On a meteor mechanism of aerosol formation in the upper atmosphere

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Air dustiness is able to strongly influence the state of high atmosphere and processes which proceed there. Quite a number of phenomena which occur in the high atmosphere is associated with the influx of cosmic dust, such as an increase in the intensity of the scattered solar radiation field, natural radiation and resonance scattering in lines of different atoms and ions, the mirror reflection of radio waves from a meter range of ionized meteor trails, etc. Kinetics of such processes depend strongly on the dust volume concentration and on the particle size distribution. The latter quantities are determined by mechanism of particle generation.

Ablation of moving celestial bodies is one of the origins of dust influx in high atmosphere, due to their quasi-continuous fragmentation on a large number of fine particles. One of the mechanisms of ablation being discussed in the physical theory of meteors is breaking-off of liquid melted layer formed on the solid meteor body by the air pressure head due to hydrodynamic instability of liquid surface. The similarity in hydrodynamic conditions of meteor body (MB) to the fragmentation of liquid droplet in a speedy gas flow consists in the fact that the values of Weber criterion We, criterion of gradient instability GI and parameter which determines the existence of "gradient" instability mechanism, are close for meteoroid and for drop. The performance of hydrodynamic instability of the melt film in a high-speed air flow past MB as a mechanism of particle dispersion was considered in (Girin and Kopyt, 1994) and estimations of the droplet size and frequency of the particle separation were obtained.

Certain class of middle-sized meteoroid exists (Bronshten, 1983) which are able to be melted throughout all their depth. In this case the MB behaviour is fully similar to the liquid drop behaviour in a speedy flow. Thus, we can apply the elaborated recently drop atomization theory (Girin, 2014), based on the "gradient" instability mechanism, to the middle-sized meteoroid ablation. At the same time, when the meteoroid trajectory has a slow slope, the air density is changing gradually and application of the droplet atomization theory turns out to be feasible.

Quantitative description of heat and mass transfer in a meteor wake is important in the physical theory of meteors (Bronshten, 1983). Mathematical modeling of the meteor wake structure requires finding the distribution of all torn-off particles by sizes, as well as of its evolution in space and time. The distributions of stripped droplets by sizes are calculated here and the example is given in the figure. Calculated dependence of MB radius on time is close to linear.

Calculations yield quite a large number of particles for the speedy iron meteors, which are two orders less in sizes than the parent meteoroid. The coarse fraction is generated always at the beginning, and the fine one – at the end of the process when the MB radius is small. With MB velocity diminishing, the particle sizes increase as $V_\infty^{-0.5}$ while their number decreases.

Bimodal meteor particle distribution may exist due to the "hump" in the dependence of the growth rate factor on the "surface" Weber number. At smaller GI values this effect becomes more distinct, as the distribution of a stone meteoroid shows. The "hump" can also be in work in the case of the more viscous meteor body substance. The distribution of particles in the case of stone meteoroid, whose viscosity is 30 times greater than the iron one has two maxima. In this case the boundary layer thickness δ_l is only 6 times less than meteoroid diameter, so, the particle sizes are larger and their number is lesser.

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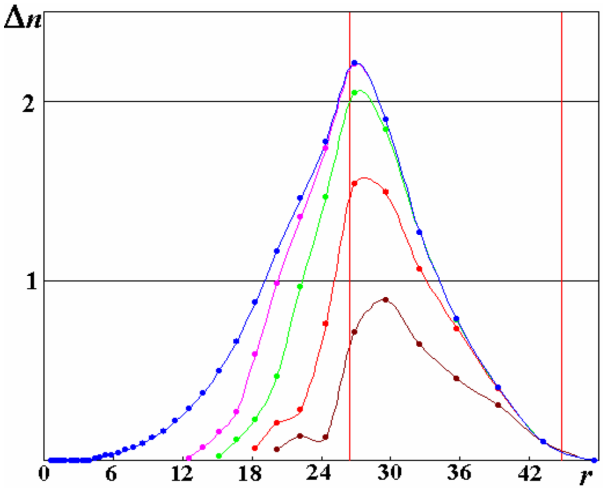

Figure 1. Distributions of stripped droplets by sizes, $\Delta n(r)\cdot 10^4$; r in μm. Iron meteor, $V_\infty = 60 km/\mathrm{sec}$, $R_0 = 3.0 mm, \mathrm{Re}_\infty = 529, \mathrm{GI} = 13.0$. Brown, red, green, crimson – intermediate distributions at $\tau = 0.44, \tau = 0.89, \tau = 1.39, \tau = 1.80$; $\tau = t/t_{\mathrm{ch}}$. Blue – final distribution at $\tau = 2.72$; $t_{\mathrm{ch}} = 2.16\cdot 10^{-3}\,\mathrm{sec}$.