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A COMPLEX PERSEID SPECTRUM

BY

P. M. MILLMAN

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A Complex Perseid Spectrum

BY

PETER M. MILLMAN*

DURING observations of the Perseid meteor shower in August, 1952, the spectrum on the third page of this article was photographed by the writer at Meanook Meteor Observatory, Alberta, with the assistance of G. A. Brealey. This is a station operated by the Dominion Observatory, Ottawa, and is located in latitude 54° 36′ 56″ north, longitude 113° 20′ 45″ west, at 2,240 feet above sea level. At the same time, A. A. Griffin and J. M. Grant were taking direct photographs of the Perseids at the Newbrook Meteor Observatory 25.6 miles distant, at latitude 54° 19′ 26″ north, longitude 112° 57′ 15″ west, elevation 2,200 feet.

The meteor appeared in Cygnus at 0:52:44 MST, August 13, 1952. Its visual magnitude was estimated as −2 by Mr. Griffin at Newbrook. I was walking down to the power house in Meanook at the time to check the frequency control of the generators and did not see the meteor itself. The flash, however, was bright enough to be seen on the ground, and when I looked up the train was clearly evident, remaining visible to the naked eye for between 10 and 12 seconds. From the appearance of the Meanook spectrum photograph, the Newbrook estimate of visual magnitude may have been a bit faint. The distance of the meteor from Newbrook (where sky conditions were poor, with considerable cloud) was 5 to 10 per cent greater than from Meanook (where the sky was clear). Thus it is quite possible that the meteor was brighter than magnitude −4 at maximum light, as seen from the spectrum-camera site.

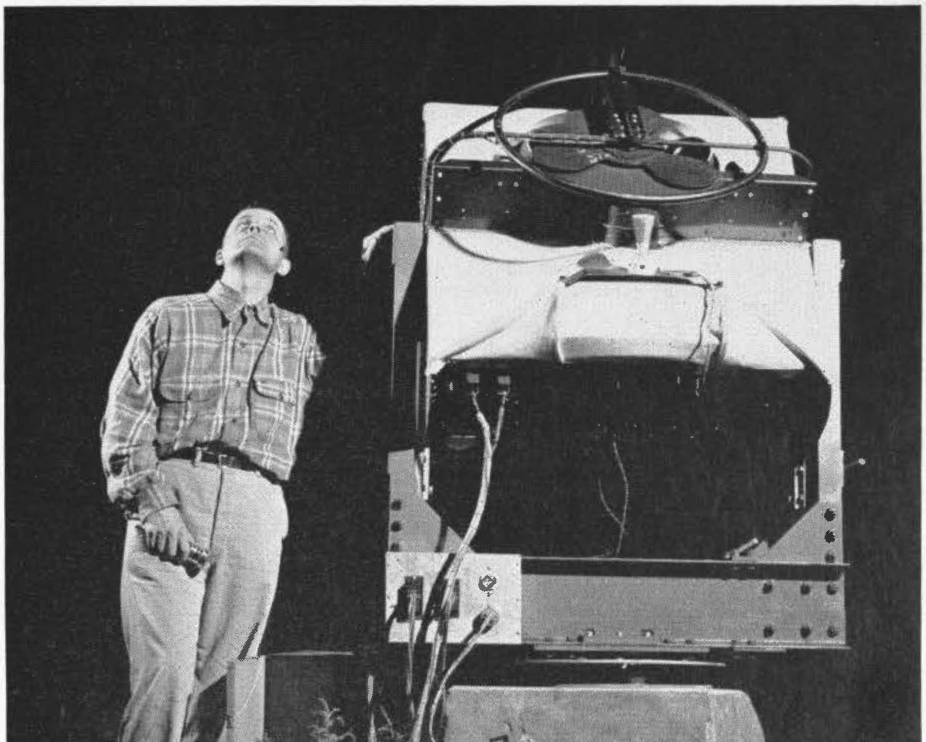
The picture was taken with a Williamson aerial camera, equipped with a Pentac lens of 2.75 inches aperture and of 8-inch focus. This camera was one of three on the same mounting, which was designed by the Radio and Electrical Engineering Division of the National Research Council, Ottawa.[1] A similar mounting, in use near Ottawa, is illustrated here. At Meanook, a four-vane rotating shutter covered the lens 24 times per second, giving equal intervals of exposure and occultation, thus chopping a meteor trail into segments, whose lengths indicate the meteor's velocity.

To form the spectrum, in front of the lens was placed a Bausch and Lomb replica grating, mounted on glass and ruled with 200 lines per millimeter. It must be remembered that a grating, in contrast to a prism, gives a direct image and a number of spectrum images on both sides of this. In old-fashioned gratings the percentage of light in any one image was small. Modern techniques of cutting the grating grooves now make it possible to concentrate most of the light into one specific spectrum image. Thus, at Meanook we used such a blazed grating, which directed about three quarters of the incident light into the first-order spectrum above the direct image as the picture is here oriented.

The emulsion was Eastman Super XX Aero film, which comes in rolls 56 feet long and 5½ inches wide. This is sensitive to light from the ultraviolet through the visible spectrum to a wave length just to the red of the Hα line of hydrogen.

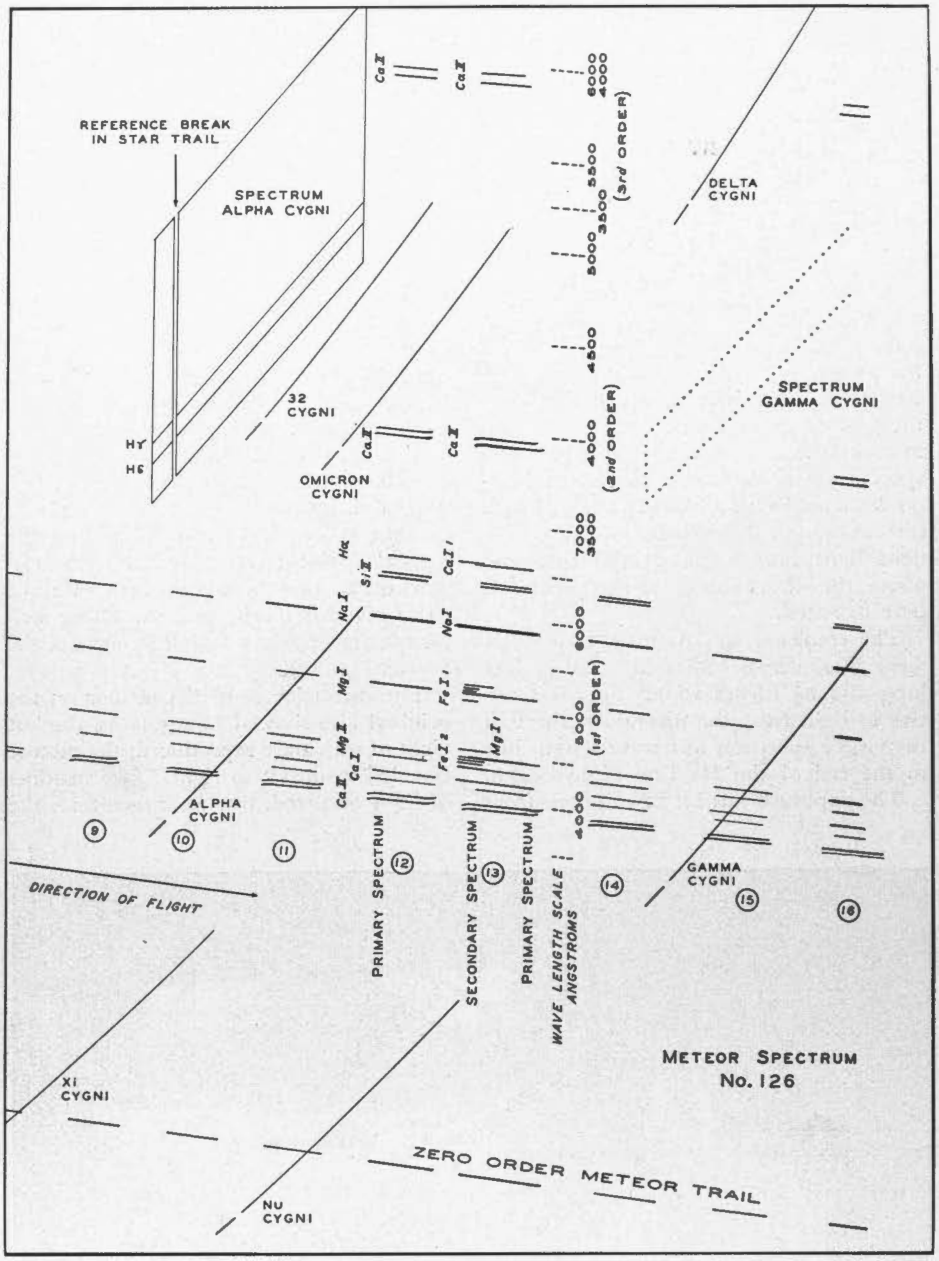
The exposure was for 22 minutes, from 0:40 to 1:02 MST, and the lens was covered for 20 seconds at 0:42. The direct images of the star trails can be seen running diagonally from lower left to upper right, with the 20-second break clearly visible near the beginning of each trail. The brightest star in the photograph is Deneb, a white supergiant star of apparent magnitude 1.3. Its spectrum can be seen above its direct trail, and on the original exhibits strongly the very narrow dark lines of hydrogen typical of these high-luminosity *A* stars. Other stellar spectra appear very faintly against the sky background.

The direct image of the meteor on the original film showed 16 segments, the last eight of which are reproduced; the meteor traveled from left to right. Two maxima of light occurred, one at segment 13, the



Peter M. Millman and a battery of meteor spectrographs similar to the one with which the Perseid spectrum on page 377 was obtained. Photograph by George Hunter for the Dominion Observatory.

*National Research Council, Canada, formerly at the Dominion Observatory, Ottawa.



This chart provides a key to the photograph of the Perseid meteor spectrum opposite, which was made with a diffraction grating. It shows at the bottom a direct image of the meteor itself in the zero order, broken into segments by a rotating shutter. But the turning of the shutter was too rapid to affect the star trails, which appear in the zero order also. Next upward in the picture is the spectrum of the first order, with the violet H and K lines of ionized calcium prominent, together with lines of many other elements. Then come spectra of the second and third orders, but these are relatively weak and show practically only the H and K lines. The first-order spectrum of Deneb contains typical hydrogen absorption lines. A portion of the meteor fragmented off between segments 12 and 13, producing the secondary spectrum of lower excitation. From the original negative of this picture all of the lines in the table on page 378 have been identified. Dominion Observatory photograph.

other at the end of the trail, segment 16. The first of these segments is compound, for it shows a secondary image trailing behind the primary. This secondary image resulted from a portion broken off from the main meteor mass, giving a spectrum of much lower excitation and hence very different from the primary spectrum.

A direct photograph of the same Perseid was secured at Newbrook, where the height of appearance was 112 kilometers, according to a preliminary reduction of the two photographs. Segment 1 on the Meanook plate corresponds to a height of 107 kilometers. The heights of the last 11 segments of the spectrum photograph are: Segment 6, 97.8 kilometers; 7, 95.8; 8, 93.9; 9, 91.9; 10, 90.0; 11, 88.1; 12, 86.2; (secondary, 85.0) 13, 84.3; 14, 82.4; 15, 80.5; 16, 79.0.

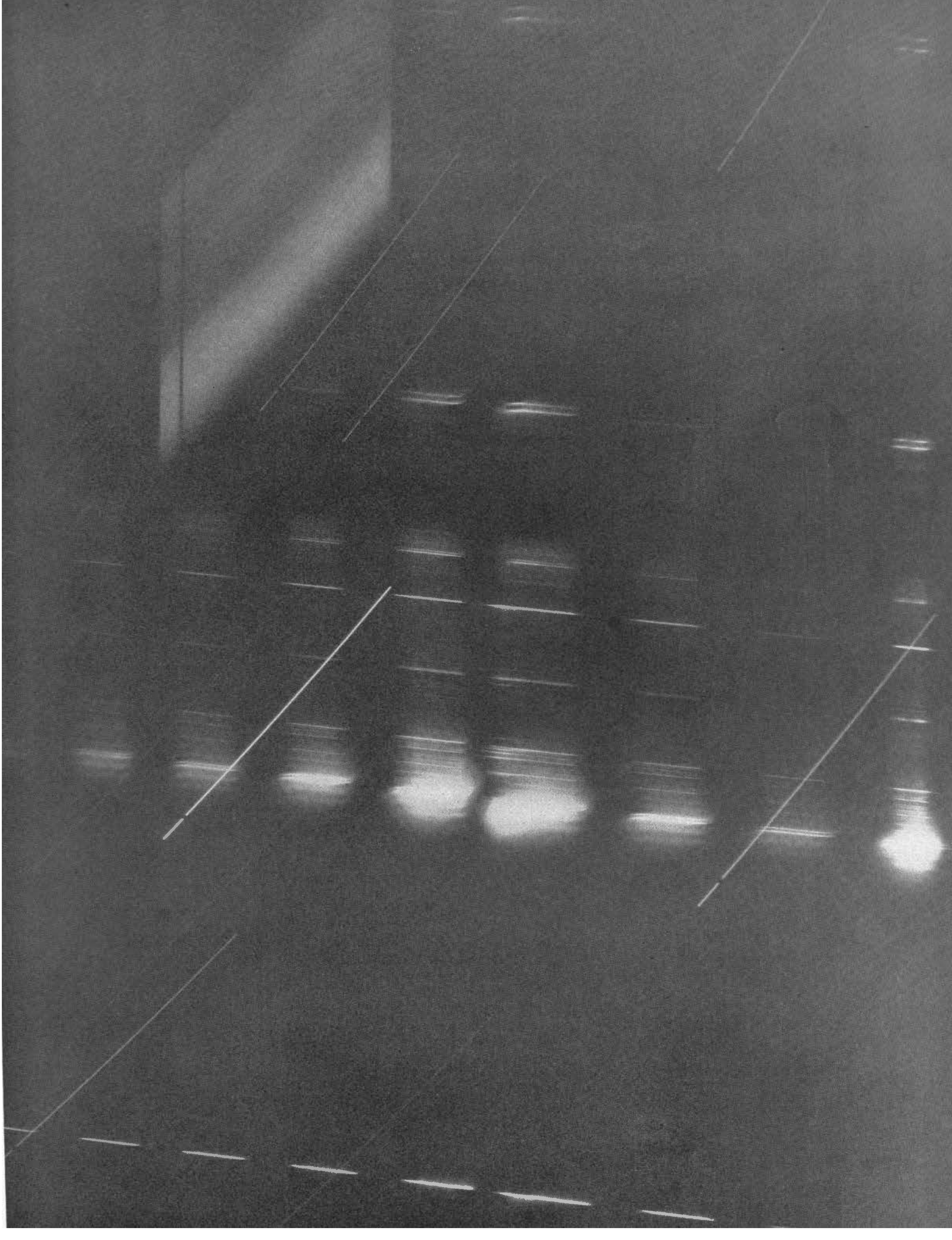
The visual persistent train that I plotted at Meanook was found to occupy a position from segment 6 to segment 13, corresponding to heights from 98 to 84 kilometers. The lower end of the visual train apparently coincided with the first light maximum of the primary mass, and with the maximum light of the secondary, which was trailing the main mass by about 1.5 kilometers at this point. (The height of the secondary spectrum here is nearly the same as that of the brightest part of the train spectrum of a 1949 Perseid recorded at Ottawa.[2])

The apparent radiant point of this meteor was at altitude 48°, azimuth 51° east of north, very close to the average position of the Perseid radiant for the date. A preliminary calculation of the observed velocity gives just over 60 kilometers per second, again in close agreement with the mean for the Perseid shower.

It will be noticed that the images of the ionized calcium lines are twisted at the ends, making them resemble integration symbols. This peculiar appearance results from lens aberrations, which are stronger at the violet end of the spectrum. The resulting slightly out-of-focus image is shifted when part of the lens is covered by the shutter, as is the case at either end of a segment of the trail.

This meteor spectrum is No. 126 on the world list.[3] More than 100 lines were measured in the primary spectrum and over 30 in the secondary. The features of the primary agree well with those of typical Perseids,[4] but they are shown here in greater detail than in any other meteor spectrum yet photographed. Thus Table I, in which are given the wave lengths of the lines measured, serves as a convenient guide to lines normally present in the spectra of fast meteors. The strongest lines are marked with asterisks. The reader should be able to pick out most of the lines with the help of the wave-length scales given in the key to the photograph. In general, the observed meteor wave lengths agree very well with those predicted from blends of laboratory wave lengths.

An atom of any element may exist in one of a number of states, each characterized by a definite amount of potential energy of the atom. When an atom changes from a higher energy level to a lower, light may be emitted, and this light has a wave length inversely proportional to the energy lost by the atom. If the energy levels in an atom are themselves complex, one pair of levels may have several possible energy differences, and give rise to several wave lengths, or spectral lines. These are said to form a multiplet, and a single multiplet may contain many lines. In discussing spectrum photographs such as this one, it is convenient to consider the multiplets as units, since the lines of one multiplet generally appear or disappear together. Therefore Table I also shows the multiplets identified for each element, num-



bered as in the tables by Charlotte E. Moore, in *Contributions from Princeton Observatory*, No. 20, 1945.

The secondary spectrum, produced by the material that broke off from the main mass, has a marked absence of all the ionized lines but those of CaII (singly ionized calcium), which appear at greatly reduced strength. On the other hand, multiplets arising from the ground levels of the neutral atoms are unusually strong, notably FeI 1, FeI 2, MgI 1, and CaI 1. Generally the spectra of fast meteors show the ionized lines of magnesium, silicon, iron, and calcium, but this secondary spectrum confirms evidence from other meteor spectra that the light from the small particles or dust trailing behind a fast meteor may be of relatively low excitation. Bursts in meteor trains seem to result from rapid disintegration of a portion of the main mass, which increases the number of trailing dust particles; thus it is not surprising that the excitation of the iron vapor tends to be lower at bursts, as was found by the writer in 1935.[5]

In all, 66 multiplets of nine neutral elements (FeI, MnI, CaI, SiI, AlI, MgI, NaI, NI, and HI) and of four ionized elements (FeII, CaII, SiII, and MgII) have been identified in the spectrum of this meteor. The photometric study of this photograph has not been completed.

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2. Millman, P. M., *Nature, 165*, 1013, 1950.
3. Millman, P. M., *Journal* of the Royal Astronomical Society of Canada, *47*, 217, 1953.
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TABLE I – WAVE LENGTHS MEASURED IN SPECTRUM NO. 126

Primary Spectrum I.A.	*Multiplets Identified*	*Secondary Spectrum I.A.*
	FeI 23	3612
3706.9	FeI 5 FeI 21	
3740.7		
3766.1		
3813.9	FeI 4 FeI 20 MgI 3	
3833.4		
3843.5		
3859.6	SiII 1	
3868.2		
3886.8		
3933.5*	CaII 1 SiI 3	3927.5
3968.7*	FeI 43	3963.7
4005.3		
4031.0	MnI 2	
4045.2		4045.0
4063.4		4063.7
4071.3		
4105.3	SiI 2	
4116.4	FeII 28	
4129.9	FeI 3 FeII 27 SiII 3	
4143.0		
4177.5	FeI 42	
4188.5	FeI 152	
4201.1		
4211.2		4214.7
4226.5*	CaI 2	4225.2*
4235.4		
4249.1		
4254.8		4254.8
4261.8		
4272.4		4270.0
4291.0	FeI 41	4290.7
4307.7		4307.7
4325.6		4324.8
4338.5		
4352.8	MgI 14	
4376.5		4375.0*
4383.3*		
4394.2		
4404.9		4403.4
4415.6		
4427.8	FeI 2 CaI 4	4426.2*
4433.9		
4462.0	FeII 37	4460.9*
4481.4*	MgII 4	4482.5*
4508.1	FeII 38	
4516.6		
4523.1		
4531.0		
4546.0		
4552.6		
4556.9		
4570.2	MgI 1 CaI 23	4569.4
4584.7		
4616.9		
4630.1		
4647.4		
4666.4		
4700.7	MgI 11	
4863.1	FeI 318 HI 1	
4873.9		
4888.8		
4923.0	FeII 42 FeI 16	
4957.6		
5012.8		
5018.4		
5024.4		
5040.2	SiII 5	
5056.8	FeI 1	
5110.2		5108.8*
5126.8		
5143.8		
5170.3*	MgI 2	5167.9*
5184.0*		5180.9
5186.2	FeII 49 CaI 49	
5206.1		5206.4
5229.8		5225.6
5249.2		5248.6
5269.1	FeI 15 FeII 48 CaI 22?	5271.6
5301.8		
5313.7		
5326.0		5327.8
5369.4		
5403.4		
5429.4		5432.6
5453.2		5454.1
		5484.3
	MgI 9	5531.4
5559.9	NI 25?	
5591.3	CaI 21	
5603.9		
5635.9	FeI 1087?	
5659.6		
5683.4	NaI 6	
5861.3	CaI 47	
5870.7		
5892.4*	NaI 1	5891.0*
5948.0	SiI 6	
5979.4	SiII 4	
6008.3	NI 16?	
6124.5	CaI 3	
6159.4	FeII 74? CaI 20 NaI 5	6163.3
6316.9	FeI 13? FeI 168 MgI 23	
6347.3*	SiII 2	
6371.2*		
6399.1		
6438.9	CaI 18	
6448.6	CaI 19	
6459.3		
6465.6		
6478.5		
6486.4		
6494.2		
6505.6		
6562.9	FeI 268 HI 1	
	CaI 1	6573.0
		6594.6
6620.3	NI 20?	
6657.7		
6695.7	AlI 5?	

Footnote to table:—
Where three wave lengths are close-spaced the values refer to the center and the wings of a single line or band.