Meteor science

Analysis of the SonotaCo video meteor orbits.

Peter Vereš and Juraj Tóth
Faculty of Mathematics, Physics and Informatics, Comenius University, Mlynska Dolina, 84248 Bratislava, Slovakia.
Email: toth@fmph.uniba.sk

Since 2007 the Japanese video network provided significant amount of meteor data observed by multi station video meteor network located in Japan. The network detects meteors mostly up to +2 magnitude and is probably the most accurate and largest freely accessible video meteor database up-to-date. In this paper we present our analysis on the qualitative aspects of the meteor orbits derived from the multi station video observation and the separation of the shower meteors from the sporadic background.

1 Introduction

The SonotaCo database of the meteor orbits consists of 38710 entries. Of those, 37% were identified as shower meteors. Data were taken by 35 video meteor stations during years 2007 and 2008 in Japan [1]. The survey goal was to cover the entire year. Each database entry is equivalent to the heliocentric orbit derived from the multi station video observation. In addition to the heliocentric orbit, the meteor is identified as shower of sporadic meteor, characterized by the apparent position on the sky plane, angular velocity, magnitude and derived physical parameters, such as geocentric velocity, relative height of the meteor trail above the surface, duration of the visible trail, etc. All parameters were derived by the UFOOrbit software and orbits derived by the UFOAnalyzer software, both made by SonotaCo. The notable advantage of the database is the very similar camera setup of the network stations (e.g. lenses and CCD TV cameras) and unique tool for astrometric and velocity reduction, which almost lacks individual observer influences. This makes the database very homogenous.

2 Database reduction

In order to separate high quality orbits, we set multiple constraints on the database. The constrained parameters are presented in the parentheses. Usually we adopted quality determination according to Q3 condition for the high precision computation (internal set of parameters for UFOOrbit). The most important, the entire meteor trail had to be inside the field of view of at least two video meteor stations (inout=3). Astrometric accuracy and velocity determination drop with the observed trail length, therefore the meteor trail had to be longer than 1 degree ($Q_o > 1$) and the duration of the trail was over 0.3 seconds ($dur > 0.3$). There parameters were set with respect to the network camera setup. This provides at least 10 positions and velocity measurements per meteor trail. Also the parameter $Q_e$ (cross angle of two observed plains) had to be larger than 20 degrees. The apparent velocity and derived velocities from two stations may differ, our constrain allows the difference less than 10% ($dv12% < 10$). One trail observed from two stations must be detected to reach at least 50% overlap (Gm%) and ground projection of the same meteor observed and derived for two different stations must not have higher deviation than 0.1 degree(dGP). Finally, the total quality assessment parameter larger than 0.7 (QA).

Number of meteor orbits that fulfill quality constraints is 8890. 47% are meteors identified as shower meteors (IAU established meteor showers and showers from the IAU working list). 292 meteors are on hyperbolic orbits ($a < 0$ and $e > 1$), of those 144 are sporadic and 148 were assigned to a meteor shower (mostly Perseids, Orionids, Leonids, Dec. Monocerotids, sigma Hydrids).

Three-step algorithm of meteor shower identification by SonotaCo is following. Particular meteor must be observer during the known meteor shower activity (J6 catalog defined, [1]) plus 10 days variation. The back-traced meteor trail must lie within 100% of known meteor radiant. The geocentric velocity must be within 10% of the known mean shower geocentric velocity.

3 Shower meteors identification

Assignment of a meteor to a meteor shower is not a trivial task. In our analysis, we employed orbit similarity criteria to distinguish shower meteors from the non-shower component of the SonotaCo video meteor database. Particularly, Southworth-Hawkins D-criterion ($DSH$) was used for selected meteor showers [2]. Considering individual behavior of meteor stream orbits in comparison to the mean orbit, we calculated the distribution of D-criterion for Perseids (reference mean orbit by [3]), Orionids [3], Geminids [4], Leonids [3], sigma Hydrids [5] and Southern delta Aquarids [7]. Histogram of D-criterion of mentioned meteor showers separated from all meteors (independently from the UFOOrbit identification of meteor showers) are presented on Figure 1. The boundary D-criterion for particular shower was derived from the point where the distribution of D-criterion became eventually dispersed in the sporadic background (dashed line in the plot of Figure 1 and 2). If the meteor has a lower value of the specific D-criterion we consider it as a shower meteor. Finally, we compared how many particular shower
Table 1: Meteor showers identification according to UFOOrbit algorithm and Southworth-Hawkins D-criterion. Shower-name, $D_{SH}$-found limit for certain meteor shower identification, $All < D_{SH}$-shower meteors derived according to D-criterion from the entire subset of data (shower and non-shower), $%$-percentage of shower meteors in the shower component according to UFOOrbit that did not fulfill D-criterion, Data-number of shower meteors identified by UFOOrbit, Non-sporadic meteors according to UFOOrbit belonging to the shower according to D-criterion.

| Shower | $D_{SH}$ | $All < D_{SH}$ | $%$ Data | Data Non |
|--------|----------|----------------|----------|----------|
| PER    | 0.30     | 907            | 3.5      | 931      | 9        |
| ORI    | 0.20     | 408            | 8.8      | 416      | 29       |
| GEM    | 0.20     | 881            | 3.9      | 916      | 1        |
| LEO    | 0.20     | 90             | 15.2     | 105      | 1        |
| HYD    | 0.30     | 200            | 11.2     | 215      | 9        |
| SDA    | 0.15     | 103            | 2.0      | 104      | 1        |

meteors belong to the 8890 sample according to the method by UFOOrbit and D-criterion. According to D-criterion, some of shower meteors (by UFOOrbit classification) do not belong to the meteor shower and on the contrary, some sporadic meteors (by UFOOrbit) belong to the meteor shower but only in few cases. Results are presented in Table 1.

Although 47% of 8890 meteors are sporadic meteors according to UFOOrbit classification, our investigation on 6 meteor showers implies that the sporadic population in the database is contaminated by shower meteors in a very small number (see Table 1, column Non). To obtain a rough estimate of the sporadic meteor population, we applied Southworth-Hawkins D-criterion equal to 0.25 for 16 major showers that may have the most significant contribution to the sporadic background of the SonotaCo database. We used reference mean orbits of these meteor showers: Quadrantids, Lyrids, pi Puppids, eta Aquarids, Arietids, sigma Hydrids, June Bootids, Southern delta Aquarids, Perseids, Draconids, Orionids, Southern Taurids, Northern Taurids, Leonids, Geminids and Ursids (mean orbits from the photographic data, [5]). Radiant positions after the first separation procedure are plotted in the density graph on Figure 3. We examined the higher density of radiant on solar longitudes $265^\circ \pm 30^\circ$ ($\alpha = 75^\circ - 115^\circ$, $\delta = 10^\circ - 28^\circ$) and considered it as a contamination from the Taurid complex (the position of the clump was similar as if Taurids were active longer, meteors have similar geocentric velocities and orbits). To separate assumed Taurid complex contamination, we used Steel D-criterion equal to 0.2 for the mean orbit of the Southern and Northern Taurids [7]. This criterion is not sensitive to the argument of the perihelion and the ascending node, therefore it removes similar orbits even when the meteor was observed beyond the established activity period. Finally, the sporadic meteor count was

Figure 1: Southworth-Hawkins D-criteria for shower meteors from the reduced database. Dashed line represents the limit that we adopted to distinguish shower meteor from the sporadic background.
Figure 2: Southworth-Hawkins D-criteria for SDA. Dashed line represents the limit that we adopted to distinguish shower meteor from the sporadic background.

Figure 3: Density plots of sporadic population radiants from the reduced UFOOrbit orbit database (left) and corrected sporadic population - strong meteor shower members were separated using D-criteria.

Figure 4: Orbits of Geminids meteors derived by the UFOOrbit algorithm. Non-Geminids were identified as Geminids by UFOOrbit but did not fulfill D-criterion for orbital similarity and are apparently displaced from the standard meteor stream.

Figure 5: Earth apex corrected ecliptical coordinates of sporadic meteor radiants. Color palette scale represents geocentric velocity distribution, orbit inclination respectively.

4 Conclusion

The database of video observed meteors by SonotaCo contains meteors that are relatively well distinguished...
as shower or sporadic meteors among the high quality subset of data. For further analysis of the meteor membership to the particular shower we recommend to use additional tools for shower identification such as orbit similarity D-criteria and orbital evolution with respect to the mean reference orbit of the shower and the assumed parent body. Meteors that were misidentified as shower meteors for several examined meteor showers represent only small numbers of the shower group identified by UFOOrbit. Separated sporadic meteors demonstrated expected sky plane distribution in respect to the Earth apex with the exceptional denser region which might be a part of the wide Taurid complex. After all, the subset of video meteor orbits we selected provides reliable data for both shower and sporadic meteors.

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