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Abstract

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A SUPPOSITION ON THE NATURE OF THE LUMINOUS PARTICLES OBSERVED BY COSMONAUTS

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It is proposed that the luminous particles observed by cosmonauts through the windows of spacecraft when entering the Earth’ s shadow are probably micrometeorites heated to incandescence upon collision with the surface of the craft, or particles of the craft’ s surface torn away upon collision.

At spacecraft flight altitudes of 200–300 km, the amount of micrometeorites in the form of small particles is 10^{-17}–10^{-18} $\mathrm{g \cdot cm^{-3}}$. If it is assumed that the micrometeorites have sizes of 1-50 μ and a density of 3-8 $\mathrm{g \cdot cm^{-3}}$, then at altitudes of 160-300 km there will be several particles in 1 m^3. A spacecraft will experience thousands of collisions per second.

Upon collision with the body of the craft, depending on the nature of the collision, the particles acquire energy up to $mu^2/2$ (m is the particle mass, u is the velocity of the particle relative to the craft). Some of the micrometeorites and particles torn from the skin upon collision will melt or evaporate, while some will heat up to the melting or sublimation temperature. In a collision it is also possible for particles of the craft’ s surface to arise that are heated to a high temperature.

Let us consider the radiation of a heated particle formed upon collision. The particle temperature T after collision will rapidly decrease. Assuming for particles so small in size a temperature uniformly distributed over the volume (Biot criterion $\mathrm{Bi} \ll 0.1$), one may write the heat-balance equation for a particle in vacuum

$$c_{\text{vol}} V\,dT + \varepsilon\sigma S\left(T^4 - T_\phi^4\right)d\tau = 0, \tag{1}$$

where c_{vol} is the volumetric heat capacity; V is the volume; S is the surface; ε is the emissivity of the particle surface; σ is the Stefan–Boltzmann constant; τ is time; T_ϕ is the temperature characterizing the integral radiation of the surrounding medium.

Denoting the particle temperature after collision by T_0 and, at visible-radiation temperatures, neglecting the quantity T_ϕ^4 in comparison with T^4, after the simplest transformations we obtain the solution of the heat-balance equation

Fig. 1. Temperature of particles after collision

Figure 1: Fig. 1. Temperature of particles after collision

Fig. 2. Illuminances produced by particles on the cosmonaut’ s pupil

Figure 2: Fig. 2. Illuminances produced by particles on the cosmonaut’ s pupil

$$T = T_0 \sqrt[3]{\frac{1}{1 + \frac{3\varepsilon\sigma S T_0^3}{c_{\text{vol}} V}\tau}}. \tag{2}$$

The luminous intensity of the visible radiation of the particles is

$$I = \varepsilon S_{\text{pr}} B(T), \tag{3}$$

where $B(T)$ is the brightness of the visible radiation of a black body (^{1}), and S_{pr} is the area of the particle projection.

The illuminance at the cosmonaut’ s pupil is

$$E = \frac{pI}{L^2}, \tag{4}$$

where p is the transmittance of the window, and L is the distance from the cosmonaut to the particle.

When moving point sources of light are observed, the value of the threshold illuminance depends on the angular velocity of the source’ s motion and on the brightness of the background. When observing against a dark background (brightness less than 10^{-3} nit), the value of the threshold illuminance can be determined from the empirical formula obtained by N. I. Pinegin (^{2}),

$$E_{\text{thr}} \cong 3 \cdot 10^{-9}(1 + \omega) \text{ lx}, \tag{5}$$

where ω is the angular velocity in $\text{deg} \cdot \text{sec}^{-1}$.

Let us consider several examples of the radiation of particles and the possibility of their observation by cosmonauts. Let the particles have the shape of a sphere with a volumetric heat capacity $c_{\text{vol}} = 1 \text{ cal} \cdot \text{cm}^{-3}$ and a surface emissivity $\varepsilon = 0.8$. The initial temperature of the particles after collision is 2500°K,

Fig. 1. Temperature of particles after collision

Fig. 2. Illuminances produced by particles on the cosmonaut’ s pupil.

and they move in the cosmonaut' s field of view with angular velocities $\omega = 10^4 \div 10^6$ deg · sec^{-1} at a distance $L = 1$ m.

Figure 1 presents the temperature dependences for particles of diameter 1, 10, and 50 μ, and Fig. 2 the illuminances produced by these particles on the cosmonaut' s pupil, as a function of the time after the moment of collision. Figure 2 also shows the values of the threshold illuminance E_{thr} at angular velocities $\omega = 10^4,\ 10^5,\ 10^6$ deg · sec^{-1}.

Particles of diameter 1 μ will practically not be observed by cosmonauts. Particles of diameter 10 μ, moving with angular velocity $\omega = 10^4$ deg · sec^{-1}, may be visible for 2–3 msec; at an angular velocity greater than 10^5 deg · sec^{-1}, particles of diameter 10 μ will practically not be visible. Particles of diameter 50 μ, moving with velocities $\omega \ll 10^5$ deg · sec^{-1}, will be clearly visible for tens of milliseconds; at an angular velocity $\omega = 10^6$ deg · sec^{-1}, particles of diameter 50 μ will be visible for 4–5 msec.

Photometric measurements of the illuminance and duration of the glow of particles may be used for the investigation of micrometeorites in the upper layers of the atmosphere.

In conclusion, I consider it my pleasant duty to express my gratitude to N. I. Pinegin for his interest in the work and for discussion of the results obtained.

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