

**A METEORITE-PRODUCING FIREBALL OBSERVED OVER MOROCCO ON 5 DECEMBER 2015.**  
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**Introduction:** Most meteoroids impacting the Earth's atmosphere ablate completely. However, some fireball events may produce, under favourable conditions, a non-zero terminal mass. In these cases these materials reach the ground as meteorites. By recovering these meteorites we can obtain unique samples coming from other celestial bodies that provide helpful information about the origin and evolution of our Solar System. For this reason, the analysis of potential meteorite-producing fireballs is one of our goals. For this purpose we are performing a systematic monitoring of meteor and fireball activity over Spain and neighbouring countries by means of different recording techniques. We also focus on meteor spectroscopy, since this technique provides information about the chemical nature of meteoroids ablating in the atmosphere. In this context, we present here a preliminary analysis of a potential meteorite-dropping event that took place over Morocco on 5 December 2015.

**Instrumentation and methods:** To record the fireball analyzed here we have employed an array of low-lux CCD video cameras manufactured by Watec Co. (models 902H and 902H2 Ultimate). These monitor the night sky and operate in a fully autonomous way by means of software developed by the first author [1]. The atmospheric trajectory and orbital data of the event were obtained with the Amalthea software [2].



Figure 1. Sum-pixel image of the fireball discussed here.

**The 5 December 2015 event:** On 5 December 2015 at 21h43m28.9±0.1s UTC a mag.  $-14\pm 1$  fireball (Figure 1) was recorded by our meteor observing stations located at Sevilla, La Hita and La Sagra astronomical observatories. This slow-moving event was also reported by numerous eyewitnesses located at the south and the center of Spain. The emission spectrum of this bolide was also recorded by two spectrographs located at La Hita.

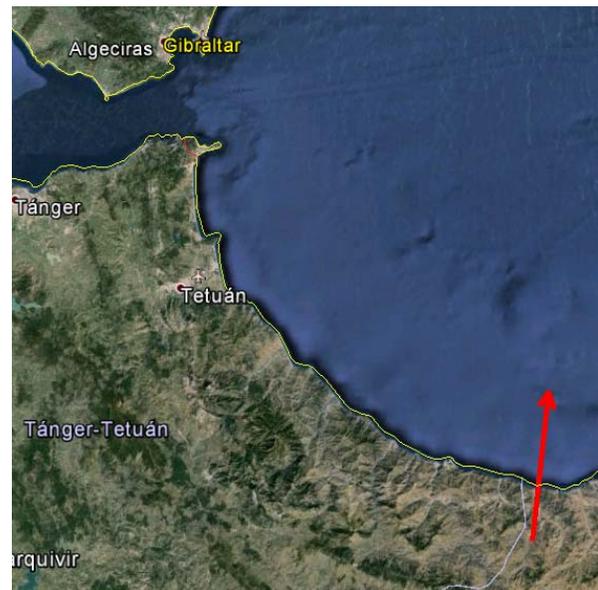


Figure 2. Projection on the ground of the atmospheric trajectory of the fireball analyzed in this work.

<b>a (AU)</b>	$5.4\pm 0.6$	<b><math>\omega</math> (°)</b>	$32.4\pm 0.2$
<b>e</b>	$0.83\pm 0.01$	<b><math>\Omega</math> (°)</b>	$73.14338\pm 10^{-5}$
<b>q (AU)</b>	$0.915\pm 0.001$	<b>i (°)</b>	$1.62\pm 0.04$

Table 1. Orbital data (J2000) of the progenitor meteoroid before its encounter with our planet.

**Atmospheric trajectory, radiant and orbit:** According to our analysis, the fireball started at an altitude  $H_b=93.1\pm 0.4$  km over Wahran (Morocco). The meteoroid stroke the atmosphere with a velocity  $V_\infty=17.4\pm 0.2$  km/s and the apparent radiant was located at the equatorial coordinates  $\alpha=32.4^\circ$ ,  $\delta=10.2^\circ$ . The bolide penetrated till a final height  $H_c=18.3\pm 0.4$  km over the Mediterranean Sea. The projection on the ground of the atmospheric trajectory is shown in Figure 2. This atmospheric path is shown in Figure 3. The orbital parameters of the parent meteoroid before its

encounter with our planet are listed in Table 1. The projection on the ecliptic of this heliocentric orbit is shown in Figure 4. According to the value of the Tisserand parameter with respect to Jupiter ( $T_J=2.1$ ), the meteoroid followed a Jupiter Family Comet orbit.



Figure 3. Atmospheric trajectory of the bolide.

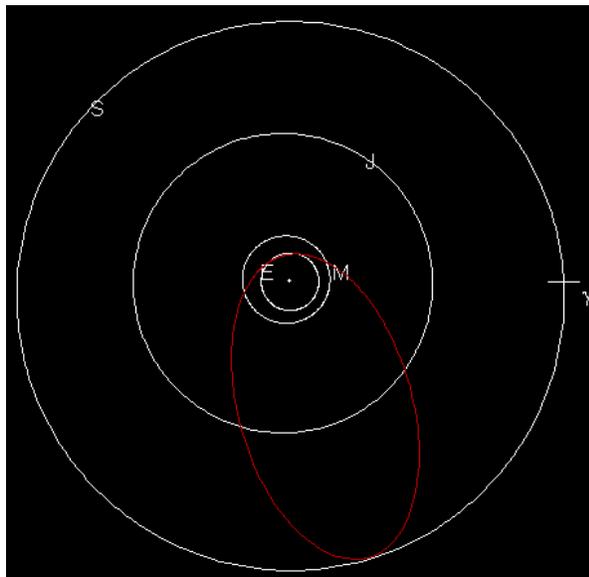


Figure 4. Projection on the ecliptic plane of the heliocentric orbit of the parent meteoroid.

The maximum brightness of the bolide was reached as a consequence of a flare that took place at an altitude of  $41 \pm 1$  km above the sea level. The estimated tensile strength of the meteoroid at this stage yields  $(8.5 \pm 0.6) \cdot 10^6$  dyn/cm<sup>2</sup>.

The analysis of the terminal point of this deep-penetrating fireball shows that the meteoroid was not

completely destroyed in the atmosphere. Thus, a fragment with a mass of about 200 g survived the ablation process and fell into the Mediterranean Sea as a meteorite. The emission spectrum of this event and the precise circumstances of the dark flight are currently under analysis.

**Conclusions:** We have presented a preliminary analysis of a potential meteorite-dropping multi-station fireball recorded over Morocco on 5 December 2015. The meteoroid followed a Jupiter Family Comet orbit before its encounter with our planet. The high-tensile-strength progenitor meteoroid penetrated the atmosphere till an ending altitude of about 18 km. A 200 gram fragment survived the ablation process and fell into the Mediterranean Sea as a meteorite.

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**References:** [1] Madiedo J.M. (2014), *Earth, Planets & Space*, 66, 70. [2] Madiedo J.M. et al. (2011), *NASA/CP-2011-216469*, 330.