.1025	— 96	—.1396	— .562	.9461
						Mean					76.9498

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued*).

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ' ''	' ''	' ''	''	' ''	' ''		° ' ''
2	266 44 0	44 25	13 28	+ 7	57 48	+15 21	+183	177 15 15
3	45 17	44 12	13 34	+12	58 30	+15 21	+183	15 3
10	267 14 38	13 58	13 7	− 6	27 19	−11 59	+178	16 3
11	12 58	13 44	14 13	+ 2	27 37	−12 3	+176	16 6
12	11 6	9 35	15 35	+ 6	26 2	−12 3	+176	15 13
13	11 3	11 43	13 8	+12	24 43	−12 3	+176	14 7
15	22 30	24 28	12 13	− 8	35 34	−19 4	−169	15 10
16	25 5	26 10	10 58	−27	36 8	−19 28	−151	15 17
18	26 52	25 48	11 3	−23	37 40	−19 30	−149	16 26
20	22 0	24 2	12 38	− 9	35 30	−19 30	−149	15 20
				Mean				177 15 24.0
11	268 23 45	24 35	14 13	+ 2	38 25	− 4 7	+ 60	178 34 9
12	21 18	22 28	15 35	+ 6	37 34	− 4 7	+ 60	34 0
13	23 40	24 24	13 8	+12	37 22	− 4 7	+ 60	34 1
15	28 42	29 56	12 13	− 7	41 25	− 6 31	− 57	34 13
18	30 20	30 52	11 3	−25	41 14	− 6 40	− 51	33 26
19	30 22	30 00	11 22	−15	41 18	− 6 40	− 51	34 19
				Mean				178 34 1.3
3	101 6 44	4 42	13 34	+18	19 35	−12 54	−178	11 5 43
11	100 40 27	38 44	14 13	+ 5	53 53	+10 15	−165	2 38
13	42 10	42 40	13 8	+17	55 50	+10 15	−165	5 30
				Mean				11 4 37.0
11	119 16 43	11 55	14 13	+ 6	28 38	+11 41	−234	29 38 16
11	260 49 18	50 32	14 13	+ 2	4 10	− 8 19	+117	170 56 2.0
1	268 18 42	19 55	12 2	+ 6	31 26	+ 8 10	+ 93	172 40 22
2	16 50	17 32	13 28	+ 6	30 45	+ 8 6	+ 93	40 24
3	17 37	18 22	13 34	+ 9	31 43	+ 8 6	+ 93	40 28
4	26 12	26 36	12 39	+ 8	39 11	+ 0 36	+ 87	39 43
5	27 43	27 50	11 38	+ 6	39 31	+ 0 18	+ 75	40 8
6	26 38	27 51	11 38	+23	39 16	+ 0 18	+ 75	40 18
7	22 58	23 47	12 52	+12	36 26	+ 0 15	+ 73	40 28
8	33 25	33 30	13 3	+ 8	46 38	− 6 15	+ 92	40 44
9	31 55	32 2	14 30	+18	46 46	− 6 15	+ 92	40 34
10	33 5	33 55	13 7	+ 3	46 40	− 6 20	+ 91	40 32
11	32 24	33 5	14 13	+ 2	46 59	− 6 23	+ 90	40 37
12	30 31	31 8	15 35	+ 5	46 30	− 6 23	+ 90	40 50
13	32 30	33 5	13 8	+ 8	46 3	− 6 23	+ 90	40 36
15	38 40	40 8	12 13	− 8	51 31	−10 6	− 88	40 34
16	40 45	41 30	10 58	−30	51 35	−10 19	− 80	40 18
17	42 13	43 27	11 10	−19	53 41	−10 19	− 80	40 48
18	262 40 53	41 27	11 3	−27	52 46	−10 20	− 79	41 8
19	40 12	40 58	11 22	−17	51 40	−10 20	− 79	40 51
20	37 53	38 32	12 38	−10	50 40	−10 20	− 79	40 6
				Mean				172 40 30.0

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
33	2	.9723	.9735	124	—21	115	.9944	+ 80	—.1815	—0.587	34.8134
	3	.9855	.9747	137	—21	115	.0029	+ 58	—.1815	— .587	.8197
(4)	11	.6619	.6613	111	—21	115	.6818	— 25	+.1430	— .701	.8133
	12	.6594	.6642	118	—21	115	.6827	— 21	+.1430	— .701	.8146
	13	.6615	.6579	131	—21	115	.6819	— 4	+.1430	— .701	.8155
	15	.5516	.5545	98	+21	113	.5759	— 36	+.2264	+ .815	.8092
	18	.5535	.5761	99	+20	116	.5880	— 19	+.2317	+ .887	.8292
						Mean					34.8164
34	2	.4744	.4310	106	—20	116	.4726	+ 78	+.0184	—0.296	34.4950
	11	.4828	.5022	105	—21	113	.5119	— 25	—.0154	— .158	.4920
(37)	13	.5002	.4982	106	—21	113	.5187	— 4	—.0154	— .158	.5009
						Mean					34.4960
35	11	.5791	.5869	73	—14	105	.5993	— 16	+.0507	—0.529	22.6416
	13	.5724	.5822	79	—14	101	.5938	— 3	+.0507	— .529	.6374
(66)						Mean					22.6395
36	2	.5805	.5901	97	—13	102	.6039	+ 51	—.1805	—0.967	22.4161
	3	.5566	.5800	111	—13	104	.5884	+ 38	—.1805	— .967	.3993
(1)	10	.2344	.2589	84	—14	102	.2637	— 9	+.1412	— .952	.3918
	11	.2540	.2531	79	—14	102	.2702	— 16	+.1420	— .945	.3985
	12	.2634	.2490	91	—14	102	.2741	— 13	+.1420	— .945	.4027
	13	.2619	.2501	106	—14	102	.2553	— 3	+.1420	— .945	.4049
	15	.1350	.1192	63	+13	98	.1444	— 23	+.2249	+ .918	.3788
	18	.1366	.1154	112	+13	102	.1487	— 12	+.2301	+ .826	.3882
						Mean					22.3977
37	2	.6800	.6808	146	—28	114	.7029	+109	+.0296	—0.246	46.7402
	3	.6756	.6848	145	—28	114	.7026	+ 79	+.0296	— .246	.7369
(35)	4	.7040	.6981	146	—29	114	.7234	— 1	+.0022	— .007	.7254
	5	.7052	.7086	145	—27	114	.7294	+ 21	+.0011	+ .210	.7353
	6	.7098	.6964	144	—27	118	.7259	+ 43	+.0011	+ .210	.7340
	7	.7106	.6976	146	—27	114	.7267	+ 44	+.0010	+ .236	.7351
	8	.7296	.7294	141	—29	114	.7514	— 61	—.0236	— .200	.7191
	9	.7345	.7399	142	—29	114	.7592	— 21	—.0236	— .200	.7309
	10	.7349	.7305	145	—29	114	.7550	— 20	—.0239	— .133	.7274
	11	.7333	.7332	145	—29	114	.7556	— 34	—.0241	— .106	.7267
	12	.7322	.7305	145	—29	114	.7537	— 29	—.0241	— .106	.7253
	13	.7242	.7366	145	—29	114	.7527	— 6	—.0241	— .106	.7266
	15	.7390	.7317	164	+29	118	.7658	— 50	—.0383	— .039	.7220
	16	.7152	.7370	232	+28	117	.7631	— 32	—.0391	— .184	.7184
	17	.7358	.7275	197	+28	114	.7648	— 34	—.0391	— .184	.7199
	18	.7323	.7253	232	+28	114	.7655	— 26	—.0392	— .196	.7212
	19	.7366	.7198	195	+28	114	.7612	— 16	—.0392	— .196	.7179
	20	.7277	.7378	172	+28	116	.7637	— 59	—.0392	— .196	.7161
						Mean					47.7266

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Corrections plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″		′ ″	′ ″		° ′ ″
2	111 10 24	10 52	13 28	+14	24 20	−10 22	−165	21 13 59
3	10 48	11 30	13 34	+20	25 3	−10 22	−165	13 48
11	110 54 46	55 46	14 13	+ 6	9 35	+ 8 15	−147	16 26
12	51 35	51 35	15 35	+11	7 21	+ 8 15	−147	14 54
13	53 10	55 24	13 8	+19	7 46	+ 8 15	−147	15 32
15	49 17	48 43	12 13	+ 1	1 14	+13 6	+126	14 46
18	52 48	52 7	11 3	− 2	3 29	+13 25	+ 97	16 39
				Mean				21 15 9.1
2	236 3 27	3 30	13 28	− 7	16 49	+20 56	+199	146 39 57
11	41 28	40 4	14 13	− 4	54 55	−16 30	+207	39 8
13	40 23	40 53	13 8	− 8	53 38	−16 30	+207	38 46
				Mean				146 39 17.0
11	213 17 2	17 24	14 13	− 6	31 20	−24 2	+269	123 8 24
13	17 25	17 40	13 8	−17	30 23	−24 3	+269	8 21
				Mean				123 8 22.5
2	171 48 14	47 43	13 28	− 5	1 22	+16 30	+ 44	82 19 8
3	45 48	51 2	13 34	− 9	1 50	+16 30	+ 44	18 42
10	172 18 12	19 36	13 7	− 3	31 58	−13 8	+ 83	18 59
11	18 17	20 29	14 13	− 2	33 34	−13 13	+ 91	20 23
12	18 48	16 43	15 35	− 4	33 17	−13 13	+ 91	20 48
13	19 20	18 40	13 8	− 8	32 0	−13 13	+ 91	19 44
15	29 8	29 8	12 13	+ 2	41 23	−21 1	−139	19 13
18	29 55	31 11	11 3	+27	42 3	−21 30	−183	18 37
				Mean				82 19 26.8
2	239 6 5	6 55	13 28	− 5	19 53	+15 3	+146	149 36 49
3	7 28	8 15	13 34	− 7	21 19	+15 3	+146	37 21
4	22 14	22 52	12 39	− 7	35 4	+ 1 8	+152	36 32
5	24 14	24 12	11 38	− 6	35 45	+ 0 33	+145	37 2
6	24 0	25 7	11 38	− 7	36 5	+ 0 33	+145	37 47
7	19 22	20 25	12 52	− 8	32 38	+ 0 29	+143	37 19
8	35 38	35 52	13 3	− 6	48 42	−11 37	+148	37 46
9	34 12	34 12	14 30	− 7	48 35	−11 37	+148	37 21
10	35 18	35 28	13 7	− 3	48 28	−11 48	+151	37 13
11	34 18	34 52	14 13	− 3	48 45	−11 52	+151	37 16
12	31 55	32 33	15 35	− 5	47 44	−11 52	+151	36 57
13	34 2	34 35	13 8	− 6	47 20	−11 52	+151	36 46
15	44 32	45 45	12 13	−11	57 11	−18 47	−156	37 9
16	46 17	47 26	10 58	−32	57 18	−19 11	−152	36 43
17	48 28	49 4	11 10	−22	59 34	−19 11	−152	37 23
18	46 30	47 0	11 3	−29	57 19	−19 13	−151	36 22
19	46 3	46 18	11 22	−20	57 12	−19 13	−151	37 4
20	44 18	44 55	12 38	−13	57 1	−19 13	−151	37 8
				Mean				149 37 6.6

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
38	2	.1008	.0942	337	—66	113	.1274	+255	+.0898	+0.043	112.2433
	3	.0889	.1011	340	—66	113	.1252	+187	+.0898	+ .043	.2343
(32)	11	.2728	.2700	336	—68	113	.3009	— 80	—.0711	+ .187	.2242
	12	.2472	.2810	335	—68	113	.2935	— 67	—.0711	+ .187	.2181
	13	.2560	.2598	336	—68	112	.2873	— 14	—.0711	+ .187	.2172
	15	.3051	.3069	345	+68	113	.3500	—118	—.1127	— .335	.2212
	18	.2970	.2856	334	+65	113	.3339	— 60	—.1154	— .475	.2064
	19	.2952	.2910	392	+65	113	.3415	— 37	—.1154	— .475	.2163
	20	.2980	.3130	360	+65	113	.3507	—139	—.1154	— .475	.2153
						Mean					112.2206
39	1	.8614	.8446	383	—67	130	.8886	+222	—.1662	—0.433	113.7390
	2	.8448	.8534	383	—68	105	.8822	+259	—.1651	— .473	.7369
(8)	3	.8484	.8438	415	—68	106	.8825	+190	—.1651	— .473	.7303
	6	.7040	.7114	506	—66	105	.7533	+102	—.0060	— .798	.7473
	9	.5794	.5372	466	—69	103	.5994	— 50	+.1274	— .517	.7152
	10	.5686	.5601	362	—69	107	.5955	— 46	+.1295	— .575	.7130
	11	.5678	.5612	354	—70	105	.5945	— 81	+.1302	— .598	.7089
	13	.5601	.5579	404	—70	108	.5943	— 15	+.1302	— .598	.7153
	15	.4675	.4617	322	+69	108	.5057	—119	+.2062	+ .724	.7093
	16	.4474	.4601	324	+66	108	.4946	— 76	+.2106	+ .809	.7080
	17	.4422	.4408	317	+66	108	.4818	— 81	+.2106	+ .809	.6947
	18	.4532	.4473	331	+66	108	.4919	— 61	+.2110	+ .816	.7073
	19	.4398	.4573	326	+66	108	.4897	— 37	+.2110	+ .816	.7075
	20	.4372	.4402	324	+66	108	.4797	—141	+.2110	+ .816	.6871
						Mean					113.7157
40	2	.1750	.1744	288	—57	138	.2061	+219	+.0763	—0.025	96.3040
	3	.1687	.1808	290	—57	138	.2063	+160	+.0763	— .025	.2983
(33)	11	.3050	.3063	287	—59	138	.3367	— 69	—.0605	+ .119	.2708
	12	.2842	.3048	288	—59	138	.3256	— 58	—.0605	+ .119	.2608
	13	.3034	.3065	289	—59	138	.3361	— 12	—.0605	+ .119	.2759
	15	.3279	.3275	308	+59	138	.3726	—101	—.0959	— .267	.2632
	18	.3268	.3224	393	+56	138	.3777	— 52	—.0982	— .414	.2690
						Mean					96.2774
41	2	.0414	.0432	120	—20	126	.0646	+ 78	—.0685	—0.650	33.9956
(38)	15	.8546	.8660	131	+21	126	.8878	— 35	+.0841	+ .426	.9739
						Mean					33.9848
42	2	.2542	.2492	422	—73	112	.2864	+281	—.1703	—0.508	123.1377
	3	.2624	.2463	457	—73	107	.2920	+205	—.1703	— .508	.1357
(7)	16	.8572	.8356	345	+72	112	.8879	— 82	+.2172	+ .833	.1076
	18	.8465	.8353	356	+72	110	.8833	— 66	+.2176	+ .839	.1051
	19	.8395	.8350	352	+72	112	.8794	— 40	+.2176	+ .839	.1038
						Mean					123.1180

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
2	256° 27′ 28″	28′ 18″	13′ 28″	+ 2″	41′ 24″	+ 5′ 53″	+ 64	166° 48′ 40″
3	28 27	29 48	13 34	+ 6	42 48	+ 5 53	+ 64	49 10
11	39 4	39 28	14 13	+ 1	53 30	− 4 38	+ 63	48 44
12	37 35	37 32	15 35	+ 1	53 10	− 4 38	+ 63	49 6
13	39 10	39 43	13 8	+ 5	52 39	− 4 38	+ 63	48 48
15	44 12	46 52	12 13	−10	57 35	− 7 20	− 62	49 34
18	46 0	47 10	11 3	−29	57 9	− 7 31	− 58	48 27
19	46 42	46 48	11 22	−19	57 48	− 7 31	− 58	49 55
20	44 13	44 55	12 38	−12	57 0	− 7 31	− 58	49 22
				Mean				166 49 5.1
1	103 8 12	9 4	12 2	+14	20 54	− 3 54	− 56	13 16 53
2	6 25	7 13	13 28	+12	20 29	− 3 52	− 55	17 17
3	7 12	8 24	13 34	+18	21 40	− 3 52	− 55	17 34
6	4 30	6 2	11 38	+38	17 32	− 0 9	− 35	17 27
9	102 59 56	0 22	14 30	+32	15 11	+ 3 0	− 54	17 22
10	103 1 2	1 55	13 7	+ 7	14 42	+ 3 2	− 52	17 4
11	102 59 52	0 38	14 13	+ 5	14 33	+ 3 4	− 50	16 48
13	103 00 2	0 53	13 8	+18	13 51	+ 3 4	− 50	17 1
15	102 59 47	0 47	12 13	− 2	12 28	+ 4 51	+ 45	17 16
16	103 1 13	2 23	10 58	−12	12 34	+ 4 57	+ 38	17 16
17	2 22	3 13	11 10	− 7	13 50	+ 4 57	+ 38	16 56
18	0 55	1 57	11 3	−10	12 19	+ 4 58	+ 37	16 40
19	102 59 48	1 5	11 22	− 2	11 47	+ 4 58	+ 37	16 57
20	59 16	59 44	12 38	− 3	12 5	+ 4 58	+ 37	17 30
				Mean				13 17 8.6
2	252 27 5	26 16	13 28	0	40 8	+ 7 3	+ 74	162 48 38
3	28 4	28 28	13 34	+ 1	41 51	+ 7 3	+ 74	49 27
11	40 35	41 15	14 13	0	55 8	− 5 34	+ 75	49 30
12	39 43	38 5	15 35	+ 1	55 30	− 5 34	+ 75	50 34
13	40 15	40 53	13 8	+ 2	53 44	− 5 34	+ 75	49 1
15	46 13	47 45	12 13	−11	59 1	− 8 48	− 74	49 27
18	47 52	47 58	11 3	−30	58 28	− 9 1	− 69	48 12
				Mean				162 49 15.6
2	212 1 28	2 24	13 28	−13	15 11	+20 8	+158	122 37 16
15	49 32	51 18	12 13	− 6	2 32	−25 17	−199	35 44
				Mean				122 36 30.0
2	105 25 50	26 42	13 28	+12	39 56	− 3 22	− 50	15 37 16
3	27 17	27 13	13 34	+18	41 7	− 3 22	− 50	37 33
16	21 57	23 13	10 58	−10	33 22	+ 4 19	+ 33	37 24
18	21 7	22 12	11 3	− 9	32 46	+ 4 20	+ 32	36 28
19	21 42	21 17	11 22	− 4	32 47	+ 4 20	+ 32	37 18
				Mean				15 37 11.8

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
43	1	.1198	.1144	199	—38	108	.1423	+127	+.0087	—0.377	65.1589
	2	.1202	.1164	202	—39	105	.1434	+148	+.0086	— .340	.1624
(34)	3	.1072	.1286	206	—39	105	.1434	+108	+.0086	— .340	.1584
	10	.1334	.1292	201	—40	105	.1562	— 27	—.0072	— .231	.1433
	11	.1330	.1302	199	—40	105	.1563	— 47	—.0072	— .204	.1418
	12	.1372	.1324	201	—40	105	.1597	— 39	—.0072	— .204	.1460
	13	.1285	.1371	204	—40	105	.1580	— 8	—.0072	— .204	.1474
	15	.1291	.1129	231	+40	114	.1578	— 68	—.0116	+ .063	.1402
	16	.1065	.1251	339	+38	110	.1628	— 44	—.0120	— .084	.1453
	18	.1013	.1075	327	+38	108	.1500	— 35	—.0120	— .098	.1332
	19	.1082	.1001	277	+38	105	.1445	— 21	—.0120	— .098	.1291
	20	.1226	.1394	243	+38	108	.1682	— 81	—.0120	— .098	.1468
						Mean					65.1461
44	2	.1214	.1514	187	—34	108	.1614	+130	—.0286	—0.496	57.1394
	3	.0957	.1632	194	—34	108	.1552	+ 95	—.0286	— .496	.1297
(36)	10	.1050	.0813	182	—35	104	.1172	— 23	+.0219	— .396	.1317
	11	.1076	.0924	179	—35	107	.1240	— 41	+.0221	— .372	.1372
	13	.0948	.0884	191	—35	104	.1165	— 7	+.0221	— .372	.1331
	15	.0611	.0733	214	+35	107	.1017	— 60	+.0347	+ .240	.1335
						Mean					57.1341
45	2	.2294	.1670	379	—63	111	.2336	+253	—.1844	—0.609	106.0667
	15	.7967	.7729	300	+64	111	.8250	—111	+.2306	+ .832	.0552
(54)						Mean					106.0610
46 (67)	11	.3643	.3373	157	—27	124	.3757	— 32	+.1385	—0.932	44.4990
47	12	.6216	.5740	391	—80	32	.6184	— 78	—.0516	+0.063	130.5598
	13	.5923	.5929	386	—80	32	.6127	— 17	—.0516	+ .063	.5602
(63)	19	.6220	.6042	478	+76	30	.6579	— 43	—.0838	— .362	.5652
						Mean					130.5617
48	1	.8930	.8908	202	—30	115	.9198	+ 99	—.1233	—0.849	50.7955
	2	.8974	.8948	198	—30	114	.9235	+116	—.1224	— .832	.8020
(44)	3	.8927	.9083	222	—30	114	.9303	+ 85	—.1224	— .832	.8057
	4	.7802	.7702	214	—31	114	.8041	— 1	—.0091	— .686	.7861
	5	.7692	.7614	208	—29	114	.7938	+ 33	—.0044	— .499	.7863
	6	.7539	.7722	265	—29	116	.7975	+ 45	—.0044	— .499	.7912
	7	.7687	.7475	233	—29	110	.7887	+ 47	—.0039	— .472	.7834
	8	.6814	.6796	213	—30	114	.7093	— 64	+.0941	— .809	.7866
	9	.6653	.6743	245	—30	114	.7019	— 22	+.0941	— .809	.7834
	10	.6770	.6815	181	—31	114	.7048	— 21	+.0957	— .771	.7885
	11	.6818	.6780	172	—31	114	.7046	— 36	+.0962	— .755	.7875
	12	.6745	.6767	192	—31	114	.7023	— 30	+.0962	— .755	.7858
	13	.6705	.6747	215	—31	114	.7016	— 7	+.0962	— .755	.7874
	15	.6026	.5930	199	+31	116	.6316	— 53	+.1522	+ .672	.7871
	16	.5727	.5882	298	+30	116	.6241	— 34	+.1555	+ .547	.7832
	17	.5852	.5900	251	+30	116	.6265	— 36	+.1555	+ .547	.7854
	18	.5812	.5751	293	+29	115	.6211	— 27	+.1558	+ .534	.7811
	19	.5778	.5737	246	+29	114	.6138	— 16	+.1558	+ .534	.7749
	20	.5964	.5919	256	+29	116	.6334	— 63	+.1558	+ .534	.7898
						Mean					50.7880

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession. etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	233 26 4	27 20	12 2	— 9	38 35	+11 13	+101	143 50 37
2	23 47	24 40	13 28	— 8	37 34	+11 8	+104	50 19
3	25 44	25 45	13 34	—10	39 8	+11 8	+104	50 59
10	46 0	47 2	13 7	— 5	59 33	— 8 44	+108	51 7
11	45 4	45 52	14 13	— 4	59 37	— 8 47	+109	50 58
12	43 15	43 33	15 35	— 7	58 52	— 8 47	+109	50 55
13	45 53	45 35	13 8	—11	58 41	— 8 48	+109	50 56
15	53 28	55 5	12 13	—11	6 19	—13 55	—114	51 24
16	55 58	55 13	10 58	—29	6 5	—14 13	—113	50 42
18	54 56	55 52	11 3	—27	6 48	—14 15	—112	51 3
19	54 48	56 15	11 22	—19	6 35	—14 15	—112	51 39
20	52 13	52 18	12 38	—12	4 42	—14 15	—112	50 1
				Mean				143 50 53.3
2	223 19 12	16 18	13 28	—11	31 2	+12 35	+108	133 45 16
3	17 30	19 20	13 34	—16	31 43	+12 35	+108	45 3
10	41 55	41 54	13 7	— 7	54 54	— 9 53	+116	45 22
11	38 43	41 17	14 13	— 5	54 8	— 9 56	+117	44 23
13	40 55	40 51	13 8	—16	53 45	— 9 56	+117	44 55
15	50 8	50 40	12 13	— 9	2 28	—15 45	—126	45 39
				Mean				133 45 6.3
2	112 43 4	42 0	13 28	+14	56 14	— 3 12	— 53	22 53 43
15	37 44	37 40	12 13	+ 2	49 57	+ 4 1	+ 40	53 53
				Mean				22 53 48.0
11	174 32 24	32 0	14 13	— 2	46 23	— 7 6	+ 52	84 39 5.0
12	249 19 12	20 30	15 35	— 2	35 24	— 4 12	+ 56	159 31 43
13	22 41	23 17	13 8	— 1	36 6	— 4 12	+ 56	32 38
19	28 15	29 0	11 22	—21	39 38	— 6 48	— 53	32 30
				Mean				159 32 17.0
1	195 28 36	29 55	12 2	—14	41 4	+11 41	+ 68	105 53 22
2	25 48	26 26	13 28	—12	39 24	+11 36	+ 74	52 27
3	27 57	28 55	13 34	—19	41 41	+11 36	+ 74	53 50
4	38 16	39 26	12 39	—16	51 15	+ 0 52	+102	52 9
5	41 17	42 49	11 38	—15	53 26	+ 0 25	+119	54 26
6	40 58	41 57	11 38	—39	52 27	+ 0 25	+119	53 52
7	36 23	26 53	12 52	—25	49 5	+ 0 22	+121	53 32
8	48 38	50 8	13 3	—19	2 7	— 9 0	+ 80	53 24
9	48 10	49 2	14 30	—33	2 33	— 9 0	+ 80	53 32
10	48 54	48 46	13 7	— 8	1 49	— 9 9	+ 89	52 51
11	47 28	49 7	14 13	— 6	2 25	— 9 12	+ 92	53 15
12	45 25	47 0	15 35	—10	1 37	— 9 12	+ 92	53 9
13	47 28	48 43	13 8	—18	0 56	— 9 12	+ 92	52 41
15	55 32	57 4	12 13	+ 1	8 32	—14 35	—110	52 58
16	57 25	59 15	10 58	+ 9	9 27	—14 54	—121	53 20
17	59 30	0 18	11 10	+ 6	11 11	—14 54	—121	53 28
18	57 5	57 12	11 3	+ 7	8 18	—14 56	—122	51 48
19	57 7	57 45	11 22	+ 4	8 52	—14 56	—122	53 11
20	54 57	56 52	12 38	+ 1	8 33	—14 56	—122	53 7
				Mean				105 53 10.6

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.					
49 (87)	11	.7198	.6913	191	—35	110	.7311	— 41	+.0740	—0.648	57.7927
50	1	.8328	.8330	229	—34	110	.8622	+115	—.1125	—0.818	58.7507
	2	.8461	.8266	225	—35	108	.8650	+134	—.1117	— .798	.7565
(43)	3	.8240	.8310	245	—35	108	.8581	+ 98	—.1117	— .798	.7460
	6	.7042	.7006	292	—34	110	.7380	+ 52	—.0040	— .447	.7335
	9	.6356	.6495	272	—35	108	.6759	— 26	+.0858	— .773	.7492
	10	.6264	.6376	206	—36	106	.6584	— 24	+.0872	— .732	.7338
	11	.6362	.6416	197	—36	108	.6646	— 42	+.0877	— .714	.7389
	12	.6252	.6469	217	—36	108	.6637	— 35	+.0877	— .714	.7387
	13	.6383	.6366	239	—36	108	.6674	— 8	+.0877	— .714	.7451
	15	.5651	.5525	231	+36	110	.5953	— 61	+.1389	+ .623	.7361
	16	.5421	.5413	350	+34	112	.5901	— 39	+.1418	+ .494	.7343
	17	.5392	.5627	292	+34	112	.5935	— 42	+.1418	+ .494	.7374
	18	.5536	.5380	341	+34	110	.5931	— 31	+.1421	+ .481	.7383
	19	.5278	.5230	285	+34	108	.5669	— 19	+.1421	+ .481	.7133
	20	.5624	.5660	242	+34	108	.6014	— 73	+.1421	+ .481	.7424
						Mean					58.7396
51 (42)	2	.8800	.9059	340	—63	118	.9249	+243	—.0074	—0.409	106.9365
52	1	.3976	.3860	312	—45	137	.4295	+149	—.1365	—0.883	76.2966
	2	.3822	.3992	306	—45	136	.4277	+174	—.1355	— .869	.2984
(45)	3	.3848	.4191	339	—45	136	.4422	+127	—.1355	— .869	.3082
	10	.1701	.1525	277	—46	136	.1953	— 31	+.1061	— .818	.2878
	11	.1598	.1582	263	—47	136	.1915	— 54	+.1067	— .802	.2825
	12	.1513	.1481	293	—46	136	.1853	— 46	+.1067	— .802	.2771
	13	.1288	.1570	334	—46	136	.1826	— 10	+.1067	— .802	.2780
	15	.0628	.0610	299	+46	140	.1077	— 80	+.1689	+ .729	.2780
	16	.0323	.0501	446	+44	136	.1011	— 51	+.1725	+ .611	.2763
	18	.0378	.0366	435	+44	136	.0960	— 41	+.1729	+ .599	.2725
						Mean					76.2855
53	1	.0292	.0332	338	—44	136	.0715	+148	—.1840	—0.969	75.8899
	2	.0322	.0274	326	—45	136	.0688	+173	—.1827	— .970	.8909
(2)	3	.0089	.0216	375	—45	136	.0592	+127	—.1827	— .970	.8767
	6	.8531	.8279	499	—44	140	.8973	+ 68	—.0066	— .798	.8873
	7	.8662	.8756	411	—43	136	.9186	+ 70	—.0058	— .778	.9098
	9	.6960	.7096	452	—45	136	.7544	— 34	+.1411	— .968	.8797
	10	.7138	.7182	288	—46	136	.7511	— 31	+.1433	— .957	.8790
	11	.7125	.7225	269	—46	136	.7507	— 54	+.1441	— .952	.8772
	12	.7044	.7109	310	—46	136	.7449	— 45	+.1441	— .952	.8723
	13	.7131	.7071	363	—46	136	.7527	— 10	+.1441	— .952	.8836
	15	.5971	.5812	281	+46	140	.6332	— 79	+.2283	+ .927	.8655
	16	.5842	.5820	382	+44	140	.6370	— 51	+.2331	+ .848	.8759
	17	.5973	.5906	333	+44	140	.6430	— 54	+.2331	+ .848	.8816
	18	.5763	.5611	376	+44	138	.6218	— 41	+.2336	+ .838	.8621
	19	.5838	.5694	333	+44	134	.6248	— 25	+.2336	+ .838	.8667
	20	.5980	.5938	292	+44	136	.6404	— 94	+.2336	+ .838	.8754
						Mean					75.8796

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′		° ′ ″
11	204 39 45	41 48	14 13	— 6	54 54	— 8 53	+ 95	114 46 4.0
1	199 0 26	1 14	12 2	—14	12 37	+10 3	+ 66	109 23 46
2	198 58 34	59 32	13 28	—13	12 18	+10 28	+ 71	24 12
3	59 36	1 17	13 34	—20	13 41	+10 28	+ 71	24 41
6	199 12 8	13 4	11 38	—39	23 35	+ 0 23	+107	24 53
9	18 10	18 50	14 30	—33	32 27	— 8 7	+ 76	24 17
10	18 23	18 46	13 7	— 8	31 34	— 8 14	+ 82	23 29
11	18 7	18 59	14 13	— 6	32 40	— 8 17	+ 85	24 23
12	16 8	15 50	15 35	—11	31 23	— 8 17	+ 85	23 48
13	17 48	18 55	13 8	—19	31 33	— 8 17	+ 85	24 11
15	25 28	27 22	12 13	— 1	38 37	—13 8	—100	24 34
16	26 21	28 21	10 58	+ 7	38 26	—13 25	—109	23 53
17	28 37	29 22	11 10	+ 2	40 12	—13 25	—109	24 3
18	27 32	27 36	11 3	+ 3	38 40	—13 27	—109	23 44
19	26 53	27 40	11 22	+ 2	38 41	—13 27	—109	24 34
20	24 43	26 12	12 38	— 1	38 5	—13 27	—109	24 13
				Mean				109 24 10.7
2	229 19 12	20 3	13 28	— 9	32 57	+ 6 48	+ 61	139 41 7.0
1	191 1 24	2 38	12 2	—14	13 49	+ 7 20	+ 39	101 21 36
2	190 59 52	0 53	13 28	—12	13 38	+ 7 17	+ 43	22 10
3	191 0 5	1 12	13 34	—18	13 54	+ 7 17	+ 43	21 32
10	14 25	15 6	13 7	— 7	27 46	— 5 44	+ 53	22 0
11	13 8	13 45	14 13	— 5	27 35	— 5 46	+ 55	21 38
12	11 20	11 38	15 35	— 9	26 55	— 5 46	+ 55	21 40
13	13 55	14 13	13 8	—17	26 55	— 5 46	+ 55	21 53
15	18 23	19 38	12 13	+ 2	31 15	— 9 9	— 68	21 23
16	20 32	20 28	10 58	+14	31 42	— 9 21	— 76	21 25
18	18 40	20 4	11 3	+11	30 36	— 9 22	— 76	19 57
				Mean				101 21 31.4
1	170 48 12	48 55	12 2	— 5	0 31	+ 4 47	+ 7	81 5 34
2	46 22	46 50	13 28	— 5	59 59	+ 4 45	+ 11	5 48
3	47 0	48 15	13 34	— 8	1 4	+ 4 45	+ 11	5 59
6	53 52	53 47	11 38	—20	5 8	+ 0 10	+ 52	5 54
7	49 3	49 42	12 52	—11	2 3	+ 0 9	+ 54	5 52
9	55 12	56 25	14 30	—17	10 1	— 3 41	+ 16	5 56
10	56 10	56 38	13 7	— 2	9 29	— 3 45	+ 22	5 31
11	55 16	56 45	14 13	— 2	10 12	— 3 46	+ 25	6 4
12	53 20	54 3	15 35	— 4	9 13	— 3 46	+ 25	5 47
13	56 6	56 52	13 8	— 7	9 30	— 3 46	+ 25	6 17
15	59 44	0 28	12 13	+ 9	12 28	— 5 59	— 39	5 56
16	171 1 32	2 18	10 58	+29	13 22	— 6 6	— 52	6 28
17	1 52	3 37	11 10	+20	14 14	— 6 6	— 52	5 44
18	1 17	1 6	11 3	+27	12 42	— 6 7	— 52	5 26
19	0 10	0 48	11 22	+17	12 8	— 6 7	— 52	5 41
20	170 58 45	59 57	12 38	+11	12 10	— 6 7	— 52	5 58
				Mean				81 5 52.2

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean. *s*	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance. σ
54	1	.4460	.4362	344	—45	137	.4820	+151	—.1890	—0.972	77.2956
	2	.4637	.4137	333	—46	135	.4806	+176	—.1876	— .975	.2981
(3)	3	.4183	.4360	385	—46	134	.4716	+129	—.1876	— .975	.2844
	9	.0746	.0985	468	—46	134	.1393	— 34	+.1449	— .975	.2683
	10	.0965	.1053	294	—47	134	.1362	— 31	+.1472	— .969	.2679
	11	.0990	.0974	274	—47	134	.1315	— 55	+.1480	— .964	.2616
	12	.0802	.0902	316	—47	134	.1227	— 46	+.1480	— .964	.2537
	13	.0853	.0943	372	—47	134	.1329	— 10	+.1480	— .964	.2675
	15	.9911	.9729	227	+47	130	.0196	— 81	+.2344	+ .946	.2570
	16	.9606	.9866	375	+45	135	.0263	— 52	+.2394	+ .873	.2717
	17	.9814	.9784	330	+45	135	.0281	— 55	+.2394	+ .873	.2732
	18	.9590	.9661	373	+45	134	.0150	— 41	+.2398	+ .864	.2618
	20	.9690	.9765	293	+45	135	.0172	— 96	+.2398	+ .864	.2585
						Mean					77.2707
55	12	.6444	.6202	416	—82	17	.6525	— 81	—.0089	—0.194	134.6330
	13	.5973	.5996	417	—82	17	.6186	— 17	—.0089	— .194	.6055
(59)	18	.6110	.5766	670	+79	20	.6557	— 72	—.0146	— .108	.6325
						Mean					134.6237
56	2	.3874	.3912	474	—69	130	.4329	+267	—.2077	—0.833	117.2412
	3	.3788	.3658	541	—69	126	.4222	+196	—.2077	— .833	.2234
(6)	11	.0598	.0434	398	—71	122	.0867	— 84	+.1639	— .908	.2305
	15	.9152	.9111	354	+71	124	.9584	—122	+.2597	+ .979	.2185
	16	.8690	.8820	360	+68	124	.9210	— 78	+.2653	+ .993	.1913
	18	.8900	.8905	372	+68	124	.9368	— 63	+.2658	+ .993	.2091
	19	.8798	.8847	368	+68	124	.9285	— 38	+.2658	+ .993	.2033
						Mean					117.2168
57 (53)	2	.7927	.7629	445	—64	122	.8204	+245	—.2098	—0.881	107.6238
58	2	.8308	.8107	349	—53	138	.8597	+205	—.1171	—0.815	89.7526
	10	.6051	.6227	316	—55	138	.6493	— 37	+.0917	— .752	.7276
(47)	11	.6066	.6086	303	—55	134	.6414	— 64	+.0922	— .735	.7178
	12	.5642	.5797	336	—55	134	.6091	— 54	+.0922	— .735	.6865
	13	.6056	.6115	374	—55	134	.6496	— 12	+.0922	— .735	.7312
	15	.5336	.5150	353	+54	135	.5741	— 94	+.1459	+ .649	.7189
	16	.5061	.5177	533	+52	137	.5797	— 60	+.1490	+ .521	.7294
	18	.4881	.4839	519	+52	135	.5522	— 48	+.1493	+ .508	.7032
	20	.5215	.5150	371	+52	132	.5693	—111	+.1493	+ .508	.7140
						Mean					89.7201

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Corrections plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	167 59 33	0 3	12 2	− 4	11 46	+ 4 18	+ 2	78 16 18
2	56 40	57 8	13 28	− 3	10 19	+ 4 16	+ 6	15 37
3	57 56	58 47	13 34	− 6	11 50	+ 4 16	+ 6	16 14
9	168 4 55	5 15	14 30	−14	19 21	− 3 18	+ 11	15 37
10	5 39	7 8	13 7	− 2	19 29	− 3 22	+ 17	15 52
11	5 12	6 10	14 13	− 1	19 53	− 3 23	+ 20	16 6
12	2 52	3 53	15 35	− 3	18 54	− 3 23	+ 20	15 49
13	5 55	6 20	13 8	− 6	19 10	− 3 23	+ 20	16 18
15	8 37	10 20	12 13	− 7	21 34	− 5 22	− 34	15 41
16	10 10	11 55	10 58	+31	22 31	− 5 28	− 46	16 17
17	12 2	13 53	11 10	+21	24 28	− 5 28	− 46	16 38
18	9 24	10 24	11 3	+28	21 25	− 5 29	− 47	14 49
20	8 30	9 18	12 38	+12	21 44	− 5 29	− 47	16 12
				Mean				78 15 57.5
12	234 16 10	16 58	15 35	− 7	32 2	− 4 17	+ 52	144 28 15
13	18 53	20 5	13 8	− 9	32.28	− 4 17	+ 52	28 54
18	24 55	25 28	11 3	−27	36 36	− 6 56	− 54	28 31
				Mean				144 28 33.3
2	132 39 28	40 15	13 28	+11	53 31	− 0 52	− 32	42 53 27
3	40 56	41 2	13 34	+16	54 49	− 0 52	− 32	53 51
11	39 11	39 40	14 13	+ 6	53 45	+ 0 41	− 25	53 46
15	40 7	40 53	12 13	+ 9	52 52	+ 1 5	+ 16	53 44
16	41 32	42 5	10 58	+20	53 6	+ 1 6	+ 7	53 46
18	40 40	41 35	11 3	+20	52 31	+ 1 7	+ 6	52 50
19	40 16	40 50	11 22	+14	52 9	+ 1 7	+ 6	53 17
				Mean				42 53 31.6
2	138 30 38	32 40	13 28	+10	45 17	− 0 16	− 29	48 45 51.0
2	197 16 8	16 14	13 28	−12	29 27	+ 6 45	+ 44	107 37 28
10	29 3	30 16	13 7	− 8	42 39	− 5 18	+ 52	37 19
11	28 26	28 22	14 13	− 5	42 32	− 5 20	+ 54	37 0
12	26 57	27 23	15 35	−10	42 35	− 5 20	+ 54	37 45
13	29 3	29 25	13 8	−19	42 3	− 5 20	+ 54	37 26
15	34 12	35 23	12 13	+ 1	47 2	− 8 27	− 64	37 53
16	35 58	36 52	10 58	+ 7	47 38	− 8 38	− 70	37 58
18	34 41	35 58	11 3	+ 5	46 28	− 8 39	− 71	36 33
20	32 46	34 18	12 38	+ 1	46 11	− 8 39	− 71	37 20
				Mean				107 37 24.4

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Cor-rected Mean.	Scale Varia-tion.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*				σ
59	1	.9381	.9276	369	—57	148	.9731	+189	—.1024	—0.787	96.8795
	2	.9478	.9312	364	—57	148	.9793	+221	—.1017	— .767	.8899
(41)	3	.9334	.9322	394	—57	148	.9756	+162	—.1017	— .767	.8803
	10	.7559	.7671	337	—59	148	.7985	— 39	+.0796	— .695	.8653
	11	.7572	.7653	323	—59	148	.7967	— 69	+.0800	— .676	.8611
	12	.7542	.7318	350	—59	148	.7812	— 58	+.0800	— .676	.8467
	13	.7580	.7381	388	—59	148	.7901	— 12	+.0800	— .676	.8602
	15	.6890	.6809	380	+59	146	.7379	—101	+.1266	+ .579	.8618
	16	.6440	.6572	581	+56	146	.7232	— 65	+.1293	+ .446	.8517
	17	.6586	.6644	482	+56	147	.7244	— 69	+.1293	+ .446	.8525
	18	.6513	.6443	564	+56	146	.7188	— 52	+.1296	+ .433	.8488
	19	.6702	.6610	471	+56	148	.7275	— 32	+.1296	+ .433	.8595
	20	.6762	.6707	399	+56	146	.7279	—120	+.1296	+ .433	.8511
						Mean					96.8622
60	2	.7962	.7690	422	—58	145	.8276	+222	—.2024	—0.968	97.6350
	13	.4324	.4264	473	—60	146	.4795	— 13	+.1597	— .985	.6253
(51)	15	.3186	.3134	338	+59	146	.3645	—102	+.2530	+ .998	.6201
						Mean					97.6268
61	1	.3070	.3036	397	—63	122	.3432	+211	—.0862	—0.737	108.2686
	2	.3178	.3030	389	—64	122	.3473	+246	—.0856	— .712	.2772
(40)	3	.3112	.2954	423	—64	122	.3436	+180	—.0856	— .712	.2669
	5	.2298	.2492	408	—62	120	.2784	+ 48	—.0031	— .323	.2760
	6	.2046	.2209	480	—62	122	.2591	+ 97	—.0031	— .323	.2616
	7	.2193	.1991	442	—61	120	.2515	+101	—.0027	— .295	.2551
	9	.1560	.1612	454	—65	126	.2024	— 48	+.0658	— .681	.2547
	10	.1578	.1520	368	—66	126	.1900	— 44	+.0669	— .633	.2444
	11	.1635	.1619	356	—66	126	.1966	— 77	+.0673	— .613	.2483
	12	.1466	.1568	383	—66	126	.1883	— 65	+.0673	— .613	.2412
	13	.1485	.1453	415	—66	126	.1867	— 14	+.0673	— .613	.2447
	15	.0917	.0877	425	+66	122	.1433	—113	+.1064	+ .506	.2449
	16	.0790	.0780	647	+63	122	.1540	— 72	+.1087	+ .367	.2602
	17	.0733	.0785	537	+63	122	.1404	— 77	+.1087	+ .367	.2461
	18	.0579	.0615	628	+63	122	.1333	— 58	+.1089	+ .354	.2409
	19	.0782	.0768	524	+63	122	.1407	— 35	+.1089	+ .354	.2506
	20	.0894	.0866	445	+63	122	.1433	—134	+.1089	+ .354	.2433
						Mean					108.2544
62	2	.5976	.6115	483	—66	125	.6504	+265	—.1918	—0.977	111.4726
	3	.5722	.5680	504	—66	124	.6179	+186	—.1918	— .977	.4322
(57)	18	.1430	.1066	539	+65	130	.1899	— 60	+.2453	+ .886	.4406
						Mean					111.4485

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
1	202 13 14	14 32	12 2	—16	25 39	+ 6 38	+ 43	112 32 45
2	11 48	13 5	13 28	—14	25 40	+ 6 35	+ 46	33 32
3	12 44	14 37	13 34	—20	26 55	+ 6 35	+ 46	33 53
10	25 8	25 22	13 7	— 8	38 14	— 5 10	+ 53	33 2
11	23 46	24 18	14 13	— 6	38 9	— 5 12	+ 54	32 45
12	21 55	23 7	15 35	—11	37 55	— 5 12	+ 54	33 13
13	24 20	25 4	13 8	—19	37 53	— 5 12	+ 54	33 24
15	29 20	30 35	12 13	— 2	42 9	— 8 15	— 63	33 12
16	30 13	31 50	10 58	+ 2	42 2	— 8 25	— 68	32 44
17	32 40	33 57	11 10	— 1	44 27	— 8 25	— 68	33 33
18	30 18	31 20	11 3	0	41 52	— 8 26	— 69	32 11
19	30 15	31 5	11 22	— 2	42 00	— 8 26	— 69	33 8
20	28 45	29 52	12 38	— 3	41 53	— 8 26	— 69	33 16
				Mean				112 33 7.5
2	156 50 25	50 51	13 28	+ 2	4 8	+ 2 3	— 9	67 7 8
13	53 37	54 41	13 8	+ 1	7 18	— 1 37	+ 1	6 5
15	56 2	58 2	12 13	+11	9 26	— 2 34	— 13	6 28
				Mean				67 6 33.7
1	207 10 48	12 2	12 2	—16	23 11	+ 6 12	+ 43	117 29 51
2	8 43	9 52	13 28	—14	22 31	+ 6 9	+ 45	29 56
3	9 24	11 10	13 34	—20	23 31	+ 6 9	+ 45	30 2
5	18 0	19 2	11 38	—17	29 52	+ 0 13	+ 62	30 19
6	17 4	18 27	11 38	—37	28 46	+ 0 13	+ 62	29 38
7	12 40	13 33	12 52	—26	26 33	+ 0 12	+ 62	30 28
9	20 16	21 4	14 30	—32	34 38	— 4 46	+ 48	29 39
10	21 2	21 36	13 7	— 8	34 18	— 4 50	+ 52	29 26
11	19 56	20 56	14 13	— 6	34 33	— 4 52	+ 53	29 29
12	18 13	18 35	15 35	—11	33 48	— 4 52	+ 53	29 26
13	20 33	21 8	13 8	—19	33 39	— 4 52	+ 53	29 30
15	25 25	26 33	12 13	— 3	38 9	— 7 42	— 60	29 46
16	26 32	28 16	10 58	— 3	38 19	— 7 52	— 63	29 35
17	28 15	29 31	11 10	— 6	39 57	— 7 52	— 63	29 37
18	26 20	26 53	11 3	— 6	37 40	— 7 53	— 63	28 34
19	26 15	26 40	11 22	— 3	37 47	— 7 53	— 63	29 30
20	24 26	25 40	12 38	— 3	37 38	— 7 53	— 63	29 36
				Mean				117 29 40.1
2	165 20 35	21 26	13 28	— 2	34 27	+ 2 42	+ 1	75 38 9
3	21 48	22 25	13 34	— 4	35 37	+ 2 42	+ 1	38 25
18	30 0	30 27	11 3	+29	41 45	— 3 28	— 30	37 16
				Mean				75 37 56.7

Table V.—Results of Measures of Distance. (*Concluded.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Parallax *Co-efficient.*	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s				σ
63	2	.7541	.7438	470	−65	133	.7946	+250	−.1809	−0.967	109.6263
	11	.4323	.4440	389	−67	133	.4757	− 78	+.1426	− .946	.5984
(48)	13	.4072	.4136	524	−67	126	.4607	− 14	+.1426	− .946	.5898
	15	.3026	.2808	411	+66	124	.3438	−114	+.2259	+ .920	.5701
	16	.2991	.3042	555	+64	128	.3683	− 73	+.2307	+ .837	.6024
	17	.2860	.2935	488	+64	128	.3498	− 78	+.2307	+ .837	.5834
	18	.2766	.2810	550	+63	126	.3447	− 59	+.2312	+ .829	.5806
	19	.3023	.2725	483	+63	126	.3466	− 36	+.2312	+ .829	.5848
	20	.3147	.2970	425	+63	134	.3600	−136	+.2312	+ .829	.5882
						Mean					109.5916
64	1	.1776	.1780	535	−70	123	.2260	+234	−.2010	−0.965	120.0360
	2	.1922	.1778	520	−71	123	.2316	+273	−.1996	− .974	.0468
(46)	3	.1634	.1586	602	−71	123	.2157	+200	−.1996	− .974	.0236
	4	.0126	.9952	575	−73	123	.0558	− 3	−.0149	− .971	.0281
	5	.0018	.9997	558	−69	123	.0514	+ 53	−.0072	− .889	.0381
	6	.9536	.9504	818	−69	123	.0286	+107	−.0072	− .889	.0207
	7	.9913	.0029	664	−68	124	.0585	+111	−.0064	− .874	.0520
	9	.8060	.8200	741	−72	123	.8816	− 53	+.1542	− .981	.0179
	10	.8454	.8412	457	−73	123	.8834	− 49	+.1566	− .985	.0225
	11	.8628	.8512	427	−73	123	.8941	− 86	+.1575	− .984	.0304
	12	.8466	.8533	492	−73	123	.8936	− 72	+.1575	− .984	.0313
	13	.8351	.8323	584	−73	123	.8865	− 15	+.1575	− .984	.0299
	15	.7124	.7110	422	+73	123	.7629	−125	+.2495	+ .989	.0126
	17	.6883	.6890	477	+70	124	.7451	− 85	+.2548	+ .935	.0034
	19	.6955	.6875	481	+70	123	.7484	− 39	+.2553	+ .929	.0117
	20	.6944	.6862	434	+70	126	.7428	−149	+.2553	+ .929	.9951
						Mean					120.0250
65	2	.0835	.0878	479	−76	34	.1161	+294	−.0945	−0.743	129.0415
	15	.8134	.8004	506	+78	46	.8567	−135	+.1179	+ .547	128.9681
(50)	18	.7827	.7731	749	+75	43	.8515	− 69	+.1206	+ .398	.9703
	20	.8129	.8114	532	+75	43	.8641	−160	+.1206	+ .398	.9738
						Mean					128.9884
66	2	.9326	.9067	523	−72	122	.9659	+277	−.1821	−0.970	121.7990
	11	.6092	.6052	433	−75	123	.6443	− 87	+.1437	− .950	.7671
(49)	13	.6028	.5993	585	−75	122	.6532	− 16	+.1437	− .950	.7831
	18	.4338	.4378	610	+70	128	.5056	− 65	+.2329	+ .836	.7427
						Mean					121.7730

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Concluded.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. *p*	Proper Motion.	Parallax *Coefficient.*	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	′ ″	′ ″		° ′ ″
2	171 47 50	48 36	13 28	— 5	1 36	+ 3 25	+ 8	82 6 4
11	54 45	55 13	14 13	— 2	9 10	— 2 42	+ 19	6 4
13	54 32	55 23	13 8	— 2	8 4	— 2 42	+ 19	5 53
15	57 35	59 8	12 13	+ 8	10 43	— 4 17	— 29	5 57
16	58 45	00 32	10 58	+30	10 6	— 4 23	— 37	5 1
17	172 0 50	1 45	11 10	+19	12 47	— 4 23	— 37	6 6
18	171 58 36	59 25	11 3	+28	10 32	— 4 23	— 38	5 5
19	58 36	59 6	11 22	+17	10 30	— 4 23	— 38	5 52
20	57 8	58 32	12 38	+10	10 38	— 4 23	— 38	6 15
				Mean				82 5 48.6
1	159 29 58	30 42	12 2	+ 1	42 23	+ 1 57	— 7	69 44 31
2	27 58	28 33	13 28	+ 1	41 45	+ 1 56	— 4	44 40
3	28 30	29 42	13 34	0	42 40	+ 1 56	— 4	44 41
4	30 58	31 25	12 39	0	43 51	+ 0 9	+ 10	43 29
5	32 37	32 45	11 38	0	44 19	+ 0 4	+ 23	44 23
6	31 30	33 2	11 38	— 6	43 48	+ 0 4	+ 23	44 17
7	27 32	27 55	12 52	— 8	40 28	+ 0 4	+ 25	44 2
9	31 23	31 55	14 30	— 4	46 5	— 1 30	— 1	44 5
10	32 38	33 35	13 7	+ 1	46 15	— 1 32	+ 2	44 23
11	31 37	32 12	14 13	+ 1	46 8	— 1 32	+ 4	44 6
12	29 26	30 7	15 35	+ 2	45 23	— 1 32	+ 4	44 3
13	31 28	32 32	13 8	+ 1	45 9	— 1 32	+ 4	44 2
15	34 5	35 40	12 13	+11	47 16	— 2 26	— 13	44 26
17	37 0	37 53	11 10	+23	49 0	— 2 29	— 21	44 18
19	34 50	35 2	11 22	+20	46 38	— 2 29	— 22	44 0
20	33 28	34 33	12 38	+13	46 52	— 2 29	— 22	44 29
				Mean				69 44 14.7
2	204 24 48	25 48	13 28	—14	38 32	+ 5 3	+ 36	114 44 48
15	39 12	40 48	12 13	— 3	52 10	— 6 20	— 49	45 13
18	40 5	41 10	11 3	— 2	51 39	— 6 28	— 52	44 2
20	38 30	39 10	12 38	— 3	51 25	— 6 29	— 52	44 51
				Mean				114 44 43.5
2	171 6 10	7 7	13 28	— 5	20 1	+ 3 1	+ 7	81 24 4
11	11 43	12 37	14 13	— 2	26 21	— 2 23	+ 16	23 33
13	12 10	12 34	13 8	— 7	25 23	— 2 23	+ 16	23 30
18	15 34	16 12	11 3	+28.	27 24	— 3 52	— 33	22 30
								81 23 24.2

Table VII.—For Proper Motion.

(See Paragraphs 11–12 and 17–18.)

Star No.	In Distance.		In Position Angle.		
	S_1	S_2	S_5	S_6	S_7
1	—.2384	—.0035	+.9712	.007 43	+.007 216
2	—.9977	—.0000	+.0681	.009 17	+.000 624
3	—.9997	—.0000	—.0237	.008 75	—.000 207
4	—.9968	—.0000	—.0794	.009 03	—.000 717
5	—.7484	—.0029	+.6632	.012 95	+.008 588
6	—.9997	—.0000	—.0228	.010 53	—.000 240
7	—.9979	—.0000	+.0649	.012 29	+.000 798
8	—.3231	—.0073	+.9464	.016 36	+.015 483
9	—.8917	—.0009	—.4526	.008 72	—.003 947
10	+.1802	—.0049	+.9836	.010 09	+.009 925
11	+.1589	—.0066	+.9873	.013 48	+.013 309
12	—.0319	—.0093	+.9995	.018 63	+.018 621
13	+.3395	—.0045	+.9406	.010 17	+.009 566
14	—.4216	—.0118	+.9068	.028 84	+.026 152
15	—.9606	—.0007	—.2780	.019 16	—.005 326
16	—.9419	—.0019	+.3360	.033 01	+.011 091
17	+.3379	—.0054	+.9412	.012 13	+.011 417
18	+.2877	—.0065	+.9577	.014 30	+.013 695
19	—.7295	—.0018	—.6840	.007 76	—.005 308
20	+.4677	—.0053	+.8838	.013 56	+.011 984
21	—.9264	—.0032	—.3767	.044 91	—.016 918
22	+.5569	—.0031	+.8306	.009 04	+.007 509
23	+.5665	—.0038	+.8240	.011 20	+.009 229
24	+.1855	—.0568	+.9827	.117 38	+.115 349
25					
26					
27	—.5863	—.0085	—.8100	.026 06	—.021 109
28	—.6038	—.0028	—.7971	.008 95	—.007 134
29	+.7608	—.0058	+.6488	.027 76	+.018 011
30	+.9269	—.0039	+.3753	.054 36	+.020 401
31	—.4932	—.0063	—.8699	.016 70	—.014 527
32	—.5183	—.0048	—.8552	.013 00	—.011 118
33	+.8631	—.0037	+.5049	.028 72	+.014 501
34	—.0903	—.0144	—.9959	.028 99	—.028 871
35	+.3090	—.0200	—.9510	.044 16	—.041 996
36	+.8577	—.0059	—.5141	.044 64	—.022 941
37	—.1433	—.0103	—.9897	.020 95	—.020 734
38	—.4283	—.0036	—.9036	.008 91	—.008 051
39	+.7852	—.0017	+.6192	.008 79	+.005 443
40	—.3641	—.0045	—.9314	.010 39	—.009 677

TABLE VII.—FOR PROPER MOTION. (*Concluded.*)

(See Paragraphs 11–12 and 17–18.)

Star No.	In Distance.		In Position Angle.		
	S_1	S_2	S_5	S_6	S_7
41	+.3234	—.0132	—.9463	.029 42	—.027 840
42	+.8099	—.0014	+.5866	.008 12	+.004 763
43	—.0424	—.0077	—.9991	.015 35	—.015 336
44	+.1342	—.0086	—.9909	.017 50	—.017 341
45	+.8777	—.0011	+.4792	.009 43	+.004 519
46	+.8362	—.0034	—.5484	.022 47	—.012 323
47	—.3107	—.0035	—.9505	.007 66	—.007 281
48	+.5812	—.0065	—.8137	.019 69	—.016 022
49	+.4478	—.0069	—.8941	.017 30	—.015 468
50	+.5301	—.0061	—.8479	.017 02	—.014 431
51	+.0343	—.0047	—.9994	.009 35	—.009 344
52	+.6442	—.0038	—.7648	.013 11	—.010 027
53	+.8692	—.0016	—.4943	.013 18	—.006 515
54	+.8926	—.0013	—.4508	.012 94	—.005 833
55	—.0531	—.0037	—.9986	.007 43	—.007 420
56	+.9887	—.0001	+.1500	.008 53	+.001 280
57	+.9988	—.0000	+.0482	.009 29	+.000 448
58	+.5565	—.0039	—.8309	.011 15	—.009 265
59	+.4832	—.0040	—.8755	.010 32	—.009 035
60	+.9632	—.0004	—.2689	.010 24	—.002 754
61	+.4063	—.0039	—.9137	.009 24	—.008 443
62	+.9128	—.0007	—.4084	.008 97	—.003 663
63	+.8604	—.0012	—.5096	.009 13	—.004 653
64	+.9498	—.0004	—.3129	.008 33	—.002 606
65	+.4494	—.0031	—.8933	.007 75	—.006 923
66	+.8669	—.0010	—.4984	.008 21	—.004 092

Table VIII.—For Parallax.

(See Paragraphs 14 and 22.)

Star No.	In Distance.		In Position Angle.	
	s_3	s_4	s_8	s_9
1	+.080	+.825	− 52.6	− 4.6
2	+.941	+.330	− 14.6	+ 51.4
3	+.957	+.259	− 8.3	+ 50.7
4	+.962	+.215	− 5.0	+ 53.2
5	+.613	+.726	− 71.1	+ 38.2
6	+.957	+.260	− 10.0	+ 61.1
7	+.941	+.328	− 19.3	+ 68.9
8	+.165	+.829	−114 6	− 1.3
9	+.918	−.106	+ 19.1	+ 52.8
10	−.320	+.718	− 67.6	− 30.8
11	−.301	+.727	− 90.9	− 39.7
12	−.121	+.790	−131.3	− 35.0
13	−.466	+.641	− 63.3	− 39.5
14	+.265	+.825	−197.3	+ 15 9
15	+.958	+.049	+ 17.0	+116.8
16	+.847	+.524	−112.7	+156.0
17	−.464	+.642	− 75.5	− 47.0
18	−.419	+.668	− 91.4	− 51.8
19	+.799	−.332	+ 31.0	+ 43.4
20	−.579	+.561	− 77.0	− 61.1
21	+.940	−.037	+ 73.1	+273.8
22	−.656	+.494	− 47.1	− 44.3
23	−.665	+.487	− 57.7	− 55.4
24	−.325	+.716	−779.8	−372.7
25				
26				
27	+.681	−.470	+131.6	+130.8
28	+.696	−.455	+ 44 1	+ 45.6
29	−.823	+.296	−102.8	−158.3
30	−.940	+.036	− 85.8	−331.6
31	+.602	−.543	+ 93.0	+ 76.9
32	+.623	−.524	+ 70.6	+ 61.4
33	−.899	+.155	− 74.0	−172.3
34	+.237	−.753	+199.8	+ 73.8
35	−.151	−.829	+309.6	+ 5.4
36	−.740	−.640	+203.1	−173.8
37	+.286	−.734	+142.3	+ 59.3
38	+.545	−.587	+ 52.3	+ 38.4
39	−.842	+.266	− 30.5	− 50.9
40	+.488	−.627	+ 63.7	+ 41.5

TABLE VIII.—FOR PARALLAX. (*Concluded.*)

(See Paragraphs 14 and 22.)

Star No.	In Distance.		In Position Angle.	
	S_3	S_4	S_8	S_9
41	—.165	—.829	+206 0	+ 2.0
42	—.861	+.234	— 26.1	— 47.6
43	+.192	—.769	+107.0	+ 34.9
44	+.022	—.812	+124.3	+ 21.8
45	—.909	+.131	— 22.5	— 56.8
46	—.714	—.660	+107.2	— 83.1
47	+.440	—.656	+ 48.5	+ 28.5
48	—.431	—.797	+125.1	— 33.3
49	—.292	—.823	+117.1	— 13.2
50	—.377	—.810	+111.3	— 22.6
51	+.118	—.790	+ 65.9	+ 17.4
52	—.498	—.776	+ 79.7	— 28.2
53	—.754	—.627	+ 58.4	— 52.6
54	—.783	—.600	+ 53.8	— 54.6
55	+.202	—.765	+ 51.7	+ 17.4
56	—.965	—.157	+ 0.4	— 51.1
57	—.959	—.240	+ 7.2	— 54.3
58	—.405	—.804	+ 71.9	— 16.9
59	—.328	—.818	+ 68.9	— 10.3
60	—.877	—.477	+ 30.3	— 51.1
61	—.249	—.827	+ 63.4	— 4.4
62	—.808	—.572	+ 34.8	— 39.6
63	—.743	—.637	+ 41.4	— 35.7
64	—.858	—.508	+ 27.1	— 40.2
65	—.293	—.823	+ 52.5	— 5.9
66	—.751	— 630	+ 36.6	— 32.6

Table IX.—Mean Results.

Star No.	Distance.	Position Angle.	α′—α	δ′—δ	No. of Plates.	Durchmusterung.	
						No.	Mag.
	″	° ′ ″	″	″		°	
1	3771.42	307 44 19.4	—3824.94	+2291.19	10	38.4318	7.2
2	3055.07	235 25 23.3	—3176.65	—1745.70	6	37.4154	9.1
3	3202.47	230 9 10.8	—3101.33	—2063.32	5	37.4155	9.3
4	3103.85	226 58 31.0	—2861.47	—2127.48	2	37.4157	9.3
5	2163.15	273 6 36.6	—2746.93	+ 108.47	19	38.4325	6.0
6	2660.10	230 12 33.1	—2581.61	—1710.30	19	37.4159	7.5
7	2279.03	235 15 9.0	—2368.76	—1305.58	2	37.4161	9.5
8	1712.84	302 42 34.5	—1838.55	+ 921.62	6	38.4331	9.3
9	3213.79	204 35 20.2	—1681.35	—2925.69	6	37.4166	9.1
10	2775.08	332 1 31.7	—1670.41	+2447.56	6	38.4332	9.2
11	2078.41	330 48 8.3	—1297.85	+1812.35	3	38.4333	9.4
12	1503.97	319 53 21.3	—1237.16	+1148.44	3	38.4334	9 5
13	2754.25	341 24 38.4	—1127.39	+2609.07	17	38.4335	9.0
14	971.48	296 47 43.5	—1104.18	+ 436.52	11	38.4336	8.8
15	1462.27	215 20 57.0	—1070.60	—1194.04	8	37.4170	8.5
16	848.59	251 12 59.6	—1020.22	— 274.47	8	37.4171	9.4
17	2308 80	341 20 48.0	— 946.63	+2186.47	6	[38.4338]	[9.4]
18	1958.83	338 22 5.9	— 924.37	+1819.88	9	38.4337	9.0
19	3610.25	188 17 34.5	— 653.13	—3573.00	4	37.4172	8.3
20	2066.13	349 29 58.9	— 482.39	+2031.26	12	38.4339	8.9
21	623.86	209 16 22.4	— 386.98	— 544.37	7	37.4173	8.8
22	3100.22	355 24 41.4	— 319.06	+3090.17	7	38.4340	9.1
23	2500.62	356 4 29.8	— 219.69	+2494.70	19	38.4341	8.2
24	238.68	333 13 7.5	— 136.82	+ 213.06	2	38.4342	9.5
25		**61¹ Cygni**				38.4343	5.0
26	19.39	*61² Cygni*			19	38.4344	5.3
27	1074.60	177 15 24.0	+ 65.11	—1073.38	10	37.4175	9.0
28	3130.15	178 34 1.3	+ 98.35	—3129.18	6	37.4176	8.7
29	1008.91	11 4 37.0	+ 247.35	+ 990.04	3	38.4348	9.5
30	515.04	29 38 16.0	+ 324.32	+ 447.54	1	38.4349	9.4
31	1677.09	170 56 2.0	+ 333.84	—1656.26	1	37.4177	9.5
32	2155.55	172 40 30.0	+ 346.56	—2138.10	19	37.4178	7.5
33	975.29	21 15 9.1	+ 450.96	+ 908.72	7	38.4350	9.5
34	966.32	146 39 17.0	+ 673.17	— 807.78	3	37.	
35	634.19	123 8 22.5	+ 674.16	— 347.24	2	37.4179	8.6
36	627.41	82 19 26.8	+ 790.67	+ 83.07	8	38.4351	9.5
37	1336.94	149 37 6.6	+ 855.80	—1154.21	18	37.4180	7.7
38	3143.57	166 49 5.1	+ 900.87	—3061.70	9	37.4181	9.0
39	3185.45	13 17 8.6	+ 941.74	+3099.16	14	38.4353	8.4
40	2696.96	162 49 15.6	+1002.82	—2577.83	7	37.4182	9.4

TABLE X.—CATALOGUE OF STARS ABOUT 61[1] CYGNI.

Star No.	A.G. Lund.	Right Ascension, 1873.	Precession, *J*	Sec.Var., *K*	Declination, 1873.	Precession, *L*	Sec.Var., *M*
		h m s	s	s	° ′ ″	″	″
1		20 56 57.333	+2.3031	+0.0041	38 45 44.59	+13.991	+0.235
2		57 40.552	2.3357	.0041	37 38 27.70	14.036	.237
3		57 45.574	2.3384	.0041	37 33 10.08	14.041	.237
4		58 1.564	2.3396	.0041	37 32 5.92	14.058	.237
5		58 9.200	2.3235	.0042	38 09 21.87	14.066	.236
6		20 58 20.222	+2.3375	+0.0041	37 39 3.10	+14.077	+0.237
7		58 34.412	2.3353	.0042	37 45 47.82	14.092	.236
8		59 9.759	2.3206	.0042	38 22 55.02	14.129	.234
9		59 20.239	2.3496	.0042	37 18 47.71	14.140	.237
10		59 20.968	2.3097	.0043	38 48 20.96	14.140	.232
11		20 59 45.806	+2.3161	+0.0043	38 37 45.75	+14.166	+0.233
12		59 49.852	2.3211	.0043	38 26 41.84	14.170	.233
13		59 57.170	2.3107	.0043	38 51 2.47	14.178	.232
14		59 58.717	2.3270	.0043	38 14 49.92	14.179	.234
15		21 00 0.956	2.3391	.0042	37 47 39.36	14.181	.235
16		21 00 4.314	+2.3324	+0.0043	38 02 58.93	+14.185	+0.234
17		00 9.220	2.3145	.0043	38 43 59.87	14.190	.233
18		00 10.704	2.3172	.0044	38 37 53.28	14.192	.233
19		00 28.787	2.3578	.0043	37 08 0.40	14.210	.237
20		00 40.170	2.3172	.0044	38 41 24.66	14.222	.232
21		21 00 46.530	+2.3369	+0.0044	37 58 29.03	+14.229	+0.234
22		00 51.058	2.3099	.0044	38 59 3.57	14.233	.231
23		00 57.683	2.3149	.0044	38 49 8.10	14.240	.232
24		01 3.208	2.3321	.0044	38 11 6.46	14 246	.233
25		**21 01 12.329**	**2.3343**	**.0044**	**38 07 33.40**	**14.260**	**.233**
26			See	*Contribu*	*tion* No. 13.		
27		01 16.670	+2.3422	+0.0044	37 49 40.02	+14.259	+0.234
28		01 18.886	2.3572	.0044	37 15 24.22	14.262	.235
29		01 28.819	2.3276	.0044	38 24 3.44	14.272	.232
30		01 33.950	2.3321	.0044	38 15 0.94	14.277	.233
31		21 01 34.585	+2.3387	+0.0044	37 39 57.14	+14.278	+0.234
32		01 35.433	2.3511	.0044	37 31 55.30	14.279	.235
33		01 42.393	2.3290	.0044	38 22 42.12	14.286	.232
34		01 57.207	2.3425	.0044	37 54 5.62	14.301	.234
35		01 57.273	2.3392	.0044	38 01 46.16	14.301	.233
36		21 02 5.040	+2.3364	+0.0044	38 08 56.47	+14.309	+0.233
37		02 9.382	2.3458	.0044	37 48 19.19	14.313	.234
38		02 12.387	2.3597	.0044	37 16 31.70	14.316	.235
39		02 15.112	2.3147	.0045	38 59 12.56	14.319	.230
40		02 19.184	2.3565	.0044	37 24 35.57	14.324	.234

Table IX.—Mean Results. (*Concluded.*)

Star No.	Distance.	Position Angle.	α′—α	δ′—δ	No. of Plates.	Durchmusterung.	
						No.	Mag.
	″	° ′ ″	″	″		°	
41	952.00	122 36 30.0	+1017.45	— 514.25	2	37.4183	9 5
42	3448.83	15 37 11.8	+1195.67	+3319.79	5	38.4356	8.9
43	1824.90	143 50 53.3	+1360.90	—1475.72	12	37.4185	9.0
44	1600.46	133 45 6.3	+1463.45	—1109.29	6	37.4186	9.5
45	2971.02	22 53 48.0	+1484.97	+2734.35	2	38.4357	9.3
46	1246.52	84 39 5.0	+1578.37	+ 113.27	1	38.4358	9.5
47	3657.35	159 32 17.0	+1604.53	—3429.64	3	37.4187	9.0
48	1422.69	105 53 10.6	+1736.87	— 392.98	19	37.4189	7.9
49	1618.91	114 46 4.0	+1863.84	— 682.32	1	37.4191	9.4
50	1645.44	109 24 10.7	+1968.78	— 551.20	15	37.4192	9.0
51	2995.55	139 41 7.0	+2442.53	—2291.17	1	37.4195	9.5
52	2136.94	101 21 31.4	+2658.96	— 429.20	10	37.4197	9.1
53	2125.57	81 5 52.2	+2672.78	+ 320.52	16	38.4362	7.8
54	2164.54	78 15 57.5	+2698.53	+ 431.63	13	38.4363	9.1
55	3771.13	144 28 33.3	+2753.46	—3078.19	3	37.4198	8.7
56	3283.52	42 53 31.6	+2867.24	+2396.00	7	38.4364	9.0
57	3014.80	48 45 51.0	+2903.97	+1977.36	1	38.4365	9.3
58	2513.28	107 37 24.4	+3036.08	— 771.78	9	37.4201	9.3
59	2713.34	112 33 7.5	+3172.80	—1052.51	13	37.4202	8.8
60	2734.76	67 6 33.7	+3215.61	+1051.59	3	38.4367	9.0
61	3032.47	117 29 40.1	+3401.30	—1413.65	17	37.4203	8.3
62	3121.94	75 37 56.7	+3855.71	+ 757.20	3	38.4369	9.3
63	3069.92	82 5 48.6	+3871.48	+ 404.48	9	38.4370	9.0
64	3362.19	69 44 14.7	+4027.23	+1145.36	16	38.4372	7.8
65	3613.27	114 44 43.5	+4147.41	—1532.77	4	37.4209	8.4
66	3411.15	81 23 24.2	+4295.50	+ 488.97	4	38.4375	8.4

TABLE X.—CATALOGUE OF STARS ABOUT 61[1] CYGNI. (*Concluded.*)

Star No.	A.G. Lund.	Right Ascension, 1873.	Precession, *J*	Sec. Var., *K*	Declination, 1873.	Precession, *L*	Sec. Var., *M*
		h m s	s		° ′ ″	″	
41		21 02 20.159	+2.3415	+0.0045	37 58 59.15	+14.325	+0.233
42		02 32.040	2.3140	.0045	39 2 53.19	14.336	.230
43		02 43.056	2.3498	.0045	37 42 57.68	14.348	.234
44		02 49.892	2.3476	.0045	37 49 4.11	14.355	.233
45		02 51.327	2.3194	.0045	38 53 7.75	14.356	.230
46		21 02 57.554	+2.3391	+0.0045	38 9 26.67	+14.362	+0.232
47		02 59.298	2.3648	.0045	37 10 23.76	14.364	.235
48		03 8.120	2.3434	.0045	38 1 0.42	14.373	.232
49		03 16.585	2.3459	.0045	37 56 11.08	14.382	.232
50		03 23.581	2.3453	.0045	37 58 22.20	14.389	.232
51		21 03 55.164	+2.3595	+0.0045	37 29 22.23	+14.421	+0.233
52		04 9.593	2.3470	.0046	38 0 24.20	14.435	.231
53		04 10.514	2.3415	.0046	38 12 53.92	14.436	.231
54		04 12.231	2.3409	.0046	38 14 45.03	14.438	.231
55		04 15.893	2.3662	.0045	37 16 15.21	14.442	.233
56		21 04 23.478	+2.3272	+0.0046	38 47 29.40	+14.450	+0.229
57		04 25.927	2.3302	.0046	38 40 30.76	14.452	.230
58		04 34.734	2.3508	.0046	37 54 41.62	14.461	.232
59		04 43.849	2.3532	.0046	37 50 0.89	14.470	.232
60		04 46.703	2.3382	.0046	38 25 4.99	14.473	.230
61		21 04 59.082	+2.3567	+0.0046	37 43 59.75	+14.486	+0.231
62		05 29.376	2.3427	.0047	38 20 10.60	14.516	.230
63		05 30.428	2.3454	.0047	38 14 17.88	14.517	.230
64		05 40.811	2.3406	.0048	38 26 38.76	14.527	.229
65		05 48.823	2.3603	.0047	37 42 0.63	14.536	.231
66		05 58.696	2.3463	.0048	38 15 42.37	14.546	.229

Table XI.—Limiting Values of Parallax Coefficients for $\Pi = +0.''3597$.

In Distance.

Use Parallax Coefficient $S_3 P_3 + S_4 P_4$ as the argument in the body of table.

	d .0000	*d* .0010	*d* .0020	*d* .0030	*d* .0040	*d* .0050	*d* .0060	*d* .0070	*d* .0080	*d* .0090	*d* .0100	*d* .0110
	.0000	.0740	.1519	.2297	.3076	.3855	.4634	.5412	.6191	.6970	.7749	.8528
d .0000												
	.0039	.0818	.1596	.2375	.3154	.3933	.4712	.5490	.6269	.7048	.7827	.8605
1												
	.0117	.0896	.1674	.2453	.3232	.4011	.4789	.5568	.6347	.7126	.7905	.8683
2												
	.0195	.0973	.1752	.2531	.3310	.4089	.4867	.5646	.6425	.7204	.7982	.8761
3												
	.0273	.1051	.1830	.2609	.3388	.4166	.4945	.5724	.6503	.7282	.8060	.8839
4												
	.0350	.1129	.1908	.2687	.3466	.4244	.5023	.5802	.6581	.7359	.8138	.8917
5												
	.0428	.1207	.1986	.2765	.3543	.4322	.5101	.5880	.6658	.7437	.8216	.8995
6												
	.0506	.1285	.2064	.2843	.3621	.4400	.5179	.5958	.6736	.7515	.8294	.9073
7												
	.0584	.1363	.2142	.2920	.3699	.4478	.5257	.6035	.6814	.7593	.8372	.9151
8												
	.0662	.1441	.2219	.2998	.3777	.4556	.5335	.6113	.6892	.7671	.8450	.9228
.0009												
	.0740	.1519	.2297	.3076	.3855	.4634	.5412	.6191	.6970	.7749	.8528	.9306

In Position-Angle.

Use Parallax Coefficient $S_8 P_3 + S_9 P_4$ as the argument in the body of table.

	00″	10″	20″	30″	40″	50″	60″	70″	80″	90″	100″
	0.0	26.4	54.2	82.0	109.8	137.6	165.4	193.2	221.0	248.8	276.6
0.″											
	1.4	29.2	57.0	84.8	112.6	140.4	168.2	196.0	223.8	251.6	279.4
1.											
	4.2	32.0	59.8	87.6	115.4	143.2	171.0	198.8	226.6	254.4	282.2
2.											
	7.0	34.8	62.6	90.4	118.2	146.0	173.8	201.6	229.4	257.2	285.0
3.											
	9.7	37.5	65.3	93.1	120.9	148.7	176.5	204.3	232.1	259.9	287.7
4.											
	12.5	40.3	68.1	95.9	123.7	151.5	179.3	207.1	234.9	262.7	290.5
5.											
	15.3	43.1	70.9	98.7	126.5	154.3	182.1	209.9	237.7	265.5	293.3
6.											
	18.1	45.9	73.7	101.5	129.3	157.1	184.9	212.7	240.5	268.3	296.1
7.											
	20.9	48.7	76.5	104.3	132.1	159.9	187.7	215.5	243.3	271.1	298.9
8.											
	23.6	51.4	79.2	107.0	134.8	162.6	190.4	218.2	246.0	273.8	301.6
9.											
	26.4	54.2	82.0	109.8	137.6	165.4	193.2	221.0	248.8	276.6	304.4

The Position of 61^2 Cygni.

26. When we correct the measured coördinates of 61^2 *Cygni* with respect to 61^1 *Cygni*, it is, of course, necessary to take into account the very considerable proper motion of the measured star as well as of the central star.

On account of the shortness of time over which the RUTHERFURD plates extend, a value of the relative motion deduced from them alone would have very small weight. On the other hand, the mean of the measured distances and of the measured angles is entitled to great weight as representing the true value of the distance and angle of these stars at the mean of the dates of observation, 1873.546. I have, accordingly, with the latter as a basis, deduced trigonometrically a set of formulæ which represent the motion of either of these stars relative to the other; assuming the motion of each to be uniform and on the arc of a great circle. In these formulæ have then been substituted constants derived from the proper motion of each star separately, as determined from meridian observations in the manner used in my "Declinations and Proper Motions of Fifty-six Stars,"* to which reference is made for an explanation of the method.

27. For 61^1 *Cygni* I have used AUWERS' values as previously quoted on page 62; but for 61^2 *Cygni* the results given here have been derived from the data of Table XII.

61^1 *Cygni* $\rho = 5.''20521$ $\chi = 51°38'42''$ $t = 1807.$
61^2 *Cygni* $\rho = 5.\ \ 15192$ $\chi = 53\ \ 33\ \ 47$ $t = 1858.$

By the usual formulæ† these become:

61^1 *Cygni* $\rho_0 = 5.''20521$ $\chi_0 = 51°42'13''$ 1873.546.
61^2 *Cygni* $\rho_0' = 5.\ \ 15192$ $\chi_0' = 53\ \ 34\ \ 37$ 1873.546.

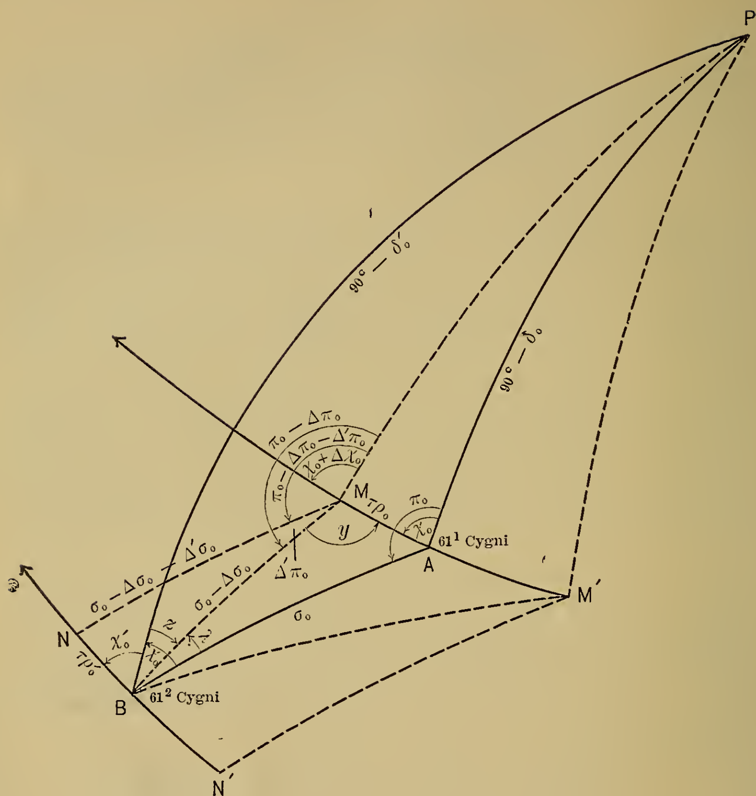
We have also:

61^1 *Cygni* $\delta_0 = 38°7'35''$

and from the RUTHERFURD measures:

For 61^2 *Cygni*, relative to 61^1, $\sigma_0 = 19.''3823$ $\pi_0 = 114°41'30''$ at 1873.546.

* *Contribution from the Observatory of Columbia College, New York.*—No. 8.
† Chauvenet: Manual of Spherical and Practical Astronomy, Vol. I, §380.



$AB = \sigma_0 =$ True distance at 1873.546 from the mean of all the measured distances.

$MN =$ Distance measured on plate of the date, t, corrected except for proper motion.

$\rho_0, \rho_0' =$ The proper motions of 61¹ and 61² *Cygni* at the epoch 1873.546.

AM, $BN =$ Arcs traveled over in the time $\tau = t - 1873.546$.

$\Delta\sigma_0 =$ The change in σ_0 due to the proper motion of only *61¹* from A to M.

$\Delta'\sigma_0 =$ The change in $(\sigma_0 - \Delta\sigma_0)$ due to the proper motion of only *61²* from B to N.

$PAB = \pi_0 =$ True angle at 1873.546 from the mean of all the measured angles.

$PMN =$ Position-angle measured on plate of the date, t, corrected except for proper motion.

$\chi_0, \chi_0' =$ The position-angles of the proper motion of *61¹* and *61²* at 1873.546.

$PBA = \lambda_0'$, also y, z, λ are auxiliary angles having the significance shown above.

$\Delta\pi_0 =$ The change in π_0 due to the proper motion of only *61¹* from A to M.

$\Delta'\pi_0 =$ The change in $(\pi_0 - \Delta\pi_0)$ due to the proper motion of *61²* from B to N.

28. Let the angles and arcs have the significance attached to them in the figure; where P is the Pole; PA and PB hour-circles through 61^1 and 61^2 respectively at 1873.546, and $M'M$ and $N'N$ the paths of proper motion. Then, as the arc AB joining 61^1 and 61^2 is the mean of all the measures of distance, it may be assumed as the true distance at the mean date of observation. In like manner PAB is assumed as the true position-angle at the same date. The problem before us is to (1) determine the distance MN at the end of the interval τ years; (2) determine the angle PMN at the end of the same interval. In both these cases evidently we regard the only cause of motion of the stars to be that known as proper motion, *i.e.*, uniform motion on the arc of a great circle.

Let all angles count from the hour circle positively towards the east, *i.e.*, counter-clockwise in the figure; or else from the arc AB, but always likewise positive when counter-clockwise, as shown by the direction of the arrows in the figure.

29. Let us first suppose that 61^2 remains motionless while 61^1 advances from A to M during the time τ; then the change in distance is given by the formula:

$$\begin{aligned}\Delta\sigma_0 = {} & (\tau\rho_0)\cos(\pi_0 - \chi_0)\\ & + (\tau\rho_0)^2\left\{-\frac{1}{2\sigma_0}\sin^2(\pi_0-\chi_0)\right\}\\ & + (\tau\rho_0)^3\left\{-\frac{1}{2\sigma_0^2}\sin^2(\pi_0-\chi_0)\cos(\pi_0-\chi_0)\right\}\\ & + (\tau\rho_0)^4\left\{\frac{1}{2\sigma_0^3}\left[\tfrac{1}{4}\sin^4(\pi_0-\chi_0)-\sin^2(\pi_0-\chi_0)\cos^2(\pi_0-\chi_0)\right]\right\}.\end{aligned}$$

When the proper constants have been substituted in this we have:

$$\Delta\sigma_0 = [9.657224](\tau\rho_0) + [8.311234_n](\tau\rho_0)^2 + [6.68105_n](\tau\rho_0)^3 + [3.6310_n](\tau\rho_0)^4.$$

Thus is obtained the auxiliary distance BM agreeing of course with the formula of paragraph 11, as far as terms in τ^2.

30. Now during the same interval of time τ, suppose 61^1 to remain still and 61^2 to be in motion. Then the change of distance is given by the formula:

$$\begin{aligned}\Delta'\sigma_0 = {} & (\tau\rho_0')\cos(\chi_0'-z)\\ & + (\tau\rho_0')^2\left\{-\frac{1}{2(\sigma_0-\Delta\sigma_0)}\sin^2(\chi_0'-z)\right\}\\ & + (\tau\rho_0')^3\left\{-\frac{1}{2(\sigma_0-\Delta\sigma_0)^2}\sin^2(\chi_0'-z)\cos(\chi_0'-z)\right\}\\ & + (\tau\rho_0')^4\left\{\frac{1}{2(\sigma_0-\Delta\sigma_0)^3}\left[\tfrac{1}{4}\sin^4(\chi_0'-z)-\sin^2(\chi_0'-z)\cos^2(\chi_0'-z)\right]\right\}\end{aligned}$$

which may be computed for each plate separately after $\Delta\sigma_0$ has been computed by the preceding formula; and where the value of z is obtained from the following relations:*

$$z = \lambda - \lambda_0'.$$

$$\lambda_0' = \overline{180° - \pi_0} - \sigma_0 \sin \pi_0 \tan \delta_0$$

$$\cot \lambda = \frac{1}{\tau\rho_0} \cdot \frac{\sigma_0}{\sin(\pi_0 - \chi_0)} - \cot(\pi_0 - \chi_0).$$

By substitution of the constants for these stars these become:

$$\lambda_0' = 65°18'16''.5$$

$$\cot \lambda_0 = 21.75560 \frac{1}{\tau\rho_0} - 0.509789$$

hence

$$z = \lambda - 65°18'16''.5$$

which may be computed for each plate.

Thus the variation in distance due solely to the proper motions of 61^1 and 61^2 *Cygni* in the assumed direction at the assumed rate may be expressed by

$$\Delta\sigma_0 + \Delta'\sigma_0$$

as computed for each value of τ, and printed in columns nine and ten of Table XIII. This quantity is additive to the observed distance on each plate to reduce to the mean epoch.

31. By the formula of paragraph 17 may be computed values of K or $\Delta\chi_0$ applicable to the new mean epoch adopted, thus:

$$\Delta\chi_0 = [9.7895]\ \tau\rho$$

where the number in brackets is a logarithm as usual.

We also have, as in paragraph 30,

$$\cot \Delta'\pi_0 = \frac{1}{\tau\rho_0'} \cdot \frac{\sigma - \Delta\sigma_0}{\sin(\chi_0' - z)} - \cot(\chi_0' - z)$$

and

$$\cot y = \frac{1}{\sigma_0} \cdot \frac{\tau\rho_0}{\sin(\pi_0 - \chi_0)} - \cot(\pi_0 - \chi_0)$$

* Jordan: *Handbuch der Vermessungskunde*, 4te Auflage. Bd. III, § 359, 342.

whence is obtained by substitution of the constants and from the figure:

$$\Delta\pi_0 = 62°59'17'' + (y - \Delta\chi_0) \qquad \text{before epoch,}$$
$$= -117° \; 0'43'' + (y - \Delta\chi_0) \qquad \text{after epoch,}$$

and thus the total change of angle is

$$\Delta\pi_0 + \Delta'\pi_0$$

additive to the observed position-angle. These quantities are printed in columns seven and eight of Table XIII.

When these corrections for proper motion have been applied to the preceding columns of Table XIII we get in the next-to-the-last column of the Table the distance and angle of *61*[2] good for 1873.546 corrected for all known motions of either star, except for difference of parallax if there be any such difference. This oint will be considered in the following *Contribution*, No. 13.

TABLE XII.—PROPER MOTION OF 61^2 *Cygni.*

Authority.	Date of Observation. *t*	Epoch of Catalogue, *T*	No. of Obs. *n*	Position at Epoch of Catalogue.	Reduction to 1875+Syst. Correction. *A′*	Reduced Position. *B*	Wgt.	C.—O. *R*
				RIGHT ASCENSION.				
				20^h+		$21^h\ 1^m+$		
				m s	m s	s		s
Br. 2745	1753.8	1755	2	55 57.41	+5 21.767	19.177	0.3	—.031
Pi. xx:476	1806.2	1800	17	57 57.80	+3 21.497	19.297	0.3	—.089
Abo 482	1828.	1830	62	59 18.34	+2 0.805	19.145	4.0	+.089
Pond 946	1830.	1830	16	59 18.73	+2 0.737	19.467	1.0	—.230
Tay. 9785	1835.	1835	5	59 32.24	+1 47.368	19.608	0.4	—.365
12 Yr_1 1887	1839.	1840	30	59 45.14	+1 34.086	19.226	3.0	+.022
12 Yr_2 1887	1845.	1845	40	59 58.61	+1 20.598	19.208	3.0	+.047
6 Yr. 1358	1850.8	1850	45	60 12.11	+1 7.153	19.263	3.0	—.001
Rad_1 5107	1853.0	1845	19	59 58.76	+1 20.550	19.310	3.0	—.046
Yarn. 9477	1854.8	1860	23	60 37.08	+0 42.174	19.254	2.0	+.012
Rad_2 2059	1856.4	1860	11	60 38.93	+0 40.377	19.307	2.0	—.039
7 Yr. 1743	1856.9	1860	48	60 38.95	+0 40.308	19.258	3.0	+.011
Quet. 9276	1861.6	1865	18	60 51.11	+0 28.134	19.244	3.0	+.031
N. 7 Yr. 2394	1864.0	1864	17	60 49.70	+0 29.569	19.269	3.0	+.009
Poulk.	1866.2	1865	27	60 52.448	+0 26.839	19.287	8.0	—.007
9 Yr. 1976	1872.3	1872	13	61 11.185	+0 8.091	19.276	3.0	+.011
Romb. 4784	1877.9	1875	7	61 19.37	+0 0.002	19.372	4.0	—.078
10 Yr. 3532	1883.6	1880	14	61 32.656	—0 13.394	19.262	3.0	+.039
Green. Yearly	1893.7	1893	10	62 7.565	—0 48.294	19.271	2.4	+.042
Results.	1858.58	1875	424	m s 61 19.291			51.4	
				DECLINATION.				
				37°+		38°7′+		
				′ ″	′ ″	″		″
Br. 2745	1753.8	1755	1	33 43.9	+34 13.76	57.66	0.2	—0.78
Pi. xx:476	1805.8	1800	13	46 34.0	+21 26.49	60.49	0.3	—2.21
Abo 482	1828.	1830	33	55 4.7	+12 54.11	58.81	4.0	+0.07
Tay. 9785	1835.	1835	9	56 30.47	+11 29.19	59.66	0.5	—0.59
12 Yr_1 1887	1839.	1840	31	57 55.71	+10 3.00	58.71	3.0	+0.47
12 Yr_2 1887	1844.	1845	36	59 22.02	+ 8 36.89	58.91	3.0	+0.40
6 Yr. 1358	1851.2	1850	35	60 48.67	+ 7 10.90	59.57	3.0	—0 06
Rad_1 5107	1853.2	1845	18	59 23.2	+ 8 36.32	59.52	3.0	+0.04
Yarn. 9477	1854.0	1860	113	63 22.6	+ 4 37.25	59.85	3.0	—0.27
7 Yr. 1743	1857.0	1860	44	63 40.53	+ 4 19.02	59.55	3.0	+0.11
Rad_2 2059	1858.8	1860	10	63 41.8	+ 4 18.51	60.31	2.0	—0.60
N. 7 Yr. 2394	1864.2	1864	19	64 49.69	+ 3 9.90	59.59	3.0	+0.27
9 Yr. 1976	1871.9	1872	14	67 8.90	+ 0 51.16	60.06	3.0	.00
Romb. 4784	1877.9	1875	7	68 0.7	+ 0 0.02	60.72	4.0	—0.50
10 Yr. 3532	1883.6	1880	15	69 26.61	— 1 26.54	60.07	3.0	+0.31
Green. Yearly	1893.7	1893	10	73 12.43	— 5 11.81	60.62	2.4	+0.03
Results.	1857.69	1875	408	68′ 0.″150			40.4	

Probably an error of 5″ in Quetelet's declination, hence it has been discarded.

TABLE XIII.—POSITION OF 61^2 *Cygni*.

Plate.	Observed Dist.		Corrections for		Cor-rected Mean.	Scale Varia-tion.	Distance at Date of each Plate.	Correction for Proper Motion of		Distance at	Parallax *Co-efficient.*
	East.	West.	Refr.	Scale.	s	v'	$28''.0124(s+v')$	61^1 *Cygni*	61^2 *Cygni*	1873.546	
							″	″	″	″	
1	0.6843	0.6716	3	+ 5	0.6788	+1	19.0176	—5.2484	+5.4774	19.2466	—0.767
2	.6900	.6866	3	0	.6886	+2	.2949	—5.2191	+5.4468	.5226	— .745
3	.6968	.6846	3	0	.6910	+1	.3594	—5.2191	+5.4468	.5871	— .745
4	.6918	.6916	3	0	.6920	0	.3846	—1.6956	+1.7739	.4629	— .572
5	.6877	.6865	3	0	.6874	0	.2557	—1.5652	+1.6381	.3286	— .369
6	.6834	.7012	3	— 2	.6924	+1	.3986	—1.5652	+1.6381	.4715	— .369
7	.6968	.6864	3	+ 3	.6922	+1	.3930	—1.5505	+1.6229	.4654	— .341
8	.6934	.6935	3	0	.6937	—1	.4294	+0.7173	—0.7583	.3884	— .715
9	.6852	.6910	3	0	.6883	0	.2809	+0.7173	—0.7583	.2399	— .715
10	.6951	.6940	2	0	.6947	0	.4602	+0.7448	—0.7877	.4173	— .670
11	.7023	.7016	2	+ 1	.7023	0	.6731	+0.7546	—0.7981	.6296	— .650
12	.6955	.6951	3	+ 1	.6958	0	.4910	+0.7546	—0.7981	.4475	— .650
13	.6963	.6992	3	+ 1	.6982	0	.5583	+0.7546	—0.7981	.5148	— .650
15	.6966	.6987	3	— 6	.6974	—1	.5330	+1.5946	—1.7030	.4246	+ .550
16	.6839	.7047	4	0	.6947	0	.4602	+1.6312	—1.7433	.3481	+ .415
17	.6935	.6958	3	+ 3	.6953	0	.4770	+1.6312	—1.7433	.3649	+ .415
18	.6774	.6957	4	+ 3	.6873	0	.2529	+1.6348	—1.7471	.1406	+ .401
19	.6868	.6846	4	0	.6861	0	.2193	+1.6348	—1.7471	.1070	+ .401
20	.6905	.6889	3	+10	.6910	—1	.3538	+1.6348	—1.7471	19.2415	+0.401
					Means		19.3823			19.3868	

TABLE XIII, *Concluded.*—POSITION OF 61^2 *Cygni.*

Plate.	Observed Position Angle		Zero Correction plus precession, etc.	Refrac.	Corrected Mean Angle at Date of each Plate. p	Correction for Proper Motion of		Angle at 1873.546	Parallax Coefficient.
	East.	West.				61^1 *Cygni*	61^2 *Cygni*		
	° ′ ″	° ′ ″	′ ″	″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
1	203 25 46	203 43 17	12 2	—16	113.46 30	+18 31 4	—17 53 47	114 23 47	+6354
2	204 6 26	203 7 26	13 28	—14	51 10	+18 27 0	—17 49 51	28 19	+6732
3	203 20 11	203 31 18	13 34	—20	39 5	+18 27 0	—17 49 51	16 14	+6732
4	203 44 56	203 47 23	12 39	—18	57 56	+ 7 58 50	— 7 44 37	12 9	+8536
5	203 30 8	204 48 33	11 38	—17	114 18 4	+ 7 28 2	— 7 14 49	31 17	+9464
6	204 45 51	204 36 21	11 38	—39	49 52	+ 7 28 2	— 7 14 49	63 5	+9464
7	203 30 28	204 1 21	12 52	—26	1 42	+ 7 24 31	— 7 11 24	14 49	+9533
8	204 15 3	204 9 3	13 3	—20	24 32	— 4 42 11	+ 4 35 26	17 47	+7149
9	205 21 46	203 56 36	14 30	—33	52 38	— 4 42 11	+ 4 35 26	45 53	+7149
10	204 41 33	205 2 20	13 7	— 8	115 4 34	— 4 54 37	+ 4 46 55	56 52	+7689
11	204 3 57	205 29 54	14 13	— 6	0 32	— 4 59 5	+ 4 51 16	52 43	+7889
12	204 49 18	204 22 36	15 35	—11	114 51 32	— 4 59 5	+ 4 51 16	43 43	+7889
13	204 34 43	203 57 12	13 8	—19	29 11	— 4 59 5	+ 4 51 16	21 22	+7889
15	204 54 37	205 7 44	12 13	— 4	115 13 0	—13 8 31	+12 49 0	53 29	—9045
16	204 58 47	204 47 40	10 58	— 1	3 42	—13 37 52	+13 17 42	43 32	—9677
17	206 5 42	205 55 25	11 10	— 2	116 9 37	—13 37 52	+13 17 42	109 27	—9677
18	204 39 30	204 36 40	11 3	— 2	114 48 17	—13 40 49	+13 20 34	28 2	—9715
19	204 55 18	204 58 48	11 22	— 3	115 8 20	—13 40 49	+13 20 34	48 5	—9715
20	205 11 40	205 39 0	12 38	— 2	38 10	—13 40 49	+13 20 34	114 77 55	—9715
			Means		114 41 30			114 41 30	

IV.—*The Parallax of 61[1] Cygni, deduced from the Rutherfurd Photographic Measures.*

By Herman S. Davis.

Read May 3d, 1897.

32. For the purpose of determining the parallax of *61[1] Cygni* the measures of both distance and position-angle have been used as recorded in the preceding catalogue of sixty-five stars. The method adopted for getting the parallax from the measures of distance is the same as has been used in previous investigations at this Observatory.* Briefly stated this consists of correcting the observed distances for refraction, aberration, errors of the scale, proper motion of 61[1] *Cygni*, etc. These distances so corrected may be obtained from Table V by taking the sums of the quantities in columns eight, nine and ten. These sums are printed in columns two and three of Table XVI.

33. Then particular pairs of comparison stars were so chosen that their components should be as nearly as possible equally distant from 61[1] *Cygni* and differing 180° in position-angle. Table XIV contains a catalogue of these stars with memorandum of some other observers who have used the same stars for determining the parallax of 61 *Cygni.*

In the equations of condition of Table XVII have been introduced an unknown y varying with the time, as a correction of the assumed proper motion; and another unknown x, as the correction of the assumed mean of the distances. The coefficients of the parallax have been obtained as follows: Using the symbols of paragraph 14, the quantities of column eleven, Table V are

$$S_3 P_3 + S_4 P_4.$$

Denoting by primed letters all symbols belonging to the *less distant* of the two comparison stars of each pair, we have as the coefficient of the parallax

$$(S_3 P_3 + S_4 P_4) - (S_3' P_3 + S_4' P_4)$$

when the absolute term of the equations is the *difference* of the distance of the comparison stars from 61[1] *Cygni*, after these dif-

* *The Parallax of μ and θ Cassiopeiæ*, by Harold Jacoby.
The Parallax of η Cassiopeiæ, by Herman S. Davis.

ferences have been corrected by their proportional part of the variation of distance. This variation is deduced from the deviation of the *sum* of the distances on the various plates from the mean of all the plates. See Table XVI, columns four to seven inclusive.

Equations of condition thus formed are in Table XVII. At the foot of each page of this table will be found the normal equations, the deduced values of the unknowns, with their probable errors and the probable error of one equation of unit weight.

Eight different stars combined in five pairs were used for the determination of the parallax by measures of distance.

34. Whereas heretofore only measures of distance were used for parallax, in the present research measures of angle have also been used. For it has been recently shown* in the case of eight stars among the *Pleiades* whose average distance is 2160″, ranging from 631″ to 3160″, that the displacement on the arc of a great circle by reason of the probable error of observation is but little larger in measures of angle than of distance. This research on the measures of 61[1] *Cygni* has shown in addition that, for the seven stars whose measurement of position-angle I have used, the probable error for one plate of unit weight is ±0″.149 in angle, whereas for the eight stars used in distance it is ±0″.191. The average distance of these stars is only 1956″, ranging from 1075″ to 2754″. This fully justifies the use of position-angle for parallax determination from the RUTHERFURD photographic plates in the present and in future reductions.

35. In the use of measures of position-angle the seven stars were selected irrespective of distance but as equally distributed in angle as possible.

Several methods of reduction suggested themselves, but the following was adopted. The observed angles were corrected as described in paragraphs 16–21. The "reduced angles," obtained from adding together columns six and seven of Table VI and the "variation" of paragraph 21, are printed in Table XVIII.

If x' and y' be introduced for error of the adopted mean of the angles and of proper motion respectively, and the parallax coefficient

$$S_8 P_3 + S_9 P_4$$

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* *On the Permanence of the Rutherfurd Photographic Plates*, by HAROLD JACOBY. Page 282.

from column eight, Table VI, be used, the equations of condition can be formed as in Table XVIII. The solution of these equations is given at the bottom of each page; where also will be found the probable errors of the unknowns; likewise the probable error of one equation of unit weight expressed as change of position-angle and also as reduced to the arc of a great circle by aid of the

$$\text{“Factor”} = 28''.0124 \cdot \sigma \cdot \sin 1'' = [6.1329]\, \sigma$$

36. The values of parallax given by the measures of distance of the various pairs of stars are collected in the first part of Table XV, with their weights, p, deduced from the least-square solution, and the corresponding probable errors, r_π. As the stars 5 and 6 enter respectively into each of two pairs, the "combining weights" of those pairs, (p), were used in computing the mean of the five determinations. The (r_π) is the probable error of the parallax when (p) is regarded as the weight. Hence

$$\text{Parallax} = +0''.3999 \pm 0''.0230.$$

In the second part of Table XV are given the values of parallax deduced from the measures of position-angle, with their probable errors r_π. Hence

$$\text{Parallax} = +0''.3326 \pm 0''.0189.$$

When these two values are combined with weights which are the reciprocals of the squares of their respective probable errors there results the

$$\text{Mean relative parallax of } 61^1\ \textit{Cygni} = +0''.360 \pm 0''.0146$$

TABLE XIV.—COMPARISON STARS.

Comp. Star. No.	Approximate position referred to 61¹ *Cygni*. Distance.	Angle.	Durchmusterung. Number.	Mag.	Remarks.
64	3362″	69°.74	38°:4372	7.8	
6	2660	230.21	37:4159	7.5	
39	3185	13.29	38:4353	8.4	
5	2163	273.11	38:4325	6.0	Johnson.
53	2126	81.10	38:4362	7.8	
54	2165	78.27	38:4363	9.1	
48	1423	105.89	37:4189	7.9	Johnson : [Pritchard] : Wilsing.
14	971	296.79	38:4336	8.8	[Pritchard].
37	1337	149.62	37:4180	7.7	[Pritchård].
27	1075	177.26	37:4175	9.0	Johnson : [Pritchard].
48	1423	105.89	37:4189	7.9	
43	1825	143.85	37:4185	9.0	
32	2156	172.68	37:4178	7.5	
23	2501	356.08	38:4341	8.2	
13	2754	341.41	38:4335	9.0	

TABLE XV.—RESULTS.

FROM MEASURES OF DISTANCE.

Comp. Stars.	Relative Parallax of 61^1 *Cygni*	Weights.		Probable Error.			Relative Weights. $\frac{1}{(r_\pi)^2}$
		p	(p)	r_1	r_π	(r_π)	
64– 6	+0.″5211	26.2675	17.5117	±0.1641	±0.″0373	±0.″0457	479.3
39– 6	+0.4497	19.8822	13.2548	.2562	.0429	.0525	362.7
5–53	+0.3733	22.8220	15.2147	± .2020	±0.0400	±0.0490	416.3
54– 5	+0.2431	21.8784	14.5856	.1576	.0409	.0500	399.2
48–14	+0.3888	8.4314	8.4314	± .1840	±0.0658	±0.0658	230.7
Results	**+ 0.″3999**		68.9982	±0.″1912	± **0.″0230**		**1888.2**

FROM MEASURES OF POSITION-ANGLE.

Comp. Stars.	Relative Parallax of 61^1 *Cygni*	Weights.		Probable Error.			Relative Weight. $\frac{1}{r_\pi^2}$
		p	σ^2	(r_1)	r_1	r_π	
37	+0.″3028	196 129.40	2278.	±15.″70	±0.″1018	±0.″0354	796.9
27	+0.3779	157 834.62	1471.	29.27	.1525	.0395	641.2
48	+0.2794	110 142.84	2580.	25.49	.1758	.0473	447.5
43	+0.3299	79 259.74	4245.	18.52	.1638	.0557	322.0
32	+0.3442	63 960.30	5921.	12.37	.1293	.0620	259.9
23	+0.3334	44 572.46	7968.	12.33	.1496	.0743	181.0
13	+0.4401	36 689.52	9667.	±12.32	±0.1646	±0.0819	149.0
Results	**+0.3326**	688 588.88			±0.″1488	±**0.″0189**	**2797.5**

Table XVI.—Observational Data.

Comparison Stars 64 and 6.

Plate No.	Corrected Distance.		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 64	Star 6					
1	120.0484	94.9562	215.0046	—.0152	25.0922	—.0018	25.0904
2	.0593	.9648	.0241	—.0347	.0945	—.0041	.0904
3	.0361	.9600	214.9961	—.0067	.0761	—.0008	.0753
4	.0406	.9519	.9925	—.0031	.0887	—.0004	.0883
5	.0495	.9559	215.0054	—.0160	.0936	—.0019	.0917
6	.0321	.9487	214.9808	+.0086	.0834	+.0010	.0844
7	.0632	.9609	215.0241	—.0347	.1023	—.0041	.0982
8							
9	.0305	.9480	214.9785	+.0109	.0825	+.0013	.0838
10	.0351	.9526	.9877	+.0017	.0825	+.0002	.0827
11	.0430	.9487	.9917	—.0023	.0943	—.0003	.0940
12	.0439	.9499	.9938	—.0044	.0940	—.0005	.0935
13	.0425	.9357	.9782	+.0112	.1068	+.0013	.1081
15	119.9999	.9668	.9667	+.0227	.0331	+.0027	.0358
16							
17	.9914	.9781	.9695	+.0199	.0133	+.0023	.0156
18							
19	.9998	.9805	.9803	+.0091	.0193	+.0011	.0204
20	.9832	.9701	.9533	+.0361	.0131	+.0042	.0173
	Adopted mean, 214.9894				Assumed value, 25.0730		

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 64 AND 6.

Plate.					Residuals. Scale.	Arc.
1	$1.00x$	$-1.14y$	-1.84Π	$+1.74=0$	+0.46	+0″.13
2	1.00	−1.13	−1.87	+1.74 = 0	+0.39	+ .11
3	1.00	−1.13	−1.87	+0.23 = 0	−1.12	− .31
4	1.00	−0.08	−1.94	+1.53 = 0	−0.23	− .06
5	1.00	−0.04	−1.85	+1.87 = 0	+0.27	+ .08
6	1.00	−0.04	−1.85	+1.14 = 0	−0.46	− .13
7	1.00	−0.04	−1.83	+2.52 = 0	+0.96	+ .27
9	1.00	+0.88	−1.90	+1.08 = 0	−0.86	− .24
10	1.00	+0.89	−1.93	+0.97 = 0	−1.03	− .29
11	1.00	+0.90	−1.93	+2.10 = 0	+0.10	+ .03
12	1.00	+0.90	−1.93	+2.05 = 0	+0.05	+ .01
13	1.00	+0.90	−1.93	+3.51 = 0	+1.51	+ .42
15	1.00	+1.42	+1.99	−3.72 = 0	+1.42	+ .40
17	1.00	+1.45	+1.94	−5.74 = 0	−0.69	− .19
19	1.00	+1.45	+1.93	−5.26 = 0	−0.23	− .06
20	1.00	+1.45	+1.93	−5.57 = 0	−0.54	− .15
					$[vv]=9.81$	

Normal Equations.

$$+16.0000x + 6.6400y - 14.8800\Pi + 0.1900 = 0$$
$$+16.1850 + 9.3353 - 25.1545 = 0$$
$$+58.0200 - 78.1820 = 0$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi = +1.8602 \pm 0.1143$	$\Pi = +0''.5211 \pm 0''.0320$
$y = -0.2695 \pm 0.2073$	$y = -0.0755 \pm 0.0581$
$x = +1.8299 \pm 0.2276$	$x = +0.5126 \pm 0.0638$

Probable error of one equation = (Scale.) $\pm 0''.5859$ = (Arc.) $\pm 0''.1641$

Table XVI.—Observational Data.

Comparison Stars 39 and 6.

Plate No.	Corrected Distance.		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 39	Star 6					
1	113.7446	94.9562	208.7008	—.0261	18.7884	—.0023	18.7861
2	.7430	.9648	.7078	—.0331	.7782	—.0030	.7752
3	.7364	.9600	.6964	—.0217	.7764	—.0020	.7744
4							
5							
6	.7575	.9487	.7062	—.0315	.8088	—.0028	.8060
7							
8							
9	.7218	.9480	.6698	+.0049	.7738	+.0004	.7742
10	.7204	.9526	.6730	+.0017	.7678	+.0002	.7680
11	.7166	.9487	.6653	+.0094	.7679	+.0008	.7687
12							
13	.7230	.9357	.6587	+.0160	.7873	+.0014	.7887
15	.7000	.9668	.6668	+.0079	.7332	+.0007	.7339
16	.6976	.9552	.6528	+.0219	.7424	+.0020	.7444
17	.6843	.9781	.6624	+.0123	.7062	+.0011	.7073
18	.6968	.9650	.6618	+.0129	.7318	+.0012	.7330
19	.6970	.9805	.6775	—.0028	.7165	—.0003	.7162
20	.6766	.9701	.6467	+.0280	.7065	+.0025	.7090
	Adopted mean, 208.6747				Assumed value, 18.7560		

Table XVII.—Parallax Equations.

Comparison Stars 39 and 6

Plate.					Residuals Scale.	Residuals Arc.
1	1.00x	—1.14y	—1.30Π	+3.01 = 0	+0.52	+″.15
2	1.00	—1.13	—1.37	+1.92 = 0	—0.68	— .19
3	1.00	—1.13	—1.37	+1.84 = 0	—0.76	— .21
6	1.00	—0.04	—1.76	+5.00 = 0	+2.10	+ .59
9	1.00	+0.88	—1.43	+1.82 = 0	—0.29	— .08
10	1.00	+0.89	—1.52	+1.20 = 0	—1.05	— .29
11	1.00	+0.90	—1.55	+1.27 0	—1.03	— .29
13	1.00	+0.90	—1.55	+3.27 = 0	+0.97	+ .27
15	1.00	+1.42	+1.73	—2.21 = 0	+0.92	+ .26
16	1.00	+1.45	+1.81	—1.16 = 0	+2.09	+ .59
17	1.00	+1.45	+1.81	—4.87 = 0	—1.61	— .45
18	1.00	+1.45	+1.81	—2.30 = 0	+0.96	+ .27
19	1.00	+1.45	+1.81	—3.98 = 0	—0.72	— .20
20	1.00	+1.45	+1.81	—4.70 = 0	—1.44	— .40

$[vv] = 20.23$

Normal Equations.

$$+14.0000x + 8.8000y - 1.0700\Pi + 0.1100 = 0$$
$$+19.5704 \quad +14.8265 \quad -28.9273 = 0$$
$$+37.0751 \quad -63.9392 = 0$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi = +1.6054 \pm 0.2051$	$\Pi = +0''.4497 \pm 0''.0575$
$y = +0.2941 \pm 0.3330$	$y = +0\ .0821 \pm 0\ .0933$
$x = -0.0694 \pm 0.3291$	$x = -0\ .0194 \pm 0\ .0922$

Probable error of one equation = ±0.9145 (Scale) = ±0″.2562 (Arc)

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 5 AND 53.

Plate No.	Corrected Distance.		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 5	Star 53					
1	77.2195	75.9023	153.1218	—.0225	1.3172	—.0002	1.3170
2	.2144	.9034	.1178	—.0185	.3110	—.0002	.3108
3	.2131	.8892	.1023	—.0030	.3239	—.0000	.3239
4							
5							
6	.2135	.8975	.1110	—.0117	.3160	—.0001	.3159
7	.2180	.9198	.1378	—.0385	.2982	—.0003	.2979
8							
9	.2093	.8921	.1014	—.0021	.3172	—.0000	.3172
10	.2058	.8913	.0971	+.0022	.3145	+.0000	.3145
11	.2092	.8894	.0986	+.0007	.3198	+.0000	.3198
12	.2103	.8845	.0948	+.0045	.3258	+.0000	.3258
13	.2093	.8958	.1051	—.0058	.3135	—.0001	.3134
15	.2244	.8536	.0780	+.0213	.3708	+.0002	.3710
16	.2169	.8650	.0819	+.0174	.3519	+.0002	.3521
17	.2201	.8707	.0908	+.0085	.3494	+.0001	.3495
18	.2254	.8513	.0767	+.0226	.3741	+.0002	.3743
19	.2317	.8559	.0876	+.0117	.3758	+.0001	.3759
20	.2199	.8646	.0845	+.0148	.3553	+.0001	.3554

Adopted mean, 153.0993 Assumed value, 1.3330

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 5 AND 53.

Plate.					Residuals. Scale.	Residuals. Arc.
1	1.00x	—1.14y	+1.90Π	—1.60 = 0	+0.41	+0″.11
2	1.00	—1.13	+1.90	—2.22 = 0	—0.21	— .06
3	1.00	—1.13	+1.90	—0.91 = 0	+1.10	+ .31
6	1.00	—0.04	+1.47	—1.71 = 0	—0.41	— .11
7	1.00	—0.04	+1.42	—3.51 = 0	—2.28	— .64
9	1.00	+0.88	+1.88	—1.58 = 0	+0.16	+ .04
10	1.00	+0.89	+1.85	—1.85 = 0	—0.15	— .04
11	1.00	+0.90	+1.83	—1.32 = 0	+0.35	+ .10
12	1.00	+0.90	+1.83	—0.72 = 0	+0.95	+ .27
13	1.00	+0.90	+1.83	—1.96 = 0	—0.29	— .08
15	1.00	+1.42	—1.75	+3.80 = 0	+0.64	+ .18
16	1.00	+1.45	—1.57	+1.91 = 0	—1.02	— .29
17	1.00	+1.45	—1.57	+1.65 = 0	—1.28	— .36
18	1.00	+1.45	—1.55	+4.13 = 0	+1.22	+ .34
19	1.00	+1.45	—1.55	+4.29 = 0	+1.38	+ .39
20	1.00	+1.45	—1.55	+2.24 = 0	—0.67	— .19
					$[vv]$ = 14.87	

Normal Equations.

$$+16.0000x + 9.6600y + 8.2700\Pi + 0.6400 = 0$$
$$+20.3820 - 12.1142 + 24.9478 = 0$$
$$+47.2107 - 58.9600 = 0$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi = +1.3326 \pm 0.1510$	$\Pi = +0''.3733 \pm 0''.0423$
$y = -0.1213 \pm 0.2593$	$y = -0\ .0340 \pm 0\ .0726$
$x = -0.6556 \pm 0.2826$	$x = -0\ .1836 \pm 0\ .0792$

Probable error of one equation = ± 0.7211 (Scale) = ± 0″.2020 (Arc)

Table XVI.—Observational Data.

Companion Stars 54 and 5.

Plate No.	Corrected Distance		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 54	Star 5					
1	77.3081	77.2195	154.5276	—.0383	0.0886	0	0.0886
2	.3106	.2144	.5250	—.0357	.0962	0	.0962
3	.2969	.2131	.5100	—.0207	.0838	0	.0838
4							
5							
6							
7							
8							
9	.2808	.2093	.4901	—.0008	.0715	0	.0715
10	.2803	.2058	.4861	+.0032	.0745	0	.0745
11	.2740	.2092	.4832	+.0061	.0648	0	.0648
12	.2661	.2103	.4764	+.0129	.0558	0	.0558
13	.2799	.2093	.4892	+.0001	.0706	0	.0706
15	.2449	.2244	.4693	+.0200	.0205	0	.0205
16	.2605	.2169	.4774	+.0119	.0436	0	.0436
17	.2620	.2201	.4821	+.0072	.0419	0	.0419
18	.2507	.2254	.4761	+.0132	.0253	0	.0253
19							
20	.2474	.2199	.4673	+.0220	.0275	0	0.0275

Adopted mean, 154.4893 Assumed value, 0.0590

Table XVII.—Parallax Equations.

Comparison Stars 54 and 5.

Plate.					Residuals. Scale.	Residuals. Arc.
1	1.00x	—1.14y	—1.91Π	+2.96 = 0	—0.10	—0″.03
2	1.00	—1.13	—1.90	+3.72 = 0	+0.68	+ .19
3	1.00	—1.13	—1.90	+2.48 = 0	—0.56	— .16
9	1.00	+0.88	—1.89	+1.25 = 0	+0.34	+ .10
10	1.00	+0.89	—1.86	+1.55 = 0	+0.68	+ .19
11	1.00	+0.90	—1.84	+0.58 = 0	—0.27	— .08
12	1.00	+0.90	—1.84	—0.32 = 0	—1.17	— .33
13	1.00	+0.90	—1.84	+1.16 = 0	+0.31	+ .09
15	1.00	+1.42	+1.77	—3.85 = 0	—1.01	— .28
16	1.00	+1.45	+1.59	—1.54 = 0	+1.17	+ .33
17	1.00	+1.45	+1.59	—1.71 = 0	+1.00	+ .28
18	1.00	+1.45	+1.57	—3.37 = 0	—0.68	— .19
20	1.00	+1.45	+1.57	—3.15 = 0	—0.46	— .13
					[vv] = 6.96	

Normal Equations.

$$+13.0000x + 8.2900y - 6.8900\Pi - 0.2400 = 0$$
$$+18.2763 + 9.8622 - 26.2564 = 0$$
$$+41.1755 - 47.5103 = 0$$

Solution.

In units of 2d dec. place of scale.	In Arc.
$\Pi = +0.8680 \pm 0.1203$	$\Pi = +0''.2431 \pm 0''.0337$
$y = +1.0570 \pm 0.2044$	$y = +0\ .2961 \pm 0\ .0573$
$x = -0.1955 \pm 0.2369$	$x = -0\ .0548 \pm 0\ .0664$

Probable error of one equation = ±0.5626 (Scale) = ±0″.1576 (Arc).

Table XVI.—Observational Data.

Comparison Stars 48 and 14.

Plate No.	Corrected Distance		Sum of Distances	Mean *minus* Sum	Difference of Distances	Scale Corr.	Corrected Difference
	Star 48	Star 14					
1							
2	50.8127	34.6771	85.4898	—.0210	16.1356	—.0039	16.1317
3	.8164	.6853	.5017	—.0329	.1311	—.0062	.1249
4							
5							
6							
7							
8							
9							
10	.7984	.6690	.4674	+.0014	.1294	+.0003	.1297
11	.7972	.6765	.4737	—.0049	.1207	—.0009	.1198
12	.7955	.6742	.4697	—.0009	.1213	—.0002	.1211
13	.7971	.6601	.4572	+.0116	.1370	+.0022	.1392
15	.7785	.6805	.4590	+.0098	.0980	+.0018	.0998
16	.7762	.6744	.4506	+.0182	.1018	+.0034	.1052
17							
18	.7742	.6928	.4670	+.0018	.0814	+.0003	.0817
19	.7680	.6859	.4539	+.0149	.0821	+.0028	.0849
20	.7829	.6834	.4663	+.0025	.0995	+.0005	.1000
	Adopted mean, 85.4688				Assumed value, 16.1130		

TABLE XVII.—PARALLAX EQUATIONS.

COMPARISON STARS 48 AND 14.

Plate.					Residuals. Scale.	Residuals. Arc.
2	1.00x	—1.13y	—1.55Π	+1.87 = 0	+0.32	+0″.09
3	1.00	—1.13	—1.55	+1.19 = 0	—0.36	— .10
10	1.00	+0.89	—1.42	+1.67 = 0	+0.23	+ .06
11	1.00	+0.90	—1.38	+0.68 = 0	—0.71	— .20
12	1.00	+0.90	—1.38	+0.81 = 0	—0.58	— .16
13	1.00	+0.90	—1.38	+2.62 = 0	+1.23	+ .34
15	1.00	+1.42	+1.19	—1.32 = 0	+0.84	+ .24
16	1.00	+1.45	+0.93	—0.78 = 0	+1.02	+ .29
18	1.00	+1.45	+0.90	—3.13 = 0	—1.37	— .38
19	1.00	+1.45	+0.90	—2.81 = 0	—1.05	— .30
20	1.00	+1.45	+0.90	—1.30 = 0	+0.46	+ .13
					[vv] = 7.58	

Normal Equations.

$$+11.0000x + 8.5500y - 3.8400\Pi - 0.5000 = 0$$
$$+16.2023 \quad + 5.4665 \quad -11.7759 = 0$$
$$+17.2456 \quad -21.5984 = 0$$

Solution.

In units of 2d dec. place of scale.	In Arc.
Π = +1.3880 ±0.2261	Π = +0″.3888 ±0″.0634
y = —0.0359 ±0.2918	y = —0 .0101 ±0 .0818
x = +0.5579 ±0.3485	x = +0 .1563 ±0 .0976

	Scale.	Arc.
Probable error of one equation	±0.6568 =	±0″.1840

TABLE XVIII.—PARALLAX EQUATIONS.
POSITION-ANGLE. STAR 37.

Plate.	Reduced Angle.					Residuals in arc of great circle.
2	149°35′56″	1.00x'	—1.13y'	+146.Π	—54″ = 0	—″.11
3	36 28	1.00	—1.13	+146.	—22 = 0	+ .10
4	35 37	1.00	—0.08	+152.	—73 = 0	— .25
5	36 10	1.00	—0.04	+145.	—40 = 0	— .05
6	36 55	1.00	—0.04	+145.	+ 5 = 0	+ .24
7	36 28	1.00	—0.04	+143.	—22 = 0	+ .07
8	36 53	1.00	+0.88	+148.	+ 3 = 0	+ .21
9	36 28	1.00	+0.88	+148.	—22 = 0	+ .05
10	36 19	1.00	+0.89	+151.	—31 = 0	— .00
11	36 22	1.00	+0.90	+151.	—28 = 0	+ .02
12	36 3	1.00	+0.90	+151.	—47 = 0	— .10
13	35 52	1.00	+0.90	+151.	—58 = 0	— .18
15	38 5	1.00	+1.42	—156.	+75 = 0	+ .07
16	37 38	1.00	+1.45	—152.	+48 = 0	— .10
17	38 18	1.00	+1.45	—152.	+88 = 0	+ .16
18	37 16	1.00	+1.45	—151.	+26 = 0	— .24
19	37 58	1.00	+1.45	—151.	+68 = 0	+ .03
20	38 2	1.00	+1.45	—151.	+72 = 0	+ .06
	149 36 50 = Adopted Mean.					

Normal Equations.

$$+18.00x' + 11.56y' + \quad 864.00\Pi - \quad 12.00 = 0$$
$$+ 19.86 \quad - \quad 876.04 \quad + \quad 474.39 = 0$$
$$+ 402194.00 \quad - 115427.00 = 0$$

Solution.

$\Pi = + \ 0''.3028 \pm 0''.0355$ $[vv] = 8127.$

$y' = - \ 3 \ .9189 \pm 6 \ .039$ $\sigma = 1336''.94$

$x' = - \ 11 \ .3531 \pm 6 \ .368$ Factor = .00648

In Angle. Arc of great circle.

Probable error of one equation = ± 15″.70 = ± 0″.1018

Table XVIII.—Parallax Equations.

Position-Angle. Star 27.

Plate.	Reduced Angle.					Residuals in arc of great circle.
2	177°14′ 9″	1.00x'	—1.13y'	+183.Π	— 59.″=0	+″.03
3	13 57	1.00	—1.13	+183.	— 71. =0	— .03
10	14 59	1.00	+0.89	+178.	— 9. =0	+ .21
11	15 3	1.00	+0.90	+176.	— 5. =0	+ .23
12	14 10	1.00	+0.90	+176.	— 58. =0	— .05
13	13 4	1.00	+0.90	+176.	—124. =0	— .39
15	16 11	1.00	+1.42	—169.	+ 63. =0	— .12
16	16 11	1.00	+1.45	—151.	+ 63. =0	— .08
18	17 20	1.00	+1.45	—149.	+132. =0	+ .28
20	16 14	1.00	+1.45	—149.	+ 66. =0	— .07

177 15 8.0 = Adopted Mean.

Normal Equations.

$+10.00x' + 7.10y' + 454.00\Pi - 2.00 = 0$
$+14.10 - 670.99 + 438.50 = 0$
$+287354.00 - 107966.00 = 0$

Solution.

$\Pi = + 0''.3797 \pm 0''.0737$	$[vv]$	$= 13187.$
$y' = - 7\ .1257 \pm 12\ .65$	σ	$= 1074''.60$
$x' = -11\ .8966 \pm 14\ .69$	Factor	$= .00521$

In Angle. Arc of great circle.
Probable error of one equation $= \pm 29''.27 = \pm 0''.1525$

Table XVIII.—Parallax Equations.

Position-Angle. Star 48.

Plate.	Reduced Angle.					Residuals in arc of great circle.
1	105°52′58″	1.00x'	—1.14y'	+ 68.Π	— 3″ = .0	+″.03
2	52 0	1.00	—1.13	+ 74.	—61 = .0	— .35
3	53 23	1.00	—1.13	+ 74.	+22 = .0	+ .22
4	51 32	1.00	—0.08	+102.	—89 = .0	— .48
5	53 43	1.00	—0.04	+119.	+42 = .0	+ .46
6	53 9	1.00	—0.04	+119.	+ 8 = .0	+ .22
7	52 48	1.00	—0.04	+121.	—13 = .0	+ .08
8	52 55	1.00	+0.88	+ 80.	— 6 = .0	+ .06
9	53 3	1.00	+0.88	+ 80.	+ 2 = .0	+ .12
10	52 19	1.00	+0.89	+ 89.	—42 = .0	— .16
11	52 42	1.00	+0.90	+ 92.	—19 = .0	— .00
12	52 36	1.00	+0.90	+ 92.	—25 = .0	— .04
13	52 8	1.00	+0.90	+ 92.	—53 = .0	— .24
15	53 38	1.00	+1.42	—110.	+37 = .0	+ .00
16	54 4	1.00	+1.45	—121.	+63 = .0	+ .16
17	54 12	1.00	+1.45	—121.	+71 = .0	+ .22
18	52 32	1.00	+1.45	—122.	—29 = .0	— .47
19	53 55	1.00	+1.45	—122.	+54 = .0	+ .10
20	53 51	1.00	+1.45	—122.	+50 = .0	+ .07
	105 53 1.0 = Adopted Mean.					

Normal Equations.

$$+19.00x' + 10.42y' + 484.00\Pi + 9.00 = 0$$
$$+21.16 - 836.67 + 280.52 = 0$$
$$+201090.00 - 50207.00 = 0$$

Solution.

Π = +0″.2794 ± 0″.0766	[vv] = 22847.
y' = +2 .0965 ± 8 .487	σ = 1422″.69
x' = —8 .7418 ± 8 .453	Factor = .00690

	In Angle.	Arc of great circle.
Probable error of one equation	= ±25″.49	= ±0″.1758

Table XVIII.—Parallax Equations.

Position-Angle. Star 43.

Plate.	Reduced Angle.					Residuals in arc of great circle.
1	143° 50′ 1″	1.00x'	—1.14y'	+101.Π	—48.″ = 0	—″.01
2	49 42	1.00	—1.13	+104.	—67. = 0	— .17
3	50 22	1.00	—1.13	+104.	—27. = 0	+ .18
10	50 28	1.00	+0.89	+108.	—21. = 0	+ .07
11	50 19	1.00	+0.90	+109.	—30. = 0	— .01
12	50 16	1.00	+0.90	+109.	—33. = 0	— .03
13	50 17	1.00	+0.90	+109.	—32. = 0	— .02
15	52 5	1.00	+1.42	—114.	+76. = 0	+ .23
16	51 23	1.00	+1.45	—113.	+34. = 0	— .14
18	51 43	1.00	+1.45	—112.	+54. = 0	+ .04
19	52 19	1.00	+1.45	—112.	+90. = 0	+ .36
20	50 41	1.00	+1.45	—112.	— 8. = 0	— .51

143 50 49.0 = Adopted Mean.

Normal Equations.

$$+12.00x' + 7.41y' + 181.00\Pi - 12.00 = 0$$
$$+17.50 - 772.69 + 411.17 = 0$$
$$+142537.00 - 54985.00 = 0$$

Solution.

$\Pi = +0''.3299 \pm 0''.0658$	$[vv] = 6788.$
$y' = -9\ .8126 \pm 6\ .845$	$\sigma = 1824''.90$
$x' = +2\ .0830 \pm 7\ .280$	Factor = .00885

In Angle. Arc of great circle.

Probable error of one equation = ±18″.52 = ±0″.1638

Table XVIII.—Parallax Equations.

Position-Angle. Star 32.

Plate.	Reduced Angle.					Residuals in arc of great circle.
1	172°39′49″	1.00x'	—1.14y'	+93.Π	—30.″=0	+0″.08
2	39 51	1.00	—1.13	+93.	—28. =0	+ .10
3	39 55	1.00	—1.13	+93.	—24. =0	+ .14
4	39 12	1.00	—0.08	+87.	—67. =0	— .43
5	39 41	1.00	—0.04	+75.	—38. =0	— .18
6	39 51	1.00	—0.04	+75.	—28. =0	— .07
7	40 2	1.00	—0.04	+73.	—17. =0	+ .03
8	40 11	1.00	+0.88	+92.	— 8. =0	+ .10
9	40 1	1.00	+0.88	+92.	—18. =0	— .00
10	39 59	1.00	+0.89	+91.	—20. =0	— .03
11	40 5	1.00	+0.90	+90.	—14. =0	+ .03
12	40 18	1.00	+0.90	+90.	— 1. =0	+ .17
13	40 4	1.00	+0.90	+90.	—15. =0	+ .02
15	41 6	1.00	+1.42	—88.	+47. =0	— .02
16	40 47	1.00	+1.45	—80.	+28. =0	— .19
17	41 17	1.00	+1.45	—80.	+58. =0	+ .12
18	41 36	1.00	+1.45	—79.	+77. =0	+ .32
19	41 19	1.00	+1.45	—79.	+60. =0	+ .14
20	40 34	1.00	+1.45	—79.	+15. =0	— .33

172°40 19.0 = Adopted Mean.

Normal Equations.

$$+19.00x' + 10.42y' + 649.00\Pi - 23.00 = 0$$
$$+21.16 - 546.78 + 445.80 = 0$$
$$+138871.00 - 49582.00 = 0$$

Solution.

$\Pi = +0''.3442 \pm 0''.0489$ $[vv] = 5382.$

$y' = -9\ .5621 \pm 4\ .251$ $\sigma = 2155.''55$

$x' = -5\ .3013 \pm 4\ .638$ Factor = .01045

	In Angle.	Arc of great circle.
Probable error of one equation	= ±12.″37	= ±0.″1293

Table XVIII.—Parallax Equations.

Position-Angle. Star 23.

Plate.	Reduced Angle.						Residuals in arc of great circle.
1	356°4′49″	1.00x	—1.14y	—79.Π	+ 8.″	= 0	—0″.08
2	5 12	1.00	—1.13	—79.	+31.	= 0	+ .20
3	4 49	1.00	—1.13	—79.	+ 8.	= 0	— .08
4	5 20	1.00	—0.08	—73.	+39.	= 0	+ .31
5	4 14	1.00	—0.04	—62.	—27.	= 0	— .45
6	4 40	1.00	—0.04	—62.	— 1.	= 0	— .13
7	5 7	1.00	—0.04	—60.	+26.	= 0	+ .20
8	4 50	1.00	+0.88	—78.	+ 9.	= 0	— .08
9	4 57	1.00	+0.88	—78.	+16.	= 0	+ .00
10	5 0	1.00	+0.89	—77.	+19.	= 0	+ .04
11	4 42	1.00	+0.90	—76.	+ 1.	= 0	— .17
12	4 58	1.00	+0.90	—76.	+17.	= 0	+ .02
13	5 11	1.00	+0.90	—76.	+30.	= 0	+ .18
15	4 1	1.00	+1.42	+73.	—40.	= 0	— .07
16	4 13	1.00	+1.45	+66.	—28.	= 0	+ .05
17	3 59	1.00	+1.45	+66.	—42.	= 0	— .12
18	4 24	1.00	+1.45	+65.	—17.	= 0	+ .18
19	3 40	1.00	+1.45	+65.	—61.	= 0	— .36
20	4 39	1.00	+1.45	+65.	— 2.	= 0	+ .36

356 4 41.0 = Adopted Mean.

Normal Equations.

$$+19.00x' + 10.42y' - 555.00\Pi - 14.00 = 0$$
$$+21.16 \quad + 448.60 \quad - 248.42 = 0$$
$$+97481.00 \quad - 26185.00 = 0$$

Solution.

$\Pi = +\ 0''.3334 \pm 0''.0584$ $[vv] = 5349.$

$y' = -\ 0\ .6676 \pm 4\ .237$ $\sigma = 2500''.62$

$x' = +10\ .8423 \pm 4\ .652$ Factor = .01213

In Angle. Arc of great circle.

Probable error of one equation = $\pm 12''.33$ = $\pm 0''.1496$

TABLE XVIII.—PARALLAX EQUATIONS.

POSITION-ANGLE. STAR 13.

Plate.	Reduced Angle.						Residuals in arc of great circle.
1	341°25′ 9″	1.00x	—1.14y	—73.Π	+23.″	=0	+0″.11
2	24 30	1.00	—1.13	—73.	—16.	=0	— .41
3	25 10	1.00	—1.13	—73.	+24.	=0	+ .12
4	25 40	1.00	—0.08	—72.	+54.	=0	+ .46
5	25 0	1.00	—0.04	—66.	+14.	=0	— .04
6	24 55	1.00	—0.04	—66.	+ 9.	=0	— .11
7	25 6	1.00	—0.04	—65.	+20.	=0	+ .05
10	25 14	1.00	+0.89	—74.	+28.	=0	+ .04
11	25 13	1.00	+0.90	—74.	+27.	=0	+ .02
12	24 59	1.00	+0.90	—74.	+13.	=0	— .16
13	25 4	1.00	+0.90	—74.	+18.	=0	— .10
15	23 54	1.00	+1.42	+74.	—52.	=0	— .20
16	24 13	1.00	+1.45	+69.	—33.	=0	+ .03
17	24 19	1.00	+1.45	+69.	—27.	=0	+ .11
18	24 47	1.00	+1.45	+69.	+ 1.	=0	+ .48
19	23 52	1.00	+1.45	+69.	—54.	=0	— .26
20	23 59	1.00	+1.45	+69.	—47.	=0	— .16

341 24 46.0 = Adopted Mean.

Normal Equations.

$$+17.00x' + 8.66y' - 365.00\Pi + 2.00 = 0$$
$$+19.62 \quad + 601.51 \quad - 270.02 = 0$$
$$+85293.00 \quad -30221.00 = 0$$

Solution.

$\Pi = +\ 0''.4401 \pm 0''.0643$	$[vv]$	$= 4672.$
$y' = -\ 4\ .9631 \pm 4\ .591$	σ	$= 2754''.25$
$x' = +11\ .8592 \pm 4\ .582$	Factor	$= .01336$

In Angle. Arc of great circle.
Probable error of one equation $= \pm 12''.32 = \pm 0''.1646$

The Parallax of 61^2 Cygni.

37. If the coefficients for parallax of 61^2 *Cygni* be computed by the formulæ of paragraphs 14 and 22, we have:

$$S_3 = -0.296 \qquad S_8 = +9777.$$
$$S_4 = -0.822 \qquad S_9 = -1120.$$

With these, and the values of P_3 and P_4 of paragraph 14, have been obtained the quantities printed in the last column of Table XIII.

38. The measured distances duly corrected for proper motions of both stars are given in the last-but-one column of Table XIII. Table XIX contains the equations of condition of the form:

$$x + (t-1873.546)y + (S_3P_3 + S_4P_4)\,\Pi + \sigma - \sigma_0' = 0$$

from which are derived the values of the unknowns given on the same page.

39. In column nine of Table XIII are given in like manner the corrected position-angles from which the equations of condition of Table XX have been formed after the manner of paragraph 35. They are of the form

$$x' + (t-1873.546)y' + \sigma\cdot\sin 1''\cdot\,(S_8P_3 + S_9P_4)\,\Pi + \sigma\cdot\sin 1''\cdot\,(\pi - \pi_0') = 0.$$

The resulting values of the unknowns will be found on the same page.

40. In both these cases, however, we cannot assume the parallax of the reference star to be *nil*. Its value has been shown to be $+0.''360 \pm ''.015$. The mean by weight of the values of parallax of *61*¹ with respect to *61*² obtained from distance and from angle is $+0''.072 \pm ''.028$, wherefore the concluded value of the

$$\text{Parallax of } 61^2 \text{ Cygni} = 0''.288 \pm ''.031$$

referred indirectly to all the comparison stars given in Table XIV.

TABLE XIX.—PARALLAX EQUATIONS IN DISTANCE.

COMPARISON STAR, *61¹ Cygni*.

Plate.					v.
1	1.00x	—1.69y	—0.77Π	—0″.140 = 0	—0″.248
2	1.00	—1.68	—0.74	+ .136 = 0	+ .032
3	1.00	—1.68	—0.74	+ .200 = 0	+ .096
4	1.00	—0.63	—0.57	+ .076 = 0	+ .022
5	1.00	—0.59	—0.37	— .058 = 0	— .085
6	1.00	—0.59	—0.37	+ .085 = 0	+ .058
7	1.00	—0.58	—0.34	+ .078 = 0	+ .055
8	1.00	+0.33	—0.71	+ .001 = 0	— .045
9	1.00	+0.33	—0.71	— .147 = 0	— .193
10	1.00	+0.34	—0.67	+ .030 = 0	— .010
11	1.00	+0.35	—0.65	+ .243 = 0	+ .205
12	1.00	+0.35	—0.65	+ .061 = 0	+ .023
13	1.00	+0.35	—0.65	+ .128 = 0	+ .090
15	1.00	+0.87	+0.55	+ .038 = 0	+ .168
16	1.00	+0.90	+0.42	— .039 = 0	+ .075
17	1.00	+0.90	+0.42	— .022 = 0	+ .092
18	1.00	+0.91	+0.40	— .246 = 0	— .134
19	1.00	+0.91	+0.40	— .280 = 0	— .168
20	1.00	+0.91	+0.40	— .146 = 0	— .033

Normal Equations.

$$+19.000\,000x + 0.010\,000y - 5.350\,000\Pi - 0''.002\,000 = 0$$
$$+15.492\,500 \quad +5.728\,200 \quad -0\;.957\,070 = 0$$
$$+6.262\,300 \quad -0\;.691\,430 = 0$$

Solution.

	Weights.
$x = +0''.0362 \pm 0''.0249$	12.08
$y = +0\;.0272 \pm 0\;.0295$	8.59
$\Pi = +0\;.1282 \pm 0\;.0533$	2.64

Probable error of one equation $= \pm 0''.0865$. $[vv] = 0.2634$

Table XX.—Parallax Equations in Angle.

Comparison Star, *61¹ Cygni.*

Plate.					v.
1	$1.00x'$	$-1.69y'$	$+0.597\Pi$	$-''.100=0$	$+''.005$
2	1.00	−1.68	+ .633	− .074=0	+ .033
3	1.00	−1.68	+ .633	− .142=0	+ .065
4	1.00	−0.63	+ .802	− .165=0	− .103
5	1.00	−0.59	+ .890	− .058=0	+ .006
6	1.00	−0.59	+ .890	+ .122=0	+ .186
7	1.00	−0.58	+ .896	− .150=0	− .086
8	1.00	+0.33	+ .672	− .134=0	− .128
9	1.00	+0.33	+ .672	+ .025=0	+ .031
10	1.00	+0.34	+ .723	+ .087=0	+ .095
11	1.00	+0.35	+ .742	+ .063=0	+ .072
12	1.00	+0.35	+ .742	+ .013=0	+ .022
13	1.00	+0.35	+ .742	− .113=0	− .104
15	1.00	+0.87	− .850	+ .068=0	− .031
16	1.00	+0.90	− .910	+ .012=0	− .092
17	1.00	+0.90	− .910	+ .383=0	+ .279
18	1.00	+0.91	− .913	− .076=0	− .181
19	1.00	+0.91	− .913	+ .037=0	− .068
20	1.00	+0.91	− .913	+ .205=0	+ .100

Normal Equations.

$$+19.000\,000x + 0.010\,000y + 4.225\,000\Pi + 0''.003\,000 = 0$$
$$+15.492\,500 - 8.612\,500 + 1\ .231\,450 = 0$$
$$+12.145\,003 - 1\ .012\,807 = 0$$

Solution.

	Weights.
$x' = -0''.0115 \pm ''.0200$	16.57
$y' = -0\ .0510 \pm\ .0273 = -0^\circ.151 \pm 0^\circ.081$	8.87
$\Pi = +0\ .0512 \pm\ .0321$	6.42

Probable error of one equation $= \pm 0''.0813$ $[vv] = 0.2326$

Incidentally it should be noticed that the assumed annual change in distance of *61^2* from *61^1* was —0″.128, the negative sign being used to indicate separation. From the value of y in Table XIX the correction to this is 0″.027. Thus the RUTHERFURD plates for an interval of only 2.6 years give:

Annual increase of distance = 0″.101 ±″.030.

In like manner, the assumed increase of position-angle being 0°.370 and Table XX, giving as a correction a further increase of 0°.151, there results:

Annual increase of angle = 0°.521 ±°.081.

But what is of greater significance, there is also a difference of parallax:

$$(61^1 \text{ Cygni} - 61^2 \text{ Cygni}) = + 0''.072 \pm {}''.028$$

41. This result is so surprising and yet the difference of parallax obtained from angles and from distances is so accordant within the limits of their respective probable errors that I have deemed it advisable to use the very excellent series of measures of the distance of these two stars given by WILSING in *Sitzungsberichten* der Königl. Preuss. Akademie der Wissenschaften*, 1893, Bd. 40, to see what value of the difference of parallax, if any, might be deduced from them.

42. Using AUWERS' values of the right ascension and declination of 61^1 *Cygni* for 1875.0 and his constants of precession we have:

$$\left.\begin{aligned} \alpha &= 21^h\ \ 2^m\ \ 0^s.6 \\ \delta &= 38^\circ\ 12'\ 48''.6 \end{aligned}\right\} \text{for } 1891.0$$

I have taken $p = 114^\circ.692$ for 1873 with an annual variation of 0°.50 which gives $p = 123^\circ.5$ for 1891.0 quite accurately enough; as an error of a whole degree would, demonstrably, have no sensible effect upon the deduced value of parallax. Therefore:

$$S_3 = [9.9849] \sin 350^\circ.8 = -0.154$$
$$S_4 = [9\ 9181] \sin 271^\circ.3 = -0.828$$

With these and the values of P_3 and P_4 computed for each date of WILSING's plates† were formed the parallax coefficients

$$S_3P_3 + S_4P_4$$

which are found in the equations of condition of Table XXI.

*Since given more fully in *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, Nr. 36, Bd. XI, 1897.

†*Sitzungsberichten*, etc., pages 883–4.

TABLE XXI.—WILSING'S MEASURES.

No.	Date.			Meas. Dist.	Equations of Condition.	Corrected Distance.	Distance *minus* Mean. *v*
				″	″	″	″
1	1890	Oct.	14.43	21.04	1.*x*—0.22*y* —.82Π+.04=0	20.986	+.004
2			22.43	20.90	1 —0.19 —.79 —.10	20.847	—.135
3		Nov.	5.32	20.89	1 —0.16 —.70 —.11=0	20.842	—.140
4		Dec.	17.24	20.95	1 —0.04 —.21 —.05=0	20.935	—.047
5	1891	Feb.	4.29	20.99	1 +0.10 +.48 —.01=0	21.024	+.042
6		May	5.48	21.04	1 +0.34 +.70 +.04=0	21.073	+.091
7			8.49	20.97	1 +0.35 +.68 —.03	21.001	+.019
8			11.46	21.04	1 +0.36 +.65 +.04	21.071	+.089
9			11.47	20.87	1 +0.36 +.65 —.13	20.901	—.081
10			12.47	20.81	1 +0.36 +.64 —.19	20.837	—.145
11			29.46	20.94	1 +0.40 +.46 —.06	20.947	—.035
12		June	5.49	20.91	1 +0.42 +.37 —.09=0	20.907	—.075
13			16.44	20.85	1 +0.46 +.22 —.15	20.831	—.151
14			17.47	20.81	1 +0.46 +.21 —.19	20.790	—.192
15			17.49	20.76	1 +0.46 +.21 —.24	20.740	—.242
16		Aug.	18.40	21.12	1 +0.63 —.60 +.12=0	21.017	+.035
17			18.41	21.11	1 +0.63 —.60 +.11	21.005	+.023
18			18.43	21.10	1 +0.63 —.60 +.10	20.995	+.013
19			22.42	21.01	1 +0.64 —.64 +.01	20.901	—.081
20			23.44	21.03	1 +0.64 —.65 +.03	20.920	—.062
21			27.41	21.06	1 +0.66 —.69 +.06	20.946	—.036
22			27.42	21.20	1 +0.66 —.69 +.20	21.086	+.104
23			28.45	21.04	1 +0.66 —.69 +.04	20.926	—.056
24			28.46	21.16	1 +0.66 —.69 +.16	21.046	+.064
25			29.38	21.02	1 +0.66 —.70 +.02	20.905	—.077
26			31.37	21.03	1 +0.67 —.72 +.03	20.912	—.070
27			31.39	21.06	1 +0.67 —.72 +.06	20.942	—.040
28		Sept.	6.44	21.02	1 +0.69 —.76 +.02=0	20.896	—.086
29			6.45	21.12	1 +0.69 —.76 +.12	20.996	+.014
30			7.42	21.16	1 +0.69 —.77 +.16	21.036	+.054
31			7.43	21.16	1 +0.69 —.77 +.16	21.036	+.054
32			9.46	20.95	1 +0.69 —.78 —.05	20.825	—.157
33			11.38	20.97	1 +0.69 —.79 —.03	20.844	—.138
34			23.41	21.03	1 +0.72 —.83 +.03	20.898	—.084
35			23.43	21.14	1 +0.72 —.83 +.14	21.008	+.026
36			24.35	20.87	1 +0.72 —.83 —.13	20.738	—.244
37			24.36	21.22	1 +0.72 —.83 +.22	21.088	+.106
38			30.37	20.90	1 +0.75 —.84 —.10	20.764	—.218
39			30.38	21.04	1 +0.75 —.84 +.04	20.904	—.078

TABLE XXI.—WILSING'S MEASURES, (*Continued*).

No.	Date.		Meas. Dist.	Equations of Condition.	Corrected Distance.	Distance *minus* Mean. *v*
			″	″	″	″
40	1891 Oct.	1.37	21.00	1.*x*+0.75*y* —.84Π+.00=0	20.864	—.118
41		1.37	21.07	1 +0.75 —.84 +.07	20.934	—.048
42		6.35	21.01	1 +0.77 —.84 +.01	20.873	—.109
43		6.37	21.13	1 +0.77 —.84 +.13	20.993	+.011
44		9.36	21.32	1 +0.78 —.84 +.32	21.182	+.200
45		10.30	21.31	1 +0.78 —.84 +.31	21.172	+.190
46		20.43	21.13	1 +0.80 —.80 +.13	20.994	+.012
47		23.42	21.21	1 +0.81 —.79 +.21	21.074	+.092
48		23.43	21.08	1 +0.81 —.79 +.08	20.944	—.038
49		28.36	21.10	1 +0.82 —.76 +.10	20.965	—.017
50	Oct.	29.32	21.17	1 +0.82 —.75 +.17=0	21.036	+.054
51	Nov.	3.32	21.13	1 +0.84 —.72 +.13	20.998	+.016
52		3.33	21.11	1 +0.84 —.72 +.11	20.978	—.004
53		5.41	21.06	1 +0.84 —.70 +.06	20.930	—.052
54		5.42	21.03	1 +0.84 —.70 +.03	20.900	—.082
55		19.30	21.34	1 +0.88 —.57 +.34	21.217	+.235
56		29.33	21.23	1 +0.91 —.46 +.23	21.115	+.133
57		29.34	21.41	1 +0.91 —.46 +.41	21.295	+.313
58	Dec.	7.23	21.31	1 +0.93 —.35 +.31=0	21.202	+.220
59		11.33	21.25	1 +0.94 —.30 +.25	21.147	+.165
60		12.30	21.18	1 +0.95 —.29 +.18	21.077	+.095
61		12.31	21.26	1 +0.95 —.29 +.26	21.157	+.175
62		17.32	21.13	1 +0.96 —.21 +.13	21.033	+.051
63		17.33	21.07	1 +0.96 —.21 +.07	20.973	—.009
64		25.27	21.32	1 +0.98 —.10 +.32	21.230	+.248
65		25.29	21.11	1 +0.98 —.10 +.11	21.020	+.038
66		25.30	21.09	1 +0.98 —.10 +.09	21.000	+.018
67	1892 Jan.	7.24	21.07	1 +1.02 +.09 +.07=0	20.994	+.012
68		7.26	21.12	1 +1.02 +.09 +.12	21.044	+.062
69		17.29	21.14	1 +1.04 +.24 +.14	21.075	+.093
70		17.30	21.10	1 +1.04 +.24 +.10	21.035	+.053
71		20.25	21.26	1 +1.05 +.28 +.26	21.198	+.216
72		20.27	21.18	1 +1.05 +.28 +.18	21.118	+.136
73		20.28	21.09	1 +1.05 +.28 +.09	21.028	+.046
74	May	8.53	21.08	1 +1.35 +.67 +.08=0	21.028	+.046
75		11.52	21.08	1 +1.36 +.64 +.08	21.024	+.042
76		11.53	21.07	1 +1.36 +.64 +.07	21.014	+.032
77		26.54	21.05	1 +1.40 +.48 +.05	20.977	—.005
78		26.56	21.10	1 +1.40 +.48 +.10	21.027	+.045
79	June	8.49	21.05	1 +1.43 +.32 +.05=0	20.960	—.022
80		8.51	21.07	1 +1.43 +.32 +.07	20.980	—.002
81		17.55	21.17	1 +1.46 +.20 +.17	21.068	+.086
82		28.48	21.16	1 +1.49 +.04 +.16	21.041	+.059

TABLE XXI.—WILSING'S MEASURES, (*Concluded*).

No.	Date.	Meas. Dist.	Equations of Condition.	Corrected Distance.	Distance *minus* Mean. v
		"	"	"	"
83	1892 Dec. 22.36	21.12	$1.x + 1.97y - .13\Pi + .12 = 0$	20.947	—.035
84	1893 Jan. 7.24	21.16	1 +2.02 +.10 +.16	21.003	+.021
85	7.28	21.12	1 +2.02 +.10 +.12	20.963	—.019
86	11.25	21.15	1 +2.03 +.16 +.15	20.997	+.015
87	28.26	21.10	1 +2.08 +.40 +.10	20.964	—.018
88	Feb. 4.26	21.19	1 +2.10 +.49 +.19	21.060	+.078
89	Mar. 23.61	20.98	1 +2.23 +.83 —.02=0	20.869	—.113
90	23.64	21.00	1 +2.23 +.83 .00	20.889	—.093
91	27.62	21.06	1 +2.24 +.84 +.06	20.949	—.033
92	Apr. 6.57	20.95	1 +2.27 +.84 —.05=0	20.837	—.145
93	18.59	21.02	1 +2.30 +.80 +.02	20.900	—.082
94	21.50	21.05	1 +2.31 +.79 +.05	20.929	—.053
95	May 9.55	21.11	1 +2.36 +.66 +.11=0	20.974	—.008
96	10.51	21.11	1 +2.36 +.65 +.11	20.973	—.009
97	15.56	21.10	1 +2.37 +.60 +.10	20.958	—.024
98	23.57	21.09	1 +2.39 +.52 +.09	20.939	—.043
99	June 1.50	21.12	1 +2.41 +.41 +.12=0	20.957	—.025
100	7.49	21.15	1 +2.43 +.34 +.15	20.980	—.002
101	14.49	21.16	1 +2.45 +.24 +.16	20.979	—.003
102	24.44	21.13	1 +2.48 +.10 +.13	20.935	—.047
103	July 4.44	21.22	1 +2.51 —.04 +.22=0	21.009	+.027
104	15.41	21.21	1 +2.54 —.19 +.21	20.984	+.002
105	Aug. 3.41	21.24	1 +2.59 —.44 +.24	20.988	+.006
106	Aug. 4.41	21.23	1 +2.59 —.46 +.23=0	20.977	—.005
107	10.39	21.17	1 +2.61 —.52 +.17	20.909	—.073
108	31.45	21.26	1 +2.67 —.72 +.26	20.977	—.005
109	Sept. 1.49	21.27	1 +2.67 —.73 +.27=0	20.986	+.004
110	15.48	21.22	1 +2.71 —.81 +.22	20.926	—.056

21.00 = Assumed Mean. $\Sigma vv = 1''.1032$

Mean = 20.982

43. From these equations are obtained the following normal equations and values of the unknowns :

Normal Equations.

$$+110.0000x + 129.0300y - 19.1300\Pi + 10.3300 = 0$$
$$+215.2083 - 3.9695 + 15.7599 = 0$$
$$+39.4805 - 3.4429 = 0$$

Solution.

	Weights.
$x = +0''.0180 \pm 0''.0014$	25.49
$y = -0\ .0824 \pm 0\ .0093$	54.42
$\Pi = +0\ .0876 \pm 0\ .0123$	30.81

Probable error of one equation $= \pm 0''.0684$

$[vv] = 1''.1006$

44. It will be noticed that this difference of parallax between *61*[1] and *61*[2] is in very close agreement with the $+0''.072 \pm .''028$ derived from the Rutherfurd measures. Its probable error and the sum of the squares of the residuals when compared with similar quantities* in Wilsing's determination of the parallax of 61[2] *Cygni* would indicate that it has as real an existence in the measures as his own values of the parallax of *61*[2] itself ; while at the same time bearing testimony to the excellent quality of his measures.

45. Yet this difference of parallax does not preclude the possibility of orbital motion of either *61*[1] or *61*[2] about a dark companion, as has been suggested by Wilsing to account for the systematic irregularity of his measures—a suggestion which the outstanding residuals, after corrections for this difference of parallax have been applied to the measures, would in a degree confirm. And yet it is greatly to be regretted that points numbered 1, 2, 3, and 4 of his curve† are determined by only 4, 2, 2, and 2, exposures on 2, 1, 1, and 1 plates respectively, in contrast with the other points which are determined by the means of from 11 to 40 exposures ; and that the most critical portion of the curve (that from January 15th, 1892, to January 13th, 1893) is determined by two points only, from 15 and 11 exposures on only 5 and 4 plates respectively. Moreover, for the reasons stated on page 160 of this paper, the testimony of the Pritchard measures, adduced by

* $[vv] = 2.691$; 2.390 and 1.681 on pages 109, 114 and 120 respectively, *Publicationen*, etc.

† *Sitzungsberichten*, etc., pages 884–5.

JACOBY* to corroborate WILSING, should be given no weight at the present time.

On the other hand, it is still an open question whether or not the parallaxes obtained from RUTHERFURD measures may not be affected by systematic errors, the nature and origin as well as existence of which are at present unknown. The case of *β Cygni*† as well as Mrs. Davis' deduction of a similarly large parallax from the measures‡ of "Bradley 3077" give room for this suspicion. It is for this reason that the confirmation of difference of parallax by WILSING's measures is all the more instructive.

46. It should be stated in this connection also, that even if such orbital motion exist, its amplitude is so greatly diminished by this difference of parallax of the two stars as to reduce the sum of the squares of the residuals formed in means for the 22 groups of WILSING's Table on page 885§ from 0.1708 to 0.1052 or by nearly forty per cent.

In the following Table, are reproduced, in column two, these twenty-two mean residuals‡ and in column three are given also the mean of the residuals for the same plates from the last column of Table XXI, whereby to facilitate their comparison as to the effect produced by the introduction of the parallax into the equations.

I have also made a second solution of these 110 equations on the assumption that there might be a term whose coëfficient is‖

$$\tan \zeta \cos (p - q)$$

to account for the unequal effect on the two stars of the atmospheric dispersion. The solution of the equations and the resulting residuals are not contradictory of WILSING's conclusions (from the similarity of the spectra of 61^1 and 61^2) that there is no reason for the introduction of this term. In column four are given, however, the means of the residuals resulting from this solution.

Monthly Notices, Vol. LIV, page 117. See also, *Vierteljahrsschrift*, for 1891, Vol. 26, p. 146.

† *Astronomical Journal*, No. 287: On the Probable Large Parallax of β Cygni, by Harold Jacoby.

‡ Contribution from the Observatory of Columbia University, New York, No. 14.

§ *Sitzungsberichten*, etc.

‖ *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, No 36, page 144.

¶ *Monthly Notices*, Vol. LV, page 123. But see also Vol. LVIII, page 83.

Table XXII.—Wilsing's Measures.

(See Paragraph 46.)

No. of Point on Curve.	Mean of Residuals.			Weight.		Mean Date.
	Wilsing.	With Parallax.	With Paral. and Atmos. Dispersion.	Plates.	Expos.	
1	+.″041	—.″066	—.″073	2	4	1890 Oct. 18
2	—.039	—.140	—.142	1	2	Nov. 5
3	+.001	—.047	—.084	1	2	Dec. 17
4	+.031	+.042	—.041	1	2	1891 Feb. 4
5	—.039	—.010	+.052	6	12	May 13
6	—.179	—.165	—.145	4	8	June 14
7	+.071	—.015	—.003	12	24	Aug. 25
8	+.031	—.063	—.047	12	24	Sept. 17
9	+.111	+.018	+.026	10	19	Oct. 13
10	+.131	+.077	+.066	8	16	Nov. 11
11	+.151	+.111	+.069	9	17	Dec. 17
12	+.091	+.088	+.018	7	14	1892 Jan. 15
13	—.009	+.032	+.043	5	15	May 16
14	+.011	+.030	+.038	4	11	June 15
15	—.009	+.007	—.061	6	40	1893 Jan. 13
16	—.159	—.080	—.043	3	19	Mar. 24
17	—.169	—.093	—.054	3	24	April 15
18	—.089	—.021	—.014	4	34	May 14
19	—.049	—.019	+.004	4	32	June 11
20	+.021	+.012	+.026	3	24	July 18
21	+.011	—.028	—.002	3	25	Aug. 15
22	+.031	—.026	—.022	2	18	Sept. 8

47. Several astronomers have investigated the parallax of these stars by measures with reference to the point mid-way between 61^1 and 61^2; others with reference to either star independently of the other. In Table XXIII are gathered many of the results of such investigations where the stars were individually observed. When the same measures have been reduced in several different ways or by different persons, that result which is regarded as definitive has been printed in heavy type, the lightface type being used in other cases. The numbers in the last column refer to the list of reference books given on pages 159–160.

TABLE XXIII.—VARIOUS VALUES OF PARALLAX OF 61^1 CYGNI.

Method.	Star of Comparison.	Parallax of 61^1 Cygni.	Probable error r	Authority.	Ref. No.
δ	Absolute	+0″.349	±0″.080	Peters	2
$\Delta\delta$	38°4351	.4654	.0497	Ball	8
$\Delta\delta$	38°4351	.400	.055	Ramb. Ball	15
a	Absolute (?)	.50	.094	Belopolsky	10
Δa		.21	.03	Flint	16
Photography	Ten Stars	.30	.031	Kapteyn	17
		Distance.			
Photography	37°4189	[+0″.4294]	±0″.0162	Pritchard	12
"	38°4336	[.4414]	.0222	Pritchard	12
"	37°4175	[.4448]	.0212	Pritchard	12
"	38°4348	[.4193]	.0182	Pritchard	12
Photography	38°4372—37°4159	.5211	.0373	Davis	13
"	38°4353—37°4159	.4497	.0429	Davis	13
"	38°4325—38°4362	.3733	.0400	Davis	13
"	38°4363—38°4325	.2431	.0409	Davis	13
"	37°4189—38°4336	.3888	.0658	Davis	13
Photography	37°4189	.405	.026	Wilsing	14
		Position Angle.			
Photography	37°4180	+0″.3028	±0″.0354	Davis	13
"	37°4175	.3779	.0395	Davis	13
"	37°4189	.2794	.0473	Davis	13
"	37°4185	.3299	.0557	Davis	13
"	37°4178	.3442	.0620	Davis	13
"	38°4341	.3334	.0743	Davis	13
"	38°4335	.4401	.0819	Davis	13

TABLE XXIII.—VARIOUS VALUES OF PARALLAX OF 61^2 CYGNI.

Method.	Star of Comparison.	Parallax of 61^2 Cygni.	Probable error r	Authority.	Ref. No.
$\Delta\delta$, Microm.	38°4351	+0″.4676	±0″.0321	Ball	9
"	38°4345	.2698	.0130	A. Hall	11
"	38°4345	.3217	.0213	A. Hall	11
"	$\Delta\alpha = -63^s.5$, $\Delta\delta = -34''$	.2005	.0246	A. Hall	11
$\Delta\alpha$	Absolute (?)	.55	.091	Belopolsky	10
Photography	Ten Stars.	.36	.034	Kapteyn	17
		Distance.			
Micrometer	38°4345	0″.5092	±0″.0355	O. Struve	3
"	"	.5179	.0328	Lamp's Struve	6
Micrometer	38°4345	.4365	.0738	Socoloff's Schweizer	5
"	"	.4885	.0824	Socoloff's Schweizer	5
"	"	.4388	.0654	Lamp's Socoloff's Schweizer	6
"	"	.5220	.0770	Lamp's Socoloff's Schweizer	6
"	"	.4594	.0637	Lamp's Schweizer	6
"	"	.4715	.0684	Lamp's Schweizer	6
Photography	37°4189	[.4250]	.0176	Pritchard	12
"	38°4336	[.4508]	.0191	Pritchard	12
"	37°4175	[.4320]	.0190	Pritchard	12
"	38°4348	[.4303]	.0178	Pritchard	12
Photography	61^1 *Cygni*	.288	.031	Davis	13
Photography	37°4189	.357	.017	Wilsing	14
		Position-Angle.			
Micrometer	38°4345	+0″.5008	±0″.0466	O. Struve	3
"	"	.4913	.0371	Lamp's Struve	6
Micrometer	38°4345	.3761	.0439	Socoloff's Schweizer	5
"	"	.4926	.0546	Socoloff's Schweizer	5
"	"	.3925	.0438	Lamp's Socoloff's Schweizer	6
"	"	.4957	.0512	Lamp's Socoloff's Schweizer	6
"	"	.3818	.0457	Lamp's Schweizer	6
"	"	.4824	.0517	Lamp's Schweizer	6

48. While there is some dependence of one result on another in those instances where the same star of comparison was used, yet, as the measures were made by independent observers and dissimilar methods, and show in themselves no indication of a parallax of the comparison-star, it is not improper to combine all these individual results into means by weights proportional to the reciprocal of the square of the probable error. Thus we have the mean of previous determinations of the

$$\text{Parallax of } 61^1 \text{ Cygni} = 0.''417 + 0''.0216$$

and, in like manner excluding my own determinations:

$$\text{Parallax of } 61^2 \text{ Cygni} = 0''.335 + 0''.0076$$

which give:

$$61^1 - 61^2 = +0.''082 \pm 0''.023 \quad [+0''.054 \pm 0''.010]$$

and if the Rutherfurd results be included as given in Table XXIII, this becomes:

$$61^1 - 61^2 = +0''.048 \pm 0''.014 \quad [+0''.035 \pm 0''.009]$$

The numbers placed in the brackets are what these values would have been had Pritchard's results not been discarded.

49. Let us now tabulate these differences of parallax of the two stars under consideration:

Davis' Rutherfurd,—direct measures of distance	+0''.128	+''.053	
Davis' Rutherfurd,—direct measures of angles	+ .051	.032	
Adopted Mean =		+ 0''.072	± ''.028
Davis' Wilsing,—direct measures of distance		+ .088	.012
Wilsing's $(61^1 - 6) - (61^2 - 6)$*		+ .048	.031
Mean of all determinations† previous to Rutherfurd =		+ .082	.013
Mean of all determinations including Rutherfurd =		+ .048	.014

The magnitude and accordance of these values when considered in connection with their respective probable errors leave little room for doubt as to the reality of the difference of parallax detected by the measures of the Rutherfurd plates, and discarding Pritchard's results in no respect lessens the force of the argument. So that if 61^1 *Cygni* be really a binary system of which

**Publicationen des Astrophysikalischen Observatoriums zu Potsdam*: Nr. 36. page 148.

†As determined from Table XXIII on pages 155–6, using only the values in bold type.

one member is a dark body* it is nevertheless far removed from the influence of 61² *Cygni*, which would account for the as yet unproved† orbital motion of *61*¹ and *61*² around a centre of gravity common to the two. The probabilities in favor of the existence of such orbital motion, if they really have the *same* parallax, are fully as strong as are those against the juxtaposition in line of sight of two stars having so nearly the same large apparent motion, if they are really separated in space by the distance which this *difference* of parallax indicates.

This presents to us therefore one of those cases where the exceedingly strong probability against an event happening is perhaps overruled by its actual occurrence.

The evidence here presented as to a difference of parallax is at any rate of sufficient weight to demand a more extended series of photographic measures of the same degree of precision as WILSING's and extending over more than two years. Perhaps Prof. Wilsing would himself be willing to continue his series of plates. It is also highly desirable to reinforce the evidence of a variable proper motion of *61*¹ by independent methods, such as is afforded by the spectroscope, for example.

* *Publications of the Lick Observatory*, Vol. II, 1894. Page 122. BURNHAM records his inability to see at 1889.463 and 1889.502 a companion to either star, though using the 36-inch telescope with powers up to 1000.

† *Monthly Notices*, Vol. XXXV, page 323. *Ast. Nach.*, Vol. 132, pages 87 and 199. BURNHAM in *The Sideral Messenger*, Vol. X, page 1, and MANN, *ibid.* page 13.

Reference Books.—(See Table XXIII.)

(1.) Bessel—Astronomische Nachrichten, No. 365–6, and Vol. XVII.

(2.) Peters—Recherches sur la Parallaxe des Étoiles Fixes. Recueil de Mémoires présentés à l' Académie des Sciences par les Astronomes de Poulkova. Vol. I, page 136.

(3.) Struve—Nouvelle Détermination de la Parallaxe annuelle des Étoiles *a* Lyræ et 61 Cygni. Memoires de l' Académie Impériale des Sciences de St.-Pétersbourg, VII Série. Vol. I, No. 1, page 44.

(4.) Auwers—Untersuchungen über die Beobachtungen von Bessel und Schlüter am Königsberger Heliometer zur Bestimmung der Parallaxe von 61 Cygni. Abhandlungen der Academie zu Berlin, 1868: page 113.

(5.) Socoloff—Parallaxes des Étoiles observées par G. Schweizer. Annales de l' Observatoire de Moscou, Vol. VIII, 2, pages 89–90.

(6.) Lamp—Neue Berechnung der Parallaxe von 61 Cygni aus den Beobachtungen von Schweizer in Moskau 1863–1866, Kiel, 1883, pages 52–9.

(7.) Johnson—Introduction to the Observations with the Heliometer. Part II of Astronomical Observations made at the Radcliffe Observatory in the year 1853. Vol. XIV, page xxxix.

(8.) Ball—On a new Determination of the Parallax of the Preceding Star of 61 Cygni by the Method of Differences of Declination. Astronomical Observations and Researches made at Dunsink. Part III, page 27.

(9.) Ball—Further Researches on the Parallax of 61 Cygni. Astronomical Observations and Researches made at Dunsink. Part V, page 166.

(10.) Belopolsky—Astronomische Nachrichten, No. 2888.

These values of parallax are computed from discordances in right ascension between observations made six months apart on the transit instrument by Wagner at Poulkova in 1862–1870.

(11.) Hall—Observations for Stellar Parallax. Washington Observations for 1883, Appendix II, pages 54 and 67.

(12.) PRITCHARD—Researches in Stellar Parallax by the aid of Photography, from Observations made at the Oxford University Observatory, Oxford, 1889.

In the formation of Table XXIII, giving the various values of the parallax of 61 *Cygni* hitherto published, I have not placed Pritchard's values in bold type, because they cannot be regarded as trustworthy. They have been discarded in taking the means of the determinations for 61^1 and 61^2. I have examined the eight sets of normal equations given in the work on 61 *Cygni* (pages 17–63) and among the eight sets have not found one which is correct in every quantity. The set on page 30 first attracted my attention and so it may be used for illustration. As given there the quantities are:

$$\begin{aligned} -\ 1''.3140 &= +\ 88.0000\,x - 6.7889\,d\mu - 2.5442\,\pi \\ +\ 4\ .3827 &= -\ 6.7889 \quad + 8.4762 \quad + 9.7965 \\ +17\ .1716 &= -\ 2.5442 \quad + 9.7965 \quad +38.7724 \end{aligned}$$

These should be:

$$\begin{aligned} -\ 1''.2180 &= +\ 88.0000\,x - 6.7889\,d\mu - 0.9281\,\pi \\ +\ 4\ .3853 &= -\ 6.7889 \quad + 8.4783 \quad + 9.7854 \\ +17\ .1967 &= -\ 0.9281 \quad + 9.7854 \quad +38.7849 \end{aligned}$$

This criticism applies not only to the normals for 61 *Cygni* but for many of the other stars as well. No attempt has been made to verify all the numbers in each set of normals, nor indeed to extend the test to all sets of normals given in the book, but it can be stated that at least one number is wrong in each of the fourteen sets given on pages 17, 23, 30, 36, 47, 52, 58, 73, 75, 87, 104, 106, 107 and 113.

(13.) DAVIS—Contributions from the Observatory of Columbia University, New York, No. 13.

(14.) WILSING—Untersuchungen über die Parallaxe und die Eigenbewegung von 61 Cygni nach Photographischen Aufnahmen. Publicationen des Astrophysikalischen Observatoriums zu Potsdam, No. 36, pages 152 and 148.

(15.) RAMBAUT—On the Effects of Atmospheric Dispersion on the Position of a Star. Monthly Notices, Vol. LV, page 123.

(16.) FLINT—Research Work at the Washburn Observatory. The Astrophysical Journal, Vol. VI, page 420.

A preliminary announcement of results now in process of computation.

(17.) KAPTEYN—Bestimmung von 250 Parallaxen. Astronomische Nachrichten, Bd. 145, S. 300.

V.—*The Rutherfurd Photographic Measures of Thirty-four Stars near "Bradley 3077."*

BY HERMAN S. DAVIS.

Read May, 1897.

1. The methods of reduction employed in the formation of this catalogue are the same as have been described in my paper on *Sixty-five Stars near 61 Cygni*, except that no corrections for parallax were applied. The computations have been almost entirely performed by Mrs. Davis, who has also rendered considerable assistance in the computations connected with all my other papers on the *Rutherfurd Measures*.

In this presentation of results the Tables have been given numbers to correspond with the similar tables in the paper on *61 Cygni*, reference to which will make clear any matter not sufficiently intelligible from the captions to the various columns.

2. Nearly the mean date of observation, 1874.0, was selected as the epoch to which the observations were reduced. Thus we have:

$$\Delta p_{73} = -8'' + [0.919]\,A + [0.246_n]\,B + [0.167_n]\,C + [9.537]\,D$$
$$\Delta p_{74} = \quad 0 \quad + [0.919]\,A + [0.246_n]\,B + [0.167_n]\,C + [9.537]\,D$$

as the correction for precession, nutation and aberration in position-angle; and, for all years, to correct for aberration in distance:

$$\Delta s = \{[4.058]C + [4.416_n]D\}s$$

3. The logarithms of the Besselian day-numbers, taken from the *American Ephemeris*, are:

Plates.	log A.	log B.	log C.	log D.
1, 2, 3,	9.786	0.808_n	1.053	1.213
4, 5, 6,	9.805	0.801_n	0.958	1.253
7, 8,	9.336	0.857_n	0.776_n	1.287_n
9, 10,	9.411	0.854_n	0.418_n	1.306_n
11, 12.	9.417	0.854_n	0.364_n	1.307_n

4. ARGELANDER'S position and proper motion of this star as given in *Mittlere Positionen von 160 Sternen* have been adopted. For 1874.0 they are:

$$\alpha = 23^h\ 07^m\ 13^s.356 \qquad \mu = +0^s.24867$$
$$\delta = 56^\circ\ 28'\ 21''.95 \qquad \mu' = +0''.2685$$

From these are derived:

$$\rho = 2''.07765 = 0^d.07416 \qquad \chi = 82^\circ\ 34'\ 29''$$

The values of P_1, P_2, P_5, and K, depending hereon, are in Table VII on page 184; and S_1, S_5, S_6, and S_7, are in Table VIII.

5. For determining the correction for scale-variation, stars numbered 3, 9, 19, 20, 31 and 33 have been used. These are so distributed that

$$\Sigma s_s = 428^d.6222, \quad \Sigma \cos p = -0.01, \quad \text{and } \Sigma \sin p = -0.10$$

Therefore the

$$\text{Scale variation} = \frac{\Sigma s_s - (s_3 + s_9 + s_{19} + s_{20} + s_{31} + s_{33})}{\Sigma s_s} s.$$

This factor of s will be found on page 184.

6. The correction for orientation variation on page 184 has been deduced in the same manner as described in paragraphs 19–21 of the paper on *61 Cygni*, except that Mrs. Davis has reduced the orientation to the mean of all the plates excluding that numbered six, regarding for very obvious reasons the mean of the remaining eleven as nearer the truth than the mean of the entire twelve. Thus the corrections actually applied reduces the orientation to the mean of the remaining eleven plates. The nine stars whose numbers are 8, 9, 10, 11, 14, 16, 17, 20 and 33 after correction for proper motion have been used as standards. They give:

$$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = +6.0 \quad \text{and} \quad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = -2.3$$

7. For calculating the difference of right ascension and of declination the following constants have been used:

$$\log P = 0.257799 \qquad \log R = 9.5094_n \qquad \log T = 4.5633_n$$
$$\log Q = 5.1221 \qquad \log S = 0.0458 \qquad \log U = 9.4870_n$$

Also, by paragraph 24 of *Catalogue of Sixty-five Stars near 61 Cygni*.

$$n = \sigma \sin \pi$$
$$m = \sigma \cos \pi$$
$$\alpha' - \alpha = Pn + Qnm + Rn^3 + Snm^2$$
$$\delta' - \delta = m + Tn^2 + Un^2m$$

TABLE I.—GENERAL DATA.—Observatory of L. M. Rutherfurd, New York.

Lat. = 40° 43′ 48″.5 Long. = $4^h 55^m 56^s.62$ W

Plate.	Date.	Sidereal Time.	Hour Angle.	Barom.	Att. Therm.	Ext. Therm.	Tel. Therm.	Focus.	Zero.	ζ	q	log κ
		h m s	h m s		°	°	°			°	°	
1	1873 Nov. 14	1 54 3	2 46 53	30.132	29	28	30	8.0	58.60	31.09	+102.42	6 4709
2	Nov. 14	2 28 3	3 20 53	30.132	29	28	30	8.0	63.73	35.73	+ 94.30	6.4707
3	Nov. 14	3 4 3	3 56 53	30.132	29	28	30	8.0	59.19	40.70	+ 86.73	6.4704
4	Nov. 22	2 45 33	3 38 23	30.418	36	35	36	7.8	54.68	38.16	+ 90.51	6.4682
5	Nov. 22	3 18 23	4 11 13	30.418	36	35	36	7.8	58.90	42.67	+ 83.92	6.4679
6	Nov. 22	3 50 43	4 43 33	30.418	36	35	36	7.8	40.86	47.08	+ 77.89	6.4676
7	1874 June 1	19 7 7	19 59 54	29.984	60	55	60	7.7	54.11	41.15	— 86.09	6.4437
8	June 1	19 44 23	20 37 10	29.984	60	55	60	7.7	54.73	36.00	— 93.86	6.4440
9	June 12	18 27 27	19 20 14	29.950	71	69	70	7.64	54.15	46.57	— 78.58	6.4305
10	June 12	19 0 17	19 53 4	29.950	71	69	70	7.64	48.89	42.09	— 84.75	6.4312
11	June 13	18 59 43	19 52 30	30.300	59	57	60	7.7	54.21	42.16	— 84.64	6.4466
12	June 13	19 33 33	20 26 20	30.300	59	57	60	7.7	54.35	37.50	— 91.51	6.4469

Table II.—Corrections for Refraction.

Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
Plate 1.				Plate 2.			
			″				″
102°	282°	+.410	0.0	94°	274°	+.456	0.0
112	292	.406	− 3.9	104	284	.451	− 5.5
122	302	.397	− 7.2	114	294	.438	−10.4
132	312	.383	− 9.7	124	304	.417	−13.9
142	322	.365	−11.1	134	314	.392	−15.8
152	332	.345	−11.1	144	324	.365	−15.8
162	342	.328	− 9.7	154	334	.339	−13.9
172	352	.314	− 7.2	164	344	.319	−10.4
182	2	.304	− 3.9	174	354	.306	− 5.5
192	12	.301	0.0	184	4	.301	0.0
202	22	.304	+ 3.9	194	14	.306	+ 5.5
212	32	.314	+ 7.2	204	24	.319	+10.4
222	42	.328	+ 9.7	214	34	.339	+13.9
232	52	.345	+11.1	224	44	.365	+15.8
242	62	.365	+11.1	234	54	.392	+15.8
252	72	.383	+ 9.7	244	64	.417	+13.9
262	82	.397	+ 7.2	254	74	.438	+10.4
272	92	.406	+ 3.9	264	84	.451	+ 5.5
282	102	.410	0.0	274	94	.456	0.0
Plate 3.				Plate 4.			
			′				″
87°	267°	+.521	0.0	91°	271°	+.483	0.0
97	277	.515	− 7.8	101	281	.477	− 6.5
107	287	.496	−14.7	111	291	.462	−12.2
117	297	.466	−19.8	121	301	.437	−16.4
127	307	.430	−22.5	131	311	.407	−18.7
137	317	.391	−22.5	141	321	.375	−18.7
147	327	.355	−19.8	151	331	.344	−16.4
157	337	.326	−14.7	161	341	.320	−12.2
167	347	.306	− 7.8	171	351	.305	− 6.5
177	357	.300	0.0	181	1	.299	0.0
187	7	.306	+ 7.8	191	11	.305	+ 6.5
197	17	.326	+14.7	201	21	.320	+12.2
207	27	.355	+19.8	211	31	.344	+16.4
217	37	.391	+22.5	221	41	.375	+18.7
227	47	.430	+22.5	231	51	.407	+18.7
237	57	.466	+19.8	241	61	.437	+16.4
247	67	.496	+14.7	251	71	.462	+12.2
257	77	.515	+ 7.8	261	81	.477	+ 6.5
267	87	.521	0.0	271	91	.483	0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$	Position Angle, p		$\frac{\sigma - s}{s} \times 10^3$	$\pi - p$
PLATE 5.				PLATE 6.			
84°	264°	+.552	″ 0.0	78°	258°	+.644	″ 0.0
94	274	.544	— 8.9	88	268	.634	—12.2
104	284	.523	—16.8	98	278	.603	—22.8
114	294	.489	—22.6	108	288	.557	—30.8
124	304	.448	—25.7	118	298	.502	—35.0
134	314	.403	—25.7	128	308	.441	—35.0
144	324	.361	—22.6	138	318	.385	—30.8
154	334	.328	—16.8	148	328	.339	—22.8
164	344	.307	— 8.9	158	338	.309	—12.2
174	354	.299	0.0	168	348	.299	0.0
184	4	.307	+ 8.9	178	358	.309	+12.2
194	14	.328	+16.8	188	8	.339	+22.8
204	24	.361	+22.6	198	18	.385	+30.8
214	34	.403	+25.7	208	28	.441	+35.0
224	44	.448	+25.7	218	38	.502	+35.0
234	54	.489	+22.6	228	48	.557	+30.8
244	64	.523	+16.8	238	58	.603	+22.8
254	74	.544	+ 8.9	248	68	.634	+12.2
264	84	.552	0.0	258	78	.644	0.0
PLATE 7.				PLATE 8.			
274°	94°	+.498	″ 0.0	266°	86°	+.432	″ 0.0
284	104	.491	— 7.6	276	96	.427	— 5.3
294	114	.473	—14.3	286	106	.414	— 9.8
304	124	.444	—19.3	296	116	.394	—13.3
314	134	.409	—21.9	306	126	.370	—15.1
324	144	.372	—21.9	316	136	.344	—15.1
334	154	.336	—19.3	326	146	.320	—13.3
344	164	.308	—14.3	336	156	.300	— 9.8
354	174	.288	— 7.6	346	166	.286	— 5.3
4	184	.282	0.0	356	176	.282	0.0
14	194	.288	+ 7.6	6	186	.286	+ 5.3
24	204	.308	+14.3	16	196	.300	+ 9.8
34	214	.336	+19.3	26	206	.320	+13.3
44	224	.372	+21.9	36	216	.344	+15.1
54	234	.409	+21.9	46	226	.370	+15.1
64	244	.444	+19.3	56	236	.394	+13.3
74	254	.473	+14.3	66	246	.414	+ 9.8
84	264	.491	+ 7.6	76	256	.427	+ 5.3
94	274	.498	0.0	86	266	.432	0.0

TABLE II.—CORRECTIONS FOR REFRACTION. (*Concluded.*)

Position Angle, p		$\frac{\sigma-s}{s} \times 10^3$	$\pi-p$	Position Angle, p		$\frac{\sigma-s}{s} \times 10^3$	$\pi-p$
PLATE 9.				PLATE 10.			
			"				"
281°	101°	+.580	0.0	275°	95°	+.498	0.0
291	111	.571	—10.8	285	105	.491	— 7.9
301	121	.544	—20.2	295	115	.471	—14.8
311	131	.504	—27.2	305	125	.442	—20.0
321	141	.454	—31.0	315	135	.405	—22.7
331	151	.400	—31.0	325	145	.367	—22.7
341	161	.350	—27.2	335	155	.330	—20.0
351	171	.310	—20.2	345	165	.301	—14.8
1	181	.283	—10.8	355	175	.280	— 7.9
11	191	.274	0.0	5	185	.274	0.0
21	201	.283	+10.8	15	195	.280	+ 7.9
31	211	.310	+20.2	25	205	.301	+14.8
41	221	.350	+27.2	35	215	.330	+20.0
51	231	.400	+31.0	45	225	.367	+22.7
61	241	.454	+31.0	55	235	.405	+22.7
71	251	.504	+27.2	65	245	.442	+20.0
81	261	.544	+20.2	75	255	.471	+14.8
91	271	.571	+10.8	85	265	.491	+ 7.9
101	281	.580	0.0	95	275	.498	0.0
PLATE 11.				PLATE 12.			
			"				"
275°	95°	+.518	0.0	268°	88°	+.452	0.0
285	105	.511	— 8.2	278	98	.447	— 5.9
295	115	.490	—15.4	288	108	.432	—11.1
305	125	.459	—20.7	298	118	.409	—14.9
315	135	.421	—23.6	308	128	.383	—17.0
325	145	.381	—23.6	318	138	.353	—17.0
335	155	.342	—20.7	328	148	.326	—14.9
345	165	.312	—15.4	338	158	.304	—11.1
355	175	.291	— 8.2	348	168	.289	— 5.9
5	185	.284	0.0	358	178	.284	0.0
15	195	.291	+ 8.2	8	188	.289	+ 5.9
25	205	.312	+15.4	18	198	.304	+11.1
35	215	.342	+20.7	28	208	.326	+14.9
45	225	.381	+23.6	38	218	.353	+17.0
55	235	.421	+23.6	48	228	.383	+17.0
65	245	.459	+20.7	58	238	.409	+14.9
75	255	.490	+15.4	68	248	.432	+11.1
85	265	.511	+ 8.2	78	258	.447	+ 5.9
95	275	.518	0.0	88	268	.452	0.0

Table III.—Corrections for Precession, etc., to 1874 and Zero Corrections.

Plate No.	Precession, etc.		Zero Correction ½(East + West)	Special Correction Mean.	Adopted Mean.
	Position Angle Correction.	Distance Factor × 10³			
	″		′ ″	″	′ ″
1	− 2.9	−.0297	+20 31	−35	+19 56
2	− 2.9	−.0297	22 23	−38	21 45
3	− 2.9	−.0297	20 50	−31	20 19
4	+ 1.0	−.0363	19 16	−54	18 22
5	+ 1.0	−.0363	20 52	−44	20 8
6	+ 1.0	−.0363	14 39	−35	14 4
7	+16.6	+.0437	19 18	−41	18 37
8	+16.6	+.0437	19 36	−42	18 54
9	+11.5	+.0497	19 5	−52	18 13
10	+11.5	+.0497	17 22	−52	16 30
11	+11.2	+.0502	19 14	−36	18 38
12	+11.2	+.0502	+19 21	−41	+18 40

Table IV.—Tangent Correction.

This correction is always *negative*, and is here expressed in terms of the *fourth* decimal place of the micrometer readings.

Distance.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
20.	− 0	− 0	− 0	− 0	− 0	− 1	− 1	− 1	− 1	− 1
30.	2	2	2	2	2	3	3	3	3	3
40.	4	4	4	5	5	6	6	6	7	7
50.	8	8	8	9	9	10	10	11	11	12
60.	13	13	14	15	16	17	17	18	19	20
70.	21	22	23	24	25	26	27	28	30	31
80.	32	34	35	36	37	38	40	41	42	43
90.	45	46	48	50	52	53	55	57	59	61
100.	62	64	65	67	69	71	73	75	77	79
110.	81	83	85	87	90	93	95	98	100	103
120.	106	109	112	114	117	120	123	126	129	132
130.	−135	−138	−141	−145	−148	−151	−155	−158	−162	−165

TABLE V.—RESULTS OF MEASURES OF DISTANCE.

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s			σ
1	11	.9218	.9090	625	+62	80	.9802	− 46	−.0334	123.9422
(2)	12	.8604	.9280	557	+62	94	.9536	− 52	−.0334	.9150
						Mean				123.9286
2	1	.0565	.0314	426	−35	118	.0851	− 11	+.0088	117.0928
(5)	2	.0288	.0212	480	−35	118	.0715	+ 31	+.0088	.0834
	4	.0233	.0122	512	−42	108	.0658	+135	+.0073	.0866
	5	.0191	.0307	603	−35	112	.0831	+ 21	+.0073	.0925
	7	.0681	.0718	508	+51	118	.1278	− 8	−.0290	.0980
	8	.0672	.0506	473	+51	118	.1134	+ 8	−.0290	.0852
	11	.0588	.0687	518	+59	118	.1234	− 44	−.0312	.0878
	12	.0788	.0600	490	+59	118	.1263	− 49	−.0312	.0902
						Mean				117.0896
3	1	.8405	.8320	308	−23	126	.8747	− 7	+.0092	75.8832
(37)	2	.8343	.8318	345	−23	126	.8751	+ 20	+.0092	.8863
	3	.8370	.8265	393	−23	126	.8787	+ 3	+.0092	.8882
	4	.8290	.8253	365	−28	119	.8700	+ 87	+.0077	.8864
	5	.8246	.8268	414	−28	120	.8736	+ 14	+.0077	.8827
	6	.8246	.8302	470	−28	126	.8815	− 39	+.0077	.8853
	7	.8677	.8751	377	+33	125	.9222	− 5	−.0305	.8912
	8	.8702	.8771	326	+33	125	.9193	+ 5	−.0305	.8893
	9	.8731	.8745	434	+38	118	.9301	− 30	−.0327	.8944
	10	.8802	.86[illegible]8	376	+38	119	.9221	+ 11	−.0327	.8905
	11	.8722	.8724	392	+38	126	.9251	− 28	−.0329	.8894
	12	.8680	.8923	342	+38	120	.9275	− 32	−.0329	.8914
						Mean				75.8882
4	1	.6812	.6768	297	−24	125	.7156	− 8	+.0090	79.7238
(4)	2	.6670	.6668	336	−24	126	.7075	+ 21	+.0090	.7186
	3	.6482	.6546	393	−24	125	.6976	+ 3	+.0090	.7069
	4	.6526	.6361	357	−29	122	.6861	+ 92	+.0075	.7028
	5	.6528	.6540	421	−29	121	.7015	+ 15	+.0075	.7105
	6	.6520	.6515	500	−29	125	.7082	− 41	+.0075	.7116
	7	.7078	.7126	359	+35	126	.7590	− 5	−.0297	.7288
	8	.7097	.7233	330	+35	126	.7624	+ 5	−.0297	.7332
	9	.7018	.7226	382	+40	122	.7634	− 31	−.0319	.7284
	10	.7171	.7008	355	+40	122	.7575	+ 12	−.0319	.7268
	11	.7009	.7205	368	+40	126	.7609	− 30	−.0321	.7258
	12	.7038	.7110	340	+48	126	.7548	− 34	−.0321	.7193
						Mean				79.7197
5	1	.4787	.5182	383	−36	112	.5337	− 12	+.0062	120.5387
(7)	2	.4734	.4791	408	−36	108	.5136	+ 32	+.0062	.5230
	4	.4728	.4666	425	−44	108	.5079	+139	+.0052	.5270
	7	.5138	.5006	406	+53	109	.5533	− 8	−.0206	.5319
	9	.5070	.5259	389	+60	109	.5615	− 47	−.0220	.5348
						Mean				120.5311

TABLE VI.—RESULTS OF MEASURES OF ANGLE.

Plate	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
11	351 38 20	39 25	18 38	+10	261 57 41	— 0 2	261 57 53
12	40 50	41 45	18 40	+ 4	262 0 2	— 0 2	57 22
				Mean	261 58 52		261 57 38
1	331 22 50	23 32	19 56	+11	241 43 18	+ 0 6	241 43 58
2	19 8	21 30	21 45	+15	42 20	+ 0 6	43 33
4	24 22	25 7	18 22	+16	43 22	+ 0 5	43 56
5	21 45	23 11	20 8	+17	42 53	+ 0 5	44 1
7	23 43	25 45	18 37	+20	43 41	— 0 21	44 23
8	24 50	27 3	18 54	+12	45 3	— 0 21	44 23
11	24 58	25 45	18 38	+22	44 22	— 0 22	44 14
12	27 10	28 17	18 40	+13	46 37	— 0 22	43 37
				Mean	241 43 57		241 44 1
1	2 29 48	31 34	19 56	+ 4	272 50 41	— 0 4	272 51 11
2	27 40	28 38	21 45	+ 2	49 56	— 0 4	50 59
3	31 3	32 6	20 19	— 4	51 50	— 0 4	51 25
4	31 57	34 8	18 22	— 2	51 22	— 0 4	51 47
5	30 6	30 50	20 8	— 6	50 30	— 0 4	51 29
6	30 12	31 32	14 4	—17	44 39	— 0 4	51 42
7	30 26	31 32	18 37	+ 2	49 38	+ 0 14	50 55
8	31 48	33 13	18 54	— 3	51 22	+ 0 14	51 17
9	33 15	33 48	18 13	+ 9	51 54	+ 0 15	51 13
10	33 42	35 27	16 30	+ 2	51 6	+ 0 15	51 6
11	31 26	32 34	18 38	+ 2	50 40	+ 0 15	51 9
12	34 28	34 54	18 40	— 3	53 18	+ 0 15	50 55
				Mean	272 50 35		272 51 16
1	335 57 10	57 27	19 56	+10	246 17 24	+ 0 7	246 18 5
2	54 33	55 42	21 45	+13	17 5	+ 0 7	18 19
3	57 25	58 13	20 19	+16	18 24	+ 0 7	18 10
4	58 8	00 0	18 22	+17	17 43	+ 0 6	18 18
5	56 1	57 2	20 8	+15	16 55	+ 0 6	18 4
6	56 45	58 5	14 4	+14	11 43	+ 0 6	18 56
7	57 48	59 20	18 37	+18	17 29	— 0 24	18 8
8	59 23	00 38	18 54	+10	19 5	— 0 24	18 22
9	336 00 2	1 50	18 13	+29	19 38	— 0 26	18 16
10	1 38	2 42	16 30	+19	18 59	— 0 26	18 18
11	335 58 39	59 45	18 38	+20	18 10	— 0 26	17 58
12	336 1 27	3 8	18 40	+12	21 10	— 0 26	18 6
				Mean	246 17 49		246 18 15
1	303 48 8	49 33	19 56	+ 8	214 8 54	+ 0 12	214 9 40
2	45 14	46 12	21 45	+14	7 41	+ 0 12	9 0
4	48 57	51 5	18 22	+17	8 40	+ 0 10	9 19
7	49 6	50 40	18 37	+19	8 49	— 0 41	9 11
9	51 40	54 10	18 13	+22	11 30	— 0 44	9 50
				Mean	214 9 7		214 9 24

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s			σ
6	1	.6300	.6668	206	—18	108	.6767	— 6	+.0079	60.6840
(6)	7	.6482	.6756	237	+27	104	.6974	— 4	—.0260	.6710
	8	.6311	.6802	229	+27	104	.6903	+ 4	—.0260	.6647
	11	.6501	.6848	242	+30	104	.7037	— 23	—.0280	.6734
	12	.6314	.7006	234	+30	104	.7015	— 26	—.0280	.6709
						Mean				60.6728
7	1	.4126	.4174	280	—27	132	.4491	— 9	+.0058	89.4540
(8)	2	.4182	.4170	297	—27	132	.4534	+ 24	+.0058	.4616
	3	.4091	.4190	329	—27	135	.4533	+ 3	+.0058	.4594
	4	.4038	.3977	307	—32	132	.4371	+103	+.0049	.4523
	7	.4462	.4322	292	+39	135	.4814	— 6	—.0193	.4615
	9	.4520	.4428	276	+44	132	.4882	— 35	—.0207	.4640
	11	.4362	.4448	291	+45	135	.4832	— 33	—.0208	.4591
	12	.4324	.4485	297	+45	135	.4838	— 38	—.0208	.4592
						Mean				89.4589
8	1	.4792	.4746	226	—17	98	.5063	— 6	+.0063	58.5120
(36)	2	.4758	.4712	235	—17	96	.5037	+ 16	+.0063	.5116
	3	.4737	.4681	245	—17	98	.5023	+ 2	+.0063	.5088
	4	.4762	.4686	240	—21	92	.5023	+ 67	+.0052	.5142
	5	.4792	.4766	246	—21	95	.5087	+ 11	+.0052	.5150
	6	.4765	.4783	253	—21	98	.5092	— 30	+.0052	.5114
	7	.4964	.4917	249	+26	95	.5298	— 4	—.0208	.5086
	8	.5143	.5112	209	+26	95	.5446	+ 4	—.0208	.5242
	9	.4998	.5047	297	+29	94	.5430	— 23	—.0223	.5184
	10	.5128	.5015	248	+29	90	.5427	+ 8	—.0223	.5212
	11	.4968	.5012	257	+29	95	.5359	— 22	—.0224	.5113
	12	.4998	.4960	221	+29	95	.5312	— 25	—.0224	.5063
						Mean				58.5136
9	1	.6254	.6327	120	— 9	—12	.6387	— 3	+.0093	29.6477
(1)	2	.6082	.6068	134	— 9	— 9	.6189	+ 8	+.0093	.6290
	3	.6143	.6124	154	— 9	—12	.6264	+ 1	+.0093	.6358
	4	.6158	.5907	143	—11	—16	.6147	+ 34	+.0077	.6258
	5	.6198	.6114	162	—11	—13	.6292	+ 5	+.0077	.6374
	6	.5928	.6051	185	—11	—12	.6149	— 15	+.0077	.6211
	7	.6592	.6639	147	+13	— 9	.6764	— 2	—.0307	.6455
	8	.6626	.6476	128	+13	— 9	.6681	+ 2	—.0307	.6376
	9	.6701	.6652	169	+15	—15	.6844	— 12	—.0329	.6503
	10	.6486	.6434	147	+15	—16	.6604	+ 4	—.0329	.6279
	11	.6690	.6858	153	+15	— 9	.6931	— 11	—.0331	.6589
	12	.6680	.6870	134	+15	—13	.6909	— 13	—.0331	.6565
						Mean				29 6394

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle π
1	319° 8′ 16″	10′ 5″	19′ 56″	+11″	229° 29′ 17″	+ 0′ 18″	229° 30′ 9″
7	11 20	12 14	18 37	+22	30 46	— 0 59	30 50
8	11 21	13 29	18 54	+14	31 33	— 0 59	30 15
11	11 43	12 58	18 38	+24	31 23	— 1 3	30 34
12	12 53	15 58	18 40	+16	33 22	— 1 3	29 41
				Mean	229 31 16		229 30 18
1	300 40 20	41 54	19 56	+ 6	211 1 9	+ 0 17	211 2 0
2	38 36	38 53	21 45	+12	0 42	+ 0 17	2 6
3	41 35	41 28	20 19	+21	2 12	+ 0 17	2 8
4	41 25	43 31	18 22	+16	1 6	+ 0 14	1 49
7	43 42	44 35	18 37	+18	3 3	— 0 57	3 9
9	45 50	46 45	18 13	+19	4 49	— 1 1	2 52
11	43 47	44 37	18 38	+18	3 8	— 1 2	2 20
12	46 12	47 45	18 40	+15	5 53	— 1 2	2 13
				Mean	211 2 45		211 2 20
1	39 59 28	00 26	19 56	— 9	310 19 45	— 0 24	310 19 55
2	56 38	57 52	21 45	—15	18 45	— 0 24	19 28
3	40 0 35	2 8	20 19	—23	21 18	— 0 24	20 33
4	1 48	3 2	18 22	—18	20 29	— 0 20	20 38
5	39 59 44	59 48	20 8	—26	19 28	— 0 20	20 11
6	59 30	00 51	14 4	—34	13 41	— 0 20	20 28
7	58 3	59 55	18 37	—20	17 16	+ 1 20	19 39
8	59 12	59 50	18 54	—15	18 10	+ 1 20	19 11
9	40 1 2	1 44	18 13	—27	19 9	+ 1 25	19 38
10	1 30	3 46	16 30	—21	18 47	+ 1 25	19 57
11	39 59 5	59 40	18 38	—22	17 38	+ 1 26	19 18
12	40 1 25	2 50	18 40	—17	20 31	+ 1 26	19 19
				Mean	310 18 45		310 19 51
1	0 27 0	25 25	19 56	+ 5	270 46 13	— 0 9	270 46 38
2	24 22	25 12	21 45	+ 3	46 35	— 0 9	47 33
3	28 12	27 34	20 19	— 3	48 8	— 0 9	47 38
4	27 45	27 18	18 22	+ 1	45 55	— 0 7	46 17
5	27 47	24 28	20 8	— 5	46 11	— 0 7	47 7
6	26 40	27 42	14 4	—15	41 0	— 0 7	48 0
7	28 26	28 50	18 37	+ 3	47 18	+ 0 29	48 50
8	28 2	31 00	18 54	— 3	48 22	+ 0 29	48 32
9	30 8	32 55	18 13	+12	49 57	+ 0 32	49 33
10	29 28	32 32	16 30	+ 4	47 34	+ 0 32	47 51
11	27 57	27 23	18 38	+ 4	46 22	+ 0 32	47 8
12	30 48	31 5	18 40	— 2	49 35	+ 0 32	47 29
				Mean	270 46 56		270 47 43

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean. s	Scale Variation.	Proper Motion.	Final Corrected Distance. σ
10	1	.5694	.5805	71	− 6	82	.5897	− 2	+.0092	18.5987
(3)	2	.5719	.5707	80	− 6	82	.5869	+ 5	+.0092	.5966
	3	.5654	.5760	93	− 6	82	.5876	+ 1	+.0092	.5969
	4	.5708	.5648	86	− 7	80	.5837	+ 21	+.0076	.5934
	5	.5722	.5796	100	− 7	79	.5931	+ 3	+.0076	.6010
	6	.5602	.5624	118	− 7	82	.5806	− 9	+.0076	.5873
	7	.6199	.6315	86	+ 8	84	.6435	− 1	−.0303	.6131
	8	.6193	.6273	78	+ 8	83	.6402	+ 1	−.0303	.6100
	9	.6193	.6354	93	+ 9	80	.6455	− 7	−.0325	.6123
	10	.6271	.6077	85	+ 9	80	.6348	+ 3	−.0325	.6026
	11	.6221	.6370	88	+ 9	83	.6476	− 7	−.0327	.6142
	12	.6156	.6302	81	+ 9	79	.6397	− 8	−.0327	.6062
						Mean				18.6027
11	1	.8040	.8069	321	−31	114	.8386	− 10	+.0022	105.8398
(13)	2	.7998	.7846	320	−31	113	.8251	+ 28	+.0022	.8301
	3	.8079	.7994	323	−31	114	.8369	+ 4	+.0022	.8395
	4	.7984	.7982	319	−38	113	.8304	+122	+.0018	.8444
	5	.7858	.8043	329	−38	114	.8283	+ 19	+.0018	.8320
	6	.8105	.7979	351	−38	114	.8396	− 54	+.0018	.8360
	7	.8096	.8005	300	+46	111	.8434	− 7	−.0072	.8355
	8	.8069	.7925	302	+46	111	.8383	+ 7	−.0072	.8318
	9	.8170	.8218	295	+53	115	.8584	− 41	−.0077	.8466
	10	.8217	.7905	292	+53	113	.8446	+ 15	−.0077	.8384
	11	.8097	.8067	302	+53	114	.8478	− 39	−.0077	.8362
	12	.8047	.7993	304	+53	114	.8418	− 45	−.0077	.8296
						Mean				105.8366
12	3	.0888	.0700	43	− 4	48	.0881	0	+.0053	12.0934
(9)	6	.0682	.0690	52	− 4	48	.0782	− 6	+.0044	.0820
	7	.0909	.1093	38	+ 5	48	.1092	− 1	−.0176	.0916
	11	.1478	.1806	39	+ 6	48	.1735	− 5	−.0190	.1540
						Mean				12.1052
13	1	.0319	.0384	73	− 7	112	.0529	− 2	+.0024	24.0551
(10)	2	.0380	.0307	72	− 7	111	.0518	+ 6	+.0024	.0584
	3	.0364	.0349	73	− 7	112	.0533	+ 1	+.0024	.0558
	4	.0286	.0345	72	− 9	111	.0489	+ 28	+.0020	.0537
	5	.0258	.0495	75	− 9	112	.0554	+ 4	+.0020	.0578
	6	.0384	.0380	80	− 9	112	.0564	− 12	+.0020	.0572
	7	.0418	.0258	68	+11	111	.0527	− 2	−.0078	.0447
	8	.0542	.0408	69	+11	111	.0665	+ 2	−.0078	.0589
	9	.0473	.0495	67	+12	111	.0673	− 9	−.0084	.0580
	10	.0457	.0405	66	+12	111	.0621	+ 3	−.0084	.0540
	11	.0405	.0475	69	+12	112	.0632	− 9	−.0085	.0538
	12	.0508	.0479	69	+12	110	.0684	− 10	−.0085	.0589
						Mean				24.0552

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	340 10 45	9 22	19 56	+10	250 30 9	+ 0 22	250 31 5
2	6 59	7 55	21 45	+12	29 23	+ 0 22	30 52
3	10 50	10 13	20 19	+14	31 5	+ 0 22	31 6
4	9 37	12 42	18 22	+12	29 43	+ 0 18	30 30
5	8 42	11 48	20 8	+12	30 35	+ 0 18	31 56
6	11 7	10 51	14 4	+10	25 13	+ 0 18	32 38
7	14 10	12 28	18 37	+16	32 12	— 1 13	32 2
8	15 52	18 55	18 54	+ 8	36 25	— 1 13	34 53
9	15 36	14 45	18 13	+26	33 50	— 1 18	31 36
10	18 27	19 15	16 30	+17	35 38	— 1 18	34 5
11	13 54	13 57	18 38	+18	32 51	— 1 19	31 46
12	15 35	17 13	18 40	+10	35 14	— 1 19	31 17
				Mean	250 31 52		250 31 59
1	275 37 43	39 10	19 56	— 2	185 58 20	+ 0 18	185 59 12
2	35 33	36 32	21 45	+ 1	57 48	+ 0 18	59 13
3	38 0	39 25	20 19	+ 5	59 6	+ 0 18	59 3
4	38 55	40 35	18 22	+ 3	58 10	+ 0 15	58 54
5	36 16	38 15	20 8	+ 9	57 33	+ 0 15	58 51
6	36 45	37 52	14 4	+19	51 41	+ 0 15	59 3
7	40 10	41 13	18 37	+ 1	59 20	— 1 0	59 23
8	40 58	42 47	18 54	+ 5	186 0 51	— 1 0	59 32
9	42 15	44 20	18 13	— 5	1 26	— 1 4	59 26
10	43 28	44 48	16 30	+ 1	0 39	— 1 4	59 20
11	40 46	42 15	18 38	0	0 9	— 1 5	59 18
12	43 52	45 30	18 40	+ 5	3 26	— 1 5	59 43
				Mean	185 59 2		185 59 15
3	296 47 36	44 50	20 19	+20	207 6 52	+ 2 12	207 8 43
6	43 50	46 28	14 4	+34	206 59 47	+ 1 49	8 43
7	297 00 30	00 55	18 37	+16	207 19 35	— 7 16	13 22
11	296 57 10	59 18	18 38	+16	17 8	— 7 50	9 32
				Mean	207 10 50		207 10 5
1	276 49 34	50 6	19 56	— 2	187 9 44	+ 1 18	187 11 36
2	45 12	46 0	21 45	+ 2	7 23	+ 1 18	9 48
3	48 37	48 27	20 19	+ 7	8 58	+ 1 18	9 55
4	48 28	48 32	18 22	+ 4	6 56	+ 1 5	8 30
5	48 32	51 20	20 8	+11	10 15	+ 1 5	12 23
6	47 48	49 27	14 4	+21	3 3	+ 1 5	11 15
7	55 40	57 54	18 37	+ 2	15 26	— 4 18	12 11
8	56 38	59 32	18 54	+ 6	17 5	— 4 18	12 28
9	57 27	58 28	18 13	— 7	16 3	— 4 37	10 30
10	59 31	57 45	16 30	+ 2	15 10	— 4 37	10 18
11	57 23	58 26	18 38	+ 2	16 35	— 4 39	12 10
12	277 00 42	4 8	18 40	+ 5	21 10	— 4 39	13 53
				Mean	187 12 19		187 11 15

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean. s	Scale Variation.	Proper Motion.	Final Corrected Distance. σ
14 (11)	1	.9921	.9886	241	—23	123	.0214	— 8	+.0015	79.0221
	2	.9942	.9893	238	—23	123	.0225	+21	+.0015	.0261
	3	.9912	.9902	239	—23	123	.0215	+ 3	+.0015	.0233
	4	.9856	.9872	237	—29	123	.0164	+91	+.0012	.0267
	5	.9839	.9894	241	—29	123	.0170	+14	+.0012	.0196
	6	.0009	.9952	251	—29	123	.0295	—40	+.0012	.0267
	7	.0067	.9917	224	+35	123	.0343	— 5	—.0048	.0290
	8	.9980	.9899	224	+35	123	.0290	+ 5	—.0048	.0247
	9	.0037	.0073	224	+39	124	.0411	—31	—.0051	.0329
	10	.0043	.0031	218	+39	123	.0386	+11	—.0051	.0346
	11	.0001	.0040	227	+40	122	.0378	—29	—.0052	.0297
	12	.9977	.9912	225	+40	123	.0302	—33	—.0052	.0217
						Mean				79.0264
15						*Bradley 3077*				
16 (12)	1	.8460	.8478	246	—24	128	.8787	— 8	+.0010	79.8789
	2	.8421	.8386	243	—24	128	.8720	+21	+.0010	.8751
	3	.8450	.8397	240	—24	128	.8737	+ 3	+.0010	.8750
	4	.8380	.8354	240	—29	126	.8672	+92	+.0008	.8772
	5	.8317	.8400	241	—29	128	.8667	+15	+.0008	.8690
	6	.8454	.8426	247	—29	128	.8755	—41	+.0008	.8722
	7	.8456	.8497	227	+35	126	.8833	— 5	—.0032	.8796
	8	.8386	.8396	227	+35	126	.8753	+ 5	—.0032	.8726
	9	.8440	.8532	233	+40	126	.8854	—31	—.0034	.8789
	10	.8516	.8420	222	+40	126	.8825	+12	—.0034	.8803
	11	.8385	.8405	231	+40	126	.8761	—30	—.0034	.8697
	12	.8381	.8349	227	+40	126	.8727	—34	—.0034	.8659
						Mean				79.8746
17 (34)	1	.1610	.1509	118	—12	101	.1763	— 4	—.0026	39.1733
	2	.1661	.1638	119	—12	102	.1855	+10	—.0026	.1839
	3	.1664	.1624	121	—12	101	.1850	+ 1	—.0026	.1825
	4	.1569	.1605	119	—14	102	.1790	+45	—.0022	.1813
	5	.1613	.1573	124	—14	102	.1801	+ 7	—.0022	.1786
	6	.1685	.1719	134	—14	101	.1919	—20	—.0022	.1877
	7	.1522	.1574	112	+17	111	.1784	— 3	+.0086	.1867
	8	.1550	.1482	114	+17	111	.1754	+ 3	+.0086	.1843
	9	.1546	.1376	108	+19	111	.1696	—15	+.0121	.1802
	10	.1376	.1481	108	+19	105	.1656	+ 6	+.0121	.1783
	11	.1445	.1444	112	+20	101	.1673	—15	+.0122	.1780
	12	.1461	.1446	113	+20	102	.1684	—17	+.0122	.1789
						Mean				39.1811

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	271 7 32	9 8	19 56	− 5	181 28 11	+ 0 25	181 29 10
2	5 10	6 43	21 45	− 2	27 40	+ 0 25	29 12
3	8 5	8 55	20 19	+ 4	28 53	+ 0 25	28 57
4	8 44	10 50	18 22	+ 1	28 10	+ 0 20	28 59
5	7 22	8 8	20 8	+ 5	27 58	+ 0 20	29 21
6	6 21	8 5	14 4	+15	21 32	+ 0 20	28 59
7	10 35	11 40	18 37	− 2	29 43	− 1 21	29 25
8	11 18	12 33	18 54	+ 3	30 53	− 1 21	29 13
9	12 55	15 18	18 13	−10	32 9	− 1 27	29 46
10	14 3	14 57	16 30	− 3	30 57	− 1 27	29 15
11	11 34	12 30	18 38	− 5	30 35	− 1 28	29 21
12	14 28	15 20	18 40	+ 2	33 36	− 1 28	29 30
				Mean	181 29 11		181 29 16
1	268 8 40	10 24	19 56	− 5	178 29 23	+ 0 25	178 30 22
2	6 23	7 8	21 45	− 2	28 29	+ 0 25	30 1
3	9 17	10 12	20 19	+ 1	30 4	+ 0 25	30 8
4	9 52	11 38	18 22	− 2	29 5	+ 0 20	29 54
5	7 56	9 50	20 8	+ 4	29 5	+ 0 20	30 28
6	7 23	9 14	14 4	+13	22 35	+ 0 20	30 2
7	11 22	13 27	18 37	− 4	30 57	− 1 21	30 39
8	12 40	14 3	18 54	+ 1	32 17	− 1 21	30 37
9	13 28	15 57	18 13	−14	32 41	− 1 27	30 18
10	15 0	15 57	16 30	− 2	31 56	− 1 27	30 14
11	12 38	13 43	18 38	− 5	31 44	− 1 27	30 31
12	14 28	16 47	18 40	0	34 18	− 1 27	30 13
				Mean	178 30 13		178 30 17
1	98 30 35	31 20	19 56	− 2	8 50 52	− 0 47	8 50 39
2	27 55	30 13	21 45	+ 2	50 51	− 0 47	51 11
3	31 38	31 55	20 19	+ 9	52 15	− 0 47	51 7
4	33 5	33 0	18 22	+ 5	51 29	− 0 39	51 19
5	29 6	30 26	20 8	+13	50 7	− 0 39	50 31
6	29 42	30 30	14 4	+23	44 33	− 0 39	51 1
7	26 3	28 3	18 37	+11	45 51	+ 2 35	49 29
8	27 41	28 27	18 54	+ 7	47 5	+ 2 35	49 21
9	28 47	30 28	18 13	− 3	47 48	+ 2 47	49 39
10	29 34	31 40	16 30	+ 3	47 10	+ 2 47	49 42
11	27 50	29 25	18 38	+ 3	47 19	+ 2 48	50 21
12	29 18	30 12	18 40	+ 6	48 31	+ 2 48	48 41
				Mean	8 48 39		8 50 15

Table V.—Results of Measures of Distance. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	s			σ
18	1	.3692	.3590	88	— 8	113	.3832	— 3	—.0053	28.3776
(33)	3	.3860	.3727	101	— 8	113	.3998	+ 1	—.0053	.3946
	4	.3821	.3729	95	—10	124	.3982	+ 33	—.0044	.3971
	6	.3806	.3646	122	—10	112	.3948	— 14	—.0044	.3890
	11	.3330	.3232	90	+14	113	.3496	— 11	+.0188	.3673
	12	.3444	.3357	91	+14	113	.3616	— 12	+.0188	.3792
						Mean				28.3841
19	1	.9604	.9622	182	—17	103	.9871	— 5	—.0013	55.9853
(14)	2	.9638	.9538	178	—17	103	.9837	+ 15	—.0013	.9839
	3	.9560	.9669	174	—17	104	.9865	+ 2	—.0013	.9854
	4	.9503	.9490	176	—20	104	.9747	+ 64	—.0011	.9800
	5	.9515	.9655	172	—20	103	.9830	+ 10	—.0011	.9829
	6	.9636	.9625	169	—20	103	.9872	— 28	—.0011	.9833
	7	.9464	.9467	172	+24	100	.9752	— 4	+.0042	.9790
	8	.9410	.9460	162	+24	100	.9711	+ 4	+.0042	.9757
	9	.9478	.9522	188	+28	100	.9806	— 22	+.0045	.9829
	10	.9449	.9497	168	+28	103	.9763	+ 8	+.0045	.9816
	11	.9503	.9477	176	+28	106	.9790	— 21	+.0046	.9815
	12	.9530	.9375	165	+28	103	.9738	— 24	+.0046	.9760
						Mean				55.9815
20	1	.5073	.5128	269	—27	134	.5432	— 9	—.0033	89.5390
(35)	2	.5142	.5126	273	—27	135	.5471	+ 24	—.0033	.5462
	3	.5201	.5099	284	—27	134	.5497	+ 3	—.0033	.5467
	4	.5090	.5036	275	—32	134	.5396	+103	—.0027	.5472
	5	.5176	.5086	291	—32	134	.5480	+ 16	—.0027	.5469
	6	.5228	.5256	322	—32	134	.5622	— 46	—.0027	.5549
	7	.4895	.4994	256	+39	132	.5327	— 6	+.0108	.5429
	8	.4880	.4998	264	+39	133	.5331	+ 6	+.0108	.5445
	9	.4948	.4784	247	+44	129	.5242	— 35	+.0116	.5323
	10	.4964	.4906	249	+44	134	.5318	+ 13	+.0116	.5447
	11	.4836	.4807	259	+45	134	.5216	— 33	+.0117	.5300
	12	.4925	.4884	266	+45	134	.5306	— 38	+.0117	.5385
						Mean				89.5428
21	1	.9995	.0222	122	—10	119	.0337	— 3	—.0059	32.0275
(22)	3	.0215	.0238	130	—10	119	.0463	+ 1	—.0059	.0405
	4	.0225	.0284	128	—12	124	.0492	+ 37	—.0049	.0480
	6	.0242	.0170	132	—12	119	.0443	— 16	—.0049	.0378
	7	.9806	.9690	132	+14	121	.0013	— 2	+.0195	.0206
	8	.9991	.9762	112	+14	121	.0122	+ 2	+.0195	.0319
	9	.9821	.9786	157	+16	122	.0097	— 12	+.0209	.0294
	11	.9916	.9710	137	+16	121	.0085	— 12	+.0210	.0283
	12	.0040	.9812	118	+16	121	.0179	— 14	+.0210	.0375
						Mean				32.0335

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	116 31 5	31 42	19 56	+ 5	26 51 24	− 0 56	26 51 2
3	34 8	34 50	20 19	+19	55 7	− 0 56	53 50
4	35 7	38 0	18 22	+14	55 9	− 0 47	54 51
6	32 25	33 14	14 4	+34	47 28	− 0 47	53 48
11	29 35	29 14	18 38	+16	48 18	+ 3 20	51 52
12	32 24	30 35	18 40	+14	50 23	+ 3 20	51 5
				Mean	26 51 18		26 52 45
1	254 20 16	22 27	19 56	− 9	164 41 9	+ 0 35	164 42 18
2	18 45	19 38	21 45	−10	40 47	+ 0 35	42 29
3	21 12	21 48	20 19	− 9	41 40	+ 0 35	41 54
4	22 3	24 22	18 22	−10	41 24	+ 0 29	42 22
5	18 50	22 6	20 8	− 8	40 28	+ 0 29	42 0
6	20 30	21 18	14 4	− 5	34 53	+ 0 29	42 29
7	24 34	25 40	18 37	−14	43 30	− 1 54	42 39
8	25 47	26 45	18 54	− 6	45 4	− 1 54	42 51
9	27 8	28 50	18 13	−24	45 48	− 2 3	42 49
10	29 26	28 11	16 30	−15	45 3	− 2 3	42 45
11	26 18	27 40	18 38	−16	45 21	− 2 3	43 32
12	27 40	29 58	18 40	− 8	47 21	− 2 3	42 40
				Mean	164 42 42		164 42 34
1	102 41 28	43 28	19 56	0	13 2 24	− 0 20	13 2 38
2	39 38	40 45	21 45	+ 5	2 2	− 0 20	2 49
3	42 35	43 28	20 19	+11	3 32	− 0 20	2 51
4	43 27	45 10	18 22	+ 8	2 49	− 0 16	3 2
5	40 45	42 10	20 8	+15	1 51	− 0 16	2 38
6	41 10	41 42	14 4	+27	12 55 57	− 0 16	2 48
7	40 53	41 48	18 37	+ 7	13 0 5	+ 1 6	2 14
8	42 3	43 8	18 54	+ 8	1 38	+ 1 6	2 25
9	43 27	44 25	18 13	+ 3	2 12	+ 1 10	1 26
10	43 50	45 32	16 30	+ 6	1 17	+ 1 10	2 12
11	41 32	42 47	18 38	+ 6	0 53	+ 1 11	2 18
12	43 56	45 30	18 40	+ 8	3 31	+ 1 11	2 4
				Mean	13 1 31		13 2 27
1	223 10 27	13 8	19 56	−10	133 31 34	+ 0 48	133 32 56
3	10 35	12 2	20 19	−22	31 15	+ 0 48	31 42
4	11 24	15 35	18 22	−19	31 32	+ 0 39	32 40
6	9 13	11 20	14 4	−33	23 48	+ 0 39	31 34
7	13 28	14 32	18 37	−21	32 16	− 2 36	30 43
8	15 6	17 0	18 54	−15	34 42	− 2 36	31 47
9	16 50	20 25	18 13	−28	36 23	− 2 48	32 39
11	17 5	17 45	18 38	−23	35 40	− 2 49	33 5
12	16 7	17 37	18 40	−17	35 15	− 2 49	29 48
				Mean	133 32 29		133 31 53

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist. East.	Observed Dist. West.	Corrections for Refrac.	Corrections for Aberr.	Corrections for Scale.	Corrected Mean s	Scale Variation.	Proper Motion.	Final Corrected Distance. σ
22	8	.2376	.2377	295	+45	125	.2775	+ 7	+.0040	102.2822
(15)	11	.2489	.2607	320	+51	134	.2987	—38	+.0043	.2992
	12	.2472	.2366	301	+51	125	.2830	—43	+.0043	.2830
						Mean				102.2881
23	1	.5766	.5912	410	—37	84	.6175	— 12	—.0016	124.6147
(16)	2	.5746	.5729	404	—37	84	.6068	+ 33	—.0016	.6085
	4	.5400	.5510	397	—45	84	.5770	+144	—.0013	.5901
	5	.5488	.5608	389	—45	82	.5853	+ 23	—.0013	.5863
	6	.5830	.6004	381	—45	82	.6214	— 63	—.0013	.6138
	7	.5582	.5378	392	+54	84	.5889	— 8	+.0054	.5935
	8	.5514	.5656	364	+54	85	.5967	+ 8	+.0054	.6029
	10	.5485	.5727	385	+62	84	.6016	+ 18	+.0058	.6092
	11	.5523	.5609	397	+63	84	.5989	— 46	+.0058	.6001
	12	.5545	.5378	370	+63	104	.5878	— 53	+.0058	.5883
						Mean				124.6007
24	1	.5444	.5442	238	—20	107	.5750	— 6	—.0043	66.5701
(21)	2	.5444	.5316	241	—20	107	.5690	+ 18	—.0043	.5665
	3	.5391	.5332	240	—20	106	.5669	+ 2	—.0043	.5628
	4	.5466	.5563	240	—24	109	.5821	+ 77	—.0035	.5863
	5	.5401	.5340	237	—24	107	.5672	+ 12	—.0035	.5649
	6	.5583	.5482	234	—24	107	.5832	— 34	—.0035	.5763
	7	.5331	.5149	245	+29	110	.5606	— 5	+.0140	.5741
	8	.5166	.5144	214	+29	110	.5490	+ 5	+.0140	.5635
	9	.5112	.4964	290	+33	110	.5453	— 26	+.0150	.5577
	11	.5372	.5161	253	+33	107	.5641	— 25	+.0151	.5767
	12	.5177	.5113	223	+33	106	.5489	— 28	+.0151	.5612
						Mean				66.5691
25	1	.5484	.5453	396	—35	123	.5851	— 11	—.0022	118.5818
(17)	2	.5400	.5337	391	—35	123	.5746	+ 32	—.0022	.5756
	3	.5540	.5545	383	—35	123	.5913	+ 4	—.0022	.5895
	4	.5350	.5390	386	—43	123	.5735	+137	—.0018	.5854
	5	.5296	.5345	378	—43	123	.5677	+ 22	—.0018	.5681
	7	.5290	.5176	383	+52	123	.5690	— 8	+.0071	.5753
	8	.5395	.5224	352	+52	124	.5737	+ 8	+.0071	.5816
	9	.5226	.5122	428	+59	123	.5683	— 46	+.0076	.5713
	11	.5294	.5288	393	+60	123	.5766	— 44	+.0076	.5798
	12	.5205	.5310	358	+59	123	.5697	— 50	+.0076	.5723
						Mean				118.5781

TABLE VI.—RESULTS OF MEASURES OF ANGLE. *(Continued.)*

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
8	254 45 34	46 15	18 54	— 6	165 4 42	— 1 3	165 3 20
11	44 57	46 50	18 38	—15	4 17	— 1 8	3 23
12	47 47	48 55	18 40	— 8	6 53	— 1 8	3 7
				Mean	165 5 17		165 3 17
1	252 10 42	11 42	19 56	—10	162 30 58	+ 0 16	162 31 48
2	8 48	9 52	21 45	—10	30 55	+ 0 16	32 18
4	11 56	14 7	18 22	—11	31 13	+ 0 13	31 55
5	9 28	11 32	20 8	—10	30 28	+ 0 13	31 44
6	9 56	11 8	14 4	— 5	24 31	+ 0 13	31 51
7	13 3	14 13	18 37	—15	32 0	— 0 52	32 11
8	13 53	15 27	18 54	— 7	33 27	— 0 52	32 16
10	16 26	17 50	16 30	—16	33 22	— 0 56	32 11
11	13 38	15 12	18 38	—17	32 46	— 0 56	32 4
12	16 2	18 13	18 40	— 8	35 40	— 0 56	32 6
				Mean	162 31 32		162 32 2
1	235 18 8	19 22	19 56	—11	145 38 30	+ 0 26	145 39 30
2	15 38	16 32	21 45	—16	37 34	+ 0 26	39 7
3	18 42	19 8	20 19	—20	38 54	+ 0 26	38 59
4	19 20	19 53	18 22	—17	37 41	+ 0 22	38 32
5	16 34	18 50	20 8	—22	37 28	+ 0 22	38 53
6	16 48	18 18	14 4	—27	31 10	+ 0 22	38 39
7	20 35	21 45	18 37	—21	39 26	— 1 27	39 2
8	21 48	23 18	18 54	—14	41 13	— 1 27	39 27
9	23 26	26 48	18 13	—31	42 49	— 1 33	40 20
11	21 23	23 22	18 38	—23	40 37	— 1 34	39 17
12	23 2	26 6	18 40	—16	42 58	— 1 34	38 46
				Mean	145 38 56		145 39 8
1	248 57 30	58 56	19 56	—10	159 17 59	+ 0 16	159 18 49
2	55 48	56 46	21 45	—12	17 50	+ 0 16	19 13
3	58 18	59 38	20 19	—13	19 4	+ 0 16	18 59
4	59 18	00 35	18 22	—13	18 5	+ 0 14	18 48
5	57 0	58 55	20 8	—13	17 53	+ 0 14	19 10
7	249 00 7	1 32	18 37	—17	19 9	— 0 54	19 18
8	1 15	2 5	18 54	— 8	20 26	— 0 54	19 13
9	2 18	4 18	18 13	—27	21 4	— 0 58	19 10
11	1 18	2 45	18 38	—18	20 22	— 0 58	19 38
12	2 55	4 58	18 40	—10	22 26	— 0 58	18 50
				Mean	159 19 26		159 19 7

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean. s	Scale Variation.	Proper Motion.	Final Corrected Distance. σ
		East.	West.	Refrac.	Aberr.	Scale.				
26	1	.9975	.0135	183	—15	114	.0330	— 5	—.0091	49.0234
(29)	2	.0162	.0226	207	—15	114	.0492	+13	—.0091	.0414
	3	.0286	.0154	242	—15	114	.0553	+ 2	—.0091	.0464
	4	.0159	.0140	220	—18	121	.0464	+56	—.0075	.0445
	5	.0173	.9999	259	—18	120	.0439	+ 9	—.0075	.0373
	6	.0185	.0212	309	—18	110	.0591	—25	—.0075	.0491
	7	.9586	.9565	221	+21	114	.9923	— 3	+.0299	.0219
	8	.9839	.9789	203	+21	114	.0144	+ 3	+.0299	.0446
	11	.9594	.9571	228	+25	124	.9951	—18	+.0322	.0255
	12	.9566	.9410	209	+25	120	.9834	—21	+.0322	.0135
						Mean				49.0348
27 (20)	12	.8166	.8112	298	+45	132	.8570	—38	+.0144	89.8676
28	4	.7395	.7356	265	—23	117	.7720	+72	—.0056	62.7736
(24)	6	.7193	.7225	269	—23	114	.7554	—32	—.0056	.7466
	11	.7391	.7261	285	+31	114	.7741	—23	+.0241	.7959
	12	.6891	.6803	243	+31	113	.7219	—26	+.0241	.7434
						Mean				62.7649
29	1	.0709	.0682	200	—15	110	.0982	— 5	—.0094	51.0883
(28)	2	.0724	.0725	227	—15	110	.1038	+14	—.0094	.0958
	3	.0856	.0750	264	—15	110	.1154	+ 2	—.0094	.1062
	4	.0794	.0760	242	—19	117	.1109	+59	—.0078	.1090
	5	.0785	.0611	280	—19	114	.1065	+ 9	—.0078	.0996
	6	.0877	.0677	329	—19	110	.1189	—26	—.0078	.1085
	7	.9937	.9865	246	+22	115	.0276	— 3	+.0309	.0582
	8	.0371	.0175	219	+22	113	.0619	+ 3	+.0309	.0931
	11	.0104	.0034	254	+26	110	.0451	—19	+.0333	.0765
	12	.0354	.0176	228	+26	113	.0624	—22	+.0333	.0935
						Mean				51.0929
30 (30)	4	.5448	.5838	259	—22	110	.5977	+69	—.0072	59.5974
31	1	.4623	.4634	307	—24	137	.5014	— 8	—.0053	82.4953
(23)	2	.4626	.4558	314	—24	137	.4984	+22	—.0053	.4953
	3	.4533	.4532	318	—24	137	.4928	+ 3	—.0053	.4878
	4	.4606	.4474	318	—30	136	.4929	+95	—.0044	.4980
	5	.4502	.4638	318	—30	140	.4963	+15	—.0044	.4934
	6	.4646	.4577	316	—30	137	.5000	—42	—.0044	.4914
	7	.4279	.4294	327	+36	141	.4756	— 6	+.0173	.4923
	8	.4457	.4360	279	+36	138	.4826	+ 6	+.0173	.5005
	9	.4184	.4200	386	+41	136	.4720	—32	+.0186	.4874
	10	.4276	.4293	323	+41	140	.4754	+12	+.0186	.4952
	11	.4321	.4333	336	+41	137	.4806	—31	+.0187	.4962
	12	.4344	.4208	290	+41	140	.4712	—35	+.0187	.4864
						Mean				82.4933

Table VI.—Results of Measures of Angle. (*Continued.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected. Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	156 31 26	34 24	19 56	+10	66 53 1	— 0 10	66 53 25
2	29 3	30 55	21 45	+13	51 57	— 0 10	52 54
3	31 42	33 17	20 19	+15	53 5	— 0 10	52 34
4	33 38	35 55	18 22	+14	53 23	— 0 9	53 43
5	31 1	32 35	20 8	+14	52 10	— 0 9	53 4
6	31 5	32 18	14 4	+15	46 1	— 0 9	52 59
7	31 20	30 45	18 37	+18	49 58	+ 0 34	51 35
8	30 52	31 58	18 54	+ 9	50 28	+ 0 34	50 43
11	32 25	34 26	18 38	+19	52 23	+ 0 37	53 14
12	33 13	35 15	18 40	+13	53 7	+ 0 37	51 6
				Mean	66 51 33		66 52 32
12	236 48 54	50 17	18 40	—15	147 8 1	— 1 11	147 4 12
4	216 8 8	10 18	18 22	—17	126 27 18	+ 0 18	126 28 5
6	6 47	8 0	14 4	—35	20 53	+ 0 18	28 18
11	9 50	13 3	18 38	—21	29 43	— 1 18	28 39
12	11 12	14 53	18 40	—16	31 26	— 1 18	27 30
				Mean	126 27 20		126 28 8
1	168 36 24	38 27	19 56	+ 8	78 57 29	— 0 2	78 58 1
2	33 52	35 5	21 45	+ 8	56 21	— 0 2	57 26
3	36 8	38 8	20 19	+ 7	57 34	— 0 2	57 11
4	38 28	38 36	18 22	+ 8	57 2	— 0 2	57 29
5	35 23	37 50	20 8	+ 5	56 49	— 0 2	57 50
6	36 16	36 30	14 4	— 1	50 26	— 0 2	57 31
7	37 2	36 42	18 37	+10	55 39	+ 0 7	56 49
8	38 30	38 32	18 54	+ 3	57 28	+ 0 7	57 16
11	39 16	39 55	18 38	+13	58 27	+ 0 7	58 48
12	39 38	42 6	18 40	+ 5	59 37	+ 0 7	57 6
				Mean	78 56 41		78 57 33
4	150 3 18	5 32	18 22	+16	60 23 3	— 0 10	60 23 22
1	228 14 25	15 55	19 56	—11	138 34 55	+ 0 20	138 35 49
2	12 0	13 53	21 45	—16	34 26	+ 0 20	35 53
3	15 42	16 5	20 19	—22	35 50	+ 0 20	35 49
4	16 0	17 28	18 22	—19	34 47	+ 0 16	35 32
5	14 8	15 30	20 8	—24	34 33	+ 0 16	35 52
6	13 55	14 50	14 4	—31	27 55	+ 0 16	35 18
7	17 7	18 8	18 37	—22	35 53	— 1 6	35 50
8	18 3	19 36	18 54	—14	37 30	— 1 6	36 5
9	19 25	21 48	18 13	—30	38 19	— 1 10	36 13
10	20 45	21 43	16 30	—23	37 21	— 1 10	35 56
11	18 52	19 5	18 38	—24	37 13	— 1 11	36 16
12	19 38	22 5	18 40	—17	39 15	— 1 11	35 26
				Mean	138 35 40		138 35 50

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Concluded.*)

Star No.	Plate.	Observed Dist.		Corrections for			Corrected Mean.	Scale Variation.	Proper Motion.	Final Corrected Distance.
		East.	West.	Refrac.	Aberr.	Scale.	*s*			σ
32	1	.2646	.2658	344	—32	120	.3005	— 10	—.0062	109.2933
(32)	2	.2655	.2600	368	—32	138	.3014	+ 29	—.0062	.2981
	4	.2768	.2702	384	—40	128	.3128	+125	—.0052	.3201
	7	.2306	.2495	364	+48	130	.2863	— 7	+.0205	.3061
	8	.2388	.2309	368	+48	130	.2815	+ 7	+.0205	.3027
	9	.2557	.2180	349	+54	139	.2831	— 43	+.0219	.3007
	10	.2360	.2386	355	+54	128	.2831	+ 16	+.0219	.3066
	11	.2292	.2214	368	+55	138	.2735	— 41	+.0221	.2915
	12	.2333	.2124	370	+55	118	.2693	— 46	+.0221	.2868
						Mean				109.3007
33	1	.0454	.0412	321	—28	140	.0812	— 9	—.0078	95.0725
(31)	2	.0511	.0403	357	—28	144	.0876	+ 25	—.0078	.0823
	3	.0424	.0366	412	—28	140	.0865	+ 4	—.0078	.0791
	4	.0404	.0354	377	—34	144	.0812	+109	—.0064	.0857
	5	.0409	.0282	441	—34	144	.0843	+ 17	—.0064	.0796
	6	.0380	.0428	529	—35	138	.0982	— 48	—.0064	.0870
	7	.0000	.9866	366	+42	143	.0430	— 6	+.0256	.0680
	8	.0001	.9929	356	+42	142	.0451	+ 6	+.0256	.0713
	9	.0036	.9918	366	+47	140	.0476	— 37	+.0274	.0713
	10	.9968	.0042	360	+47	143	.0500	+ 14	+.0274	.0788
	11	.9996	.9859	373	+48	143	.0388	— 35	+.0276	.0629
	12	.0000	.9922	364	+48	144	.0463	— 40	+.0276	.0699
						Mean				95.0757
34	7	.9473	.9391	472	+54	118	.9957	— 8	+.0158	124.0107
(19)	8	.9583	.9454	410	+54	118	.9981	+ 8	+.0158	.0147
	11	.9655	.9507	490	+62	108	.0122	— 46	+.0171	.0247
	12	.9702	.9496	427	+62	113	.0082	— 52	+.0171	.0201
						Mean				124.0175
35	10	.5560	.5567	516	+57	119	.6164	+ 17	+.0251	114.6432
(27)	11	.5637	.5550	535	+58	114	.6209	— 43	+.0253	.6419
						Mean				.6426

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Concluded.*)

Plate.	Observed Position Angle. East.	Observed Position Angle. West.	Zero Correction plus precession, etc.	Refrac.	Corrected Mean. p	Proper Motion.	Final Corrected Angle. π
	° ′ ″	′ ″	′ ″	″	° ′ ″	′ ″	° ′ ″
1	123 33 26	35 6	19 56	+ 7	33 54 19	— 0 13	33 54 40
2	31 20	32 52	21 45	+14	54 5	— 0 13	54 59
4	35 45	37 38	18 22	+16	55 20	— 0 11	55 38
7	33 42	34 58	18 37	+18	53 15	+ 0 43	55 1
8	34 55	35 55	18 54	+14	54 33	+ 0 43	54 57
9	35 42	37 33	18 13	+22	55 13	+ 0 46	55 3
10	37 3	38 19	16 30	+19	54 30	+ 0 46	55 1
11	35 10	35 40	18 38	+19	54 22	+ 0 46	55 22
12	37 10	38 13	18 40	+16	56 38	+ 0 46	54 46
				Mean	33 54 42		33 55 3
1	137 57 13	58 37	19 56	+10	48 18 1	— 0 11	48 18 24
2	54 50	56 2	21 45	+16	17 27	— 0 11	18 23
3	57 53	58 23	20 19	+22	18 49	— 0 11	18 17
4	58 37	00 23	18 22	+19	18 11	— 0 9	18 31
5	56 2	57 58	20 8	+24	17 32	— 0 9	18 26
6	56 15	57 18	14 4	+31	11 21	— 0 9	18 19
7	56 45	57 41	18 37	+22	16 12	+ 0 37	17 52
8	57 38	59 4	18 54	+14	17 29	+ 0 37	17 47
9	58 53	00 58	18 13	+30	18 39	+ 0 39	18 22
10	138 00 7	1 45	16 30	+23	17 49	+ 0 39	18 13
11	137 57 36	58 55	18 38	+24	17 18	+ 0 40	18 12
12	138 00 23	2 5	18 40	+17	20 11	+ 0 40	18 13
					48 17 25		48 18 15
7	231 32 22	33 3	18 37	—22	141 50 57	— 0 46	141 51 14
8	33 2	34 40	18 54	—14	52 32	— 0 46	51 27
11	33 8	34 38	18 38	—24	52 7	— 0 49	51 32
12	34 47	37 13	18 40	—16	54 24	— 0 49	50 57
				Mean	141 52 30		141 51 18
10	213 4 38	6 18	16 30	—19	123 21 39	— 0 41	123 20 43
11	2 32	3 35	18 38	—20	21 21	— 0 41	20 54
				Mean	123 21 30		123 20 48

TABLE VII.—FOR PROPER MOTION, ETC.

Plate No.	$t-1874$ τ	P_1	P_5	F	Correction for Variation. Scale $\times 10^3$	Correction for Variation. Orientation.
				"		′ ″
1	—0.127	—.0094	—1942.6	+0.4	—.00957	+0 34
2	— .127	—.0094	—1942.6	+0.4	+.02660	+1 7
3	— .127	—.0094	—1942.6	+0.4	+.00373	—0 21
4	— .105	—.0078	—1606.2	+0.3	+.11455	+0 29
5	— .105	—.0078	—1606.2	+0.3	+.01820	+1 3
6	— .105	—.0078	—1606.2	+0.3	—.05086	+7 7
7	+ .418	+.0310	+6394.2	—1.3	—.00677	+1 3
8	+ .418	+.0310	+6394.2	—1.3	+.00677	—0 19
9	+ .448	+.0332	+6852.9	—1.4	—.03896	—0 56
10	+ .448	+.0332	+6852.9	—1.4	+.01446	—0 15
11	+ .451	+.0334	+6898.7	—1.4	—.03733	+0 14
12	+ .451	+.0334	+6898.7	—1.4	—.04223	—2 38

TABLE VIII.—FOR PROPER MOTION.

Star No.	In Distance.	In Position Angle.		
	s_1	s_5	s_6	s_7
1	—1.000	—.0104	.0081	—.00008
2	—0.935	—.3558	.0085	—.00304
3	— .984	+.1783	.0132	+.00235
4	— .960	—.2803	.0125	—.00352
5	— .664	—.7481	.0083	—.00621
6	—0.838	—.5454	.0165	—.00899
7	— .622	—.7829	.0112	—.00875
8	— .673	+.7401	.0171	+.01265
9	— .990	+.1428	.0337	+.00482
10	— .978	—.2087	.0538	—.01122
11	—0.232	—.9727	.0094	—.00919
12	— .568	—.8231	.0826	—.06795
13	— .253	—.9676	.0416	—.04022
14	— .155	—.9879	.0126	—.01250
15				
16	—0.103	—.9947	.0125	—.01245
17	+ .280	+.9601	.0255	+.02450
18	+ .563	+.8263	.0352	+.02911
19	+ .137	—.9906	.0179	—.01769
20	+ .349	+.9370	.0112	+.01047
21	+0.630	—.7768	.0312	—.02424
22	+ .130	—.9915	.0098	—.00970
23	+ .174	—.9847	.0080	—.00791
24	+ .453	—.8916	.0150	—.01339
25	+ .229	—.9734	.0084	—.00821
26	+0.963	+.2709	.0204	+.00553
27	+ .430	—.9030	.0111	—.01005
28	+ .721	—.6932	.0159	—.01104
29	+ .998	+.0633	.0196	+.00124
30	+ .926	+.3777	.0168	+.00634
31	+0.559	—.8292	.0121	—.01005
32	+ .661	+.7508	.0092	+.00687
33	+ .826	+.5636	.0105	+.00593
34	+ .510	—.8599	.0081	—.00693
35	+ .757	—.6532	.0087	—.00570

Table IX.—Mean Results.

Star No.	Distance.	Position Angle.	$\alpha'-\alpha$	$\delta'-\delta$	No. of Plates.	Durchmusterung.	
						No.	Mag.
	"	° ′ ″	"	"		°	
1	3471.54	261 57 38	—6200.11	— 528.57	2	56.2942	9.4
2	3279.96	241 44 1	—5170.81	—1583.43	8	55.2898	9.1
3	2125.81	272 51 16	—3846.67	+ 89.36	12	56.2952	7.5
4	2233.14	246 18 15	—3677.83	— 912.64	12	56.2953	8.6
5	3376.37	214 9 24	—3363.40	—2806.80	5	55.2908	9.3
6	1699.59	229 30 18	—2321.22	—1109.73	5	56.2956	8.5
7	2505.96	211 2 20	—2303.23	—2153.15	8		
8	1639.11	310 19 51	—2279.93	+1055.07	12	56.2958	7.0
9	830.27	270 47 43	—1503.17	+ 9.01	12	56.2961	9.0
10	521.11	250 31 59	— 888.41	— 174.55	12	56.2962	9.0
11	2964.74	185 59 15	— 548.13	—2948.90	12	55.2915	9.3
12	339.10	207 10 5	— 279.71	— 301.78	4	56.2963	8.7
13	673.84	187 11 15	— 151.89	— 668.58	12	56.2964	9.1
14	2213.72	181 29 16	— 102.40	—2212.98	12	55.2917	8.2
15		*Bradley*	*3077*			56.2966	6.0
16	2237.48	178 30 17	+ 104.00	—2236.73	12	55.2919	7.6
17	1097.56	8 50 15	+ 307.73	+1084.43	12	56.2969	8.0
18	795.11	26 52 45	+ 654.24	+ 708.74	6	56.2970	9.1
19	1568.18	164 42 34	+ 740.56	—1513.29	12	55.2920	9.3
20	2508.31	13 2 27	+1043.41	+2442.43	12	57.2712	8.0
21	897.34	133 31 53	+1172.55	— 619.58	9	56.2972	9.3
22	2865.34	165 3 17	+1311.41	—2770.35	3	55.2922	9.5
23	3490.36	162 32 2	+1851.74	—3333.34	10	55.2925	8.5
24	1864.76	145 39 8	+1883.65	—1543.60	11	55.2926	8.5
25	3321.66	159 19 7	+2076.84	—3112.52	10	55.2928	8.3
26	1373.58	66 52 32	+2296.06	+ 533.57	10	56.2974	9.4
27	2517.41	147 4 12	+2439.97	—2119.69	1		
28	1758.20	126 28 8	+2540.40	—1052.30	4		
29	1431.23	78 57 33	+2548.30	+ 266.85	10	56.2975	9.4
30	1669.47	60 23 22	+2643.71	+ 817.13	1	56.2976	9.5
31	2310.84	138 35 50	+2732.23	—1741.73	12	55.2929	7.6
32	3061.77	33 55 3	+3151.75	+2529.88	9	57.2715	8.5
33	2663.30	48 18 15	+3647.57	+1756.88	12	56.2978	7.0
34	3474.03	141 51 18	+3808.68	—2748.62	4	55.2933	8.9
35	3211.41	123 20 48	+4794.57	—1791.25	2	55.2935	9.4

TABLE X.—CATALOGUE OF STARS.

Star No.	Helsingfors-Gotha No.	Right Ascension, 1874.	Precession, J	Sec. Var., K	Declination, 1874.	Precession, L	Sec. Var. M
		h m s	s	s	° ′ ″	″	″
1		23 0 20.015	+2.5557	+.0276	56 19 33.38	+19.378	+.088
2	13747	1 28.635	2.5709	.0279	56 1 58.52	19.404	.086
3	13768	2 56.911	2.5746	.0286	56 29 51.31	19.436	.084
4	13773	3 8.167	2.5814	.0285	56 13 9.31	19.440	.084
5		3 29.129	2.5939	.0283	55 41 35.15	19.447	.084
6	13801	4 38.608	+2.5952	+.0289	56 9 52.22	+19.472	+.082
7		4 39.807	2.6004	.0288	55 52 28.80	19.473	.083
8	13805	4 41.361	2.5846	.0293	56 45 57.02	19.473	.082
9	13814	5 33.145	2.5973	.0294	56 28 30.96	19.491	.081
10	13826	6 14.129	2.6041	.0296	56 25 27.40	19.505	.080
11	13829	6 36.814	+2.6206	+.0292	55 39 13.05	+19.513	+.080
12	13836	6 54.709	2.6105	.0298	56 23 20.17	19.519	.079
13	13837	7 3.230	2.6134	.0298	56 17 13.37	19.522	.079
14	13839	7 6.529	2.6213	.0295	55 51 28.97	19.523	.079
15	**13841**	**23 7 13.356**	**2.6116**	**.0300**	**56 28 21.95**	**19.525**	**.078**
16	13844	7 20.289	+2.6233	+.0296	55 51 5.22	+19.527	+.079
17	13848	7 33.871	2.6093	.0303	56 46 26.38	19.532	.078
18	13850	7 56.972	2.6145	.0303	56 40 10.69	19.539	.077
19	13852	8 2.727	2.6259	.0299	56 3 8.66	19.541	.078
20	13856	8 22.917	2.6098	.0308	57 9 4.38	19.548	.077
21		8 31.526	+2.6255	+.0303	56 18 2.37	+19.551	+.077
22		8 40.783	2.6369	.0303	55 42 11.60	19.554	.077
23	13870	9 16.805	2.6445	.0300	55 32 48.61	19.565	.076
24	13871	9 18.933	2.6367	.0303	56 2 38.35	19.566	.076
25	13875	9 31.812	2.6454	.0301	55 36 29.43	19.570	.076
26		9 46.427	+2.6310	+.0308	56 37 15.52	+19.575	+.074
27		9 56.021	2.6445	.0304	55 53 2.26	19.578	.076
28		10 2.716	2.6407	.0304	56 10 49.65	19.580	.076
29		10 3.243	2.6347	.0304	56 32 48.80	19.580	.076
30		10 9.603	2.6332	.0304	56 41 59.08	19.582	.076
31	13885	10 15.505	+2.6455	+.0306	55 59 20.22	+19.584	+.075
32	13894	10 43.473	2.6300	.0316	57 10 31.83	19.593	.073
33	13903	11 16.527	2.6385	.0316	56 57 38.83	19.603	.073
34	13907	11 27.268	2.6600	.0308	55 42 33.33	19.606	.073
35		12 32.994	2.6652	.0313	55 58 30.70	19.626	.071

VI.—*The Præsepe Group; Measurement and Reduction of the Rutherfurd Photographs.*

By Frank Schlesinger.

Read April 4, 1898.

I.

Description of the Plates.

The collection of astronomical photographs presented by the late Lewis M. Rutherfurd to the Observatory of Columbia University contains eleven photographs of Præsepe taken with his larger and improved instrument; only eight of these were measured and reduced, three having been judged inferior to the rest. According to Rutherfurd's invariable practice, each plate shows two complete pictures of the group separated by about a millimetre in right ascension, the driving clock of the instrument having been stopped for a few seconds after the completion of the first or eastern impression. Near the west edge of the plate still a third image of each of the brighter stars in the group is found, separated by about forty millimetres from the two other impressions, the driving clock having been stopped for an interval of about three minutes after the completion of the second impression, and then started again and allowed to run long enough to permit the brighter stars to leave well-defined images. The object in securing these third impressions or *trails* was to afford means for orienting the group, but in the present work they were not used for this purpose, the orientation having been effected in another way. It is important, however, to know how accurately the use of trails will give the orientation, and they were therefore completely measured and reduced, and the results compared with those obtained by the method actually employed, which is of unquestioned accuracy but may not be always available.

A perpendicular to the plate passing through the optical centre of the object glass pierces the plate at a point whose approximate position must be known in order to reduce the measures of the stars to right ascensions and declinations. Rutherfurd so adjusted his plate holder that this point coincides approximately with the image of the central star of the group, numbered 15 in the following pages.

Table I gives the data of exposure for the plates. Plates VI, X and XI do not appear, these being the ones that were not measured, on account of their inferiority. This is due to the fact that the photographic images of the stars on these plates, when viewed under the microscope of the measuring machine were neither so round nor so well defined as on the other plates and therefore did not admit of so accurate measurement. The irregularity of the images is not due to a deterioration of the plates since they were taken, but to the bad behavior of RUTHERFURD's clock during the exposures. For this reason these three plates were never measured, it being deemed probable that more reliable results are to be obtained from the eight plates actually reduced, than if all the plates had been measured, in spite of the greater number of observations in the latter case. In this connection I should also say that not all the stars which appear on the plates were measured. A few whose images come near the edges of the plates were rejected, for not only are these images much distorted, but as we shall see later, the corrections become uncertain as we recede from the centre of the plate.

TABLE I.—PHOTOGRAPHS OF PRÆSEPE.

Observatory of L. M. Rutherfurd, New York.

Lat. = 40°43′48″.5 Long. = $4^h55^m56^s.62$ W.

No.	Date.	Sidereal Time.	Bar.	Thermometers.			Focus
				Att.	Ext.	Tel.	
		h m s		°	°	°	
I	1870 Apr. 24	10 45 05	30.01	60	55	58	8.4
II	1870 Apr. 24	11 25 35	30.01	60	55	58	8.4
III	1870 Apr. 25	11 10 35	30.26	53	47	53	8.4
IV	1870 Apr. 25	11 59 35	30.26	53	47	53	8.4
V	1877 Apr. 14	10 39 38	30.06	47	45	48	7.8
VII	1877 Apr. 25	11 26 02	30.06	57	56	58	7.7
VIII	1877 Apr. 25	11 53 32	30.06	57	56	58	7.7
IX	1877 May 2	10 57 08	29.86	47	46	48	7.8

The column marked "sidereal time" gives the mean of four instants for each plate: beginning of east exposure, end of east exposure, beginning of west exposure and end of west exposure; each exposure lasted six minutes. Three thermometers were read: attached, external and telescope, the last being in contact with the telescope-tube. The last column, marked "focus," gives the reading of a micrometer head attached to the eye end of the telescope and shows the position of the plate holder; this information is not used in the reductions and is given only to provide for the possibility of determining a relation between this reading and the scale-value after a sufficient number of the photographs made with this instrument has been reduced.

II.

Measurement of the Plates.

The plates were measured with the older Repsold Measuring Machine of this Observatory, which is a counterpart of the one by the same maker belonging to the University of Leyden except that an alteration has been made which obviates "projection errors." (See III.) A full description of the Leyden machine is given in the "Bulletin du Comité Permanent," Vol. 1, page 169, and also in the recent work by Dr. Scheiner, "Photographie der Gestirne," page 148. The machine is so constructed that the position of a star may be determined either by position angle and distance or by rectangular coördinates; the latter method was adopted in the present case. A star which is to be measured may be brought into the field of the reading microscope by moving the plate along a straight guiding cylinder and then moving the microscope at right angles to the cylinder on another straight guiding way. The wire of the micrometer is made to bisect the image of the star and the micrometer head is read. Then the whole microscope is revolved through a small vertical angle and the wire set upon a scale of millimetres placed parallel to the motion of the microscope. The difference of the two readings on star and scale, together with the number of the line on the scale gives us the position of the star. Having gone through the same operation for all the stars we obtain their relative positions, at least in one direction; the plate is now revolved through 90° by means of the graduated circle and the stars are again measured; these two sets of measures are sufficient to fix the relative positions of the stars, but in order to secure greater accuracy and especially to eliminate personality the plate is turned 180° and 270° respectively from its original position, and the stars are read a third and a fourth time. By means of the trails or otherwise the plate may be so placed in the machine that a circle of declination through the central star shall be approximately parallel to the guiding cylinder; in this way we obtain rectangular coördinates which are nearly in the directions of right ascensions and declinations, thus rendering their conversion into the latter a comparatively easy matter.

Two observers alternated in the measurements, one recording while the other observed; the details of each morning's work, which usually lasted a little over two hours, are as follows: the first observer reads the circle, runs and temperature, the second reads on the central star thus: East image, scale, scale, east image; west image, scale, scale, west image. Continuing, the second observer goes through the same operations for usually three other stars, experience having shown that four stars could be read conveniently without fatiguing the eye; thus the observers alternate till twenty or twenty-five stars have been read and then the temperature is recorded a second time. The morning's work is now half finished; the same stars are then observed in the reverse order, care being taken that each observer shall now read those stars that he had not read in the first half; having finally gotten back to the central star, temperature, runs and the circle are read as at the beginning. This process of repeating all the measurements in the reverse order, eliminates the effects of any change in the machine or in the observers that is proportionate to the time, for the mean of the two times of observation is nearly the same for all the stars. In the first half of the morning's work the micrometer head is set at about $9.^R0$ when pointed at a star; but in the second half the reading is made $9.^R5$; in this way periodic errors of the screw are nearly eliminated, for both star and scale are read with two different parts of the screw separated by half a turn.

The measurements made in the first position of the plate, *i. e.*, with the stars having the greatest *right ascensions* farthest from the cylinder are recorded as "x direct;" on the next day the plate is turned 90° in a counter-clockwise direction so that now the stars having the greatest *north polar distances* are farthest from the cylinder. The measurements taken in this position are called "y direct," while those taken in the two opposite positions, 180° and 270° from the original position are called respectively "x reversed" and "y reversed." As only twenty or twenty-five stars could be measured on each day, and as the photographs of Præsepe show about forty-five stars that admit of measurement, it was necessary to spend two days on each position of the plate. To eliminate the effect of a possible motion of the plate or of the scale the central star 15 was read each day by both observers. After three of the plates had been measured, viz.: III, VII and IX, it was decided to read the central star more often, so that on the succeeding plates four such readings were made every day, instead of two.

Three observers were engaged in the measurement of the first five plates, but only two were concerned in the work for any single day. Care was always taken to have the same pair of observers make both the direct and the reversed measurements of a particular set of stars, in order to eliminate personality. Suppose one of the observers has contracted the habit of always setting the micrometer wire too far to the right of the centre of a star's image by an amount depending upon the size of the image; the distance between two stars as obtained by such an observer will be subject to an error which depends upon the difference of magnitudes of the stars. But when the plate is reversed 180°, the same observer will get a distance which is too small by as much as the first distance was too large or vice versa; consequently the mean of the two measurements will be free from such personality as we have supposed. However, this method of measurement does not eliminate all personality, for the star images are seldom round and are usually more sharply defined on one edge than upon the other; two observers will thus sometimes differ considerably in their estimations of the true centre of the image.

Table II gives the runs, circle reading, etc., for each day. Runs were observed twice daily, once before and once after the measurement of the stars; the number in the column headed "runs" is the mean of the two determinations expressed in millimetres. The circle was also read twice, employing two microscopes 180° apart for each reading; in the column marked "circle" the degrees and minutes are always taken from the right-hand microscope, while the number of seconds is the mean of both microscopes. The thermometer occupied a fixed position near the plate and was graduated in Fahrenheit degrees. The last column gives the initials of the three observers, Kretz, Hays and Schlesinger.

TABLE II.—DAILY RECORDS.

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate, and Stars Measured.	Obs'rs.
		Plate III.			
		° ′ ″			
Jan. 12	—0.0029	185 58 00	63.3	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–24, 26, 28, 29, 45.	S, K
" 13	—0.0026	275 57 57	67.0	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33.	S, H
" 18	—0.0026	5 58 00	63.2	*x* reversed; see Jan. 12.	S, K
" 19	—0.0021	185 57 57	60.8	*x* direct; 1, 2, 5, 7, 15, 23A, 25, 27, 31–37; 39, 40, 43–45.	K, H
" 20	—0.0016	95 58 02	63.6	*y* reversed; see Jan. 13.	S, H
" 21	—0.0025	275 58 01	65.2	*y* direct; 1, 5, 7, 15, 23A, 27, 31–37, 39, 40, 43–45.	S, H
" 23	—0.0035	5 58 00	60.5	*x* reversed; see Jan. 19.	K, H
" 26		275 58 00		Trails; 15, 23, 27, 31.	S, K
" 27	—0.0020	95 58 00	61.6	*y* reversed; see Jan. 21.	S, H
		Plate IX.			
		° ′ ″			
Feb. 5	+0.0028	177 37 02	63.2	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
" 8		267 37 01		Trails; 15, 23, 31, 37.	S, K
" 9	+0.0016	267 37 00	62.2	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22-29, 33.	K, H
" 10	+0.0010	267 36 58	63.6	*y* direct; 1, 5, 7, 15, 23A, 31–40, 43–45.	S, H
" 11	+0.0021	87 37 02	60.9	*y* reversed; see Feb. 10.	S, H
" 13	+0.0006	87 37 01	63.5	*y* reversed; see Feb. 9.	K, H
" 16	+0.0031	357 37 02	64.2	*x* reversed; see Feb. 19.	K, H
" 17	—0.0016	357 37 00	65.9	*x* reversed; see Feb. 5.	S, K
" 19	+0.0036	177 37 02	66.4	*x* direct; 1, 2, 5, 7, 15, 23A, 31–40, 43–45.	K, H
		Plate VII.			
		° ′ ″			
Feb. 26	+0.0026	86 54 00	63.8	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31–33, 45.	S, H
" 27	+0.0030	356 54 00	62.1	*y* reversed; see Mar. 1.	S, K
Mar. 1	+0.0039	176 54 02	59.4	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31–33.	S, K
" 2	+0.0011	176 54 02	65.1	*y* direct; 1, 5, 7, 7A, 15, 19, 21, 23A, 33–45.	K, H
" 3	+0.0039	86 53 58	65.9	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 21, 23A, 34–45	S, H
" 4	+0.0044	266 53 56	66.8	*x* reversed; see Feb. 26.	S, H
" 5		176 54 00		Trails; 15, 22, 23, 31.	S, H
" 6	+0.0045	356 54 03	65.8	*y* reversed; see Mar. 2.	K, H
" 8	+0.0026	266 54 00	60.8	*x* reversed; see Mar. 3.	S, H

TABLE II.—DAILY RECORDS. (*Continued.*)

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate, and Stars Measured.	Obsr's.
		Plate VIII.			
Mar. 15	+0.0036	177° 02′ 28″	56.8	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31, 45.	S, K
" 16	+0.0036	267 02 30	62.6	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22, 29, 31, 33.	K, H
" 17	+0.0039	357 02 31	60.4	*x* reversed; see Mar. 15.	S, K
" 18	+0.0036	357 02 27	62.3	*x* reversed; see Mar. 25.	S, H
" 20	+0.0050	87 02 32	62.0	*y* reversed; see Mar. 16.	K, H
" 22	+0.0045	87 02 28	64.6	*y* reversed; see Mar. 24.	S, K
" 23		267 02 29		Trails; 15, 22, 23, 31.	K, H
" 24	+0.0042	267 02 34	63.9	*y* direct; 1, 5, 7, 7A, 15, 19, 23A, 32–45.	S, K
" 25	+0.0045	177 02 29	62.8	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 32–45.	S, H
		Plate II.			
Apr. 3	+0.0015	276° 00′ 00″	65.9	*y* direct; 2, 4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33.	K, H
" 5	+0.0015	185 59 59	65.9	*x* direct; 2, 4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
" 6	+0.0001	96 00 02	67.8	*y* reversed; see Apr. 3.	K, H
" 7	+0.0018	6 00 00	67.8	*x* reversed; see Apr. 5.	S, K
" 8	+0.0035	6 00 00	67.6	*x* reversed; see Apr. 10.	S, H
" 9	+0.0046	276 00 00	64.7	*y* direct; 1, 5, 7, 7A, 15, 19, 23A, 27, 31–40, 43–45.	K, H
" 10	+0.0055	185 59 58	65.6	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 31–40, 43–45.	S, H
" 14	+0.0062	95 59 59	65.9	*y* reversed; see Apr. 9.	K, H
		Plate IV.			
Apr. 24	+0.0101	186° 16′ 58″	69.7	*x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
" 28	+0.0109	6 17 01	65.9	*x* reversed; see Apr. 24.	S, K
" 29	+0.0151	276 17 00	66.9	*y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33.	S, K
May 1	+0.0165	96 17 02	67.5	*y* reversed; see Apr. 29.	S, K
" 3	+0.0155	96 16 58	65.0	*y* reversed; see May 5.	S, K
" 4	+0.0136	186 16 58	66.0	*x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 31–40, 43–45.	S, K
" 5	+0.0156	276 16 57	66.9	*y* direct; 1, 5, 7, 7A, 15, 19, 23A, 27, 31–40, 43–45.	S, K
" 6	+0.0160	6 17 00	68.8	*x* reversed; see May 4.	S, K
" 8		276 17 01		Trails; 15, 23, 31, 37.	S, K

TABLE II.—DAILY RECORDS. (*Concluded.*)

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate, and Stars Measured.	Obs'rs.
		Plate I.			
Nov. 3	—0.0080	187° 10′ 05″	65.3	x direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29.	S, K
" 4	—0.0062	187 10 04	63.8	x direct; 1, 2, 5, 7, 15, 23A, 31–40, 43, 44.	S, K
" 6	—0.0076	277 10 06	65.4	y direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 33.	S, K
" 10	—0.0056	277 10 03	65.0	y direct; 1, 5, 7, 15, 23A, 31–40, 43, 44.	S, K
" 11	—0.0064	7 10 07	67.0	x reversed; see Nov. 3.	S, K
" 13	—0.0066	7 10 05	64.1	x reversed; see Nov. 4.	S, K
" 16	—0.0069	97 10 05	65.2	y reversed; see Nov. 6.	S, K
" 17		277 10 08		Trails; 15, 23, 31, 37.	S, K
" 18	—0 0065	97 10 05	64.6	y reversed; see Nov. 10.	S, K
		Plate V.			
Nov. 20	—0.0041	176° 09′ 07″	64.5	x direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45.	S, K
" 23	—0.0060	176 09 07	64.2	x direct; 1, 2, 5, 7, 15, 19, 23A, 31, 32, 34, 35, 37, 39, 40, 43–45.	S, K
" 24	—0.0061	266 09 07	68.7	y direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29.	S, K
" 26	—0.0059	266 09 06	71.0	y direct; 1, 5, 7, 15, 19, 23A, 31, 32, 34, 35, 37, 39, 40, 43–45.	S, K
" 27	—0.0068	356 09 07	68.5	x reversed; see Nov. 20.	S, K
" 30	—0.0072	356 09 04	63.4	x reversed; see Nov. 23.	S, K
Dec. 1	—0.0065	86 09 07	66.1	y reversed; see Nov. 24.	S, K
" 2	—0.0058	86 09 08	65.4	y reversed; see Nov. 26.	S, K

On the next page is given a specimen of the recording sheets; all the measurements relating to the same star for any one plate are recorded on one sheet. The forms are not designed for the separate reduction of the two impressions of a group which appear on each plate, but the mean of the measurements on the two images of a star is taken at once; that is, each star is treated as though it occupied the middle point between its two images. The place of this point is known when we have given the lines of the scale used in the measurement and the quantity $\frac{1}{2}m$, which is obtained thus: from the reading on the scale we subtract the reading on the star, and the mean of these differences for both images is taken, giving "Mean of Diff's;" as the scale is one of millimetres and as *two* complete turns of the screw correspond to a space on the scale we divide by 2 and get $\frac{1}{2}m$. In reading on the scale it was made a rule to select the line having the next lower number; consequently the place of a star is obtained by *adding* $\frac{1}{2}m$ to the mean of the numbers of the lines used; in rare cases, however, the next higher line was employed when it came nearly opposite to a star, as on March 24; this has been indicated by affixing a minus sign to $\frac{1}{2}m$. In the y measurements the same line was always used for both images, since the latter differ only in apparent right ascension.

Table III gives the uncorrected observations; it is only necessary to set down the numbers of the lines used and $\frac{1}{2}m$, for these not only fix the place of the star but, as we shall see later, they are sufficient for the application of all instrumental corrections. The numbers of the stars are in the order of increasing right ascensions and are those given by Professor Schur,* excepting 7*A* and 23*A*, which do not appear in his triangulation of the group. The table gives the observations of $\frac{1}{2}m$ by both observers, followed by the difference reduced to seconds of arc in order to facilitate a comparison.

* "Astronomische Mittheilungen der K. Sternwarte zu Göttingen," part IV.

Præsepe. Plate VIII. Star 7.

March 25, 1897; x direct.

	Star. Microm.	Scale. Line.	Scale. Microm	Diff's of Mean
East	9 053 .050	74	10.680 .681	
Mean	9.0515		10.6805	1.6290
West	9.050 .051	76	9.280 .280	
Mean	9 0505		9.2800	0.2295

Mean of Diff's = 0.9292
$\frac{1}{2}m$ = 0.4546
Measured by Hays.
Recorded by Schl.

	Star. Microm.	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.597 .598	74	11.229 .230	
Mean	9.5975		11.2295	1 6320
West	9.579 .574	76	9.800 .800	
Mean	9.5765		9.8000	0.2235

Mean of Diff's = 0.9278
$\frac{1}{2}m$ = 0.4639
Measured by Schl.
Recorded by Hays.

March 24, 1897; y direct.

	Star. Microm.	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.030 .030	36	9.009 .010	
Mean	9.0300		9.0095	—0.0205
West	9 050 .050	36	9.009 .009	
Mean	9.0500		9.0090	—0.0410

Mean of Diff's = —0.0308
$\frac{1}{2}m$ = —0.0154
Measured by Schl.
Recorded by Kretz.

	Star. Microm	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.547 .540	36	9.515 .518	
Mean	9.5435		9.5165	—0 0270
West	9.562 .560	36	9.517 .517	
Mean	9.5610		9 5170	—0.0440

Mean of Diff's = —0.0355
$\frac{1}{2}m$ = —0.0178
Measured by Kretz.
Recorded by Schl.

March 18, 1897; x reversed.

	Star. Microm.	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.024 .035	44	10.513 .512	
Mean	9.0295		10.5125	1.4830
West	9.013 .023	43	9.910 .910	
Mean	9.0180		9.9100	0 8920

Mean of Diff's = 1.1875
$\frac{1}{2}m$ = 0.5938
Measured by Schl.
Recorded by Hays.

	Star. Microm.	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.550 .543	44	11.021 .020	
Mean	9.5465		11.0205	1 4740
West	9.535 .535	43	10.420 .419	
Mean	9.5350		10.4195	0 8845

Mean of Diff's = 1.1792
$\frac{1}{2}m$ = 0.5896
Measured by Hays.
Recorded by Schl.

March 22, 1897; y reversed.

	Star. Microm.	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.081 .085	83	10.214 .212	
Mean	9.0830		10.2130	1.1300
West	9.070 .069	83	10.212 .211	
Mean	9.0695		10.2115	1.1420

Mean of Diff's = 1.1360
$\frac{1}{2}m$ = 0.5680
Measured by Schl.
Recorded by Kretz.

	Star. Microm.	Scale. Line.	Scale. Microm.	Diff's of Mean
East	9.555 .555	83	10.681 .684	
Mean	9.5550		10.6825	1 1275
West	9.545 .540	83	10.683 .683	
Mean	9.5425		10.6830	1.1405

Mean of Diff's = 1.1340
$\frac{1}{2}m$ = 0.5670
Measured by Kretz.
Recorded by Schl.

Table III.—Plate I: x Measurements.

Star.	x direct.				x reversed.			
	Lines.	½ m, or Scale *minus* Star.		S—K	Lines.	½ m, or Scale *minus* Star.		S—K
		Schl.	Kretz.			Schl.	Kretz.	
15	60,61	0.9016	0.8984	+0.″19	57,58	0.6695	0 6681	+0.″07
15	60,61	0.9010	0.8994	+ .07	57,58	0.6685	0.6696	— .06
2	94,95	0.4114	0.4114	.00	24,25	0.1652	0.1635	+ .08
3	93,94	0.2961	0.2954	+ .04	25,26	0.2798	0.2782	+ .08
4	91,92	0.5395	0.5419	— .13	27,28	0.0356	0.0348	+ .04
6	78,79	0.3274	0.3290	— .08	40,41	0.2472	0.2455	+ .08
8	71,72	0.4849	0.4878	— .15	47,48	0.0884	0.0849	+ .19
10	70,71	0.5885	0.5859	+ .14	48,49	— .0174	— .0169	— .03
11	69,70	0.7241	0.7252	— .06	48,49	0.8429	0.8451	— .12
14	61.62	0.1022	0.1020	+ .01	57,58	0.4649	0.4684	— .19
16	60	0.4836	0.4858	— .12	58,59	0.5859	0.5871	— .06
17	58,59	0.5726	0.5739	— .07	60,61	— .0020	— .0006	— .07
18	57,58	0.0299	0.0321	— .12	61,62	0.5404	0.5391	+ .07
20	56.57	0.6860	0.6865	— .03	61,62	0.8866	0.8865	.00
22	54,55	0.7451	0.7494	— .23	63,64	0 8208	0.8221	— .08
23	53,54	0.3750	0.3759	— .05	65,66	0.1946	0.1944	+ .01
24	51,52	0.2446	0.2451	— .03	67,68	0.3272	0.3256	+ .08
25	50,51	0.6644	0.6640	+ .02	67,68	0.9106	0.9080	+ .13
26	50,51	0.5456	0.5480	— .13	68,69	0.0282	0.0231	+ .27
27	50,51	0.2915	0.2942	— .14	68,69	0.2752	0.2784	— .17
28	50,51	0.0596	0.0622	— .14	68,69	0.5080	0.5075	+ .03
29	49,50	0.4759	0.4772	— .07	69,70	0.0936	0.0944	— .04
15	60,61	0.9005	0.8999	+0.″02	57,58	0.6698	0.6682	+0.″08
15	60,61	0.9009	0.8990	+ .12	57,58	0.6688	0.6669	+ .10
1	95,96	0.4069	0.4066	+ .02	23,24	0.1675	0.1684	— .05
2	94,95	0.4126	0.4120	+ .03	24,25	0.1625	0.1616	+ .05
5	82,83	0.5152	0.5181	— .15	36,37	0.0534	0.0540	— .03
7	75,76	0.5840	0.5830	+ .05	43,44	— .0130	— .0164	+ .18
23A	52,53	0.3599	0.3531	+ .36	66,67	0.2135	0.2155	— .11
31	48,49	0.8738	0.8725	+ .08	69,70	0.6971	0.6972	— .01
32	47,48	— .0078	— .0088	+ .05	71,72	0.5745	0.5799	— .29
33	45,46	0.3332	0.3376	— .23	73,74	0.2350	0.2410	— .32
34	44,45	0.6959	0.7006	— .25	73,74	0.8731	0.8708	+ .13
35	42,43	0.7008	0.7029	— .12	75,76	0.8659	0.8645	+ .08
36	41,42	0.2239	0.2221	+ .09	77,78	0.3489	0.3515	— .14
37	41,42	0.0792	0.0799	— .04	77,78	0.4944	0.4919	+ .13
38	37,38	0.4668	0.4691	— .12	81,82	0.1081	0.1061	+ .10
39	36,37	0.7224	0.7174	+ .26	81,82	0.8555	0.8554	.00
40	34,35	0.8836	0.8819	+ .08	83,84	0.6880	0.6890	— .05
43	27,28	— .0094	— .0124	+ .16	91,92	0.5789	0.5781	+ .04
44	26,27	0.4574	0.4624	— .26	92,93	0.1164	0.1168	— .02

Table III.—Plate I: *y* Measurements.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*S—K*	Line.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	52	0.3166	0.3169	—0″.02	67	0.2538	0.2550	—0″.06
15	52	0.3140	0.3176	— .19	67	0.2551	0.2545	+ .03
2	48	0.8969	0.8979	— .06	70	0.6722	0.6735	— .07
3	34	0.3140	0.3131	+ .05	85	0.2620	0.2640	— .11
4	17	0.2278	0.2255	+ .12	102	0.3502	0.3512	— .05
6	66	0.5180	0.5181	— .01	53	0.0520	0.0530	— .05
8	67	0.2651	0.2636	+ .08	52	0.3064	0.3069	— .03
10	45	0.2985	0.2952	+ .17	74	0.2756	0.2744	+ .06
11	39	0.5589	0.5594	— .03	80	0.0149	0.0134	+ .08
14	73	0.2576	0.2595	— .10	46	0.3138	0.3102	+ .19
16	18	0.0766	0.0752	+ .07	101	0.4996	0.5044	— .25
17	36	0.1639	0.1634	+ .03	83	0.4050	0.4050	.00
18	37	0.0128	0.0138	— .05	82	0.5598	0.5579	+ .10
20	36	0.2369	0.2336	+ .17	83	0.3358	0.3385	— .14
22	68	—.0124	—.0101	— .12	51	0.5811	0.5822	— .06
23	65	0.5135	0.5144	— .05	54	0.0558	0.0571	— .07
24	35	0.6510	0.6511	— .01	83	0.9205	0.9208	— .03
25	46	0.1918	0.1918	.00	73	0.3802	0.3779	+ .12
26	23	0.2064	0.2035	+ .15	96	0.3684	0.3689	— .03
27	45	0.0530	0.0535	— .03	74	0.5215	0.5174	+ .22
28	56	0.2920	0.2919	+ .01	63	0.2778	0.2786	— .04
29	79	0.9150	0.9150	.00	39	0.6569	0.6605	— .19
33	15	0.0512	0.0539	— .14	104	0.5241	0.5222	+ .10
15	52	0.3161	0.3172	—0″.06	67	0.2540	0.2525	+0″.08
15	52	0.3174	0.3172	+ .01	67	0.2535	0.2536	— .01
1	68	0.0005	0.0006	— .01	51	0.5711	0.5720	— .05
5	81	0.2686	0.2674	+ .06	38	0.3002	0.2992	+ .05
7	33	0.2762	0.2805	— .23	86	0.2989	0.2975	+ .07
23A	67	0.1061	0.1066	— .03	52	0.4675	0.4684	— .05
31	36	0.5514	0.5510	+ .02	83	0.0161	0.0155	+ .03
32	12	0.7218	0.7219	— .01	106	0.8538	0.8489	+ .26
33	15	0.0512	0.0515	— .02	104	0.5244	0.5242	+ .01
34	48	0.4732	0.4788	— .30	71	0.0906	0.0889	+ .09
35	85	0.7528	0.7519	+ .05	33	0.8198	0.8231	— .16
36	63	0.1924	0.1936	— .06	56	0.3759	0.3762	— .02
37	39	0.0658	0.0655	+ .02	80	0.5042	0.5071	— .15
38	56	0.0759	0.0802	— .23	63	0.4912	0.4900	+ .06
39	62	0.3799	0.3780	+ .10	57	0.1916	0.1932	— .08
40	17	0.4095	0.4081	+ .07	102	0.1689	0.1674	+ .08
43	59	0.2589	0.2636	— .25	60	0.3096	0.3105	— .05
44	78	0.6826	0.6850	— .13	40	0.8895	0.8870	+ .12

TABLE III.—(*Continued.*) PLATE II: x MEASUREMENTS.

Star.	x direct. Lines.	½ m, or Scale *minus* Star. Schl.	½ m, or Scale *minus* Star. Kretz.	$S—K$	x reversed. Lines.	½ m, or Scale *minus* Star. Schl.	½ m, or Scale *minus* Star. Kretz.	$S—K$
				″				″
15	63,64	0.7105	0.7096	+0.05	54,55	0.8424	0.8400	+0.12
15	63,64	0.7085	0.7099	— .07	54,55	0.8422	0.8426	— .02
2	97,98	0.2185	0.2192	— .04	21,22	0.3390	0.3380	+ .05
4	94,95	0.3538	0.3585	— .25	24,25	0.2039	0.1984	+ .29
6	81,82	0.1314	0.1352	— .20	37,38	0.4219	0.4200	+ .10
8	74,75	0.2901	0.2916	— .08	44,45	0.2625	0.2612	+ .07
10	73,74	0.3949	0.3975	— .14	45,46	0.1579	0.1584	— .03
11	72,73	0.5386	0.5364	+ .12	46	0.5189	0.5141	+ .25
14	64	0.4098	0.4100	— .01	54,55	0.6420	0.6401	+ .10
16	62,63	0.7976	0.7986	— .05	55,56	0.7551	0.7531	+ .10
17	61,62	0.3892	0.3901	— .05	57,58	0.1654	0.1615	+ .21
18	59,60	0.8448	0.8468	— .12	58,59	0.7078	0.7072	+ .03
20	59,60	0.5010	0.4991	+ .10	59,60	0.0539	0.0565	— .14
22	57,58	0.5558	0.5589	— .16	61	0.4941	0.4908	+ .19
23	56,57	0.1874	0.1871	+ .02	62,63	0.3664	0.3642	+ .12
24	54,55	0.0610	0.0612	— .01	64,65	0.4884	0.4902	— .10
25	53,54	0.4784	0.4780	+ .02	65,66	0.0745	0.0722	+ .12
26	53,54	0.3661	0.3669	— .04	65,66	0.1869	0.1885	— .09
27	53,54	0.1111	0.1118	— .04	65,66	0.4440	0.4401	+ .21
28	52,53	0.8736	0.8748	— .06	65,66	0.6789	0.6774	+ .08
29	52,53	0.2845	0.2878	— .17	66,67	0.2669	0.2612	+ .30
45	25	0.4730	0.4744	— .07	93,94	0.5818	0.5840	— .12
		Schl.	Hays	$S—H$		Schl.	Hays	$S—H$
				″				″
15	63,64	0.7105	0.7124	—0.10	54,55	0.8412	0.8419	—0.03
15	63,64	0.7130	0.7108	+ .12	54,55	0.8408	0.8409	— .01
1	98,99	0.2198	0.2182	+ .08	20,21	0.3396	0.3376	+ .10
2	97,98	0.2161	0.2202	— .22	21,22	0.3398	0.3376	+ .12
5	85,86	0.3189	0.3158	+ .16	33,34	0.2370	0.2384	— .07
7	78,79	0.4000	0.3978	+ .12	40,41	0.1598	0.1588	+ .05
7A	74,75	0.3018	0.3010	+ .04	44,45	0.2538	0.2531	+ .04
19	59,60	0.8144	0.8172	— .15	58,59	0.7409	0.7334	+ .39
23A	55,56	0.1681	0.1626	+ .29	63,64	0.3889	0.3884	+ .03
31	51,52	0.6891	0.6871	+ .12	66,67	0.8675	0.8676	— .01
32	49,50	0.8098	0.8086	+ .06	68,69	0.7445	0.7426	+ .10
33	48,49	0.1569	0.1561	+ .04	70,71	0.3988	0.4004	— .08
34	47,48	0.5111	0.5140	— .15	71	0.5398	0.5425	— .15
35	45,46	0.5094	0.5122	— .15	73	0.5412	0.5445	— .18
36	44	0.5342	0.5275	+ .36	74,75	0.5245	0.5174	+ .38
37	43,44	0.8969	0.8980	— .05	74,75	0.6581	0.6594	— .07
38	40,41	0.2764	0.2762	+ .01	78,79	0.2790	0.2751	+ .21
39	39,40	0.5344	0.5344	.00	79	0.5228	0.5226	+ .01
40	37,38	0.6996	0.6971	+ .13	80,81	0.8536	0.8578	— .21
43	29,30	0.8098	0.8078	+ .11	88,89	0.7468	0.7445	+ .13
44	29,30	0.2696	0.2618	+ .41	89,90	0.2901	0.2881	+ .11
45	25	0.4734	0.4758	— .12	93,94	0.5821	0.5852	— .16

TABLE III.—(*Continued.*) PLATE II: *y* MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*K—H*	Line.	½ *m*, or Scale *minus* Star.		*K—H*
		Kretz.	Hays.			Kretz.	Hays.	
15	51	0.4148	0.4171	″ —0.12	68	0.1352	0.1344	″ +0.04
15					68	0.1355	0.1368	— .07
2	48	0.0102	0.0088	+ .07	71	0.5406	0.5432	— .14
4	16	0.3411	0.3412	— .01	103	0.2192	0.2192	.00
6	65	0.6206	0.6175	+ .16	53	0.9330	0.9344	— .08
8	66	0.3665	0.3671	— .03	53	0.1856	0.1838	+ .10
10	44	0.3996	0.3972	+ .13	75	0.1539	0.1514	+ .13
11	38	0.6644	0.6645	— .01	80	0.8918	0.8906	+ .07
14	72	0.3570	0.3578	— .04	47	0.1970	0.1950	+ .11
16	17	0.1786	0.1791	— .03	102	0.3780	0.3768	+ .06
17	35	0.2662	0.2641	+ .11	84	0.2851	0.2858	— .04
18	36	0.1135	0.1128	+ .04	83	0.4404	0.4381	+ .12
20	35	0.3360	0.3325	+ .19	84	0.2159	0.2160	— .01
22	67	0.0880	0.0889	— .05	52	0.4618	0.4609	+ .05
23	64	0.6105	0.6099	+ .03	54	0.9411	0.9408	+ .03
24	34	0.7494	0.7484	+ .06	84	0.8025	0.8048	— .13
25	45	0.2892	0.2860	+ .17	74	0.2620	0.2612	+ .04
26	22	0.3085	0.3072	+ .07	97	0.2479	0.2501	— .11
28	55	0.3882	0.3879	+ .02	64	0.1601	0.1598	+ .02
29	79	0.0066	0.0085	— .10	40	0.5452	0.5449	+ .02
33	14	0.1540	0.1538	+ .01	105	0.4014	0.3988	+ .14
15	51	0.4176	0.4178	″ —0.01	68	0.1374	0.1369	″ +0.03
15	51	0.4146	0.4166	— .11	68	0.1348	0.1381	— .17
1	67	0.1062	0.1050	+ .06	52	0.4448	0.4442	+ .03
5	80	0.3721	0.3734	— .07	39	0.1791	0.1778	+ .07
7	32	0.3801	0.3786	+ .08	87	0.1742	0.1741	+ .01
7A	47	0.6575	0.6584	— .04	71	0.8970	0.8958	+ .07
19	77	0.3065	0.3075	— .05	42	0.2455	0.2440	+ .08
23A	66	0.1972	0.1936	+ .19	53	0.3584	0.3549	+ .19
27	44	0.1530	0.1530	.00	75	0.4005	0.3972	+ .17
31	35	0.6549	0.6524	+ .13	83	0.9032	0.9024	+ .05
32	11	0.8212	0.8249	— .21	107	0.7351	0.7302	+ .26
33	14	0.1548	0.1532	+ .08	105	0.4031	0.4030	+ .01
34	47	0.5749	0.5725	+ .13	71	0.9784	0.9769	+ .10
35	84	0.8458	0.8426	+ .16	34	0.7100	0.7115	— .08
36	62	0.2885	0.2879	+ .03	57	0.2629	0.2646	— .09
37	38	0.1672	0.1659	+ .07	81	0.3884	0.3875	+ .05
38	55	0.1725	0.1746	— .11	64	0.3778	0.3762	+ .08
39	61	0.4712	0.4724	— .06	58	0.0776	0.0781	— .03
40	16	0.5089	0.5050	+ .21	103	0.0502	0.0514	— .06
43	58	0.3500	0.3474	+ .14	61	0.2022	0.2029	— .04
44	77	0.7740	0.7744	— .02	41	0.7819	0.7749	+ .37
45	26	0.9096	0.9109	— .06	92	0.6474	0.6468	+ .03

TABLE III.—(*Continued.*) PLATE III: x MEASUREMENTS.

Star.	x direct.				x reversed.			
	Lines.	½ m, or Scale *minus* Star.		$S—K$	Lines.	½ m, or Scale *minus* Star.		$S—K$
		Schl.	Kretz.			Schl.	Kretz.	
				"				"
15	56	0.3911	0.3919	—0.04	62,63	0.6618	0.6571	+0.25
2	89,90	0.4000	0.3988	+ .06	29	0.6560	0.6566	— .04
3	88,89	0.2970	0.2958	+ .06	30,31	0.2614	0.2550	+ .34
4	86,87	0.5528	0.5500	+ .16	32	0.5092	0.5078	+ .06
6	73,74	0.3035	0.3024	+ .06	45,46	0.2494	0.2486	+ .04
8	66,67	0.4601	0.4549	+ .28	52	0.5961	0.5900	+ .31
10	65,66	0.5760	0.5751	+ .06	53	0.4779	0.4745	+ .17
11	64,65	0.7194	0.7164	+ .15	53,54	0.8316	0.8298	+ .10
14	56	0.5784	0.5782	+ .01	62,63	0.4718	0.4712	+ .04
16	55	0.4950	0.4929	+ .11	63,64	0.5551	0.5549	+ .02
17	53,54	0.5736	0.5715	+ .10	65	0.4799	0.4765	+ .19
18	52	0.5315	0.5326	— .05	66,67	0.5189	0.5174	+ .07
20	51,52	0.6865	0.6869	— .02	67	0.3662	0.3678	— .08
22	49,50	0.7265	0.7282	— .08	68,69	0.8251	0.8240	+ .05
23	48,49	0.3615	0.3651	— .19	70,71	0.1871	0.1900	— .16
24	46,47	0.2424	0.2431	— .04	72,73	0.3086	0.3092	— .03
26	45,46	0.5581	0.5551	+ .15	73	0.4976	0.4960	+ .10
28	45	0.5479	0.5492	— .07	73,74	0.5059	0.5044	+ .08
29	44,45	0.4485	0.4481	+ .02	74	0.6046	0.6075	— .15
45	17,18	0.1620	0.1652	— .18	101,102	0.3970	0.3919	+ .28
		Kretz.	Hays.	$K—H$		Kretz.	Hays.	$K—H$
				"				"
15	56	0.3914	0.3921	—0.04	62,63	0.6609	0.6606	+0.01
1	90,91	0.3850	0.3879	— .15	28,29	0.1676	0.1706	— .15
2	89,90	0.4021	0.3982	+ .19	29,30	0.1490	0.1516	— .15
5	77,78	0.4799	0.4805	— .03	41	0.5679	0.5720	— .21
7	70,71	0.5824	0.5838	— .07	48	0.4679	0.4664	+ .08
23A	47,48	0.3338	0.3400	— .33	71,72	0.2149	0.2169	— .12
25	45,46	0.6594	0.6636	— .23	73	0.3872	0.3941	— .37
27	45,46	0.2888	0.2896	— .04	73,74	0.2650	0.2638	+ .07
31	44	0.3776	0.3795	— .10	74,75	0.6784	0.6780	+ .03
32	42	0.5044	0.5028	+ .09	76,77	0.5489	0.5510	— .11
33	40,41	0.3505	0.3565	— .31	78,79	0.2052	0 2025	+ .15
34	39,40	0.6875	0.6896	— .12	79	0.3648	0.3654	— .04
35	37,38	0.6701	0.6732	— .16	81	0.3848	0.3850	— .01
36	36,37	0.2011	0.2008	+ .01	82,83	0.3482	0.3489	— .04
37	36	0.5816	0.5810	+ .03	82,83	0.4754	0.4729	+ .13
39	31,32	0.7004	0.7045	— .22	87	0.3522	0.3499	+ .12
40	30	0.3930	0.3948	— .11	88,89	0.6641	0.6649	— .05
43	22	0.4799	0.4785	+ .07	96,97	0.5762	0.5755	+ .03
44	21,22	0.4258	0.4301	— .24	97	0.6301	0.6301	.00
45	17,18	0.1648	0.1620	+ .14	101,102	0.3924	0.3916	+ .04

TABLE III.—(*Continued.*) PLATE III: *y* MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*S—H*	Line.	½ *m*, or Scale *minus* Star.		*S—H*
		Schl.	Hays.			Schl.	Hays.	
15	53	0.7856	0.7866	—0″.06	65	0.7708	0.7681	+0″.14
2	50	0.3928	0.3918	+ .05	69	0.1626	0.1632	— .04
3	35	0.8020	0.8015	+ .03	83	0.7534	0.7555	— .11
4	18	0.7200	0.7194	+ .03	100	0.8375	0.8408	— .17
6	67	0.9966	0.9959	+ .05	51	0.5574	0.5572	+ .01
8	68	0.7408	0.7428	— .10	50	0.8144	0.8135	+ .05
10	46	0.7719	0.7692	+ .14	72	0.7849	0.7830	+ .10
11	41	0.0348	0.0328	+ .11	78	0.5232	0.5200	+ .16
14	74	0.7250	0.7204	+ .24	44	0.8316	0.8282	+ .17
16	19	0.5458	0.5422	+ .18	100	0.0146	0.0119	+ .14
17	37	0.6339	0.6324	+ .08	81	0.9212	0.9208	+ .03
18	38	0.4796	0.4758	+ .21	81	0.0778	0.0741	+ .20
20	37	0.7001	0.7011	— .05	81	0.8534	0.8512	+ .12
22	69	0.4481	0.4520	— .20	50	0.1001	0.0995	+ .04
23	66	0.9716	0.9748	— .18	52	0.5775	0.5795	— .11
24	37	0.1121	0.1108	+ .07.	82	0.4415	0.4392	+ .13
25	47	0.6516	0.6499	+ .10	71	0.9010	0.8996	+ .08
26	24	0.6665	0.6665	.00	94	0.8871	0 8880	— .04
28	57	0.7496	0.7475	+ .11	61	0.8059	0.8040	+ .10
29	81	0.3720	0.3685	+ .18	38	0.1829	0.1800	+ .15
33	16	0.5105	0.5121	— .10	103	0.0479	0.0425	+ .28
15	53	0.7829	0.7849	—0″.10	65	0.7679	0.7654	+0″.14
1	69	0 4875	0.4878	— .03	50	0.0631	0.0631	.00
5	82	0.7499	0.7450	+ .25	36	0.8035	0.8031	+ .02
7	34	0.7538	0.7535	+ .02	84	0.8054	0.8001	+ .29
23A	68	0.5646	0.5611	+ .19	50	0.9911	0.9874	+ .21
27	46	0.5160	0.5145	+ .08	73	0.0391	0.0369	+ .12
31	38	0.0155	0.0181	— .14	81	0.5379	0.5371	+ .04
32	14	0.1861	0.1812	+ .25	105	0.3760	0.3750	+ .05
33	16	0.5112	0.5112	.00	103	0.0484	0.0438	+ .24
34	49	0.9341	0.9330	+ .05	69	0.6175	0.6154	+ .11
35	87	0.2068	0.2039	+ .15	32	0.3486	0.3469	+ .08
36	64	0.6476	0.6454	+ .12	54	0.9068	0.9066	+ .02
37	40	0.5184	0.5215	— .16	79	0.0340	0.0320	+ .11
39	63	0.8299	0.8256	+ .22	55	0.7232	0.7225	+ .03
40	18	0.8654	0.8618	+ .20	100	0.6912	0.6911	+ .01
43	60	0.7026	0.7032	— .03	58	0.8524	0.8500	+ .13
44	80	0.1296	0.1265	+ .17	39	0.4255	0.4234	+ .12
45	29	0.2606	0.2582	+ .13	90	0.2991	0.2939	+ .28

TABLE III.—(*Continued.*) PLATE IV: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star. Schl.	½ *m*, or Scale *minus* Star. Kretz.	*S—K*	Lines.	½ *m*, or Scale *minus* Star. Schl.	½ *m*, or Scale *minus* Star. Kretz.	*S—K*
15	58,59	0.1086	0.1090	—0.″02	60,61	0.4401	0.4376	+0.″13
15	58,59	0.1098	0.1102	— .02	60,61	0.4404	0.4382	+ .12
2	91,92	0.6132	0.6136	— .02	27	0.4422	0.4411	+ .06
3	90,91	0.4950	0.4922	+ .15	28	0.5600	0.5594	+ .04
4	88,89	0.7311	0.7309	+ .01	29,30	0.8258	0.8249	+ .05
6	75,76	0.5378	0.5355	+ .12	43	0.5160	0.5156	+ .02
8	68,69	0.7006	0.6994	+ .06	50	0.3525	0.3500	+ .13
10	67,68	0.7929	0.7919	+ .06	50,51	0.7615	0.7609	+ .03
11	67	0.4274	0.4251	+ .12	51,52	0.6255	0.6258	— .02
14	58,59	0.3225	0.3204	+ .11	60,61	0.2276	0.2272	+ .02
16	57,58	0.1772	0.1769	+ .02	61,62	0.3724	0.3735	— .06
17	55,56	0.7785	0.7760	+ .13	62,63	0.7741	0.7760	— .09
18	54,55	0.2394	0.2390	+ .02	64,65	0.3106	0.3105	+ .01
20	54	0.3919	0.3916	+ .02	64,65	0.6571	0.6581	— .05
22	52	0.4664	0.4679	— .08	66,67	0.5841	0.5841	.00
23	50,51	0.5970	0.5962	+ .04	68	0.4560	0.4542	+ .10
24	48,49	0.4505	0.4506	— .01	70	0.6004	0.6036	— .17
25	48	0.3772	0.3728	+ .23	70,71	0.6758	0.6746	+ .06
26	47,48	0.7520	0.7505	+ .07	70,71	0.8045	0.8032	+ .08
27	47,48	0.5058	0.5064	— .03	71	0.5465	0.5438	+ .15
28	47,48	0.2779	0.2762	+ .08	71,72	0.2745	0.2740	+ .03
29	46,47	0.7029	0.7000	+ .15	72	0.3510	0.3495	+ .08
45	19,20	0.3636	0.3658	— .12	99,100	0.1926	0.1918	+ .04
15	58	0.6106	0.6114	—0.″03	60,61	0.4404	0.4411	—0.″03
15	58	0.6108	0.6094	+ .06	60,61	0.4415	0.4379	+ .19
1	92,93	0.6165	0.6235	— .37	26	0.4415	0.4395	+ .10
2	91,92	0.6136	0.6129	+ .04	27	0.4419	0.4405	+ .07
5	79,80	0.7375	0.7375	.00	38,39	0.8199	0.8202	— .01
7	72,73	0.7816	0.7840	— .12	45,46	0.7742	0.7744	— .02
7A	68,69	0.6918	0.6942	— .13	50	0.3619	0.3602	+ .09
19	54,55	0.2284	0.2284	.00	64,65	0.3215	0.3205	+ .05
23A	49,50	0.5751	0.5765	— .07	69	0.4772	0.4790	— .10
31	46	0.5839	0.5828	+ .05	72,73	0.4711	0.4691	+ .11
32	44,45	0.1821	0.1831	— .05	74,75	0.3680	0.3692	— .06
33	42,43	0.5291	0.5280	+ .05	76	0.5155	0.5175	— .11
34	42	0.4086	0.4081	+ .03	76,77	0.6442	0.6416	+ .14
35	40	0.4341	0.4365	— .13	78,79	0.6210	0.6191	+ .10
36	38,39	0.4386	0.4406	— .11	80	0.6144	0.6154	— .06
37	38,39	0.2875	0.2868	+ .04	80,81	0.2640	0.2649	— .05
38	34,35	0.6826	0.6850	— .12	84	0.3724	0.3726	— .02
39	34	0.4401	0.4415	— .07	84,85	0.6141	0.6149	— .04
40	32	0.5829	0.5836	— .03	86,87	0.4729	0.4742	— .07
43	24,25	0.2176	0.2154	+ .12	94,95	0.3385	0.3400	— .08
44	23,24	0.6931	0.6961	— .15	95	0.3649	0.3628	+ .12
45	19,20	0.3628	0.3605	+ .12	99,100	0.1922	0.1905	+ .09

TABLE III.—(*Continued.*) PLATE IV: y MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		$S-K$	Line.	½ *m*, or Scale *minus* Star.		$S-K$
		Schl.	Kretz.			Schl.	Kretz.	
15	54	0.3544	0.3561	—0.09″	65	0.1952	0.1934	+0.10″
15	54	0.3545	0.3578	— .17	65	0.1926	0.1939	— .07
2	50	0.9360	0.9344	+ .07	68	0.6195	0.6199	— .02
3	36	0.3470	0.3464	+ .03	83	0.2059	0.2051	+ .04
4	19	0.2672	0.2691	— .10	100	0.2875	0.2898	— .12
6	68	0.5526	0.5525	+ .01	50	0.9996	1.0015	— .12
8	69	0 2996	0.3001	— .03	50	0.2510	0.2481	+ .15
10	47	0.3356	0.3349	+ .03	72	0.2148	0.2164	— .08
11	41	0.5992	0.5962	+ .16	77	0.9564	0.9561	+ .03
14	75	0.2926	0.2945	— .10	44	0.2558	0.2565	— .04
16	20	0.1172	0.1185	— .07	99	0.4378	0.4361	+ .09
17	38	0.2076	0.2078	— .01	81	0.3446	0.3442	+ .02
18	39	0.0536	0.0534	+ .01	80	0.4979	0.4991	— .06
20	38	0.2798	0.2785	+ .07	81	0.2716	0.2736	— .11
22	70	0.0256	0.0255	+ .01	49	0.5252	0.5246	+ .03
23	67	0.5522	0.5525	— .02	52	—.0032	0.0002	— .18
24	37	0.6928	0.6925	+ .02	81	0.8572	0.8588	— .10
25	48	0.2345	0.2330	+ .08	71	0.3155	0.3162	— .04
26	25	0.2515	0.2508	+ .04	94	0.3014	0.3042	— .15
28	58	0.3315	0.3305	+ .05	61	0.2180	0.2182	— .01
29	81	0.9495	0.9505	— .06	37	0.6024	0.6021	+ .02
33	17	0.1019	0.0998	+ .11	102	0.4535	0.4555	— .11
15	54	0.3538	0.3568	—0.15″	65	0.1951	0.1922	+0.15″
15	54	0.3562	0.3579	— .08	65	0.1929	0.1904	+ .13
1	70	0.0282	0.0304	— .12	49	0.5239	0.5224	+ .07
5	83	0.2979	0.2979	.00	36	0.2529	0.2540	— .06
7	35	0.3186	0.3182	+ .02	84	0.2356	0.2362	— .03
7A	50	0.5930	0.5936	— .03	68	0.9646	0.9656	— .07
19	80	0.2471	0.2455	+ .08	39	0.3060	0.3088	— .15
23A	69	0.1386	0.1401	— .08	50	0.4115	0.4120	— .03
27	47	0.0961	0.0966	— .03	72	0.4552	0.4564	— .06
31	38	0.5966	0.5961	+ .02	80	0.9584	0.9589	— .04
32	14	0.7720	0.7728	— .04	104	0.7861	0.7886	— .13
33	17	0.1015	0.1024	— .05	102	0.4555	0.4562	— .04
34	50	0.5242	0.5254	— .06	69	0.0256	0.0276	— .11
35	87	0.7922	0.7922	.00	31	0.7645	0.7664	— .10
36	65	0.2356	0.2331	+ .13	54	0.3152	0.3154	— .01
37	41	0.1111	0.1115	— .02	78	0.4406	0.4410	— .02
38	58	0.1198	0.1186	+ .06	61	0.4311	0.4320	— .05
39	64	0.4198	0.4202	— .02	55	0.1292	0.1296	— .02
40	19	0.4612	0.4622	— .05	100	0.0895	0.0895	.00
43	61	0.2991	0.3002	— .06	58	0.2488	0.2490	— .01
44	80	0.7300	0.7276	+ .13	38	0.8281	0.8304	— .13
45	29	0.8686	0.8679	+ .03	89	0.6874	0.6874	.00

TABLE III.—(*Continued.*) PLATE V: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*. or Scale *minus* Star.		*S—K*	Lines.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	55,56	0.2626	0.2598	+0″.15	63,64	0.3082	0.3041	+0″.22
15	55,56	0.2629	0.2598	+ .16	63,64	0.3078	0.3055	+ .12
2	88,89	0.7681	0.7676	+ .03	29,30	0.8032	0.8031	+ .01
3	87,88	0.6692	0.6708	— .08	30,31	0.9018	0.9005	+ .06
4	85,86	0.9279	0.9281	— .02	32,33	0.6450	0.6451	— .01
6	72,73	0.6664	0.6684	— .11	45,46	0.8999	0.9011	— .07
8	65,66	0.8274	0.8279	— .03	52,53	0.7400	0.7415	— .08
10	64,66	0.4472	0.4454	+ .10	53,54	0.6195	0.6194	+ .01
11	64,65	0.0944	0.0921	+ .12	54,55	0.4770	0.4764	+ .03
14	55,56	0.4405	0.4400	+ .03	63,64	0.1269	0.1251	+ .10
16	54,55	0.3751	0.3738	+ .07	64,65	0.1938	0.1938	.00
17	52,54	0.4486	0.4476	+ .05	65,66	0.6221	0.6204	+ .09
18	51,52	0.4046	0.4030	+ .08	67,68	0.1645	0.1631	+ .07
20	51,52	0.0611	0.0592	+ .10	67,68	0.5110	0.5089	+ .11
22	49,50	0.0939	0.0929	+ .05	69,70	0.4755	0.4735	+ .11
23	47,48	0.7248	0.7234	+ .07	70,71	0.8448	0.8422	+ .14
24	45,46	0.6199	0.6192	+ .04	72,74	0.4516	0.4486	+ .17
25	45,46	0.0336	0.0326	+ .05	73,74	0.5389	0.5368	+ .11
26	44,46	0.4384	0.4380	+ .02	73,74	0.6342	0.6314	+ .15
27	44,45	0.6610	0.6584	+ .14	73,74	0.9106	0.9106	.00
28	44,45	0.4170	0.4146	+ .13	74,75	0.1540	0.1514	+ .14
29	43,44	0.8122	0.8128	— .03	74,75	0.7590	0.7554	+ .19
45	16,17	0.5412	0.5450	— .20	102,103	0.0298	0.0298	.00
15	55,56	0.2614	0.2596	+0″.10	63,64	0.3075	0.3050	+0″.13
15	55,56	0.2590	0.2598	— .04	63,64	0.3069	0.3049	+ .11
1	89,90	0.7531	0.7504	+ .14	28,29	0.8219	0.8161	+ .31
2	88,89	0.7692	0.7650	+ .22	29,30	0.8012	0.8020	— .05
5	76,77	0.8410	0.8396	+ .08	41,42	0.7296	0.7272	+ .13
7	69,71	0.4560	0.4555	+ .02	48,49	0.6126	0.6108	+ .10
19	51,52	0.3436	0.3415	+ .11	67,68	0.2275	0.2262	+ .07
23A	46,47	0.7032	0.7029	+ .02	71,72	0.8665	0.8656	+ .04
31	43,44	0.2522	0.2494	+ .15	75,76	0.3184	0.3155	+ .15
32	41,42	0.3892	0.3901	— .05	77,78	0.1858	0.1832	+ .14
34	39,40	0.0630	0.0658	— .15	79,80	0.5071	0,5039	+ .17
35	37,38	0.0308	0.0279	+ .15	81,82	0.5371	0.5326	+ .24
37	35,36	0.4526	0.4510	+ .08	83,84	0.1158	0.1126	+ .17
39	31,32	0.0745	0.0725	+ .11	87,88	0.4980	0.4962	+ .10
40	29,30	0.2818	0.2772	+ .24	89,90	0.2950	0.2902	+ .25
43	21,22	0.3564	0.3550	+ .07	97,98	0.2196	0.2159	+ .20
44	20,21	0.7966	0.7962	+ .02	97,98	0.7794	0.7735	+ .31
45	16,17	0.5421	0.5444	— .12	102,103	0.0304	0.0251	+ .28

TABLE III.—(*Continued.*) PLATE V: *y* MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*S—K*	Line.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	54	0.7016	0.7006	+0.″05	64	0.8646	0.8650	—0.″02
15	54	0.6999	0.7008	— .05	64	0.8625	0.8652	— .14
2	51	0.3171	0.3152	+ .10	68	0.2526	0.2556	— .16
3	36	0.7258	0.7270	— .06	82	0.8448	0.8426	+ .11
4	19	0.6431	0.6422	+ .05	99	0.9318	0.9300	+ .08
6	68	0.9181	0.9175	+ .02	50	0.6506	0.6496	+ .05
8	69	0.6558	0.6568	— .05	49	0.9089	0.9072	+ .10
10	47	0.6930	0.6931	— .01	71	0.8759	0.8748	+ .06
11	41	0.9518	0.9546	— .13	77	0.6155	0.6144	+ .06
14	75	0.6389	0.6386	+ .02	43	0.9291	0.9300	— .04
16	20	0.4612	0.4616	— .02	99	0.1106	0.1068	+ .20
17	38	0.5500	0.5489	+ .06	81	0.0182	0 0166	+ .08
18	39	0.3969	0.3975	— .03	80	0.1698	0.1715	— .09
20	38	0.6178	0.6168	+ .05	80	0.9494	0.9476	+ .08
22	70	0.3664	0.3648	+ .08	49	0.2002	0.2016	— .07
23	67	0.8894	0.8892	+ .02	51	0.6755	0.6768	— .07
24	38	0.0304	0.0291	+ .07	81	0.5392	0.5402	— .05
25	48	0.5638	0.5661	— .12	71	—.0008	—.0005	— .02
26	25	0.5840	0.5829	+ .06	94	—.0120	—.0119	— .01
27	47	0.4309	0.4311	— .01	72	0.1349	0.1350	— .01
28	58	0.6628	0.6626	+ .01	60	0.9031	0.9042	— .05
29	82	0.2832	0.2811	+ .11	37	0.2871	0.2846	+ .13
15	54	0.7029	0.7028	+0.″01	64	0.8622	0.8644	—0.″13
15	54	0.7035	0.7011	+ .13	64	0.8644	0.8636	+ .03
1	70	0.4172	0.4164	+ .04	49	0.1516	0.1570	— .29
5	83	0.6724	0.6675	+ .26	35	0.8962	0.8986	— .12
7	35	0.6772	0.6771	+ .01	83	0.8942	0.8971	— .14
19	80	0.5896	0.5870	+ .14	39	—.0152	—.0150	— .01
23A	69	0.4802	0.4760	+ .22	50	0.0929	0.0920	+ .05
31	38	0.9318	0.9305	+ .08	80	0.6404	0.6350	+ .29
32	15	0.1042	0.1020	+ .12	104	0.4722	0.4699	+ .12
34	50	0.8502	0.8475	+ .15	68	0.7165	0.7156	+ .05
35	88	0.1154	0.1148	+ .03	31	0.4542	0.4576	— .18
37	41	0.4381	0.4368	+ .07	78	0.1349	0.1339	+ .c5
39	64	0.7380	0.7364	+ .08	54	0.8279	0.8278	+ .01
40	19	0.7798	0.7792	+ .03	99	0.7938	0.7948	— .06
43	61	0.6096	0.6090	+ .03	57	0.9594	0.9584	+ .04
44	81	0.0361	0.0339	+ .12	38	0.5328	0.5342	— .07
45	30	0.1700	0.1699	+ .01	89	0.3978	0.4001	— .13

TABLE III.—(*Continued.*) PLATE VII: x MEASUREMENTS.

Star.	x direct.				x reversed.			
	Lines.	½ m, or Scale *minus* Star.		$S-H$	Lines.	½ m, or Scale *minus* Star.		$S-H$
		Schl.	Hays.			Schl.	Hays.	
				"				"
15	61,62	0.6390	0.6438	—0.25	56,58	0.4129	0.4134	—0.03
2	95,96	0.1465	0.1489	— .13	23,24	0.4122	0.4078	+ .23
3	93,95	0.5530	0.5496	+ .17	24,25	0.5062	0.5049	+ .07
4	92,93	0.3122	0.3115	+ .04	26,27	0.2438	0.2468	— .16
6	78,80	0.5484	0.5484	.00	39,40	0.5079	0.5094	— .08
8	72 73	0.2074	0.2076	— .01	46,47	0.3484	0.3449	+ .18
10	71,72	0.3296	0.3339	— .23	47,48	0.2242	0.2252	— .05
11	70,71	0.4775	0.4796	— .11	47,49	0.5779	0.5730	+ .25
14	61,62	0.8200	0.8219	— .10	56,57	0.7348	0.7306	+ .22
16	60,61	0.7609	0.7619	— .05	57.58	0.7938	0.7931	+ .03
17	59,60	0.3314	0.3268	+ .24	59,60	0.2208	0.2222	— .07
18	57,58	0.7879	0.7915	— .20	60,61	0.7640	0.7655	— .07
20	57,58	0.4450	0.4424	+ .14	60,62	0.6079	0.6100	— .10
22	55,56	0.4754	0.4781	— .14	62,64	0.5755	0.5742	+ .07
23	54,55	0.1081	0.1092	— .06	64,65	0.4446	0.4468	— .11
24	51,53	0.5110	0.5112	— .01	66,67	0.5442	0.5444	— .01
25	51,52	0.4162	0.4139	+ .12	67,68	0 1366	0.1356	+ .05
26	51,52	0.3231	0.3251	— .10	67,68	0.2321	0.2316	+ .03
27	50,52	0.5444	0.5456	— .06	67,68	0.5095	0.5095	.00
28	50,51	0.8028	0.8031	— .01	67,68	0.7540	0.7515	+ .13
29	50,51	0.1946	0.1925	+ .11	68,69	0.3584	0.3595	— .06
31	49,50	0.6379	0.6386	— .04	68,70	0.4170	0.4178	— .04
32	47,48	0.7781	0.7770	+ .06	70,71	0.7778	0.7756	+ .11
33	46,47	0.1226	0.1226	.00	72,73	0.4316	0.4350	— .18
45	22,24	0.4344	0.4370	— .13	95,96	0.6214	0.6179	+ .19
		Schl.	Kretz	$S-K$		Schl.	Kretz.	$S-K$
				"				"
15	61,62	0.6420	0.6444	—0.12	56,58	0.4105	0.4090	+0.08
1	96,97	0.1244	0.1286	— .22	22,23	0.4282	0.4268	+ .07
2	95,96	0.1474	0.1480	— .03	23,24	0.4101	0.4068	+ .17
5	83,84	0.2168	0.2158	+ .05	35.36	0.3389	0.3389	.00
7	76,77	0.3461	0.3411	+ .26	42,43	0.2086	0.2081	+ .03
7A	72.73	0.2332	0.2351	— .10	46,47	0.3231	0.3216	+ .08
19	57.58	0.7251	0.7224	+ .14	60,61	9.8312	0.8338	— .14
21	56,58	0.4262	0.4250	+ .06	61.62	0.6336	0.6280	+ .30
23A	52,54	0 5909	0.5854	+ .28	65,66	0.4660	0.4674	— .07
34	45,46	0.4486	0.4469	+ .09	73.74	0.1078	0.1046	+ .17
35	43,44	0.4162	0.4164	— .01	75.76	0.1359	0.1390	— .16
36	41,43	0.4652	0.4626	+ .14	76,77	0.5950	0.5931	+ .10
37	41,42	0.8426	0.8446	— .12	76,77	0.7156	0.7064	+ .49
38	38,39	0.2091	0.2134	— .23	80,81	0.3486	0.3459	+ .14
39	37,38	0.4620	0.4608	+ .06	80,82	0.5946	0.5924	+ .12
40	35,36	0.6735	0.6731	+ .02	82,84	0.3860	0.3824	+ .19
41	31,32	0.6124	0.6054	+ .37	86,88	0.4504	0.4526	— .12
42	29,30	0.6276	0.6230	+ .24	88,90	0.4315	0.4300	+ .07
43	27,28	0.7438	0.7431	+ .04	90,91	0.8136	0.8128	+ .03
44	27,28	0.1826	0.1789	+ .20	91,92	0.3741	0.3744	— .02
45	22,24	0.4362	0.4340	+ .11	95,96	0.6239	0.6222	+ .09

TABLE III.—(*Continued.*) PLATE VII: y MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*S—K*	Line.	½ *m*, or Scale *minus* Star.		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
15	62	0.0196	0.0186	+0.05″	57	0.5301	0.5302	—0.01″
2	58	0.6448	0.6446	+ .01	60	0.9095	0.9045	+ .28
3	44	0.0536	0.0534	+ .01	75	0.4972	0.4942	+ .16
4	26	0.9754	0.9744	+ .07	92	0.5794	0.5774	+ .11
6	76	0.2415	0.2414	+ .01	43	0.3114	0.3072	+ .22
8	76	0.9804	0.9799	+ .02	42	0.5731	0.5720	+ .06
10	55	0.0164	0.0149	+ .08	64	0.5348	0.5346	+ .01
11	49	0.2788	0.2782	+ .03	70	0.2735	0.2714	+ .11
14	82	0.9624	0.9610	+ .06	36	0.5922	0.5928	— .03
16	27	0.7882	0.7840	+ .23	91	0.7689	0.7664	+ .13
17	45	0.8736	0.8712	+ .14	73	0.6788	0.6784	+ .02
18	46	0.7182	0.7169	+ .07	72	0.8365	0.8336	+ .16
20	45	0.9394	0.9379	+ .10	73	0.6142	0.6149	— .04
22	77	0.6870	0.6864	+ .03	41	0.8685	0.8691	— .04
23	75	0.2095	0.2090	+ .03	44	0.3416	0.3448	— .16
24	45	0.3472	0.3462	+ .05	74	0.2028	0.2011	+ .09
25	55	0.8854	0.8852	+ .02	63	0.6631	0.6628	+ .02
26	32	0.9052	0.9058	— .02	86	0.6512	0.6496	+ .08
27	54	0.7488	0.7494	— .03	64	0.8004	0.7996	+ .05
28	65	0.9808	0.9806	+ .01	53	0.5726	0.5720	+ .03
29	89	0.6049	0.6022	+ .14	29	0.9515	0.9535	— .12
31	46	0.2505	0.2515	— .05	73	0.3002	0.3026	— .13
32	22	0.4230	0.4215	+ .08	97	0.1355	0.1334	+ .11
33	24	0.7514	0.7492	+ .11	94	0.8048	0.8038	+ .05
		Kretz.	Hays.	*K—H*		Kretz.	Hays.	*K—H*
15	62	0.0182	0.0246	—0.34″	57	0.5318	0.5329	—0.06″
1	77	0.7418	0.7462	— .23	41	0.8111	0.8120	— .04
5	90	0.9979	0.9966	+ .08	28	0.5592	0.5605	— .06
7	43	—.0005	—.0001	— .02	76	0.5508	0.5521	— .06
7A	58	0.2669	0.2690	— .11	61	0.2860	0.2868	— .04
19	87	0.9085	0.9064	+ .10	31	0.6464	0.6486	— .12
21	86	0.3856	0.3829	+ .14	33	0.1770	0.1775	— .02
23A	76	0.7939	0.7956	— .08	42	0.7582	0.7600	— .10
33	24	0.7534	0.7530	+ .02	94	0.8038	0.8059	— .12
34	58	0.1652	0.1675	— .12	61	0.3841	0.3861	— .11
35	95	0.4320	0.4320	.00	24	0.1251	0.1244	+ .04
36	72	0.8776	0.8750	+ .14	46	0.6749	0.6749	.00
37	48	0.7515	0.7538	— .12	70	0.8013	0.8045	— .17
38	65	0.7550	0.7541	+ .05	53	0.8013	0.8026	— .07
39	72	0.0530	0.0519	+ .06	47	0.5000	0.5019	— .10
40	27	0.0934	0.0952	— .10	92	0.4606	0.4615	— .05
41	54	0.4615	0.4634	— .10	65	0.0902	0.0882	+ .11
42	54	0.3646	0.3646	.00	65	0.1885	0.1909	— .13
43	68	0.9215	0.9211	+ .01	50	0.6322	0.6345	— .12
44	88	0.3458	0.3438	+ .10	31	0.2065	0.2076	— .06
45	37	0.4842	0.4869	— .14	82	0.0679	0.0672	+ .04

TABLE III.—(*Continued.*) PLATE VIII: x MEASUREMENTS.

Star.	x direct. Lines.	½ m, or Scale *minus* Star. Schl.	Kretz.	$S-K$	x reversed. Lines.	½ m, or Scale *minus* Star. Schl.	Kretz.	$S-K$
15	60,61	0.2671	0.2648	+0.12″	58.59	0.2850	0.2819	+0.16″
15					58,59	0.2851	0.2828	+ .12
2	93.94	0.7701	0.7728	— .14	24,25	0.7856	0.7825	+ .17
3	92.93	0.6742	0.6731	+ .06	25,27	0.3849	0.3842	+ .04
4	90,92	0.4280	0.4276	+ .02	27,28	0.6299	0.6285	+ .07
6	77,78	0.6768	0.6800	— .17	40,42	0.3745	0 3741	+ .02
8	70,72	0.3415	0.3375	+ .21	47,48	0.7154	0.7150	+ .02
10	69 71	0.4545	0.4509	+ .19	48,49	0.6002	0.5968	+ .18
11	68,70	0.6009	0.6011	— .01	49 50	0.4522	0.4505	+ .09
14	60 61	0.4509	0.4502	+ .04	57.59	0.5990	0.5988	+ .02
16	59,60	0.3821	0.3795	+ .14	59,60	0.1725	0.1725	.00
17	57.59	0.4562	0.4515	+ .25	60,61	0.5979	0.5978	+ .01
18	56.57	0.4119	0.4091	+ .15	62,63	0.1374	0.1385	— .06
20	55.57	0.5689	0.5650	+ .21	62.63	0.4841	0.4874	— .18
22	53 55	0.6064	0.6061	+ .01	64,65	0.4450	0.4465	— .08
23	52 53	0.7400	0.7380	+ .11	65.66	0.8161	0.8162	.00
24	50.51	0.6309	0.6234	+ .40	67,69	0.4269	0.4252	+ .09
25	49.51	0.5430	0.5401	+ .15	68,69	0.5071	0.5089	— .10
26	49 51	0.4416	0.4394	+ .12	68,69	0.6129	0 6110	+ .10
27	49 50	0.6729	0.6702	+ .14	68,70	0 3799	0.3794	+ .03
28	49 50	0.4262	0 4281	— .10	68,70	0.6234	0.6234	.00
29	48.49	0.8270	0.8258	+ .07	69,70	0.7252	0.7242	+ .05
31	48,49	0.2589	0.2556	+ .17	70,71	0.2974	0.2940	+ .18
45	21,22	0.5558	0.5545	+ .07	96 98	0.5000	0.4980	+ .10
		Schl.	Hays.	$S-H$		Schl.	Hays.	$S-H$
15	60,61	0.2681	0.2700	—0.10″	58.59	0.2839	0.2840	—0.01″
15	60.61	0.2664	0.2661	+ .02	58,59	0.2852	0.2856	— .02
1	94.95	0.7576	0.7529	+ .24	23,24	0.8044	0.7984	+ .32
2	93.94	0.7709	0.7736	— .14	24.25	0.7872	0.7855	+ .08
5	81,82	0.8511	0.8485	+ .13	36,37	0.7059	0.7065	— .03
7	74.76	0.4639	0.4646	— .03	43.44	0.5938	0.5896	+ .22
7A	70.72	0.3661	0.3594	+ .35	47,48	0.6921	0.6902	+ .10
19	56.57	0.3584	0.3575	+ .05	62 63	0.1961	0.1901	+ .31
23A	51,52	0.7201	0.7181	+ .10	66.67	0.8364	0.8356	+ .05
32	46,47	0.3970	0.3920	+ .26	72,73	0.1592	0.1631	— .21
33	44,45	0.7401	0.7400	+ .01	73.74	0.8152	0.8174	— .11
34	43,45	0.5712	0.5742	— .17	74.75	0.4800	0.4814	— .07
35	41,43	0.5529	0.5520	+ .04	76 77	9.5016	0.5000	+ .08
36	40,41	0.5946	0.5938	+ .04	77,79	0.4630	0.4615	+ .08
37	40:41	0.4676	0.4679	— .02	77,79	0.5885	0.5921	— .19
38	36,37	0.8402	0.8384	+ .08	81,82	0.7172	0.7172	.00
39	35.37	0.5885	0.5916	— .17	82.83	0.4624	0.4592	+ .17
40	34,35	0.2886	0.2882	+ .02	84,85	0.2649	0.2655	— .03
41	30,31	0.2381	0.2302	+ .42	88,89	0.3200	0.3199	+ .01
42	28,29	0.2592	0.2594	— .01	90,91	0.3016	0.2991	+ .13
43	26,27	0.3708	0.3731	— .12	82,93	0.1818	0.1814	+ .02
44	25,26	0.8192	0.8188	+ .03	92,93	0.7378	0.7345	+ .17
45	21,22	0.5601	0.5591	+ .05	96,98	0.5009	0.4981	+ .14

TABLE III.—(*Continued.*) PLATE VIII: *y* MEASUREMENTS.

Star.	*y* direct.				*y* reversed.			
	Line.	½ *m*, or Scale *minus* Star.		*K—H*	Line.	½ *m*, or Scale *minus* Star.		*K—H*
		Kretz.	Hays.			Kretz.	Hays.	
				″				″
15	55	0.0068	0.0070	—0.01	64	0.5411	0.5416	—0.03
15					64	0 5421	0.5425	— .02
2	51	0.6239	0.6241	— .01	67	0.9258	0.9290	— .19
3	37	0.0348	0.0326	+ .12	82	0.5169	0.5194	— .13
4	19	0.9572	0.9590	— .08	99	0.5984	0.6002	— .10
6	69	0.2228	0.2200	+ .15	50	0.3288	0.3249	+ .21
8	69	0.9606	0.9614	— .03	49	0.5875	0.5898	— .12
10	48	—.0029	0.0000	— .15	71	0.5505	0.5512	— .04
11	42	0.2579	0.2596	— .09	77	0.2900	0.2915	— .08
14	75	0.9466	0.9432	+ .16	43	0.6034	0.6072	— .20
16	20	0.7739	0.7724	+ .07	98	0.7801	0.7820	— .11
17	38	0.8599	0 8614	— .07	80	0.6928	0.6949	— .11
18	39	0.7045	0.7068	— .12	79	0.8506	0.8478	+ .15
20	38	0.9272	0.9284	— .05	80	0.6249	0.6264	— .08
22	70	0.6700	0.6721	— .11	48	0.8775	0.8769	+ .04
23	68	0.1906	0.1938	— .17	51	0 3525	0.3596	— .37
24	38	0.3356	0.3372	— .08	81	0.2140	0.2150	— .05
25	48	0 8722	0.8729	— .03	70	0.6748	0.6775	— .14
26	25	0 8939	0.8966	— .13	93	0.6598	0.6611	— .07
27	47	0.7358	0.7394	— .19	71	0.8111	0.8096	+ .08
28	58	0.9688	0.9678	+ .04	60	0.5792	0.5779	+ .07
29	82	0.5856	0 5869	— .07	36	0.9645	0.9650	— .04
31	39	0.2340	0.2400	— .32	80	0.3161	0.3192	— .16
33	17	0.7346	0.7341	+ .03	101	0.8170	0.8195	— .14
		Schl.	Kretz.	*S—K*		Schl.	Kretz.	*S—K*
				″				″
15	55	0 0095	0.0072	+0.12	64	0.5411	0.5409	+0.01
15	55	0.0105	0.0076	+ .15	64	0.5458	0.5418	+ .21
1	70	0 7176	0.7158	+ .09	48	0.8352	0.8331	+ .10
5	83	0.9740	0.9754	— .09	35	0.5774	0.5751	+ .12
7	36	—.0154	—.0178	+ .13	83	0.5680	0.5670	+ .05
7A	51	0.2508	0.2484	+ .13	68	0.3062	0.3025	+ .20
19	80	0.8938	0.8884	+ .28	38	0.6646	0.6609	+ .20
23A	69	0.7815	0.7792	+ .12	49	0.7719	0.7688	+ .16
32	15	0.4090	0.4109	— .10	104	0 1476	0.1456	+ .11
33	17	0.7384	0.7378	+ .03	101	0.8194	0.8171	+ .13
34	51	0.1562	0.1560	+ .01	68	0.3972	0.3955	+ .09
35	88	0.4174	0.4150	+ .13	31	0.1369	0.1330	+ .21
36	65	0.8636	0.8619	+ .10	53	0.6901	0.6880	+ .11
37	41	0.7460	0.7445	+ .08	77	0.8105	0.8101	+ .02
38	58	0.7471	0.7446	+ .13	60	0.8075	0.8049	+ .14
39	65	0.0412	0 0418	— .03	54	0.5091	0.5089	+ .01
40	20	0.0869	0.0869	.00	99	0.4692	0.4708	— .08
41	47	0.4586	0.4596	— .05	72	0.0951	0 0960	— .05
42	47	0.3562	0.3532	+ .16	72	0.2010	0.1981	+ .15
43	61	0.9196	0.9135	+ .33	57	0.6349	0.6349	.00
44	81	0.3348	0.3334	+ .07	38	0.2199	0.2176	+ .12
45	30	0.4771	0.4782	— .06	89	0.0745	0.0785	— .21

TABLE III.—(*Continued.*) PLATE IX: *x* MEASUREMENTS.

Star.	*x* direct.				*x* reversed.			
	Lines.	½ *m*, or Scale *minus* Star.		*S—K*	Lines.	½ *m*, or Scale *minus* Star		*S—K*
		Schl.	Kretz.			Schl.	Kretz.	
				″				″
15	54,55	0.8900	0.8901	—0.01	63,64	0.6599	0.6628	—0.15
2	88,89	0.3924	0.3978	— .29	30,31	0.1621	0.1625	— .02
3	87,88	0.3025	0.3008	+ .09	31,32	0.2570	0.2544	+ .14
4	85,86	0.5701	0.5648	+ .28	32,34	0.4876	0.4918	— .22
6	72.73	0.2920	0.2899	+ .11	46,47	0.2621	0.2621	.00
8	65,66	0.4511	0.4461	+ .26	53,54	0.1020	0.1029	— .05
10	64,65	0.5751	0.5730	+ .11	53,55	0.4780	0.4776	+ .02
11	63,64	0.7320	0.7318	+ .01	54,55	0.8220	0.8205	+ .07
14	55,56	0.0608	0.0609	— .01	63,64	0.4905	0.4886	+ .10
16	53.55	0.5259	0.5236	+ .12	64,65	0.5291	0.5299	— .04
17	52,53	0.5848	0.5914	— .35	65,67	0.4656	0.4661	— .03
18	50,52	0.5451	0.5448	+ .01	67,68	0.5085	0.5105	— .11
20	50.51	0.6969	0.6962	+ .04	67,68	0.8598	0.8592	+ .04
22	48,49	0.7159	0.7158	+ .01	69,70	0.8362	0.8382	— .10
23	47,48	0.3495	0.3515	— .11	71,72	0.2038	0.2044	— .03
24	45,46	0.2512	0.2520	— .04	73,74	0.2981	0.2989	— .04
25	44.45	0.6609	0.6601	+ .04	73.74	0.8926	0.8914	+ .07
26	44,45	0.5798	0.5791	+ .04	73,75	0.4729	0.4739	— .05
27	44,45	0.2938	0.2900	+ .20	74,75	0.2616	0.2608	+ .04
28	43,45	0.5416	0.5436	— .11	74,75	0.5095	0.5086	+ .05
29	43,44	0.4295	0.4300	— .03	75,76	0.1226	0.1228	— .01
45	16,17	0.1870	0.1888	— .10	102,103	0.3682	0.3689	— .04
		Kretz.	Hays.	*K—H*		Kretz.	Hays.	*K—H*
				″				″
15	54,55	0.8899	0.8898	+0.01	63,64	0.6629	0.6628	+0.01
1	89.90	0.3738	0.3658	+ .42	29,30	0.1809	0.1800	+ .05
2	88,89	0.3938	0.3946	— .04	30,31	0.1600	0.1602	— .01
5	76,77	0.4536	0.4546	— .05	42,43	0.0996	0.0986	+ .05
7	69,70	0.5980	0.5940	+ .21	48,50	0.4599	0.4625	— .13
23A.	46,47	0.3264	0.3236	+ .14	72,73	0.2242	0.2258	— .08
31	42,43	0.8836	0.8880	— .22	75,76	0.6685	0.6692	— .04
32	40,42	0.5325	0.5338	— .07	77,78	0.5216	0.5194	+ .12
33	39.40	0.3811	0.3829	— .10	79.80	0.1719	0.1732	— .07
34	38,39	0.6959	0.6980	— .12	79,80	0.8624	0.8601	+ .13
35	36,37	0.6520	0.6511	+ .05	81,82	0.9028	0.9005	+ .13
36	35,36	0.2006	0.1999	+ .04	83,84	0.3488	0.3510	— .12
37	35,36	0.0874	0.0931	— .30	83,84	0.4661	0.4621	+ .21
38	31,32	0.4465	0.4495	— .16	87,88	0.1064	0.1052	+ .06
39	30,31	0.7034	0.6981	+ .28	87,88	0.8530	0.8550	— .10
40	28,29	0.9286	0.9256	+ .17	89,90	0.6300	0.6298	+ .01
43	20,22	0.4879	0.4882	— .01	97,98	0.5671	0.5681	— .05
44	20,21	0.4152	0.4138	+ .07	98,99	0.1415	0.1409	+ .03
45	16,17	0.1885	0.1902	— .09	102,103	0.3685	0.3682	+ .02

TABLE III.—(*Concluded.*) PLATE IX: *y* MEASUREMENTS.

Line.	*y* direct. Star.	½ *m*, or Scale *minus* Star. Kretz.	Hays.	*K—H*	*y* reversed. Line.	½ *m*, or Scale *minus* Star. Kretz.	Hays.	*K—H*
				"				"
15	56	0.6574	0.6586	—0.06	62	0.8968	0.8969	0.00
2	53	0.2924	0.2885	+ .21	66	0.2601	0.2619	— .10
3	38	0.7025	0.7022	+ .02	80	0.8546	0.8548	— .02
4	21	0.6201	0.6211	— .05	97	0.9386	0.9390	— .03
6	70	0.8824	0.8836	— .05	48	0.6685	0.6701	— .08
8	71	0.6176	0.6160	+ .08	47	0.9336	0.9311	+ .12
10	49	0.6535	0.6530	+ .02	69	0.8961	0.8986	— .12
11	43	0.9194	0.9174	+ .10	75	0.6335	0.6356	— .11
14	77	0.5956	0.5951	+ .03	41	0.9594	0.9579	+ .10
16	22	0.4234	0.4211	+ .12	97	0.1318	0.1336	— .10
17	40	0.5092	0.5088	+ .02	79	0.0488	0.0450	+ .20
18	41	0.3556	0.3512	+ .23	78	0.2010	0.2028	— .10
20	40	0.5775	0.5768	+ .04	78	0.9788	0.9775	+ .05
22	72	0.3186	0.3181	+ .03	47	0.2341	0.2351	— .05
23	69	0.8454	0.8441	+ .06	49	0.7089	0.7101	— .06
24	39	0.9861	0.9831	+ .17	79	0.5705	0.5735	— .16
25	50	0.5185	0.5192	— .04	69	0.0304	0.0294	+ .05
26	27	0.5389	0.5426	— .20	92	0.0139	0.0171	— .17
27	49	0.3845	0.3856	— .06	70	0.1659	0.1660	— .01
28	60	0.6129	0.6126	+ .02	58	0.9371	0.9361	+ .06
29	84	0.2345	0.2326	+ .10	35	0.3168	0.3154	+ .07
33	19	0.3819	0.3838	— .10	100	0.1718	0.1716	+ .01
		Schl.	Hays.	*S—H*		Schl.	Hays.	*S—H*
				"				"
15	56	0.6586	0.6598	—0.06	62	0.8946	0.8964	—0.11
1	72	0.3909	0.3881	+ .15	47	0.1674	0.1626	+ .25
5	85	0.6366	0.6354	+ .06	33	0.9176	0.9172	+ .03
7	37	0.6385	0.6375	+ .05	81	0.9169	0.9132	+ .21
23A	71	0.4271	0.4246	+ .13	48	0.1265	0.1219	+ .24
31	40	0.8852	0.8874	— .13	78	0.6710	0.6731	— .11
32	17	0.0584	0.0532	+ .28	102	0.5040	0.5041	— .01
33	19	0.3802	0.3842	— .21	100	0.1728	0.1711	+ .09
34	52	0.7965	0.7979	— .07	66	0.7548	0.7551	— .01
35	90	0.0624	0.0638	— .07	29	0.4945	0 4920	+ .13
36	67	0.5094	0.5024	+ .37	52	0.0486	0.0412	+ .39
37	43	0.3850	0.3868	— .10	76	0.1650	0.1701	— .27
38	60	0.3900	0.3834	+ .35	59	0.1671	0.1660	+ .06
39	66	0.6850	0.6826	+ .13	52	0.8684	0.8680	+ .03
40	21	0.7210	0.7229	— .10	97	0.8329	0.8329	.00
43	63	0.5462	0.5432	+ .15	56	0.0040	0.0062	— .12
44	82	0.9712	0.9688	+ .11	36	0.5834	0.5864	— .16
45	32	0.1102	0.1076	+ .14	87	0.4465	0.4474	— .05

III.

Instrumental Corrections.

The first step towards turning the foregoing measures into right ascensions and declinations will be to apply the following instrumental corrections, which are here considered in the order of their application.

1° *Division Errors of the Scale.*

Just before beginning the measurement of the Præsepe plates a thorough examination of the division errors of the scale was completed. The details of this investigation together with the determinations of other constants of the measuring machine are reserved for another publication from this observatory. It will suffice for present purposes to set down merely the final results.

Previous to the above investigation the scale had also been examined by the *Kaiserliche Normal Aichungs Kommission* at Berlin; the results of this determination were published in the "Annals of the New York Academy of Sciences," Vol. IX, page 206. The two determinations agree quite well, the largest difference for any line being 0.″11, and usually the agreement is much closer. As the investigation at Columbia was made with the same microscope and under the same conditions in which the plates were measured, it was thought best to use only our own results, as given in Table IV. The coördinates of a star depend upon several divisions for one plate, and the same star usually comes opposite different divisons for different plates. It follows therefore that our final positions will be nearly independent of inaccuracies in the determination of the division errors; for example, the right ascension of Star 1 depends upon eighteen different lines of the scale and its declination depends upon thirteen. In Table IV the corrections are given in millimetres, and are always to be added to observed readings.

2° *Corrections for Runs and Screw Errors.*

The screw used in the measurements is of such a pitch that two complete turns of the micrometer head correspond to one space on the scale; the micrometer head is divided into one hundred equal parts and may therefore be read directly to half-microns

TABLE IV.—DIVISION ERRORS OF THE SCALE.

Line.	Correction in mm.	Line.	Correction in mm.	Line.	Correction in mm.
0	0.0000	44	+0.0029	88	+0.0025
1	+0.0011	45	+0.0020	89	+0.0026
2	—0.0007	46	+0.0021	90	+0.0018
3	—0.0001	47	+0.0006	91	+0.0027
4	+0.0002	48	+0.0013	92	+0.0025
5	—0.0004	49	+0.0015	93	+0.0026
6	+0 0001	50	+0.0007	94	+0.0026
7	—0.0013	51	+0.0018	95	+0.0026
8	—0.0008	52	+0.0030	96	+0.0019
9	—0.0009	53	+0.0024	97	+0.0008
10	—0.0001	54	+0.0032	98	+0.0014
11	+0.0014	55	+0.0028	99	+0.0004
12	+0.0006	56	+0.0030	100	+0.0019
13	+0.0014	57	+0.0034	101	+0.0004
14	+0.0016	58	+0.0038	102	—0.0005
15	+0.0015	59	+0.0034	103	+0.0002
16	+0.0009	60	+0.0034	104	+0.0014
17	+0.0008	61	+0.0038	105	+0.0009
18	+0.0012	62	+0.0044	106	+0.0012
19	+0.0012	63	+0.0058	107	+0.0002
20	+0.0007	64	+0.0050	108	+0.0012
21	+0.0015	65	+0.0053	109	0.0000
22	+0.0016	66	+0.0059	110	—0 0002
23	+0.0014	67	+0.0050	111	+0.0002
24	+0.0012	68	+0.0052	112	—0.0006
25	+0.0007	69	+0.0057	113	—0.0013
26	+0.0026	70	+0.0054	114	+0.0005
27	+0.0033	71	+0.0056	115	—0.0003
28	+0.0026	72	+0.0047	116	0.0000
29	+0.0020	73	+0.0046	117	+0.0020
30	+0.0035	74	+0.0047	118	+0.0022
31	+0.0030	75	+0.0037	119	+0.0026
32	+0.0022	76	+0.0052	120	+0.0021
33	+0.0024	77	+0.0045	121	+0.0014
34	+0.0013	78	+0.0041	122	+0.0024
35	+0.0032	79	+0.0040	123	+0.0015
36	+0.0024	80	+0.0033	124	+0.0024
37	+0.0025	81	+0.0043	125	+0.0012
38	+0.0016	82	+0.0029	126	+0.0018
39	+0.0025	83	+0.0050	127	+0.0014
40	+0.0033	84	+0.0034	128	+0.0005
41	+0.0020	85	+0.0021	129	+0.0015
42	+0.0025	86	+0.0014	130	0.0000
43	+0.0024	87	+0.0026		

and by estimation to twentieths of a micron. The details of the operation of observing runs were to set the micrometer head at about $5.^r0$ and to read on the scale as follows:

Line 70, Line 65, Line 65, Line 70.

These two lines were selected because they have practically the same division errors, thus avoiding an extra correction, and also because they happen to have more accurately determined division errors than most other lines. The correction for runs need not be applied to the separate readings on the stars and on the scale but may be applied to the quantity $\frac{1}{2}m$ directly; for let us put

$2R =$ reading on Line 65, *minus* reading on Line 70, *minus* $10.^r0000$.

Dividing by 2 we obtain R, the quantity given in Table II; we must then add to $\frac{1}{2}m$ the correction

$$-\left(\tfrac{1}{2}m\right)\frac{R}{5}\text{ millimetres.}$$

This correction may conveniently be combined with the correction for non-periodic errors of the screw or variations in its pitch; investigation showed that the following quantities must be added to observed readings of the micrometer head in order to reduce them to what they would have been had the screw been of uniform pitch, but of the same total length:

Reading of the Micrometer Head.	Correction in Millimetres.
r	
5.0	0.
6.0	+ 0.0005
7.0	+ 0.0002
8.0	— 0.0003
9.0	— 0.0012
10.0	— 0.0017
11.0	— 0.0022
12.0	— 0.0021
13.0	— 0.0022
14.0	— 0.0014
15.0	0.

The screw is actually longer than ten turns, but as only this length was used in the determination of the error of runs the rest of the screw was not investigated. It will be observed that the corrections progress uniformly in the interval from $9.^r0$ to $11.^r0$; advantage was taken of this fact to make the application of the corrections a simple matter. For if the micrometer head be set at $9.^r0$ when the microscope is pointed at a star, then the reading on the scale will lie between $9.^r0$ and $11.^r0$ because a whole space of the scale corresponds to two turns of the micrometer head; consequently the correction to the difference of the readings on scale and star will be proportionate to that difference, that is to $\frac{1}{2}m$; the correction to the latter is easily seen to be

$$-(\tfrac{1}{2}m) \times 0.0010 \text{ millimetres.}$$

Adding this to the correction for runs we obtain

$$-(\tfrac{1}{2}m)\left(0.00010 + \frac{R}{5}\right) \text{ millimetres.}$$

As an example let us correct the first observation given on the specimen sheet on page 199. The date being March 25, we get from Table II,

$$R = +0.0045.$$

Consequently the correction for runs and screw errors is

$$-(\tfrac{1}{2}m) \times 0.0019 \text{ millimetres.}$$

A table may now be constructed with the argument $\frac{1}{2}m$ which applies to all observations taken on March 25.

$\frac{1}{2}m$.	Correction.
0.0	0.0000 millimetres.
0.1	— 0.0002
0.2	— 0.0004
0.3	— 0.0006
0.4	— 0.0008
0.5	— 0.0010
0.6	— 0.0011
0.7	— 0.0013
0.8	— 0.0015
0.9	— 0.0017
1.0	— 0.0019

For the star given on the specimen sheet the correction is — 0.0009. During the second half of each morning's observations when the micrometer head is set at $9.^r5$ instead of at $9.^r0$ it sometimes happens that the reading on the scale exceeds $11.^r0$, in which case the correction will not be exactly proportionate to $\frac{1}{2}m$; but the error committed by using the same table throughout will never reach $0.''02$, and in most cases is entirely negligible.

3°. Having applied the corrections given above we have now to change the measures into rectangular coördinates x and y, referred to the central star 15 as origin, one axis being parallel to the cylinder and the other at right angles to it. For this purpose we subtract the mean of all the readings on the central star for any one day from the readings of all the other stars that were measured on that day. As we wish to have positive values of x for those stars which have greater right ascensions than the central star, we must subtract the reading "x direct" from the reading on Star 15; but we must subtract the reading on Star 15 from the reading "x reversed." Similiarly to get positive values of y for those stars having greater declinations than the central star, we subtract the reading on Star 15 from each "y direct" and the contrary for "y reversed."

4° *Rotation Corrections.*

It was found very difficult to set the circle at exactly 90° plus the reading for the previous day. Even when this had been accomplished the circle-reading was sometimes found to have changed a little during the measurement of the stars. A correction is therefore necessary to reduce the rectangular coördinates to what they would have been had the readings of the circle for different days differed only by multiples of 90°. Let

$Q =$ the number of seconds which occurs most often in the circle readings of a particular plate.

$Q - i =$ the number of seconds in the reading for any day.

Then we have,*

$$\text{Correction for } x = -y.\, i \sin 1.''$$
$$\text{" \quad " } y = +x.\, i \sin 1.''$$

For the present measurements these corrections are very small, never exceeding 0.''05; they have however been applied throughout.

The values of Q adopted for the various plates are as follows:

Plate		$Q =$
Plate	I	5''
	II	0
	III	0
	IV	58
	V	7
	VII	0
	VIII	29
	IX	2

5° *Scale-value corrections.*

The scale being made of German silver has a greater coefficient of expansion than the glass plate, and hence it would appear that if the temperature changed during the measurement of a plate,

* "Permanence of the Rutherfurd Photographic Plates" by Harold Jacoby, Annals of the N. Y. Acad. of Sciences, Vol. IX, p. 267.

the coördinates would require a correction to reduce them to what they would have been had the temperature remained constant. Investigation shows, however, that such a correction is unnecessary by reason of its minuteness, at least within the limits of the range of temperature at which the present plates were measured. To ascertain the amount of the correction, two well defined specks, such as may be found in the film of any plate, were selected, one near either edge of the plate, and the distance between them was measured at various temperatures. On the morning of April 30, 1897, this distance was measured six times each by Mr. Kretz and myself with the following results:

	Schlesinger:	Kretz:
	104.1548 *mm.*	104.1505 *mm.*
	67	514
	36	505
	30	497
	50	540
	25	517
Mean,	104.1543	104.1513
Probable Error,	±0.00042	±0.00041

The temperature of the measuring room had been kept at 69.°3 during the measurement by means of artificial heat, the heating apparatus being at the other end of the room from that occupied by the measuring machine. The heat was now turned off and the plate allowed to assume the natural temperature of the atmosphere; on the afternoon of the same day, three hours having elapsed since the first series was completed, the distance between the specks was again measured by the same observers as follows:

	Schlesinger:	Kretz:
	104.1550 *mm.*	104.1557 *mm.*
	70	44
	63	48
	87	60
	90	53
	70	75
Mean,	104.1572	104.1556
Probable Error,	±0.00041	±.00031

The temperature for this series was 52.°2. Denoting by v the increase in the measured distance due to an increase of 1° in the temperature we have

Schlesinger:	Kretz:
$v = -0.00017$ *mm.*	$v = -0.00025$ *mm.*
± 0.000034	± 0.000030

These two values are not very accordant, but they agree sufficiently well for present purposes. As, however, some doubts were entertained as to whether the plates had been thoroughly cooled in the intervening three hours, and as to whether it would not be better to measure the distance between the specks at a season when artificial heat could be entirely dispensed with, the following third series of observations was undertaken by myself, several days elapsing between the various measurements. No artificial heat was allowed in the measuring room during the whole period.

May 20, 1897. Temperature = 73.°6.

104.1530 *mm.*
10
18
30
58
48
25
68

Mean, 104.1536 ± 0.00047

May 22, 1897. Temperature = 69.°6.

104.1534 *mm.*
36
26
44
34
39
54
76

Mean, 104.1543 ± 0.00036

May 29, 1897. Temperature = 71.°0.

104.1548 *mm.*
26
28
64
34
28
36
34

Mean, 104.1537 ± 0.00031

July 27, 1897. Temperature = 82.°1.

104.1532 *mm.*
525
505
530
520
495
510
542
510
522
548
525

Mean, 104.1522 ± 0.00031

Denoting by v as before the increase in the distance due to an increase of 1° in the temperature, and by L the distance between the specks at the temperature 69.°6 we have the following four observation equations:

$L - 104.1543 = 0$	weight	3
$L + 1.4\,v - 104.1537 = 0$	"	5
$L + 4.0\,v - 104.1536 = 0$	"	2
$L + 12.5\,v - 104.1522 = 0$	"	5

The weights are calculated from the probable errors given above, the probable error of an equation of weight unity being

$$\pm 0.00067$$

Solving by least squares we get

$$v = -0.00015 \pm 0.000032$$

Taking into account the two previous series, the mean by weight is

$$v = -0.00019 \text{ mm.}$$

which very probably does not differ from its true value by as much as 0.00005.

Now the largest coördinate in the Præsepe measures is less than forty millimetres, and the greatest deviation for any single day from the mean of the temperatures for the corresponding plate is less than 5°; consequently the largest correction which it will ever be necessary to apply is

$$0.00037 \text{ mm.}$$

which corresponds to 0.″02. As this is so small, even in the extreme case, no appreciable error will be committed by neglecting the correction altogether. We may indeed conclude that for the scale under consideration and for the Rutherfurd plates, a correction for change in the scale-value will be unnecessary so long as the temperature does not vary more than 10° during the measurement of a single plate.

6° *Projection Errors* and *Deviation of the Cylinder from Straightness.*

In the present work corrections have been applied for neither of these; the first were discussed by Donner * and are very small in most cases; it is indeed very difficult to determine them with sufficient accuracy. Repsold has recently devised a new guiding way which is free from this source of error; the measuring machine used for the Præsepe plates had been furnished with such a guiding way in 1896. As regards the straightness of the cylinder, investigation showed that it had been admirably made †; the greatest error which we shall commit in assuming it to be straight is 0.″04; the reversal of each plate and the insertion of different plates in different positions in the measuring machine will tend to eliminate even this small error.

Having now completed the consideration of all the instrumental corrections which it is necessary to apply, I shall conclude this subject by correcting the measurements of Star 7, Plate VIII, as given on page 199, or in Table III.

	March 25, x direct:	March 24, y direct:	March 18, x reversed:	March 22, y reversed:
Lines, ...	74,76	36	43,44	83
$\frac{1}{2}m$; First obs'v'r.,..	0.4646	— 0.0154	0.5938	0.5680
Second " ..	0.4639	— 0.0178	0.5896	0.5670
Mean, ...	0.4643	— 0.0166	0.5917	0.5675
Cor. for Runs, etc.,	— 9	0	— 11	— 11
Div. Correction, ...	+ 50	+ 24	+ 26	+ 50
Corrected $\frac{1}{2}m$, ...	0.4684	— 0.0142	0.5932	0 5714
Measurement, ...	75.4684	35.9858	44.0932	83.5714

Where two lines have been used the division correction is the mean of the division corrections for the separate lines; the final "measurement" is then obtained by adding the mean of the numbers of the lines to the corrected $\frac{1}{2}m$. The corresponding measurements for the central star 15 when similiarly corrected are:

* "Détermination des Constantes nécessaires pour la Reduction des Clichés." Acta Societatis Scientiarum Fennicae, Vol. XXI.

† "Permanence of the Rutherfurd Plates" by Harold Jacoby; Annals of the N. Y. Acad. of Sciences, Vol. IX, page 210.

	March 25, x direct:	March 24, y direct:	March 18, x reversed:	March 22, y reversed:
	60.7692	55.0133	58.7883	64.5497
	7695	0104	7887	5457
	7731	0100	7870	5448
	7712	0123	7871	5450
Mean,	60.7708	55.0115	58.7878	64.5463

Taking the differences between these and the corresponding measurements for Star 7, having regard to signs, we get:

Coördinates, ...	—14.6976	—19.0257	—14.6946	—19.0251
Rotation Cor., ...	0	+ 4	+ 2	0
Final Coörd., ...	—14.6976	—19.0253	—14.6944	—19.0251

These are the quantities given in Table V, which needs no further explanation. In comparing the direct with the reversed coördinates, it should be remembered that unity in the fourth decimal place corresponds to about 0.″005 of arc of a great circle.

TABLE V.—CORRECTED COÖRDINATES. PLATE I.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.5052	.5028	—34.5040	+15.6854	.6850	+15.6852
2	—33.5104	.5082	—33.5093	— 3.4200	.4188	— 3.4194
3	—32.3942	.3922	—32.3932	—18.0042	.0055	—18.0049
4	—30.6393	.6348	—30.6370	—35.0918	.0906	—35.0912
5	—21.6168	.6161	—21.6165	+28.9521	.9571	+28.9546
6	—17.4281	.4236	—17.4258	+14.2048	.2048	+14.2048
7	—14.6839	.6843	—14.6841	—19.0394	.0412	—19.0403
8	—10.5876	.5849	—10.5862	+14.9500	.9500	+14.9500
10	— 9.6888	.6886	— 9.6887	— 7.0204	.0201	— 7.0203
11	— 8.8264	.8270	— 8.8267	—12.7576	.7577	—12.7576
14	— 0.2020	.2022	— 0.2021	+20.9438	.9455	+20.9446
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.9159	.9173	+ 0.9166	—34.2424	.2429	—34.2426
17	+ 2.3272	.3293	+ 2.3283	—16.1534	.1504	—16.1519
18	+ 3.8697	.8712	+ 3.8705	—15.3037	.3022	—15.3030
20	+ 4.2144	.2182	+ 4.2163	—16.0818	.0826	—16.0822
22	+ 6.1437	.1546	+ 6.1541	+15.6744	.6760	+15.6752
23	+ 7.5258	.5276	+ 7.5267	+13.2000	.2000	+13.2000
23A	+ 8.5446	.5478	+ 8.5462	+14.7914	.7874	+14.7894
24	+ 9.6569	.6587	+ 9.6578	—16.6650	.6664	—16.6657
25	+10.2385	.2420	+10.2402	— 6.1255	.1240	— 6.1248
26	+10.3560	.3580	+10.3570	—29.1131	.1110	—29.1120
27	+10.6100	.6095	+10.6098	— 7.2644	.2646	— 7.2645
28	+10.8422	.8406	+10.8414	+ 3.9756	.9756	+ 3.9756
29	+11.4264	.4272	+11.4268	+27.6000	.5983	+27.5992
31	+12.0292	.0308	+12.0300	—15.7662	.7623	—15.7642
32	+13.9115	.9104	+13.9110	—39 5974	.5944	—39.5959
33	+15.5667	.5705	+15.5686	—37.2662	.2662	—37.2662
34	+16.2032	.2048	+16.2040	— 3.8424	.8368	— 3.8396
35	+18.1994	.1978	+18.1986	+33.4348	.4344	+33.4346
36	+19.6786	.6824	+19.6805	+10.8790	.8794	+10.8792
37	+19.8224	.8254	+19.8239	—13.2516	.2506	—13 2512
38	+23.4340	.4385	+23.4362	+ 3.7612	.7620	+ 3.7616
39	+24.1815	.1872	+24.1844	+10.0636	.0626	+10.0631
40	+26.0190	.0207	+26.0198	—34.9100	.9092	—34.9096
43	+33.9119	.9091	+33.9105	+ 6.9450	.9450	+ 6.9450
44	+34.4409	.4470	+34.4440	+26.3683	.3666	+26.3674

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE II.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.5040	.5037	—34.5038	+15.6928	.6954	+15.6941
2	—33.5044	.5036	—33.5040	— 3.4064	.4061	— 3.4062
4	—30.6440	.6420	—30.6430	—35.0756	.0789	—35.0772
5	—21.6032	.6037	—21.6035	+28.9578	.9610	+28.9594
6	—17.4227	.4214	—17.4221	+14.2064	.2055	+14.2059
7	—14.6867	.6812	—14.6840	—19.0368	.0348	—19.0358
7A	—10.5894	.5874	—10.5884	— 3.7603	.7585	— 3.7594
8	—10.5806	.5799	—10.5803	+14.9550	.9538	+14.9544
10	— 9.6862	.6838	— 9.6850	— 7.0164	.0154	— 7.0159
11	— 8.8272	.8259	— 8.8266	—12.7520	.7530	—12.7525
14	— 0.2004	.2006	— 0.2005	+20.9444	.9442	+20.9443
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.9121	.9122	+ 0.9122	—34.2378	.2359	—34.2368
17	+ 2.3210	.3230	+ 2.3220	—16.1492	.1480	—16.1486
18	+ 3.8660	.8664	+ 3.8662	—15.3018	.3032	—15.3025
19	+ 3.8978	.8967	+ 3.8972	+25.8933	.8950	+25.8942
20	+ 4.2114	.2147	+ 4.2130	—16.0802	.0786	—16.0794
22	+ 6.1538	.1518	+ 6.1528	+13.1972	.1972	+13.1972
23A	+ 8.5476	.5505	+ 8.5490	+14.7833	.7834	+14.7834
24	+ 9.6502	.6500	+ 9.6501	—16.6680	.6658	—16 6669
25	+10.2337	.2350	+10.2344	— 6.1280	.1255	— 6.1268
26	+10.3454	.3492	+10.3473	—29.1082	.1090	—29.1086
27	+10.6000	.6032	+10.6016	— 7.2620	.2598	— 7.2609
28	+10.8382	.8390	+10.8386	+ 3.9732	.9757	+ 3.9744
29	+11.4256	.4253	+11.4254	+27.5944	.5926	+27.5935
31	+12.0266	.0287	+12.0276	—15.7620	.7641	—15.7630
32	+13.9074	.9049	+13.9061	—39.5946	.5894	—39.5920
33	+15.5584	.5616	+15.5600	—37.2621	.2607	—37.2614
34	+16.2032	.2031	+16.2031	— 3.8444	.8394	— 3.8419
35	+18.2036	.2038	+18.2037	+33.4284	.4314	+33.4299
36	+19.6828	.6814	+19.6821	+10.8745	.8752	+10.8749
37	+19.8174	.8190	+19.8182	—13.2498	.2495	—13.2496
38	+23.4373	.4378	+23.4375	+ 3.7584	.7606	+ 3.7595
39	+24.1793	.1830	+24.1812	+10.0571	.0604	+10.0587
40	+26.0170	.0153	+26.0162	—34.9106	.9091	—34.9098
43	+33.9056	.9042	+33.9049	+ 6.9342	.9360	+ 6.9351
44	+34.4474	.4480	+34.4477	+26.3596	.3632	+26.3614
45	+38.7409	.7417	+38.7413	—24.5064	.5066	—24.5065

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE III.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4942	.4942	—34.4942	+15.7075	.7076	+15.7076
2	—33.5073	.5094	—33.5084	— 3.3957	.3940	— 3.3948
3	—32.4044	.4030	—32.4037	—17.9840	.9844	—17.9842
4	—30.6587	.6538	—30.6562	—35.0679	.0660	—35.0670
5	—21.5902	.5939	—21.5920	+28.9642	.9662	+28.9652
6	—17.4130	.4134	—17.4132	+14.2124	.2157	+14.2141
7	—14.6935	.6974	—14.6954	—19.0312	.0342	—19.0327
8	—10.5682	.5685	—10.5684	+14.9584	.9602	+14.9593
10	— 9.6864	.6859	— 9.6862	— 7.0159	.0138	— 7.0148
11	— 8.8284	.8312	— 8.8298	—12.7523	.7510	—12.7517
14	— 0.1866	.1878	— 0.1872	+20.9390	.9420	+20.9405
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8979	.8959	+ 0.8969	—34.2431	.2410	—34.2420
17	+ 2.3194	.3190	+ 2.3192	—16.1527	.1504	—16.1516
18	+ 3.8596	.8590	+ 3.8593	—15.3089	.3060	—15.3074
20	+ 4.2056	.2076	+ 4.2066	—16.0852	.0818	—16.0835
22	+ 6.1663	.1653	+ 6.1658	+15.6676	.6737	+15.6706
23	+ 7.5299	.5297	+ 7.5298	+13.1907	.1931	+13.1919
23A	+ 8.5566	.5554	+ 8.5560	+14.7819	.7820	+14.7820
24	+ 9.6504	.6490	+ 9.6497	—16.6740	.6688	—16.6714
25	+10.2314	.2295	+10.2305	— 6.1371	.1310	— 6.1340
26	+10.3361	.3369	+10.3365	—29.1205	.1154	—29.1180
27	+10.6036	.6032	+10.6034	— 7.2689	.2712	— 7.2700
28	+10.8441	.8452	+10.8447	+ 3.9637	.9659	+ 3.9648
29	+11.4440	.4462	+11.4451	+27.5865	.5912	+27.5888
31	+12.0134	.0165	+12.0150	—15.7675	.7700	—15.7688
32	+13.8892	.8889	+13.8891	—39.6008	.6048	—39.6028
33	+15.5390	.5422	+15.5406	—37.2750	.2731	—37.2740
34	+16.2035	.2034	+16.2034	— 3.8514	.8503	— 3.8508
35	+18.2207	.2234	+18.2221	+33.4219	.4217	+33.4218
36	+19.6910	.6868	+19.6889	+10.8652	.8620	+10.8636
37	+19.8112	.8124	+19.8118	—13.2630	.2656	—13.2643
39	+24.1897	.1879	+24.1888	+10.0472	.0462	+10.0467
40	+25.9978	.0012	+25.9995	—34.9216	.9212	—34.9214
43	+33.9138	.9114	+33.9126	+ 6.9199	.9170	+ 6.9184
44	+34.4648	.4650	+34.4649	+26.3452	.3448	+26.3450
45	+38.7302	.7281	+38.7292	—24.5248	.5266	—24.5257

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE IV.

Star.	x			y		
	Direct.	Rev'd.	Mean.	D rect.	Rev'd.	Mean.
1	—34.5081	.5005	—34.5043	+15.6765	.6747	+15.6756
2	—33.5014	.4986	—33.5000	— 3.4249	.4234	— 3.4241
3	—32.3816	.3810	—32.3813	—18.0095	.0107	—18.0101
4	—30.6188	.6162	—30.6175	—35.0890	.0904	—35.0897
5	—21.6262	.6230	—21.6246	+28.9437	.9424	+28.9430
6	—17.4268	.4245	—17.4256	+14.1982	.2015	+14.1999
7	—14.6724	.6690	—14.6707	—19.0377	.0411	—19.0394
7A	—10.5836	.5818	—10.5827	— 3.7664	.7693	— 3.7678
8	—10.5906	.5902	—10.5904	+14.9470	.9494	+14.9482
10	— 9.6824	.6814	— 9.6819	— 7.0229	.0209	— 7.0219
11	— 8.8172	.8155	— 8.8164	—12.7601	.7583	—12.7592
14	— 0.2114	.2107	— 0.2110	+20.9386	.9403	+20.9394
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.9326	.9340	+ 0.9333	—34.2394	.2372	—34.2383
17	+ 2.3349	.3362	+ 2.3356	—16.1490	.1489	—16.1490
18	+ 3.8712	.8732	+ 3.8722	—15.3017	.3015	—15.3016
19	+ 3.8816	.8832	+ 3.8824	+25.8905	.8886	+25.8896
20	+ 4.2190	.2192	+ 4.2191	—16.0778	.0775	—16.0777
22	+ 6.1440	.1465	+ 6.1452	+15.6732	.6741	+15.6737
23	+ 7.5157	.5178	+ 7.5168	+13.1976	.1967	+13.1971
23A	+ 8.5374	.5399	+ 8.5387	+14.7866	.7864	+14.7865
24	+ 9.6622	.6640	+ 9.6631	—16.6652	.6606	—16.6629
25	+10.2376	.2372	+10.2374	— 6.1234	.1220	— 6.1227
26	+10.3627	.3652	+10.3639	—29.1068	.1060	—29.1064
27	+10.6071	.6077	+10.6074	— 7.2612	.2614	— 7.2613
28	+10.8355	.8374	+10.8364	+ 3.9759	.9771	+ 3.9765
29	+11.4120	.4129	+11.4124	+27.5930	.5960	+27.5945
31	+12.0288	.0305	+12.0297	—15.7623	.7610	—15.7616
32	+13.9279	.9289	+13.9284	—39.5870	.5883	—39.5876
33	+15.5832	.5771	+15.5802	—37.2559	.2551	—37.2555
34	+16.2028	.2030	+16.2029	— 3.8344	.8350	— 3.8347
35	+18.1752	.1798	+18.1775	+33.4338	.4318	+33.4328
36	+19.6722	.6738	+19.6730	+10.8808	.8800	+10.8804
37	+19.8242	.8250	+19.8246	—13.2450	.2459	—13.2454
38	+23.4288	.4324	+23 4306	+ 3.7647	.7636	+ 3.7642
39	+24.1717	.1728	+24.1722	+10 0655	.0655	+10.0655
40	+26.0288	.0312	+26 0300	—34.8968	.8938	—34.8953
43	+33.8955	.8986	+33.8970	+ 6 9446	.9455	+ 6.9450
44	+34.4188	.4232	+34.4210	+26.3714	.3697	+26.3706
45	+38.7495	.7503	+38.7499	—24.4909	.4900	—24.4904

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE V.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4912	.4900	—34.4906	+15.7164	.7130	+15.7147
2	—33.5065	.5062	—33.5064	— 3.3860	.3897	— 3.3878
3	—32.4083	.4072	—32.4077	—17.9751	.9772	—17.9762
4	—30.6656	.6644	—30.6650	—35.0600	.0620	—35.0610
5	—21.5824	.5810	—21.5817	+28.9692	.9680	+28.9686
6	—17.4077	.4090	—17.4084	+14.2193	.2187	+14.2190
7	—14.6985	.6980	—14.6982	—19.0254	.0321	—19.0288
8	—10.5690	.5682	—10.5686	+14.9581	.9598	+14.9589
10	— 9.6874	.6894	— 9.6884	— 7.0102	.0116	— 7.0109
11	— 8.8342	.8320	— 8.8331	—12.7484	.7500	—12.7492
14	— 0.1788	.1805	— 0.1797	+20.9386	.9374	+20.9380
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8868	.8872	+ 0.8870	—34.2418	.2394	—34.2406
17	+ 2.3130	.3152	+ 2.3141	—16.1528	.1520	—16.1524
18	+ 3.8581	.8571	+ 3.8576	—15.3042	.3044	—15.3043
19	+ 3.9180	.9201	+ 3.9190	+25.8858	.8814	+25.8836
20	+ 4.2016	.2034	+ 4.2025	—16.0850	.0826	—16.0838
22	+ 6.1697	.1684	+ 6.1690	+15.6671	.6672	+15.6672
23	+ 7.5392	.5374	+ 7.5383	+13.1906	.1916	+13.1911
23A	+ 8.5584	.5599	+ 8.5592	+14.7780	.7756	+14.7768
24	+ 9.6428	.6431	+ 9.6429	—16.6726	.6745	—16.6736
25	+10.2291	.2308	+10.2299	— 6.1376	.1352	— 6.1364
26	+10.3236	.3257	+10.3246	—29.1198	.1210	—29.1204
27	+10.6022	.6037	+10.6030	— 7.2723	.2700	— 7.2711
28	+10.8461	.8451	+10.8456	+ 3.9626	.9622	+ 3.9624
29	+11.4492	.4498	+11.4495	+27.5812	.5812	+27.5812
31	+12.0096	.0100	+12.0098	—15.7728	.7723	—15.7726
32	+13.8710	.8778	+13.8744	—39.6013	.6038	—39.6025
34	+16.1957	.1977	+16.1967	— 3.8561	.8526	— 3.8543
35	+18.2316	.2267	+18.2292	+33.4117	.4098	+33.4108
37	+19.8083	.8070	+19.8077	—13.2664	.2697	—13.2680
39	+24.1869	.1882	+24.1876	+10.0364	.0376	+10.0370
40	+25.9806	.9837	+25.9822	—34.9250	.9260	—34.9255
43	+33.9056	.9072	+33.9064	+ 6.9073	.9062	+ 6.9068
44	+34.4653	.4661	+34.4657	+26.3334	.3336	+26.3335
45	+38.7196	.7170	+38.7183	—24.5324	.5328	—24.5326

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE VII.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4817	.4843	—34.4830	+15.7221	.7231	+15.7226
2	—33.5043	.5043	—33.5043	— 3.3759	.3763	— 3.3761
3	—32.4086	.4100	—32.4093	—17.9669	.9658	—17.9664
4	—30.6694	.6673	—30.6684	—35.0474	.0472	—35.0473
5	—21.5742	.5714	—21.5728	+28.9724	.9737	+28.9730
6	—17.4069	.4056	—17.4062	+14.2230	.2216	+14.2223
7	—14.7014	.7022	—14.7018	—19.0236	.0206	—19.0221
7A	—10.5922	.5894	—10.5908	— 3.7542	.7547	— 3.7545
8	—10.5673	.5687	—10.5680	+14.9603	.9586	+14.9595
10	— 9.6920	.6904	— 9.6912	— 7.0050	.0060	— 7.0055
11	— 8.8388	.8402	— 8.8395	—12.7439	.7446	—12.7443
14	— 0.1793	.1816	— 0.1805	+20.9396	.9388	+20.9392
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8806	.8805	+ 0.8806	—34.2354	.2364	—34.2359
17	+ 2.3125	.3090	+ 2.3108	—16.1506	.1493	—16.1500
18	+ 3.8524	.8514	+ 3.8519	—15.3052	.3057	—15.3054
19	+ 3.9198	.9222	+ 3.9210	+25.8832	.8854	+25.8843
20	+ 4.1979	.1962	+ 4.1971	—16.0844	.0854	—16.0849
21	+ 4.7178	.7213	+ 4.7196	+24.3594	.3554	+24.3574
22	+ 6.1656	.1624	+ 6.1640	+15.6664	.6633	+15.6648
23	+ 7.5330	.5340	+ 7.5335	+13.1890	.1872	+13.1881
23A	+ 8.5558	.5590	+ 8.5574	+14.7731	.7745	+14.7738
24	+ 9.6320	.6332	+ 9.6326	—16.6755	.6736	—16.6745
25	+10.2276	.2252	+10.2264	— 6.1370	.1348	— 6.1359
26	+10.3185	.3214	+10.3199	—29.1174	.1180	—29.1177
27	+10.5986	.5979	+10.5982	— 7.2726	.2710	— 7.2718
28	+10.8415	.8406	+10.8410	+ 3.9608	.9590	+ 3.9599
29	+11.4500	.4474	+11.4487	+27.5814	.5797	+27.5806
31	+12.0062	.0064	+12.0063	—15.7710	.7727	—15.7718
32	+13.8671	.8658	+13.8664	—39.6006	.6022	—39.6014
33	+15.5207	.5220	+15.5214	—37.2730	.2721	—37.2726
34	+16.1972	.1980	+16.1976	— 3.8560	.8536	— 3.8548
35	+18.2277	.2290	+18.2284	+33.4081	.4088	+33.4084
36	+19.6808	.6854	+19.6831	+10.8540	.8588	+10.8564
37	+19.8020	.8021	+19.8020	—13.2730	.2723	—13.2726
38	+23.4334	.4379	+23.4356	+ 3.7330	.7316	+ 3.7323
39	+24.1835	.1831	+24.1833	+10.0310	.0340	+10.0325
40	+25.9716	.9742	+25.9729	—34.9286	.9282	—34.9284
41	+30.0359	.0402	+30.0381	— 7.5610	.5599	— 7.5605
42	+32.0193	.0197	+32.0195	— 7.6587	.6003	— 7.6595
43	+33.9009	.9016	+33.9012	+ 6.8994	.9014	+ 6.9004
44	+34.4624	.4636	+34.4630	+26.3208	.3246	+26.3227
45	+38.7094	.7085	+38.7090	—24.5388	.5361	—24.5374

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE VIII.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—34.4857	.4866	—34.4862	+15.7100	.7124	+15.7112
2	—33.5032	.5024	—33.5028	— 3.3848	.3846	— 3.3847
3	—32.4060	.4011	—32.4036	—17.9734	.9738	—17.9736
4	—30.6600	.6560	—30.6580	—35.0517	.0524	—35.0520
5	—21.5811	.5808	—21.5809	+28.9670	.9680	+28.9675
6	—17.4127	.4101	—17.4114	+14.2171	.2192	+14.2182
7	—14.6976	.6944	—14.6960	—19.0253	.0251	—19.0252
7A	—10.5962	.5969	—10.5966	— 3.7603	.7626	— 3.7615
8	—10.5749	.5718	—10.5733	+14.9556	.9570	+14.9563
10	— 9.6885	.6880	— 9.6882	— 7.0098	.0096	— 7.0097
11	— 8.8362	.8352	— 8.8357	—12.7488	.7488	—12.7488
14	— 0.1844	.1852	— 0.1848	+20.9374	.9392	+20.9383
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8857	.8885	+ 0.8871	—34.2371	.2353	—34.2362
17	+ 2.3126	.3134	+ 2.3130	—16.1488	.1500	—16.1494
18	+ 3.8562	.8560	+ 3.8561	—15.3028	.3060	—15.3044
19	+ 3.9104	.9097	+ 3.9100	+25.8812	.8832	+25.8822
20	+ 4.2000	.2031	+ 4.2016	—16.0818	.0820	—16 0819
22	+ 6.1610	.1636	+ 6.1623	+15.6656	.6687	+15.6672
23	+ 7.5284	.5337	+ 7.5310	+13.1874	.1886	+13 1880
23A	+ 8.5506	.5521	+ 8.5513	+14.7729	.7760	+14.7744
24	+ 9.6418	.6438	+ 9.6428	—16.6723	.6726	—16.6724
25	+10.2268	.2256	+10.2262	— 6.1372	.1347	— 6.1360
26	+10.3278	.3292	+10.3285	—29.1152	.1163	—29.1158
27	+10.5974	.5974	+10.5974	— 7.2728	.2689	— 7.2708
28	+10.8416	.8408	+10.8412	+ 3.9608	.9648	+ 3.9628
29	+11.4424	.4426	+11.4425	+27.5784	.5800	+27.5792
31	+12.0110	.0137	+12.0124	—15.7707	.7748	—15.7727
32	+13.8756	.8780	+13.8768	—39.6012	.6014	—39.6013
33	+15.5298	.5320	+15.5309	—37.2751	.2712	—37.2732
34	+16.1969	.1962	+16.1966	— 3.8543	.8544	— 3.8544
35	+18.2171	.2166	+18.2168	+33.4060	.4086	+33.4073
36	+19.6751	.6778	+19.6764	+10.8545	.8562	+10.8554
37	+19.8014	.8057	+19.8035	—13.2662	.2670	—13.2666
38	+23.4306	.4318	+23.4312	+ 3.7362	.7382	+ 3.7372
39	+24.1790	.1761	+24.1776	+10.0346	.0351	+10.0348
40	+25.9807	.9800	+25.9804	—34.9247	.9232	—34.9240
41	+30.0339	.0342	+30.0340	— 7.5534	.5538	— 7.5536
42	+32.0097	.0144	+32.0120	— 7.6577	.6576	— 7.6576
43	+33.8966	.8960	+33.8963	+ 6.9064	.9093	+ 6.9079
44	+34.4516	.4494	+34.4505	+26.3255	.3264	+26.3259
45	+38.7120	.7129	+38.7124	—24.5322	.5326	—24.5324

TABLE V.—(*Concluded.*) CORRECTED COÖRDINATES. PLATE IX.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean
1	—34.4800	.4842	—34.4821	+15.7316	.7334	+15.7325
2	—33.5050	.5025	—33.5037	— 3.3680	.3664	— 3.3672
3	—32.4120	.4079	—32.4100	—17.9574	.9570	—17.9572
4	—30.6766	.6746	—30 6756	—35.0392	.0384	—35.0388
5	—21.5667	.5659	—21.5663	+28.9755	.9802	+28.9778
6	—17.4034	.4030	—17.4032	+14 2269	.2304	+14.2286
7	—14.7092	.7056	—14.7074	—19.0220	.0194	—19.0208
8	—10.5617	.5612	—10.5614	+14.9613	.9682	+14.9648
10	— 9.6866	.6860	— 9.6863	— 7.0064	.0018	— 7.0041
11	— 8.8444	.8424	— 8.8434	—12.7406	.7372	—12.7389
14	— 0.1718	.1718	— 0.1718	+20.9388	.9407	+20 9397
15	0.0000	.0000	0.0000	0.0000	.0000	0.0000
16	+ 0.8652	.8684	+ 0.8668	—34.2368	.2330	—34.2349
17	+ 2.3019	.3048	+ 2.3033	—16.1486	.1504	—16.1495
18	+ 3.8459	.8481	+ 3.8470	—15.3053	.3054	—15.3054
20	+ 4.1952	.1981	+ 4.1966	—16.0804	.0809	—16.0807
22	+ 6.1756	.1759	+ 6.1758	+15.6626	.6655	+15.6640
23	+ 7.5408	.5429	+ 7.5418	+13.1893	.1902	+13.1898
23A	+ 8.5656	.5620	+ 8.5638	+14.7698	.7735	+14.7716
24	+ 9.6386	6369	+ 9.6378	—16.6742	.6750	—16 6746
25	+10.2299	.2300	+10.2300	— 6.1412	.1352	— 6.1382
26	+10.3108	.3114	+10.3111	—29.1168	.1175	—29.1171
27	+10.5979	.5991	+10.5985	— 7.2740	.2707	— 7.2724
28	+10.8479	.8466	+10.8473	+ 3.9552	.9610	+ 3.9581
29	+11.4602	.4605	+11.4603	+27 5766	.5815	+27.5790
31	+12.0046	.0050	+12.0048	—15.7726	.7764	—15.7745
32	+13 8562	.8568	+13.8565	—39.6046	.6040	—39.6043
33	+15.5071	.5086	+15.5079	—37.2773	.2739	—37.2756
34	+16.1936	.1964	+16.1950	— 3.8618	.8610	— 3.8614
35	+18.2386	.2367	+18.2376	+33.4038	.4042	+33.4040
36	+19.6886	.6863	+19.6875	+10.8493	.8510	+10.8502
37	+19.7985	.8004	+19.7994	—13.2732	.2738	—13.2735
38	+23.4416	.4410	+23.4413	+ 3.7287	.7290	+ 3.7289
39	+24.1886	.1881	+24.1884	+10.0280	.0287	+10.0284
40	+25 9634	.9639	+25.9637	—34.9383	.9338	—34.9360
43	+33.9029	.9006	+33.9018	+ 6.8892	.8907	+ 6.8899
44	+34.4765	.4747	+34.4756	+26.3112	.3123	+26.3117
45	+38.7025	.7012	+38.7018	—24.5497	.5502	—24.5499

IV.

Method of Reduction.

The measured coördinates having been cleared of instrumental errors, it remains to convert them into right ascensions and declinations. For this purpose the following constants must be known for each plate:

1°. The right ascension of the centre of the plate, in this case the central star 15.

2°. The declination of the same star.

3°. The scale-value, or the number of seconds corresponding to one space on the scale.

4°. The orientation correction, or the angle through which we must rotate the coördinate axes in order that they may point respectively in the directions of a parallel of declination and a circle of declination through the central star.

The first plan that suggested itself for determining these constants was to employ the two existing heliometer researches upon the group. In 1856 to 1858 Professor Winnecke of Bonn measured the position angles and distances of forty-four stars from the central star 15; and in 1889 to 1892 Professor Schur of Göttingen triangulated thirty-eight stars and derived the places of seven more by measuring the position angles and distances from stars in the triangulation. The results of both researches were published in one volume by Professor Schur, part IV of the "Astronomische Mittheilungen von der K. Sternwarte zu Göttingen." The stars whose positions are there given include almost all those appearing on the photographs, and consequently very accurate values of the four constants could be obtained by comparing the measured coördinates of a large number of stars with their heliometer places. Another plan is to determine the constants by comparison with meridian observations. While this is not as accurate as the preceding, it has the advantage of being independent of the heliometer results, thus rendering a comparison with the latter more instructive.

The course that I have actually pursued is this: the constants were first determined for each plate separately by comparing the coördinates of some of the stars with meridian observations. For a star which appears on all the plates we have thus eight determinations of its right ascension, and eight of its declination, and a catalogue of the group may now be formed by taking the means. Finally a least square solution was made to determine how much the constants would have to be changed on the average, so as to secure the best possible agreement with the heliometer places. It is evident that if we now apply to our catalogue positions the corrections which result from these average changes in the constants we shall obtain the same results as though we had used the heliometer places to determine the constants for the separate plates, and had then taken the means.

The meridian observations used are those quoted by Professor Schur in the work mentioned above; they were used by him to help fix the place of his triangulation in the sky. Five stars were observed, the central star and four others distributed symmetrically over the plate; they are admirably fitted for our purpose, being at sufficiently large distances from the central star to insure accurate determinations of the scale-value and orientation, and yet not so distant as to have their photographic images much distorted. Their magnitudes are such that they appear on all of the plates with good images. The stars were observed both at Berlin and Göttingen;* the positions obtained at the former observatory and reduced to the A. G. catalogue system are as follows:

Star.	Epoch.	Equinox of 1890.0.	
4	1890.26	$8^h31^m28.^s444$,	$+19°39'00''.65$
5	.51	32 02. 359	20 35 28 .43
15	.26	33 23. 463	20 09 55 .38
40	.51	35 00. 573	19 39 04 .35
44	.26	35 33. 417	20 33 03 .28

Each star was observed four times, and the probable error of a single observation is given as

$\pm 0.^s012$ in right ascension,
$\pm 0.''25$ in declination.

At Göttingen each star was observed six times with these results:

* "Astronomische Mittheilungen von der K. Sternwarte zu Göttingen," Part IV, pages 139 et seq.

Star.	Epoch.	Equinox of 1890.0.	
4	1891.52	8^h31^m 28.425,	+19°38′59″.83
5	.37	32 02.388	20 35 27 .75
15	.55	33 23.462	20 09 55 .52
40	.89	35 00.607	19 39 04 .03
44	.89	35 33.447	20 33 03 .40

Giving these observations the weight $\frac{1}{3}$, and those at Berlin the weight unity, as was done by Professor Schur, we get finally:

Star.	Epoch.	Equinox of 1890 0.	
4	1890.58	8^h31^m 28.440,	+19 39′00″.45
5	.72	32 02.366	20 35 28 .26
15	.58	33 23.463	20 09 55 .42
40	.86	35 00.582	19 39 04 .27
44	.67	35 33.425	20 33 03 .31

As the epochs of these observations are from thirteen to twenty years later than the dates of our plates, it is necessary to apply proper motions, for which the following values have been adopted:

4	—0.ˢ0054	+0″.007
5	—0. 0005	+0 .038
15	—0. 0049	+0 .017
40	—0. 0040	+0 .011
44	—0. 0044	+0 .015

These are the values given by Professor Schur in his catalogue of the group, but they are not derived directly from a comparison of his places with those of Winnecke. Systematic corrections have been added to make the proper motion of the group as a whole conform with observations by Bradley and by Tobias Mayer; these corrections are:

—0.ˢ0003 +0″.039.

The necessity for such a large correction in declination is accounted for by Professor Schur, by assuming that either in the Bonn or in the Göttingen observations, or perhaps in both, the declination of the group as a whole was incorrectly determined; we shall have occasion to refer to this circumstance later.

The plates were taken at practically only two dates, 1870.3 and 1877.3; applying the corresponding proper motions to the meridian observations and reducing them to the equinox of 1875.0, we get:

For Plates I, II, III and IV,

	$\Delta\alpha$	$\Delta\delta$
4	—1723″.34	—1856″.74
5	—1220 .23	+1531 .02
15	0	0
40	+1459 .38	—1849 .36
44	+1948 .13	+1390 .16
	α_0	δ_0
15	128°07′55″.26	+20°13′01″.26

For Plates V, VII, VIII and IX,

	$\Delta\alpha$	$\Delta\delta$
4	—1723″.40	—1856″.81
5	—1219 .75	+1531 .17
15	0	0
40	+1459 .48	—1849 .40
44	+1948 .19	+1390 .15
	α_0	δ_0
15	128°07′51″.75	+20°13′01″.38

$\Delta\alpha$ and $\Delta\delta$ are obtained by subtracting the right ascension and declination of Star 15 from those of the five comparison stars.

The numerical work in the problem before us, namely, to determine the constants of the plates, will be greatly decreased by first assuming an approximate scale-value and then determining how much this is in error. Such an approximate value is furnished by the reduction of Rutherfurd's photographs of the Pleiades where it was found that

1 millimetre = 52.″87

Let us suppose that this scale-value has been applied to the measured coördinates x and y of each of the comparison stars, giving X and Y; then the quantities X sec δ_0 and Y will be nearly equal to the corresponding $\Delta\alpha$ and $\Delta\delta$ respectively. The causes of difference are the following:

a. Transformation Corrections (see below), *Refraction*, *Precession*, etc.

b. Orientation, use of incorrect *scale-value*, etc.

c. Errors of observation, both in the measured coördinates and in the meridian places.

Let us first consider the causes of difference under *a*; we shall then determine the orientation, true scale-value etc., by comparing the corrected coördinates with the corresponding values of $\Delta\alpha$

and $\Delta\delta$, eliminating the errors of observation as far as possible by means of a least-square solution.

I. Transformation Corrections.

An astronomical photograph may be regarded as a central projection of a portion of the celestial sphere upon a tangent plane. The point on the plate which corresponds to the point of tangency is the foot of the perpendicular let fall from the optical centre of the object glass upon the plane of the plate. The rigorous relations between the rectilinear coördinates referred to this point as origin, and the right ascension and declination of a star, were given in simple form by Professor Turner in Vol. XVI, of "Observatory," page 374. Previous to this, however, Ball and Rambaut gave these relations in the form of series in their paper "On the Relative Positions of 223 stars in χ Persei," Transactions of the Royal Irish Academy, Vol. XXX, page 247. In our notation these formulas would be

$$\Delta\alpha - X\sec\delta_0 = (X\sec\delta_0)\,Y\tan\delta_0 - \tfrac{1}{3}(X\sec\delta_0)^3 + (X\sec\delta_0)\,Y\tan^2\delta_0$$
$$\Delta\delta - Y = -\tfrac{1}{4}(X\sec\delta_0)^2\sin 2\delta_0 - \tfrac{1}{3}Y^3 - \tfrac{1}{2}(X\sec\delta_0)^2\,Y$$

The elegance of these formulas lies in the fact that the coefficients of the powers and products of X and Y, are functions of δ_0 only, and are therefore constant for a plate, or indeed for an entire zone. For most plates these series are sufficiently accurate, but when the declination or the measured coördinates are large they fail; in such cases we do not need to resort to the rigorous formulas but we have merely to extend the series to higher terms, as was done by Professor Jacoby in a review of a paper by Professor Donner, in the Vierteljahrschrift for 1895, page 114. In the same place, formulas are also given in which $\Delta\alpha$ and $\Delta\delta$ appear in the second members, instead of X and Y as above. Omitting terms of higher degree than the third, which is permissible for the Præsepe plates, these formulas may be written

$$\Delta\alpha - X\sec\delta_0 = \Delta\alpha\cdot\Delta\delta\cdot\tan\delta_0 - \tfrac{1}{3}\Delta\alpha^3\left(1 - \tfrac{3}{2}\sin^2\delta_0\right)$$
$$\Delta\delta - Y = -\tfrac{1}{4}\Delta\alpha^2\cdot\sin 2\delta_0 - \tfrac{1}{2}\Delta\alpha^2\cdot\Delta\delta\cdot\cos 2\delta_0 - \tfrac{1}{3}\Delta\delta^3$$

The use of these formulas presupposes a knowledge of the approximate values of $\Delta\alpha$ and $\Delta\delta$ for each star. They possess two points of advantage over the inverse forms: first, there is one term less in the expression for $\Delta\alpha - X\sec\delta_0$; and second, they give slightly more accurate values for the corrections as they do not involve errors of orientation, scale-value, etc., such as would be incurred through the use of the measured X and Y in the second members. I have therefore used the latter expressions for computing the transformation corrections given in Table VI, employing the heliometer values of Δa and $\Delta \delta$ given by Professor Schur. It will be remembered that Rutherfurd was careful to make the central star 15 coincide with the foot of the perpendicular let fall from the optical centre of the object glass upon the plane of the plate. As our measured coördinates are referred to this star as origin, Table VI applies equally to all the plates.

TABLE VI.—TRANSFORMATION CORRECTIONS.

Star.	$\Delta\alpha - X \sec \delta_0$	$\Delta\delta - Y$	Star.	$\Delta\alpha - X \sec \delta_0$	$\Delta\delta - Y$
	"	"		"	"
1	—2.83	—3.01	24	—0.85	—0.22
2	+0.66	—2.80	25	—0.34	—0.26
3	+3.15	—2.58	26	—1.60	—0.23
4	+5.75	—2.23	27	—0 41	—0.28
5	—3.33	—1.22	28	+0.23	—0.29
6	—1.31	—0.77	29	+1.68	—0.36
7	+1.49	—0.52	31	—1.01	—0.35
7A	+0.21	—0.27	32	—2.92	—0.39
8	—0.84	—0.29	33	—3.08	—0.53
10	+0.36	—0.23	34	—0.34	—0.65
11	+0.60	—0.19	35	+3.24	—0.89
14	—0.02	—0.01	36	+1.13	—0.98
15	0.00	0.00	37	—1.41	—0.97
16	—0.16	+0.05	38	+0.45	—1.38
17	—0.20	—0.01	39	+1.28	—1.47
18	—0.31	—0.03	40	—4.84	—1.59
19	+0.54	—0.06	41	—1.24	—2.24
20	—0.36	—0.04	42	—1.35	—2.54
22	+0.51	—0.10	43	+1.19	—2.89
23	+0.53	—0.15	44	+4 79	—3.05
23A	+0.67	—0.18	45	—5.12	—3.66

II. CORRECTIONS FOR REFRACTION.

Formulas for clearing rectangular coördinates of the effects of refraction were first published by Dr. Rambaut in the "Astronomische Nachrichten," No. 3125. Professor Turner has shown how these may be much simplified by employing the coördinates of the zenith as projected upon the plate.* His formulas, however, will not serve in the transformation of rectangular coördinates into right ascensions and declinations unless we apply an

* Monthly Notices, R.A.S., November, 1893.

extra correction for orientation. (See note at the end of this paper.) The formulas that I have preferred to use are those given by Professor Jacoby;* while these are not quite so simple as those of Professor Turner, they take into account the orientation correction mentioned. Let

φ = the latitude, $+40°44'$ in this case.

$\theta - a_0$ = the hour angle of the centre of the plate, from Table I.

δ_0 = the declination of the centre, $+20°13'$

β = the constant of refraction, computed in the usual way and then multiplied by $\frac{66}{65}$ to allow for the increased refrangibility of photographic rays.†

Now let us compute:

$$\tan N = \cos(\theta - a_0) \cot \varphi$$
$$G = \cot(\delta_0 + N)$$
$$H = \tan(\theta - a_0) \sin N \operatorname{cosec}(\delta_0 + N)$$
$$M_x = \beta(1 + H^2)$$
$$N_x = \beta(G - \tan\delta_0) H \sec\delta_0$$
$$M_y = \beta(G + \tan\delta_0) H \cos\delta_0$$
$$N_y = \beta(1 + G^2)$$

Then the corrections for refraction take the form:

$$\text{Correction for } X \sec\delta_0 = M_x \cdot X \sec\delta_0 + N_x \cdot Y$$
$$\text{" \quad " } \quad Y = M_y \cdot X \sec\delta_0 + N_y \cdot Y$$

The coefficients of $X \sec \delta_0$ and of Y in the second members are constant for an entire plate. We may then construct Table VII, in which the number of the plate is the argument.

TABLE VII.—REFRACTION COEFFICIENTS.

Plate.	M_x	N_x	M_y	N_y
I.	0.000356	0.000017	0.000114	0.000349
II.	0.000423	0.000042	0.000174	0.000375
III.	0.000404	0.000031	0.000153	0.000373
IV.	0.000523	0.000086	0.000255	0.000424
V.	0.000357	0.000015	0.000110	0.000354
VII.	0.000423	0.000042	0.000174	0.000375
VIII.	0.000491	0.000074	0.000233	0.000404
IX.	0.000377	0.000023	0.000131	0.000360

All the coefficients are positive.

* Astronomical Journal, No. 387.

† Bulletin du Comité Permanent, I, 464; and Scheiner and Rambaut, Astron. Nach. 3255.

III. Precession and Nutation.

These merely change the position of the axes to which the group is referred; it follows therefore that their *differential* effect upon X and Y is simply to rotate the coördinate axes through a small angle. When we determine the constants of a plate by comparing the measures of some of the stars with their true positions, it is evident that we need apply no corrections for precession and nutation to the measures of the comparison stars. Thus if we employ the places of the latter as referred to the equinox of 1875.0, then the value for the orientation which we shall get will include the necessary correction for precession and nutation. On the other hand, if we correct the places of the comparison stars for precession and nutation, then it would not only be necessary to apply the resulting orientation correction to the *other* stars, but we should also have to apply to them additional corrections for precession and nutation.

IV. Aberration.

It was shown by Bessel* that aberration changes the position angles around a point equally, and changes the distances by a constant factor, no matter in what direction the distance is measured. Consequently, as in the case of precession and nutation, we need apply no correction for aberration to the measures of the comparison stars, since the resulting orientation and scale-value corrections will be appropriately modified to include its whole effect.

Thus we see that the coördinates of our five comparison stars need be corrected only for transformation and refraction. We must bear in mind, however, that the orientation and the scale-value which we shall then obtain are not the true values of these constants: the former must be corrected for precession, nutation and aberration, and the latter simply for aberration.

We are now ready to find the constants of the plates. Let

$p =$ the correction to the scale-value, so that the true scale-value is $52''.87\ (1 + p)$.

$r =$ the orientation correction, or the small angle through which the axes are to be rotated in the direction of decreasing position angles.

* "Astronomische Untersuchungen," Vol. I, page 207.

k = the number of seconds of arc of a great circle through which the axes are to be translated in the direction of decreasing right ascensions.

c = the number of seconds of arc of a great circle through which the axes are to be translated in the direction of decreasing declinations.

The corrections to the rectangular coördinates arising from p are then:

For X, $+p \cdot X$
" Y, $+p \cdot Y$

On account of the orientation corrections, remembering that r is small, we have the corrections:

For X, $+r \cdot Y$
" Y, $-r \cdot X$

Finally, k and c give the corrections:

For X, $+k$
" Y, $+c$

Combining all these corrections, we have:

For X, $+p \cdot X + r \cdot Y + k$
" Y, $+p \cdot Y - r \cdot X + c$

Let us now compute n_x and n_y for each comparison star, from the following equations:

$n_x \sec \delta_0 = X \sec \delta_0$ *plus* corrections for transformation and refraction, *minus* $\Delta\alpha$.

$n_y = Y$ *plus* corrections for transformation and refraction, *minus* $\Delta\delta$.

Then for each comparison star we have two equations of the following form from which to determine p, r, k and c:

$$pX + rY + k + n_x = 0$$

$$pY - rX + c + n_y = 0$$

Owing to the way in which the coefficients of the unknowns are repeated in these equations we do not need to make the least square solution in the usual manner, but as Professor Jacoby has pointed out,* we may find the unknowns very simply. Thus, let ν = the number of comparison stars, and let us denote by square brackets the sum of ν quantities.

* Monthly Notices of the Royal Astronomical Society, May, 1896.

Put

$$A = [XX] + [YY] - \frac{1}{v}([X]^2 + [Y]^2)$$

$$C = [X \cdot n_x] + [Y \cdot n_y] - \frac{1}{v}([X][n_x] + [Y][n_y])$$

$$E = [Y \cdot n_x] - [X \cdot n_y] - \frac{1}{v}([Y][n_x] - [X][n_y])$$

Then we have:

$$p = -\frac{C}{A}, \text{ with the weight } A.$$

$$r = -\frac{E}{A}, \quad \text{"} \quad \text{"} \quad \text{"} \quad A.$$

$$k \quad -\frac{1}{v}([X]p + [Y]r + [n_x]), \text{ with the weight, } v - \frac{[X]^2 + [Y]^2}{[XX] + [YY]}$$

$$c = -\frac{1}{v}([Y]p - [X]r + [n_y]), \quad \text{"} \quad \text{"} \quad \text{"} \quad v - \frac{[X]^2 + [Y]^2}{[XX] + [YY]}$$

The following will be found a convenient check on the computations: the sum of the residuals for the right ascension equations is equal to zero, and similarly for the declination equations.*

The above method of solution is rendered still simpler in the present case, as we are going to use the same comparison stars for all the plates. Hence all the terms in the expressions for A, C and E are constant except those which involve n_x or n_y. Thus, selecting the coördinates of the comparison stars from any plate in Table V, and multiplying them by 52.87 we have, with sufficient accuracy:

	X	Y
4	—1620″	—1850″
5	—1140	+1530
15	0	0
40	+1370	—1850
44	+1820	+1390

Consequently, for all the plates,

* This is indeed a general check for any set of observation equations in which one of the unknowns enters with a constant coefficient; if this unknown is missing from some of the equations, then the sum of the residuals for those equations in which it does appear is equal to zero. The theorem may be easily modified to include the case of unequal weights.

$$A = 20{,}080{,}000$$

$$C = [X \cdot n_x] + [Y \cdot n_y] - 86\,[n_x] + 156\,[n_y]$$

$$E = [Y \cdot n_x] - [X \cdot n_y] + 156\,[n_x] - 86\,[n_y]$$

$$p = -\frac{C}{20{,}080{,}000}\,; \text{ weight, } 20{,}080{,}000$$

$$r = -\frac{E}{20{,}080{,}000}\,; \quad \text{``} \quad 20{,}080{,}000$$

$$k = -86p + 156r - 0.20\,[n_x]\,; \text{ weight, } 4.96$$

$$c = +156p + 86r - 0.20\,[n_y]\,; \quad \text{``} \quad 4.96$$

It now remains to show how the right ascensions and declinations of all the stars may be computed. The constants of the plate give rise to the corrections:

$$\text{For } X \sec \delta_0, \quad +p \cdot X \sec \delta_0 + r \sec \delta_0 \cdot Y + k \sec \delta_0$$
$$\text{`` } Y \quad , \quad +p \cdot Y \quad - r \cdot X \quad + c$$

The corrections for refraction are:

$$\text{For } X \sec \delta_0, \quad + M_x \cdot X \sec \delta_0 + N_x \cdot Y$$
$$\text{`` } Y \quad , \quad + M_y \cdot X \sec \delta_0 + N_y \cdot Y$$

We have still to add corrections for transformation, which vary from star to star, but are the same for different plates. Now let us define a_1 and δ_1 as the *projected* right ascension and declination respectively of a star, the true right ascension and declination being given thus:

$a = a_1$ *plus* the correction for transformation.

$\delta = \delta_1$ *plus* the correction for transformation.

Then collecting the corrections given above:

$$a_1 = (1 + p + M_x)\, X \sec \delta_0 + (N_x + r \sec \delta_0)\, Y + (a_0 + k \sec \delta_0)$$
$$\delta_1 = (1 + p + N_y)\, Y \quad + (M_y - r \cos \delta_0)\, X \sec \delta_0 + (\delta_0 + c)$$

Hence, to get the projected right ascension and declination of any star, the constants of the plate having been determined, we need only compute the six coefficients in the parentheses and perform the simple operations indicated. These coefficients, it is needless to remark, are constant for an entire plate.

As an example of the above methods I have set down the details of the computations for the constants of Plate VIII.

Right Ascensions.

Star	4	5	15	40	44
x : (Table V),	—30.6580	—21.5809	0	+25.9804	+34.4505
$X \sec \delta_0 = 52.87 \sec \delta_0 \cdot x$,	—1727.″31	—1215.″89	0″	+1463.″77	+1940.″98
$M_x \cdot X \sec \delta_0$: (Tab. VII),	— 0.85	— .60	0	+ 0.72	+ 0.95
$N_x \cdot Y$: (See below),	— 0.14	+ .12	0	— 0.14	+ 0.11
$\Delta a - X \sec \delta_0$: (Tab. VI),	+ 5.75	— 3.33	0	— 4.84	+ 4.79
$- \Delta a$: (Page 237),	+1723.40	+1219.75	0	—1459.48	—1948.19
$n_x \sec \delta_0$:	+ 0.85	+ 0.05	0	+ 0.03	— 1.36
n_x :	+ 0.80	+ 0.05	0	+ 0.03	— 1.28

Declinations.

Star.	4	5	15	40	44
y : (Table V),	—35.0520	+28.9675	0	—34.9240	+26.3259
$Y = 52.87\, y$:	—1853.″20	+1531.″51	0″	—1846.″43	+1391.″85
$N_y \cdot Y$: (Table VII),	— 0.75	+ 0.62	0	— 0.75	+ 0.56
$N_x \cdot X \sec \delta_0$: (See above),	— 0.40	— 0.28	0	+ 0.34	+ 0.46
$\Delta\delta - Y$: (Table VI),	— 2.23	— 1.22	0	— 1.59	— 3.05
$-\Delta\delta$: (Page 237),	+1856.81	—1531.17	0	+1849.40	—1390.15
n_y :	+ 0.23	— 0.54	0	+ 0.97	— 0.33

$[X \cdot n_x] = -3650 \quad [Y \cdot n_x] = -3240 \quad [n_x] = -0''.40$

$[X \cdot n_y] = +980 \quad [Y \cdot n_y] = -3510 \quad [n_y] = +0''.33$

$p = +0.000352 \quad \pm 0.000030$

$r = +0.000211 \quad \pm 0.000030$

$k = +0.''08 \quad \pm 0.''061$

$c = +0.''01 \quad \pm 0.''061$

Having found the constants, we may now proceed to get the right ascension and declination of each star on the plate. For this purpose we compute the coefficients:

For Right Ascensions. For Declinations.

$52.87\,(1 + p + M_x) \sec \delta_0 = 56.3887 \qquad 52.87\,(1 + p + N_y) = 52.9100$

$N_x + r \sec \delta_0 = +0.000299 \qquad M_y - r \cos \delta_0 = +0.000035$

$a_0 + k \sec \delta_0 = 128°07'54''.84 \qquad \delta_0 + c = 20°13'01''.39$

A slight change has been made in the two coefficients in the first line, our formulas requiring $(1+p+M_x)$ and $(1+p+N_y)$. This change, however, merely amounts to combining two multiplications into one; thus, instead of first computing $X \sec \delta_0$ and then multiplying this by $(1+p+M_x)$, we may apply the factor $52.87(1 + p + M_x) \sec \delta_0$ to x directly. The formulas require that we know $X \sec \delta_0$ in computing the correction to the declination, but for this purpose we may use $52.87(1 + p + M_x) \sec \delta_0 \cdot x$, the quantity which we have just computed and which is practically equal to $X \sec \delta_0$ for this purpose. Similarly in the declination we may compute at once $52.87(1 + p + N_y)$.

Employing these coefficients for Star 7 we have:

Right Ascension:		Declination:	
x: (Tab. V),	— 14.6960	y: (Tab. V),	— 19.0252
$52.87(1+p+M_x) \sec \delta_0 \cdot x$:	— 828.″69	$52.87(1+y+N_y) \cdot y$:	— 1006″.62
	= — 13′48.69		= —16′46″.62
$(N_x + r \sec \delta_0) \cdot Y$:	— 0.30	$(M_y - r \sec \delta_0) \cdot X \sec \delta_0$:	— 0.03
$\alpha_0 + k \sec \delta_0$:	128°07 54 .84	$\delta_0 + c$:	+20°13 01 .39
α_1 =	127°54′05″.85	δ_1 =	+19°56′14″.74

These give the projected position; the true right ascension and declination are found by adding the transformation corrections from Table VI, giving:

$$\alpha = 127°54'7''.34\,,\ \delta = +\,19°56'14''.22,$$

which are corrected for refraction, precession, nutation and aberration, and are referred to the mean equinox of 1875.0.

V.

Results.

Least-square solutions entirely similar to that given in detail in the last section lead to the following values of p, r, etc., for the various plates :

Constants of the Plates.

Plate.	p	r	Probable Error of p or r.	k	c	Probable Error of k or c.
				″	″	″
I.	+0.000100	+0.001054	±0.000037	—0.06	0.00	±0.075
II.	+ 125	+ 844	± 45	—0.18	—0.15	±0.092
III.	+ 125	+ 409	± 32	—0.22	—0.06	±0.066
IV.	+ 209	+ 1435	± 41	0.00	—0.03	±0.082
V.	+ 261	+ 172	± 22	—0.01	+0.01	±0.044
VII.	+ 342	— 35	± 24	+0.02	—0.04	±0.049
VIII.	+ 352	+ 211	± 30	+0.08	+0.01	±0.061
IX.	+ 365	— 326	± 24	—0.06	—0.01	±0.048

The average probable error of p or r is

±0.000032

which corresponds to an uncertainty of about 0″.06 in the coördinates of the outlying stars. The great diversity in the values of r is due in small part to corrections for precession, nutation and aberration, but chiefly to the accidental position in which the plate was inserted in the measuring machine.

The following are the residuals for the five comparison stars, used in computing the values of p, r, k and c given above.

Residuals from the Right Ascension Equations :

Plate.	Star 4.	Star 5.	Star 15.	Star 40.	Star 44.
	″	″	″	″	″
I	0.00	+0.03	—0.01	+0.07	—0.09
II	— .24	+ .31	— .18	+ .42	— .31
III	— .14	+ .20	— .23	+ .28	— .11
IV	— .19	+ .13	.00	+ .39	— .33
V	— .01	+ .13	— .06	+ .25	— .31
VII	— .07	+ .09	+ .02	+ .14	— .18
VIII	— .08	+ .05	+ .08	+ .21	— .26
IX	+ .10	— .09	— .06	+ .12	— .08
Means,	— .08	+ .11	— .06	+ .24	—.21

Residuals from the Declination Equations:

Plate.	Star 4.	Star 5.	Star 15.	Star 40.	Star 44.
	"	"	"	"	"
I	—0.13	+0.20	+0.01	+0.10	—0.18
II	— .03	+ .20	— .15	+ .11	— .13
III	— .07	+ .13	— .06	+ .16	— .16
IV	— .00	+ .23	— .04	+ .07	— .26
V	— .09	+ .34	.00	— .01	— .24
VII	— .10	+ .22	— .04	+ .08	— .16
VIII	— .08	+ .25	+ .01	+ .04	— .22
IX	— .02	+ .23	— .01	+ .03	— .23
Means,	— .06	+ .22	— .03	+ .07	— .20

Employing the constants in the manner described at length in the last section, we obtain the quantities α_1 and δ_1 which have been tabulated in the following pages. It will be remembered that α_1 and δ_1 are the projected right ascension and declination of a star respectively; the transformation correction being the same for all the plates, may just as well be applied to the means; and it is evident that this procedure does not affect in any way the comparison of the right ascensions or declinations of a star as derived from different plates. The columns headed "At Epoch of Plate" give the coördinates uncorrected for proper motion. The calculation of the latter is very simple in this case as the plates were taken at practically only two dates, 1870.3 and 1877.3; hence the annual proper motion is obtained by subtracting the mean of the places on plates of the earlier date from the mean for the later date, and dividing the difference by 7. The columns marked "P. M." give the correction for proper motion necessary to reduce the place of the star to the epoch 1875.0.

Probable errors are given for the right ascension and the declination of each star, and also for the proper motions; they were calculated thus:

Let m = the number of plates of date 1870.3 on which the star was measured.

n = the number of date 1877.3.

$[vv]$ = the sum of the squares of the residuals obtained by subtracting the mean from the separate observations reduced to the epoch 1875.0.

Then the probable error of a quantity having the weight unity is:

$$\pm 0.6745 \sqrt{\frac{[vv]}{m+n-2}}$$

The weight of a right ascension or a declination at the epoch 1875.0 is

$$\frac{49mn}{22.1\,m + 5.3\,n}$$

For a proper motion the weight is

$$\frac{49mn}{m+n}$$

Most of the stars appear on all eight plates; for such we have simply,

$$\text{Probable error of } \alpha_1 \text{ or of } \delta_1 = \pm 0.103 \sqrt{[vv]}$$

$$\text{“ “ of proper motion} = \pm 0.028 \sqrt{[vv]}$$

Two of the stars were observed only on plates taken in 1877, and consequently it was not possible to reduce them to the epoch 1875.0 by using proper motions determined from the plates themselves, as has been done for all the other stars. The proper motions used for these two stars are those given by Professor Schur on page 298 of his memoir, and are as follows:

Star.	P. M. in Right Ascension.	P. M. in Declination.
41	—0″.042	+0″.012
42	—0 .066	+0 .036

These were used for an interval of only 2.3 years.

Star 1.

Plate.	Right Ascension: At Epoch of Plate.	Right Ascension: P. M.	Right Ascension: At Epoch 1875.0.	Declination: At Epoch of Plate.	Declination: P. M.	Declination: At Epoch 1875.0.
I	127°35′31″.25	—0″.43	30″.82	20°26′52″.60	+0″.15	52″.75
II	30 .80	— .43	.37	.47	+ .15	.62
III	30 .94	— .43	.51	.52	+ .15	.67
IV	31 .16	— .43	.73	.64	+ .15	.79
V	30 .46	+ .21	.67	.84	— .07	.77
VII	30 .47	+ .21	.68	.79	— .07	.72
VIII	30 .45	+ .21	.66	.60	— .07	.53
IX	30 .22	+ .21	.43	.90	— .07	.83
Mean,			127°35′30″.61	Mean,		20°26′52″.71
Probable Error,			±.041	Probable Error,		±.026
Proper Motion,			—0.091 ±0.011	Proper Motion,		+0.032 ±0.007

Star 2.

Plate.	Right Ascension: At Epoch of Plate.	Right Ascension: P. M.	Right Ascension: At Epoch 1875.0.	Declination: At Epoch of Plate.	Declination: P. M.	Declination: At Epoch 1875.0.
I	127°36′26″.17	—0″.31	25″.86	20°10′02″.04	+0″.15	2″.19
II	26 .21	— .31	.90	.10	+ .15	.25
III	26 .03	— .31	.72	.06	+ .14	.20
IV	26 .15	— .31	.84	.14	+ .14	.28
V	25 .74	+ .15	.89	.26	— .07	.19
VII	25 .65	+ .15	.80	.32	— .07	.25
VIII	25 .60	+ .15	.75	.24	— .07	.17
IX	25 .71	+ .15	.86	.40	— .07	.33
Mean,			127°36′25″.83	Mean,		20°10′02″.23
Probable Error,			±.018	Probable Error,		±.015
Proper Motion,			—0.066 ±0.005	Proper Motion,		+0.031 ±0.004

STAR 3.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°37′28″.20	—0″.38	27″.82	19°57′10″.51	+0″.01	10″.52
III	27 .95	— .38	.57	.32	+ .01	.33
IV	27 .98	— .38	.60	.42	+ .01	.43
V	27 .53	+ .19	.72	.50	.00	.50
VII	27 .39	+ .19	.58	.39	.00	.39
VIII	27 .36	+ .19	.55	.34	.00	.34
IX	27 .62	+ .19	.81	.49	— .01	.48
Mean,			127°37′27″.66	Mean,		19°57′10″.43
Probable Error,			±.032	Probable Error,		±.021
Proper Motion,			—0.081 ±0.009	Proper Motion,		+0.002 ±0.006

STAR 4.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°39′06″.16	—0″.29	5″.87	19°42′06″.67	+0″.01	6″.68
II	5 .92	— .29	.63	.72	+ .01	.73
III	6 .04	— .29	.75	.68	+ .01	.69
IV	5 .97	— .29	.68	.74	+ .01	.75
V	5 .60	+ .14	.74	.66	.00	.66
VII	5 .54	+ .14	.68	.70	.00	.70
VIII	5 .52	+ .14	.66	.73	.00	.73
IX	5 .71	+ .14	.85	.77	— .01	.76
Mean,			127°39′05″.73	Mean,		19°42′06″.71
Probable Error,			±.024	Probable Error,		±.010
Proper Motion,			—0.061 ±0.007	Proper Motion,		+0.002 ±0.003

STAR 5.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°47′38″.48	—0″.14	8″.34	20°38′33″.84	+0″.17	34″.01
II	.68	— .14	.54	33 .71	+ .17	33 .88
III	.57	— .14	.43	33 .64	+ .17	33 .81
IV	.48	— .14	.34	33 .74	+ .17	33 .91
V	.35	+ .07	.42	33 .97	— .08	33 .89
VII	.41	+ .07	.48	33 .99	— .09	33 .90
VIII	.38	+ .07	.45	34 .01	— .09	33 .92
IX	.22	+ .07	.29	34 .01	— .09	33 .92
Mean,	127°47′38″.41			Mean,	20°38′33″.91	
Probable Error,	±.022			Probable Error,	±.015	
Proper Motion,	—0.030 ±0.006			Proper Motion,	+0.037 ±0.004	

STAR 6.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°51′33″.81	—0″.32	33″.49	20°25′33″.46	+0″.21	33″.67
II	.66	— .32	.34	.16	+ .21	.37
III	.77	— .32	.45	.30	+ .21	.51
IV	.97	— .32	.65	.52	+ .21	.73
V	.47	+ .16	.63	.66	— .10	.56
VII	.34	+ .16	.50	.61	— .10	.51
VIII	.26	+ .16	.42	.64	— .10	.54
IX	.20	+ .16	.36	.76	— .10	.66
Mean,	127°51′33″.48			Mean,	20°25′33″.57	
Probable Error,	±.031			Probable Error,	±.031	
Proper Motion,	—0.069 ±0.009			Proper Motion,	+0.044 ±0.009	

Star 7.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°54′06″.35	—0″.33	6″.02	19°56′14″.87	—0″.03	14″.84
II	6 .36	— .33	6 .03	.70	— .03	.67
III	6 .16	— .33	5 .83	.63	— .03	.60
IV	6 .46	— .33	6 .13	.88	— .03	.85
V	5 .91	+ .16	6 .07	.76	+ .01	.77
VII	5 .81	+ .16	5 .97	.74	+ .01	.75
VIII	5 .85	+ .16	6 .01	.74	+ .01	.75
IX	5 .77	+ .17	5 .94	.66	+ .01	.67
Mean,		127°54′06″.00		Mean,	19°56′14″.74	
Probable Error,		±.025		Probable Error,	±.024	
Proper Motion,		—0.071 ±0.007		Proper Motion,	—0.006 ±0.007	

Star 7A.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
II	127°57′58″.00	—0″.47	57″.53	20°09′42″.62	—0″.09	42″.53
IV	58 .26	— .47	.79	.55	— .09	.46
VII	57 .61	+ .23	.84	.57	+ .04	.61
VIII	57 .25	+ .23	.48	.34	+ .04	.38
Mean,		127°57′57″.66		Mean,	20°09′42″.50	
Proper Motion,		—0.100		Proper Motion,	—0.019	

STAR 8.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°57′59″.38	—0″.34	9″.04	20°26′12″.54	+0″.12	12″.66
II	59 .38	— .34	.04	.51	+ .12	.63
III	59 .64	— .34	.30	.63	+ .12	.75
IV	59 .42	— .34	.08	.69	+ .12	.81
V	59 .08	+ .17	.25	.79	— .06	.73
VII	58 .90	+ .17	.07	.69	— .06	.63
VIII	58 .86	+ .17	.03	.70	— .06	.64
IX	58 .95	+ .17	.12	.88	— .06	.82
	Mean,		127°57′59″.12	Mean,		20°26′12″.71
	Probable Error,		±.028	Probable Error,		±.022
	Proper Motion,		—0.072 ±0.008	Proper Motion,		+0.025 ±0.006

STAR 10.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°58′48″.65	—0″.19	48″.46	20°06′50″.40	+0″.14	50″.54
II	.76	— .19	.57	.33	+ .14	.47
II I	.83	— .19	.64	.27	+ .14	.41
IV	.77	— .19	.58	.34	+ .14	.48
V	.47	+ .09	.56	.52	— .07	.45
VII	.34	+ .09	.43	.58	— .07	.51
VIII	.42	+ .09	.51	.48	— .07	.41
IX	.67	+ .09	.76	.56	— .07	.49
	Mean,		127°58′48″.56	Mean,		20°06′50″.47
	Probable Error,		±.028	Probable Error,		±.012
	Proper Motion,		—0.040 ±0.008	Proper Motion,		+0.029 ±0.003

STAR 11.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	127°59′36″.89	—0″.35	36″.54	20°01′46″.90	+0″.10	47″.00
II	36 .86	— .35	.51	46 .86	+ .10	46 .96
III	36 .96	— .35	.61	46 .80	+ .10	46 .90
IV	37 .08	— .35	.73	46 .76	+ .10	46 .86
V	36 .63	+ .17	.80	46 .95	— .05	46 .90
VII	36 .36	+ .17	.53	46 .96	— .05	46 .91
VIII	36 .40	+ .17	.57	46 .83	— .05	46 .78
IX	36 .29	+ .17	.46	47 .16	— .05	47 .11
Mean,			127°59′36″.59	Mean,		20°01′46″.93
Probable Error,			±.032	Probable Error,		±.027
Proper Motion,			—0.075 ±0.009	Proper Motion,		+0.021 ±0.008

STAR 14.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°07′45″.06	—0″.20	44″.86	20°31′29″.10	+0″.13	29″.23
II	44 .81	— .20	.61	29 .00	+ .13	.13
III	44 .98	— .20	.78	28 .88	+ .13	.01
IV	45 .15	— .20	.95	29 .01	+ .13	.14
V	44 .82	+ .10	.92	29 .07	— .06	.01
VII	44 .60	+ .10	.70	29 .19	— .06	.13
VIII	44 .75	+ .10	.85	29 .23	— .06	.17
IX	44 .64	+ .10	.74	29 .26	— .06	.20
Mean,			128°07′44″.80	Mean,		20°31′29″.13
Probable Error,			±.031	Probable Error,		±.022
Proper Motion,			—0.042 ±0.009	Proper Motion,		+0.027 ±0.006

STAR 15.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°07′55″.19	—0″.25	54″.94	20°13′01″.26	+0″.12	1″.38
II	55 .07	— .25	54 .82	.11	+ .12	.23
III	55 .02	— .25	54 .77	.20	+ .12	.32
IV	55 .26	— .25	55 .01	.23	+ .12	.35
V	54 .74	+ .12	54 .86	.39	— .06	.33
VII	54 .77	+ .12	54 .89	.34	— .06	.28
VIII	54 .84	+ .12	54 .96	.39	— .06	.33
IX	54 .69	+ .13	54 .82	.37	— .06	.31
Mean,		128°07′54″.88		Mean,	20°13′01″.32	
Probable Error,		±.022		Probable Error,	±.012	
Proper Motion,		—0.054 ±0.006		Proper Motion,	+0.025 ±0.003	

STAR 16.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°08′44″.80	—0″.34	44″.46	19°42′50″.00	+0″.03	50″.03
II	.79	— .34	.45	50 .08	+ .03	50 .11
III	.73	— .34	.39	49 .91	+ .03	49 .94
IV	.98	— .34	.64	49 .85	+ .03	49 .88
V	.38	+ .17	.55	49 .97	— .01	49 .96
VII	.41	+ .17	.58	50 .00	— .01	49 .99
VIII	.32	+ .17	.49	49 .95	— .01	49 .94
IX	.15	+ .17	.32	50 .08	— .01	50 .07
Mean,		128°08′44″.48		Mean,	19°42′49″.99	
Probable Error,		±.028		Probable Error,	±.021	
Proper Motion,		—0.073 ±0.008		Proper Motion,	+0.006 ±0.006	

Star 17.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°10′05″.46	—0″.27	5″.19	19°48′46″.81	+0″.09	46″.90
II	5 .17	— .27	4 .90	.83	+ .09	.92
III	5 .36	— .27	5 .09	.81	+ .08	.89
IV	5 .57	— .27	5 .30	.75	+ .08	.83
V	5 .03	+ .13	5 .16	.88	— .04	.84
VII	5 .06	+ .13	5 .19	.90	— .04	.86
VIII	5 .01	+ .13	5 .14	.93	— .04	.89
IX	4 .83	+ .14	4 .97	.99	— .04	.95
Mean,	128°10′05″.12			Mean,	19°48′46″.89	
Probable Error,	±.035			Probable Error,	±.011	
Proper Motion,	—0.058 ±0.010			Proper Motion,	+0.018 ±0.003	

Star 18.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°11′32″.44	—0″.22	32″.22	19°59′31″.64	+0″.10	31″.74
II	32 .26	— .22	32 .04	.53	+ .10	.63
III	32 .20	— .21	31 .99	.44	+ .10	.54
IV	32 .28	— .21	32 .07	.48	+ .10	.58
V	32 .05	+ .11	32 .16	.74	— .05	.69
VII	31 .95	+ .11	32 .06	.60	— .05	.55
VIII	32 .04	+ .11	32 .15	.64	— .05	.59
IX	31 .86	+ .11	31 .97	.69	— .05	.64
Mean,	128°11′32″.08			Mean,	19°59′31″.62	
Probable Error,	±.024			Probable Error,	±.019	
Proper Motion,	—0.046 ±0.007			Proper Motion,	+0.021 ±0.005	

Star 19.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0	At Epoch of Plate.	P. M.	At Epoch 1875.0.
II	128°11′36″.06	—0″.25	35″.81	20°35′50″.68	+0″.09	50″.77
IV	36 .37	— .25	36 .12	.64	+ .09	.73
V	35 .95	+ .12	36 .07	.69	— .04	.65
VII	35 .86	+ .12	35 .98	.87	— .04	.83
VIII	35 .72	+ .12	35 .84	.82	— .04	.78
Mean,		128°11′35″.96		Mean,	20°35′50″.75	
Proper Motion,		—0.053		Proper Motion,	+0.019	

Star 20.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°11′51″.88	—0″.20	51″.68	19°58′50″.40	+0″.08	50″.48
II	.77	— .20	.57	.42	+ .08	.50
III	.75	— .20	.55	.39	+ .08	.47
IV	.77	— .20	.57	.40	+ .08	.48
V	.49	+ .10	.59	.50	— .04	.46
VII	.42	+ .10	.52	.37	— .04	.33
VIII	.51	+ .10	.61	.50	— .04	.46
IX	.58	+ .10	.68	.68	— .04	.64
Mean,		128°11′51″.60		Mean,	19°58′50″.48	
Probable Error,		±.016		Probable Error,	±.023	
Proper Motion,		—0.042 ±0.004		Proper Motion,	+0.016 ±0.006	

STAR 22.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°12′43″.03	—0″.32	42″.71	20°26′50″.07	+0″.13	50″.20
II	42 .70	— .32	.38	.12	+ .13	.25
III	42 .98	— .32	.66	.04	+ .13	.17
IV	43 .08	— .32	.76	.04	+ .13	.17
V	42 .36	+ .16	.52	.20	— .06	.14
VII	42 .33	+ .16	.49	.20	— .06	.14
VIII	42 .57	+ .16	.73	.35	— .06	.29
IX	42 .63	+ .16	.79	.28	— .06	.22
	Mean,		128°12′42″.63	Mean,		20°26′50″.20
	Probable Error,		±.040	Probable Error,		±.015
	Proper Motion,		—0.068 ±0.011	Proper Motion,		+0.027 ±0.004

STAR 23.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Place.	P. M.	At Epoch 1875.0.
I	128°14′60″.24	—0″.23	60″.01	20°34′39″.08	+0″.19	39″.27
II	59 .92	— .23	59 .69	38 .93	+ .19	.12
III	59 .81	— .23	59 .58	38 .91	+ .19	.10
IV	60 .20	— .23	59 .97	38 .94	+ .19	.13
V	59 .85	+ .11	59 .96	39 .21	— .09	.12
VII	59 .54	+ .11	59 .65	39 .18	— .09	.09
VIII	59 .71	+ .11	59 .82	39 .18	— .09	.09
IX	59 .69	+ .11	59 .80	39 .41	— .09	.32
	Mean,		128°14′59″.81	Mean,		20°34′39″.16
	Probable Error,		±.044	Probable Error,		±.025
	Proper Motion,		—0.049 ±0.012	Proper Motion,		+0.040 ±0.007

Star 23A.

Plate.	Right Ascension: At Epoch of Plate.	Right Ascension: P. M.	Right Ascension: At Epoch 1875.0.	Declination: At Epoch of Plate.	Declination: P. M.	Declination: At Epoch 1875.0.
I	128°15′57″.80	—0″.32	57″.48	20°26′03″.10	+0″.09	3″.19
II	.74	— .32	.42	2 .80	+ .09	2 .89
III	.70	— .32	.38	3 .00	+ .09	3 .09
IV	.96	— .32	.64	2 .96	+ .09	3 .05
V	.42	+ .16	.58	3 .10	— .05	3 .05
VII	.28	+ .16	.44	3 .09	— .05	3 .04
VIII	.27	+ .16	.43	3 .12	— .05	3 .07
IX	.29	+ .16	.45	3 .12	— .05	3 .07
	Mean,		128°15′57″.48	Mean,		20°26′03″.06
	Probable Error,		±.024	Probable Error,		±.022
	Proper Motion,		—0.069 ±0.007	Proper Motion,		+0.020 ±0.006

Star 24.

Plate.	Right Ascension: At Epoch of Plate.	Right Ascension: P. M.	Right Ascension: At Epoch 1875.0.	Declination: At Epoch of Plate.	Declination: P. M.	Declination: At Epoch 1875.0.
I	128°16′58″.57	—0″.21	58″.36	19°58′19″.27	+0″.07	19″.34
II	58 .24	— .21	58 .03	.16	+ .07	.23
III	58 .57	— .21	58 .36	.22	+ .07	.29
IV	58 .67	— .21	58 .46	.11	+ .07	.18
V	58 .19	+ .10	58 .29	.29	— .03	.26
VII	57 .89	+ .10	57 .99	.24	— .03	.21
VIII	58 .32	+ .10	58 .42	.27	— .03	.24
IX	58 .38	+ .10	58 .48	.38	— .04	.34
	Mean,		128°16′58″.30	Mean,		19°58′19″.26
	Probable Error,		±.051	Probable Error,		±.016
	Proper Motion,		—0.045 ±0.014	Proper Motion,		+0.015 ±0.004

STAR 25.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°17′32″.03	—0″.25	31″.78	20°07′36″.79	+0″.07	36″.86
II	31 .70	— .25	.45	.67	+ .07	.74
III	31 .57	— .25	.32	.60	+ .07	.67
IV	31 .95	— .25	.70	.69	+ .07	.76
V	31 .39	+ .12	.51	.73	— .03	.70
VII	31 .38	+ .12	.50	.82	— .03	.79
VIII	31 .38	+ .12	.50	.75	— .03	.72
IX	31 .59	+ .13	.72	.86	— .04	.82
Mean,	128°17′31″.56			20°07′36″.76		
Probable Error,	±.043			±.016		
Proper Motion,	—0.054 ±0.012			+0.015 ±0.004		

STAR 26.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0
I	128°17′37″.23	—0″.30	36″.93	19°47′20″.91	+0″.03	20″.94
II	36 .92	— .30	.62	21 .01	+ .03	21 .04
III	36 .98	— .29	.69	20 .83	+ .03	20 .86
IV	37 .12	— .29	.83	20 .76	+ .03	20 .79
V	36 .49	+ .14	.63	20 .82	— .02	20 .80
VII	36 .64	+ .15	.79	20 .90	— .02	20 .88
VIII	36 .79	+ .15	.94	20 .89	— .02	20 .87
IX	36 .56	+ .15	.71	21 .09	— .02	21 .07
Mean,	128°17′36″.77			19°47′20″.91		
Probable Error,	±.034			±.028		
Proper Motion,	—0.063 ±0.009			+0.007 ±0.008		

Star 27.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°17′52″.80	—0″.17	52″.63	20°06′36″.49	+0″.15	36″.64
II	.35	— .17	.18	.67	+ .15	.82
III	.56	— .16	.40	.50	+ .15	.65
IV	.71	— .16	.55	.43	+ .15	.58
V	.42	+ .08	.50	.70	— .07	.63
VII	.34	+ .08	.42	.73	— .07	.66
VIII	.30	+ .08	.38	.71	— .07	.64
IX	.39	+ .08	.47	.86	— .08	.78
	Mean,		128°17′52″.44	Mean,		20°06′36″.68
	Probable Error,		±.037	Probable Error,		±.022
	Proper Motion,		—0.035 ±0.010	Proper Motion,		+0.032 ±0.006

Star 28.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°18′06″.53	—0″.19	6″.34	20°16′31″.01	+0″.07	31″.08
II	.26	— .19	.07	30 .96	+ .07	31 .03
III	.44	— .19	.25	30 .78	+ .07	30 .85
IV	.58	— .19	.39	30 .93	+ .07	31 .00
V	.21	+ .09	.30	30 .98	— .03	30 .95
VII	.03	+ .09	.12	30 .97	— .03	30 .94
VIII	.22	+ .09	.31	31 .08	— .03	31 .05
IX	.22	+ .09	.31	31 .06	— .04	31 .02
	Mean,		128°18′06″.26	Mean,		20°16′30″.99
	Probable Error,		±.030	Probable Error,		±.020
	Proper Motion,		—0.040 ±0.008	Proper Motion,		+0.015 ±0.006

STAR 29.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°18′40″.95	—0″.29	40″.66	20″.52	+0″.17	20″.69
II	40 .52	— .29	.23	.31	+ .17	.48
III	40 .87	— .29	.58	.40	+ .17	.57
IV	41 .08	— .29	.79	.37	+ .17	.54
V	40 .50	+ .14	.64	.48	— .08	.40
VII	40 .30	+ .14	.44	.71	— .08	.63
VIII	40 .50	+ .14	.64	.62	— .08	.54
IX	40 .38	+ .14	.52	.81	— .08	.73
	Mean,		128°18′40″.56	Mean,		20°37′20″.57
	Probable Error,		±.046	Probable Error,		±.030
	Proper Motion,		—0.062 0.012	Proper Motion,		+0.036 ±0.008

STAR 31.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°19′12″.34	—0″.27	12″.07	19°59′06″.84	+0″.10	6″.94
II	12 .31	— .27	12 .04	6 .88	+ .10	6 .98
III	11 .93	— .27	11 .66	6 .93	+ .10	7 .03
IV	12 .18	— .27	12 .91	6 .64	+ .10	6 .74
V	11 .64	+ .13	11 .77	6 .94	— .05	6 .89
VII	11 .73	+ .13	11 .86	7 .02	— .05	6 .97
VIII	11 .95	+ .13	12 .08	6 .88	— .05	6 .83
IX	11 .83	+ .13	11 .96	7 .07	— .05	7 .02
	Mean,		128°19′11″.92	Mean,		19°59′06″.92
	Probable Error,		±.041	Probable Error,		±.027
	Proper Motion,		—0.057 ±0.011	Proper Motion,		+0.022 ±0.008

Star 32.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°20′56″.93	—0″.28	56″.65	19°38′06″.20	+0″.03	6″.23
II	57 .02	— .28	.74	.35	+ .03	.38
III	56 .98	— .28	.70	.17	+ .03	.20
IV	57 .20	— .28	.92	.05	+ .03	.08
V	56 .51	+ .14	.65	.28	— .02	.26
VII	56 .61	+ .14	.75	.27	— .02	.25
VIII	56 .71	+ .14	.85	.11	— .02	.09
IX	56 .64	+ .14	.78	.32	— .02	.30
Mean,			128°20′56″.76	Mean,		19°38′06″.22
Probable Error,			±.026	Probable Error,		±.028
Proper Motion,			—0.059 ±0.007	Proper Motion,		+0.007 ±0.008

Star 33.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°22′30″.50	—0″.34	30″.16	19°40′09″.34	+0″.04	9″.38
II	30 .37	— .34	30 .03	.57	+ .04	.61
III	30 .14	— .34	29 .80	.34	+ .04	.38
IV	30 .53	— .34	30 .19	.32	+ .04	.36
VII	29 .92	+ .17	30 .09	.50	— .02	.48
VIII	30 .02	+ .17	30 .19	.29	— .02	.27
IX	29 .71	+ .17	29 .88	.57	— .02	.55
Mean,			128°22′30″.05	Mean,		19°40′09″.43
Probable Error,			±.048	Probable Error,		±.037
Proper Motion,			—0.072 ±0.013	Proper Motion,		+0.009 ±0.010

STAR 34.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°23′08″.33	—0″.27	8″.06	20°09′37″.37	+0″.10	37″.47
II	8 .29	— .27	8 .02	.32	+ .10	.42
III	8 .33	— .27	8 .06	.30	+ .10	.40
IV	8 .49	— .27	8 .22	.36	+ .10	.46
V	7 .80	+ .13	7 .93	.44	— .05	.39
VII	8 .06	+ .13	8 .19	.58	— .05	.53
VIII	8 .08	+ .13	8 .21	.48	— .05	.43
IX	7 .88	+ .14	8 .02	.47	— .05	.42
Mean,		128°23′08″.09		Mean,	20°09′37″.44	
Probable Error,		±.029		Probable Error,	±.012	
Proper Motion,		—0.058 ±0.008		Proper Motion,	+0.022 ±0.003	

STAR 35.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°25′03″.01	—0″.27	2″.74	20°42′28″.84	+0″.14	28″.98
II	2 .92	— .27	.65	28 .80	+ .14	28 .94
III	3 .04	— .27	.77	28 .86	+ .14	29 .00
IV	3 .01	— .27	.74	28 .82	+ .14	28 .96
V	2 .78	+ .13	.91	28 .86	— .07	28 .79
VII	2 .58	+ .13	.71	29 .12	— .07	29 .05
VIII	2 .59	+ .13	.72	29 .00	— .07	28 .93
IX	2 .41	+ .14	.55	29 .17	— .07	29 .10
Mean,		128°25′02″.72		Mean,	20°42′28″.97	
Probable Error,		±.028		Probable Error,	±.025	
Proper Motion,		—0.058 ±0.008		Proper Motion,	+0.030 ±0.007	

STAR 36.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°26′25″.18	—0″.45	24″.73	20°22′35″.73	+0″.16	35″.89
II	25 .14	— .45	.69	.67	+ .16	.83
III	25 .17	— .44	.73	.59	+ .15	.74
IV	25 .40	— .44	.96	.63	+ .15	.78
VII	24 .59	+ .22	.81	.96	— .08	.88
VIII	24 .54	+ .22	.76	.78	— .08	.70
IX	24 .54	+ .22	.76	.92	— .08	.84
	Mean,		128°26′24″.78	Mean,		20°22′35″.81
	Probable Error,		±.028	Probable Error,		±.022
	Proper Motion,		—0.095 +0.007	Proper Motion,		+0.033 ±0.006

STAR 37.

Plate.	Right Ascension:			Declination:		
	At Epoch of Plate.	P. M.	At Epoch 1875.0.	At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°26′31″.81	—0″.28	31″.53	20°01′19″.38	+0″.05	19″.43
II	.61	— .28	.33	.56	+ .05	.61
III	.50	— .28	.22	.31	+ .05	.36
IV	.89	— .28	.61	.28	+ .05	.33
V	.28	+ .14	.42	.42	— .02	.40
VII	.29	+ .14	.43	.34	— .03	.31
VIII	.32	+ .14	.46	.49	— .03	.46
IX	.27	+ .14	.41	.58	— .03	.55
	Mean,		128°26′31″.43	Mean,		20°01′19″.43
	Probable Error,		±.032	Probable Error,		±.029
	Proper Motion,		—0.059 ±0.006	Proper Motion,		+0.011 ±0.008

Star 38.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°29′56″.44	—0″.21	56″.23	20°16′19″.07	+0″.08	19″.15
II	.48	— .21	.27	19 .16	+ .08	.24
IV	.66	— .21	.45	18 .93	+ .07	.00
VII	.17	+ .10	.27	19 .08	— .04	.04
VIII	.15	+ .10	.25	19 .17	— .04	.13
IX	.32	+ .10	.42	19 .24	— .04	.20
Mean,			128°29′56″.32	Mean,		20°16′19″.13
Probable Error,			±.031	Probable Error,		±.030
Proper Motion,			—0.045 ±0.008	Proper Motion,		+0.016 ±0.008

Star 39.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°30′39″.00	—0″.35	38″.65	20°21′52″.34	+0″.07	52″.41
II	38 .72	— .35	.37	.34	+ .07	.41
III	38 .82	— .35	.47	.32	+ .07	.39
IV	39 .01	— .35	.66	.24	+ .07	.31
V	38 .44	+ .17	.61	.30	— .03	.27
VII	38 .33	+ .17	.50	.42	— .03	.39
VIII	38 .34	+ .17	.51	.38	— .03	.35
IX	38 .33	+ .17	.50	.56	— .04	.52
Mean,			128°30′38″.53	Mean,		20°21′52″.38
Probable Error,			±.027	Probable Error,		±.021
Proper Motion,			—0.075 ±0.008	Proper Motion,		+0.015 ±0.006

Star 40.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°32′19″.74	—0″.42	19″.32	19°42′13″.48	+0″.05	13″.53
II	.92	— .42	.50	.60	+ .05	.65
III	.78	— .42	.36	.65	+ .05	.70
IV	.92	— .42	.50	.54	+ .05	.59
V	.14	+ .21	.35	.67	— .02	.65
VII	.22	+ .21	.43	.65	— .02	.63
VIII	.29	+ .21	.50	.61	— .02	.59
IX	.20	+ .21	.41	.61	— .02	.59
Mean,			128°32′19″.42	Mean,		19°42′13″.62
Probable Error,			±.020	Probable Error,		±.014
Proper Motion,			—0.090 ±0.006	Proper Motion,		+0.010 ±0.004

Star 41.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
VII	128°06′08″.44	+0″.10	8″.54	20°06′21″.68	—0″.03	21″.65
VIII	.30	+ .10	.40	.78	— .03	.75
Mean,			128°06′08″.47	Mean,		20°06′21″.70

Star 42.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
VII	128°38′00″.16	+0″.15	00″.31	20°06′16″.46	—0″.08	16″.38
VIII	59 .83	+ .15	59 .98	.29	— .08	.21
Mean,			128°38′00″.14	Mean,		20°06′16″.30

STAR 43.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°39′47″.04	—0″.46	46″.58	20°19′06″.94	+0″.03	6″.97
II	46 .71	— .46	.25	.77	+ .03	.80
III	46 .88	— .45	.43	.72	+ .03	.75
IV	47 .05	— .45	.60	.56	+ .03	.59
V	46 .32	+ .22	.54	.68	— .02	.66
VII	46 .27	+ .22	.49	.82	— .02	.80
VIII	46 .32	+ .22	.54	.95	— .02	.93
IX	46 .06	+ .23	.29	.74	— .02	.72
	Mean,		128°39′46″.46	Mean,		20°19′06″.78
	Probable Error,		±.036	Probable Error,		±.035
	Proper Motion,		—0.097 ±0.010	Proper Motion,		+0.007 ±0.010

STAR 44.

Plate.	Right Ascension: At Epoch of Plate.	P. M.	At Epoch 1875.0.	Declination: At Epoch of Plate.	P. M.	At Epoch 1875.0.
I	128°40′18″.28	—0″.23	18″.05	20°36′14″.23	+0″.07	14″.30
II	18 .27	— .23	18 .04	.33	+ .07	.40
III	18 .49	— .22	18 .27	.31	+ .07	.38
IV	18 .26	— .22	18 .04	.21	+ .07	.28
V	18 .05	+ .11	18 .16	.40	— .03	.37
VII	17 .95	+ .11	18 .06	.42	— .03	.39
VIII	17 .87	+ .11	17 .98	.36	— .03	.33
IX	18 .08	+ .11	18 .19	.33	— .04	.29
	Mean,		128°40′18″.10	Mean,		20°36′14″.34
	Probable Error,		±.027	Probable Error,		±.013
	Proper Motion,		—0.048 ±0.008	Proper Motion,		+0.015 ±0.004

STAR 45.

Plate.	Right Ascension: At Epoch of Plate.	Right Ascension: P. M.	Right Ascension: At Epoch 1875.0.	Declination: At Epoch of Plate.	Declination: P. M.	Declination: At Epoch 1875.0.
II	128°44′17″.78	—0″.33	17″.45	19°51′23″.45	+0″.08	23″.53
III	.62	— .33	.29	.38	+ .08	.46
IV	.98	— .33	.65	.22	+ .08	.30
V	.26	+ .16	.42	.44	— .04	.40
VII	.34	+ .16	.50	.56	— .04	.52
VIII	.39	+ .16	.55	.45	— .04	.41
IX	.23	+ .16	.39	.43	— .04	.39
Mean,			128°44′17″.46	Mean,		19°51′23″.43
Probable Error,			±.032	Probable Error,		±.022
Proper Motion,			—0.070 ±0.009	Proper Motion,		+0.017 ±0.006

The final results of the measurements have been collected on the next page; the right ascensions and declinations are obtained from α_1 and δ_1, which are printed in the foregoing pages in slightly bolder type, by adding the transformation corrections given in Table VI, page 239. The magnitudes are those of the Bonn Durchmusterung.

Catalogue of the Relative Positions and Proper Motions of 42 Stars in the Præsepe Group.

Mean Equinox of 1875.0. **Epoch 1875.0.**

Star.	Mag. B. D.	Right Ascension.	Proper Motion.	Declination.	Proper Motion.	No. of Plates.
		° ′ ″	″	° ′ ″	″	
1	8.8	127 35 27.78	—0.091	+20 26 49.70	+0.032	8
2	8.2	36 26.49	— .066	+20 09 59.43	+ .031	8
3	8.4	37 30.81	— .081	+19 57 07.85	+ .002	7
4	7.2	39 11.48	— .061	+19 42 04.48	+ .002	8
5	8.0	47 35.08	— .030	+20 38 32.69	+ .037	8
6	8.4	51 32.17	— .069	+20 25 32.80	+ .044	8
7	9.0	54 07.49	— .071	+19 56 14.22	— .006	8
7A	8.9	57 57.87		+20 09 42.23		4
8	9.0	57 58.28	— .072	+ 20 26 12.42	+ .025	8
10	8.0	58 48.92	— .040	+20 06 50.24	+ .029	8
11	8.8	127 59 37.19	— .075	+20 01 46.74	+ .021	8
14	8.0	128 07 44.78	— .042	+20 31 29.12	+ .027	8
15	7.0	07 54.88	— .054	+20 13 01.32	+ .025	8
16	8.0	08 44.32	— .073	+19 42 50.04	+ .006	8
17	7.2	10 04.92	— .058	+19 48 46.88	+ .018	8
18	8.2	11 31.77	— .046	+19 59 31.59	+ .021	8
19	9.0	11 36.50		+20 35 50.69		5
20	8.2	11 51.24	— .042	+19 58 50.44	+ .016	8
22	7.0	12 43.14	— .068	+20 26 50.10	+ .027	8
23	7.3	15 00.34	— .049	+20 34 39.01	+ .040	8
23A	9.0	15 56.81	— .069	+20 26 02.88	+ .020	8
24	8.2	16 57.45	— .045	+19 58 19.04	+ .015	8
25	8.5	17 31.22	— .054	+20 07 36.50	+ .015	8
26	7.0	17 35.17	— .063	+19 47 20.68	+ .007	8
27	7.3	17 52.03	— .035	+20 06 36.40	+ .032	8
28	8.5	18 06.49	— .040	+20 16 30.70	+ .015	8
29	8.8	18 42.24	— .062	+20 37 20.21	+ .036	8
31	7.2	19 10.91	— .057	+19 59 06.57	+ .022	8
32	9.0	20 53.84	— .059	+19 38 05.83	+ .007	8
33	8.2	22 26.97	— .072	+19 40 08.90	+ .009	7
34	7.1	23 07.75	— .058	+20 09 36.79	+ .022	8
35	8.7	25 05.96	— .058	+20 42 28.08	+ .030	8
36	9.0	26 25.91	— .095	+20 22 34.83	+ .033	7
37	7.7	26 30.02	— .059	+20 01 18.46	+ .011	8
38	9.0	29 56.77	— .045	+20 16 17.75	+ .016	6
39	8.6	30 39.81	— .075	+20 21 50.91	+ .015	8
40	8.7	32 14.58	— .090	+19 42 12.03	+ .010	8
41	9.5	36 07.23		+20 06 19.46		2
42	9.3	37 58.79		+20 06 13.76		2
43	7.5	39 47.65	— .097	+20 19 03.89	+ .007	8
44	8.9	40 22.88	— .048	+20 36 11.29	+ .015	8
45	8.4	128 44 12.34	— .070	+19 51 19.77	+ .017	7

VI.

Discussion of Results.

Let us first ascertain what is the probable error of a measured coördinate, being careful not to let personalities in the observing enter into our result. Each coördinate was measured completely, that is in both the direct and in the reversed positions, by two observers. The difference between the two complete measurements will be free from personalities and may be ascribed to errors of observation. This difference, which I shall call v, may easily be computed from Table III; say the two observers are Schlesinger and Kretz, then subtract $(S—K)$ *direct*, from $(S—K)$ *reversed* and the difference is double the amount by which one observer's complete measurement differs from the other's, or $2v$. The probable error of a final coördinate is then given by,

$$\pm \frac{0.6745}{2}\sqrt{\frac{[vv]}{n}}$$

Proceeding in this way for all the plates we obtain the following probable errors. Only those stars were used, thirty-three in number, which appear on all the plates.

	Probable Error of a final x.	Probable Error of a final y.
Plate I	±0″.034	±0″.031
II	.036	.029
III	.023	.023
IV	.024	.020
V	.020	.027
VII	.034	.020
VIII	.032	.025
IX	.037	.027
Means,	±0″.030	±0″.025

The greater uncertainty in right ascension is due to the fact that the images are usually elongated in that direction and are therefore more difficult to bisect. The elongation was caused by the failure of Rutherfurd's clock to keep pace exactly with the diurnal motion of the group, sometimes lagging slightly or sometimes moving too rapidly.

In the tabulation of results the probable error of each right ascension and declination is given. We may compute the probable error of right ascension of a star as derived from a single plate by the expression

$$\pm 0.6745\sqrt{\frac{[vv]}{264 - 66}} \cos \delta_0$$

where $[vv]$ is the sum of the squares of all the residuals in right ascension for the thirty-three stars which appear on all eight plates; the factor $\cos \delta_0$ serves to reduce the probable error to arc of a great circle. The expression for the probable error of a single declination is identical with the above except that $\cos \delta_0$ is omitted. In this way we obtain the probable errors,

In Right Ascension.	In Declination.
$\pm 0''.081$	$\pm 0''.058$

If we do not confine ourselves to the thirty-three stars as above, but use all the stars, we get

$\pm 0''.080$	$\pm 0''.060$

Thus it appears that the uncertainty in a right ascension or in a declination is considerably greater than that in the corresponding measured coördinate. We may conclude from this that when a large number of plates is available, better results will be attained, for a given expenditure of time and labor, by measuring a large number of plates rather than measuring a few with all the elaboration used in the present research. But for the Rutherfurd photographs such elaboration is amply justified by the very limited number of existing photographs of so early a date.

It might appear at first as though a large part of the discrepancy between the two sets of probable errors, namely, those for the measured coördinates, and those for the resulting right ascension and declination, could be accounted for by the uncertainty of the constants used for the several plates. That such is not the case appears from the following considerations: the residuals for the five comparison stars, given on pages 247 and 248, exhibit a remarkable uniformity, showing that the greater part of these residuals is due to inaccuracies in the meridian observations. It follows, therefore, that the probable errors given for the constants p, r, k and c, are due not so much to errors in measuring the plate as to errors in the meridian places. To obtain more precise information on this point, let us correct the meridian places of each of the comparison stars by the mean of the residuals for that star, and suppose we have effected thes leat-square solutions anew, using now the corrected meridian places. It can easily be shown that the new solutions would lead to exactly the same values of the constants as had been first obtained, but now each residual will be altered by a certain quantity, namely, the amount of the corresponding correction to the meridian place. We may then subtract at once the mean of the residuals for a star, from the corresponding residual in each least-square solution and then compute the probable errors of the constants. The results of such a computation are as follows:

		Probable Error of *p* or *r*.	Probable Error of *k* or *c*
Plate	I	±0.000013	±0″.026
	II	24	.049
	III	16	.032
	IV	16	.032
	V	15	.030
	VII	08	.016
	VIII	11	.022
	IX	20	.041
Means,		±0.000015	±0″.031

The former means were

±0.000032	±0″.065

and these must be regarded as indicating the uncertainty in the absolute values of the constants; if the constants which we have obtained are in error, then there will be a decided tendency to error in the same direction on *different* plates, and the smaller probable errors given above indicate how much we should expect the adopted values of the constants to differ from each other as obtained for different plates. Consequently only a small part of the discrepancy between the probable errors of the measured coördinates and of the right ascensions and declinations can be due to uncertainties in the adopted constants.

The discrepancy is probably caused by inaccuracies, and in some cases neglect, of instrumental corrections. For example, the difference between the two complete measurements of a coördinate is independent of errors in the determination of the division corrections, because the two observers always used the same lines; but not so with the differences of the right ascensions or declinations as derived from different plates. Similarly, the corrections for temperature and straightness of the scale, which we have neglected, do not affect the agreement of the measured coördinates. Possibly too, there have been distortions of the film, but the smallness of the probable errors on the whole must rather be taken as evidence against such distortions. It is important to note that the close agreement of the right ascensions and declinations for different plates affords a striking confirmation of the permanence of the Rutherfurd plates, which in the present case have been measured a quarter of a century after they were made.*

If we consider the probable errors of the measured coördinates, we see that the uncertainty is considerably greater upon some plates than upon others. Notwithstanding, equal weights have been assigned to all the plates, since it appears that the uncertainty in a measured coördinate forms only a small part of the uncertainty in the corresponding right ascension or declination.

Let us now compare the photographic results with those of the heliometer. In his memoir upon the group, Professor Schur has given the places of forty-five stars referred to the mean equinox and epoch of 1875.0, which are the same as those used in the present paper. Of these stars all but five appear on the photographs. The following table gives first the uncorrected or direct differences obtained by subtracting the right ascension, declination and proper motion of each star in our catalogue, from the corresponding quantities in Schur's. The differences in right ascension and in proper motion in right ascension have been multiplied by cos δ_0 to reduce them to arc of a great circle.

*See, in this connection, "On the Permanence of the Rutherfurd Photographs," by Harold Jacoby, Annals of the N. Y. Acad. of Sciences, Vol. IX.

COMPARISON WITH HELIOMETER RESULTS.
HELIOMETER *minus* PHOTOGRAPHS.

Star.	Right Ascension.		Declination.		Proper Motion.		No. of Plates.
	Direct Diff's.	Corr'd. Diff's.	Direct Diff's.	Corr'd. Diff's.	Diff's in R. As.	Diff's in Decl.	
	"	"	"	"	"	"	
1	—0.04	+0.07	+0.40	—0.08	+0.016	—0.015	8
2	— .03	— .02	+ .46	— .04	— .014	— .020	8
3	— .17	— .24	+ .61	+ .10	+ .011	+ .004	7
4	+ .24	+ .09	+ .73	+ .20	— .019	+ .005	8
5	— .15	+ .03	+ .67	+ .13	+ .021	+ .001	8
6	— .05	+ .06	+ .55	— .02	— .011	— .032	8
7	+ .12	+ .06	+ .67	+ .07	— .004	+ .018	8
8	— .11	+ .01	+ .50	— .10	— .004	— .020	8
10	+ .11	+ .12	+ .72	+ .10	— .030	— .022	8
11	— .01	— .03	+ .67	+ .04	+ .003	— .013	8
14	— .26	— .10	+ .74	+ .08	— .032	— .008	8
15	— .11	— .06	+ .52	— .15	— .019	— .008	8
16	+ .38	+ .25	+ .57	— .12	— .007	+ .001	8
17	+ .22	+ .18	+ .70	+ .01	— .017	— .019	8
18	+ .16	+ .13	+ .62	— .08	— .023	— .028	8
19	— .27	— .09	+ .71	+ .04			5
20	+ .03	.00	+ .66	— .04	— .035	— .022	8
22	— .20	— .07	+ .67	— .02	— .007	— .017	8
23	— .08	+ .04	+ .79	+ .09	— .020	— .031	8
24	— .06	— .09	+1.04	+ .31	— .016	— .011	8
25	— .02	.00	+ .62	— .10	— .016	— .011	8
26	+ .20	+ .10	+ .69	— .05	— .014	— .006	8
27	+ .08	+ .10	+ .87	+ .14	— .032	— .033	8
28	— .25	— .18	+ .68	— .04	— .028	— .014	8
29	— .51	— .31	+ .73	+ .02	— .004	— .026	8
31	+ .01	— .02	+ .80	+ .06	— .007	— .017	8
32	+ .32	+ .17	+ .80	+ .04	— .014	— .002	8
33	+ .07	— .07	+ .74	— .02	+ .009	— .011	7
34	+ .07	+ .11	+ .94	+ .19	+ .002	— .010	8
35	— .32	— .09	+ .66	— .08	— .009	— .026	8
36	— .13	— .02	+ .79	+ .03	+ .037	— .030	7
37	— .06	— .07	+ .68	— .10	— .001	— .006	8
38	— .05	+ .03	+ .93	+ .14	— .018	— .008	6
39	— .14	— .03	+ .77	— .02	+ .008	— .010	8
40	+ .08	— .04	+ .57	— .25	+ .028	+ .001	8
41	— .11	— .09	+ .78	— .05			2
42	— .23	— .20	+ .66	— .18			2
43	— .16	— .06	+ .91	+ .07	+ .031	— .002	8
44	— .11	+ .09	+ .71	— .12	— .017	.000	8
45	— .07	— .13	+ .58	— .30	+ .018	+ .011	7

The corrected differences in right ascension and declination were obtained by adding systematic corrections and also by modifying the scale-value and orientation of the photographs. That is, a least-square solution was made to determine how much the constants of the plates would have to be changed so as to secure the best possible agreement between the two catalogues. Each star gives two equations of the form,

$$Xdp + Ydr + dk + da = 0$$
$$Ydp - Xdr + dc + d\delta = 0$$

where da and $d\delta$ are the uncorrected or direct differences in the table. The least-square solution may be carried out in a manner entirely similar to that previously used. The differences for stars 18, 20, 24 and 25 were not used because these stars were not included in Schur's triangulation, but each was merely located by position angle and distance from the nearest star in the triangulation. Stars 19, 41 and 42 were also excluded in making the least-square solution because of the small number of plates on which they appear. The remaining stars, thirty-three in number, give the following corrections to the contents:

$$dp = +0.000011 \pm 0.000009$$
$$dr = +0.000098 \pm 0.000009$$
$$dk = +0''.047 \quad \pm 0''.014$$
$$dc = -0''.667 \quad \pm 0''.014$$

The probable error of one equation is

$$\pm 0''.080$$

a quantity which speaks well for the accuracy of all three researches concerned. The corrected differences in the table are now obtained by adding to each uncorrected difference

$X{\cdot}dp + Y{\cdot}dr + dk$ in the right ascensions,

and $Y{\cdot}dp - X{\cdot}dr + dc$ in the declinations.

From the above value for dp we see that the meridian observations gave a scale-value which agrees very closely with that obtained from the heliometer places; the largest effect that dp has on either coördinate of any star is only about 0''.02. On the other hand the value of dr, or the change in the orientation constant is quite large, corresponding to a correction of about 0''.20 in the coördinates of outlying stars. The meridian observations which we used to determine the orientation of the group, were also employed by Schur for the same purpose, and were found by him to give results which practically agreed with those obtained by an independent method. As we have adopted Schur's proper motions for the comparison stars, to reduce their places to the epochs of the plates, we can only conclude that the somewhat large value of *dr* is due to the fact that the relative positions of these stars with respect to the rest of the group have been differently determined by the photographs on the one hand, and the heliometers on the other. This explanation is borne out by the comparatively large values of the corrected differences for the comparison stars, numbers 4, 5, 15, 40 and 44.

The large value for *dk*, or the systematic correction in declination, was to be expected. We have already remarked (see page 236) that the proper motions used for the comparison stars were not derived by Schur from the direct differences between the two heliometer determinations of the places of these stars, but that systematic corrections,

$$+ 0^{s}.0003 \text{ and } - 0''.039$$

were added to the proper motions in right ascension and declination respectively. Hence we must expect the photographic places to differ from those of the heliometer for the epoch of 1875.0, by

$$+ 0''.071 \text{ and } - 0''.612,$$

the proper motion having been used for an interval of 15.7 years. These corrections agree quite well with the values of *dk* and *dc* respectively, as obtained above.

VII.

Orientation by Trails. Scale-Value.

An independent method for orienting a stellar photograph is furnished by the "trails" or third images of some of the brighter stars. The Rutherfurd photographs previously reduced depend upon this mode of orientation, and the present research offers an admirable opportunity for testing its accuracy. Four trails have been measured and reduced on each Præsepe plate, and the resulting values of the orientation corrections were compared with the results obtained from a comparison with meridian observations, and also with those obtained with the use of the heliometer places. On Plate II the trails were too faint to admit of measurement, and on Plate V they were missing altogether.

The trails were measured in a different manner from that used for the other images. The plate was first set in the position which it occupied when "y direct" had been measured for the stars, and the micrometer was set and read on the east image of a star whose trail was to be measured. Then, without touching the microscope, the plate was moved along the cylinder till the corresponding trail came into view. This was always possible because the plate had been approximately oriented when first set in the machine. Two readings were made upon the trail and the plate was then moved back to the east image, which was read a second time. The same operations were gone through for the west image, and the mean of all the readings on the images was subtracted from the mean of the readings on the trail, thus giving the *offset* in declination by which the trail differed from the middle point between the two images. All the above operations were repeated in the opposite position of the plate, namely that corresponding to "y reversed," except that in the latter case the mean of the readings on the trail was subtracted from that for the images, so as to get the same sign for the offset as before. Each trail was thus measured by two observers separately, so that in all, sixteen readings were made on each trail, and eight upon each of the images. The resulting offsets are tabulated below in millimetres.

TRAIL MEASUREMENTS.

Plate. \ Star.	15.	22.	23.	27.	31.	37.
I	—.0443		—.0193		—.0084	+.0183
III	—.0676		—.0404	—.0398	—.0292	
IV	—.0535		—.0312		—.0169	+.0070
VII	—.0772	—.0422	—.0499		—.0294	
VIII	—.1054	—.0766	—.0718		—.0510	
IX	—.0850		—.0568		—.0356	—.0070

The distance from each trail to the middle point between the corresponding images was measured approximately as follows, being practically the same for all the stars upon a plate :

Plate,	I	III	IV	VII	VIII	IX	
s,	35.0,	35.1,	35.0,	39.3,	48.1,	39.4	millimetres.

We shall now consider what corrections must be applied to the above offsets in order that the true orientations of the plates may be computed from them.

Instrumental Corrections. The only correction of this kind is that for rotation, the data for which have already been given in Table II. Using the same notation as before the correction to the offset is

$$-s.\ i.\ \sin 1''$$

which is the same for all four stars. Having applied this connection, the offset may now be converted into seconds of arc by multiplying by the approximate scale value, 52.87.

Transformation Corrections. For the present purpose it will be convenient to use Ball and Rambaut's formulas quoted on page 238, in which $X \sec \delta_0$ and Y appear in the second members instead of $\Delta\alpha$ and $\Delta\delta$. We need only the second of these formulas :

$$\Delta\delta - y = -\tfrac{1}{4}\,(X \sec \delta_0)^2 \sin 2\delta_0 - \tfrac{1}{3}\,Y^3 - (X \sec \delta_0)^2\, Y$$

For the trail, $X \sec \delta_0$ is diminished by

$$z = 52.87 \cdot s \cdot \sec \delta_0,$$

while Y remains practically unchanged. Hence the correction to the offset is,

$$+\tfrac{1}{4} \sin 2\delta_0 \cdot z \cdot (z - 2X \sec \delta_0) + z \cdot (z - 2X \sec \delta_0)\ Y$$

Refraction Corrections. The trails were taken somewhat later than the principal images of the group, and as the zenith distance changed in the interval, the refraction-coefficients will also be changed. Denoting by M_y' and N_y' what these coefficients become for the trails, we have the correction to the offset,

$$M' \cdot z + (M_y - M_y') X \sec \delta_0 + (N_y - N_y') Y$$

The first term is constant for all four stars, and the two remaining terms are small. To calculate M_y' and N_y' we must know how much the hour angle has changed in the interval between the exposures for the principal images and that for the trail. As each of the former lasted six minutes and as the exposure for the trail was much shorter, we may safely adopt seven minutes of time as the change in the hour-angle. M_y' and N_y' may then be calculated with sufficient accuracy by interpolating in Table VII.

After these corrections have been applied it will be convenient to transform the offsets into position angles, which may be done by the formula

$$p = 270^\circ + \sin^{-1} \left\{ \frac{\text{offset}}{z \cdot \cos \delta_0} \right\}$$

Precession, Nutation and Aberration. Formulas for correcting position angles for these were deduced in convenient form by Bessel* ; let

$$\alpha' = 20'' \sec \delta_0 \sin \alpha_0$$

$$\beta' = \sec \delta_0 \cos \alpha_0$$

$$\gamma' = \tan \delta \cos \alpha_0$$

$$\delta' = \tan \delta_0 \sin \alpha_0$$

A, B, C, D = Bessel's star-numbers, tabulated for each day in the year in the ephemerides.

The true position angle at the beginning of the *same* year is found by adding to the observed position angle the correction,

$$(-A\alpha' + B\beta' + C\gamma' + D\delta')$$

Then to reduce this to beginning of *another* year we add

$$+ 20''.06 \sec \delta_0 \sin \alpha_0 \cdot t$$

where t is the integer corresponding to the difference of the years, and must be considered positive if we are reducing an observation to a later year than that in which it was made.

As an example of the reduction of trail measurements, I have set down the calculations in detail for the trail of Star 23, Plate I.

* "Astronomische Untersuchungen" Vol. I., pg. 202.

Offset,	— 0.0193	millimetres
Rotation Corr'n.,	+ 0.0005	
	— 0.0188	
In arc,	— 0''.99	
Transf. Corr'n.,	+ 1 .75	
Refraction	+ 0 .24	
Corrected offset	+ 1''.00	
Position Angle,		270 + 111''.9
$-(A\alpha' + B\beta' + C\gamma' + D\delta')$,		+ 2 .6
$20.06''$ sec δ_0 sin $a_0 \cdot t$,		+ 84 .0
True Position Angle,		270° + 198''.5

Consequently we have from this star,

$$r = +0.000963$$

Similar calculations for all the trails gave the following results in which r has been multiplied by 10^6 throughout.

ORIENTATION BY TRAILS. VALUES OF $r \times 10^6$.

Plate. \ Star.	15.	22.	23.	27.	31.	37.
I	+954		+963		+840	+873
III	+334		+390	+118	+288	
IV	+851		+777		+757	+706
VII	—128	+186	—140		— 52	
VIII	+122	+152	+111		+113	
IX	—360		—341		—248	—254

Taking the mean for the four stars on each plate and setting down again the values of r previously obtained by comparison with the meridian observations, we have,

	Orientation by Trails.	Orientation by Merid. Obs.
Plate I	+ 0.000908	+ 0.001054
III	+ 282	+ 409
IV	+ 773	+ 1435
VII	— 34	— 35
VIII	+ 124	+ 211
IX	— 301	— 326
Means	+ 292	+ 458

In comparing these it will be remembered that a difference of 0.000100 corresponds to about 0''.20 in the coördinates of the outlying stars of the group. The results are decidedly adverse to the accuracy of this mode of orientation, especially as a comparison with the heliometer places indicates a further correction of

$$+0.000098$$

to the orientations obtained by using the meridian places. T! large discrepancies are probably due to jarring of the plate duri g exposure, caused by stopping and starting the clock-work severa. times; the large difference for Plate IV admits of no other obvious explanation.

Let us now examine the scale-values of the different plates. The values of p given at the beginning of Section V include aberration and temperature effects. Formulas for the former correction are thus given by Bessel:*

$$\gamma = -(\cos\delta_0 \sin\alpha_0 + \tan\omega \sin\delta_0)$$
$$\delta = +(\cos\delta_0 \cos\alpha_0)$$

Then the true distance is found by adding to the observed distance s,

$$-s(C\gamma + D\delta),$$

C and D being as before, the Besselian star numbers.

We may also correct the values of p for the temperature at which the plates were measured by adding

$$+0.0000017\,(T - 65°),$$

T being the temperature in Fahrenheit degrees at which the plate was measured, given in Table II. This expression is easily derived from the value of v on page 223. Corrections for the temperature at which the plate was exposed ought also to be applied, but sufficient data to establish a connection between this quantity and the scale-value are lacking. After a greater number of Rutherfurd's photographs have been reduced we may have more definite information on this point.

The true scale-value S (so far as it can be obtained without the last correction), is given thus,

$$S = 52''.87\,[1 + p - C\gamma - D\delta + 0.0000017\,(T° - 65°)]$$

The following table gives the corrections and the resulting scale value for each plate. The corrections for temperature are very small and might well have been neglected. The last two columns give the readings of the thermometer attached to the telescope and of the "focus," which have been copied from Table I for convenience of reference.

* "Astronomische Untersuchungen," Vol. I, page 208.

SCALE-VALUE.

Plate.	Cor. for Aberration.	Cor. for Temp.	Corrected Scale-Value.	Tel. Therm.	Focus.
I	—0.000099	0.000000	52.8701	+58°	8.4
II	— 99	+ 2	52.8715	58	8.4
III	— 100	— 3	52.8712	53	8.4
IV	— 100	+ 4	52.8760	53	8.4
V	— 98	+ 3	52.8788	48	7.8
VII	— 99	— 2	52.8827	58	7.7
VIII	— 99	— 5	52.8831	58	7.7
IX	— 98	— 2	52.8840	48	7.8

The mean of the scale-values is

$$52''.8772$$

and if we adopt the correction of + 0.000009 as indicated by comparison with the heliometer places, this becomes

$$52''.8776.$$

However, either of these must still be regarded as only an approximate value, since the separate values for the different plates, as given above, vary in a way that cannot be fully explained by a connection with the readings either of the telescope thermometer or of the "focus."

The above investigations on the orientation and on the scale-value lead to the same conclusion; it will usually be better to determine all the constants of a plate by comparing the measures of some of the stars with their positions as known through meridian observations or otherwise, than to attempt to reduce them by means of a predetermined scale-value and orientation. In any case it is necessary to appeal to such known positions to determine the values of k and c, or the absolute place of the group in the sky. The positions of two stars are theoretically sufficient to determine all four constants, but in most cases it will be possible to find enough stars to eliminate errors of observation to a large extent.

In conclusion, I wish to acknowledge my indebtedness to Messrs. Kretz and Hays for assisting me in the measurement of the plates, and to Professor Jacoby, who has kindly explained to me the methods used by him in the measurement and reduction of stellar photographs, and who has also suggested some improve-

ments in the paper in reading over the proofs. Finally I desire to express my thanks to Professor Rees, Director of the Observatory, for the interest he has shown in my work, and for securing its publication.

Note on Refraction Formulas for Photographic Plates.

Formulas for correcting the measured rectangular coördinates of a star upon a photographic plate for refraction, may be easily derived from the well known general formulas of Bessel. On page 166, Vol. 1. of his "Astronomische Untersuchungen" he gives the following corrections to the differences of right ascension and declination:

$$\Delta\,(\alpha' - \alpha) = s\cdot k\,[\tan^2\zeta\cos(p-q)\sin q - \tan\zeta\sin q\tan\delta_0\cos p + \sin p]\sec\delta_0$$

$$\Delta\,(\delta' - \delta) = s\cdot k\,[\tan^2\zeta\cos(p-q)\cos q + \tan\zeta\sin q\tan\delta_0\sin p + \cos p]$$

Substituting

$$X = s\sin p$$
$$Y = s\cos p$$
$$G = \tan\zeta\sin q$$
$$H = \tan\zeta\cos q$$

we obtain

$$\Delta\,(\alpha' - \alpha) = k\,X\sec\delta_0\,(I + H^2) \quad + k\,Y\,(G - \tan\delta_0)\,H\sec\delta_0$$
$$\Delta\,(\delta' - \delta) = k\,X\,(G + \tan\delta)\,H \quad + k\,Y\,(I + G^2)$$

These formulas become identical with those of Professor Jacoby when we change k into β in order to allow for the increased refrangibility of photographic rays.

One point in the above deduction deserves mention; the quantities δ_0, etc., were intended by Bessel to be the means of corresponding quantities for the two stars whose distance along the arc of the great circle joining them has been measured. We have treated them as though they referred to one end of that arc; however, this merely amounts to neglecting terms in the second and higher powers of s, which may be done for most photographic plates.

If we omit the middle term in each bracket in Bessel's formulas we obtain the formulas given by Professor Turner; the omission of these terms, as has been repeatedly pointed out, corresponds to a rotation of the axes, and is, therefore, of no importance when we determine the constants of a plate by comparing the measured coördinates of some of the stars with their known places. Turner's formulas are

$$\Delta X = kX \cdot (1 + H^2) + kY \cdot GH$$
$$\Delta Y = kX \cdot GH \qquad + kY \cdot (1 + G^2)$$

These formulas may be simplified when we use the above method for determining the constants, as I pointed out in the *Astronomical Journal*, No. 430 ; rejecting so much of the correction for refraction as may be regarded as either an orientation correction or a scale-value correction, we have remaining

$$\Delta X = kX \cdot (H^2 - G^2)$$
$$\Delta Y = kX \cdot 2\,GH$$

These formulas might have been used for the reduction of the Præsepe plates, but as we wished to know the true orientation and scale-value for each plate, extra corrections to these constants would have been necessary. Only four of the comparison stars used need corrections for refraction; so that in the present case nothing would have been gained by the use of the last formulas. When, however, the number of comparison stars is greater, or when we do not care especially to know the true orientation and scale-value of a plate, these formulas will save some labor.

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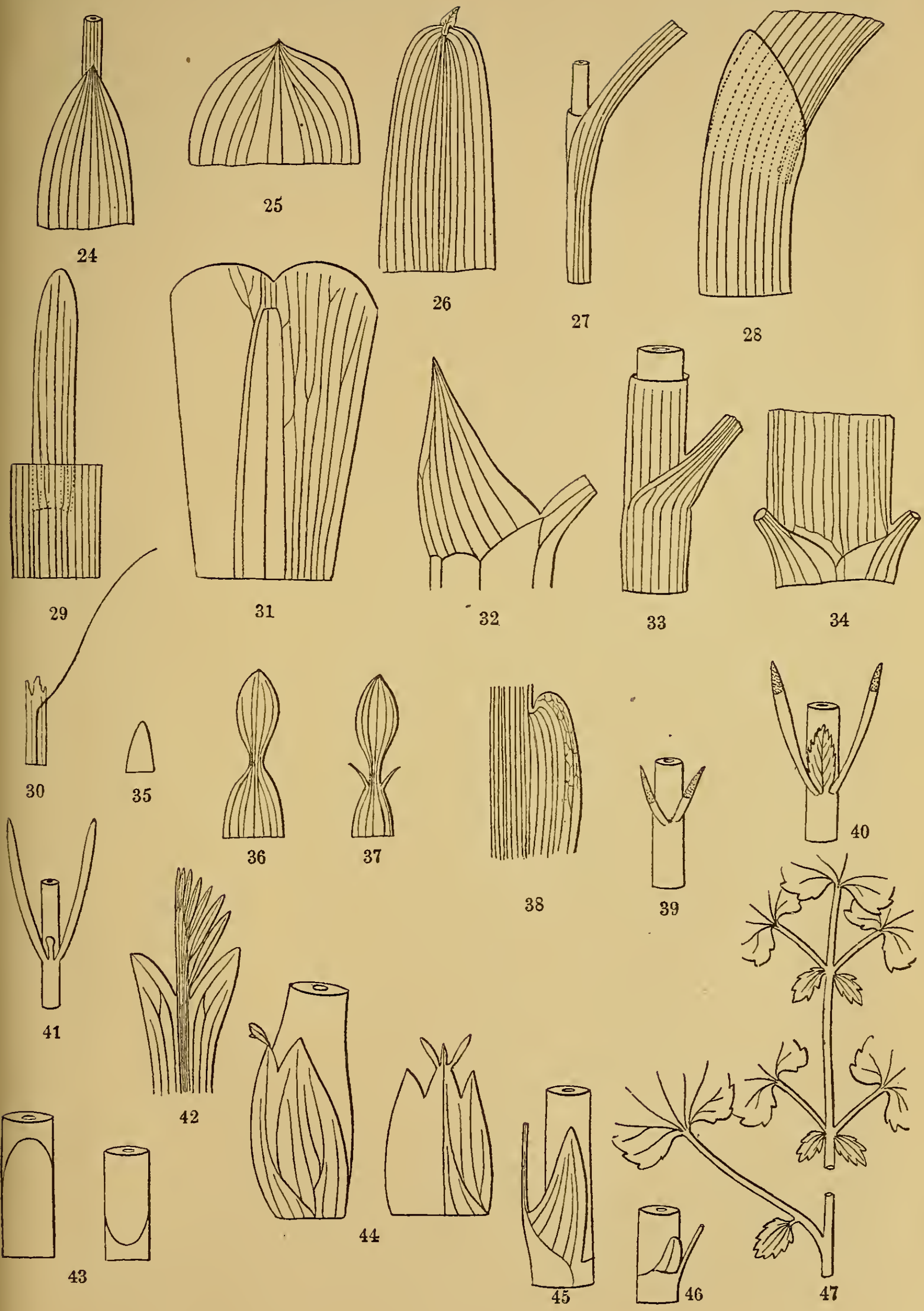
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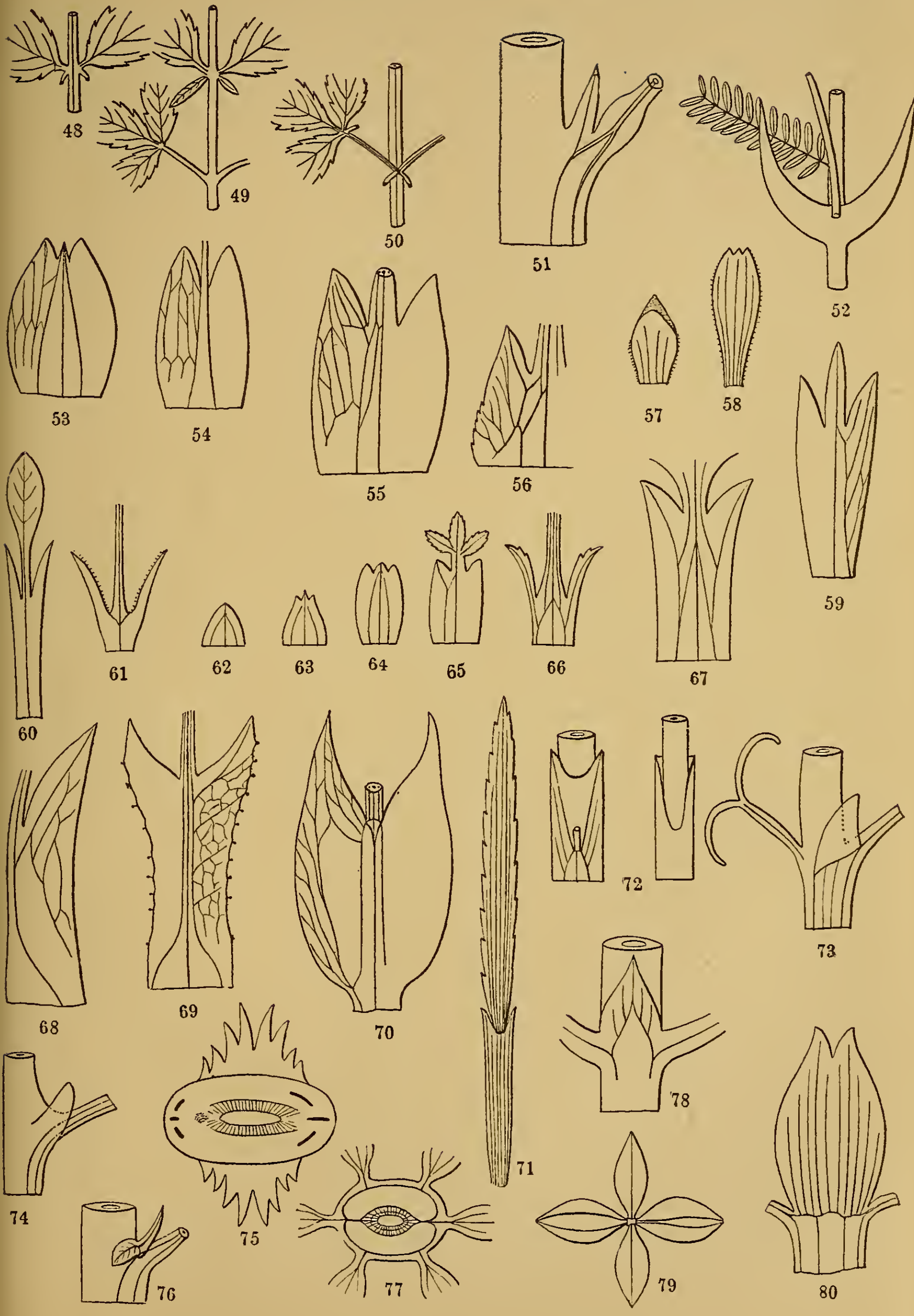
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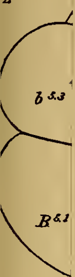

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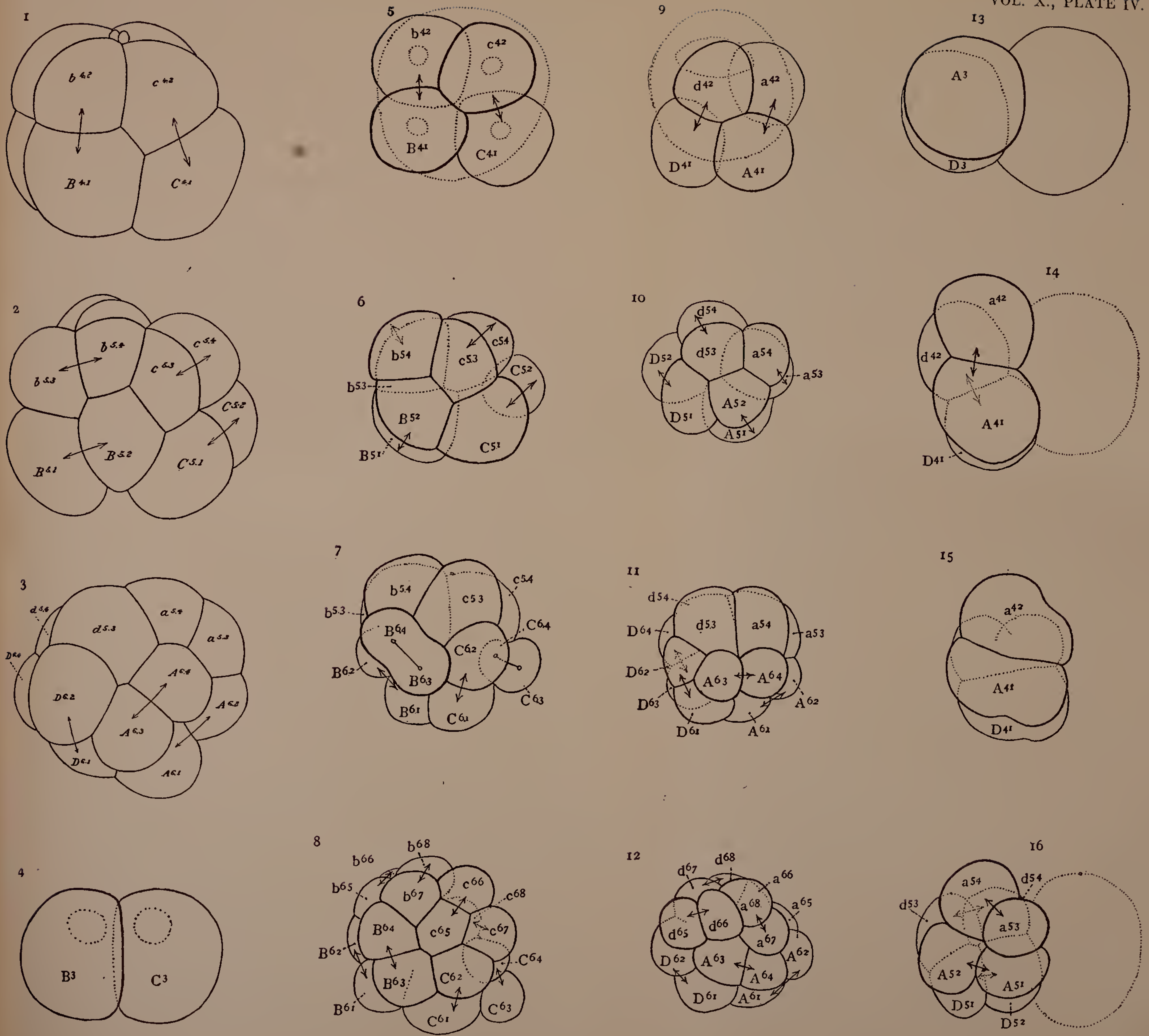
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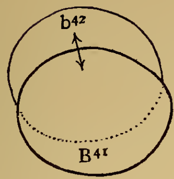

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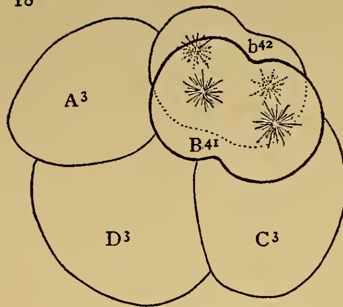

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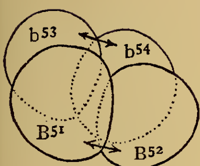

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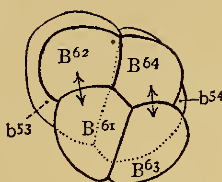

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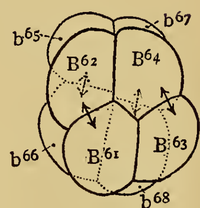

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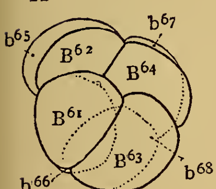

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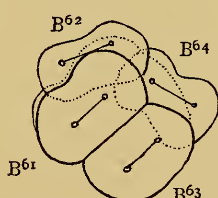

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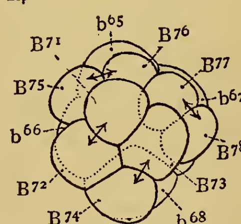

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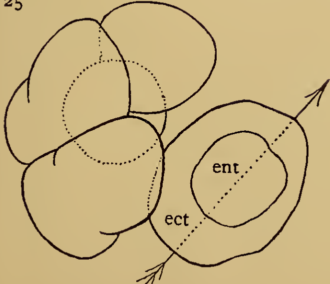

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