A DEEP-PENETRATING FIREBALL PRODUCED BY AN ASTEROIDAL METEOROID. F. Espartero[1,2], J.M. Madiedo[3,4], A.J. Castro-Tirado[5]. [1] Depto. de Astrofísica y CC. de la Atmósfera, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, 28040 Madrid, Spain. [2]Observatorio Astronómico de Andalucía, 23688 La Pedriza, Alcalá la Real, Jaén, Spain. [3]Facultad de Ciencias Experimentales, Universidad de Huelva, Huelva, Spain. [4]Departamento de Fisica Atomica, Molecular y Nuclear. Universidad de Sevilla. 41012 Sevilla, Spain. [5]Instituto de Astrofísica de Andalucía, CSIC, Apt. 3004, 18080 Granada, Spain.

Introduction: Very bright deep-penetrating fireballs deserve special attention, since these events may give rise to meteorites. Thus, although most meteoroids impacting our atmosphere ablate completely, some fireball events may produce, under favourable conditions, a non-zero terminal mass. The identification of the parent bodies in the Solar System of these meteoroids is of a paramount importance in meteor science, since this allows establishing the likely sources of these materials. For this purpose a continuous monitoring of meteor and fireball activity over Spain and neighbouring areas is being performed in the framework of the SPanish Meteor Network (SPMN). In addition, meteor spectroscopy can provide chemical information about meteoroids ablating in the atmosphere. With this aim, the SMART project was developed (acronym for Spectroscopy of Meteoroids in the Atmosphere by means of Robotic Techniques). This work focuses on the preliminary analysis of a deep-penetrating sporadic fireball event recorded over the south of Spain on Dec. 5, 2013. Its emission spectrum is also presented. The likely source of the meteoroid is discussed on the basis of an orbital analysis.

Figure 1. Composite image of the SPMN051213 fireball imaged from Sevilla.

Instrumentation and methods: The meteor observing stations that recorded the fireball discussed here employ an array of low-lux monochrome CCD video devices [1, 2]. These systems work in an autonomous way by means of a software package developed for this purpose. Most of these CCD cameras are configured as video spectrographs by means of transmission diffraction gratings (1000 grooves/mm) attached to the objective lens. The atmospheric trajectory, radiant and meteoroid orbit have been obtained with the AMALTHEA software [3]. The fireball spectrum has been reduced with the CHIMET software [4]. The ORBEX application, also developed by JM Madiedo, has been employed to find the likely parent body of the progenitor meteoroid.

The December 5 event: A fireball (Figure 1) was simultaneously recorded on Dec. 5, 2013 at 20h40m12.7±0.1s UTC from four meteor observing stations located in Andalusia (Sevilla, Sierra Nevada, El Arenosillo and La Pedriza) and one station in the center of Spain (La Hita). In addition, its emission spectrum was recorded by two spectrographs operating at El Arenosillo and La Pedriza, respectively. With an estimated absolute magnitude of –11±1, the event lasted around 6.5 seconds and was witnessed by several casual observers in the south of Spain. No fragmentation was observed along its luminous path. It received the code SPMN051213 after the recording date.

Atmospheric trajectory, radiant and orbit: The progenitor meteoroid struck the atmosphere with an initial velocity V_∞=16.9±0.1 km/s. The fireball started its luminous path at 90.4±0.5 km above the ground level, with the terminal point located at a height of 34.0±0.5 km. Although this height is above the limit usually considered for meteorite-dropping events, the bolide was quite remarkable for both its duration and its ability to penetrate deeply in the atmosphere. The radiant position and orbital parameters are summarized in Table 1. These data confirm the sporadic nature of the event. The orbit of the meteoroid is plotted in Figure 2.

Radiant data			
	Observed	Geocentric	Heliocentric
R.A. (º)	46.1±0.1	48.2±0.1	-
Dec. (º)	-3.75±0.04	-10.2±0.1	-
V_∞ (km/s)	16.9±0.1	12.5±0.1	37.7±0.1
Orbital parameters			
a (AU)	3.36±0.04	**ω (º)**	39.71±0.09
e	0.619±0.008	**Ω (º)**	73.6787 ± 10^{-4}
q (AU)	0.8984±0.0008	**i (º)**	8.99±0.04

Table 1. Radiant and orbital data (J2000).

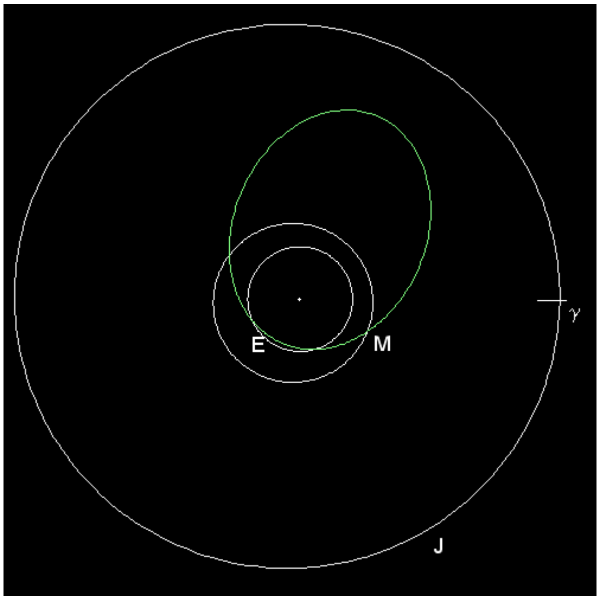

Figure 2. Projection on the ecliptic plane of the heliocentric orbit of the progenitor meteoroid.

Emission spectrum: The calibrated spectrum of the fireball is shown in Figure 3, where the main emission lines have been highlighted. As usual, most features in the signal correspond to neutral Fe. On the other hand, the spectrum is dominated by the emission from Fe I-4 in the ultraviolet. The intensity of the Mg I-2, Na I-1 and Fe I-15 multiplets is also very noticeable. The contribution from atmospheric N_2 can also be seen in the red region. Further analysis will be performed in order to get an insight into the chemical nature of the meteoroid.

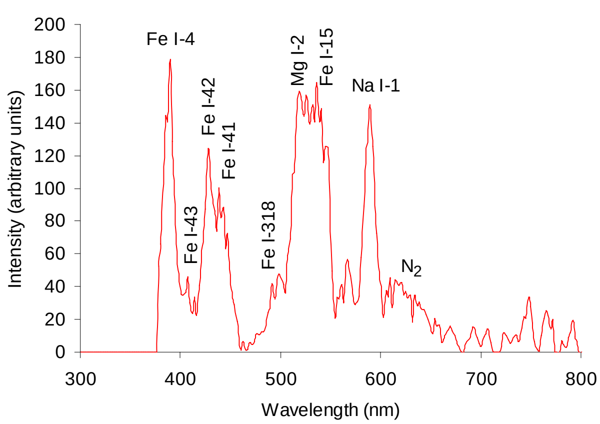

Figure 3. Calibrated emission spectrum.

Orbital analysis and parent body: The value of the Tisserand parameter with respect to Jupiter yields T_J=3.24, which suggests an asteroidal origin for the meteoroid. The ORBEX application, working with 100 clones created around the orbit of this particle, suggested several potential parent bodies with a D_{SH} dissimilarity criterion [5] below 0.15. These clones were integrated backwards in time together with the orbital elements of the above-mentioned asteroids by means of the Mercury 6 symplectic integrator [6], and the results were reduced by ORBEX. The gravitational influence of Venus, the Earth-Moon system, Mars, Jupiter and Saturn were taken into account for these calculations. As a result of this analysis we have found that the best candidate as parent body of the meteoroid is the potentially hazardous asteroid (PHA) 31669 (1996JT6). However, the orbit of this NEO is similar to that of the meteoroid (DSH≤0.15) during a period of about 2000 years, as shown in Figure 4.

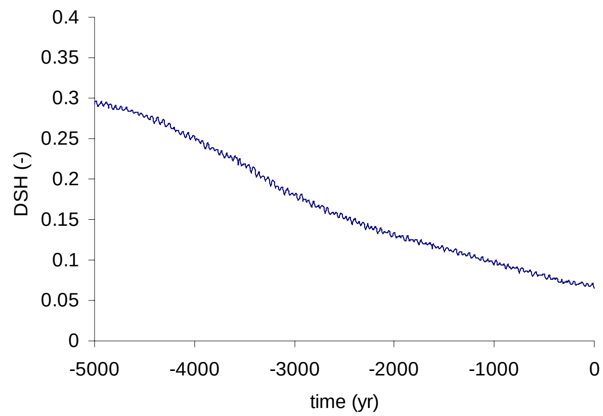

Figure 4. Evolution with time of the D_{SH} criterion calculated for NEO 31669 and the progenitor meteoroid of the SPMN051213 fireball.

Conclusions: We have analyzed a deep-penetrating sporadic fireball recorded over the south of Spain. Its atmospheric trajectory and radiant were obtained, and the orbit of the meteoroid was calculated. The terminal point of the luminous trajectory discards a meteorite-dropping event. The main contributions in the emission spectrum produced by the fireball have been identified. The best candidate as parent body of the meteoroid is one PHA: NEO 3116 (1996TJ6).

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