XIV. *An Account of some Astronomical Tables in the Library of the Rev. C. Turnor, A.M. F.R.S. &c. By Mr. Richard Harris, Assistant Secretary of the Society. Communicated by the Rev. R. Main.*

Read January 10, 1845.

The two volumes of *Astronomical Tables*, which form the subject of the following remarks, are the property of the Rev. Charles Turnor, A.M. F.R.S.* to whose liberality the writer has been indebted for permission to make a full examination of their contents, and also to copy such portions as might be expected to prove of interest to the astronomical antiquary.† The successful labours of Delambre and other writers have left so little to be done in the general illustration of the state of science during the middle ages, that it is only from a careful examination and collation of such MSS. as these, that we can hope for any addition to our store of information on this interesting subject. The following remarks were written under this conviction, yet they are not offered to the Society without diffidence, since it is certain they contain nothing new, and probably little that has not already been more clearly explained by writers possessing more intimate acquaintance with the construction and peculiarities of the tables used by the early European astronomers.

* Since the above paper was read, the MSS. therein mentioned have been presented to the Society by Mr. Turnor.—Sec.

† The only account of these MSS. with which I am acquainted is that recently published in the *Cycle of Celestial Objects*, vol. ii. p. 525. The present paper was commenced at the request of the author, Capt. W. H. Smyth, R.N.; and the hints by which that request was accompanied have afforded me the means of giving greater completeness to the details than I could possibly have done, had I relied entirely on my own knowledge of ancient astronomical literature.

One of the volumes now under examination is without date or title; but, from its containing a calendar for the year 1349, there can be little doubt of that portion, at least, having been written in the early part of the fourteenth century. The other volume contains a calendar for several years, commencing with 1347; and the epoch of the tables affords a further clue to the determination of the age to which it belongs. Both MSS. are in excellent preservation; the writing is on vellum, and the ink is still so fresh, that, when the eye becomes familiar with the form of the characters, the tables may be read as easily as those in every-day use. Of the history of one of these volumes nothing is known: the other bears the title *Tabulæ Mediorum Motuum Omnium Planetarum*, and, from an inscription on the fly-leaf, it appears that it once belonged to the fraternity of Tolerants, or Grey Friars, at Babewell, near Bury St. Edmund's: there is also the name, "Franciscus Goldingham," in a more modern handwriting, on a corner of the same page; but nothing to shew how the MS. came into his possession. The tables, which form the principal portion of this volume, were computed for the meridian of Oxford, and bear the general title, *Almanak Editum Oxoniæ*. This title may have been adopted from prudential motives. Oxford had long been the seat of British science, and the celebrity of the University gave a high character to works issued under its sanction; the mere association of the name may, therefore, have been regarded, at the time, as a guarantee for the superior accuracy and completeness of these tables. Erroneous as is the theory on which they are based, we cannot regard them without interest: such records mark the progress of human intelligence, and unfold to us the successive steps by which the sublimest of the sciences has attained its present state of perfection.

The first table contains the places of the sun, moon, and five planets, for intervals of twenty years, commencing with 1340 and ending with 1600, and is followed by tables of their motions for years, months, days, hours, and fractional parts of hours, and the necessary data for computing the conjunctions and oppositions of the sun and moon from 1341 to 1601. Next follow tables of the equation of the sun; of the horary motion of the sun and moon, and of the equations of the moon, *Saturn, Jupiter, Mars, Venus*, and *Mercury*. A few brief directions respecting the method of using the tables are also given, and the words, "Complete sunt Tabule cum Canonibus super Meridiem Civitatis Oxonie ordinate, etc." mark the end of this part of the volume.

The first table of the second part is headed, "Tabula continens verum locum Solis pro quodlibet tempore atque situ in Oxonia constitutæ;" the second, "Tabula continens elongacionem veram Lune a Sole;" the third, "Tabula continens verum locum Saturni in Longitudine;" the fourth, fifth, sixth, and seventh, are similar tables of the longitude of *Jupiter, Mars, Venus,* and *Mercury;* the eighth is entituled "Tabula continens veram Latitudinem Saturni ab orbe Signorum;" and the next four are corresponding tables of the latitude of the other four planets. These are followed by tables of the motions of the heavenly bodies, the epoch of which is 1348, arranged for years from 1 to 10,000, with auxiliary tables for months, days, and hours. A table of the geographical position of several remarkable places, and two or three minor matters, followed by a few explanatory remarks, close the second part.

Like most astronomical works of that period, the *Oxford Almanac* appears to have been chiefly formed from the famous Alphonsine Tables, the requisite correction being applied throughout for the difference of meridians, and some trifling alterations made in the method of arrangement to suit the convenience of computers. The mean longitude of the sun on January 1, 1340, is 288° 11′ 2″; the mean annual motion, 359° 45′ 39″: the mean longitude of the moon at the same epoch is 71° 22′ 10″; the mean annual motion, 129° 23′ 3″; the longitude of the ascending node, 89° 36′ 1″; mean annual motion, 19° 19′ 42″; the mean anomaly, 341° 28′ 57″; annual motion, 88° 43′ 15″; equation of the centre, 13° 9′; mean synodical revolution, $29^{d}\ 12^{h}\ 44^{m}\ 3^{s}$.

The following are the principal elements of the planetary tables:—

	Mean Longitude, 1340.	Mean Annual Motion.	Apogee, 1340.	Equation of the Centre.	Second Equation.
	s ° ′ ″	s ° ′ ″	s ° ′ ″	° ′	° ′
Saturn	8 28 33 45	0 12 13 35	8 11 35 13	6 31	6 13
Jupiter	6 5 55 49	1 0 20 29	5 21 48 31	5 57	11 3
Mars	7 8 35 44	6 11 17 5	4 13 23 44	11 24	41 10
Venus	6 13 44 31	7 15 1 42	2 29 36 54	2 10	45 59
Mercury ...	9 24 14 13	1 23 56 47	6 28 51 4	3 2	22 2

The geographical table is similar to those given in most works of this kind. The longitudes are reckoned, apparently, from Ferro, the most westerly of the Canary Islands, and the roughness of the approximation, in both elements, forms a striking contrast to the nice determinations of modern times.

Tabula Longitudinis et Latitudinis Civitatum Diversarum.

	Longitude.	Latitude.		Longitude.	Latitude.
	g m	g m		g m	g m
Euerdia..........	8 0	41 55	Bononia.........	32 30	44 0
Cepta...........	8 0	35 20	Pisa............	33 0	45 0
Corduba.........	9 20	37 30	Florencia........	33 25	42 30
Toletum.........	11 0	39 54	Roma...........	36 25	41 50
Oxonia..........	17 56	51 50	Alexandria.......	51 20	31 0
Londoñ..........	19 26	51 39	Egyptus.........	55 0	34 0
Colcestria........	20 26	51 40	Constantinop'....	56 40	43 40
Lecestria.........	19 40	52 50	Damascus........	60 0	33 0
Eboracus........	19 0	54 0	Antiochia........	63 20	35 30
Berwyk..........	19 0	56 50	Barcinona........	64 0	30 30
Parisius..........	23 0	48 50	Jerusalem........	66 0	32 0
Cartago.........	27 0	37 0	Altufa...........	69 0	35 30
Colonia..........	27 10	49 0	Armenia.........	77 0	41 30
Mons Pess'.......	28 20	44 40	Babilonia Vet'....	78 0	35 0
Marcilia.........	30 15	45 0	Arym...........	90 0	0 0

The third part of this volume contains a Calendar and Astronomical Ephemeris, in which the places of the sun, moon, and planets, are given in regular order for every day of the year, together with the correction for their motion in hours, minutes, seconds, &c. besides the usual list of saints' days, and other matters relative to the Church. The ephemeris was computed for 1347, but was intended for permanent use, tables being added which contain the requisite corrections for determining the places of the heavenly bodies on the corresponding days for several years.

These are followed by "Tabulæ Magistri Johannis de Lineriis de quinque Planetis retrogradis," which are curious, if only as being the production of a writer famous in his day but now forgotten.* Weidler mentions his Ob-

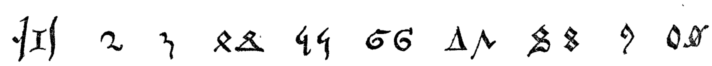
* The name of this author is sometimes written Johannes de Ligneriis. I have also found occasional mention of Johannes de Liueriis or Liveriis, which is evidently the same name mispelt.

servations of Forty-eight Fixed Stars, and "Canones super Almanach," and a treatise entitled, "Canones Primum Mobilis," is preserved among the Arundel MSS. According to Sherburne, he is reckoned by Petrus Cirvellus Daiocensis to have been "one of the four most celebrious astronomers that had flourished between the times of Alphonsus and Purbacchius." The tables which bear his name in the present collection occupy but a few pages; their nature and object are sufficiently indicated in their title, and as they present but few peculiarities extract or comment is unnecessary.

Next in order are planetary and lunar tables without title, and unaccompanied by the usual directions for use. On the last page of this section is a table "de Corda et Arcu," and another containing the motion of the eighth sphere, or firmament of the fixed stars, for each year from 1300 to 1930, computed on the assumption that the equinoctial points have a libration of 10° 45′ east and west of their mean place.

Tables of proportional parts of the mean daily motion, for hours, minutes, and seconds; tables "de Concordia" and "de Discordia," and one containing the result, in sexagesimals, of the multiplication of any number of minutes or seconds, by any factor from 1 to 60, form the concluding portion of this volume.

Before closing the account of this MS. it may be necessary to mention that the two sections of the *Oxford Almanac* are in the same hand-writing; but the other parts are quite distinct, and appear to have been bound with it merely from motives of convenience. As the volume consists almost entirely of tables it offers an excellent opportunity for the selection of specimens of the numerals in use at the beginning of the fourteenth century. The following are the principal varieties, and five hundred years have but slightly modified their forms:*—



The other volume contains a set of solar, lunar, and planetary tables; a table of the length of shadows; "Tabulæ diversitatis aspectus," computed for seven climates, with a special table for Toledo, and "Tabula equationis 12

* Those in the other volume are similar, with the exception of the 2, which is written , and in two or three places .

domorum," for the same city; tables of the trepidation or libration in longitude, and of the agreement of the Christian with the Arabic, Persian, and other eras; tables of sines and declinations; a catalogue of thirty-five fixed stars; and a list of remarkable places, with their latitudes and longitudes. These tables occupy about one hundred and twenty quarto pages; they were all written by the same hand, and appear to be more ancient than the remaining parts of the same volume. They are followed by a calendar for the year 1349, and tables of the motions of the planets, occupying together about sixty pages. The third part consists entirely of lunar tables, *cum canonibus*. The concluding pages of the volume are occupied with examples of the use of the preceding tables, and a few precepts headed "Canones Tabularum ARZACHEL."

The Toledo tables, usually attributed to ARZACHEL, are not uncommon in MS. collections. DELAMBRE mentions two copies in the *Bibliothèque du Roi*, and others may be found in our public libraries. Their author flourished about the year 1080, and from their being computed for the meridian of Toledo, it is probable that he resided in that city. These tables enjoyed a long period of popularity, and were only superseded by those of the renowned ALPHONSO of Castile, of which they formed the groundwork. The TURNOR MS. appears to be a transcript of ARZACHEL'S work, though there is no stronger evidence of the fact than the title given to the precepts and the general agreement of the elements of the tables with those of others possessing stronger proofs of authenticity.

The following elements will convey an idea of the state of the science at the time these tables were formed:—

	s	°	′	″
Mean motion of the sun in one lunar year	11	18	54	19
Greatest equation	0	1	59	20
Apogee	2	17	50	0
Mean daily motion of the moon	0	13	10	35
Mean daily motion of anomaly	0	13	3	54
Greatest equation of the centre	0	13	9	0
Motion of the node in nineteen lunar years	11	26	48	33
Obliquity of the ecliptic....................	0	23	33	30

	Apogee.	Node.*	Motion in thirty Lunar Years.	Equation of the Centre.	Second Equation.
	s ° ′	s ° ′	s ° ′ ″	° ′	° ′
Saturn	8 0 5	3 10 30	11 25 40 31	6 31	6 13
Jupiter	5 14 30	3 0 1	5 13 20 19	5 15	11 3
Mars	4 1 51	1 1 51	5 21 3 1	11 24	41 9
Venus	2 17 50	11 17 50	7 14 16 48	1 59	45 59
Mercury	6 17 30	9 17 30	8 27 26 31	3 2	22 2

It is affirmed by Riccioli that Arzachel adopted the notion of a libration or trepidation of the equinoctial points within the limits of 10° east and west, at the rate of one degree in seventy-five years. In this MS., however, we find a table of equations computed on the supposition that the point of intersection of the ecliptic and equinoctial move in a small circle described with a radius of 4° 18′ 43″; the limits of the libration in longitude being 10° 45′ east and west from the mean place, and its period about 4181 lunar years and 7 months.

This doctrine agrees, in every essential particular, with the *idée malheureuse* of Thebit Ben Korah, as given by Delambre.

The following table contains the arc described by each planet in its retrograde motion, and the time of its duration :—

Tabula Retrogradationis Quinque Planetarum.

Nomina Planetarum.	Saturnus.	Jupiter.	Mars.	Venus.	Mercurius.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Long. major.	7 14 10	7 49 14	19 53 32	16 25 26	7 52 22
Dies.	147 47	123	80	43	21
Long. media.	7 16 20	9 12 16	16 18 44	12 17 10	12 17 10
Dies.	138	121	73	41 40	22 32
Long. minor.	7 18 0	9 54 40	11 12 14	14 50 38	15 12 0
Dies.	136	118	64 30	40 40	66 48

* In the original, this term is written Jeuzahar and Jeusehar. Delambre has Genzahar (*Hist. de l'Astron. du Moyen Age*, p. 177), which is probably a typographical error. Hyde states (*In Ulugh Beighi Tabulas Stellarum Fixarum Commentarii*, p. 14), that the head and tail of the dragon were called "Okda," *Nodus*, and "Gjauzahr," *Locus Venenosus*, terms

The ancient astronomers made much use of the gnomon as an instrument of observation: in order to simplify and abridge the labour of reducing these observations, Arzachel constructed a table of sines to a radius of 150 equal parts or minutes, subdivided into sexagesimal seconds and thirds. In the table of shadows he divides the gnomon into twelve digits, and each digit into sixty minutes; hence, the length of the shadow being also estimated in digits, the altitude of the sun or moon may be found without trouble, and an approximate solution of many important problems may be given with ease and expedition. This is, in point of fact, a table of co-tangents, for the length of a shadow cast on a plane surface by a vertical style is evidently equal to the co-tangent of the altitude of the celestial body, reckoned on an arc of a circle whose radius is equal to the height of the gnomon.

We read in the *Almagestum Novum* of Riccioli, that Arzachel determined the greatest declination of the sun to be 23° 34′: in the table of declinations in this volume, the obliquity of the ecliptic is assumed to be 23° 33′ 30″, and in the heading of the table it is stated to be the corrected value as determined by *Magister Ebuzak El Zekel.*

The catalogue of thirty-five stars is curious and interesting, since it is not improbable that it may have been drawn up from a copy of Ptolemy's great catalogue, which has either perished or escaped the notice of modern commentators. The arrangement is somewhat singular: its author seems to have divided the stars into seven distinct classes, and then to have arranged the stars in each class in the order of the signs. The first class, containing thirteen stars, includes two, *Hazel Altair* and *Raz Elmare,* marked by Ptolemy, of the second magnitude; the other eleven are of the first magnitude. The second class consists of ten stars of the second magnitude: the third contains two only, each of which is of the third magnitude. The five which form the fourth class are also of the third magnitude, with the exception of *Monir Alhenahar,* which Ptolemy marks of the fourth. Of the three stars which form the fifth class, the first two are of the third magnitude; the third, *Rocubez Aldigega,* is of the fifth magnitude. The sixth class consists of Nebulæ; and the seventh contains but a single object, one of three stars in

analogous to the *Syndesmus Anabibazon* and *Syndesmus Catabibazon* of the Greeks. On consulting an eminent orientalist, I have been informed that Gau-zahr (Poison-place) is Persian, Arabicised into Jauzahr, for anciently (as now, in Egypt) jím was pronounced gím. Perhaps it was thought the serpent had poison in his tail as well as in his tongue.

the constellation now called *Coma Berenices,* designated by Ptolemy as ἀμαυροὶ, *obscuræ.*

The epoch of this catalogue is uncertain; the words *Anno Arab.* 577. *Loca Stellarum,* on the upper part of the page, being, apparently, in a different hand-writing from the rest of the MS. This uncertainty is much to be regretted, as no useful result can now be obtained from a comparison of the positions here given with those deduced from modern observations. On comparing the stars' places, as referred to the ecliptic, in this and the more ancient catalogues, it becomes apparent that the latitudes are those of Ptolemy: the longitudes also admit of arrangement under two divisions, in the first of which the difference from Ptolemy's place is $+ 15^\circ\ 7'$, and in the other only $14^\circ\ 55'$; a discordance for which it is not easy to account, unless by supposing either that different quantities were used in bringing up the stars, or that their positions were computed for different epochs and incorporated in the present catalogue, without attention being paid to the necessary correction for the change of longitude during the interval.

The following is a literal copy of the catalogue, the original contractions being retained throughout. The first column, containing the ordinal numbers, has been prefixed for the sake of convenient reference.

Tabula Stellarum Fixarum, et Latitudinis earum, et quantum distent ab equinotio.

No.	Nomina Stellarum Fixarum.	Loca Stellarum.			Latitudiēs earum.		Preces. Latit.	Latido Stellarū ab eq'n'tis.		Preces. Lōgit.	G'ds. eqb. medant Celum.	
		Signa.	g'ds.	mta.	g'dus.	mta.		g'ds.	m'a.		g'ds.	mta.
1	Aldebaran, i. Vespera	Taurus	27	47	5	10	M'idia.	14	41	Sept.	{59 56	22 24
2	Rigil Algebar Pes Orionis	Gemi.	4	57	31	50	M'idia.	10	10	M'idi.	{73 64	53 49
3	Alhashoc	Gemi.	10	7	22	50	Sept.	44	34	Sept.	{65 63	31 28
4	Mankib Algebar Humers. Orionis	Gemi.	16	57	17	0	M'idies	5	59	Sept.	{80 78	22 30
5	Ascare Alabor. Canis Sirius prims.	Canc.	2	47	39	10	M'idies	15	38	M'idies	{93 92	19 5
6	Ascare Algumaice Sirius scd's	Cāc.	14	17	16	10	M'idies	6	43	Sept.	{103 102	22 17
7	Calbalacet Cor Leonis	Leo.	17	57	0	10	Sept.	15	51	Sept.	{138 140	17 13
8	Alchimechalazel Jaculū tollens	Libra.	11	47	2	0	M'id.	6	26	M'idi.	{190 189	40 36
9	Alcimec Arameh Jaclm feriens	Libra.	12	7	31	50	Sept.	24	25	Sept.	{206 204	45 56
10	Annazel Alwalza Vultur cadens	Cap'cor.	2	27	62	0	Sept.	38	27	Sept.	{273 271	17 20
11	Hazel Altair Vultur volans	Cap'cor.	{19 17	30 48}	29	10	Sept.	6	34	Sept.	{286 285	15 35
12	Fom Alhout Algenubi Os Piscis M'idiani	Aq'ris.	21	57	23	0	M'id.	35	49	M'id.	334	21
13	Raz Elmare Caput Speculi	Aries	2	25	26	0	Sept.	24	39	Sept.	350	·4
14	Razagul Cap. Gorgonis	Taurs.	14	35	23	0	Sept.	38	4	Sept.	32	44
15	Raz Athoum Almualhar Caput Geminorum pos.	Canc.	8	15	9	0	Sept.	32	57	Sept.	99	42
16	Raz Athonuam Almuh Cap. eis. anterius	Canc.	11	35	6	15	Sept.	29	16	Sept.	103	15
17	Calb Alacrab, i. Cor. Scorpionis	Scorpis.	27	47	3	0	M'id.	22	38	M'id.	{233 234	12 24

No.	Nomina Stellarum Fixarum.	Loca Stellarum.			Latitudiēs earum.		Preces. Latit.	Latido Stellarū ab eq'n'tis.		Preces. Lōgit.	G'ds. eqb. medant Celum.	
		Signa.	g'ds.	mta.	g'dus.	mta.		g'ds.	m'a.		g'ds.	mta.
18	Racbat Aram Genu Sagitarii	Cap'co.	1	55	18	0	M'id.	41	33	M'id.	272	26
19	Arcob Arami Talus ei.	Cap'c.	2	40	23	0	M'id.	46	32	M'id.	273	35
20	Deheb Adigeia Cauda Galline	Aq'ris.	24	17	60	0	Sept.	42	35	Sept.	302	7 51
21	Mankib Alferaz Humers. Equi.	Pisces	17	17	31	0	Sept.	23	18	Sept.	334	21 41
22	Kalb Alhouz Cor Piscis	Aries	18	48	26	20	Sept.	31	28	Sept.	4	33
23	Aune Algurab Collū Corvi	V'go.	29	15	19	40	M'id.	17	39	M'idies	170	30
24	Scemel Mennanuata Australe de eamediū	Aries	22	35	8	20	Sept.	16	32	Sept.	17	5
25	Arcob Alennen Talus dexter	Gem'i	10	35	8	0	Sept.	30	4	Sept.	67	35
26	Monir Alhenahar	Gem'i	29	35	10	50	M'id.	12	43	Sept.	89	39
27	Raz Alain Caput Celubri	Sag.	9	25	36	0	Sept.	13	39	Sept.	253	0
28	Jach Felez Alferaz Jube Equi.	Aq'r.	20	8	22	50	Sept.	6	52	Sept.	315	20
29	Daneb Camuz Cauda Ceti	Pisc.	20	35	20	20	M'id.	22	19	M'id.	0	51
30	Scoulet Alacrab Spina Scorpii	Sag.	12	25	13	0	M'd.	35	23	M'id.	248	47
31	Rocubez Aldigega Genua Galline	Aq'r.	27	5	63	45	Sept.	46	34	Sept.	302	4
32	Raz Algauze Caput Geminorum	Gem'i	11	55	13	50	Sept.	8	37	Sept.	74	25
33	Cedre Alceratan Pectus Cancri	Canc.	25	15	0	40	M'id.	21	51	Sept.	117	26
34	Aai Narram Ocl's Sagitarii	Cap'c.	0	5	0	45	Sept.	22	48	M'idies	270	4
35	Adarfa. Finu.	V'go.	9	27	25 11	10 50	Sept.	19	0	Sept.	164 166	49 24

The first column of the following table contains the ordinal numbers in the preceding catalogue; the second contains Flamsteed's number and Bayer's letter, with the name of the constellation to which each star belongs; the third contains the ordinal number in Mr. Baily's edition of Ptolemy's catalogue, printed in the thirteenth volume of the *Memoirs* of the *Royal Astronomical Society;* and the fourth and fifth exhibit the excess of the longitudes and latitudes of the stars in this catalogue above those of the same stars as recorded in that work.

No.	Star.		No. in Baily's Ptolemy.	Difference from Ptolemy's Longitude.	Difference from Ptolemy's Latitude.
				° ′	° ′
1	87 Tauri	α	393	+ 15 7	0 0
2	19 Orionis	β	768	15 7	+ 0 20
3	13 Aurigæ	α	222	15 7	+ 0 20
4	58 Orionis	α	735	14 57	0 0
5	9 Canis Majoris	α	818	15 7	0 0
6	10 Canis Minoris	α	848	14 47	0 0
7	32 Leonis	α	469	15 27	0 0
8	67 Virginis	α	510	15 7	0 0
9	16 Bootis	α	110	15 7	+ 0 20
10	3 Lyræ	α	149	15 7	0 0
11	53 Aquilæ	α	288	{15 40 / 13 58}	0 0
12	24 Piscis Australis	α	1011	14 57	0 0
13	21 Andromedæ	α	315	14 35	0 0
14	26 Persei	β	202	14 55	0 0
15	66 Geminorum	α	424	14 55	− 0 30
16	78 Geminorum	β	425	14 55	0 0
17	21 Scorpii	α	553	15 7	− 1 0
18	Sagittarii	α	593	14 55	0 0
19	Sagittarii	β	592	15 0	0 0
20	50 Cygni	α	163	15 7	0 0
21	53 Pegasi	β	317	15 7	0 0
22	43 Andromedæ	β	346	14 58	+ 1 0
23	2 Corvi	ε	929	14 55	0 0
24	6 Arietis	β	363	+ 14 55	0 0

No.	Star.		No. in Baily's Ptolemy.	Difference from Ptolemy's Longitude.	Difference from Ptolemy's Latitude.
				° ′	° ′
25	23 Aurigæ	γ	230	+ 14 55	+ 3 0
26	31 Geminorum	ξ	441	14 55	+ 0 20
27	55 Ophiuchi	α	234	14 35	0 0
28	8 Pegasi	ε	331	14 48	+ 0 20
29	16 Ceti	β	733	14 55	0 0
30	35 Scorpii	λ	565	14 55	− 0 20
31	43 Cygni	ώ	175	14 55	− 1 0
32	39 Orionis	λ	734	14 55	− 2 40
33	41 Cancri	ε	449	14 55	+ 0 20
34	35 Sagittarii	ν^2	577	14 55	0 0
35	{ 4 Comæ Berenices		495	15 7	+ 0 10
	{ 94 Leonis	β	488	14 57	0 0

NOTES TO THE PRECEDING CATALOGUE.

No. 6. In the Venice edition of Ptolemy, by Liechtenstein, the longitude of this star is 20′ less than that adopted by Mr. Baily, and probably identical with that used in the computation for this catalogue.

No. 22. The latitude here given agrees with that adopted by Liechtenstein and by Trapezuntius in the Venice edition of 1528.

No. 31. The latitude here given agrees with that of Ptolemy, according to Liechtenstein, Trapezuntius, and the Florence MS. as quoted by Halma. Mr. Baily supposes the *Rucba Al Degjâgje* of Ulugh Beigh to be the cluster of stars formed by 43, 45, and 46 *Cygni*.

No. 32. *Caput Geminorum* is evidently an error: it should be *Caput Orionis*. In Liechtenstein, the latitude of this star is 18° 50′. Mr. Baily gives 16° 30′, adding, in a note, that this is nearly 3° too great, and supposes that there is some mistake in all the copies. The new evidence afforded by the present catalogue increases this probability, and an argument is furnished in support of the opinion that the compiler of these tables had access to a text of Ptolemy, which has hitherto escaped the notice of commentators.

No. 33. The latitude here given is the same as Liechtenstein's.

No. 35. There is some difficulty in identifying this star. Flamsteed's 7 and 23 *Comæ Berenices* constitute the *Al Daphîra* of Ulugh Beigh, but their position does not agree with that here given. The longitudes and latitudes assigned to 4 *Comæ Berenices* and 94 *Leonis*, by Ptolemy, agree very nearly with the positions here indicated; but if these two stars, collectively, form the *Adarfa* of this catalogue, the right ascension and declination of one or both stars here given must be erroneous.

XV. *On the Use of a New Micrometer, and its Application to the Determination of the Parallax of Mars at his ensuing Opposition.* By M. Boguslawski, *Professor of Astronomy, and Director of the Royal Observatory at Breslau, &c. &c. Communicated by Sir J. F. W.* Herschel, *Bart. D.C.L., &c.*

Read April 11, 1845.

The micrometer, which it is the object of this paper to describe, is, perhaps, for the purpose intended, the most simple of all known micrometers, and at the same time it admits of several other useful applications. Its principal singularity consists in this, that its scale is never dependent upon the individual telescope employed, but is always derived from observation. It is, therefore, independent of the optical power of the telescope used, except only as far as the distinctness and precision of the images are concerned. Even the smaller telescopes, with less magnifying powers, but with larger fields of view, have particular advantages in determining the differences of declination.

In some of the forthcoming numbers of the *Astronomische Nachrichten* it will be shewn, by numerous observations of planets and comets, that this micrometer, applied to a comet-searcher of 2 feet, with a magnifying power of from 24 to 28, could compete, on several occasions, with our heliometer of $3\frac{1}{2}$ feet, and a magnifying power of from 40 to 140. Besides many other applications of this micrometer, which will be explained in my forthcoming account of its construction and use for observing differences of right ascensions and declinations of stars, it may be advantageously employed in determining the sun's parallax from that of *Mars*, particularly this year, at his ensuing opposition, as he approaches unusually near to the earth.

The construction of this micrometer may be explained in a few words. It consists simply of one *wire, thread,* or *lamina,* which is placed in the common focus of the object-glass and eye-piece of a telescope, as a diameter across the field of view, in such a manner as to turn round the centre in every direction, and to make any angle π with the declination circle.

If, then, α° be the right ascension in time of any known star, δ° its declination, τ° the time of passage across the micrometer in the chosen and fixed position π, A the right ascension, D the declination, and T the time of passage of an unknown star across the micrometer; then

$$T - \tau^{\circ} = A - \alpha^{\circ} - \frac{D - \delta^{\circ}}{15 \cos \frac{1}{2}(D + \delta^{\circ})} \tan \pi \ldots\ldots\ldots\ldots\ldots (1)$$

Let α' be the right ascension of another known star, δ' its declination, and τ' the time across the micrometer; then, in a similar manner,

$$\tau' - \tau^{\circ} = \alpha' - \alpha^{\circ} - \frac{\delta' - \delta^{\circ}}{15 \cos \frac{1}{2}(\delta' + \delta^{\circ})} \tan \pi \ldots\ldots\ldots\ldots\ldots (2)$$

Eliminating tan π between the equations (1) and (2), there results,

$$T - \tau^{\circ} = A - \alpha^{\circ} - \{(\alpha' - \alpha^{\circ}) - (\tau' - \tau^{\circ})\} - \frac{D - \delta^{\circ}}{\delta' - \delta^{\circ}} \cdot \frac{15 \cos \frac{1}{2}(\delta' + \delta^{\circ})}{15 \cos \frac{1}{2}(D + \delta^{\circ})} \ldots (3)$$

Designating the fractional expression $\frac{15 \cos \frac{1}{2}(\delta' + \delta^{\circ})}{15 \cos \frac{1}{2}(D + \delta^{\circ})}$ by e, a quantity which differs insensibly from unity, except when the objects observed are in the vicinity of the pole; then

$$\{(A - \alpha^{\circ}) - (T - \tau^{\circ})\}(\delta' - \delta^{\circ}) = \{(\alpha' - \alpha^{\circ}) - (\tau' - \tau^{\circ})\}(D - \delta^{\circ})e \ldots (4)$$

Now, if θ°, θ', and Θ be the times of transit of the same three objects for any other position of the micrometer transverse to the former, making an angle φ with the declination circle (φ being obtuse when π is acute, and *vice versa*), then also

$$\{(A - \alpha^{\circ}) - (\Theta - \theta^{\circ})\}(\delta - \delta^{\circ}) = \{(\alpha' - \alpha^{\circ}) - (\theta' - \theta^{\circ})\}(D - \delta^{\circ})e \ldots (5)$$

and, consequently,

$$\left.\begin{aligned} A - \alpha^{\circ} &= T - \tau^{\circ} + \{(\alpha' - \alpha^{\circ}) - (\tau' - \tau^{\circ})\} \cdot \frac{(\Theta - \theta^{\circ}) - (T - \tau^{\circ})}{(\theta' - \theta^{\circ}) - (\tau' - \tau^{\circ})} \\ \text{or} \quad &= \Theta - \theta^{\circ} + \{(\alpha' - \alpha^{\circ}) - (\theta' - \theta^{\circ})\} \cdot \frac{(T - \tau^{\circ}) - (\Theta - \theta^{\circ})}{(\tau' - \tau^{\circ}) - (\theta' - \theta^{\circ})} \end{aligned}\right\} \ldots (I)$$

$$D - \delta^{\circ} = \frac{\delta' - \delta^{\circ}}{e} \cdot \frac{(\Theta - \theta^{\circ}) - (T - \tau^{\circ})}{(\theta' - \theta^{\circ}) - (\tau' - \tau^{\circ})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (II)$$

In this manner, the difference of right ascension between the unknown star and the known one, whose right ascension is α°, is deduced in a *direct* manner, as well as the difference of declination, provided the declinations of the stars be not so great as to render the value of e sensibly different from unity. With greater declinations, a single approximation will suffice.

The determination of right ascension will be the more accurate, the nearer the micrometer stands in one of the two positions to the declination circle, which, indeed, may be taken as a third position, and combined with the other two; in this case, the times of the three passages are designated by t°, T, and t'.

The determination of declination will increase in accuracy, in proportion as $(\theta' - \theta^\circ) - (\tau' - \tau^\circ)$ becomes greater in respect of $(\Theta - \theta^\circ) - (T - \tau^\circ)$, or, in other words, the nearer either π, or φ, or both approach to a right angle, whilst D lies between δ° and δ'. In this consists the advantage of a larger field of view.

The right ascension and declination being determined solely by comparing *two* observations made *at different times*, it becomes necessary that the observations of bodies in motion be always reduced to the same epoch E. If in the unit of time, m be the motion of the body in seconds of time in right ascension, and μ the motion of the same in declination in seconds of arc; then the variation in the time of passage, produced in the time T − E, is

$$\Delta \mathrm{T} = (\mathrm{T} - \mathrm{E}) \left\{ m - \frac{\mu}{\delta' - \delta^\circ} [(\alpha' - \alpha^\circ) - (\tau' - \tau^\circ)] \right\}$$
$$\Delta \Theta = (\Theta - \mathrm{E}) \left\{ m - \frac{\mu}{\delta' - \delta^\circ} [(\alpha' - \alpha^\circ) - (\theta' - \theta^\circ)] \right\}$$
$$\Delta T = (T - \mathrm{E}) \left\{ m - \frac{\mu}{\delta' - \delta^\circ} [(\alpha' - \alpha^\circ) - (t' - t^\circ)] \right\}$$

The effect of refraction may be neglected, except in very rare cases. But, in general, the stars will be so chosen that α° and α' will not differ much from A, and the objects will be so far from the horizon, that the effect of refraction on $A - \alpha^\circ$ and $\alpha' - \alpha^\circ$, $D - \delta^\circ$ and $\delta' - \delta^\circ$ could not be considered as *proportional* to these quantities. It happens, therefore, usually, that the *scale and the object* measured are altered in *like* manner, and that, consequently, the measurement is correct under all circumstances.

The simplicity of construction, and the precision of the results of this "Difference Micrometer,"* render it well adapted for determining the parallax of *Mars* at his ensuing opposition when he approaches nearest to the earth, and thence the parallax of the sun. This is principally the case in

* This name has been adopted, because all the effects of the micrometer are dependent upon *differences.*

ascertaining the parallax in declination, because, under certain circumstances, a greater precision may be obtained, when the difference of declination of the two stars *is very small*, and the declination of the planet intermediate to those of the stars. Besides, great advantage may be expected from the facility with which this micrometer can be applied; and, therefore, a greater number of observations can be obtained, and not subject to the condition of being taken absolutely at the same time.

Let the latitude of the observatory be ψ, the hour-angle of *Mars*, at the moment of actual observation (properly that corresponding to the mean of the two times of the two requisite observations with the difference micrometer in the two opposite positions) h, the observed right ascension of the planet A, and declination D, both *reduced*, on account of the motion of the planet, to the same epoch for *two* observatories. Let the western station be W, the eastern E, the northern N, the southern S; then the horizontal parallax of *Mars*, p, as deduced from the observed and reduced difference of right ascension of *Mars* at both stations, will be

$$p = \frac{(A_E - A_W) \cos D}{\cos \psi_W \sin h_W - \cos \psi_E \sin h_E};$$

and as deduced from the observed and reduced difference of declination,

$$p = \frac{(D_S - D_N) \sec D}{\sin \psi_N - \sin \psi_S + \tan D \cos \psi_S \cos h_S - \tan D \cos \psi_N \cos h_N};$$

and, finally, when Δ is the true distance of *Mars* from the earth (the mean distance of the earth from the sun being considered unity),

$$P = \text{the sun's horizontal parallax} = \Delta \times p,$$

which, consequently, results from the different parallaxes in altitude of *Mars* in right ascension, with so much greater accuracy, as the meridian difference of the two stations increases, and likewise as they approach the equator; and from the parallaxes in declination with a precision in proportion to the increase of the difference of latitude of the two stations.

The accuracy will be further increased if at one (for this purpose the northern) station, the planet be observed near the meridian, and at the other (the southern) at a distance from the meridian approaching to six hours. Very satisfactory results have been obtained by this micrometer during the last seven years.

The construction of a difference micrometer will cause very little trouble. A straight wire or lamina diametrically fixed in the focus of the eye-piece will be sufficient. It must also be observed, that in turning the eye-piece in or out, the change of the focus of the object-glass must be counteracted, and the shaking of the eye-piece must be prevented by a screw or cramp. The best for that purpose are the micrometer eye-pieces. These are simply placed in a tube which can be pushed, and both be turned in a second tube which is to be screwed to the eye-tube. The laminas have been tested as most proper to be applied; they render the illumination of the field unnecessary. With stars the immersion and emersion must be observed, but with planets the immersion of the second limb and the emersion of the first limb.

As it is of more importance to determine the parallax in declination than that in right ascension, those observations will require the greater attention, by which a more exact determination of difference of declination may be expected; that is, those observations at which *Mars*, in respect to declination, is situated between two stars, which have a very small difference of declination.

As the observations can be made at any place and nearly during the whole of the time that *Mars* remains above the horizon, a great number of observers and stations is desirable, particularly in the southern hemisphere.

H. VON BOGUSLAWSKI.