ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES



*Astron. Astrophys. Suppl. Ser.* **117,** 255-259 (1996)

# Photometric variability of P Cygni: 1985-1993

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Received July 5; accepted September 5, 1995

**Abstract.** — We present $V$ light curves of P Cygni from JD 2446200−9300 (1985-1993). Inspection of the light curves, and Fourier and autocorrelation analysis, show that the star varies on time scales of about 40 to several hundred days. No one time scale stands out, though 40, 120 and 160 days are noticeable in the autocorrelation diagram of the combined 1985-1993 data.

**Key words:** stars: P Cygni; stars: variable

## 1. Introduction

P Cygni (34 Cyg, HR 7763, HD 193237, $V\sim4.9$, SpT B1Ia+) is an extremely luminous blue variable (LBV) supergiant, and is the prototype hot mass-losing star. Between 1600 and 1700, it exhibited large variations in brightness from magnitude 3 to 6 but, since 1800, it has remained approximately constant at $V\sim4.9$. The star is known to vary by about $0.2^{\rm m}$ on a time scale of a few weeks, but until recently, there was very little systematic data on the photometric variability of this important star. Percy et al. (1988), hereinafter Paper I, published 225 photoelectric observations made in 1985 and 1986; de Groot (1989) is also monitoring this star with the Automatic Photometric Telescope in Arizona. These studies confirm that P Cygni varies on a number of time scales from a few days to several months.

Lamers & de Groot (1992) have also determined, from historical observations, that P Cygni has steadily increased its visual brightness between 1700 and 1988 by 0.15±0.02 magnitude per century. El Eid & Hartmann (1993) suggest that only half of this increase can be explained by current models of stellar evolution. It is interesting to note that American Association of Variable Star Observers (AAVSO) *visual* ovservations of P Cygni show a slow brightening, of a similar order of magnitude, over the past 50 years (J.A. Mattei, private communication). The most comprehensive analysis of past observations of P Cyg (spectroscopic, photometric and polarimetric) is by van Gent & Lamers (1986).

On the theoretical side: there have been important developments in the understanding of the structure and stability of LBVs, most recently as a result of the use of improved radiative opacities (e.g. Glatzel et al. 1994). A comprehensive study of the wind of P Cygni has recently been published (Scuderi et al. 1994). This and other papers adopt the following parameters for the star: $\log(L/L_{\odot}) = 5.86\pm$ 0.10, $T_{\rm eff} = 19300\pm$ 700, $R/R_{\odot} = 76\pm8$, and $E(B-V) = 0.63\pm0.05$ which were initially derived by Lamers et al. (1983).

Scuderi et al. (1994) also present some photometric and spectroscopic data for JD 2447348−8467, which overlaps some of our data.

The purposes of the present paper are:

– i) to present and describe the $V$ light curves of P Cyg, 1985-1993. (The 1985-1986 light curves were described in Paper I),
– ii) to analyze the light curves for regularity, using Fourier and autocorrelation techniques,
– iii) to compare the photometric variations with the spectroscopic variations (1990-92) recently reported by Stahl et al. (1994).

## 2. Observations

Photometric ($UBV$) observations were made, using the same comparison stars as in Paper I, at the following observatories: the University of Toronto 0.4 m reflector, as part of the program described by Percy et al. (1988); Tartu Observatory, as described by Luud et al. (1977); and at several backyard observatories which participate in the American Association of Variable Star Observers (AAVSO) photoelectric photometry program (Landis et al. 1992), particularly those of Wayne E. Clark, Howard J. Landis, Russell E. Milton, and James Wood. In general, observations were made and reduced as described in

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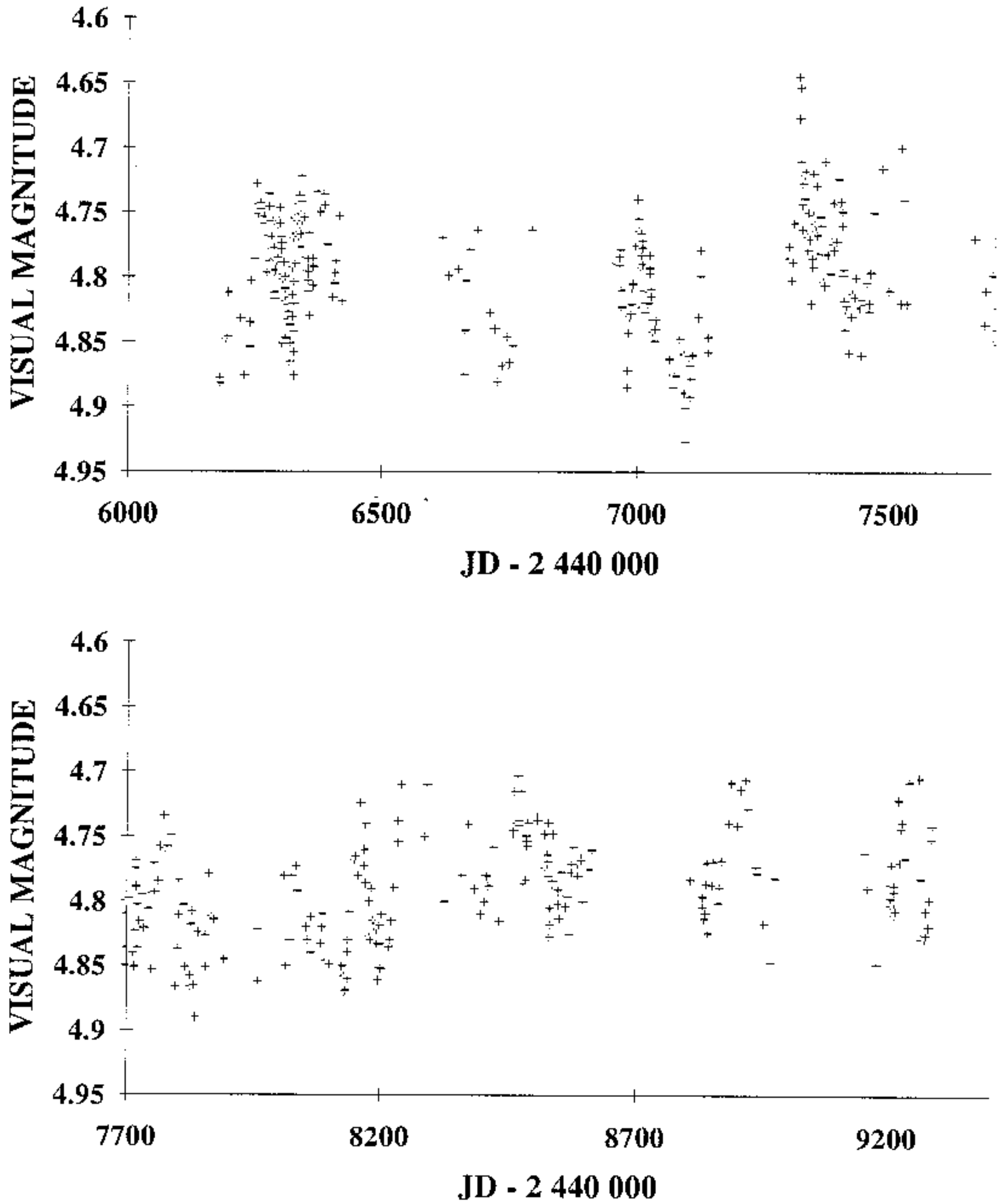


**Fig. 1.** $V$ light curve of P Cygni. The comparison star 22 Cyg was assumed to have $V = 4.949$

Paper I; they will be deposited in the IAU Archive for Unpublished Photoelectric Data (Schmidt 1994).

## 3. Analysis and results

The analysis and interpretation of the results was based on: i) inspection of the light curves; ii) Fourier analysis based on the date-compensated method of Ferraz-Mello (1981) implemented in a computer program from the Maria Mitchell Observatory, kindly provided by Dr. E.P. Belserene; and iii) autocorrelation analysis (Percy et al. 1993).

Visual inspection of the light curves (Fig. 1) shows clear evidence for variability on a variety of time scales, from 40 days (e.g. 1985: Paper I), through 100-200 days (e.g. 1987, 1991, 1992), to several hundred days (e.g. 1987→1988 and 1989→1991). There are occasional brightenings over a period of a few days, as noted in Paper I, and by De Groot (1989).

Fourier analysis of the 1985-1987 data showed a promising peak (marginally statistically significant) at a

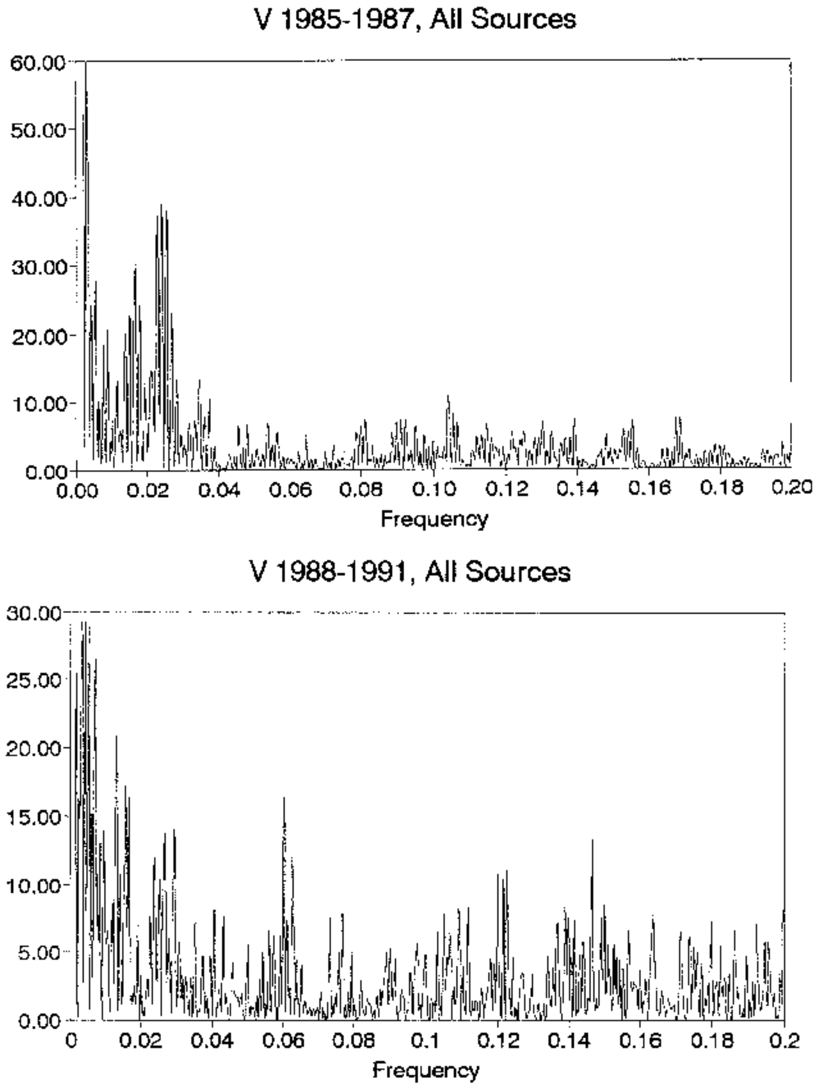


**Fig. 2.** Power spectra for $V$ observations of P Cygni, for 1985-87 (top) and 1988-91 (bottom)

period of about 40 days (Fig. 2, top), along with low-frequency peaks. The 1988-91 power spectrum continued to show low-frequency peaks, but the peaks around 40 days are much reduced. There are peaks around 15-20 days, and around 60-70 days none of them dominant or statistically-significant.

The autocorrelation diagrams (Fig. 3) show: i) for the 1985-1987 data, minima at 50, 120 and $\geq$ 260 days; ii) for the 1988-1990 data, minima at 150 and 260 days; and iii) for the 1991-1993 data, a broad minimum at 140-220 days. None of these minima is particularly distinct.

The net result of the period analysis is that P Cygni can show variability on time scales from $\sim$40 to several hundred days. No one time scale stands out, though 40, 120 and 160 days are noticeable in the autocorrelation diagram of the combined 1985-1993 data.

We also looked for correlations between the photometric variations and the spectroscopic variations (expansion velocity and peak intensity of H and He emission lines) published by Stahl et al. (1994). The overlap between the data sets is limited, especially because of the seasonal gaps, but there are several maxima and minima in the region of overlap.

**a) Light curve**. The light curve shows a long plateau from JD ($-$2448000) 0$-$130, a pronounced maximum at 160, a pronounced minimum at 200, then after a seasonal gap a shallow minimum at 430, a shallow maximum at 460, and a shallow minimum at 555.

**b) Expansion velocity**. The velocity curve shows a sharp maximum at 85, a sharp minimum at 150, a poorly-defined maximum at 200; then a prominent maximum from 400-450 (possibly separated by a slight minimum at 430), and a conspicuous minimum at 550. There is no clear

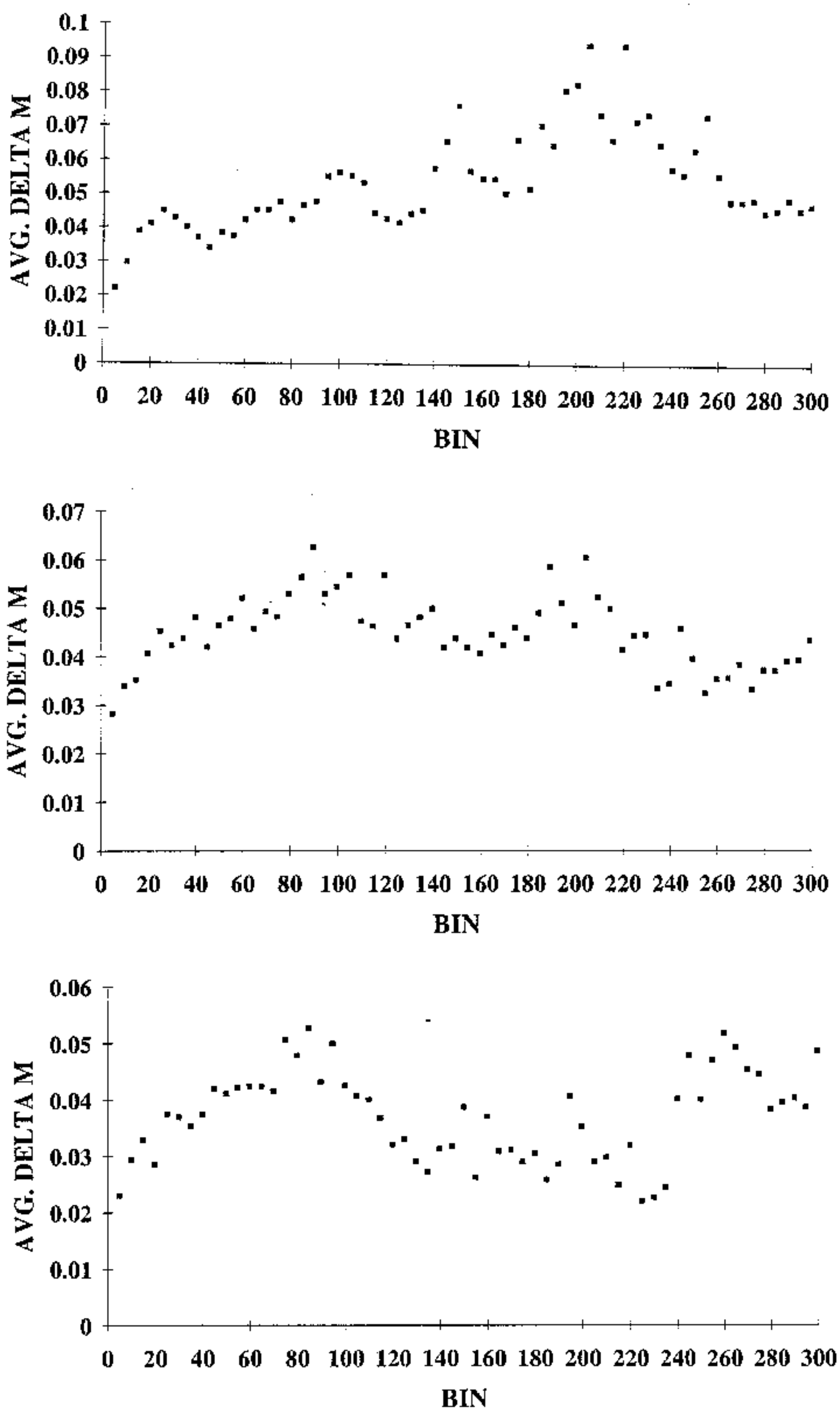


**Fig. 3.** Autocorrelation diagram (mean $|\Delta V|$ versus lag $\Delta t$) for $V$ observations of P Cygni. The panels are 1985-87 (top), 1988-90 (middle) and 1991-93 (bottom)

correlation between the expansion velocity curve and the light curve, either in terms of coincidence between maxima and minima, or their conspicuousness.

**c) Peak emission intensity**. The peak intensity curves show a sharp minimum at 75, a sharp maximum at 100, a deep minimum at 150, a poorly-defined maximum at 200, a high maximum at 400, a minimum at 450, and a maximum at 555. There thus appears to be a distinct *anti-correlation* between the peak emission intensity curve and the light curve, in the sense that maxima of one coincide with minima of the other.

## 4. Discussion and conclusions

We have presented the $V$ light curve of P Cygni for 1985-1993, and analyzed it for periodicity using Fourier and autocorrelation techniques. No one time scale is conspicuous, though 40, 120 and 160 days are noticeable in the autocorrelation diagram of the combined 1985-1993 data. These results are in agreement with previous studies by van Gent & Lamers (1986), Percy et al. (1988), Kolka (1994), Scuderi et al. (1994) and others.

*Acknowledgements.* We thank the AAVSO photoelectric observers, and the archivist Howard J. Landis, for supplying their observations. The University of Toronto observations were made by summer students Michael Richer, René Plume, Matthew Lister, David Fleming, Charles Shepherd, Kathy Hayhoe, Jason Harlow and Inese Ivans, all of whom were supported by Summer Undergraduate Research Awards from the Natural Sciences and Engineering Research Council of Canada (NSERCC). We also thank Laurits Leedjarv for making the Tartu Observatory observations, and Indrek Kolka for providing them. Allen Attard and Matthew Szczesny were participants in the University of Toronto Mentorship Program, which enables outstanding senior high school students to work on research projects with faculty members. Allen Attard was also supported by the Canadian government's SEED summer employment program.

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