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

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## Abstract

Recent developments of 3D simulations of cool giants and supergiants with the CO5BOLD code have explored a wider range of stellar parameters and with greater temporal and spatial resolution. Important pulsation properties such as the fundamental pulsation frequency can be extracted from the 3D models. This poster presents how the fundamental frequency can be extracted and the difficulties in doing so. With the extracted pulsation properties, correlation was investigated between the extracted periods and the stars' stellar parameters taken as input for the 3D models, with preliminary results showing good agreement to both observations and current theoretical understanding.

## Introduction

Global 3D models of pulsating asymptotic giant branch (AGB) and red supergiant (RSG) stars give many useful insights into the physical mechanisms that contribute to the pulsation of the star. 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 utilization of 3D simulations thus allows the explicit study of the interaction between convection and pulsation, which plays an important role in the underlying mechanisms leading to the production of stellar winds and massive outflows associated with AGB and RSG stars.

## Pulsation frequency extraction process

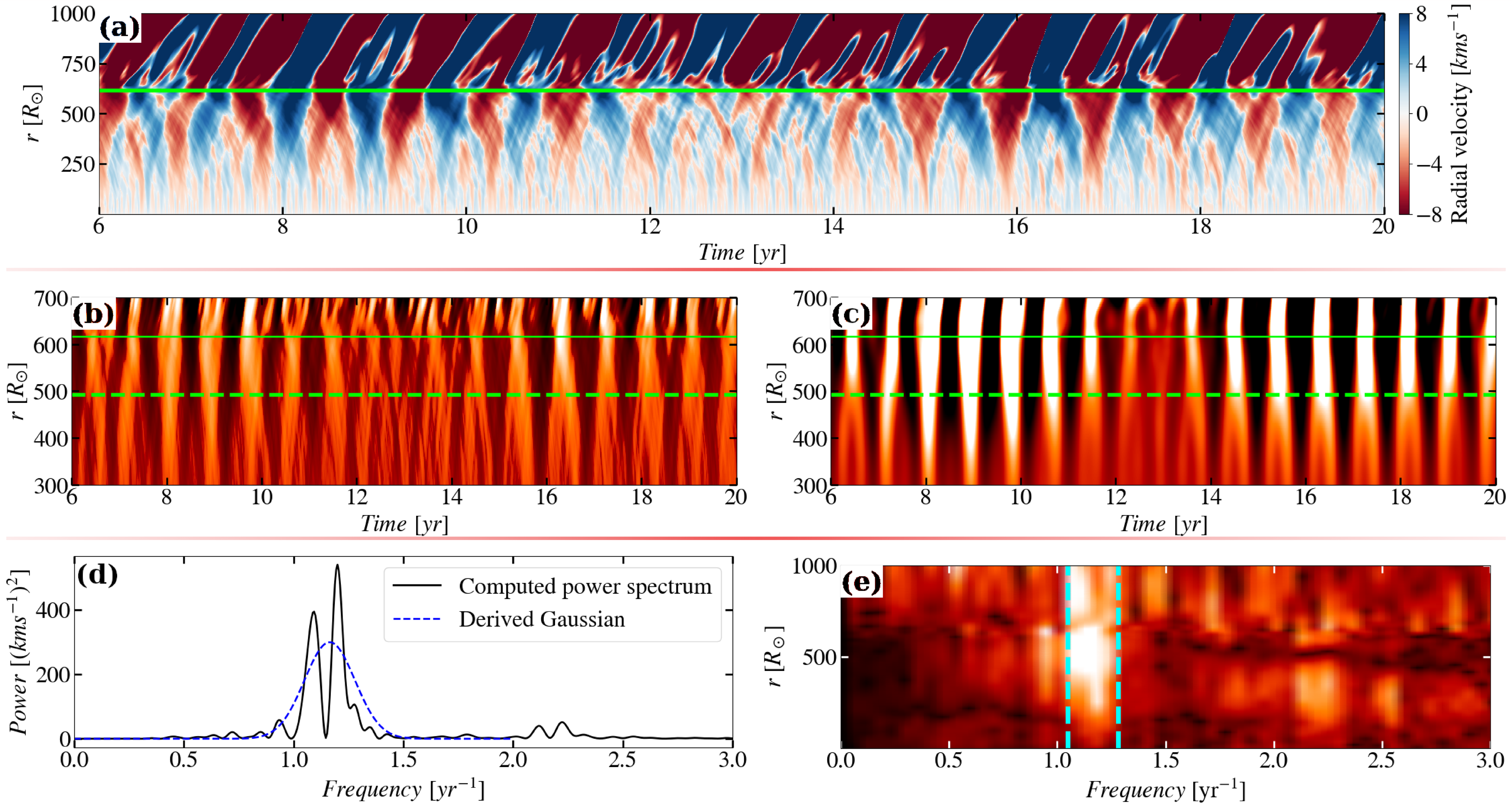


**Fig. 1:** Intermediate plots to extract the pulsation frequencies from a 3D model. The modelled star here is a cool supergiant and has the stellar parameters: $Mass = 8M_\odot$, $Radius = 620R_\odot$ & $Luminosity = 40000L_\odot$.

Due to the large pulsation amplitude and the non-linear interaction of pulsations and convection, extracting the pulsation frequency is non-trivial. However, the fundamental pulsation frequency can be extracted as follows:

- Top: The radial component of the gas velocity from a 3D simulation was spherically averaged to produce (a) - the spherically averaged radial velocity, with the green line showing the location of the stellar photosphere.
- Middle: (b) is (a) magnified around the photospheric layer with a different colour scale. The Fast Fourier Transform (FFT) was applied at all depths to (b) and a masked Inverse FFT was done to recover the primary pulsation signal (c). The region between the solid green line and the dashed line is where radial pulsations should dominate.
- Bottom: The unmasked FFT signal was averaged to obtain a final power spectrum (d). A peak-finding and weighted averaging algorithm was applied to obtain the best representative fundamental frequency. (d) also shows a Gaussian fitted from the derived parameters and (e) shows the unmasked 3D FFT spectrum with the full width at half maximum of the corresponding Gaussian.

## Results

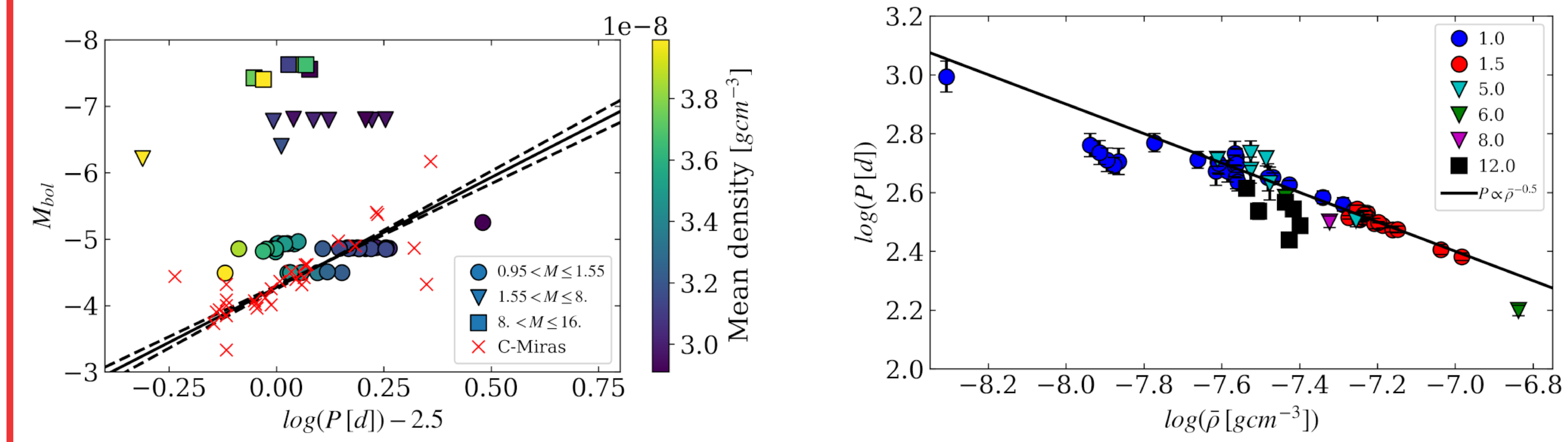


**Fig. 2:** The extracted fundamental pulsation periods against (left) a period-luminosity relation (black lines) derived from the observed Carbon-rich Miras (red crosses) in [2]; (right) the period-mean density relation (black line). Other symbols in the legend indicate the model stellar mass in $M_\odot$.

Pulsation frequencies have previously been extracted following similar methods as seen in [1]. The number of available 3D models to do this analysis has increased significantly since then, with a wider range within the stellar parameters of mass, radius, surface temperature and surface gravity. From the extracted fundamental pulsation frequencies, Fig. 2 shows:

- 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.

## 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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