Self-Excited pulsations of AGB and RGB stars in global 3D models

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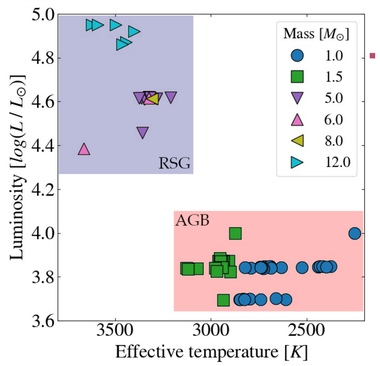
Introduction

Recent 3D simulations of cool giants and supergiants with the CO^{5}BOLD radiation-hydrodynamics code cover a wider range of stellar parameters and with greater temporal and spatial resolution than before. These global 3D models produce self-excited pulsations in asymptotic giant branch (AGB) and red supergiant (RSG) stars. In such evolved stars, the pulsations play a major role in developing massive outflows. With a global setup, the 3D models not only enable investigation of the turbulent nature of the cool outer layers and the propagation of shock waves, but also allow us to look deep into the stellar interior where convection dominates.

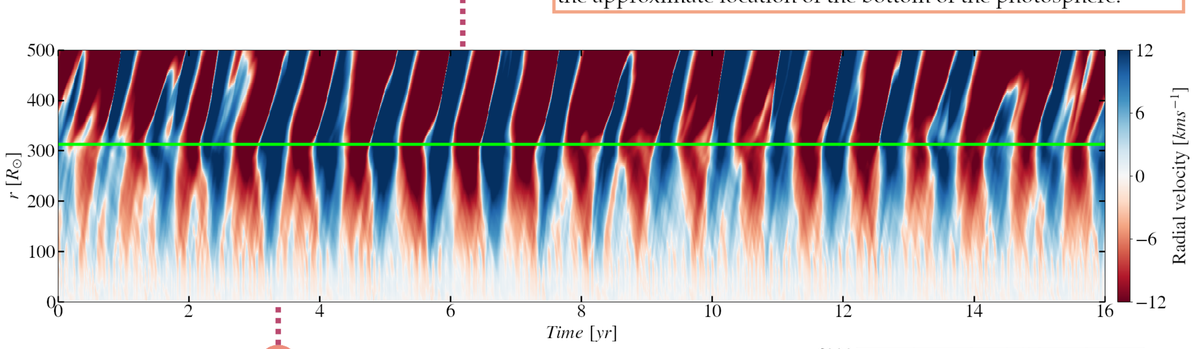
The analyses of the pulsation properties and excitation mechanisms contribute crucially to our understanding of the stellar outflows associated with AGB and RSG stars. The fundamental pulsation frequency and other important pulsation parameters can be derived from the 3D models. This poster presents how to extract the fundamental frequency and the difficulties involved. With the extracted pulsation properties, a correlation was investigated between the extracted periods and the stellar parameters used as input for the 3D models, with preliminary results showing good agreement with both observations and current theoretical understanding.

Method

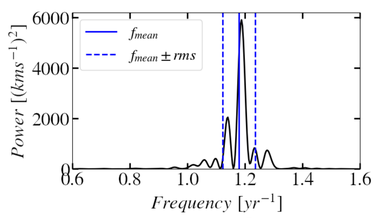


1 Global model parameters such as the mass and effective temperature are used as input for the CO^{5}BOLD simulations. Scan the QR code to watch the motion of gas density in 2D slices of a simulated AGB star!

2 The star being simulated in the video linked above has the stellar parameters: M=1.5M$_\odot$; R=310R$_\odot$; T$_{\rm eff}$=2900K & L=7000L$_\odot$. The radial component of the gas velocity from the 3D simulation was spherically averaged to obtain the spherically averaged radial velocity shown below. The green line indicates the approximate location of the bottom of the photosphere.

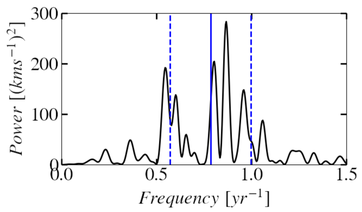


3 The power spectrum obtained from the Fast Fourier Transform (FFT) was averaged over a thin layer at the photosphere, producing the spectrum on the right. A peak-finding and weighted averaging algorithm was applied to obtain the best representative fundamental frequency with its corresponding uncertainty.

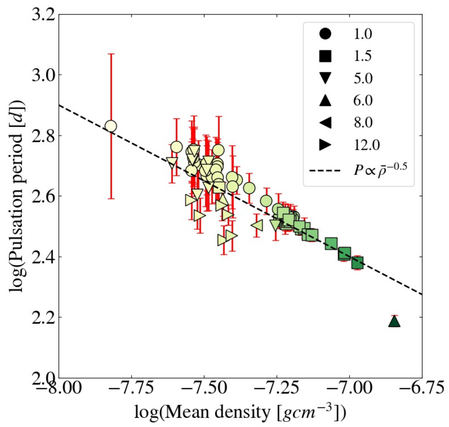


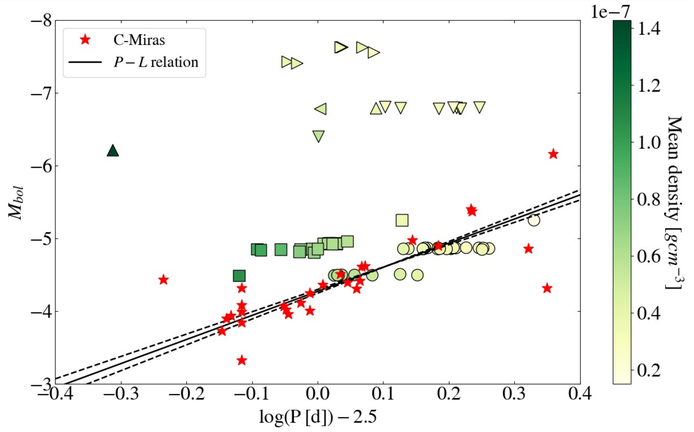
4 The FFT spectrum above shows a regularly pulsating AGB star, where a single strong frequency dominates. However, for an AGB star with lower mass and surface gravity, the FFT spectrum on the left is obtained.

5 Due to the large pulsation amplitude and the non-linear interaction of pulsations and convection, extracting the pulsation frequency is non-trivial. But this is interesting!



Results & conclusions





The figure above shows the extracted fundamental pulsation periods against: (left) the mean density, overplotted is the period-mean density relation (dashed line); (right) a period-luminosity relation (black lines) derived from the observed Carbon-rich Miras (red marks) in [2]. Other symbols in the legend indicate the model stellar mass in $M_\odot$.

Similar methods have been used in [1] to extract the pulsation frequencies. Since then, the number of 3D models to do the analysis on has increased significantly, with a wider range of stellar parameters of mass, radius, surface temperature, and surface gravity. The figure above presents:

- Our modelled AGBs are consistent with a well known period-luminosity relation for Miras;
- The higher-mass models do not lie on the same period-luminosity relation as the Miras. This is consistent with observations;
- The excited pulsations agree with the established theoretical period-mean density relation, even though the non-linear interaction between convection and pulsations in some models is strong.

References

[1] Freytag, B., Liljegren, S., and Höfner, S. Global 3D radiation-hydrodynamics models of AGB stars. *A&A* (2017).

[2] Whitelock, PA., Menzies, JW., and et al. Asymptotic giant branch stars in the fornax dwarf spheroidal galaxy. *MNRAS* (2009).

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