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Meteor Databases in Astronomy

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Abstract. There are specific problems of databases in meteor science such as making meteor databases into the modern research tools. Special institutes and virtual observatories exist for the meteor data storage where the data is online and in open access. However, there are also numerous databases without the open access, such as for example, three radar databases: Kharkiv database with 250,000 meteor orbits in Ukraine, New Zealand database with 500,000 meteor orbits, and Canadian database with more than 3 million meteor orbits. One of the reasons the open access is absent for these databases could be the complexity in the copyright compliance. In the framework of the creation of the modern effective research tool in the meteor science, we discuss here the case of the Kharkiv meteor database.

Keywords. Meteors, databases, orbits, astronomy, radars.

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1. Introduction

The purpose of this article is to show the scope, progress and challenges of the global meteor resource in astronomy. Meteor astronomy tasks are inseparable from the Earth's environmental well-being. A known threat to the environment of the Earth by asteroids and comets is called the asteroid-comet hazard. Meteors (meteoroids) and meteorites are associated with asteroids and comets that could be the parent bodies of invading meteoroids, or belong to the ensemble of their general movement. The integral influx of meteoric matter on the Earth can be represented (Kruchinenko, 2012) as

$$\lg N_R = 7.86 - 0.892 \lg m$$

Where N_R the influx of bodies with mass m per year for the entire Earth in the mass range of 10^{-18} - 10^{22} g. The daily influx of meteoric matter on Earth, according to different estimates, is up to 20-500 tons per day. The amount of meteorites influx is about 800 meteorites per year, and the deposition of objects such as Tunguska Event is 1 in 1,300 years. The daily top estimate of the number of celestial bodies with masses under 0.01 g, burning in the upper atmosphere over the whole Earth, is given as 200 million events. Each method of observation and the recording equipment have their own individual statistics. Canadian Meteor Orbit Radar (CMOR) every day registers about 2,500 meteors meteor orbits for up to 8th magnitude (Brown *et al.*, 2004). Kharkiv highly sensitive radar MARS (Meteor Automatic Radar System) estimates the intensity of the observed meteor stream at 3-4 thousand reflections per hour, registering meteors of up to 12th magnitude with the narrow directional antenna (Kashcheyev *et al.*, 1967). The average daily volume of information for meteor radar complexes of the Kharkiv type comprises about 400 sporadic orbits, and 30,000 registrations (Fedynsky *et al.* 1976). Meteors have an interdisciplinary nature, and they can be studied in many aspects. In terms of the asteroid-comet hazard, the need arises for interaction (and connection)

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between the databases of meteoroid orbits and similar databases of other minor bodies in the Solar System. Registration of meteoroids in the Earth's atmosphere is a one-time event, therefore both the nature of the meteor phenomena and the calculated orbits are considered probabilistic. The increase in the flow of the new information and new data does not remove the value of the existing accumulated data. There is an acute problem of processing and analysis of that data for specific purposes. We focus here on the analysis of selected databases in meteor astronomy.

2. History of meteor research and the Meteor Data Centre (MDC)

Due to the international program "Geophysical Year" (IGY1957), a lot of new effective technologies and necessary structures were implemented in the research and in the organization of research. In particular, the World Data Centres were established, the first artificial Earth satellite was launched, and the radar techniques were introduced in meteor studies. The IGY1957 program had its roots in the geophysical studies. At the same time, it became the first program of joint astronomical and geophysical research. For a meteor research this duet was organic because a meteor manifests its geophysical nature as a phenomenon in the Earth's atmosphere, and its astronomical nature as a cosmic particle with its own orbit. A particular property of the meteoric phenomena as ionized meteor trail to reflect radio waves made it possible to use radio methods to study meteors, and on the other hand, to use this property for the meteor radio connection, and for the time and frequency metrology. The IGY1957 program raised several questions (challenges still facing modern astroinformatics) on unification, storage, sharing of data, etc. It has given an impetus to the development of tools and methods of processing the geophysical and astronomical data, including arrays of large volumes of data and automation of measurement. The meteor research under the IGY1957 program was guided by the Commission 22 of the International Astronomical Union (IAU). Subsequently, under the patronage of the Commission's IAU 22 (now Division F Commission F1: Meteors, Meteorites and Interplanetary Dust) the IAU MDC was created and is now operational. The IAU MDC acts as a central depository for meteor orbits obtained by photographic, video, radar, or other methods. Since 2016 version of the online site is still in the process of development, it does not yet display all the planned data. A lot of attention is dedicated to the database associated with meteor showers (Jopek & Jenniskens, 2011). A detailed documentation of photographic and video (CAMS) orbits is designed and is available online on that site, e.g. (Neslusan, Porubchan & Svoren, 2014), (Jenniskens, 2011), where CAMS – Cameras for All-sky Meteor Surveillance in USA and beyond. IAU MDC website (Kanuchova & Jopek, 2016) contains the chain of relations which almost completely reflects the trends and content of the modern meteor resource, particularly, own database: list of all showers −701; MDC orbital database (4,873 photographic and 110,521 video (CAMS) meteors). The IAU MDC site connects also with: Virtual Meteor Observatory (VMO); The Canadian Meteor Orbit Radar (CMOR); International Meteor Organization (IMO); IMO VMDB (Visual Meteor Database) - 4,000,000 meteors; EDMOND (The European viDeo MeteOr Network Database) – 83,369 orbits; SonotaCo Meteor Data Sets –227,579 orbits; Near Earth Objects Dynamic Site (NEODyS); Asteroids Dynamic Site (ASTDYS); Meteorite orbits info; All Sky Fireball Network; IAU Minor Planet Center. Still, some meteor resources are not reflected in the IAU MDC. Among these resources is the meteor network in France – FRIPON (Fireball Recovery and Inter Planetary Observation network; https://www.fripon.org). Also not included in the IAU MDC database are meteoroids registrations performed from space vehicles.

Table 1. Some meteor databases in Kharkiv, Ukraine (Kolomiyets & Voloshchuk, 2013).

Type	Period	N Orbits	Notes	Type(cont)	Period	N	Notes
Total	1959-60	12,500	8^m	Total	1972-78	250,000	12^m
Sporadic	1959	360	8^m	Sample	1975	5,317	12^m
Geminids	1959	298	8^m	Sample	1976	4,000	12^m
195 showers	1959-60	3,500	8^m/Math	Sporadic	1972-78	160,000	12^m
Total	1968-70	4,242	$8^m/2^0$N 45^0E	5160 showers	1972-78	100,000	12^m/Math
Total	1970	1,088	$8^m/2^0$N 45^0E	Eta Aquariids	1986	41	12^m
Total	1968-70	90,000	12^m	Orionids	1985-86	19	12^m

3. Large-volume radar data MARS, AMOR, CMOR

Although the IAU MDC site has a link to the existing radar UWO CMOR, where the total number of meteor orbits registered since 2002 already exceeds 3,000,000 units, the database of these orbits is not publicly available. Large-volume radar databases from the past years of the XX century, such as MARS (Meteor Automatic Radar System) in Ukraine – 250,000 orbits from 70s (Kashcheyev & Tkachuk, 1980), and AMOR (Advanced Meteor Radar), New Zealand – 500,000 orbits in 90s (Baggaley *et al.*, 2001), are also not posted on the internet. The absence of these databases may be due to the difficulty of publishing such a large number of orbits, with the result that the open access may violate someone's copyrights. No open access still exists for the observations from the latest radars, such as MAARSY (Middle Atmosphere Alomar Radar System) and SAAMER (Southern Argentina Agile Meteor Radar), which are used for current geophysical and astronomical meteor research. In Table 1, we show the statistics of the MARS database.

4. Discussion

Meteor databases are divided by the observational methods (visual, optical, radar, in situ, etc.), by the parameters that are either fixed or calculated (number, orbit), by the areas of study (astronomy, geophysics, communication, etc.), and by the types of studied problems (applied, or fundamental). The databases are also separated for sporadic and stream meteors. A specific feature of the meteor research is the presence of a significant number of amateur observations, the role of which in our days is gaining more and more importance. Such situation has a positive side, e.g. in the search for fallen meteorites based on a large number of amateur observations (organized by some meteor networks: CAMS in USA, EDMOND in Europe, FRIPON in France, etc.). There is also a problematic side of the issue, such as the implementation of amateur observations in the professional tools for building a model of distribution of meteor substance in the Solar System and modelling the influx of meteor matter in the Earth's atmosphere, or the development of meteoroid environment model from the point of view of space flight safety. However, in some cases, the amateur observations are very successful, for example, the Japanese SonotaCo (SonotaCo, 2009). In that framework, the software packages were made which are now used by both amateurs and professionals, e.g. UFOAnalyzerV2, UFOOrbitV2, etc. (available at http://sonotaco.com/soft/). We would like to mention the important international organizational structures, such as the IAU Commission F1 (with the IAU MDC), and IMO (with a virtual meteor observatory, VMO, as its node), ESA and NASA organizations, whose virtual space is open for cooperation with everyone. At the same time, the meteor databases of the IAU MDC, IMO and others are not yet incorporated into the modern powerful official structure of the International Virtual Observatory Alliance for astronomical research (IVOA). VMO IMO, however, already applies IVOA standards in their developments. But in the IVOA structure there is no section on meteor research, neither at international nor at the local level. For example, there is no section of meteor studies in the UVO (Ukrainian Virtual Observatory). There are several meteor centres in Ukraine, e.g. in Kiev, Odessa (optical observations), that also do not have meteor database online. In Ukraine, there is another structure for storing data. It is the World Data Center (WDC) for Geoinformatics and Sustainable Development, shortly, WDC-Ukraine. The WDC-Ukraine meteor division hasn't own meteor databases. There are links with IMO and Odessa meteor group. Moving new and archival data to the virtual space is a vital task of meteor researchers from post-Soviet space. All meteor centres in the Soviet Union were participants in large international projects starting from 1957 and almost till 90s, and have accumulated considerable resources. One centre can be distinguished here — the Ukrainian Centre of meteor radar studies in Kharkiv, which since 1971 is based in Kharkiv National University of Radio Electronics (KhNURE). In 60 years, the centre in Kharkiv has accumulated a significant amount of observations and results, in particular, there is an unpublished database of 250, 000 orbits of meteoroids in the mass range 0.001–0.000001 g, and a published database of 5160 meteor showers and associations (not adapted to the IAU MDC standard), as well as a large amount of data on film, and a significant developments in the interpretation of observations.

5. Conclusions

We remark here on the high level of the IAU MDC, IMO, and some other meteor resources, and stress the need for further development and promotion of meteor databases, in particular radar, into the virtual space up to IVOA level. We would like to mention that, with appropriate funding, Kharkiv National University of Radio Electronics can accept the job of preparing the online release of the data stored in the Radio Astronomy laboratory of KhNURE, and create a Ukrainian virtual meteor observatory.

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