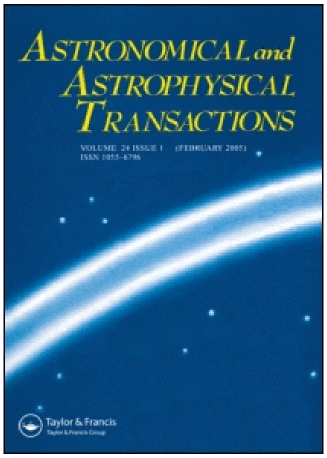

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

On the value of the initial ionization degree in the meteor trail

V. A. Bronshten [a]
[a] Committee for Meteorites of the Russian Academy of Sciences, Moscow, Russia

Online Publication Date: 01 April 2004
To cite this Article: Bronshten, V. A. (2004) 'On the value of the initial ionization degree in the meteor trail', Astronomical & Astrophysical Transactions, 23:2, 153 - 155
To link to this article: DOI: 10.1080/10556790410001654105
URL: http://dx.doi.org/10.1080/10556790410001654105

Astronomical and Astrophysical Transactions
Vol. 23, No. 2, April 2004, pp. 153–155

ON THE VALUE OF THE INITIAL IONIZATION DEGREE IN THE METEOR TRAIL

V. A. BRONSHTEN*

Committee for Meteorites of the Russian Academy of Sciences, 11-34 Bolshoy Golovin Pereulok, Moscow 107045, Russia

(Received 13 October 2003)

The initial ionization degree in the meteor trail calculated by means of three different methods was found to be equal to 0.01–0.017. The unreality of the estimation of 0.5 obtained by Smirnov was demonstrated. The fact that Smirnov's other suggestion about the re-evaluation of the photometric meteor mass scale on the basis of the determination of the non-radiating mass cannot be justified is also shown.

Keywords: Meteor ionization, Meteor trail, Non-radiating mass

1 INTRODUCTION

The value of the initial ionization x_0 in the meteor trail could be required in the course of solving many problems in meteor physics. Its meaning is close to that often employed in meteor physics for the ionization coefficient β, which is defined as the number of free electrons formed in the meteor plasma on one evaporated atom (McKinley, 1961). A detailed survey of all determinations of β is contained in the book by Lebedinets (1980) (see also Bronshten (1983)), where the dependence of β on the meteor velocity has also been discussed (β increases with increasing velocity).

2 DETERMINATION OF x_0

To determine the value of x_0, we have used three independent methods, and these are described in the following.

2.1 Method 1: From Radar Observations

Let us take as an example a fireball of -6^m (such a fireball was examined by Smirnov (1995, 1997)). The linear electron density of the trail of this fireball according to the formula given by

* Deceased on 1 February, 2004.

ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/10556790410001654105

McKinley (1961, p. 230), is equal to 2.5×10^6 electrons cm^{-1}. Its initial radius is 1m = 100 cm (McKinley, 1961; Bronshten, 1983). Then, the volume density of electrons in the trail will be 8×10^{11} cm^{-3}.

Next we calculate the density of neutral atoms. The meteoroid creating the fireball of -6^m, having a velocity of 30 km s^{-1}, will have a mass of 400 g. If we suppose that it is stony with a density of 3 g cm^{-3}, the cross-sectional area will be 30 cm^2. Assuming the atmospheric density at a height of 65 km to be $f = 1.7 \times 10^{-7}$g cm^{-3} and the specific heat of ablation to be $Q = 1.4 \times 10^{10}$ erg g^{-1} (Bronshten, 1983), there will be a mass loss in the course of ablation equal to 1.6×10^{-4} g cm^{-1}. If the mean molecular mass of the meteoroid's atom is equal to 40, its mass will be equal to 6.4×10^{-23} g. From these data we obtain a linear atomic density of 2.5×10^{18} atoms cm^{-1} and a volume density of vapours 8×10^{13} cm^{-3}. Therefore, $x_0 = 10^{-2}$.

2.2 Method 2: From the Intensity of Spectral Bands

From Table 21 of the book by Bronshten (1983) we can obtain the summed mass of nine principal meteor elements (without O) expressed in units of the mass of the iron atom (1.89). Since oxygen constitutes 0.41 of the mass of stony meteorites (Krinov, 1960), the summed mass of those elements including oxygen in the same units will be equal to 3.2. The calcium ion share (this ion is the most widespread among meteor ions), according to the same Table 21 (Bronshten, 1983), constitutes 0.055 of the conventional units or 0.017 of the whole mass. Such a value according to this calculation can be attributed to the initial ionization value in the trail of a stony meteoroid.

2.3 Method 3: From Saha's Formula

It is well known that Saha's formula can be applied to the plasma where thermodynamic equilibrium can be realized. However, in the meteor plasma this condition will never reached (Bronshten, 1983). This it seems that we should exclude the application of Saha's formula for meteor plasma. However, the difference from equilibrium conditions, as was shown by Bronshten (1983), should not exceed 20%; therefore we can use Saha's formula for order-of-magnitude evaluations.

We shall use for comparison the result of Biberman *et al*. (1982) as cited by Smirnov (1995, 1997) for a caesium–argon plasma. In their example, $x_0 = 0.5$. The ionization potential χ of caesium is equal to 3.9 eV, and that of calcium (the principal source of electrons in the meteor plasma) is 6.1 eV, the difference between these values is $\Delta\chi = 2.2$ eV. According to Saha's formula, the ratio of the ionization degrees of the two plasmas is equal to $\exp(\Delta\chi/kT)$. We can take for the meteor plasma $T = 6000$ K and therefore $kT = 0.55$ eV. So, the ratio formulated above is equal to $e^4 = 50$ and the value of x_0 for the meteor plasma will be 0.01, in good agreement with values obtained above.

3 DISCUSSION

In two papers published recently, Smirnov (1995, 1997) without valid reasons evaluates the initial ionization in a meteor trail as $x_0 = 0.5$. This evaluation was made by analogy with such a value adopted by Biberman *et al*. (1982) for the caesium–argon plasma at a temperature and external pressure close to those realized in the meteor plasma.

The main mistake in Smirnov's method is connected with the difference between the ionization potentials of caesium (3.9 eV) in Biberman's example and calcium (6.1 eV), which is the main source of ionization in the meteor plasma. We cannot mechanically transfer the results obtained for the case of the ionization of caesium in the meteor plasma where the ionization of calcium and other meteor atoms takes place (the ionization potentials of those are equal to from 4.3 eV for potassium up to 8.1 eV for silicon).

So, either the value $x_0 = 0.5$ is not real or the method used by Smirnov for its determination is erroneous.

4 ON THE SO-CALLED NONRADIATING METEOR MASS

In his publications (see for example Smirnov (1997)), Smirnov developed the problem of the non-radiating mass of the meteoroid. In fact, at the moment, only a small share of all atoms of a given element can radiate. This is connected with the fact that each atom radiates only during a very short interval of time, much less than the interval between the successive acts of radiation. This fact in itself is trivial. Smirnov calculated the ratio of two such intervals and found that the radiating mass of meteor vapour constituted only 10^{-4} of their whole mass. Hitherto the reasons that Smirnov gave have been assumed to be correct and have arouse no objections. However, his suggestion that the evaluations of the meteoroid's masses derived from the photometric curves should be increased 10^4 times is incorrect because the relation between the brightness of a meteor and the mass loss by the meteoroid is regulated by the value of the coefficient τ of radiation intensity (also called the luminosity coefficient). In this coefficient the relation between the radiating and non-radiating masses has already been taken into account. Therefore, the concept of a non-radiating mass does not require a revision of the photometric mass scale.

References

Biberman, L. M., Vorobyev, V. S. and Yakubov, I. T. (1982) *The Kinetics of Nonequilibrium Low-temperature Plasma*, p. 375, Nauka, Moscow (in Russian).

Bronshten, V. A. (1983) *Physics of Meteoric Phenomena*, Reidel, Dordrecht.

Krinov, E. L. (1960) *Principles of Meteoritics*, Pergamon, Oxford.

Lebedinets, V. N. (1980) *Dust in the Upper Atmosphere and in Space: Meteors*, Gidrometeoizdat, Leningrad (in Russian).

McKinley, D. W. R. (1961) *Meteor Science and Engineering*, McGraw-Hill, New York.

Smirnov, V. A. (1995) *Earth, Moon, Planets* **68**, 515.

Smirnov, V. A. (1997) *Planet. Space Sci.* **45**, 847.