*VARIABILITY IN Ap STARS

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It can be estimated that nearly half of all spectral type A stars are not normal. Normality is defined by many criteria; hence normality in stellar classification is not a simple concept. Some of the observational data presently available for the peculiar A, or Ap, and the metallic A, or Am stars in Table I will illustrate this point.

TABLE I

CHARACTERISTICS OF Ap AND Am STARS.

CHARACTERISTIC	Ap	Am
Metal Abundance:	Very overabundant, often 1-2 orders of magnitude: particularly Si, Fe, Cr, Mn, Sr, Hg, Eu, & other rare earths. Weak Ca and often weak He.	Overabundant, but not so much as in Ap stars, except Sr & Sc. Very weak Ca.
Spectral Type:	B8-A4 primarily with mean spectral type B9.5. Hence Ap stars are mostly B stars. Si & Hg/Mn are the hottest subgroups with $-0.15 \leq$ B-V$\leq$ 0.05. Sr/Cr Eu stars have $-0.1\leq$ B-V$\leq$ 0.2. Located just above main sequence on H-R diagram.	A3-F2, luminosity classes IV & V ($0.1\leq$ B-V$\leq$ 0.35) with mean spectral type F0. Hence most Am stars are F stars! Located just above the main sequence on H-R diagram. (see Figure 1).
Magnetic Field:	Several hundred to several thousand gauss. Babcock's star (HD 215441) possesses a 34,000 gauss field, Terrestrial & solar fields are on the order of 1 gauss.	Probably none. Early reported fields in Am stars are now thought to be misclassified (actually Ap).
Rotation:	Slow rotators, V = 0-100 km/sec. Normal A stars have V = 50-300 km/sec.	Slow rotators, V = 0-100 km/sec. Usually less than 25 km/sec.
Binary Occurrence:	Less than 20% of stars in this spectral range are binaries. Of these, all are visual binaries with periods of years.	Probably all. 80% are spectroscopic binaries with periods of days. The rest are likely seen pole-on.

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Number Known:	More than 100 with M_V <7.0.	More than 100 with M_V <6.5.
Galactic Distribution:	Random except hottest stars (near plane). Over 2 dozen in galactic clusters; hottest in youngest.	Random. About 2 dozen in older open cluster (Coma, Hyades, Praesape).

Table I was constructed primarily from Ledoux (1966) and Cameron (1967), updated with numerous, more recent observations found in the literature.

Slow rotation and the position of these stars on the Hertzsprung-Russell (color-magnitude) diagram seem to imply that these stars are either pre- or post-main sequence stars. Galactic distribution of Ap stars sheds little light on their relative ages, while that of Am stars might indicate further evolution. This question remains unanswered.

My specific concern is with the variability of these objects. Consideration of the previous observational data will show that Ap and Am stars are limited in their similarities. In addition, only Ap stars display any intrinsic variability. See Table II (same references as for Table I).

TABLE II

VARIABILITY OF Ap STARS

Magnetic Field:	Several hundred to several thousand gauss. Maxima and Minima are often of unequal strength, e.g. 21 Aquilae: -590 to +170 gauss. Many of those carefully examined Ap stars display periodic magnetic variability, on the order of days.
Light:	M_V varies 0-0^{m}2, often periodically (see Figure 2). Periods are usually 1-20^d, but range to over 200^d.
Spectrum:	Change in line shapes due to magnetic splitting (Zeeman Effect) and intensities. Periods comparable to light variations.
Color:	B-V color index varies 0-0^{m}1 in very complicated fashion. Some Ap stars are reddest at magnetic maximum, some are bluest, while others display more complex behavior.

The problem is to explain these observed variations with a simple physical model. The most successful model to date is due to Deutsch (1958), entitled the Magnetic Oblique Rotator (see Figure 3). The rotational axis, ω, is inclined at an angle, θ, to the magnetic axis, $\overline{NS}$. As the star rotates the magnetic field strength is seen to vary with the period of rotation. The magnetic poles appear as "spots" on the stellar surface, affecting the observed light output in two possible ways. First, if the magnetic spots are of unequal strength, the stronger spot will be hotter, making the star appear bluer. Or, metals might segregate to the stronger magnetic pole, slightly blocking the energy output at that point. Hence the star would appear redder.

Much work remains to be done in this field. The periodicities of both magnetic and light variations are well established for only a very few stars. Although Ap stars are small amplitude variables, many (e.g. β CrB, α^2 CVn, and α And) are naked eye stars easily accessible to 3-color (UBV) photometry with smaller telescopes, a worthy project for observers to undertake.

REFERENCES

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Stepien, K. 1968, Ap. J., 154, 945.

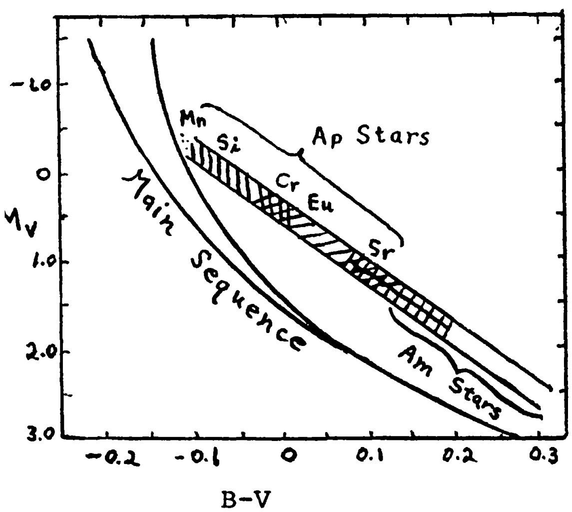

Figure 1. H-R Diagram of Ap and Am stars. (Cameron 1967, 242)

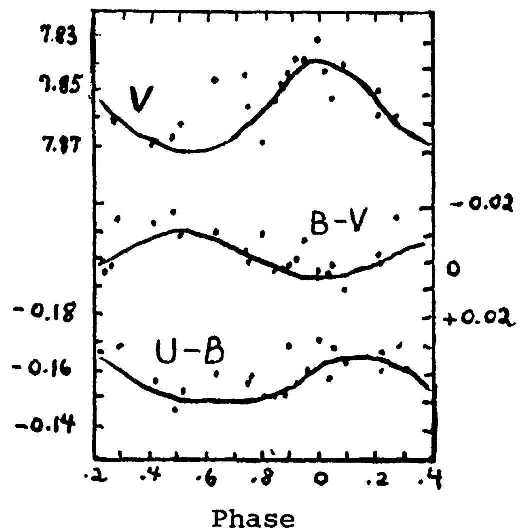

Figure 2. Light curve of HD 19216, period $7^d.7$. (Stepien 1968, 953)

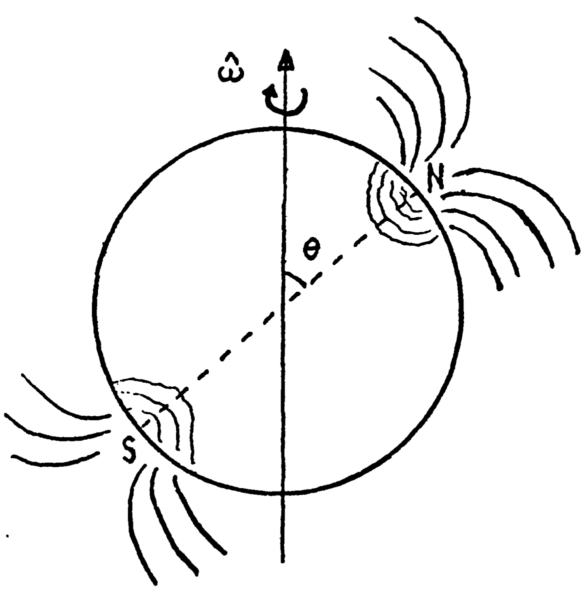

Figure 3. Magnetic Oblique Rotator (see text).