IAU MDC Meteor Orbits Database - A Sample of Radio-Meteor Data from the Hissar Observatory

M. Narziev · L. Neslušan · T. J. Jopek · R. P. Chebotarev · V. Porubčan · J. Svoreň

Received: date / Accepted: date

Abstract We announce an upgrade of the IAU MDC photographic and video meteor orbits database. A sample of 8916 radio-meteor data determined by the radar observations at the Hissar (Gissar) Astronomical Observatory, Dushanbe, Tajikistan, are added to the database. Along with the radiant coordinates, velocities, and orbital elements the Hissar radio-meteor sample contains the heights, linear electron densities, stellar magnitudes, and masses of the meteoroids. The new 2018 version of the IAU MDC database contains 4873 photographic, 110521 video, and 8916 radio meteor records. The data are freely available on the website at the address [https://www.astro.sk/~ne/IAUMDC/PhVR2018/].

M. Narziev, Institute of Astrophysics of Academy of Sciences of the Republic of Tajikistan, Tajikistan
E-mail: mirhusseyn.narzi@mail.ru
L. Neslušan, J. Svoreň Astronomical Institute, Slovak Academy of Sciences, 05960 Tatranská Lomnica, Slovakia
E-mail: ne@ta3.sk, astrsven@ta3.sk
T. J. Jopek Astronomical Observatory Institute, Faculty of Physics, Adam Mickiewicz University, ul. Słoneczna 36, 60-286 Poznań, Poland
E-mail: jopek@amu.edu.pl
R. P. Chebotarev, Institute of Astrophysics of Academy of Sciences of the Republic of Tajikistan, Tajikistan
[Dr. Roman Petrovich Chebotarev made a lot of work to prepare the catalog presented in this paper. Unfortunately, he passed away before the work was finished. He was the head of the radar laboratory and leader of the team creating the radio complex MIR-2, which was essential to collect the Hissar database.]
V. Porubčan Astronomical Institute, Slovak Academy of Sciences, 05960 Tatranská Lomnica, Slovakia & Faculty of Mathematics, Physics and Informatics, Comenius University, 84248 Bratislava, Slovakia
E-mail: porubcan@fmph.uniba.sk
Keywords meteor radiants · meteoroid orbits · radio meteors · meteor database

1 The orbital database of the IAU Meteor Data Center

Our knowledge of the structure of meteoroid streams as well as an abundance of the sporadic meteoroids has been derived, mostly, from observations of the meteor phenomena in the Earth’s atmosphere. Several research teams systematically or during observational campaigns recorded meteors using different observational techniques: traditional and digital photography, radar, video and TV equipment. Obtained results were published in a printed form or in the way of a local database. Since the eighties of the previous century [Lindblad 1987] the IAU Meteor Data Center (MDC) collects the orbital and geophysical parameters of the individual meteoroids. These data are freely accessible on the dedicated website posted at the server maintained by the Astronomical Institute of Slovak Academy of Science in Tatranská Lomnica. The last version of the IAU MDC database issued in 2016 contains the collection of 4873 photographic records [Lindblad et al. 2003; Neslušan et al. 2014, 2016] and the new video-based catalog of 110521 meteors observed by the Cameras for All-sky Meteor Surveillance system (CAMS) [Gural 2011; Jenniskens and Gural 2011; Jenniskens et al. 2011; Jenniskens and Nénon 2016; Jenniskens et al. 2016a,b,c).

The photographic and video observations provide us only with the information about the night-time meteors: the shower and the sporadic components. Admittedly, some video databases [SonotaCo 2009, 2016] contain a small fraction of the day-time meteors, but the day-time showers have mostly been studied on the basis of the radio-meteor data. The reason is simple, the radio-meteor observations do not depend on any specific atmospheric or day-night conditions. Therefore we find it valuable to incorporate to the IAU MDC collection a sample of 8916 radio-meteor data gained at the Hissar Astronomical Observatory in Tajikistan.

The dates of observations of 8916 radio-meteors span the synoptic-year interval from December 1968 until December 1969. Such rather small sample do not enable a complex study of meteor showers, but it can serve for various comparisons between the radar, video, and photographic techniques. In this paper, we introduce the Hissar radio-meteor data which are available on the IAU MDC website [https://www.astro.sk/~ne/IAUMDC/PhVR2018/].

2 Apparatus and data processing

The Hissar radio-meteor station of the Institute of Astrophysics, Academy of Sciences of Tajikistan is located in Dushanbe; its geographic coordinates are: $\phi=38.6^\circ$N, $\lambda=68.8^\circ$E. The meteors were observed by the radar complex MIR-2 system (the meteor pulse radar of the second generation) which was constructed

---

1 The commonly accepted definition of the day-time or night-time meteor shower does not exist. In practice some researches use the rule—the elongation of the radiant of a day-time shower from the Sun is less than 20–30 deg [Rendtel 2014].

2 Because of the transcription of Russian texts to English, name “Hissar” has often been written as “Gissar”.

in 1964-1968. Its detailed structure, principles of operation, and technical characteristics are described in (Chebotarev et al., 1970; Chebotarev and Isamutdinov, 1970).

The MIR-2 system consisted of a transmitter working at the wavelength 8 [m] (37.4 [MHz]) with the output pulse power of 65 [kW] and five receiving antennas. Four of them were located at 3.9 to 4.0 [km] from the central receiver. The bandwidth of the primary and remote receivers was 600 [kHz]. The receivers sensitivity threshold was equal to 8·10^{-14} [W]. For further processing only those meteors were used which were recorded by all receivers and had at least first maximum in the
amplitude-time characteristics (ATC), and which were not substantially distorted by the noise.

The results of the radar observations displayed on the cathode-ray tubes were recorded photographically. For recorded meteors it was found: the date and time of the meteor appearance, the distance to the meteor trail from the main central antenna, the distance to the meteor trail from each of the four receiving antennas. For each receiving channel of the amplitude-time characteristics (ATC), the positions of the beginning and the first four maxima were measured. Using these data and two methods described in Chebotarev (1970) and Chebotarev (1976) the angular coordinates of the azimuth and the zenith distance of the mirror point on the meteor trail and the velocity of the meteoroid were determined. If the value of the measured radio-echo duration for the central point enables to determine the value of the linear electron density, then the height of meteor trail, together with the radio magnitude and mass of a meteoroid were also determined, simultaneously with the radiant coordinates and velocity.

If the distances between the central and four remote receiving points are around 4 km, then using the bearing-time method proposed by Chebotarev (1976), the accuracy of the MIR-2 system estimated by the root-mean-square errors (RMSE) is as follows: $\sigma_d = \pm 20$ m for the distances, $\sigma_t = \pm 1$ millisecond for time measurements. In case of the long-range version of the bearing-time method the RMSE of the azimuth of the meteor radiant $\sigma_{AR} = \pm 1.8^\circ / \sin Z_R$, and the zenith distance $\sigma_{ZR} = \pm 1.2^\circ$, where $Z_R$ is the zenith distance of the radiant. The relative error of the meteor velocity equals to 3%. The RMSEs of the azimuth and zenith distance of the reflecting point are $\sigma_A = \pm 0.9 \sin Z$ and $\sigma_Z = \pm 0.9 \cos Z$ respectively, where $Z$ is the zenith distance of the reflecting point. The RMSE of the height of the reflecting point relative to the main remote station equals to $\sigma_h = \pm 2.0$ km.

It should be noted that in case of the bearing-time method one can use the amplitude-time pictures of inferior quality with 1-2 extremes only, instead of 3-4 which are necessary for the pulse-diffraction method. This approximately doubles the sensitivity of the method (based on the number of measured radiants and velocities), but increases the error $\sigma_A$ by the factor of 1.5. The speed of the meteor in the bearing-time method was determined both by the time of flight of the individual sections of the meteor path and using the diffraction pattern. Consistency of these velocities allowed to estimate the accuracy of the measurements. The final measured speed was either the average of the two, or it equalled to the velocity with a smaller measurement error.

3 Hissar radio-meteor data sample

The Hissar 8916 meteors were observed within the period from December 12, 1968 until December 24, 1969. Most of their radio magnitudes spans the interval 0–5.5 m (see Figure 1A) with maximum at 3.3 m. However isolated cases of one bright bolide ($-8.6$ m) and bright meteoroids were recorded. The bulk masses of the meteoroids falls into interval $10^{-4}$–1 g. The distribution of ecliptic longitudes of the Sun at the meteor apparitions, as shown in Figure 1B, is not a uniform one. A few gaps and two distinct picks are seen. The December pick certainly corresponds to the
Geminids shower (#4/GEM). The second pick observed in May is not related with a prominent meteor shower. Instead, in this month, in most cases, the sporadic meteors were observed. This is clearly seen in Figure 1C and 1D – where only one pick corresponding to Geminids geocentric radiants is seen. Using the break-point method (Neslušan et al., 1995, 2013), we found that in the Hissar sample the relatively well-defined Geminid stream would consist of ~800 meteoroids.

The histogram of the geocentric velocity is plotted in Figure 1E and its characteristic bimodal distribution is apparent. The bimodal nature of this distribution arise from that the values of geocentric velocities are superposition of the two components, the meteoroid and the Earth heliocentric orbital velocities. Figure 1F illustrates the distribution of the meteoroid heliocentric velocity. In the right tail of this distribution we noted that 148 meteoroids moved on the hyperbolic heliocentric orbits. Most of them (possibly all) are not really hyperbolic and they occurred due to measurement uncertainties, particularly due to the uncertainty of the geocentric velocity. However, considering the recent discovery of 1I/‘Oumuamua, a mildly active comet and the first interstellar small body recorded inside the solar system, we shouldn’t neglect the existence of the interstellar meteoroids. The Hammer-Aitoff projection of the geocentric radiants of 8916 radio-meteors is illustrated in Figure 2. Most radiants are located on the northern hemisphere. Except of Geminids and some not yet identified widespread clusters at the center of diagram 2A, the radiants located above the celestial equator are distributed almost uniformly. In Figure 2B the ecliptic Earth apex centered reference frame was used. The helion and antihelion concentrations are clearly seen.

4 IAU MDC database: the list of parameters and the data format

The 2016 version of the MDC orbital database includes 41 photographic catalogs (Neslušan et al., 2014) and one video meteor catalog (Neslušan et al., 2016). Each individual catalog incorporates some amount of the data records and each data record contains the values of several dozen of compulsory and supplementary parameters. The eleven compulsory parameters are: the identification code, the date of meteor fall, the orbital elements (perihelion distance, eccentricity, inclination, argument of perihelion, and longitude of ascending node), the geocentric radiant coordinates (right ascension and declination), and the geocentric and heliocentric velocities.

The supplementary parameters can be different depending on the observational technique used. The unification of all parameters of all individual catalogs represents the maximal meteor data record stored in the database. In the database version 2016, the maximal meteor data record consisted of 31 parameters. It was adjusted to the photographic and video meteor data.

Incorporation of the radio-data required adding another three parameters: the stellar magnitude of the radio-meteor, the height of the central point of the meteor trail, and the linear electron density of the central point of the meteor trail (a common logarithm of this quantity). The complete list of 34 meteor parameters of the current 2018 version of the MDC database is given in Table 1.

---

3 The shower designations #4/GEM fulfills the meteor shower nomenclature rules delineated in, e.g., (Jopek and Jenniskens, 2013; Jopek and Kaňuchová, 2017).
Fig. 2 The Hammer-Aitoff diagram of the geocentric radiants of 8916 Hissar meteors. In the diagram, the sky is seen from a position situated outwardly the celestial sphere. In plot A), the equatorial coordinates are used, the sinusoid-like dashed curve represents the ecliptic. In plot B), the same radiants are plotted in the ecliptic coordinates with the ecliptic longitude shifted in such a way that the apex of the Earth’s motion around the Sun is in the origin of the coordinate frame. Due to the geographical location of the Hissar station, many sporadic meteors with southern radiants were observed. On the right in plot A), the very compact concentration of the Geminids is clearly seen. Two other widespread clusters nearby the ecliptic are located around the center of the upper diagram.

The data in the MDC database version 2018 are stored in the standard and single-line (reduced-data) formats. The data formats were introduced in version 2013 [Neslušan et al., 2014] and since then, the formats are fixed and used in each subsequent version, version 2018 including.

Since the database version 2016 [Neslušan et al., 2016], the IAU MDC provides the data in the Excel sheet format. In version 2018, this format is unchanged in
Table 1. The list of parameters included in the new 2018 version of the IAU MDC orbital database. No.P. is the serial number of the parameter; C.P. is the code of the parameter. For the angular parameters Equinox 2000.0 is obligatory. The asterisks mark the parameters which are regarded as compulsory.

| No.P. | C.P. | Explanation |
|-------|------|-------------|
| *1    | #IC: | IAU MDC identification code |
| 2     | ANo: | unique number/code assigned to the meteor by the author |
| *3    | Yr:  | year of the meteor detection |
| *4    | Mn:  | month of the meteor detection |
| *5    | Day: | day and fraction of day of the detection in the UTC time scale |
| 6     | LS:  | solar longitude corresponding to the date of the meteor detection [deg] |
| 7     | mv:  | maximum photographic brightness of meteor [magnitude] |
| 8     | HB:  | height of the beginning of meteor trail [km] |
| 9     | HM:  | height of the maximum brightness [km] |
| 10    | HE:  | height of the end of meteor trail [km] |
| *11   | RA:  | right ascension of the geocentric radiant [deg] |
| *12   | DEC: | declination of the geocentric radiant [deg] |
| 13    | Vi:  | extra-atmospheric velocity [km s\(^{-1}\)] |
| *14   | Vg:  | geocentric velocity [km s\(^{-1}\)] |
| 15    | Vh:  | heliocentric velocity [km s\(^{-1}\)] |
| 16    | cZ:  | cosine of the zenith distance of geocentric radiant |
| 17    | Qm:  | quality code |
| *18   | q:   | perihelion distance [AU] |
| *19   | e:   | numerical eccentricity of the orbit |
| 20    | 1/a: | reciprocal semi-major axis [AU\(^{-1}\)] |
| 21    | a:   | semi-major axis [AU] |
| 22    | Q:   | aphelion distance [AU] |
| *23   | i:   | inclination of the orbit to the ecliptic [deg] |
| *24   | arg: | argument of perihelion [deg] |
| *25   | nod: | longitude of ascending node [deg] |
| 26    | pi:  | longitude of perihelion [deg] |
| 27    | Sh:  | the IAU meteor shower code |
| 28    | Mas: | pre-atmospheric photometric mass [g] |
| 29    | lgM: | common logarithm of the mass |
| 30    | cor: | remark on correction (if appears) |
| 31    | crh: | remark on extreme hyperbola |
| 32    | mr:  | magnitude (stellar) of radio meteor |
| 33    | Hrf: | the height of the central point of the meteor trail [km] |
| 34    | LpA: | common logarithm of linear electron density of the central point of meteor trail, \(p_{0}\) [electron cm\(^{-1}\)] |

The case of the photographic and video CAMS data. We were, however, forced to establish a new form of the Excel sheet for the Hissar radio-data because of the different set of the supplementary parameters submitted with this catalog. There are 23 columns with 23 parameters arranged in order:

#IC, Yr, Mn, Day, Hrf, mr, RA, DEC, Vi, Vg, Vh, cZ, q, e, 1/a, a, Q, i, arg, nod, pi, LpA, lgM.

The codes are explained in Table 1. Information about a given meteor is written in single line.

As already mentioned, the 2018 version of the IAU MDC orbital database can be freely downloaded from the website: https://www.astro.sk/~ne/IAUMDC/PhVR2018/
In each available format, all data can be downloaded as a single compressed ZIP file or each component catalog can be downloaded separately as a plain file.

We recapitulate that the upgraded 2018 IAU MDC orbital database contains 4873 photographic, 110 521 video, and 8916 radio-meteor records. Also, we remind that detailed descriptions of the data sources, listed parameters, formats, and corrections introduced to the submitted data are given in the database documentation which is also included in the ZIP archives or can be downloaded separately as the PDF file.

The IAU MDC orbital database is maintained on an unpaid voluntary basis. Several colleagues have asked us — what reference to the orbital database they should include in a published paper? The correct references are:

- Porubčan, V., Svoreň, J., Neslušan, L., Schunová, E., 2011, The Updated IAU MDC Catalogue of Photographic Meteor Orbits. Proc. of the Meteoroids Conference held in Breckenridge, Colorado, USA, May 24–28, 2010, Meteoroids: The Smallest Solar System Bodies. NASA/CP–2011-216469, Cooke, W. J., Moser, D. E., Hardin, B. F., and Janches, D. (eds), pp 338-341.
- Neslušan, L., Porubčan, V., Svoreň, J., 2014, IAU MDC Photographic Meteor Orbits Database: Version 2013, Earth Moon and Planets 111, pp 105-114.
- Neslušan, L., Jenniskens P., Porubčan, V., Svoreň, J., 2016, Central Bureau Electronic Telegram No. 4255.
- and also this paper.

Acknowledgements  This work has been supported, in part, by the VEGA - the Slovak Grant Agency for Science, grants Nos. 2/0023/18 (J. Svoreň) and 2/0037/18 (L. Neslušan), and by the Slovak Research and Development Agency under contract APVV-16-0148 (V. Porubčan).

T.J. Jopek contribution was supported by 2016/21/B/ST9/01479 project, founded by the National Science Centre in Poland.

This research has made use of NASA’s Astrophysics Data System Bibliographic Services.

References

Chebotarev, R. P. 1970. Range-finder radio method for determination of angular coordinates of meteor trails. Komety i Meteor 19, 46-52.
Chebotarev, R. P., Sidorin, V. N., Polushkin, G. A., Bibarsov, R. S., Isamutdinov, S. O., Koltakov, V. M. 1970. Complex of techniques for radio echo studies of meteors in Dushanbe. Bjull. Inst. Astrofizikii 55, 24-28.
Chebotarev, R. P., Isamutdinov, S. O. 1970. Multibeam indicator for a meteor radar. Bjull. Inst. Astrofizikii 55, 34-39.
Chebotarev, R. P. 1976. The potential of a bearing versus time radar method for determining the radiants and velocities of individual meteors. Komety i Meteor 24, 19-27.
Gural, P. S. 2011. The California All-sky Meteor Surveillance (CAMS) System. Proceedings of the International Meteor Conference, 29th IMC, Armagh, Northern Ireland, 28-31.
Jenniskens, P., Gural, P. S. 2011. Discovery of the February Eta Draconids (FED, IAU#427): the dust trail of a potentially hazardous long-period comet. WGN, Journal of the International Meteor Organization 39, 93-97.
Jenniskens, P., Gural, P. S., Dynneson, L., Grigsby, B. J., Newman, K. E., Borden, M., Koop, M., Holman, D. 2011. CAMS: Cameras for All-sky Meteor Surveillance to establish minor meteor showers. Icarus 216, 40-61.

Jenniskens, P., Nénon, Q., Albers, J., Gural, P. S., Habermaa, B., Holman, D., Morales, R., Grigsby, B. J., Samuels, D., Johanninck, C. 2016a. The established meteor showers as observed by CAMS. Icarus 266, 331-354.

Jenniskens, P., Nénon Q., Gural P.S., Albers J., Haberman B., Johnson B., Holman, D., Morales R., Grigsby B.J., Samuels D., Johanninck C. 2016b. CAMS confirmation of previously reported meteor showers. Icarus, Vol. 266, pp. 355-370.

Jenniskens, P., Nénon, Q. 2016. CAMS verification of single-linked high-threshold D-criterion detected meteor showers. Icarus 266, 371-383.

Jenniskens, P., Nénon, Q., Gural, P. S., Albers, J., Haberman, B., Johnson, B., Morales, R., Grigsby, B. J., Samuels, D., Johanninck, C. 2016c. CAMS newly detected meteor showers and the sporadic background. Icarus 266, 384-409.

Joepk, T. J., Jenniskens, P. M. 2011. The Working Group on Meteor Showers Nomenclature: A History, Current Status and a Call for Contributions. Meteoroids: The Smallest Solar System Bodies, 7-13.

Jopek, T. J., Kaňuchová, Z. 2017. IAU Meteor Data Center - the shower database: A status report. Planetary and Space Science 143, 3-6.

Lindblad, B. A. 1987. The IAU Meteor Data Center in Lund. Publications of the Astronomical Institute of the Czechoslovak Academy of Sciences 67, 201-204.

Lindblad, B. A., Neslušan, L., Porubčan, V., Svoreň, J. 2003. IAU Meteor Database of photographic orbits – version 2003. Earth Moon and Planets 93, 249-260.

Neslušan L., Svoreň J., Porubčan V. 1995. A Procedure of Selection of Meteors from Major Streams for Determination of Mean Orbits. Earth, Moon, Planets, 68, 427-433.

Neslušan L., Svoreň J., Porubčan V. 2013. The Method of Selection of Major-Showers Meteors Revisited. Earth, Moon, Planets 110, 41-66.

Neslušan, L., Porubčan, V., Svoreň, J. 2014. IAU MDC Photographic Meteor Orbits Database: Version 2013. Earth Moon and Planets 111, 105-114.

Neslušan, L., Jenniskens P., Porubčan, V., Svoreň, J. 2016. Central Bureau Electronic Telegram No. 4255.

Porubčan, V., Svoreň, J., Neslušan, L., Schunová, E. 2011. The Updated IAU MDC Catalogue of Photographic Meteor Orbits. Proc. of the Meteoroids Conference held in Breckenridge, Colorado, USA, May 24-28, 2010, Meteoroids: The Smallest Solar System Bodies. NASA/CP–2011-216469. Cooke, W. J., Moser, D. E., Hardin, B. F., and Janches, D. (eds), 338-341.

Rendel, J. 2014. Daytime meteor showers. Proceedings of the International Meteor Conference, Giron, France, 18-21 September 2014, 93-97.

SonotaCo 2009. A meteor shower catalog based on video observations in 2007-2008. WGN, Journal of the International Meteor Organization 37, 55-62.

SonotaCo 2016. Observation error propagation on video meteor orbit determination. WGN, Journal of the International Meteor Organization 44, 42-45.