Asteroseismic Modelling of Tau Ceti - a Benchmark for the PLATO Stellar Science

Kamakshi Kaushik[1], Orlagh Creevey[1], Maria Pia Di Mauro[2], Louis Manchon[3]

1. Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, France
2. INAF- Istituto di Astrofisica e Planetologia Spaziali, Italy
3. LIRA, Observatoire de Paris, Université PSL, Sorbonne Université, Université Paris Cité, CY Cergy Paris Université, CNRS

Context:

- The **PLATO** (PLAnetary Transits and Oscillations of stars) mission, scheduled for launch in late 2026, aims to detect and characterize Earth-like planets orbiting low-mass stars.
- Achieving the scientific objectives of PLATO requires precise and accurate determinations of fundamental stellar properties.
- To support this goal, the PLATO consortium established the **Benchmark Stars Working Group**, tasked with delivering a set of well-characterized stars that can be used to:
  - Validate stellar analysis pipelines,
  - Support the development and calibration of next-generation stellar models,
  - Provide reference targets for the validation of PLATO observations and data products.
- **τ Ceti** → valuable benchmark target, one of the lowest-mass stars in the PLATO benchmark catalogue with both asteroseismic observations and a confirmed planetary system.

Objective: detailed modelling study of τ Ceti to refine its stellar properties and assess its role as a benchmark star for the PLATO mission.

Observational Constraints:

- Adopted observational constraints listed below (literature compilation).
- Two T_{eff} scales — spectroscopic and interferometric — carried through independently to test sensitivity

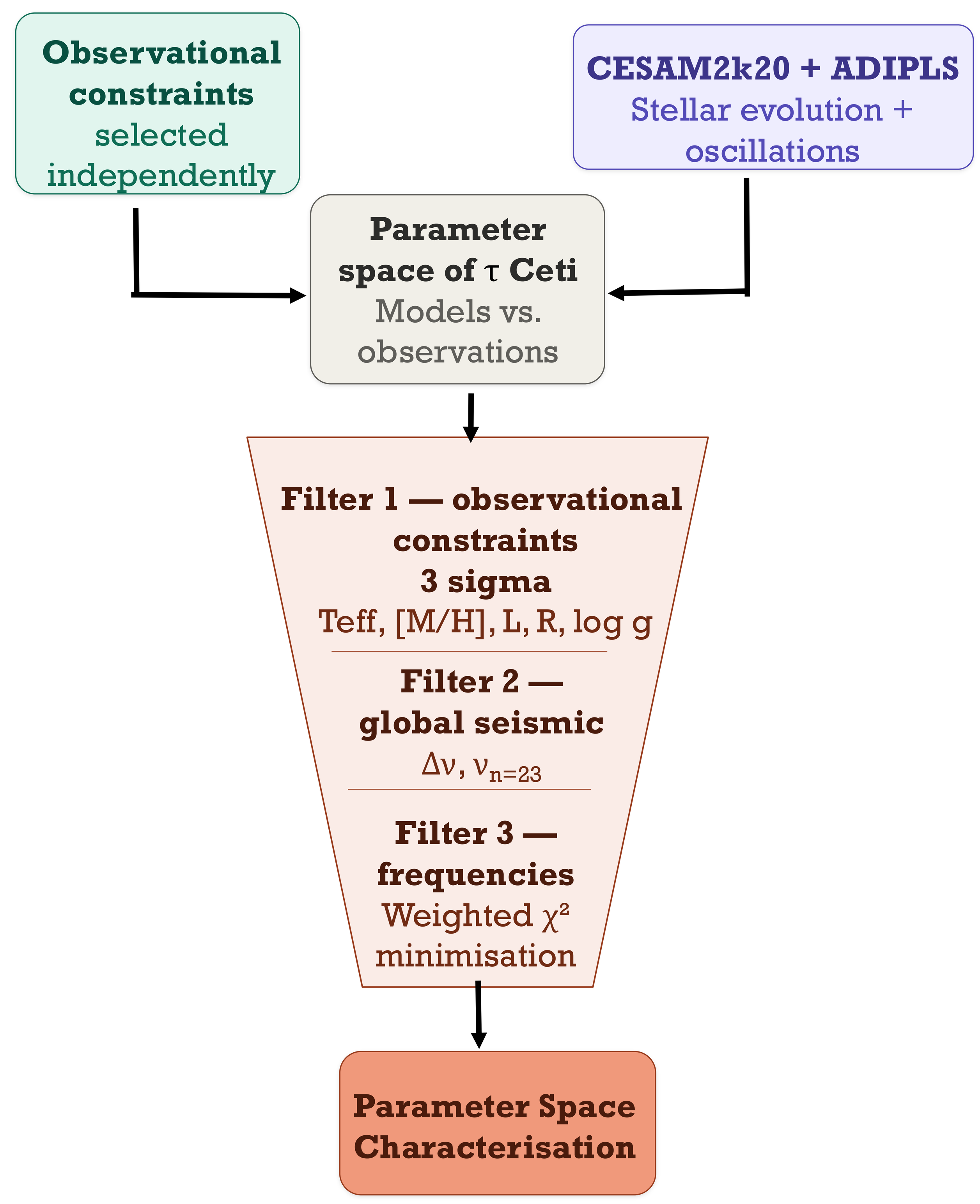
Observations	Value	Reference
Effective Temperature (K)	5383 ± 40	Ibañez Bustos et al. (subm.)
	5320 ± 40	Korolik et.al (2023)
Radius (R_{sun})	0.80 ± 0.02	Ibañez Bustos et al. (subm.)
Luminosity (L_{sun})	0.484 ± 0.01	Ibañez Bustos et al. (subm.)
Metallicity [M/H]	-0.34 ± 0.1	Casamiquela et. al (2026)
log g (dex)	4.48 ± 0.05	Korolik et.al (2023)

Methodology:

- Using initial parameter estimates from our literature review, we constructed a comprehensive grid of stellar evolutionary models using CESAM2k20 to explore the relevant parameter space and identify the best-fitting models consistent with observational constraints. The grid spans as follows:

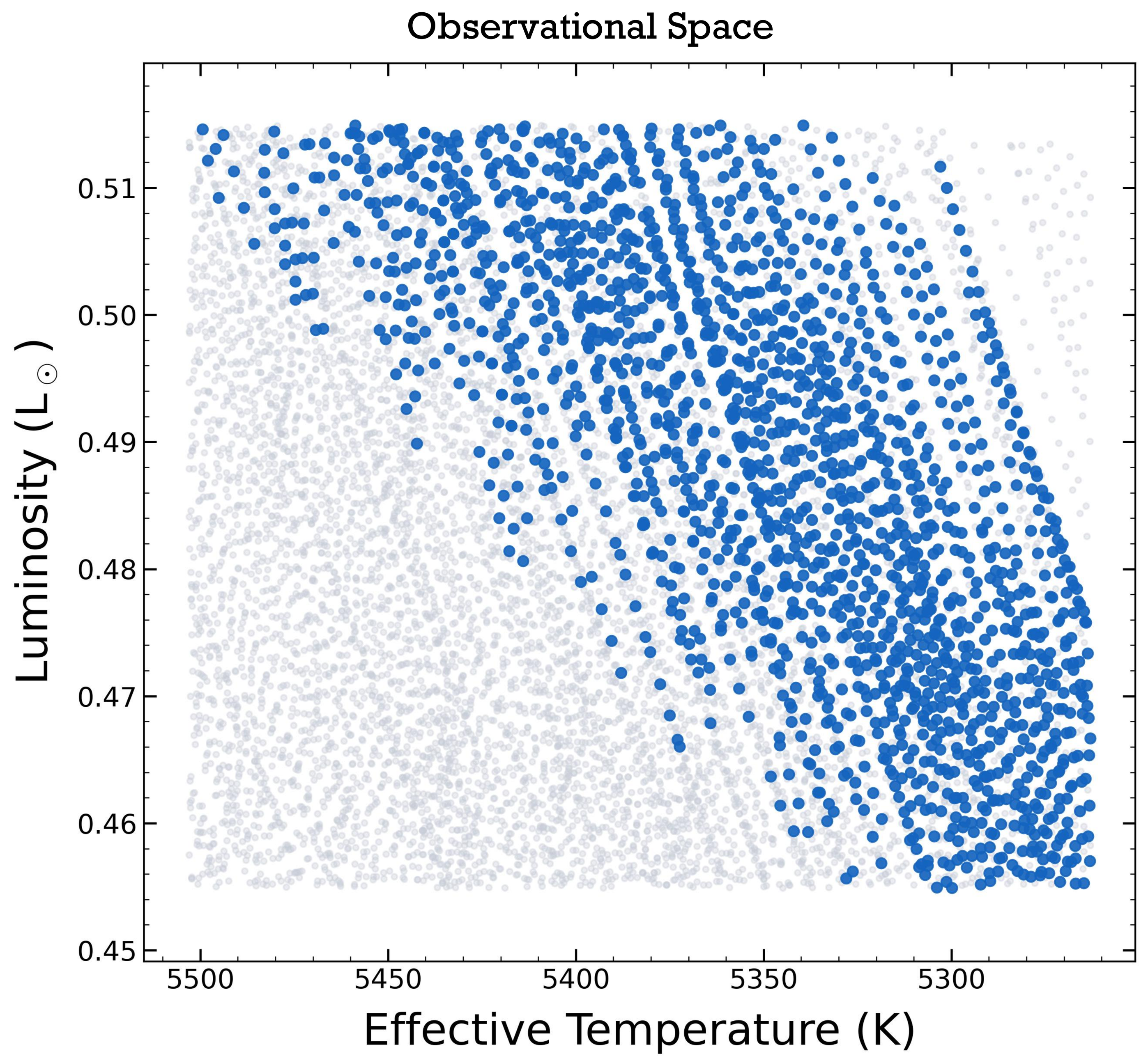
Input Parameters	Range	Step size
Mass	0.76-0.84	0.01
Y	0.255-0.275	0.010
[M/H]	-0.55-0.25	0.05
α_{MLT}	1.44-1.64	0.10
Age	0-12 Gyr	100 Myr

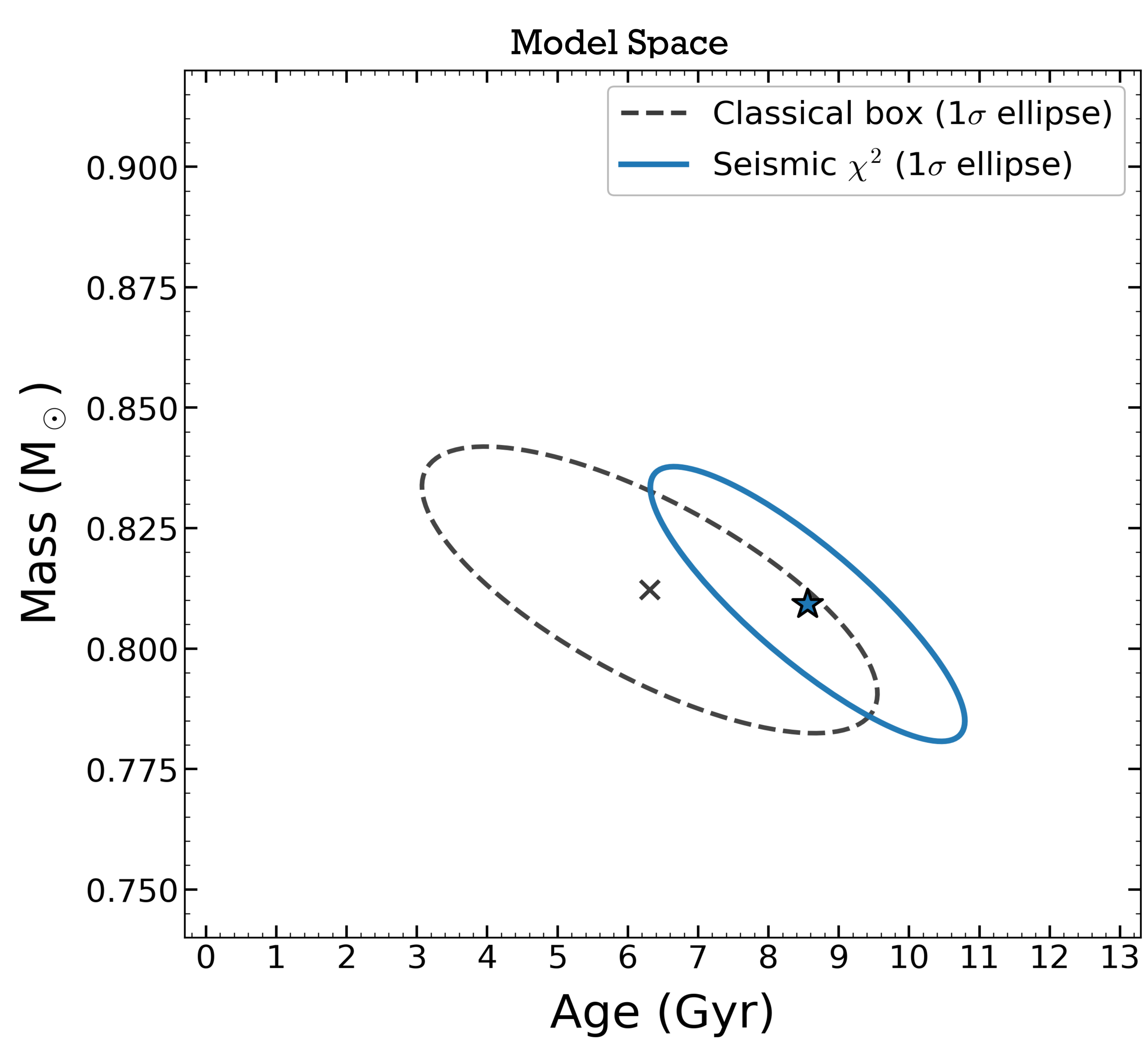
- Resulting stellar structure models were processed through the inbuilt ADIPLS interface to compute adiabatic oscillation frequencies for modes of degree ℓ = 0–3, spanning the frequency range 100–6000 μHz and including approximately 20–25 radial orders per degree.



Results:

Figure left: HR diagram showing the selected models using the classic constraints (grey) and the selected models by including the seismic constraints (blue).
Figure right: the 1sigma error ellipsoid showing the position of tau Ceti in mass-age space without (Grey) and with (blue) seismic constraints.





Conclusion:

- We characterized τ Ceti using CESAM2k20 grid-based modelling, deriving M = 0.81 ± 0.03 M⊙ and an age of 8.7 +2.2/−2.8 Gyr (1σ).
- We explored both Zi and Yi and found consistent results irrespective of the choice; Yi could still be explored further using a finer grid.
- Tighter constraints on age and Y require higher-precision seismology: longer baselines and improved S/N on individual mode frequencies.

Acknowledgement: This work is supported by the "Action Thématique Physique Stellaire" of CNRS/INSU PN ASTRO co-funded by CEA and CNES.