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The computer programs to check the internal consistency of the meteor-shower data

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Abstract. At times, it becomes necessary to verify the internal consistency of meteor shower characteristics, regardless they are one's own observations or information taken from the literature. A check of internal consistency also appears desirable when the shower characteristics are reported to the Meteor Data Center (MDC) of the International Astronomical Union (IAU). In this article, we describe and provide software that we have developed, which is capable of performing checks of internal consistency between the mean geocentric parameters (solar longitude, geocentric radiant, and geocentric velocity) and mean orbital elements (perihelion distance, eccentricity, argument of perihelion, longitude of ascending node, and inclination) of a shower or several showers. The program is freely accessible (Fortran77 source code as well as executable static binary code) along with this article or from the IAU MDC web pages.

Key words: meteor showers – geocentric parameters – orbital elements – meteoroid data verification – software

1. Introduction

The Meteor Data Center of the International Astronomical Union (IAU MDC, hereafter) provides, via its web site (https://www.iaumeteordatacenter.org/), both individual meteoroids (Orbital Database) and meteor shower data (Shower Database), see Rudawska et al. (2021). These data include, with some exceptions concerning the meteor showers, both geocentric and heliocentric parameters. There is a close relationship between geocentric and heliocentric parameters for individual meteoroids. The latter are calculated using the values of the geocentric parameters. Here we also have the possibility of performing inverse calculations. Thus, for geocentric and heliocentric individual meteoroid data given in the literature or online catalogs, we have the opportunity to check their mutual consistency. In the past and quite recently, such a check has been done many times, both for photographic and radio data, e.g. by Jopek (1986, 1991); Jopek et al. (2003); Koseki (1986); Lindblad (1991, 1992); Lindblad et al. (2001, 2003); Svoreň et al. (2008); Neslušan et al. (2012, 2014). It turned out that for several hundred meteoroids there were various types of numerical inconsistencies, which show how important it is to verify individual meteoroid data.

It would, therefore, be expected that inconsistencies may be encountered for a part of the data of meteoroid streams listed in the IAU MDC. One shower in the MDC can be reported by more than a single author team; each report of shower is regarded as its "solution". As far as we know, with the exception of Koseki (2016), the verification of the internal consistency of the meteor shower solution's characteristics given in the IAU MDC has never taken place. We are referring here to the internal inconsistency of the data and not to the errors we corrected in Hajduková et al. (2023), which were related to differences between submitted parameters and their values in the source publications. To this end, we would like to use a method similar to that used for testing individual meteoroid data.

However, in the case of meteoroid streams, a close relationship between the mean geocentric and heliocentric parameters is most often not the case. Usually, mean values of geocentric and heliocentric parameters are calculated separately, as arithmetic means of individual meteoroid parameters, members of a given stream. This causes some difficulties in verifying the meteoroid stream data. Therefore, we are forced to use a procedure of approximate nature.

In the following sections, we describe the method for assessing the internal consistency of meteoroid stream data and the resulting software for determining such consistency.

2. Calculation of geocentric parameters

In the following, we consider a hypothetical "mean meteoroid" moving in the mean orbit of a given meteoroid stream. If the mean orbital elements, perihelion distance, q, eccentricity, e, argument of perihelion, ω, longitude of ascending node, Ω, and inclination, i, are known, then it is possible to find the point of the mean orbit, where the mean meteoroid approaches the Earth's orbit, and next, to calculate the meteor's geocentric radiant, geocentric velocity, and solar longitude of the point of approach. The calculated values can be compared with their observed counterparts given in the IAU MDC list. A significant difference between the corresponding values indicates an inconsistency in the data.

In the past, as well as sometimes nowadays, it is assumed that the orbit of each meteoroid colliding with the Earth must cross the orbit of our planet. In general, this is not true, but in the past, and perhaps even now, some authors, when calculating the orbit of a meteoroid, make this assumption which simplifies the calculation process. Precise calculations also require knowledge of the observed position of the meteoroid relative to the center of the Earth.

However, the aforementioned assumption is definitely not met for the mean orbit of a stream, which is calculated as a simple arithmetic average of a given element of all individual meteoroids belonging to the stream. Hence, to calculate the mean shower's geocentric parameters more simply, the known mean orbit of the stream has to be modified to achieve the crossing of the Earth's orbit. This modification was carried out by the most appropriate of six methods, which were also considered in creating the computer program that calculates the meteor radiant (Neslušan et al., 1998). The most appropriate method provides us with the crossing point of both meteoroid and Earth orbits and, hence, with the date in the year when the crossing happens.

There is, however, a difference between the calculation of the position of Earth in the case of an individual meteoroid and the mean meteoroid. The mean orbit of a stream is often calculated based on the meteor data collected during a period spanning several years. Even in a single year, the position of this planet is different at the moments of the fall of individual members of the stream. In the case of a mean meteoroid, its exact time of fall cannot be found. We can determine only the mean solar longitude in a specific year. We chose the year 2000. Since the mean orbits of known streams have been determined in the twentieth and twenty-first centuries, the choice of the fixed year does not result in a significant deviation in the Earth's position since its orbit changes negligibly during about two centuries.

When the crossing point is recognized, by one of the six considered methods, we know the true anomaly of the mean meteoroid at this point; therefore, we can calculate the components of its heliocentric velocity vector, $\boldsymbol{V}_h$. At the crossing point, the Earth's heliocentric velocity vector, $\boldsymbol{V}_E$, is also known. From these two vectors, the geocentric velocity vector, $\boldsymbol{V}_g$, of the mean meteoroid can be calculated as

$$\boldsymbol{V}_g = \boldsymbol{V}_E - \boldsymbol{V}_h, \tag{1}$$

whereby the direction to the radiant is pointed out by vector $-\boldsymbol{V}_g$.

At the crossing point, the ecliptic longitude, λ_E, and the heliocentric radius vector of the Earth, $\boldsymbol{r}_E$, which is identical with the heliocentric radius vector of the mean meteoroid are also known; while the moment of activity of a meteor swarm is represented by the corresponding solar ecliptic longitude $\lambda_\odot$

$$\lambda_\odot = \lambda_E + 180^\circ, \tag{2}$$

and the magnitude of the mean meteoroid's geocentric velocity (in [au/day]) can be calculated as

$$V_g = k\sqrt{M_\odot}\sqrt{\frac{2}{r_E} - \frac{1-e}{q}}, \tag{3}$$

where k is the Gauss gravitational constant.

The geocentric parameters, solar longitude, right ascension and declination of the geocentric radiant and the geocentric velocity are calculated in the above-outlined way by the program *radiants.f*. Before using it, one has to prepare the input data file (its default name is *allshowers11jan2023.db*; the name can, however, be defined in the input-parameter file *inparams.rad*, see below). The structure of this file should remain constant. The file should contain the mean parameters of all showers to be checked. The data on each shower must be given in one line, whereby the data are arranged in order:

IAU No. of the shower (IAU shower number),
additional number (AdNo.) of the solution of the shower,
mean solar longitude [deg],
mean right ascension of geocentric radiant [deg],
mean declination of geocentric radiant [deg],
mean geocentric velocity [km s^{-1}],
mean perihelion distance [au],
mean eccentricity [1],
mean argument of perihelion [deg],
mean longitude of ascending node [deg],
mean inclination [deg], and
number of meteors in a given solution (if unknown give -1).

Before the run of the *radiants* program, another input file, *inparams.rad*, must be prepared. In this file, we can define the names of the files with the input and output data and the acceptable difference (tolerance) of the checked parameters. Namely, the values calculated by the original author and by us are expected to differ because of various reasons, such as using different methods of radiant determination, calculation of the position of the Earth in different years, etc. For example, if we choose the tolerance for the right ascension of the geocentric radiant equal to 3°, only the difference larger than 3° between the original and our calculated values will occur in the list of the differences given in their output file (see below). Each value that should be given in *inparams.rad* is described in the previous line of this file.

After running the program *radiants*, two (or three) output files will occur. Their default names are *check_orb.d* and *errors_geo.inf* (but the user can define other names in the file *inparams.rad* if they wish). In the file *check_geo.d*, there is a list of the following geocentric quantities of all considered shower solutions:

serial number of solution,
IAU No. of the shower,
additional number (AdNo.) characterizing the particular solution of the shower,
solar longitude [deg],
right ascension of geocentric radiant [deg],
declination of geocentric radiant [deg],
geocentric velocity [km s^{-1}],

and the method of the modification of orbit to cross the orbit of the Earth (Q, B, W, A, H, P; the description can be found in (Neslušan et al., 1998)).
IAU No. and AdNo. are the unique identification codes of a given solution. (Unfortunately, in a few cases the AdNo. was changed in the past versions of the MDC list; it is fixed from January 1, 2024.)

The geocentric parameters are given in two lines, whereby the values published by the original author are in the first and the values calculated by the program are in the second line. See below an example, an extract of the content of the file *check_geo.d*:

```
Example 1 (check_geo.d):

ser.No. IAU AdNo  LS        RA      DEC       Vg   method
-------------------------------------------------------
    1      1   0  128.900  306.600   -8.200  22.200
                  129.283  306.446   -8.364  22.108   H

    2      1   1  122.300  306.700   -9.300  23.400
                  122.415  303.344  -10.024  23.127   H

    3      1   3  127.660  307.680   -9.920  22.800
                  128.803  307.258   -9.354  22.381   H

    4      1   4  127.900  307.100   -8.900  22.600
                  127.922  306.675   -9.041  22.520   H

    5      1   5  123.300  302.900   -9.900  22.200
                  123.238  302.609  -10.012  22.137   H

    6      1   8  125.400  306.500   -9.200  23.000
                  125.028  304.328   -9.654  22.806   H

    7      1  10  115.200  300.000  -11.900  25.000
                  115.231  299.651  -12.028  24.880   H

    8      1  11  124.100  304.300   -9.900  23.200
                  124.100  303.947   -9.947  23.135   A

    9      1  12  130.400  307.700   -8.300  21.900
                  130.491  307.161   -8.328  21.740   H

   10      2   0  217.300   48.700   13.000  28.000
                  217.364   49.464   13.390  27.722   H
```

```
 11      2  1  207.600   40.600   10.300  27.800
               208.021   41.619   10.677  27.451   H

 12      2  2  221.500   51.700   14.000  28.200
               221.646   52.242   14.113  28.015   H

 13      2  3  196.000   31.000    8.000  27.920
               196.062   30.613    9.866  27.633   H

 14      2  5   16.000   30.900    8.100  28.200
               195.973   31.225    8.159  27.922   H

 15      2  6   34.400   47.900   12.800  26.600
               214.081   47.253   12.711  26.551   H

 16      2  8  224.500   54.900   14.600  28.000
               224.580   55.520   14.748  27.726   H

 17      2  9   22.400   36.800    9.700  28.600
               200.505   36.183    9.765  29.489   Q

 18      2 10   41.600   51.800   13.700  27.400
               221.576   52.436   13.900  27.190   H

 19      2 11  242.100   65.300   14.900  23.400
               242.125   65.619   15.067  23.351   H

 20      2 12   85.100   82.900   14.900  20.600
               264.973   82.962   15.091  20.566   H
```

The found differences in the verified parameters, larger than the defined tolerances (by the user in file *inparams.rad*), are written into the output file *errors_geo.inf*. Each difference is given in one line, which contains the IAU No. of the shower, the AdNo. of its solution, the value of the parameter published by the original author ("observed" value), and the value of this parameter as re-calculated by the program. There can be several wrong parameters in one shower solution, therefore the differences for this solution are then written in several lines. See below an example, an extract of the file *errors_geo.inf*:

```
Example 2 (errors_geo.inf):

IAU No. =   11  AdNo. =  0  V_g_orig = 36.000  V_g_rec. = 33.806
IAU No. =   11  AdNo. =  1   LS_orig = 280.50   LS_rec. = 339.90
```

```
IAU No. =   11  AdNo. =  1   RA_orig = 182.10   RA_rec. = 170.67
IAU No. =   11  AdNo. =  1  DEC_orig =   2.60  DEC_rec. =   5.73
IAU No. =   16  AdNo. =  3   RA_orig = 134.40   RA_rec. = 128.67
IAU No. =   16  AdNo. =  3  V_g_orig = 58.900  V_g_rec. = 55.880
IAU No. =   18  AdNo. =  4   LS_orig = 231.10   LS_rec. = 320.92
IAU No. =   18  AdNo. =  4   RA_orig =  21.70   RA_rec. = 133.03
IAU No. =   18  AdNo. =  4  DEC_orig =  33.50  DEC_rec. =  39.84
IAU No. =   21  AdNo. =  0  V_g_orig = 20.000  V_g_rec. = 17.010
IAU No. =   21  AdNo. =  4  DEC_orig =   2.90  DEC_rec. =   6.16
IAU No. =   21  AdNo. =  4  V_g_orig = 18.800  V_g_rec. = 16.898
```

Sometimes, there is a need to know the geophysical parameters determined by every method used to modify the mean orbit. The user can specify such a request in the input file *inparams.rad*, writing another, extensive, output file, which is named by the program *debug.d*.

For every shower solution, there is given the minimum-orbit intersection distance (MOID) between the orbit of the Earth and the post-perihelion and pre-perihelion arcs of the solution orbit, and all calculated parameters, when the known orbit of the solution is modified to exactly cross the Earth's orbit, by each of the six methods used (Q, B, W, A, H, and P; see (Neslušan et al., 1998)). In more detail, there are three values of each parameter also listed in the input data file: the value published by the original author, the value calculated by the program for the node on the post-perihelion arc, and the value calculated by the program for the node on the pre-perihelion arc of the mean orbit of the solution. The Southworth & Hawkins (1963) D criterion between the originally published mean orbit and the modified orbit crossing the orbit of our planet in the first or second node is also given along with the heliocentric speed.

An example of a part of the *debug.d* file for one solution and one method of the modification of the mean orbit is below.

```
Example 3 (debug.d):

IAU No. =   1  AdNo. =  0
   MOID:            0.0214  0.0009
    P-method:
D_1, D_2:            0.026   0.001
q:            0.602   0.600   0.602
e:            0.770   0.771   0.770
arg.:       266.670 275.943 266.292
node:       128.900 119.773 129.272
i:            7.680   6.716   7.643
lambda_sun: 128.900 299.773 129.272
R.A.:       306.600 306.273 307.237
```

```
DEC.:          -8.200 -28.949  -8.330
V_g:           22.200  22.322  22.332
V_h(calc.):            38.267  37.542
```

3. Calculation of orbital elements

We again consider a hypothetical "mean meteoroid" moving in the mean orbit of a given meteoroid stream. This time, the mean geocentric parameters, solar longitude, $\lambda_{\odot}$, right ascension, α, and declination, δ, of geocentric radiant, and geocentric velocity, V_g, are known and a program named *elements.f* calculates the orbital elements, perihelion distance, q, eccentricity, e, argument of perihelion, ω, longitude of ascending node, Ω, and inclination, i.

It is the inverse calculation with respect to that performed by the program *radiants.f*. Both calculations are useful. Sometimes, the cause of a large difference cannot be revealed by the first program but can be revealed by the second program. For example, if there is a typing error in the mean argument of perihelion of a solution, we obtain all calculated geocentric parameters significantly different from those published by the original author. However, the inverse calculation of orbital elements results only in a difference in the argument of perihelion.

The names of input and output files as well as the tolerance in the checked orbital elements can be specified when one wants to use a program *elements*, in the input file *inparams.ele*. The input data file, with all mean parameters for all checked shower solutions, is identical with the input data file for the program *radiant* (its default name is *allshowers11jan2023.db*).

There are again two output files created by the program *elements*. Their default names are *check_orb.d* and *errors_orb.inf* (they can be changed in the file *inparams.ele*). File *check_orb.d* contains the re-calculated orbital elements for every solution. In the individual columns of this file, there are given: serial number of the given solution, IAU No. of the shower, number of its solution, perihelion distance, eccentricity, argument of perihelion, longitude of ascending node, and inclination. The orbital elements are written in two lines. While the values published by the original author can be seen in the first line, the values calculated by the program *elements* are in the second line. See below an extract of the content of the file *check_orb.d*:

```
Example 4 (check_orb.d):

ser.No. IAU AdNo   q         e        arg.     node       i
-----------------------------------------------------------
    1     1  0  0.60200  0.77010  266.670  128.900    7.680
                0.59710  0.75842  267.403  128.078    7.860
```

```
2     1  1  0.55000  0.76800  273.300  122.300    7.700
            0.50719  0.74188  280.113  121.678    8.125

3     1  3  0.59000  0.77000  269.000  127.660    7.000
            0.56579  0.76247  271.335  126.914    6.796

4     1  4  0.58600  0.77000  268.400  127.900    7.400
            0.57631  0.75969  270.079  127.107    7.538

5     1  5  0.58600  0.75000  269.200  123.300    7.300
            0.58152  0.74559  270.044  122.841    7.394
```

Output data file with the default name *errors_.inf* contains the list of values which differ more than the specified tolerance. Again, one wrong parameter is written in one line. The line consists of the IAU No. of the shower, the AdNo. of its solution, the value of the parameter published by the original author ("observed" value), and the corresponding value calculated by the program *elements*. See below an extract of the content of the file *errors_orb.inf*:

```
Example 5 (errors_orb.inf):

IAU No. =    1 AdNo. =  1  arg_orig = 273.3  arg_rec. = 280.1
IAU No. =    2 AdNo. =  3    i_orig =   3.0    i_rec. =   5.5
IAU No. =    5 AdNo. =  0    i_orig =  30.8    i_rec. =  28.0
IAU No. =    5 AdNo. =  3    i_orig =  27.2    i_rec. =  17.2
IAU No. =    5 AdNo. =  3  arg_orig = 152.8  arg_rec. = 146.5
IAU No. =    6 AdNo. =  2    e_orig = 0.968    e_rec. = 1.057
IAU No. =   11 AdNo. =  1    q_orig = 0.382    q_rec. = 0.003
IAU No. =   11 AdNo. =  1    e_orig = 0.851    e_rec. = 0.994
IAU No. =   11 AdNo. =  1    i_orig =   3.5    i_rec. =  46.9
IAU No. =   11 AdNo. =  1  arg_orig = 349.1  arg_rec. = 359.3
IAU No. =   13 AdNo. =  4  arg_orig = 172.3  arg_rec. = 166.9
IAU No. =   13 AdNo. =  7  arg_orig = 171.1  arg_rec. = 164.8
IAU No. =   13 AdNo. =  8  arg_orig = 170.8  arg_rec. = 165.7
IAU No. =   16 AdNo. =  3  nod_orig =  76.5  nod_rec. =  85.4
IAU No. =   17 AdNo. =  0    q_orig = 0.350    q_rec. = 0.296
IAU No. =   17 AdNo. =  0  arg_orig = 294.9  arg_rec. = 303.9
IAU No. =   18 AdNo. =  4  nod_orig = 321.1  nod_rec. = 229.6
IAU No. =   20 AdNo. =  6    e_orig = 0.810    e_rec. = 0.757
```

4. Types of the differences

Both introduced programs should serve to reveal significant internal inconsistencies in the meteor shower data. The user alone must however define what a difference in a given parameter should be regarded as a discrepancy, i.e. they must set the tolerance limit. A good choice of tolerance limits can be made with the help of the distributions of the absolute values of differences in the checked set of parameters which are shown in Figs. 1 (geocentric parameters) and 2 (orbital elements). In more detail, these figures show the distributions of the differences of checked parameters between the values as given in the MDC list and those calculated by us using the programs. When selecting tolerance limits, none should be overly strict to avoid the detection of many acceptable differences. In the calculation resulting in the examples presented above, the tolerance in declination of radiant and inclination of orbit was 2.5°, and the tolerance in the other angular elements 5°. The tolerance in geocentric velocity (perihelion distance and eccentricity) was 1.5 km s^{-1} (0.05 au and 0.05).

On the other hand, the checking of consistency would not be very accurate (will not serve its purpose) if the tolerance was too large. When compromising, a difference of a parameter may only slightly exceed the tolerance limit, and the published value can, thus, be still acceptable. For example, the published mean inclination of solution AdNo. 3 of the shower with the IAU No. 2 (the second line in Example 5 above) is 3° and the calculated inclination is 5.543°. The difference is 2.543°, which exceeds the tolerance in inclination of 2.5° only about 0.043°. This is not a significant difference; the solution can be regarded as correct.

In Fig. 2d, we can see that the number of showers does not decrease with the increasing difference, but there is a peak at the difference $\Delta\Omega \approx 2°$. Our analysis revealed that this peak occurs because many authors considered the Earth orbit to be circular, when they calculated the orbital elements. In Fig. 3a, we see that $\Delta\Omega$ of many showers acquires a value near 2° in two specific, relatively narrow intervals of Ω. When we construct the function $\Delta\Omega = \Delta\Omega(\Omega)$, whereby $\Delta\Omega$ is the difference of Ω calculated by considering the elliptical and circular Earth's orbit, then the curve showing the dependence (Fig. 3b) matches the sinusoid-like accumulation of points of many real showers. Two sinusoid-like curves correspond one to the showers colliding with the Earth in the ascending and second to the showers in the descending node of their orbit.

Another type is a simple typing error. An example of such an error was the value of the mean longitude of the ascending node in solution AdNo. 4 of the shower with the IAU No. 18 in the recent version of the MDC data. The value was equal to 321.1° (the second last line in Example 5 above). We see that the corresponding calculated value is 229.6°, therefore numerals "2" and "3" were obviously interchanged in the published value. When the value of 321.1° is corrected to 231.1°, none of the parameters of this solution are listed as incorrect in the file *errors_geo.inf* or *errors_orb.inf*. The mean longitude of the ascending

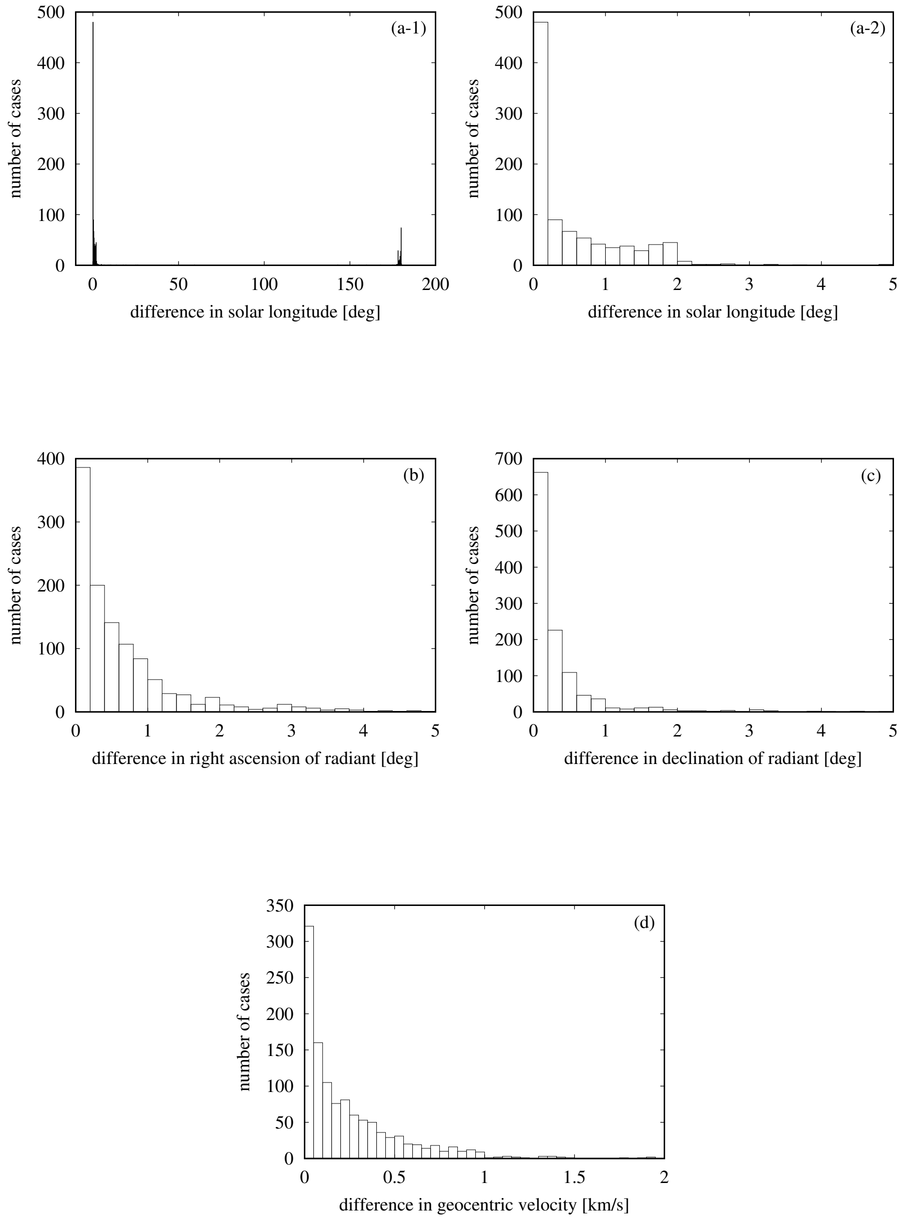

Figure 1. Distributions of absolute values of differences between the solar longitudes (panels a-1, a-2), right ascensions (b) and declinations (c) of geocentric radiants, and geocentric velocities (d) as given in the MDC list of showers (the version on January 11, 2023, with 1182 complete solutions) and calculated with the help of a program created within this work.

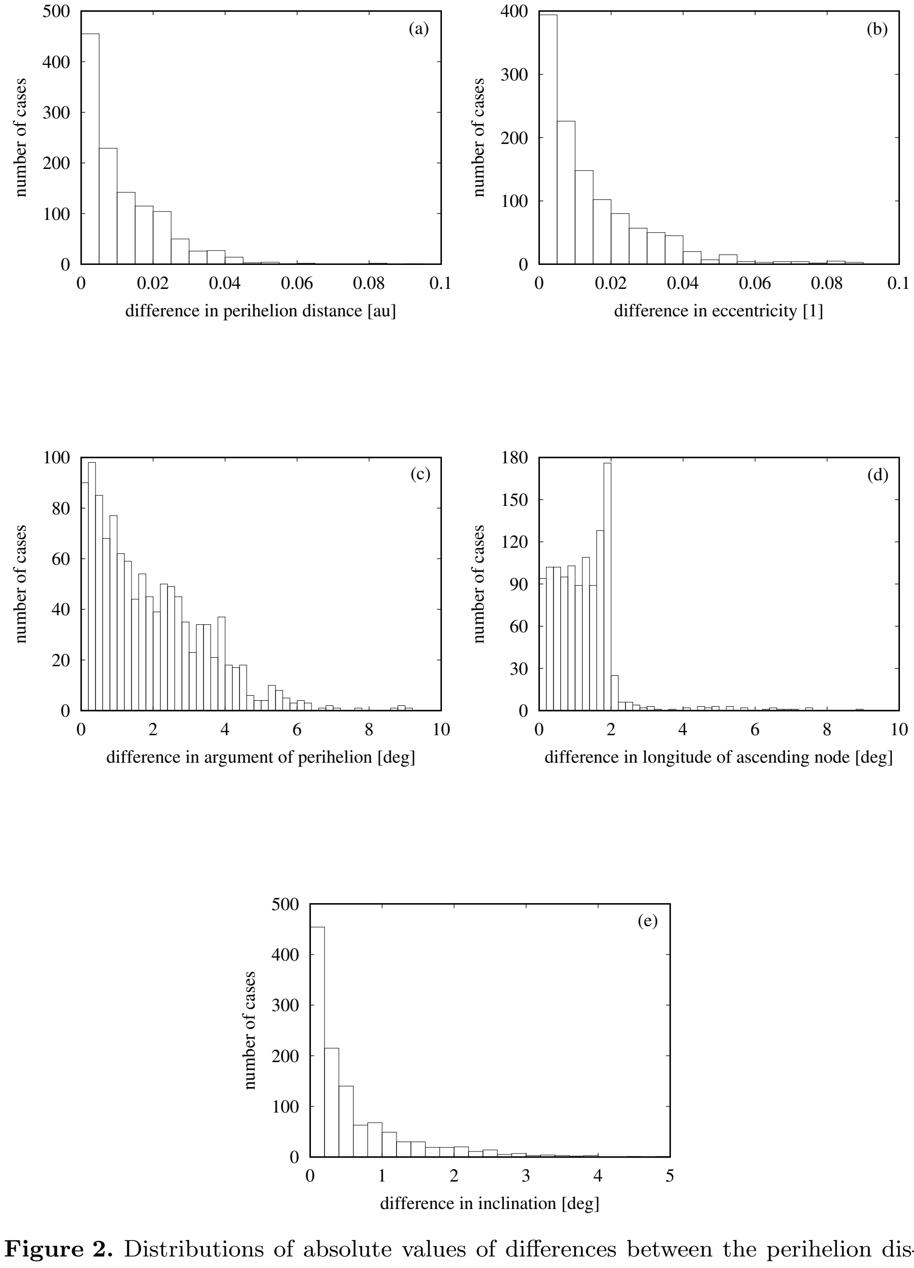

Figure 2. Distributions of absolute values of differences between the perihelion distances (panel a), eccentricities (b), arguments of perihelion (c), longitudes of ascending node (d), and inclinations (e) as given in the MDC list of showers (the version on January 11, 2023, with 1182 complete solutions) and calculated with the help of a program created within this work.

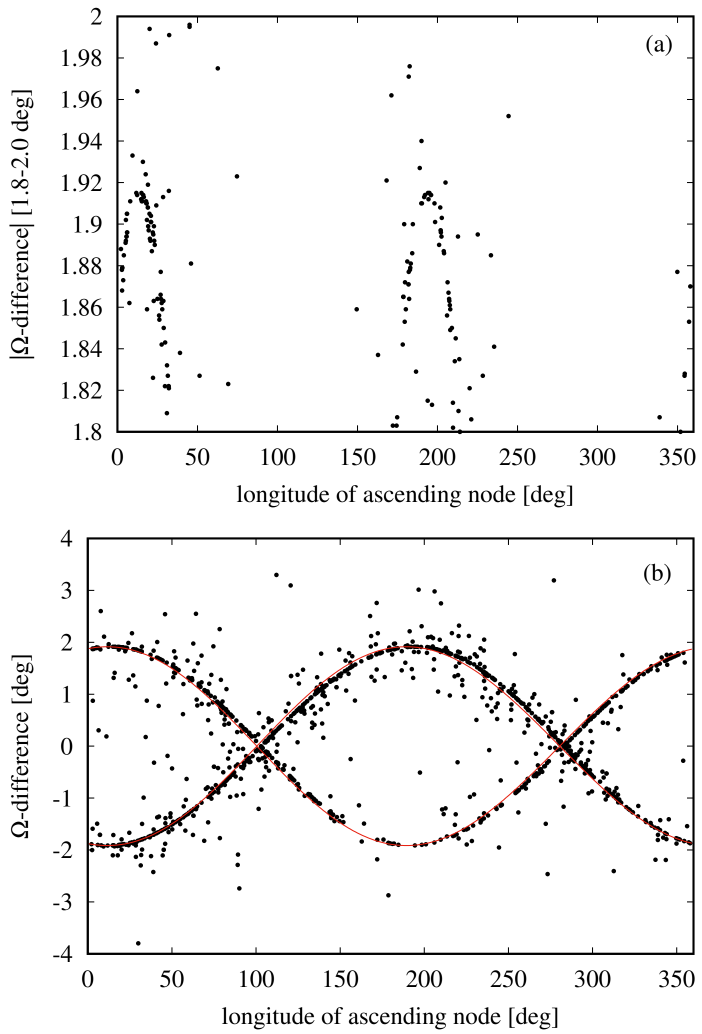

Figure 3. The figure to explain the reason for the highest peak in the distribution of the differences in longitude of ascending node, Ω, which is seen in Fig. 2d. In panel (a), the size of the difference of Ω in the interval from 1.8° to 2.0° (the highest peak in Fig. 2d) as the function of Ω is shown. This difference is more abundant in two specific intervals of this orbital element. In panel (b), there is shown the Ω-difference as depends on Ω in the interval -4° to $+4^\circ$ (black points). One can observe a twofold sinusoid-like behavior of the difference between many showers. The smallest derivative of these curves is just in the intervals of the peak. The red curves show the difference when Ω is calculated considering the true, elliptical, and circular orbits of the Earth. One curve corresponds to the showers colliding with our planet in the ascending and the other in the descending node of their orbit.

node is then consistent with the mean solar longitude of this solution, which equals just 231.1°. (The erroneous value was, meanwhile, corrected; the right value can be found on the current MDC website.)

In Fig. 1a-1, we can see quite a lot of differences in the solar longitude equal to ∼180°. Obviously, the solar longitude was misidentified with the longitude of the Earth. A wrong identification of the quadrant can also occur at other angular parameters.

Some solutions are completely inconsistent. An example of such a solution is AdNo. 1 of the shower IAU No. 11. When its geocentric parameters are calculated using the program *radiants*, the large differences, above the tolerance limits, are found in the solar longitude, right ascension and declination of radiant (the second to fourth lines of Example 2 above). Using the program *elements* for the reverse calculation, one can find significant differences in perihelion distance, eccentricity, inclination, and argument of perihelion (the seventh to tenth lines of Example 5). The cause of the inconsistency in such a case is unknown.

The errors of the above-outlined types can occur due to a wrong determination of parameters (in the far past, the calculations were performed manually). Or, the inconsistency occurred due to a mistake when the data were re-written. The authors often create a table of geocentric data of showers and another table with their orbital elements. When merging these tables, the geocentric (orbital) parameters belonging to the previous or next showers in the table may be erroneously read and merged with the orbital (geocentric) parameters of the given shower. Of course, other reasons are not excluded.

5. Access to the software

The programs are freely accessible with this article, `https://www.astro.sk/caosp/Eedition/FullTexts/vol54no1/pp57-71.dat/`, and on the website of the IAU MDC[1], in the download section of the Shower Database part. In more detail, the Fortran77 source code of both programs, *radiants.f* and *elements.f* as well as the executable static binary codes, *radiants.exes* and *elements.exes*, are provided together with the template input and output data files. These files can be immediately run on the machines with the UNIX/Linux operation system. File *readme* with the description of the whole package is attached.

We recommend that researchers who deal with meteor showers use the programs and verify, in this independent way, the mutually dependent shower parameters.

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[1] https://www.iaumeteordatacenter.org/

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