

THE SIMULTANEOUS DISAPPEARANCE OF JUPITER'S FOUR MOONS, WITH SOME NOTES UPON THE LAWS THAT GOVERN THEIR MOTIONS.

BY F. ABBOTT, F. R. A. S.

The four satellites, which accompany the planet Jupiter, are known to disappear when they enter into the planet's shadow, causing eclipses much more frequent than, but in other respects quite analogous with those of the moon. Galileo, who first contemplated those phenomena, at once inferred that observations of this kind might be rendered subservient to the promotion of geographical science. It only required that the course of these satellites should be reduced into tables of sufficient exactness to rectify a multitude of errors in the determination of longitude.

The system, composed of Jupiter and his four satellites, is a world in itself that mirrors to us those rapid revolutions which are constantly taking place in the general system of the universe. The study, therefore, of the inequalities of these satellites becomes to astronomical knowledge of the utmost importance.

The three first satellites of Jupiter, as well as the planet itself, are subjected to the mutual action of two very remarkable laws, not less simple or constant than those of Kepler. There is a reciprocal dependence between their movements and their position, so that the place of two of them being known, that of the third is readily determined.

All the satellites except the fourth are eclipsed at every revolution. Their orbits are ellipses slightly eccentric, they describe equal areas in equal times, and the cubes of their mean distances are in proportion to the square of their periodic times, the mean *sideral* revolution of the first is half the time of that of the second; the second half that of the third; the mean longitude of the first, minus three times that of the second, plus twice that of the third, is always equal to  $180^\circ$ . Or the angular velocity of the first, added to twice that of the third, is equal to three times the angular velocity of the second; it is not difficult therefore to prove that if from the mean longitude of the first, added to twice that of the third, there be subtracted three times the mean longitude of the second, the remainder will be a constant angle which is found to be  $180^\circ$ . So that when the first satellite is eclipsed, the other two will always be between Jupiter and the sun, and *vice versá*.

One consequence of this state of things is, that they can never be all three eclipsed at the same time. Laplace discovered these laws, and demonstrated that they are necessary results from the mutual actions of the satellites, and that the same cause tends to perpetuate their operation.

Delambre next made these *theorems* of Laplace the basis of his researches, and occupied several years in the composition of eclipitic tables founded upon them.—Arising out of these researches, it was found by most careful observations, that when the earth is in that part of her orbit which is nearest to Jupiter, the eclipses appear to happen 8m. 13s. *sooner* than the tables predicted; and when in that part of her orbit which is the farthest from him, 8m. 13s. *later* than the tables predicted; from the mean of 6,000 eclipses observed by Delambre, this disagreement between *observation* and *calculation* was satisfactorily settled at 8m. 13s. while both were considered equally correct.

We learn therefore from the foregoing results, that by a law of nature the three first satellites of Jupiter can never become eclipsed all at the same time. The simultaneous disappearance, however, does not apply to eclipses properly so called, that is to say, the passage of the satellite through the cone of the planet's shadow, but it may happen that all are either eclipsed, occulted, or projected on the body of the planet, in which cases they are equally invisible, except under peculiar circumstances with good telescopes.

Instances from observation of Jupiter being denuded of his satellites are recorded as follows:—The first by Mr. Molyneux, in his Optics, November 2nd (old style) 1681; by Sir William Herschel, May, 23rd, 1802; by Mr. Wallis, April 15th, 1826; by Mr. Griesback and Mr. Daws, September 27th, 1843.

The first three satellites (Io, Europa, and Ganymede) move nearly in the plane of Jupiter's equator, in orbits very nearly circular; on this account they pass through the planet's shadow, and are eclipsed every revolution, but the inclination of the fourth satellite (*Callisto*) is about  $8^{\circ}$ , and its eccentricity large, so that when this satellite is seen to pass across Jupiter's body, or behind it, the apparent path is frequently very far from the centre. The Rev. Robert Main records one such transit when the satellite merely grazed the upper part of the disc.

The announcement of the Astronomer Royal, to the Astronomical Society, of the approaching and rare phenomena of the concealment of Jupiter's four satellites "on August 21st," will occur to Hobart Town mean time as follows:—On the

22nd of August at 6h. 3m. a.m. the third satellite will enter on Jupiter's face; at 6h. 58m. the second will be eclipsed; 7h. 17m. the fourth will enter on Jupiter's face; 7h. 53m. the first will enter Jupiter's face. Times of reappearance respectively 9h. 38m., 10h. 2m., 10h. 12m., 11h. 43m. Jupiter will therefore be without satellites for one hour and three quarters.

Professor Airy made this announcement at one of the Royal Astronomical Society's meetings on account of it being favorable for observation at Greenwich Mean Time, but when reduced to Hobart Time Mean Time the phenomenon is found to take place by daylight; we have, however, a similar occurrence with the exception of the fourth satellite on the 25th of August, which, if the sky be clear, will be advantageously situated for observation in Tasmania.

The order of disappearance and reappearance of the satellites for H. T. M. T. will be as follows:—

|  | h. m. s.       |
|--|----------------|
| Third satellite will eclipse and disappear at..... | 7 29 12.4 p.m. |
| Second ditto will occult and disappear at.....     | 8 16           |
| First ditto will transit and immerse .....         | 8 44           |
| First ditto will immerse from transit at .....     | 11 3           |
| Third ditto will occult and reappear at.....       | 11 6           |
| Second ditto will occult and reappear at.....      | 11 8           |

With an inverting telescope the fourth satellite will appear to the west of Jupiter, and moving eastward.

Jupiter will rise on the 25th at 5h. 23m. p.m., and set on the 26th at 6h. 47m. a.m., at which time he will be in opposition to the Sun.

*Observatory, 8th July, 1867.*