Assessing risk from dangerous meteoroids in main meteor showers

Andrey Murtazov

Astronomical observatory, Ryazan State University, Ryazan, Russia
a.murtazov@rsu.edu.ru

The risk from dangerous meteoroids in main meteor showers is calculated. The showers were: Quadrantids–2014; Eta Aquariids–2013, Perseids–2014 and Geminids–2014. The computed results for the risks during the shower periods of activity and near the maximum are provided.

1 Introduction

Bright meteors are of serious hazard for space vehicles.

A lot of attention has been recently paid to meteor investigations in the context of the different types of hazards caused by comparatively small meteoroids.

Furthermore, the investigation of risk distribution related to collisions of meteoroids over 1 mm in diameter with space vehicles is quite important for the long-term forecast regarding the development of space research and circumterrestrial ecology problems (Beech, et al., 1997; Wiegert, Vaubaillon, 2009).

Considered hazardous are the meteoroids that create meteors brighter than magnitude 0.

Previously we assessed the average flux (and, consequently, the risk) according to the results of our Perseids dangerous meteoroids 2007–2013 observations. At that time it was $F \approx 0.1/km^2.day$, and the proportion of dangerous meteoroids in the flux in 2007–2013 was 0.051 ± 0.008 (Murtazov, 2013).

2 Calculation results

We calculated the dangerous meteoroid flux and the number of collisions for the main meteor showers: Quadrantids–2014, Eta Aquariids–2013, Perseids–2014, and Geminids–2014. We approximated the data derived from the International Meteor Organization (IMO) and found the shower profiles (*Figure 1*).

The approximation was made by means of the exponential functions $F = F_0 \cdot \exp\{-A(\lambda - \lambda_\odot)\}$, where F_0 [$km^{-2} \cdot c^{-1}$] is the maximum flux for the Solar longitude $\lambda_\odot$.

The integration of $F(\lambda)$ within the shower activity time results in the total number of the flux meteoroids and this is the characteristic of their collision risk.

The population indices of the above showers are quite close to each other (2.1 ± 2.6), therefore the average proportion of dangerous meteors in the shower was taken as 5%.

The activity periods of these showers (IMO) are: Quadrantids–2014; 1^d; Eta Aquariids–2013; 10^d, Perseids–2014; 14^d and Geminids–2014; 4^d.

Our calculations have shown that the average collisions N of dangerous meteoroids for these showers in their activity periods are:

- Quadrantids–2014: $N = (2.6 \pm 0.5) \cdot 10^{-2}$ km^{-2};
- Eta Aquariids–2013: $N = (2.8) \cdot 10^{-1}$ km^{-2};
- Perseids–2014: $N = (8.4 \pm 0.8) \cdot 10^{-2}$ km^{-2};
- Geminids–2014: $N = (4.8 \pm 0.8) \cdot 10^{-2}$ km^{-2}.

Consequently, the average value of collision risk was:

- Quadrantids–2014: $R = 0.03$ $km^{-2}day^{-1}$;
- Eta Aquariids–2013: $R = 0.03$ $km^{-2}day^{-1}$;
- Perseids–2014: $R = 0.006$ $km^{-2}day^{-1}$;
- Geminids–2014: $R = 0.012$ $km^{-2}day^{-1}$.

In other words, the average number of collisions between dangerous 1 km^2 meteoroids and the flat surface perpendicular to the shower occurred not more often than once in 33 days.

Moreover, these average values significantly differ from the collision risks during shower maximums.

During the near maximum periods the meteoroid risk increases:

- Quadrantids–2014: During 0.25^d $R = 1.2 \cdot 10^{-2}$ km^{-2} – 1 collision per 1 km^2 on the average during 21^d;
- Eta Aquariids–2013: During 1.0^d $R = 5 \cdot 10^{-2}$ km^{-2} – 1 collision per 1 km^2 on the average during 20^d;
- Perseids–2014: During 1.0^d $R = 1.2 \cdot 10^{-2}$ km^{-2} – 1 collision per 1 km^2 on the average during 80^d;
- Geminids–2014: During 0.25^d $R = 1 \cdot 10^{-2}$ km^{-2} – 1 collision per 1 km^2 on the average during 25^d.

Of course, these numbers are not very big, but such showers look very eye-catching on the celestial sphere. For instance, the risk index for the Perseid dangerous meteoroids conforms to the hourly rate HR = 5 in the entire sky.

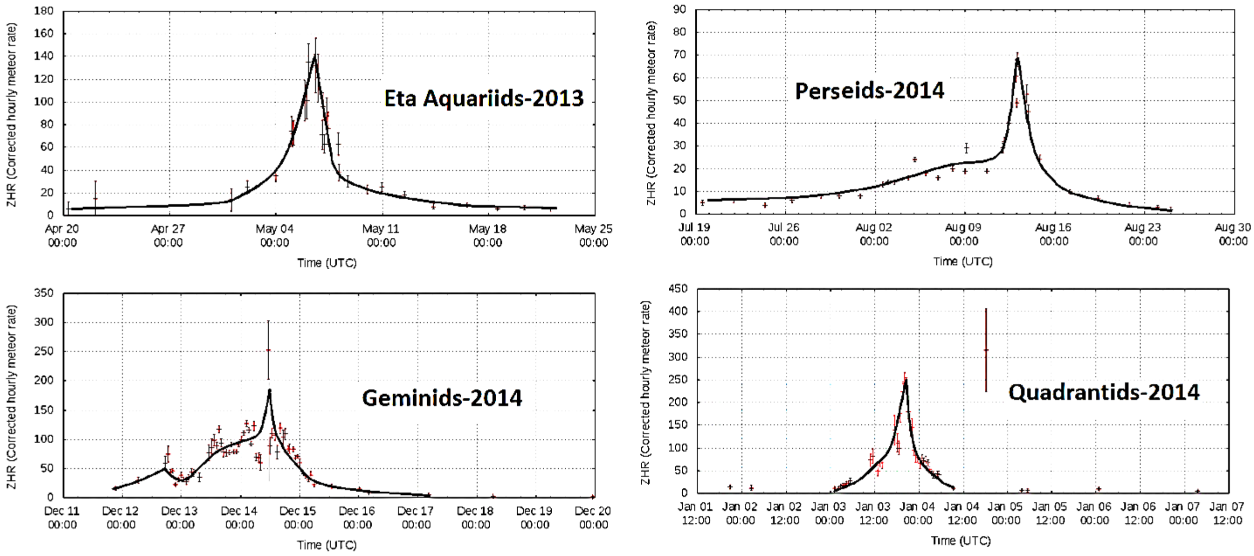

Figure 1 – Averaged profiles of main meteor showers (IMO).

3 Conditions of shielding satellites by the Earth

Besides, a satellite turning in the orbit may be shielded from meteoroids by the Earth. Then its collision risk will decrease.

In the satellite celestial sphere of the satellite-centric reference system the Earth disk moves along the satellite orbit equator, while the meteor radiant *R* makes a small circle in a plane parallel to the equatorial plane (*Figure 2*) (Murtazov, 2014). Here, ♈, ☉, ☊ are directions to vernal equinox, the Sun, ascending node; ε, i, b_E, b_R – obliquity of ecliptic, orbital inclination of satellite, ecliptic latitude of the satellite orbit, ecliptic latitude of the radiant.

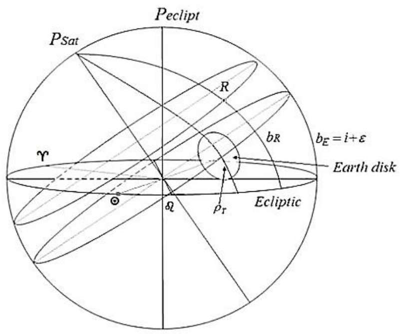

Figure 2 – Celestial sphere in satellite-centric reference system.

Since the latitude of the Earth disk center $\varnothing_E$ shown here is equal to 0, in the satellite-centric coordinate system

$$\begin{cases} \varnothing_R = b_R - i - \varepsilon, \\ \varnothing_E = 0, \end{cases} \qquad (1)$$

where $\varnothing_R$ is the satellite-centric latitude of the radiant. Then the condition of entering the shade is

$$b_R - i - \varepsilon \leq \rho_E, \qquad (2)$$

where ρ_E is the angular radius of the Earth for a satellite.

Satellites for which the condition $b_R - i - \varepsilon > \rho_E$ holds do not fall within the Earth's shade.

Consequently, the obtained results can be used to calculate the meteoroid risk for satellites turning in different orbits and having different orientations regarding the direction towards the meteor shower.

4 Conclusions

Of course, the risk from dangerous meteoroids in space is not very big but the circumterrestrial space is highly populated with satellites; therefore their total area of collisions is rather large. So the total risk for the whole of the satellite population may become significant and should not be neglected.

References

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