EXPLOSIONS IN NEAR-EARTH ORBITS AND THEIR RELATION WITH SOLAR ACTIVITY AND WITH METEOR STREAMS

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ABSTRACT

A comparison analysis of explosions in near-Earth orbits with solar activity was performed. It was shown that maximum of explosions correlate with minima and maxima of the 11-years cycles. This may be due to interaction of corpuscular radiation from the Sun with spacecraft. Seasonal variations of the rate of explosions correlate with seasonal variations of meteor streams. In GEO rate of explosions correlate with periods of shadowing. Obtained dependencies of explosion rates from solar activity can be explained by electric effects on satellites surfaces and interior. It is possible that a meteoroids collision with a spaceship inspires a three-dimensional electric charge that burns parts of the spaceship surface and sets on fire the remaining fuel.

1. INTRODUCTION

An important source causing constipation of the surrounding space is explosions in orbits. They create hundreds of observable fragments and an enormous number of small particles forming “clouds” in orbits. Artificial satellites were put into different near-Earth orbits. A majority of them are located in three intervals of orbits height: LEO (Low Earth Orbit) - with altitude less then 5000 km, High orbits (including Semisynchronous Earth Orbit and GEO transfer orbit) - with altitude 10000 - 40000 km and GEO (Geosynchronous Earth Orbit) with altitude about 36000 km. On LEO orbits space debris with size as small as 10 cm are tracked with modern radars. Many explosions producing debris were detected.

The main sources of debris causing constipation of the surrounding space are explosions of upper stages of rockets and artificial satellites. Explosions create hundreds of observable fragments and an enormous number of small particles forming "clouds" in orbits. LEO orbits are purified from space debris by the Earth's atmosphere. The influence of the atmosphere on the decrease of debris population in LEO was studied in many papers (see for example [1].

In [1] it was shown that the number of fragments on LEO is sufficiently decreasing after each solar maximum. But the increase of fragments is not compensated by their decrease due to atmosphere, a growth of fragments take place. On high orbits with large eccentricity tracking is also made with radars. Atmospheric drag results in lowing the altitude of the orbit.

In contrast to LEO, where mainly radars achieve tracking, in GEO the main tracking devices are optical instruments. Observations are carried out in several countries (USA, Russia, Europe, Japan) using telescopes with 0.5 - 1.5 m aperture. Currently objects in GEO of size less than 0.5 m are not included in the catalogue. It seems that this is the reason for very few explosions on GEO were reported. The nature of artificial objects on GEO is the same as on LEO and one can expect that real number of explosions on GEO is much larger then reported.

There are another incidents except explosions that happen with satellites and rocket bodies in space. Some unoperated objects suddenly change its orbit. In 1995 we studied such events in GEO and obtain 15 objects that change its orbit [2]. Late we enlarge the number of obtained events to 19 [3]. Precise orbit calculation by Sochilina et al [4] provide more then 40 events of sudden change of orbital elements of GEO objects: both satellites and rocket bodies.

A certain irregularity was found by comparing the number of explosions at the beginning (1961) and at the end (1998) of the discussed period. This can be explained by the spontaneous increase of the number of objects remaining in orbit and by continuous influence of the environment. Very complicated physical-chemical processes in the atmosphere are connected with mutual interaction of neutral and ionized particles in the geomagnetic field. It is reasonable to assume that an artificial body moving in such an environment will be drawn into these processes. Explosions may even occur after some time by objects that seem "quite safe" from the technologic point of view.

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2. OBSERVATIONAL DATA AND TIME ANALYSIS

We have considered explosions at all heights from 150 km to the height of GEO. In [5] the information about 157 explosions in orbits is collected. These explosions occurred during 37 years from 1961 to 1998. All explosions were classified by nature into 6 types. 53 explosions referred as deliberate (d), 49 as propulsion (p), 41 as unknown (u), 9 as battery (B), 4 as aerodynamics (A) and 1 as collision (C). We excluded from our consideration explosions that occur due to collision and aerodynamics. The remaining 152 explosions are unevenly distributed along years.

In addition to explosions we take into consideration evens of sudden changes of orbital elements. In [4] there are reported 46 satellites and upper stages of rockets on GEO that suffer such events from 1991 to 1996. Some of these objects suffered not single change of orbital elements. For our study we take into account the first change of orbits.

We tried to determine main natural sources of events happened with satellites. They are: meteor flux, solar activity, geomagnetic activity, cosmic ray variations, upper atmosphere variations, shadowing conditions. All these sources have their own time scales of variations.

Explosions of space objects occur after different time after the launch: from few minutes to 30 years. We denote this time as "event period" (t). We divide all events in 4 groups:

- explosions of the first group of objects occur with $t < 1$ day (instant events);
- explosions of the second group of objects occur with $1 < t < 40$ days (short time events);
- explosions of the third group of objects occur with $40 < t < 1500$ days (medial time events);
- explosions of the fourth group of objects occur with $t > 1500$ days (long time events).

Events obtained by change of orbital parameters are related to medial and long time events.

We studied the distribution of the number of explosions vs. event period for all groups except instant events. This distribution proved to be a Poisson type with different parameters (t_0) for different groups of events.

$$N(t) = A\, t \exp(-t/t_o), \qquad (1)$$

The values of (t_0) are presented in Table 1.

For "u" type explosions we obtain that the distribution of number of explosions vs. event period have some maxima superimposed on Poisson distribution. The values and dispersions of these maxima are the following:

$t_1 = 438$; $\sigma_1 = 39$;
$t_2 = 3557$; $\sigma_2 = 223$.

Table 1.

Group of events	t_o
short time	10 days
medial time	1 year
long time (explosions)	6.5 years
long time (change of orbit)	5.5 years

Obtained distributions are shown on Fig. 1 - Fig. 4

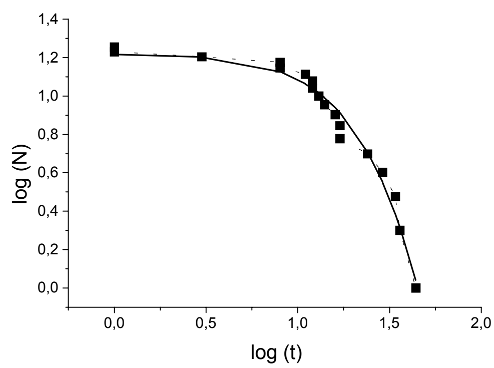

Fig. 1. Dependence of the logarithm of the number of explosions with event time greater then t from logarithm t for short time events (squares and dashed line). Solid line represents Poisson distribution with t_o from table 1.

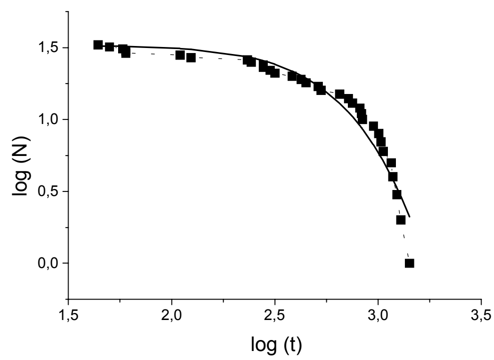

Fig. 2. Dependence of the logarithm of the number of explosions with event time greater then t from logarithm t for medial time events (squares and dashed line). Solid line represents Poisson distribution with t_o from table 1.

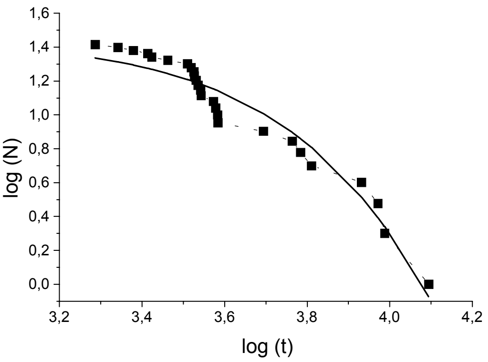

Fig. 3. Dependence of the logarithm of the number of explosions with event time greater then t from logarithm t for long time events (squares and dashed line). Solid line represents Poisson distribution with t_o from Table1.

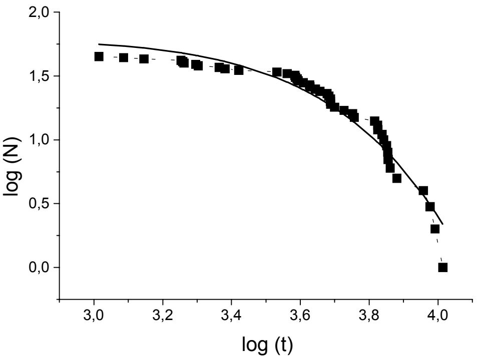

Fig. 4. Dependence of the logarithm of the number of explosions with event time greater then t from logarithm t for sudden changes of orbital elements (squares and dashed line). Solid line represents Poisson distribution with t_O from table 1.

The distribution of sudden changes of orbital elements is similar to that for long time events. It seems to that nature of these two types of events may be similar.

3. CORRELATION OF EXPLOSIONS WITH SOLAR ACTIVITY

Some explosions of first three groups occur in the same date with proton events of solar flares. During such events the flux of solar cosmic rays is large. The dates of solar proton events were taken from [6] for events before 1987 and from [7] for events since 1976. These catalogues are not identical by technique of event selection. We considered them separately.

Only explosions of "d" and "B" types have correlation with solar particle events. The probability that coincidence of an explosion and solar particle event is about 2% for "d" and 20% for "B" explosions. The correlation is stronger for instant "d" events and decrease with increase of event period.

It seems that "p" and "u" explosions do not correlate with solar particle events (probability of coincidence is larger then 75%).

The flux of cosmic rays in the vicinity of the Earth is not stable: there exist two maxima during 11-year cycle of solar activity. During maximum of solar activity the maximum of solar cosmic rays take place, and during minimum of solar activity the maximum of galactic cosmic do occur. These variations take place in high-energy particles both outside and inside Earth radiation belts. The amplitude of variations is most large in energy range from 10 Mev to 10 Gev.

We studied the distribution of the number of explosions vs. year in 11-year cycle of solar activity. There is no correlation for instant and short time explosions of all types. But for "p", "B" and "u" type medial and long time explosions we obtained the dependence (see Fig. 5). Twice during the 11-year period of solar activity maximum of the number of explosions take place. We did not studied such distribution for events of accident orbit change because they are known only from 1991 till 1996, that is less then the duration of the period of solar activity.

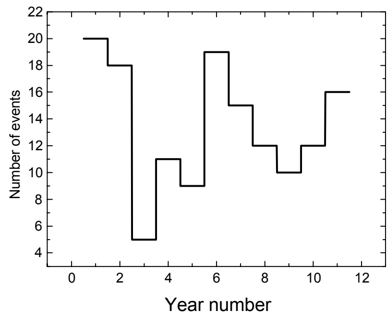

Fig. 5. Distribution of the annual number of explosions during the 11-year cycle of solar activity.

A majority of explosions took place inside Earth magnetosphere. Charged particles of low energy (less then 10 Gev) do not pass through the magnetosphere. An analysis of solar wind parameter variations in the heliosphere obtained from board of various space ships during a long time, showed that mass and energy flows from the Sun (solar wind) are subject to 11-year variations being in anti-phase to the 11-year cycles of solar activity. During the maximum of solar wind flux magnetosphere is compressed and the flux of charged particles in radiation belts becomes high. Moreover at this time the maximum of galactic cosmic rays take place.

4. CORRELATION OF EXPLOSIONS WITH METEOR STREAMS

Another external factor causing explosions are collisions with micrometeorites of natural origin. Fig. 6 shows the distribution of meteors and the number of explosions for 30 years (by months). It can be deduced from this figure that burning a part of their surfaces follows the probability of explosions being caused by collision of spaceships with meteoroids. The mass of micrometeors is too low to make a hole in spacecraft. Possible mechanism may consider impact charge production and plasma current [8]. Correlation between rate of explosions and meteor is shown on Fig. 7. Correlation coefficient in significantly high (r = 0.84).

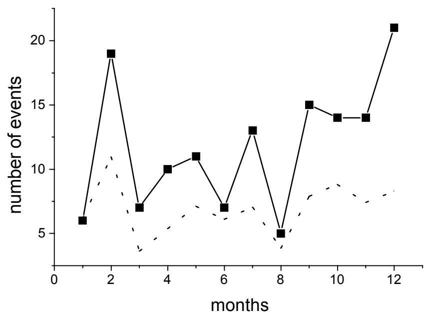

Fig. 6. Seasonal variations of monthly rate of explosions (solid line) and meteor flux (dashed line).

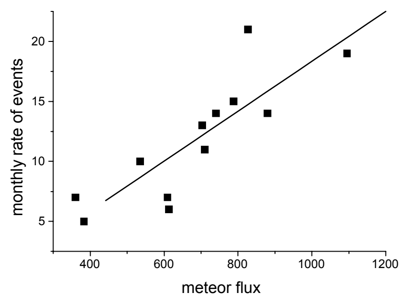

Fig. 7. Correlation between monthly rate of explosions and meteor flux.

Seasonal variations of sudden changes of orbital parameters of objects on GEO are shown on Fig. 8. They are quite different with respect to explosions. Annually two maxima occur: in spring and in autumn. Just during these seasons objects on GEO enter Earth's shadow. During the shadow period the electric potential of spacecraft's surface increase. Meteoroid impact charge production and plasma current are proportional to electric potential of spacecraft's surface.

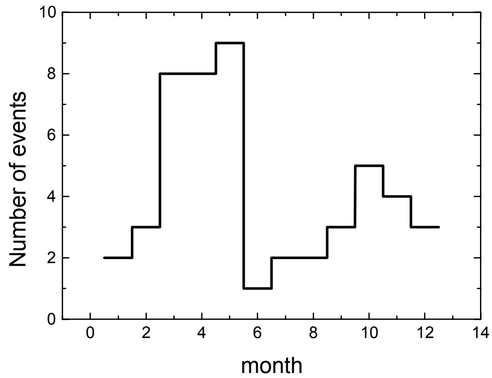

Fig. 8. Seasonal variations of monthly rate of events of sudden change of orbital elements of GEO objects.

5. CONCLUSIONS

Explosions of space objects occur after different time after the launch: from few minutes to 30 years. In short time after the launch spacecraft are sensitive to rapid changes of charged particle flux due to solar particle events. In this case “d” and “B” type explosions occur. There are four time scales for explosions: few hours, ten days, one year and six years.

It is shown that the distribution of the number of explosions vs. year in 11-year cycle of solar activity has two maxima. Moreover it is shown that the maxima of explosions distribution coincide with the maximum of solar cosmic rays and galactic cosmic rays.

Another external factor causing explosions is collisions with micrometeorites of natural origin.

Only combination of charged particle flux and micrometeoroid impacts can give explanation to explosions distribution.

Obtained dependencies of explosion rates from solar activity can be explained by electric effects on satellites surfaces and interior. It is possible that a meteoroids collision with a spaceship inspires a three-dimensional electric charge that burns parts of the spaceship surface and sets on fire the remaining fuel.

6. ACKNOWLEDGEMENTS

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