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Orbit and Spectroscopy of a Deep-penetrating Fireball Produced by an Asteroidal Meteoroid

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Abstract

We present a preliminary analysis of a deep-penetrating sporadic fireball recorded over the South of Spain on Dec. 5, 2013. Its emission spectrum is also described. The likely parent of the meteoroid is discussed on the basis of an orbital analysis.

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

1. 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 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 (Spectroscopy of Meteoroids in the Atmosphere by means of Robotic Techniques) was developed. This work focuses on the preliminary analysis of a deep-penetrating fireball recorded over Spain on Dec. 5, 2013.

2. Instrumentation

The meteor stations that recorded the fireball discussed here employ an array of monochrome CCD video devices [1, 2]. These work in an autonomous way. Most of these cameras are configured as video spectrographs by means of diffraction gratings attached to the objective lens. The atmospheric path, 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.

3. The December 5, 2013 event

A fireball (Fig. 1) was recorded on Dec. 5, 2013 at 20h40m12.7±0.1s UTC from four meteor observing stations in Andalusia (Sevilla, Sierra Nevada, El Arenosillo and La Pedriza) and one station in the center of Spain (La Hita). Its emission spectrum was recorded by two spectrographs. With an absolute magnitude of –11±1, the event lasted around 6.5 seconds and was witnessed by several casual observers in the south of Spain. It received the code SPMN051213. The progenitor meteoroid struck the atmosphere with a 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. The bolide was quite remarkable for both its duration and its ability to penetrate deeply the atmosphere. The radiant position and orbital parameters are summarized in

Tab. 1. These confirm the sporadic nature of the event. The orbit of the meteoroid is plotted in Fig. 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).

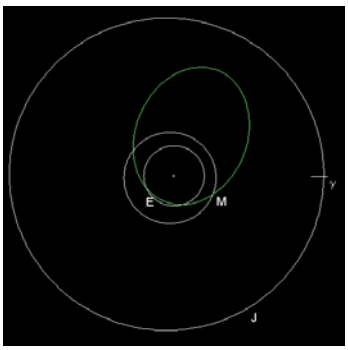

Figure 2. Projection on the ecliptic plane of the heliocentric orbit of the progenitor meteoroid.

The calibrated spectrum of the fireball is shown in Fig. 3, where the main emission lines have been highlighted. Most features in it correspond to Fe I. 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 very noticeable. The contribution from N_2 can be seen in the red region. Further analysis will be performed to get an insight into the chemical nature of the meteoroid.

The value of the Tisserand parameter 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. We have found that the best candidate as parent body of the meteoroid is the 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 Fig. 4.

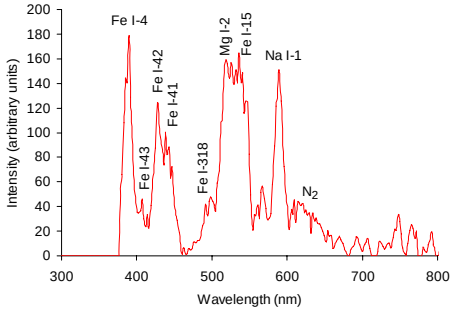

Figure 3. Calibrated emission spectrum.

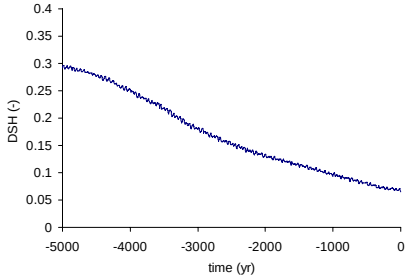

Figure 4. Evolution with time of the D_{SH} criterion calculated for NEO 31669 and the progenitor meteoroid of the SPMN051213 fireball.

6. Summary and 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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