ORBIT, CHEMICAL COMPOSITION AND ATMOSPHERIC FRAGMENTATION OF A METEOROID FROM INSTANTANEOUS PHOTOGRAPHS

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INTRODUCTION

Difficulties in the interpretation of the meteor phenomenon have been mainly caused by the impossibility of dividing in time and space the information obtained from the observations. To a certain extent the use of the method of instantaneous exposures can help to overcome these difficulties. The present paper deals with the study of a bright meteor N 770533, broken into many fragments and its spectrum, which was doubly photographed in 1977, July , $19^h\ 30^m\ 56^s$ UT in Dushanbe (Figure 1). The photographs were taken by the method of instantaneous exposures, which has been described by Babadzhanov and Kramer (1968). To take the photographs of spectra, transparent replica diffraction gratings with light concentration in the first order have been used. Rotating shutters made it possible to obtain meteor images in integrated light with duration of 0.00056s every 0.02s, as well as to obtain spectra with durations of 0.00056s and 0.0033s every 0.02s. A panchromatic emulsion with spectral sensitivity 3800 to 7000 Å was used.

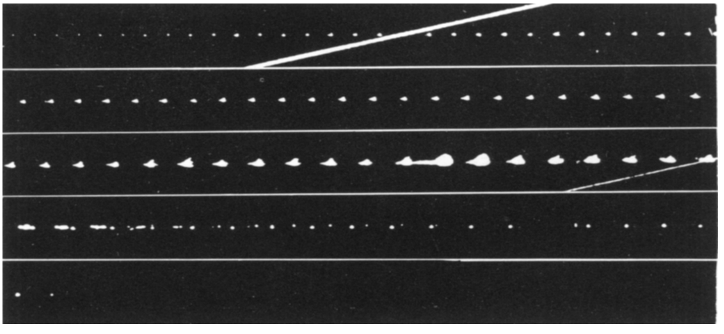

Fig. 1: Instantaneous photograph of meteor No 770533.

I. Halliday and B. A. McIntosh (eds.), Solid Particles in the Solar System, 111–115.

OBSERVATIONS AND CALCULATIONS

The meteor was photographed by six meteor patrol cameras. The quality of the photographs was quite sufficient to enable reduction. The heights of meteor appearance, maximum light and disappearance were 92 km, 69.5 km and 60 km respectively. Pre-atmospheric velocity, v_∞ = 23 km/s and the velocity at the point of disappearance v_e = 15 km/s were determined from the double-station photographs. The apparent radiant and the elements of the orbit are (1950.0):

$d = 283\overset{\circ}{.}7$	a = 3.70 AU	$\Omega = 116\overset{\circ}{.}41$
$\delta = 4\overset{\circ}{.}9$	e = 0.791	$\omega = 243\overset{\circ}{.}05$
$\cos Z_R = 0.8$	q = 0.771 AU	$i = 14\overset{\circ}{.}54$

The meteor orbit at aphelion stretches beyond the orbit of Jupiter and is similar in size and shape to the orbit of Denning's comet (1881 V). (Editor's note: The longitude of the node and the argument of perihelion differ by 50° or more between the comet and the meteor.)

The light curve has been computed from measurements made by the microphotometer MF-4 and by comparison with photometric standards and stars trails in the neighbourhood of the meteors image. The brightness of the meteor flare was found to be equal to -5.4 magnitude. The minimum magnitude was equal to $+2\overset{m}{.}2$. The initial mass determined from the formula

$$m_\infty = \frac{2}{\tau_0} \int_{-\infty}^{+\infty} I v^{-3} dt$$

with the use of $\tau_0 = 10^{-19}$ c.g.s.0^{mag} was found to be 22.4 g. Before the flare the meteoroid lost only 5.3 g (24%) while 17.1 g (76%) was lost during and after the flare.

FRAGMENTS

During the flare (or immediately after it) the meteoroid broke into numerous fragments. There are 69 instantaneous meteor images from the point of meteor appearance till the moment of flare and 23 photographs of 5 "submeteors" caused by the larger separated fragments. To determine the atmospheric trajectories and the individual velocities of "submeteors" instantaneous photographs together with the usual corresponding one have been used. The light curves of "submeteors" made it possible to determine the photometric masses of the fragments. From the reliable values of deceleration of the largest fragment, its dynamic mass $m_d = (\Gamma A \delta^{-2}\ {}^{3}\rho v^2 \dot{v}^{-1})^3$ has been determined. Taking $\Gamma A \delta^{-2}\ {}^{3} = 1$ we obtain the result which is in comparatively good agreement with photometric masses m_p. Thus at H = 66,8 km, m_d = 1 g and m_p = 0.72 g, at H = 63 km, m_d = 0.48 g and m_p = 0.3 g.

On the instantaneous photograph the deviation of the trajectory of the second fragment in relation to the direction of the motion of the first one, equal to 10', is clearly visible. The normal component of the fragment's velocity is v_n = 66 m/s, the photometric mass of the fragment N2 at the moment of its separation from the main body was found to be equal to 0.4 g and consequently, the energy of separation was 10^7 erg.

SPECTRUM

The zero order of the spectrum is located near the centre of the photograph while the first order is located 72 mm from it. Its linear dispersion is 67 Å/mm. The width of the spectrum of the meteor flare is 29 mm (Figure 2). Only the beginning of break-up can be observed in the spectrum. The absence of the remaining part is due to insufficient brightness. 53 instantaneous images of the spectrum have been obtained of which 45 have durations of 0.0033 and 8 0.00056.

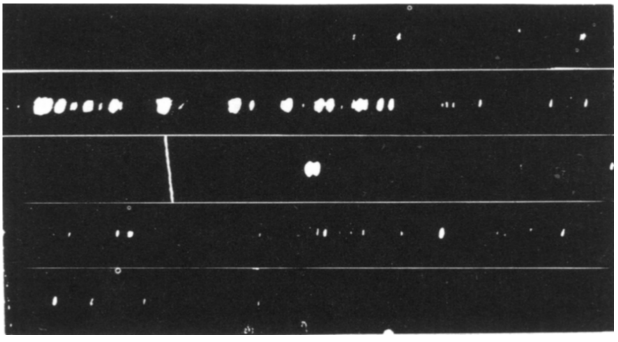

Fig. 2. Spectrum of the meteor flare. (Editor's note: The spectrum is shown in five separate bands. From top to bottom these cover the regions 4900-5135A, 5135-5640A, 5640-6137A, 6137-6637A, 6637-6843A.)

Spectrum was measured with the measuring engine "Ascorecord" and microphotometer MF-4. A total of 62 lines for the flare have been measured. From the measurements made by MF-4, 15 more blended lines have been revealed.

The blue part of the spectrum is absent on the photograph and the spectrum begins with the line 4895 Å. On the 46 instantaneous images of the spectrum only the Na doublet shows and is clearly resolved. The majority of bright lines of the flare spectrum belong to 42 different multiplets of Fe I. The rest belong to Mg I, Ca I, Ni I, Cr I, Mn I and Co I. The first positive system of molecular nitrogen N_2 has been

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detected. A very weak continuous spectrum can be observed in the region from 5890 to 6900 Å. Spectra can also be observed on the 4 instantaneous images, adjacent to the flare consisting mainly of lines of Fe I, Mg I and Na I. The spectrum belongs to the X type according to Millman's classification.

Absolute magnitudes of spectral lines of the meteor flare were determined from measurements of image density on MF-4. The characteristic density curve was constructed using zero order star images obtained without the shutter. The differences in trailing velocities of the meteor and star images on the film and corrections for the absorption in the Earth's atmosphere have been taken into account. Since the diffraction gratings transmit practically all light in the interval of wave length 4000-7000 Å, no correction for absorption is required. The intensities were obtained from absolute magnitudes according to log I = 9.72 - 0.4 M.

The short exposure of the spectrum eliminates the noncontrolled contribution in line radiation caused by radiation of wakes, trains and other effects (Ceplecha 1973). This creates favourable conditions for the investigation of physical phenomena of meteors. In the meteor light curves of Figure 3, the solid line corresponds to the normal and

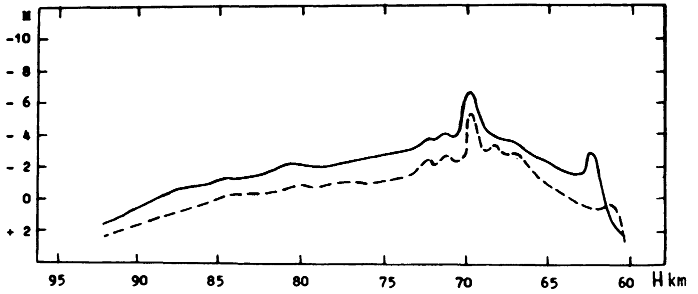

Fig. 3. Photometric curves of meteor according to instantaneous (broken line) and usual (solid line) photographs.

the dashed one to the instantaneous photographs. From the normal photograph the meteor is ∿2 magnitude brighter because of the super-imposing of the meteor train radiation.

First of all we have determined the excitation temperature of neutral iron atoms as the most strong radiator. According to Ceplecha's method (1964) we have constructed the emission curve of growth from 14 Fe I lines in the interval of 4988 - 5616 Å, for which there are reliable data of oscillator strengths (Bridges and Kornblith 1978). Local thermodynamic equilibrium was assumed. The excitation temperature was calculated as $T = 4035^{\circ}K$ and the total number of excited iron atoms in the radiating gas is $N = 7.6 \times 10^{22}$. Thus the content of Fe I in the flare was 7.1 g in agreement with the data of common mass evaporated during the flare (10.5 g). Investigations of the lines of other elements will show the degree of deviation of the radiating gas from thermodynamic equilibrium and will allow quantitative determination of the content of other elements.

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