HYDROGEN-LINE PHOTOMETRY OF CLOSE BINARIES

J.D. Dorren and M.J. Siah
Biruni Observatory, Shiraz University, Shiraz, Iran
E.F. Guinan and G.P. McCook
Villanova University, Villanova, PA 19085, USA

A program of Hα and Hβ narrow- and intermediate-band photometry of close binaries has been carried out at Biruni Observatory since 1977 and at Villanova University Observatory since 1971. The advantages of this type of photometry for close binary work are discussed. Stars which have extensive coverage are listed and results for Cyg X-1, WZ Sge, W Ser and HR 1099 are briefly discussed.

1 INTRODUCTION

Hα and Hβ photometry of close binaries is a powerful technique which can be used to extract useful information about stellar temperatures, or Hydrogen-line emission strengths arising from the presence of gas streams, envelopes and disks, or about centers of surface activity in RS CVn-type stars. The method, developed by Strömgren (1958) and Crawford (1958) is to employ pairs of intermediate and narrow band interference filters centered near the rest wavelengths of the Balmer lines Hα (6563A) and Hβ (4861A). The narrow-band filters are sufficiently wide (FWHM ~ 25-35A) to allow for the Doppler shifts due to binary motion, yet narrow enough to be sensitive to the line feature. On the other hand, the intermediate bandpass filters are sufficiently broad (FWHM ~ 150-300A) to remain little affected by the presence of the line. They therefore provide a measure of the continuum. A photoelectric Hα or Hβ index is defined in the following way:

$$\text{H-index} = -2.5 \log (F_N/F_I) + \text{constant}$$

where F_N and F_I are the stellar fluxes measured through the narrow and intermediate bandpass filters respectively. The method of Hβ photometry has been fully described by Crawford and Mander (1960), and used by Crawford and others chiefly in

M. J. Plavec, D. M. Popper and R. K. Ulrich (eds.), Close Binary Stars: Observations and Interpretation, 59–63.

the study of O- to F-type stars which are cluster members. Empirical calibrations of the Hβ system have been carried out (Crawford, 1975 and refs. therein) which relate the β index to such parameters as M_V, T_{eff} and to standard color indices such as c_1, b-y, and m_1. A comprehensive bibliography of Hβ photometry (as well as uvby photometry) is given by Philip and Perry (1979). Similar systems have been developed for Hα (Abt and Golson 1966, and Baliunas et al. 1975). Andrews (1968) has also obtained Hα indices for 976 B- and A-type stars by spectrophotometry. These studies show that the α index is more sensitive to emission than the β index. Additional advantages of Hα and Hβ photometry are the following: speed of measurement of the index and accuracy of line strength determination; the adequacy of a modest aperture telescope; results which are practically independent of atmospheric extinction and are not appreciably affected by interstellar reddening. On the other hand this method, unlike spectroscopy, does not provide line profiles or equivalent widths directly.

2 OBSERVATIONS AND RESULTS

Table I lists the stars for which we have extensive Hα or Hβ photometry. This encompasses stars of a wide range of dimensions, masses and spectral types, and periods from 83 min. to over 20 years. Except for the star R CMa which was observed in New Zealand in 1968, all the data was obtained using the 51-cm reflector at Biruni Observatory or the 38-cm reflector at Villanova Observatory, and in several cases the same stars were observed at both sites. The observations at Biruni were carried out by Dorren, Guinan and Siah, while the data at Villanova were obtained by Guinan and McCook or by students under their direction. The Biruni observations commenced in 1977 and cover a total of about 200 nights while the Villanova Hα /Hβ program began in 1971 and covers about 425 nights. Descriptions of the filters and instrumentation at Biruni and Villanova are to be found in Guinan et al. (1979)

TABLE I STARS WITH EXTENSIVE Hα AND/OR Hβ PHOTOMETRY.

RS CVn-type Binaries and Related Objects	- λAnd, ζAnd, RS CVn, BY Dra, Z Her, HR 1099, HR 4665, HR 5110, HD 224085
Detached and Semi-Detached Systems	- R CMa, δCap, RZ Cas, V380 Cyg, AI Dra, DI Her, TX Leo, βPer, λTau, TX Uma, εUMi
Contact-Over-Contact Binary Systems	- VW Cep, AM Leo, V566 Oph, V1010 Oph, W UMa, AW UMa
Strongly Interacting Systems With Hot Components	- UW CMa, AO Cas, IM Mon, HD 47129
Binaries in the Rapid Phase of Mass Transfer and Systems with Disks	- SX Cas, Cyg X-1, TT Hya, βLyr, νSgr, μSgr, W Ser
Systems With Cool Supergiant Components	- ζAur, 31 Cyg, 32 Cyg, VV Cep, θHer, KQ Pup
Cataclysmic and Symbiotic Variables	- Nova Cyg 1975, Nova Cyg 1978, P Cyg, CH Cyg, WZ Sge
Be Stars	- γCas, 28 Cyg, φPer, 48 Per, Pleione
Surveys (Indices only)	- Brighter members of the Pleiades, Bright Be stars, Bright Northern Hemisphere Close Binaries

https://doi.org/10.1017/S0074180900064603 Published online by Cambridge University Press

and Guinan and McCook (1974) respectively. The observing procedure was the usual one of measuring the light of the variable relative to a suitably chosen comparison star. The intermediate bandpass measures yield essentially continuum measures. Light curves and Hα , Hβ and color indices were extracted from the observations, except for the surveys for which only the Hα and Hβ indices were measured. Detailed discussions for the following stars are available: R CMa (Guinan 1976), γCas (Baliunas and Guinan 1976), 32 Cyg (Guinan and McCook 1974), Cyg X-1 (Guinan et al., 1979) β Per (Guinan et al., 1976) and a survey of bright Be stars (Baliunas et al., 1975). Here we select a few stars to illustrate the types of results obtainable.

HR 1099 (V711 Tau): The Hα index reveals strong, variable Hα emission which does not appear to be phase dependent. Sharp Hα enhancements (flares) of duration a few days to a few weeks have been detected. Smaller variations also appear to be present for the OI λ7774 index. As shown in fig.1, a large increase in Hα emission was observed around 22/23 October, 1977 (JD 2443440); several smaller Hα "flares" are also seen as well as a clear build-up of Hα emission prior to the large radio flare of March 1978.

Cygnus X-1: In 1977 the Hβ index showed a systematic variation with phase, with increased Hβ absorption (or decreased emission) near phase 0.4. A possible mechanism for the variation was suggested (Guinan et al., 1979) in which it was attributed to the projection of a gas stream on the O-star. The data

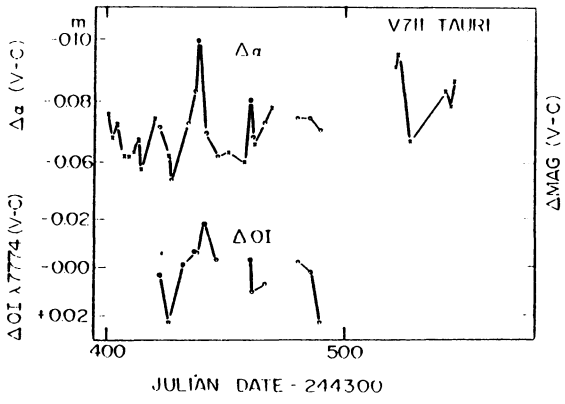

Fig. 1. Variation of the differential α and OI λ7774 indices with Julian Day Number, where emission increases upwards.

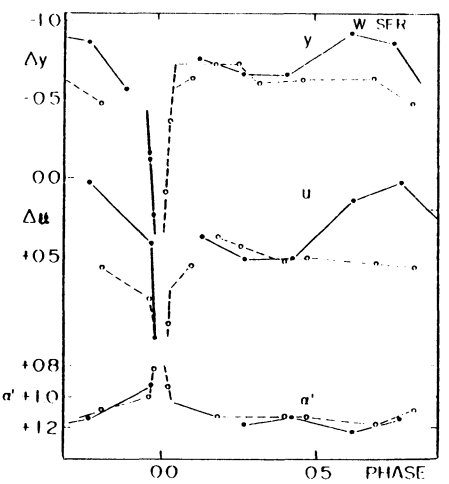

Fig. 2. The y and u observations and unstandardised α-indices for W Ser consecutive cycles are represented by different symbols.

https://doi.org/10.1017/S0074180900064603 Published online by Cambridge University Press

obtained in 1978 indicate that both the λ4870 light curve and the β-variation have changed. The light curve appears more symmetrical with maxima of nearly equal heights, while the β-index shows little marked phase dependence.

W Ser: Of all the eclipsing systems studied so far, including those of the surveys, W Ser shows the strongest net Hα emission. During May and June of 1978 uvby and Hα observations of W Ser were made at Biruni in which two cycles of the orbit were covered. The y and u observations and the α indices are shown in fig.2. The light curves are peculiar, showing one minimum which is deeper in y than u. During the first cycle a large increase in light (particularly in u) is seen before the eclipse. The α index appears to vary smoothly with phase, with greatest emission occurring during the light minimum, and appears to be little affected by the light changes from cycle to cycle.

WZ Sge: This star was observed with Hα narrow- and intermediate band filters during its recent outburst in Dec. 1978. An approximately sinusoidal light variation was seen at λ6585 with a total range of 0.3 mag and a phase-dependent variation in α was found with an increase in net emission during the light minimum.

REFERENCES

Abt, H.A. and Golson, J.C.: 1966, Astrophys. J. 143, pp.306-312.
Andrews, P.J.: 1968, Monthly Notices Roy. Astron. Soc. 72, pp.35-99.
Baliunas, S.L., and Guinan, E.F.: 1976, Publ. Astron. Soc. Pac. 88, pp.10-12.
Baliunas, S.L., Ciccone, M., and Guinan, E.F.: 1975, Publ. Astron. Soc. Pac. 87, pp.969-974.
Crawford, D.L.: 1958, Astrophys. J. 128, pp.185-206.
Crawford, D.L.: 1975, in B. Hauck and B.E. Westerlund (eds.) Problems of Calibration of Absolute Magnitudes and Temperatures of Stars, pp.93-113.
Crawford, D.L., and Mander, J.: 1966, Astron. J. 71, pp.114 118.
Guinan, E.F., and McCook, G.P.: 1974, Publ. Astron. Soc. Pac. 86, pp.947-951.
Guinan, E.F., McCook, G.P., Bachmann, P.J., and Bistline, W.: 1976, Astron J. 81, pp.57-66.
Guinan, E.F.: 1977, Astron. J. 82, pp.51-66.
Guinan, E.F., Dorren, J.D., Siah, M.J., and Koch, R.H.: 1979, Astrophys. J. 229, pp.296-303.
Philip, A.G.D., and Perry, C.L.: 1979, Publ. of Dudley Obs. and Louisiana State University (preprint).
Strömgren, B.: 1958, in D.J. O'Connell (ed.), Stellar Populations, Interscience Publishers, New York, p.385.

DISCUSSION FOLLOWING DORREN, SIAH, GUINAN AND MC COOK

Oswalt: For the RS CVn and BY Dra systems on your program have you noted any correlations between variations in the Hα index and the distortion wave often present in the light curves? For example, has there been any tendency for strongest emission to occur near times of wave maximum or minimum?

Guinan: Of the stars listed in Table I, RSCVn, Z Her, V711 Tau (HR 1099), BY Dra, and HD 224085 show emission at Hα. Only two--RS CVn and HD 224085 show evidence of an emission variation which is phase-locked. In the case of RS CVn this variation is associated with the eclipses and for HD 224085 the Hα variation is shifted approximately a quarter period from the light variation.

Rucinski: The star HD 224085 has recently been named II Pegasi.

Garmany: Have you looked at HD 108? It is an O supergiant which Hutchings found to have about a 4-day period but Conti and Vreux have since cast doubt on. It has strong Hα emission from which the mass loss is determined, but this loss is not borne out by recent IUE observations. You could enter the controversy and perhaps say something about the nature of the variability.

Guinan: HD 108 has not been observed by us yet. I thank you for your suggestion and I will place the star on our 1979/1980 observing program.

Scarfe: Have you observed any long-term variations in the emission from β Lyrae?

Guinan: Yes. Long term as well as short variations in the net Hα and Hβ line strengths appear to have occurred. Only the 1971 and 1972 data have been reduced and when the 1973 to 1975 observations are processed more can be said.

Rodono: How long have you been observing RS CVn and BY Dra? Since their brightness variations undergo periodic short- and long-term changes it would be interesting to have your observations extended for a long period of time.

Guinan: Hα wide and narrow-band and uvby photometry of RS CVn was obtained on about 25 nights during May and June of 1977. The observations were made at Biruni Obs. by Dorren, Siah and myself. The program on BY Dra was just initiated this year.

https://doi.org/10.1017/S0074180900064603 Published online by Cambridge University Press