

*Notes for the observer***Mutual phenomena of Jovian satellites in 1990-1991****R. Vasundhara***Indian Institute of Astrophysics, Sarjapur Road, Koramangala, Bangalore 560 034*

Twice during a Jovian year, the equatorial plane of the planet sweeps across the sun and the inner solar system. During a few months around this time, the Galilean satellites frequently eclipse (occult) each other when any two of them are aligned with the sun (earth).

The observations of mutual phenomena would help to examine new problems and to improve the solutions of old ones. The mid-times of the events are capable of being measured to an accuracy of about 1s, which corresponds to better than 20 km in relative orbital longitude; the observed drop in magnitude would help to estimate the relative latitude corrections.

In the post Voyager era is it always worth while to make such observations? Yes! for the following reasons: Although certain quantities like the radii and the surface features have been determined with high accuracy by the spacecrafts, the albedos are not yet well known and the asymmetry of some of the light curves of mutual phenomena still remains unexplained. About the ephemerides, more observations are certainly needed. Carefully observed light curves yield relative longitudes that are accurate at least to several tens of kilometers. Consequently, a series of precisely timed events observed over a span of several decades has the potential of detecting secular changes in Io's orbital elements arising from tidal interaction with the planet. Much interest now centres on improving satellite ephemerides to assist in guiding the Galileo spacecraft during several extreme close approaches.

The mutual events during 1973 and 1979 were extensively observed all around the world. The residuals of 1973 observations were used by Leiske (1980) to improve the constants of motion of the satellites. The 1985-86 campaign by K. Aksnes & Franklin was again a success (Galilean Satellite Observers 1990).

The next mutual eclipse season will commence 1990 end and will continue till middle of 1991. Table 1 gives the predictions of mutual phenomena that are observable from most parts of India (Aksnes & Franklin 1989). The first column gives the UT date. Second through fifth columns give the timings of beginning of penumbral phase, beginning of umbral phase, end of umbral phase, and end of penumbral phase for eclipses. For occultations, the third and fourth columns give beginning and end times. The sixth column identifies the event type: e.g. 2O3 or 2E3 means Europa occulting or eclipsing Ganymede either partially (P), totally (T), or annularly (A). The seventh column gives an indication of light loss (DL) for occultations only, DL is normalized to the

Table 1

Date (UT)	BEG	PU	BEG	U/O	.END	U/O	END	PU	Event	DL	V1	V2	Dist
90/12/18			18	32.9	18	47.9			2O3 A	0.23	5.55	4.93	9.4
90/12/25	18	53.2					19	04.5	2E3 P	0.03	5.52	4.89	10.7
90/12/25			21	58.7	22	15.7			2O3 A	0.23	5.52	4.89	9.4
90/12/28			19	19.9	20	22.5			2O1 P	-0.03	5.50	5.29	4.2
91/01/01	22	45.3	22	49.3	22	57.3	23	01.3	2E3 P	0.13	5.49	4.86	10.5
91/01/08			13	36.8	13	52.1			2O1 P	0.12	5.46	5.26	5.7
91/01/10			15	48.1	15	58.4			4O2 P	0.62	6.01	5.46	8.8
91/01/15	15	18.7	15	20.7	15	36.4	15	38.4	2E1 A	0.69	5.45	5.24	5.7
91/01/15			16	13.4	16	25.7			2O1 P	0.15	5.45	5.24	5.8
91/01/18			17	08.1	17	46.1			2O1 P	0.39	5.44	5.23	2.0
91/01/22	18	14.7	18	16.4	18	27.7	18	29.4	2E1 A	0.71	5.44	5.23	5.9
91/01/22			18	37.2	18	48.2			2O1 P	0.20	5.44	5.23	5.9
91/01/23	13	31.4	13	39.4	14	35.0	14	43.0	2E3 P	0.29	5.44	4.81	8.2
91/01/23			15	20.9	18	13.9			2O3 A	0.23	5.44	4.81	6.9
91/01/23	19	49.7	20	14.2	20	25.9	20	50.4	2E3 P	0.03	5.44	4.82	5.2
91/01/29			20	54.5	21	04.5			2O1 P	0.26	5.44	5.23	5.9
91/01/29	20	56.2	20	57.7	21	07.0	21	08.5	2E1 A	0.68	5.44	5.23	5.9
91/02/05			23	07.9	23	17.3			2O1 P	0.33	5.44	5.24	5.9
91/02/05	23	30.3	23	31.6	23	39.3	23	40.6	2E1 A	0.69	5.44	5.24	5.9
91/02/16			14	24.6	14	32.9			2O1 A	0.40	5.47	5.26	5.8
91/02/16	15	13.2	15	14.4	15	21.1	15	22.2	2E1 A	0.69	5.47	5.26	5.6
91/02/23			16	34.5	16	42.2			2O1 P	0.38	5.49	5.29	5.7
91/02/23	17	38.0	17	39.2	17	45.2	17	46.3	2E1 A	0.68	5.49	5.29	5.5
91/03/01	16	12.1	16	21.3	16	36.0	16	45.1	4E2 P	0.79	6.07	5.52	9.0
91/03/02			18	44.5	18	51.5			2O1 P	0.31	5.52	5.32	5.7
91/03/09			20	54.6	21	00.9			2O1 P	0.24	5.56	5.35	5.5
91/03/18	19	37.7					19	47.4	4E2 T	0.36	6.17	5.62	6.7
91/03/20	13	51.7	13	53.0	13	57.4	13	58.7	2E1 A	0.52	5.62	5.42	4.6
91/03/27			14	23.7	14	28.0			2O1 P	0.09	5.67	5.46	5.2
91/03/27	16	10.5	16	11.7	16	15.7	16	16.8	2E1 P	0.46	5.67	5.46	4.3
91/04/03			16	37.1	16	40.8			2O1 P	0.05	5.72	5.51	5.1
91/04/03	18	28.3	18	29.6	18	33.0	18	34.3	2E1 P	0.38	5.72	5.51	4.0
91/04/04	13	53.3					15	28.6	4E1 P	0.21	6.28	5.52	4.6
91/04/13	16	04.9					16	11.2	1E4 P	0.07	5.58	6.36	6.8
91/04/23	14	52.3					14	57.0	3E1 P	0.04	5.22	5.65	3.3
91/04/28	14	26.6					14	30.6	2E1 P	0.08	5.89	5.68	3.1
91/04/30	15	30.6					15	42.3	3E4 P	0.18	5.27	6.47	9.0
91/05/07	15	12.3	15	15.8	15	16.8	15	20.3	3E2 P	0.39	5.32	5.95	7.5
91/05/17	14	46.7	14	47.9	14	51.2	14	52.4	1E2 P	0.68	5.80	6.02	2.6
91/06/02	14	10.9	14	13.1	14	17.1	14	19.3	2E3 A	0.32	6.10	5.48	7.0
91/06/20	13	30.7	13	32.8	13	39.8	13	42.0	3E1 P	0.83	5.55	5.98	5.3
91/06/25			14	04.0	14	08.3			1O2 P	0.09	5.99	6.21	5.0

\*Extracted from Aksnes & Franklin (1989).

combined light of both satellites, V1 and V2 (columns eight and nine). The tenth column provides the distance in Jovian radii from the planet's centre at mid event.

For eclipses which occur near opposition and for all occultations, both the satellites (or more) will have to be included in the focal plane aperture. In such cases measurements should be made of all the satellites, individually before and after the events at least once in order to estimate the brightness ratio. Timing accuracy of 0.1s and in the

worst case 1s should be aimed. Precise magnitude drop at mid event can only be achieved if the sky background light is carefully estimated. For events which occur at distances closer than  $4R_J$  to Jupiter, sky measurements should be taken at the 'satellite free' side of the planet, and preferably also at north and south of the planet at the same distance. For events occurring at larger distances, sky determinations equally displaced from the satellites in 2 or 4 directions are acceptable.

The author would be pleased to provide further information if needed.

### References

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