# PHOTOMETRIC STUDY OF RX CEPHEI

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## Abstract

Photoelectric observations of RX Cephei from Zsoldas and McAdam (1993) and the authors, and long term visual observations from Schmude and the AAVSO were analyzed. RX Cep, whose variability has been questioned, appears to have become 0.15 magnitude brighter between 1990 and 2000. There is also some evidence of a 350-day period. The *B-V* color index of this star may also be calculated as 1.12±0.04.

## 1. Introduction

RX Cephei is reported to be a variable star of visual magnitude range 7.2 to 8.2 and possible period of 55 days (Kholopov *et al.* 1985). There is also, however, some evidence that this star is not variable; for example, RX Cep is a 7.50 magnitude non-variable star in the *Millennium Star Atlas* (Sinnott and Perryman 1997). Furthermore, Zsoldos and McAdam (1993) measured the photoelectric magnitude of RX Cep 14 times between September 1990 and December 1991 and found that the *V* magnitude held steady at +7.44. Zsoldos and McAdam (1993) also analyzed 2866 visual observations of this star made over more than 20 years by observers from the British Astronomical Association, Variable Star Section. Using a computer program that searches for period changes, they found possible periods of one year, 1538 days, and 1307 days. The one-year period was considered unlikely and perhaps due to seasonal effects. The two longer periods were attributed to differences between observers in the 20+ year data set. Zsoldos and McAdam also analyzed five sets of earlier visual or photographic data but again found no conclusive evidence for variable activity and in the end, concluded that RX Cep is constant. These contradictory conclusions impelled the authors to carry out an independent study of RX Cep. Preliminary results were presented at the 88th and 89th AAVSO spring meetings.

## 2. Materials and Method

Data analyzed in this study are: 1) 53 photoelectric *V* and *B* measurements made by Schmude; 2) 306 visual observations by Schmude; and 3) ~7300 visual observations from the AAVSO International Database (Mattei 1999).

The visual observations were made by comparing the magnitude of RX Cep to one or more comparison stars. In the case of Schmude's values, the same two comparison stars from the *AAVSO Variable Star Atlas* (Scovil 1990) were always used and are listed in Table 1. A potential problem with Schmude's data is possible systematic errors from atmospheric extinction. Most of Schmude's data were collected in the evening, and during this observing window the circumpolar RX Cep is lowest in the sky in May. Atmospheric reddening and extinction is therefore greatest in May and may introduce systematic error with a period of one year.

All photoelectric data were collected with a SSP-3 solid-state photometer and Johnson *B* and *V* filters (Optec 1997; Schmude 1992) connected to a 0.10-m f/9 refracting telescope. Measurements were made in the order: CKLCVCVCVCE, where C is the comparison star, K and L are two check stars, V is RX Cep, and E is a star used in computing the extinction coefficient. An RX Cep magnitude measurement was the average of the three V measurements. Each C measurement consisted of three ten-second sky measurements made near the comparison star followed by three ten-second star + sky measurements and then three more ten-second sky measurements. Each K, L, and V measurement was done in the same way as the C measurement. The star for the E measurements was far from the north celestial pole and so it drifted out of the photometer field of view in about 15–20 seconds. Therefore ten one-second sky, star + sky, and sky measurements were made of star E.

All magnitude measurements were corrected for extinction and standard transformation as outlined in Hall and Genet (1988). Extinction coefficients were measured on almost all dates. Values of $k_B'' = -0.03$ and $k_V'' = 0.00$ were used for secondary extinction correction factors (Hall and Genet 1988). Transformation coefficients were measured using the two-star method with the resulting values of $\varepsilon_B = 0.170$ and $\varepsilon_V = 0.006$.

## 3. Results

The visual and photoelectric data on RX Cep hint at variability. The first period is 350±10 days with an amplitude of 0.12 magnitude, while the second period is 7500±500 days with an amplitude of 0.07 magnitude. There is, however, no evidence for a 55-day period.

### 3.1. Evidence for a 350-day period

Twenty-day averages of Schmude's visual magnitudes are plotted in Figure 1. The data were analyzed using the AAVSO Time Series (TS) software package, and a 350-day cycle with an amplitude of 0.12 magnitude was detected. Although the data look convincing, the 350-day cycle is close to one year, so systematic errors arising from atmospheric extinction remain a possibility. It was for this reason that photoelectric measurements were carried out. The photoelectric magnitudes of RX Cep and other relevant data are listed in Table 2. Figure 2 shows the differences in *V* magnitude among RX Cep (V), comparison star HD 4853 (C), check star HD 5848 (K), and check star HD 166205 (L). The C-K and C-L differences are relatively constant, which suggests that these three stars remained nearly constant in brightness throughout late 1999 and early 2000. The signal-to-noise ratio for the check stars was ~15 times larger than for RX Cep, indicating that data scatter is lower for the check stars. The V-C plot shows a gradual decline in brightness starting about 180 days after Sep. 14.000, 1999 (JD 2451436); in fact, the respective monthly average *V* magnitudes for RX Cep are: 7.27, 7.30, 7.28, 7.30, 7.30, 7.32, 7.30, 7.37, and 7.43 for September 1999–May 2000. The photoelectric data span only 209 days and so cannot confirm a 350-day period, nevertheless, the data show small brightness changes.

### 3.2. Further evidence for variability of RX Cep

The visual magnitudes in the AAVSO International Database and those from two longtime AAVSO observers (initials OV and SHS) are plotted in Figure 3 as 500-day averages. The data cover the time period from 1961 (JD 2437600) to July 1999 (JD 2451389). The photoelectric measurements by Zsoldos and McAdam and Schmude are also plotted as open circles in Figure 3, and the Hipparcos measurements are represented by the square. The average photoelectric magnitude in early 1991 was +7.44, which is ~0.13 magnitude fainter than the average magnitude in early 2000; this value is consistent with the visual results. Finally, a magnitude of 7.50 is given in the *Millennium Star Atlas* which is based on Hipparcos data collected between 1989 and mid-1993 (Sinnott and Perryman 1997); this magnitude is also near the minimum shown in Figure 3. Based on Figure 3, the authors conclude that RX Cep brightened from a *V* magnitude of +7.45 in 1990 to +7.30 in 2000. In Figure 3 (lower plot) one can also see maxima at ~JD 2443000 and ~2450500 and minima at ~JD 2440000 and ~2447500 which are consistent with a 7500-day period.

### 3.3. Color Index

The *B* and *V* magnitudes of RX Cep were measured five times for a resulting value of $B\text{-}V = 1.12 \pm 0.04$. The uncertainty includes the random error along with an uncertainty of 0.02 magnitude in the color index of the comparison star and a 0.01 magnitude uncertainty in the extinction and color correction terms. The *V* measurements are ~0.15 magnitude brighter than the visual values. These results are consistent with Stanton (1999), who shows that the visual magnitude ($m_V$) is related to the Johnson *V* magnitude through:

$$m_V = V + 0.210(B\text{-}V) \tag{1}$$

Equation (1) shows that the *V* magnitude will be brighter than the visual, which is consistent with the results in Figure 3.

## 4. Conclusions

Visual and photoelectric data in the early 1990s and in 1999–2000 suggest that RX Cephei has increased by 0.15 magnitude between 1990 and 2000. There is, however, no conclusive evidence that this star has periodic variability. The $B$-$V$ color index of RX Cep is calculated as 1.12±0.04. We recommend that RX Cep be monitored photoelectrically or with a CCD camera over several seasons to resolve the question of periodicity.

## 5. Acknowledgements

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Table 1. Comparison and check stars used for RX Cep.

| *Star HD* | *R.A. (2000.0)* | *Dec. (2000.0)* | *Magnitude Visual* | *B* | *V* | *Comments* |
|---|---|---|---|---|---|---|
| 7340 | $01^h18^m$ | +81° 34' | 7.7 | — | — | Used in Schmude's visual study |
| 9653 | 01 41 | +81 26 | 7.1 | — | — | Used in Schmude's visual study |
| 4853 | 00 55 | +83 42 | — | 5.71 | 5.59 | Comparison Star (C)-photoelectric study |
| 5848 | 01 09 | +86 15 | — | 5.46 | 4.25 | Check Star (K)-photoelectric study |
| 166205 | 17 32 | +86 35 | — | 4.38 | 4.36 | Check Star (L)-photoelectric study |

*B and V magnitudes from Hirshfeld and Sinnott (1991); visual magnitudes from Kholopov et al. (1985).*

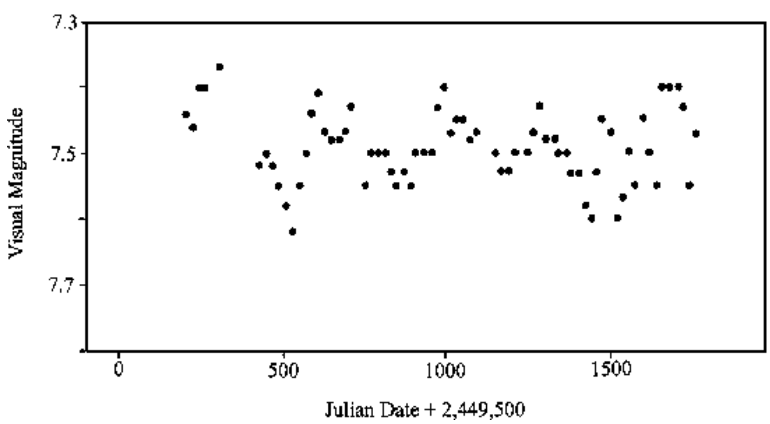


Figure 1: Magnitude versus Julian date for Schmude's visual estimates of RX Cep. Data are plotted as 20-day averages.