CORRELATION OF HEIGHT AND FORBIDDEN OXYGEN LINE STRENGTH FOR PERSEID METEORS

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During the 1977 and 1978 Perseid showers, seventeen meteors were simultaneously photographed with a spectrograph and with a camera equipped with a rotating shutter. Of the eight best examples, the half in whose spectra the forbidden line of neutral oxygen at λ5577 was relatively strongest appeared and disappeared at heights about 9 km. greater than did the half in whose spectra the line at λ5577 was relatively weak. Structural or compositional differences in the meteoroidal particles appear to be the most likely explanation for these height variations. A by-product of the investigation was an average value of -8.8 km/sec^2 for the deceleration of the meteors over the observed trajectories.

INTRODUCTION

Since the identification in the spectra of meteors of the forbidden neutral oxygen line at λ5577 (Halliday 1958), hereafter referred to as the green line, varying degrees of correlation have been proposed relating its strength to meteoric velocity, geomagnetic activity (Halliday 1960), solar activity (Halliday 1960, Russell 1973a), the strength of the H and K lines of ionized calcium (Russell 1963), the altitude of the radiant and atmospheric tides (Russell 1973b). In 1972 two Perseid spectra were photographed on the same film (Russell 1973b), the brighter showing no green line but the fainter showing it prominently. This pronounced change of line strength on such a short time scale provided evidence that, in addition to the environmental considerations, some difference in the physical properties of the meteoroids might be a major factor in the variation of the strength of the line. Ceplecha (1968) has shown that the beginning heights of meteors tend to cluster around two or three values. Cook (1973) finds that similar discrete levels exist for the beginning heights of shower meteors. They attribute this effect also to compositional or structural differences in the meteoroids. It appeared worthwhile, therefore, to investigate the possibility of a correlation between the strength of the green line and the height of appearance and disappearance of the meteors that exhibit this feature in their spectra.

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OBSERVATIONS

The instrumentation consisted of two cameras. Camera A, with an f 2.5 lens of 178 mm focal length, was equipped with a 25° prism. Camera M has an f 3.5 lens of 100 mm focal length, in front of which a rotating shutter was mounted that occulted the lens 20 times a second for 1/40 second. Both cameras were located at one observing site and directed toward the same point in the sky. Five Perseid meteors were photographed by both instruments on 1977 August 13 between 10^h and $10^h\ 50^m$ U.T. Twelve additional pairs were recorded 1978 August 12 between $6^h\ 49^m$ and $10^h\ 4^m$ U.T. The eight best pairs serve as the basis for this study.

REDUCTIONS

The right ascensions and declinations of the points of appearance and disappearance of the meteors were calculated by the method of dependencies (Schlesinger 1911) from shutter-chopped images of Camera M. The average error in the 24 coordinates of 12 check stars, determined by the same procedure, was 1.75 minutes of arc. Appropriate corrections for precession, daily motion, and zenith attraction were applied to the Perseid radiant coordinates of Wright and Whipple (1953).

The calculation of meteor heights from single-station observations through a rotating shutter requires values for both the linear and the angular velocity. The former was assumed to be 60 km/sec, an assumption made by Millman et al. (1971) in single-station height calculations. The angular velocities were obtained by least squares solutions for dx/dt as a function of x, the measured coordinate along the trail, dx/dt then being converted to angular velocity ω with the aid of the plate scale. Designating the tangential velocity as V_T, the distance of the meteor from the observer as D_M, its angular distance from the radiant as D_R, the angular altitude of the meteor as h_M, and its height above the observer's horizon plane as H_o, $V_T = 60$ km/sec $\sin D_R$; $D_M = V_T/\omega_{rad}$; $H_o = D_M \sin H_M$. Finally H_o is corrected for the altitude of the observer and for the earth's curvature to give H, the height above sea level.

It soon became evident that the calculated heights were internally inconsistent. The assumed linear length of the observed trajectory, 60 km/sec x t sec, multiplied by the sine of the radiant altitude should equal the difference in the heights of appearance and disappearance above the plane of the observer's horizon. In all cases the difference in the altitudes is too small. The most obvious probable source of this inconsistency is the assumption of a constant velocity. Terminal velocities were thereupon calculated, by successive approximations, that would provide internal consistency. They appear in column five of Table 1. The first four columns of the table contain the designation of the meteor, the number of segments into which each trail was chopped, and the heights of appearance and disappearance above sea level. Column six contains the average decelerations over the observed paths.

Table 1
Height, Velocity and Spectral Data on Perseid Meteors

Meteor No.	No. of Segments	Beginning Height km	End Height km	Velocity at disappearance km/sec	Deceleration km/sec^2	No. of Spectral Lines	Strength of λ5577
77A104	7	107.8	92.3	58.9	-3.4	4	5
77A106	7 1/4	98.9	81.6	57.5	-6.9	3	1 1/2
77A108	9 1/3	95.1	75.6	52.3	-16.5	14	2
78A31a	14	107.4	84.4	55.3	-7.0	25	4
78A31b	12	105.0	85.1	56.7	-5.7	4	5
78A37a	11	97.3	76.4	54.0	-11.4	16	3
78A37b	12	91.3	76.1	55.5	-7.8	7	3
78A38	9 1/4	101.0	81.9	54.4	-12.1	14	4

DISCUSSION

Jacchia et al. (1967) state that for most meteors, the velocity does not change by more than a few percent in the course of the observed trajectory. These Super-Schmidt results and those of an earlier study by Jacchia (1948) made with cameras more nearly similar to those used here are compared in Table 2 with the meteors of Table 1. Clearly the assumption of minimal deceleration becomes less valid with increasing atmospheric penetration.

Table 2
Perseid Meteor Accelerations

Investigators	Number of Meteors	Mean Height km	Mean Acceleration km/sec^2	p.e. km/sec^2
Jacchia et al.	11	102.2	-1.8	±1.6
Jacchia	10	92.4	-5.5	±2.5
Russell	8	91.1	-8.8	±2.8

The main thrust of this investigation, however, is the possible correlation of height with green-line strength. Columns 7 and 8 in Table 1 give the approximate number of spectral lines in each spectrum and the strength of the green line on the following arbitrary scale: 1) Not visible, 2) Discernible, 3) Easily visible but fainter than the sodium D-line, 4) Stronger than the D-line outside of bursts, 5) Strongest spectral feature. Table 3 lists the mean heights of appearance and disappearance grouped according to green-line strength. It will be noted in Table 1 that neither for the height of appearance nor disappearance does the greatest height in group 1 exceed the lowest height in group 2.

Table 3
Meteor Heights vs Green-line Strengths

Group No.	No. of Meteors	λ5577 Strength	Average Height of Appearance	Average Height of Disappearance
1	4	1.5-3	95.6 ± 2.2 km	77.4 ± 1.9 km
2	4	4-5	105.3 ± 2.1 km	85.9 ± 3.0 km

Millman et al.(1971), using an image orthicon, found the green line present in all 14 of the Perseid spectra that they studied. When the spectra were grouped according to the decreasing duration of the green line, no significant systematic trend in the beginning heights was noted among their four groups, but for the end heights there was a trend toward higher values for meteors of shorter green-line duration. These conclusions appear at first to be at variance with the data in Table 3. Millman, however, grouped his meteors according to green-line duration, whereas the meteors in this paper are grouped according to green-line strength relative to that of the spectrum in general and the D-line in particular. If Millman's meteors are also placed in two groups according to the ratio of the strength of the green line to that of the D-line (G/D), the six with the greatest G/D ratio disappeared at an average height of 96.2 km whereas for the six with the smallest G/D ratio the average height of disappearance was 94.5 km, which indicates a trend in the same direction but of smaller magnitude than that shown in this study.

Since the green line characteristically appears before the balance of the meteoric radiation, it is not surprising that the group 2 meteors have higher altitudes of appearance than those of group 1. The greater heights of disappearance for group 2 can not be so directly explained. The assumption of a structural or chemical difference, as invoked to explain characteristics of Draconid meteors, may therefore be warranted.

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