On the Luminous Efficiency of Meteors[1]

FRANCO VERNIANI[2]

Introduction

By far the most precise astronomical data for meteor orbits have been obtained by use of photographic techniques (Jacchia and Whipple, 1961). Photographic data also make it possible to evaluate physical quantities, including those that cannot be determined by other means of investigation, such as Jacchia's fragmentation index. Such basic quantities as the masses of meteoroids are, however, still very uncertain, although the photographic technique, by providing a light curve, is much more helpful than other means of investigation. The large uncertainty results from the lack of knowledge of the luminous efficiency of meteors. The purpose of this work is to extract, from the Harvard photographic meteors, direct information concerning this parameter.

Since the luminous intensity I of a meteor is generally accepted to be proportional to the kinetic energy of the ablated atoms,[3] the luminosity equation is usually written in form

$$I=-\frac{1}{2}\tau v^2\frac{dm}{dt}, \qquad (1)$$

m and v being the mass and velocity of the body; τ, the luminous efficiency; and $\frac{dm}{dt}$, the rate of the mass loss in atomic (or molecular) form. The gas-cap radiation will be neglected because the meteors that we will refer to have been photographed in blue emulsion, and there is experimental evidence that such radiation is important only in the red and the infrared regions (Millman and Cook, 1959).

The proportionality between I and $\frac{dm}{dt}$, i.e., between the luminous intensity and the rate of ablation of free atoms, is quite clear. In contrast, the proportionality between I and v^2 seems much harder to understand. It is actually easy to envisage a very intricate dependence of I, i.e., of τ, on the velocity v. Let us consider the spectrum of a meteor with a given velocity. If we progressively increase the velocity, the intensity of the single lines will change; some low-excitation lines will fade out; new lines will appear; and certainly the total emitted light will not be a simple function of the velocity. It is evident, moreover, that the luminous intensity depends on the spectral range that one considers. In the following we will refer to a visual luminous intensity I_v and to a photographic luminous intensity I_p, defined by the sensitivity of the blue emulsion generally used in Harvard photographic studies. Accordingly, we will have two different luminous efficiencies τ_p and τ_v, defined by

$$I_p=-\frac{1}{2}\tau_p v^2\frac{dm}{dt} \qquad (2)$$

and

$$I_v=-\frac{1}{2}\tau_v v^2\frac{dm}{dt}. \qquad (2a)$$

If we assume, as is generally accepted, that the dependence of the luminous efficiency on the velocity can be expressed by a power law of the form $\tau\sim v^n$, and if we introduce the color index of the meteors C, which is defined as the difference M_p-M_v between the photographic and the visual magnitudes, we get

$$C=-2.5\log\frac{I_p}{I_v}=-2.5\log\frac{\tau_{op}}{\tau_{ov}}-2.5(n_p-n_v)\log v. \qquad (3)$$

The symbols are self-explanatory.

---

[1] This work was supported in part by grant NsG 87-60 from the National Aeronautics and Space Administration.

[2] On leave: Centro Nazionale per la Fisica dell'Atmosfera del C.N.R., Roma, Italia.

[3] The photographed spectra of meteors confirm that the kinetic energy lost by deceleration of the body does not contribute to the light.