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MULTI-STATION OBSERVATIONS OF THE 2014 URSID METEOR OUTBURST. M. Moreno-Ibáñez^{1,2}, J.M. Trigo-Rodríguez¹, J.M. Madiedo^{3,4}, J. Vaubaillon⁵, M. Gritsevich^{6,2,7}, L.G. Morillas⁸, E. Blanch⁹, P. Pujols¹⁰, F. Colas⁵ and P. Dupuy¹¹. ¹Institute of Space Sciences (IEEC-CSIC), Barcelona, Spain mmoreno@ice.csic.es; trigo@ice.csic.es ²Finnish Geospatial Research Institute, Masala, Finland. ³Facultad de Ciencias Experimentales, Universidad de Huelva, Huelva, Spain. ⁴Departamento de Física Atómica, Facultad de Física, Universidad de Sevilla, Molecular y Nuclear, Sevilla, Spain. ⁵Institut de mécanique céleste et de calcul des éphémérides - Observatoire de Paris PSL, Paris, France. ⁶Department of Physics, University of Helsinki, Helsinki, Finland. ⁷Institute of Physics and Technology, Ural Federal University, Ekaterinburg, Russia. ⁸IES Cañada de las Fuentes, Jaén, Spain. ⁹Observatori de l'Ebre (OE, CSIC – Univ. Ramon Llull), Tarragona, Spain. ¹⁰Agrupació Astronòmica d'Osona (AAO), Vic, Spain. ¹¹Dax Observatoire, Dax, France.

Introduction: The Ursid meteor shower (hereafter URS) has become a very interesting topic of research. It usually shows a low ZHR, around 10 meteors/hour. However, several outbursts have been reported in the past years. This increase of the meteor activity not only occurs when the parent comet, 8P/Tuttle, orbits its perihelion, but also when the comet is near its aphelion. This uncommon behavior has been deeply analyzed [1, 2]. As it has been suggested [1], the orbital mean motion resonance and the radiation pressure would cause a lag and an orbit decay between the parent comet and the dust trails detached at perihelion passages. As a result, the comet 8P/Tuttle would orbit in the 13:15 resonance with Jupiter and some compact dust trails would eventually orbit in the 6:7 resonance with a time difference with the comet position of half the period of the comet (13.5 years).

The prediction of the last Ursid meteor aphelion outburst was scheduled for the night of 22nd – 23rd December of 2014. The Spanish Meteor Network (SPMN) in collaboration with (FRIPON) set up a campaign to monitor the meteor shower and eventually retrieve orbital data that supported previous results and predictions. The bad weather conditions partially hampered the observations, but we were able to accurately obtain the atmospheric trajectory, the radiant and the orbit information of four Ursid meteors.

Astrometric reduction and observations: The SPMN and FRIPON stations that provided Ursid outburst data are listed in Table 1. The SPMN stations consists of an array of low-light CCD video cameras which can cover several sky regions, obtain point-like star images and detect meteors showing an apparent magnitude of $+3\pm 1$ [3, 4]. Coordinate positions of the fireball were obtained by creating a composite image of all frames where the stars coordinates were measured and taken as reference using our SPMN astrometric software [4]. The heliocentric orbit was computed using our previously tested software package [5]. As for the FRIPON stations, they are provided with DMK 23G445 all sky cameras which allow exposures of 30ms [6]. Besides, we included a forward-scatter radio

system operating at a frequency of 143.05 MHz. This was located in Jaén (Spain), listening to the Grand Réseau Adapté à la Veille Spatiale (GRAVES) radar located in Dijon, France (<http://www.onera.fr/dcps/graves>).

Our campaign resulted in the optical detection of 29 Ursid video meteors during the night of 22nd and 23rd of December of 2014. We inferred a mean ZHR of 19 ± 3 meteors/hour ($r=1.8\pm 0.6$), which is in agreement with the simulated mean ZHR (around 10 meteor/hour) provided in [2]. The forward-scatter meteor detections also detected the expected activity. Other reports describe the Ursid activity increase and agree with our observations [7-10]. Despite the joint network effort, we found no common meteor observations in both networks due to the large distance of the stations and the more limiting magnitude detection of the FRIPON detectors. Only eleven SPMN multi-station meteor were detected. Among them, we rejected those which showed convergence angles smaller than 20° [11], and those with trajectories that partially fell out the camera FOV. Finally, we derived the orbital elements and the corresponding errors for four Ursid meteors. We present the mean orbit of these meteors in Table 2, and Fig.1 shows a comparison of one meteoroid orbit to that of the comet.

Discussion: As discussed by [1], the dust trails causing the outburst shall have kept a compact formation over time due to the orbit resonances. These dust trails consist of cometary material detached from its parent body in the years 1392 and 1405, during its perihelion passage. We present here the averaged orbital parameters of four bright URS meteors in order to check their membership to those trails. We found that the semi-major axis, the eccentricity, the perihelion distance and the geocentric velocity values are well within the range of these values registered in the previous 2000 outburst larger sample [1], which was suggested to be provoked by both the 1392 and 1405 dust trails. It is remarkable, though, that the orbit inclination of a couple of meteors is lower, and could be an effect of successive close approaches to Earth. We have ob-

tained a mean apparent radiant similar to that of [1] and, in agreement with computational simulations (see Table 3).

Some minor orbital discrepancies are attached to the poor ability of the Ursids to produce light. This is of particular relevance during the astrometric analysis of the meteor luminous atmospheric trajectory. The beginning points are particularly difficult to be resolved, causing some inaccuracy in the values retrieved for the trajectory slope and meteor entry velocity, which will ultimately affect the derivation of the orbital elements. In any case, the uncertainty in the derived values takes into account reasonable margin for this instrumental bias.

Conclusions: We have obtained the orbital elements of four Ursid meteors detected during the predicted aphelion outburst of 2014. A co-joint observation campaign between the SPMN and FRIPON network confirms the increase of meteor activity reported by other observations. We registered similar ZHR, population index and apparent radiant positions. Despite some minor inclination discrepancies that could be caused by gravitational effects in previous approaches to Earth, the orbital elements of the four meteors match with the predicted and observed orbit of the compact dust trail that provoked this outburst. We

cannot rule out that the small geocentric velocity of some URS meteors could hamper our capacity of measuring the first stages of ablation, then decreasing systematically the beginning velocities.

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Network	Station	Longitude	Latitude (N)	Alt. (m)
SPMN	Montsec	00° 43' 46" E	42° 03' 05"	1570
SPMN	Montseny	02° 31' 14" E	41° 43' 17"	300
SPMN	Folgueroles	02° 19' 33" E	41° 56' 31"	580
SPMN	Ebre Obs.	00° 29' 44" E	40° 49' 16 "	50
FRIPON	Pic du Midi	00° 08' 34" E	42° 56' 11"	2876
FRIPON	Dax Obs.	01° 01' 49.8" W	43° 41' 36.4"	470

Table 1: SPMN and FRIPON stations involved in the URS campaign.

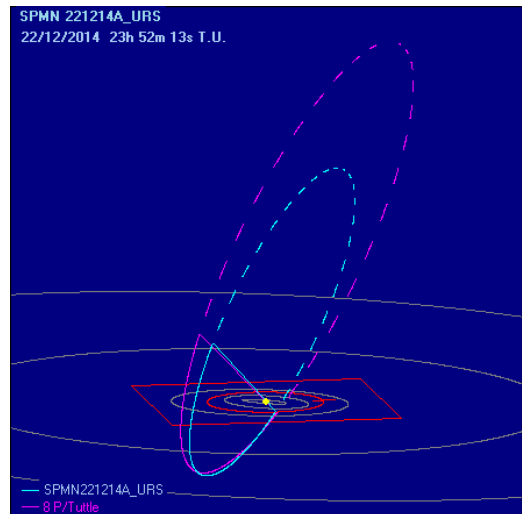


Fig 1.Heliocentric Orbit of one of the meteoroids compared to the comet 8P/Tuttle.

Meteor Code	q (AU)	a (AU)	e	i (°)	ω (°)	Ω (°)
Mean Orbit	0.95618±0.01	3.98±0.4	0.755±0.03	49.8±0.7	203.9±0.7	270,8967±0.03

Table 2: Mean Orbital elements of the 4 multi-station Ursids meteors registered in Dec. 2014 (J2000.0).

Number of values averaged	RA (°)	DEC (°)	V _g (km s ⁻¹)	Source
Prediction N=19	220.85	+75.4	33.21	J. Vaubaillon (IMCCE)
Double station N=4	219.85±0.2	76.0±0.2	32.3	This work
Single station N=19	217.9	+76.4	-	[8]

Table 3: Predicted apparent radiant positions and averaged geocentric velocity (V_g) of the 2014 Ursid dust trail members according to J. Vaubaillon, compared with our double station results and [8] single station results. Equinox (2000.0).