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HD101065—THE MOST PECULIAR STAR?

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HD101065 was discovered by Przybylski (1961) to have a very unusual spectrum. Six colour photometry suggested an effective temperature, \( T_{\text{eff}} \sim 6030 \text{K} \) corresponding to a spectral type G0. Later he examined a list of about 3000 spectral lines (Przybylski 1963) with wavelengths between 3600 and 4800A. Almost all of these were identified as due to rare earths with the exception of very weak Hydrogen and Calcium (H & K). The strongest lines were due to Holmium and Dysprosium. No Iron or Iron-peak elements could be identified in these optical spectra. As a result of these observations Przybylski suggested that HD101065 was the coolest Ap star known.

The relevance of this finding can be seen if we consider the properties of the Ap stars in general. Their spectral types range from B2—F2V (IV?). All show "anomalous" spectra superimposed on an underlying normal spectrum for the spectral type. The apparent abundance anomalies themselves show a temperature dependence. The hottest stars exhibit overabundances of Manganese, while those at the cooler end of the range are overabundant in Europium, Chromium and Strontium. In between are the Si-overabundant stars. All have high magnetic fields with \( B \geq 1000 \text{G} \). They are variable photometrically, in field strength and in the strengths of the anomalous spectra with periods of a few days. There are no kinematical peculiarities. The Ap stars are disk population reflecting their early spectral types.

These properties are interpreted in terms of stars with a strong oblique magnetic field. In addition their atmospheres have minimal convection and so a diffusion mechanism is invoked to account for the observed abundances. Various ionic species vary in their cross sections for photon capture. Thus in a given radiation field certain ions will diffuse outward as a result of enhanced rate of photon capture. In the absence of appreciable convection this will lead in time to the outermost layers of the star having enhanced abundances of those ions. When a detailed consideration is given to this effect a reasonably good account can be given of the observed overabundances in the Ap stars and their variation with effective temperature. The presence of a magnetic field may increase this effect since it will help to further stabilize the stellar atmosphere,
especially close to the magnetic poles. Thus in the presence of a magnetic field there will be surface inhomogeneities in respect of the overabundances. As the star rotates, in the oblique rotator model, variability will result in phase with the magnetic field strength variations.

Can HD101065 be regarded as an Ap star? Certainly the rare earths are strongest in the coolest Ap stars. In particular, the Eu-Cr-Sr Ap star HD51418 exhibits strong lines due to Holmium and Dysprosium in its spectrum as does HD101065. Wolff and Hagen (1976) detected a 2000G magnetic field further reinforcing the case for a comparison with the Ap stars. Perhaps most significantly Kurtz and Wegner (1979) showed that Przybylski's star is photometrically variable—but with a period of only 12 mins! Since then Kurtz (1982) has discovered 4 further Ap stars, of otherwise conventional Ap characteristics, which oscillate with periods of between 6 and 12 mins. These variations are obviously not based in rotation. Kurtz argues convincingly that they are oscillating in very high order modes of vibration.

So HD101065 appears to fit many of the defining characteristics of Ap stars except for (a) its low T_{eff} and (b) the apparent absence of Iron and Iron-peak elements in its spectrum. Both points would argue against the diffusion hypothesis of the abundance anomalies. A low T_{eff} would imply a deep convection zone which would mix the outer layers in a time far shorter than the diffusion time. Complete absence of Iron and the Iron-peak elements would imply that the underlying star is fundamentally peculiar in its chemical composition requiring some special circumstances for its generation.

Wegner and Petford (1974) examined red wavelength spectra (4800-7100A) and concluded the following.

1. Of the 20 strongest Iron lines in the solar spectrum 16 were present in HD101065.
2. A total of 313 Iron lines were identified in HD101065. The probability of this occurring by chance they estimated to be 10^{-3}.
3. From the appearance of the Balmer discontinuity and the equivalent width of H_{\gamma} on an earlier spectrum by Warner, they estimated a spectral type for HD101065 of F0(T_{eff} = 7400K).
4. Using the observed density of lines to estimate the blanketing effect on the observed (R-I) colours they derived T_{eff} \sim 7000K.
5. Based on the above spectral type they carried out an abundance analysis using a curve of growth analysis and concluded that the abundance of Iron was normal and that of the Lanthanides was \sim 10^{5} times normal.

Cowley et al (1977) examined blue region spectra and also detected the presence, albeit weakly, of Iron itself and the Iron-peak elements Titanium and Cobalt.

The present work was carried out jointly with G. Wegner and D. J. Cummins of the Pennsylvania State University and D. J. Stickland of the Royal Greenwich Observatory. It is based on ultraviolet spectra taken with the IUE satellite. Spectra were taken of HD101065 at low resolution (\sim 6A) over both the long-(1950-3200A) and short-(1150-1900A) wavelength ranges. A series of high-resolution (\sim 0.1A) spectra were also taken over the long-wavelength region.

The low-resolution data were combined with visible and near infrared photometry to give energy distribution for the star between 2.5\mu m and 1200A approximately
(Figure 1). Also shown in the same figure are continuous energy distributions from model atmospheres of solar composition by Kurucz (1979). A comparison of the two sets of curves in respect of their Balmer discontinuities and 1700A discontinuities clearly favours an effective temperature for Przybylski’s Star of between 7000 and 8000K.

The high resolution spectra were examined for lines. 1725 lines and their wavelengths were measured and these compared with the NBS lists of lines (Meggers, Corliss and Scribner 1975). The following species were judged to be definitely present; CoII, CrII, GdII, HoII, FeII, MgI, II, MnII, TmII, TiII, ZrII. Furthermore a comparison was made between the laboratory intensities and the equivalent widths of the stellar lines. The results of this comparison are shown in Figure 2 for MnII and FeII, showing that a reasonably good correlation exists and adding weight to the line identifications. A comment should be added in relation to the determination of line equivalent widths however. The spectrum of HD101065 is so heavily blanketed that it is not clear where the continuum lies. The equivalent widths determined in this study were derived by adopting a “pseudo-continuum” which passes through the highest peaks of the star’s spectrum. This should approximate to the true continuum minus a constant flux.

Figure 1. Spectral distribution of flux for Przybylski’s Star (upper curve) and model stellar atmospheres by Kurucz (1979). The features marked ‘X’ are flaws.
Figure 2. A comparison between laboratory and stellar line intensities for two Iron-peak elements.

Analysis of these spectra is continuing. The results of this first study however would appear to favour the earlier spectral type for HD101065 and the presence of Iron and the Iron-peak elements in the spectrum. These in turn support the argument that the star is an Ap star but of somewhat extreme spectral peculiarity. A fuller account of this work will be found in Wegner et al (1983).

References


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