

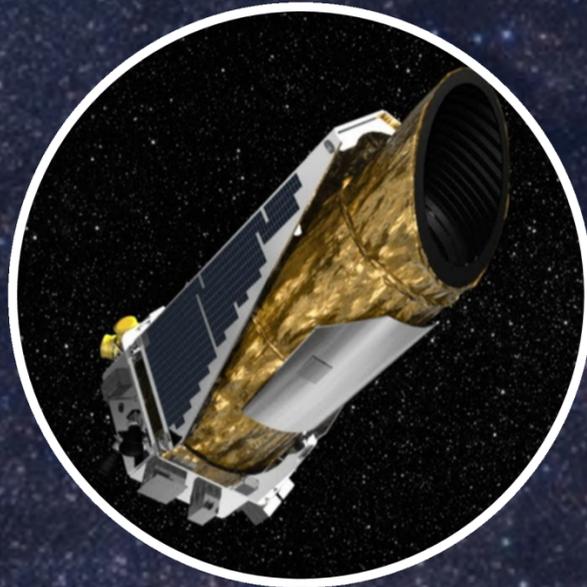
# Predicting asteroseismic properties of Red Giants in our Galaxy's inner parsec

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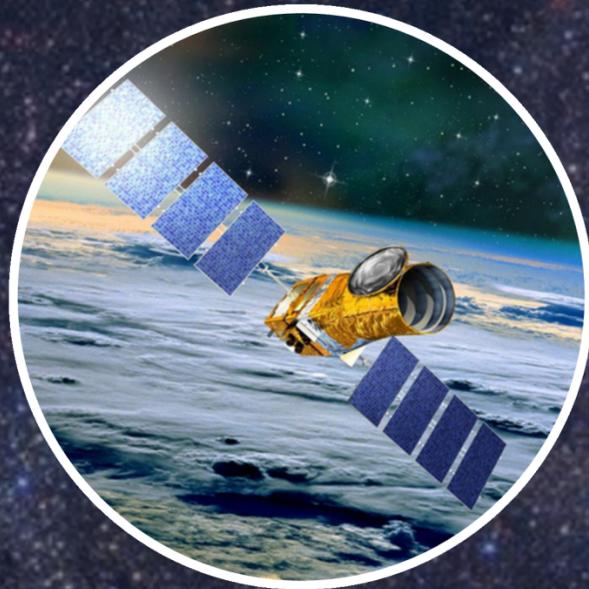
# State of the art

## Current missions



Kepler (NASA)

CoRoT (CNES with ESA)



TESS (NASA)



Credit:

NASA Ames/W Stenzel

CNES/D. Ducros

NASA's Goddard Space Flight Center/Chris Meaney

- Current space missions → provide revolutionizing high quality **asteroseismic** data → finally revealed accurate intrinsic properties.
- Reveals: **high variance in metallicities** (orders of magnitude) never seen before → raises questions about the origin of these stars:
  - Belong to **different populations**? How many?
  - Is this only consistent with a **merger of galaxies**?



Credit:  
NASA/STScI/WikiSky



Credit:  
EHT Collaboration

# Objectives

How can we answer these questions?

1. Model and calibrate these stars in detail (first time).
  - Constrain: **masses** and **metallicities**.
  - Verify: describe them with only two metallicity benchmarks.
2. Asteroseismology (dual purpose)
  - Theoretical predictions for validation.
  - Results: Provide insight for future missions.

# Early results

- MESA: Model the higher and lower metallicity stars (not trivial!)
- Plot: Evolutionary RGB tracks + [Do et al. 2015].

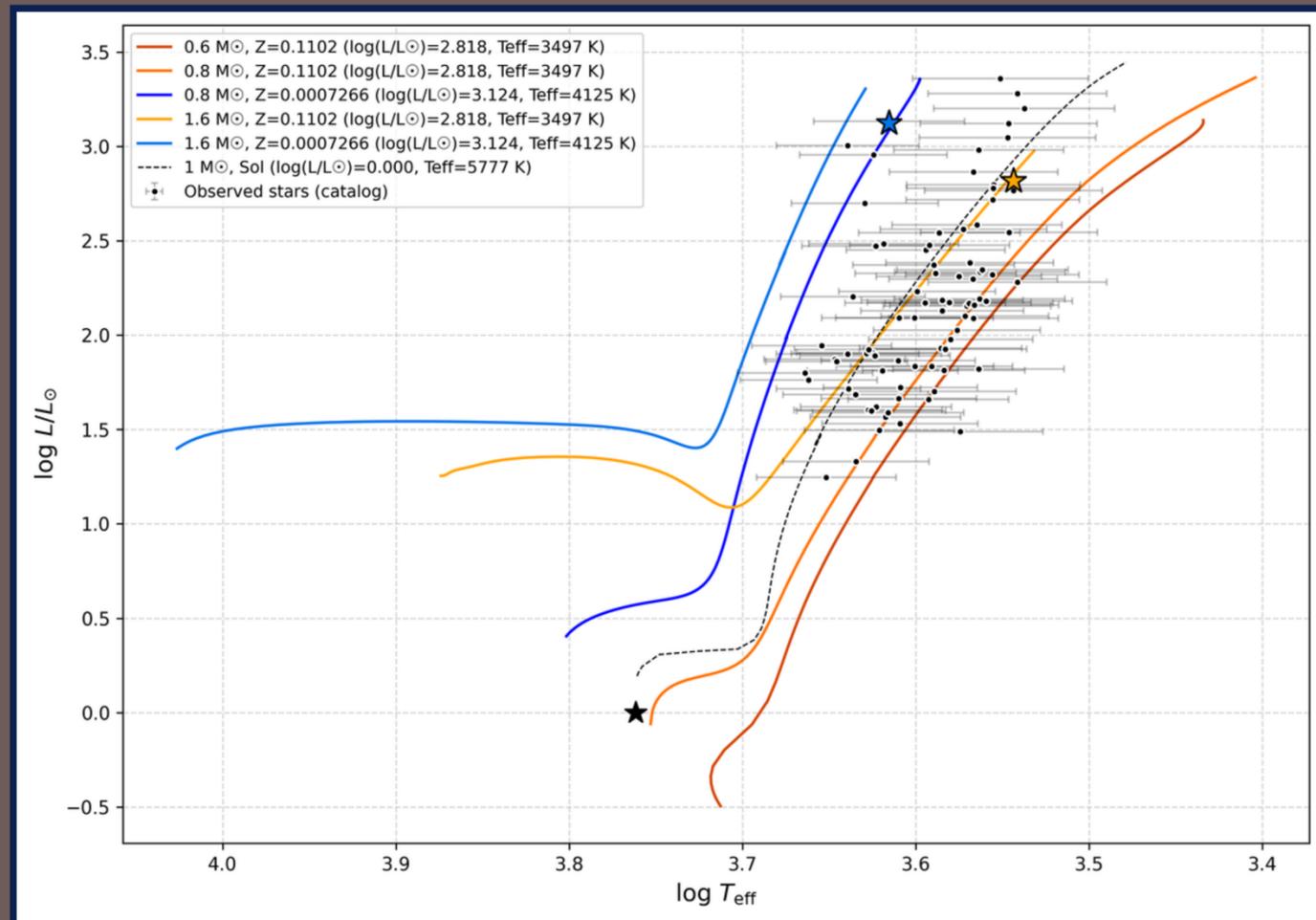
$$\log_{10} \left( \frac{L}{L_{\odot}} \right) = \frac{4.75 - m_K + 5 \log(d/10\text{pc}) + A_K - BC_K}{2.5}$$

Conclusions:

- **Can fit ~ 97% of the stars** (1st objective).
- Catalogue can't be explained by a single Z.
- Low Z stars best fitted by lower M models.
- High Z stars best fitted by high M models.

Credit: [Do et al. 2015]

Star	$m_K$	$A_K$	S/N	Teff (K)	$\sigma_{\text{Teff}}$ (K)	log(g)	$\sigma_{\log(g)}$	[M/H]	$\sigma_{[M/H]}$
High metallicity (E5-1 001)	12.0	2.58	42	3497	413	3.04	0.91	0.96	0.32
Low metallicity (NE1-1 003)	11.4	2.41	133	4125	413	3.98	0.91	-1.27	0.32



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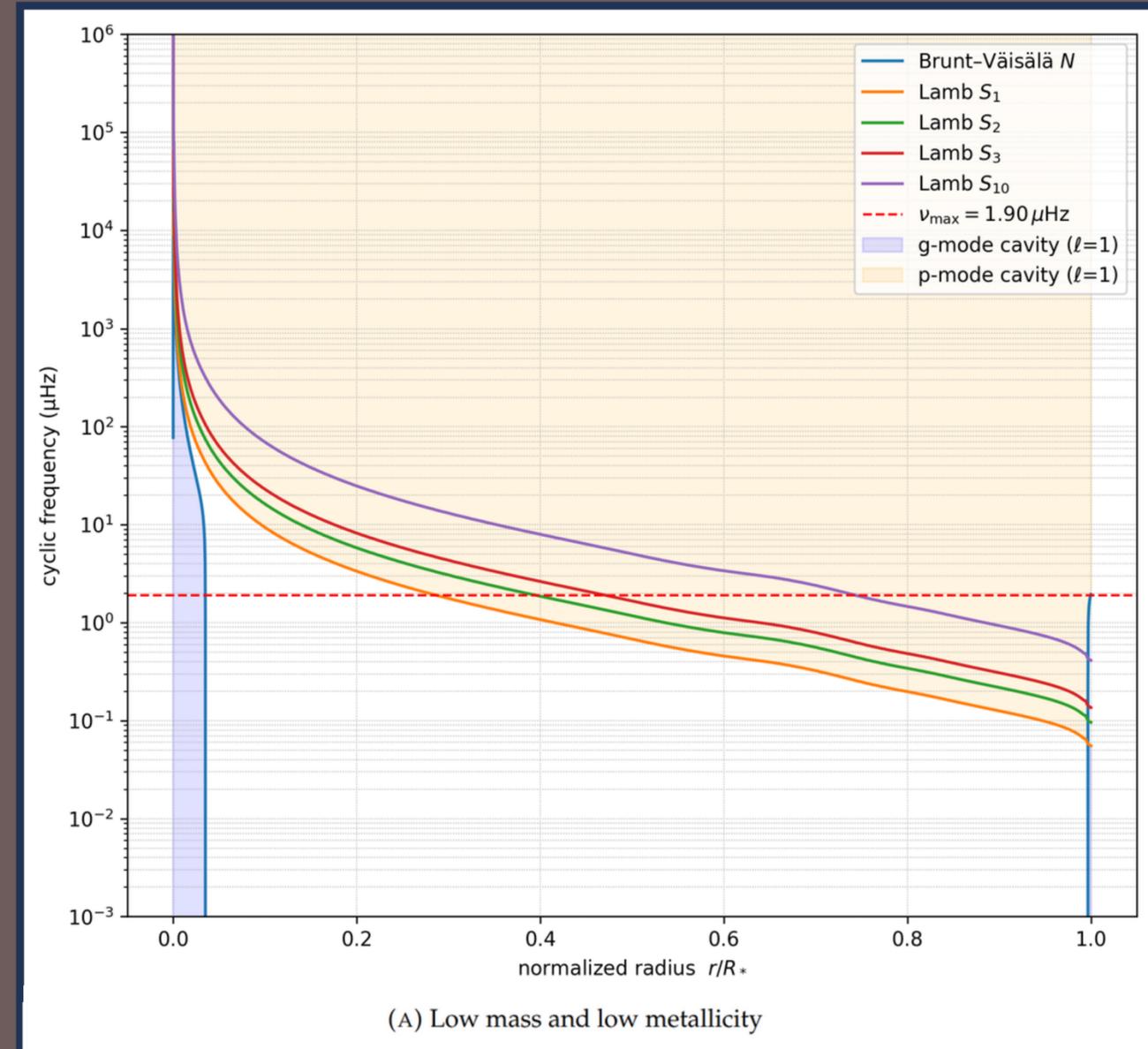
Access the internal structure: **propagation diagrams**  
 (Characteristic frequencies vs R + cavities highlighted)

$$N^2 = g \left( \frac{1}{\Gamma_1 P} \frac{dP}{dr} - \frac{1}{\rho} \frac{d\rho}{dr} \right) \quad S_l^2 = \frac{l(l+1)c_s^2}{r^2}$$

$$\nu_{\max} = \nu_{\max,\odot} \frac{M/M_\odot}{(R/R_\odot)^2} \left( \frac{T_{\text{eff}}}{T_{\text{eff},\odot}} \right)^{-1/2}$$

Mixed modes:

- **g-mode** cavity (blue) in **radiative core**.
- **p-mode** cavity (red) in **convective envelope**.



# Early results

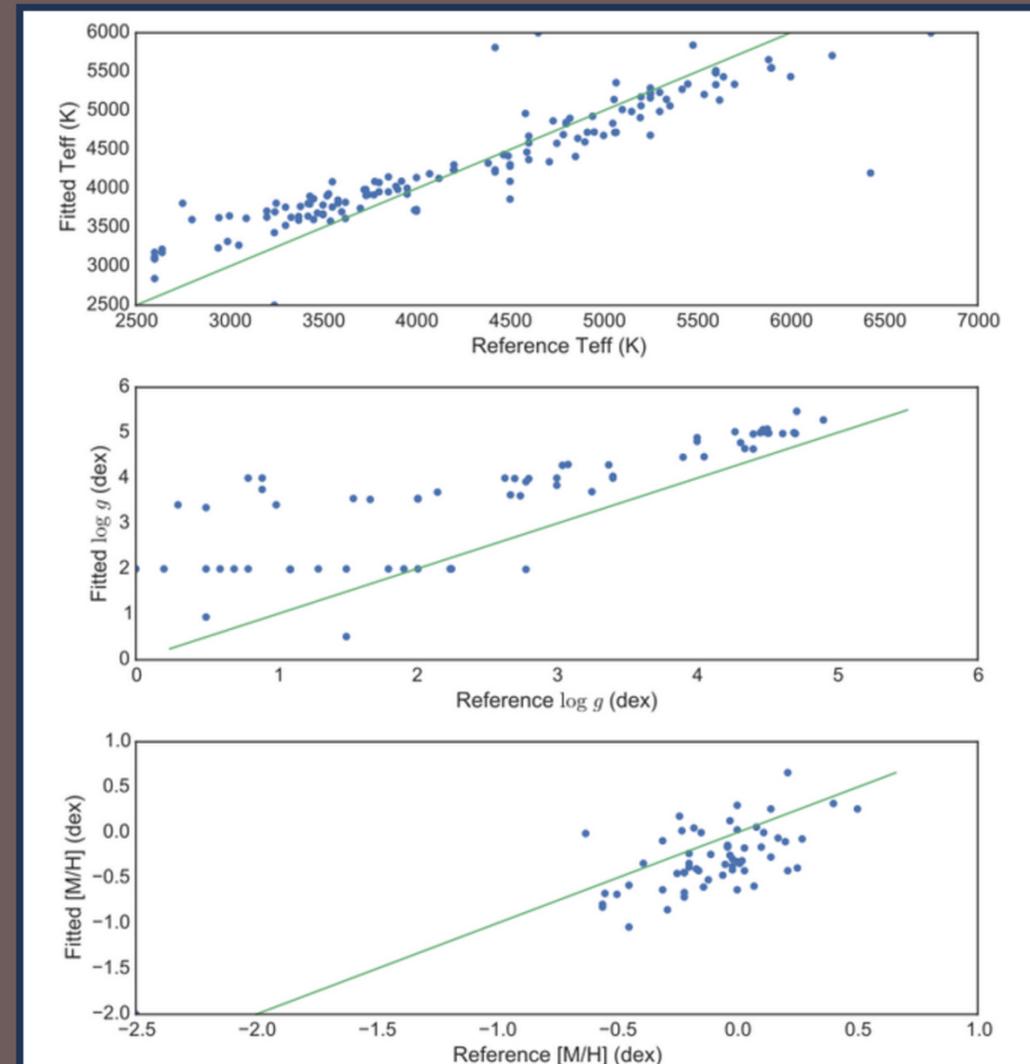
Discrepancy between our guesses and [Do et al. 2015]:

- Higher Z:  $M = 174.59 M_{\odot}$
- Lower Z:  $M = 1799.34 M_{\odot}$

This discrepancy may arise from:

- Spectral model (and wavelength range) used in [Do et al.] not adequate to fit  $\log(g)$ .
- Stresses the struggle to measure masses/ radii.

$$\frac{M}{M_{\odot}} = \left( \frac{R}{R_{\odot}} \right) \frac{g}{g_{\odot}} = 10^{\log g - \log g_{\odot}} 10^{\log \frac{L}{L_{\odot}}} \left( \frac{T_{\text{eff},\odot}}{T_{\text{eff}}} \right)^4$$



**Figure 2.** Comparison of the best-fit values for the SPEX spectral library to literature values tabulated in Cesetti et al. (2013) for (top)  $T_{\text{eff}}$ , (middle)  $\log g$ , and (bottom)  $[M/H]$ . More stars from SPEX have  $T_{\text{eff}}$  measurements than  $\log g$  or  $[M/H]$ .

Credit: Do et al. 2015

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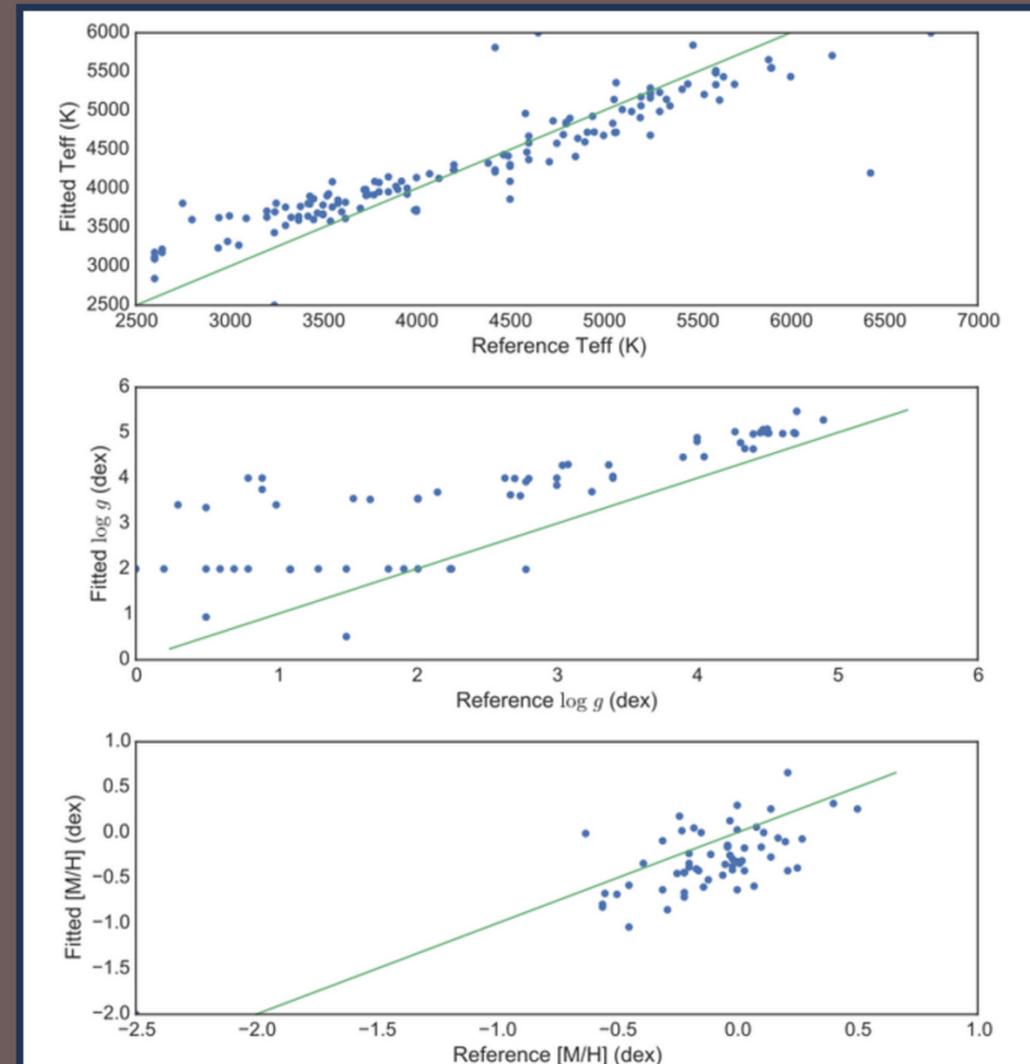
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$$\frac{M}{M_{\odot}} \simeq \left( \frac{\nu_{\max}}{\nu_{\max,\odot}} \right)^3 \left( \frac{\Delta\nu}{\Delta\nu_{\odot}} \right)^{-4} \left( \frac{T_{\text{eff}}}{T_{\text{eff},\odot}} \right)^{3/2}$$

$$\frac{R}{R_{\odot}} \simeq \left( \frac{\nu_{\max}}{\nu_{\max,\odot}} \right) \left( \frac{\Delta\nu}{\Delta\nu_{\odot}} \right)^{-2} \left( \frac{T_{\text{eff}}}{T_{\text{eff},\odot}} \right)^{1/2}$$



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# End game

Run statistical study of this dispersion of metallicities and try to figure out **which of the two hypothesis is the best fit** for our models and observations.



different populations



merger of galaxies

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**Thank you!**

Credit: ESO/Noguerras-Lara et al.