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The parent body search – testing D-criteria

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Abstract

Meteor Observation Networks, such as the double-station meteor network developed in CABERNET project (PODET-MET), will provide soon a vast amount of meteors' observation data with the aim to calculate each orbit of the meteoroids. In order to retrieve the parent body from such collected data set, we compare the already existing procedures aiming to determine the origin of meteoroid streams. Among the methods, two dissimilarity functions based on the orbital elements ([7] and [3]), and two functions defined by quasi-invariants ([6] and [5]) are tested using artificial data set for which the parent body is known.

1. Introduction

As soon as a meteoroid leaves its parent body, its orbit is constantly perturbed. The meteoroid endures planetary perturbations, mutual collisions and non-gravitational (radiative) forces. Each orbit is independent but evolves in a similar way as the other particles ejected by the parent body. Hence, the existence of a structure composed of meteoroids having similar orbits (called a meteoroid stream) is maintained over a long period of time (i.e. as long as the perturbations still allows one to define the stream).

Our goal is to develop a method allowing us to perform a quick and effective search for parent body and apply it to each observed meteor. The outcome of this method will be a probability of association between a meteoroid and a comet or asteroid, that will unveil the genetic relations between small bodies of the solar system, and advance our knowledge of the origin and evolution of the entire solar system.

2. Dissimilarity functions

To find a parent body of an observed meteor we use dissimilarity functions, which we call D-criteria. The most common and widely used criterion was introduced by Southworth and Hawkins in 1963, [7]. It was later modified by Drummond [3], Jopek [5], Steel *et al.* [8] and also Asher *et al.* [1]. Nonetheless slightly changes, all of them are based on orbital elements (a, q, e, i, ω, and Ω).

Other authors, as Valsecchi *et al.* [9], Jopek *et al.* [6] or Jenniskens [4] brought new approaches to the identification of the stream. Here dissimilarity functions are partly based on quasi-dynamical invariants. The latest introduced criterion [6] is defined in the domain of the heliocentric vectorial elements.

3. Method

In order to test each and every function, we generate artificial data for which we know exactly their parent body as well as the year of ejection. The model of generation and evolution of meteoroid stream in the solar system is taken from Vaubaillon *et al.* [10]. When a test particle crosses the ecliptical plane, it's orbital parameters are saved if it's close enough to the Earth (within 0.05 astronomical units from our planet). The orbital elements of each particle is then used to look for possible parent bodies, among all known comets and asteroids. We consider that the tested method works if it is able to find out the correct parent body and determine the conditions needed to reach this goal. The following meteoroid streams were tested: Leonids, Perseids, Draconids and τ-Herculids. We decide to reject several methods because of conceptual similarities between criteria (eg. [7], [3] or [5]), dedicated application to a given stream ([8], [1]) or because of the assumptions that a meteoroid is observed at heliocentric distance $r \approx 1$ AU ([9] - whereas the simulated data set includes particles as far as 0.01 AU from the Earth). Thus, we test four dissimilarity functions:

- DV – dissimilarity function defined in the domain of heliocentric vectorial elements, [6].
- SH – Southworth & Hawkins function, [7], based on the orbital elements.

- DH – Jopek's hybrid of SH and Drummond [3] dissimilarity functions, [5].
- DJ – function introduced by Jenninskens [4], which uses integrals of motion [2].

A meteor is associated to a parent body if $D(\mathbf{O_i}, \mathbf{O_j}) < D_c$, where D_c is an assumed constant threshold below which two orbits $\mathbf{O_i}$ and $\mathbf{O_j}$ are considered to be similar.

4. Results and Conclusions

In order to choose which method is better to use, we need to analyse false positive and false negative according to threshold values. We assumed that a given sample of a stream should be identified (i.e. association with appropriate parent body is found) in 90%. This value of D_c, for which we obtained it, has been used to plot the Figure 1.

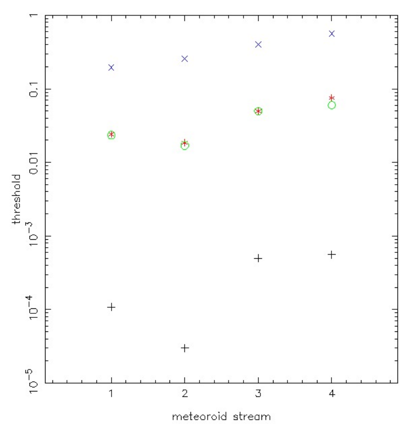

Figure 1: Threshold values found for tested dissimilarity functions: DV ($+$), SH ($*$), DH ($\circ$), and DJ ($\times$), for a given stream: Perseids (1), Leonids (2), Draconids (3) and τ Herculids (4).

All of the tested dissimilarity functions provided reasonable results. What is understandable the reliability of a given function depends on a given stream. The threshold value D_c also depends on the stream and its orbital evolution. Thus, most dispersed streams (eg. Draconids) need higher D_c than less perturbed ones (e.g. Leonids). DV and DJ functions are conceptually different from SH and DH. Thus, here we expected to see significant differences. The results for DH and SH are comparable (see Figure 1). On the basis of obtained results, we cannot decide yet which of the methods is the better one. Because of this we need to do more analysis and test methods on real data.

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