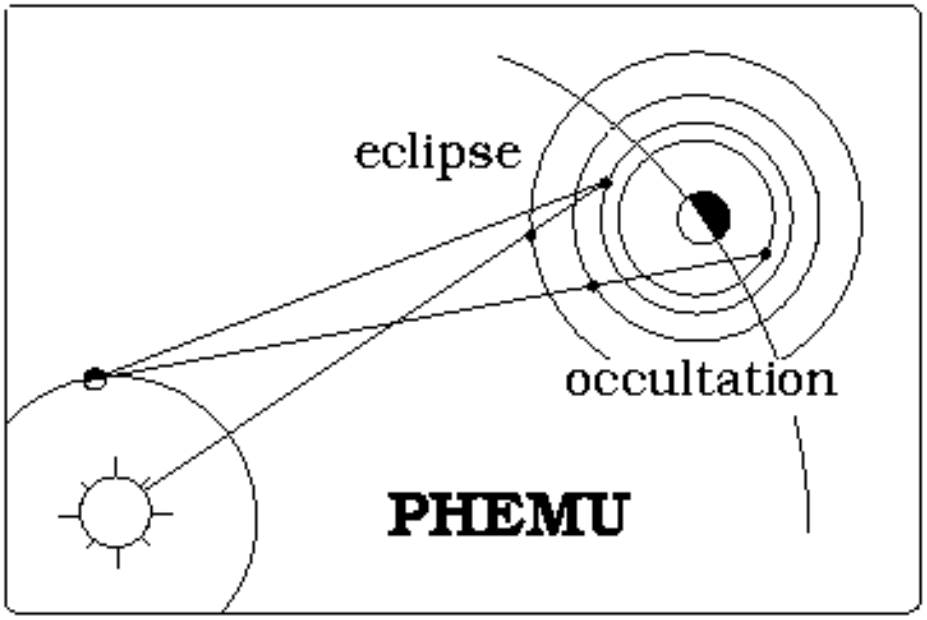
The campaigns of observation of the mutual phenomena of the Galilean satellites
The campaign 2014-2015



J.E. Arlot,
IMCCE/obs. de Paris

Mutual phenomena: rare phenomena

They occur only near the equinox on the planet

Jupiter: 2009, 2015 (every 6 years)
Saturn: 2009 (every 15 years)
Uranus: 2007 (every 42 years)

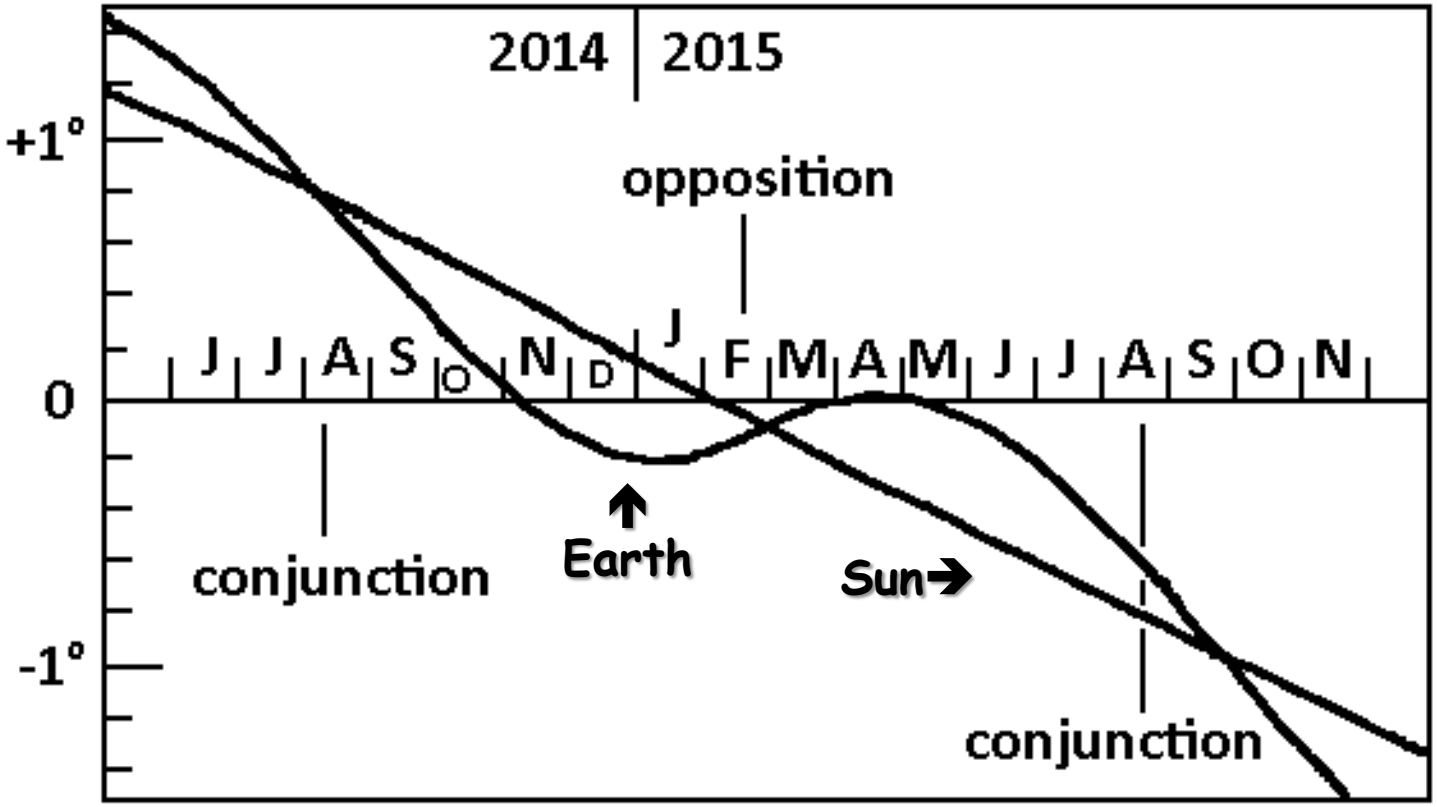
Equinoxes on the giant planets: Jupiter

Jupiter: 2009, 2015 (every 6 years)

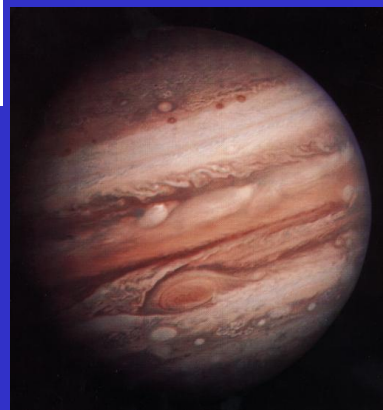
The Galilean satellites and also the small inner satellites are concerned

Amalthea, Thebe

The jovicentric declination of the Earth and the Sun



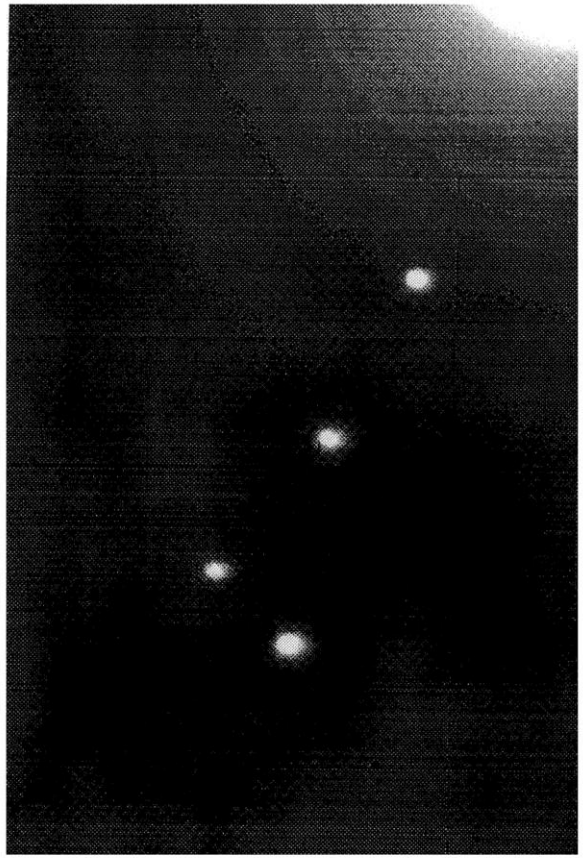
Mutual events occur when this declination is smaller than one degree



The Galilean satellites are too bright!

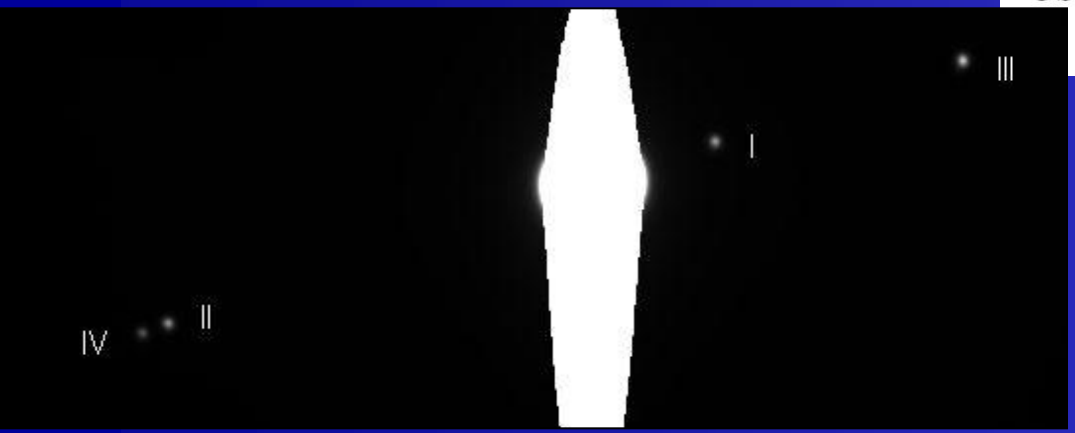
- Direct imaging difficult
- Easy observation of mutual events

as seen in a 80cm-telescope ➔



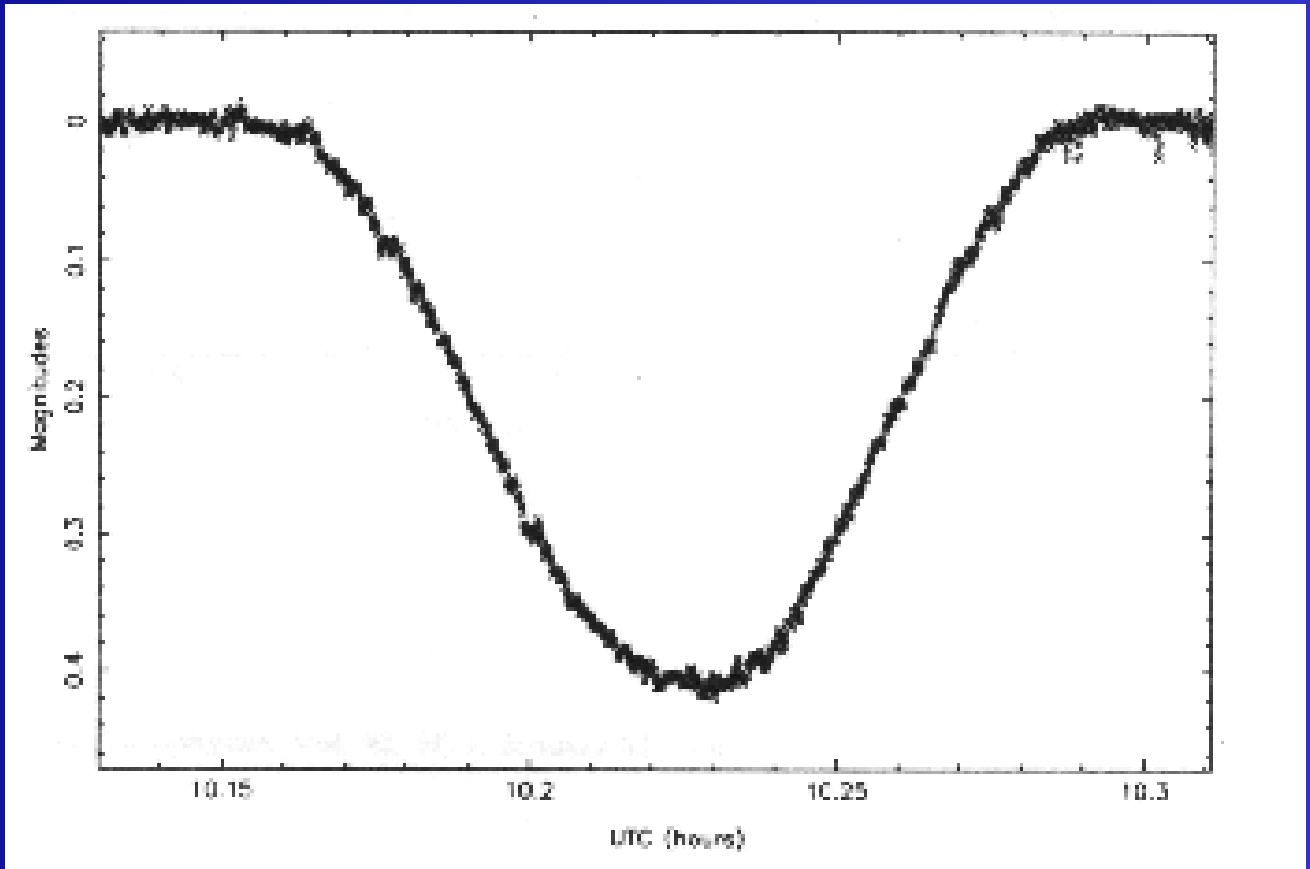
The Galilean Satellites in May 1993
Observation made at Observatoire de Haute Provence
(0.80m telescope R filter)

as seen in a 30cm-telescope :



Observing in R-band or V-band

Below the light curve of the light flux received from the satellites during a mutual events. The shape of the light curve depends on the ephemerides and on the physical parameters of the satellites.



Summary of observational campaigns

	Number of observations	Number of sites of observation	Number of observed events	Number of observable events
Jupiter				
1973	91	26	65	176
1979	18	7	9	60
1985	166	28	64	248
1991	374	56	111	221
1997	275	42	148	390
2003	361	42	116	360
2009	523	68	206	237
Saturn				
1980	14	6	13	213
1995	66	16	43	182
2009	26	15	17	131
Uranus				
2007	52	19	36	193

- The progress until today
  - change in the observers (more amateurs)
  - change in the instruments (smaller aperture and 2D photometry)
  - change in the network (more countries)

Occurrences Jupiter	Size of the telescopes		Photometry	
	< 60cm (amateurs)	> or = 60cm (professionals)	1 D	2 D
1973	4	20	24	0
1979	3	7	10	0
1985	12	12	21	3
1991	37	19	39	17
1997	35	10	15	30
2003	34	15	8	41
2009	52	10	0	62
Saturn 1995	5	11	8	8
Uranus 2007	4	11	0	15

Astronomy & Astrophysics manuscript no. catal03-v6
June 20, 2008

The PHEMU03 catalogue of observations of the mutual phenomena of the Galilean satellites of Jupiter

J.-E. Arlot[1], W. Thuillot[1], C. Ruatti[1], A. Ahmad[2], A. Amossé[47], P. Anbazhagan[50], M. Andreyev[5], A. Antov[12], M. Appakutty[50], D. Asher[2], S. Aubry[1], N. Baron[1], N. Bassiere[1], M. Berthe[3], R. Bogdanovski[12], F. Bosq[25], E. Bredner[6], D. Buettner[7], M. Buromsky[40], S. Cammarata[27], R. Casas[8], G. D. Chis[9], A.A. Christou[2], J.-P. Coquerel[44], R. Corlan[10], C. Cremaschini[11], D. Crussaire[26], J. Cuypers[32], M. Dennefeld[46], P. Descamps[1], A. Devyatkin[22], D. Dimitrov[12], T.N. Dorokhova[13], N.I. Dorokhov[13], G. Dourneau[25], M. Dueñas[14,51], A. Dumitrescu[10], N. Emelianov[43], D. Ferrara[27], D. Fiel[15], A. Fienga[1], T. Flatres[39], S. Foglia[11], J. Garlitz[16], J. Gerbos[17], R. Gilbert[1], R.M.D. Goncalves[18], D. Gonzāles[14,51], S. Yu. Gorda[19], D.L. Gorshanov[22], M. W. Hansen[41], M. Harrington[2], T.R. Irsmambetova[20], Y. Ito[21], V. Ivanova[12], I.S. Izmailov[22], M. Yu. Khovritchev[22], E.V. Khrutskaya[22], J. Kieken[25], T. P. Kisseleva[22], K. Kuppuswamy[50], V. Lainey[1], M. Lavayssiére[23], P. Lazzarotti[24], J.-F. Le Campion[25], E. Lellouch[26], Z.L. Li[42], E. Lo Savio[27], M. Lou[14,51], E. Magny[44], J. Manek[28], W. Marinello[11], G. Marino[27], J.P. McAuliffe[2], M. Michelli[11], D. Moldovan[9], S. Montagnac[44],V. Moorthy[50], O. Nickel[29], J.M. Nier[44], T. Noel[30], B. Noyelles[1,3], A. Oksanen[31], D. Parrat[44],T. Pauwels[32], Q.Y. Peng[33], G. Pizzetti[11], V. Priban[38] B. Ramachandran[2], N. Rambaux[1,25], M. Rapaport[25], P. Rapavy[17], G. Rau[44], J.-J. Sacré[39], P.V. Sada[34], F. Salvaggio F.[27], P. Sarlin[44], C. Sciuto[27], G. Selvakumar G.[50], A. Sergeyev A.[5], M. Sidorov M.[22], S. Sorescu[10], S.A. Spampinato[11], I. Stellmacher[1], E. Trunkovsky[43], V. Tejfel[35], V. Tudose[10], V. Turcu[9], I. Ugarte[2], P. Vantyghem[45], R. Vasundhara[4], J. Vaubaillon[1], C. Velu[50], A.K. Venkataramana[50], J. Vidal-Sāinz[14,51], A. Vienne[1,3], J. Vilar[36], P. Vingerhoets[49], W. Vollman[37]

(Affiliations can be found after the references)

Received

ABSTRACT

Context. In 2003 the Sun and the Earth passed through the equatorial plane of Jupiter and therefore through the orbital planes of its main satellites.

Aims. During this period, phenomena of mutual eclipses and occultations occurred and have been observed and we now present the catalogue of the data gathered.

Methods. Light curves of mutual eclipses and occultations were recorded by the observers of the international campaign PHEMU03 organized by the Institut de mécanique céleste, Paris, France.

Results. We made 361 observations of 116 mutual events from 42 sites. The corresponding data are given in this paper. For each observation, information is given about the telescope, the receptor, the site and the observational conditions.

Conclusions. This paper gathers together all these data and gives a first estimate of the precision. The catalogue of these rare events published in this paper intends to be an improved basis of accurate astrometric data useful for the development of dynamical models.

Key words. Jupiter – Galilean satellites – Mutual events – Eclipses – Occultations – Astrometry

1. Introduction

Observations of mutual events of the natural satellites are performed intensively since 1973 and they had been proved to be a very accurate way to get astrometric measurements of the natural satellites. As we did in the past, we encouraged the observers to make as many observations as possible and we organized and coordinated an international campaign in order to catch these rare events. This campaign named PHEMU03 al- to the observers of our international network made of 42 sites. [1]

We provide in this paper all the data collected by our network: note that 19 more observations were made (at Meudon, Pulkovo, Armagh, Nauchny, Novara, Sendai, Terskol, Sobota

[1] tables 4 and figures are available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via

Astronomy & Astrophysics manuscript no. phemu09-catal08
March 20, 2014

The PHEMU09 catalogue and astrometric results of the observations of the mutual occultations and eclipses of the Galilean satellites of Jupiter made in 2009.

J.-E. Arlot [1], N. Emelianov [2,1], M. I. Varfolomeev [2], A. Amossé [3], C. Arena [4], M. Assafin [40], L. Barbieri [5], S. Bolzoni [6], F. Bragas-Ribas [54], J.I.B. Camargo [54], F. Casarramona [8], R. Casas [37], A. Christou [9], F. Colas [1], A. Collard [3], S. Combe [10], M. Constantinescu [11], G. Dangl [12], P. De Cat [34], S. Degenhardt [13], M. Delcroix [14], A. Dias-Oliveira [54], G. Dourneau [15,57], A. Douvris [16], C. Druon [3], C.K. Ellington [17], G. Estraviz [8], P. Farissier [10], A. Farmakopoulos [16], J. Garlitz [18], D. Gault [19], T. George [20], S. Yu. Gorda [42], J. Grismore [21], D.F. Guo [22], D. Herald [56], M. Ida [23], M. Ishida [23], A.V. Ivanov [24], B. Klemt [7], N. Koshkin [25], J.F. Le Campion [15,57], A. Liakos [26], S.L. Liao [27], S.N. Li [27], B. Loader [28], C. Lopresti [29], E. Lo Savio [4], A. Marchini [30], G. Marino [4], G. Masi [53], A. Massallé [8], R. Maulella [29], J. McFarland [9], K. Miyashita [32], C. Napoli [4], B. Noyelles [33,1,3], T. Pauwels [34], H. Pavlov [35], Q.Y. Peng [36], C. Perelló [8], V. Priban [38], J. Prost [39], S. Razemon [3], J.P. Rousselle [3,58], J. Rovira [8], R. Ruisi [41], N. Ruocco [31], F. Salvaggio [4], G. Sbarufatti [43], L. Shakun [25], A. Scheck [44], C. Sciuto [4], D.N. da Silva Neto [55], N.V Sinyaeva [45], A. Sofia [4], A. Sonka [11], J. Talbot [46], Z.H. Tang [27], V.G. Tejfel [45], W. Thuillot [1], K. Tigani [16], B. Timerson [47], E. Tontodonati [48], V. Tsamis [16], M. Unwin [49], R. Venable [50], R. Vieira-Martins [54,1,40], J. Vilar [51], P. Vingerhoets [34], H. Watanabe [52], H.X. Yin [22], Y. Yu [27], R. Zambelli [29]

(Affiliations can be found after the references)

Received XX Xxxxx 2014 / Accepted XX Xxxxx 2014

ABSTRACT

Context. In 2009, the Sun and the Earth passed through the equatorial plane of Jupiter and therefore the orbital planes of its main satellites. It will be the equinox on Jupiter. This occurrence will make possible mutual occultations and eclipses between the satellites. Experience has shown that the observations of such events will provide accurate astrometric data able to bring new information on the dynamics of the Galilean satellites. Observations are made under the form of photometric measurements but need to be made through the organization of a world wide campaign of observation maximizing the number and the quality of the data obtained.

Aims. This work focuses on processing the complete database of photometric observations of the mutual occultations and eclipses of the Galilean satellites of Jupiter made during the international campaign in 2009. The final goal is to derive new accurate astrometric data.

Methods. We used an accurate photometric model of mutual events adequate of accuracy of observation. Our original method is applied to derive astrometric data from photometric observations of mutual occultations and eclipses of the Galilean satellites of Jupiter.

Results. We process the 457 light curves obtained during the international campaign of photometric observations of the Galilean satellites of Jupiter in 2009. As compared with the theory, for successful observations, the r.m.s. of 'O-C' residuals are equal to 45.8 and 81.1 mas in right ascension and declination, respectively and the mean 'O-C' residuals are equal to -2 mas and -9 mas in right ascension and declination respectively for mutual occultations and -6 mas and +1 mas in right ascension and declination respectively for mutual eclipses.

Key words. ephemerides – planets and satellites: general

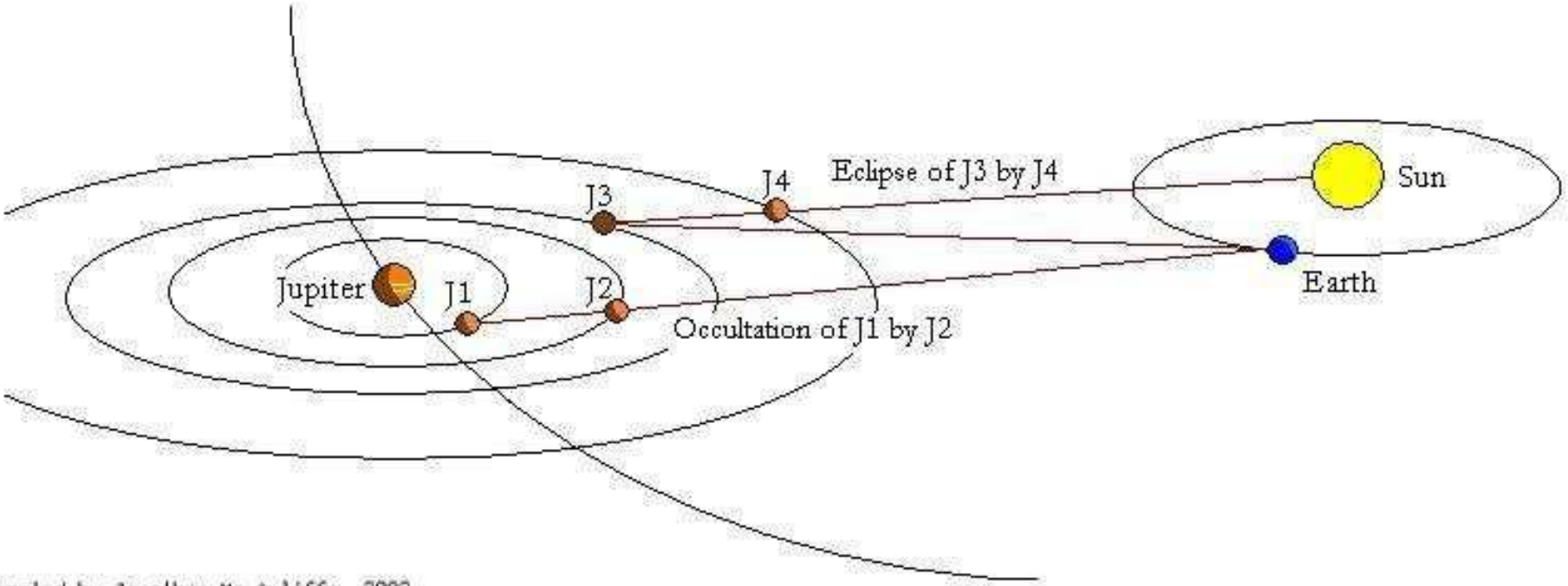
1. Introduction

Photometric observations of mutual occultations and eclipses of natural satellites of planets offer an efficient source of new astrometric data. We have taken the oppor-

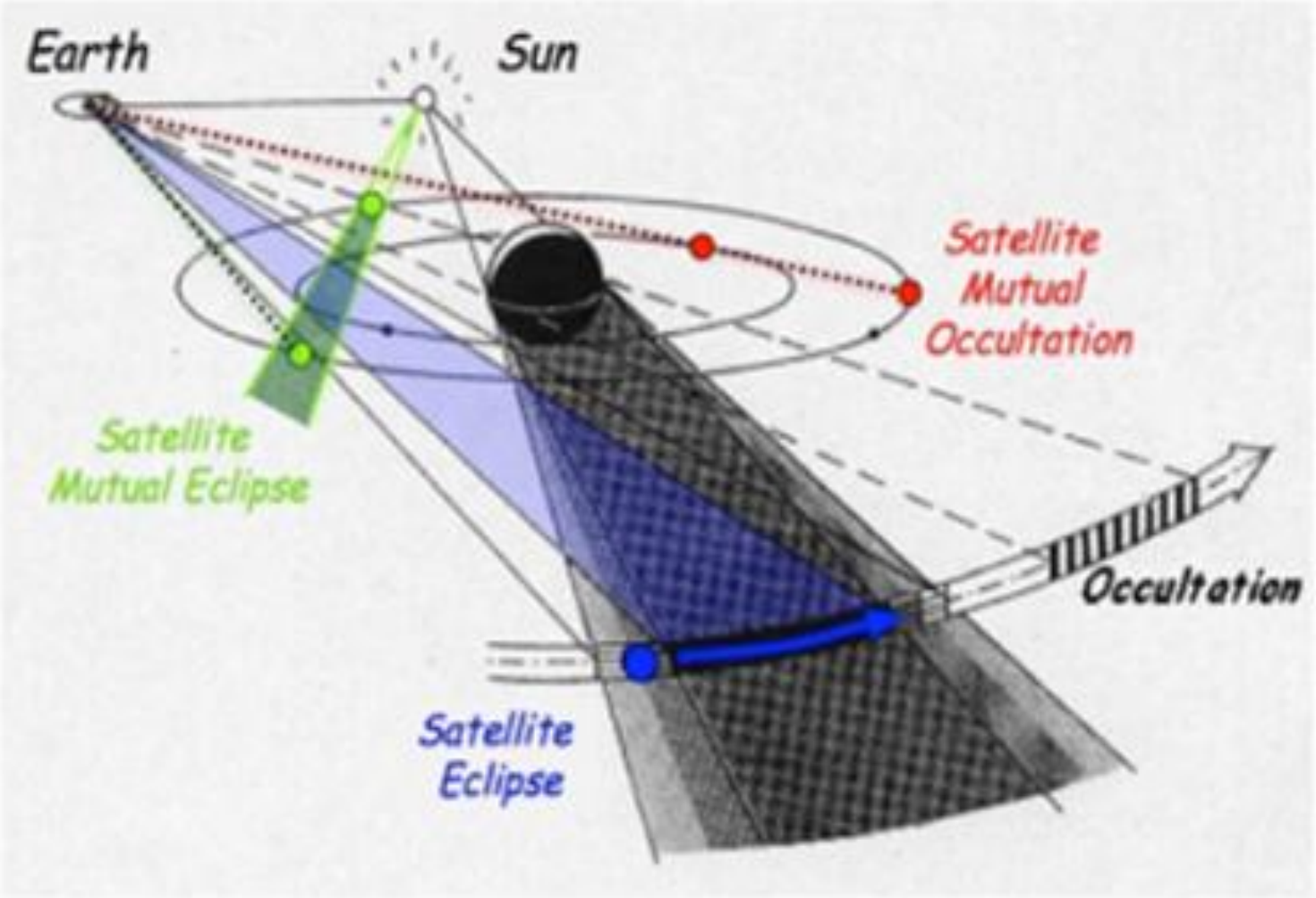
Send offprint requests to: J.-E. Arlot

Publication of catalogues of the observed events (above in 2003 and in 2009) accessible on databases via Internet

Mutual phenomena: the observation



The geometry of the mutual events and of the eclipse and occultation by Jupiter



Geometry of a mutual phenomenon

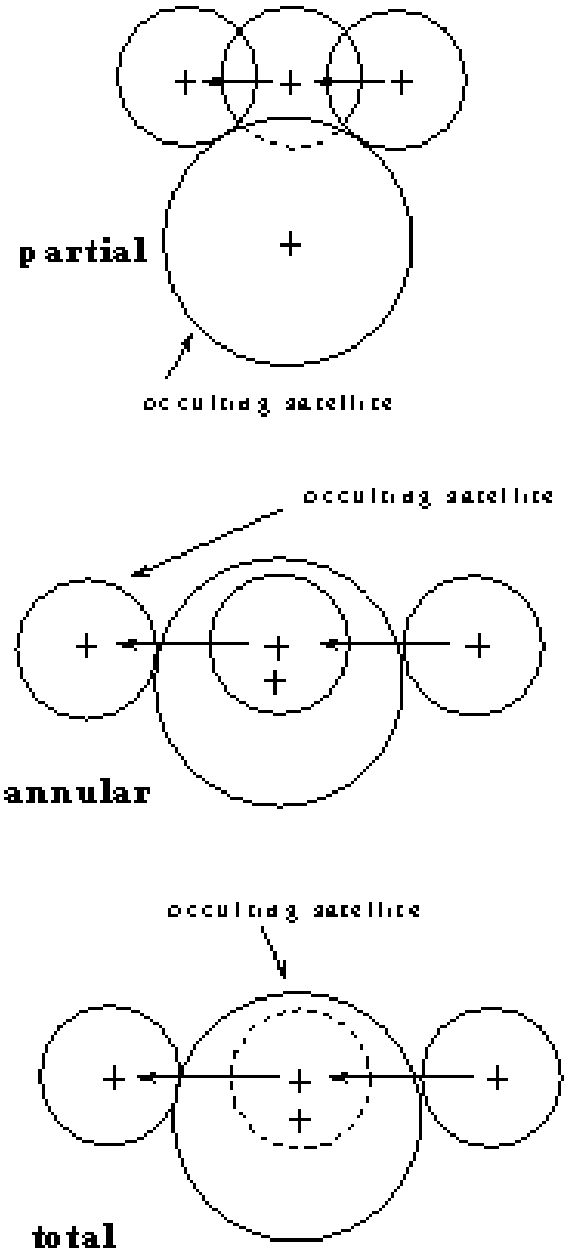


Fig. 3 – Occultations.

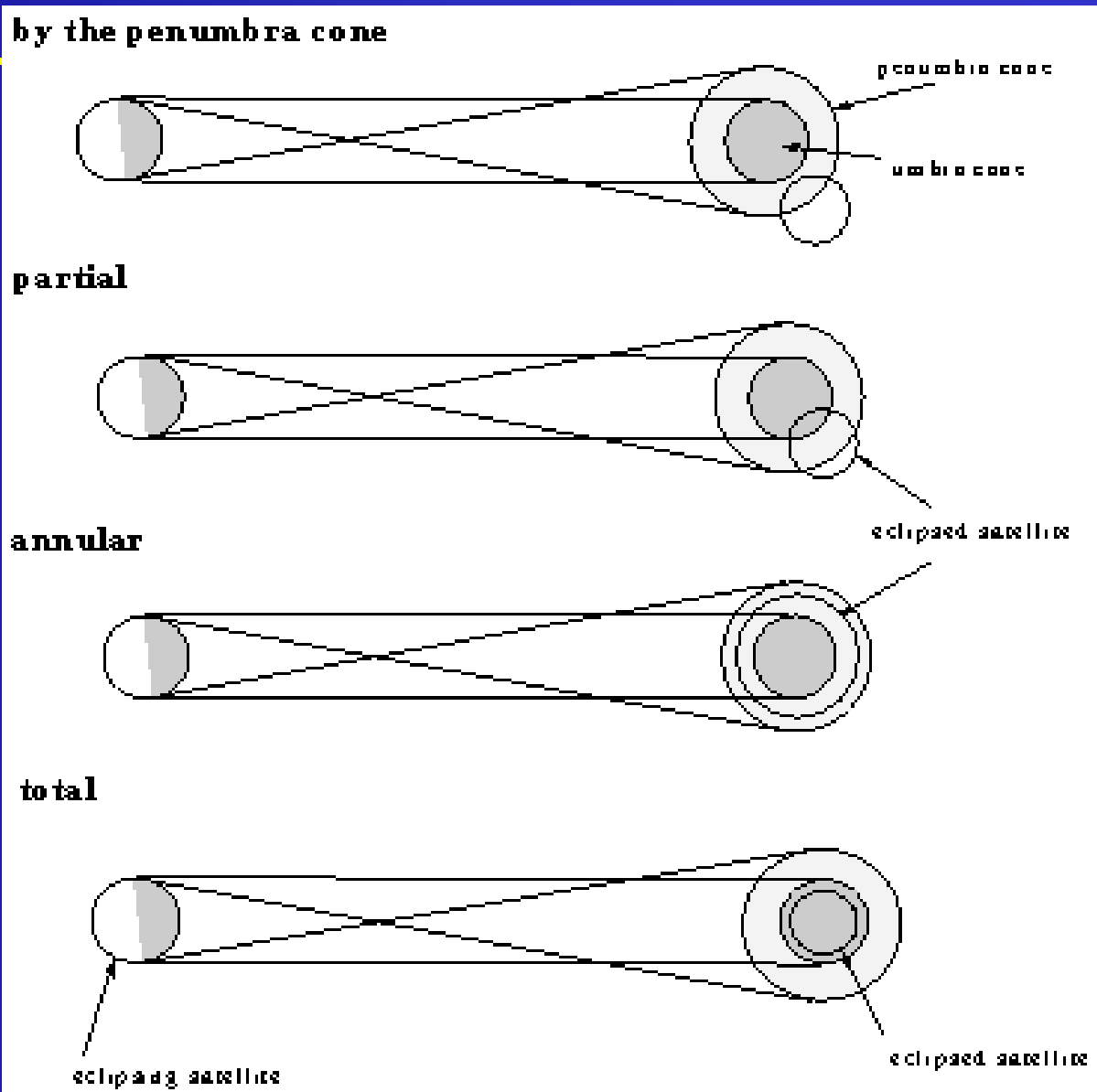
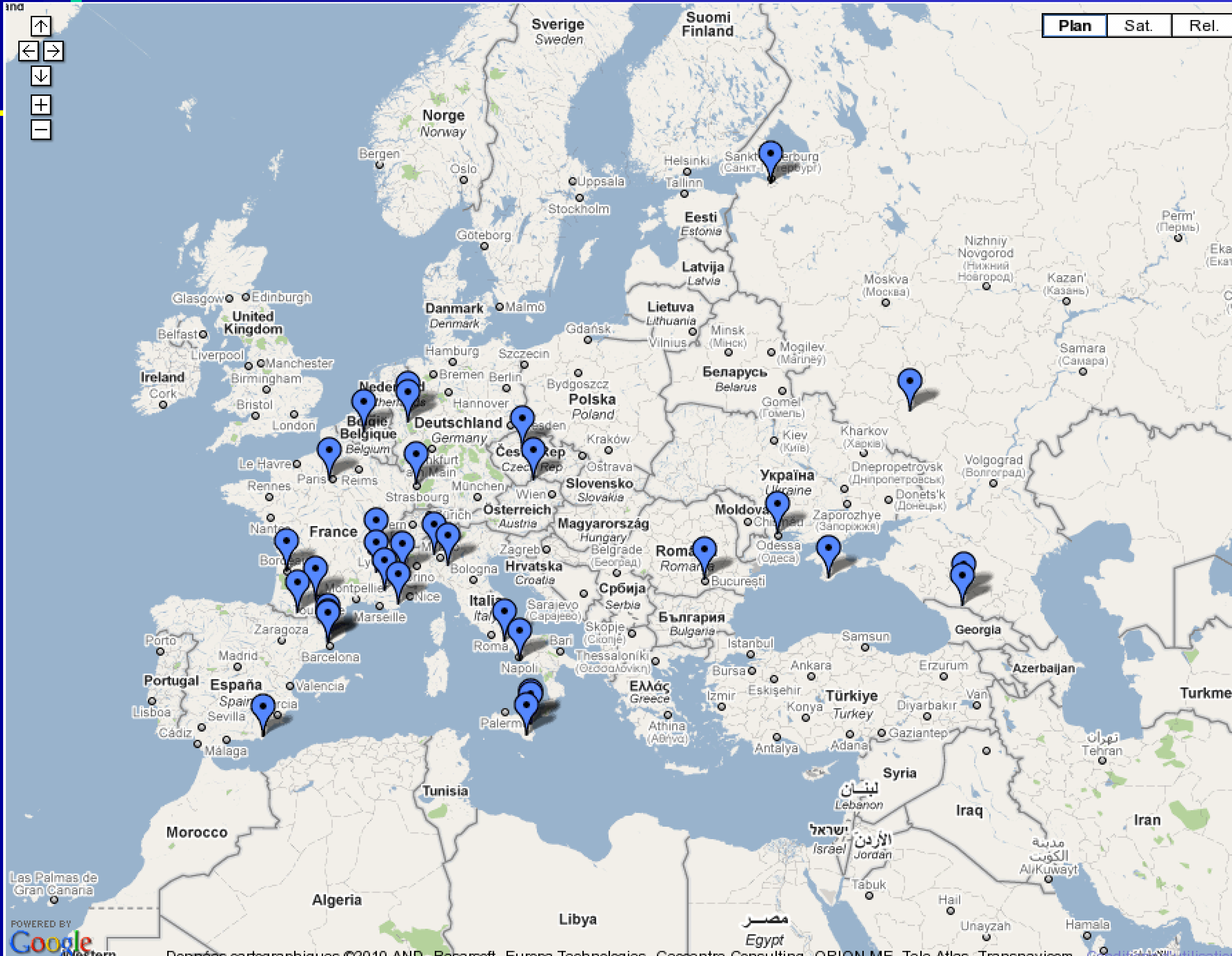


Fig. 4 – Eclipses.

What happens during a mutual event?

We record the light sent by the satellites as a function of the Universal Time (to 0.1 second of time)

The sites of observation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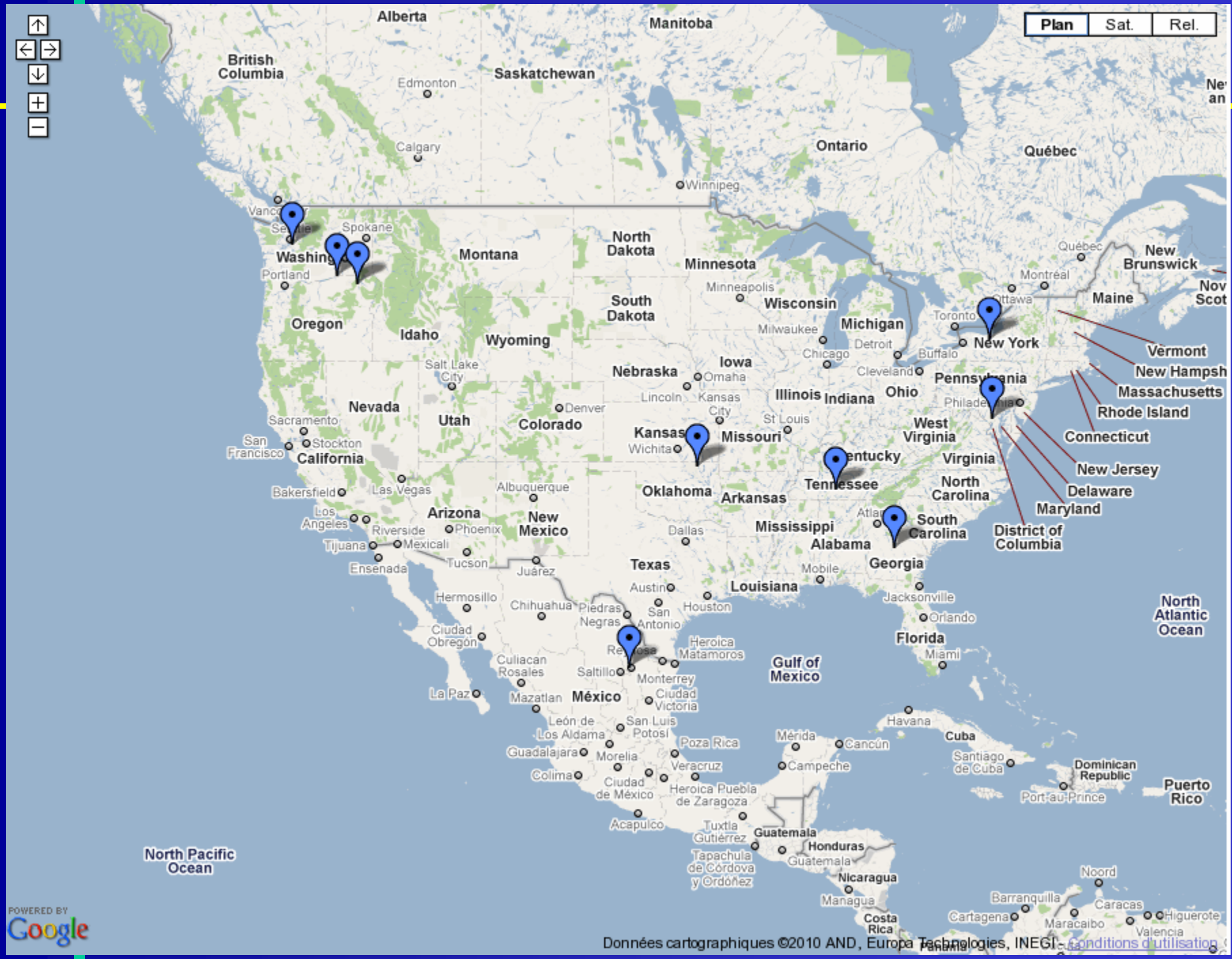
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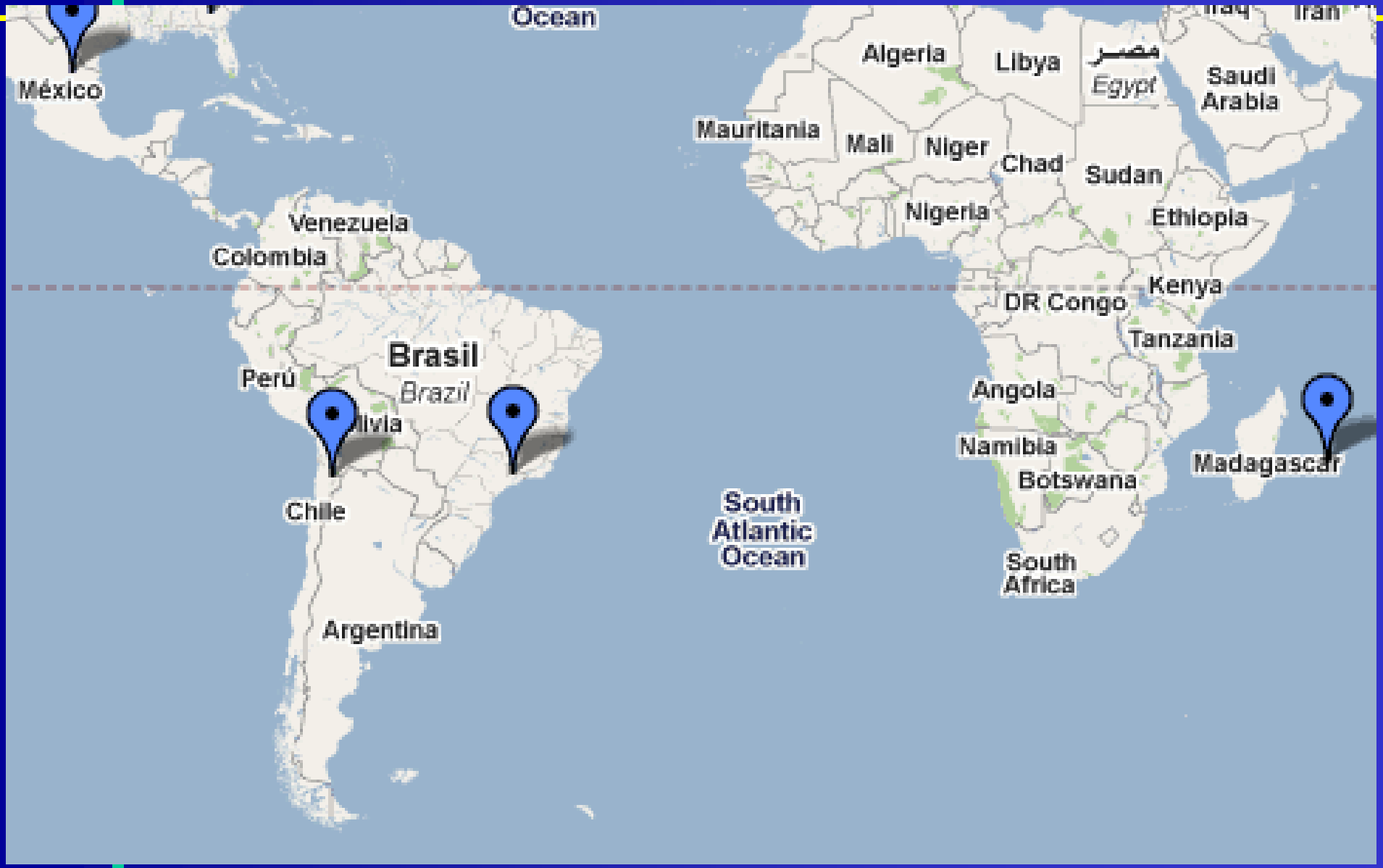
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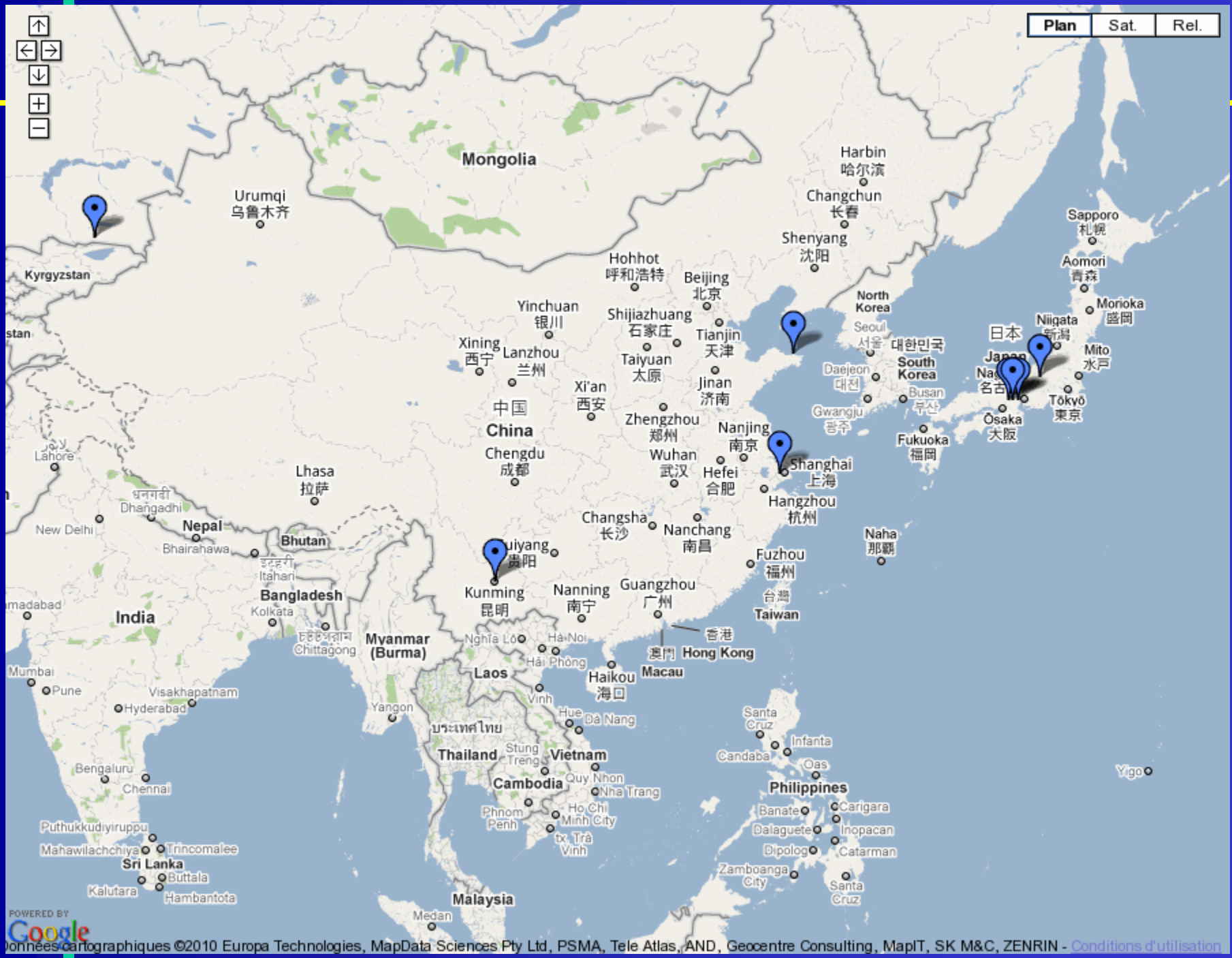
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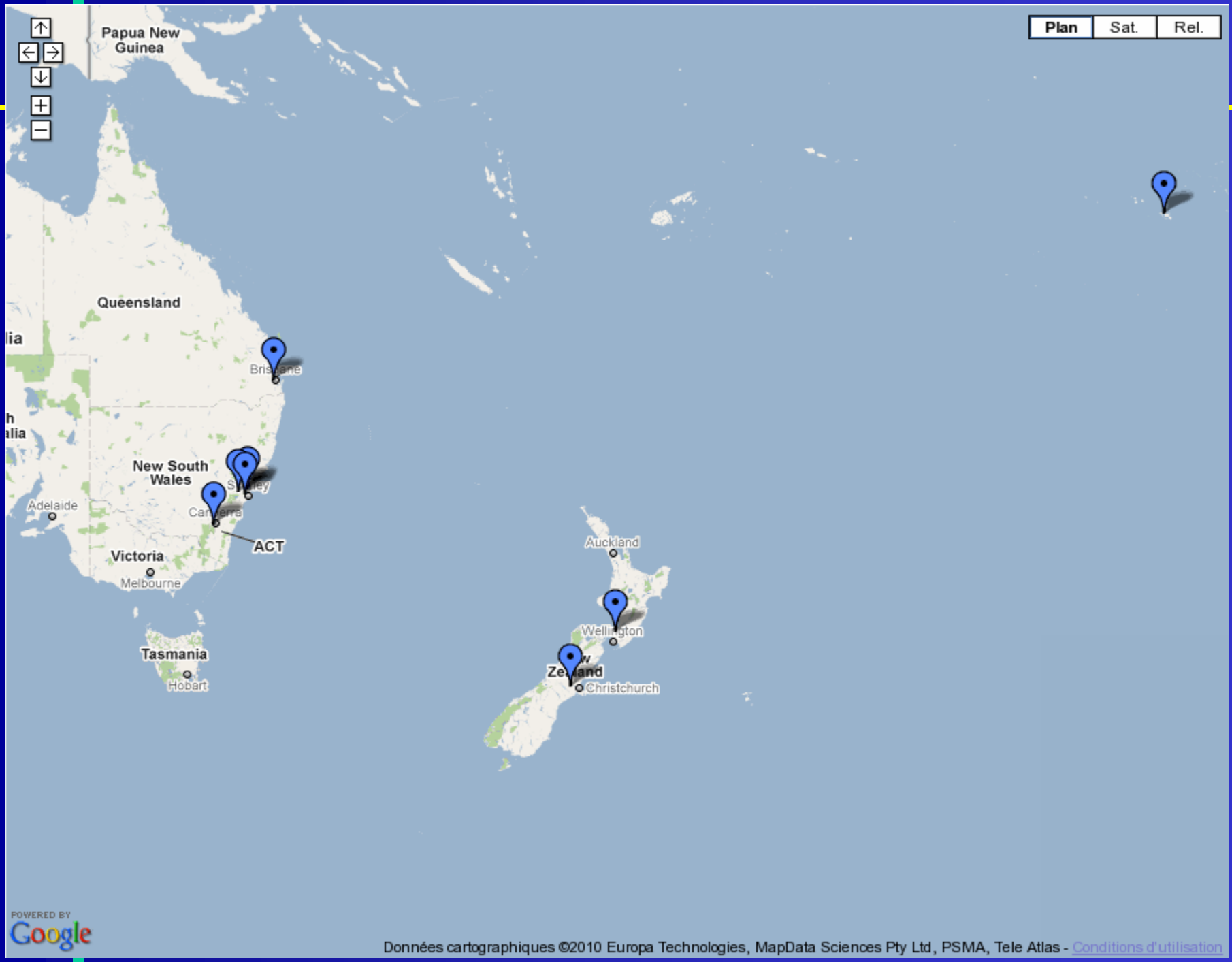
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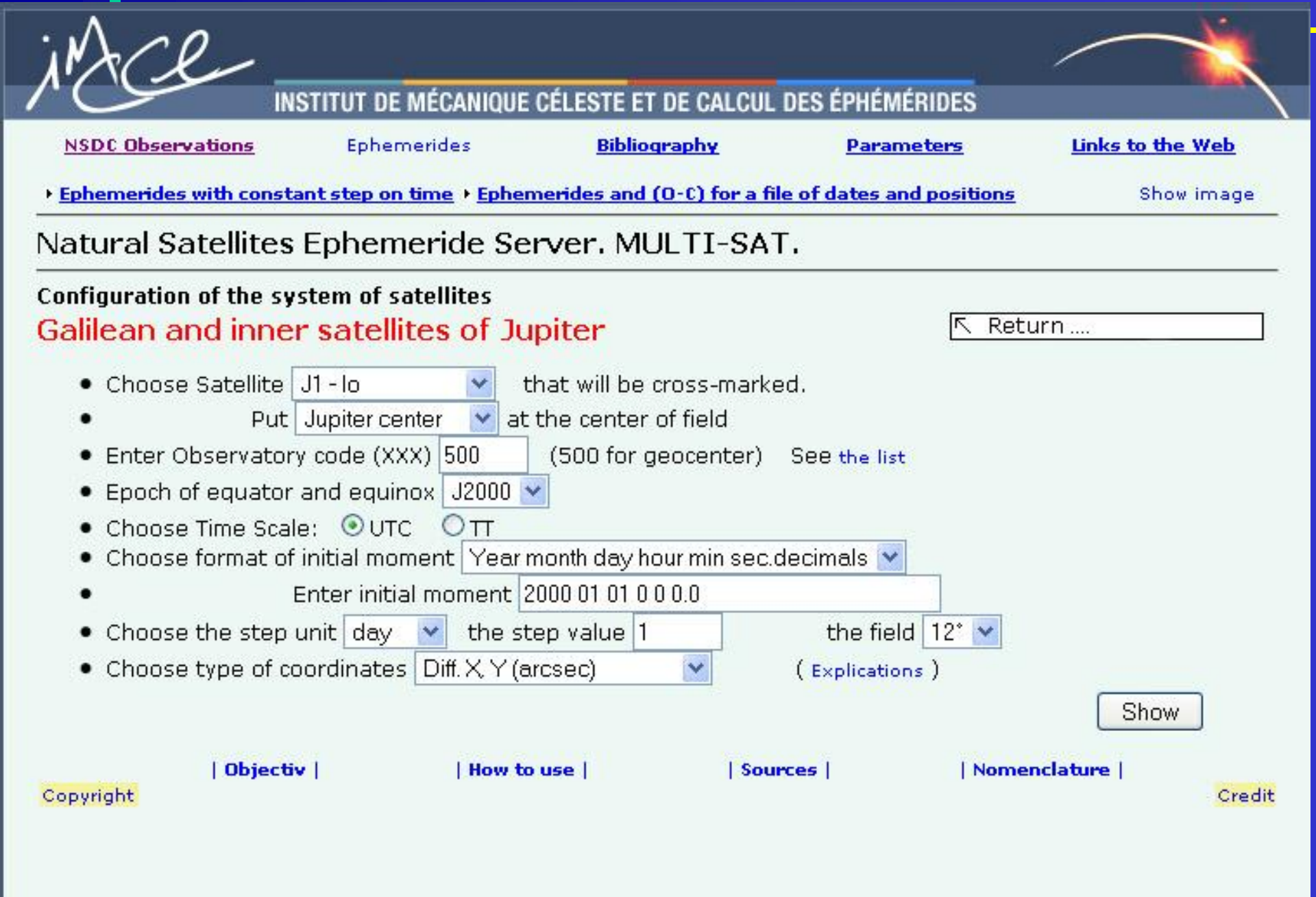
Web page for the configurations of the Galilean satellites



INSTITUT DE MÉCANIQUE CÉLESTE ET DE CALCUL DES ÉPHÉMÉRIDES

NSDC Observations | Ephemerides | Bibliography | Parameters | Links to the Web

Ephemerides with constant step on time | Ephemerides and (O-C) for a file of dates and positions | Show image

Natural Satellites Ephemeride Server. MULTI-SAT.

Configuration of the system of satellites

Galilean and inner satellites of Jupiter

Return ....

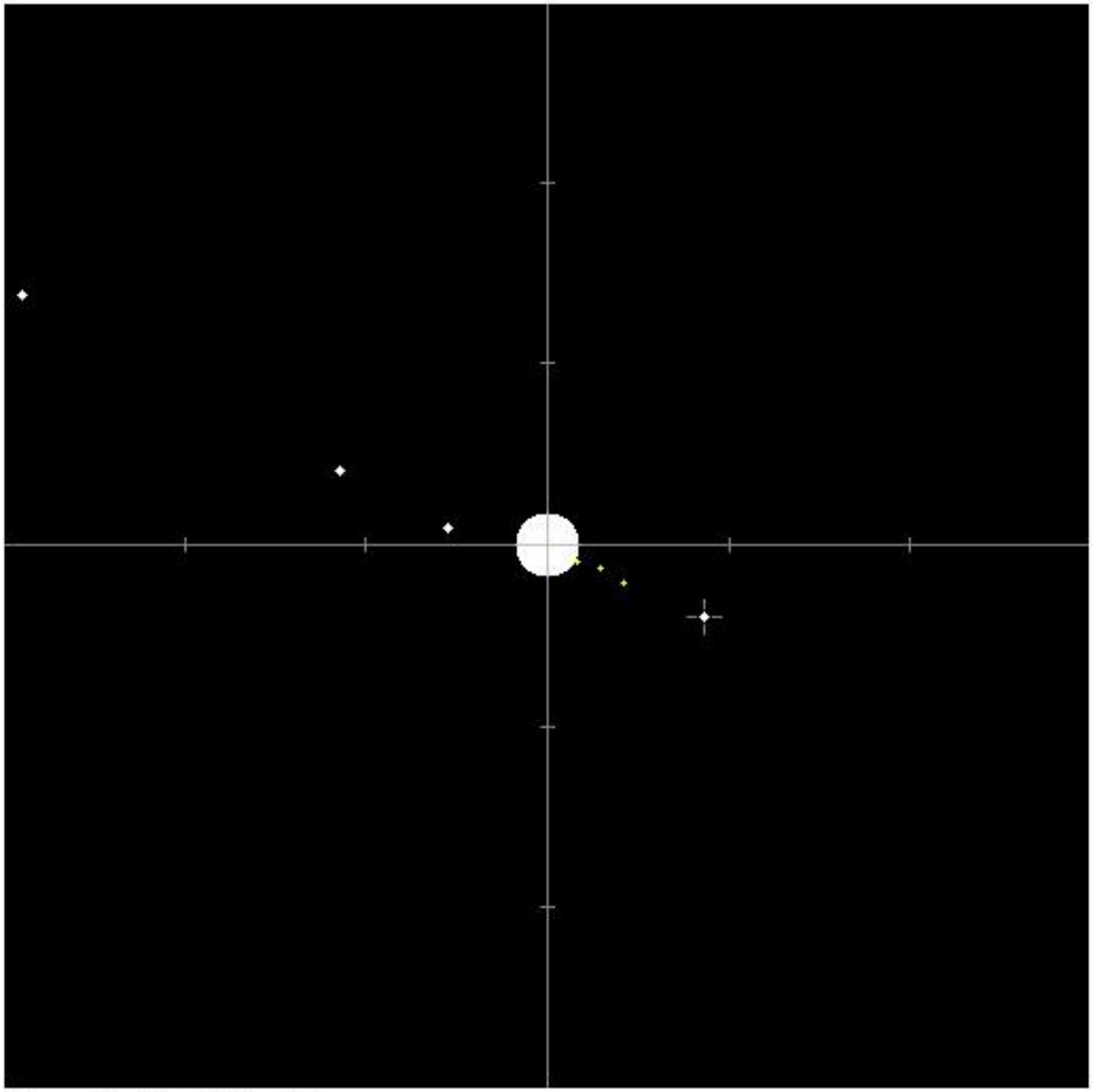
- Choose Satellite: J1 - Io — that will be cross-marked.
- Put: Jupiter center — at the center of field
- Enter Observatory code (XXX): 500 (500 for geocenter) See the list
- Epoch of equator and equinox: J2000
- Choose Time Scale: (•) UTC ( ) TT
- Choose format of initial moment: Year month day hour min sec.decimals
- Enter initial moment: 2000 01 01 0 0 0.0
- Choose the step unit: day — the step value: 1 — the field: 12°
- Choose type of coordinates: Diff. X, Y (arcsec) (Explications)

Show

| Objectiv | How to use | Sources | Nomenclature |

Copyright Credit

Results



Present field : **12' x 12'**
Time moment: **2000 1 1 0 0 0.00 (UTC)**
Observatory: **Geocenter**

IMCCE/SAI. Natural Satellites Ephemeride Server. MULTI-SAT.

Satellites of Jupiter

Reference body:
Jupiter
Marked satellite:
J1 Io
Epoch of equator and equinox J2000
Differential coordinates

Refresh image
With 12' field scale
One time step of 1.0000 days
- Back
- Non
- Forward

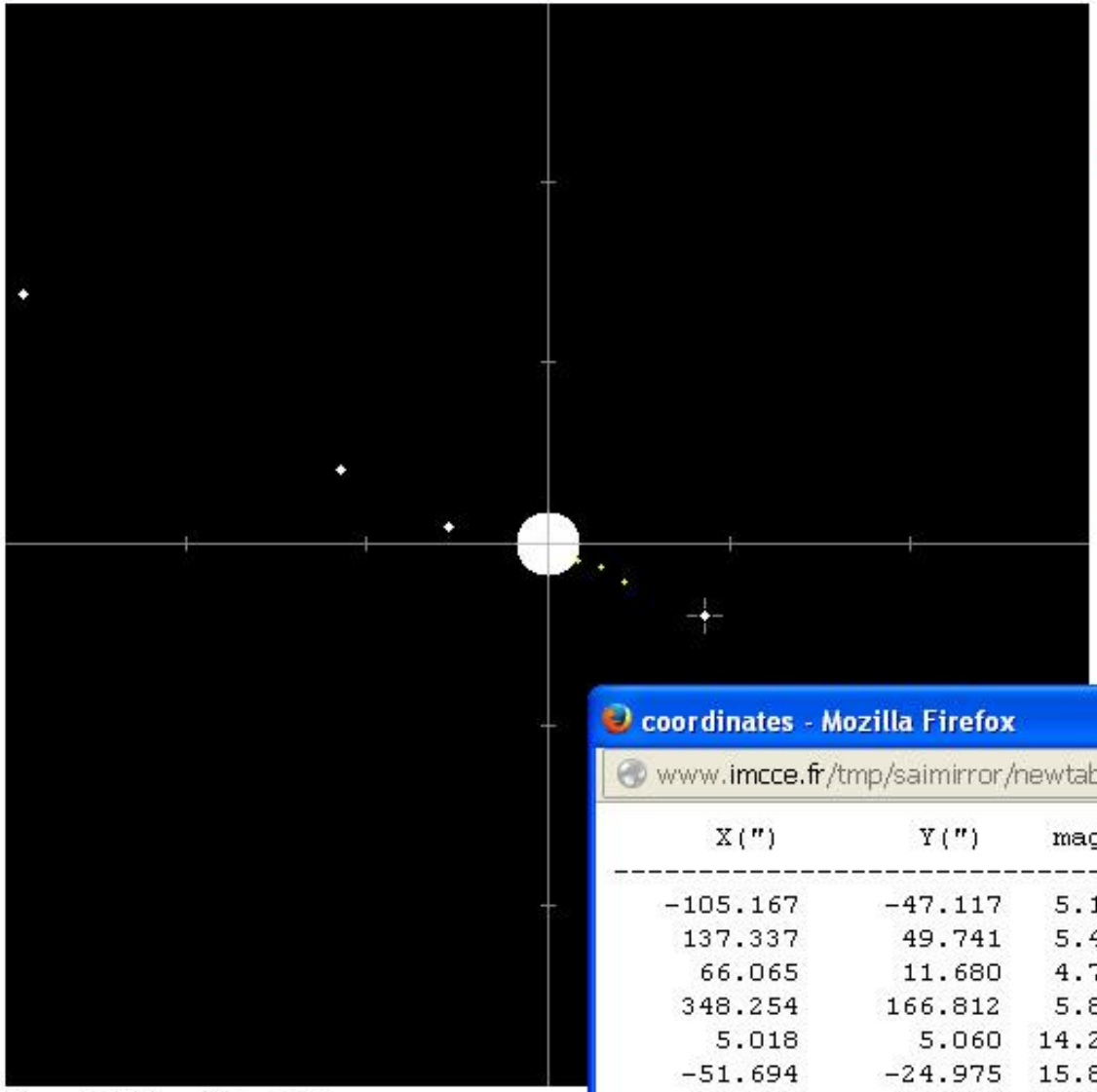
Marked satellite:
J1 Io

Center of the field:
$\alpha = 1^h\ 35^m\ 24.471^s$
$\delta = 8^\circ\ 35'\ 10.38''$

N
E + W
S

Coordinates and magnitudes

Results



Present field : **12' x 12'**
Time moment: **2000 1 1 0 0 0.00** (UTC)
Observatory: **Geocenter**

IMCCE/SAI. Natural Satellites Ephemeride Server. MULTI-SAT.

Satellites of Jupiter

Reference body:
Jupiter
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Epoch of equator and equinox J2000
Differential coordinates

Refresh image
With 12' field scale
One time step of 1.0000 days
Back

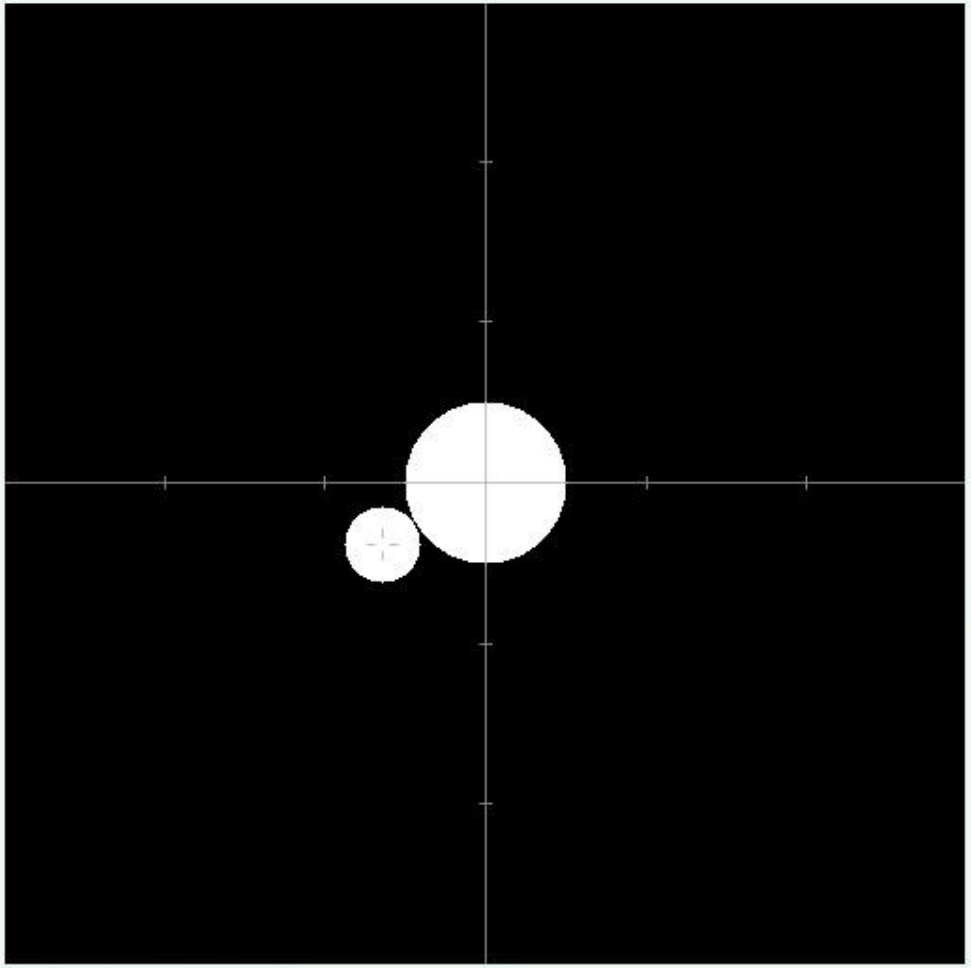
N
E + W
S

nitudes

coordinates - Mozilla Firefox

www.imcce.fr/tmp/saimirror/newtab.htm

X(")	Y(")	mag	Satellite
-105.167	-47.117	5.1	J1 Io
137.337	49.741	5.4	J2 Europe
66.065	11.680	4.7	J3 Ganymede
348.254	166.812	5.8	J4 Callisto
5.018	5.060	14.2	J5 Amalthea
-51.694	-24.975	15.8	J14 Thebe
-35.777	-15.022	19.2	J15 Adrastea
-20.667	-10.400	17.6	J16 Metis



Present field : **1" x 1"**
Time moment: **2009 2 6 11 26 10.00 (UTC)**
Observatory: **Geocenter**

IMCCE/SAI. Natural Satellites Ephemeride Server. MULTI-SAT.

Satellites of Saturn

Reference body:
S3 Tethys
Marked satellite:
S2 Enceladus
Epoch of equator and equinox J2000
Differential coordinates

Refresh image
With 1" field scale
One time step of 1.0000 days
Back
Non
Forvard

Marked satellite:
S2 Enceladus

Center of the field:
$\alpha = 11^h\ 28^m\ 27.662^s$
$\delta = 5^\circ\ 48'\ 9.83''$
N
E + W
S

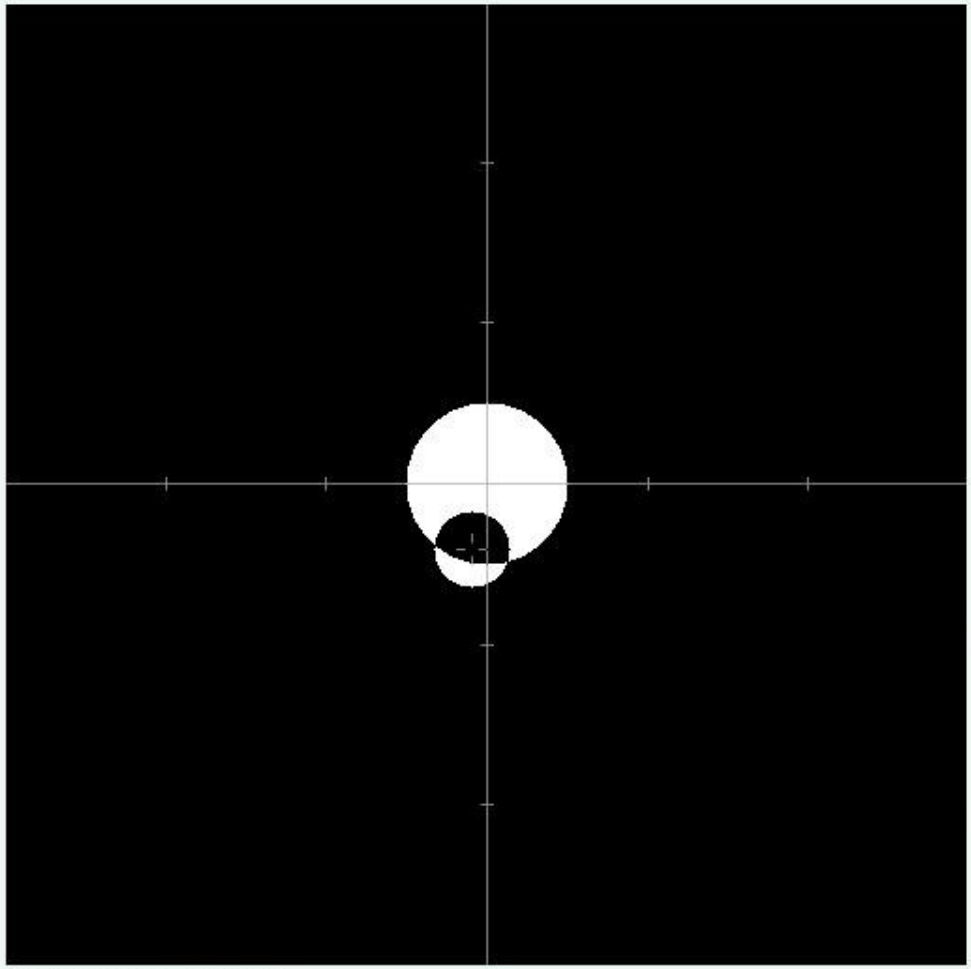
Coordinates and magnitudes

IMCCE-SAI: Natural Satellites Service. Ephemerides. Satellites configuration - Mozilla Firefox

Fichier Edition Affichage Aller à Marque-pages Outils ?

http://www.imcce.fr/cgi-bin/saimirror/nss-eph3.cgi

Démarrage Dernières nouvelles ... MinitelNet



Present field : **1" x 1"**
Time moment: **2009 2 6 11 28 0.00 (UTC)**
Observatory: **Geocenter**

IMCCE/SAI. Natural Satellites Ephemeride Server. MULTI-SAT.

Satellites of Saturn

Reference body:
S3 Tethys
Marked satellite:
S2 Enceladus
Epoch of equator and equinox J2000
Differential coordinates

Refresh image
With 1" field scale
One time step of 1.0000 days
Back
Non
Forvard

Marked satellite:
S2 Enceladus

Center of the field:
$\alpha = 11^h\ 28^m\ 27.654^s$
$\delta = 5^\circ\ 48'\ 9.97''$

N
E + W
S

Coordinates and magnitudes

Terminé

démarrer 5h10'11 Wanadoo 4 Firefox encelade Adobe Photoshop Ele... 17:06

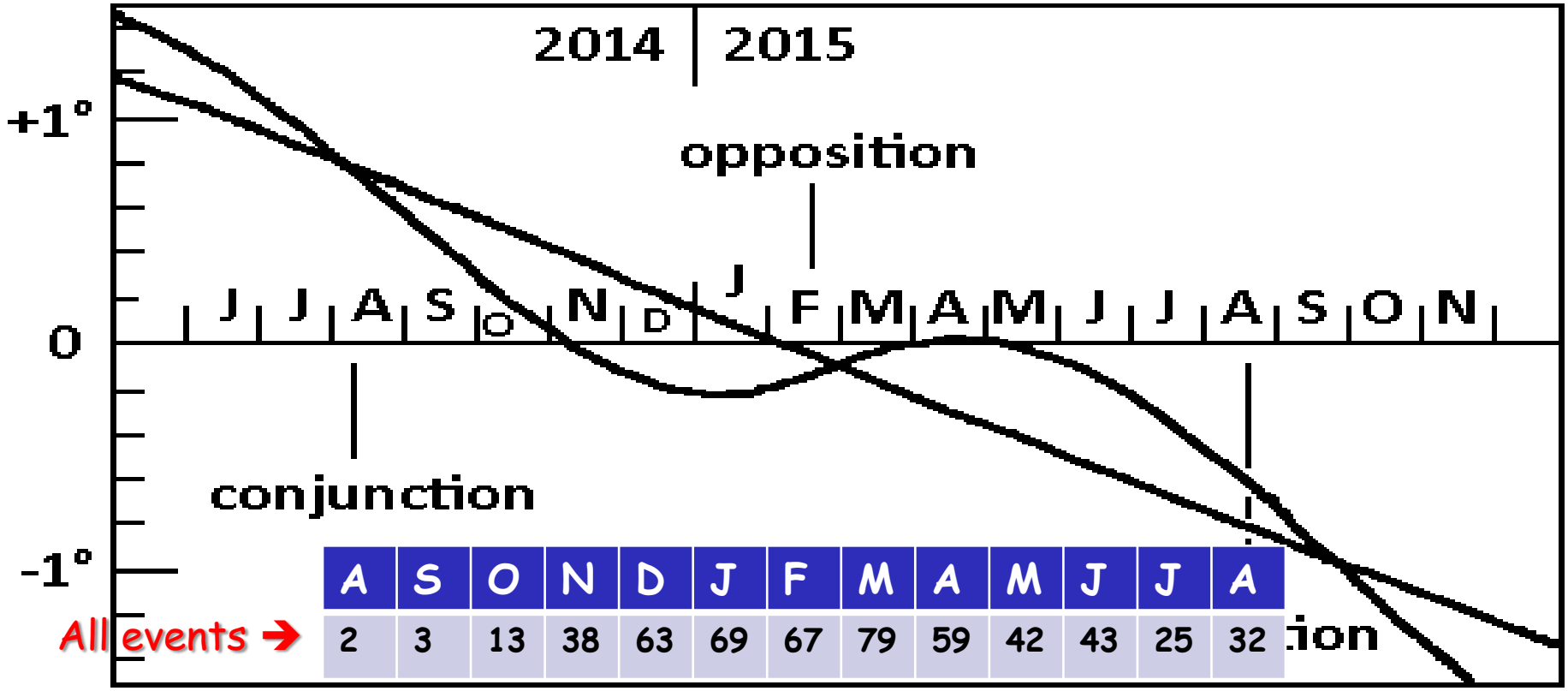
Period	Declination of Jupiter
1967-1968	$+20^{\circ}$ to $+10^{\circ}$
1973-1974	-22° to -10°
1979-1980	$+12^{\circ}$ to $+\ 8^{\circ}$
1985-1986	-22° to -14°
1990-1991	$+18^{\circ}$ to $+20^{\circ}$
1997-1998	-18° to $-\ 4^{\circ}$
2002-2003	$+23^{\circ}$ to $+18^{\circ}$
2009-2010	-20° to -10°
2014-2015	$+23^{\circ}$ to $+15^{\circ}$

Favorable occurrences: either for the Northern hemisphere
either for the Southern hemisphere

The dates of the 2014-2015 campaign of observation

	Jupiter
opposition	**6 February 2015**
conjunction	16 July 2014 and 18 August 2015
passage of the Sun in the equatorial plane (equinox)	5 February 2015
passage of the Earth in the equatorial plane (disappearance of the rings)	8 November 2014, 10 April and 5 May 2015
observing period	September 2014-June 2015
declinations of the planets	+22 to +20 degrees

Number of events each month

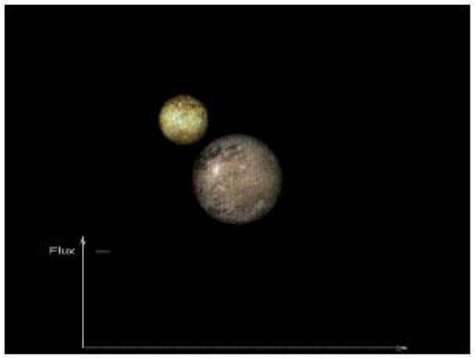


	A	S	O	N	D	J	F	M	A	M	J	J	A
All events →	2	3	13	38	63	69	67	79	59	42	43	25	32

	A	S	O	N	D	J	F	M	A	M	J	J	A
Visible in Paris →	0	0	4	8	27	21	41	30	26	8	7	2	0

2015: equinoxe on Jupiter

THE CAMPAIGN OF OBSERVATIONS PHEMU15 OF THE MUTUAL PHENOMENA OF THE SATELLITES OF JUPITER (Aug. 2014 - Aug. 2015)



A mutual occultation: the photometric signal

Important facts and dates in 2014-2015:

	Jupiter
opposition	February 6, 2015
conjunction with Sun	Jul. 2014 & Aug. 2015
transit of the Sun in the equatorial plane of the planet (equinox)	February 5, 2015
transit of the Earth in the equatorial plane of the planet	Nov. 8 2014, April 10 and May 5, 2015
Declination of the planet	+22 to +20 deg.

In 2014-2015, a series of eclipses and occultations will occur among the satellites of Jupiter thanks to the equinox on this planet occurring in 2015. The observation of these events provides valuable data and is possible even with a small telescope. However, in order to be scientifically useful, the observations must be performed very carefully following very precise instructions.

The technical notes PHEMU provide more information.

Prediction of mutual events occurring in 2014-2015

- **Tables of predictions of the events** of the Galilean satellites (2014-2015)

Tools for the observers of the mutual events

- **Interactive software providing the visibility of the mutual phenomena of the Galilean satellites of Jupiter for any site of observation**
- **Interactive software computing the phenomena of the Galilean satellites by the planet Jupiter for any site of observation**
- **Interactive software providing the configurations and positions of the Galilean satellites for a given date**
- **Download a software for your PC for the determination of the configurations of the satellites for a given date**

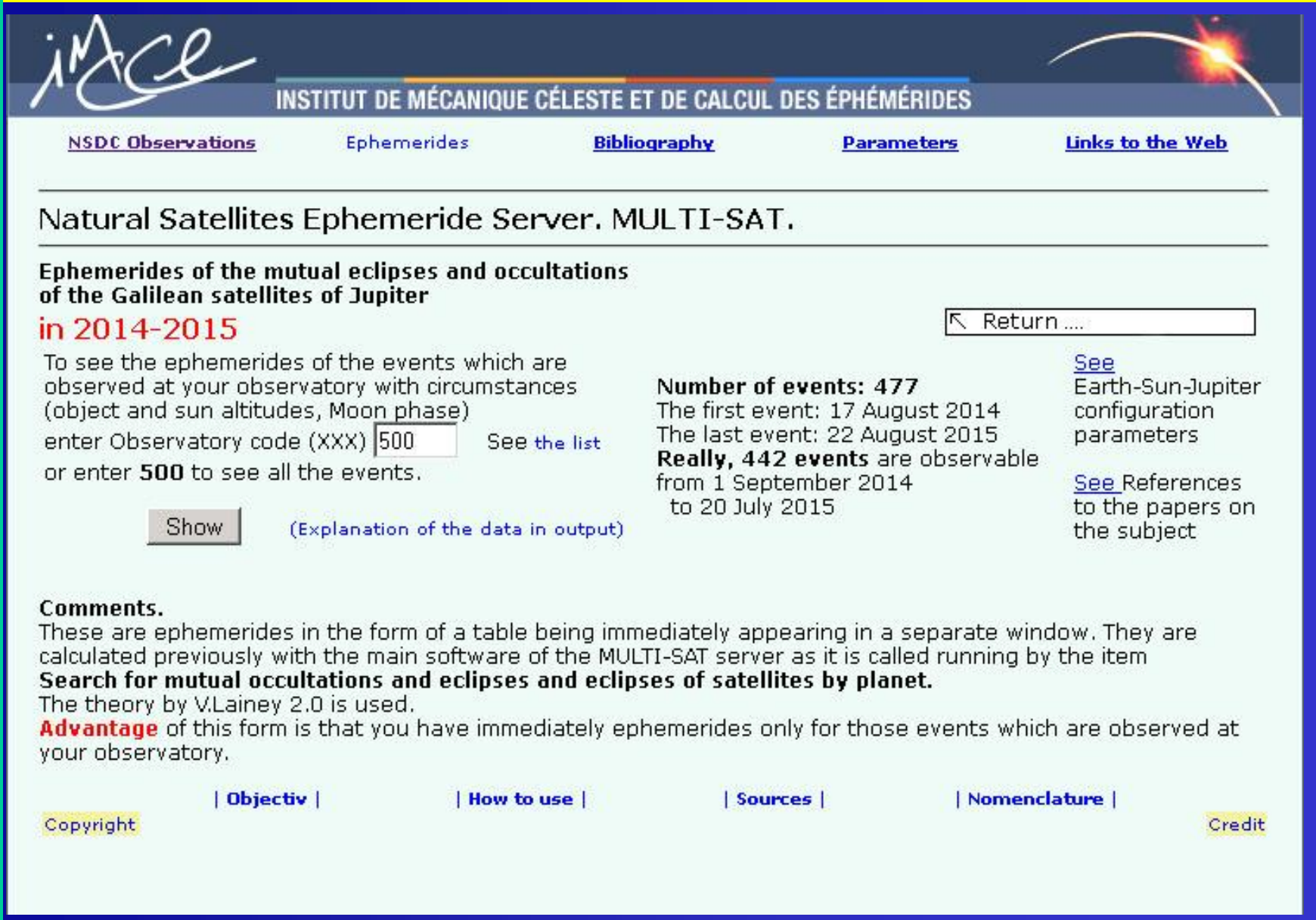
Download here the observational sheet to be filled up and sent back after each observation.

Technical Notes PHEMU

- **Technical Note n°1 : Presentation of the galilean satellites and of the mutual events** - PDF
- Technical Note n°2 : Presentation of the satellites of Saturn and Uranus (in preparation)
- **Technical Note n°3 : The photometric observation of the mutual events** - PDF
- **Technical Note n°4 : The observation of the mutual events using video camera** - PDF
- **Technical Note n°5 : The observation of the mutual events with a CCD camera** - PDF
- **Technical Note n°6 : Examples of light curves obtained during the past campaigns of observation** - PDF

http://www.imcce.fr/phemu

Finding the observable phenomena



Planet: Jupiter (DE405)
Planet
Observatory N: 007 - Paris
Timescale: UTC
Mean equator and equinox of J2000. ICRF.

Mutual events of satellites:

Date	begin: h	m	s	end: h	m	s	Type	Dur(m)	Impact	m	Δm	limb(")	dist(")		Planet(°)	Sun(°)	Moon phase
2014 10 21	2	1	19	2	4	20	2O3	3.0	0.943	4.8	0.007	129.32		:	18.541	-41.230	0.180
2014 10 24	5	8	30	5	11	37	2O4	3.1	0.869	5.3	0.017	37.33		:	48.757	-12.995	0.022
2014 10 28	5	31	53	5	40	2	2O3	8.1	0.535	4.8	0.159	136.22		:	52.642	-10.094	0.296
2014 10 31	2	26	31	4	37	45	4E3	131.2	0.044	4.9	1.393	231.83	48.20	:	28.107	-40.461	0.501
2014 11 2	5	53	16	6	12	7	4O1	18.8	0.268	5.1	0.868	33.92		:	55.373	-7.798	0.657
2014 11 9	2	57	3	2	58	37	1O2	1.6	0.906	4.9	0.019	9.52		:	37.819	-38.045	0.844
2014 11 16	5	7	28	5	10	13	1O2	2.8	0.661	4.9	0.132	5.01		:	55.243	-18.332	0.405
2014 11 19	3	2	3	3	9	20	4O3	7.3	0.596	4.7	0.230	56.18		:	43.684	-39.450	0.225
2014 11 23	3	26	3	3	27	16	3O2	1.2	0.977	4.6	0.003	13.13		:	48.625	-36.409	0.051
2014 11 25	2	9	53	3	38	30	3E4	88.6	0.331	4.7	0.292	314.34	54.84	:	39.316	-48.615	0.187
2014 11 27	22	4	2	22	13	48	2O4	9.8	0.091	5.1	0.211	148.23		:	1.483	-56.793	0.392
2014 11 30	6	29	27	6	33	42	3O2	4.3	0.663	4.6	0.155	4.89		:	50.886	-8.104	0.562
2014 12 2	23	25	44	23	32	48	2O3	7.1	0.884	4.5	0.020	167.58		:	17.751	-63.232	0.756
2014 12 4	6	32	34	6	37	36	4E2	5.0	0.900	5.1	0.076	97.33	110.03	:	48.862	-8.318	0.847
2014 12 6	6	58	30	7	49	53	4O2	51.4	0.691	5.1	0.214	153.52		:	44.631	-4.811	0.973
2014 12 6	22	11	17	22	19	8	3O1	7.9	0.254	4.4	0.521	86.18		:	8.090	-58.393	0.961
2014 12 9	22	37	2	22	49	5	2E3	12.1	0.675	4.5	0.144	207.22	43.47	:	14.220	-61.135	0.774
2014 12 10	23	45	22	23	49	51	1O3	4.5	0.536	4.4	0.168	2.14		:	26.167	-64.298	0.711
2014 12 12	22	36	3	22	43	25	1E4	7.4	0.609	4.9	0.183	138.01	102.38	:	16.031	-61.150	0.594
2014 12 12	23	12	44	2	19	51	2O1	187.1	0.974	4.7	0.003	82.89		:	22.103	-63.726	0.593
2014 12 14	1	6	54	1	15	55	3O1	9.0	0.327	4.4	0.449	95.70		:	40.871	-59.749	0.529
2014 12 14	20	54	58	21	53	58	3O1	59.0	0.088	4.4	0.567	92.52		:	1.060	-48.082	0.479
2014 12 17	2	24	5	2	40	43	2E3	16.6	0.432	4.5	0.338	209.89	38.01	:	51.925	-49.905	0.341
2014 12 18	5	33	40	6	21	9	2O3	47.5	0.419	4.4	0.216	34.92		:	49.340	-19.353	0.268
2014 12 19	22	18	5	22	36	29	2O1	18.4	0.809	4.7	0.053	3.19		:	17.779	-59.239	0.153
2014 12 20	5	31	14	5	51	33	2O1	20.3	0.161	4.7	0.517	97.71		:	48.712	-19.935	0.132
2014 12 21	3	13	5	3	32	29	4E1	19.4	0.136	4.8	1.113	99.93	80.34	:	55.948	-42.637	0.070
2014 12 21	4	11	41	4	23	4	3O1	11.4	0.343	4.3	0.434	102.66		:	55.207	-33.052	0.067
2014 12 22	2	5	48	2	20	10	3O1	14.4	0.321	4.3	0.456	103.68		:	52.185	-53.018	0.028
2014 12 22	5	20	42	5	28	32	4E1	7.8	0.719	4.8	0.336	90.31	88.96	:	49.017	-21.807	0.031
2014 12 24	6	24	22	6	45	44	2E3	21.4	0.190	4.4	0.588	210.00	31.89	:	39.360	-11.893	0.169

The mutual events

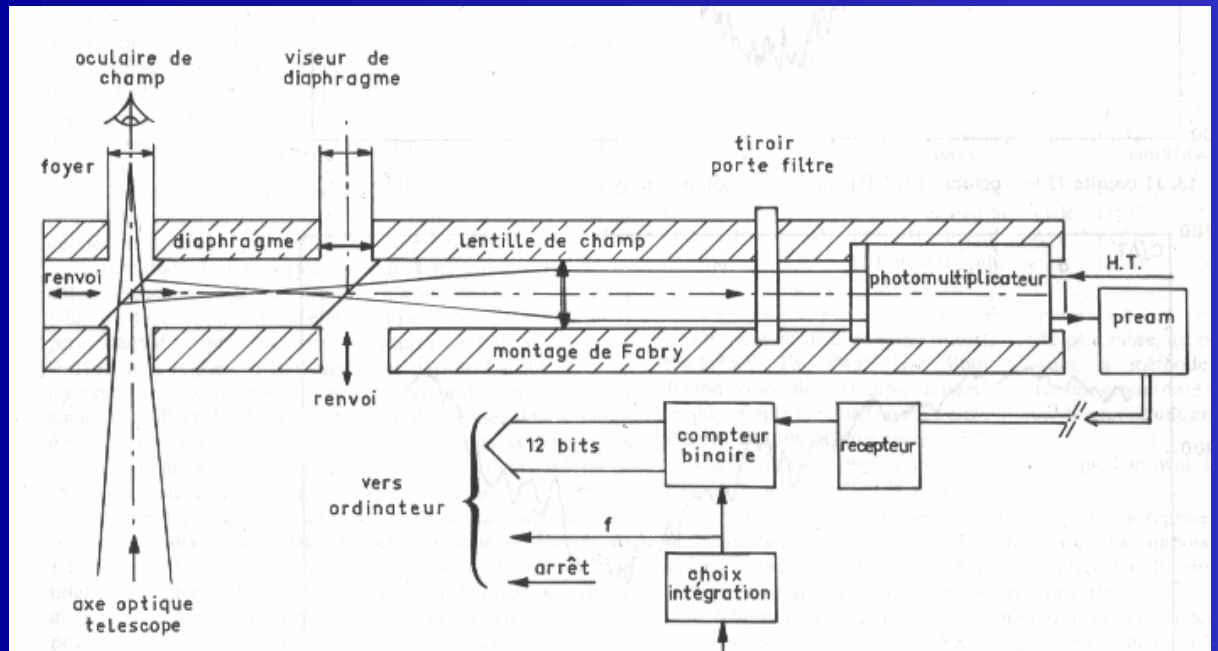
- They are photometric observations
- Each photometric point must be recorded to UTC at the nearest 0.1 s
- What is to observe ?

Which instruments to observe the mutual events?

- A « small telescope »: confident observations were made in the past with a 6-cm instrument: the stability of the instrument and the guiding are essential.
- A CCD camera or a web-cam put at the focus of the instrument will provide usable images: attention, the gain of the camera must be fixed and not automatic during the observation
- Each image must be dated in Universal Time (UTC) to the nearest 0.1 second of time: the clock inside the PC computer is not confident. GPS time is convenient.
- Avoid compressing the images when recorded.

← CCD image of the four galilean satellites put slightly out of focus to avoid saturation and to have more pixels illuminated

From the 1D photometer to the 2D CCD image

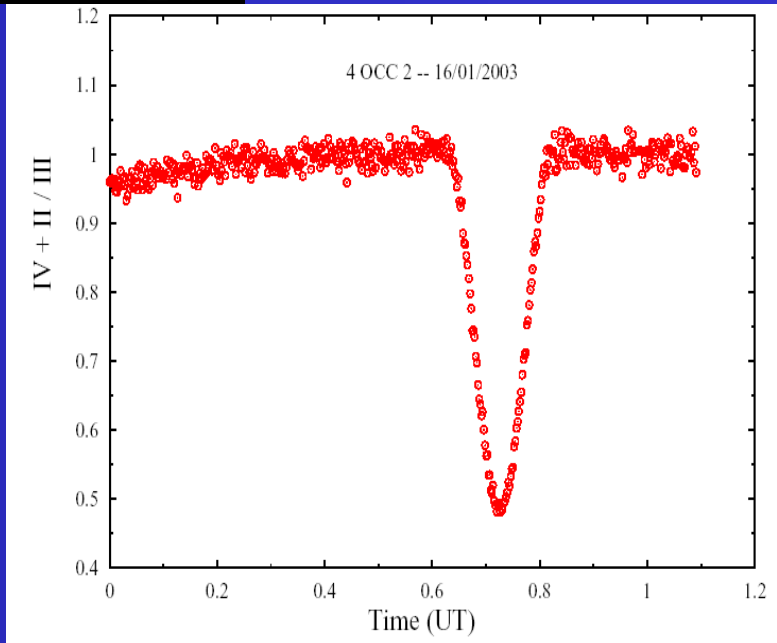


← Fabry photometer for a total illumination of the cathode

Observing the mutual events

The Galilean satellites

A photometric timing:
0,1 sec = 1 km
An astrometric measure:
0.1 arcsec = 300 km



High resolution mutual occultation and eclipse

We do not need high resolution for photometry and astrometry

Observing the small inner satellites

Events for the inner small satellites available on:
http://www.imcce.fr/hosted_sites/saimirror/nsspheOhe.htm

The best observing conditions are for:
Amalthea, mv=14 at 30" from the limb of Jupiter

The maximum duration
of an eclipse of Amalthea
is 8 minutes

Infra-red observations

For difficult observing conditions:

- Very close to the limb of Jupiter
- During twilight

And for the eclipses of Amalthea (mv=14)

Use the absorption band of the methane:

- Jupiter darker
- Sky darker

Bands: 890 nm, 1.3 micrometer, 2.2 micrometers, …

Be careful, the fluxes are fainter!

➔ Need of larger telescopes!

Conclusion

- Rare evnets will occur in 2014-2015
- We need a worldwide network of observers
- Join the campaign!
- Site Web: http://www.imcce.fr/phemu
- e-mail: phemu@imcce.fr