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THREE INTERESTING STARS

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The three interesting stars are CO Aur, HR 7308 and XZ Ceti.

CO Aur is a Pop. I Cepheid, pulsating in two modes with periods $P_1 = 1.78$ days and $P_2 = 1.43$ days. The ratio of these periods indicates radial pulsation in the first and second overtones. Antonello and Mantegazza (1984) Fourier decompose the light curve of CO Aur and offer further evidence favoring overtone pulsation, based upon the Fourier diagrams of Simon and Lee (1981). Mantegazza (1983) estimates a temperature for CO Aur of $\log T_e = 3.825 \pm 0.023$.

Employing the Lagrangian code described by Aikawa and Simon (1983), we have constructed two linear nonadiabatic (LNA) pulsation models for CO Aur, both with normal Pop. I composition ($X = 0.70$, $Z = 0.02$) and an evolutionary mass-luminosity relation. The first model has $M = 5.2 M_\odot$, $L = 1500 L_\odot$ and $T_e = 6700$ K, corresponding to the temperature quoted above. The periods and growth rates (P, η) for the three lowest radial modes of this model are $(2.41, -6.55E-3)$, $(1.81, -1.26E-2)$ and $(1.45, -1.51E-2)$. Although the periods of the first and second overtones match those of CO Aur quite well, all of the modes are linearly stable and thus not expected to appear at finite amplitude.

Thus we are forced to try a lower temperature, which leads to the second model: $M = 5 M_\odot$, $L = 1100 L_\odot$, $T_e = 6300$ K. This temperature is just below the bottom of the range given by Mantegazza (1983). The periods and growth rates for the first three modes of the model are as follows: $(2.36, -8.95E-4)$, $(1.78, 4.22E-3)$, $(1.43, 9.19E-3)$. In this case not only are the first and second overtone periods extremely close to the observed values, but the fundamental mode is linearly stable while the two overtones are unstable. Although limit cycle characteristics cannot be directly inferred from linear growth rates, nonetheless this model is certainly not inconsistent with pulsation in the first and second overtones. We conclude that the temperature of CO Aur probably falls at the low end of Mantegazza's estimated range.

HR 7308 is also an apparently normal Pop. I Cepheid (Percy and Evans 1980; van Genderen 1981) with a constant period $P = 1.49$ days, but variable amplitude. The amplitude covers a range from about 5 to 20 km/sec in radial velocity and 0.05 to 0.30 in visual magnitude over a timescale of about 1200 days. According to Breger (1981) and Burki, *et al.* (1982), HR 7308 seems to be pulsating in a single modulated radial mode. Based on published Q-values, Burki, *et al.* (1982) take this mode to be a second or higher overtone. The temperature of HR 7308 is estimated to be $\log T_e = 3.786 \pm 0.01$ (Burki, *et al.* 1982).

We have constructed an LNA pulsation model for HR 7308, assuming Pop. I composition and evolutionary mass, and using the temperature given above. The parameters are: $M = 5 M_\odot$, $L = 1000 L_\odot$, $T_e = 6110$ K. In agreement with Burki, *et al.* (1982), we find that the fundamental and first overtone periods of this model are far too long for HR 7308. On the other hand, the second overtone period matches the observed value and has a growth rate exceeding that of the fundamental by a factor 13, and that of the first overtone by a factor of nearly 2. Higher overtones are all linearly stable. Thus for any reasonable Pop. I mass, second overtone pulsation seems required to reproduce the period of HR 7308. A somewhat more detailed discussion is given by Simon (1984).

The third object of our interest is XZ Ceti, a small amplitude pulsator with a sinusoidal light curve and a period $P = 0.82$ days which suggests an RR Lyrae star of Bailey type ab (fundamental mode). Based upon recent observations, Teays and Simon (1984) derive a temperature $T = 6500$ K for this star, and then construct a series of LNA models with Pop. II composition. Arguments are made which seem to rule out pulsation in the fundamental mode. This leaves as viable alternatives two first overtone models corresponding respectively to a BL Herculis star and an anomalous Cepheid. Teays and Simon (1984) argue that the latter model is preferable, in which case XZ Ceti resembles the globular cluster star V 19 (Zinn and King 1982) an object whose anomalously high mass is believed to have resulted from binary mass exchange.

The three stars CO Aur, HR 7308 and XZ Ceti, each unique in its own right, share the following properties: 1) each is quite cool, perhaps lying near its respective red edge; and 2) each is probably an overtone pulsator. Thus there seems to exist a region toward the red where overtone pulsation is favored. However, a cautionary note ought to be inserted here: none of the models described in this report included convection. While both Deupree (1977) and Stellingwerf (1984) found that the first overtone red edge lies considerably to the blue of the fundamental red edge, at least one of Stellingwerf's convective overtone models showed finite amplitude instability, indicating that overtone pulsation might be possible at or beyond the red edge, given a redward direction of evolution. Thus, at the moment, the potential effects of convection on our problem are not completely clear.

In any event, evidence now appears to exist for first and/or second overtone pulsation in at least three stars. A fourth candidate might be the double-mode δ Scuti star VZ Cnc. Like CO Aur this star has a period ratio of 0.80 suggesting the first and second overtones. Cox, et al. (1984) reject this interpretation (in favor of an explanation which involves the settling of helium) at least in part because VN Cnc seems to be near the red edge in the H-R diagram. However, our three interesting stars indicate that overtone pulsation in cool objects should not be ruled out. As more observations are made of small amplitude pulsators the list of such objects may well grow.

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