Astron. Astrophys. 237, 259–266 (1990)

ASTRONOMY AND ASTROPHYSICS

Research Note

The mutual phenomena of the Galilean satellites of Jupiter: predictions for the 1991 occurrence

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Received February 7, accepted February 27, 1990

Abstract. This paper gives the predictions of the mutual events of the Galilean satellites of Jupiter which will occur in 1991. We call for as many observations as possible for these events.

Key words: mutual phenomena – Galilean satellites of Jupiter

1. Introduction

In 1991 a favorable period of about 7 months will allow the observation of mutual phenomena involving the Galilean satellites of Jupiter. The positive declination of Jupiter is favorable for observatories in the northern hemisphere, and it is desirable to try to observe as many events as possible.

2. The mutual phenomena

The configuration of the orbits of the Galilean satellites of Jupiter induces phenomena between the satellites themselves twice each Jovian year of 11.6 years. The four satellites have orbits which are nearly in the equatorial plane of Jupiter. When the Earth goes through this plane, i.e. when the Jovian declination of the Earth becomes zero, the satellites may occult one another for a terrestrial observer. Similarly, when the Sun goes through the equatorial plane of Jupiter, i.e. when the Jovian declination of the Sun becomes zero, the satellites may enter the umbra or the penumbra of the other satellites. Because of the small size of the satellites and the very small inclination of their orbits to the Jovian equator, mutual phenomena do not occur for each geocentric conjunction (for the occultations) or heliocentric one (for the eclipses) during the favorable period. This favorable period occurs when the jovicentric declinations of the Earth and the Sun are smaller than a defined quantity. These phenomena are easily predictable with modern computers and their observation – which presents no major difficulties – gives interesting information about the Galilean satellites themselves. In 1991, the mutual events do not occur exactly during the opposition of Jupiter with the Sun, and are thus less favorable than in 1985. However, the declination of Jupiter is greater, so they are more favorable in the northern hemisphere where observatories are more numerous than in the southern hemisphere.

3. Basis of the predictions for 1991

For the calculations, we used the same algorithm as for the previous periods (Arlot, 1978, 1984). This algorithm gives a precision which varies with each phenomenon: the faster the relative velocity between the involved satellites, the greater the precision (generally better than 6 seconds of time). For the calculations of the dates of the phenomena, we used the G-5 ephemerides (Arlot, 1982) of the Galilean satellites. We used also the ephemerides of the planets of the JPL DE 102 (Newhall et al., 1983) and the radii of the satellites given by Voyager (Morrison, 1983). These radii are: for J1, 1816 km; for J2, 1563 km; for J3, 2638 km, and for J4, 2410 km.

4. Explanation of the tables

Table 1 gives the dates of the predicted phenomena. These dates are given in the TDB time-scale (Temps Dynamique Barycentrique, cf. Connaissance des Temps for 1990). This time-scale is very close to the Ephemeris Time (ET) or to the International Atomic Time plus 32 s (TAI + 32 s). One obtains the times of the mutual phenomena in the Universal Time scale (UT) by subtracting about 57 seconds of time from the times in Table 1. The exact value to be subtracted should be confirmed nearer the time of the events.

Are given in Table 1:

Columns 1–3: year, month, day of the instant of maximum of the considered phenomenon.

Columns 4–7: type of phenomenon: 1 OCC 2 means J1 occults J2; 3 ECL 4 means that J3 eclipses J4; C means very close approach with possible event; P means partial phenomenon – nothing is indicated when an eclipse is by the penumbra –; A means annular and T means total (dates of the beginning of the totality are given in the notes).

Table 1. Dates of the mutual events in 1991 (notes are explained in the text)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1990	10	29	2 OCC 3 C	18 59 48	0.0	0	(2)
1990	11	5	2 OCC 3 C	22 24 53	0.0	0	(2)
1990	11	13	2 OCC 3 P	1 48 34	0.064	393	
1990	11	13	2 OCC 4 C	5 39 29	0.0	0	(2)
1990	11	20	2 OCC 3 P	5 11 11	0.171	552	
1990	11	21	1 OCC 2 C	9 21 53	0.0	0	(2) (3)
1990	11	24	1 OCC 2 C	22 25 22	0.0	0	(2) (3)
1990	11	27	2 OCC 3 P	8 33 18	0.256	656	
1990	11	28	1 OCC 2 C	11 28 26	0.0	0	(2) (3)
1990	12	2	1 OCC 2 C	0 31 2	0.0	0	(2) (3)
1990	12	3	2 OCC 1 C	8 10 7	0.0	0	(2)
1990	12	4	2 OCC 3 A	11 55 2	0.479	737	
1990	12	5	1 OCC 2 C	13 33 15	0.0	0	(2) (3)
1990	12	6	2 OCC 1 C	21 18 45	0.0	0	(2) (6)
1990	12	9	4 OCC 1 C	0 12 35	0.0	0	(2)
1990	12	10	2 OCC 1 C	10 26 55	0.0	0	(2)
1990	12	11	2 OCC 3 A	15 17 46	0.479	815	
1990	12	13	2 OCC 1 C	23 35 50	0.0	0	(2) (7)
1990	12	17	2 OCC 1 C	12 44 23	0.0	0	(2) (7)
1990	12	18	2 OCC 3 A	18 41 16	0.479	900	
1990	12	21	2 OCC 1 C	1 53 58	0.0	0	(2)
1990	12	24	2 OCC 1 C	15 3 17	0.0	0	(2)
1990	12	25	2 ECL 3	18 59 40	0.027	635	
1990	12	25	2 OCC 3 A	22 8 2	0.479	1014	
1990	12	28	2 OCC 1 C	4 14 8	0.0	0	(2)
1990	12	28	2 OCC 1 P	19 52 46	0.060	4616	(5)
1990	12	31	2 OCC 1 C	17 25 3	0.0	0	(2)
1991	1	1	2 OCC 1 P	6 31 27	0.206	2396	
1991	1	1	2 OCC 1 P	10 38 34	0.139	1763	
1991	1	1	2 ECL 3 P	22 53 59	0.123	944	
1991	1	2	2 OCC 3 A	1 40 47	0.479	1186	
1991	1	4	2 OCC 1 C	6 38 20	0.0	0	(2)
1991	1	4	2 OCC 1 P	18 6 34	0.270	1886	(3)
1991	1	5	2 OCC 1 P	0 20 35	0.152	1172	
1991	1	7	2 OCC 1 C	19 52 19	0.0	0	(2)
1991	1	8	2 OCC 1 P	5 57 14	0.336	1770	(7)
1991	1	8	2 ECL 1 A	7 38 37	0.753	2806	
1991	1	8	2 ECL 1 A	11 59 7	0.750	2305	
1991	1	8	2 OCC 1 P	13 46 5	0.169	960	
1991	1	9	2 ECL 3 P	3 3 39	0.238	1291	
1991	1	9	2 OCC 3 A	5 26 8	0.480	1487	

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	1	10	4 OCC 2 P	15 55 21	0.246	590	
1991	1	11	2 OCC 1 P	9 10 20	0.002	226	(2)
1991	1	11	2 OCC 1 P	17 48 29	0.407	1778	(7)
1991	1	11	2 ECL 1 A	19 1 34	0.718	2038	(7)
1991	1	12	2 ECL 1 A	1 54 16	0.747	1445	
1991	1	12	2 OCC 1 P	3 6 23	0.189	838	
1991	1	13	3 OCC 1 C	1 57 10	0.0	0	(2)
1991	1	13	3 OCC 1 C	11 37 59	0.0	0	(2) (7)
1991	1	14	2 OCC 1 P	22 31 7	0.009	425	(2)
1991	1	15	2 OCC 1 A	5 42 30	0.149	1884	(7)
1991	1	15	2 ECL 1 P	6 40 54	0.618	1861	(7)
1991	1	15	2 ECL 1 A	15 30 11	0.737	1136	
1991	1	15	2 OCC 1 P	16 21 9	0.212	762	
1991	1	16	2 ECL 3 A	7 43 43	0.318	1867	
1991	1	16	2 OCC 3 A	9 41 4	0.480	2197	
1991	1	16	2 OCC 3 C	22 14 50	0.0	0	(2)
1991	1	18	2 OCC 1 P	12 1 29	0.023	769	
1991	1	18	2 OCC 1 P	17 28 19	0.384	2172	(3)
1991	1	18	2 ECL 1 P	18 17 55	0.479	1890	(3)
1991	1	19	2 ECL 1 A	4 59 47	0.725	959	
1991	1	19	2 OCC 4 C	5 19 47	0.0	0	(2)
1991	1	19	2 OCC 1 P	5 34 15	0.238	706	
1991	1	20	3 OCC 1 C	5 52 11	0.0	0	(2)
1991	1	20	3 OCC 1 C	10 13 17	0.0	0	(2)
1991	1	22	2 OCC 1 P	1 48 26	0.055	1778	
1991	1	22	2 OCC 1 P	5 1 32	0.271	3150	
1991	1	22	2 ECL 1 P	5 48 25	0.315	2212	
1991	1	22	2 ECL 1 A	18 23 36	0.716	848	
1991	1	22	2 OCC 1 P	18 44 17	0.266	665	
1991	1	23	2 ECL 3 A	14 5 20	0.314	4815	(5)
1991	1	23	2 OCC 3 A	16 39 41	0.480	14941	(5)
1991	1	23	2 ECL 3 P	20 25 37	0.033	3545	
1991	1	25	2 ECL 1	16 13 53	0.004	2950	(2)
1991	1	26	2 ECL 1 A	7 45 17	0.707	764	(4)
1991	1	26	2 OCC 1 P	7 53 40	0.297	630	(4)
1991	1	29	2 OCC 1 P	21 1 0	0.330	602	(4) (6)
1991	1	29	2 ECL 1 A	21 3 49	0.701	704	(4) (6)
1991	2	2	2 OCC 1 P	10 8 14	0.365	576	
1991	2	2	2 ECL 1 A	10 21 27	0.697	654	
1991	2	5	2 OCC 1 P	23 14 3	0.399	553	
1991	2	5	2 ECL 1 A	23 37 1	0.697	615	
1991	2	9	2 OCC 1 A	12 20 2	0.148	530	

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	2	9	2 ECL 1 A	12 52 10	0.698	581	
1991	2	13	2 OCC 1 A	1 24 58	0.148	509	
1991	2	13	2 ECL 1 A	2 5 47	0.701	554	
1991	2	16	2 OCC 1 A	14 30 15	0.148	487	
1991	2	16	2 ECL 1 A	15 19 13	0.705	530	
1991	2	20	2 OCC 1 P	3 34 48	0.404	465	
1991	2	20	2 ECL 1 A	4 31 29	0.709	509	
1991	2	20	3 OCC 4 P	15 57 48	0.010	2943	
1991	2	21	3 OCC 4 P	2 2 41	0.180	7781	(5)
1991	2	23	2 OCC 1 P	16 39 50	0.365	443	
1991	2	23	2 ECL 1 A	17 43 43	0.711	490	
1991	2	27	2 OCC 1 P	5 44 20	0.324	420	
1991	2	27	2 ECL 1 A	6 54 60	0.712	474	
1991	3	1	4 OCC 2 C	9 45 32	0.0	0	(2)
1991	3	1	4 ECL 2 P	16 31 59	0.739	2014	
1991	3	2	4 ECL 2	5 12 32	0.059	1548	
1991	3	2	2 OCC 1 P	18 49 21	0.284	397	
1991	3	2	2 ECL 1 A	20 6 16	0.710	459	
1991	3	6	2 OCC 1 P	7 54 1	0.244	374	
1991	3	6	2 ECL 1 A	9 16 47	0.706	445	
1991	3	9	2 OCC 1 P	20 59 15	0.207	349	
1991	3	9	2 ECL 1 A	22 27 19	0.697	432	
1991	3	10	2 ECL 4	3 44 57	0.167	689	
1991	3	13	2 OCC 1 P	10 4 17	0.172	325	
1991	3	13	2 ECL 1 A	11 37 15	0.682	420	
1991	3	16	2 OCC 1 P	23 9 51	0.140	299	
1991	3	17	2 ECL 1 A	0 47 11	0.661	408	
1991	3	17	4 OCC 3 C	19 18 23	0.0	0	(2)
1991	3	17	4 OCC 3 P	23 45 24	0.050	12255	(5)
1991	3	18	3 ECL 2	16 29 31	0.005	160	(2)
1991	3	18	4 ECL 2	19 44 25	0.261	538	
1991	3	20	2 OCC 1 P	12 15 18	0.111	274	
1991	3	20	2 ECL 1 A	13 56 36	0.631	397	
1991	3	20	4 ECL 3	23 10 22	0.008	667	(2)
1991	3	24	2 OCC 1 P	1 21 20	0.085	248	
1991	3	24	2 ECL 1 A	3 6 3	0.596	386	
1991	3	25	3 ECL 2	19 43 7	0.101	338	(6)
1991	3	27	2 ECL 4	11 57 11	0.051	424	
1991	3	27	2 OCC 1 P	14 27 17	0.063	222	
1991	3	27	2 ECL 1 A	16 15 4	0.554	374	
1991	3	29	1 ECL 3	6 18 13	0.018	541	

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	3	31	2 OCC 1 P	3 33 49	0.045	195	
1991	3	31	2 ECL 1 P	5 24 7	0.508	363	
1991	4	1	1 ECL 2 P	12 16 14	0.210	241	(3)
1991	4	1	3 ECL 2	22 57 27	0.384	428	
1991	4	3	2 OCC 1 P	16 40 18	0.030	169	
1991	4	3	2 ECL 1 P	18 32 46	0.459	351	
1991	4	4	4 ECL 1	14 42 32	0.102	1141	(5)
1991	4	5	1 ECL 2 P	1 23 4	0.290	256	(3)
1991	4	5	1 ECL 3 P	10 54 21	0.084	1706	
1991	4	5	4 ECL 1	13 49 52	0.000	95	(2)
1991	4	7	2 OCC 1 P	5 47 18	0.019	142	
1991	4	7	2 ECL 1 P	7 41 27	0.408	339	
1991	4	8	1 ECL 2 P	14 29 58	0.377	267	(3)
1991	4	9	3 ECL 2 P	2 12 14	0.742	482	
1991	4	10	2 OCC 1 P	18 54 19	0.011	116	
1991	4	10	2 ECL 1 P	20 49 49	0.356	326	
1991	4	12	1 ECL 2 P	3 36 55	0.469	279	(3)
1991	4	12	3 OCC 4 P	10 31 30	0.172	3851	(5)
1991	4	13	1 ECL 4	16 10 6	0.046	352	
1991	4	13	2 ECL 4	21 16 45	0.014	332	
1991	4	14	2 OCC 1 P	8 1 49	0.005	90	(2)
1991	4	14	2 ECL 1 P	9 58 11	0.304	313	
1991	4	15	3 ECL 4 P	1 35 32	0.334	1331	
1991	4	15	1 ECL 2 P	16 43 57	0.561	289	(3)
1991	4	16	3 ECL 2 P	5 27 54	0.961	512	
1991	4	16	3 ECL 1	12 11 6	0.002	109	(2) (8)
1991	4	17	2 OCC 1 P	21 9 22	0.002	65	(2)
1991	4	17	2 ECL 1 P	23 6 17	0.252	299	
1991	4	19	1 ECL 2 P	5 51 3	0.651	298	(3)
1991	4	20	4 ECL 3	23 12 58	0.024	519	
1991	4	21	2 OCC 1 P	10 17 20	0.000	39	(2) (6)
1991	4	21	2 ECL 1 P	12 14 22	0.201	286	(6)
1991	4	21	4 ECL 1	18 54 11	0.432	455	(6) (9)
1991	4	22	4 ECL 2	13 28 46	0.011	287	
1991	4	22	1 ECL 2 P	18 58 14	0.731	305	(3)
1991	4	23	3 ECL 2 P	8 43 48	0.953	521	
1991	4	23	3 ECL 1	14 55 56	0.050	263	
1991	4	24	2 OCC 1 P	23 25 23	0.000	17	(2)
1991	4	25	2 ECL 1 P	1 22 14	0.153	270	
1991	4	26	1 ECL 2 P	8 5 29	0.800	312	(3)
1991	4	28	2 OCC 1 P	12 33 47	0.000	13	(2)
1991	4	28	2 ECL 1	14 30 3	0.110	252	

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	4	29	1 ECL 4	20 58 38	0.456	556	(3)
1991	4	29	1 ECL 2 A	21 12 48	0.854	318	(3)
1991	4	29	2 ECL 4 A	22 18 8	0.439	2020	
1991	4	30	3 ECL 2 P	12 0 21	0.746	508	
1991	4	30	3 ECL 4	15 38 32	0.128	649	
1991	4	30	3 ECL 1	17 42 9	0.200	349	
1991	5	2	2 OCC 1 P	1 42 18	0.000	35	(2)
1991	5	2	2 ECL 1	3 37 43	0.073	233	
1991	5	3	1 ECL 2 A	10 20 14	0.886	323	
1991	5	4	1 ECL 3	19 52 28	0.009	228	(2)
1991	5	5	2 OCC 1 P	14 51 6	0.002	57	(2)
1991	5	5	2 ECL 1	16 45 20	0.045	211	
1991	5	6	1 ECL 2 A	23 27 44	0.890	326	
1991	5	7	3 ECL 2 P	15 17 21	0.436	476	
1991	5	7	3 ECL 1 P	20 30 13	0.458	413	
1991	5	8	4 ECL 1 P	1 26 17	0.587	1026	
1991	5	8	4 ECL 1 P	10 52 40	0.809	1328	(7)
1991	5	9	4 ECL 1 A	3 37 59	0.732	684	
1991	5	9	2 OCC 1 P	4 0 0	0.005	79	(2)
1991	5	9	2 ECL 1	5 52 47	0.025	186	
1991	5	10	4 ECL 3 A	4 45 10	0.675	1409	
1991	5	10	1 ECL 2 A	12 35 22	0.866	329	
1991	5	11	1 ECL 3	22 40 18	0.051	308	
1991	5	12	2 ECL 3	4 30 10	0.002	178	(2)
1991	5	12	2 OCC 1 P	17 9 11	0.011	100	
1991	5	12	2 ECL 1	19 0 11	0.012	157	
1991	5	14	1 ECL 2 P	1 43 1	0.822	332	
1991	5	14	3 ECL 2	18 35 7	0.163	417	
1991	5	14	3 ECL 1 P	23 21 10	0.724	475	
1991	5	16	3 ECL 4 A	0 56 39	0.613	886	
1991	5	16	2 OCC 1 P	6 18 27	0.021	119	
1991	5	16	2 ECL 1	8 7 27	0.004	116	(2)
1991	5	17	1 ECL 4	6 16 25	0.421	521	
1991	5	17	1 ECL 2 P	14 50 52	0.765	333	
1991	5	19	1 ECL 3 P	1 25 54	0.146	355	(6)
1991	5	19	2 ECL 3	7 46 18	0.036	359	(6)
1991	5	19	2 OCC 1 P	19 27 59	0.034	138	
1991	5	19	2 ECL 1	21 14 41	0.000	59	(2)
1991	5	21	1 ECL 2 P	3 58 43	0.700	333	
1991	5	21	3 OCC 2 C	18 17 2	0.0	0	(2)
1991	5	21	3 ECL 2	21 54 1	0.035	315	
1991	5	22	3 ECL 1 P	2 16 41	0.912	540	

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	5	23	2 OCC 1 P	8 37 34	0.053	155	
1991	5	24	1 ECL 2 P	17 6 49	0.628	333	
1991	5	25	4 ECL 3	18 31 15	0.525	807	(3)
1991	5	26	1 ECL 3 P	4 10 9	0.283	383	(8)
1991	5	26	2 ECL 3 P	11 1 40	0.140	440	
1991	5	26	2 OCC 1 P	21 47 22	0.077	171	
1991	5	28	1 ECL 2 P	6 14 54	0.554	332	
1991	5	28	3 OCC 2 P	21 45 27	0.000	23	(2)
1991	5	29	3 ECL 2	1 13 51	0.000	79	(2)
1991	5	29	3 ECL 1 A	5 18 51	0.991	621	
1991	5	30	2 OCC 1 P	10 57 14	0.107	186	
1991	5	31	1 ECL 2 P	19 23 15	0.483	330	
1991	6	2	1 ECL 4	11 2 34	0.021	309	(3)
1991	6	2	2 ECL 3 A	14 16 22	0.284	481	
1991	6	3	2 OCC 1 P	0 7 16	0.143	199	
1991	6	3	3 OCC 4 C	22 6 16	0.0	0	(2)
1991	6	4	1 OCC 2 C	6 53 10	0.0	0	(2)
1991	6	4	3 ECL 4 P	7 12 43	0.331	1247	
1991	6	4	1 ECL 2 P	8 31 35	0.415	327	
1991	6	5	3 OCC 2 P	1 17 15	0.085	326	
1991	6	5	3 ECL 1 P	8 32 58	0.983	752	
1991	6	5	3 ECL 1 P	23 39 29	0.411	1682	
1991	6	6	3 ECL 1 P	6 4 59	0.336	1324	
1991	6	6	2 OCC 1 P	13 17 24	0.185	210	
1991	6	7	1 OCC 2 C	20 4 38	0.0	0	(2)
1991	6	7	1 ECL 2 P	21 40 15	0.352	324	
1991	6	9	2 ECL 3 A	17 30 36	0.369	494	
1991	6	10	2 OCC 1 P	2 27 38	0.235	219	
1991	6	10	4 ECL 3	4 11 1	0.208	791	
1991	6	11	4 ECL 1	4 51 20	0.115	889	(3)
1991	6	11	1 OCC 2 C	9 16 22	0.0	0	(2)
1991	6	11	1 ECL 2 P	10 48 54	0.293	322	
1991	6	11	4 ECL 1	17 8 45	0.162	689	
1991	6	12	3 OCC 2 P	4 51 41	0.217	437	
1991	6	12	3 OCC 1 C	8 51 23	0.0	0	(2)
1991	6	12	3 ECL 1 P	12 11 0	0.955	1065	
1991	6	12	3 ECL 1 P	21 51 54	0.769	1506	(7)
1991	6	13	3 ECL 1 P	10 13 39	0.583	803	
1991	6	13	2 OCC 1 P	15 37 58	0.290	226	
1991	6	14	1 OCC 2 C	22 28 36	0.0	0	(2)
1991	6	14	1 ECL 2 P	23 57 55	0.239	317	
1991	6	16	2 ECL 3 A	20 44 37	0.342	482	

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	6	17	2 OCC 1 P	4 48 23	0.351	231	
1991	6	18	1 OCC 2 P	11 41 3	0.003	72	(2)
1991	6	18	1 ECL 2 P	13 6 54	0.191	312	
1991	6	18	1 OCC 4 C	13 20 55	0.0	0	(2)
1991	6	19	3 OCC 2 T	8 29 14	0.259	496	(10)
1991	6	19	3 OCC 1 C	12 34 0	0.0	0	(2)
1991	6	19	1 ECL 3 P	18 20 10	0.118	4965	(5)
1991	6	19	1 ECL 4	20 19 16	0.000	101	(2)
1991	6	19	3 ECL 4	20 33 39	0.050	539	
1991	6	19	3 OCC 1 C	23 59 43	0.0	0	(2) (7)
1991	6	20	2 ECL 4	4 48 47	0.028	442	
1991	6	20	3 ECL 1 P	13 37 36	0.834	663	
1991	6	20	2 OCC 1 P	17 58 54	0.412	233	
1991	6	22	1 OCC 2 P	0 54 5	0.032	164	
1991	6	22	1 ECL 2 P	2 16 21	0.149	305	
1991	6	23	2 ECL 3 A	23 58 1	0.221	444	
1991	6	24	2 OCC 1 A	7 9 27	0.148	233	
1991	6	25	1 OCC 2 P	14 7 18	0.076	220	
1991	6	25	1 ECL 2	15 25 46	0.113	298	
1991	6	26	3 OCC 2 T	12 9 40	0.259	513	(11)
1991	6	26	4 OCC 2 P	15 37 47	0.117	539	
1991	6	26	3 OCC 1 P	17 42 54	0.049	1475	
1991	6	26	3 OCC 1 P	21 18 37	0.029	1433	
1991	6	27	4 ECL 2	13 49 40	0.028	1111	
1991	6	27	3 ECL 1 P	16 44 57	0.976	584	
1991	6	27	4 OCC 1 C	20 8 30	0.0	0	(2)
1991	6	27	2 OCC 1 P	20 20 5	0.404	229	
1991	6	27	4 OCC 2 C	21 14 16	0.0	0	(2)
1991	6	28	4 ECL 2	19 30 5	0.412	867	
1991	6	29	1 OCC 2 P	3 21 11	0.130	263	
1991	6	29	4 OCC 3 P	4 3 38	0.095	830	
1991	6	29	1 ECL 2	4 35 44	0.083	290	
1991	6	29	4 ECL 3	10 11 17	0.005	531	(2)
1991	6	30	1 OCC 3 C	16 7 6	0.0	0	(2)
1991	7	1	2 ECL 3	3 11 16	0.079	376	
1991	7	1	2 OCC 1 P	9 30 45	0.330	221	
1991	7	2	1 OCC 2 P	16 35 13	0.190	299	
1991	7	2	1 ECL 2	17 45 39	0.060	280	
1991	7	3	3 OCC 2 P	15 53 31	0.171	485	
1991	7	4	3 ECL 1 P	19 43 26	0.942	521	
1991	7	4	2 OCC 1 P	22 41 29	0.250	208	
1991	7	5	3 OCC 4 C	1 19 58	0.0	0	(2)

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	7	5	2 OCC 4 P	6 29 32	0.040	259	
1991	7	6	1 OCC 2 P	5 50 1	0.255	331	
1991	7	6	1 ECL 2	6 56 14	0.042	270	
1991	7	7	1 OCC 3 C	19 4 17	0.0	0	(2)
1991	7	7	1 ECL 3	20 31 55	0.118	351	(3)
1991	7	8	2 OCC 3 C	4 30 35	0.0	0	(2)
1991	7	8	2 ECL 3	6 23 44	0.012	256	
1991	7	8	2 OCC 1 P	11 52 15	0.171	190	(3)
1991	7	9	1 OCC 2 P	19 5 0	0.323	357	
1991	7	9	1 ECL 2	20 6 48	0.028	263	
1991	7	10	3 OCC 2 P	19 41 33	0.062	391	
1991	7	11	3 OCC 1 C	21 10 28	0.0	0	(2)
1991	7	11	3 ECL 1 P	22 36 37	0.722	461	
1991	7	12	2 OCC 1 P	1 3 4	0.097	162	(3)
1991	7	13	1 OCC 2 P	8 20 54	0.388	381	
1991	7	13	1 ECL 2	9 18 10	0.019	249	
1991	7	13	4 OCC 2 C	23 37 6	0.0	0	(2)
1991	7	14	4 OCC 1 P	1 52 54	0.360	379	
1991	7	14	4 OCC 3 P	19 52 21	0.098	394	
1991	7	14	1 OCC 3 P	22 3 30	0.098	252	
1991	7	14	1 ECL 3	23 18 17	0.046	313	
1991	7	15	2 OCC 3 P	8 1 32	0.068	236	(8)
1991	7	15	2 OCC 1 P	14 13 53	0.035	119	(3)
1991	7	16	1 OCC 2 T	21 37 2	0.425	402	(12)
1991	7	16	1 ECL 2	22 29 34	0.012	228	
1991	7	17	3 OCC 2 P	23 34 11	0.001	95	(2)
1991	7	19	3 OCC 1 P	0 18 16	0.018	165	
1991	7	19	3 ECL 1 P	1 25 49	0.408	398	
1991	7	19	2 OCC 1 C	3 24 45	0.0	0	(2) (3)
1991	7	20	1 OCC 2 T	10 54 12	0.425	420	(13)
1991	7	20	1 ECL 2	11 41 55	0.007	210	(2)
1991	7	22	1 OCC 3 P	1 5 23	0.266	343	
1991	7	22	1 ECL 3	2 6 45	0.013	256	
1991	7	22	1 OCC 4 P	5 35 13	0.047	392	
1991	7	22	2 OCC 3 A	11 32 38	0.479	338	(8)
1991	7	22	2 OCC 4 C	16 32 31	0.0	0	(2) (3)
1991	7	22	2 OCC 1 C	16 35 36	0.0	0	(2) (3)
1991	7	22	1 OCC 4 P	16 43 7	0.201	830	(3)
1991	7	23	1 OCC 4 P	8 17 30	0.328	492	
1991	7	24	1 OCC 2 P	0 11 42	0.381	435	
1991	7	24	1 ECL 2	0 54 23	0.004	188	(2)
1991	7	24	3 OCC 4 P	9 30 17	0.315	1022	
1991	7	25	3 OCC 2 C	3 33 1	0.0	0	(2)

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	7	26	3 OCC 1 P	3 22 9	0.159	294	
1991	7	26	3 ECL 1	4 12 36	0.142	324	
1991	7	26	2 OCC 1 C	5 46 30	0.0	0	(2) (3)
1991	7	27	1 OCC 2 P	13 30 32	0.321	448	
1991	7	27	1 ECL 2	14 8 3	0.002	163	(2)
1991	7	29	1 OCC 3 A	4 11 14	0.356	394	(1)
1991	7	29	1 ECL 3	4 58 29	0.001	161	(1) (2)
1991	7	30	4 OCC 3 P	7 4 14	0.190	546	(1)
1991	7	31	1 OCC 2 P	2 49 53	0.263	459	(1)
1991	7	31	1 ECL 2	3 21 59	0.001	131	(1) (2)
1991	7	31	4 OCC 1 C	12 6 8	0.0	0	(1) (2)
1991	8	1	3 OCC 2 C	7 38 48	0.0	0	(1) (2)
1991	8	2	3 OCC 1 T	6 22 57	0.321	330	(1) (14)
1991	8	2	3 ECL 1	6 57 8	0.024	221	(1) (3)
1991	8	3	1 OCC 2 P	16 11 2	0.209	468	(1)
1991	8	3	1 ECL 2	16 37 32	0.000	87	(1) (2)
1991	8	5	1 OCC 3 P	7 23 12	0.277	421	(1)
1991	8	7	1 OCC 2 P	5 33 0	0.160	473	(1)
1991	8	8	3 OCC 2 C	11 55 23	0.0	0	(1) (2)
1991	8	9	3 OCC 4 C	0 28 11	0.0	0	(1) (2)
1991	8	9	3 OCC 1 P	9 21 53	0.303	313	(1) (3)
1991	8	10	1 OCC 2 P	18 57 34	0.117	477	(1)
1991	8	25	1 OCC 2 P	1 13 24	0.008	402	(1) (2)
1991	8	26	1 OCC 3 P	18 54 55	0.056	841	(1)
1991	8	27	1 OCC 3 P	1 18 20	0.314	1692	(1)
1991	8	27	1 ECL 3 P	2 3 52	0.330	1585	(1)
1991	8	27	1 ECL 3	16 1 58	0.058	555	(1)

Table 1 (continued)

Year	Month	Day	Event	Date of the maximum	Flux drop	Duration (s)	Notes
1991	8	27	1 OCC 3 P	16 32 51	0.181	533	(1)
1991	8	28	1 OCC 2 C	15 15 42	0.0	0	(1) (2)
1991	8	28	1 OCC 2 C	19 47 46	0.0	0	(1) (2)
1991	8	30	3 OCC 2 P	5 5 59	0.092	4546	(1) (5)
1991	8	30	3 OCC 2 T	10 3 11	0.260	6827	(1) (5) (15)
1991	8	30	3 ECL 2 P	12 9 57	0.997	4109	(1) (5)
1991	8	31	3 ECL 2 P	13 28 21	0.626	1226	(1)
1991	8	31	3 OCC 2 P	14 28 22	0.103	838	(1)
1991	9	3	1 ECL 3	19 17 39	0.001	177	(1) (2)
1991	9	3	1 OCC 3 P	20 3 48	0.001	89	(1) (2)
1991	9	7	3 ECL 2 P	17 35 5	0.990	1134	
1991	9	7	3 OCC 2 T	18 57 2	0.259	900	(16)
1991	9	14	3 ECL 2 P	21 28 7	0.990	996	
1991	9	14	3 OCC 2 P	23 10 8	0.206	714	
1991	9	22	3 ECL 2 P	1 11 27	0.632	819	
1991	9	22	3 OCC 2 P	3 12 17	0.000	77	(2)
1991	9	29	3 ECL 2	4 48 28	0.140	592	
1991	10	6	3 ECL 2	8 20 55	0.000	97	(2)
1991	10	20	3 OCC 1 C	7 51 19	0.0	0	(2)
1991	11	3	3 ECL 1	8 13 59	0.051	897	(7)
1992	3	22	2 ECL 3 A	8 54 55	0.362	5525	(5)
1992	3	22	2 ECL 3	15 33 43	0.010	2345	
1992	3	29	2 OCC 2 A	10 9 6	0.480	5047	
1992	4	5	2 ECL 3 P	2 45 17	0.218	3145	(3)

Columns 8–10: for G-5 ephemerides: the date of the maximum of the phenomenon (minimum of light).

Column 11: the flux drop at the minimum of light (from 0 for no event to 1 for total disappearance; note that the flux drop is calculated referred to the light-flux of both satellites for the occultations and of the only eclipsed satellite for the eclipses – so that the flux drop may never be 1 for the occultations–).

Column 12: the duration of the event in seconds of time.

Column 13: Notes to the table, which are as follows:

(1) Phenomena for which the apparent distance Jupiter Sun is less than 15°.

(2) Grazing phenomena: their light-flux drops are less than 0.01. Such events are very difficult to observe. Anyway, it can appear that the real amplitude is larger than the predicted one, so the phenomenon is easily observable.

(3) Phenomena occurring at a distance of less than one Jovian radius from the limb of Jupiter.

(4) Special multiple events: an occultation of J1 by J2 just followed by an eclipse of J1 by J2 on January 29 and vice versa on January 26.

(5) Very long phenomena: during them the 2 implied satellites have the same apparent speed so that the precision of the calculated dates is not good.

(6) Events for which the apparent distance to the Moon is less than 5 degrees.

(7) Events occurring in the front of the disk of Jupiter.

(8) and (9) Events occurring just after an eclipse by Jupiter.

(10) Total event from $8^{h}28^{m}14^{s}$ to $8^{h}30^{m}15^{s}$ on June 19.

(11) Total event from $12^{h}9^{m}3^{s}$ to $12^{h}10^{m}18^{s}$ on June 26.

(12) Total event from $21^{h}36^{m}50^{s}$ to $21^{h}37^{m}13^{s}$ on July 16.

(13) Total event from $10^{h}54^{m}4^{s}$ to $10^{h}54^{m}20^{s}$ on July 20.

(14) Total event from $6^{h}22^{m}41^{s}$ to $6^{h}23^{m}12^{s}$ on Aug. 2.

(15) Total event from $9^{h}49^{m}57^{s}$ to $10^{h}16^{m}25^{s}$ on Aug. 30.

(16) Total event from $18^{h}55^{m}22^{s}$ to $18^{h}58^{m}41^{s}$ on Sept. 7.

In Table 1, mutual phenomena occurring behind Jupiter or in the shadow of Jupiter are of course not given, nor are phenomena occurring when the apparent distance Jupiter-Sun is less than 5°.

Table 2 gives the number of phenomena for each satellite. Table 3 gives the number of events as a function of their duration. Close approaches for 58 events with a 0-second duration may be mutual events because of the uncertainty on the impact parameter due to theoretical causes.

Table 4 gives the number of events observable from several observatories (grazing events have been eliminated, as well as events which are difficult to observe). We selected phenomena occurring when Jupiter is more than 5°, 25°, and 45° above the horizon and the Sun is greater than 5° below the horizon. It is clear that the best observational conditions are obtained for the observatories whose latitudes are close to the declination of Jupiter (about +16° to +20° during the period of the mutual phenomena). The last column of Table 4 gives the number of events occurring when Jupiter is more than 45° above the horizon even with the Sun above the horizon: in daylight, observations are possible at 2.2 μm that increases the possibilities of observations. If someone wishes to have the list of phenomena observable from a special observatory, please contact the author.

Table 2

Satellite	Number of occultations	Number of eclipses
1	101	70
2	54	60
3	32	38
4	15	15

Table 3. Statistics on the durations of the mutual events

Duration (s)	Occultations	Eclipses
1 to 99	13	5
100 to 299	37	38
300 to 599	47	82
600 to 999	18	25
1000 to 1499	7	14
1500 to 2499	10	14
2500 to 3999	3	4
4000 to 5999	2	4
6000 to 8499	2	0
8500 to 14941	1	0

Table 4. Visibility of the mutual events

Observatories	Elevation of Jupiter			
	>45°	>25°	>5°	>45°
	(elevation of the Sun < −5°)			
Purple Mountain (China)	34	44	64	76
Canary Islands (Spain)	32	48	63	66
San Pedro Martir (Mexico)	30	46	64	74
Dodaira (Japan)	31	50	62	69
Mauna Kea (Hawaii)	31	41	59	74
McDonald (USA)	28	47	61	71
Wise Observatory (Israel)	28	47	66	66
Catania (Italy)	26	42	64	61
OHP (France)	26	45	70	59
Brasopolis (Brazil)	13	39	58	26
Pulkovo (USSR)	13	37	65	35
La Silla (Chile)	1	33	55	1
AAT (Australia)	0	30	52	1
Sutherland (South Africa)	0	27	55	0

Notes: 1) Difficult-to-catch events have been eliminated. 2) For the last column, no constraints have been made on the elevation of the Sun.

5. Observation campaign

Observations of the mutual phenomena of the Galilean satellites are always of great interest and we encourage observers to observe them. As in 1985 (Arlot and Thuillot, 1988), we will organize a campaign of observations. If you wish to join us, and to receive Technical Notes made in order to help the observers, please, contact the author. In these notes, we will describe possible instruments (single-channel photometers, two-dimensional receptors) as well as observational techniques and methods used for the reduction of the data. Because of the great interest of such observations, I look forward to very good observational data in 1991.

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