Multi-instrumental observations of the 2014 Ursid meteor outburst

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1. Introduction

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- Similar date than Geminids, which are more predictable and numerous.
- Usually low ZHR (<10)
- Bad weather conditions in mid-December.

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- Jupiter Family
- Trapped in a 15:13 resonance with Jupiter => T~13.6 yr.
- Aphelion: 10 AU.
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- ZHR > 100 when the comet is at its aphelion.
- This increase occurs each 13.6 years approx.
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Any explanation? (Jenniskens et al. (2002)

- Mean motion resonances.
- The meteor swarms detached during certain years evolve to a different orbit an get trapped in a 7:6 resonance with Jupiter=> Period roughly fixed.
- T swarm/ T comet = 1,011 => In around 45 or 46 orbits (~620 yr) the comet and the swarm are out of phase.

2. The Campaign

Details of the SPMN and FRIPON stations involved in the Ursid aphelion outburst campaign.

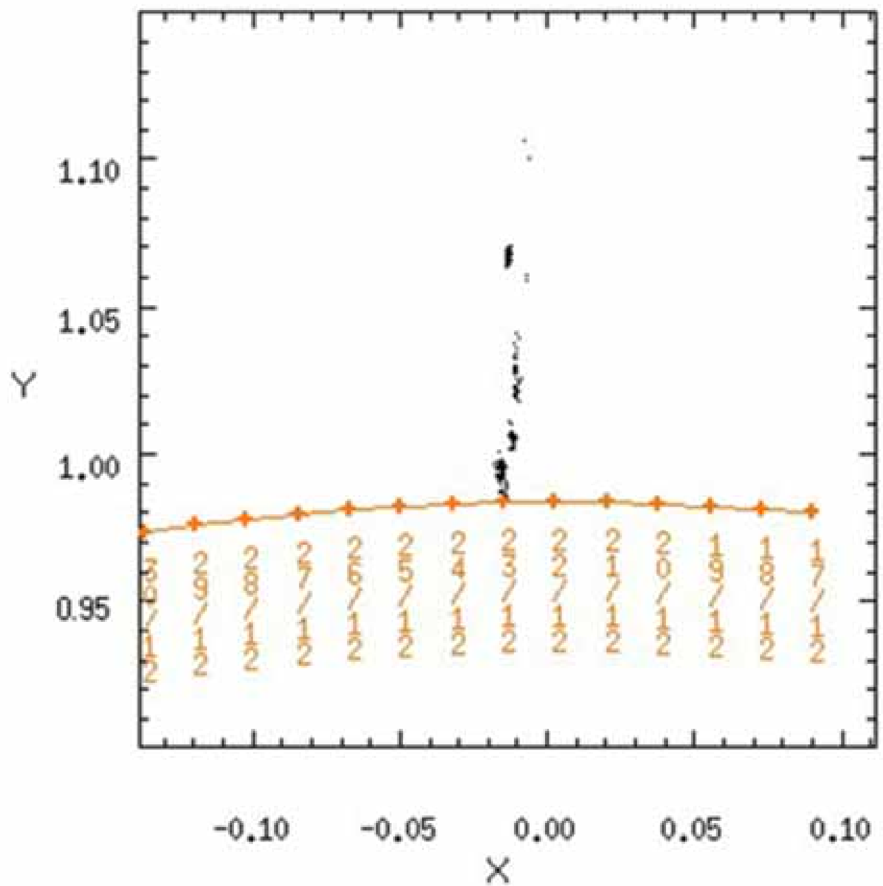
Network	Station (Province)	Longitude	Latitude (N)	Altitude (m)	Imaging system
SPMN	Montsec (Lleida)	00°43′46″E	42°03′05″	1570	AS
SPMN	Montseny (Girona)	02°31′14″E	41°43′17″	300	WFV
SPMN	Folgueroles (Barcelona)	02°19′33″E	41°56′31″	580	WFV
SPMN	Ebre Observatory	00°29′44″E	40°49′16″	50	WFV
FRIPON	Pic du Midi	00°08′34″E	42°56′11″	2876	AS
FRIPON	Dax Observatory	01°01′49.8″W	43°41′36.4″	470	AS

Note. Acronyms for the different imaging systems are AS (low-scan-rate CCD all-sky camera) and WFV (Wide-field video cameras).

Forward -Scatter Radio system at 143.05 MHz:

- Transmitter: from Grand Reseau Adapté á la Veille Spatialle radar (Dijon).
- Receiver: 8 dBi six-element Yagi antenna and a Yaesu FT817 ND receiver (Jaén).

3. Outburst Predictions



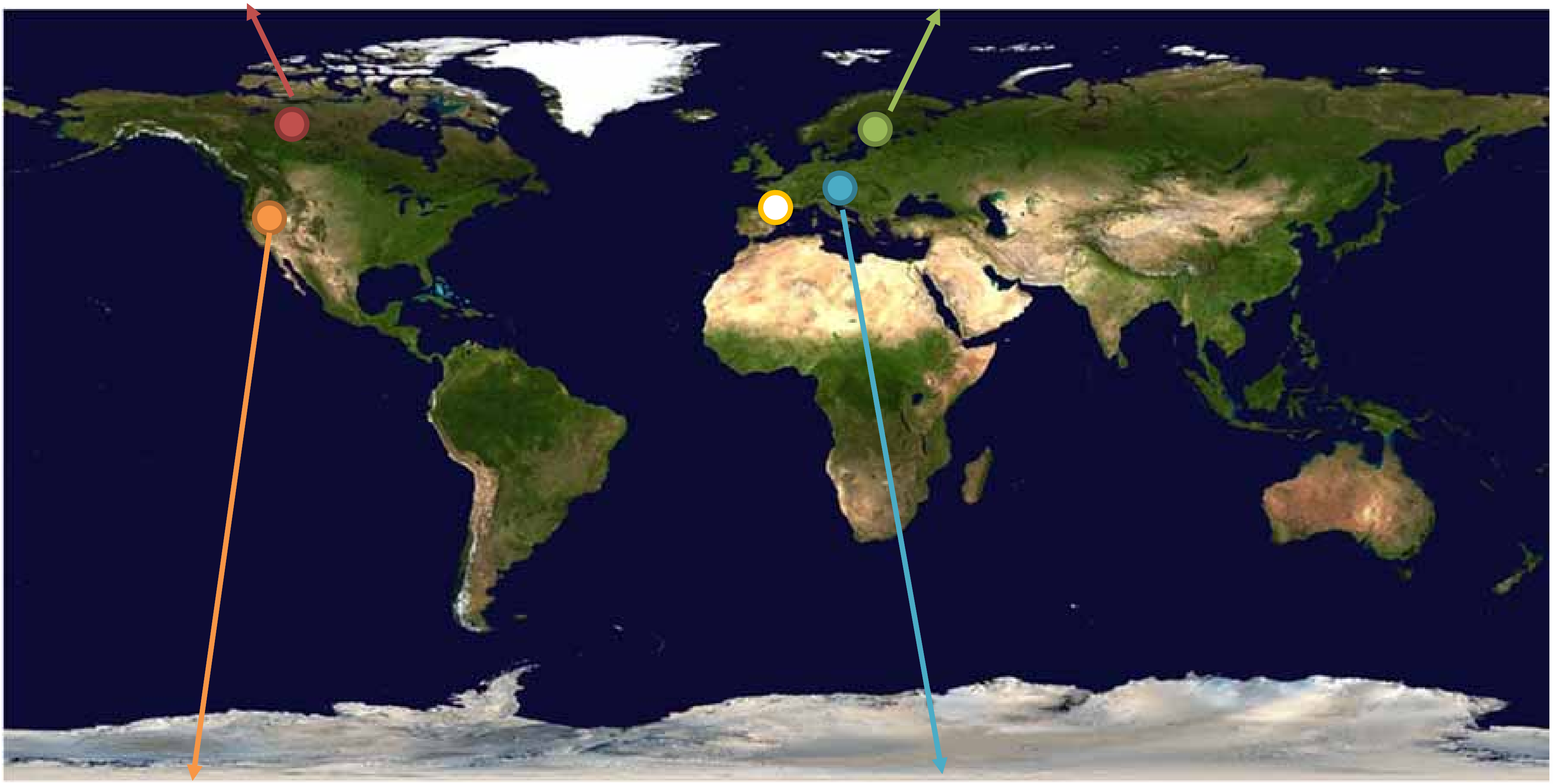
Nodes of the dust trails encountering the Earth in 2014. The trajectory of the Earth is also plotted. X and Y values indicate the coordinates on the ecliptic plane.

Author	Swarm	Date	Time	Solar Long.
J. Vaubaillon	1392	Dec. 23	00:46 h	270,745 º
Jenniskens (2006)	1405	Dec. 22	23:38 h	270,838º
Jenniskens (2006) [filament]	-	Dec. 22	17:05 h	270,56º

4. Outburst Observations

Canadian Meteor Orbit Radar: Up to 85 meteors between 23:15 h (UT) (Dec. 22) and 00:45 h (UT) (Dec. 23) (Brown 2014).

Radio meteor detections by Yrjola (Kuusankoski, Finland) reporting high Ursid meteor activity in this period (Jenniskens 2014).

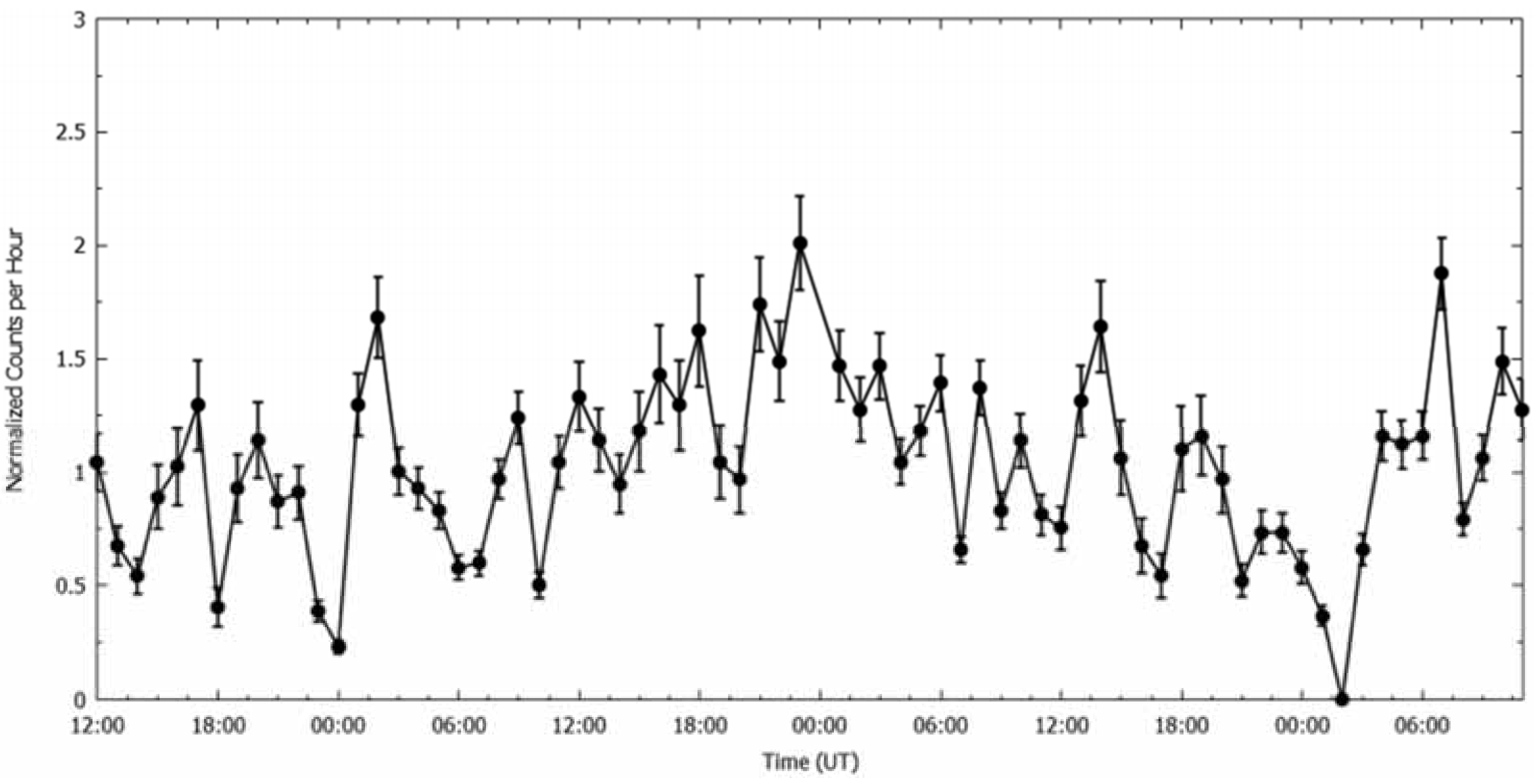


NASA's Camera for All-sky Meteor Surveillance project in California: 20 meteors during the main activity time (01:32h UT Dec. 23 to 04:00h Dec. 23) and 15 more after this time (Jenniskens 2014) (Dec. 23) at λ = 270.85º.

Gajdos, Toth and Kornos (2015), using *AMOS all-sky camera*: 19 meteors between 21:20h UT Dec. 22 and 05:35h UT Dec. 23.

The SPMN-FRIPON campaign

- Optically:29 Ursid meteors with a population index of 1.8 ± 0.6 which is similar to the 1.7 found by Molau (2014).
- The mean Ursid ZHR was around 19, in agreement with the ZHR = 10 prediction of Jenniskens (2006); but peaking with a ZHR = 45 ± 19, which is also close to the value reported in Molau (2014).
- Radio Scatter: significant activity between 00.00h and 01.00h on Dec. 23.



Radio meteors counts normalized per hour (over the mean number of counts each hour) detected at Jaén forward-scatter station, from December 21 at 12h (UT) to December 24 at 12h (UT). An increase activity was observed in the night of December 22–23.

5. Results

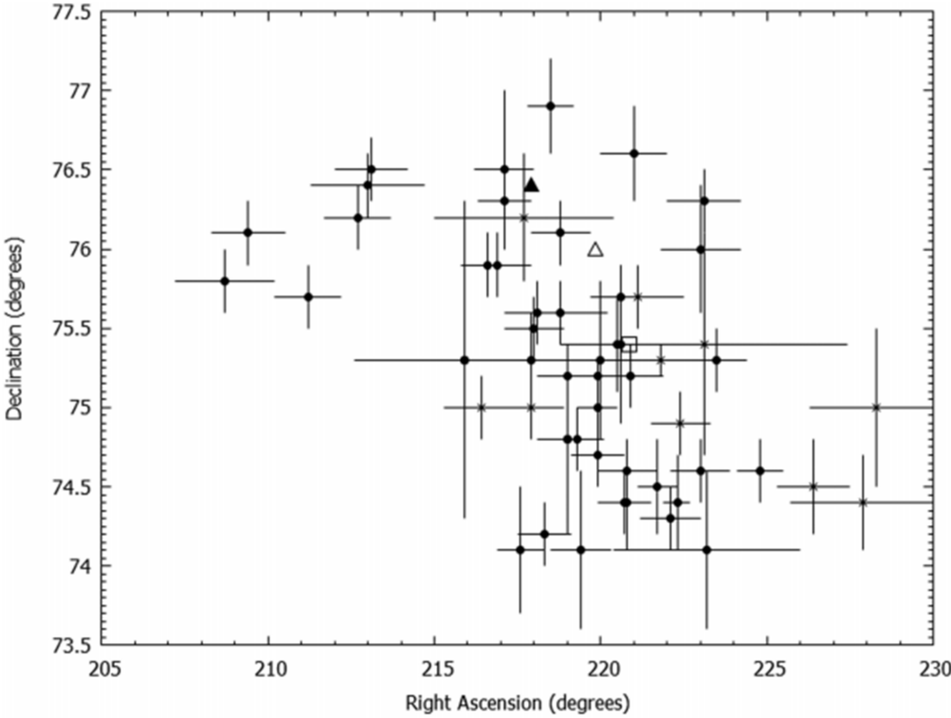
- Reduction pipeline and astrometric analysis as in Trigo-Rodriguez et al. (2004)
- Orbital parameters retrieved using AMALTHEA software (Madiedo et al. 2011).

Trajectory and radiant data for four multistation Ursid meteors registered in 2014 December (J2000.0).

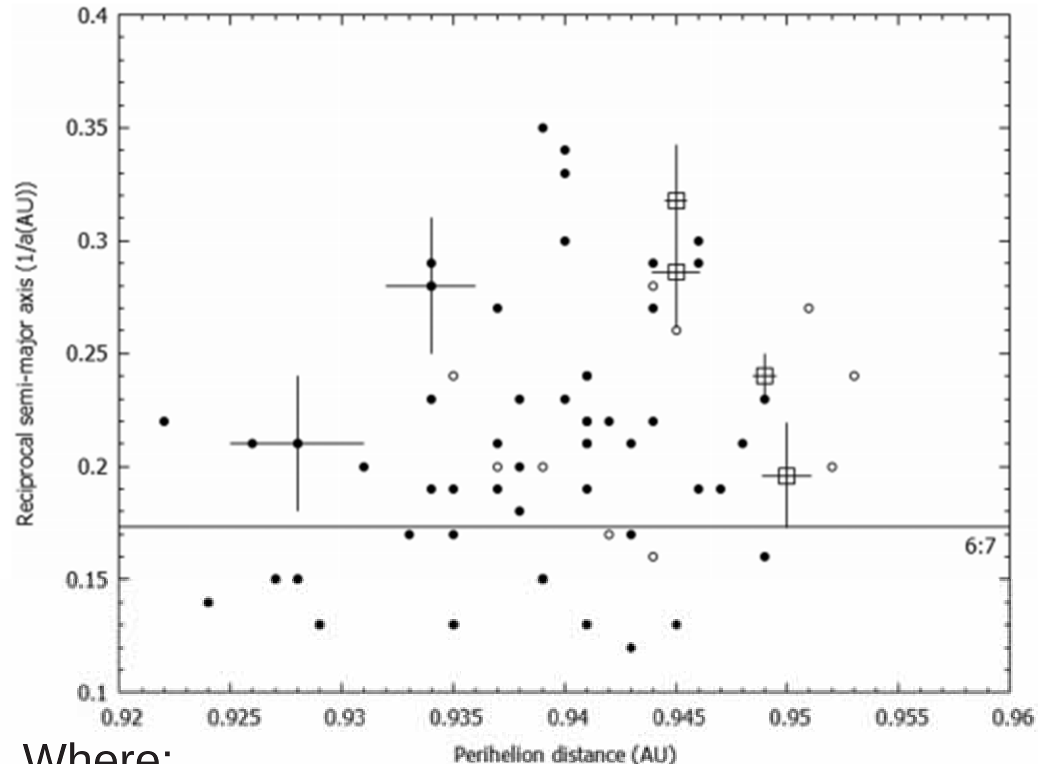
Meteor code	M_v	H_b (km)	H_e (km)	α_g (°)	δ_g (°)	V_∞ (km s^{-1})	V_g (km s^{-1})	V_h (km s^{-1})
SPMN 221214A	−3	93.5	85.5	225.43 ± 0.23	74.47 ± 0.21	33.8 ± 0.4	32.1	39.1
SPMN 231214A	−4	88.6	85.6	225.4 ± 0.3	75.88 ± 0.21	32.2 ± 0.4	30.1	39.0
SPMN 231214B	−5	96.3	69.7	229.6 ± 0.5	75.9 ± 0.4	33.7 ± 0.3	31.7	40.4
SPMN 231214C	−4	93.3	75.8	227.3 ± 0.4	76.7 ± 0.4	32.2 ± 0.4	30.1	39.4

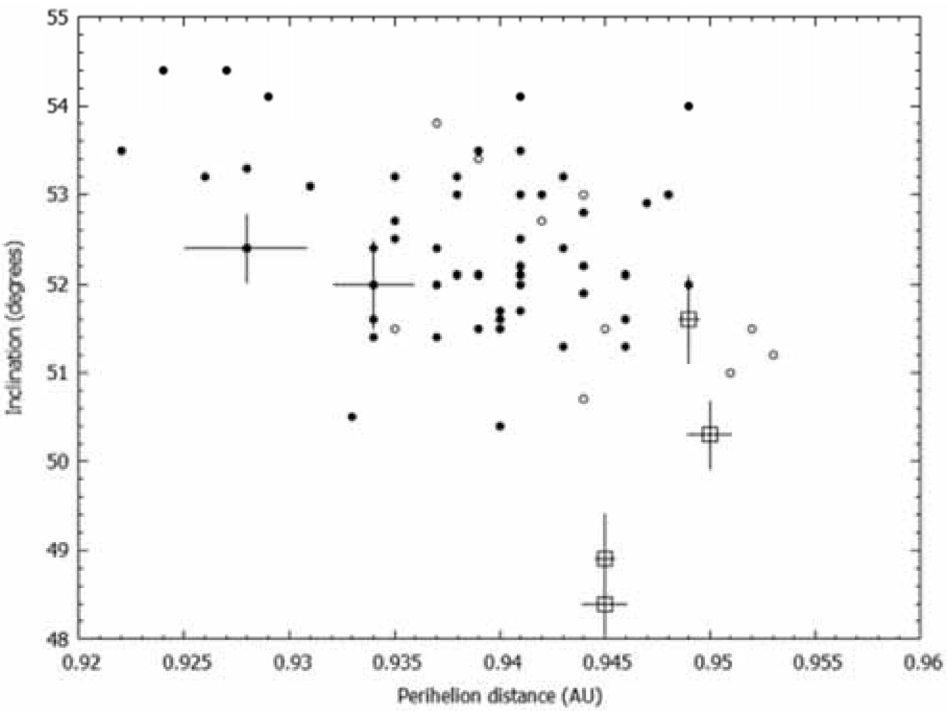
Orbital elements for four multistation Ursids meteors registered in 2014 December (J2000.0).

Meteor code	Day	q (AU)	a (AU)	e	i (°)	ω (°)	Ω (°)
SPMN 221214A	22.964 847 22	0.9486 ± 0.0014	4.16 ± 0.17	0.772 ± 0.025	51.6 ± 0.5	203.3 ± 0.3	270.8240
SPMN 231214A	23.038 005 79	0.9450 ± 0.0005	3.15 ± 0.24	0.700 ± 0.023	48.9 ± 0.5	205.2 ± 0.3	270.8986
SPMN 231214B	23.055 568 39	0.9503 ± 0.0011	5.1 ± 0.6	0.815 ± 0.021	50.3 ± 0.4	202.4 ± 0.3	270.9165
SPMN 231214C	23.086 087 96	0.9448 ± 0.0011	3.5 ± 0.3	0.731 ± 0.020	48.4 ± 0.4	205.0 ± 0.3	270.9477



- *Empty Square: J Vaubaillon simulation.*
- *Empty Triangle: Our observations (avge.).*
- *Filled Triangle: Observations of Gajdos et al. (2015)- Single station detection.*





Where:

· Ursid **aphelion outburst** in the year 2000: (*filled circles*) as in Jenniskens et al. (2002);

· **Perihelion outburst** of 1997 (*empty circles*) as in Jenniskens et al. (2002);

· The four Ursids meteors studied in **this work** (*open squares*).

6. Conclusions

(1) Video and forward-scatter detections along with other reports indicate high meteor activity associated with an Ursid dust trail crossing the Earth's orbit at solar longitude at $\lambda 0$ = 271.8º on 2014 December 23.

(2) The outburst was characterized by relatively large meteoroids (population index of 1.8), producing bright meteors and some fireballs that were recorded by our all-sky systems and video cameras.

(3) The mean Ursid ZHR was around 19 meteors/h, peaking with a ZHR of 45 ± 19 at around solar longitude λ = 271.85º.

(4) Two of the four Ursid orbits exhibit similar orbital elements to the previously recorded meteoroids during outbursts. The other two were measured slightly below the expected geocentric velocity, and their measurements were probably affected by low meteor brightness on the very beginning trajectory segment. However, the meteor orbits retrieved are well within the range of values of previous aphelion outbursts.

(5) Despite some minor inaccuracies, the four meteoroids have orbits that seem to be associated with the 1405 or 1392 dust trails that provoked the outburst and are captured in the two-body mean motion resonance with Jupiter.

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