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Linking meteoroid streams to their parent bodies by means of orbital association software tools

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A Microsoft-Windows-compatible software, called ORAS (ORbital Association Software), has been developed for verifying possible associations between orbits using different existing criteria. Applying this software revealed a likely association for the orbit of a Northern χ-Orionid (ORN) fireball and Asteroid (PHA) 2008 XM_1. A numerical integration 4000 years backwards in time for the orbital parameters shows that this asteroid is a better match for this Northern χ-Orionid than Asteroid (NEO) 2002 XM_{35}.

1 Introduction

Some meteoroid streams have well-defined parent bodies, but the origin of most other streams remains unknown. The identification of their progenitor bodies is crucial to increase our knowledge on the origin and evolution of meteoroid streams. Parent body identification opens the possibility to extract valuable chemical information, and infer additional information on physical processes that may have occurred on that asteroid or comet as, such as, for instance, cometary activity, violent collisional disruptions, or break-ups.

Traditionally, meteoroid streams have been linked with a potential parent body on the basis of the similarity between their orbits. One of the first proposals to quantify this similarity is the so-called D-criterion, originally proposed by Southworth and Hawkins (1963). It is based on a scalar function depending on the values of the semi-major axis, the eccentricity, and the inclination. If, in addition, the longitude of the ascending node and the argument of the perihelion are also taken into consideration, we obtain the so-called D_{SH}-criterion. Alternative versions of this criterion have been proposed by other authors (Drummond, 1981; Jopek, 1993; Valsecchi et al., 1999; Jenniskens, 2008). 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. To minimize the probability of finding false matches, it is crucial to integrate the orbits of the bodies backwards in time to analyze the evolution of the respective orbital parameters. In this way, real, physical associations can be established, as opposed to coincidential matches at one particular instant of time; see, e.g., Trigo-Rodríguez et al., 2007).

To make progress in this interesting field, we have developed a software package to establish meteoroid-parent body dynamic associations on the basis of the computation of dissimilarity criteria over a continuous period of time. ORAS (ORbital Association Software) is an MS-Windows-compatible software developed within the SPMN under C++ to identify which minor bodies could be the likely parent body of a given meteoroid stream.

2 Description of the ORAS software

As already mentioned, ORAS is a Microsoft-Windows-compatible application that has been developed under the C++ programming language. By entering the orbital data of a given meteoroid, or an averaged orbit for a set of meteoroid stream members, the software can search through several databases in order to establish a potential link with other bodies in the Solar System. The values of the semi-major axis, the eccentricity, the orbital inclination, the longitude of the ascending node, and the argument of the perihelion must be provided. Then, the user specifies which database containing information about small bodies in the Solar System will be used and which dissimilarity criterion must be employed. The current version of ORAS can use the NeoDys and MPC databases.

Regarding the dissimilarity criterion, several choices are also available: Southworth and Hawkins (1963), Drumond (1981), Jopek (1993), Valsecci et al. (1999) and Jenniskens (2008). The cut-off value for the corresponding criterion must also be entered. In this way, only objects for which this criterion provides a value below the cut-off value will be considered. The objects that match these search criteria are shown on a list, metioning their name, orbital data, and corresponding value of the dissimilarity parameter. The lower this value, the smaller the distance is between both orbits. Alternatively, instead of using one of the above-mentioned databases, the user may select only one object from any of these databases to perform the calculations, or specify the orbital parameters of the object of interest him- or herself.

3 The parent body of the Northern χ-Orionids (ORN)

The χ-Orionid meteoroid stream, which is a part of the Taurid complex (Jenniskens, 2006), has northern (ORN) and southern (ORS) branches. The activity period of the Northern χ-Orionids (ORN) extends from November 16 to December 16, with a maximum on December 10.

We investigated the potential parent body of the ORN stream with the ORAS software. For this purpose, we used the orbital parameters of the SPMN061211 ORN fireball (Madiedo, 2012), shown in Figure 1, as well as the averaged orbit (Table 1) of seven ORN meteors considered by Porubčan et al. (2006). The Southworth and Hawkings dissimilarity criterion was used, and two candidates from the NeoDys database were obtained. One of them was NEO 2002 XM_{35} ($D_{SH} = 0.14$), which had been previously proposed as the potential parent body of the ORN stream (Porubčan et al., 2006). However, we have found that the Potentially Hazardous Asteroid (PHA) 2008 XM_1, which was discovered after the paper by Porubčan et al. was published, provides a much better result ($D_{SH} = 0.05$).

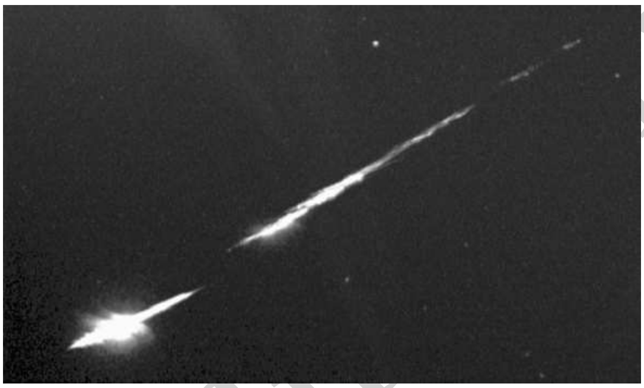

Figure 1 – Composite image of the SPMN061211 ORN fireball recorded together with its emission spectrum from El Arenosillo meteor observing station on December 6, 2001, at $20^h32^m59\overset{s}{.}4 \pm 0\overset{s}{.}1$ UT. Note that the zero-order image is close to the bottom-right border.

A numerical integration backwards in time of the orbital parameters shown in Table 1 was performed in order to test the link between the Northern χ-Orionid meteoroid stream and these two NEOs. The calculations were performed by means of the Mercury 6 software (Chambers, 1999). 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 backwards for 4000 years. As can be seen in Figure 2, the results clearly confirm that during this period the value of the D_{SH}-criterion is lower for the PHA 2008 XM_1. Consequently, this analysis suggests that Apollo asteroid 2008 XM_1 is a much better match as a parent body of the Northern χ-Orionid meteoroid stream than 2002 XM_{35}. In addition, this orbital analysis also indicates a likely dynamic link between these two asteroids.

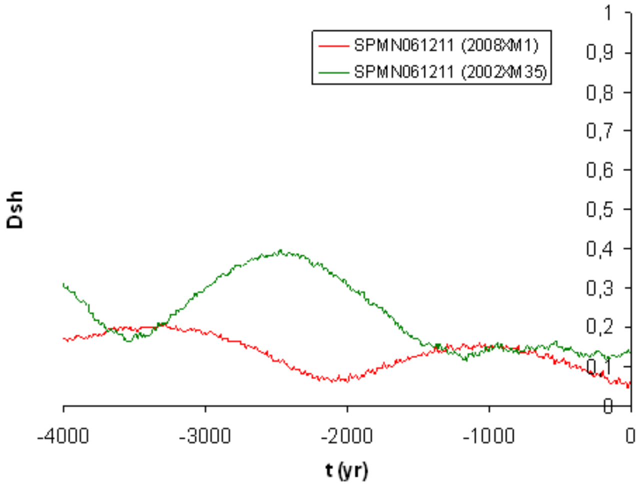

Figure 2 – Values of the D_{SH}-criterion calculated from the backward numerical integration over 4000 years of the orbital parameters of the SPMN061211 ORN fireball and the two NEOs considered here.

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4 Conclusions

We have developed a software package, called ORAS (ORbital Association Software), to find potential parent bodies of meteoroid streams. ORAS can browse both the NeoDys and the Minor Planet Center (MPC) databases in order to find such associations. The results obtained by this software can be checked and confirmed by performing an integration of the corresponding orbital parameters backwards in time with, for instance, the Mercury 6 symplectic integrator. One of the latest results obtained in this way is the likely association between the Northern χ-Orionid meteoroid stream (ORN) and the Potentially Hazardous Asteroid 2008 XM_1. Our analysis also suggests a plausible dynamic link between this asteroid and the Near-Earth Object 2002 XM_{35}, which was formerly considered as a parent body candidate for this meteoroid stream (Porubčan et al., 2006).

Table 1 – Orbital parameters for the SPMN061211 ORN fireball (Trigo-Rodriguez, 2007), averaged orbit for 7 ORN meteors (Porubčan et al., 2006), and orbital data for the two NEOs considered here.

Object	a	e	i	ϖ	Ω
SPMN061211	2.2 AU	0.79	3°.2	281°.5	254°.2322
ORN (N=7)	2.143 AU	0.779	3°.3	280°.4	256°.8
2002 XM_{35}	2.3304 AU	0.8361	3°.0845	313°.4382	229°.2701
2008 XM_1	2.3679 AU	0.7822	4°.9954	276°.1411	259°.8564

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