PHILOSOPHICAL

TRANSACTIONS.

XIX. *On the remarkable Appearances at the Polar Regions of the Planet* Mars, *the Inclination of its Axis, the Poſition of its Poles, and its ſpheroidical Figure; with a few Hints relating to its real Diameter and Atmoſphere. By* William Herſchel, *Eſq. F. R. S.*

Read March 11, 1784.

WHAT I have to offer on the ſubject of the remarkable appearances at the polar regions of Mars, as well as what relates to the inclination of the axis, the poſition of the poles, and the ſpheroidical figure of that planet, is founded on a ſeries of obſervations which I ſhall deliver in this paper; and

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after they have been given in the order they were made, it will be eaſy to ſhew, by a few deductions from them, that my theory of this planet is ſupported by facts which will ſufficiently authoriſe the concluſions I have drawn from them. For the ſake of better order and perſpicuity, however, I ſhall treat each ſubject apart, and begin with the remarkable appearances about the polar regions. The obſervations on them were made with a view to the ſituation and inclination of the axis of Mars; for to determine theſe we cannot conveniently uſe the ſpots on its ſurface, in the manner which is practiſed on the ſun. The quantities to be meaſured are ſo ſmall, and the obſervations of the center of Mars ſo precarious, and attended with ſuch difficulties (ſince an error of only a few ſeconds would be fatal) that we muſt have recourſe to other methods.

When I found that the poles of Mars were diſtinguiſhed with remarkable luminous ſpots *, it occurred to me, that we might obtain a good theory for ſettling the inclination and nodes of that planet's axis, by meaſures taken of the ſituation of thoſe ſpots. But, not to proceed upon grounds that wanted confirmation, it became neceſſary to determine by obſervation, how far theſe polar ſpots might be depended upon as permanent; and in what latitude of the globe of Mars they were ſituated; for, if they ſhould either be changeable, or not be at the very poles, we might be led into great miſtakes by overlooking theſe circumſtances. The following obſervations will aſſiſt us in the inveſtigation of theſe preliminary points.

* A bright ſpot near the ſouthern pole, appearing like a polar zone, has alſo been obſerved by M. MARALDI. See Dr. SMITH's Optics, § 1094.

1777,

1777, April 17. 7 h. 50′. There are two remarkable bright ſpots on Mars. In fig. 1. tab. VI. they are marked *a* and *b*. The line AB expreſſes the direction of a parallel of declination. 10 feet reflector, 9 inches aperture, power 211 *.

10 h. 20′. They are both quite gone out of the diſk.

1779, This year, in all my obſervations on Mars, there is no mention of any bright ſpots, ſo that I believe there were none remarkable enough to attract my attention. However, as my view was particularly directed to the phænomena of this planet's diurnal rotation, it is poſſible I might overlook them.

1781, March 13. 17 h. 40′. 20 feet reflector. I ſaw a very lucid ſpot on the ſouthern limb of Mars of a conſiderable extent. See fig. 2.

June 25. 11 h. 36′. 7 feet reflector, power 227. Two luminous ſpots appeared at *a* and *b*, fig. 3.; *a* is larger than *b*.

12 h. 15′. With 460. *a* is thicker than *b*, but *b* is rather longer.

13 h. 12′. *a* is grown thicker, and *b* become thinner.

June 27. 11 h. 20′. The two lucid ſpots are on Mars.

June 28. 11 h. 15′. They are both viſible; *a*, fig. 4. is much thicker than *b*.

12 h. 55′. A line joining *a* and *b* does not go through the center.

June 30. 10 h. 48′. The ſpot *a* is viſible. fig. 5.

11 h. 35′. Both ſpots are to be ſeen.

* Phil. Tranſ. vol. LXXI. p. 127. and fig. 17.

1781, July 3. 10 h. 54′. *a* seems to be larger than I have seen it, fig. 6.

11 h. 24′. *b* is not yet visible, fig. 7.

12 h. 36′. I perceive part of *b*, fig. 8.

July 4. 12 h. 9′. *a* is very full; *b* extremely thin, and barely visible.

12 h. 18′. *a* and *b* are not quite opposite each other.

12 h. 49′. *b* is increased.

July 15. 9 h. 54′. *a* is visible, fig. 9.

11 h. 35′. *b* invisible.

12 h. 12′. *b* not to be seen.

July 16. 11 h. 9′. The bright spot *a* is very large.

July 17. 11 h. 15′. No other bright spot but *a*.

July 19. 13 h. 31′. *a* visible.

July 20. 10 h. 3′. I suppose the bright spot *a* on Mars is, very nearly, the south pole; which therefore must lie in sight. There is no second bright spot *b* visible to night.

10 h. 56′ *b* not visible; the night very fine.

July 22. 11 h. 14′. At *a* and *b*, fig. 10. are bright spots; *a* is larger than *b*. Most probably the south pole is in view, and the north pole just hid from our sight. If the spots are polar, or nearly so, then *a* must, on a supposition of the south pole's being in view, appear larger than *b*; and if *b* extend a little more from the north pole one way than another, it must be subject to some change in its appearance from the revolution of Mars on its axis.

July 30. 9 h. 43′. Both spots visible.

August 8. 10 h. 4′. Only *a* visible, fig. 11.

August 17. 9 h. 21′. Only *a* in sight.

1781,

1781, August 23. 8 h. 44′. *a* as usual, and part of *b* visible, fig. 12.

Sept. 7. The white spot *a* is very large.

1783, May 20. Mars has a singular appearance. At *a*, fig. 13. is the polar spot, which is bright, and seems to project above the disk by its splendour, causing a break at *c*.

July 4. *a* is very bright.

July 23. 14 h. 45′. *a* is very lucid.

August 16. I saw the bright spot with the 20 feet reflector as usual.

Aug. 26. The lucid spot on Mars is its south pole, for it remains in the same place, while the dark equatorial spots perform their constant gyrations: it is nearly circular.

Aug. 29. The south polar spot is in the same situation.

Sept. 9. As usual.

Sept. 22. The south polar spot is of a circular shape, and very brilliant and white. I had a beautiful and distinct view of it when it was about the meridian, and measured its little diameter in the equatorial direction of Mars. With a power of 932 it gave 1′ 41‴, and I saw it very distinctly. The outward edge of the spot came just up to the upper limb; a favourable haziness, taking off every troublesome ray, gave me objects in general exceedingly well defined, especially Mars.

Sept. 23. 9 h. 55. The polar spot *a*, fig. 14. as usual.

Sept. 24. The same.

1783, Sept. 25. 12 h. 30′. The bright ſouth polar ſpot *a*, fig. 15. ſeems to be fixed in its place, and goes nearly up to the margin of the diſk; it is perfectly round.

12 h. 55′. The track of the equatorial ſpots is incurvated, being convex towards the north, ſee *e*, *q*, fig. 23.: this confirms the white ſpot's being at the ſouth pole. With long attention I can perceive the edge of the diſk of Mars beyond the ſpot, extending about ¼ diameter of the ſpot.

Sept. 26. 12 h. 10′. The ſpot *a* is in a line with the center and the end of the hook, fig. 16.

Sept. 27, 28, 29. The ſpot as uſual.

Sept. 30. 10 h. 30′. The polar ſpot as in fig. 17.

Oct. 1. 9 h. 55′. I am inclined to think, that the white ſpot has ſome little revolution, and therefore is not with its center exactly at the pole of Mars; it is rather probable, that the real pole, though within the ſpot, may lie near the circumference of it, or one-third of its diameter from one of the ſides. A few days more will ſhew it, as I ſhall now fix my particular attention upon it.

10 h. 17′. The bright ſpot is certainly not ſo far upon the diſk as it uſed to be formerly, and is either reduced or has a ſmall motion; which of the two is the caſe will be ſeen in a few hours.

13 h. 3′. The bright ſpot has a little motion; for it is now come farther into the diſk.

I concluded now, in general, that none of the bright ſpots on Mars were exactly at the poles, though they could certainly not be far from them: for what has been juſt related of the

1st, 2d, and 3d of October 1783, shews plainly, that the appearance of the southern spot *a* was a little affected by the diurnal motion of the planet; and the observations of the 3d and 4th of July 1781, shew also that the spot *b* could not be exactly at the north pole; and that, perhaps, the visible branch of the latter extended pretty far towards the equator. However, the south polar spot of the year 1783, being very small and nearly round, afforded a good opportunity for determining its polar distance, by noting the different angles of position it assumed while Mars revolved on its axis; to this end many observations were taken at different hours of the same night, which will be found among the measures of the angles of position in the next division of my subject. And since the different degrees of brilliancy, as well as the proportional apparent magnitude of the spot, would also contribute to the investigation of this point, I continued my remarks on those particulars, as follows.

1783, Oct. 2. 7 h. 59′. The bright spot near the south pole is about half visible.

Oct. 4. 8 h. 0′. The polar spot seems to project above the disk as formerly, and is very small.

Oct. 5. 11 h. 13′. The spot is very small, and seems actually to be in the circumference.

11 h. 30′. The spot is small, and seems to be with its farthest side in the circumference of the disk; or it may, perhaps, be partly beyond it, and therefore not all in sight.

11 h. 50′. I see the spot much clearer than I did before.

13 h. 15′. The white spot is more in sight, and of its usual size, but does not seem much to change its position;

ſition; however, what change there is ſhews that it has been beyond the pole, as it appears to have been direct while the equatorial ſpots were retrograde.

1783, Oct. 9. 11 h. 48′. The white polar ſpot increaſes in ſize. At 10 h. 35′. it was as in fig. 18. but is now larger, and coming round towards that part of its orbit which is neareſt to us. See fig. 24.

Oct. 10. 6 h. 20′. I ſee no white polar ſpot; but the planet is too low for any obſervation to be depended on.

6 h. 55′. The white ſpot begins to be viſible; at leaſt I ſee it now, the planet being higher than before, fig. 19.

9 h. 55′. With 460, the white ſpot is conſiderably increaſed, and ſhews a circular form, fig. 20.

Oct. 11. 7 h. 46′. The bright ſpot is very viſible; the evening fine; with 278.

Oct. 16. 7 h. 7′. The ſpot is very luminous.

9 h. 55′. It ſeems rather lengthened; perhaps it may be arrived at the extreme of its parallel of declination.

Oct. 17. 7 h. 47′. The white ſpot *a*, fig. 21. is very bright.

13 h. 7′. It is leſs in appearance than it was in the beginning of the evening.

Oct. 23. 6 h. 46′. The bright ſpot is very large and luminous; I ſuppoſe it to be in the nearer parts of its little orbit.

7 h. 11′. It is ſituated as in fig. 22.

Oct. 24. 7 h. 1′. The white ſpot is very large.

Oct. 27. 8 h. 45′. It is very large and round.

Nov. 1. 7 h. 47′. The ſpot is round and bright.

1783, Nov. 11. The deficiency of light which occasions Mars to appear gibbous, reaches over the south polar spot towards the preceding limb, and hides it.

Nov. 14. Mars is gibbous, and the polar spot is thereby rendered invisible.

Nov. 17. 6 h. 0′. The south polar spot is under the falcated defect of light.

6 h. 30′. I do not know whether there be not a faint glimpse of the polar spot left; the weather is too bad to determine it.

I have added fig. 25. (tab. X.) to shew the connection of the 15th, 17th, 18th, 19th, 20th, 21st, and 22d figures, which complete the whole equatorial circle of appearances on Mars, as they were observed in immediate succession. The center of the circle marked 17 is placed on the circumference of the inner circle, by making its distance from the center of the circle, marked 15, answer to the interval of time between the two observations, properly calculated and reduced to sidereal measure. The same has been done with regard to the circles marked 18, 19, &c. And it will be found, by placing any one of these connected circles, so as to have its contents in a similar situation with the figures in the single representation which bears the same number, that there is a sufficient resemblance between them; but some allowance must undoubtedly be made for the unavoidable distortions occasioned by this kind of projection.

In order to bring these observations on the bright spots into one view, I have placed them at the circumference of three circles (see fig. 26, 27, 28. tab. VII. VIII. IX.) divided into degrees, representing the parallels of declination in which they revolved about the poles of Mars. The diviſion of the circles marked 360 is where a ſpot paſſes that meridian of the planet which is turned towards the earth, and where, conſequently, it appears to us in its greateſt luſtre. The motion of the ſpot is according to the numbers 30, 60, 90, and ſo on to 360. In calculating the daily places of the ſpots I have uſed the ſidereal period of 24 h. 39′ 21″,67 determined in my paper on the rotation of Mars*; and have alſo made proper allowances for the alterations of the geocentric longitudes calculated from the ſituations of that planet given in the Nautical Almanack; by which means the ſidereal is reduced to a proper ſynodical period.

The following three tables contain the reſult of the calculations, and ſerve to explain the arrangement of the obſervations in the circles. In the firſt column are the times when the obſervations were made. In the ſecond, the ſidereal places of the ſpot in degrees and minutes. In the third column are the geocentric longitudes of Mars at the time of the obſervations. In the fourth, the neceſſary corrections on account of theſe different longitudes. In the fifth column are the corrected or ſynodical places of the ſpots; and, according to the numbers in that column, they are marked on the circles, where conſequently each ſpot is repreſented as it muſt have appeared to be ſituated at the time of obſervation.

* Phil. Tranſ. vol. LXXI. p. 134.

TABLE I.

Time of observation.				Sider. place.		Geoc. longit.			Correction.		Synod. place.	
	D.	H.	M.	D.	M.	S.	D.	M.	D.	M.	D.	M.
June	25	11	36	359	31	9	24	35	+0	0	359	31
	25	12	15	0	0	9	24	35	+0	0	0	0
	25	13	12	13	52	9	24	34	−0	1	13	51
	27	11	20	357	28	9	24	12	−0	23	357	5
	28	11	15	316	40	9	24	1	−0	34	316	6
	30	10	48	290	56	9	23	38	−0	57	289	59
	30	11	35	302	23	9	23	38	−0	57	301	26
July	3	10	54	263	40	9	22	55	−1	40	262	0
	3	11	24	270	58	9	22	55	−1	40	269	18
	3	12	10	282	9	9	22	55	−1	40	280	29
	3	12	36	288	29	9	22	55	−1	41	286	48
	4	12	9	272	20	9	22	40	−1	55	270	25
	4	12	49	282	4	9	22	40	−1	55	280	9
	15	9	54	134	7	9	19	43	−4	52	129	15
	15	11	35	158	42	9	19	42	−4	53	153	49
	15	12	12	167	42	9	19	42	−4	53	162	49
	16	11	9	142	48	9	19	26	−5	9	137	39
	17	11	15	134	40	9	19	9	−5	26	129	14
	19	13	31	148	37	9	18	34	−6	1	142	36
	20	10	3	88	25	9	18	21	−6	14	82	11
	20	10	56	101	19	9	18	20	−6	15	95	4
	22	11	14	86	32	9	17	49	−6	46	79	46
	30	9	43	347	46	9	16	5	−8	30	339	16

TABLE II.

Time of observation.				Sider. place.		Geoc. longit.			Correction.		Synod. place.	
	D.	H.	M.	D.	M	S.	D.	M	D.	M.	D.	M.
June	25	11	36	86	51	9	24	35	+1	40	88	31
	25	12	15	96	20	9	24	35	+1	40	98	0
	25	13	12	110	12	9	24	34	+1	39	111	51
	28	11	15	53	0	9	24	1	+1	6	54	6
	30	10	48	27	16	9	23	38	+0	43	27	59
	30	11	35	38	43	9	23	38	+0	43	39	26
July	3	10	54	0	0	9	22	55	+0	0	0	0
	4	12	9	8	40	9	22	40	−0	15	8	25
	15	9	54	230	27	9	19	43	−3	12	227	15
	15	10	12	234	50	9	19	43	−3	12	231	38
	15	11	35	255	2	9	19	42	−3	13	251	49
	15	12	12	264	2	9	19	42	−3	13	260	49
	16	11	9	339	8	9	19	26	−3	29	235	39
	19	13	31	244	57	9	18	34	−4	21	240	36
	20	10	3	184	45	9	18	21	−4	34	180	11
	20	10	56	197	39	9	18	20	−4	35	193	4
	30	9	43	84	6	9	16	5	−6	50	77	16

TABLE III.

Time of observation.			Sider. place.		Geoc. longit.			Correction.		Synod. place.	
D.	H.	M.	D.	M.	S.	D.	M.	D.	M.	D.	M.
Sept. 25	13	30	6	32	0	9	54	+6	44	13	16
Oct. 1	10	17	262	5	0	8	6	+4	56	267	1
1	13	3	302	29	0	8	5	+4	55	307	24
2	7	59	218	55	0	7	50	+4	40	223	25
4	8	0	200	0	0	7	15	+4	5	204	5
4	8	46	211	12	0	7	15	+4	5	215	17
5	11	13	237	23	0	6	55	+3	45	241	8
5	11	30	241	31	0	6	55	+3	45	245	16
5	11	50	246	23	0	6	55	+3	45	250	8
5	13	15	267	4	0	6	54	+3	44	270	48
5	14	0	278	1	0	6	53	+3	43	281	44
7	8	20	176	8	0	6	23	+3	13	179	21
7	10	5	201	41	0	6	22	+3	12	204	53
7	11	50	227	14	0	6	21	+3	11	230	25
9	11	48	207	35	0	5	49	+2	39	210	14
10	6	55	126	42	0	5	37	+2	27	129	9
10	7	50	140	5	0	5	36	+2	26	142	31
10	9	55	170	30	0	5	34	+2	24	172	54
10	12	11	203	36	0	5	33	+2	21	205	57
16	7	7	72	9	0	4	15	+1	5	73	14
16	7	46	81	39	0	4	15	+1	4	82	43
16	9	55	113	2	0	4	14	+1	4	114	6
17	7	47	72	19	0	4	3	+0	53	73	12
17	13	7	150	11	0	4	0	+0	50	151	1
23	6	46	0	0	0	3	10	−0	0	0	0
24	7	1	354	0	0	3	2	−0	8	353	52

From the appearance and disappearance of the bright north polar spot in the year 1781, we collect that the circle of its motion, represented by fig. 26. was at some considerable distance from the pole. By a calculation, made according to the principles hereafter explained, its latitude must have been about 76° or 77° north; for I find that, to the inhabitants of Mars, the declination of the sun, June 25. 12 h. 15′ of our time, was about 9° 56′ south *; and the spot must have been at least so

* See p. 259. and 260.

far removed from the north pole as to fall a few degrees within the enlightened part of the diſk, to become viſible to us.

The ſouth pole of Mars could not be many degrees from the center of the large bright ſouthern ſpot of the year 1781, whoſe courſe is traced in fig. 27; though the ſpot was of ſuch a magnitude as to cover all the polar regions farther than the 70th or 65th degree, and in that part which was on the meridian July 3, at 10 h. 54′, perhaps a little farther.

In the next diviſion of our ſubject will be ſhewn, that the inclination and poſition of the axis of Mars are ſuch, that the whole circle, fig. 28. (which will appear to be in about 81° 52′ of ſouth latitude on the globe of Mars) was in view all the time the obſervations on the bright ſouth polar ſpot of the year 1783, which are marked upon it, were made, but in ſo oblique a ſituation as to be projected into a very narrow ellipſis. See fig. 24. where *m n* is the little ellipſis in which the ſpot *a* revolved about the pole. Hence then we may eaſily account for the obſerved magnitude and brightneſs of the ſpot Oct. 23, 24, and 27. when it was expoſed to us in its meridian ſplendour. Its ſituations Oct. 16. and 17. on one extreme of the parallel, as well as thoſe of Oct. 5. and Nov. 1. on the other, gave us alſo a bright view of it: and, when we paſs over to that half of the circle which lies beyond the pole, the much greater obliquity into which the ſpot muſt there be projected will perfectly account for its being ſmaller at 13 h. 7′ of Oct. 17. than at 7 h. 47′ of the ſame evening. It will alſo explain its ſmallneſs Oct. 4. and its increaſe Oct. 9. We ſhall have occaſion hereafter to recur to the ſame figure, ſo that I take no notice at preſent of the angles of poſition which are marked upon it.

4 *Of*

Of the direction or nodes of the axis of Mars, *its inclination to the ecliptic, and the angle of that planet's equator with its own orbit.*

From the foregoing article we may gather, that the bright polar ſpots on Mars are the moſt convenient objects for determining the ſituation of the axis of this planet; I ſhall therefore collect, in one view, all the meaſures I have taken of theſe ſpots for that purpoſe. Before I conſtructed a micrometer for taking the angle of poſition, I uſed to draw a line through the figure delineated of Mars to repreſent the parallel of declination; in a few of my firſt obſervations, therefore, I can only take the ſituation of the polar ſpots from ſuch drawings, and of conſequence no great accuracy in the angles, as to the exact number of degrees, can be expected.

1777, April 17. 7 h. 50′. A line drawn through the middle of the two bright polar ſpots *a* and *b*, fig. 1. makes an angle of about 63°, with a parallel of declination AB; the ſouthern ſpot preceding and the northern following.

My reaſon for chuſing a line drawn through both the ſpots rather than through one of them and the center is, firſt, that they were not ſituated quite oppoſite each other, and therefore, unleſs other obſervations had pointed out which was moſt polar, I ſhould evidently run the greater riſk in fixing on one of them in preference to the other. In the next place, we find by the ſecond obſervation, page 235. that in two hours and a half both ſpots were intirely gone out of the diſk. This plainly

plainly denotes, that they were both in the ſame half of a ſphere orthographically projected, and divided by a plane paſſing through the axis of Mars and the eye, but that neither of them were polar. Now, a line drawn through two points not far from oppoſite each other, both in the ſame hemiſphere, and both removed from the poles of it, muſt approach more to a paralleliſm with the axis, than a line drawn through either of them and the center.

1779, May 9. There being no bright ſpots by which to judge of the poſition of the poles, it is eſtimated from a well known dark equatorial ſpot, with a line drawn through the figure to denote a parallel of declination. By very rough eſtimation it is about 42° ſouth preceding.

May 11. The ſame figure, being drawn again in another ſituation, and alſo with a line giving a parallel of declination, points out, by the ſame rough eſtimation, 62° ſouth preceding.

1781, June 25. 11 h. 35′. The poſition of the ſpots *a* and *b*, fig. 3. with regard to a parallel of declination, meaſured with a micrometer 74° 32′. The ſpot *a* was ſouth preceding, and *b* north following.

July 15. 10 h. 12′. The angle of poſition, of the center of the ſpot *a*, fig. 9. through the center of the diſk, 74° 18′ ſouth preceding.

1783, Auguſt 16. Poſition of the ſpot *a*, 64° ſouth following the center; but as the planet is not full, the center becomes dubious, and the meaſure therefore may not be quite accurate, though taken with a 20 feet reflector; power 200.

Sept.

1783, Sept. 9. Poſition of the ſuppoſed ſouth pole of Mars 65° 12′ ſouth following; 7 feet reflector; power 460.

Sept. 22. Poſition of the ſame 52° 9′ ſ. following; 460.

Sept. 25. 13 h. 30′. Poſition of the ſouth polar ſpot 56° 27′. very accurately taken, by biſecting the diſk of Mars through the bright ſpot, and ſuppoſing the planet now near enough the oppoſition to induce no material error. Hitherto I have taken it through a ſuppoſed center by endeavouring to allow a little for what I thought the deficiency in the diſk; but not to-night.

Oct. 4. 8 h. 46′. Poſition of the ſpot 51° 21′; Mars too low and hazy to depend much on the meaſure with ſo high a power as 460.

Oct 5. The motion of the polar ſpot being now ſtrongly ſuſpected, or rather already known, I took the following meaſures, by way of diſcovering its quantity.

11 h. 50′. Poſition very exactly taken 50° 6′ ſ. following.

14 h. 0′. Poſition of the ſpot 49° 45′.

Oct. 7. 8 h. 20′. Poſition 55° 12′. In order to ſee how far this meaſure might be truſted to, I ſet 49° 36′ in the micrometer, which was evidently too ſmall; next I took 51° 36′, which was alſo too ſmall; after this, I took a new meaſure, and found 55° 24′, which appeared to me very exact. 10 h. 5′. The poſition now was 53°. 11 h. 50′. It meaſured 52° 12′. As there is nothing to diſtinguiſh the center, it is extremely difficult to pleaſe one's ſelf in bringing the ſpot into a line with it.

1783, Oct. 10. 7 h. 50′. Poſition of the polar ſpot 57° 12′; with 460, very accurate. I tried a few parts leſs of the micrometer, but found the meaſure too little. I ſee pretty diſtinctly, but the air is tremulous.

9 h. 55′. Poſition 52° 42′; very diſtinct.

12 h. 11′. Poſition 46° 30′; I ſee not quite ſo well now as I could wiſh.

14 h. 1′. Poſition 44° 12′; but liable to great uncertainty, on account of tremulous air; it becomes more difficult to diſtinguiſh the center when the planet is not perfectly defined.

Oct. 16. 7 h. 7′. Poſition 63° 9′. By way of trial I ſet 59° 36′, which was too ſmall; alſo 60° 24′ was too ſmall; again, 61° 24′ was not large enough. Then, taking a freſh meaſure, I found it 62° 48′, which I thought right.

9 h. 55′. I took three meaſures, and thought the third, which was 65° 0′, the beſt of all, for I ſaw the planet and the ſpot remarkably well.

Oct. 27. 8 h. 45′. Poſition of the polar ſpot 59° 30′. I took three other meaſures, of which 60° 39′ appeared to me the beſt; it was taken with long attendance and many changes and trials of the wires in different poſitions; but the gibboſity of Mars is ſuch, that meaſures of the ſituation of the ſpot are now no longer to be depended on.

Theſe poſitions, I believe, will be ſufficient for the purpoſe of ſettling the latitude of the polar ſpots, and thereby obtaining a correct meaſure of the ſituation of the real pole. I have referred thoſe of the ſouth polar ſpot of the year 1783 to the ſame circle which contains the obſervations that were made on

2 the

the apparent brightneſs and magnitude of that ſpot, that they may be compared together. (See fig. 28.) The agreement of the meaſures, and the phænomena attending the motion of the ſpot, are ſufficient to point out the meridian of the circle; for which, from a due conſideration of theſe circumſtances, I have fixed on the place where the ſpot was Oct. 10. 6 h. 46′.

Of the angles collected in fig. 28. we find 65° 0′ the largeſt, and 49° 45′ the ſmalleſt; but, on account of the different ſituation of the earth and Mars, the angle meaſured 7′ leſs Oct. 16. than it would have done had the planets remained in the places they were in Oct. 5. when the other meaſure was taken. This being added, we have 65° 7′. The difference between the two poſitions is 15° 22′. Now, the conſtruction of fig. 28. being admitted, we ſee that the angles were nearly taken at the oppoſite extremes of the circle in which the ſpot moved. However, by the 5th column of Tab. III. Oct. 5. we have the ſituation of the ſpot in the circle with reſpect to the meridian 281° 44′, and Oct. 16. 114° 6′: therefore the ſouth polar diſtance of the center of the ſpot is found, by taking half the ſum of the ſines of theſe angles to radius, as 7° 41′ (half of 15° 22′) to a fourth number, which is 8° 8′; and the latitude of the circle, in which the ſpot moved about the pole, therefore is 81° 52′ ſouth. This being determined, we have the following correction for the angles of poſition: radius is to ſine of the angular diſtance of the ſpot from the meridian as 8° 8′ to the required quantity. This muſt be added or ſubtracted, according as the caſe requires; and thereby we ſhall have the poſition of the true pole from any one of the meaſures.

I ſhall now apply the above to determine the ſituation of the axis of Mars. To this end, we ſee that, in the firſt place, the measures must be corrected for the latitude of the spot; next, they must be reduced to a heliocentric observation, which will also correct them from the difference occasioned by the different situation of the planets when they were taken. This being done, we may select two observations at a proper distance; from which, by trigonometry, we shall have the node and inclination of the axis. When these elements are obtained, it will be easy to see how other observations agree with them; which will afford the means of correcting or verifying the former calculations.

Let T, fig. 29. (tab. X) be the earth; ♋ Q *q* ♑ the ecliptic as seen from T; P the point of the heavens towards which the north pole of the earth is directed; M the place of the orbit of Mars μ *m* M, where an observation of the poles of that planet has been made, which is to be reduced to its heliocentric measure. And, first, suppose it to have been made at the time of the opposition of that planet. Then, the place M or Q in the ecliptic being given, we have the sides Q ♋, ♋ P; whence the angle Q, of the right-angled triangle P ♋ Q, is found. This being added to, or taken from, the observed angle of position of the axis of Mars, according to circumstances easily to be determined, reduces it to its heliocentric position. But if this observation was not made at the time of an opposition, but at some other place *m*, a second correction is to be applied in the following manner.

Let the angle *q*, of the triangle P ♋ *q*, be found as before, and properly applied to the position of the axis of Mars now at *m*; then make the angle *m* S μ, at the sun S, equal to the angle S *m* T, and μ will be the heliocentric place, where the angle of position, when seen from S, will appear to be as it was found at *m*, after the application of the first correction:

 for

for S μ being parallel to T m, and ſuppoſing the axis of Mars to preſerve its paralleliſm while it moves from m to μ, appearances of Mars at μ to an eye at S, muſt be the ſame as they are at m to an eye at T.

The following table contains the reſult of calculations relating to the angles of fig. 28. In the firſt column are the times when the obſervations were made. In the ſecond, the angles as they were taken. In the third column are the quantities of the angles Q, q, calculated from the geocentric longitudes contained in the third column of the third table. In the fourth column are the corrections for the ſituation of the ſpot in the circle of latitude obtained from the ſines of the angles in the fifth column of the third table. In the fifth are the corrections requiſite on account of the change of ſituation of the planets, during the interval between the ſeveral days on which the meaſures were taken; theſe are obtained from the third column of this table, and I have aſſumed the 4th of October, as being the obſervation neareſt the oppoſition, to which I have reduced the other meaſures. In the ſixth column are the angles of the ſecond, corrected by the quantities contained in the fourth and fifth columns, applied according to their ſigns.

TABLE

TABLE IV.

Time of observation.			Angles taken.		Angle Q.		First correction.		Second correct.	Angles corrected.	
D.	H.	M.	D.	M.	D.	M.	D.	M.	M.	D.	M.
Sept. 25	13	30	56	27	+23	10	−1	52	−8	54	27
Oct. 4	8	46	51	21	+23	18	+4	42	−0	56	3
5	11	50	50	6	+23	19	+7	39	+1	57	46
5	14	0	49	45	+23	19	+7	59	+1	57	45
7	8	20	{ 55 55	12 24 }	+23	21	−0	7	+2	{ 55 55	7 19
7	10	5	53	0	+23	21	+3	26	+3	56	29
7	11	50	52	12	+23	21	+6	16	+3	58	31
10	7	50	57	12	+23	22	−4	57	+4	52	19
10	9	55	52	42	+23	22	−1	7	+4	51	39
16	7	7	{ 63 62	9 48 }	+23	25	−7	47	+7	{ 55 55	29 8
16	9	55	65	0	+23	25	−7	23	+7	57	45

As we have no particular reason to select one measure rather than another, a mean of all the 13 will probably be nearest the truth; so that by these observations, which, as we said before, are reduced to the 4th of October, 1783, we find the position of the axis of Mars that day to have been 55° 41′ south following.

From the appearances of the south polar spot in 1781, represented fig. 27. we may conclude, that its center was nearly polar. We find it continued visible all the time Mars revolved on its axis; and, to present us generally with a pretty equal share of the luminous appearance, a spot which covered from 45° to 60° of a great circle on the globe of Mars could not have any considerable polar distance: however, a small correction in the angle of position seems to be necessary, which should be taken from the measure of the 15th of July, because that branch of the spot which probably extended farthest towards the

the equator, was then in the *following* quadrant. The meaſure of both the ſpots on June the 25th, 1781, is ſtill more to be depended on, as giving us very nearly the poſition of the true pole; for it appears evident from the phænomena of the bright north-polar ſpot in fig. 26. that that ſpot was in the meridian when the meaſure was taken, while the ſouthern ſpot was in the *preceding* quadrant near its greateſt limit. Now, ſince an angle at the circumference of a circle is but half the angle at the center, when the arches which ſubtend theſe angles are equal, the correction neceſſary to be applied to the meaſure taken through the two ſpots will be but one half of the correction which would have been requiſite had it been taken through the center; therefore, in order to reduce this to the condition of the former, we may ſuppoſe it to have been taken through the center of Mars when the ſpot was only 30, or 150 degrees from the meridian. It is alſo neceſſary to add 1° 54′ to the angle of July 15, which it would have meaſured more had the planets remained where they were June 25. This done, we may have the polar diſtance of the center of the ſpot as before. Half the ſum of the ſines (of 231° 38′ and 150°) to radius, as 50′ (half the difference between 74° 32′ and 76° 12′) to a fourth number, which is 1° 18′.

I ſhould obſerve here, that the meaſures of the angle of poſition would be too large before the ſpot came to the meridian, and too ſmall afterwards, the axis of Mars being ſouth preceding; whereas, in fig. 28. they would be too ſmall before, and too large after, the meridian paſſage, the pole being ſouth following.

Theſe two obſervations arranged as thoſe in the fourth table, and reduced to the time of the 25th of June, will ſtand as follows.

TABLE

TABLE V.

Time of observation.			Angles taken.		Angle Q.		First correction.	Second correct.	Corrected Angle.	
D.	H.	M.	D.	M.	D.	M.		D. M	D.	M.
June 25	11	36	74	32	−10	14	+ { half of 1° 18′	−0 0	75	11
July 15	10	12	74	18	− 8	20	−1 1	+1 54	75	11

I am to remark, that we have here admitted both measures as equally good; and that, therefore, the result is a mean of them both, and shews the axis of Mars, June 25, 1781, to have been 75° 11′ south preceding.

Our next business will be to reduce these two geocentric observations to a heliocentric measure. This is to be done, as we have shewn before, by a calculation of the angle Q, fig. 29. The result of it shews, that 10° 14′ are to be subtracted from the mean corrected angle of position, reduced to June 25, 1781, and 23° 18′ to be added to the angle which is the corrected mean of 13 measures, reduced to Oct. 4, 1783. Hence we learn, that on those days and hours, when the heliocentric places of Mars were 9 s. 24° 35′, and 0 s. 7° 15′ (which would happen about July 18, 1781, and Sept. 29, 1783) an observer placed in the sun would have seen, on the former, the axis of Mars inclined to the ecliptic 64° 57′, the north pole being towards the left; and on the latter, he would have seen the same axis inclined to the ecliptic 78° 59′, the north pole being then towards the right.

The first conclusion we may draw from these principles is, that the north pole of Mars must be directed towards some point of the heavens between 9 s. 24° 35′ and 0 s. 7° 15′; because the change of the situation of the pole from left to right, which

which happened in the time the planet paſſed from one place to the other, is a plain indication of its having gone through the node of the axis. Next, we may alſo conclude, that the node muſt be conſiderably nearer the latter point of the ecliptic than the former; for, whatever be the inclination of the axis, it will be ſeen under equal angles at equal diſtances from the node.

But, by a trigonometrical proceſs of ſolvinga few triangles, we ſoon diſcover both the inclination of the axis, and the place where it interſects the ecliptic at rectangles (which, for want of a better term, I have perhaps improperly called its node). Accordingly I find, by calculation, that the node is in 17° 47′ of Piſces, the north pole of Mars being directed towards that part of the heavens; and that the inclination of the axis to the ecliptic is 59° 42′.

We ſhall now compare the obſervations of an earlier date with theſe principles, to ſee how far they agree. Some of the particulars and calculations relating to them are as follow.

T A B L E VI.

Times of Obſervation.				Eſtimations.	Geoc. longit.			Angle Q.		2d correct.
	D.	H.	M.	D.	S.	D.	M.	D.	M.	
1779, May	9	12	0	42	7	22	20	+14	45	+ 0
May	11	12	0	62	7	21	40	+15	11	+ 26
1777, Apr.	17	7	50	63	6	3	34	+23	26	

May the 9th, 1779, as we have ſeen, the angle of poſition was roughly eſtimated at 42°, and May 11. at 62°. The great diſagreement of theſe coarſe eſtimations is undoubtedly owing to the very different ſituation of the dark ſpot from which they

 were

were taken; however, ſince we do not mean to uſe theſe obſervations in our calculations, they may ſuffice in a general way to ſhew, that the axis of Mars was actually about that time in ſuch a ſituation as our principles give it: for, reducing the two poſitions to the 9th of May, that of the 11th, from an allowance of 26′ for the ſituation of the planets, will become 62° 26′; and a mean of the two, 50° 13′ ſouth preceding; which, reduced to a heliocentric obſervation, gives 66° 30′, the north pole lying towards the left. Now, on calculating from the poſition of the node and inclination of the axis before determined, we find, that the heliocentric angle was 62° 49′, the north pole pointing towards the left; and a nearer agreement with theſe principles could hardly be expected from eſtimations ſo coarſe. If we go to the year 1777, and take the poſition of the two bright ſpots obſerved the 17th of April, we have 63° ſouth preceding; this, reduced to a heliocentric quantity, gives 86° 26′ of inclination, the north pole being to the left. By calculating we find, that that pole was then actually 81° 27′ inclined to the ecliptic, and pointed towards the left as ſeen from the ſun.

The inclination and ſituation of the node of the axis of Mars with reſpect to the ecliptic being found may thus be reduced to that planet's own orbit. Let EC, fig. 30. (tab. X.) be a part of the ecliptic; OM part of the orbit of Mars; PEO a line drawn from P, the celeſtial pole of Mars, through E, that point which has been determined to be the place of the node of the axis of Mars in the ecliptic, and continued to O where it interſects the orbit of Mars. Now, if according to Mr. DE LA LANDE we put the node of the orbit of Mars for 1783, in 1 s. 17° 58′, we have from the place of the node of the axis (that is, 11 s. 17° 47′) to the place of the node of the orbit;

an arch EN of 60° 11′; in the triangle NEO, right-angled at E, there is alſo given the angle ENO, according to the ſame author, 1° 51′, which is the inclination of the orbit of Mars to the ecliptic. Hence we find the angle EON 89° 5′, and ſide ON 60° 12′. Again, when Mars is in the node of its orbit N, we have, by calculation from our principles, the angle PNE = 63° 7′, to which, adding the angle ENO = 1° 51′, we have PNO = 64° 58′; from which two angles PON and PNO with the diſtance ON, we obtain the inclination of the axis of Mars, and place of its node with reſpect to that planet's own orbit; the inclination being 61° 18′, and the place of the node of the axis 58° 31′ preceding the interſection of the ecliptic with the orbit of Mars, or in our 19° 28′ of Piſces.

Being thus acquainted with what the inhabitants of Mars will call the obliquity of their ecliptic, and the ſituation of their equinoctial and ſolſtitial points, we are furniſhed with the means of calculating the ſeaſons on Mars; and may account, in a manner which I think highly probable, for the remarkable appearances about its polar regions.

But firſt it may not be improper to give an inſtance how to reſolve any query concerning the martial ſeaſons. Thus, let it be required to compute the declination of the Sun on Mars, June 25, 1781, at midnight of our time. If ♈ ♉ ♊ ♋, &c. fig. 31. (tab. X.) repreſent the ecliptic of Mars, and ♈ ♋ ♎ ♑ the ecliptic of our planet, A*a*, *b*B, the mutual interſection of the martial and terreſtrial ecliptics, then there is given the heliocentric longitude of Mars, ♈*m* = 9 s. 10° 30′; then taking away ſix ſigns, and ♎ *b*, or ♈*a* = 1 s. 17° 58′, there remains *bm* = 1 s. 22° 32′. From this arch, with the given inclination, 1° 51′, of the orbits to each other, we have coſine of inclination to radius, as tangent of *bm* to tangent of BM = 1 s. 22° 33′. And taking away B♈ = 1 s. 1° 29′, which is the complement to ♑ B (or ♋ A, already ſhewn to be 1 s. 28° 31′) there will remain ♈M = 0 s. 21° 4′, the place of Mars in its own orbit *; that is, on the time abovementioned, the ſun's longitude on Mars will be 6 s. 21° 4′, and the obliquity of the martial ecliptic 28° 42′ being alſo given, we find, by the uſual method, the ſun's declination 9° 56′ ſouth.

The analogy between Mars and the earth is, perhaps, by far the greateſt in the whole ſolar ſyſtem. Their diurnal motion is nearly the ſame; the obliquity of their reſpective ecliptics, on which the ſeaſons depend, not very different; of all the ſuperior planets the diſtance of Mars from the ſun is by far the neareſt alike to that of the earth: nor will the length of the martial year appear very different from that which we enjoy, when compared to the ſurpriſing duration of the years of Jupiter, Saturn, and the Georgium Sidus. If, then, we find that the globe we inhabit has its polar regions frozen and covered with mountains of ice and ſnow, that only partly melt when alternately expoſed to the ſun, I may well be permitted to ſurmiſe that the ſame cauſes may probably have the ſame effect on the globe of Mars; that the bright polar ſpots are owing to the vivid reflection of light from frozen regions; and that the reduction of thoſe ſpots is to be aſcribed to their being expoſed to the ſun. In the year 1781, the ſouth polar ſpot was extremely large, which we might well expect, ſince that pole had but lately been involved in a whole twelvemonth's darkneſs and abſence of the ſun; but in 1783 I found it conſiderably ſmaller than before, and it decreaſed continually

* If no very great accuracy be required, we may add 3 s. 10° 34′ to any given place of our ecliptic, which will at once reduce it to what it ſhould be called on the orbit of Mars, and will always be true to within a minute.

from

from the 20th of May till about the middle of September, when it feemed to be at a ftand. During this laft period the fouth pole had already been above eight months enjoying the benefit of fummer, and ftill continued to receive the fun-beams; though, towards the latter end, in fuch an oblique direction as to be but little benefited by them. On the other hand, in the year 1781, the north polar fpot, which had then been its twelve-month in the fun-fhine, and was but lately returning to darknefs, appeared fmall, though undoubtedly increafing in fize. Its not being vifible in the year 1783 is no objection to thefe phænomena, being owing to the pofition of the axis, by which it was removed out of fight; moft probably, in the next oppofition we fhall fee it renewed, and of confiderable extent and brightnefs; as, by the pofition of the axis of Mars, the fun's fouthern declination will then be no more than 6° 25′ on that planet.

Of the fpheroidical figure of Mars.

That a planetary globe, fuch as Mars, turning on an axis, fhould be of a fpheroidical form, will eafily find admittance, when two familiar inftances in Jupiter and the earth, as well as the known laws of gravitation and centrifugal force of rotatory bodies, lead the way to the reception of fuch doctrines. So far from creating difficulties or doubts, it will rather appear fingular, that the fpheroidical form of this planet, which the following obfervations will eftablifh, has not already been noticed by former aftronomers; and yet, reflecting on the general appearances of Mars, we foon find that opportunities for making obfervations on its real form cannot be very frequent: for, when it is near enough to view it to an advantage, we fee it generally gibbous, and its oppoſitions are ſo ſcarce, and of ſo ſhort a duration, that in more than two years time we have not above three or four weeks for ſuch obſervations. Beſides, aſtronomers being already uſed to ſee this planet generally diſtorted, the ſpheroidical form might eaſily be overlooked.

Obſervations relating to the polar flattening of Mars.

1783, Sept 25. 9 h. 50′. I can plainly ſee that the equatorial diameter of Mars is longer than the polar. Meaſure of the equatorial diameter 21″ 53‴; of the polar diameter 21″ 15‴ *full meaſure*, that is, certainly not too ſmall. The wires were ſet as outward tangents to the diſk, and the zero, as well as the meaſures, were taken by the light of Mars.

Sept. 28. 14 h. 25′. I ſhewed the difference of the polar and equatorial diameters of Mars to Mr. WILSON, Aſſiſtant Profeſſor of Aſtronomy at Glaſgow. He ſaw it perfectly well, ſo as to be entirely convinced it was not owing to any defect or diſtortion occaſioned by the eye lens; and, becauſe I wiſhed him to be ſatisfied of the reality of the appearance, while he was obſerving, I reminded him of ſeveral well known precautions; ſuch as cauſing the planet to paſs directly through the center of the field of view, and judging of its figure at the time when it was moſt diſtinct and beſt defined, and ſo forth.

Sept. 29. I ſhewed the difference of the polar and equatorial diameters of Mars to Dr. BLAGDEN and Mr. AUBERT. Dr. BLAGDEN not only ſaw it immediately,

diately, but thought the flattening almoſt as much as that of Jupiter. Mr. AUBERT alſo ſaw it very plainly, ſo as to entertain no manner of doubt about the appearance.

As we cannot take too many opportunities of confirming our own obſervations by the eyes of other obſervers, I eſteemed it a very fortunate circumſtance to have the honour of a viſit from theſe gentlemen at ſo particular a time, Mars being this day within 37 hours of the oppoſition, and yeſterday when Mr. WILSON ſaw it, within about two days and a half.

1783, Sept. 30. 10 h. 52′. The difference in the diameters of Mars is very evident and conſiderable.

Meaſure of the equatorial diameter 22″ 9‴ with 278.
Second meaſure - - 22″ 31‴ full large.
Polar diameter very exact - 21″ 26‴.

Oct. 1. 10 h. 50′. I took meaſures of the diameters of Mars with my 20-feet reflector. The equatorial meaſured 103 parts of the micrometer; the polar 98. The value of the diviſions in ſeconds and thirds not being well determined, on account of ſome late change in the focal length of the ſeveral 20-feet object metals I uſe, we have only from theſe meaſures the proportion of the diameters as 103 to 98.

13 h. 15′. Every circumſtance being favourable, I took the following meaſures of the diameters of Mars with my 7-feet reflector, and a diſtinct power of 625.

Equatorial diameter 22″ 12‴ narrow meaſure.
22″ 46‴ rather full.
22″ 35‴ exact.

Polar

Polar diameter 21″ 24‴

21″ 33‴ very exact.

I saw Mars perfectly well all the time I measured, with all its figures upon the disk appearing distinctly; and, I think, these measures may be depended upon better than any I have yet taken.

1783, Oct 5. 14 h. 0′. The difference of the diameters is very sensible.

Oct. 7. 9 h. 43′. The flattening of the poles is very visible.

13 h. 40′. I turned my Newtonian 7-feet reflector one quarter round, so as to bring the place to look in at to the bottom; and, as well as the uneasy posture would allow, I saw the flattening of the poles the same as when I looked in at the side; power 460.

14 h. 30′. With a 3½ feet achromatic telescope and a single eye lens, I saw the difference of the polar and equatorial diameters very plainly.

Oct. 9. 8 h. 40′. I turned my reflector 90° round, so as now to look in at the upper end, but saw not the least difference in appearances; for, returning it again immediately to its usual position, in both cases the equatorial diameter appeared a little longer than the other; power 278, and the evening fine.

I turned the great speculum one quadrant in its cell, but appearances were not in the least altered; the equatorial diameter still was a little longer than the polar one.

I tried a very fine new object speculum, and found also the equatorial diameter a little longer than the polar one.

1783,

1783, Oct. 9. 10 h. 47′. The flattening at the poles very visible.

Oct. 10. 9 h. 55′. A little of the polar flattening is visible, so as to admit of no doubt; power 460, very distinct.

11 h. 32′. Mars visibly flattened, but not much; the achromatic shews it also.

11 h. 42′. The disk of Mars is visibly spheroidical.

Oct. 11. 7 h. 37′. Mars is plainly gibbous, therefore measures and estimations of the diameters must for the future be improper.

11 h. 12′. It is rather difficult to say of what shape Mars is now, for it is partly flattened and partly gibbous; but the gibbous side not being quite in the polar direction of Mars, this produces altogether an odd mixture of shapes: however, upon the whole, the polar diameter is still rather the smallest.

11 h. 13′. The *preceding* side of Mars shews the flattening of the poles, while the *following* is terminated by an elliptical arch.

Oct. 12. 11 h. 12′. The flattening upon the whole is visible.

Oct. 17. 13 h. 7′. The effect of gibbosity is scarcely equal to the flattening; or, upon the whole, the planet is still rather broader over the equator than over the poles.

Nov. 1. 7 h. 56′. The semi-disk, which is *full*, is evidently part of an oblate spheroid; but, to an eye not attentively looking for it, and knowing the shape and exact situation of the poles of Mars, this would probably not appear.

1783, Nov. 10. 9 h. 30′. The gibboſity of Mars is now ſuch, that the polar diameter is conſiderably longer than the equatorial; but the deficiency not being exactly from pole to pole, makes the diſk of a crooked, irregular figure, and renders preciſion in this eſtimation impoſſible; otherwiſe the phaſe of Mars would have made a pretty good micrometer upon the equatorial diameter, and it was with ſuch a view I had directed my attention to this circumſtance: appearances, however, are viſibly in favour of the polar diameter's being the longeſt.

We find that the quick alterations in the viſible diſk of Mars, during the time it is in the beſt ſituation for us to obſerve it, are ſuch, that if we were to uſe many meaſures which have been taken of its diameters, we ſhould be obliged to have recourſe to a computation of its phaſes, in order to make proper allowance for them. Now, ſince theſe changes are in a longitudinal direction, and the poles of Mars are not perpendicular to the ecliptic, it would bring on a calculation of ſmall quantities, which it is always beſt not to run into where it can be avoided. For this reaſon, I ſhall at once ſettle the proportion of the equatorial to the polar diameter of this planet, from the meaſures which were taken on the very day of the oppoſition. I prefer them alſo on another account, which is, that they were made in a very fine, clear air, and were repeated with a very high power, and with two different inſtruments, of whoſe faithful repreſentation of celeſtial objects, the many obſervations on very cloſe double ſtars I have made with them have given me very evident proofs.

As

As we are at present only in quest of the proportion of one diameter to the other, the measures of the 20-feet reflector, though not given in angular quantities, will equally suffice for the purpose. By them we have the equatorial diameter to the polar as 103 to 98, or as 1355 to 1289. I have turned the proportion into the latter numbers by way of comparing them the better with the measures of the 7-feet reflector. By that instrument the equator of Mars, Oct. 1. we find, was measured three times; but from the remarks annexed to the different results, I think the third measure should be used. Indeed, on taking the difference of the two first. which is 34''', and dividing by three, we have the quotient $11\frac{1}{3}'''$; then, allotting two-thirds to the first, because the remark says positively "narrow measure," it becomes 22'' $34\frac{2}{3}'''$, and taking one-third from the second, which is expressed doubtfully, "rather too full," it becomes 22'' $35\frac{1}{3}'''$: this reflection on the two first measures gives additional validity to the third, which is 22''35''', or 1355'''. The polar diameter was measured twice; and as no reason appears against either of the observations, I shall take the mean of both, which is 21'' 29''', or 1289'''; so that by these measures the equatorial diameter of Mars is to the polar as 1355 to 1289. A less perfect agreement between the proportions of the diameters arising from the measures of the 20-feet reflector and those which we have just now deduced from the 7-feet, would have been sufficient for our purpose, as we might easily have excused one or two thousandths of the whole quantity; however, we have no cause to be displeased with this coincidence, though it should in part be owing to accident, and therefore shall admit the above proportion, and proceed to a farther examination of it.

In the firft place, it will be neceffary to fee whether any correction be required on account of the different heliocentric and geocentric fouth latitude of Mars; which would apparently comprefs the polar diameter a little, by the defect of illumination on the north. On computation we find, that a difference arifing from that caufe would give the longitudinal diameter to the latitudinal as 20000 to 19987; which being much lefs than one thoufandth part of the whole, may therefore be neglected.

But next, a very confiderable correction muft be admitted, when we take into account the pofition of the axis of Mars. The declination of the fun on that planet, at the time the meafures were taken, was not lefs than 27° fouth; fo that the poles were not in the circumference of the difk by all that quantity. On a fuppofition then, that the figure of Mars is an elliptical fpheroid, we are now to find the real quantity of the polar diameter from the apparent one. It has been proved, that, in the ellipfis, the exceffes of any diameters above the polar one are as the fquares of the cofines of the latitudes*; but the diameter at rectangles to the equator of Mars, which was expofed to our view in the late oppofition, was not the polar one, but fuch as muft take place in a latitude of 63°. Putting therefore $m =$ cofine of 63°, $a = 1355$, $b = 1289$, $x =$ the polar axis, we have $1 : m^2 :: a - x : b - x$. And $\frac{b - m^2 a}{1 - m^2} = x$; which gives us 1272 nearly, for the polar diameter. The true proportion, therefore, of the equatorial to the polar diameter will be as 1355 to 1272; which, reduced to fmaller but lefs accurate numbers, is 16 to 15 nearly.

* Aftr. par M. DE LA LANDE, § 2680.

I fhall

I ſhall now alſo mention ſome of the other meaſures, but with a view only to ſhew that they are very conſiſtent with the above determination. From thoſe of the 30th of September, for inſtance, we collect the proportion of the diameters of Mars as 1340 to 1286; or, reduced to our former numbers, 1355 to 1300. Now, ſince theſe meaſures were taken the night before the oppoſition, they muſt on that account be as good as the former; and, had thoſe of the day of oppoſition not been preferred, becauſe they were oftener repeated, and the ſuperior power of the 7, and great light of the 20-feet reflector, gave them additional weight, I ſhould have taken them into the account; the very ſmall difference, however, cannot but ſtrengthen the reſults of the former meaſures.

From the obſervations of the 25th of September we have the proportion of the diameters as 1313 to 1275; and if the equatorial meaſure be increaſed in the ratio of 20000 to 19953, on account of the different heliocentric and geocentric longitude, Mars not being at the full, it will give the ratio of 1316 to 1275; or, conforming to our former numbers, as 1355 to 1312. I have not been very ſtrict in the application of the correction deduced from the phaſes of Mars, ſince no other uſe was intended to be made of theſe numbers than merely to ſhew, that they do not very greatly differ from thoſe we have aſſigned before *.

It

* If more ſtrictneſs be required, let EC, fig. 32. be the ecliptic; PS its poles; *ps* the poles of Mars, and *eq* its equator. Then, the angle *pm*C being found, by calculation, we ſhall have C*m* (radius) to *cm* (coſine of the difference between the heliocentric and geocentric longitude) as *qv* (ſine of the angle *qmv* or *pm*C) to *ov*. Then, ſince with Mars C*c* can never be very great, the ſmall triangle *qno* may be taken for ſimilar to *qvm*; therefore *qm* (radius) is to *qv* (ſine of *pm*C)

It was obſerved, Oct. 17, 1783, that the equatorial diameter of Mars was ſtill greater than the polar, notwithſtanding the depredation of the defect of light upon it. On calculating the phaſes, we find, that the longitudinal diameter was, that day, to the latitudinal one as 19711 to 20000, which therefore could not be an equal balance to oppoſe the ſpheroidical figure ſo as to render it inviſible.

But, Nov. 10. the proportion of the longitudinal diameter to the latitudinal one, from a computation of the phaſe of Mars, muſt have been as 18762 to 20000; and accordingly it was by obſervation found to be more than ſufficient to take off all appearance of the polar flattening, and leave a viſible exceſs in the axis above the equator.

To obviate any doubts concerning a fallacy that might ariſe from the convexity of the eye-glaſs, or irregular ſhape of the ſmall ſpeculum, I need only refer, for the latter, to the experiments of the 7th and 9th of October, 1783: for ſhould the ſhort diameter of my ſmall plane ſpeculum have occaſioned a compreſſing of the polar diameter of Mars when expoſed to it, half a turn of the teleſcope muſt bring the other diameter of that ſpeculum into the ſame ſituation, and a contrary effect would have followed. With regard to the former, not only the experiments made with the achromatic, but principally the obſervation with the 20-feet reflector, where I uſed a compound eye-piece magnifying only about 300 times, will ſufficiently exculpate the eye-glaſſes. It is alſo well known, that in a ſingle lens the diſtortion of the images, if any ſuch there

pmC) as qo ($=qv-vo$) to qn; which is the required correction or deficiency of the equatorial diameter eq of Mars.

Or, putting $m\text{C}=1$ and $vq=m=$ coſine of the angle $\text{P}mp$; it will be $qn=m^2 \cdot c\text{C}$.

7 ſhould

ſhould be, will equally affect the wires of the micrometer, and give a true meaſure notwithſtanding; and the compound eye-piece I uſed with the 20-feet reflector had likewiſe the ſame advantage, for it is conſtructed on the plan lately propoſed by Mr. RAMSDEN in the Philoſophical Tranſactions *, which he was ſo obliging as to communicate to me about a twelve-month ago, and which I immediately adapted to my large micrometers.

On the ſubject of the figure of Mars I ought to remark alſo, that perhaps the meaſures which were taken of its diameters during the laſt oppoſition will enable us to aſcertain its real ſize with greater accuracy than has been done before. The micrometer which can diſtinguiſh with preciſion between the equatorial and polar diameters of this ſmall planet, will certainly be admitted as an evidence of conſiderable conſequence; and ſince the reſult of theſe meaſures is pretty different from what former obſervations give us, I ſhould not omit mentioning it.

We have ſeen that the equatorial diameter, on the day of the oppoſition, meaſured 22″ 35‴. The diſtance of Mars from the earth at that time was .40457, the mean diſtance of the earth from the ſun being 1; therefore, 22″ 35″ reduced to the ſame diſtance will be no more than 9″ 8‴.

I ſhall conclude this ſubject with a conſideration relating to the atmoſphere of Mars. Dr. SMITH † reports an obſervation of CASSINI's, where "a ſtar in the water of Aquarius, at the "diſtance of ſix minutes from the diſk of Mars, became ſo "faint before its occultation, that it could not be ſeen by the "naked eye, nor with a 3-feet teleſcope." It is not men-

* Vol. LXXIII. p. 94.

† Optics, § 1096.

tioned

tioned what was the magnitude of the ſtar; but, from the circumſtance of its becoming inviſible to the naked eye, we may conclude, that it muſt have been of the ſixth or ſeventh magnitude at leaſt. The reſult of this obſervation would indicate an atmoſphere of ſuch an extraordinary extent, ſince at the diſtance of 36 ſemi-diameters of the planet it ſhould ſtill be denſe enough to render ſo conſiderable a ſtar inviſible, that it will certainly not be amiſs to give an obſervation or two which ſeem of a very different import.

1783, Oct 26. There are two ſmall fixed ſtars preceding Mars, of different ſizes; with 460 they appear both duſky red, and are pretty unequal; with 278 they appear conſiderably unequal. The diſtance from Mars of the neareſt, which is alſo the largeſt, with 227 meaſured 3′ 26″ 20‴. Some time after, the ſame evening, the diſtance was 3′ 8″ 55‴, Mars being retrograde. I ſaw them both very diſtinctly. I viewed the two ſtars with a new 20-feet reflector of 18,7 inches aperture, and found them, as I expected, very bright.

Oct. 27. I ſee the two ſmall ſtars again. The ſmall one is not quite ſo bright in proportion to the large one as it was laſt night, being a good deal nearer to Mars, which is now on the ſide of the ſmall ſtar; but when I draw the planet aſide, or out of view, I ſee it then as well as I did laſt night, The diſtance of the ſmall ſtar meaſured 2′ 56″ 25‴ *.

* The meaſures were accurate enough for the purpoſe, though not otherwiſe to be depended on nearer than, perhaps, ſix or eight ſeconds.

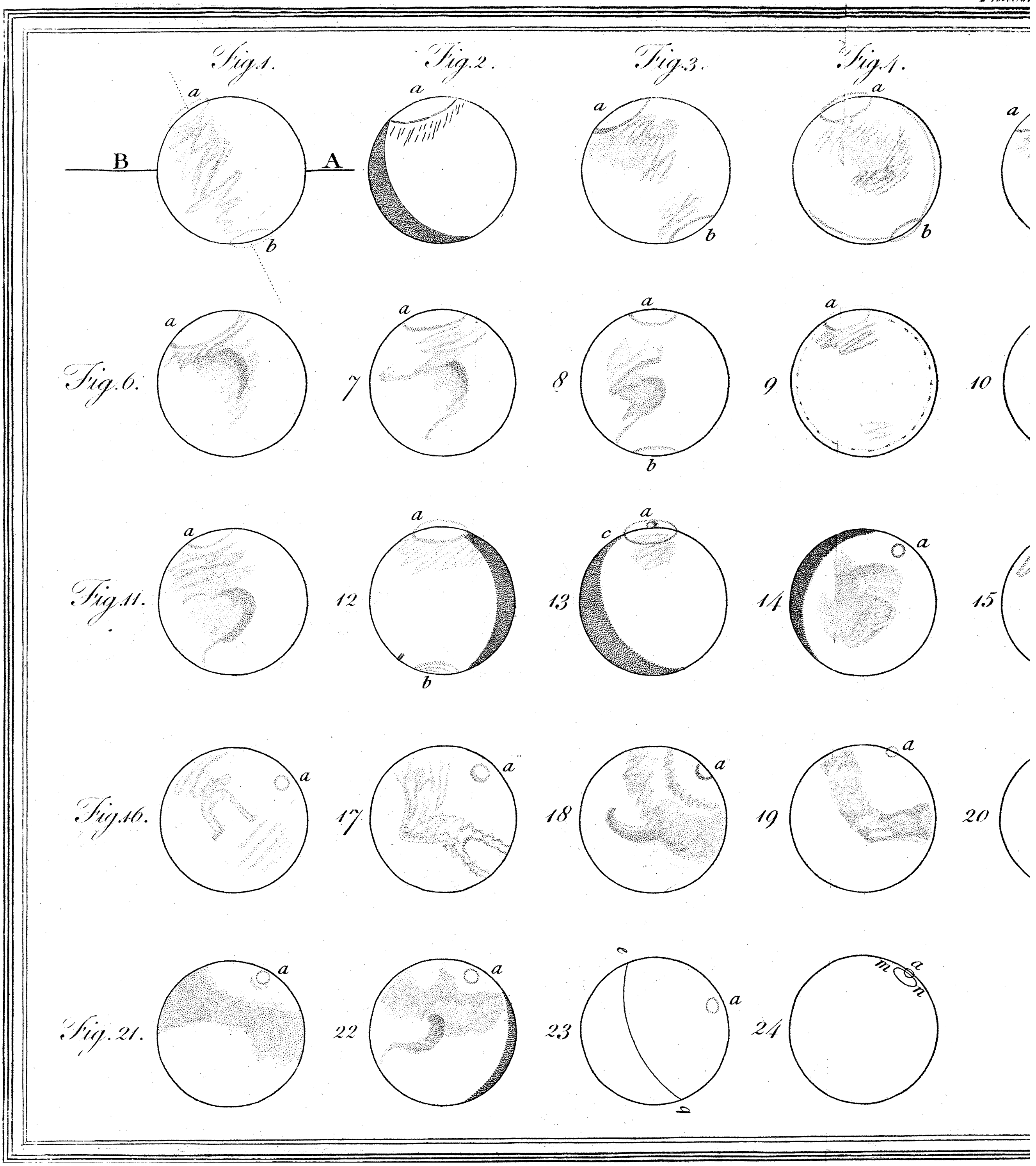
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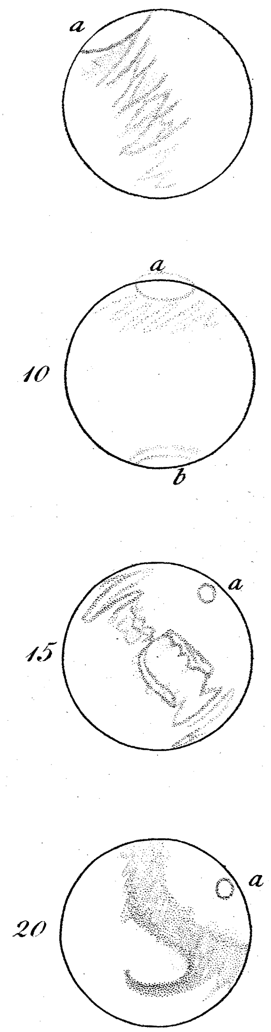
Fig. 5.



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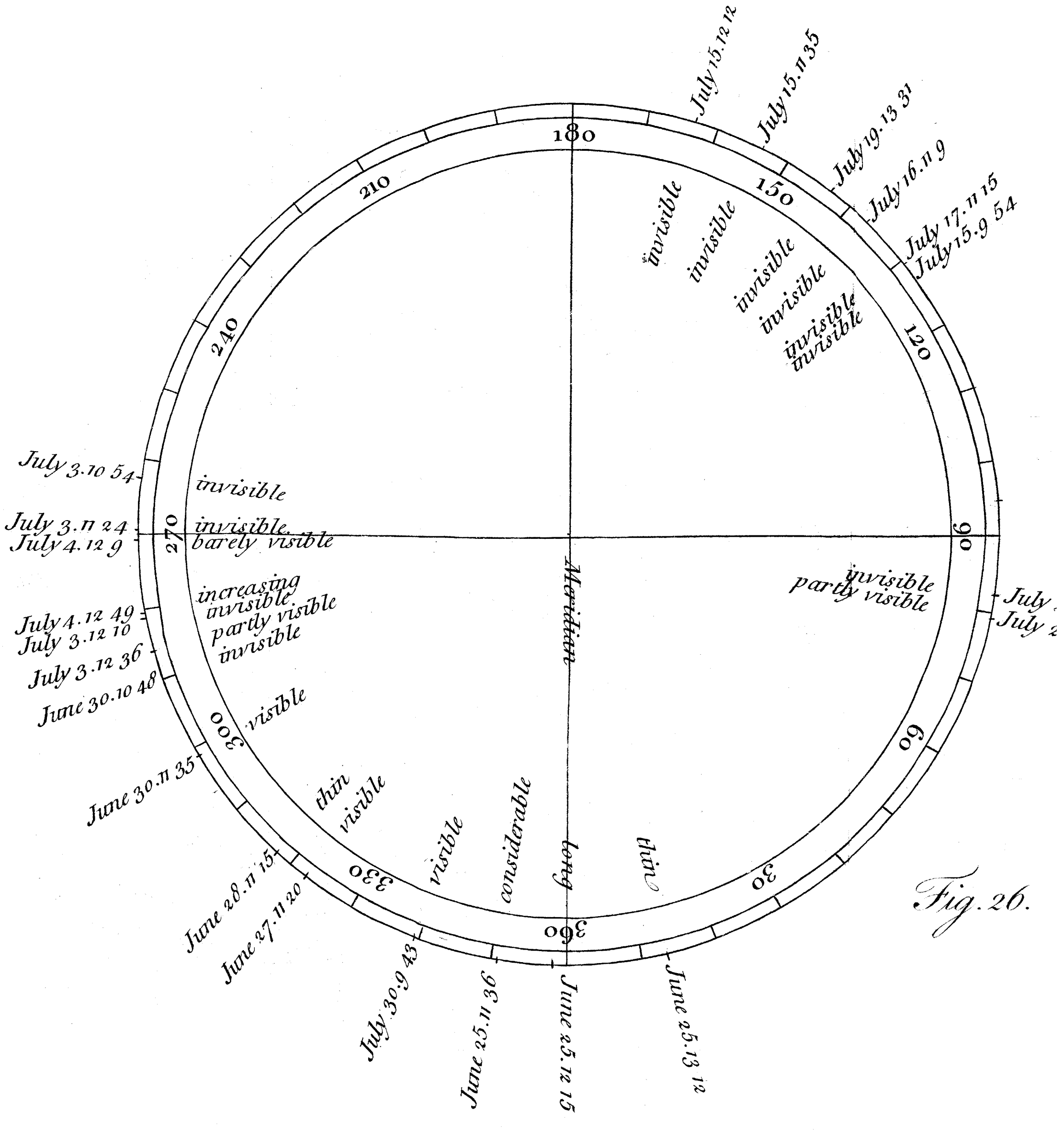
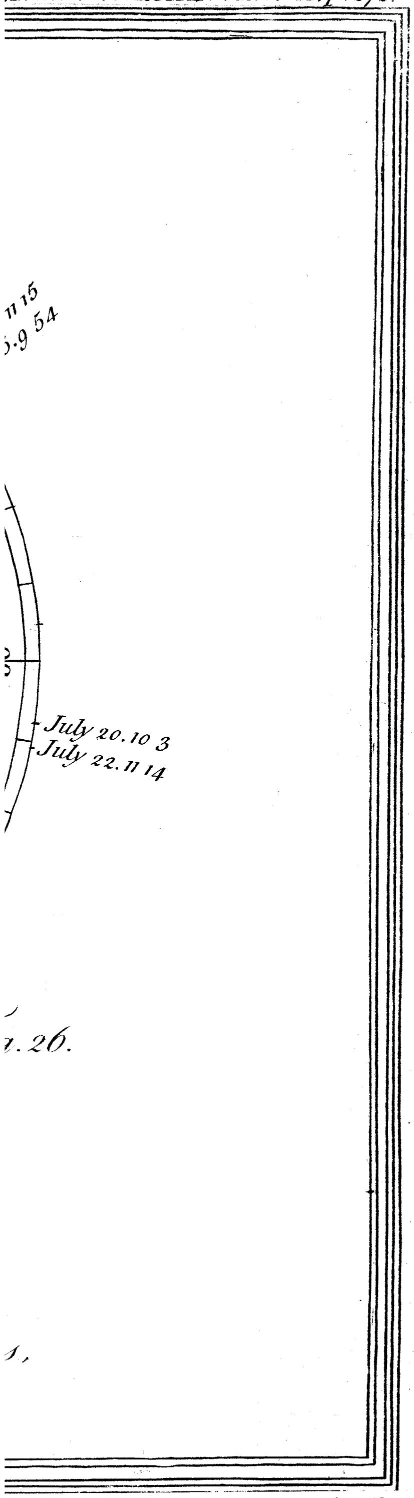


Fig. 26.

Track of the bright north polar spot on Mars, in June & July 1781.



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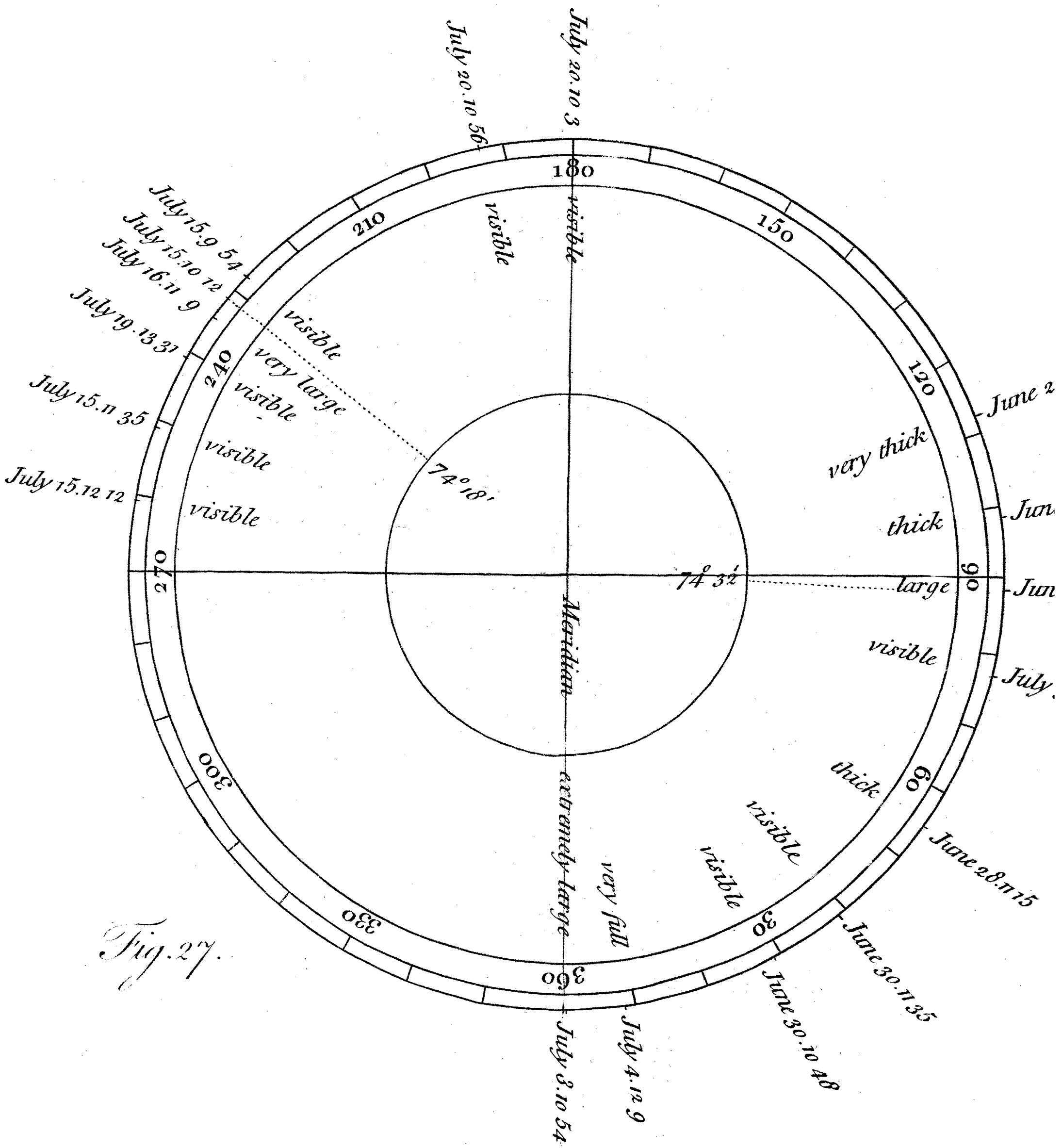
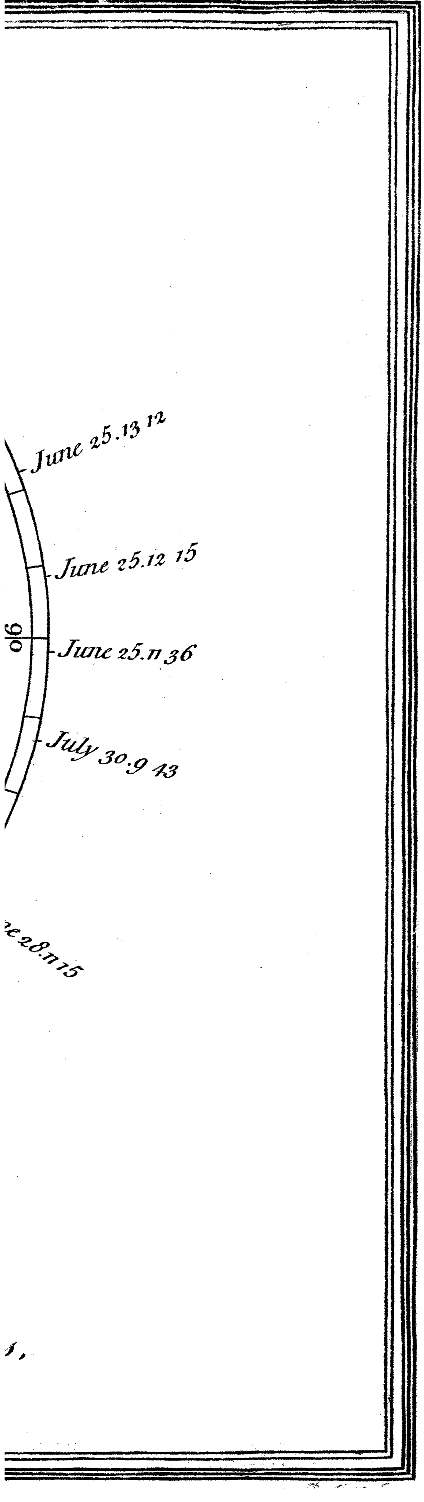


Fig. 27.

Track of the bright south polar spot on Mars, in June & July 1781.


June 25.13 12
June 25.12 15
90
June 25.11 36
July 30.9 43
ne 28.11 15

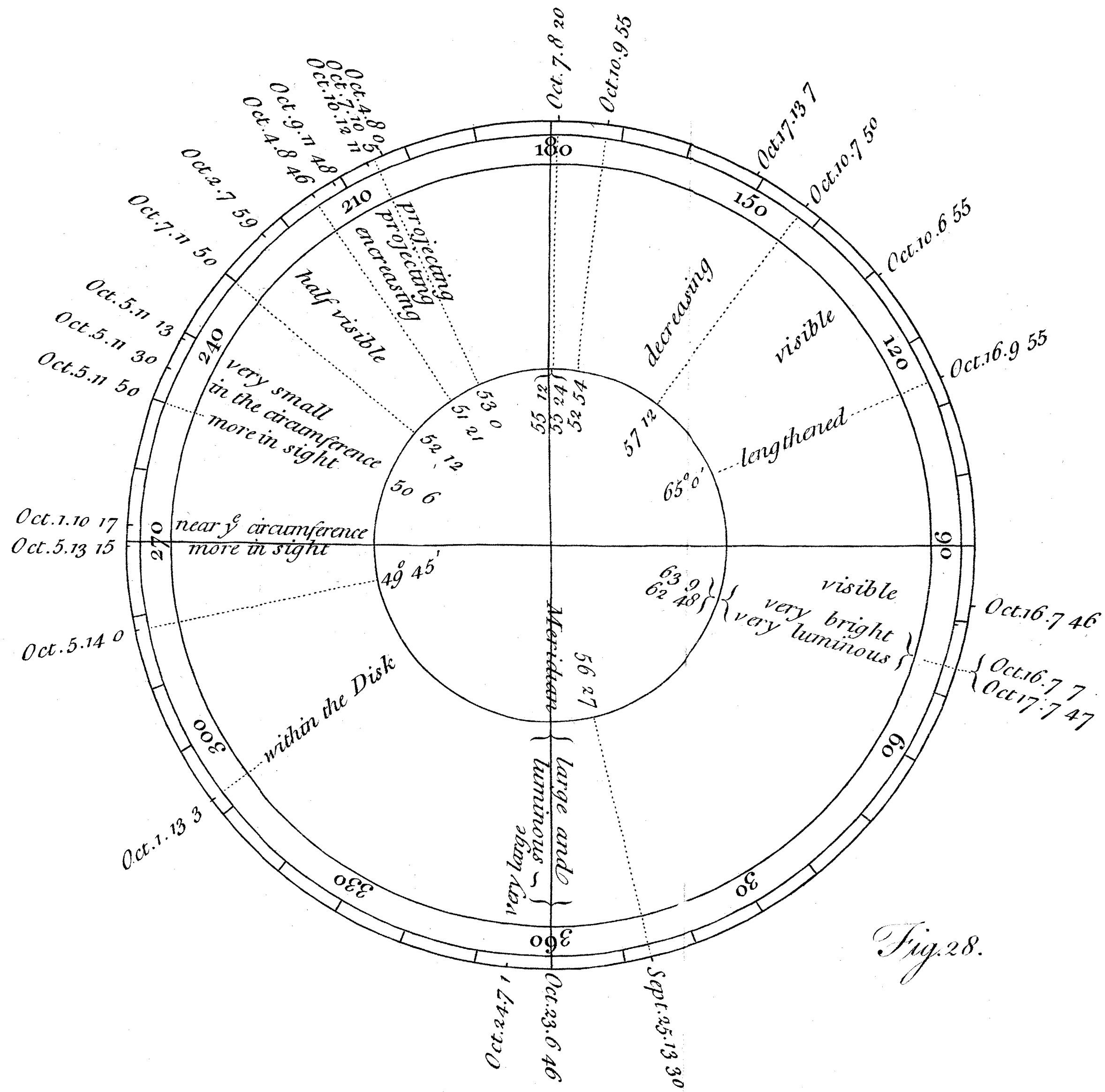


Fig. 28.

Track of the bright South polar spot on Mars, in October 1783.

Basire Sc.

Fig. 25.

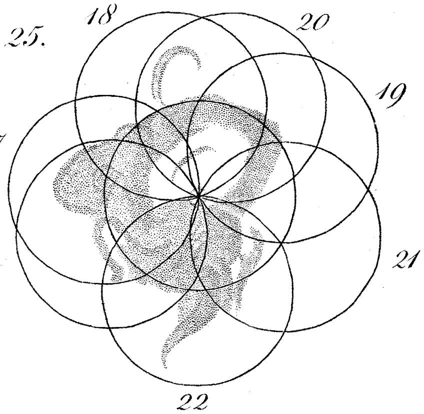


Fig. 29.

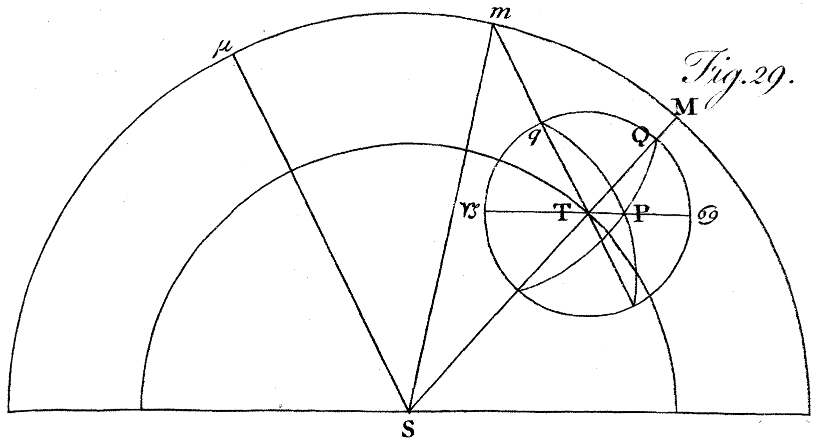


Fig. 30.

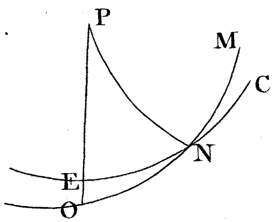


Fig. 31.

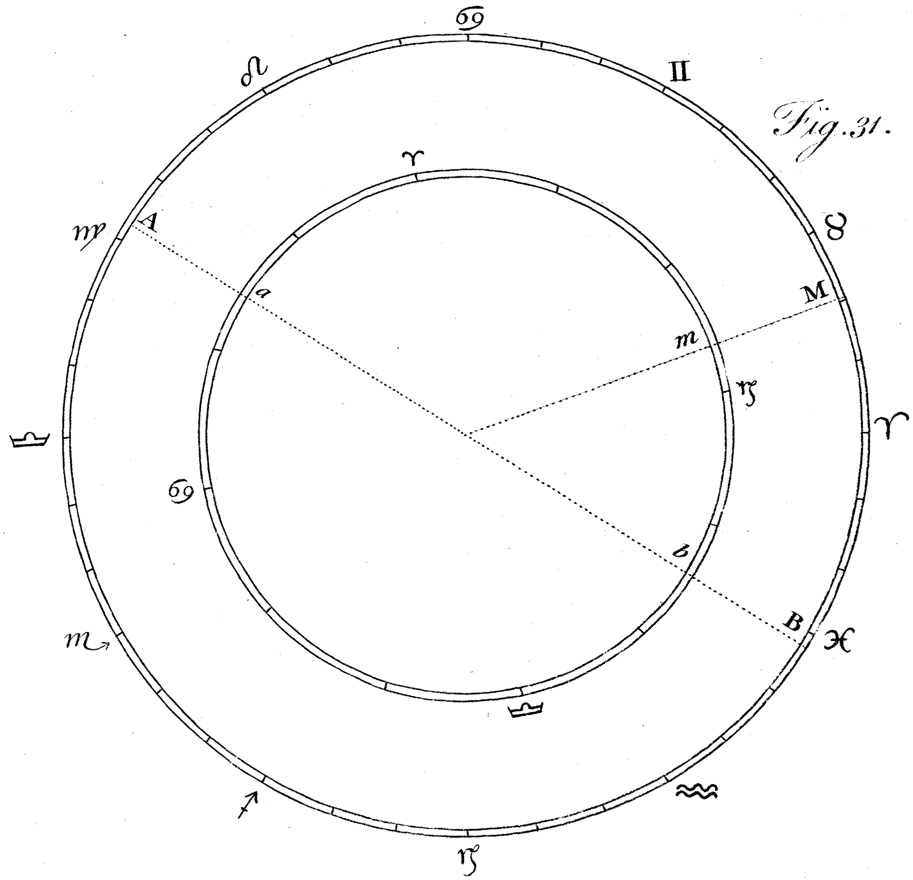
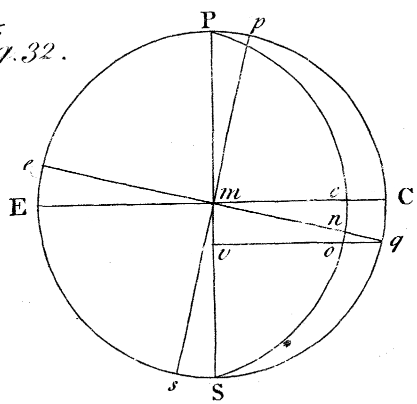


Fig. 32.



Basire Sc.

The largest of the two stars on which the above observations were made cannot exceed the twelfth, and the smallest the thirteeenth or fourteenth magnitude; and I have no reason to suppose that they were any otherwise affected by the approach of Mars, than what the brightness of its superior light may account for. From other phænomena it appears, however, that this planet is not without a considerable atmosphere; for, besides the permanent spots on its surface, I have often noticed occasional changes of partial bright belts, as in fig. 1. and 14.; and also once a darkish one, in a pretty high latitude, as in fig. 18. And these alterations we can hardly ascribe to any other cause than the variable disposition of clouds and vapours floating in the atmosphere of that planet.

Result of the contents of this paper.

The axis of Mars is inclined to the ecliptic 59° 42′.

The node of the axis is in 17° 47′ of Pisces.

The obliquity of the ecliptic on the globe of Mars is 28° 42′.

The point Aries on the martial ecliptic answers to our 19° 28′ of Sagittarius.

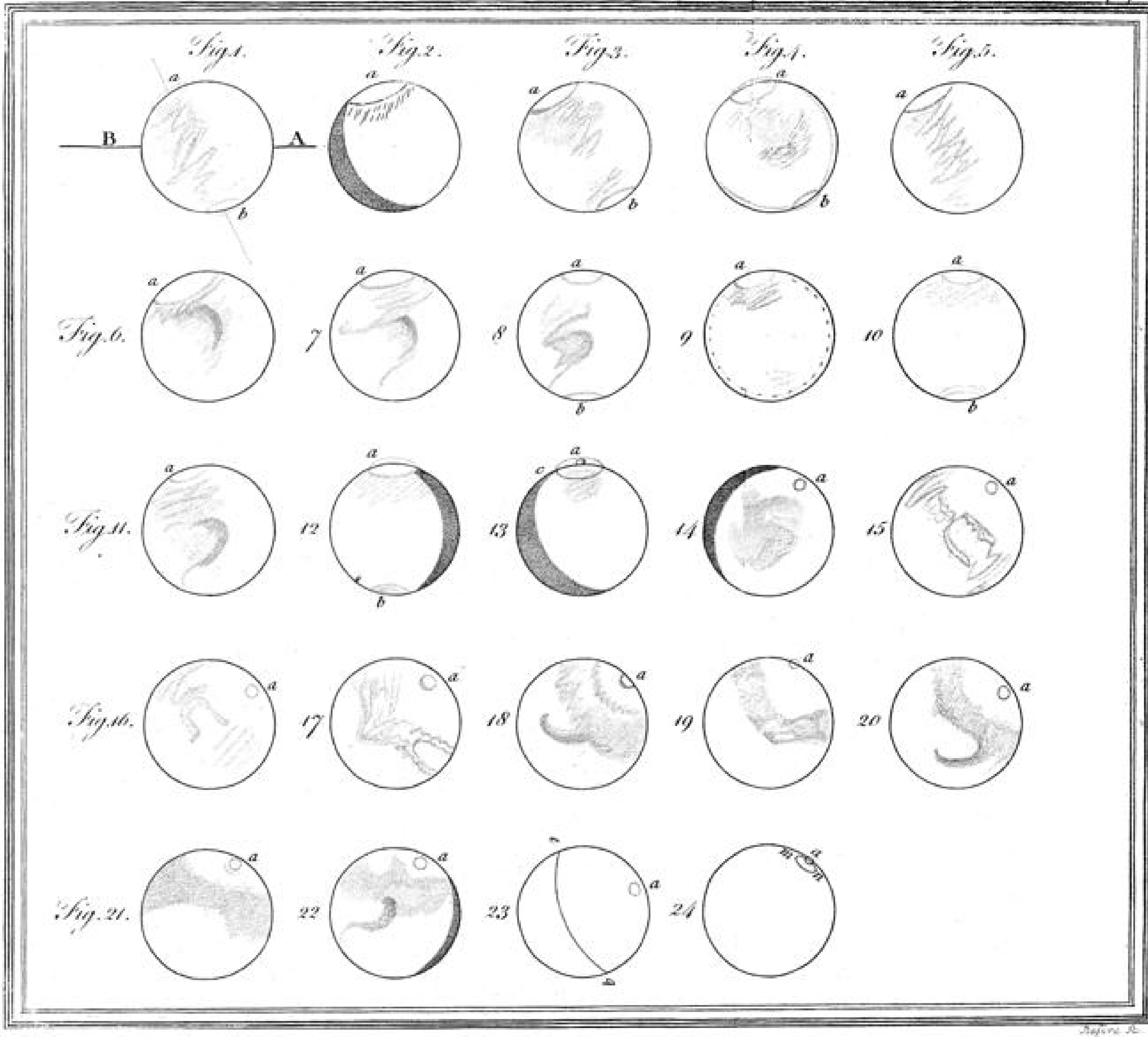
The figure of Mars is that of an oblate spheroid, whose equatorial diameter is to the polar one as 1355 to 1272, or as 16 to 15 nearly.

The equatorial diameter of Mars, reduced to the mean distance of the earth from the sun, is 9″ 8‴.

And that planet has a considerable but moderate atmosphere, so that its inhabitants probably enjoy a situation in many respects similar to ours.

Datchet, Dec. 1, 1783.

W. HERSCHEL.



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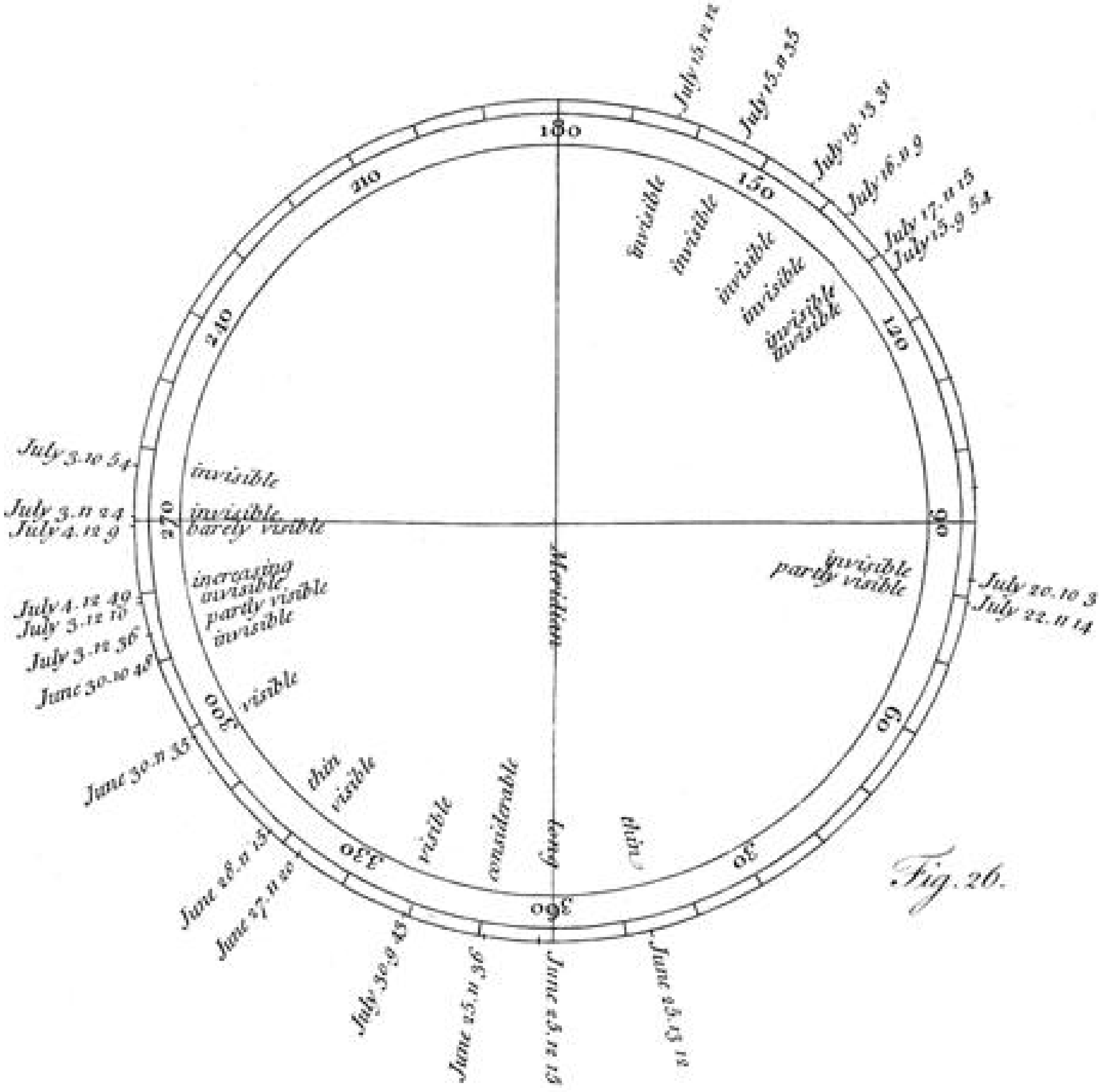
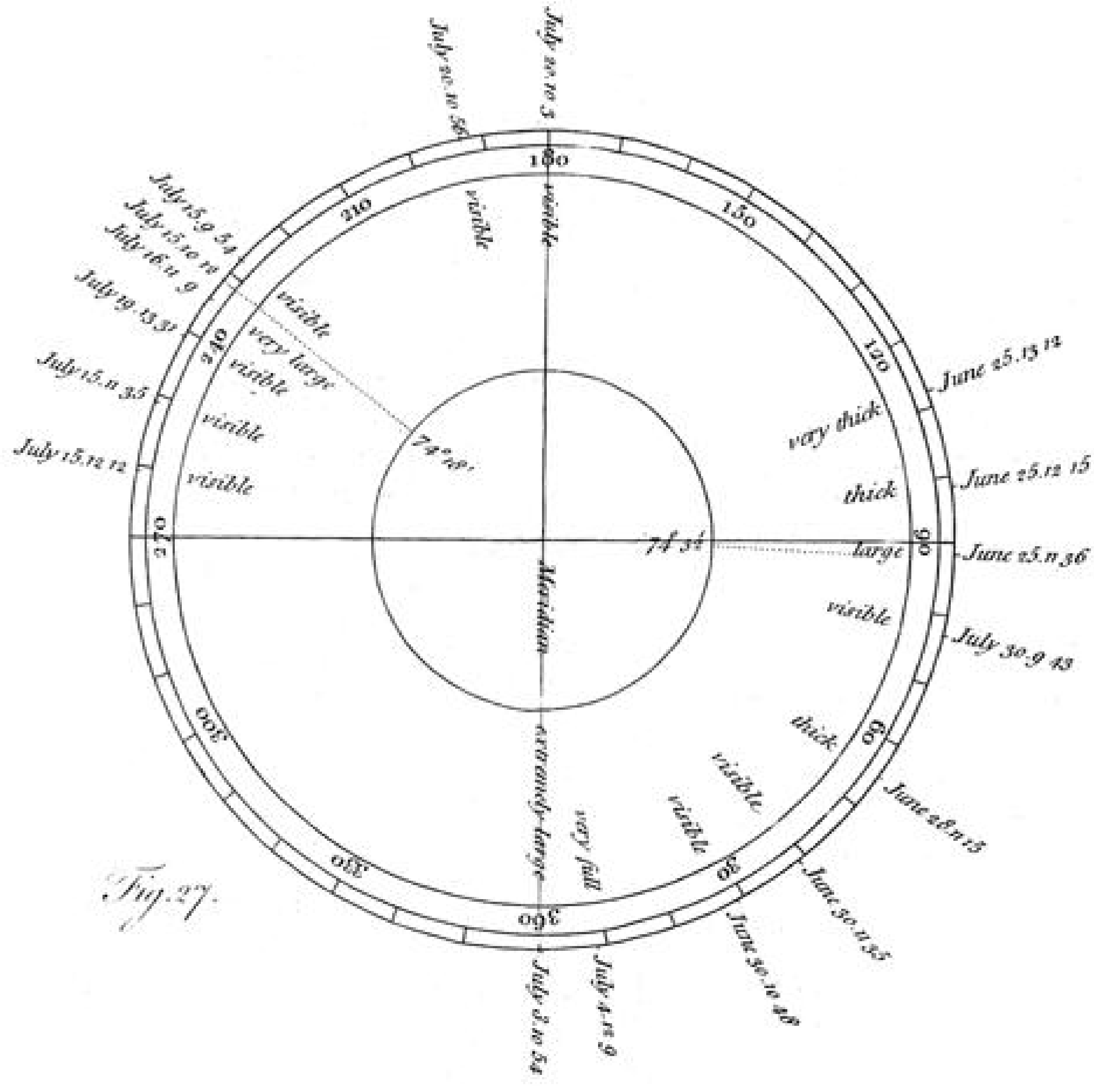


Fig. 26.

Track of the bright north polar spot on Mars, in June & July 1781.

Basire sc.



Track of the bright south polar spot on Mars, in June & July 1781.