ASTEROSEISMOLOGY OF TESS LUMINARIES IN THE PLATO ERA

Eva Panetier

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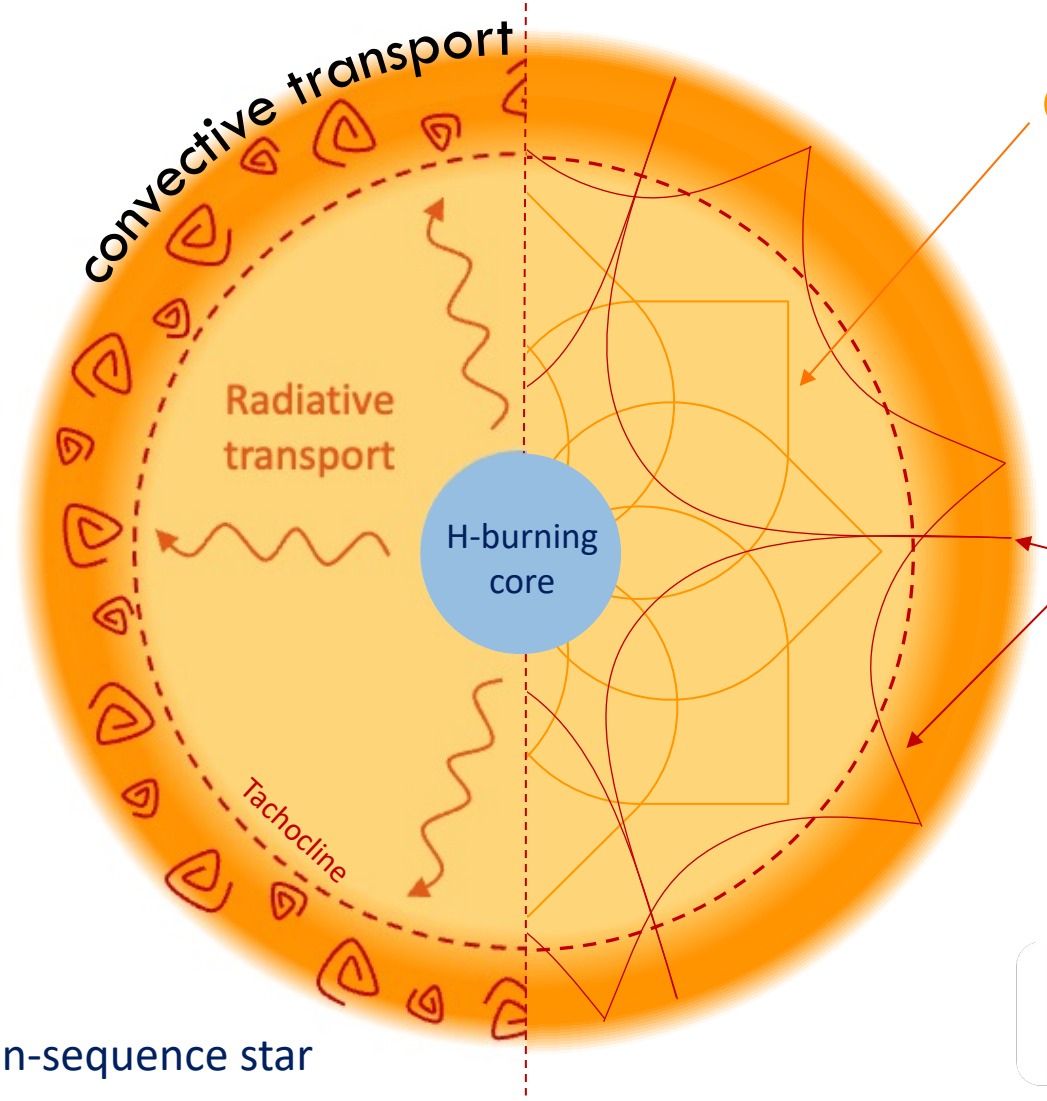
THE MUSIC OF MAIN-SEQUENCE SOLAR-LIKE STARS



Main-sequence star

g modes

→ Sensitive to the radiative zone
→ Corresponds to lower frequency
→ Evanescent in the convective zone of main sequence stars

[García et al. 2007; Breton et al. 2023]

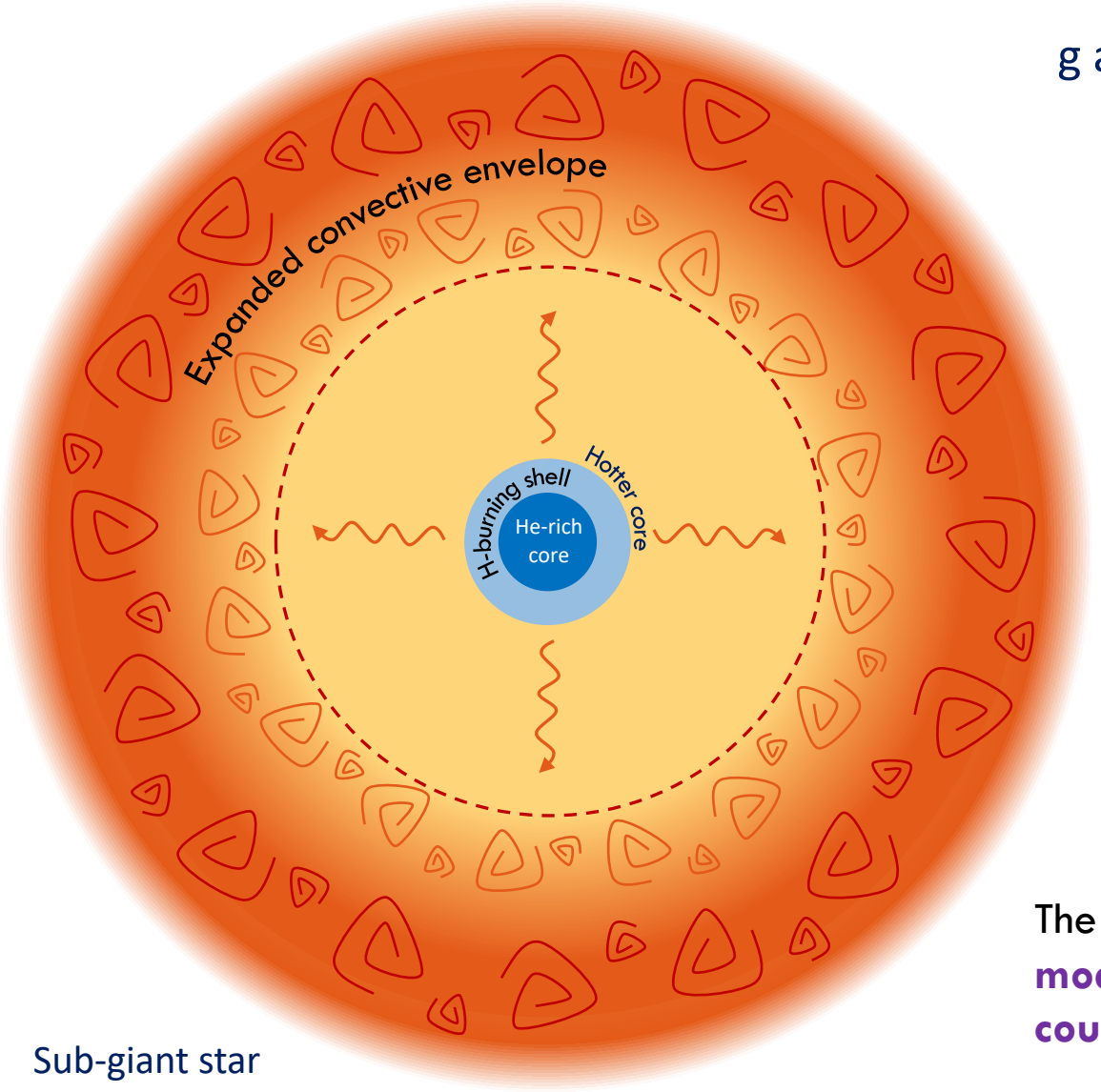
p modes

→ More sensitive to the outer layers
→ Stochastic excitation by turbulent convection
→ Corresponds to higher frequency

[Goldreich & Keeley, 1977; Kumar & Goldreich, 1988; Balmforth, 1992; Belkacem et al. 2008]

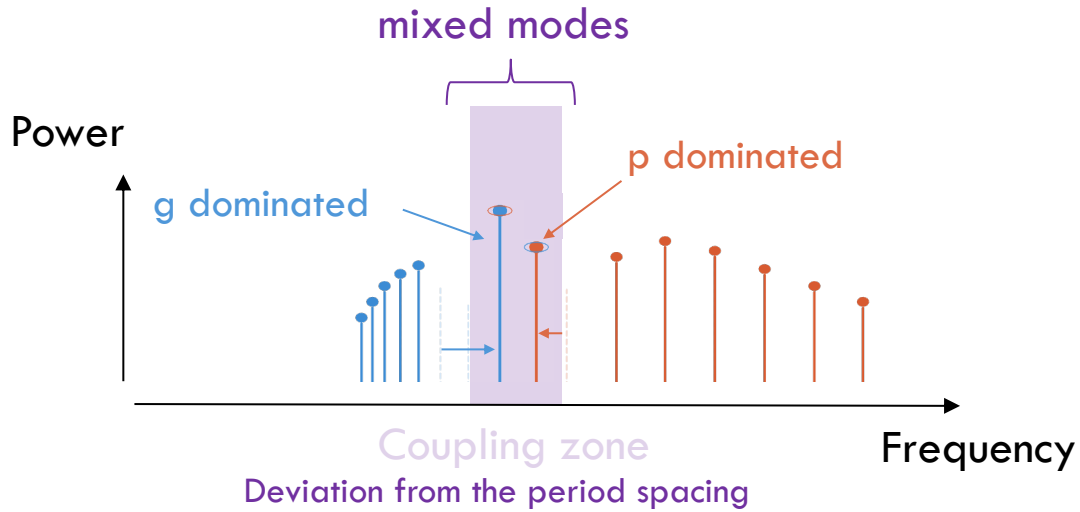
⇨ Inferring **mass, radius** and **age** (with spectroscopic inputs)
⇨ Information about the **internal structure** of the star

THE FORMATION OF MIXED MODES IN SUB-GIANTS



Sub-giant star

g and p-modes cavities couple forming **mixed modes**



g modes ⟶ acquire p-mode amplitude (visible to photometric observations)

p modes ⟶ acquire g-mode sensitivity to the core

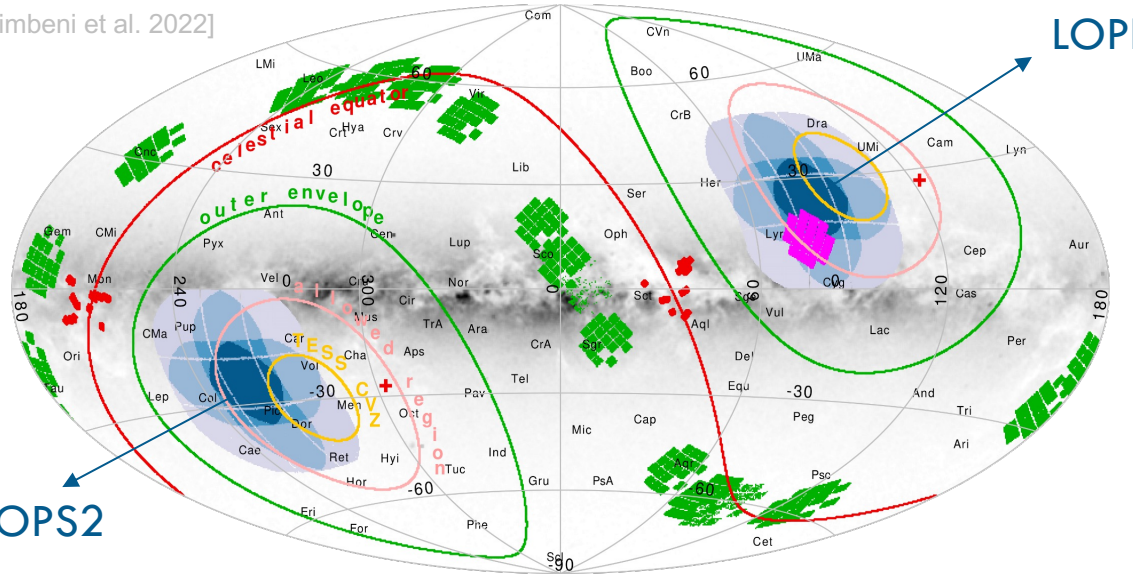
The mechanisms governing **the emergence of the first mixed modes** during the subgiant phase, as well as **the strength of the coupling** between the cavities, are still poorly understood.

THE UPCOMING PLATO MISSION

[Rauer et al. 2014, 2025]

- Characterise Earth-like planets orbiting solar-like stars
- 4 years of nominal mission, focus on two dedicated regions of the sky (LOP fields)

[Nascimbeni et al. 2022]



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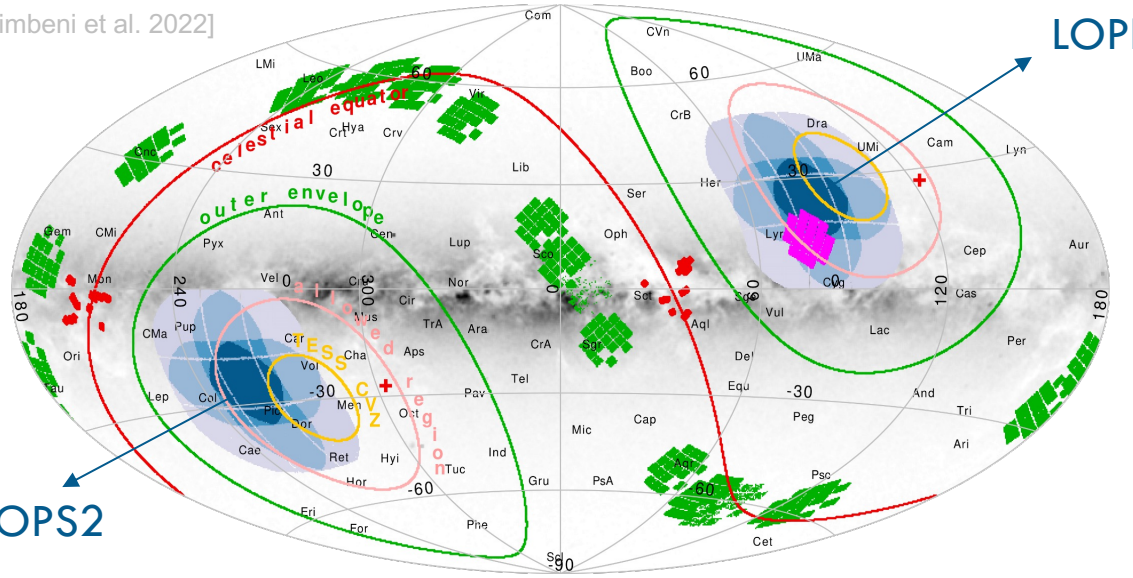

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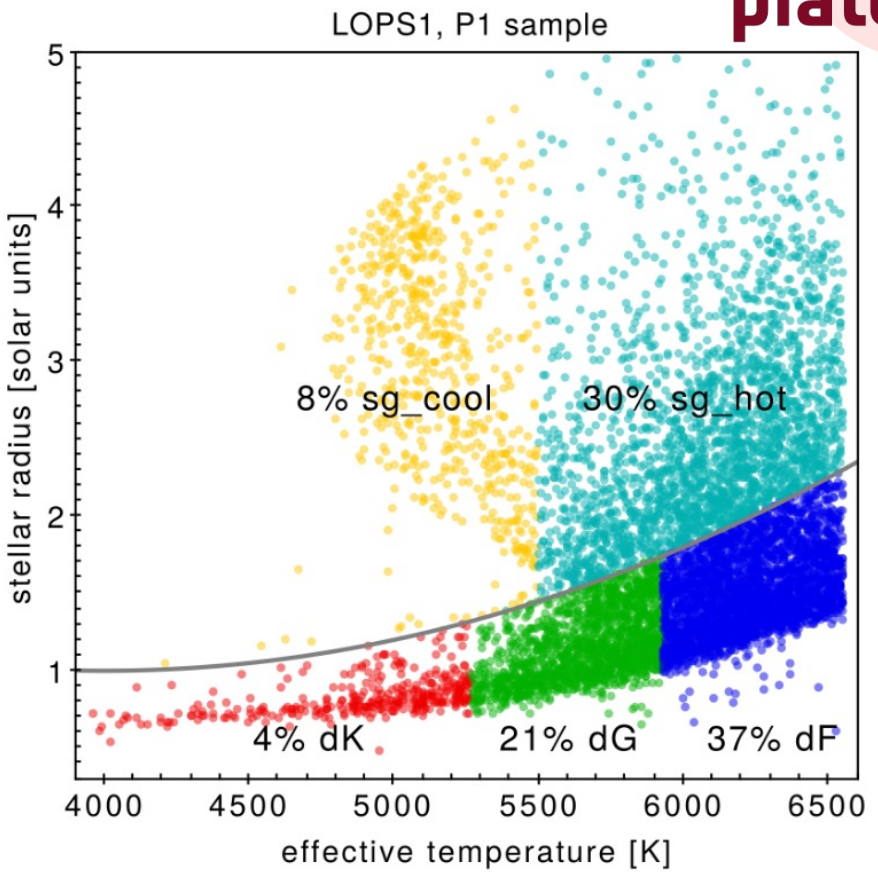


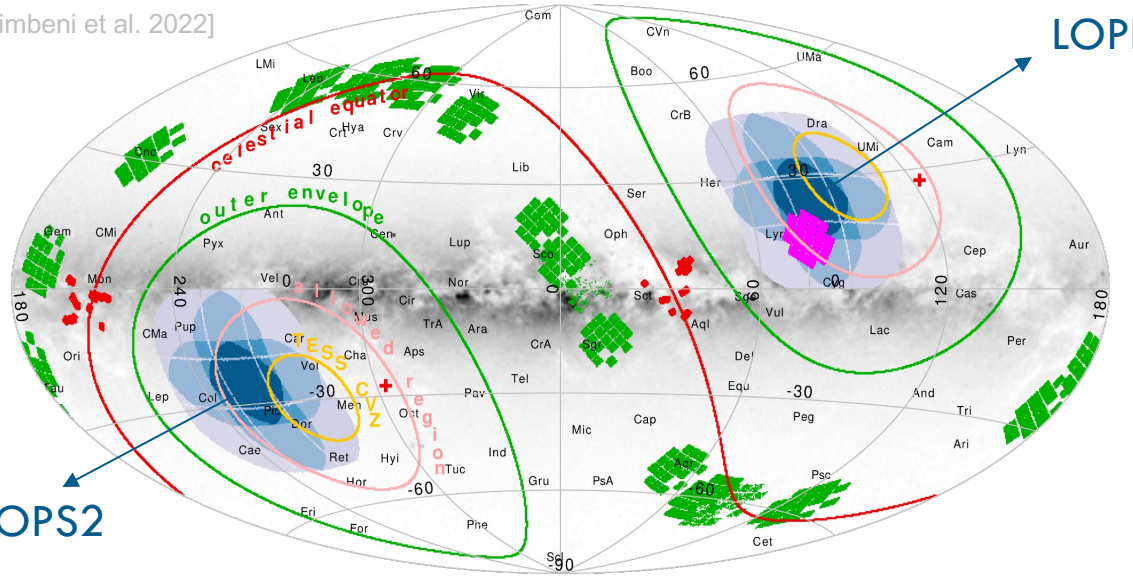
- Focus on bright stars, expected to detect thousands of solar-like oscillators
- **High quality data for main sequence and sub-giant stars**

THE UPCOMING PLATO MISSION

[Rauer et al. 2014, 2025]

- Characterise Earth-like planets orbiting solar-like stars
- 4 years of nominal mission, focus on two dedicated regions of the sky (LOP fields)
- Coming with **a fully automated seismic pipeline** to extract the oscillation frequencies

[Nascimbeni et al. 2022]



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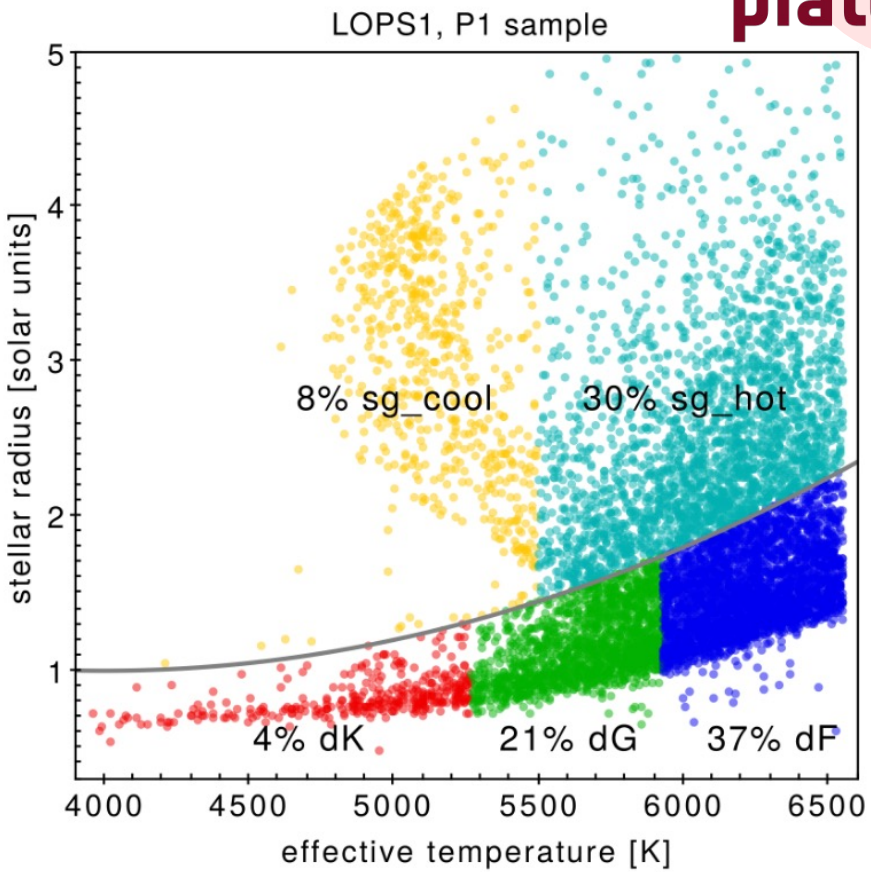

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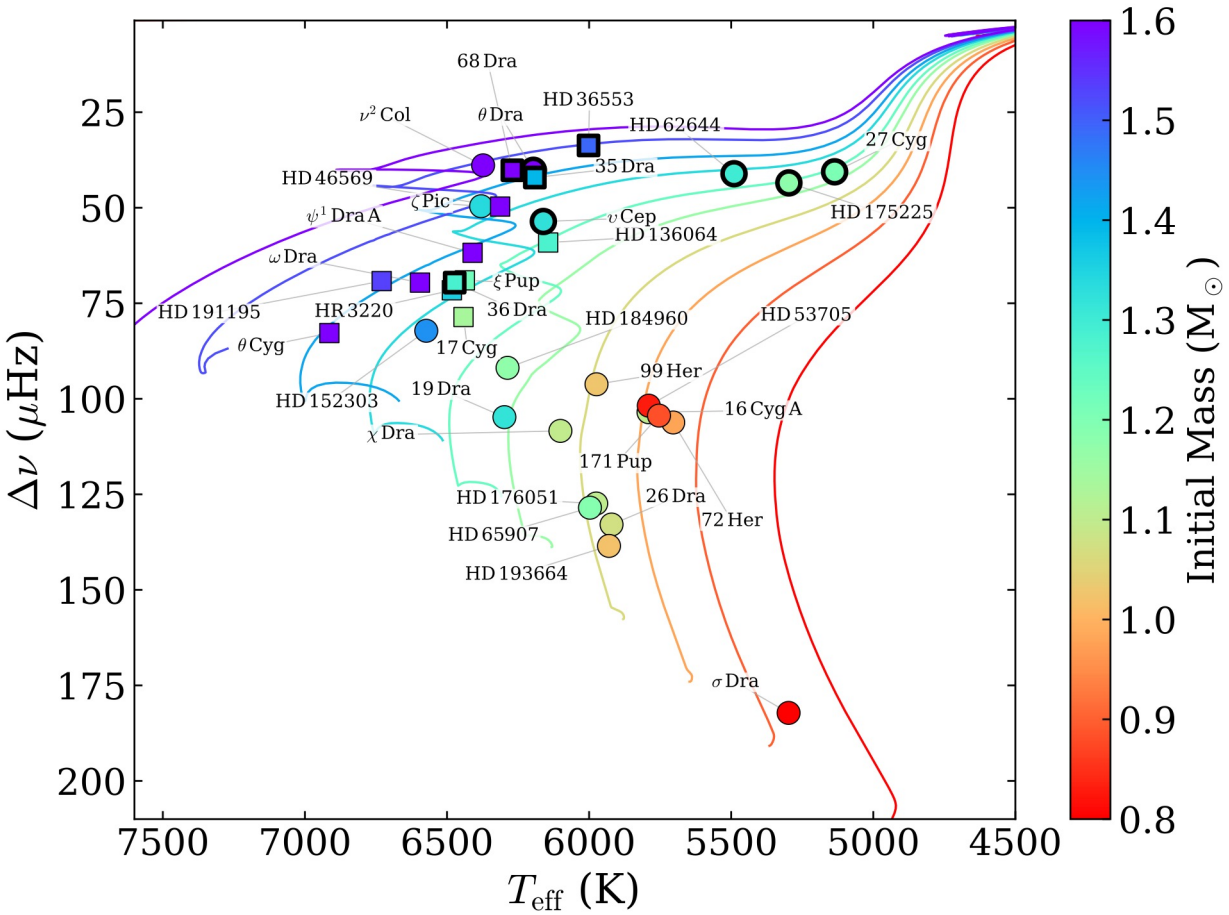
THE TESS LUMINARIES SAMPLE (TLS)

[Ricker et al. 2015]

Seismic Hertzsprung-Russel diagram



[Panetier et al. 2026]

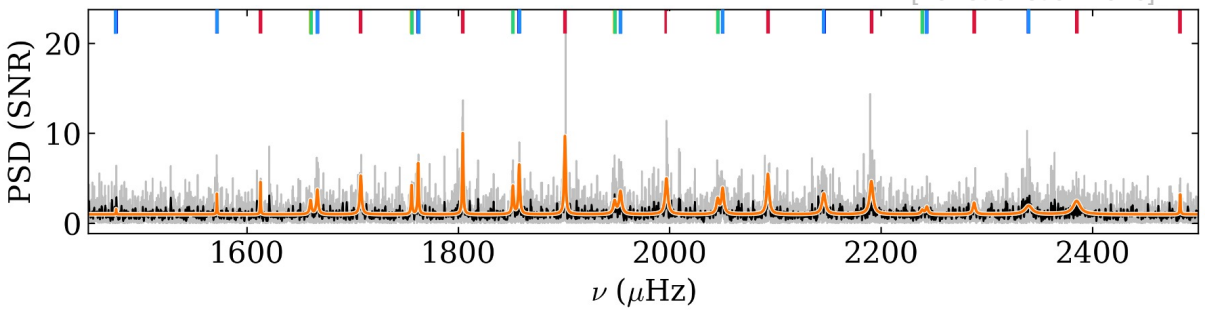
- 196 bright ($V < 6$) main sequence and sub-giant solar-like pulsators, including 128 new detections
  → Possible follow-up with ground-based instruments
- 34 TLS are in the PLATO LOPs, and included in the PLATO input catalogue as part of the core science

[Lund et al. 2025]

EXTRACTING THE MODE PROPERTIES

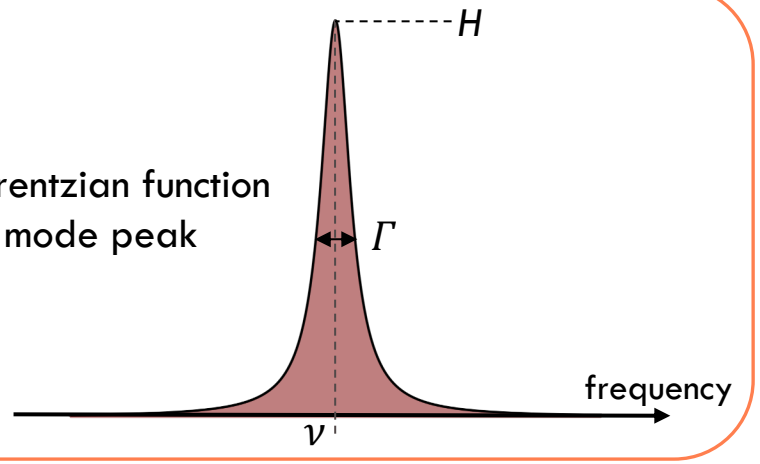
99 Her (main-sequence star)

[Panetier et al. 2026]



1. Mode parameters

→ Fitting of a Lorentzian function to each detected mode peak



➡ Frequency, width, height

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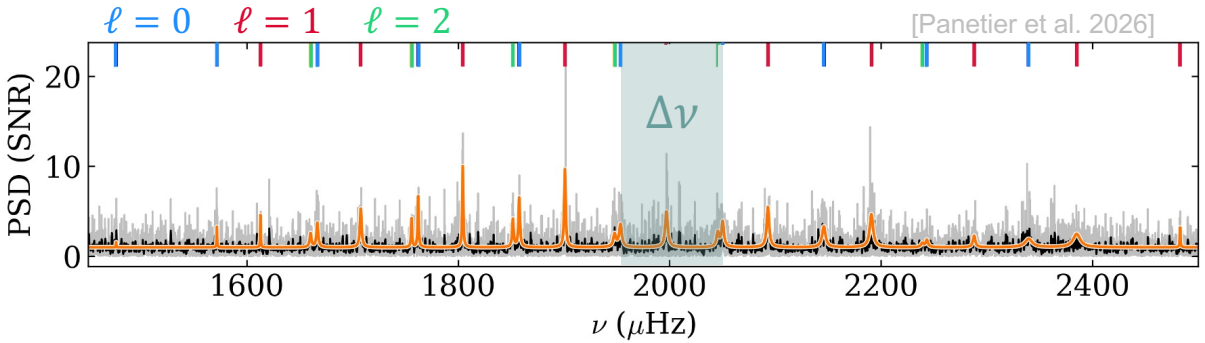

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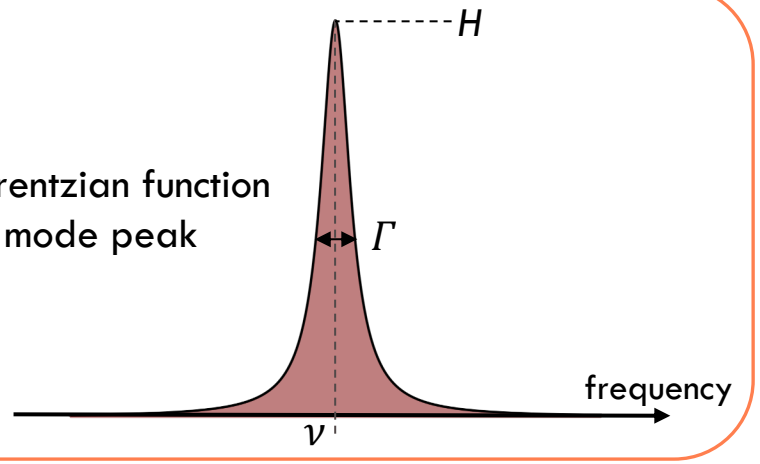


➡ Frequency, width, height

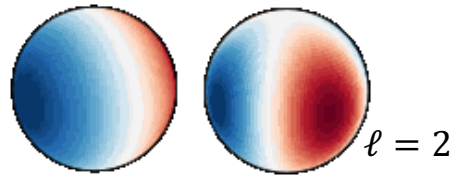
2. Mode identification

Each oscillation correspond to an eigenmode and eigenfrequency, describing movements of the stellar material

→ identified by three wavenumbers n, ℓ, m

[Bonev et al. 2023]

ℓ: number of nodal lines on the surface



➡ Radial order n, angular degree ℓ

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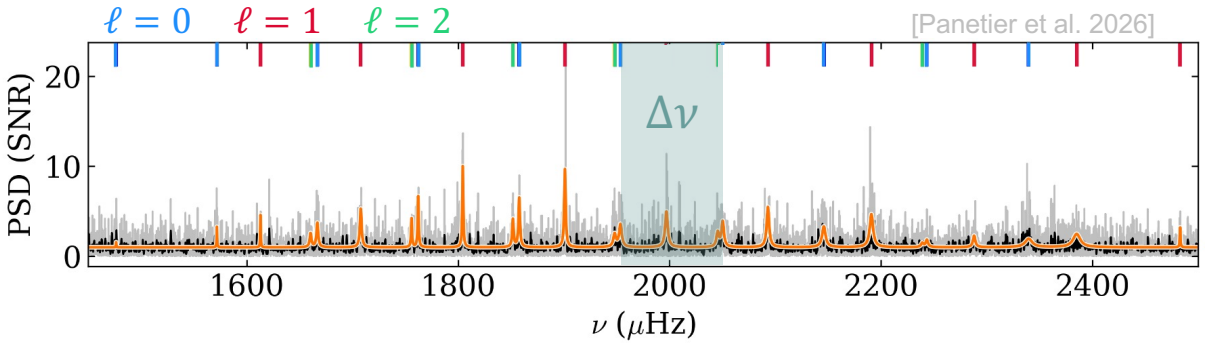
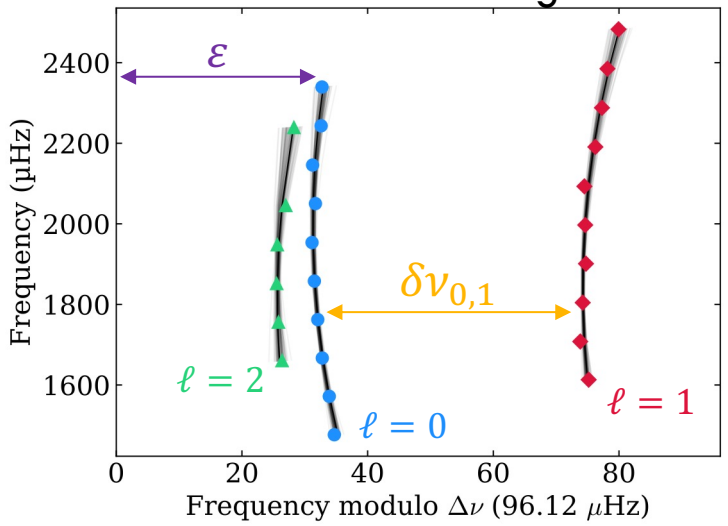


The echelle diagram



→ Asymptotic formulation of the p mode frequencies

[Tassoul, 1980]

$$\nu_{\mathrm{p},n\ell} \simeq \Delta\nu \left(n + \frac{\ell}{2} + \varepsilon \right)$$

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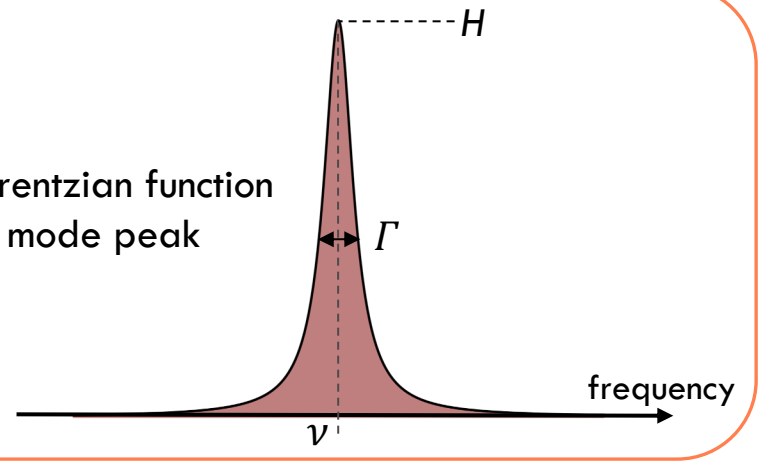

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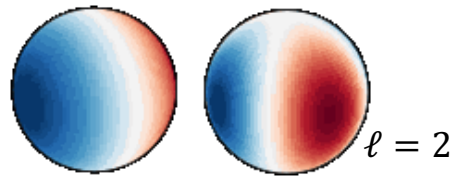


➡ Radial order n, angular degree ℓ

THE SEISMIC PIPELINES

apollinaire

Inference
Ensemble-sampling MCMC (emcee)

Frequency priors
Manual input guesses (in this work)

Note
A more automated mode also exist

[Breton et al. 2022]

FAMED™ PIPELINE

Inference method
Nested sampling Monte Carlo

Frequency priors
Data-driven: S/N significance
+ Bayesian model comparison

Note
No asymptotic prior imposed a priori

[Corsaro et al. 2014, 2020]

PBjam

Inference method
Dynesty nested sampling (background) and emcee MCMC (peak-bagging)

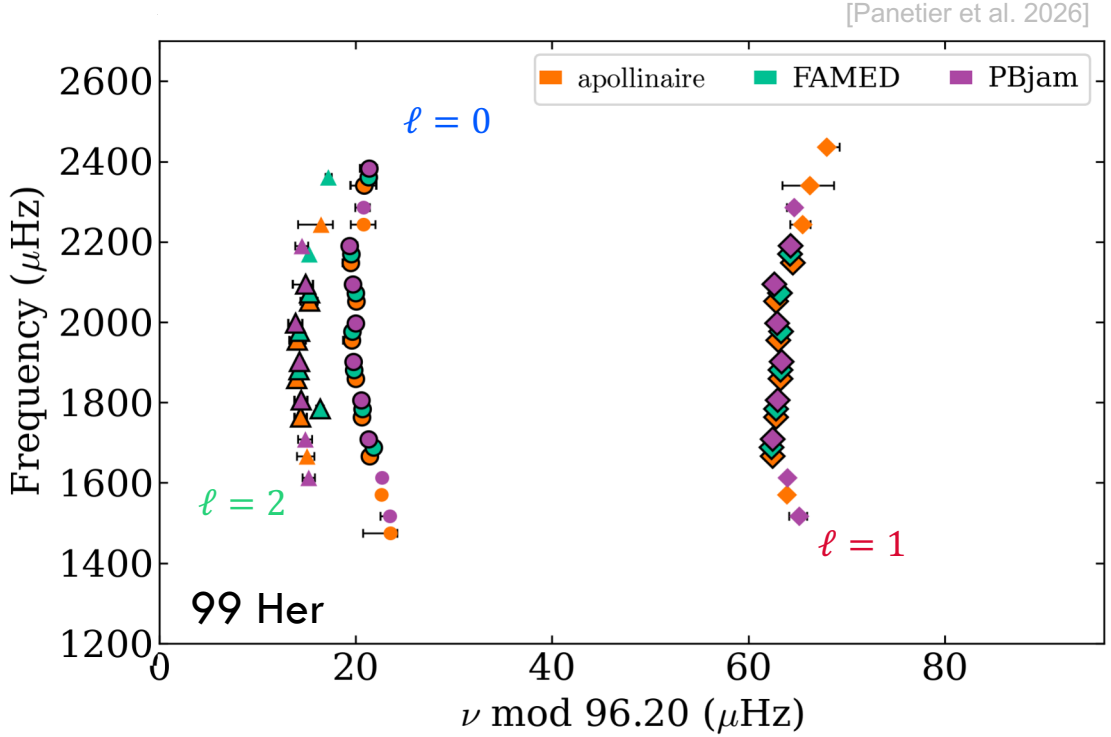
Frequency priors
Empirical relations + empirical priors from thousands of *Kepler*/K2/TESS/model stars

Note
Basis of the official PLATO pipeline

[Nielsen et al. 2021, 2025]

P-MODE DETECTION

[Panetier et al. 2026]



- For main sequence stars, very good agreement between the pipelines

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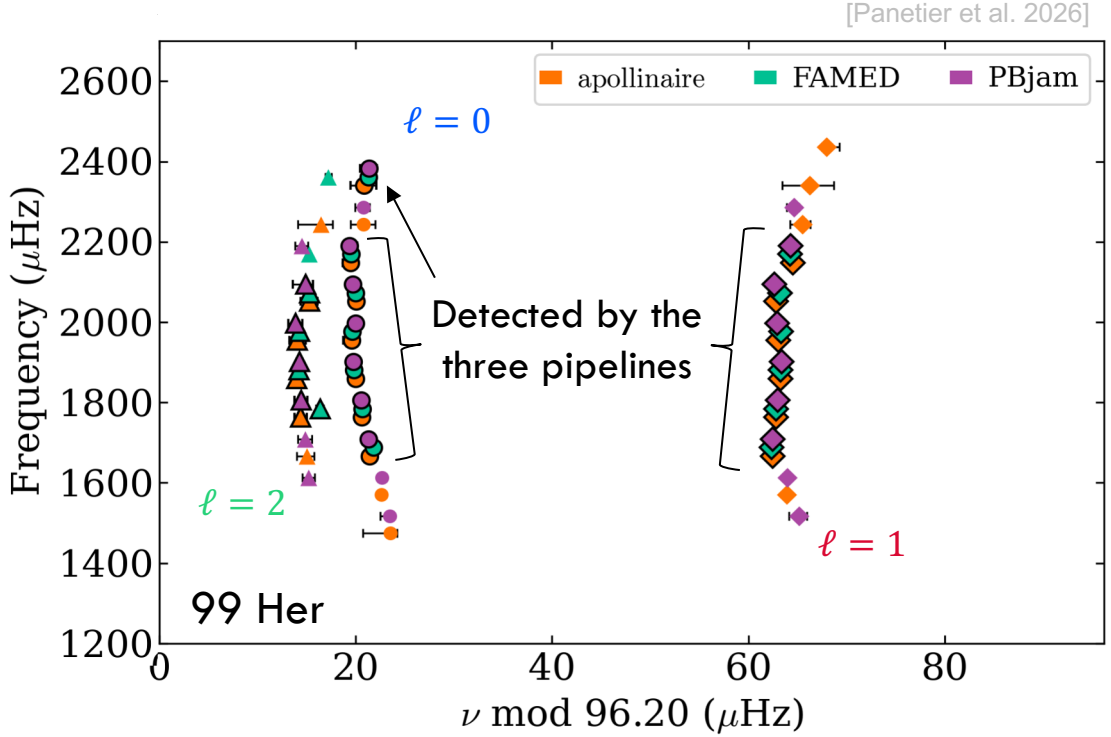

- For main sequence stars, very good agreement between the pipelines
- Differences in the number of detected modes

P-MODE DETECTION

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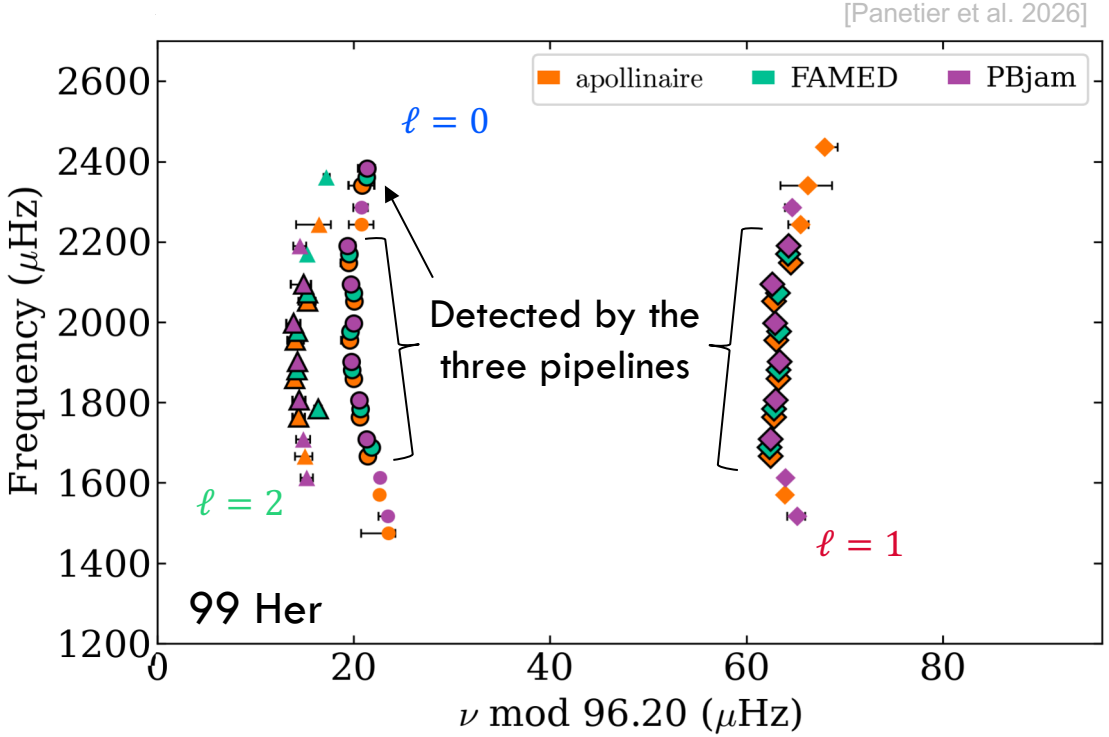
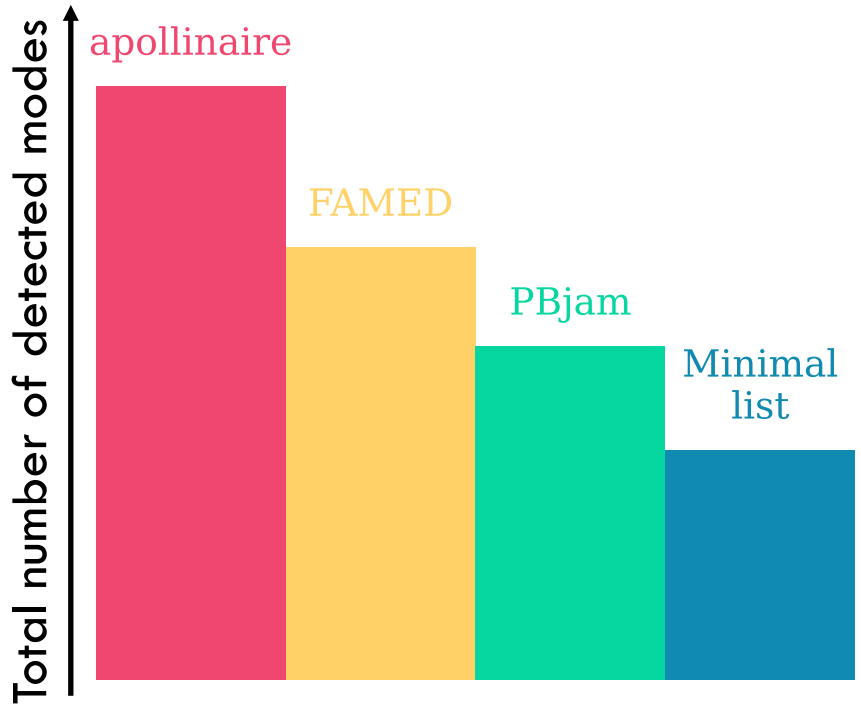
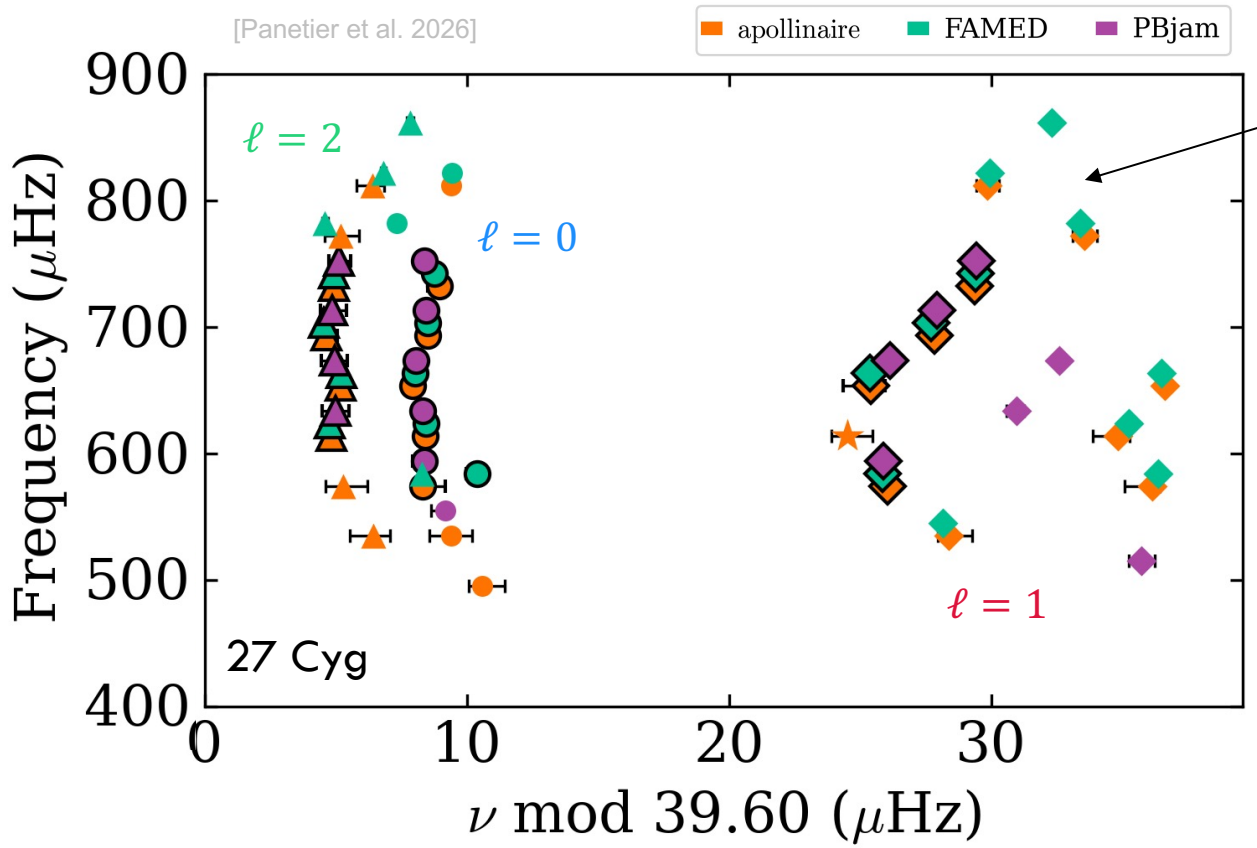


- Choice of a **minimal list** of modes with the modes detected by all pipelines
- Choice of **a reference pipeline** for each star

- For main sequence stars, very good agreement between the pipelines
- Differences in the number of detected modes



MIXED MODE DETECTION IN SUBGIANTS



The presence of g- component causes the frequencies of the $\ell = 1$ **mixed modes** to deviate from the pure p-mode ridge

→ Asymptotic formulation of the p mode frequencies

[Tassoul, 1980]

$$\nu_{\mathrm{p,n}\ell} \simeq \Delta\nu \left(n + \frac{\ell}{2} + \varepsilon \right)$$

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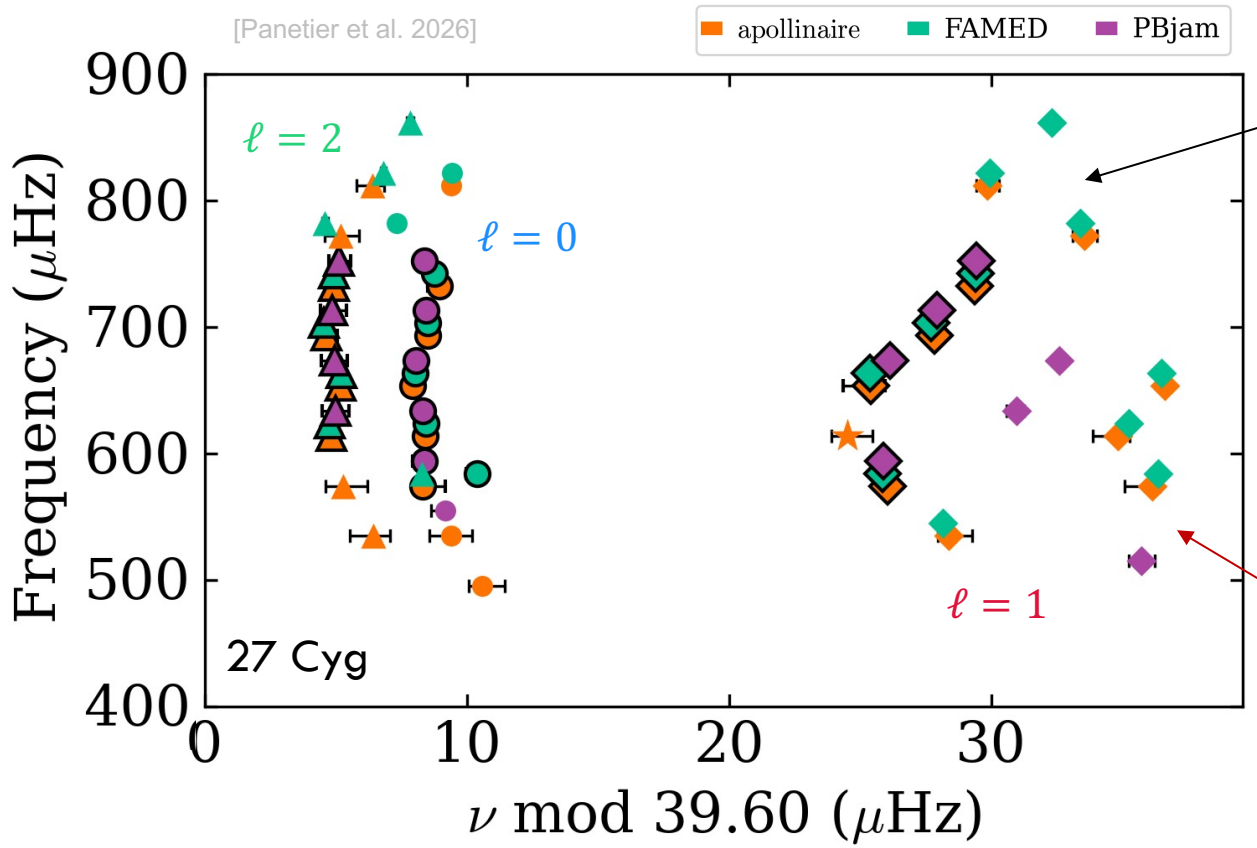

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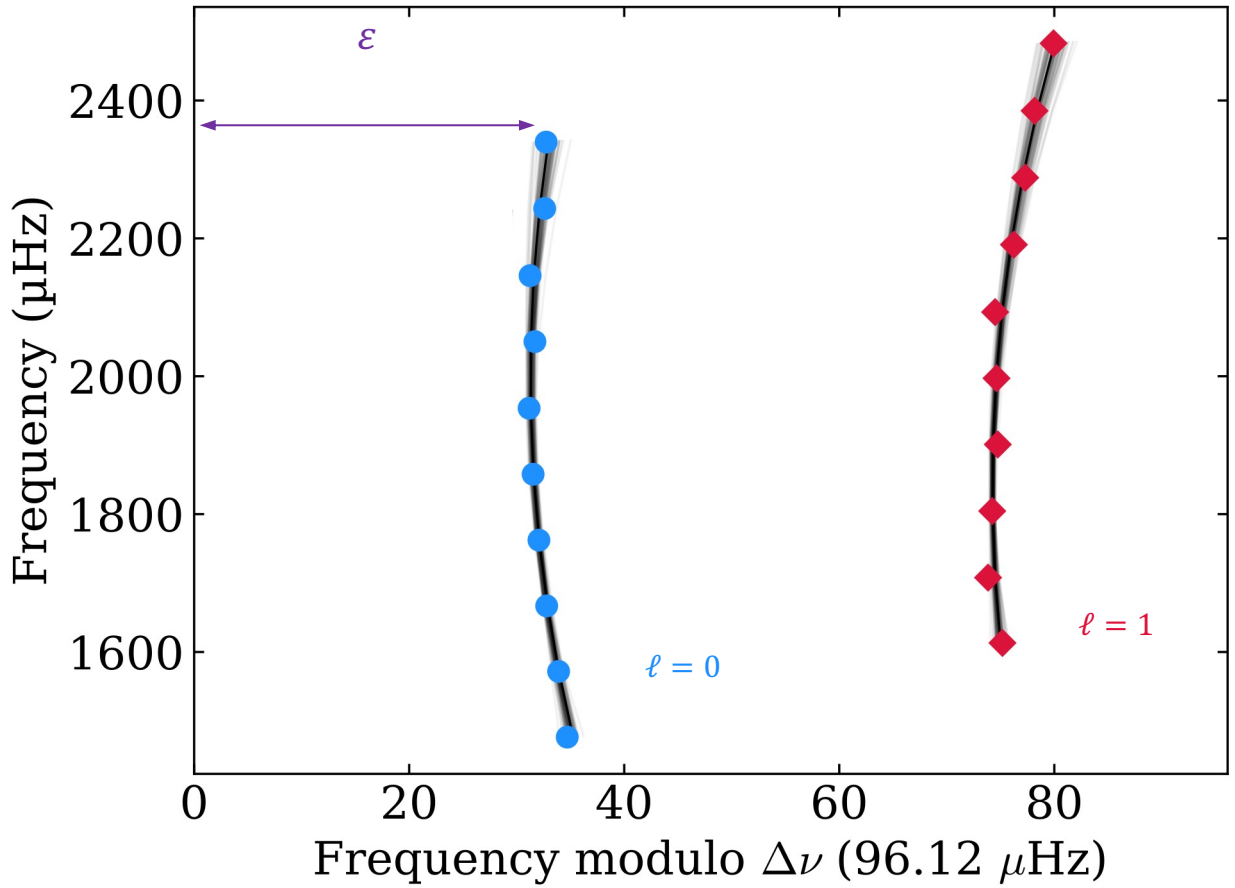
~~Asymptotic formulation of the p-mode frequencies~~

[Ta… 80]

$$\nu \approx \Delta\nu \left(n + \frac{\ell}{2} + \right)$$

Pipelines do not detect the same mixed modes

RIDGE IDENTIFICATION



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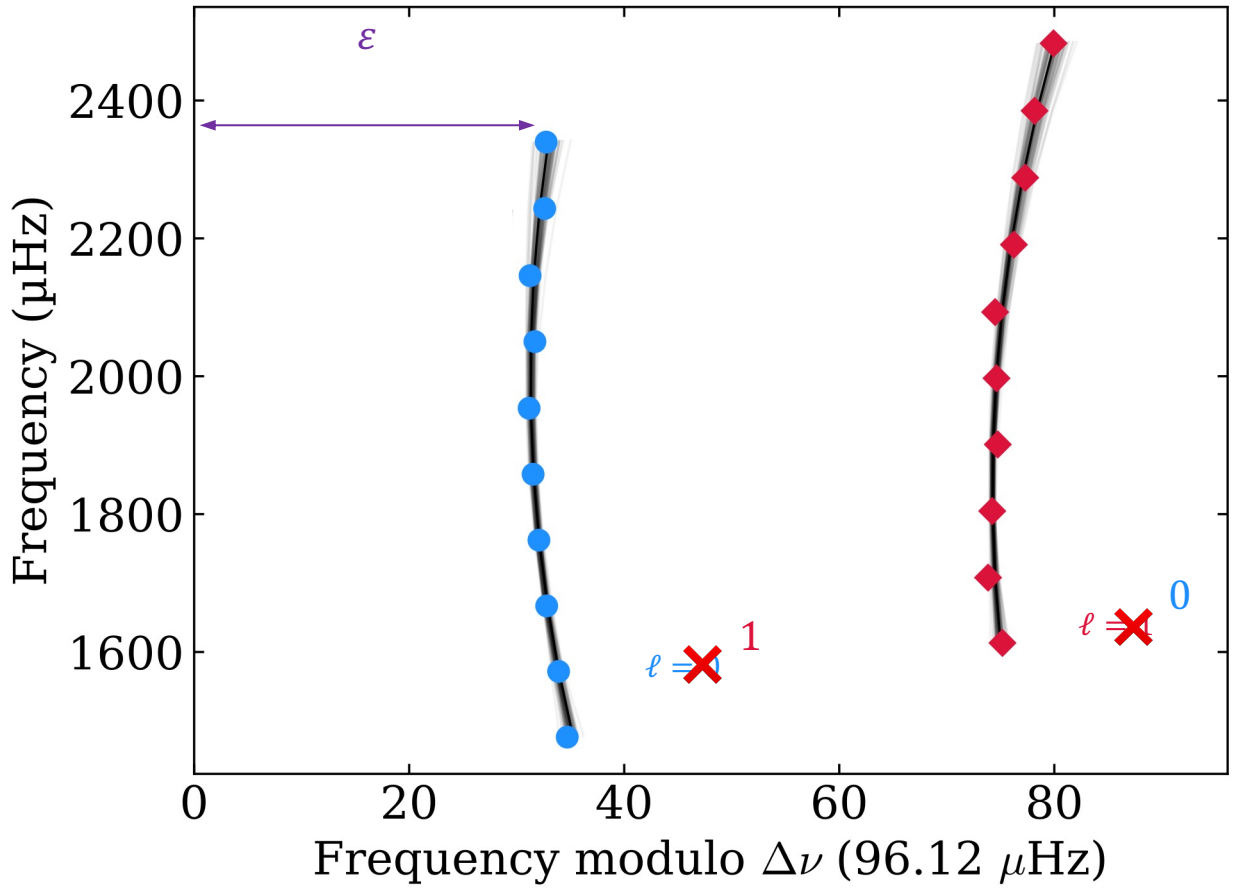

- The identification of $\ell = 0$ and $\ell = 1$ modes is not consistent across pipelines
- More significant in hotter F-type stars with thinner convective envelopes and broader oscillation modes

CONCLUSIONS

- Characterising bright main-sequence and sub-giant stars with TESS
  - → 26 newly characterised stars with extracted mode parameters
  - → TESS allows reliable asteroseismic analysis
  - → Upcoming modelisation of these stars in Bétrisey et al. (in prep.)

Panetier et al. (2026)
Accepted for publication in A&A

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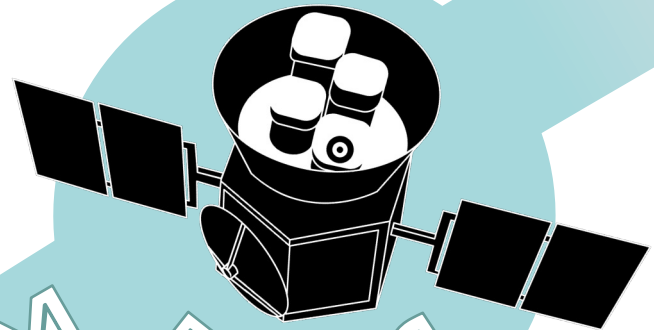
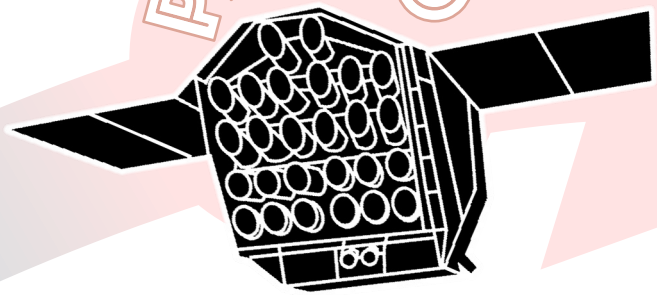
FROM TESS TO PLATO



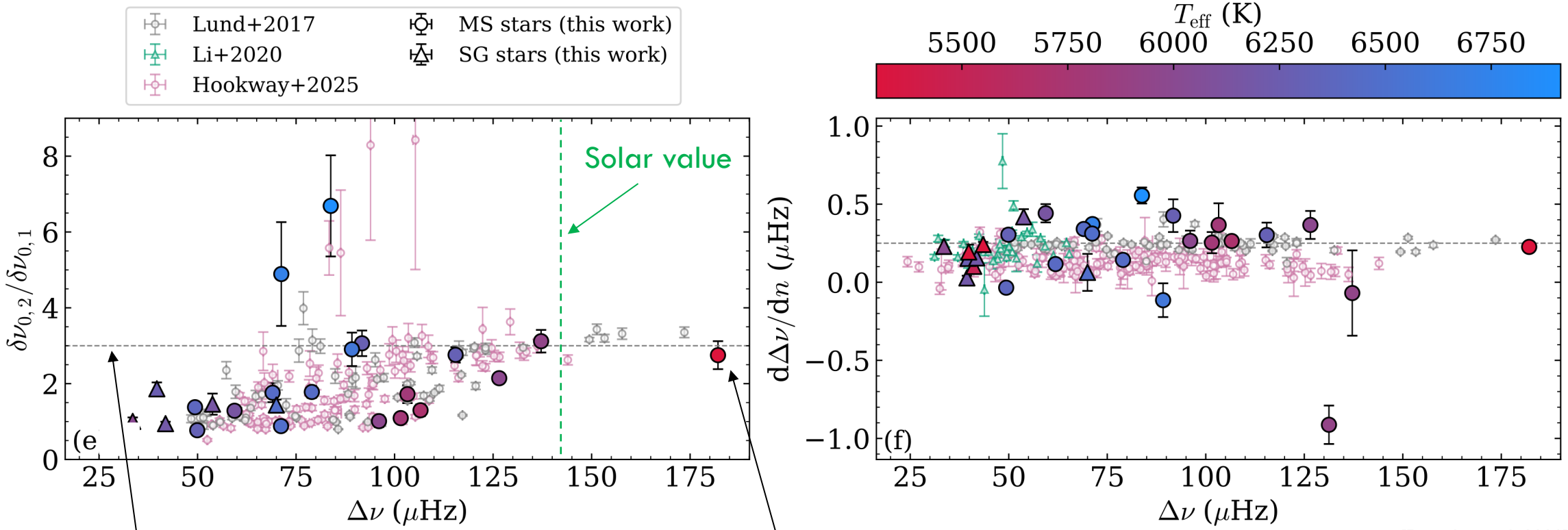
[Ricker et al. 2015]



[Rauer et al. 2025]

- Set of optimal stars to prepare the PLATO mission
  - → Stars of different fundamental properties, falling in the PLATO mission's objectives
  - → Manually extracting the modes won't be possible for PLATO stars
  - → But the automated pipelines do not always agree on the mode detection and identification

CROSS COMPARISON WITH LITERATURE STARS



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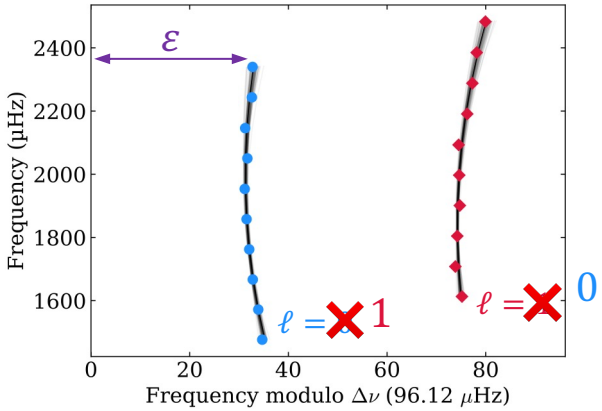

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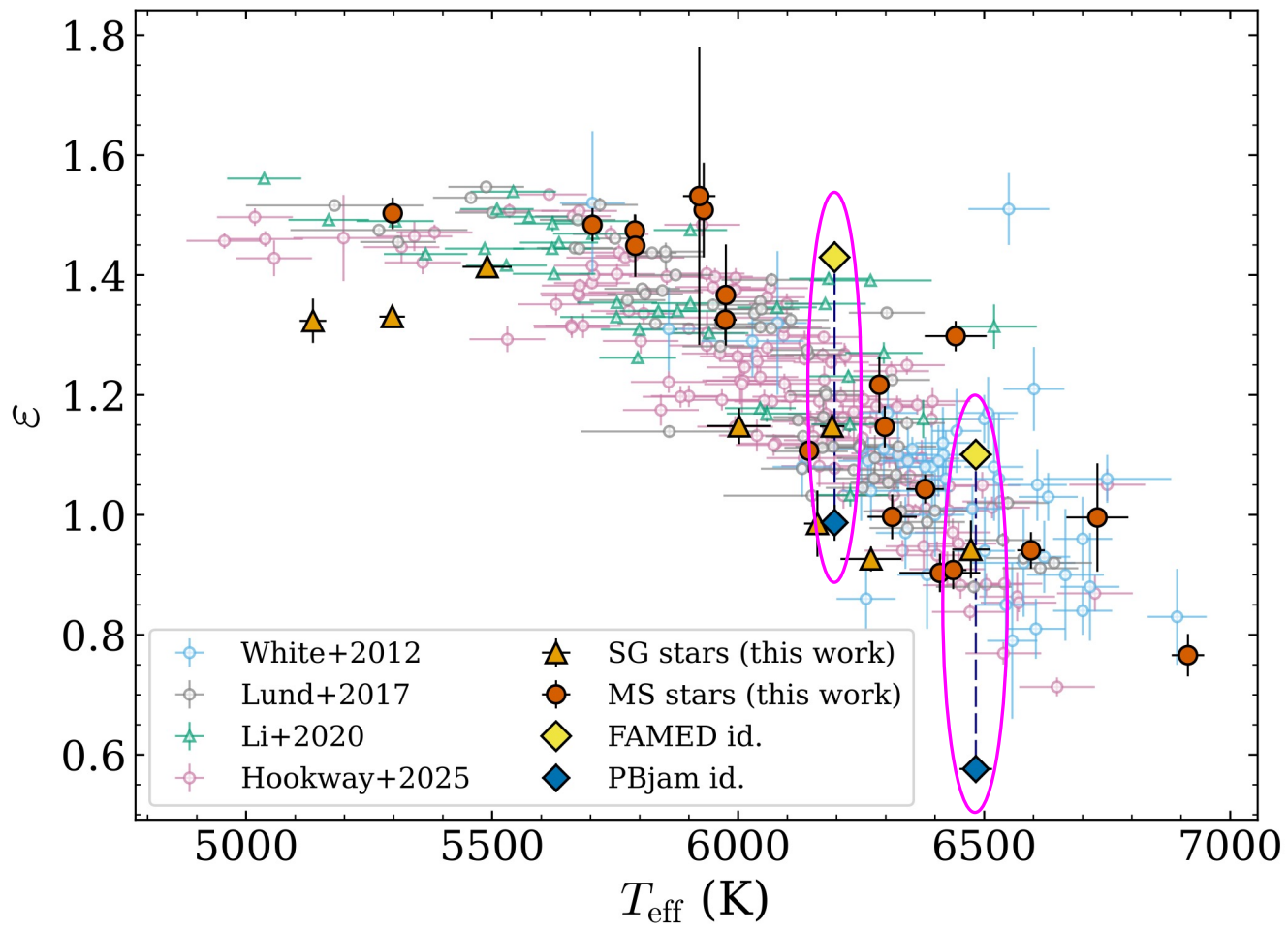

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