RADIATION OF LARGE METEOROIDS DECELERATED IN THE EARTH'S ATMOSPHERE.

O.P.Popova, D.O.Glazachev, E.D.Podobnaya, V.V. Svetsov and V.V. Shuvalov, IDG RAS,Leninsky pr.38 (1), Moscow 119334, Russia; olga_idg@rambler.ru

Introduction:

The fraction of initial kinetic energy transformed into light production during the flight and fragmentation of cosmic objects is poorly known. For 0.1-10 m scale bodies integral luminous efficiency τ was determined based on radiation hydrodynamic simulations [1]. In general integral efficiency is a complex function of velocity, size, entry angle and composition. Fragmentation model was included in determining of the luminous efficiency, multiple additional parameters such as material strength, the air and vapor opacities etc also play a role [1]. Independent confirmation of the theoretical estimates [1] were made by Brown et al. [2], who compared empirical energy estimates for meter-scale impactors derived from infrasonic periods with optical energies of the same events measured by US Government sensors. Obtained dependences suggest that this value should be 5-15% for bodies of chondritic composition with energy between 0.1-50 kton with the efficiency increasing as energy increases [1,2]. Applying these relations to Chelyabinsk event results in τ~15-20% [3,4], but it should be noted that the relations are being extended outside the range of original definition. Application of these relations to even larger objects may lead to overestimation of radiation energy and they can't be used for estimates of thermal radiation in hazardous impact scenarios.

Scaling relations for large meteoroids. Cosmic bodies of asteroidal and cometary origin, with a size from 20 to approximately 100 m, are destroyed and decelerated with the transfer of their energy to the air at heights from 20–30 to several kilometers. Systematic numerical simulations of their interaction with atmosphere in a frame of hydrodynamic model, including consideration of the radiation accompanying the entry of such objects were conducted [5]. The integral luminous efficiencies for bodies with energies 0.6 – 450 Mt entering the atmosphere at different angles varies from several percent to 10-20%, and is dependent on kinetic energy, entry angle and other parameters. For Chelyabinsk meteoroid the luminous efficiency is estimated as 17% [6], close to the estimates mentioned above.

Analyzes of simulation results permit to suggest scaling relations, which allow to estimate irradiated energy and to approximate radiative fluxes on the surface based only on impactor properties. These relations may be used for quick evaluation of the thermal radiation. In most cases an uncertainty in estimates based on the scaling relations does not exceed 10-20%, although it may reach 50%.

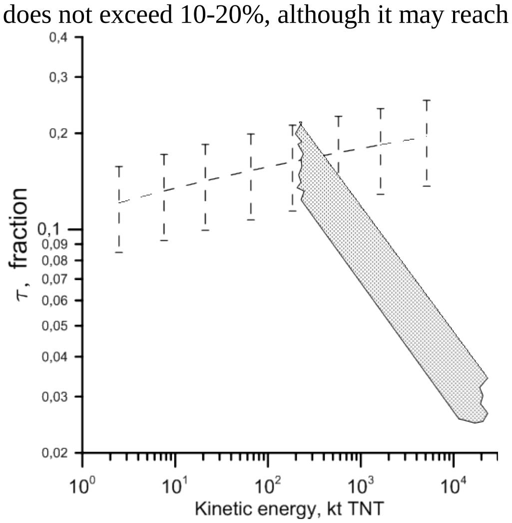

Figure 1: Filled area corresponds to the asteroids entered with V=20 km/s at angles 30-60°. Dashed line represents extrapolation of integral luminous efficiency [1] for smaller chondritic meteoroids (with 30% uncertainty).

As the fireballs can significantly differ in shape from point explosions, corresponding radiation field can be heterogeneous. The inclusion of heterogeneity of the radiation field to the approximation allows us to obtain better agreement.

The integral luminous efficiency for chondritic bodies of different sizes entering at 30-60° with velocity 20 km/s obtained based on scaling relations is compared with that for smaller meteoroids in Fig.1. The efficiency τ is decreasing with energy for large objects unlike the dependence for small bodies. The same is valid for cometary objects although corresponding values of τ are larger. It can be assumed that this is connected with an increase of the optical thickness of the emitting region, which leads to radiation losses mainly from its surface.

Summary: Analyzes of numerical simulation results permit to suggest simplified approximations, which allow to estimate radiative fluxes on the Earth's surface for an entering body with arbitrary choosen size, velocity and entry angle and can be used to predict impact consequences. The dependence of integral luminous efficiency on kinetic energy demonstrates the maximum at energies ~0.5 Mt.

Acknowledgements

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References:

[1] Nemtchinov I. V. et al. (1997) Icarus 130: 229-274. [2] Brown P. et al. (2002) Nature 420: 294-296.[3] Brown P. et al.(2013) Nature 503: 238-241. [4] Popova O. et al.(2013) Science 342: 269-243. [5] Svetsov, V.V. and Shuvalov V.V. (2017) EPSC-abstracts 11: EPSC2017-26. [6] Svetsov V.V. et al. (2017) Solar System Research, submitted.