Inside the Stars, IAU Colloquium 137
ASP Conference Series, Vol. 40, 1993
Werner W. Weiss and Annie Baglin (eds.)

β Cas: SIMULTANEOUS STROMGREN PHOTOMETRY

E. RODRIGUEZ, A. ROLLAND, P. LOPEZ DE COCA, R. GARRIDO
Instituto de Astrofísica de Andalucía. Apartado 3004. 18080 Granada. Spain.

S.F. GONZALEZ-BEDOLLA
Instituto de Astronomía. UNAM. Apartado Postal 70-264. CP-4510. México D.F. Mexico

The observations were carried out in August, 1983 using the 75 cm telescope at Sierra Nevada Observatory in Spain. This telescope is equipped with a six-channel *uvbyβ* photometer for simultaneous measurements in *uvby* and the narrow and wide H_β channels, respectively. The observations were collected during four nights in the four *uvby* filters and one more night was devoted to measuring β Cas in the *n* and *w* bands of the H_β Crawford system. In all cases, a calibrated neutral filter was used for β Cas. The comparison star was C1=HR 9085 ($V=5.^m55$, F0III).

The analysis of frequencies was carried out using the Discrete Fourier Transform method, as described in López de Coca et al. (1984), to the observational *uvby* points collected. The periodograms showed a principal peak at $\nu=9.91\ cd^{-1}$. After prewhitening for this frequency, the resulting periodograms did not show any trace of another peak, suggesting the monoperiodic nature of this star, in agreement with Antonello et al. (1986). Under the assumption of monoperiodicity of β Cas, the classical O-C method can easily be applied. Nine times of maxima were obtained for the four nights by using the method described in Rodríguez et al. (1990), where each light maximum has been derived as an average over the four *uvby* bands. When the O-C method was applied, the least squares fit converged to a linear ephemeris with the following elements: $T_o=2445568.^d5097$ ($\pm0.^d0007$) and $P_o=0.^d10091$ ($\pm0.^d00002$). This linear ephemeris satisfactorily reproduces our data of β Cas.

To derive the physical parameters such as effective temperature, T_e, gravity, log g, absolute magnitude, M_v, and pulsation constant, Q, the method described in López de Coca et al. (1990) has been used. Considering the indices of $b\text{-}y=0.^m216$, $m_1=0.^m177$, $c_1=0.^m785$ (Hauck and Mermilliod 1990) and $\beta=2.^m721$ (obtained from our data), the following values of $T_e=7170$ K, log g=3.62 and $M_v=1.^m6$ can be obtained for β Cas. The Q value corresponding to the period of $P=0.^d10091$ is $0.^d024$. Values of $-0.^m004$ and 0.2 can also be obtained for δm_1 and [Me/H], respectively, using the reference lines given by Philip and Egret (1980) and Nissen's (1981) calibration for metal abundances. From a comparison with the ($\Delta m_1^*,\beta$) grids from Rodríguez et al. (1991), a m_1 index variation of about $0.^m002$ reversed, as compared with the light curve variation, must be expected over the cycle of pulsation of β Cas.

The lack of other pulsation frequencies excludes methods based on period ratios or frequency differences in order to determine the nature of radial or nonradial pulsation in this star and to identify the pulsation mode. However, Garrido et al. (1990) have shown, using *uvby* photometry, that the "amplitude ratio versus phase shift" diagrams for the (*v*,*y*) and (*b*,*y*) pairs of bands are discriminant between radial and low order nonradial pulsations for δ Sct stars. It is also true from the amplitude ratio, Δ(b-y)/Δy, versus phase shift, $\phi_{b-y}-\phi_y$, diagrams.

In Table I are listed the phase shifts, in degrees, and amplitude ratios between the different bands and colour indices, derived from the results of the Fourier analysis. In agreement with other δ Sct pulsators (Garrido and Rodríguez 1990; Rolland et al. 1991; Rodríguez et al. 1992), it is shown that the maximum light in the *v*, *b* and V bands occurs after that corresponding to the *u* band in about 0.03 cycles. From Table I it can also be seen that the curves for the b-y index is very close to the light curve whereas the c_1 index curve is shifted with respect to V curve in the sense that the maximum in c_1 occurs around 0.09 cycles after the maximum in V. These effects can be explained in terms of temperature and gravity variations along a pulsational cycle (Garrido and Rodríguez 1990). These effects can also be seen in Figure 1, where synthetic light and colour indices curves are shown. These synthetic curves were constructed using the results from the Fourier analysis.

It is also possible to see in both Figure 1 and Table I that the maximum light in the *y* filter occurs before both maxima in the *v* and *b* filters. In addition, the maximum in b-y also occurs after that corresponding to the *y* band. These effects suggest nonradial pulsation in β Cas. Furthermore, a close inspection of the phase shifts and amplitude ratios in Table I and the diagrams given by Garrido et al. (1990) leads to nonradial pulsation with l=1 as the most reliable mode identification, although the observed Δ(b-y)/Δy=0.25($\pm$0.02) ratio seems too high. This disagreement disappears if we consider a specific model with the appropiate T_e, log g and Q values (7200 K, 3.6, $0.^d024$) of this star, by using the Kurucz's (1979) models, and an increasing of the α_T(b) parameter by 0.3 (Watson 1988) is applied. The radial number, k, can be estimated from the constant of pulsation Q. A comparison with theoretical Q values given by Fitch (1981) for l=1 indicates the second overtone, k=2, corresponding to the obtained Q value of $0.^d024$.

Nonradial pulsation is not unusual for low amplitude δ Sct stars, especially when more than one frequency is excited. Observations have shown that a number of these variables pulsate with a large number of simultaneously excited nonradial p modes. However, nonradial pulsation has been also found for low amplitude δ Sct stars where only one pulsation frequency is present. An example is τ Peg. At present, τ Peg is the only δ Sct star known that shows both only one frequency and nonradial pulsation. Breger (1991) finds that this star pulsates in a nonradial p_3 or p_4 mode with l=2. Thus, the detection of only one frequency of pulsation is not an indication of radial pulsation for stars with low amplitude. Similar to τ Peg, β Cas may be a second example of low amplitude δ Sct star with a single pulsation frequency that shows nonradial pulsation.

REFERENCES

Antonello, E., Pastori, L., Poretti, E. 1986, Inf. Bull. Var. Stars, No. **2958**
Breger, M. 1991, Astr. Ap., **250**, 107
Garrido, R., García-Lobo, E., Rodríguez, E. 1990, Astr. Ap., **234**, 262
Garrido, R., Rodríguez, E. 1990, Ap. Space Sci., **169**, 205
Hauck, B., Mermilliod, M. 1990, Astr. Ap. Suppl., **86**, 107

Kurucz, R.L. 1979, Ap. J. Suppl., **40**, 1

López de Coca, P., Garrido, R., Rolland, A. 1984, Astr. Ap. Suppl., **58**, 441

López de Coca, P., Rolland, A., Rodríguez, E., Garrido, R. 1990, Astr. Ap. Suppl., **83**, 51

Nissen, P.E. 1981, Astr. Ap., **97**, 145

Philip, A.G.D., Egret, D. 1980, Astr. Ap. Suppl., **40**, 199

Rodríguez, E., López de Coca, P., Rolland, A., Garrido, R. 1990, Rev. Mex. Astron. Astrofís., **20**, 37

Rodríguez, E., Rolland, A., López de Coca, P., García-Lobo, E., Sedano, J.L. 1992, Astr. Ap. Suppl., **93**, 189

Rodríguez, E., Rolland, A., López de Coca, P., Garrido, R. 1991, Astr. Ap., **247**, 77

Rolland, A., Rodríguez, E., López de Coca, P., García-Pelayo, J.M. 1991, Astr. Ap. Suppl., **91**, 347

Watson, R.D. 1988, Ap. Space Sci., **140**, 255

TABLE I Phase shifts and amplitude ratios

u-v (degrees)	u-b (degrees)	u-y (degrees)	v-b (degrees)	v-y (degrees)	b-y (degrees)	(b-y)-y (degrees)	c_1-y (degrees)
13.1	12.0	10.9	−1.1	−2.2	−1.1	−5.3	−34.0
2.2	2.1	2.3	1.7	1.9	1.8	3.4	5.2
u/v	u/b	u/y	v/b	v/y	b/y	(b-y)/y	c_1/y
0.84	1.00	1.26	1.19	1.49	1.26	0.25	0.58
3	4	5	4	5	4	2	5

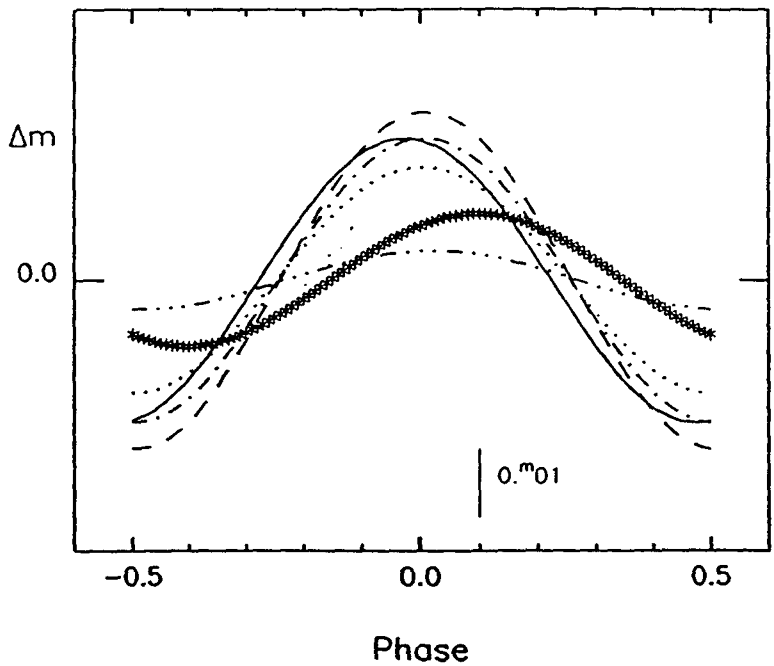

Fig. 1. Synthetic light curve and colour index variations of β Cas versus phase. u:——, v:- - -, b:-.-.-, V:....., (b-y):-...-...-, c_1:***.**