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ON THE METEOR TRAIL SPECTRA

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Meteor radiation appears as a result of collisions between evaporated meteoroid atoms and air molecules. Depending on duration, this radiation is usually divided into the following types:

- radiation of the meteor head itself with a typical duration of about 1 s,
- radiation of a 'coma' surrounding or immediately following the meteor head,
- radiation of a trail formed as a result of fragments lagging behind or by the afterglow of meteor matter atoms and ions and air caused by chemical processes,
- radiation of a meteor train forming from a 'tail' as a result of various chemical and dynamical processes.

To investigate physical processes caused by each of the above types, it is necessary to obtain the corresponding experimental data.

The lifetime of a trail is usually 10^{-3} -10^{-1} and that of a meteor train depending on brightness, height, velocity and atmospheric conditions, may be from 1 to 10^{3} s.

The spectra of trails and short-period meteor trains were obtained by photographic cameras supplied with rotating shutters whereas determination of spectra of stable (long-period) trains remains a problem of meteor spectroscopy.

The television and optical electronics methods for meteor observations used at the Physical Technology Institute of the Turkmen Academy of Sciences since 1972 have opened up new possibilities of obtaining and investigating the spectra of trails and short-lived trains. Due to high sensititivity, these methods allowed spectrograms of meteors to be taken with exposures of 0.5-1.3 sec. The spectra of a head, trail and train are obtained as a separate series of photographs. Fig. 1 shows the photograph of a meteor spectrum and its train as two consecutive stills obtained on September 18, 1979 of the polar region of the sky, with the help of a TV frame-grabbing device. The first still shows the first half of a meteor head spectrum and the second one - its second half and the spectral lines referring to the train glow. The following spectral lines were identified in this meteor train spectrum: 5183.6°A(MgI), 5890.0°A(NaI), 7771.9°A(OI) and the forbidden oxygen line 5577°A. OVEZGELDYEV et al., (1976) investigated the peculiarities of the 5577°A line in the meteor trail spectra obtained with the help of a TV system. It was noted that this line usually appears at greater heights as compared with other lines of a meteor spectrum, i.e., at 100-120 km. However, further meteor observations with image-tubes revealed that the green oxygen line also appeared in a burst at 82-85 km. Fig. 2a shows a photometric tracing of a section of a meteor burst spectrum obtained during observations of the Perseids with an exposure of 1 sec on August 11, 1980. Fig. 2b shows a photometric tracing of the same spectrum region but in the meteor train. In Fig. 2a one can see only two bright lines referring to MgI(5183.6°A) and NaI(5890.0°A) and

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Fig. 1 Photograph of a meteor spectrum and its train in two consecutive stills, the first showing the beginning of a meteor path (upper left) the second - its end and the train spectrum (upper middle of frame). Dispersion goes from upper right to lower left.

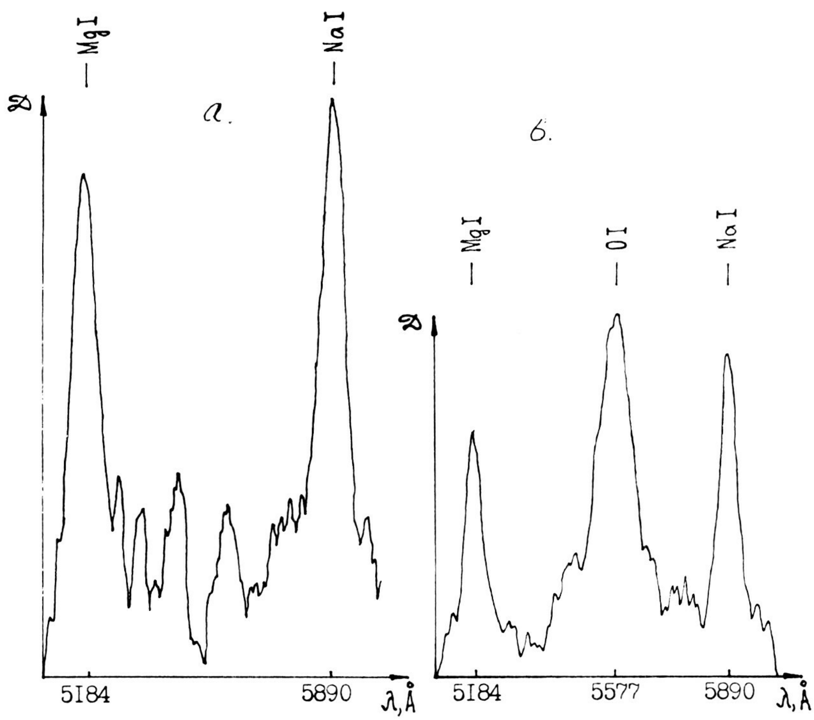

Fig. 2 a) Photometric record of a part of a Perseid meteor explosion spectrum,
b) the same after the explosion (train).

it is seen from Fig. 2b that the green oxygen line appeared in the trail spectrum after the explosion. Determination of height parameters for this meteor showed that the explosion was observed at 82.5 km. Apparently in this case, it was at the moment of explosion that the required linear density $O^+(^1S°)$ reached the 10^{14} cm^{-1} needed for the green oxygen line radiation formation (according to the following reactions):

$$O^+ + O_2 \rightarrow O_2^+ + O(^1S) \qquad k = 2,5 \times 10^{-11} cm^3/sec$$

$$O_2^+ + e \rightarrow O(^1S) + O(^1D) \qquad k = 3 \times 10^7 \ cm^3/sec$$

So, it can be clearly seen that the television and optical electronic methods allow investigation of meteor train spectra with high enough time resolution to allow the sequence of lines formation in a train and to investigate temporal variations of separate spectral lines. Fig. 3 presents typical temporal decay variations of lines 5183.6°A(MgI), 5890.0°A(NaI) and the red line 7771.9(OI) in apparent magnitudes as obtained from TV meteor observation data. The decay patterns of lines MgI and NaI are alike but that of OI(7771.9°A) proceeds more quickly. These diagrams allow one to determine the exponential decay of individual spectral lines in a meteor train. The analysis of such diagrams showed that exponential decay of MgI(5183,6°A) has time constants from 0.46 to 0.52 sec^{-1} and OI(7771.9°A) has time constants from 1.0 to 1.6 sec^{-1}. The lifetime of OI(7771.9°A) determined from TV observation data with no allowance for possible equipment persistance was 0.3 sec, a value that is in good agreement with observation data obtained by other methods.

If we assume that, as follows from KAISER (1963), the variation of meteor train brightness is proportional to the electron attachement rate ("k"), i.e. dm/dt = 1.09k, then the exponential decay dependences can help determine the speed of electron attachment in a meteor train. For example, "k" turned out to equal 0.21 for the MgI line.

In all probability, the decay of radiation of individual lines should be explained by a complex of chemical processes. For example, for MgI, the following reactions can be given:

$$Mg^+ + O_3 \rightarrow MgO^+ + O_2 \qquad k_1 = 2 \times 10^{-16} \ m^3/sec \qquad (1)$$

$$MgO^+ + e \rightarrow Mg + O \qquad k_2 = 3 \times 10^{-13} \ m^3/sec \qquad (2)$$

$$MgO^+ + O \rightarrow Mg^+ + O_2 \qquad k_3 = 10^{-16} \ m^3/sec \qquad (3)$$

Atoms of Mg as well as of O can be excited in reaction (2). As meteor trail spectra show, both these elements are the most frequently seen.

Radiation of the NaI line in meteor trains can be explained by the following reactions:

$$Na + O_3 \rightarrow NaO + O_2 \qquad (4)$$

$$NaO + O \rightarrow Na(^2p) + O_2 \qquad (5)$$

$$NaO + O \rightarrow Na(^2s) + O_2 \qquad (6)$$

$$Na(^2p) \rightarrow Na(^2s) + h\nu \qquad (7)$$

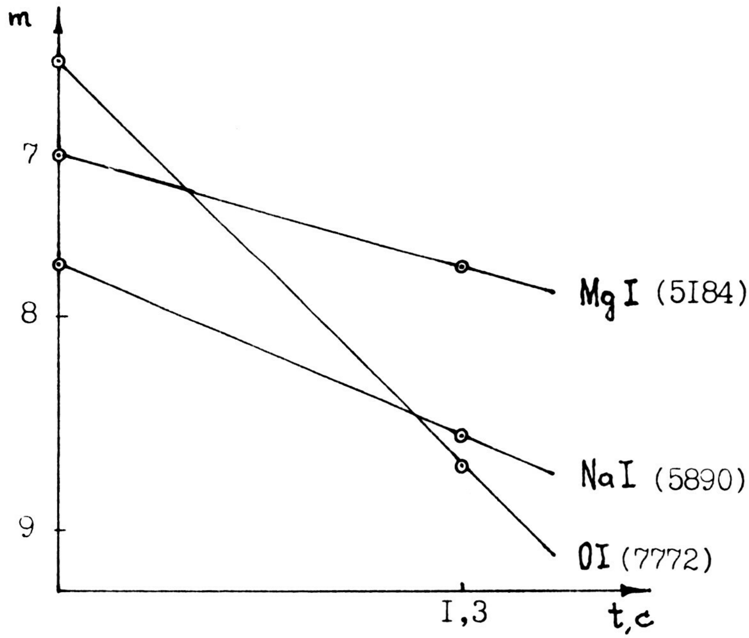

Fig. 3 Temporal dependences of spectral line decay in a meteor train.

Temporal variations of spectral lines of a meteor train obtained from our observations confirm the results of POOLE, (1978) where train radiation (L) is given as a number of photons per second, per one meter of meteor path length assuming dissociative recombination reactions is determined by the linear concentration of positive ions per cm^{-1}, as well as by electron, ozone and oxygen concentrations. Decay of the MgI line in a meteor train can be described by

$$\frac{dh_\nu}{dt} = L = -\, pbk_1\ (O_3)\ \alpha(Mg^+)$$

where $\alpha(Mg^+)$ is the linear concentration of positive Mg ions per cm^{-1} in a meteor trail, p is the photon energy produced during recombination,

$$b = \frac{k_2[e]}{k_2[e] + k_3[O]} \quad ; \quad [e] = \frac{\alpha[Mg^{\pm})}{4\pi Dt}$$

Our meteor train spectra, also showed a number of weak lines: FeI (4046°A, 4064, 4272, 4308, 4326, 4384, 4405), CaI (4455°A, 4227) and the lines of atoms of SiI, ions of SiII, CaII, MgII as well as the neutral lines of atomic and molecular nitrogen.

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