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PHOTOMETRY OF Y CANUM VENATICORUM AND R CORONAE BOREALIS

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Abstract

We present V magnitudes for Y CVn, and V magnitudes and B-V colors for R CrB. In 1980 Y CVn exhibited variability of amplitude 0.5 magnitude and period 187 days; in 1981, the amplitude was 0.15 magnitude and the period was about 98 days. The 1981 data for R CrB give evidence for an approximate 49 day cycle in V and B-V, with small minima in V showing no phase lag with respect to the reddest colors.

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1. Introduction

Y CVn and R CrB are good candidates for photometry with a small telescope. They are reasonably bright and exhibit large enough variations that their variability is not difficult to demonstrate, but their short-term variations are generally not large enough to be demonstrated easily by means of visual estimates. Furthermore, stars like Y CVn are so red that they play tricks on the eye, giving a great deal of scatter to a light curve obtained visually. Because of the need for more accurate data on these two stars, I began observing them photoelectrically in 1980 and continued through 1981. Presented here are observations in the V band for Y CVn, and V magnitudes and B-V colors for R CrB.

2. Observations

The data were obtained with the author's 6-inch f/6 Newtonian reflector. The photometer employs an RCA 931A photomultiplier tube, operated at -1000 V, and standard UBV filters from Estafilter. The diaphragm used in 1980 gave a field of view of 2.2 by 3.8 arcmin, while the one used in 1981 gave a field of view of 0.9 by 1.9 arcmin. The 1980 data were read directly from a current amplifier, while the 1981 data (with the exception of JD 2444657) were reduced from strip chart tracings.

The results presented here are from differential photometric readings. At an elevation of 200 feet in the Santa Clara Valley, the sky is often smoggy, but consistent differential photometry can be done when there is a uniform layer of "bad" air, better than on ostensibly clear nights when the sky transparency is often quite variable.

The data were reduced as follows: 1) derive instrumental magnitudes (and colors) from the net deflections and the gain settings; 2) correct for differential atmospheric extinction (and reddening); 3) transform the data to standardized differential magnitudes (and colors) on the UBV system; and 4) add these differential data to the known magnitude (and color) of the comparison star(s) to obtain standardized values. Although the data reduction was carried out to the nearest 0.001 magnitude, the final results were rounded off to the nearest 0.01 magnitude. For further reference on data reduction and the definition of parameters listed below, the reader is referred to Section 5 of the article by Hardie (1962) and to Chapters XI, XII, and XIII of Hall and Genet (1981).

The data were reduced with mean atmospheric extinction coefficients appropriate to the site: k_v = 0.52 magnitude and k'_{bv} = 0.37 magnitude. It was assumed that k''_{bv} = -0.03 magnitude. For the 1980 observations (up through JD 2444428) the transformation coefficient ε was -0.072 ± 0.011. The rest of the Y CVn data and all of the R CrB data were obtained with a different photomultiplier tube, for which ε = -0.050 ± 0.005 and μ = 0.951 ± 0.003.

The comparison star for Y CVn was β CVn, except on JD 2444459, 2444820, and 2444821, when 20 CVn was used, and on JD 2444453 when both were used. The comparison star for R CrB was δ CrB. Values of V and B-V adopted for these three comparison stars, all taken from Table 9 of Johnson et al. (1966), are given in Table I. For the purpose of reducing the Y CVn data (which were in V only), a color index of B-V = 2.54 magnitudes (that value taken from Table 9 of Johnson et al.) was assumed.

Tables II and III give the results for Y CVn and R CrB, respectively. Each V and B-V value for a given night generally represents the mean of three measurements with respect to the comparison star(s). Computing the standard deviation of the three from each mean would suggest an uncertainty of ± 0.015 magnitude for each mean. Because of the uncertainty of the transformation coefficient, ε, and the actual color difference between Y CVn and its two comparison stars, the data for Y CVn could contain systematic errors, but probably no more than 0.02 magnitude. The data for R CrB should contain negligibly small errors arising from the transformation to the UBV system, because it and its comparison star are so similar in color. Finally, variations of the extinction (and reddening) from the mean value(s) used in the data reduction could lead to further random errors of about ± 0.01 magnitude. The individual standardized magnitudes and colors therefore should be good to ± 0.03 magnitude or better.

3. Discussion

Figure 1 is the light curve of Y CVn. Figures 2 and 3 are plots of the V magnitude and B-V color, respectively, of R CrB.

The 1980 data for Y CVn demonstrate variability of 0.5 magnitude with a period of about 187 days, derived by means of a discrete Fourier transform algorithm discussed by Deeming (1975, 1976). The 1981 data exhibit variability of 0.15 magnitude with a period of about 98 days. These values seem to be consistent with Kukarkin et al. (1969), who classify this star as an SRb, meaning that its period and amplitude are known to be variable. Biskupski (1963) observed cycles of 250 days and also cycles of 90 days with lesser amplitudes of 0.1 to 0.3 magnitude.

Figures 4 and 5 are phase-magnitude plots of the 1981 data for R CrB, based on a period of 49 days and an epoch of minimum light at JD 2444740. If the 1981 data are analyzed with the same discrete Fourier transform algorithm, the peak of the power spectrum corresponds to a period of 50.7 days, but to fit the small minimum of May, 1981, with the small minimum of August, 1981, requires a 49-day period. (The small minima are not to be confused with the famous dips to approximately 14th magnitude which R CrB undergoes every few years, the last great minimum having ended in early 1978.) It also should be noted that the small minimum in September, 1980, is 245 days before the small minimum of May, 1981, which is exactly 5 cycles of 49 days. Thus, it seems that R CrB can exhibit a stable period even though the minima are of unequal depth.

In Figure 5 we see that the reddest color coincides with the small minima in V. The color appears quite constant at B-V = 0.59 magnitude for over half the cycle (phase 0.15 to 0.75) but reddens to a B-V of approximately 0.68 magnitude at the small minima in V.

Fernie (1981) has presented data for R CrB in the years 1971, 1978, 1979, and 1980, these observations ending three weeks before the start of the data presented here. Fernie found that the light curve was variable as to period, amplitude, and heights of maximum and minimum. He gives a "characteristic" period of 46 ± 5 days and claims that his data hint at a phase lag between the V and B-V curves. For one small minimum in 1971, the minimum in V seems to lag behind the reddest B-V, and for one small maximum in 1980 the maximum in V lags behind the bluest B-V. (This is what is observed quite reproduceably for RY Sagittarii (Alexander et al. 1972), another R CrB star that shows "Cepheid-like" variability.) However, the other maxima in Fernie's data exhibit no phase lag with respect to the bluest B-V colors, and the other minima in V coincide with the reddest B-V colors. Thus, on the whole there is a difference between R CrB and RY Sgr regarding this phase lag. Another interesting difference was discussed in a late paper presented by Cottrell, Lambert, and Schonberner at the January, 1982, meeting of the American Astronomical Society. They find that RY Sgr (the star with very regular photometric variations) has a variable spectrum, while R CrB (the star that usually shows an irregular light curve) has a very constant spectrum. The theoretical results of Trimble (1972) give no phase lag, but she states that a different treatment of the atmospheric opacities could lead to the phase lag. For a review of models of R CrB stars see King (1980).

We need simultaneous photometric and spectroscopic observations of a number of R CrB stars. We also need a better understanding of the opacities in their atmospheres, better estimates of their masses, and more careful consideration of the boundary conditions as part of the theoretical studies. Understanding the R CrB stars is especially interesting because they could be progenitors of at least some of the Type I supernovae (Wheeler 1978).

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TABLE I Comparison Star Magnitudes

	V	B-V
β CVn	4ᵐ27	0.59
20 CVn	4.73	0.30
δ CrB	4.63	0.80

TABLE II Photometry of Y CVn

Julian Date (2444000 +)	V	Julian Date (2444000 +)	V
342.746	5ᵐ78	657.781	5ᵐ38
348.746	5.79	691.754	5.38
366.747	5.74	692.706	5.36
378.719	5.60	694.722	5.41
397.767	5.50	700.718	5.39
398.779	5.46	741.694	5.26
400.733	5.47	759.737	5.29
408.702	5.46	764.735	5.30
425.701	5.37	765.727	5.33
428.715	5.31	778.726	5.34
436.706	5.32	793.708	5.34
437.707	5.41(?)	796.717	5.39
440.699	5.35	820.676	5.31
453.688	5.31	821.681	5.30
459.683	5.32		

TABLE III Photometry of R CrB

Julian Date (2444000 +)	V	B-V
481.674	6ᵐ25	0ᵐ70
482.672	6.29	0.68
496.649	6.45	0.67
502.649	6.41	0.73
503.653	6.39	0.72
741.715	6.06	0.65
759.716	5.80	0.60
764.713	5.81	0.58
765.710	5.80	0.60
778.708	5.88	0.60
793.730	5.89	0.60
796.743	5.90	0.58
820.706	5.83	0.57
821.717	5.84	0.57
836.698	5.99	0.69
837.697	6.00	0.65
840.694	5.98	0.66
841.696	5.97	0.63
868.642	5.88	0.57
874.640	5.90	0.66 (?)
878.635	5.88	0.61

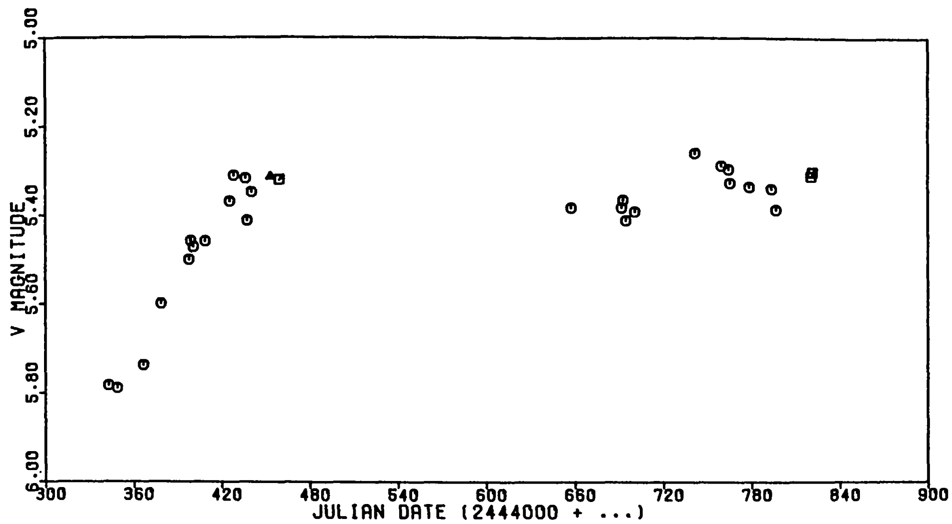

Figure 1. Light curve of Y CVn. Circles represent data with β CVn used as comparison star. Triangles represent data with 20 CVn and β CVn used as comparison stars. Squares represent data with 20 CVn used as comparison star.

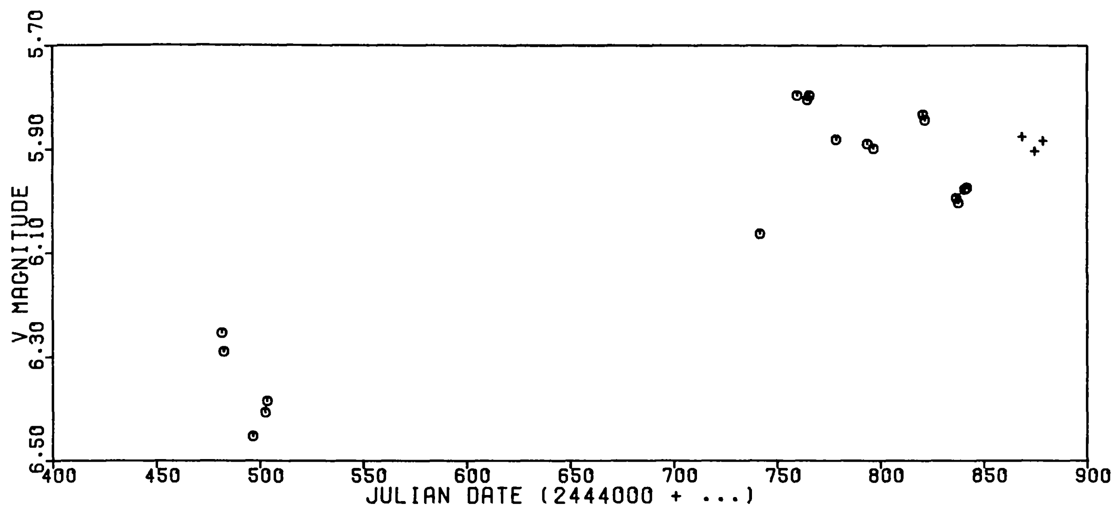

Figure 2. Light curve of R CrB, using δ CrB as comparison star. Pluses represent 1981 data taken at lower elevation angles (approximately 50°), where signal noise is greater.

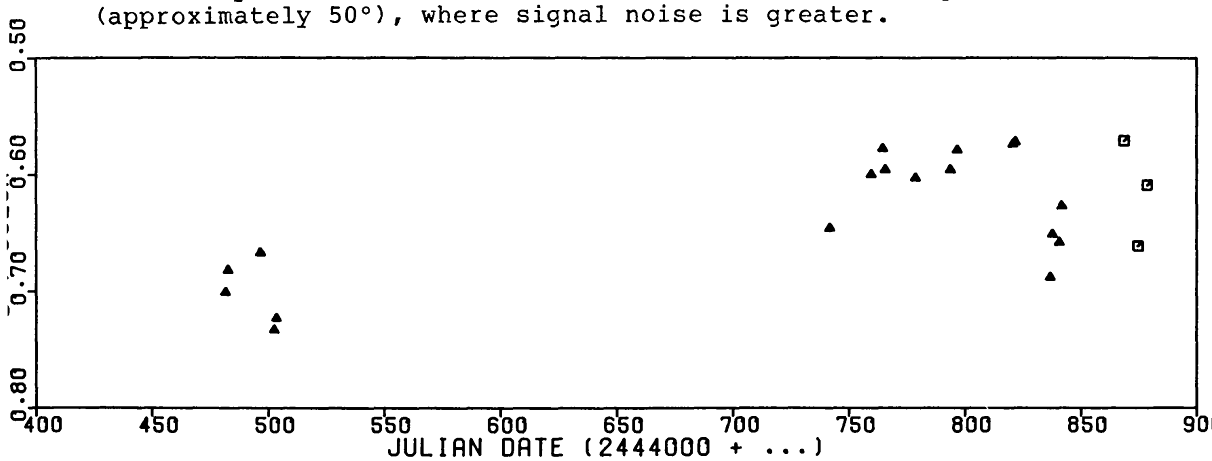

Figure 3. B-V color of R CrB vs. time. Squares represent 1981 data taken at lower elevation angles.

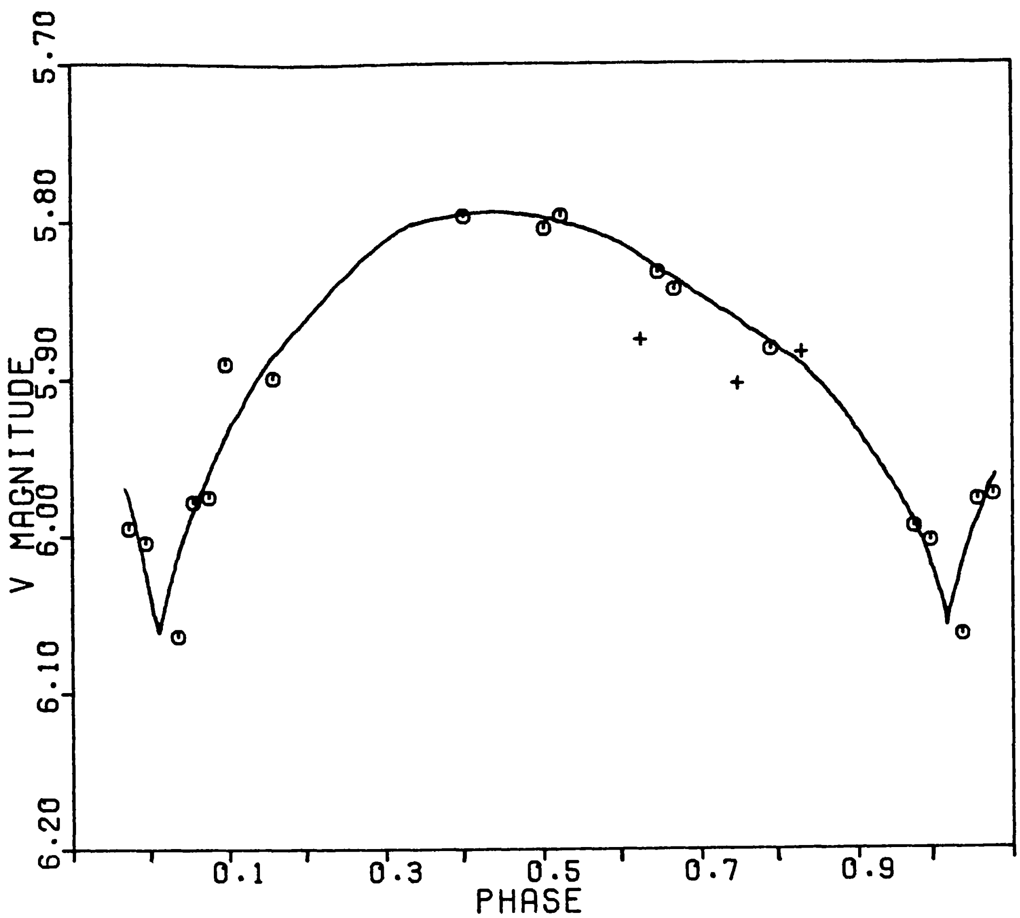

Figure 4. Phase-magnitude plot of the V magnitudes of R CrB from 1981. Period equals 49 days. Epoch of minimum equals JD 2444740. (Pluses are the same as in Figure 2).

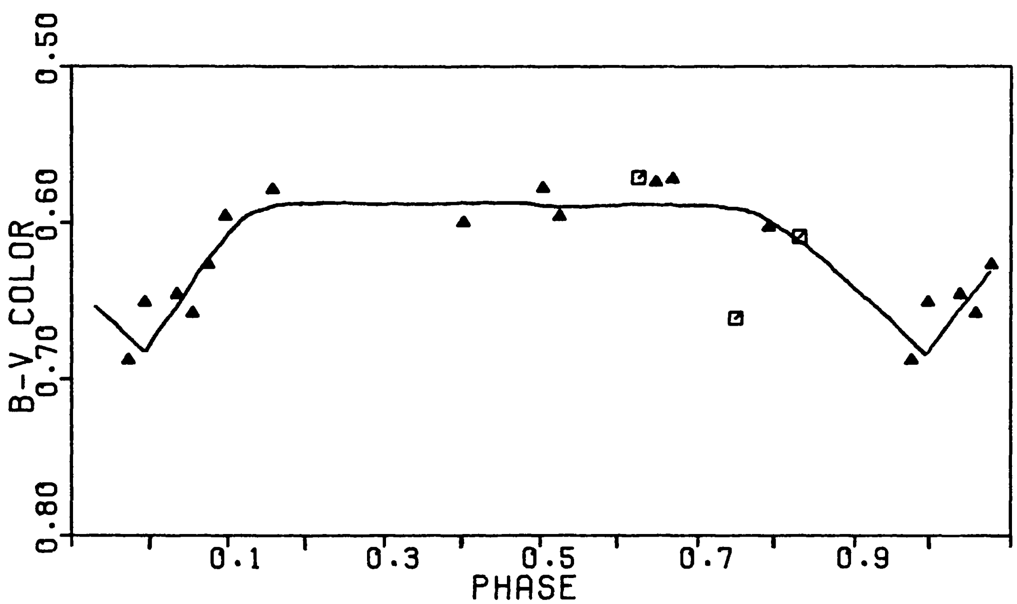

Figure 5. Phase-magnitude plot of the B-V colors of R CrB from 1981. Period equals 49 days. Epoch of minimum equals JD 2444740. (Squares are the same as in Figure 3).