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THE PHOTOMETRIC VARIABILITY (?) OF PHI CASSIOPEIAE

Phi Cassiopeiae (HR 382, HD 7927, F0Ia, V = 5.00) is a bright, luminous supergiant with a long history of suspected velocity variability. Adams et al. (1924) reported a total scatter of 10 km/s based on 13 spectra. Abt (1970) lists 20 velocities obtained at Mount Wilson in late 1929 which suggest that this star varies in velocity by 10 km/s on a time scale of about 40 days. There are, however, some large changes in velocity from night to night, which cast some doubt on this result. Abt (1957) himself observed a monotonic increase of 4 km/s in the velocity of this star over 10 nights, which suggests a time scale of a month or two. Arellano Ferro et al. (1988) recently reported variations in velocity of 6 km/s. There was no indication of a strict period longer than 15 days, though irregular variability on a longer time scale was not ruled out.

No detailed study of the photometric variability of this star has been carried out. It is not listed as a confirmed or suspected variable in the Yale Catalogue of Bright Stars. The 14 photometric observations by Moffett and Barnes (1979) show no unusual scatter. Arellano Ferro et al. (1988) obtained multi-colour photometry over 20 days, and found scatter of up to $0^{m}.06$, but they found similar scatter in the comparison stars.

Rosenzweig (1987, 1988) has carried out a detailed study of the energy distribution of this star, and has deduced the following parameters: $T_e = 7200 \pm 100$ K; $\log g = 0.4 \pm 0.1$; $R = 263 \pm 34\ R_\odot$. These parameters imply a mass of $6.3 \pm 3.6\ m_\odot$ and a bolometric magnitude of -8.3 ± 0.3, which is consistent with the value derived by assuming that the star is a member of NGC 457. This membership, however, is in some doubt (Sowell, 1987).

The part of the H-R diagram occupied by ϕ Cas is characterized by average peak-to-peak photometric variations of $0^{m}.05$ and quasi-periods of 50 to 100 days (Maeder, 1980; Lovy et al., 1984). We have therefore been making sporadic photometric observations of ϕ Cas for many years, at Toronto (Percy and Welch, 1981) and Kitt Peak. Inspired by the report of Arellano Ferro et al. (1988), we used the Automatic Photoelectric Telescope (APT) Service

(Genet et al., 1987) to make intensive UBV observations of this star for several months in 1988-89. The sporadic observations are listed in Table I, which includes the Toronto observations (Percy and Welch, 1981) for completeness. Observations were corrected for extinction and transformation in the usual way. In particular, the procedures used by the APT Service are described in detail by Genet et al. (1987). The comparison and check star were HR 326 (HD 6676, B8V, V = 5.79) and HR 442 (HD 9408, G9III, V = 4.71) respectively; these were the comparison stars used by Arellano Ferro et al. (1988).

Table I. Photometric Observations of Phi Cassiopeiae

Julian Date 2440000 +	Magnitude	V/y	Observatory
4088.734	4.994	V	Toronto
4094.804	5.022	V	Toronto
4101.734	5.006	V	Toronto
4116.731	5.014	V	Toronto
4796.828	5.009	V	Kitt Peak
4918.733	4.982	y	Kitt Peak
4919.653	4.986	y	Kitt Peak
4920.863	4.989	y	Kitt Peak
4921.650	4.989	y	Kitt Peak
4924.640	4.985	y	Kitt Peak
4925.639	4.991	y	Kitt Peak
5715.667	5.001	V	Kitt Peak
5716.583	5.019	V	Kitt Peak

The APT observations are shown in Figure 1. There is no evidence for any significant variability on a time scale of a few days, either in Table I or Figure 1. Some of the possible variability in Table I is due to the fact that some observations were made through a V filter and others through a (Strömgren) y filter. There are, however, apparent variations in Figure 1 on a time scale of 50 to greater than 100 days, with amplitudes in V, B and U of $0^m.015$, $0^m.020$ and $0^m.030$ respectively. It is not possible to be specific about the time scale because the variations are small and irregular, and the time span of the observations is only a hundred days.

Some of the variability could be instrumental in nature. The differential magnitude of the check star shows no long-term variations larger than $0^m.005$ in V and $0^m.010$ in B. There is, however, a systematic variation of $0^m.030$ in U, which is similar to that seen in ϕ Cas. Expressed differently: if the magnitude

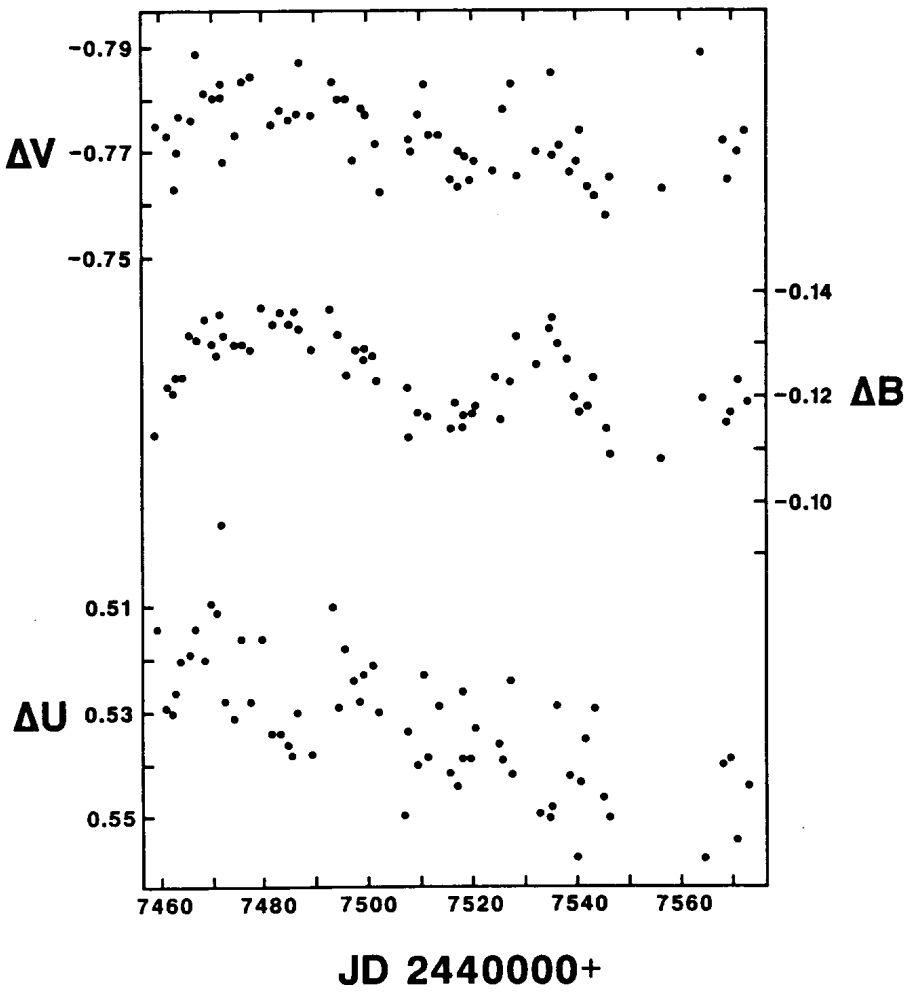

Figure 1. Photometric observations of Phi Cassiopeiae obtained in UBV with the Automatic Photoelectric Telescope Service telescope on Mt. Hopkins in Arizona. The comparison star is HR 326 (HD 6676, B8V, V = 5.79). The variations in V and B are probably real, but the variations in U are probably instrumental.

of the variable is expressed relative to the check star (which is more similar in colour), then the small variations in V and B persist, but those in U are lost in the noise.

Whether or not the variations are real, it is remarkable that they are so small. Other stars as luminous as ϕ Cas show more pronounced variations. Furthermore: if ϕ Cas were a Cepheid-like variable, then one might expect the velocity and light amplitudes to be related by: $2K = 54\ \Delta V = 35\ \Delta B$ km/s (Allen, 1973; Fernie, private communication). A velocity amplitude of 6 km/s (Arellano Ferro et al., 1988) would correspond to light amplitudes of $\Delta V = 0\overset{m}{.}11$ and $\Delta B = 0\overset{m}{.}17$, which are much larger than those observed. One must conclude that, either the velocity variations are not real, or ϕ Cas is not a Cepheid-like variable. Indeed, velocity variations have been found in other supergiants, such as Deneb, and ascribed to non-radial pulsation.

Any future photometric monitoring of ϕ Cas should be done carefully, on a long time scale, using comparison stars more suitable than the ones used in this paper.

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