RADIATION OF SPECTRA OF METEOR

V.A. Smirnov

Academy of Communication of Ukraine, *smirnovw@tm.odessa.ua*

ABSTRACT. The characteristics of meteor's, flares by the mechanism cascade radiation are investigated.

1. History of an issue

The first period of researches of meteor's spectra was a period of visual observations by A.S. Herschel before receiving the first spectrograms, achieved by S.N. Blajko in 1904 and 1907 (Smirnov, 1994). The results of meteoric spectra studies within the second period has been examined in the early 60 *s* by P. Millman (1906-1990) in his work "The General Survey of Meteor Spectra". Peter Millman, originally from missionary's family, took after his parents the "mission" – the organization of spectral meteor's researches development in various countries. Besides his regularly publishing of the lists of meteor's spectrograms made all over the world, he also dispatched his works to many young researchers and was actually their teacher. (For example, published in 1962 work in Odessa University, volume 152, page 55 – 60, by Vladimir A. Smirnov "Photometry of two spectra of meteors using a method of A. Cook and P. Millman"). Appeared, that the spectrum of a meteor is not only a function of a chemical structure, but also of velocity, or rather, reserve of meteoroids kinetic energy. It was visible from the fact that the spectrum of high-speed streams of Perseids, Orionids, Leonids belonged to an Y-type. The meteors of low-speed streams – Geminis and Giacobinid – belonged to an X-type. Also appeared, that the lines more than 120 multiplet's of the iron, on 10 multiplet's of the ionized iron each, magnesium, calcium, oxygen were identified, bands of molecular and line of the ionized nitrogen. A significant abundance of the spectral lines have given the sodium, chromium, manganese, nickel, cobalt, carbon, lithium, barium, strontium, hydrogen and also ions of magnesium, oxygen, silicon, and aluminum. More than 10 head cants of band's FeO, MgO, CaO, CN, C_2, CO, CH, CO^+ etc. The application of methods of star photometrics and spectrophotometrics to the meteoric spectra and especially photographic traces in integrated light was burdened by a plenty of regular errors. This was considered in details in the book of an author (Smirnov, 1994) of the star image of the same brightness. The same concerns also to the receiving of spectra, when any "spectral line" represents monochrome image of a meteor, as the meteor spectrograph work in a mode of expectation of a meteor flight and fix a meteor in all his volume. Spectrophotometrical analysis of a spectrogram, made by *A.* Cook and P. Millman (1955) does not raise an objection: by them the densities of radiating atoms and ions were determined as a result of absolute spectrophometry of the monochrome images in a state of "spectral bands" and "lines". However, the usage of a method of growth curve construction, and defining the self-absorption in volume of meteor's radiation by means of photometric profiles of the same imaginary "lines", is not correct.

2. The physical theory of meteors in historical aspect

The determination of the equations solutions of meteor physics clearly requires the separation according to the spatio-temporal principle (Smirnov, 1994; 1997; 2000; 2001). Otherwise one runs into contradictions upon interpreting of the actual conservation laws for the task of following the evolution of the meteor phenomenon in space and time. If dt the time interval, where $S(t)$ – cross-section of meteoroid, $\rho(H)$ is the atmospheric density at altitude H, and $v(t)$ is the velocity of the meteoroid with mass $m_\downarrow$, Γ is the coefficient of resistance, characterizing the momentum transfer to the atmospheric particles passing the meteoroid , then, the "equation of braking " of the physical theory of meteors is represented by the following formula:

$$m_\downarrow \frac{d\nu}{dt} = -\Gamma S \rho \nu^2 \tag{1}$$

In the last equation all the parameters except the empirically determined velocity and accelerations, are unknown. Also the laws of the evolution of these parameters with gradual penetration of the meteor into more dense layers of the atmosphere are unknown. Apart from this, the meteoroid mass mv is supposed to be independent from the time t in disagreement with any model of the evolution of the meteor phenomenon. Equation (4) was used again for the determination of the "dynamic masses" of meteors (Bronshten, 1981).

However, V.A.Bronshten noted in his studies that the value of the velocity being dependent on the time serves for the determination of the momentary significance of the meteoroid mass. In other words, it will admit the application of equation (1) for the case of a stationary ("momentary") meteor mass. Obviously, the application of the "equation of braking" of the meteor stipulates a stationary "dynamical" mass. Analogously, the application of the equation below of mass loss stipulates the condition of a stationary velocity V, which disagrees with the actual flight of the meteoroid. Here, the mass loss in turn defines the momentary significance of the velocity. In the third equation of physical theory – the "equation of emission" photometric data deliver the observed intensity I of meteor radiation being related with the loss of kinetic energy τW, where coefficient τ characterizes the conversion of kinetic energy of the meteoroid into radiation upon disintegration of the body by some $m(t)$. Meteor radiation emerges from the plasma generated as a consequence of the meteoroid's interaction with the atmosphere along its trajectory. The theory of meteor radiation is a physical theory of non-equilibrium, chemically active plasma. One cannot solve equation for the intensity I in integral light uniquely for the evolution of the meteor phenomenon. For every meteor, the coefficient t as well as its mass m are unknown as disintegration of each individual meteoroid. Therefore, the "photometric mass" generally differs from the "dynamical mass" obtained from (1). The absolute spectrophotometry of meteors allows determining the intensity of such monochromatic images in absolute units for every moment of the flight of the meteor. If we neglect induced emission and self-absorption in these lines, the radiation intensity emitted in a certain moment and in a unit volume of particles is determined by the total exposure of the film

$$I_{ik} = N_i A_{ik} h\nu_{ik}, \tag{2}$$

where N is a concentration of radiating particles, A_{ik} is the Einstein probability coefficient of the transition i, k, and $h\nu_{ik}$ is the energy of the quantum. (The astronomical application of (9) requires an additional factor of $1/(4\pi)$). Therefore, A.Cook and P.Millman (1955) used spectral line intensities determined in absolute units for the determination of the number of radiating atoms in the meteor spectrum. The intensity of monochrome radiation of the meteor image can be described by the sum

$$I_{ik} = I_{shock} + I_{casc}, \tag{3}$$

where I_{shock} is defined by the direct shocks of meteor plasma shock particles with electrons. I_{casc} is defined by cascaded transitions. Calculating the total power being radiated by the meteor it is needed to sum up the intensities at various wavelengths, in various time intervals, and of various area parts through which the radiation passes, in absolute units. In other words, the determination of the power P implies the calculation of the triple integral.

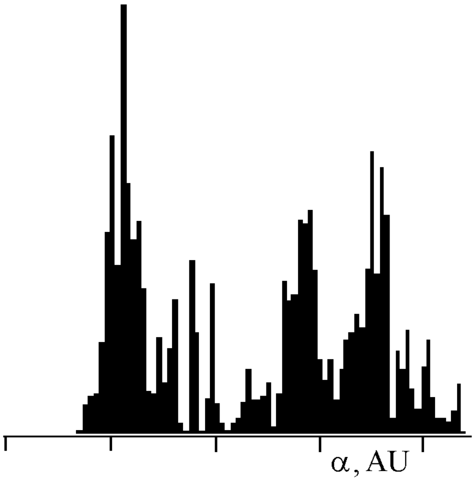

Figure 1: The distribution of the shower meteor orbits semi-major axis.

$$P = \int_{\lambda_1}^{\lambda_2} \int_{t_1}^{t_2} \int_{S} I d\lambda dt ds, \tag{4}$$

Practically, at the expense of averaging the meteor's monochromic radiation powers, the obtained intensities refer to wavelength intervals, time intervals, and an area chosen for the radiation model, for example, a sphere with 100 km radius. In this approach, we have to adopt that the radiation of spherically symmetric meteor emission takes place at 100 km distance from the camera lens. During the certain period of time t the concentration of particles in every point of the meteor path varies according to the law, described by the solution of kinetic equation (Biberman et al., 1982):

$$N(t) = N_e(t) \left(27.10^{-23} \frac{N_0^2}{T_0^{9/2}} t_0 \left[\left(\frac{t}{t_0} \right)^{0.4} - 1 \right] \right)^{1/2}, \tag{5}$$

where N_{e0}, N_0, t_0, T_0 initial values of electron concentration, of plasma particles concentration, of time and temperature.

3. Phenomenological description of meteor

The physical processes accompanying development of the meteor phenomenon proceed in various timescales. For example, frequently appearing double final flares in meteors of a Perseid's stream occur within the time, which is smaller than 0,05 seconds. However, the transmission of energy for evaporation of 1 gram of meteoroid requires much more time. Thus can be explained the significant inertness in meteors movement and independence of light streams of meteor plasma from the mechanical changes in meteoroid's structure. On the early stage of expanding all the relaxation process in plasma occurs swiftly, and gas is considered to be in the thermodynamic equilibrium. Further on, at the lower temperature in expanding ionization and dissociation processes are retarded, more energy is being consumed. However, the velocities of inverse processes, recombination, in particular, depend on density, temperature, time. The events of ionization can be neglected in this case. The process is secured only due to the recombination and subsequent cascade transition. The meteor penetrates into the dense of atmosphere layers, the density of energy flux of interaction between it and atmosphere particles (they may be considered as immovable) increases and achieves its value and may lead to radiation similar to the "laser" scenario. The task – the mechanism of a characteristic double flare of a meteor stream.

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