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VX PUPPIS - THE PUZZLE RESOLVED?

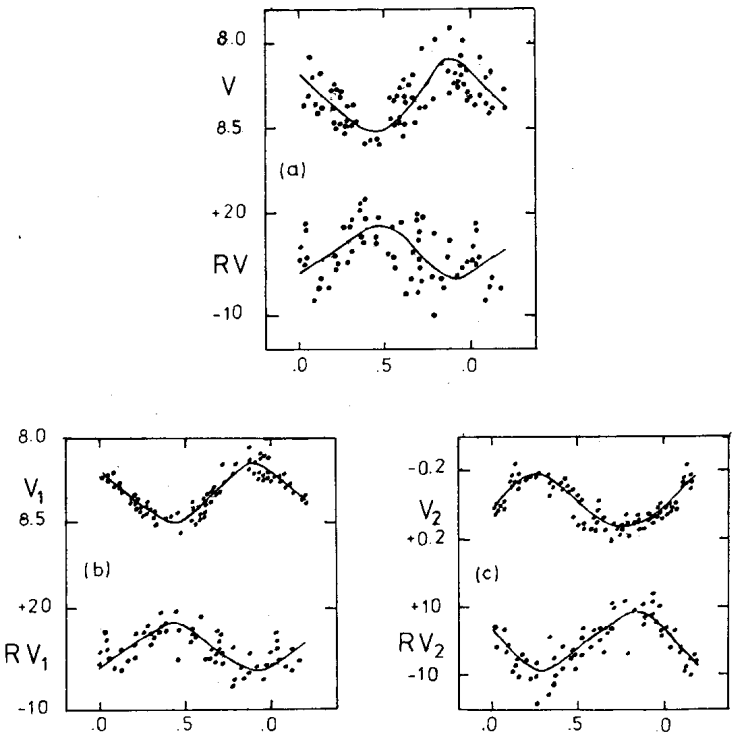
VX Puppis is a member of the class of double-mode (or beat) cepheids which show the simultaneous excitation of 2 modes of pulsation. Recently Hoffleit (1979) pointed out that the periods of P_1 = 3.01172 days and P_2 = 2.1370 days derived by Stobie (1970) appeared anomalous in that the light curve for the P_2 oscillation showed a steeper descent than ascent in marked contrast to the analysis of other double-mode cepheids. Hoffleit proposed an identification of the secondary period with P_3 = 1.8706 days for which the light curve appeared normal. The problem with either interpretation is that only 17 observations (Mitchell et al, 1964) were available to determine the secondary period although Hoffleit also noted that 12 observations by Takase (1969) roughly substantiated the period P_3. Schaltenbrand and Tammann (1971) had noted that the observations by Takase did not appear to fit the beat period derived by Stobie. Subsequently using Fourier analysis techniques Stobie (1977) showed that many secondary periods were capable of fitting the data set and that with the available photoelectric observations no unique determination was possible.

To attempt to solve this problem, Balona and Stobie (1979) undertook a study of VX Pup as part of a larger program of observing eight double-mode cepheids in the southern sky. Contemporaneous BVRI photometry and photoelectric radial velocities were obtained. We will present here only a brief summary of the frequency analysis of

the observations of VX Pup. A least squares Fourier analysis technique (Barning, 1963) was used to identify the primary and secondary frequencies and subsequently a multivariate Fourier solution of second order was fitted to the observations. The frequency range 0 to 1 cycles/day was searched for frequency components. In total 66 B,V observations and 53 radial velocity observations were frequency analysed. This presented a far more extensive and concentrated data set than available previously. Unfortunately the observations listed by Mitchell et al. and Takase could not be incorporated as it was not possible to count cycles uniquely between the different epochs of observation. Thus the results presented here are based solely on the observations of Balona and Stobie.

Frequency analysis of the B and V observations both gave identical results in identifying the primary and secondary frequencies as $f_1 = 0.33213 \pm 0.0001$ cycles/day and $f_2 = 0.46751 \pm 0.0001$ cycles/day. The search for the secondary frequency was carried out after prewhitening the observations by the sinusoid corresponding to the primary frequency. The value of f_1 is consistent with the more accurate period listed in the General Catalogue of Variable Stars (third edition) but f_2 is not consistent with either of the 2 secondary periods already mentioned. There was no ambiguity in the identification of these frequencies. This was confirmed by an analysis of the radial velocity observations (which had a different alias pattern since spectroscopic observations were obtained on some non-photometric nights). The analysis of the radial velocity observations identified the same 2 frequencies but in the reverse order. This simply meant that the amplitude of the f_2 term was larger than the f_1 term in the radial velocity observations (see table). This feature has proved to be a property of other double-mode cepheids and clearly

is a systematic effect (i.e., A_{RV}/A_V for the first overtone is always greater than A_{RV}/A_V for the fundamental). The period ratio P_2/P_1 = 0.71042 is in the range expected from the analysis of other double-mode cepheids.



Decomposition of

(a) V and RV observations of VX Puppis into component waves,

(b) primary frequency of 0.33213 cycles/day, and

(c) secondary frequency of 0.46751 cycles/day.

TABLE: SEMI-AMPLITUDES OF FREQUENCIES PRESENT IN VX PUP.

Mode	Frequency	A_B	A_V	A_{RV}
fundamental	0.33213	0.213	0.153	6.4
first overtone	0.46751	0.212	0.146	8.7

In order to check whether the shape of the light curve was reasonable, the light curve was decomposed into its component oscillations according to the frequencies given in the table. The results are shown in the figure and encouragingly the shapes of both the light curves and the radial velocity curves appear normal. The earlier results where the secondary period was inaccurately determined were caused by attempting to analyse an inadequate data set.

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