LINKING A FIREBALL TO ITS LIKELY PARENT NEAR EARTH OBJECT BY MEANS OF ORBITAL ANALYSIS SOFTWARE TOOLS. C. Alonso[1], J.M. Madiedo[1, 2], J.M. Trigo-Rodríguez[3], J.L. Ortiz[4], A.J. Castro-Tirado[4], S. Pastor[5] and J.A. de los Reyes[5]. [1]Facultad de Ciencias Experimentales, Universidad de Huelva, 21071 Huelva, Spain, madiedo@uhu.es. [2]Dpto. de Física Atómica, Molecular y Nuclear, Facultad de Física, Universidad de Sevilla, 41012 Sevilla, Spain. [3]Institute of Space Sciences (CSIC-IEEC). Campus UAB, Facultat de Ciències, Torre C5-p2. 08193 Bellaterra, Spain. [4]Instituto de Astrofísica de Andalucía, CSIC, Apt. 3004, 18080 Granada, Spain. [5]Observatorio Astronómico de La Murta. Molina de Segura, 30500 Murcia, Spain.

Introduction: The identification of their progenitor bodies is crucial to increase our knowledge on the origin and evolution of meteoroid streams. Traditionally, the similarity between two orbits has been used to link a given meteoroid stream with a potential parent body. This similarity was first expressed in terms of the so-called D-criterion, which was originally proposed by Southworth and Hawkins [1]. Alternative versions of this criterion have been proposed by other authors [2-5]. In order to establish a relationship between the orbit of the meteoroids and that of their potential parent bodies, the availability of precise orbital parameters is fundamental. Due to the chance of finding wrong parent body candidates, it is also crucial to integrate the orbits of the bodies backwards in time to analyze the evolution of these criteria and to establish real (not casual) connections [6]. In this work we analyze a double-station fireball imaged in the framework of the SPanish Meteor Network (SPMN). By using the Mercury 6 symplectic integrator [7] and orbital association software developed by us [8], we have identified a NEO as the progenitor body of the parent meteoroid.

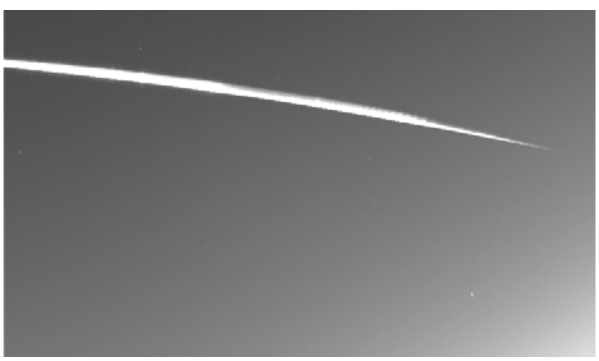

Figure 1. Composite image of the SPMN271212 fireball imaged from Sierra Nevada.

Instrumentation: Two SPMN meteor observing stations were involved in the observation of the fireball discussed here: Sierra Nevada and Molina de Segura. To image this event we have used an array of low-lux CCD video cameras (models 902H and 902H Ultimate, from Watec Corporation) working according to the PAL video standard. The operation of these systems is explained in [9, 10]. For meteor spectroscopy, we have attached holographic diffraction gratings (1000 lines/mm) to the objective lens of some of these CCD devices. In this way, we can infer information about the chemical nature of meteoroids ablating in the atmosphere.

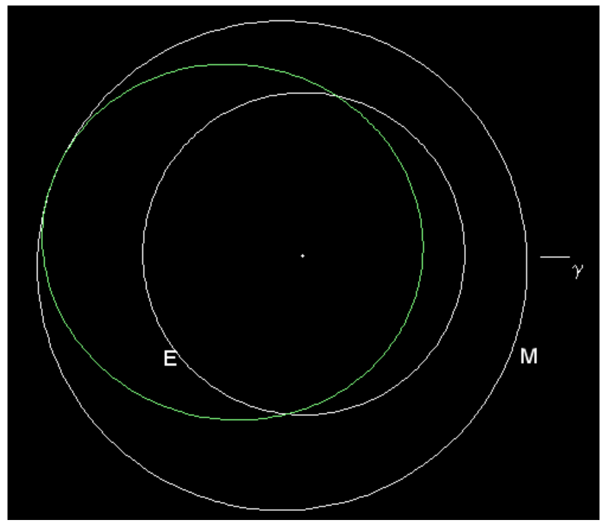

Figure 2. Projection on the ecliptic plane of the orbit of the parent meteoroid.

Radiant data			
	Observed	Geocentric	Heliocentric
R.A. (º)	266.5±0.4	277.3±0.4	
Dec. (º)	-6.9±0.3	-16.8±0.3	
V_∞ (km/s)	16.1±0.3	11.2±0.3	32.5±0.3

Orbital parameters			
a (AU)	1.18±0.01	**ω (º)**	95±1
e	0.37±0.01	**Ω (º)**	275.7841 ± 10^{-4}
q (AU)	0.73±0.01	**i (º)**	2.3±0.3

Table 1. Radiant and orbital data (J2000).

Atmospheric trajectory and orbit: The fireball shown in Figure 1 (SPMN code 271212) was recorded under twilight conditions on December 27, 2012, at 6h45m47.8±0.1s UTC. The absolute magnitude of this event was -9±1. The atmospheric trajectory and radiant were calculated with our AMALTHEA software, which employs the method of planes intersection [11]. In this way, we obtained that the luminous phase started at 80.5±0.5 km above the ground level. The bolide disappeared from the field of view of one of the cameras and behind a tree appearing in the field of view of the other CCD video device when it was located at a height of 47.0±0.5 km. So, the exact location of the terminal point could not be established, but as the bolide was not observed beyond the above mentioned tree this is constrained to a height of about 40 km. Besides, the parent meteoroid struck the atmosphere with an initial velocity V_∞=16.1±0.3 km/s. With this information, the orbit of this particle was calculated (Figure 2). The radiant and orbital parameters are summarized on Table 1.

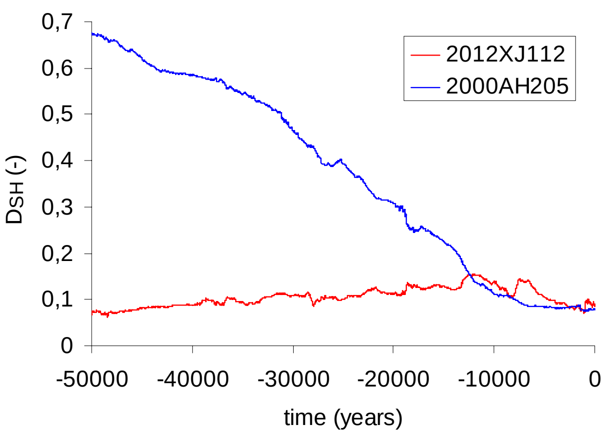

Figure 3. Evolution with time of the D_{SH} criterion calculated for the SPMN271212 fireball and NEOs 2000AH205 and 2012XJ112.

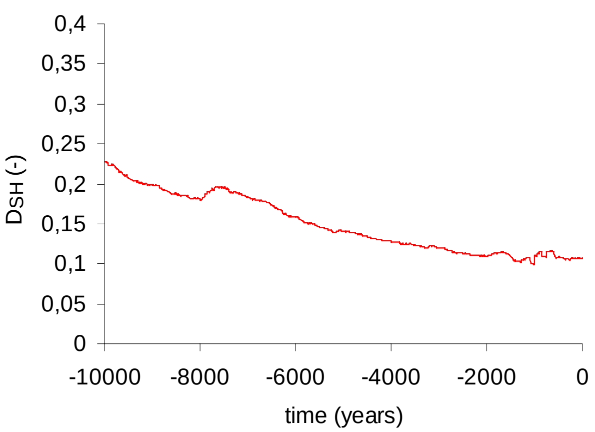

Figure 4. Evolution with time of the D_{SH} criterion calculated for NEOs 2000AH205 and 2012XJ112.

Orbital analysis: We investigated the potential parent body of the SPMN271212 fireball with our ORAS software. The Southworth and Hawkins dissimilarity criterion was used and eight candidates from the NeoDys database were obtained, all of them satisfying the condition D_{SH}<0.15. The best results, however, were obtained for NEOs 2000AH205 (D_{SH}=0.07) and 2012XJ112 (D_{SH}=0.08). A numerical integration backwards in time of the orbital parameters of the fireball and these NEOs was performed in order to test a link between them. These calculations were performed by means of the Mercury 6 software [7]. This is a hybrid symplectic integrator which is widely used in Solar system dynamics studies. The gravitational influence of Venus, the Earth-Moon system, Mars, Jupiter and Saturn were taken into account for these calculations. The orbits were integrated back for 50,000 years. As can be seen in Figure 3, the D_{SH} criterion remains below or equal to 0.15 during that period for NEO 2012XJ112, but just during about 12,000 years for 2000AH205. Consequently, the calculations suggest that Apollo asteroid 2012XJ112 is a much better candidate as parent body of the SPMN271212 fireball than 2000AH205. Besides, this orbital analysis also shows a likely dynamic link between these two NEOs, although this is limited to a time scale of about 6,000 years (Figure 4).

Conclusions: We have calculated the atmospheric trajectory, radiant and orbit for a double-station mag. -9 fireball recorded in the framework of the SPMN. The results show that the parent meteoroid of this sporadic event could have penetrated the atmosphere till a height of about 40 km. The orbital analysis performed with our ORAS software, based on the value of the Southworth and Hawkins dissimilarity criterion, provided several NEOs as potential parent bodies of this particle. The best results, however, were obtained for NEOs 2000AH205 and 2012XJ112. The integration backwards in time of the orbital elements shows a similar evolution of the meteoroid and NEO 2012XJ112 over a time scale of, at least, 50,000 years. The results are also consistent with a likely dynamic link between both NEOs during a period of about 6,000 years.

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