Peculiar Versus Normal Phenomena in A-Type and Related Stars
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VARIABILITY OF 56 ARI

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ABSTRACT From IUE archival data and visual spectrophotometric observations published by Adelman and Pyper, nearly 20 energy distributions of 56 Ari in different rotational phases were obtained. The light variations in selected spectral bands correlate with spectrum variations. The bolometric flux varies by ~ 2.5 % over the rotation period.

56 Ari = HD 19832 = SX Ari is a hot Ap star classified as B8 Si (Renson *et al.* 1991). It is spectrum (Deutch 1947), photometric (Provin 1953) and magnetic (Borra and Landstreet 1980) variable with a period of 0.73 day (Hardie and Schroeder 1963). Two sets of low–dispersion spectra of this star are available at the IUE archive and two sets of visual scans were published by Adelman and Pyper (1979) and Adelman (1983). All these observations were reduced to the absolute scale using a standard IUE software and the calibration of Vega by Hayes and Latham (1975). A few long–wave IUE spectra had to be rejected because of a systematic discrepancy of unknown origin (for details see Stępień and Czechowski 1992). Altogether 24 short–wave, 18 long–wave IUE spectra, and 21 visual scans were analysed.

Several "monochromatic" narrow–band (20 A wide in UV and ~ 100 A in visual) light curves centered on different wavelengths were formed, and compared with helium and silicon line variations (Peterson 1966, Bonsack and Wallace 1970, Aslanov and Khokhlova 1972). The lines of 56 Ari are strongly rotationally broadened ($v \sin i$ = 200 km/s, Wolff and Preston 1978), which prevents any quantitative analysis of variability of lines of other elements. However, there are indications that magnesium lines vary in phase with helium, while sulfur and iron lines in phase with silicon (Bonsack and Wallace 1970, Glaspey and Powell 1988).

Monochromatic light curves of 56 Ari change their shape with wavelength. Nevertheless, they can be divided, according to their most characteristic features, into three groups: for $\lambda \leq 1570, 1570 < \lambda < 3000$, and $\lambda \geq$ 3000 A (Fig. 1). In the first region each curve has a primary maximum in phase 0.5–0.6 and a primary minimum in phase 0.8–0.9. In addition, a secondary maximum can be seen in phase 0.1–0.2 and a secondary minimum in phase ~ 0.3. The secondary minimum deepens progressively with increasing wavelength. The λ1400 band does not differ in behavior; the light curve

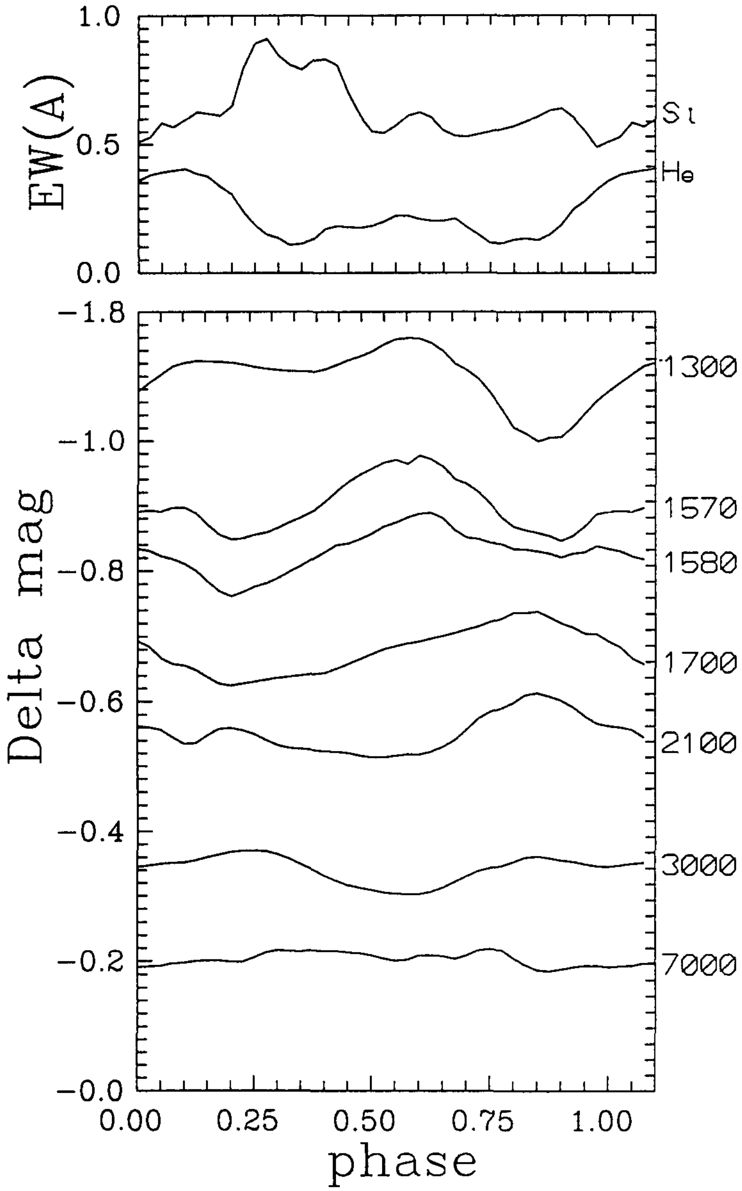

Fig. 1. Smoothed variations of equivalent width of Si II λ4128, He I λ4472 and monochromatic light variations of 56 Ari in the indicated wavelengths. The light curves were arbitrarily shifted vertically. Note a change of scale for λ1300.

in this wavelength follows a general trend. Both minima agree in phase with maxima of the equivalent width (EW) of the Si II lines (hence, also, presumably, iron peak elements), as can be seen in Fig. 1. However, an anticorrelation in amplitude occurs: the higher maximum of Si II corresponds to the secondary (shallower) minimum, and *vice versa.* Helium content varies approximately in antiphase with silicon.

Beyond $\lambda1570$ the light curve suddenly changes its shape: the hitherto primary minimum disappears and is quickly replaced by maximum (see the curve in $\lambda1700$). The curve has now one maximum in phase 0.8–0.9 and one minimum in phase 0.2–0.3. The minimum corresponds neither to maximum of EW of Si II lines nor maximum of He I lines. In still longer wavelengths the flux around the phase 0.2–0.3 increases, so that the minimum gets shifted toward the later phase (an example is a curve in $\lambda2100$).

In the third region, for $\lambda \geq 3000$, we have again two well defined maxima and two minima but they are now approximately in antiphase to the region $\lambda \leq 1570$. Such behavior is quite common among variable Ap stars and is attributed to redistribution of the flux blocked in UV by an increased line blanketing. The light curves preserve their shape throughout the visual region, until the longest observed wavelength. Broad-band photometry (e.g. Hardie and Schroeder 1963) gives similar shapes of curves in the observed bands.

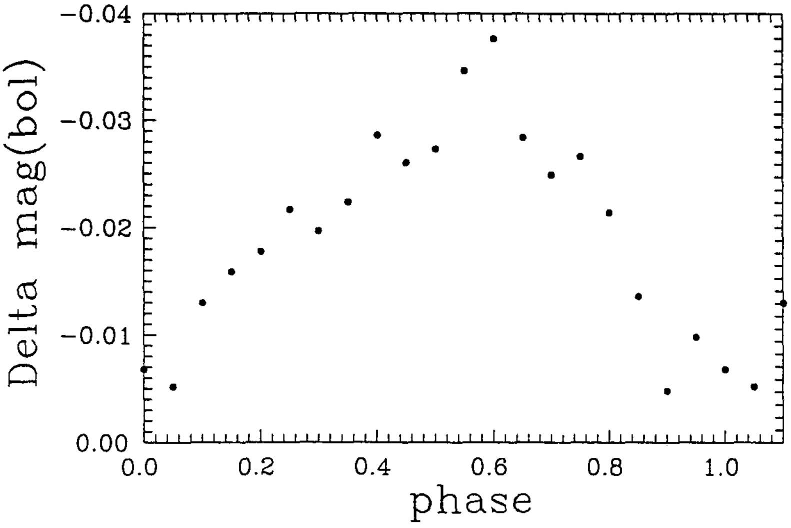

Fig. 2. Bolometric variations of 56 Ari with phase. The error of each measurement is $\lesssim$ 0.01 mag.

The sudden change of shape around 1570 A can be attributed to discontinuity of the opacity coefficient in 1530 A due to ionisation of Si I (Crivelleri and Praderie 1982). 56 Ari is relatively hot, with $T_e = 12\,200\,K$ (Stępień and Dominiczak 1987) but if silicon is strongly overabundant the ionisation jump of Si I may be large enough to show up in spectrum of even so hot star (Jamar *et al.* 1978). This explanation creates, however, other problems. Si I has another ionisation jump at λ1680 which is not seen in light variations. There is also a question, why only one silicon enriched region, visible in phase 0.8–0.9, produces a jump in this wavelength. Clearly, other elements (with a possibly different distribution) are involved.

The observed energy distributions can be integrated, hence the bolometric magnitude of the star as a function of phase can be obtained. Because the observations cover only the ranges in wavelength between 1200 and 3200 A (IUE), and 3300–7850 A (visual scans) it was necessary to supplement the integrated fluxes with fluxes from the missing ranges: 0–1200, 3200–3300, and 7850–∞ A. The flux in the range 3200–3300 A was linearly interpolated while the remaining fluxes were estimated using the data from Table 2 in Stępień and Dominiczak (1987). All these fluxes were assumed not to vary with phase. They add about 12 % of the total stellar flux. The bolometric flux of 56 Ari is plotted as a function of phase in Fig. 2. One can see that it varies by about 2.5 % over the rotational period, while the estimated error of one point in Fig. 2 is less than 1 % . The reality of bolometric variations needs an independent confirmation before one attempts a detailed discussion of possible mechanisms causing it.

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DISCUSSION (Czechowski and Stępień)

ARTRU: The observed variation around 1570 Å could also be due to an autoionization resonance of Si II. Did you also study the variation around 1780 Å? It may also be due to silicon, but is not yet identified.

STĘPIEŃ: No, we did not look at the 1780 Å region but we will do this. Thank you for this information.

MÉGESSIER: I also have a study in progress on 56 Ari. I agree with your results. My point of view is somewhat different, I think a lot of work can be done on these *IUE* data; high resolution spectra would be useful.

STĘPIEŃ: I agree. Our analysis was very limited and purely qualitative.

SCHÖNEICH: Are the bolometric variations correlated in phase with variations of other parameters?

STĘPIEŃ: The bolometric magnitude varies smoothly over the rotation period and the curve has one maximum and one minimum, whereas the light variations and spectrum variations show curves with two maxima and two minima. The magnetic curve has extrema not in phase with $M_{\rm bol}$, so I do not see any clear correlations.

COWLEY: Could it possibly be like an asteroid, bright on one side and dark on the other?

STĘPIEŃ: Why not?