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CONVECTIVE OVERSHOOTING IN WHITE DWARF AND ZZ CETI STARS

N. Falcón and J. Labrador

Depto de Física, FACYT Universidad de Carabobo, Av. Bolivar Norte, Valencia Ap. 129 CP 2001, Venezuela
nelsonfalcon@hispavista. com

The light curves of ZZ Ceti stars exhibit variations of luminosity with typical intervals between successive pulses in the range from the hundreds to the second thousands, and, in general, the "periods" are not constant.

The oscillations and pulsations (non radial g modes) in ZZ Ceti stars are usually attributed to temperature intrinsic variations (Väth et al. 2001). In standard ZZ Ceti asteroseismology the possibility of heat propagation by waves is obviated in the energy transport equation. This simplification will be spurious in the degenerate material because, the relaxation time is not negligible. The temperature gradient in stars is given, in a good approximation, by the energy transport equation.

The Fourier-Maxwell law leads to a parabolic equation for T, according to which perturbations propagate with infinite speed. Neglecting the relaxation time (τ) is, in general, a sensible thing to do because for ordinary stellar material it is very small. There are, situations where τ may not be negligible (in the degenerate material) . For example in neutron star interior τ is of the order of 10^2 s for a temperature of 10^6 K (Herrera & Falcon 1995a).

$$\frac{dT}{dr} = -\frac{3}{4ac}\frac{\kappa\rho}{T^3}(\tau\frac{\partial F}{\partial t}+F) = -\frac{3}{16ac}\frac{\kappa\rho}{T^3 r^2}(\tau\frac{\partial L}{\partial t}+L) \ . \quad (1)$$

The possibility that the time of relaxation is not negligible, in the nucleus of WD, would bear the existence of thermal waves. We consider the situation in the surrounding of the outer boundary of a convective envelope. Consider the temperature excess DT of a moving element adiabatically over the surroundings (gradient ∇). Obviously $DT \sim \nabla - \nabla_{ad}$ and DT becomes negative above the border, i. e. the overshooting elements become cooler than the surrounding, which results in a cooling of the upper layers and an increase of the gradient ∇. But now, the temperature excess DT is not monotonous, because the interior material is degenerate. For times shorter than the relaxation time the MLT theory (Herrera & Falcon 1995b) demand that $DT \sim DT^{(d)} f(x,\omega)$ f(x,w), where $DT^{(d)}$ denote the "classical" temperature difference (i. e. $\nabla - \nabla_{ad}$) and $f(x,\omega)$ is a damped oscillatory function, time dependent. Under this consideration the luminosity due to the convective flow admit a quasi periodic variation (Herrera & Falcón 1995b).

$$L = L^{(d)} \frac{1}{\omega^2+1} exp\left[\frac{\chi}{2}\left(\omega^2-1\right)\right] \quad (2)$$

$$\left[(5+\omega^2)\cos(\omega\chi) - \frac{(3-\omega^2)}{\omega}\sin(\omega\chi)\right] \ ,$$

and $\omega^2 \equiv \frac{4\tau}{\tau_d} - 1$ and $\chi \equiv \frac{t}{2\tau}$. Equation (2) connects the standard luminosity (L) of MLT and the luminosity before thermal relaxation ($L^{(d)}$) owing to the heat waves, where f is a function of time τ, relaxation time τ and thermal relaxation time τ_d. On the other hand, the calculation of the relaxation time can be done starting from the relationship:

$$\tau = \frac{k}{V^2 C_V} \approx \frac{10^{-3} T^{-2}}{\beta^2} \ , \quad (3)$$

where V, k and C_v denote respectively the thermal wave speed, the thermal conductivity for degenerate material and the specific heat from the Chandrasekhar's relationship.

The luminosity fluctuation, due to the causal propagation of the thermal flow (2) suggests an approximate model for the study of the ZZ Ceti stars. Inside the WD the matter is degenerate and the thermal conductivity is dominated by electrons, therefore the use of the Cattaneo Law is justified. The aleatory movement of certain convective globules, inside the gradient of temperature, would carry a fluctuation in the temperature and luminosity. The due luminosity variation to the convective flow could have a damped oscillatory behavior (2).

According to this model the periods of the luminosity fluctuations would be of the order of the thermal relaxation time. Also, because the convective flow is only an fraction of the total thermal flow, then the luminosity variations would be damped and small relative to the intrinsic luminosity. The behavior as erratic function of the ZZ Ceti light curves would be explained in term of the sum of several convective fluctuations along time. Several convective cells flow sequentially, each one due to some specific thermal fluctuation, they could reproduce the light curves of some ZZ Ceti stars. The results show that the luminosity had a qualitative behavior as a damped oscillation. The theoretical adjustment allows to model the curve of light piecewise; it is consistent with the presented pattern, according to which the fluctuations of the luminosity are caused to each other by independent "convective cells". However, a detailed analysis requires to consider of several cells inside the star, each one of which contributes to the total convective flow.

REFERENCES

Althaus L. G. & Benvenuto 1996, MNRAS, 278, 981

Hansen C.J. & Kawaler S. D. 1994, Stellar Interiors, Springer-Verlag, N.Y.

Herrera, L. & Falcon, N. 1995a, ApSS, 229, 105

Herrera, L. & Falcon, N. 1995b, ApSS, 234, 139

McGraw, J. T. 1977, PhD Thesis, University of Texas at Austin

Robinson, E. L. . 1979, in IAU Colloquium 53, Rochester N.Y., p 343-358

Robinson, E. L. 1983, ApJ, 262, L11-15

Väth, H. et al. 1997, in White Dwarfs. Ed. Isern et al., Kluwer Acad. Press, Dordrecht, 481