Non-linear radial pulsations driven by strange modes in high-luminosity helium stars.

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Abstract

Hydrogen-deficient early-type stars are very rare stars in their final stages of evolution. They have an extremely high surface helium abundance (> 99% by number) and have represented a considerable challenge to stellar evolution theory. Recent work supports the view that they are the product of a merger between two white dwarfs.

All very luminous helium stars (log L/L⊙ > 4) are believed to pulsate; observations have identified radial and/or nonradial modes in over seven stars ranging in effective temperature from 10 000 – 30 000 K. The periods are, however, not strictly regular but are more likely to be chaotic. Linear theory has identified strange-mode excitation as the dominant driving mechanism.

A hydrodynamic code including recent OPAL opacity data has been used to construct non-linear models of radial pulsations in high-luminosity extreme helium stars. Of particular interest is the role of the iron opacity peak in exciting additional modes. As a result, irregular pulsation modes appear and have been studied using Fourier analysis.

The features of these pulsation modes and their propagation through the stellar envelope were also studied. The models are also relevant for the interpretation of pulsations in R CrB stars.

Code

Non-linear radial pulsation code (Bridger 1984):
- Based on Christy (1967).
- Hydrogen-deficient ALExANDER + OPAL opacity data, from the web sites: http://www.phys.ox.ac.uk/~bailey/OPAL/ http://www.phys.ox.ac.uk/~bailey/ALExANDER/.
- Artificial viscosity, as described by Stehle & Soffel in 1978, with parameters C∞ = 5.0, α = 0.5.
- In the static model:
- The core is considered as an adiabatic sphere.
- At the surface, P = P∞.
- Small velocity perturbation.
- In the dynamic model:
- Models evolve until kinetic energy converges (~ 300 periods).

Models

Five models were calculated as a preliminary study of pulsations driven by strange modes. The excitation mechanism acts in very massive stars (~ 40 M⊙) but has been also identified in less massive objects such as hydrogen-deficient carbon stars and RCrB stars (Sato et al. 1984; Sato & Jeffery, 1988; Gautschy & Glatzel, 1990).

Composition was given by mass fraction X = 0.0, Y = 0.98, Z = 0.02, with a standard mixture of metals (Grevesse & Noél, 1993). Preliminary light curves and their power spectra are shown below.

Table 1. Calculated models:

<table>
<thead>
<tr>
<th>Mod.</th>
<th>log T / L⊙</th>
<th>M/M⊙</th>
<th>log T/eff</th>
<th>I(0)</th>
</tr>
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<tr>
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<td>4.05</td>
<td>0.7</td>
<td>4.10</td>
<td>14.7</td>
</tr>
<tr>
<td>2</td>
<td>4.25</td>
<td>0.8</td>
<td>4.00</td>
<td>10.9</td>
</tr>
<tr>
<td>3</td>
<td>4.25</td>
<td>0.8</td>
<td>4.10</td>
<td>4.9</td>
</tr>
<tr>
<td>4</td>
<td>4.40</td>
<td>0.9</td>
<td>4.10</td>
<td>7.2</td>
</tr>
<tr>
<td>5</td>
<td>4.40</td>
<td>0.9</td>
<td>4.25</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Conclusions

Pulsations in high-luminosity helium stars are clearly more complex than in low-luminosity helium stars such as V605 Her. Strange mode driving may be the cause, as illustrated in (Fig. 2).

The period derived from our models is comparable with those of observed helium stars (Table 2). Measuring periods will be difficult because of their complicated light curves (Fig. 1).

More detailed analysis and a comparison with linear theory is required.

References:


