Astron. Astrophys. 76, L18–L20 (1979)

ASTRONOMY AND ASTROPHYSICS

Letter to the Editor

The UV Spectrum of VV Cep in 1978

R. Faraggiana[1] and P. L. Selvelli[1,2]

[1] Astronomical Observatory of Trieste, Via Tiepolo, 11, I-34131 Trieste, Italy
[2] ESA-Villafranca Satellite Tracking Station, Apartado 54065, Madrid, Spain

Received May 11, 1979

Summary. VV Cep spectra taken by IUE in June and July 1978 are examined. At this initial phase of the chromospheric eclipse following the totality of the 1977 eclipse, the chromospheric line spectrum is well developed in the region 2500-3000 Å, superimposed to the spectrum of the hot companion. The flux distribution derived from the low resolution and large aperture spectra seems to indicate that the temperature of the secondary star is about 10000 K. The absolute magnitude derived from the Mg II lines confirms the value of $M_V = -4$ derived from a long series of astrometric measures by van de Kamp.

Key words: VV Cep - chromospheric eclipse - UV spectrum.

1. Introduction

The end of totality of the 1977 eclipse of VV Cep was predicted to occur in spring 1978 just at the time when IUE Observatory began routine observations. The first evidence of the beginning of the chromospheric eclipse for the ingress phase has been detected in the spectral region 3300-3800 Å about two years before the beginning of the totality (Wright, 1975; Faraggiana, 1976). We can forecast that chromospheric effects mainly in the lines associated with the extended atmosphere of the primary star will be observed during the two years following the fourth contact and that they will be more important in the IUE λλ range than on the ground spectra; in fact the continuum of the B star dominates in the UV range and therefore the chromospheric absorption lines become visible. The spectral type of the hot companion is still quite uncertain; no lines associated with the secondary star could be detected in the photographic region and the assigned spectral types - O8 derived in an indirect way from the study of H_α by Hutchings and Wright (1971) as well as the spectral type B1.2V, derived from photometric analysis by Wawrukiewicz and Lee (1974) - are probably too early, when compared with the present UV data.

2. Observations

VV Cep has been observed by IUE in 1978. Low resolution (LR) spectra covering the short have been converted in absolute flux (in erg s^{-1} cm^{-2} A^{-1}) using the joint US/UK/ESA calibration communicated by R.C. Bohlin and M.A.J. Snijders on Sept. 18, 1978.

3. Data analysis

a) The continuous spectrum

The observations made with the low resolution and the large aperture have been done in order to measure the continuous flux avoiding possible light loss through the 3" hole. The flux variations in the short wavelength range between June and July 1978 are given in Fig.1a. No spectrum has been obtained during the observation of April 19; the spectrum obtained on June 6 with one sixth of the exposure time of April 19 is only partly underexposed. This indicates that the star was still at least partly eclipsed during the first IUE observation.

The comparison between the two spectra of June and July indicates a variation in the flux distribution associated with the progress out of the eclipse. For λ>1450 the mean flux in July is about 0.3 in logarithm higher than (1175-2000 Å) and the long (1960-3250 Å) wavelength region have been obtained in June and July. One spectrum taken in the high resolution mode has been used for studying the Mg II resonance lines. The IUE counts for the LR

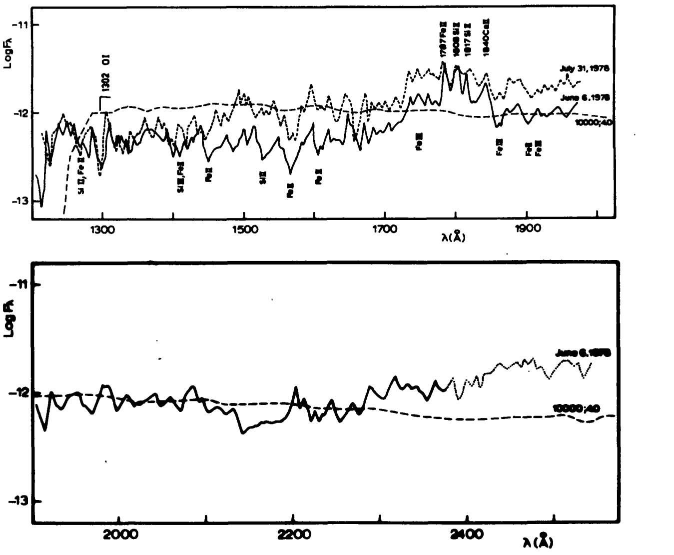

Fig. 1. The LR spectrum of VV Cep.

Send offprint requests to: R. Faraggiana

* Based on observations with the International Ultraviolet Explorer collected at the Villafranca Satellite Tracking Station of European Space Agency

in June while the flux at the top of the strong emission lines in the region around 1800 Å remained constant. These emission lines are probably formed in the extended atmosphere of the M star; they appear therefore less prominent on the July spectrum being filled up by a stronger continuum presumably due to the emerging secondary star. For $\lambda<1400$ Å the mean flux remained constant; it appears flat and is probably due to overlapping of strong chromospheric lines. What we are measuring are absolute fluxes and therefore, assuming that the constance of the flux in the region 1200-1400 Å is real, since both spectra have been obtained with the large aperture, it follows that the July spectrum in the region 1450-2000 Å presents a mean flux whose value increases with λ more than in the June spectrum. We are inclined to interpret it mainly as the flux distribution of the emerging hot companion. In fact if we assume, as a first rough approximation, the flux distribution for the primary star given by the Planck curve at 3000 K, the UV magnitudes of the M supergiant are m = 23 and m = 16 at λ = 1500 Å and at λ = 2000 Å respectively. Therefore the contribution of the M star is expected to be negligible in the region below 2000 Å as compared with that of the hot companion whose visual magnitude is 7.5 (Cowley, 1969).

The comparison between the mean flux of VV Cep with that of normal stars observed by S2/68 and with the computed fluxes of Kurucz (1979) indicates that the present mean flux distribution of VV Cep reproduces neither the theoretical nor the observed flux of any normal star whichever is the chosen temperature. If we restrict the comparison to the region longward 1450 Å, from the flatness of the flux distribution, we can make the hypothesis that the temperature of the secondary star is of the order of 10000 K or slightly less. An approximate value of the UV magnitude of the secondary star can be derived comparing VV Cep with the stars of T = 10000 K and of known magnitudes observed by S2/68. The observed flux of VV Cep at λ = 1500 Å corresponds to a magnitude of m = 9.3 and m = 8.7 in June and July respectively. It is still too early to say if these values of the UV magnitudes indicate that the secondary is a star of much lower temperature than that estimated by ground observations or if extended atmosphere of the M star and the envelope surrounding the whole system alter the energy distribution of the secondary star in this wavelength range. Probably both effects are present, but only the future observations can clarify this problem.

The observed flux of VV Cep has been qualitatively compared with the flux of the Kurucz's (1979) model T = 10000 K and log g = 4. The two sets of values agree reasonably well with each other for $1500<\lambda<2400$ while at longer wavelengths the observed flux is larger than that predicted by the model. A similar, but much more important trend has been already observed in the spectrum of η Car (Heap et al. 1978). The interstellar bump at 2200 Å indicates that the interstellar reddening of VV Cep is low, as we can expect for a star at a distance of 700 pc (van de Kamp, 1978) and consequently the abnormally high flux remains unexplained.

b) The line spectrum.

For the short wavelength region for which we obtained only low resolution spectra the identification is restricted to the main contributors of some of the more prominent features.

The O I raie ultime at λ1302 (2 ^{3}P - 3 ^{3}S) shows a P Cyg profile with the absorption core displaced at $\lambda\sim$1299 Å. In the infrared part of the spectrum the O I lines at λ7774 (3 ^{5}S - 3 ^{5}P) and λ8446 (3 ^{3}S - 3 ^{3}P) appear as strong absorption lines at epochs near the predicted secondary minimum (Glebocki and Keenan, 1967) and could not be detected long before this phase and faded out after it, making unlikely the hypothesis that they arise in the atmosphere of the M star or that the oxygen atoms belong to the envelope surrounding the whole system where the stationary [Fe II] lines are formed. The presence and the profile of the O I triplet $\lambda\lambda$1302 - 1306 suggest interpreting it as a proof of an expanding shell around the B star.

The strongest emission lines are those of Fe II at 1787 Å, the two Si II lines at 1808 and 1817 Å and the blend of Ca II at 1840 Å.

In the long wavelength region the identification of the lines is possible only on the high resolution spectrum. The predominant lines are the chromospheric lines of Ti II, V II, Cr II, Mn II and Fe II mainly of low excitation potential, i.e. the lines of low E.P. of the same ions that characterize the visual spectrum shortward the Balmer jump at the same phase. The line spectrum in the region 2500 - 3000 Å is strongly similar to that of α Cyg (Underhill, private communication) but the S II lines, strong in α Cyg, are weak or absent in VV Cep, while the V II lines are much stronger in VV Cep than in α Cyg.

The h and k lines of Mg II are present as strong emission lines with deep absorption self-reversal and violet-displaced core indicating an expanding chromosphere as already remarked by Hagen et al.(1978). The profiles of both these lines are asymmetrical, but the absorption core of λ2795 is violet-displaced more than that of λ2802 of about 0.3 Å. In α Ori- the M supergiant whose visual spectrum is very similar to that of the primary of VV Cep- the profiles of the two Mg II lines differ as regards the position of the absorption core; this is centrally placed in λ2802 and violet-displaced in λ2795 (Kondo et al., 1975). The asymmetry has been explained by the contribution of Fe I 2795.01 absorption line (Modisette et al., 1973). In VV Cep the absorption core of the Mg II lines is violet-displaced on both lines and the slightly higher displacement of λ2795 as compared with λ2802 indicates a much smaller contribution from this zero excitation potential line of Fe I than in α Ori.

The widths of Mg II lines as well as that of the K line of Ca II have been measured to derive the absolute magnitude of the primary star from the Wilson-Bappu relation. Using the McClintock et al.(1975) calibration for the h and K lines we found M_V = -4. This is in very good agreement with the value obtained by the k line of Ca II and with the absolute magnitude recently proposed by van de Kamp (1978) but is much lower than the values accepted by most of the previous researchers.

4. Conclusions

The main results found by this first preliminary analysis of the IUE spectra taken in 1978 can be summarized as follows:

- it is difficult even from UV data to assign a spectral type to the secondary star owing to the probably important contribution of the extended envelopes around the M star and the whole system; neverthless it seems that a spectral type of about A0 is probably more realistic than the earlier types assigned previously and determined by means of ground observations.
- the absolute magnitude of the primary star derived from the central emission of Mg II and Ca II lines is lower than that estimated up to 1978.

References:

Bidelman W.P.: 1954, Astrophys. J. Suppl. 1, 218

Cowley A.P.: 1969, Publ. Astron. Soc. Pacific 81, 297

Faraggiana R.: 1976, Astron. Astrophys. 46, 317

Glebocki R., Keenan P.C.: 1967, Astrophys. J. 150, 529

Hagen W., Dupree A.K., Back J.K., Holm A.V.: 1978, Bull. Astron. Soc. Am. 10, 620

Heap S.R., Boggess A., Holm A., Kinglesmith D. A., Sparks W., West D., Wu C.C., Boksenberg A., Willis A., Wilson R., Macchetto F., Selvelli P.L., Stickland D., Greenstein G. L., Hutchings J.B., Underhill A.B., Viotti R., Whelan J.A.J.: 1978, Nature 275, 15

Hutchings J.B., Wright K.O.: 1971, Monthly Notices Roy. Astron. Soc. 155, 203

Hynek J.A., Keenan P.C.: 1945, Astrophys. J. 101, 270

Kamp van de P.: 1978, Sky and Telescope 56, 397

Kondo Y., Giuli R.T., Modisette S.L., Rydgren A.E.: 1972, Astrophys. J. 176, 153

Kurucz R.L.: 1979, Astrophys. J. Suppl., in press

McClintock W., Henry R.C., Moos H.W., Linsky J.L.: 1975, Astrophys. J. 202, 733

Modisette S.L., Nicholas R.E., Kondo Y.: 1973, Astrophys. J. 186, 219

Wawrukiewiecz A.S.,Lee T.A.: 1974, Publ. Astron. Soc. Pacific 86, 51

Wright K.O.: 1975, IAU Circular N 2811