THE OPTICAL OBSERVATIONS OF METEOROIDS IN NEAR--EARTH SPACE

M.A. Smirnov, S.I.Barabanov

Institute for Astronomy, Academy of Sciences,
Pyatnitskaya st. 48, Moscow, 109017, Russia

ABSTRACT

Investigation of near Earth meteoroid particles outside the Eart's attmosphere is presented. When the dimensions of these objects are about a few meters or more, they can be observed by optical means in the distance up to one million kilometres. The idea about possibility to discover meteoroids with sizes from few metres to decametres in meteor streams by observations in the direction towards the true or apparent radiant of the stream was suggested .

Such observations were made since August 1995 of objects near the radiant of the Perseid, Geminid and Capricornid streams. Observations were made at Simeiz observatory with 1--m telescope and CCD camera and using 60-cm telescopes and CCD camera at Zvenigorod and at Zelenchuk.

The magnitude of detected objects is 13 -- 20 that correspond to diameter of objects 3-50 meters (with albedo 0.1). It seems that such objects can be detected in other meteor and fireball streams.

INTRODUCTION

The Institute for Astronomy of the Russian Academy of Sciences is accomplishing the activities in the field of Space Debris problems. The INASAN activities include the observations of GEO objects as well as natural objects in near-Earth space. These include position and photometric observations, orbit parameters determination, reconstruction of shapes and orbit evolution due to the radiation pressure which is also obtained from these observations. Moreover, investigations of space debris, optimisation of the observations, development of new methods, technique and devices are going on.

The Institute for Astronomy of the Russian Academy of Sciences (INASAN) performs three types of GEO objects observations: photographic observations using VAU camera have been performed since 1975 covering a region from 10W to 80E of the geostationary ring. Objects with a 15 magnitude are observed with a one minute exposure. Up to 40 objects are detected from each photo (5°x30°). The purpose of VAU GEO survey observations is to catalogue a non-active GEO objects i.e. space debris. In order to update the object's orbit parameters it is sufficient to observe them once or twice per year. Regular photometric observations are performed to obtain the object's field of scattered radiation which enables to determine object's structure details. Observations are performed with 1-meter telescope at Simeiz. They allow to obtain position and photometric observations of the selected geosynchronous object simultaneously. The limiting magnitude is 21. The accuracy of astrometric position determination is 1"-2" , the accuracy of brightness determination is 0.1 magnitude.

NATURAL NEAR-EARTH OBJECTS

Recently it became clear that the problem of "artificial space debris" has to be studied in tight connection with the problem of "natural space debris", the last term corresponding to small bodies in the Solar system that can approach Earth, enter into its atmosphere, and even fall onto its surface. It was widely believed that the primary source of danger of collisions on the LEO are artificial objects. The flux density of artificial and natural particles has usually been estimated for particles with size of the order of several millimetres. However, the flux of natural particles varies strongly during the year. On GEO the natural particle flux dominates the artificial. Thus, on LEO danger of collision is caused by both artificial and natural particles. Besides, in periods of activity of strong meteor streams natural particles prevail over the artificial.

The velocity of meteoroid particles is much greater then that of artificial particles. That is why, even a small particle can make a hole in a satellite. Meteoroid particles may become dangerous for spacecraft with the impact energy of about 2.2 kJ. For sporadic meteoroids (continous during the year) it correspons to the particle's mass greater then $3 \cdot 10^{-4}$ g, and for comet-type meteor streams - to the mass about 10^{-3} g.

The flux of such particles is about $4 \cdot 10^{-4}$ [m^{-2} y^{-1} (2π sterad)$^{-1}$]. In meteor streams (in periods of activity) the flux may exceed 10^{-3} . But smooth over a year it is approximately the same, that for sporadic meteoroids - (2-4)$\cdot 10^{-4}$. For more then 500 satellites in GEO with surface about 10 m^2 almost every two years one impact of a meteoroid may occur.

Our investigations in INASAN of orbital element behaviour for more than 100 passive objects in GEO show, that nineteen of them have distinct variations of semi-major axes (Ref. 1). Assuming average surface of each object 10 m^2 and time interval about 14 years we calculate a probable amount of impacts. Such events may occur about 10. This number agree with the number of semi-major axes' variations observed. It seems that small meteoroid impacts may cause flow of gas or even explosion of remaining fuel.

This raises interest to the observation of meteor stream particles. The most well known objects of the solar system in the vicinity of the Earth's orbit are meteoroids. Meteoroids are usually investigated by method of meteor astronomy when observed the impact of meteoroid in the Earth's atmosphere. Such impacts occur both: randomly and in showers. Meteor showers are produced by meteoroid streams which are a cluster of small objects in almost the same orbit produced by the disintegration of larger bodies. It seems that meteoroid streams have complex structures and include different objects: small meteoroids, ordinary meteoroids, fireballs, larger bodies including those that produce meteorites, asteroids and comets (Ref. 2).

Among faint meteors the fraction of that in streams is about 28% (Ref. 3). For larger bodies, that produce visual and photographic meteors the fraction of stream particles increase to 47%-56% (Ref. 4, 5) and for fireball constitutes 68% (Ref. 2). It is possible to suppose, that among larger bodies with dimensions meters and tens of meters the fraction in streams would be greater.

Investigations of near earth solar system objects show that they have continuos distribution in size (Ref. 6). Particles in meteor streams have size distributions that differs significantly from a sporadic particles' distribution.

When the dimensions of these objects are about a few meters or more, they can be observed by optical means in the distance up to one million kilometres like the space debris. INASAN carried out the experimental observations in order to detect the large objects in the most intensive meteor streams (Fig. 1), using the same methods and facilities as for the space debris observations. In 1994 we suggested the idea about possibility to discover by observations meteoroids with sizes from few metres to decametres in meteor streams observations in the direction towards the true or apparent radiant of the stream outside the Earth's atmosphere (Ref. 7).

Such observations were made since August 1995 of objects near the radiant of the Perseid, Geminid and Capricornid streams. Observations were made in August 1995 in Perseids at Simeiz observatory with 1-m telescope + CCD camera (4 objects detected (Ref. 7)), December 1995 in Geminids at Zvenigorod observatory with 60-cm telescope + CCD camera (1 object detected) and August 1996 in Perseids and Capricornids at Simeiz (3 objects in Perseids, 1 - in Capricornids) and at Zelenchuk in Perseids with 60-cm telescope + CCD camera (1 object detected).

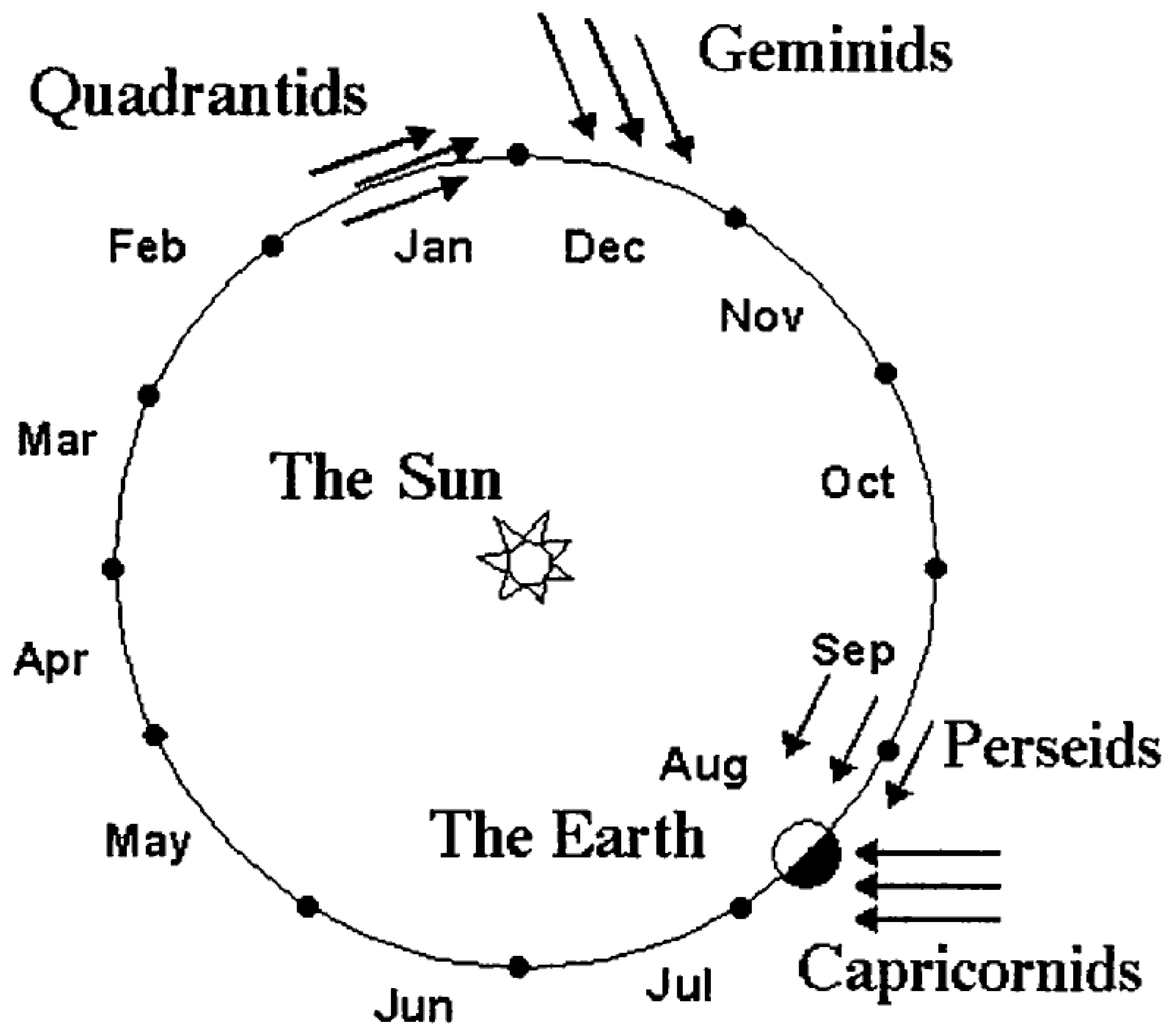

Figure 1. The main meteor streams.

The magnitude of detected objects is 13-20 that correspond to diameter of objects 3-50 meters (with albedo 0.1). The distance of objects were from 170 thousands km up to 5 millions km. On Fig. 2 are shown well known meteor flux/mass distribution for Perseid meteor stream, also our observations are shown.

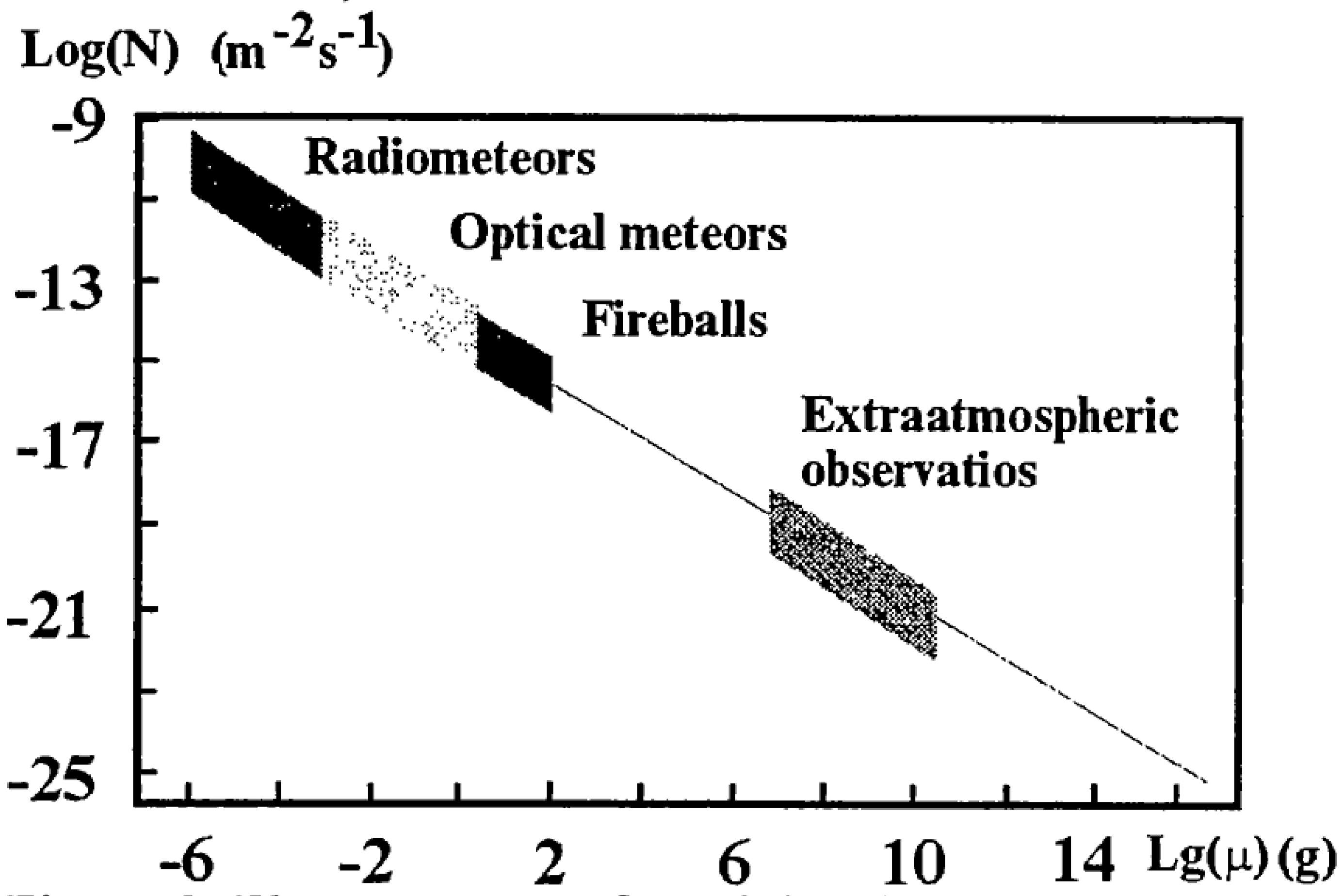

Figure 2. Flux vs. mass of particles distribution of Perseid meteor stream.

Observations were made with 1-m telescope at Simeiz observatory with reduced focus (equivalent focal length - 5.4 m) using CCD camera of 375x242 dimension. With red glass filter and exposure time 120 seconds limiting magnitude was 21. The field of view was 5x6 arc minutes without scanning. The direction of observation was chosen near the radiant by special calculations. These calculations provide areas of maximum flux density of detectable particles with our observational equipment.

We carried out multiple observations. The images of objects obtained on more then two consecutive exposures were used to select them from noise. For each object in Perseid meteor stream we obtained 2, 4, 5 and 15 frames (pictures) accordingly. The image of meteoroid is a line of 3-10 pixels length.

It seems that such objects can be detected in other meteor and fireball streams. Observations of objects in meteor streams will be continued. In this connection the next prognosed return of the very intense Leonides stream in 1998-99 gives us a good chance.

This work is supported by the Russian Foundation for Basic Research (pr. no. 96-02-19113).

REFERENCES

1. Rykhlova L.V., Kasimenko T.V., Mikisha A.M., Smirnov M.A. Explosions on the geostationary orbit, *Advances in Space Research*, Vol. 17, 1996.
2. Terentjeva A.K. Fireball streams, *Asteroids, Comets, Meteors III*, Editors Lagerkvist C.I. *et al.*, Uppsala, 579-584, 1990.
3. Kashcheyev B.L., Lebedinets V.N., Lagutin M.F. *Meteoric phenomena in the Earth's atmosphere*, Editor S.M.Poloskov, Nauka, Moscow, 1967.
4. Terentjeva A.K. Minor meteor streams, *Meteor Investigations*, No. 1, 62-132, 1966.
5. Lindblad B.A. A Stream Search Among 865 Precise Photographic Meteor Orbits, *Smitsonian Contributions to Astrophysics*, No. 12, 1-24, 1971.
6. Rabinowitz D.L., The Size Distribution of the Earth-Approaching Asteroids, *Astrophysical Journal*, Vol. 407, 412-420, 1993.
7. Barabanov S.I., Bolgova G.T., Mikisha A.M., Smirnov M.A., Detecting Large Bodies in Meteor Streams Outside the Earth's Atmosphere, *Astronomy Letters*, Vol. 22, No. 6, 847-850, 1996.