THE WHITE DWARF COMPANION OF THE Ba II STAR ζ CAP

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ABSTRACT

The Ba II star ζ Cap has a white dwarf companion. Its T_{eff} is determined to be 22000K, its mass $M \sim 1 M_{\odot}$. The importance of this finding for the explanation of abundance peculiarities is discussed.

During the course of observing chromospheric and transition layer emission of stars with different chemical abundances we also observed the Ba II class 2 star ζ Cap (G5 IIp). Figure 1 shows the tracing which we obtained at the computer screen at the IUE observatory. The intensity increases again for λ<1500A. We even see a slight intensity increase shortward of Ly α, indicating a faint B star spectrum. The energy distribution obtained after correcting for the instrumental sensitivity is seen in Figure 2. For comparison we have also plotted the energy distributions for the G8 III standard star ε Vir and for the weak Ba II star ζ Cyg (G8 IIp). These spectra are all normalized to the same visual magnitude. The intensity for λ<1500A increases with increasing Ba II anomaly of the star. For ζ Cap we see the superposition of the normal G8 II star spectrum (for λ >1600Å), the cool chromospheric emission line spectrum (1500<λ<1600Å), some intense emission lines from regions with temperatures around 100,000K, (CIV, NV), and the additional faint B type stellar spectrum (for λ<1500Å).

An estimate of the absolute magnitude shows immediately that the B star must be a white dwarf. Interpreting the decrease of the intensity for λ<1300Å as the Ly α wing we can determine the relation between T_{eff} and log g (g = gravitational acceleration) which will produce such a Ly α profile. From the calculation by Wesemael[1] et al. (1979) we find a log g, T_{eff} relation shown by the solid line in Figure 3.

If we know the absolute magnitude of ζ Cap we know the distance and the absolute flux for the companion ζ Cap B at 1300Å which gives a relation between the radius R and T_{eff}. For white dwarfs the radius determines the mass $M_{\odot}$ of the white dwarf and thereby also the gravitational acceleration g. We have used the Hamada, Salpeter [2] (1961) relation M(R) for helium white dwarfs. The spectroscopists (Kemper[3] 1975, Sneden and Smith [4] 1980) tell me that M_V = -3 for ζ Cap.

With this value we find a relation between T_{eff} and log g as shown by the dashed line for M_V = -3. The intersection with the solid line determines the best value for T_{eff} and log g (M) leading to T_{eff} = 22000K and M = 0.98$M_{\odot}$. For lower absolute brightness, i.e. a smaller distance of ζ Cap A, ζ Cap B has to be smaller and more massive. The ζ Cap companion is then very similar to Sirius B.

This observation seems to be especially important in view of the findings of McClure et al.[5] (1980) who observed radial velocity variations of all strong Ba II stars. They are now checking on the weak Ba II stars. For two of the systems they could determine mass functions which indicate masses of 1 to 2 $M_{\odot}$ for the invisible companions. They concluded that these had to be white dwarfs. Since all Ba II stars appear to have companions they concluded that the Ba anomaly is due to mass exchange between binaries rather than to mixing in the star. In fact, the strong emission lines seen in the ζ Cap system make it probable that some mass exchange is still going on. The question then arises how much of the peculiar abundances seen in red giants of both populations is due to mass exchange and how much due to actual mixing?

Whether ζ Cyg also has a white dwarf companion is not quite clear; we need to study the data more carefully. If it has one, it must be of lower temperature, probably around 14000K, but of similar mass.

These are the two brightest Ba II stars. We have since observed Ba II stars ~2.5 magnitudes fainter. So far none of them has a possible companion bright enough to be clearly recognizable on 4^h exposure spectra. We are still studying the data. Details of this study will be published in the Ap.J. Letters.

REFERENCES

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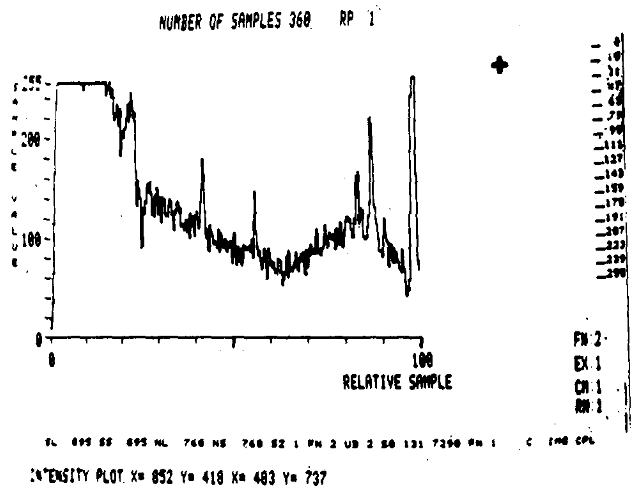

Figure 1: The short wavelength spectrum of the Ba II star ζ Cap as seen on the computer screen at the IUE observatory. The increase in intensity for λ<1500Å is attributed to a white dwarf companion. The intensity increase shortward of Ly α indicates rather high temperatures for the companion.

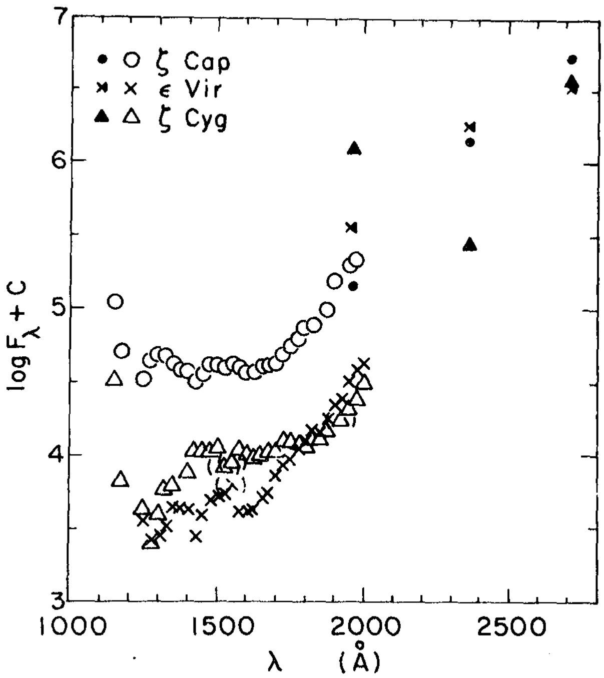

Figure 2: The energy distributions of the Barium star ζ Cap, the weak Barium star ζ Cyg and the standard star ε Vir, all normalized to the same visual magnitude. The short wavelength intensity increases with increasing Ba II anomaly.

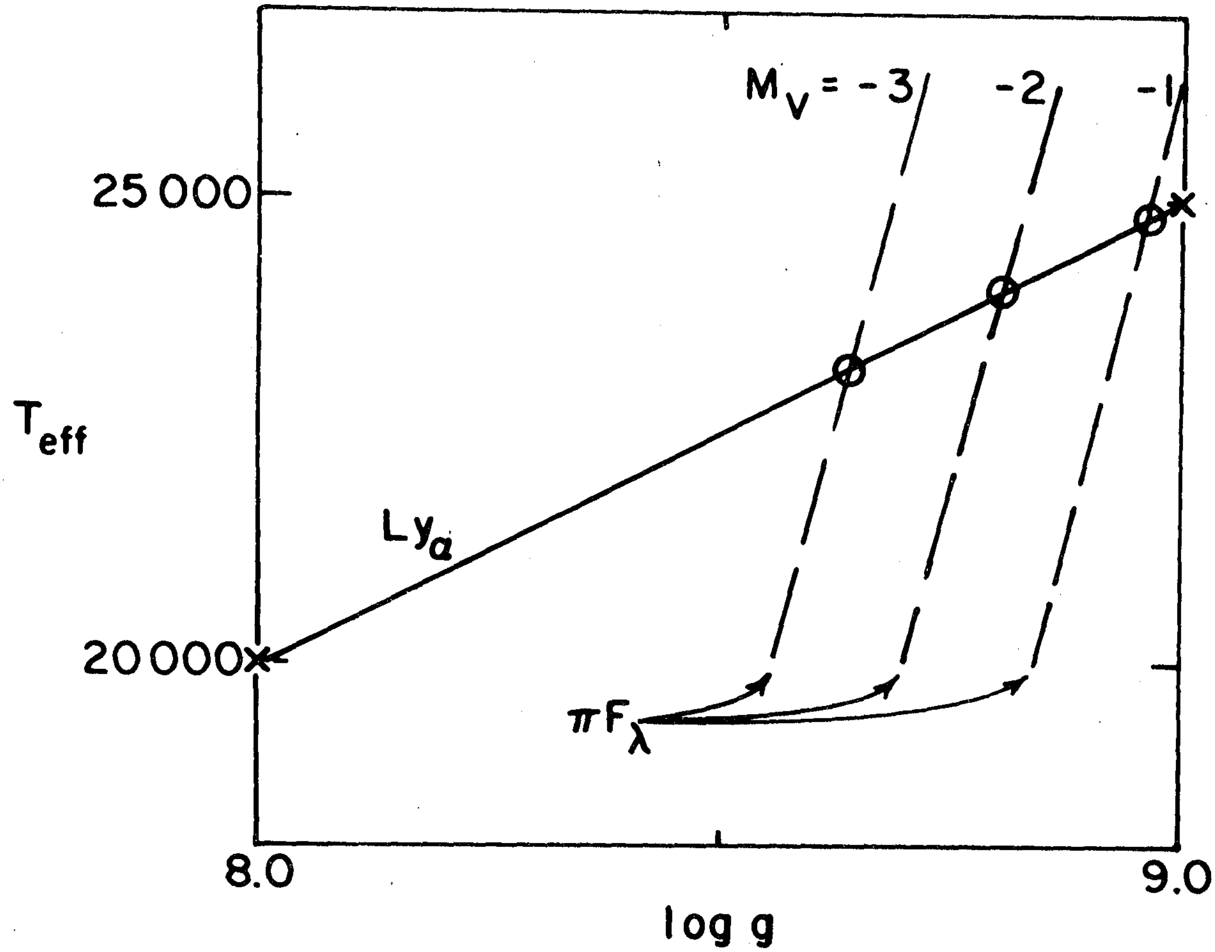

Figure 3: The T_{eff} log g plane showing the possible combinations of T_{eff} and log g giving the observed Ly α profile (solid line) for ζ Cap B and the relation between T_{eff} and log g leading to the observed absolute intensity at 1300A (dashed lines). The different lines are obtained for different absolute magnitudes for ζ Cap A leading to different distances. The intersection of the appropriate dashed line with the solid line gives the value of log g and T_{eff} for ζ Cap B.