Southern Horizons in Time-Domain Astronomy
Proceedings IAU Symposium No. 339, 2019
E. Griffin, ed.

doi:10.1017/S1743921318002879

Meteor Sky in Time-Domain Astronomy†

S. V. Kolomiyets

Kharkiv National University of Radio Electronics, Kharkiv, Ukraine
email: `svitlana.kolomiyets@nure.ua`

Abstract. Multi-wave astronomy provides a means for researchers to see and 'hear' the sky. But that is only part of their perception of the cosmos. The hot handshake of the Universe in the form of a meteor substance burning in the Earth's atmosphere, sometimes with the precipitation of meteorites threatening the environment, occurs every second. A major present challenge for meteor research is organizing observations and processing existing and new data in order to obtain information in the time domain of meteor astronomy for solving special problems. This poster discusses the concept of the meteor sky, and some approaches for constructing models of it. The database of meteors of Kharkiv National University of Radio Electronics was used.

Keywords. Meteor, meteoroid, meteor sky, radiant, database, orbit, radar, interstellar object

1. Introduction

Multi-wave studies in astronomy provide a means for researchers to see and 'hear' the sky. But that is only part of their perception of the cosmos. The hot handshake of the Universe in the form of a meteor substance burning in the Earth's atmosphere, sometimes with the precipitation of meteorites threatening the environment, occurs every second. At present, a major challenge for meteor research is organizing observations, and pursuing the tasks of processing both existing and new data in order to obtain information in the time domain of meteor astronomy for solving special problems. In the context of time-domain astronomy, the meteor sky will differ depending on the purposes and tasks of fundamental and applied research, as shown in Fig. 1. One of the modifications to consider in regard to the meteor sky is the distribution of radiants in the equatorial coordinate system $(\alpha, \delta)^o$, together with the value of the geocentric velocity of the meteoroid and the magnitude for the corresponding radiant. The sky coordinates of the radiant, the velocity and time of observation determine the orbit of the meteoroid.

The objectives of this research were to build meteor sky maps of both space and time for tackling fundamental and applied problems, based on archived databases of meteoroid orbits using information technology and other methods, and to develop and introduce the concept of a meteor sky.

Step 1. A sample of 159,320 sporadic orbits was selected from the meteor database of Kharkiv National University of Radio Electronics (NURE MBD). The archive contained 250,000 meteor orbits obtained from classical meteor radar (meteor automated radar system, MARS) between 1972–1978 (Kolomiyets 2012, 2018).

Step 2. Meteor parameters were selected (for example, as in Table 1), and models were built of the meteor sky.

Step 3. It was then possible to visualise the distribution of meteor orbits in a system of celestial coordinates using the 'Meteor Map' software; see Fig. 2b (Golovashchenko & Kolomiyets 2017), or STATISTICA for Figs. 2a, 2c and 2d.

---

† For the full poster, see http://dx.doi.org/10.1017/S1743921318002879

Table 1. The NURE MBD meteoroids and celestial objects, and some of their characteristics

N	Object	Epoch	δ^o	α^o	Vh, km/s	e	q, AU	a, AU	i^o	ω^o	Ω^o	**Q** AU	$R_{V,N}$ AU
1	H-Meteoroid V_g 31km/s	Apr 16 1977 09^h46^m	+67	274	42.9 for 1 AU	1.08	1.00	−13.0	46	177	26		9.1 1.2
2	H-Meteoroid V_g 69km/s	Sep 10 1978 08^h10^m	+74	19	60 for 1 AU	3.03	0.98	−0.48	96	195	167		1.0
3	H-Asteroid 1I/2017U1 'Oumuamua	Nov 2 2017	+39 +25	279 358	49.7 for 1 AU	1.199	0.26	−1.28	123	242	25		1.4 0.3
4	Meteoroid V_g 70km/s	Feb 12 1973 06^h24^m	−0.3	222	42.4 for 1 AU	0.99	0.84	527	152	222	323	1054	
5	TNO-Sedna	Jan 13 2016			1.04 506 AU	0.85	0.76	507	12	311	144	936	
6	TNO-Eris	dec 9 2014			3.4 for 68 AU	0.44	38	58	44	151	36	98	
7	Main-belt 1 Ceres	Jan 13 2014			17.9 2.68 AU	0.08	2.55	2.8	11	3	80	2.98	

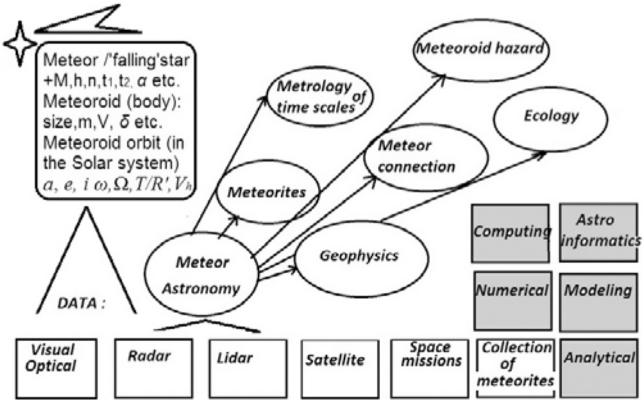

Figure 1. Illustrating the range and kind of proposals and demands for meteor information.

2. Data and results

The NURE meteor database was selected as the tool for studying the meteor sky, and also for the basis for its construction. Table 1 lists the NURE MBD meteoroids and objects in the Solar system, and some of their characteristics. It gives an idea of the possible limits ('altitudes') of the meteor sky, depending on the remoteness of an orbit's aphelion from the Sun. The illustration suggests values of the orbital parameters at which the meteor sky can be divided up according to the inclination, eccentricity and aphelion distance, or their combinations.

For objects in hyperbolic orbits (e.g., H-objects in Table 1), the radius vector (R_V or $R_N S$) of one of the nodes of the orbit was adopted in the presence of two nodes $R_{V,N}$ (V = ascending, N = descending), since there is no aphelion distance Q for an indirect estimate of the size of the orbit, or when examining the intersection of the orbit with the plane of the ecliptic (Kolomiyets & Kashcheyev 2004). One of the nodes of a meteoroid's orbit is always the point of intersection of a meteoroid with the Earth, i.e.,

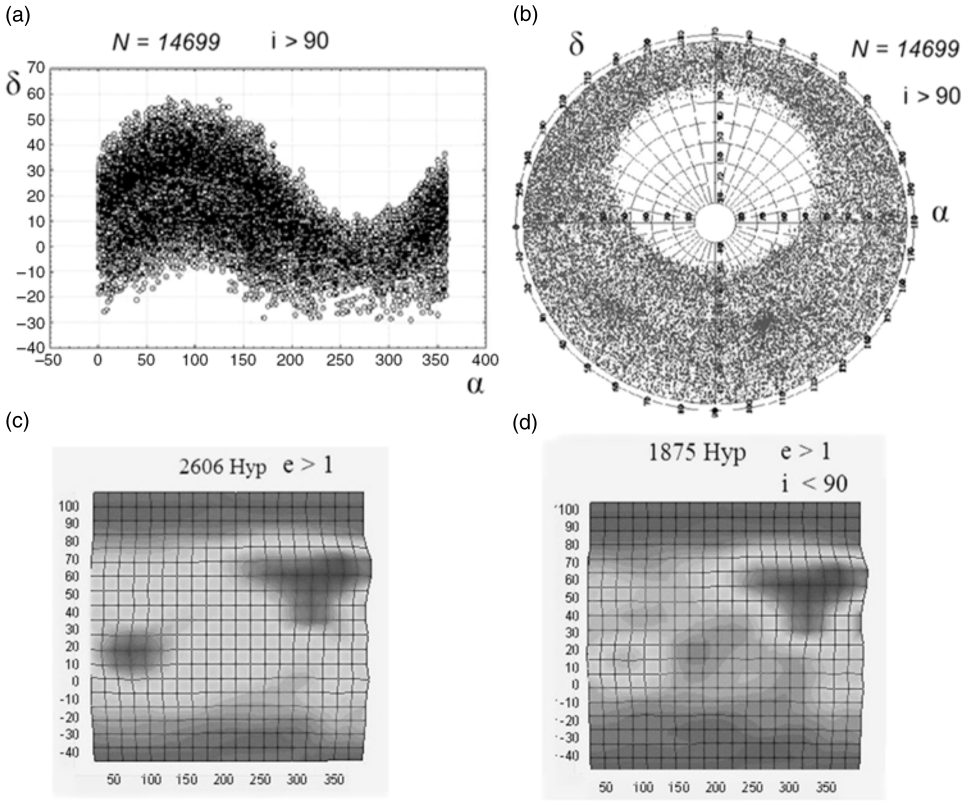

Figure 2. The meteor sky $(\alpha, \delta)^o$ of meteoroids whose orbital aphelia are located in space between the orbits of Earth and Ceres, $i > 90$ (a and b; from Golovashchenko & Kolomiyets (2017)), and for hyperbolic orbits (c: $0 < i < 180$) and d: $i < 90$.

R_V or $R_N \sim 1$ AU. To determine the direction of arrival or departure of an interstellar object in the Solar system, it is possible to use the coordinates (α, δ) of the asymptotes of the hyperbolic orbit for 'Oumuamua in Table 1. Construction of meteor maps and graphs on a plane in a non-spherical format (rectangular or square), as in Figs. 2a, 2c, and 2d, was performed using the STATISTICA programme. Fig. 2b visualises the sky using the 'Meteor Map' programme (Golovashchenko & Kolomiyets 2017), the Microsoft Visual Studio 2013 development environment.

The conditions for such research were confirmed by deriving satisfactory statistics of the meteor orbits of the NURE database: 100,341 orbits with $0.5 < e < 1.0$, i.e. 62.98% of the total number of sporadic orbits, and 102,946 orbits with $e > 0.5$ (i.e., 64.6% of all sporadic orbits). The relatively high statistics of retrograde (53,178 orbits, or 33%) and direct (106,142 orbits, or 67%) out of the total of 159,320 investigated are also favorable for the research. Fig. 2 for the meteor sky in $(\alpha, \delta)^o$ demonstrates the behavior of two meteoroid samples, one with direct and one with retrograde motion. Only the 14,699 retrograde orbits (i.e., 9.2% of the total) are presented in Fig. 2a and b. For those whose aphelia are located in space between the Earth and Ceres orbits, i.e., the main contributors to the complex of Near-Earth asteroids, the Ceres parameters are given in Table 1, line 7 (Wikipedia 2018). Direct orbits in that set include 29,751 (67% of the sample and 18.7% of the total). For the retrograde orbits, the distribution of radiants along the ecliptic is more pronounced. Of the 50,000 meteorites found on Earth to date, 99.8% are believed to have originated in the asteroid belt (Wikipedia 2018).

What about the more remote areas of the Solar system? There were 14,077 meteoroids with aphelia between 5–50 AU (8.8% of the total), including 2,263 retrograde orbits (16.1% of the sample; 1.4% of the total), and 11,814 direct orbits (83.9% of the sample; 7.4% of the total). 453 meteoroids had aphelia larger than 50 AU (0.3% of the total number), of which 118 were retrograde (26% of the sample; 0.07% of the total), and 335 were direct (74% of the sample; 0.2% of the total). It was found that the aphelia of the 159,320 meteor orbits of the NURE database investigated could reach values of 2,000 AU (Kolomiyets & Voloshchuk 2015). If so, then the meteor sky above the Earth extends to very large distances from the Sun, the order of those distances being comparable to the remoteness of the first fronts of the Oort cloud from the Sun. Yet that is not the limit of the terrestrial meteor sky. The distribution of the 2,606 radiants of both direct and retrograde hyperbolic orbits (1.6% of the total number) which may be interstellar (part of the hyperbolic orbits may be formed in the Solar system itself) was also investigated. Of those, 731 orbits (28% of the sample; 0.5% of the total) have $i > 90$. Fig. 2c shows the combined distribution (direct plus retrograde orbits) of 2,606 meteoroids. Fig. 2d shows the distribution of the radiants of 1,875 direct hyperbolic orbits (72% of the sample and 1.1% of the total). Both distributions of the hyperbolic orbits recorded on Earth (Fig. 2c, d) indicate a concentration to two regions of the meteor sky $(\alpha, \delta)^o$, one of which includes the coordinates of the apex of the Sun's motion in interstellar space ($\alpha \sim 270^o$, $\delta \sim 30^o$). The reality of recording the passage of interstellar objects through the Solar system was demonstrated by the asteroid 'Oumuamua (Meech *et al.* 2017); see Table 1.

3. Conclusion

The meteor sky is many-faceted, its parameters depending on requests received. Astronomical information is a cornerstone for answering most queries. The meteor astronomical sky itself is also many-sided. We have developed the concept of the altitude of a meteor sky as dependent upon the aphelion distance of the orbits of meteoroids. This concept was tested on observational data of a sample of 159,320 orbits in the NURE database of metors. The results showed the presence of highly elongated orbits with aphelion distances ranging from 1 to 2,000 AU (453 meteoroids of those have aphelia larger than 50 AU, i.e., 0.3% of the total), and there were also 2,606 hyperbolic orbits, i.e., 1.6% of the total. The distribution of meteoric substance contains key information about the structure and dynamics of planetary systems, and (maybe) of the Universe. The horizons of the Earth's meteor sky are part of the horizons of time-domain astronomy. These results were set in context by the first recording of an interstellar asteroid ('Oumuamua) in 2017 October, offering new modern possibilities of information and observational technologies.

Acknowledgements

This work was carried out in the framework of the state budget research of the Ministry of Education and Science of Ukraine.

References

Golovashchenko, V. A. & Kolomiyets, S. V. 2017, *Odessa Astron. Publ.*, 30, 166
Kolomiyets, S. V. 2012, *Proceedings of the 22$^{\rm nd}$ Int. Crimea Conf.*, p. 46
Kolomiyets, S. V. 2018, *P&SS*, 2018.05.015
Kolomiyets, S. V. & Kashcheyev, B. L. 2004, *Earth, Moon, and Planets*, 95, 229
Kolomiyets, S. V. & Voloshchuk, Y. I. 2015, *IAU GA*, Meeting #29
Meech, K. J. *et al.* 2017, *Nature*, 552, 378
Wikipedia, 2018, https://en.wikipedia.org/wiki/Small_Solar_System_body