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Radiation and ablation of large meteoroids decelerated in the Earth's atmosphere

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Abstract

Radiative fluxes caused by the impacts of asteroidal and cometary bodies of various sizes (20-100 m) were determined by systematic modeling. Scaling relations, which allow to estimate energy of thermal radiation, ablation efficiency and to approximate radiative fluxes on the Earth's surface are suggested.

1. Introduction

When cosmic bodies of asteroidal and cometary origin, with sizes from 20 to approximately 100 m, enter dense atmospheric layers, they are destroyed with a large probability under the action of aerodynamic forces and decelerated with the transfer of their energy to the air at heights from 20–30 to several kilometers. Earlier, numerical simulations of the disruption (with allowance for evaporation of fragments) and deceleration of similar meteoroids entering the Earth's atmosphere at various angles were performed, and the heights of an equivalent explosion point generating the same shock wave as the fall of a cosmic body with given parameters were determined [1].

Thermal radiation is one of the main hazardous factors in the impact scenarios, which could result in fire ignition over large areas. The famous Tunguska cosmic body was responsible for fires on the area of 200-500 km^2 [2]. For quick evaluation of thermal radiation, scaling relations are needed, which allow to estimate thermal exposure and thermal fluxes from assumed properties of an impactor. The point source approximation may be useful for quick estimates of thermal damage, but the position, effective altitude of the source and integral luminous efficiency should be determined. Besides, the fireballs can significantly differ in shape from point explosions, and corresponding radiation field can be heterogeneous.

Recently, systematic modeling of the entry of asteroidal and cometary bodies of different sizes (20-3000 m), including the determination of thermal fluxes and exposures, was carried out [3]. Results of these simulations provide an opportunity to derive scaling relations for thermal radiation characteristics as well as ablation efficiency.

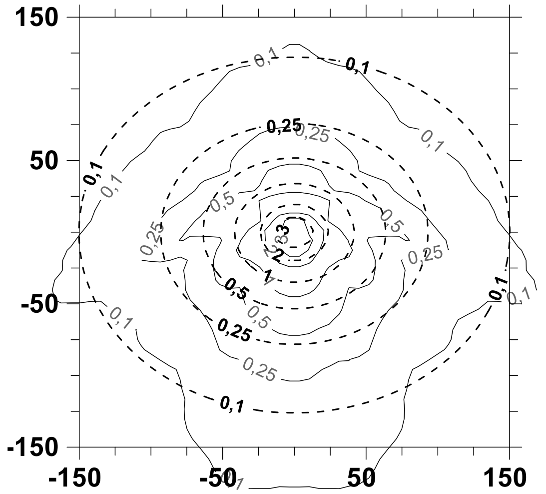
2. Thermal exposure and its approximation

Radiation fluxes were calculated by integrating the equation of radiative transfer along rays passing through a luminous area taking into account spectral dependence of radiation in a multigroup approximation [3]. An example of radiation exposure distribution on the surface is given in Fig. 1 for a 30 m comet entering the atmosphere with a 20 km/s velocity at an entry angle of 45 degrees. The thermal energy distribution on the surface demonstrates a deviation from circular symmetry, which could be expected in the case of a point source.

Analyzes of simulation results permit to suggest scaling relations, which allow to estimate irradiated energy and to approximate radiative fluxes on the surface. These relations are dependent only on cosmic body density, size, velocity and angle of entry. Two variants of application of scaling relations are shown in Fig. 1 in comparison with the result of numerical modeling. The inclusion of heterogeneity of the radiation field to the approximation allows us to obtain better agreement.

The integral luminous efficiencies are shown in Fig. 2 versus kinetic energies of bodies with energies 0.6 – 450 Mt entering the atmosphere at different angles. The efficiency of radiation varies from several percent to 10-20%, and is dependent on kinetic energy, entry angle and other parameters. In most cases an uncertainty in estimates based on the scaling relations does not exceed 10-20%, in all cases this uncertainty is smaller than 60%. As an example, a dashed line shows scaling relation estimates for the asteroids entering the atmosphere at 45^0.

(a)



(b)

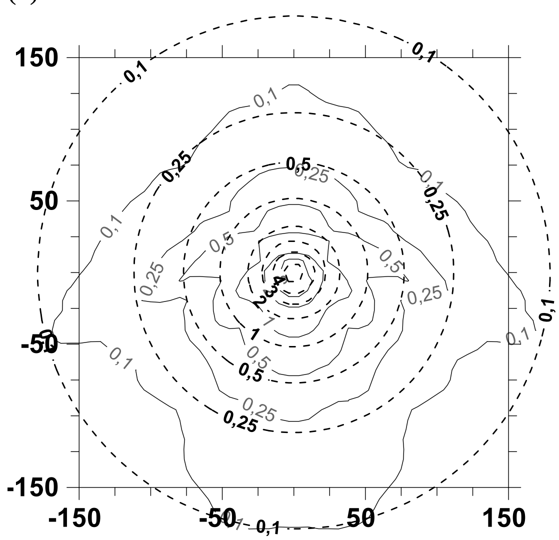


Figure 1: Distribution of radiative exposure (exposure values are given on contour lines in J/cm^2) on the surface for a 30 m cometary body that entered the atmosphere with velocity 20 km/s and entry angle 45^0. Solid lines represent corresponding numerical simulations, dashed lines demonstrate application of simplified approximations, taking into account the heterogeneity of the radiation field (a) and without it (i.e. point source approximation) (b). The axes correspond to distance in km, the trajectory is directed from below upwards, maximum luminosity point is in the point of origin of coordinates.

3. Summary

Radiative fluxes caused by the impacts of asteroidal and cometary bodies of different sizes (20-100 m) have been determined by the systematic modeling. Simplified approximations, which allow to estimate radiation energy and to describe the radiative fluxes on the surface as well as ablation efficiency, are suggested.

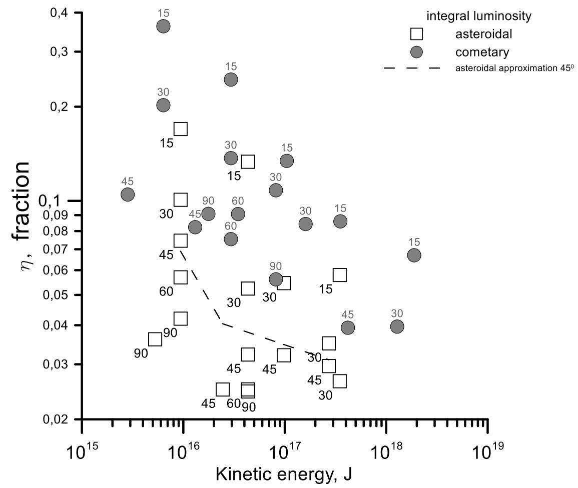


Figure 2: Integral luminous efficiency versus kinetic energy of asteroidal and cometary objects (entry angles are labelled). Dashed line corresponds to suggested scaling relation for the cases with an entry angle of 45^0.

Acknowledgements

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References

[1] Shuvalov V.V. et al.: (2016) Sol. Syst. Res., 50, 1–12, 2016.

[2] Svetsov, V.V.: Comment on “Extraterrestrial impacts and wildfires”, Palaeogeogr. Palaeoclimatol. Palaeoecol., Vol. 185, pp. 403-405, 2002.

[3] Svetsov, V.V., Shuvalov V.V.: Thermal radiation from large bolides and impact plumes. Abstract (this conference).