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Predictions of the mutual events of the Galilean satellites of Jupiter occurring in 2009–2010

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ABSTRACT

Aims. Mutual occultations and eclipses of the Galilean satellites of Jupiter will occur in 2009–2010. This paper provides predictions of these events as well as useful information for their observations. Such events are uncommon, since they only occur every 6 years when the Earth and the Sun pass through the common orbital plane of the Galilean satellites. The present dynamical models of motion of the Galilean satellites include the effects of the internal structure of the satellites on their motion. Only accurate observations such as mutual events may fit the parameters depending on the internal structure.

Methods. For these predictions, we used the best theoretical models of the motion of the Galilean satellites since the prediction of events is very sensitive to the accuracy of the relative calculated positions of the satellites.

Results. Therefore, we encourage professional and amateur astronomers to join the networks of observers in order to get as many observations as possible. Data on the predictions of the events and interactive software for their visibility are available on the web server of the IMCCE (www.imcce.fr/phemu09).

Key words. planets and satellites: individual: jupiter – eclipses – occultations – ephemerides

1. Introduction

Recent results on the accelerations in the longitudes of the Galilean satellites have shown how accurate astrometric observations may be good help for the modeling of the internal structure of the satellites (Lainey et al. 2005, 2007). This encouraged us to continue to gather as many accurate observations as possible.

The mutual events of the Galilean satellites have been extensively observed since 1973 (Arlot 1973) but have recently benefited from improvements in detectors which have made the observations easier. Having observations over long periods of time increases the possibility of obtaining results on the evolution of the orbits.

We choose to perform an observational campaign for the next Jovian equinox, allowing mutual events to occur. For that, we use the best theoretical dynamical model of motion of the Galilean satellites to predict these events.

2. The mutual events

2.1. Occurrence of the events

Since the Galilean satellites have their orbits almost in the same plane, mutual events occur regularly when the Earth (for the occultations) and the Sun (for the eclipses) pass through the orbital plane of the satellites. These planes corresponds closely to the equatorial plane of Jupiter. This occurrence takes place at the equinox on Jupiter, i.e. when the jovicentric declination of the Sun (and the Earth, which appears to be close to the Sun as seen from Jupiter) are near zero. Figure 1 shows the variation of these jovicentric declinations for the equinoxes of 2003 and 2009: the best periods for large, deep, mutual events appear to

be May 2009 for the occultations and July 2009 for the eclipses. Fortunately, the opposition of Jupiter with the Sun occurs in August 2009, allowing observations from May to November 2009.

2.2. Nature of the events

Descriptions of the mutual eclipses and occultations have been made in previous papers, especially in technical notes made for the former occurrences (2003, 1997, etc.) available on the web site of IMCCE at the address <http://www.imcce.fr/phemu09> or in Arlot (1999). Two types of events will occur:

- occultations consist of the arrival of the disk of the occulting satellite on that of the occulted satellite. Therefore, the amount of light received by a terrestrial observer decreases and increases during the event;
- eclipses correspond to the arrival of the eclipsed satellite in the shadow cone of the eclipsing satellite. In this case, only the eclipsed satellite may be observed, leading, in some cases, to a total eclipse (the complete disappearance of the eclipsed satellite).

During the occurrence of the mutual events, the magnitude of the events will be small at the beginning and the end of the period (the jovicentric declinations of the Earth and the Sun is not yet zero and the satellites are not exactly on the same line as seen from the Earth (or the Sun)). On the other hand, the magnitude of the events will be larger for the zero value of the jovicentric declination of the Earth and the Sun. Observers should be aware that the signal to noise ratio will be larger for deep phenomena.

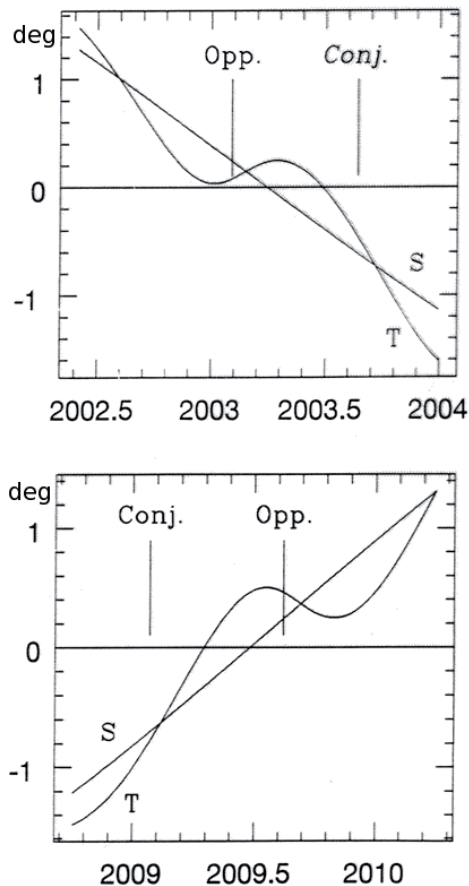


Fig. 1. Jovicentric declination of the Earth (T) and the Sun (S).

3. The predictions for 2009–2010

3.1. The model used for the predictions

The prediction of the events requires the use of an accurate model of the motion of the Galilean satellites since the occurrence of the events is very sensitive to the small inclinations of the orbits of the Galilean satellites to the equatorial plane of Jupiter. A difference of a few tenths of an arcsecond in the relative positions of the Galilean satellites may affect whether the event will occur or not. Therefore, we use the recent accurate ephemerides L1 proposed by Lainey et al. (2006). We also provide data calculated using the G5 ephemerides (Arlot 1982) which was used for the former predictions. All these ephemerides are available on the Web site of IMCCE at <http://www.imcce.fr/sat>.

The calculations for the prediction of the events differ for the occultations and for the eclipses. For the occultations, we determine the time of the first contact, maximum and last contact of the two disks of the satellites as seen from the Earth. For the eclipses, we may not consider that they are occultations as seen from the Sun because of the light-time. Therefore, we calculate the first and last contact of the eclipsed satellite with the penumbral and umbral cones and the minimum distance to the axis of the cones. The relative positions of the cones and the satellites are calculated carefully taking into account the light-time. In some cases, the relative velocity of the two satellites or of the eclipsed satellite with reference to the cones is very small, or has non linear variations. Some events have two minimums and this induces some errors in the times of the beginning and end

of these events and will make the reduction of the observation more difficult.

What are the accuracies of these predictions? Since we used two different dynamical models fitted on different sets of observations, the differences in the predictions are a good estimate of the accuracy of the predictions. In Tables 2 to 10, the difference between Cols. 6 and 7 provides the accuracy for the date of the maximum of the event, the difference between Cols. 12 and 13 provides the accuracy in magnitude drop and the difference between Cols. 14 and 15 the accuracy on the duration of the event. Note that the prediction using L1 ephemerides would be nearer the real value.

3.2. The data

The predicted mutual events are available with this paper on the web site of the IMCCE at the address: <http://www.imcce.fr/phemu09>. Tables 2 to 10 provide the detailed data calculated with the L1 ephemeris except for some data provided also calculated with the G5 ephemerides (as indicated below).

- Column 1: date of the maximum of the event.
- Column 2: nature of the event: 1 OCC 2 means that satellite 1 occults satellite 2, 3 ECL 4 means that satellite 3 eclipses satellite 4, etc.; P stands for partial, A for annular, T for total and blank means eclipse by the penumbra.
- Column 3: (only for eclipses): hour, min, s in UTC of the beginning of the eclipse by the penumbra.
- Column 4: hour, min, sec in TT of the beginning of the eclipse by the shadow or beginning of the occultation.
- Column 5: (only for total events) hour, min, s in UTC of the beginning of totality.
- Column 6: hour, min, s in TT of the maximum of the event.
- Column 7: hour, min, s in TT of the maximum of the event calculated with G5 ephemeris.
- Column 8: (only for total events) hour, min, s in UTC of the end of totality.
- Column 9: hour, min, s in TT of the end of the eclipse by the shadow or end of the occultation.
- Column 10: (only for eclipses): hour, min, s in TT of the end of the eclipse by the penumbra.
- Column 11: flux drop in the V-band (if 0, grazing event with an eventual very small signal to be detected; if 1, total event).
- Column 12: flux drop with the same albedoes for all the implied satellites (if 0, grazing event with an eventual very small signal to be detected; if 1, total event).
- Column 13: flux drop with the same albedoes for all the implied satellites (if 0, grazing event with an eventual very small signal to be detected; if 1, total event) calculated with G5 ephemeris.
- Column 14: duration of the event in seconds; no duration is indicated for grazing events. The eclipse inside the penumbra is not taken into account in the duration.
- Column 15: duration of the event in seconds calculated with G5 ephemeris; no duration is indicated for grazing events. The eclipse inside the penumbra is not taken into account in the duration.
- Column 16: apparent distance from the occulted or eclipsed satellite to the center of Jupiter in jovian radii. When this distance is less than 1, this means that the event occurs in front of the planet Jupiter. This

is a nice observation – especially the eclipses – with a good seeing, but without any scientific interest!

Column 17: impact parameter in arcsec (distance between the centers of the satellites for the occultations and from the eclipsed satellite to the axis of the shadow cone for the eclipses).

The dates are provided in Terrestrial Time (TT) since the UTC for this period is not yet available. The difference TT – UTC will, however, be near 67 s in 2009. Note that observations will be recorded in reference to UTC.

In the list of events in Tables 2 to 10, two events present two minima in the predicted light curves, because of the length of these events and of the changing velocity of the satellites during the events:

- on September 6, 2009, J1 occults J3 with a first minimum distance at 10 h 28 min and a second one at 10 h 30 min (event from 10 h to 13 h);
- on September 8, 2009, J1 occults J2 with a first minimum distance at 6 h 5 min and a second one at 7 h 30 min (event from 5 h 30 min to 8 h).

Some events will occur during an eclipse by Jupiter: we removed these events from the list but we leave the following events during which an eclipse occurs or for which the eclipse occurs just before or just after the mutual event:

- on January 20, 2009, the eclipse of J3 by J2 ends at 12h16min TT and the eclipse of J3 starts at 12h31min TT
- on May 26, 2009, the eclipse of J4 by J2 starts at 8h30min TT and the eclipse of J4 ends at 8h19min TT
- on June 3, 2009, J4 eclipses J1 from 3h27min to 3h36min TT and the eclipse of J1 starts at 3h31min TT
- on June 17, 2009, J2 occults J1 from 7h16min to 7h19min TT and the eclipse of J1 starts at 7h18min TT
- on July 15, 2009, the eclipse of J4 by J3 starts at 2h20min TT and the eclipse of J4 ends at 2h9min TT
- on July 22, 2009, the eclipse of J1 by J2 ends at 16h37min TT and the eclipse of J1 starts at 16h47min TT
- on July 26, 2009, the eclipse of J1 by J2 ends at 5h43min TT and the eclipse of J1 starts at 5h44min TT
- on August 12, 2009, the eclipse of J1 by J3 ends at 22h28min TT and the eclipse of J1 starts at 22h29min TT
- on August 30, 2009, the occultation of J3 by J1 ends at 14h48min TT and J3 is occulted by Jupiter starting at 15h0min TT
- on September 20, 2009, the eclipse of J1 by J2 starts at 23h19min TT and the eclipse of J1 ends at 23h18min TT
- on November 5, 2009, the occultation of J1 by J2 starts at 23h51min TT and the eclipse of J1 ends at 23h47min TT
- on November 9, 2009, the occultation of J1 by J2 starts at 12h58min TT and the eclipse of J1 ends at 12h44min TT

The magnitude drops are provided under several forms: first the flux drop in magnitude units more understandable for human eyes (0 = no decrease of light, unchanged magnitude of the object(s); n = increase in magnitude at the maximum of the event) and second in unit of flux (0 = no decrease of light; 1 = total disappearance of the object). We calculated the drop depending on the albedoes of the implied satellites (for the occultations) in the V-band which is commonly used by the observers. Table 1 provides the values used for the albedoes. They are taken from Morrisson and Morrison (1977) for a phase not equal to zero. Note that they have very little influence on the results (they do not influence at all the magnitude drop of the eclipses) and are

Table 1. Albedoes used for the calculation of the magnitude drop.

	satellites	V-band
J-1	Io	0.56
J-2	Europa	0.62
J-3	Ganymede	0.39
J-4	Callisto	0.14

not very different in the other bands. We also provide the flux drop without albedoes i.e. with the same albedoes for the four satellites.

During the 2009–2010 event season, 443 events were predicted. Not all of them are observable: some will remain grazing with no detectable signal, some will occur behind Jupiter or during an eclipse by the planet and some will be difficult to observe because of the conjunction of Jupiter with the Sun. Only 370 are presented here. In the next sections, we provide more information on the visibility and on the observability of these events.

3.3. The visibility of the events

Since they occur anytime and since their duration is, usually, only a few minutes, the events are observable only from selected sites where Jupiter is visible, above the horizon at the time of the event. The declination of Jupiter during the occurrence of the mutual events will be near –14 degrees. Therefore, the observations will be easier in the southern hemisphere. Table 11 provides the number of events observable from some selected sites around the world (calculated from 440 events including some grazing not in Tables 2 to 10 but provided on our web server). We considered that an event is observable when the Sun is more than 10 degrees under the horizon and Jupiter is more than 15 degrees above the horizon. Table 12 provides the number of events depending on several criteria. Note that some events may be observable or not because of the sensitivity of these events to the inclinations of the orbital planes of the satellites. We considered that these events are possibly grazing i.e. its observability depends on the possible error in the ephemerides. So, if a signal is detected during an event, one will get valuable information about the ephemerides. Note also that the total or annular events will present light curves with a flat step allowing the analysis of the scattering law of the light on the surfaces of the satellites. Short events or faint events (the flux drop of which being less than ten percent) will be difficult to catch because of the low signal to noise ratio, and observers will need near perfect photometric conditions. The long events (one hour or more) are interesting too, but observers must take into account the changing elevation of Jupiter on the sky: the event must end before Jupiter sets. The observers should be aware that the predicted times may have an error of a few minutes in some cases, even if they are within a few seconds most of the time. This difference between the observation and the prediction contains information relevant to improving the theoretical models of the motions of the satellites. Therefore, the observations should start at least 10 min before the predicted beginning and must be referred to UTC within less than one tenth of a second.

Information on the visibility of the events from any site of observation is provided on the web site of IMCCE at the address <http://www.imcce.fr/phemu09>.

Table 2. Mutual events occurring from January 13 to May 12, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 1 13	2 ECL 3 P	14 25 26.	14 32 24.		14 45 25.	14 47 46.		14 58 34.	15 5 54.	0.080	0.080	0.070	1570	1462	0.2	0.856
2009 1 13	2 OCC 3 P		15 54 50.		16 2 17.	16 3 10.		16 9 45.		0.002	0.003	0.001	895	497	0.3	0.922
2009 1 20	2 ECL 3	11 51 2.			12 3 32.	12 5 45.			12 15 38.	0.016	0.010	0.010			0.3	1.082
2009 3 27	4 OCC 3 P		5 42 56.		5 45 55.	5 47 41.		5 48 55.		0.021	0.032	0.037	359	376	8.3	1.048
2009 3 28	4 OCC 1 P		3 6 58.		3 8 53.	3 8 18.		3 10 48.		0.056	0.058	0.062	230	234	5.8	0.800
2009 4 4	2 ECL 4	15 12 11.			16 23 29.	16 22 23.			17 20 20.	0.044	0.044	0.034			6.7	1.111
2009 4 5	1 OCC 4 P		7 22 30.		7 27 50.	7 30 54.		7 33 16.		0.085	0.363	0.362	645	651	11.3	0.147
2009 4 6	1 OCC 4 P		10 1 48.		10 5 52.	10 4 37.		10 9 54.		0.066	0.281	0.292	487	493	10.3	0.340
2009 4 9	1 OCC 3 P		23 57 48.		23 59 52.	23 58 56.		0 1 55.		0.028	0.042	0.045	247	252	9.4	0.912
2009 4 13	3 OCC 1 P		0 54 14.		0 55 56.	0 55 30.		0 57 38.		0.049	0.051	0.049	204	201	4.8	0.892
2009 4 13	4 OCC 2 P		6 25 57.		6 32 49.	6 30 15.		6 39 46.		0.217	0.203	0.203	830	825	15.0	0.448
2009 4 13	4 ECL 1	17 23 60.			17 29 9.	17 28 38.			17 34 21.	0.038	0.038	0.039			3.0	1.295
2009 4 14	4 OCC 1 P		13 6 29.		13 9 17.	13 10 19.		13 12 5.		0.232	0.241	0.232	336	332	5.6	0.425
2009 4 15	4 OCC 2 P		4 51 58.		4 58 13.	4 55 58.		5 4 24.		0.314	0.293	0.284	746	743	3.4	0.231
2009 4 15	4 OCC 3 P		14 57 41.		15 3 31.	15 4 30.		15 9 20.		0.137	0.208	0.208	700	704	14.0	0.609
2009 4 17	1 OCC 3 P		3 0 27.		3 3 15.	3 2 29.		3 6 3.		0.118	0.182	0.185	336	338	8.1	0.567
2009 4 20	3 OCC 1 P		3 47 5.		3 49 43.	3 49 8.		3 52 21.		0.205	0.212	0.209	317	315	6.3	0.503
2009 4 21	2 OCC 4 P		21 27 56.		21 31 41.	21 30 47.		21 35 26.		0.038	0.166	0.160	450	444	5.3	0.537
2009 4 22	1 OCC 2 P		20 22 55.		20 23 27.	20 24 10.		20 23 59.		0.003	0.003	0.006	64	81	7.5	0.848
2009 4 24	1 OCC 3 A		5 56 52.		5 59 50.	5 59 12.		6 2 47.		0.209	0.322	0.322	355	356	6.8	0.189
2009 4 26	2 OCC 3 P		11 22 20.		11 24 21.	11 24 19.		11 26 22.		0.027	0.042	0.049	242	253	5.1	0.888
2009 4 26	3 OCC 2 P		9 31 12.		9 32 27.	9 33 11.		9 33 42.		0.045	0.043	0.049	150	157	7.8	0.727
2009 4 27	3 OCC 1 T		6 41 34.	6 44 13.	6 44 40.	6 43 57.	6 45 7.	6 47 47.		0.310	0.321	0.321	374	372	7.6	0.009
2009 4 29	1 OCC 2 P		22 39 43.		22 41 21.	22 42 6.		22 42 59.		0.106	0.100	0.108	196	201	8.0	0.611
2009 4 30	4 OCC 2 P		12 38 44.		12 39 57.	12 41 3.		12 41 11.		0.010	0.010	0.005	148	120	3.2	0.981
2009 5 1	1 OCC 3 A		8 48 43.		8 51 31.	8 51 2.		8 54 19.		0.209	0.322	0.322	336	336	5.4	0.211
2009 5 1	2 OCC 3 P		14 44 38.		14 47 32.	14 47 47.		14 50 27.		0.110	0.170	0.178	349	354	3.5	0.557
2009 5 2	2 OCC 1 P		5 6 24.		5 7 18.	5 7 36.		5 8 13.		0.017	0.018	0.024	109	119	7.0	0.810
2009 5 3	1 OCC 2 P		11 48 5.		11 49 59.	11 50 45.		11 51 53.		0.175	0.166	0.175	228	231	8.2	0.498
2009 5 4	3 OCC 2 P		4 59 5.		5 0 57.	5 0 42.		5 2 50.		0.030	0.028	0.027	225	222	7.7	0.963
2009 5 4	3 OCC 1 T		9 37 53.	9 40 56.	9 41 15.	9 40 21.	9 41 33.	9 44 37.		0.310	0.321	0.321	404	404	8.8	0.009
2009 5 5	2 OCC 1 P		18 13 51.		18 15 13.	18 15 32.		18 16 36.		0.066	0.070	0.079	165	171	6.8	0.683
2009 5 7	1 OCC 2 P		0 56 23.		0 58 28.	0 59 17.		1 0 34.		0.248	0.234	0.244	252	254	8.5	0.388
2009 5 8	1 OCC 3 P		11 37 3.		11 39 23.	11 39 1.		11 41 44.		0.113	0.174	0.173	282	282	4.0	0.622
2009 5 8	1 ECL 4	16 7 16.			16 10 31.	16 10 56.			16 13 46.	0.104	0.104	0.107			9.8	1.167
2009 5 8	2 OCC 3 A		18 4 17.		18 7 30.	18 7 59.		18 10 43.		0.168	0.261	0.261	386	388	2.1	0.210
2009 5 9	2 OCC 1 P		7 21 8.		7 22 46.	7 23 4.		7 24 25.		0.131	0.139	0.149	198	201	6.5	0.554
2009 5 10	1 OCC 2 P		14 4 26.		14 6 41.	14 7 31.		14 8 55.		0.320	0.302	0.312	269	271	8.7	0.283
2009 5 11	3 OCC 2 P		8 20 55.		8 24 11.	8 23 38.		8 27 27.		0.181	0.168	0.166	393	390	9.3	0.576
2009 5 11	3 OCC 1 P		12 37 55.		12 41 26.	12 40 21.		12 44 58.		0.228	0.236	0.240	423	424	10.0	0.476
2009 5 12	2 OCC 1 P		20 28 5.		20 29 54.	20 30 11.		20 31 43.		0.204	0.216	0.228	218	220	6.3	0.425

Table 3. Mutual events occurring from May 14 to June 6, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 5 14	1 OCC 2 P		3 12 26.		3 14 47.	3 15 38.		3 17 9.		0.389	0.367	0.376	283	284	89	0.183
2009 5 15	1 OCC 3 P		14 22 37.		14 24 5.	14 23 50.		14 25 33.		0.024	0.037	0.036	176	176	2.6	1.032
2009 5 15	2 OCC 3 A		21 20 60.		21 24 10.	21 24 52.		21 27 21.		0.168	0.261	0.261	381	381	0.8	0.148
2009 5 16	4 ECL 3	4 5 28.			4 11 59.	4 12 7.			4 18 29.	0.206	0.206	0.211			2.6	1.174
2009 5 16	2 OCC 1 P		9 34 40.		9 36 35.	9 36 53.		9 38 30.		0.281	0.298	0.310	230	232	6.0	0.295
2009 5 16	4 ECL 1 P		18 43 52.		18 44 54.	18 45 23.		18 45 56.	18 50 31.	0.482	0.482	0.483	124	127	8.5	0.559
2009 5 17	4 ECL 1 P		10 51 42.		10 56 36.	10 56 8.		11 1 31.	11 7 16.	0.572	0.572	0.575	589	593	0.9	0.377
2009 5 17	1 OCC 2 P		16 20 7.		16 22 33.	16 23 26.		16 24 60.		0.446	0.421	0.425	292	293	9.1	0.087
2009 5 17	4 ECL 1	21 4 26.			21 11 27.	21 12 3.			21 18 21.	0.285	0.285	0.298			11.8	0.956
2009 5 18	3 OCC 2 T		11 41 21.	11 44 30.	11 45 13.	11 44 24.	11 45 56.			0.279	0.259	0.259	464	462	10.7	0.009
2009 5 18	3 OCC 1 P		15 43 30.		15 47 13.	15 45 53.		15 50 57.		0.146	0.151	0.156	447	449	10.9	0.700
2009 5 19	2 OCC 1 P		22 40 54.		22 42 52.	22 43 9.		22 44 50.		0.357	0.379	0.391	237	237	5.8	0.166
2009 5 21	1 OCC 2 T		5 27 45.	5 30 3.	5 30 14.	5 31 9.	5 30 26.			0.450	0.425	0.425	300	300	9.3	0.006
2009 5 23	2 OCC 3 P		0 34 57.		0 37 47.	0 38 39.		0 40 37.		0.130	0.201	0.193	340	337	0.3	0.511
2009 5 23	2 OCC 1 A		11 46 43.		11 48 42.	11 48 59.		11 50 41.		0.402	0.426	0.426	238	238	5.5	0.038
2009 5 24	1 OCC 2 P		18 34 59.		18 37 31.	18 38 27.		18 40 3.		0.445	0.420	0.414	304	304	9.5	0.090
2009 5 25	3 OCC 2 T		15 0 11.	15 3 17.	15 4 15.	15 3 10.	15 5 13.			0.279	0.259	0.259	489	488	12.0	0.009
2009 5 25	3 OCC 1 P		19 0 22.		19 4 38.	19 2 54.		19 8 58.		0.100	0.104	0.108	515	518	11.6	0.848
2009 5 25	3 ECL 4	21 20 51.			21 24 11.	21 24 26.			21 27 30.	0.031	0.031	0.031			2.2	1.825
2009 5 26	1 ECL 4	1 19 36.			1 23 51.	1 24 17.			1 28 6.	0.343	0.343	0.349			2.3	0.652
2009 5 26	3 OCC 1 P		8 2 42.		8 14 34.	8 15 1.		8 26 40.		0.300	0.311	0.311	1438	1431	2.9	0.291
2009 5 26	2 ECL 4	8 30 33.			8 32 5.	8 32 22.			8 33 37.	0.003	0.003	0.005			0.5	1.588
2009 5 26	3 OCC 1 P		16 53 20.		16 59 8.	17 0 57.		17 4 46.		0.072	0.075	0.070	686	669	11.8	0.939
2009 5 27	2 OCC 1 P		0 52 11.		0 54 8.	0 54 25.		0 56 6.		0.397	0.422	0.413	235	234	5.3	0.088
2009 5 28	1 OCC 2 P		7 42 12.		7 44 45.	7 45 44.		7 47 19.		0.402	0.379	0.371	307	307	9.6	0.170
2009 5 29	1 ECL 3	16 51 30.			16 51 58.	16 51 50.			16 52 25.	0.000	0.000	0.000			0.8	1.563
2009 5 30	2 OCC 3 P		3 45 30.		3 47 39.	3 48 39.		3 49 49.		0.051	0.079	0.071	259	252	1.2	0.870
2009 5 30	2 OCC 1 P		13 57 12.		13 59 7.	13 59 23.		14 1 1.		0.335	0.356	0.344	229	227	5.1	0.213
2009 5 31	1 OCC 2 P		20 48 59.		20 51 33.	20 52 33.		20 54 8.		0.357	0.337	0.329	309	308	9.8	0.245
2009 6 1	3 ECL 1	18 10 25.			18 12 58.	18 12 54.			18 15 33.	0.028	0.028	0.023			9.8	1.321
2009 6 1	3 OCC 2 P		18 17 8.		18 21 9.	18 19 50.		18 25 10.		0.254	0.236	0.239	481	482	13.0	0.421
2009 6 1	3 OCC 1 P		22 44 58.		22 51 42.	22 49 4.		22 58 41.		0.095	0.099	0.102	824	823	11.6	0.884
2009 6 2	4 ECL 2 P	1 40 12.			1 57 28.	1 59 5.		2 4 53.	2 15 38.	0.563	0.563	0.564	873	886	14.3	0.291
2009 6 2	3 OCC 1 P		6 25 14.		6 37 47.	6 39 25.		6 50 1.		0.268	0.278	0.281	1486	1477	3.1	0.400
2009 6 3	2 OCC 1 P		3 1 50.		3 3 40.	3 3 56.		3 5 29.		0.269	0.285	0.274	219	217	4.9	0.334
2009 6 3	4 ECL 1 A	3 27 36.			3 31 46.	3 32 9.		3 33 5.	3 35 55.	0.425	0.425	0.423	159	160	4.1	0.180
2009 6 3	4 ECL 2 P	22 37 34.			22 44 57.	22 45 39.		22 46 21.	22 52 15.	0.500	0.500	0.503	173	193	5.6	0.494
2009 6 4	1 OCC 2 P		9 55 46.		9 58 21.	9 59 23.		10 0 56.		0.316	0.299	0.291	310	309	10.0	0.313
2009 6 4	4 ECL 3	11 34 23.			11 41 49.	11 41 58.			11 49 15.	0.140	0.140	0.138			20.0	1.252
2009 6 6	2 OCC 3 P		6 53 28.		6 54 9.	6 55 13.		6 54 50.		0.001	0.002	0.000	82	44	1.9	1.215
2009 6 6	2 OCC 1 P		16 6 3.		16 7 46.	16 8 2.		16 9 29.		0.208	0.220	0.209	206	203	4.6	0.452

Table 4. Mutual events occurring from June 7 to July 4, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 6 7	1 OCC 2 P		23 2 5.		23 4 40.	23 5 43.		23 7 15.		0.281	0.265	0.257	310	308	10.1	0.375
2009 6 8	3 ECL 1	21 28 6.			21 32 41.	21 32 31.			21 37 19.	0.122	0.122	0.109			11.0	1.106
2009 6 8	3 OCC 2 P		21 32 21.		21 36 6.	21 34 36.		21 39 51.		0.161	0.150	0.155	450	453	13.8	0.685
2009 6 9	3 ECL 1 P	10 23 37.	10 29 19.		10 33 12.	10 34 17.		10 37 6.	10 42 57.	0.150	0.150	0.144	467	445	0.1	0.973
2009 6 9	3 ECL 1 P	19 25 58.	19 31 45.		19 33 26.	19 33 6.		19 34 45.	19 40 38.	0.190	0.190	0.193	180	178	11.5	0.952
2009 6 10	2 OCC 1 P	5 9 52.	5 9 52.		5 11 27.	5 11 43.		5 13 2.		0.153	0.163	0.152	190	187	4.4	0.566
2009 6 10	3 ECL 4 A	7 22 25.	7 27 31.		7 30 34.	7 30 51.		7 33 37.	7 38 44.	0.476	0.476	0.473	366	364	15.6	0.263
2009 6 10	2 ECL 4	14 32 20.			14 39 17.	14 39 40.			14 46 17.	0.444	0.444	0.448			7.9	0.352
2009 6 11	1 ECL 4	6 9 44.			6 13 56.	6 14 23.			6 18 8.	0.455	0.455	0.450			8.0	0.384
2009 6 11	1 OCC 2 P		12 8 26.		12 11 0.	12 12 6.		12 13 36.		0.251	0.237	0.230	310	309	10.3	0.430
2009 6 13	2 OCC 1 P		18 13 16.		18 14 41.	18 14 57.		18 16 7.		0.106	0.113	0.104	172	168	4.2	0.675
2009 6 14	1 ECL 2	23 21 43.			23 22 18.	23 22 39.			23 22 55.	0.001	0.001	0.002			10.5	1.099
2009 6 15	1 OCC 2 P		1 14 16.		1 16 51.	1 17 58.		1 19 26.		0.226	0.213	0.206	311	309	10.5	0.478
2009 6 16	3 OCC 2 P		0 46 8.		0 49 28.	0 47 50.		0 52 48.		0.088	0.082	0.087	400	407	14.3	0.908
2009 6 16	3 ECL 1 P	1 21 57.	1 27 47.		1 30 49.	1 30 23.		1 33 36.	1 40 6.	0.208	0.208	0.194	349	293	11.7	0.920
2009 6 16	3 ECL 1 P	8 35 6.	8 40 56.		8 46 54.	8 48 3.		8 52 60.	8 58 21.	0.215	0.215	0.203	724	692	5.9	0.895
2009 6 16	3 ECL 1 P	23 12 5.	23 15 29.		23 17 36.	23 17 27.		23 19 40.	23 23 1.	0.307	0.307	0.312	251	256	11.8	0.812
2009 6 17	2 OCC 1 P	7 16 16.			7 17 31.	7 17 46.		7 18 46.		0.068	0.072	0.064	150	145	4.0	0.778
2009 6 18	1 ECL 2	12 29 50.			12 31 5.	12 31 26.			12 32 18.	0.009	0.009	0.012			10.7	1.032
2009 6 18	1 OCC 2 P		14 20 11.		14 22 46.	14 23 56.		14 25 23.		0.206	0.195	0.188	312	310	10.6	0.519
2009 6 19	4 ECL 2	5 7 25.			5 12 36.	5 13 12.		5 17 48.	5 17 48.	0.525	0.525	0.521	25	25	5.3	0.504
2009 6 19	4 ECL 1	8 29 28.			8 33 51.	8 34 18.		8 38 16.	8 38 16.	0.354	0.354	0.348			7.2	0.904
2009 6 19	4 ECL 3	23 16 4.			23 22 51.	23 22 49.		23 29 38.	23 29 38.	0.545	0.545	0.545			2.6	0.219
2009 6 20	4 ECL 1 P	4 53 9.	5 4 21.		5 11 29.	5 10 37.		5 18 54.	5 32 21.	0.491	0.491	0.483	873	842	6.5	0.535
2009 6 20	4 ECL 1 P	9 18 3.	9 30 57.		9 37 58.	9 39 7.		9 44 28.	9 55 9.	0.524	0.524	0.519	811	785	11.1	0.424
2009 6 22	1 ECL 2	1 38 13.			1 39 52.	1 40 14.			1 41 34.	0.026	0.026	0.031			10.9	0.966
2009 6 22	1 OCC 2 P		3 25 34.		3 28 11.	3 29 22.		3 30 49.		0.191	0.180	0.174	315	312	10.7	0.553
2009 6 23	3 OCC 2 P		3 57 53.		4 0 41.	3 59 0.		4 3 30.		0.041	0.039	0.043	336	349	14.5	1.085
2009 6 24	3 ECL 1 P	2 28 25.	2 30 56.		2 33 16.	2 33 10.		2 35 37.	2 38 4.	0.466	0.466	0.471	281	283	11.4	0.643
2009 6 25	1 ECL 2	14 47 10.			14 49 9.	14 49 32.			14 51 11.	0.052	0.052	0.059			11.0	0.903
2009 6 25	1 OCC 2 P		16 31 4.		16 33 43.	16 34 56.		16 36 23.		0.180	0.170	0.164	319	317	10.9	0.579
2009 6 27	1 ECL 3 P	3 39 19.	3 41 19.		3 42 30.	3 42 21.		3 43 42.	3 45 40.	0.256	0.256	0.252	144	141	4.4	0.647
2009 6 27	2 ECL 4	22 12 54.			22 17 44.	22 18 2.			22 22 35.	0.519	0.519	0.525			8.7	0.245
2009 6 29	1 ECL 2	3 56 11.			3 58 29.	3 58 51.			4 0 47.	0.087	0.087	0.095			11.2	0.842
2009 6 29	1 OCC 2 P		5 36 2.		5 38 45.	5 39 59.		5 41 28.		0.173	0.163	0.157	325	323	11.0	0.598
2009 6 29	3 ECL 4 A	14 51 37.	14 56 57.		15 1 5.	15 1 31.		15 5 12.	15 10 30.	0.490	0.490	0.489	494	493	6.5	0.189
2009 6 30	3 OCC 2 P	7 8 23.	7 8 23.		7 10 38.	7 8 57.		7 12 52.		0.017	0.016	0.020	269	290	14.5	1.215
2009 7 1	3 ECL 1 P	5 32 5.	5 34 10.		5 36 34.	5 36 30.		5 38 56.	5 41 1.	0.613	0.613	0.615	286	287	10.6	0.450
2009 7 2	1 ECL 2	17 5 51.			17 8 24.	17 8 48.			17 10 59.	0.122	0.122	0.127			11.3	0.785
2009 7 2	1 OCC 2 P	18 41 12.			18 43 59.	18 45 16.		18 46 47.		0.170	0.161	0.155	334	332	11.1	0.609
2009 7 4	1 ECL 3 A	6 22 54.	6 24 40.		6 26 21.	6 26 12.		6 28 1.	6 29 48.	0.337	0.337	0.332	201	199	5.6	0.421

Table 5. Mutual events occurring from July 5 to July 29, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 7 5	4 ECL 3	9 18 53.			9 23 34.	9 23 40.			9 28 15.	0 042	0 042	0 039			14 8	1 631
2009 7 6	1 ECL 2 P	6 15 35.	6 17 47.		6 18 24.	6 18 47.		6 18 56.	6 21 13.	0 144	0 144	0 151	69	87	11 5	0 730
2009 7 6	1 OCC 2 P		7 45 52.		7 48 44.	7 50 3.		7 51 38.		0 171	0 162	0 156	345	343	11 2	0 613
2009 7 6	4 ECL 1	17 36 56.			17 39 17.	17 39 42.			17 41 39.	0 054	0 054	0 049			4 9	1 437
2009 7 7	3 ECL 2	7 13 3.			7 15 31.	7 15 32.			7 18 2.	0 018	0 018	0 014			14 1	1 304
2009 7 7	3 OCC 2 P		10 16 56.		10 18 44.	10 17 8.		10 20 32.		0 007	0 007	0 010	216	248	14 2	1 296
2009 7 8	3 ECL 1 P	8 28 2.	8 29 53.		8 32 14.	8 32 12.		8 34 36.	8 36 26.	0 686	0 686	0 687	283	283	9 6	0 240
2009 7 8	2 ECL 1	12 10 19.			12 11 0.	12 11 6.			12 11 42.	0 004	0 004	0 005			4 8	1 131
2009 7 9	1 ECL 2 P	19 26 4.	19 27 55.		19 29 6.	19 29 31.		19 30 11.	19 32 10.	0 180	0 180	0 190	136	146	11 6	0 679
2009 7 9	1 OCC 2 P		20 50 51.		20 53 51.	20 55 12.		20 56 51.		0 177	0 167	0 161	360	358	11 3	0 608
2009 7 11	1 ECL 3 A	9 8 12.	9 9 54.		9 11 53.	9 11 43.		9 13 51.	9 15 34.	0 440	0 440	0 436	237	236	6 8	0 204
2009 7 12	2 ECL 1	1 15 52.			1 16 60.	1 17 6.			1 18 7.	0 018	0 018	0 021			4 4	1 044
2009 7 13	1 ECL 2 P	8 36 34.	8 38 19.		8 39 53.	8 40 18.		8 41 20.	8 43 10.	0 223	0 223	0 235	181	189	11 7	0 630
2009 7 13	1 OCC 2 P		9 55 19.		9 58 26.	9 59 49.		10 1 35.		0 185	0 174	0 169	377	375	11 4	0 596
2009 7 14	3 ECL 2	10 43 0.			10 47 32.	10 47 32.		13 27 48.	10 52 3.	0 150	0 150	0 134			14 2	1 046
2009 7 14	3 OCC 2 P		13 24 16.		13 26 2.	13 24 34.				0 005	0 005	0 009	213	253	13 7	1 329
2009 7 15	3 ECL 4	2 20 18.			2 25 21.	2 25 32.			2 30 22.	0 167	0 167	0 165			6 7	1 404
2009 7 15	2 ECL 4	7 30 59.			7 35 32.	7 35 51.			7 40 6.	0 357	0 357	0 346			5 3	0 620
2009 7 15	3 ECL 1 A	11 19 16.	11 21 0.		11 23 14.	11 23 13.		11 25 28.	11 27 12.	0 598	0 598	0 598	268	268	8 4	0 015
2009 7 15	2 ECL 1	14 21 38.			14 23 2.	14 23 8.			14 24 26.	0 044	0 044	0 049			4 0	0 958
2009 7 16	1 ECL 2 P	21 48 2.	21 49 41.		21 51 34.	21 51 59.		21 53 24.	21 55 5.	0 268	0 268	0 280	222	229	11 8	0 586
2009 7 16	1 OCC 2 P		23 0 15.		23 3 33.	23 4 59.		23 6 53.		0 197	0 186	0 181	398	396	11 5	0 576
2009 7 18	1 ECL 3 A	11 55 25.	11 57 8.		11 59 18.	11 59 7.		12 1 29.	12 3 12.	0 478	0 478	0 478	261	260	7 9	0 001
2009 7 19	2 ECL 1	3 27 25.			3 29 2.	3 29 8.			3 30 38.	0 083	0 083	0 090			3 7	0 870
2009 7 20	1 ECL 2 P	10 59 37.	11 1 13.		11 3 22.	11 3 48.		11 5 29.	11 7 4.	0 312	0 312	0 325	256	262	11 9	0 544
2009 7 20	1 OCC 2 P		12 4 45.		12 8 14.	12 9 41.		12 11 45.	12 11 45.	0 212	0 201	0 195	421	419	11 5	0 549
2009 7 21	3 ECL 2 P	14 17 28.	14 21 19.		14 23 23.	14 23 21.		14 25 30.	14 29 22.	0 322	0 322	0 302	250	223	13 9	0 795
2009 7 21	3 OCC 2 P		16 30 55.		16 33 13.	16 31 58.		16 35 32.		0 010	0 009	0 013	277	315	13 0	1 318
2009 7 22	3 ECL 1 P	14 7 24.	14 9 8.		14 11 8.	14 11 7.		14 13 9.	14 14 52.	0 662	0 662	0 662	241	241	7 0	0 220
2009 7 22	2 ECL 1	16 33 16.			16 35 3.	16 35 10.			16 36 50.	0 135	0 135	0 144			3 3	0 783
2009 7 23	4 ECL 2	23 8 2.			23 11 56.	23 12 35.			23 15 52.	0 157	0 157	0 139			12 1	1 205
2009 7 24	1 ECL 2 P	0 12 20.	0 13 54.		0 16 19.	0 16 46.		0 18 43.	0 20 16.	0 354	0 354	0 367	289	294	11 9	0 507
2009 7 24	1 OCC 2 P		1 9 56.		1 13 39.	1 15 9.		1 17 24.		0 232	0 219	0 214	448	446	11 6	0 514
2009 7 24	4 ECL 3	17 1 4.			17 9 17.	17 9 21.			17 17 30.	0 276	0 276	0 277			10 1	0 972
2009 7 25	1 ECL 3 A	14 45 45.	14 47 32.		14 49 51.	14 49 38.		14 52 10.		0 435	0 435	0 440	278	279	8 9	0 184
2009 7 26	2 ECL 1	5 39 9.			5 41 4.	5 41 10.			5 42 58.	0 181	0 181	0 187			2 9	0 695
2009 7 27	1 ECL 2 P	13 25 14.	13 26 48.		13 29 27.	13 29 55.		13 32 5.	13 33 41.	0 393	0 393	0 406	317	322	12 0	0 474
2009 7 27	1 OCC 2 P		14 14 44.		14 18 41.	14 20 13.		14 22 41.		0 254	0 240	0 235	477	476	11 6	0 474
2009 7 28	3 ECL 2 P	17 57 24.	18 0 33.		18 4 40.	18 4 36.		18 8 50.	18 11 60.	0 594	0 594	0 570	497	484	13 0	0 550
2009 7 28	3 OCC 2 P		19 38 35.		19 41 49.	19 40 50.		19 45 3.		0 021	0 020	0 025	388	422	12 0	1 268
2009 7 29	3 ECL 1 P	16 53 33.	16 55 22.		16 57 1.	16 57 0.		16 58 39.	17 0 28.	0 579	0 579	0 579	197	197	5 5	0 462

Table 6. Mutual events occurring from July 31 to August 25, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 7 31	1 ECL 2 P	2 39 34.	2 41 8.		2 44 3.	2 44 31.		2 46 58.	2 48 34.	0 42 7	0 42 7	0 44 1	3 50	3 55	12 0	0 44 6
2009 7 31	1 OCC 2 P	17 39 45.	3 20 30.		3 24 44.	3 26 18.		3 29 1.		0 28 1	0 26 5	0 26 0	5 12	5 11	11 7	0 42 6
2009 8 1	1 ECL 3 A	15 54 13.	17 41 41.		17 44 7.	17 43 51.		17 46 31.	17 48 29.	0 35 6	0 35 6	0 36 3	2 90	2 92	9 8	0 34 6
2009 8 3	1 ECL 2 P	15 55 51.	15 55 51.		15 59 2.	15 59 32.		16 2 16.	16 3 53.	0 45 7	0 45 7	0 47 1	3 85	3 89	12 0	0 42 3
2009 8 3	1 OCC 2 P	21 45 19.	16 26 2.		16 30 35.	16 32 12.		16 35 11.		0 31 0	0 29 3	0 28 8	5 49	5 48	11 7	0 37 3
2009 8 4	3 ECL 2 P	21 48 19.	21 48 19.		21 53 59.	21 53 51.		21 59 42.	22 2 44.	0 79 2	0 79 2	0 77 8	6 83	6 75	11 7	0 31 0
2009 8 4	3 OCC 2 P	19 38 38.	22 49 42.		22 54 6.	22 53 29.		22 58 32.		0 04 1	0 03 8	0 04 5	5 30	5 61	10 9	1 18 7
2009 8 5	3 ECL 1 P	5 10 48.	19 40 45.		19 41 47.	19 41 47.		19 42 50.	19 44 56.	0 41 8	0 41 8	0 41 9	1 25	1 25	3 9	0 70 7
2009 8 7	1 ECL 2 P	5 12 25.	5 12 25.		5 15 59.	5 16 30.		5 19 33.	5 21 13.	0 48 0	0 48 0	0 49 3	4 28	4 32	11 9	0 40 6
2009 8 7	1 OCC 2 P	20 39 40.	5 32 55.		5 37 49.	5 39 29.		5 42 47.		0 34 3	0 32 4	0 31 9	5 92	5 92	11 7	0 31 1
2009 8 8	1 ECL 3 A	18 29 49.	20 41 50.		20 44 25.	20 44 5.		20 47 2.	20 49 12.	0 30 2	0 30 2	0 30 6	3 11	3 12	10 6	0 47 7
2009 8 10	1 ECL 2 P	18 28 9.	18 29 49.		18 33 45.	18 34 17.		18 37 42.	18 39 25.	0 50 8	0 50 8	0 52 2	4 73	4 78	11 9	0 39 4
2009 8 10	1 OCC 2 P	18 39 51.	18 39 51.		18 45 7.	18 46 50.		18 50 30.		0 37 8	0 35 7	0 35 2	6 39	6 40	11 7	0 24 7
2009 8 12	3 ECL 2 T	1 43 56.	1 47 3.	1 53 50.	1 54 14.	1 54 2.	1 54 39.		2 4 42.	1 00 0	1 00 0	0 99 6	8 69	8 65	9 8	0 07 3
2009 8 12	3 OCC 2 P	22 22 41.	2 5 60.		2 11 48.	2 11 39.		2 17 41.	22 28 14.	0 06 7	0 06 3	0 07 1	7 01	7 31	9 5	1 08 8
2009 8 14	1 ECL 2 P	7 48 9.	7 49 54.		7 54 17.	7 54 51.		7 58 42.	8 0 31.	0 28 0	0 28 0	0 28 2	5 28	5 33	11 7	0 39 0
2009 8 14	1 OCC 2 P	21 49 41.	7 48 34.		7 54 19.	7 56 6.		8 0 10.		0 51 4	0 51 4	0 52 8	6 96	6 98	11 7	0 17 5
2009 8 14	1 OCC 2 P	0 27 54.	21 49 41.		21 58 32.	21 59 11.		22 8 18.		0 00 6	0 00 6	0 00 9	1 116	1 30 7	6 6	1 10 2
2009 8 15	1 OCC 2 P	23 49 6.	0 27 54.		0 49 4.	0 47 16.		1 5 38.		0 09 1	0 08 6	0 09 0	2 264	2 33 9	10 1	0 82 7
2009 8 15	1 ECL 2	16 24 9.	23 51 39.		0 48 35.	0 50 6.		23 57 33.		0 0 0	0 0 0	0 00 0	0 0	0 0	11 7	1 0
2009 8 15	1 ECL 3 P	16 29 34.	16 29 34.		23 54 35.	23 54 9.		17 4 57.	17 12 12.	0 27 6	0 27 6	0 28 2	3 55	3 59	11 1	0 57 1
2009 8 16	1 ECL 3 A	20 17 57.	16 53 0.		16 46 11.	16 49 36.		17 28 15.		0 43 8	0 43 8	0 43 6	2 123	2 16 9	7 0	0 17 8
2009 8 16	1 OCC 3 P	20 25 49.	20 17 57.		17 9 16.	17 17 18.		20 26 54.		0 05 2	0 07 9	0 07 5	2 115	2 27 4	7 8	1 09 8
2009 8 16	1 OCC 3 P	21 9 45.	20 33 53.		20 22 32.	20 13 31.		21 0 54.	21 6 52.	0 00 1	0 00 2	0 00 3	5 37	7 16	10 8	1 49 2
2009 8 16	1 ECL 3 A	20 57 46.	20 33 53.		20 48 17.	20 45 56.		21 10 26.		0 33 4	0 33 4	0 33 3	1 622	1 66 2	11 1	0 42 9
2009 8 17	1 OCC 2 P	14 27 31.	20 57 46.		21 4 2.	21 5 53.		21 21 32.	21 23 29.	0 44 8	0 42 3	0 42 0	7 60	7 62	11 6	0 10 0
2009 8 17	1 ECL 2 P	5 32 36.	14 27 31.		14 39 7.	14 37 59.		14 49 48.		0 51 1	0 51 1	0 52 5	5 94	6 01	11 6	0 39 4
2009 8 18	1 ECL 2	6 1 25.	5 32 36.		14 59 48.	15 0 41.		15 6 26.	15 6 26.	0 13 5	0 12 7	0 13 2	1 337	1 35 8	10 8	0 72 5
2009 8 18	3 OCC 2 P	17 43 46.	6 5 0.		5 40 13.	5 40 39.		5 47 57.		0 02 9	0 02 9	0 03 5	9 21	9 52	7 9	0 98 6
2009 8 19	3 ECL 2 P	10 9 41.	10 16 5.		6 14 8.	6 13 49.		6 23 27.	6 27 9.	0 09 7	0 09 0	0 09 9	1 107	1 11 0	7 4	0 16 9
2009 8 20	3 ECL 2	4 36 56.	4 1 36.		17 53 31.	17 52 50.		18 3 3.	18 3 3.	0 05 1	0 05 1	0 04 5	8 42	8 46	5 1	1 12 4
2009 8 21	1 OCC 2 T	3 17 3.	10 37 53.		10 16 36.	10 18 33.	10 17 7.	10 23 43.		0 45 0	0 42 5	0 42 5	6 87	6 94	11 3	0 00 3
2009 8 21	1 ECL 2 P	1 23 28.	1 27 24.		10 43 34.	10 44 13.		10 49 20.	10 51 31.	0 49 1	0 49 1	0 50 5	1 046	1 05 8	11 2	0 66 2
2009 8 22	1 OCC 2 P	23 22 56.	23 22 56.		4 10 32.	4 9 32.		4 19 2.		0 16 3	0 15 4	0 15 9	2 28	2 69	11 5	0 79 1
2009 8 22	1 ECL 2 P	0 8 20.	0 8 20.		4 43 31.	4 44 12.		4 45 19.	4 50 1.	0 07 9	0 07 9	0 08 6	4 83	4 89	11 3	0 60 9
2009 8 23	1 ECL 3 P	23 30 18.	23 30 18.		3 24 12.	3 23 30.		3 28 17.	3 31 29.	0 25 5	0 25 5	0 26 2	3 46	3 42	12 2	0 80 8
2009 8 24	1 ECL 3 P	0 5 58.	0 5 58.		1 30 19.	1 29 38.		1 33 10.	1 36 59.	0 15 9	0 15 9	0 15 6	9 41	9 47	11 5	0 00 3
2009 8 24	1 OCC 2 T	0 15 3.	0 15 3.		23 30 38.	23 32 43.	23 30 58.	23 38 37.		0 45 0	0 42 5	0 42 5	8 20	8 31	10 9	0 44 0
2009 8 25	1 ECL 2 P	0 15 49.	0 15 49.		0 15 3.	0 15 49.		0 21 60.	0 24 33.	0 45 4	0 45 4	0 46 8	8 20	8 31	10 9	0 44 0

Table 7. Mutual events occurring from August 25 to September 20, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 8 25	1 OCC 2 P		17 24 12.		17 31 46.	17 30 54.		17 39 4.		0.180	0.170	0.175	892	901	11.4	0.625
2009 8 25	1 ECL 2 P	18 8 48.	18 11 49.		18 15 6.	18 15 42.		18 18 25.	18 21 20.	0.153	0.153	0.163	396	412	11.9	0.700
2009 8 26	3 OCC 2 P		9 15 24.		9 25 39.	9 26 55.		9 36 10.		0.122	0.113	0.123	1246	1283	6.0	0.903
2009 8 26	3 ECL 2 P	10 55 22.	1 1 0 19.		11 13 2.	11 12 29.		11 26 17.	11 31 39.	0.762	0.762	0.786	1558	1577	4.5	0.435
2009 8 27	3 ECL 2	0 58 23.			1 3 36.	1 4 55.			1 8 37.	0.001	0.001	0.004			0.3	1.230
2009 8 27	3 ECL 2	22 43 5.			22 49 49.	22 49 27.			22 56 32.	0.055	0.055	0.047			8.0	1.134
2009 8 28	1 OCC 2 P		12 40 49.		12 49 40.	12 51 55.		12 58 56.		0.417	0.394	0.398	1087	1096	11.2	0.170
2009 8 28	1 ECL 2 P	13 46 53.	13 49 55.		13 58 36.	13 59 32.		14 7 51.	14 11 17.	0.383	0.383	0.396	1075	1095	10.3	0.496
2009 8 29	1 OCC 2 P		6 43 26.		6 50 3.	6 49 15.		6 56 30.		0.193	0.182	0.187	784	791	11.6	0.597
2009 8 29	1 ECL 2 P	7 36 18.	7 38 40.		7 42 19.	7 42 53.		7 46 0.	7 48 18.	0.245	0.245	0.256	440	449	12.1	0.611
2009 8 30	1 OCC 3 P	7 43 26.	7 49 18.		5 46 38.	5 48 8.		5 49 60.		0.009	0.015	0.018	401	433	11.7	1.378
2009 8 30	1 ECL 3 P	12 3 32.	12 10 2.		8 0 5.	7 57 59.		8 12 2.	8 19 20.	0.290	0.290	0.296	1365	1348	10.2	0.534
2009 8 30	1 ECL 3 A		14 24 19.		12 26 40.	12 29 47.		12 41 51.	12 47 2.	0.395	0.395	0.400	1909	1885	5.3	0.288
2009 8 30	1 OCC 3 P				14 35 16.	14 36 55.		14 46 4.		0.144	0.222	0.225	1304	1315	2.2	0.632
2009 8 31	1 ECL 3	4 58 2.			5 1 59.	5 1 33.			5 5 54.	0.058	0.058	0.056			11.9	1.132
2009 9 1	1 OCC 2 P		2 2 19.		2 12 49.	2 15 23.		2 24 2.		0.360	0.340	0.344	1303	1320	10.9	0.277
2009 9 1	1 ECL 2 P	3 48 47.	3 54 27.		4 8 53.	4 10 39.		4 27 7.	4 35 55.	0.251	0.251	0.262	1959	2069	9.1	0.606
2009 9 1	1 ECL 2	6 45 13.			7 2 25.	7 0 43.			7 15 52.	0.023	0.023	0.029			5.4	0.890
2009 9 1	1 OCC 2 P		8 49 53.		8 51 31.	8 50 20.		8 53 9.		0.000	0.000	0.002	196	414	2.7	1.136
2009 9 1	1 OCC 2 P		19 58 8.		20 4 6.	20 3 22.		20 9 55.		0.199	0.188	0.192	707	713	11.7	0.583
2009 9 1	1 ECL 2 P	20 58 56.	21 0 57.		21 4 44.	21 5 16.		21 8 26.	21 10 24.	0.337	0.337	0.349	449	460	12.2	0.526
2009 9 2	3 OCC 2 P		13 35 6.		13 50 56.	13 53 38.		14 7 42.		0.128	0.119	0.128	1955	2020	3.7	0.876
2009 9 4	3 ECL 2	3 2 49.			3 7 45.	3 7 32.			3 12 38.	0.036	0.036	0.029			10.2	1.189
2009 9 4	1 OCC 2 P		15 35 1.		15 48 53.	15 52 8.		16 4 34.		0.286	0.270	0.273	1774	1815	10.3	0.413
2009 9 4	1 OCC 2 P		20 24 14.		20 32 26.	20 30 34.		20 40 20.		0.015	0.014	0.019	966	1082	4.5	1.043
2009 9 5	1 OCC 2 P		9 11 57.		9 17 22.	9 16 40.		9 22 41.		0.202	0.191	0.196	644	649	11.8	0.574
2009 9 5	1 ECL 2 P	10 19 59.	10 21 45.		10 25 32.	10 26 2.		10 29 16.	10 31 1.	0.443	0.443	0.455	451	455	12.3	0.439
2009 9 6	1 OCC 3 P		10 2 38.		10 27 4.	10 29 45.		12 58 40.		0.094	0.145	0.152	10562	10488	7.7	0.859
2009 9 7	1 ECL 3	8 11 53.			8 13 21.	8 13 2.			8 14 54.	0.003	0.003	0.002			11.3	1.446
2009 9 8	1 OCC 2 P		5 30 18.		5 57 60.	6 5 18.		5 30 17.		0.175	0.165	0.164	0	8892	9.9	0.625
2009 9 8	1 OCC 2 P		22 23 13.		22 28 13.	22 27 33.		22 33 7.		0.201	0.190	0.195	594	599	11.8	0.572
2009 9 8	1 ECL 2 P	23 38 12.	23 39 49.		23 43 33.	23 44 2.		23 47 15.	23 48 50.	0.549	0.549	0.561	447	449	12.3	0.354
2009 9 11	3 ECL 2	7 4 38.			7 7 53.	7 7 44.			7 11 5.	0.013	0.013	0.009			12.0	1.277
2009 9 12	1 OCC 2 P		11 34 25.		11 39 2.	11 38 24.		11 43 35.		0.199	0.188	0.193	550	555	11.8	0.572
2009 9 12	1 ECL 2 P	12 55 43.	12 57 13.		13 0 51.	13 1 18.		13 4 29.	13 5 58.	0.653	0.653	0.664	436	438	12.3	0.267
2009 9 16	1 OCC 2 P		0 43 58.		0 48 16.	0 47 41.		0 52 32.		0.195	0.184	0.189	514	518	11.8	0.577
2009 9 16	1 ECL 2 P	2 11 19.	2 12 44.		2 16 16.	2 16 43.		2 19 48.	2 21 12.	0.734	0.734	0.741	424	425	12.3	0.181
2009 9 18	3 ECL 2	10 57 22.			10 57 29.	10 57 33.			10 58 2.	0.000	0.000	0.0		0	13.2	1.392
2009 9 19	1 OCC 2 P		13 53 44.		13 57 46.	13 57 12.		14 1 45.		0.190	0.179	0.184	481	485	11.8	0.583
2009 9 19	1 ECL 2 P	15 26 34.	15 27 55.		15 31 18.	15 31 44.		15 34 42.	15 36 0.	0.768	0.768	0.769	407	408	12.3	0.092
2009 9 20	2 ECL 1	23 18 43.			23 20 38.	23 20 46.			23 22 33.	0.181	0.181	0.175			3.5	0.698

Table 8. Mutual events occurring from September 21 to October 25, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 9 21	2 OCC 3 P		0 47 59.		0 50 36.	0 49 21.		0 53 14.		0 141	0 219	0 217	315	313	1 8	0 530
2009 9 23	1 OCC 2 P		3 2 25.		3 6 12.	3 5 40.		3 9 57.		0 183	0 173	0 178	452	456	11 7	0 590
2009 9 24	1 ECL 2 A	4 40 25.	4 41 45.		4 44 58.	4 45 23.		4 48 10.	4 49 28.	0 742	0 742	0 742	385	385	12 2	0 004
2009 9 24	2 ECL 1	12 25 22.			12 27 9.	12 27 17.			12 28 57.	0 140	0 140	0 131			3 9	0 779
2009 9 25	3 OCC 2 P		11 8 51.		11 11 12.	11 12 16.		11 13 32.		0 009	0 008	0 006	281	258	12 4	1 278
2009 9 26	1 OCC 2 P		16 11 30.		16 15 4.	16 14 33.		16 18 36.		0 177	0 167	0 172	426	430	11 7	0 597
2009 9 26	1 ECL 2 P	17 54 6.	17 55 25.		17 58 27.	17 58 51.		18 1 27.	18 2 45.	0 752	0 752	0 751	363	362	12 1	0 086
2009 9 28	2 ECL 1	1 32 6.			1 33 44.	1 33 52.			1 35 23.	0 090	0 090	0 083			4 2	0 860
2009 9 28	2 OCC 3 A		3 39 33.		3 42 21.	3 40 55.		3 45 9.		0 168	0 261	0 261	336	335	2 2	0 277
2009 9 28	1 OCC 3 P		14 39 0.		14 39 13.	14 38 4.		14 39 25.		0 000	0 000	0 000	24	36	8 7	1 425
2009 9 30	1 OCC 2 P		5 19 51.		5 23 13.	5 22 44.		5 26 34.		0 171	0 161	0 166	403	407	11 6	0 604
2009 9 30	1 ECL 2 P	7 6 44.	7 8 3.		7 10 52.	7 11 16.		7 13 41.	7 14 58.	0 715	0 715	0 709	338	336	12 0	0 177
2009 10 1	2 ECL 1	14 38 53.			14 40 20.	14 40 28.			14 41 49.	0 053	0 053	0 047			4 6	0 940
2009 10 1	3 OCC 1				15 16 42.	15 16 2.				0 0	0 0	0 000	0	40	5 5	1 4
2009 10 2	3 OCC 2 P		14 28 7.		14 31 39.	14 32 59.		14 35 11.		0 041	0 038	0 035	425	414	13 4	1 101
2009 10 3	1 OCC 2 P		18 28 40.		18 31 52.	18 31 24.		18 35 2.		0 165	0 156	0 161	383	386	11 5	0 608
2009 10 3	1 ECL 2 P	20 19 19.	20 20 38.		20 23 13.	20 23 36.		20 25 47.	20 27 6.	0 635	0 635	0 625	309	307	11 9	0 270
2009 10 5	2 ECL 1	3 45 47.			3 47 2.	3 47 9.			3 48 16.	0 026	0 026	0 022			4 9	1 018
2009 10 5	2 OCC 3 A		6 34 33.		6 37 26.	6 35 52.		6 40 18.		0 168	0 261	0 261	345	344	2 6	0 066
2009 10 5	1 OCC 3 P		17 16 8.		17 17 14.	17 16 17.		17 18 20.		0 006	0 009	0 010	132	136	7 7	1 311
2009 10 7	1 OCC 2 P		7 36 54.		7 39 57.	7 39 31.		7 42 59.		0 160	0 151	0 156	365	368	11 4	0 612
2009 10 7	1 ECL 2 P	9 30 60.	9 32 22.		9 34 40.	9 35 3.		9 36 59.	9 38 20.	0 530	0 530	0 518	277	274	11 7	0 362
2009 10 8	2 ECL 1	16 52 50.			16 53 45.	16 53 52.			16 54 39.	0 009	0 009	0 007			5 2	1 095
2009 10 8	3 OCC 1 P		17 50 23.		17 51 53.	17 51 6.		17 53 22.		0 026	0 027	0 030	179	184	6 7	1 202
2009 10 9	3 OCC 2 P		17 48 15.		17 52 17.	17 53 49.		17 56 17.		0 083	0 077	0 072	482	475	14 0	0 937
2009 10 10	1 OCC 2 P		20 45 41.		20 48 36.	20 48 11.		20 51 30.		0 157	0 148	0 153	349	352	11 3	0 612
2009 10 10	1 ECL 2 P	22 42 43.	22 44 9.		22 46 7.	22 46 30.		22 48 7.	22 49 33.	0 418	0 418	0 406	238	235	11 6	0 457
2009 10 12	2 ECL 1	6 0 4.			6 0 31.	6 0 38.			6 0 57.	0 001	0 001	0 000			5 5	1 171
2009 10 12	2 OCC 3 A		9 33 14.		9 36 7.	9 34 26.		9 39 1.		0 168	0 261	0 261	347	346	2 8	0 095
2009 10 14	1 OCC 2 P		9 54 4.		9 56 52.	9 56 28.		9 59 39.		0 155	0 146	0 151	335	338	11 2	0 610
2009 10 14	1 ECL 2 P	11 53 42.	11 55 13.		11 56 51.	11 57 14.		11 58 28.	12 0 1.	0 311	0 311	0 301	196	191	11 5	0 553
2009 10 15	3 OCC 1 P		20 29 22.		20 31 27.	20 30 33.		20 33 31.		0 065	0 067	0 071	250	254	7 8	1 022
2009 10 16	3 OCC 2 P		21 8 51.		21 13 4.	21 14 41.		21 17 15.		0 124	0 115	0 110	504	498	14 4	0 796
2009 10 17	1 OCC 2 P		23 2 60.		23 5 42.	23 5 19.		23 8 23.		0 155	0 146	0 151	324	327	11 1	0 603
2009 10 18	1 ECL 2 P	1 4 43.	1 6 32.		1 7 38.	1 7 59.		1 8 44.	1 10 30.	0 215	0 215	0 206	131	124	11 3	0 650
2009 10 19	2 OCC 3 A		12 35 53.		12 38 46.	12 37 1.		12 41 39.		0 168	0 261	0 261	346	346	2 9	0 203
2009 10 21	1 OCC 2 P		12 11 36.		12 14 14.	12 13 53.		12 16 50.		0 156	0 148	0 152	314	317	11 0	0 593
2009 10 21	1 ECL 2	14 15 11.			14 17 46.	14 18 8.			14 20 20.	0 148	0 148	0 144			11 1	0 747
2009 10 22	3 OCC 1 P		23 14 10.		23 16 43.	23 15 41.		23 19 17.		0 102	0 105	0 110	307	310	8 9	0 877
2009 10 24	3 OCC 2 P		0 30 41.		0 34 55.	0 36 33.		0 39 7.		0 160	0 149	0 143	506	501	14 5	0 682
2009 10 25	1 OCC 2 P		1 20 45.		1 23 19.	1 22 59.		1 25 51.		0 160	0 152	0 156	306	309	10 8	0 579

Table 9. Mutual events occurring from October 25 to November 28, 2009.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 10 25	1 ECL 2	3 25 42.			3 27 56.	3 28 18.			3 30 9.	0.093	0.093	0.086				0.847
2009 10 26	2 OCC 3 A		15 42 8.		15 45 1.	15 43 15.		15 47 54.		0.168	0.261	0.261	346	346	346	2.8
2009 10 28	1 OCC 2 P		14 29 41.		14 32 11.	14 31 53.		14 34 41.		0.167	0.158	0.162	300	303	303	10.7
2009 10 28	1 ECL 2	16 35 48.			16 37 36.	16 37 57.			16 39 22.	0.039	0.039	0.035				10.8
2009 10 30	3 OCC 1 P		2 6 8.		2 9 11.	2 7 60.		2 12 14.		0.133	0.138	0.144	367	370	370	9.9
2009 10 30	3 ECL 1	20 9 38.			20 15 41.	20 17 5.			20 21 27.	0.013	0.013	0.012				5.9
2009 10 31	3 OCC 2 P		3 54 9.		3 58 17.	3 59 51.		4 2 25.		0.186	0.172	0.166	496	491	491	14.3
2009 11 1	1 OCC 2 P		3 39 7.		3 41 36.	3 41 18.		3 44 3.	5 48 29.	0.177	0.167	0.172	296	298	298	10.5
2009 11 1	1 ECL 2	5 46 8.			5 47 18.	5 47 38.				0.009	0.009	0.007				10.6
2009 11 2	2 OCC 3 A		18 52 15.		18 55 11.	18 53 25.		18 58 6.		0.168	0.261	0.261	350	350	350	2.5
2009 11 3	1 OCC 3 P		3 56 35.		3 57 39.	3 57 39.		3 59 21.		0.020	0.030	0.032	166	170	2.9	1.097
2009 11 4	1 OCC 2 P		16 48 25.		16 50 52.	16 50 35.		16 53 18.		0.189	0.179	0.184	293	295	10.4	0.509
2009 11 5	2 OCC 1 P		23 51 16.		23 53 10.	23 52 56.		23 55 4.		0.394	0.419	0.424	228	228	4.4	0.095
2009 11 6	3 OCC 1 P		5 8 7.		5 11 48.	5 10 25.		5 15 32.		0.160	0.165	0.171	445	447	10.9	0.676
2009 11 6	3 ECL 1	18 27 45.			18 32 37.	18 33 51.			18 37 44.	0.010	0.010	0.010			0.1	1.298
2009 11 7	3 OCC 2 P		7 19 22.		7 23 21.	7 24 47.		7 27 19.		0.198	0.184	0.178	477	472	13.8	0.556
2009 11 8	1 OCC 2 P		5 58 8.		6 0 34.	6 0 19.		6 2 59.		0.206	0.195	0.199	291	293	10.2	0.475
2009 11 9	2 OCC 1 P		12 58 3.		12 59 58.	12 59 43.		13 1 53.		0.400	0.424	0.426	230	230	4.7	0.079
2009 11 9	2 OCC 3 A		22 5 31.		22 8 30.	22 6 49.		22 11 29.		0.168	0.261	0.261	358	358	2.0	0.212
2009 11 11	1 OCC 2 P		19 7 47.		19 10 12.	19 9 58.		19 12 37.		0.226	0.214	0.219	290	292	10.0	0.437
2009 11 13	2 OCC 1 A		2 5 13.		2 7 9.	2 6 52.		2 9 5.		0.402	0.426	0.426	232	232	4.9	0.057
2009 11 13	3 OCC 1 P		8 26 15.		8 31 3.	8 29 22.		8 35 55.		0.184	0.191	0.196	581	582	11.6	0.597
2009 11 13	3 OCC 1 T		22 22 15.	22 33 4.	22 35 2.	22 35 32.	22 36 59.			0.310	0.321	0.321	1553	1546	3.5	0.004
2009 11 14	3 OCC 1 P		6 11 38.		6 20 3.	6 21 50.		6 28 7.		0.189	0.196	0.193	989	981	11.6	0.583
2009 11 14	3 OCC 2 P		10 46 42.		10 50 29.	10 51 42.		10 54 15.		0.196	0.182	0.175	453	447	12.9	0.549
2009 11 15	1 OCC 2 P		8 17 50.		8 20 15.	8 20 2.		8 22 40.		0.251	0.237	0.242	290	291	9.8	0.393
2009 11 16	2 OCC 1 A		15 12 49.		15 14 46.	15 14 29.		15 16 43.		0.402	0.426	0.426	234	234	5.2	0.029
2009 11 17	2 OCC 3 A		1 22 8.		1 25 12.	1 23 38.		1 28 16.		0.168	0.261	0.261	368	368	1.2	0.119
2009 11 18	1 OCC 2 P		21 27 51.		21 30 16.	21 30 4.		21 32 41.		0.280	0.265	0.270	290	291	9.6	0.344
2009 11 20	2 OCC 1 A		4 20 48.		4 22 47.	4 22 29.		4 24 45.		0.402	0.426	0.426	236	236	5.4	0.003
2009 11 20	3 OCC 1 P		12 17 42.		12 25 34.	12 23 8.		12 33 44.		0.218	0.226	0.231	962	957	11.7	0.499
2009 11 20	3 OCC 1 T		20 33 47.	20 44 32.	20 46 24.	20 47 58.	20 48 16.			0.310	0.321	0.321	1498	1488	2.9	0.004
2009 11 21	3 OCC 1 P		10 15 12.		10 19 23.	10 20 39.		10 23 32.		0.097	0.101	0.099	500	496	11.5	0.812
2009 11 21	3 OCC 2 P		14 15 18.		14 18 48.	14 19 46.		14 22 19.		0.177	0.164	0.156	421	415	11.8	0.583
2009 11 22	1 OCC 2 P		10 38 14.		10 40 39.	10 40 28.		10 43 3.		0.314	0.297	0.302	289	290	9.4	0.290
2009 11 23	2 OCC 1 A		17 29 13.		17 31 13.	17 30 54.		17 33 12.		0.402	0.426	0.426	238	238	5.7	0.040
2009 11 24	2 OCC 3 A		4 41 60.		4 45 8.	4 43 44.		4 48 16.		0.168	0.261	0.261	377	377	0.3	0.016
2009 11 25	1 OCC 2 P		23 48 35.		23 50 59.	23 50 49.		23 53 23.		0.353	0.333	0.338	289	290	9.2	0.230
2009 11 27	2 OCC 1 P		6 38 2.		6 40 2.	6 39 42.		6 42 2.		0.397	0.422	0.415	240	239	5.9	0.082
2009 11 28	3 OCC 1 P		13 43 32.		13 45 41.	13 46 42.		13 47 50.		0.025	0.026	0.025	258	254	10.7	1.031
2009 11 28	3 OCC 2 P		17 45 36.		17 48 46.	17 49 27.		17 51 55.		0.140	0.130	0.122	379	371	10.4	0.658

Table 10. Mutual events occurring from November 29, 2009 to April 7, 2010.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
2009 11 29	1 OCC 2 P		12 59 16.		13 1 40.	13 1 30.		13 4 3.		0 39 6	0 37 4	0 37 8	287	288	9 0	0 16 5
2009 11 30	2 OCC 1 P		19 47 13.		19 49 13.	19 48 53.		19 51 14.		0 37 4	0 39 7	0 38 8	241	240	6 2	0 12 8
2009 12 1	2 OCC 3 A		8 5 9.		8 8 18.	8 7 7.		8 11 28.		0 16 8	0 26 1	0 26 1	379	380	0 9	0 18 7
2009 12 3	1 OCC 2 P		2 9 57.		2 12 19.	2 12 11.		2 14 42.		0 43 9	0 41 5	0 41 8	285	286	8 8	0 09 5
2009 12 4	2 OCC 1 P		8 56 48.		8 58 48.	8 58 26.		9 0 49.		0 34 4	0 36 5	0 35 5	241	240	6 4	0 17 6
2009 12 5	3 OCC 2 P		21 16 58.		21 19 37.	21 20 1.		21 22 16.		0 08 6	0 08 0	0 07 2	318	308	8 9	0 77 5
2009 12 6	1 OCC 2 T		15 20 55.	15 23 6.	15 23 16.	15 23 9.	15 23 26.	15 23 37.		0 45 0	0 42 5	0 42 5	282	282	8 6	0 00 6
2009 12 7	2 OCC 1 P		22 6 43.		22 8 43.	22 8 21.		22 10 44.		0 31 0	0 32 9	0 31 9	241	239	6 7	0 22 8
2009 12 8	2 OCC 3 P		11 31 46.		11 34 50.	11 33 53.		11 37 54.		0 14 9	0 23 1	0 23 3	368	370	2 3	0 38 9
2009 12 10	1 OCC 2 T		4 31 54.	4 34 8.	4 34 12.	4 34 6.	4 34 16.	4 36 30.		0 45 0	0 42 5	0 42 5	276	276	8 4	0 00 6
2009 12 11	2 OCC 1 P		11 17 3.		11 19 2.	11 18 38.		11 21 2.		0 27 4	0 29 1	0 28 1	239	237	7 0	0 28 3
2009 12 13	3 OCC 2 P		0 49 43.		0 51 30.	0 51 37.		0 53 17.		0 02 7	0 02 5	0 01 9	214	196	7 2	0 93 4
2009 12 13	1 OCC 2 P		17 43 8.		17 45 22.	17 45 17.		17 47 36.		0 40 4	0 38 2	0 37 8	268	268	8 1	0 14 7
2009 12 15	2 OCC 1 P		0 27 43.		0 29 41.	0 29 16.		0 31 38.		0 23 7	0 25 2	0 24 1	235	233	7 2	0 33 9
2009 12 15	2 OCC 3 P		15 1 27.		15 4 13.	15 3 33.		15 6 58.		0 08 7	0 13 6	0 13 8	331	334	3 9	0 61 5
2009 12 17	1 OCC 2 P		6 54 25.		6 56 34.	6 56 29.		6 58 42.		0 33 9	0 32 0	0 31 6	257	256	7 9	0 23 7
2009 12 18	2 OCC 1 P		13 38 46.		13 40 41.	13 40 16.		13 42 36.		0 19 9	0 21 1	0 20 1	229	227	7 4	0 39 7
2009 12 20	1 OCC 2 P		20 5 55.		20 7 56.	20 7 52.		20 9 57.		0 26 8	0 25 3	0 24 9	242	241	7 6	0 33 2
2009 12 22	2 OCC 1 P		2 50 9.		2 52 0.	2 51 34.		2 53 51.		0 16 1	0 17 1	0 16 1	222	218	7 7	0 45 7
2009 12 22	2 OCC 3 P		18 34 47.		18 36 47.	18 36 23.		18 38 46.		0 02 6	0 04 0	0 04 2	239	244	5 6	0 86 1
2009 12 24	1 OCC 2 P		9 17 30.		9 19 21.	9 19 18.		9 21 12.		0 19 6	0 18 5	0 18 1	222	221	7 4	0 43 3
2009 12 25	2 OCC 1 P		16 1 57.		16 3 42.	16 3 14.		16 5 28.		0 12 4	0 13 2	0 12 3	211	206	7 9	0 51 7
2009 12 27	1 OCC 2 P		22 29 15.		22 30 52.	22 30 50.		22 32 30.		0 12 6	0 11 9	0 11 6	195	194	7 1	0 53 8
2009 12 29	2 OCC 1 P		5 14 3.		5 15 41.	5 15 12.		5 17 19.		0 08 9	0 09 5	0 08 7	196	190	8 2	0 57 8
2009 12 31	1 OCC 2 P		11 41 8.		11 42 27.	11 42 25.		11 43 46.		0 06 2	0 05 9	0 05 6	157	155	6 9	0 64 7
2010 1 1	2 OCC 1 P		18 26 36.		18 28 4.	18 27 34.		18 29 32.		0 05 8	0 06 1	0 05 4	175	169	8 4	0 63 9
2010 1 4	1 OCC 2 P		0 53 19.		0 54 6.	0 54 6.		0 54 53.		0 01 3	0 01 2	0 01 0	94	90	6 6	0 76 1
2010 1 5	2 OCC 1 P		7 39 27.		7 40 40.	7 40 10.		7 41 54.		0 03 1	0 03 2	0 02 6	147	138	8 6	0 70 0
2010 1 8	2 OCC 1 P		20 52 52.		20 53 44.	20 53 12.		20 54 36.		0 01 0	0 01 0	0 00 6	104	88	8 9	0 75 9
2010 3 17	2 OCC 1 P		22 39 30.		23 0 35.	23 1 43.		23 2 5 2.		0 29 0	0 30 8	0 30 3	2733	2727	6 1	0 23 4
2010 3 21	2 OCC 1 P		9 51 53.		10 7 23.	10 8 35.		10 23 21.		0 37 9	0 40 2	0 39 7	1888	1882	2 8	0 10 5
2010 3 21	2 ECL 1 P	11 4 5.	11 7 14.		11 24 47.	11 26 43.		11 44 5.	11 48 16.	0 44 1	0 44 1	0 43 0	2212	2218	4 5	0 34 7
2010 3 24	2 OCC 1 P		21 21 2.		21 35 51.	21 37 17.		21 50 39.		0 39 7	0 42 2	0 41 7	1777	1769	0 3	0 07 1
2010 3 24	2 ECL 1 P	22 33 19.	22 35 36.		22 49 53.	22 51 24.		23 4 34.	23 7 2.	0 58 6	0 58 6	0 57 5	1739	1738	1 8	0 20 5
2010 3 28	2 OCC 1 P		8 42 23.		8 59 24.	9 1 15.		9 15 41.		0 38 2	0 40 6	0 40 0	1998	1980	2 7	0 10 0
2010 3 28	2 ECL 1 P	10 9 30.	10 11 37.		10 25 12.	10 26 37.		10 38 48.	10 40 56.	0 63 9	0 63 9	0 63 1	1632	1628	0 7	0 14 2
2010 3 31	2 OCC 1 P		16 53 25.		17 10 22.	17 6 3.		17 32 44.		0 07 1	0 07 5	0 06 1	2359	2082	9 4	0 58 8
2010 3 31	2 OCC 1 P		19 19 58.		19 56 19.	20 0 19.		20 22 39.		0 29 0	0 30 8	0 30 3	3761	3552	5 7	0 23 6
2010 3 31	2 ECL 1 P	21 47 39.	21 49 59.		22 4 26.	22 5 59.		22 18 35.		0 64 0	0 64 0	0 63 1	1716	1708	3 0	0 14 0
2010 4 4	2 ECL 1	4 36 3.	4 42 46.		4 42 46.	4 41 36.		4 49 42.		0 00 9	0 00 9	0 00 5			11 0	0 94 7
2010 4 4	2 ECL 1 P	9 8 22.	9 30 17.		9 30 17.	9 32 9.		9 47 33.		0 58 2	0 58 2	0 57 0	2170	2147	5 5	0 20 8
2010 4 7	2 ECL 1 P	19 6 27.	19 19 15.		19 55 13.	19 57 9.		20 28 1.	20 38 37.	0 135	0 135	0 166	4126	4658	9 0	0 67 9

Table 11. Visibility of the mutual events depending on the site of observation.

Observatories	(1)	(2)
Sydney (Australia)	70	131
La Silla - ESO (Chile)	68	138
Itajuba (Brazil)	66	134
Capetown (South Africa)	65	134
Mauna Kea, Hawaii (USA)	64	112
Yunnan obs. (China)	64	109
Kavalur (India)	60	115
Monterrey (Mexico)	67	111
Canarian Islands (Spain)	56	110
Mt Wilson, California (USA)	52	100
Washington DC (USA)	52	99
Nanjing (China)	51	99
Dodaira (Japan)	51	98
Pico Veleta (Spain)	49	98
Beijing (China)	49	90
Pic du Midi (France)	49	89
Catania (Italy)	46	94
Rozhen obs. (Bulgaria)	44	90
Bucarest (Romania)	44	88
Barcelona (Spain)	43	91
Topeka, Kansas (USA)	43	90
Teramo (Italy)	43	86
Naucsny (Ukraine)	42	81
Bordeaux (France)	41	86
Haute Provence obs. (France)	41	85
Belgrade (Serbia)	40	85
Stuttgart (Germany)	37	76
Paris (France)	37	76
Uccle (Belgium)	36	71
Dresden (Germany)	35	75
Irkutsk (Russia)	34	65
Pulkovo (Russia)	18	37

(1) All events, even grazing.

(2) Events easily observable: magnitude larger than 10 percent occurring at more than 1.5 jovian radius from the limb of the planet.

4. The observations of the mutual events

4.1. The receptors

The observation of the mutual events consists of the recording of the light flux as a function of time using a photometric receptor. At the present time, CCDs are the most common detectors used for this type of observation:

- the speed of the acquisition of the images allows the recording of at least 3 images per second (for short events);
- each image can be dated in UTC within an accuracy better than 0.1 s in order to obtain an astrometric accuracy of 1 kilometer for the relative position of the satellites.

Video cameras running at 25 frames per second may also be used, thanks to the brightness of the satellites. However, be sure to record the UTC time on each image. The advantage of two-dimensional receptors is the possibility of obtaining several satellites in the field. This will help for the photometric reduction, as we will see in the next section, The calibration.

Other types of detectors may be used, such as single channel photoelectric photometers for fast photometry in several spectral bands.

Photographic or visual observations should be avoided because of the poor photometric accuracy.

Table 12. Distribution of the events.

Dates		Number of events							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2009	Jan.	3	0	0	3	0	2	1	18
	Feb.	–	–	–	–	–	–	–	5
	Mar.	2	0	2	0	0	0	2	28
	Apr.	22	0	16	6	10	2	20	52
	May	45	0	41	4	28	9	36	76
	Jun.	56	1	45	10	27	32	24	103
	Jul.	53	0	52	1	25	40	13	132
	Aug.	77	1	42	34	47	49	28	163
	Sep.	58	2	46	10	26	27	31	164
	Oct.	48	1	46	1	18	13	35	133
Nov.	39	0	34	5	22	2	37	103	
Dec.	23	0	23	0	13	0	23	75	
2010	Jan.	4	0	4	0	0	0	4	50
	Feb.	–	–	–	–	–	–	–	25
	Mar.	10	0	0	10	9	4	6	3
	Apr.	3	0	0	3	1	3	0	20

(1) Total number of events.

(2) Number of events whose duration is less than 1 min.

(3) Number of events whose duration is more than 1 min and less than 10 min.

(4) Number of events whose duration is more than 10 min.

(5) Number of partial events whose magnitude of is more than 20 percent.

(6) Number of eclipses.

(7) Number of occultations.

(8) Mean distance Sun-Jupiter in degrees.

Any telescope, even small, may be used: the stability of the image and good guidance of the instrument is however necessary.

Technical notes on the use of several types of detectors are available by request from the author or on the web server of IMCCE at the address: <http://www.imcce.fr/phemu09>.

4.2. The calibration

Most of the time, the raw light-curves are difficult to analyse without a specific photometric reduction. Since we need only relative photometry (the recorded magnitude drop is measured referring to the magnitude of the satellites before and after the event). However, it is important to record a reference object not affected by the event at the same time. Using a two-dimensional receptor will allow the observer to simultaneously record the satellites involved in the event, and another satellite not involved, with constant brightness (at least during the event). Only for long events will it be useful to take into account the rotation of the satellites. A two-dimensional detector will also record the sky background simultaneously. The reduction will then easily solve the problems related to light clouds or to the variation of the elevation of the observed bodies in the sky, as well as to the brightness of the sky background before sunrise or after sunset. If using a single channel receptor, the observer will need to alternately record the sky background and a reference object either during the event for a long event (more than 20 min) or just before and after the event for a short event.

4.3. The PHEMU09 campaign of observations

In order to optimize the observations and to catch the maximum number of phenomena, we organize a campaign of

observations for the coordination of the observing sites as we have done previously allowing publication of a very complete catalog of data such as in Arlot et al. (1997) for the 1991 occurrence and in Arlot et al. (2006) and Emelianov et al. (2000) for the 1997 occurrence and in Arlot et al. (2008) for the 2003 occurrence (the database is available at the address: <http://www.imcce.fr/fr/ephemerides/donnees/nsdc/nsdf/fjuphemu.html>). The reader is encouraged to join our campaign of observations, to contact the author at arlot@imcce.fr and to get information on the campaign of observations from the web address <http://www.imcce.fr/phemu09>.

5. The interest of the observations

5.1. Astrometry of the Galilean satellites

The goal of the observation of the mutual phenomena of the Galilean satellites of Jupiter is mainly to obtain astrometric data leading to relative positions of the satellites with high accuracy. Observations of the mutual events have been shown to be more accurate than photographic or CCD direct observations of astrometric positions. The measurement of the magnitude drop at the time of the minimum distance corresponds to the measurement of this minimum distance. Thanks to the absence of an atmosphere on the satellites, the observations are more interesting than those of the eclipses by Jupiter because of the sharpness of the light curves. In the past, observations of eclipses by Jupiter have led to relative positions determined within an accuracy of 1000 km, photographic or CCD positions within 500 km and mutual events within 100 km. This accuracy for the mutual events may be improved to 20 km or better using a more sophisticated reduction involving surface reflectivity.

Such observed positions help to fit the dynamical models of the motions of the satellites. Their accuracy allows a better determination of the eccentricities which should constrain the model of tidal effects on Io and Europe and the model of the interior of these satellites. Also, these observations allow detection of non-gravitational forces, especially for Io, through the determination of an acceleration in longitude. Space probes have made some precise observations over an interval of time too short to be able to determine an acceleration. For that, we need accurate observations over a long interval of time as provided by the mutual events. The first modern observations of these events started in 1973, providing us with more than thirty years of data necessary to measure an acceleration in the motion of the satellites.

5.2. Planetology: analysis of the surfaces

Looking for a better reduction of the mutual phenomena, Vasundhara et al. (1996) and Emelianov et al. (2000) demonstrated that a new reduction considering that the satellites are

not uniform disks may help to improve the accuracy of the data. Surface effects were suspected to be non-negligible when observing the mutual events presenting light curves with an asymmetrical aspect. Taking into account the surface effects for the reduction allows the determination of unknowns related to planetologic parameters such as the porosity and the rugosity of the surfaces of the satellites themselves, implying different scattering laws affecting the observed light curves. Moreover, the observations in infrared wavelengths allow detection of volcanos and hot spots on the surface of the satellite Io, and measurement of their activity at the time of the observation (Descamps et al. 1992).

6. Conclusion

The occurrence of the mutual events in 2009–2010 is particularly favorable because of the opposition of Jupiter occurring when the mutual events are most numerous (i.e., at the time of the jovian equinox when the jovicentric declination of the Sun and the Earth is the smaller). The declination of Jupiter itself at the date of the events will be around -14 degrees, more favorable for observation from observatories in the southern hemisphere.

We encourage observers to make the most of observations during this occurrence in order to complete the collections of data gathered since 1973. Thirty-five years of such accurate data will allow a major improvement in the ephemerides of the Galilean satellites and in our knowledge of this dynamical system.

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