LXXVIII. An account of a series of observations made on the distance of the sun and moon for determining the longitude of the place of observation, with remarks on the best method of making such observations, with their calculation, deductions, &c.

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of any utility whatever. The author's papers in the Philosophical Transactions are hitherto free from this affectation, and we hope he will see the propriety of using only pure potash in future in these Elements. Sir Humphry is no less distinguished for the sublimity and beauty of his language than for his unparalleled discoveries: consequently his example in such a case must naturally become the *jus et norma loquendi*.

We understand that translations of this volume into Portuguese and Spanish have already been undertaken by gentlemen very well qualified for the arduous task.

LXXVIII. *An Account of a Series of Observations made on the Distance of the Sun and Moon for determining the Longitude of the Place of Observation, with Remarks on the best Method of making such Observations, with their Calculation, Deductions, &c.* By Mr. FIRMINGER, late Assistant at the Royal Observatory, Greenwich.

IT being generally understood, that to determine the longitude of a place by the lunar observations, it is requisite to have three separate observers, viz. one to observe the moon's altitude, another the sun's, and a third to take the distance between the limbs of the sun and moon, or the moon and a star, I was induced to make a set of observations for determining the longitude of my place without any such assistance, it having frequently occurred to me that a series of observations might be made by only one observer, which would require but little additional labour in the calculation to that which is necessary when three separate observers are employed, and the result of the trial has fully confirmed my conjecture.

The following observations, from whence this conclusion was drawn, have not the best possible arrangement; it was readily seen in making the calculation, that much of the trouble of reduction might have been avoided by a different method of taking the observations; but what has been done will, it is hoped, be sufficient to show the value of the means which have been employed.

The weather at the time of the year when these observations were made, is but seldom favourable in London, and it was owing chiefly to this circumstance that different sets of observations on the same day were taken, and which it was intended to repeat till the number of independent sets amounted to ten, by taking two or three sets each day; but the fine weather

weather did not continue sufficiently long for this purpose; nor has an opportunity offered since the period at which these observations were made to repeat them. The sets were four in number; two were taken on the 25th of October, and the remaining two on the 27th. The sun's and moon's altitude were taken from an artificial horizon, and the time at each observation noticed from a common horizontal watch showing seconds: great accuracy was not regarded in taking the moon's altitude, nor indeed of the sun's, except that set from whence the time was to be computed, for a small error in the observed altitude cannot materially affect the correction to be applied in reducing the apparent to the true distance: great care however should be observed in noticing the moment when the distance is completed, as, whatever error is committed here, will appear in the longitude, that being deduced by a comparison of the time at Greenwich, given by the observed distance compared with the distance deduced from the Nautical Almanac, and the time inferred from the sun's observed altitude.

The method which I should advise would be, first, to take a single observation of the altitude of the moon's enlightened limb, then one of the sun's lower limb*, and when these have been completed, take with the greatest care five distances at least of the proper limbs of the sun and moon. When these are finished, take another altitude of the sun, then one of the moon; these four altitudes of the sun and moon will be sufficient for clearing the distance; and if they are taken at nearly equal intervals of time before and after the time at distance, it will be only necessary to take a mean of each two corresponding altitudes, which will very nearly correspond to the apparent altitudes when the distance was taken; but a set of observations of the altitude of the proper limb of the sun should now be taken, and the time noted down with the greatest care. These observations should not be less than five, because from them the apparent time at distance is to be inferred by a comparison with the watch. From this method of proceeding little difficulty occurs, or additional trouble to the usual method by three separate observers; and I am induced to think that it possesses many advantages over that method in point of accuracy, for in the latter case the whole is com-

* This applies equally to a star when that is used instead of the sun, and is to be so understood in all cases here referred to.

pleted by one observer; and if he has a good eye, and is careful in making his different sets of observations, it is more than probable that the whole will be conducted with much greater accuracy than when three separate observers are employed, as it seldom happens that each of the observers is equally correct and careful; and should it be discovered that the one who takes the sun's altitude is inaccurate, the whole deduction will be affected with that inaccuracy: nor indeed is it scarcely possible for each observer taking the altitudes to complete his observation at the same time that the one who takes the distance has completed his; and the inaccuracy arising will be of considerable importance, should this happen to the observer who observes the object from whence the time is to be computed.

In the method I have adopted, the only inaccuracy affecting the observation arises from the altitudes of the bodies not increasing or decreasing uniformly: this, in the sun or a star, is of no importance if the observer is at all expert at making his observation, and in the moon the error will be too small generally to deserve notice. The watch by which the observations are made, should have a seconds hand, and ought not to vary more than one minute in twenty-four hours;—a good horizontal or duplex watch will answer very well, and will allow time for the observer to take his final set of observations for determining the error of the watch without hurrying himself.

The deductions derived from a mean of the four sets of observations about to be enumerated, give the longitude of the place in time 38,9 sec. west of Greenwich; or in space $9^{\circ} 31' 35''$ west*. By a reference to the best maps of London, it appears that the Polygon, Somers Town, is about 400 yards to the east of St. James's Church, Piccadilly, and the longitude of this church is according to the trigonometrical survey, $8^{\circ} 5''$ west of Greenwich. The observations give the longitude of the Polygon, Somers Town, $1^{\circ} 26' 35''$ to the west of St. James's Church, or about one mile; this added to the distance that the Polygon is to the east of St. James's Church, makes the whole error in longitude deduced from these observations about one mile and a quarter, which, taking into consideration the errors of observation, of the instruments, and of the lunar tables, will be found very small; and I am fully persuaded

* The observations were taken near the Polygon.

that

that had the number of observations been augmented to ten, and a mean of the results taken, a great part of the present error would have been removed.

I shall conclude these deductions by remarking, that a complete set of observations similar to those I have here given may be taken in the space of a quarter of an hour, or twenty minutes, by a single observer, and that they may be facilitated, and rendered a little more accurate, by the assistance of some person to write down the observation at the time: this part of the business, indeed, any one may do, and I am inclined to believe that under such circumstances the greatest error committed, will seldom exceed five miles, but will generally fall short of this distance.

I have reduced the apparent distance to the true by the method given in the supplement to the 3d edition of the requisite Tables, a method both simple and expeditious, and so easy in practice that a child of eleven years of age of moderate capacity might in a short time be fully instructed to perform the calculation.

I cannot help remarking, that many attempts have been made, and are still making, to construct machines for the more easily determining the longitude at sea; and although I am far from wishing to discourage any such attempts when conducted upon scientific principles, yet I am greatly surprised that the means of determining the longitude by the lunar observations should even at this time be thought an operose task. The improvements in the lunar tables, in the construction of sextants, and in the method of reducing the apparent to the true distance, have been such as to ensure the observer, with even but a moderate degree of experience, an accuracy far greater than is ever required in nautical practice. It may be said, that the weather is oftentimes too unfavourable to determine the longitude by the lunar method, and that for several days in the month the moon is invisible, being too near the sun. Here the use of a good time-keeper would be of great advantage, as by it the longitude would be easily carried on between the opportunities which offer, to obtain distances of the sun and moon, or the moon and a star, and even a time-keeper of very moderate performance would answer this purpose with sufficient accuracy for every nautical purpose: would it not therefore be of great advantage to the maritime department of this country to have young gentlemen designed for the service of the sea, well educated on shore, both in the practice as well as theory of finding the longitude by the means here recommended?

October

October 25, 1812.—The morning being very fine, the following observations of distances and altitudes were taken for finding the longitude:

N.B. 27" is to be added to all the observations to the 27th inclusive.

H.	M.	S.			
22	41	3	Time by watch.	42° 36' 0"	Double alt. ♀'s U. L.
22	43	5	Ditto	97 49 10	Dist. nearest limbs, ☉ & ♀
22	47	4	Ditto	48 55 50	Double altitude ☉'s L. L.
22	57	23	Time by watch	37' 38" 40	Double alt. ♀'s U. L.
23	2	0	Ditto 2nd set	97 40 00	Dist. nearest limbs ☉ & ♀
23	5	3		50 14 00	Double alt. ☉'s L. L.

	H.	M.	S.		
Oct. 27th.	20	44	00	94 11 40	Double alt. ♀'s U. L.
	20	48	00	74 53 11	} Dist. nearest limbs ☉ & ♀
	50	20		51 50	
	52	50		51 10	
Mean	20	50	23	74 52 37	
	20	55	00	31 5 30	} Double alt. ☉'s L. L.
	55	49		15 40	
	56	40		25 20	
Mean	20	55	49.6	31 15 30	
	21	0	8	90 55 30	} Double alt. ♀'s U. L.
	1	7		35 40	
	2	3		20 30	
Mean	21	1	6	90 37 13.3	
	21	5	31	33 14 40	} ☉'s L. L. double alt.
	7	6		33 10	
	7	44		41 20	
Mean	21	6	47	33 29 43	
Second set	21	16	2	87 11 10	Double alt. ♀'s U. L.
	21	19	23	74 41 10	} Dist. nearest limbs ☉ & ♀
	20	16		41 00	
	21	21		40 40	
Mean	21	20	20	74 40 56.6	
	21	53	31	36 44 50	} ☉ L. L. double alt.
	24	14		52 20	
	24	55		37 0 10	
	21	24	13.3	36 52 26	
	21	26	38	84 46 20	Double alt. ♀'s U. L.

Calculation

Calculation of the observations of the distances of the Moon's remote limb from the Sun, taken on October 25th and following days.

Calculation of the First Set, taken October 25th, 1812.

$\begin{array}{r} \text{D's H Par. N. alm. } 57' 19'' \\ \text{Appt. alt. } \odot \text{'s ct. } 24 \ 44 \ 4 \\ \text{Ditto D's do. } 21 \ 2 \ 22 \end{array} \left. \begin{array}{l} \\ \\ \end{array} \right\} \begin{array}{l} 1' 55'' \\ 51 \ 4 \end{array} \left. \begin{array}{l} \\ \\ \end{array} \right\} \begin{array}{l} 52' 59'' \text{ Tab. ix } 9.997589 \\ \text{x. } - \ 08 \end{array}$

$\begin{array}{r} 3 \ 41 \ 42 \ \text{N. V.} \ 002079 \\ \text{Dif. appt. alts. } 98 \ 21 \ 22 \ \text{N. V.} \ 1.145326 \end{array}$

$\begin{array}{r} 1.143247 \ \text{Log.} \ 6.058140 \\ 1.136896 \ \text{Log.} \ 6.055721 \end{array}$

$\begin{array}{r} \text{Dif. true alts.} \ 2 \ 48 \ 43 \ \text{N. V.} \ 0.001204 \\ \text{True distance} \ 97 \ 56 \ 16 \ \text{N. V.} \ 1.138100 \end{array}$

$\odot \text{'s L. L.} \ 48^\circ 58' 15'' \ \text{Double alt.}$

$\begin{array}{r} 24 \ 28 \ 7 \\ - \ 2 \ 7 \\ + \ 8 \\ + \ 16 \ 8 \end{array}$

$\begin{array}{r} \text{True alt.} \ 24 \ 42 \ 16 \ \odot \text{'s centre.} \\ \odot \text{'s P. D.} \ 102 \ 29 \ 7 \ \text{cosec.} \ 0.0103938 \\ \text{Latitude} \ 51 \ 31 \ 46 \ \text{sec.} \ 0.2061312 \end{array}$

$\begin{array}{r} \text{Sum} \ 178 \ 43 \ 9 \\ \text{Half sum} \ 89 \ 21 \ 34 \ \text{cos.} \ 8.0484251 \\ \text{Remainder} \ 64 \ 39 \ 18 \ \text{sin.} \ 9.9560467 \end{array}$

$\begin{array}{r} 2] \ 18 \ 2209968 \\ \text{s } 9.1104984 \end{array}$

$\begin{array}{r} 7^\circ 24' 36'' \\ 8 \end{array}$

$\begin{array}{r} 0 \ 59 \ 16 \ 48 \\ 24 \end{array}$

$\begin{array}{r} 23 \ 0 \ 43 \ 12 \\ - \ 3 \ 59 \end{array}$

$\begin{array}{r} 22 \ 56 \ 44 \end{array}$

Reduction to dist.

Appt. Time.

$\begin{array}{r} \text{Distance per N. A. at } 21^h \ 98^\circ 55' 29'' \\ \text{True distance} \ 97 \ 56 \ 16 \\ \text{Distance per N. A. at } 0 \ 97 \ 24 \ 39 \end{array}$

$\begin{array}{r} 2970 \ \text{P. L.} \ 1 \ 30 \ 50 \\ 4828 \ \text{P. L.} \ 0 \ 59 \ 13 \end{array}$

$\begin{array}{r} \text{H. M. S.} \\ 1858 \ \text{P. L.} \ 1 \ 57 \ 21 \end{array}$

$\begin{array}{r} 21 \end{array}$

$\begin{array}{r} \text{Time at Greenwich} \ 22 \ 57 \ 21 \\ \text{Appt. time at place} \ 22 \ 56 \ 44 \ \text{of Observation.} \end{array}$

$\begin{array}{r} \text{Longitude} \ 37 \ \text{W. fr. Greenwich.} \end{array}$

$\begin{array}{r} \text{Vol. 40. No. 176. Dec. 1812.} \end{array} \quad \text{F f} \quad \text{Computation}$

Computation of the Second Set, taken October 25th.

☉'s h. par.	57' 19"	} 1' 51" } 53' 22" Tab. ix.	9.997880
Appt. alt. ☉'s ct.	18 33 42		x. 08
Ditto ☉'s ct.	25 23 8	} 51 31 }	
Diff. appt. alt.	6 49 25		N. V. 007083
Appt. dist.	98 12 12	N. V.	1.142687
			<u>1.135604</u>
			1.130050
Diff. true alts.	5 56 3		005358
True dist.	97 46 56		<u>1.135408</u>

2] 50° 14' 27" Double alt. ☉'s L. L.

$$\begin{array}{r}
 25 \ 7 \ 14 \\
 - \ 2 \ 2 \\
 + \ 8 \\
 + \ 16 \ 8 \\
 \hline
 25 \ 21 \ 28
 \end{array}$$

$$\begin{array}{rcl}
 102 \ 29 \ 12 & \text{cosec.} & 0.0103938 \\
 51 \ 31 \ 46 & \text{sec.} & 0.2061312
 \end{array}$$

2] 179 22 26

$$\begin{array}{rcl}
 89 \ 41 \ 13 & \text{cos.} & 7.7374966 \\
 64 \ 19 \ 45 & \text{sine} & 9.9548682
 \end{array}$$

2] 17.9088898

$$\begin{array}{rcl}
 5^\circ \ 9' \ 57'' & s & 8.9544449 \\
 8
 \end{array}$$

$$\begin{array}{r}
 0 \ 41 \ 19 \ 36 \\
 23 \ 18 \ 40 \ 24 \\
 - \ 3 \ 3 \\
 \hline
 23 \ 15 \ 37,4
 \end{array}$$

Reduction to time at dist.

Appt. time at Observation.

October 25th, at 21h 98 55 29 Per N. Almanac dist.

Ditto at Obs. 97 46 56

Ditto at Oh. 97 24 39 P. L. 2970

1 30 50 P. L. 4193

1 8 33 P. L. 1223

2 15 50

H. M. S.

2 15 50

21

23 15 50

23 15 37,4

Longitude 6 W. from Greenwich.

Computation

of the Place of Observation.

451

Computation of the First Set, observed October 27, 1812.

☉'s H. par.	55' 47"	} 3' 15" } 40' 58"	Tab. ix.	9.995103
☉'s appt. alt.	46 10 47		Tab. x.	-7
☉'s appt. alt.	15 31 47			
	30 39 0	N. V.	139702	9.995096
Appt. dist.	75 23 51	N. V.	747888	
			608 86	5.784536
			601357	5.779132
Dif. true alt.	31 19 58		145838	
True dist.	75 21 23		747195	
☉'s alt. observed 2]	31 15 57			
	15 37 58			
	+ 16 7.8			
	+ 8.0			
	- 3 23			
☉'s true alt.	15 50 51			
☉'s P. D.	103 8 4 cosec.		0.0115126	
Latitude	51 31 46 sec.		0.2061312	
Sum	170 30 41			
Half sum	85 15 20		c 8.9175663	
Remainder	69 24 29		s 9.9713264	
			2]19.1065365	
	20 56 47		s 9.5532683	
24 ^h	8			
	2 47 34 16			
	21 12 25 44			
	- 5 26	Reduction to time at distance		
	21 6 59 7	Appt. time at distance		
October 27, at 21 ^h	75° 25' 2"	Dist. per N. Almanac		
At Obser.	75 21 23	Ditto		
28th noon	73 59 35	Ditto		
	1 25 27	P. L.	3236	
	3 39	P. L.	1.6930	
	7' 42	P. L.	1.3694	
	gh.			
	9 7 42	Time at Greenwich		
	9 7 0	Appt. time at place of observation		
Longitude	42	W. from Greenwich.		

Reduction of the Second Set of Observations taken on Oct. 27,
1812.

☉'s H. Par.	55' 46"	} 39' 41" } 42 25	
Appt. alt. ☉	43 6 16		9.995372
Do. ☉	38 11 46	} 2 44 }	- 07
	24 54 30 N. V.		9.995365
	75 12 44 N. V.		
		651744	5.814078
		644827	5.809443
	25 36 55	098283	
True dist.	75° 6' 52"	743110	
Double Alt. ☉'s LL 2)	36 52 54		
	18 26 27		
	+ 16 8		
	- 2 49		
	+ 8		
☉'s True Alt.	18 39 54		
☉'s P. D.	103 8 4 cosec.	0.0115126	
Latitude	51 31 46	sec 0.2061312	
	2) 173 19 44	c 8.7648002	
	86 39 52	s 9.9671642	
	67 59 58	2) 18.9496082	
	17 21 42	s 9.4748041	
	8		
	2 ^h 18 53 36		
	24		
	21 41 6 24		
	- 3 53	reduction to time at distance.	
Appt. Time	21 37 13 4	at distance	
Distance at	21 h. 75° 25' 2"	per Nautical Almanac.	
Obser.	75 6 52		
28th noon	73 59 38		
	1 25 27 PL	3236	
	0 18 10 PL	9960	
	0 ^h 38 17 PL	6724	
	21		
Time at Greenwich	21 38 17		
Appt. Time at Place	21 37 13		
Longitude from Greenwich	1 4 W.		

By

By collecting together the different results given above, they will stand as follows :

			M.	S.	
Oct. 25th.	1st Set	Obs.	0	37	W.
	2	Do.	0	12,6	W.
Oct. 27th.	1st Set	Do.	0	42	W.
	2	Do.	1	4	W.
		4)	2	35,6	
		Mean from Greenwich		38,9	W.

Hence the Longitude derived from the above observations comes out 38,9 s. in time West of Greenwich, or equal to 9° 31,35" in space. The reason for giving the calculations at full length has been merely to show their simplicity ; and should they tend to induce other persons interested in the determination of this useful problem to repeat them, the author's intentions will be answered. His object has been in this instance directed only to an endeavour to facilitate the acquirement of the method of determining the Longitude by a means both simple and certain.

Somers Town, Dec. 27, 1812.

LXXIX. *Proceedings of Learned Societies.*

ROYAL SOCIETY.

Nov. 26. **T**HE Croonian Lecture, by Dr. Wollaston, was read. It was an unusually brief lecture, and treated only on the integral molecules of crystals. Dr. W., improving an ingenious speculation of Dr. Hooke, assumed the principle, that the original molecules of matter are globular ; and with these globes, he very satisfactorily showed how many of the primitive forms of crystals might arise from their disposition. He acknowledged that the assumption was perfectly gratuitous ; but alleged, that at present there is no other mode of accounting for the tetrahedral and other forms of crystals.

Saturday the 30th November, being St. Andrew's day, the Royal Society held their annual meeting, at their apartments in Somerset Place, for the choice of a Council and Officers for the year ensuing, when the following gentlemen were elected :

Of the old Council :—The right hon. Sir Joseph Banks, Bart. K. B. ; Sir Charles Blagden, Knt. ; Samuel Goodenough, Lord Bishop of Carlisle ; Anthony Carlisle, Esq. ; Sir Humphry Davy, Knt. ; Samuel Lysons, Esq. ; Joseph

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