Publications of the Astronomical Society of the Pacific
105: 574–577, 1993 June

On the Absolute Magnitude of V482 Cygni, an R Coronae Borealis Star

N. KAMESWARA RAO[1]
Indian Institute of Astrophysics, Bangalore 560 034, India
Electronic mail: nkrao@iiap.ernet.in

DAVID L. LAMBERT[1]
Department of Astronomy, University of Texas, Austin, Texas 78712
Electronic mail: dll@astro.as.utexas.edu

Received 1993 January 25; accepted 1993 March 12

ABSTRACT. An identification of V482 Cygni, a R Coronae Borealis star, with a quadruple system containing a K5 III star is rejected. High-resolution spectra show that the radial velocity of V482 Cyg and the K5 III star differ by 35 km s^{-1}, and the interstellar NaD lines are much stronger in the spectrum of V482 Cyg. These observations suggest that V482 Cyg is much more distant than the K5 III star and has an absolute magnitude of $M_V \sim -5$, similar to that of R Coronae Borealis stars in the Large Magellanic Cloud.

1. INTRODUCTION

The evolutionary status of R Coronae Borealis group of hydrogen-deficient irregular variables is presently very uncertain (Schönberner 1986; Renzini 1990). An important parameter which needs to be estimated is the absolute magnitude. Generally the absolute visual magnitude of this group is given as $M_V \simeq -4$ to -5 based on the presence of a few members of this class in the LMC (Feast 1979). The similarity of Mg II *h* and *k* 2800 Å emission core widths of R Coronae Borealis and normal supergiants like Gamma Cygni led to an estimate of $M_V \simeq -4.6$ (Rao et al. 1981). Other estimates mainly by Rozenbush (1981, 1982), based on the estimates of color excess and distribution of interstellar matter around several R Coronae Borealis stars range from $M_V \simeq -3$ to $> +2$. A more direct estimate of the distance and luminosity of the R Coronae Borealis star V482 Cyg was obtained by Gaustad et al. (1988). Infrared imaging and photometric observations obtained in the *JHKL* bands led Gaustad et al. to place V482 Cyg in a quadruple system. Their estimate of $M_V \simeq -2.8$ is much fainter than some of the above estimates and would suggest that there is a large dispersion in the M_V of the R Coronae Borealis stars. Clearly, this suggestion is dependent on V482 Cyg being a member of this quadruple system.

In particular, the association of V482 Cyg and the leading member denoted as B is crucial to Gaustad et al.'s argument, as they emphasize "one of the four stars could be a chance superposition in the line of sight. If this were true of star B, the entire determination would be invalidated, for it [the M_V of V482 Cyg] is based on the spectroscopic absolute magnitude of star B." Thus we decided to obtain spectroscopic observations of both star A, the R Coronae Borealis star, and star B, the leading member of the system.

[1]Visiting Observer, Cerro-Tololo Inter-American Observatory.

2. OBSERVATIONS

The observations were obtained with the Cassegrain echelle spectrometer, mounted on 4-m telescope of Cerro-Tololo Inter-American Observatory during 1992 May 20/21. A Tektronix 1024×1024 CCD system was used as the detector. The observations were obtained when the stars were around the meridian. Thorium Argon comparison spectra were obtained just before and after the observations of the objects. The wavelength covered was between 5480 to 7080 Å, although we use only portions of this spectrum in the present investigation. The spectral resolution is about 0.15 Å (2 pixel). The usual bias, flat-field frames were obtained at the beginning and end of the night. The reduction of these observations was done at the Vainu Bappu Observatory, Kavalur using the RESPECT software package (Prabhu and Anupama 1991).

The wavelength calibration is accurate to better than 0.03 Å (or about ± 1.5 km s^{-1}) as estimated from Na D night sky emission lines in the spectra as well as from the OH emission lines in spectra of other stars obtained on the same night. The star B is located 6 arcsec in α and 4 arcsec in δ south west of A (see Gaustad et al. 1988). The separation is quite adequate to obtain individual spectra without the contamination by the other star.

Portions of the spectra are shown in Figs. 1, 2, and 3.

3. DESCRIPTION OF THE SPECTRA

3.1 Spectral Types

The star V482 Cyg is a classical F-type R Coronae Borealis star showing presence of strong C I lines (Figs. 1 and 2), C_2 bands (λ5635), and weak Hα. A detailed study of the spectrum is in progress as part of study of elemental abundances in R Coronae Borealis stars.

The star B has been classified as K5 III by Herbig, as quoted in Gaustad et al.—"with absorption Hα of normal strength and no sign of any peculiarity." Our spectrum confirms this description. The C I and C_2 lines are not

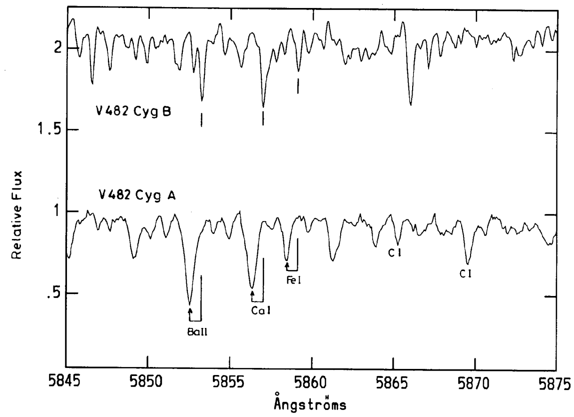

FIG. 1—The portion of the observed spectrum between 5840 and 5875 Å of star A (the R Coronae Borealis star) at bottom and star B at top. The solar correction has not been applied to the wavelength scale. Note the relative shift of the few common lines in the spectra of the two stars showing the significant difference in radial velocities.

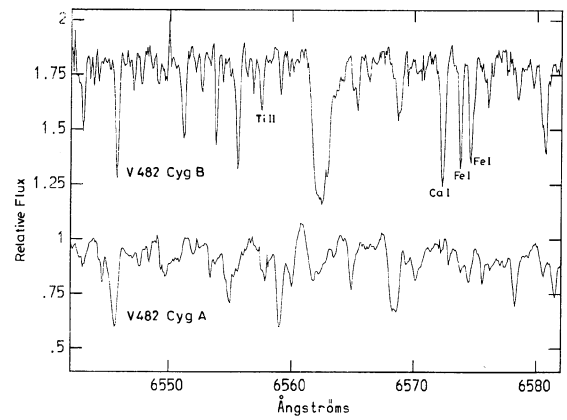

FIG. 3—Portions of the spectrum of the Hα region in both stars. The wavelength scale is adjusted for the relative shift in velocities. Note the very weak presence of Hα in star A and its great strength in star B.

present, in contrast to star A. The low-excitation neutral lines of Ti I and the Ca I 6572 Å intercombination line are fairly strong compared to the higher-excitation Fe I lines. Equivalent widths of a few lines in star B and α Boötis are given in Table 1 (Mäckle et al. 1975). On correction for the instrumental profile, the full width at half maximum of the Hα line indicates, according to the width-luminosity calibration offered by Kraft et al. (1964), that the luminosity class is III. Although we do not determine the spectral class of the star, K5 III seems to be an adequate description.

3.2 The Radial Velocities

The radial velocities of both star A and star B have been measured using lines in the spectral ranges 5835–5900 Å and 6514–6594 Å. The heliocentric radial velocity of the star A is -41.2 ± 1.4 and of star B is -6.6 ± 1.4 km s^{-1}. They differ by about 35 km s^{-1} as clearly shown by Fig. 1.

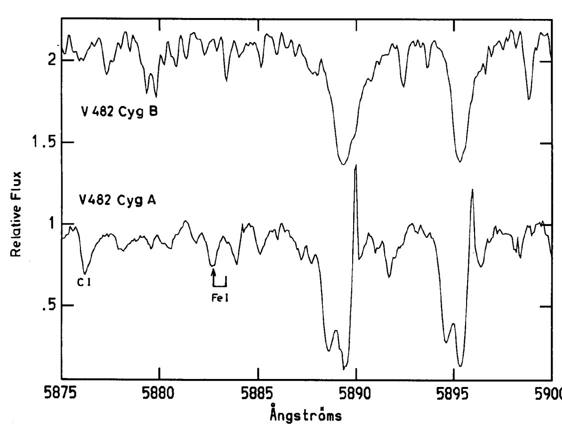

FIG. 2—Similar to Fig. 1, but showing the region of Na I D lines. Note the similarity in velocity between the stellar line of the star B and the strong interstellar component in star A. The sharp emission in the spectrum of star A is due to the night sky.

Unless either star A and/or star B is variable in velocity with a (combined) amplitude of about 35 km s^{-1}, the measured velocity difference must indicate that the two stars are not at the same distance.

The R Coronae Borealis stars are known to be low-amplitude radial-velocity variables. Herbig (1990) has

TABLE 1
The Equivalent Widths of Selected Lines

λ(Å)	Line	V482 Cyg B (mÅ)	α Boo (mÅ)
5853.18	Fe I(35)	83	
5853.68	Ba II(2)	160	130
5855.13	Fe I(1179)	61	35
5857.45	Ca I(47)	210	164
5859.61	Fe I(1181)	102	
5862.35	Fe I(1180)	91	100
5866.45	Ti I(72)	212	178
5867.57	Ca I(46)	80	
5881.76	Fe I(63)	42	
5883.84	Fe I(982)	79	
5885.61	Zr I(2)	55	
5889.95	Na I	1170	985
5895.92	Na I	803	752
6518.38	Fe I(342)	123	
6531.44	V I(48)	138	
6532.9	Ni I(64)	111	73
6543.51	V I(48)	110	
6546.24	Fe I(268), Ti I(102)	195	
6547.58	Fe I(13)	44	
6551.68	Fe I(13)	153	
6554.2	Ti I(102)	106	109
6556.07	Ti I(102)	184	130
6558.02	V I(59)	89	
6559.6	Ti II	53	62
6562.82	Hα	999	
6572.78	Ca I(2)	269	
6574.24	Fe I(13)	160	
6575.02	Fe I(206)	169	
6578.96	V I(32)	92	
6586.3	Ni I(64)	125	103
6592.92	Fe I(268)	174	
6593.88	Fe I(168)	150	

measured four spectra of V482 Cyg taken over a 2-yr interval to obtain a mean radial velocity of -40 km s^{-1} and a range of 10 km s^{-1}. Our velocity (-41 km s^{-1}) obtained about 12 yr after Herbig's spectra were taken is in excellent agreement with his mean value. If the systemic or mean radial velocity of V482 Cyg and the radial velocity of star B are to be considered identical, V482 Cyg must have, at a minimum, a velocity range of -41 to $+35$ km s^{-1}. This minimum estimate of almost 80 km s^{-1} is larger than the reported values for well observed R Coronae Borealis stars such as R CrB (8 km s^{-1} according to Raveendran et al. 1986; Herbig 1953) and RY Sagittarii (40 km s^{-1} according to Lawson 1986). Our measurements do not allow us to exclude the possibility that star B is a large-amplitude spectroscopic binary but it seems unlikely either that B can have a massive companion or that the unusual pairing of star A with B is, even more remarkably, a triple system. The velocity difference of 35 km s^{-1} between stars A and B cannot be due to the orbital motions of A and B as a visual binary.

3.3 The Na I D lines

The Na I D lines of V482 Cyg (star A) show two strong components, as illustrated in Fig. 2. The first component is dominated by the stellar line and the second component is a strong interstellar line at -12 km s^{-1}. The stellar Na I component is blueshifted by -10 km s^{-1} relative to the other lines, which probably indicates blending with other interstellar and or circumstellar components.

In contrast, the Na D lines of the star B show a strong stellar component with a minor blend as indicated by the asymmetry in the D_1 and D_2 lines. However, the velocity of the strong (stellar) component (D_1 and D_2) is blueshifted by 8 km s^{-1} relative to the other stellar lines again indicating blending by some interstellar lines.

The equivalent widths (W_λ) of the Na D_1 components in A are estimated (by fitting Gaussian profiles) to be as follows: the stellar component has 445 mÅ, and the strong interstellar component at -12 km s^{-1} has an equivalent width 500–600 mÅ. In contrast, the Na I components of star B have W_λ (D_2)$=1170$ mÅ and W_λ (D_1)$=803$ mÅ. As the equivalent widths (Table 1) show the star may have a spectral type later than K1 III (α Boo). In α Boo, the D_1 equivalent width is 752 mÅ (Mäckle et al. 1975). Even if we assume the strength of Na I D_1 is of equal strength in both stars (corresponding to K1 III), the upper limit to interstellar components is <51 mÅ, which is ten times less than the equivalent width of the interstellar component towards star A. Clearly, the R Coronae Borealis star (star A) lies behind clouds containing a much greater column density of neutral sodium that is seen towards star B.

A reasonable conjecture is that the additional clouds are primarily interstellar rather than circumstellar material ejected by the R Coronae Borealis star. We base our conjecture on the expectation that circumstellar material will be blueshifted relative to the star but the additional clouds are redshifted by 20 to 30 km s^{-1}. More significantly, our spectra of other R Coronae Borealis show no cases of redshifted circumstellar components.

4. DISCUSSION

Differences in radial velocity and the interstellar Na D absorption profiles strongly indicate that the R Coronae Borealis star V482 Cyg and star B are not members of the quadruple system identified by Gaustad et al. (1988). The much larger Na D line equivalent widths for V482 Cyg (relative to star B) suggest that the R Coronae Borealis star is more distant than B. This suggestion is fully confirmed by the distances derived on the assumption that both stars follow the galactic rotation. At the galactic longitude and latitude ($l=70°$, $b=2°$) of V482 Cyg, the radial velocity of B corresponds to a distance of about 2 kpc and of V482 Cyg to a distance of about 5 kpc (see Pottasch 1984). Star B's kinematical distance is consistent with Gaustad et al.'s estimate of 1.7 kpc. The reddening (extinction) estimates for star A from the strength of the interstellar component of the D lines as well as from the percentage polarization in V of 2.8 ± 0.1 (position angle 36°) observed by Rozenbush and Rozenbush (1990) at maximum light indicates an $E(B-V)\sim0.5\pm0.2$. This estimate is also consistent with the color from visual and photographic magnitudes at light maximum (10.9 and 12.1). Thus with the estimate of interstellar extinction A_V of 1.5 to 2, the kinematical distance would correspond to $M_V\sim-4.6$ which agrees with Feast's (1979) estimate based on the LMC R Coronae Borealis stars.

In summary, we conclude that the R Coronae Borealis star V482 Cyg is not a physical member of the quadruple system discussed by Gaustad et al. (1988). At present, the absolute visual magnitude of R Coronae Borealis stars is probably best estimated from the known examples in the LMC. This estimate, $M_V\simeq-4$ to -5 (Feast 1976) is consistent with the kinematical distance now estimated for V482 Cyg.

We thank Dr. R. E. Williams for providing Director's discretionary time for these observations and Dr. Sunetra Giridhar and Mr. Gajendra Pandey for the help with reductions. D. L. Lambert acknowledges the support of the U. S. National Science Foundation (Grant No. AST91-15090 and an International Travel Grant).

REFERENCES

Feast, M. W. 1979, IAU Coll. 46, Changing Trends in Variable Star Research, ed. F. M. Bateson (Hamilton, N.Z., University of Waikato), p. 246

Gaustad, J. E., Stein, W. A., Forrest, W. J., and Pipher, J. L. 1988, PASP, 100, 388

Herbig, G. H. 1953, The Observatory, 73, 71

Herbig, G. H. 1990, private communication

Kraft, R. P., Preston, G. W., and Wolff, S. C. 1964, ApJ, 140, 235

Lawson, W. A. 1986, in Hydrogen Deficient Stars and Related Objects, ed. K. Hunger, D. Schönberner, and N. K. Rao (Dordrecht, Reidel), p. 211

Mäckle, R., Griffin, R., and Holweger, H. 1975, A&AS, 19, 303

Pottasch, S. R. 1984, Planetary Nebulae (Dordrecht, Reidel), p. 27

Prabhu, T. P., and Anupama, G. C. 1991, BASI, 19, 97

Rao, N. K., Nandy, K., and Bappu, M. K. V. 1981, MNRAS, 195, 71p

Raveendran, A. V., Ashoka, B. N., and Rao, N. K. 1986, in Hydrogen Deficient Stars and Related Objects, ed. K. Hunger, D. Schönberner, and N. K. Rao (Dordrecht, Reidel), p. 191

Renzini, 1990, Confrontation Between Stellar Pulsation and Evolution, ASP Conf. Ser. 11, ed. C. Cacciani and G. Clementini (San Francisco, ASP), 549

Rozenbush, A. E. 1981, Astrometriya Astrofiz., 44, 13

Rozenbush, A. E. 1982, Astrometriya Astrofiz., 47, 17

Rozenbush, A. E., and Rosenbush, V. K. 1990, Inf. Bull. Var. Stars, No. 3439

Schönberner, D. 1986, in Hydrogen Deficient Stars and Related Objects, ed. K. Hunger, D. Schönberner, and N. K. Rao (Dordrecht, Reidel), p. 471