A SUPERBOLIDE RECORDED OVER SPAIN: TRAJECTORY, ORBIT AND EMISSION SPECTRA.

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Introduction: One of the most stunning astronomical phenomena that we can observe with our own eyes is the so-called superbolides: large meteoroids that produce such an extreme brightness that can be detected from space when they undergo ablation during atmospheric entry [1,2]. However, these events are infrequent and cannot be predicted because the current capabilities of asteroid survey systems do not allow the observation of meter-sized objects. It is therefore of vital importance to continuously and completely monitor the sky to rationally explain these events and analyze them both to know the cosmic origin of these space rocks and to find possible surviving meteorites.

In this regard, the Spanish Meteor Network (SPMN) has been operating for more than 25 years covering the entire peninsular territory, the Canary Islands and the Balearic Islands [3]. The SPMN has 34 stations equipped with all-sky cameras, wide-angle video, forward scatter radar and spectrometers, and continues to expand while strengthening its cooperation with the FRIPON network [4].

We have created our own pipeline for data reduction: a Python package called 3D-FireTOC for automatic fireball and bolide detection and analysis with astrometry, photometry, atmospheric trajectory calculation and heliocentric orbit computation [5,6].

The superbolide SPMN160821L: On August 16, 2021, at 23h34m03s UTC, a superbolide illuminated the sky over the Catalonian coast with a brightness greater than the full moon, reaching a magnitude of -16 (see Fig. 1). The event was observed by multiple SPMN stations listed in Table 1, but in particular was recorded from the SPMN station in Estepa, located more than 650 km away, being the farthest bolide captured and analyzed from Spain. The bolide began at a heigh of 86.7±0.4 km with a velocity of 39.4±0.4 km/s and ended at 45.40±0.23 km with an ending velocity of 34.5±0.3 km/s. The three-dimensional scaled reconstruction of the atmospheric trajectory can be seen in Figure 2.

Figure 1. SPMN160821L recorded from Sant Mateu (right), Vilavella (right) and Estepa (bottom).

Station	Longitude	Latitude	Alt.
Alpicat	0º 33´ 25" E	41º 40´ 03" N	252 m
Azara	0º 01´ 52" W	42º 04´ 15" N	441 m
Benicàssim	0º 02´ 19" E	40º 02´ 03" N	10 m
Eivissa	1º 25´ 45" E	38º 54´ 21" N	45 m
Estepa	4º 52´ 36" W	37º 17´ 29" N	537 m
Sant Mateu	0º 10´ 34" W	40º 27´ 55" N	349 m
Vilavella	0º 11´ 10" W	39º 51´ 34" N	46 m

Table 1. SPMN stations recording the studied event.

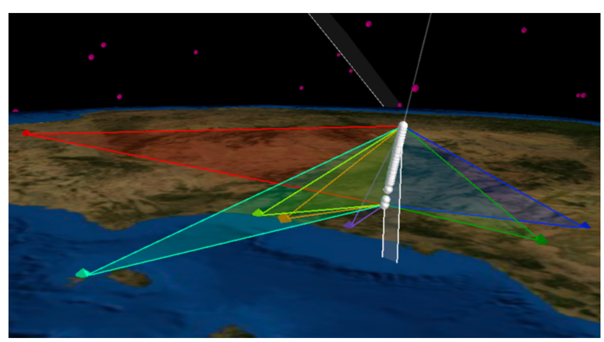

Figure 2. SPMN160821L luminous path reconstruction showing the intersection of planes.

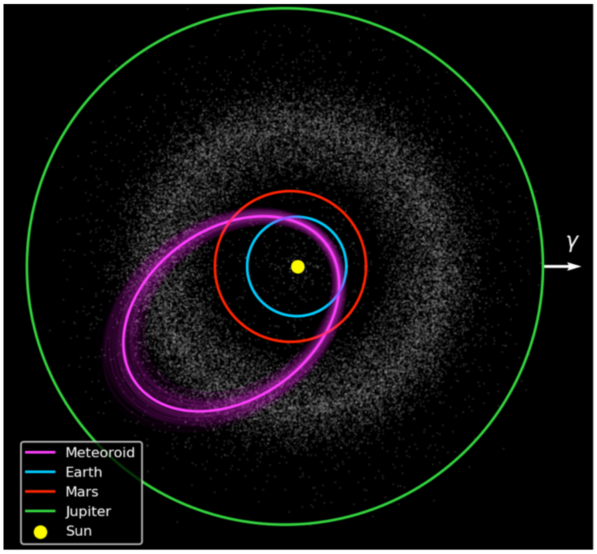

Figure 3. Heliocentric orbit of SPMN160821L.

Radiant data			
	Observed	Geocentric	Heliocentric
R.A. (º)	337.65±0.09	337.15±0.09	285.3±0.9
Dec. (º)	48.06±0.31	48.39±0.32	53.12±0.28
V_∞ (km/s)	39.4±0.4	37.6±0.4	37.01±0.31

Orbital parameters			
a (AU)	2.38±0.15	**ω (º)**	251.5±1.0
e	0.691±0.019	**Ω (º)**	144.0149±0.0001
q (AU)	0.730±0.005	**i (º)**	64.9±0.5

Table 2. SPMN160821L radiant data and orbital parameters.

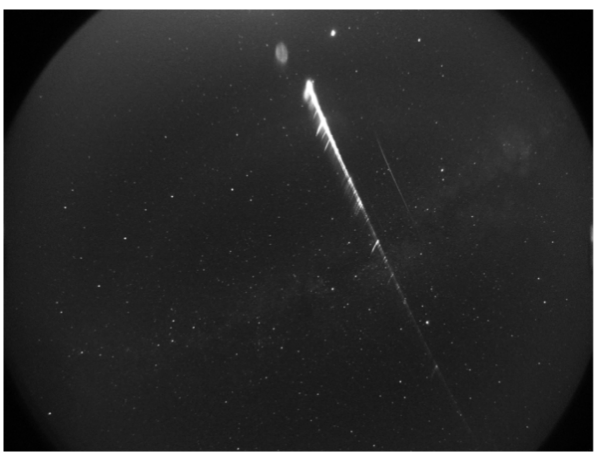

Figure 4. Emission spectra of SPMN160821L recorded from Azara.

Table 2 and Figure 3 show the computed heliocentric orbit. Applying Drummond's dissimilarity criterion [7], we find a possible dynamic association with asteroid 2014 BD33, having a D_D = 0.069±0.008. This association will be studied in more detail performing a backwards integration of the orbital elements.

The spectrum was obtained with a ZWO ASI 178 mm camera equipped with a 2.5 mm focal all-sky lens and 170º field of view, and a transmission diffraction grating of 1000 lines/mm (see Fig. 4). After a preliminary spectrum calibration, we identified the main emission lines, as shown in Figure 5.

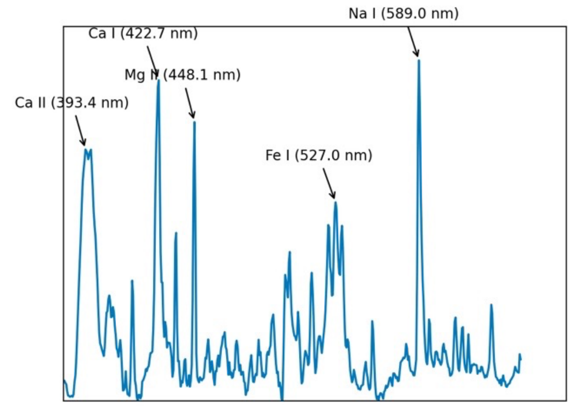

Figure 5. Main lines identified in the SPMN160821L emission spectrum.

Conclusions: The SPMN160821L superbolide was a sporadic meteoroid of cometary origin that exhibited a tensile strength of 222±7 kPa, disrupting at a height of 45.4 km over the sea level. The inferred tensile strength is consistent with the exhibited by carbonaceous chondrites, for example close to the first breakup experienced during the entry of Tagish Lake ungrouped chondrite [8]. A remarcable characteristic of the spectrum is the relatively weak Na D-lines at about 589 nm, that are often more intense in cometary meteoroids [9].

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