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A computer program for calculation of a theoretical meteor-stream radiant

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Abstract. A computer program for calculation of a theoretical meteor shower radiant is introduced. The program makes also choice of optimum method for a given parent's body orbit. Six different methods of radiant calculation are used in the program. Moreover, the program computes some additional characteristics of mean orbit of investigated shower.

Key words: Meteors, meteoroids

1. Introduction

The calculation of a theoretical meteor shower radiant is often the first step in a search for a generic relationship between a particular meteor shower and its potential parent body. A review of the methods used to determine meteor radiants from orbital elements has been published by Neslušan et al. (1994). The applicability of individual methods for a given set of orbital elements is presented there in a tabular form - see also Svoreň et al. (1993, 1994).

In this paper, we introduce a computerized form of calculation of the theoretical geocentric meteor shower radiant. The computer program enables not only a comfortable calculation, but also an exact choice of the optimum method valid for a given initial orbit. There are six different methods included in the program (the characters in parentheses are symbols referring to the particular methods in the program as well as hereinafter):

(Q) Adjustment of the orbit by variation of the perihelion distance - the q-adjustment (Hasegawa 1990).

(B) Adjustment of the orbit by variation of both the perihelion distance and eccentricity considering a minimum change (Svoreň et al. 1993).

(W) Adjustment of the orbit by variation of the argument of perihelion - i.e. rotation of the line of apsides (Steel & Baggaley 1985).

(A) Adjustment of the orbit by rotation around the line of apsides (Svoreň et al. 1993).

(H) Adjustment of the orbit by variation of the argument of perihelion and inclination - the ω-adjustment (Hasegawa 1990).

(P) Parallel shift of the velocity vector (Porter 1952).

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2. Input and output

A common task of all radiant determination methods is to modify the parent body's orbit to the mean shower orbit, whose one node, at least, crosses the Earth's orbit. Therefore, the program needs to enter the orbital elements of the parent body's orbit: *perihelion distance, eccentricity, argument of perihelion, longitude of ascending node, inclination*, and *date of perihelion passage.* Angular elements are requested to be referred to equinox 2000.0. Moreover, the program requests the year of investigation of a possible shower.

Since the orbit of the parent body may in some cases approach the Earth's orbit twice, there can in general be determined two modified - resultant - orbits crossing that of the Earth in two points of intersection. The Comet Halley orbit can serve as a representative model where two shower radiants (the $\eta-$Aquarids and Orionids) are observed. Consequently, the program calculates theoretical radiants at both approaches of the orbit of the parent body to the Earth's orbit, i.e. the user obtains two sets of output values. Methodically, the orbit of the parent body is divided to pre- and post-perihelion arcs, and the approach of each arc to the Earth's orbit is considered separately.

The Southworth-Hawkins (1963) $D-$criterion is applied to test the fit of the modified orbit with one node crossing the Earth's orbit to the orbit of the parent body. As the best, optimum orbit is evaluated that with the lowest $D-$discriminant.

The computed output values obtained by the six methods included in the program are presented in the tables at two screens. For each individual method, the first screen displays: *the equatorial coordinates of predicted geocentric radiant, mean geocentric as well as heliocentric velocities of possible shower, solar longitude of point of intersection* *of modified and Earth orbits corresponding to the time of maximum of potential shower, date of predicted maximum, and the $D-$discriminant roughly characterizing the quality of approximation.* Below the table, the information on the optimum method for a given parent body orbit is written. The second screen displays 5 geometrical orbital elements of the modified orbits (analogous as in the input set). The values of the *$D-$discriminant* are given again. The coordinates of the radiant as well as the orbital elements are referred to the same equinox as the input elements, i.e. equinox 2000.0. Below the second table further there are given *the distance between the parent body and Earth in the moment of predicted maximum, time interval between the passage of the parent body through the nearest point of its orbit (on given arc) to the Earth's orbit and predicted maximum*, and *minimum distance between the given arc of the parent body orbit and the Earth's orbit.*

3. Applicability of the program

It is obvious that an arbitrary object cannot be the parent body of an observable meteor stream. Especially for bodies in distant orbits (with respect to the Earth's orbit) it is not appropriate to associate them with observable streams and, consequently, no meaningful prediction of a meteor shower can be calculated. In practice, it is difficult to find a border between appropriate and unacceptable orbits. Each method of prediction can formally give a result also for unacceptable parent body orbits, or it (except of P method) may not give any result for a quite appropriate orbit.

In our previous papers (Svoreň et al., 1993; 1994; Neslušan et al., 1994), we suggested to distinguish between real and unreal theoretical radiants on the basis of the Southworth-Hawkins (1963) $D-$criterion, which has often been used to separate the shower meteors from a database of meteor orbits. Its limiting value represents a measure of dispersion of meteors in the observed meteor showers. As was mentioned above (Sect. 2) this criterion was applied to test the fit of the modified orbit to the parent body's orbit also in the program. Application of the considered methods on the well-known parent bodies of major meteor showers (as Lyrids, $\eta-$Aquarids, Perseids, Orionids, Leonids, and Geminids) has shown that the $D-$discriminant approximately corresponds with the deviation of the theoretical radiant (theoretical geocentric velocity) from the observed geocentric radiant (observed geocentric velocity). Therefore, one can immediately and at least approximately evaluate the quality of the calculated radiant from the $D-$discriminant. Of course, the distinction between the real and unreal predictions on the basis of the $D-$discriminant is not exact. The user has to regard it only as an approximative indication of the quality of our prediction. Some critical values of good as well as unreal prediction can perhaps be derived from the following considerations.

The values of angular deviations between the theoretical and real radiants versus the $D-$discriminant for some individual showers are shown in Fig. 1. One can see that the only value of D exceeding 0.5 (0.532) is provided by the W method for the Orionids. In this case, the deviation between the theoretical and observed radiants is about 31^o, therefore the prediction is an unrealistic one. That can also serve as an demonstrative example, why we cannot constrain ourself to only one method in a calculation of the theoretical radiant. A real prediction for the Orionids can be achieved by using A, H, or P method. As no other value exceeds ≈ 0.3, the latter value could, perhaps, be considered as a border between probable real and unreal results. In spite of this fact, a study of meteor showers from the IAU Meteor Data Center Lund catalogue (Lindblad, 1987; 1991; 1993) published in the paper by Porubčan et al. (1995) shows that the Perseids may be dispersed from their mean orbit (regarded as the parent body orbit for an ideal case, where neither the stream nor the parent body is perturbed) up to $D = 0.53$. Therefore, we can recommend value roughly 0.5 as the border between possible real and certainly unreal results rather than value 0.3.

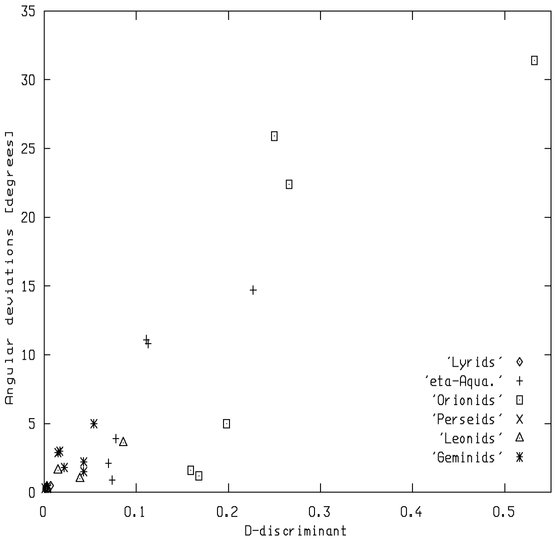

Fig. 1. The angular deviation between the theoretical and real radiants as a function of the $D-$discriminant characterizing difference between the orbit of the parent body and predicted mean shower orbit. The dependence is given for six major meteor showers with well-known parent bodies.

On the other hand, an almost perfect agreement of the theoretical and observed radiants is found for $D \leq 0.07$. Or, no deviation between both radiants exceeds 5^o, if the value of D does not exceed 0.1. So, a value roughly 0.1 can be recommended as a border between good and possible real results. Softer limits cannot be found from Fig. 1 in this way, because the complete range of the D from 0.1 to 0.5 is filled with real values for the only parent body orbit - the orbit of 1P/Halley.

Generally, the radiant is better predictable for a short-period activity shower than for a long-period activity shower. A further feature characterizing the quality of a prediction is the minimum distance between the parent body orbit (its appropriate arc) and Earth's orbit. The orbit of the 1P/Halley is the most distant orbit of all considered parent body orbits (0.155 *AU* for the pre-perihelion - Orionids - arc, and 0.066 *AU* for the post-perihelion - $\eta-$Aquarids - arc) what corresponds with the highest values of D (the averages from all methods are 0.262 and 0.112, respectively) in the predictions of associated showers. The other 4 parent orbits are distanced from the Earth's orbit 0.022 *AU* (MP 3200 Phaethon), 0.003 *AU* (55P/Tempel-Tuttle), 0.002 *AU* (C/1861 G1 (Thatcher)), and 0.001 *AU* (109P/Swift-Tuttle), whilst the corresponding values of D - the averages from all the applicable methods - are 0.032, 0.025, 0.004, and 0.002, respectively. A correlation between both the decreasing sequences is evident.

A more precise specification of the critical $D-$discriminant separating the real and unreal calculations would perhaps be possible on the basis of a detail analysis made separately for each individual method and with respect to the given orbit. However, such specifications exceed the frame of this paper.

4. The access to the program

The program is available from the authors. Interested readers are invited to obtain it:

1. By *anonymous ftp* to the server of the Astronomical Institute of the Slovak Academy of Sciences at Tatranská Lomnica at the INTERNET address: *auriga.ta3.sk* in subdirectory *pub/meteors/radiant* or by URL: *ftp://auriga.ta3.sk/pub/meteors/radiant/* (these ways are preferred).

2. By mail on the diskettes (3.5" or 5.25"). In this case one diskette (IBM formated) should be sent to the authors.

There is available the FORTRAN source text, *methods.f*, which can be immediately proceeded by the IBM FORTRAN 77 COMPILER, XLF, under OS AIX3.2 and DOS MS FORTRAN 5.1 COMPILER. Moreover, the executable DOS MS FORTRAN 5.1 compiled version, *dosmeth.exe*, is available (of course, it has to be downloaded in binary code).

In case of any problem, please contact the authors by E-mail at the address: *ne@ta3.sk*.

The use of individual parts (subroutines) of the program is permitted. This paper should be quoted in each official presentation using either the program as a whole, or whatever of its parts included in other program.

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