PULSATION OF PMS 1.8 $M_\odot$ STARS: A THEORETICAL INVESTIGATION

DORU MARIAN SURAN
ASTRONOMICAL INSTITUTE OF ROMANIAN ACADEMY,
Str. Cutitul de Argint, No.5, 75212 Bucharest 28, ROMANIA,
e-mail: suran@roastro.astro.ro

Herbig Ae stars are pre-main sequence of masses $\sim 2M_\odot$. As they trace their course toward the ZAMS, they cross the classical instability strip. At this stage, their evolution has considerably slowed down. Their structure differs from that of stars evolving after the ZAMS (δ Scuti stars) in the very deep layers where nuclear burning has only recently started. But the outer layers for stars before and after the ZAMS are expected to be similar. As these layers drive the pulsation of δ Scuti stars, it is reasonable to expect that PMS stars in the instability strip also are destabilized by the κ mechanism with a similar range of unstable modes. Indeed, recently a Herbig Ae star has been reported as a variable (Kurtz and Marang 1995).

To study more precisely the internal structure of a PMS star of 1.8 $M_\odot$, we use two different theoretical stellar models: *CESAM* code (Morel et al., 1992) and *HENYEY* code (Suran 1993), and check the consistency of the calculations (limited by possible differences in the physical estimations for the EOS, opacities, energy release, convection, overshooting effect,...). We studied also post-MS 1.8-2 $M_\odot$ stars, which lie in the region of the HR diagram as the PMS 1.8 $M_\odot$ star.

For our purpose, it is enough to assume that by the time the proto-star has arrived in the region of the HR diagram of relevance here (classical instability strip, t>5.9 Myr), complex dynamical and thermal phenomena that take place in the very early stages of PMS evolution have long disappeared and have generated an internal structure which can be computed according to a classical treatment for this kind of star.

Details of the structure of PMS models which can be of interest are the *convection* (l_{MLT} =1, 1.5 for the Henyey model, l_{MLT} =1.5 for the CESAM model), and the *gravitational and nuclear energy* release: $\epsilon = \epsilon_g + \epsilon_n$. The difference between a PMS star and a post-MS star at a given position in the HR diagram lies in the fact that the PMS star is still contracting, in a mechanical and thermal imbalance due to the release of gravitational energy. The internal structure, and therefore the pulsation characteristics, such as frequencies and growth rates, evolve on a much more rapid (Kelvin-Helmholtz) time-scale ($\sim 10^6$ yr). Because of the release of contraction (or expansion), an extra energy, due to the ϵ_g, is supplied to or retrieved from the oscillation and affects the stability of the modes. This extra energy is, however, very small and confined in the deep (or respectively outer) adiabatic regions and therefore can be neglected.

F.-L. Deubner et al. (eds.), New Eyes to See Inside the Sun and Stars, 397–398.

Numerical computations (for l=0-3, n<10) have been done with a *fully nonadiabatic code* (Suran, 1993) and compared with the *Dziembowski's code* (Goupil 1995, private communication). In our analysis we found a wide ranges of excited modes (g,f,p types and also mixed g-p modes).

Due to a similar mean density and similar outer layers, frequencies of pure p modes of given (n,l) are similar. Mixed modes and g modes, trapped in the interior, however differ (*l=2, p_2, g_2 mixed modes)*. If we suppose we have:

$$W = W(\epsilon_n) + W(\epsilon_g) + W(\kappa), \tag{1}$$

the results indicate negligible contribution from nuclear energy and contraction (or expansion) energy. Only for high-overtone g modes does the influence of ϵ_n become of importance. These kind of modes are only quasi-excited modes ($-0.05 < \eta < 0$) in the δ Scuti region (and represent in fact a prolongement of the excited high-overtone g region of the SPB stars). From a seismological point of view: mixed modes would discriminate as they are very sensitive to the structure of the inner layers which differ between PMS and MS stars. This can be done differentially

$$\nu_i(pms) - \nu_i(postMS) \tag{2}$$

at same position in the HR diagram. This could be seen particularly in the vicinity of models for which post-MS stars have developed a large μ gradient, whereas PMS stars have almost non-existent convective cores with no μ gradient .

References

Dziembowski, W. (1977), Oscilations of giants and supergiants, *Acta Astr.* **27**, pp.95.

Kurtz, D.W., Marang, F. (1995), The discovery of a δ Sct pulsational variability in the pre-main-sequence Herbig Ae star HR 5999, and the discovery of a rotational light variability in the remarkable He-weak Bp star, HR 6000, *MNRAS* **276**, pp.191.

Morel, P., Berthomieu, G., Provost, J., Lebreton, Y. (1993), CESAM solar model, *IAU Coll. 137 Inside the Stars*, eds. A.Baglin, W.Weiss, pp.54.

Suran, M.D. (1993), Asteroseismologic models with rotation, *IAU Coll 137 Inside the Stars*, eds. A.Baglin, W.Weiss, pp.560.