AN UNEXPECTED 2021 ANDROMEDID DISPLAY RECORDED FROM SPAIN BY SPMN STATIONS: A SELECTION OF BRIGHT BOLIDES PRODUCED BY LARGE METEOROIDS FROM 3D/BIELA.

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Introduction: Two of the most important and spectacular meteor storms that occurred in contemporary history were the 1872 and 1885 displays tooking place shortly after the disruption of comet 3D/Biela [1,2]. These were the first successfully predicted meteor storms, which served to discover the strong gravitational influence of Jupiter in the evolution of meteoroid streams [3,4]. These planetary perturbations made that most meteoroids evolved to non-Earth-crossing orbits, so the shower practically disappeared during the first half of the 20th century. Only a weak remnant of Andromedids was identified using photographic monitoring [5]. Two Andromedid outbursts were identified in 2011 and 2013 and explained as the leftovers of 17th century 3D dust trails [6]. We describe the appearance of extremely bright Andromedids demonstrating the existence of extremely large meteoroids.

Figure 1. SPMN061121K recorded from a) Alpicat nd b) Corbera de Llobregat.

Observational data and study case: A significant fraction of the Andromedid activity was originated from bright bolides. We are currently reducing some of these events like e.g. SPMN061121K occurred on November 6th, 2021 at 22h52m57s UTC. The SPMN network recorded this -8 magnitude fireball from four stations. The event was also recorded from three FRIPON stations, but the data were not used. Fig. 1 shows the fireball path from the two closest stations, and Table 1 provides the coordinates for all monitoring sites. The atmospheric trajectory is shown in Fig. 2.

Station	Longitude	Latitude	Alt.
Alpicat	0º 33´ 25" E	41º 40´ 03" N	255 m
Benicàssim	0º 02´ 19" E	40º 02´ 03" N	10 m
Corbera Llob.	1º 53´ 26" W	41º 24´ 33" N	501 m
Sant Mateu	0º 10´ 34" W	40º 27´ 55" N	349 m

Table 1. SPMN stations recording the studied event.

We analyzed the video recordings using our software *3D-FireTOC*, which detects the fireball motion, performs the astrometry, calculates the atmospheric trajectory and compute the heliocentric orbit [7,8].

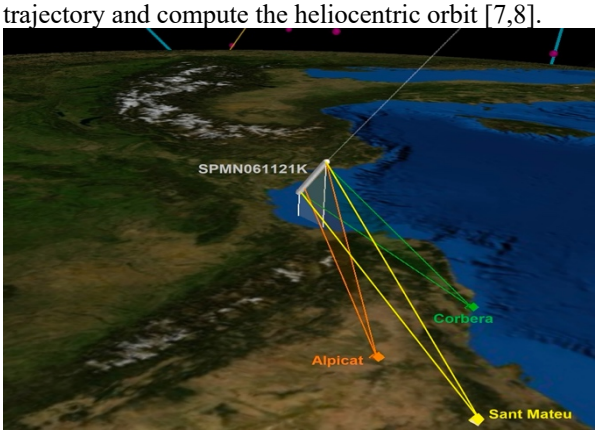

Figure 2. SPMN061121K luminous path reconstruction showing the intersection of planes from three stations. The fireball overflew the Gulf of Lion.

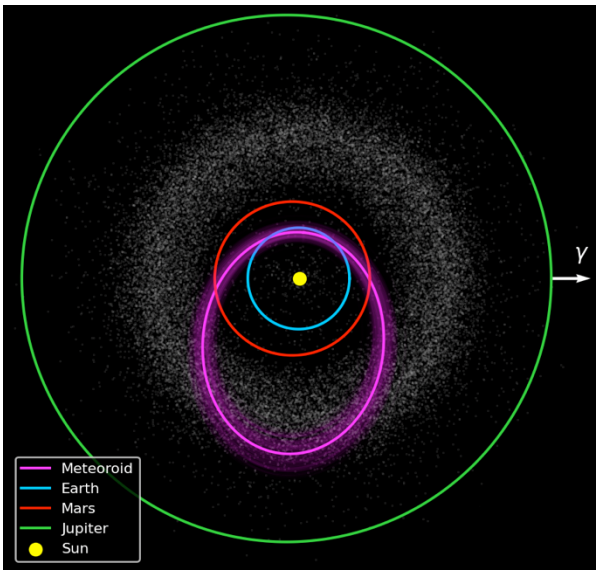

Figure 3. The orbit of SPMN061121K and that one of the Earth appears in light blue, followed by the outer planets up to Saturn (dark blue).

The fireball started at a heigh of 78.87±0.19 km with a velocity of 15.3±0.4 km/s and ended at 35.36±0.20 km having an ending velocity of 13.2±0.4 km/s (see Fig. 3). Both the speed, radiant and calculated orbital parameters point to a clear association with the Andromedids, and the 3D/Biela as parent comet (Fig. 2). In any case, there are significant orbital differences, probably due to gravitational perturbations. The radiant, velocities and orbital parameters are shown in Table 2.

Radiant data			
	Observed	Geocentric	Heliocentric
R.A. (º)	14.4±0.4	10.8±0.4	327.8±0.7
Dec. (º)	9.0±0.4	2.8±0.6	-0.54±0.11
V_∞ (km/s)	15.3±0.4	10.6±0.5	37.2±0.4
Orbital parameters			
a (AU)	2.19±0.15	**ω (º)**	40.2±0.7
e	0.59±0.03	**Ω (º)**	44.30720±0.00010
q (AU)	0.906±0.005	**i (º)**	0.56±0.11

Table 2. SPMN061121K radiant data and orbital parameters.

We are currently studying other very bright bolides produced during the 2021 Andromedid display. The disruptive nature of 3D/Biela suggests that some of these slow meteoroids could produce meteorite-dropping bolides like e.g. SPMN121121 (Fig. 4). It cannot be ruled out either that some meter-sized survivor fragments can remain as potentially hazardous asteroids (PHAs).

Figure 4. -11 magnitude SPMN121121 bolide recorded from Madrid by J. Zamorano (UCM).

Conclusions and future work: The 2021 Andromedid display not only was an unexpected source of significant meteor activity along November 2021, but also a source of large meteoroids with potential to deliver meteorites. SPMN fireball observations reveal a component of large meteoroids producing potential meteorite-dropping bolides around mid-November. Given the low geocentric velocity of this meteoroid stream, we can compute that the brightest events of the Andromedids had a mass of tens of kg [9]. It means that our planet crossed meteoroids tens of cm-sized, capable to produce extremely bright bolides like the ones described in this work. These sizes and masses also represent a significant source of hazard for the ISS or artificial satellites. Having into account that comet 3D/Biela was produced by disruption, we cannot rule out the presence of hazardous asteroids in the stream.

Acknowledgements: JMT-R, EPA and AR acknowledge financial support from the Spanish Ministry (PGC2018-097374-B-I00, PI: JMT-R; CTQ2017-89132-P, PI: AR). EPA and AR acknowledge financial support from ERC (No. 865657).

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