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RADIANTS AND ORBITAL DISTRIBUTION OF TV FAINT SPORADIC METEORS

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ABSTRACT. Double station meteor observation using TV CCD unintensified techniques was started in 2013 in Nikolaev astronomical observatory (RI NAO). During observational campaign in 2013-2016 catalog containing 1055 meteoroid orbits has been obtained. Registered meteoroid photometric masses (Kruchinenko, 2012) are between 10^{-7} and 10^{-2} kg. Distribution of radiants, velocities and elements of heliocentric orbits with accent on meteoroids with low masses are analyzed in the work. Comparison with data from meteoroid orbit catalogs SonotaCo, EDMOND and NFC networks is also given. Two kinds of databases/catalogs are distinguished: "narrow field" and "wide field" depending on which type of camera system were used in observations. For analysis of the different catalogs only sporadic meteors were selected. Comparison of sporadic meteoroid radiants and orbital elements for different databases has shown that "narrow field" observations have next typical characteristics:

1) more relative number of low-mass meteoroids (about 30%) than large databases obtained by wide-angle observations;

2) significant increasing of number of low-velocity (V_g < 20 km/s) meteors.

Meteoroids with m < 0.01 g has some specific characteristics different for wide- and narrow-angle observations:

1) "narrow-field" databases have more orbits with e < 0.8 than "wide-field" ones;

2) aphelion distances in "narrow-field" databases are mostly less than 4.6 au but inclination for such orbits mostly more than 75°, "wide-field" databases show only retrograde with aphelion distances Q > 4.6 predominantly;

3) low-mass meteoroids in "wide-field" databases caused Apex contribution only, notable part of this objects from "narrow-field" data has radiants close to Antihelion source.

Keywords: meteors, meteoroid orbits, video observation.

АБСТРАКТ. У 2013 році в Миколаївській астрономічній обсерваторії (НДІ "МАО") розпочато базисні спостереження метеорів із застосуванням телевізійної ПЗЗ-техніки. В ході спостережної кампанії 2013-2016 рр. було отримано каталог, в якому містяться 1055 орбіт метеороїдів. Зареєстровані фотометричні маси метеороїдів (Kruchinenko, 2012) знаходяться у діапазоні 10^{-7}-10^{-2} кг. В роботі проаналізовано розподіл радіантів, швидкостей та елементів геліоцентричних орбіт з акцентом на метеорні тіла з малими масами. Також наведено порівняння з даними кталогів метеороїдних орбіт SonotaCo, EDMOND та NFC. Розрізняються два типи баз даних/каталогів: "малого поля" та "широкого поля" в залежності від того, який тип оптичної системи використовувався в спостереженнях. Для аналізу різних каталогів були відібрані лише спорадичні метеори. Порівняння спорадичних метеорних радіантів та елементів орбіт для різних баз даних показало, що спостереження "малого поля" мають наступні характерні ознаки:

1) більш відносне число маломасивних метеороїдів (близько 30%), порівняно з великими базами даних, отриманими з ширококутних спостережень;

2) істотне збільшення кількості метеорів з малою швидкістю (V_g < 20 км/с).

Метеороїди з m < 0.01 г мають деякі характерні ознаки, що відрізняються також у випадках спостережень різними оптичними системами:

1) бази даних "малого поля" мають більше орбіт з e < 0.8, ніж дані "широкого поля";

2) афелійні відстані в даних "малого поля" в основному менші за 4.6 а.о., але нахили таких орбіт більші за 75°, дані ширококутних спостережень мають лише ретроградні орбіти з афелійними відстанями, що переважно більші ніж 4.6 а.о.;

3) маломасивні метеороїди в "ширококутних" даних зумовлені лише радіантами апексної групи, помітна частина таких же метеороїдів за даними спостережень малими полями зору мають радіанти близькі до групи протисонячного джерела (Antihelion source).

Ключові слова: метеори, орбіти метеороїдів, телевізійні спостереження.

1. Introduction

Study of faint meteors caused by low mass (10^{-6}-10^{-2} g) meteoroids does a significant refinement of small bodies distribution in Solar System (Koukal et al. 2015). Most part of information about these objects came from radar observation of meteors (Voloshchuk & Kasheev, 1981; Janches et al, 2003) and satellite researches (Carillo-Sanchez et al., 2015). Another way of detecting small particles is using intensified CCD technique (Vitek et al., 2016; Ohsawa et al., 2018). Recent works (Koukal et al., 2015; Kulichenko et al., 2015, Kulichenko & Shulga, 2017) have shown that unintensified TV CCD cameras with narrow fields of view (<10°) can also be used as efficient instrument for faint meteors investigation.

2. Meteoroid orbital data from TV observations

At the end of the twentieth century, there were just a few video systems around, which were operated occasionally during major showers or exceptional events. With the availability of automated meteor detection software, not only the number of video observers steadily increased, but they also organized in observing networks to join forces in creating large meteor and meteoroid orbit databases. In this work some of the largest databases of these networks were used for comparing with results obtained in RI "MAO".

2.1. "Wide field" catalogs

The largest databases obtained by both amateur and professional video meteor networks are SonotaCo (Japan) and EDMOND (Europe).

SonotaCo started operation in August 2004 and by January 2008 had grown to 31 stations with more than 130 cameras (Rentdel & Arlt, 2017). These cameras are almost exclusively non-intensified monochrome video cameras with fields of view between 30° and 90° (f=(3.8-12) mm, f/0.8). Software for meteor detecting, processing and meteoroid orbit calculation is calling UFO Tool Suite developed by SonotaCo group. The orbital data are published every year on website (http://sonotaco.jp/doc/SNM/index.html). By the end of 2017 more than 220 000 orbits were obtained by the network.

EDMOND (European viDeo MeteOr Network Database) is a database of orbits based and computed from video meteor data – observed and analysed with UFO and other (e.g. MetRec) software. It is not another camera network but it is a result of cooperation of several European networks including IMO and national observing groups from 14 countries (Rentdel & Arlt 2017). Fields of view of used cameras are between (40-90)°. UFO Orbit is main software for computation meteoroid orbits. Database contains more than 322 000 orbits for 2001-2016 and stored on website MeteorNews (https://www.meteornews.net).

2.2. "Narrow field" catalogs

NFC (Narrow Field Camera) network was created in 2014 on the base of CEMeNt (Central European MEteor NeTwork) and uses cameras with fields of view 5.4°×6.8° (f=50 mm, f/1.0). Such system allows detecting fainter meteors than in networks described above. Software for observation and calculating orbits is UFO Tools (Koukal et al. 2015). Database stored on MeteorNews website contains 1234 meteoroid orbits.

In 2013-2016 in Research Institute "Mykolaiv astronomical observatory" 1055 meteoroid orbits were obtained by double station observation. Cameras have fields of view less than 5° (4 lens: f=85 mm, f/1.8, 2 lens: f=100 mm, f/2.0). Observational system, method and results described in works Kulichenko et al. (2015), Kulichenko & Shulga (2017). For more strict comparison catalog of orbital data was calculated in format of UFO Tools software.

3. Analysis

To estimate the contribution of faint meteors in all databases the simplified model of meteoroid photometric mass m_0 (Kruchinenko, 2012) was used:

$$m_0 = \frac{1.62 \cdot 10^5 \cdot 2.512^{-M}}{V_0^4 \cdot \cos(z_R)},$$

whereas M – absolute magnitude of meteor, V_0 – preatmospheric geocentric velocity, km/s, z_R – zenithal distance of meteor radiant, radians. This parameter was used rather in statistical sense than as real meteoroid mass value. On Fig. 1, meteoroid photometric mass distributions are shown for all described databases. Catalogs based on narrow field observations show shifts of their distributions maxima towards the lower masses. Relative contribution of faint meteors in these catalogs is about 30% (Table 1).

For further analysis of the catalogs only sporadic meteors were selected. Due to low population index of shower meteors (Rentdel & Arlt, 2017) their contribution to narrow field observations cannot be compared with large catalogs. Percentage of sporadic meteors is given in the table 1.

Also group of sporadic meteoroids with photometric masses < 0.01 g were analyzed.

On Fig. 2 (a, b) solar elongation and geocentric velocity distributions of sporadic meteors for all databases are shown. Comparing with large catalogs "narrow-field" catalogs have more meteors with V_g < 20 km/s which is one of the advantages of narrow-field camera systems (Koseki, 2018). This fact can be explain rather by observational conditions than by low-mass meteoroids contribution (Fig. 2, c, d). One more typical maximum with V_g = 65 is so called Apex contribution km/s or meteors which observed in early morning observations when observer is located in the front of the Earth with respect to the Earth's direction of movement (Drolshagen et al., 2014; Kulichenko & Shulga, 2017).

Solar elongation and geocentric velocity distributions of sporadic meteors with m < 0.01 g (Fig.2, c, d) show that low mass component of sporadic background in EDMOND and SonotaCo databeses entirely caused by Apex

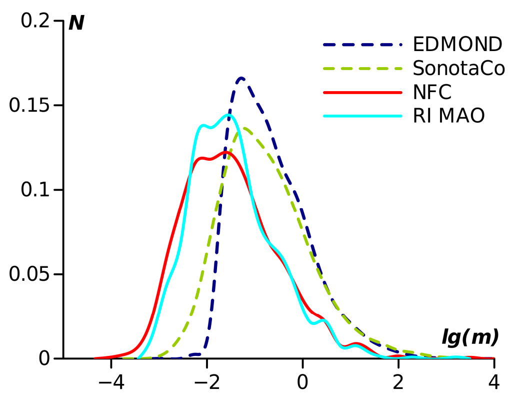

Figure 1: Meteoroid photometric mass distribution standardized by the total number of meteors (see table 1).

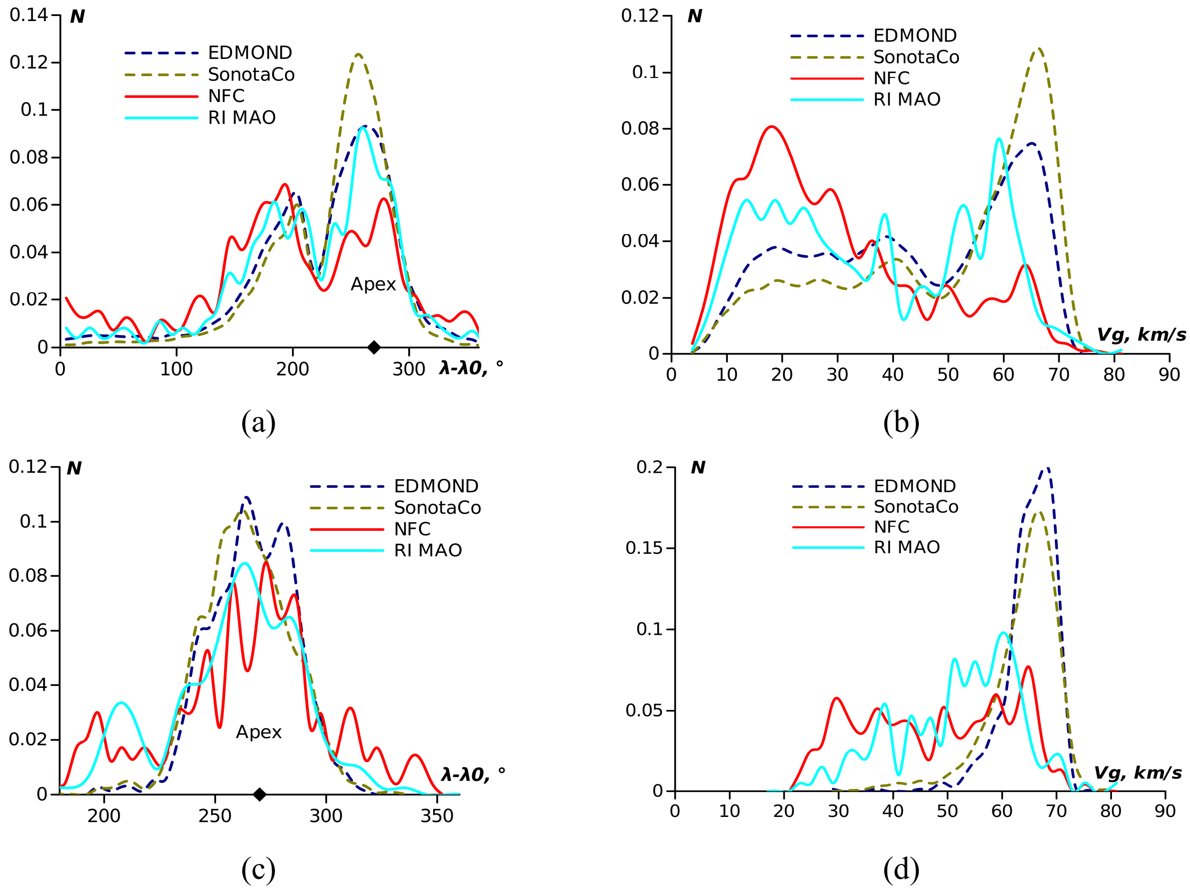

Figure 2: Solar elongation (a, c) and velocity (b, d) distributions of sporadic meteors (a, b) and sporadic meteors with m < 0.01 g (c, d)

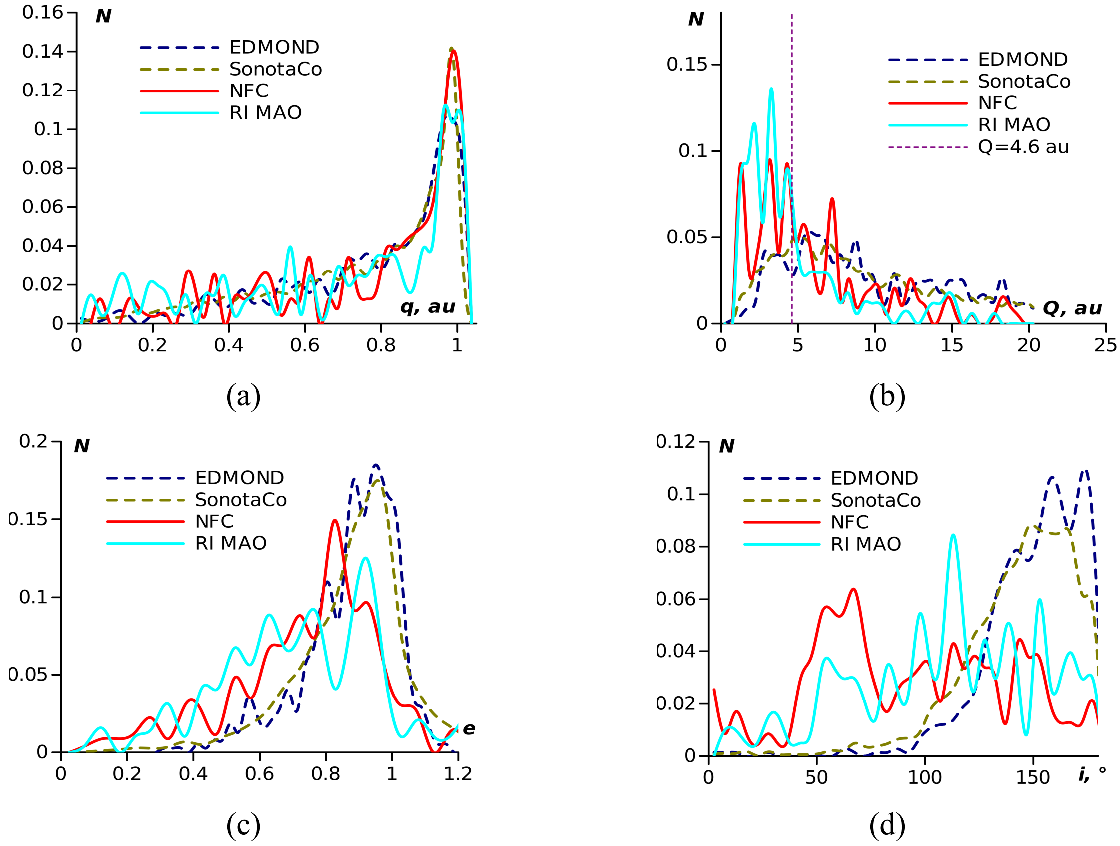

Figure 3: Perihelion distance (a), aphelion distance (b), eccentricity (c) and inclination (d) distributions for sporadic meteors with m < 0.01 g (c, d)

Table 1: Databases of meteoroid orbits obtained from video observations

Network	SonotaCo	EDMOND	NFC	RI “MAO”
Countries participants	Japan	Western and Central Europe	Czech Republic, Slovakia	Ukraine
Number of cameras (stations)	>130 (30)	(155)	6 (6)	6 (2)
Camera systems (lens focal length and aperture, field of view)	3.8–12 mm; f/0.8; 30º–90º	3–8 mm; f/0.8–f/1.4; 40º–90º	50 mm; f/1.0; 6.8°x5.4°	85-mm, 100-mm; f/1.8, f/2.0; 3.2°x4.2°, 2.7°x3.6°
Number of orbits 2013-2016	89465	209702	1244	1055
Meteoroid minimal mass, g	~ 10^{-2}	~ 10^{-2}	~ 10^{-4}	~ 10^{-4}
Average absolute magnitude	-0.8	-1.2	3.0	1.9
Limiting absolute magnitude	3.0	1.7	6.2	5.4
Number of sporadic orbits	54673 (61.1%)	97810 (46.6%)	824 (65.5%)	737 (69.9%)
Number of orbits with m < 0.01 g	5130 (7%)	750 (1%)	236 (34%)	203 (30%)
Sporadic orbits with Q < 4.6 au	21791 (24%)	40581 (19%)	557 (44%)	568 (54%)
Sporadic orbits with Q < 4.6 au and i < 75°	11770 (13%)	26529 (13%)	473 (38%)	349 (33%)
Sporadic orbits with Q<4.6 au and m < 0.01 g	1696 (1.9%)	210 (0.1%)	117 (9.3%)	138 (13.1%)
Sporadic orbits with Q < 4.6 au and i < 75° and m < 0.01 g	34 (0.04%)	7 (0.003%)	53 (4.2%)	27 (2.5%)

contribution. In NFC and RI MAO databases most part of low mass meteoroids belongs to Apex group but also there are meteoroids close to Antihelion source of sporadic meteors (λ-λ_0 = 180°).

Potential parents of low mass meteoroids can be searched by comparison of the distributions of the orbital elements of low mass sporadic meteors with distributions of NEA, short and long periodic comets (Jaksova et al., 2015). On Fig. 3 some of the orbital elements distributions for low mass meteoroids are shown. Comparing different databases it is clear that meteoroids from narrow-field catalogs have more relative numbers of low-eccentricity orbits (e < 0.8) which is typical for NEA and short periodic comets. Q-critetion of C-A (cometary or asteroid type of orbit) classification (Williams & Jopek, 2013) (Fig. 3, b) shows that catalogs NFC and RI MAO contain about 50% meteoroids with asteroid orbits but if the orbits with i > 75° are omitted it is clear that vast majority of meteoroids (Table 1) has cometary origin. As Williams & Jopek (2013) supposed such large influx of pseudo-asteroid orbits can be caused by Poynting-Robertson drag which decrease aphelion distances of comet type orbits especially for low-mass bodies.

4. Conclusion

Comparison of sporadic meteoroid radiants and orbital elements for different databases has shown that “narrow field” observations have next typical characteristics:

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Low-mass meteoroids research needs more observational data and narrow-angle cameras are efficient and relatively low-cost instrument for obtaining these kind of observations.

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