NOTES FROM OBSERVATORIES

Interference Filter Photometry of Weak Emission Lines in CQ Cephei

By M. K. Vainu Bappu and S. D. Sinvhal
Uttar Pradesh State Observatory, Naini Tal, India

The first attempt to determine a light curve of the Wolf-Rayet eclipsing binary CQ Cephei in the light of the emission line 4686 A of ionized helium was made by Hiltner.[1] The result obtained was contrary to the behaviour of the system in integrated light, in that a maximum intensity of 4686 A was observed at times of conjunctions and a minimum intensity outside eclipses. Hiltner's observations of this interesting phenomenon were made with a Cassegrain spectrograph used as a monochromator with an exit slit that allowed 72·7 A of the spectrum to fall on the photomultiplier placed behind. Subsequently we have[2] studied photographically, from spectra obtained with the Mount Wilson 60-inch reflector, the behaviour with phase of other emission lines in CQ Cephei and found that all the investigated lines indicated the same pattern of variation as reported by Hiltner for 4686 A. Since photographic methods are not capable of the same precision as photoelectric methods, we have studied the same system photoelectrically, employing interference filters, and confining our measures to the 4861 A and 5411 A emission lines of *He* II.

The observations reported herein were made with the 10-inch refractor. Second order interference filters having 70 per cent peak transmission and a width at half intensity of 50 A were used to isolate the emission lines and the continuum at 5300 A. These three filters were adjusted to yield peak transmission wavelengths of 4872 A, 5317 A and 5423 A. The continuum at 5000 A was isolated with the aid of an interference filter centered at 4997 A and having a width at half intensity of 80 A.

To estimate the continuum underlying the emission lines studied we have measured the intensity ratios (4861 A/5000 A) and (5411 A/5300 A) in the comparison star BD 56° 2813. The spectrum of this star is given in the HD catalogue as A3 and corresponds closely in colour temperature to that of a Wolf-Rayet star. As such it is a reasonable assumption to make that the ratio of continua, at the wavelengths transmitted, are identical in both the comparison star and the eclipsing system. Any departures from this assumption will only introduce a scale error in the determination of emission line variation. We have, therefore, not taken into account the loss of light at 4861 A in the comparison star caused by the presence of the $H\beta$ line in absorption.

An observing run on any night was typically as follows. Each emission line was treated separately. A series of six pairs of deflections (a pair comprising a deflection each in the regions corresponding to emission line and the neighbouring continuum) was obtained on the comparison star followed by two pairs on the sky. Six to eight pairs of deflections were then obtained on the variable star followed by two pairs on the sky in its vicinity. The filter slide was then changed for the other emission line and the same sequence of observations repeated. Such observations were continued over an interval of six to eight hours each night.

The observations reported herein were obtained on eight nights during the period 1958 October 31 to November 8. Our observations indicate that the maximum intensity of emission radiations occurs earlier by $0^{d}{\cdot}08$ than the primary minimum calculated on the basis of the epoch and period given by Hiltner. Unfortunately bad weather prevented us from verifying the change in the predicted time of primary minimum. In the diagrams reported hereinafter the necessary correction for phase has been applied. Figure 1 is a plot of the magnitude differences observed between the radiation transmitted through the interference filter centered on the emission line and that obtained through the filter isolating the continuum. Such

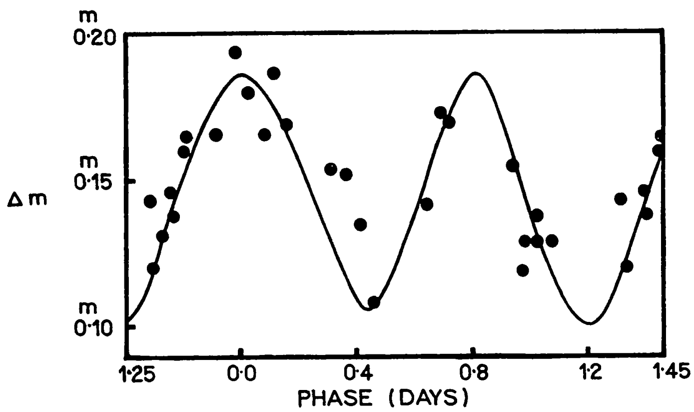

FIG. 1. Plot of the magnitude differences of CQ Cephei between the radiation transmitted through the interference filter centered on the emission line at 5411 A and that obtained through the filter isolating the continuum at 5300 A.

a procedure is identical with the derivation of an instrumental colour in conventional wide-band photometry. The scatter among the points corresponds to a probable error of about 0·01 magnitude in the ratio. Such a value of the probable error, while not very large, is still greater than values we normally come across in accurate photometry. The lower precision in this investigation stems essentially from the smallness of the deflections, caused by the faintness of the star and by the narrow pass-band of the filters employed. Figure 2 is a plot of the variations experienced by the emission lines. The data plotted in Figure 1 were treated using the ratios derived for the comparison star, to yield emission line intensities which are shown in Figure 2. The probable error of these determinations is considerably greater than those obtained for the ratios of radiation transmitted by the filters and this is caused mainly by the weakness of the emission lines. On the spectra available to us the equivalent width of the 5411 A line, out of eclipse, is about 4·5 A; that of the 4686 A line outside of eclipse, is nearly 29 A. This fact is one of the major reasons for the low scatter of points in Hiltner's monochromatic light curve at 4686 A.

The photoelectric observations reported here confirm the nature of emission line variation reported by us earlier from photographic spectrophotometry. The helium lines all vary similarly with phase and exhibit simultaneously a maximum intensity at times of conjunction. This proves that such a behaviour is an intrinsic property of the emission envelope around the star and is not caused by any selective excitation or fluorescence effects that may be responsible to some extent in the formation of the 4686 A line.

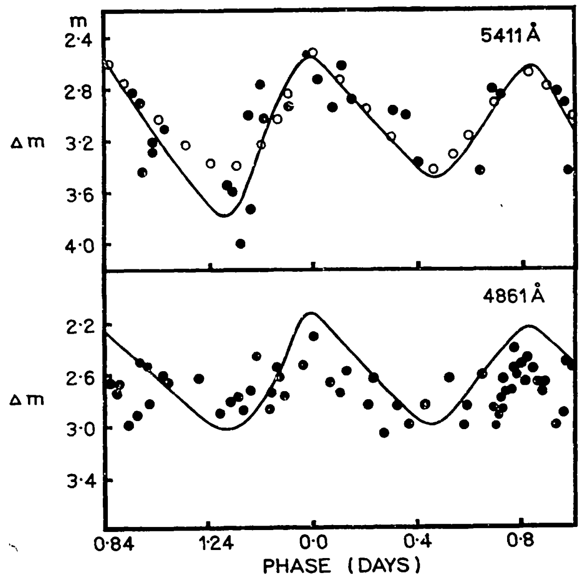

FIG. 2. Upper diagram: Plot of the 5411 A emission line intensity in CQ Cephei. The filled circles and the solid line represent our data. The open circles represent a fit of Hiltner's 4686 A emission curve to these data.

Lower diagram: Plot of the 4861 A emission line intensity in CQ Cephei. The filled circles represent our data. The solid curve is a fit of Hiltner's 4686 A emission line curve to these data.

The emission line intensities of 4861 A have a much greater scatter than those of 5411 A. The monochromatic light curve for 4861 A also has a different shape from that obtained for 5411 A. The deflections obtained for 4861 A are double in value those obtained for 5411 A and naturally should yield a higher accuracy. A behaviour contrary to such an expectation is caused solely by the large scale changes of structure observed in the profile of 4861 A.

Our observations also establish that for a convenient and accurate study of variations in emission line intensities of stars the present technique of photoelectric photometry employing narrow pass-band interference filters is quite powerful and hence brings similar investigations within the scope of small telescopes.

References

(1) W. A. Hiltner, *Ap. J.*, **112**, 477, 1950.
(2) M. K. V. Bappu and S. D. Sinvhal, *A.J.*, **60**, 125, 1955.