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PULSATING AGB STAR IN THE SYMBIOTIC NOVA PU VULPECULAE

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PU Vul is well known very slow eclipsing symbiotic nova, which exhibited outburst in 1979. The nova reached its maximum in 1983 (B = 8.9, V = 8.33). From that time the nova fades. The light-curve of the nova exhibited two minima in 1980-2 and 1993-4, explained by Vogel & Nussbaumer (1992) and Nussbaumer & Vogel (1996) as eclipses of an outbursted white dwarf by a red M4-6 giant. The pre-outburst B light curve of PU Vul taken in years 1898-1956 showed brightness fluctuations between 14 and 15 mag (Liller & Liller, 1979). Its period analysis confirmed the presence of eclipses on the 4900 day orbit and revealed another significant period $P = 231.5$ days (Chochol et al., 1997). The same period, found by Chochol et al. (1997) in J,H,K postoutburst photometry taken by Belyakina et al. (1985, 1990) and Kenyon (1986), was explained by pulsations of the AGB variable. Its bolometric luminosity $M_c^{bol} = -4.29$ ($L_c = 4100$ L$_\odot$) can be easily derived using the empirical period-luminosity relation of Hughes and Wood (1990) valid for AGB variables (Miras and SRa's).

Chochol et al. (1997) proposed that PU Vul is a triple system. The inner binary with an orbital period of 760 days consists of an outbursted white dwarf (its luminosity during the F5 supergiant mimicry stage was $L_h = 23900$ L$_\odot$) and the AGB or bright M giant with luminosity $L_c^{inn} = 5100$ L$_\odot$. The third component is an M type AGB variable ($L_c^{out} = 4100$ L$_\odot$) on 4900 days outer orbit. The luminosities of the cool components were determined from the primary and secondary eclipse in an outer orbit using the infrared K passband observations. The distance of PU Vul determined from the luminosity of the hot component and E(B-V) = 0.39 (Belyakina et al., 1985) is $d = 5.3$ kpc.

The aim of our paper is to give an independent proof of the presence of the AGB variable in PU Vul using the photoelectric observations in V and R passbands and to show, that in 1995-8 the period of pulsations was $P = 217$ days.

Photoelectric U,B,V,R observations of PU Vul were obtained in 1995 - 98 at the Skalnaté Pleso (SP) and Stará Lesná (SL) observatories of the Astronomical Institute of the Slovak Academy of Sciences. In both cases 0.6 m Cassegrain telescope equipped with a single-channel pulse-counting photoelectric photometer was used. The stars HD 193706 = BD +21°4167 (V = 7.84, B = 9.48, U = 11.46, sp. type K5) and BD +21°4165 (V = 9.23, B = 9.80, U = 9.79, sp. type F8) served as a comparison and check star, respectively. The data reduction, atmospheric extinction correction and transformation to the standard international system were carried out by the usual way. The photoelectric light-curves in U,B,V and R passbands are plotted in Fig. 1.

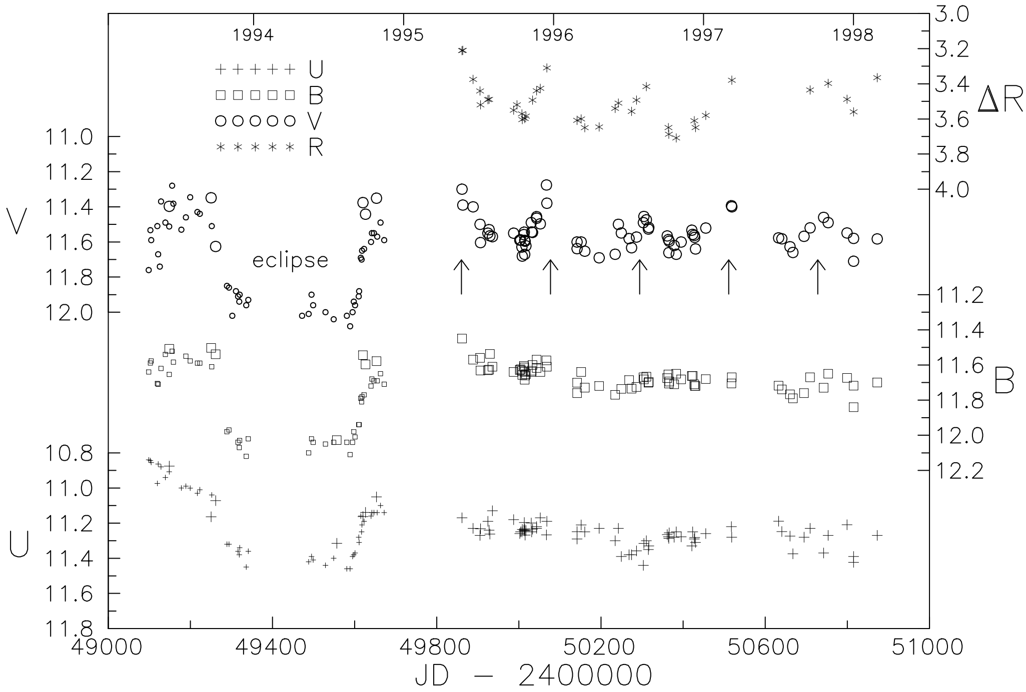

Figure 1. U,B,V and R light-curves of PU Vul since January 1993. The data till January 1995 were taken from Hric et al. (1994, 1996), Skopal et al. (1995) and Kolotilov et al. (1995). The observations taken at SP and SL are denoted by large symbols. The brightness maxima in V and R passbands are marked by arrows

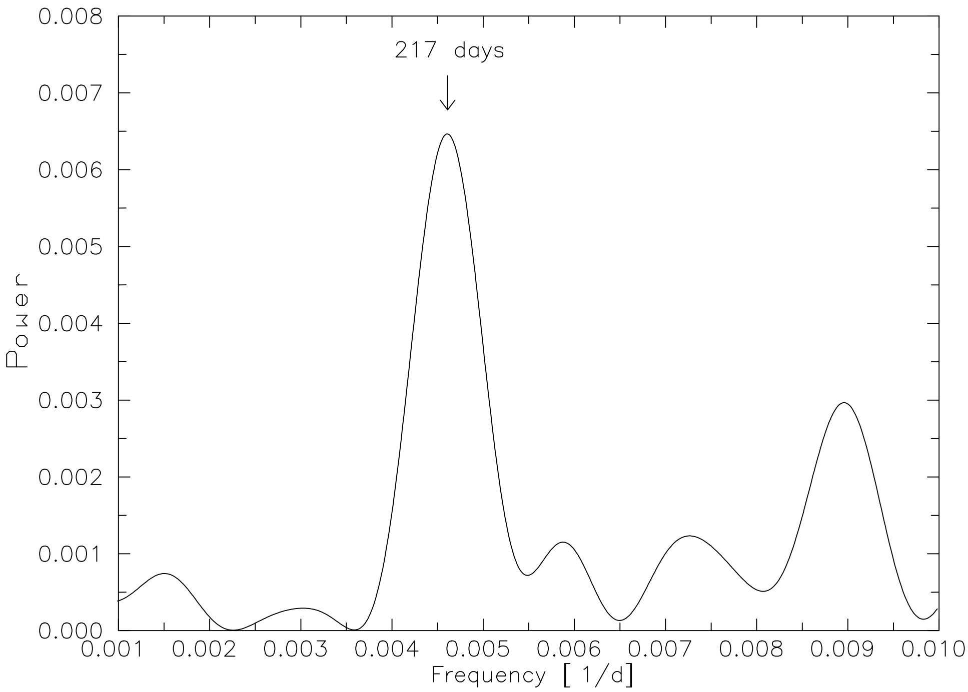

Figure 2. The power spectrum of our V observations taken since 1995

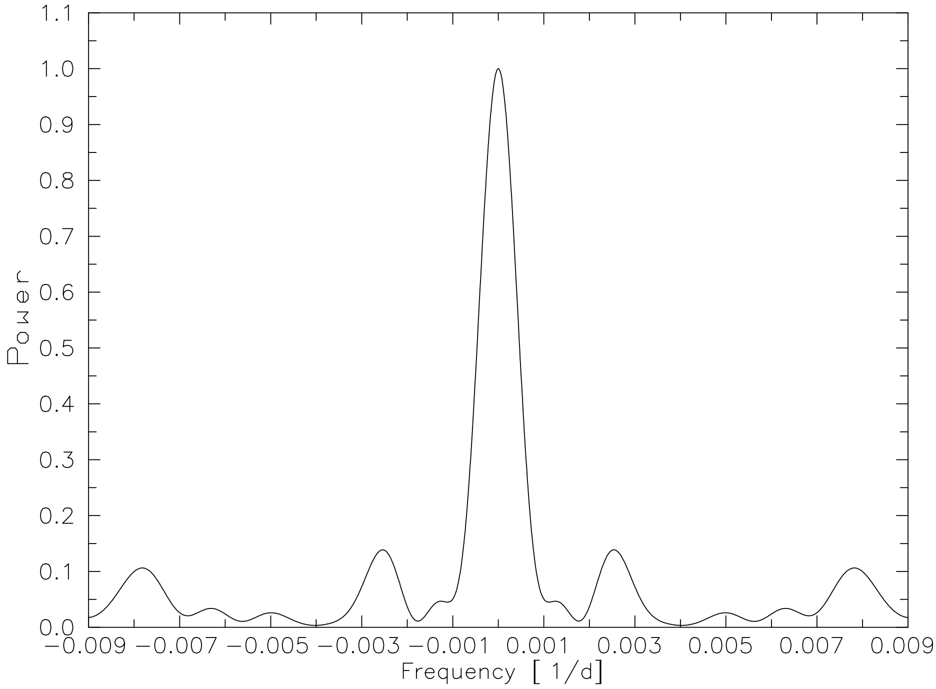

Figure 3. The spectral window corresponding to the power spectrum

It is clearly seen that the light-curve variability of PU Vul increases from U to R colour, so the source of variations is the cool component. The Fourier analysis of the V data in the interval 100 - 1000 days revealed the most significant period at 217±20 days (Figs. 2 and 3). The mean error was determined from the halfwidth of the spectral window. Corresponding phase diagram of the pulsating AGB component is displayed in Fig. 4. The brightness maxima can be predicted using the following ephemeris:

$$JD_{max} = 2\,449\,860 \ + \ 217 \times E. \quad (1)$$

The luminosity of the AGB variable can be derived using the period-luminosity relation of Hughes and Wood (1990):

$$M_c^{bol} = -4.39 - 2.91(\log \ P - 2.4), \quad (2)$$

valid for $P \leq 450$ days. Period of pulsations $P = 217$ days gives $M_c^{bol} = -4.205$ or $L_c = 3820$ $L_\odot$ (supposing $M_\odot^{bol} = 4.75$ (Allen, 1976)). The effective temperature of the M4 Mira star, corresponding to the period of pulsation 217 days, is $T_{eff} \approx 2700$ K (Allen, 1976). Its radius and mass can be determined using the Stephan-Boltzmann law and the standard pulsation equation (e.g. Feast, 1996)

$$\log P = 1.5 \log R - 0.5 \log M + \log Q, \quad (3)$$

where stellar radius R and mass M are in solar units and Q is the pulsation constant, taken to be 0.04, a value appropriate for overtone pulsation. These relations give $R_c = 282\ R_\odot$ and $M_c = 0.76$ $M_\odot$.

Acknowledgements. This work was financially supported by the VEGA grant 5038/98.

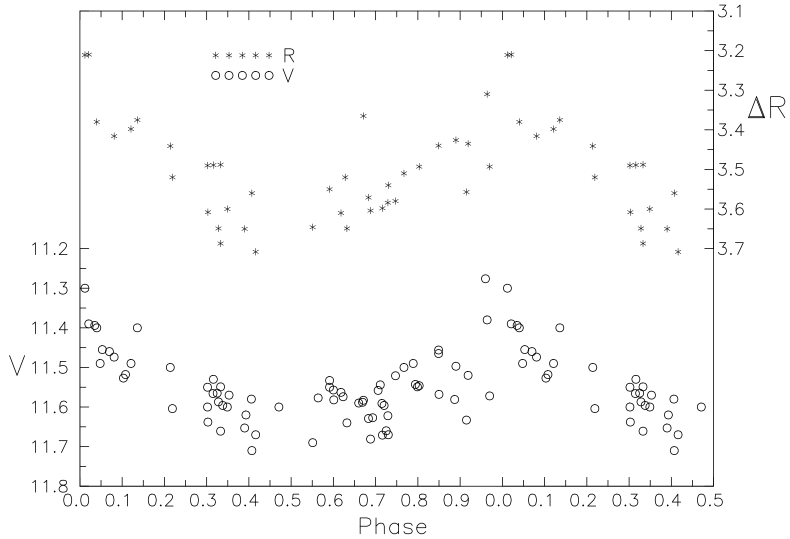

Figure 4. V and R phase diagrams for $P = 217$ days constructed from our observations since 1995

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