Structural glitches near the cores of red giants revealed by oscillations in g-mode period spacings

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in collaboration with

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Why?
Identify particular moments of evolution
Infer details of the deep internal structure
Models under study

a – ASTEC
b – MESA
Models under study

- ASTEC
- MESA
Models under study

- ASTEC
- MESA
Models under study

How do spikes in N affect the periods of the oscillations?

a – ASTEC
b – MESA
Models under study

\[ \log \left( \frac{L}{L_{\odot}} \right) = \log(T_{\text{eff}}) \]

- a – ASTEC
- b – MESA
Models under study

How do spikes in N affect the period spacing of the oscillations?

a  – ASTEC
b  – MESA
Glitch or no Glitch?
Glitch or no Glitch?

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Glitch or no Glitch?

\[ \nu = 50 \mu \text{Hz} \]

\[ \nu = 23 \mu \text{Hz} \]
Pure g-modes (model a)

Analytical toy-model:
Cowling approximation
Infinitely thin spike
Pure g-modes (model a)

Analytical toy-model:
Cowling approximation
Infinitely thin spike

\[
\Delta \Pi \approx \frac{1}{1 + \frac{\lambda}{\omega_B B^2}} \left[ \frac{\omega_g^*}{\omega} \cos \left( 2 \frac{\omega_g^*}{\omega} \right) + \left( 1 - \frac{\lambda \omega_g^*}{\omega^2} \right) \sin^2 \left( \frac{\omega_g^*}{\omega} + \frac{\pi}{4} \right) \right],
\]

where \( \omega_g^* = L \int_{r_*}^{r_2} \frac{N_0}{r} dr \) and \( B^2 \) is given by,

\[
B^2 = \left[ 1 - \frac{\tilde{A}}{2\omega} \cos \left( 2 \frac{\omega_g^*}{\omega} \right) \right]^2 + \left[ \frac{\tilde{A}}{\omega} \sin^2 \left( \frac{\omega_g^*}{\omega} + \frac{\pi}{4} \right) \right]^2.
\]
Pure g-modes (model a)

Numerical solution
Full numerical solution (model a)
The signature of the glitch in the period spacing is a change in the depth of the dips in the period spacing.
Stello KASC6

H-R Diagram

Propagation Diagram

ΔP vs. Freq.

ASTEC models
Stello KASC6

H-R Diagram

Propagation Diagram

ΔP vs. Freq.

ASTEC models

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(model b)
Pure g-modes or full solution? (model b)
Including coupling with p-modes (model b)

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Including coupling with p-modes (model b)
Including coupling with p-modes (model b)
Conclusions

• Models predict that some spikes in the Buoyancy frequency can affect the period spacing in red giant stars

• We understand the signatures left by these spikes

• If found in present or future space-based data, these signatures may allow us to:

  ➢ Identify very specific evolutionary phases
    (e.g., Luminosity bump)

  ➢ Measure the “position” of the H-shell burning layer
Pure g-modes (model a)

Analytical toy-model:
Cowling approximation
Infinitely thin spike

\[ \Delta \Pi \approx \frac{\Delta \Pi_{as}}{1 + \frac{\lambda}{\omega_B^2} \left[ \frac{\omega_g^*}{\omega} \cos \left( \frac{2 \omega_g^*}{\omega} \right) + \left( 1 - \frac{\lambda \omega_g^*}{\omega^2} \right) \sin^2 \left( \frac{\omega_g^*}{\omega} + \frac{\pi}{4} \right) \right]} \]

where \( \omega_g^* = \int_{r_*}^{R} \frac{N_0}{r} dr \) and \( B^2 \) is given by,

\[ B^2 = \left[ 1 - \frac{\tilde{A}}{2 \omega} \cos \left( \frac{2 \omega_g^*}{\omega} \right) \right]^2 + \left[ \frac{\tilde{A}}{\omega} \sin^2 \left( \frac{\omega_g^*}{\omega} + \frac{\pi}{4} \right) \right]^2 \]

![Graph showing \( \Delta \Pi \) vs. \( \nu \) for model a]