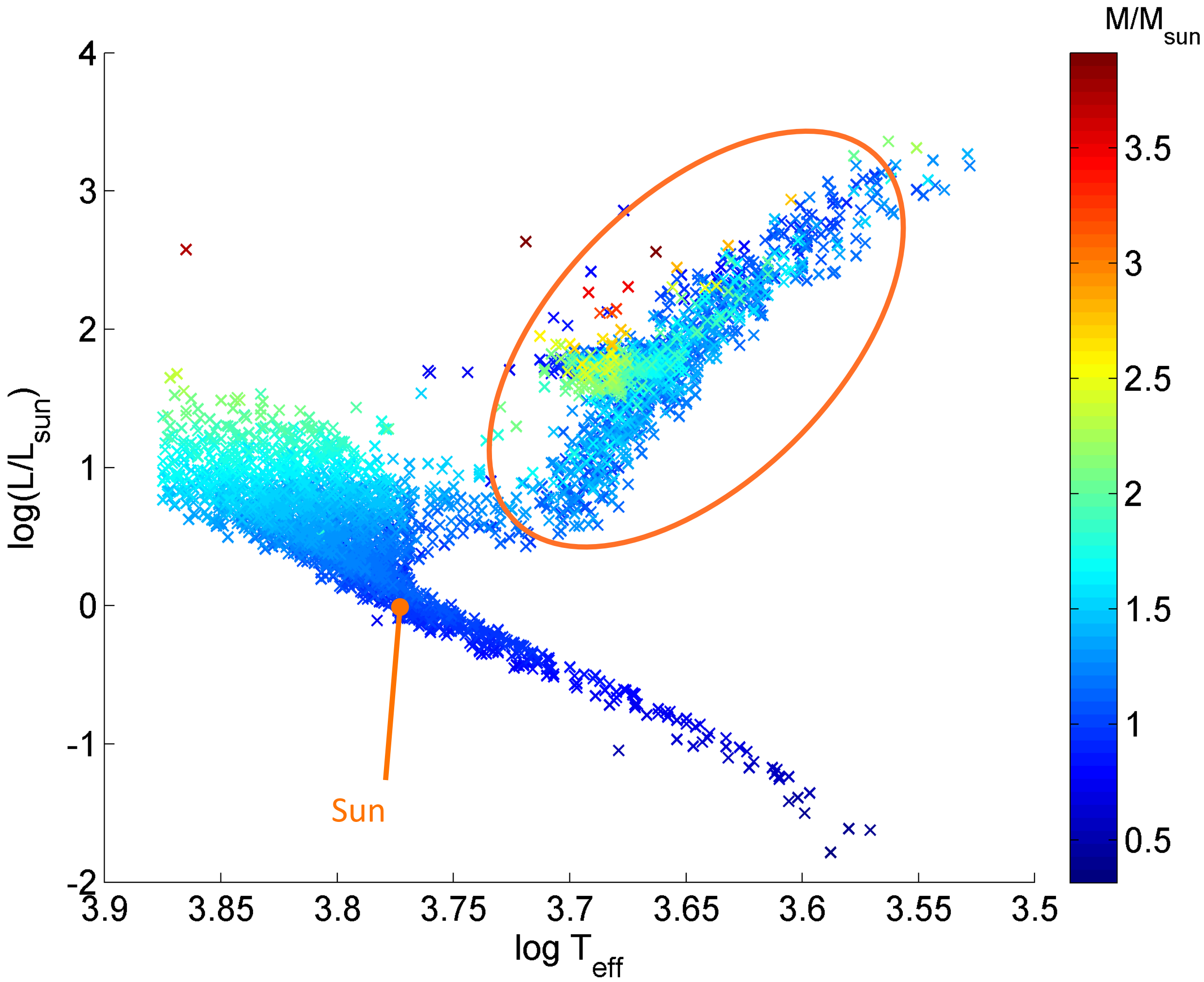
# The Linear Oscillation Zoo Within Giant Stars:

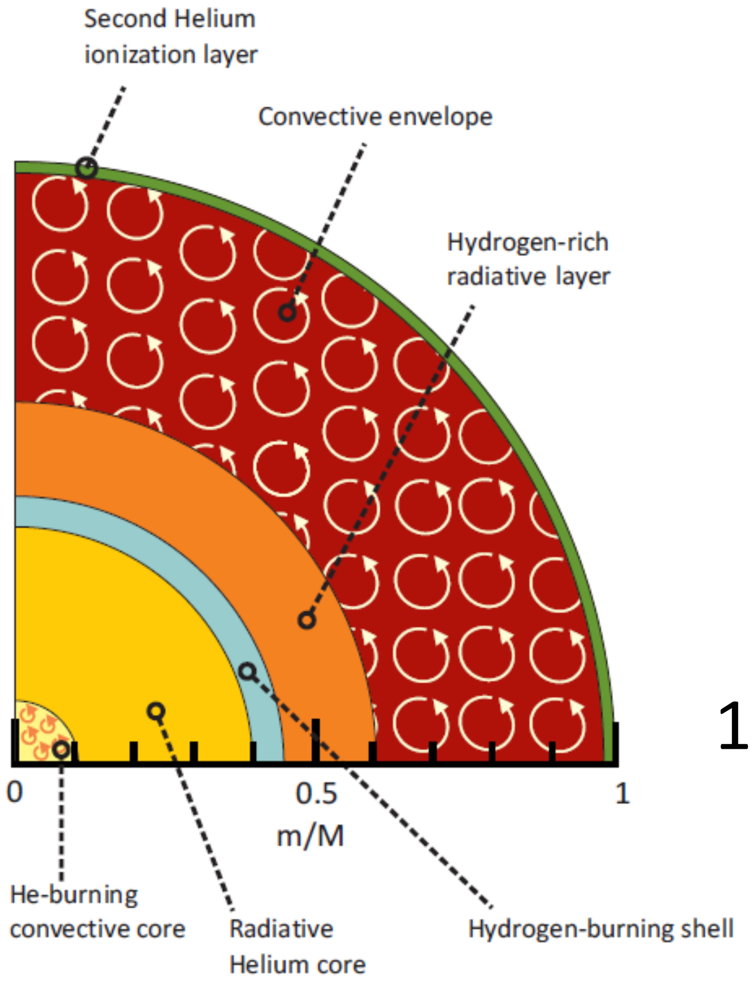
# A Probe Of Their Deep Interiors

Andrea Miglio
School of Physics and Astronomy
University of Birmingham

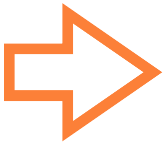
# the zoo of red giants: a unique snapshot of stellar evolution



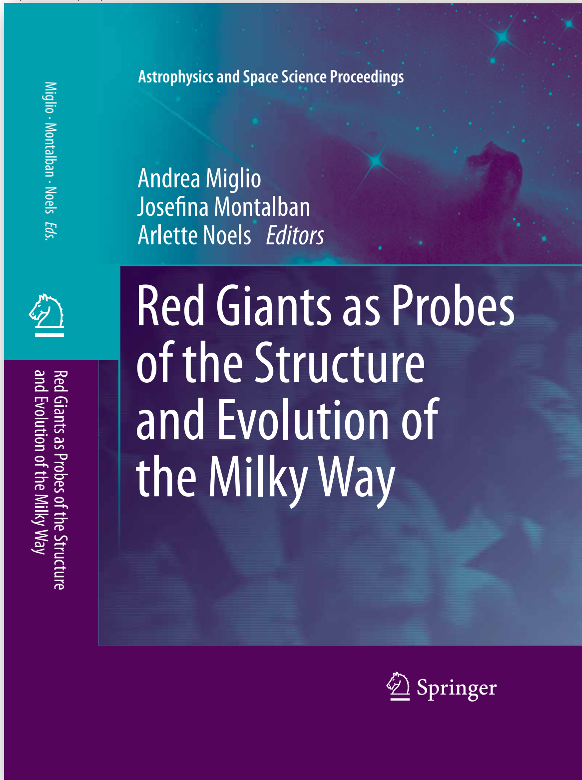
# the zoo of red giants




$1.2\ M_{sun}$



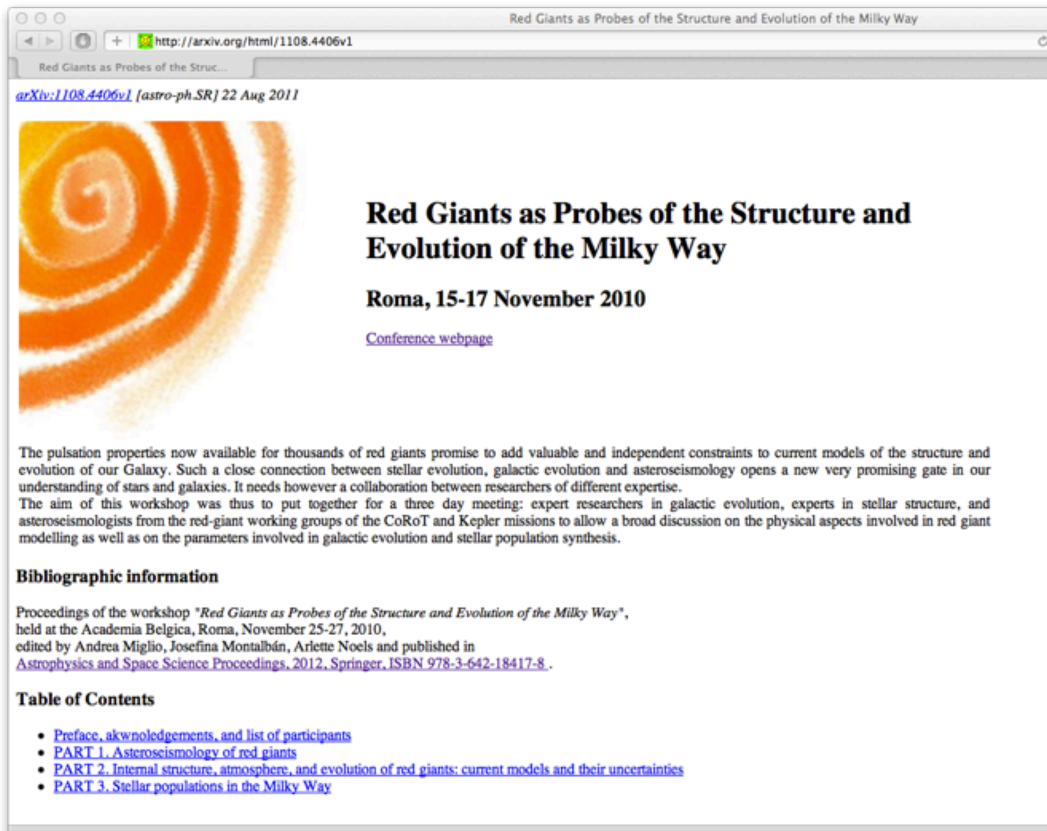
determines
oscillation spectrum




# Red Giants as Probes of the Structure and Evolution of the Milky Way

Series: Astrophysics and Space Science Proceedings

Miglio, Andrea; Montalban, Josefina; Noels, Arlette (Eds.)
2012, ISBN 978-3-642-18417-8, Hardcover



Red Giants as Probes of the Structure and Evolution of the Milky Way

http://arxiv.org/html/1108.4406v1

arXiv:1108.4406v1 [astro-ph.SR] 22 Aug 2011

## Red Giants as Probes of the Structure and Evolution of the Milky Way

**Roma, 15-17 November 2010**

Conference webpage

The pulsation properties now available for thousands of red giants promise to add valuable and independent constraints to current models of the structure and evolution of our Galaxy. Such a close connection between stellar evolution, galactic evolution and asteroseismology opens a new very promising gate in our understanding of stars and galaxies. It needs however a collaboration between researchers of different expertise.
The aim of this workshop was thus to put together for a three day meeting: expert researchers in galactic evolution, experts in stellar structure, and asteroseismologists from the red-giant working groups of the CoRoT and Kepler missions to allow a broad discussion on the physical aspects involved in red giant modelling as well as on the parameters involved in galactic evolution and stellar population synthesis.

### Bibliographic information

Proceedings of the workshop "*Red Giants as Probes of the Structure and Evolution of the Milky Way*", held at the Academia Belgica, Roma, November 25-27, 2010, edited by Andrea Miglio, Josefina Montalbán, Arlette Noels and published in Astrophysics and Space Science Proceedings, 2012, Springer, ISBN 978-3-642-18417-8 .

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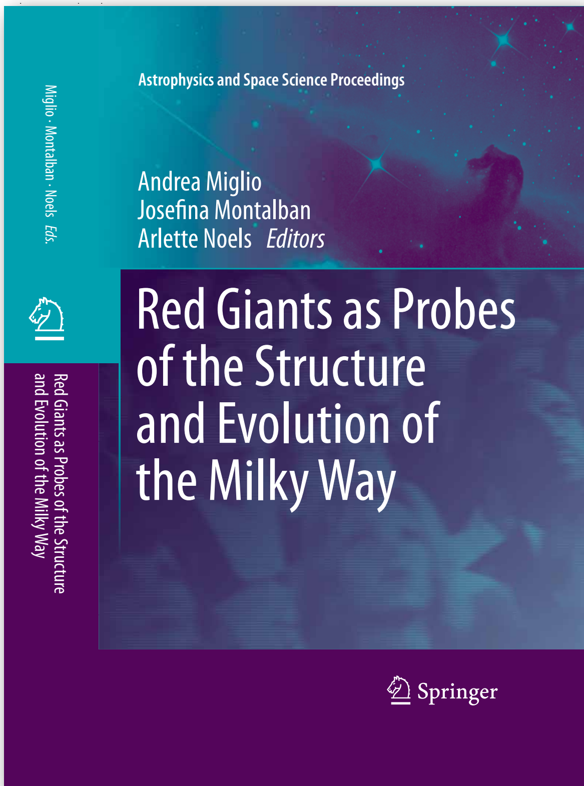


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**PART 2: Internal structure, atmosphere, and evolution of red giants: current models and their uncertainties**

**Evolution and internal structure of red giants**
Maurizio Salaris

**Uncertainties and systematics in stellar evolution models of Red Giant Stars**
Santi Cassisi

**Convection modelling and the morphology of RGBs in stellar clusters**
Paolo Ventura

**Helium burning in moderate-mass stars**
Achim Weiss

**Impact of rotational mixing on the global and asteroseismic properties of red giants**
Patrick Eggenberger

**3D picture of the convective envelope of a rotating RGB star**
Ana Palacios

**Effects of rotation and thermohaline mixing in red giant stars**
Corinne Charbonnel

**3D Model Atmospheres of Red Giant Stars**
Hans-Günter Ludwig

# the zoo of red giants

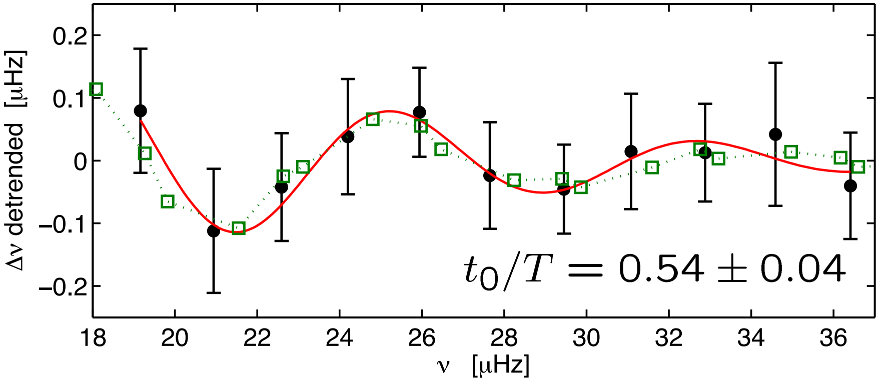
Oscillation frequencies ⇄ Features in stellar interior - global stellar parameters

specificity of seismic diagnostics: few examples

# Acoustic glitches in giants

First evidence for a sharp-structure variation in a red giant CoRoT target

HR7349




Miglio et al. 2010, A&A

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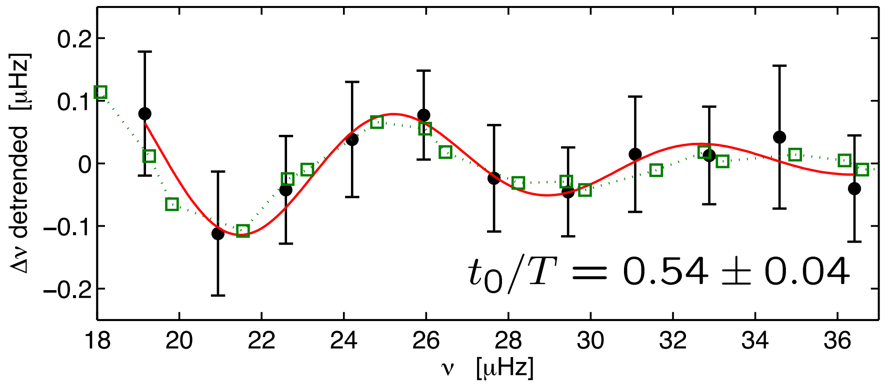
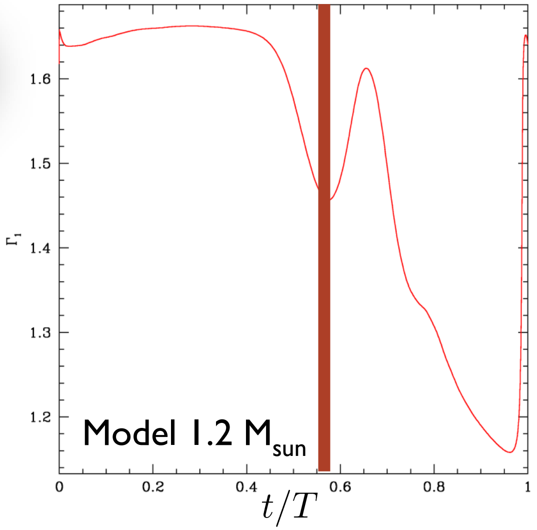


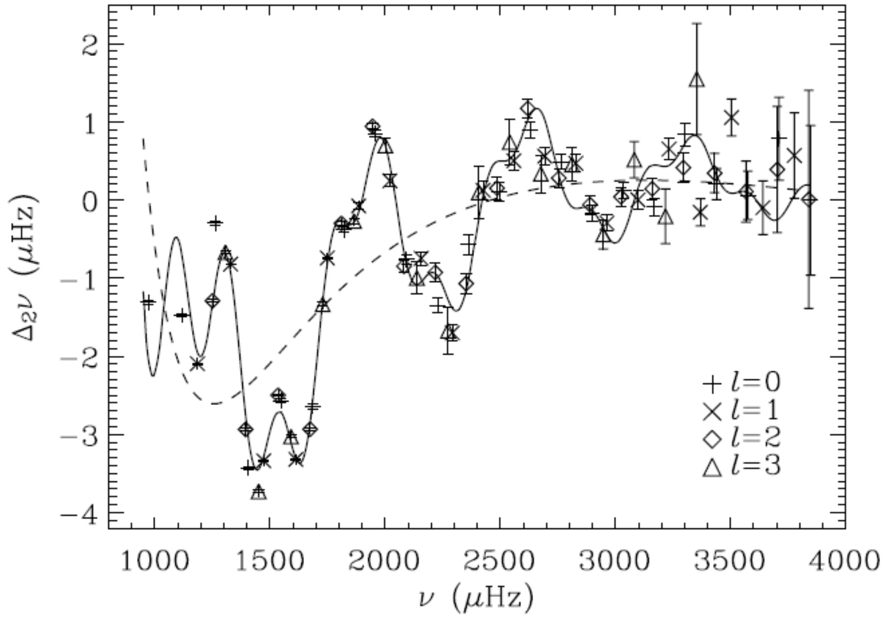

Miglio et al. 2010, A&A

$$c^2 = \Gamma_1 \frac{P}{\rho}$$

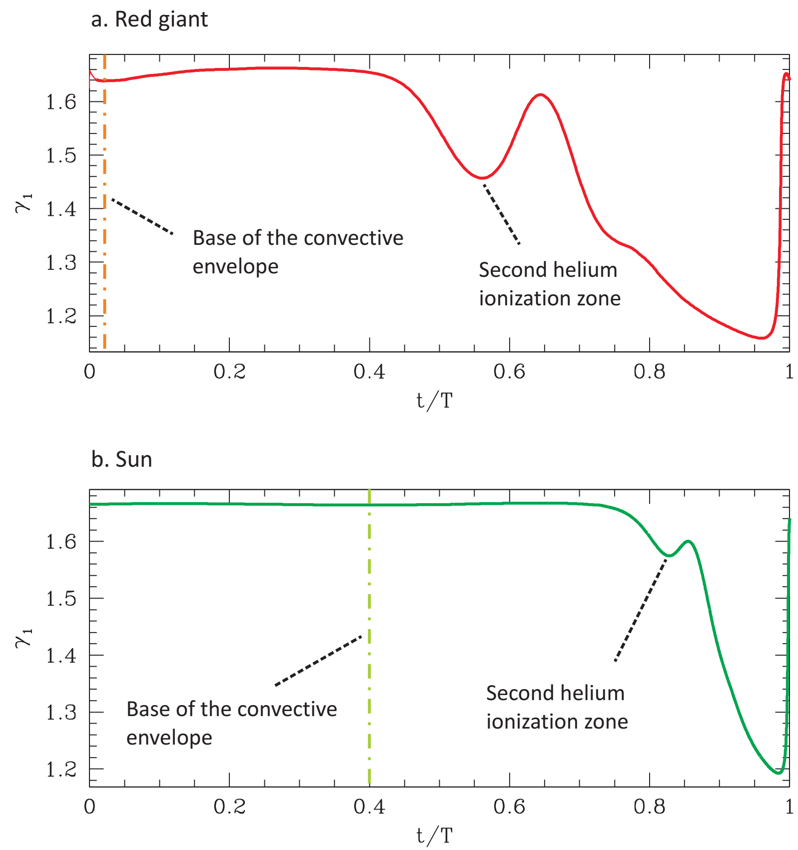


# Acoustic glitches in giants

Sun: low-degree modes



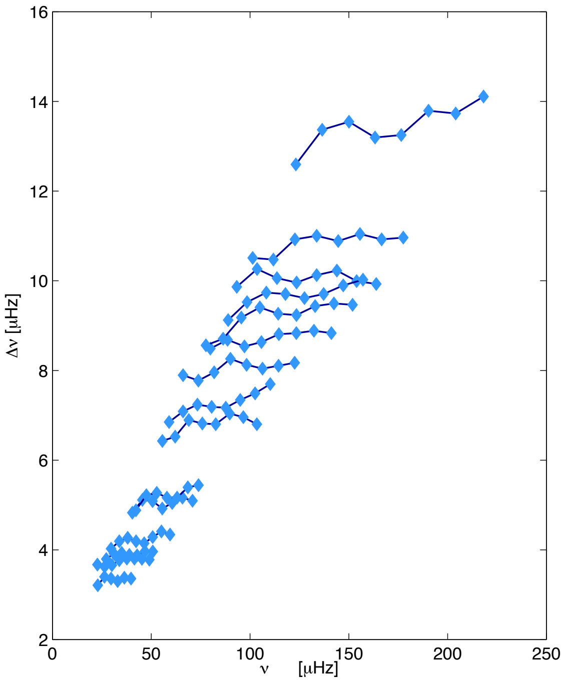

Houdek & Gough, 2007

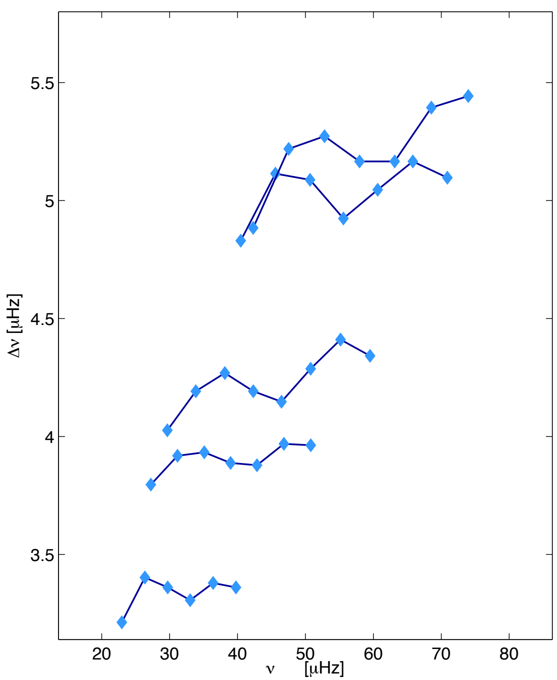



Ballot et al. 2004

# Acoustic glitches in giants

## *Kepler* data - field stars




thanks to B. Mosser

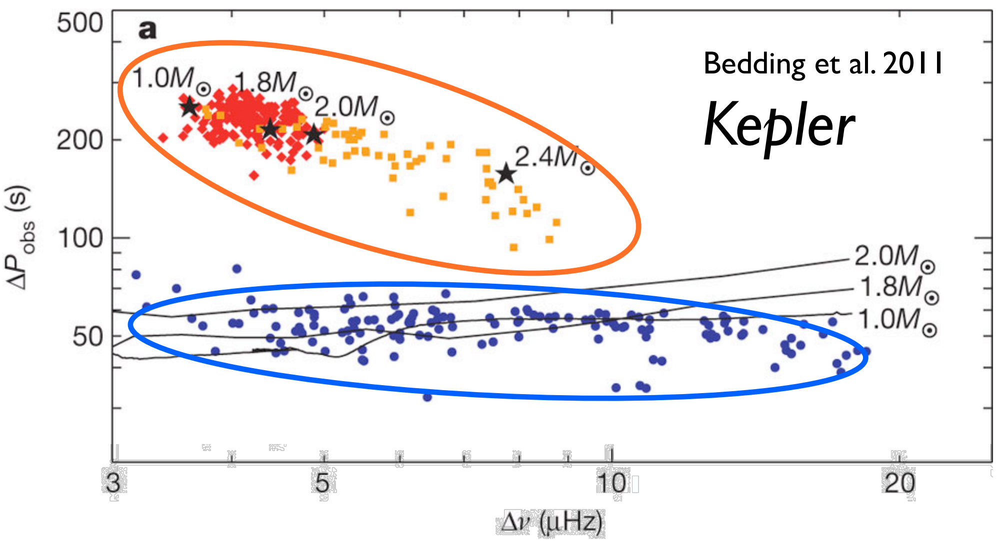
## can we estimate envelope Y ?

first steps:

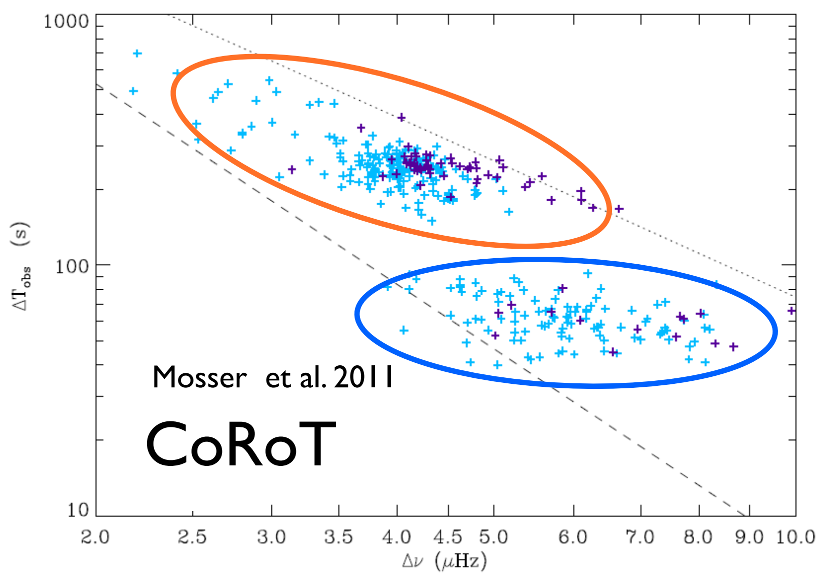
- H&H exercises
- test robustness in *Kepler* giants belonging to old open clusters

# Period spacing: evolutionary state

$$\Delta P = \frac{2\pi^2}{\sqrt{l(l+1)}} \left( \int_{r_1}^{r_2} N \frac{\mathrm{d}r}{r} \right)^{-1}$$

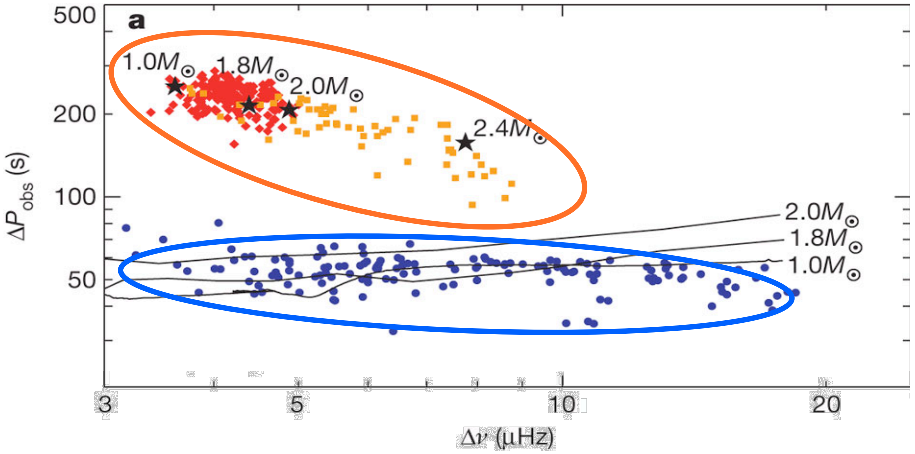



He-burning

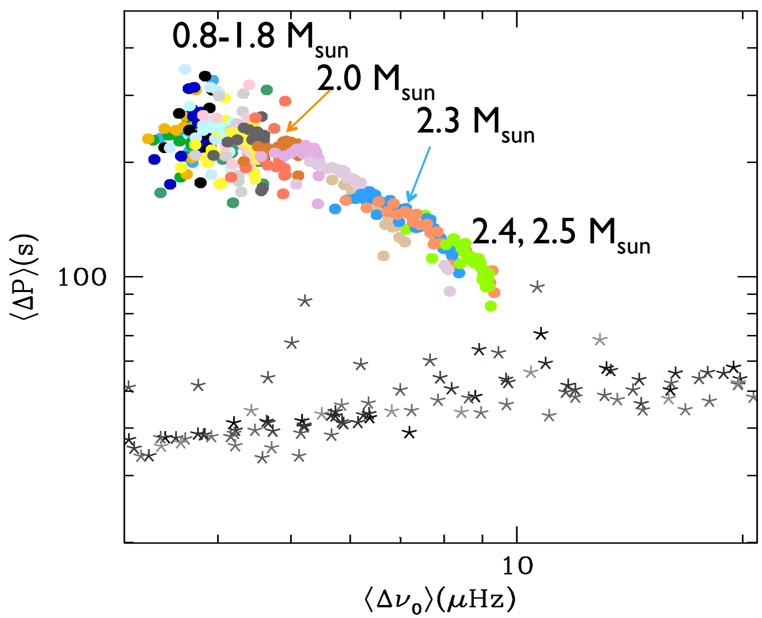



RGB

# Period spacing: evolutionary state



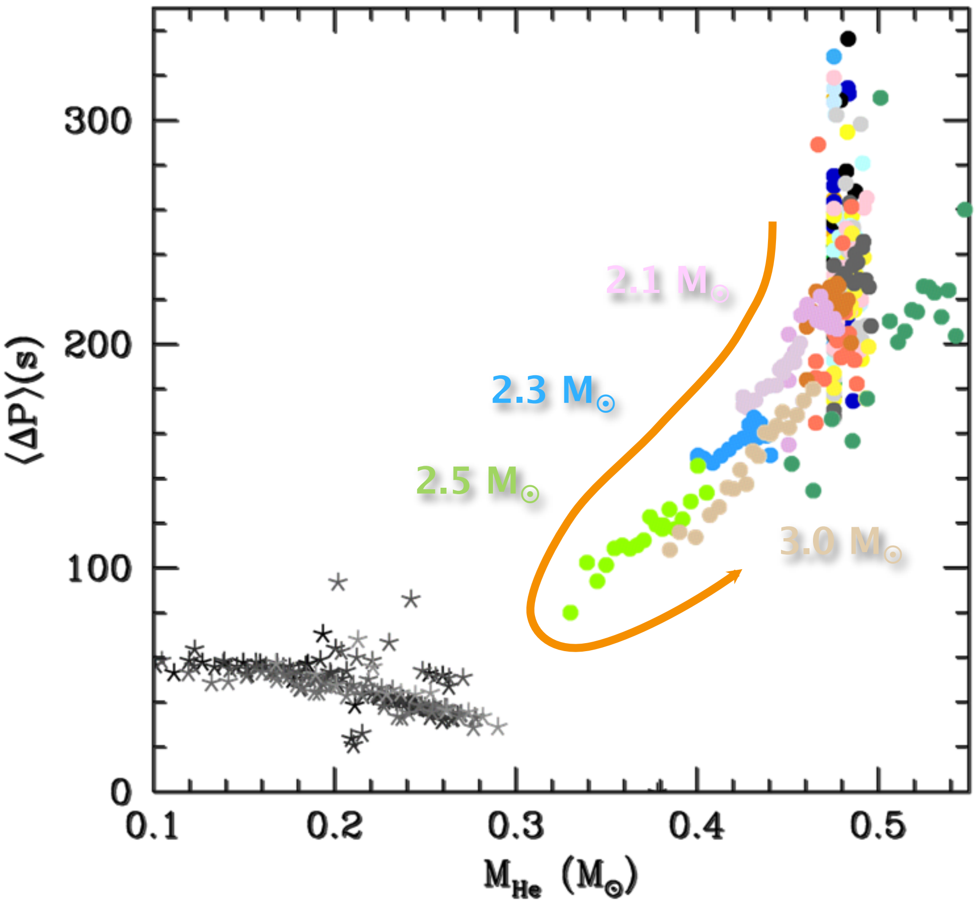

*Kepler*
Bedding et al. 2011




ATON stellar models
+
Adiabatic frequency computations (LOSC)

Montalban, Miglio, Noels, Ventura, 2011 in prep

# Period spacing: Mass of the He core

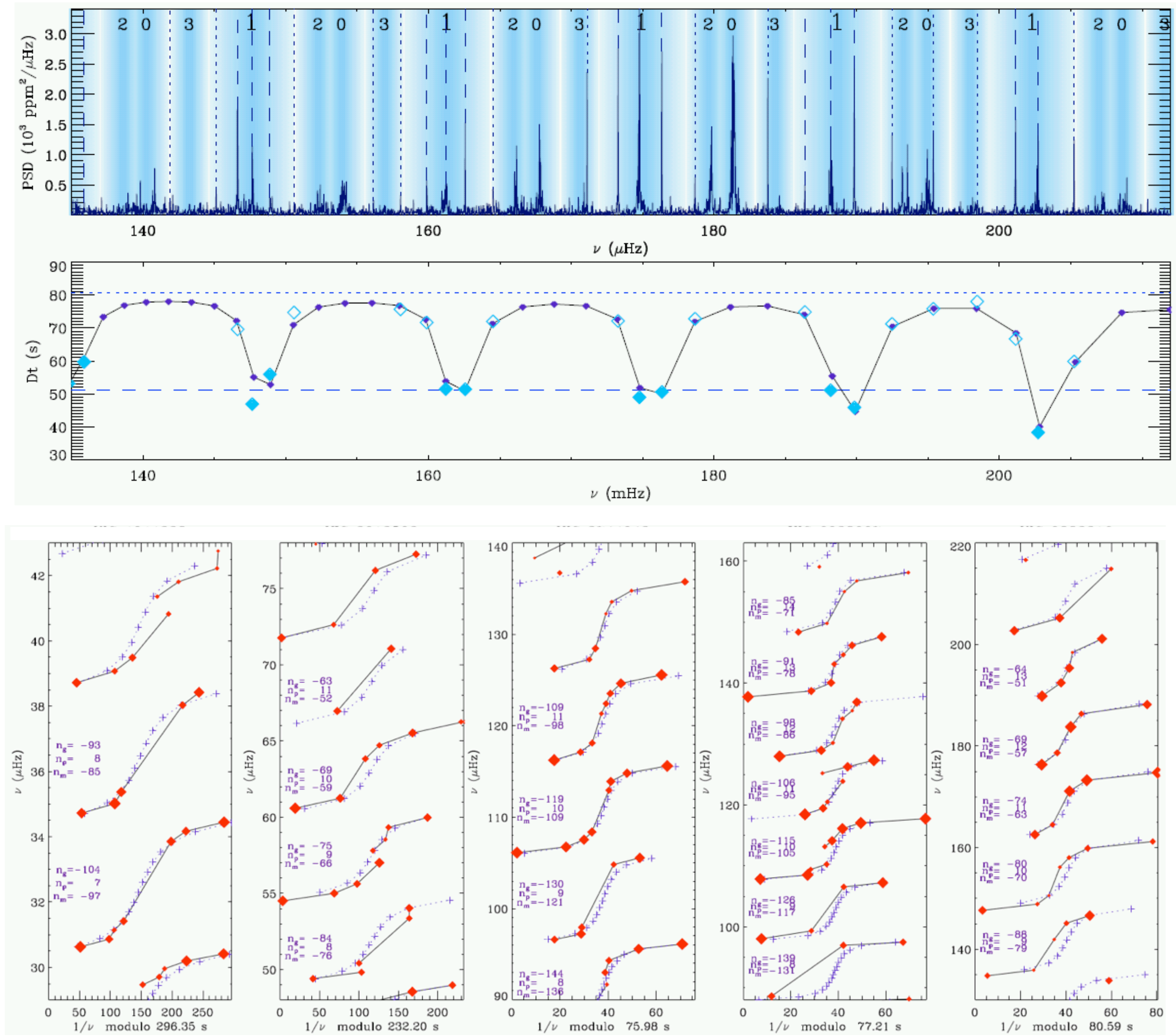



Montalban, Miglio, Noels, Ventura, 2011 in prep

Y=0.28
Z=0.02
No overshooting

in the secondary clump
M(He core) vs $M_{star}$ depends on overshooting during the MS
(Girardi et al. 1999, Castellani et al. 2000)

test of core-mixing during the MS evolutionary phase



Mosser et al. in preparation
Goupil et al. in preparation

# the zoo of red giants: global parameters

$$\Delta\nu = \sqrt{\frac{M/M_\odot}{(R/R_\odot)^3}}\,134.9\mu\text{Hz}$$

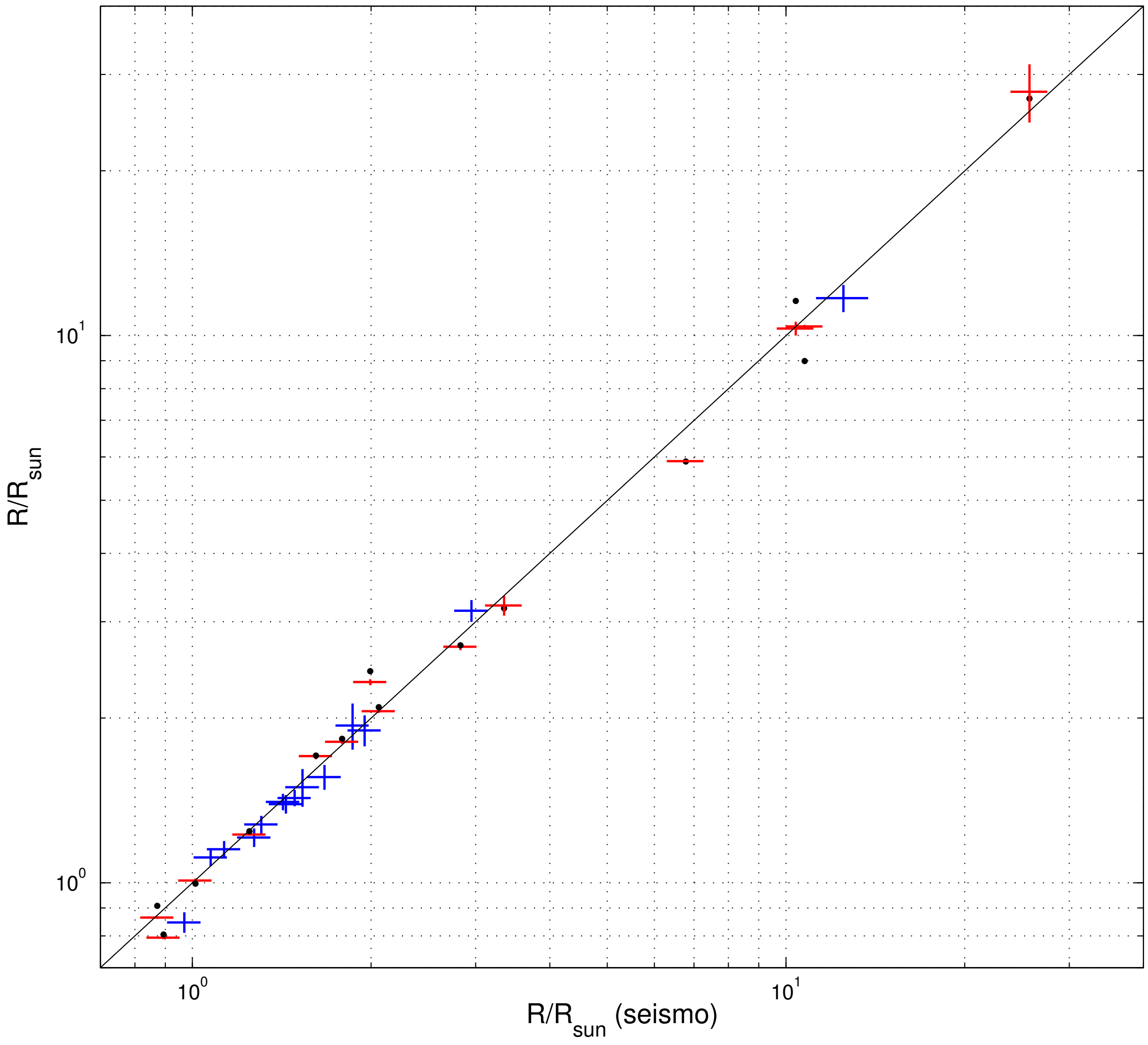
$$\nu_{\text{max}} = \frac{M/M_\odot}{(R/R_\odot)^2\sqrt{T_{\text{eff}}/5777K}}\,3.05\ \text{mHz}$$

## Mass and radius estimate:

$$\left(\frac{R}{\mathrm{R}_\odot}\right) = \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-2}\left(\frac{T_{\text{eff}}}{\mathrm{T}_{\text{eff},\odot}}\right)^{0.5}$$

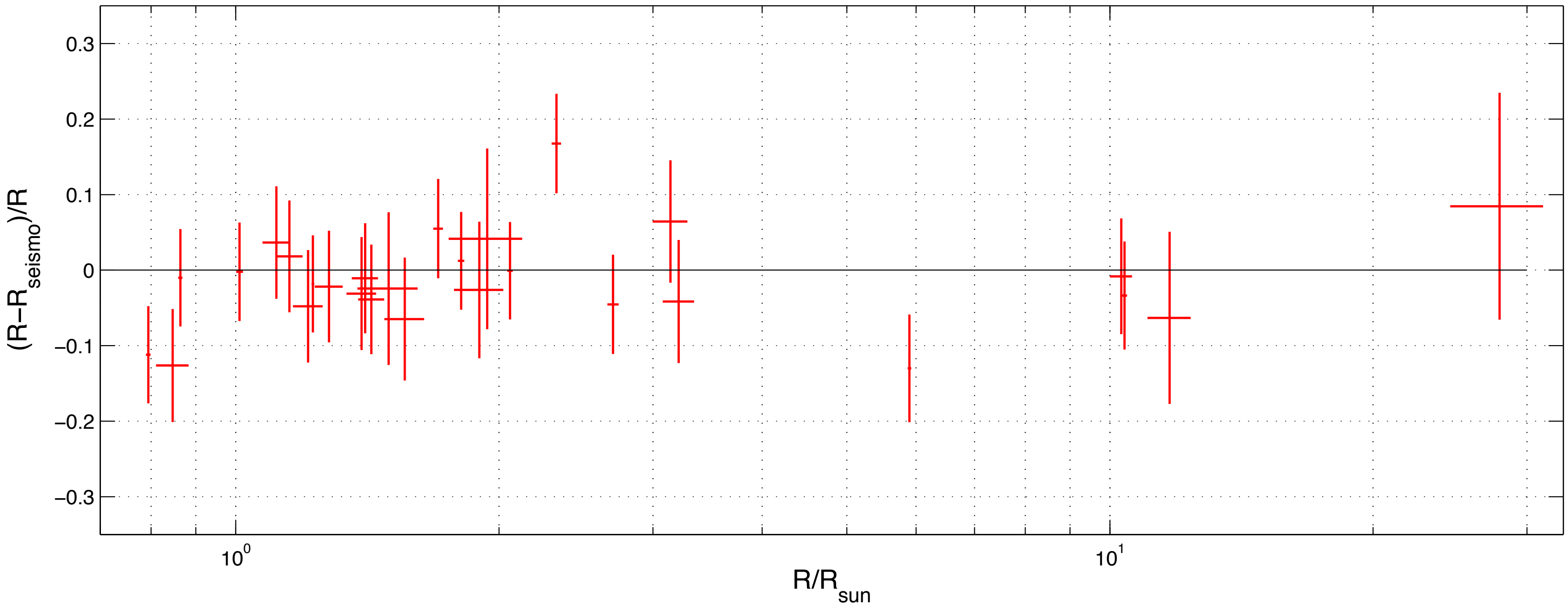
$$\left(\frac{M}{\mathrm{M}_\odot}\right) = \left(\frac{\nu_{\max}}{\nu_{\max,\odot}}\right)^{3}\left(\frac{\Delta\nu}{\Delta\nu_\odot}\right)^{-4}\left(\frac{T_{\text{eff}}}{\mathrm{T}_{\text{eff},\odot}}\right)^{1.5}$$

# Testing scaling relations




Miglio. 2011, ApSS

# Testing scaling relations



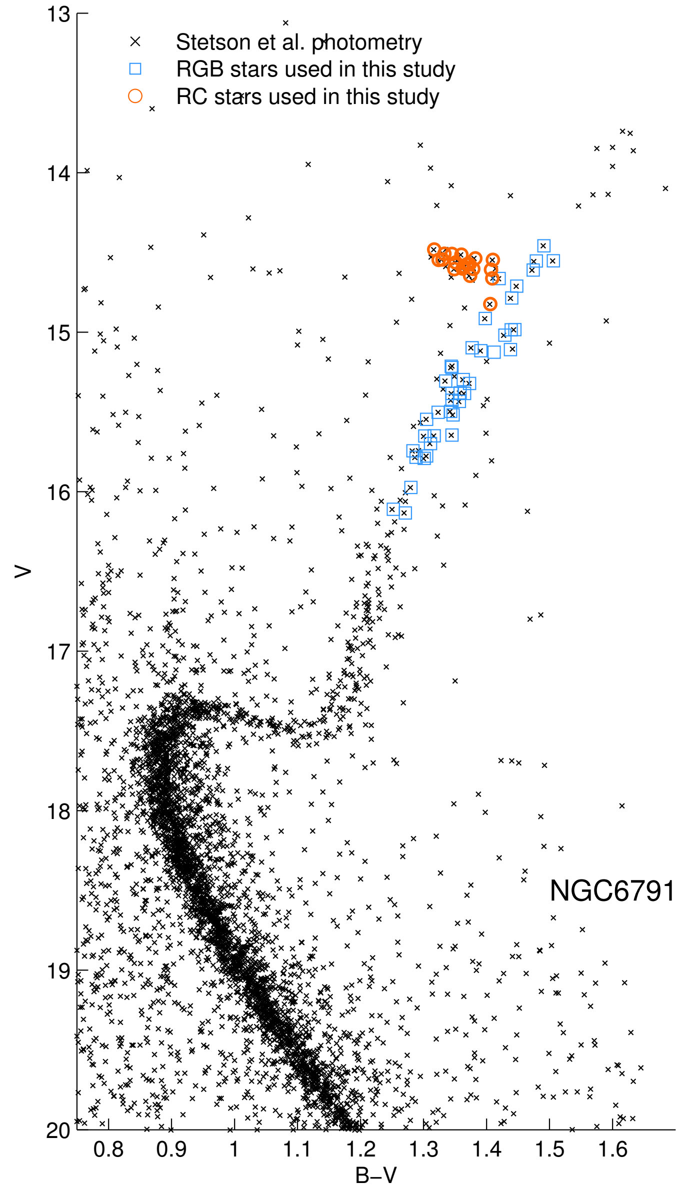

Miglio. 2011, ApSS

# Testing scaling relations

- empirical calibrations: clusters

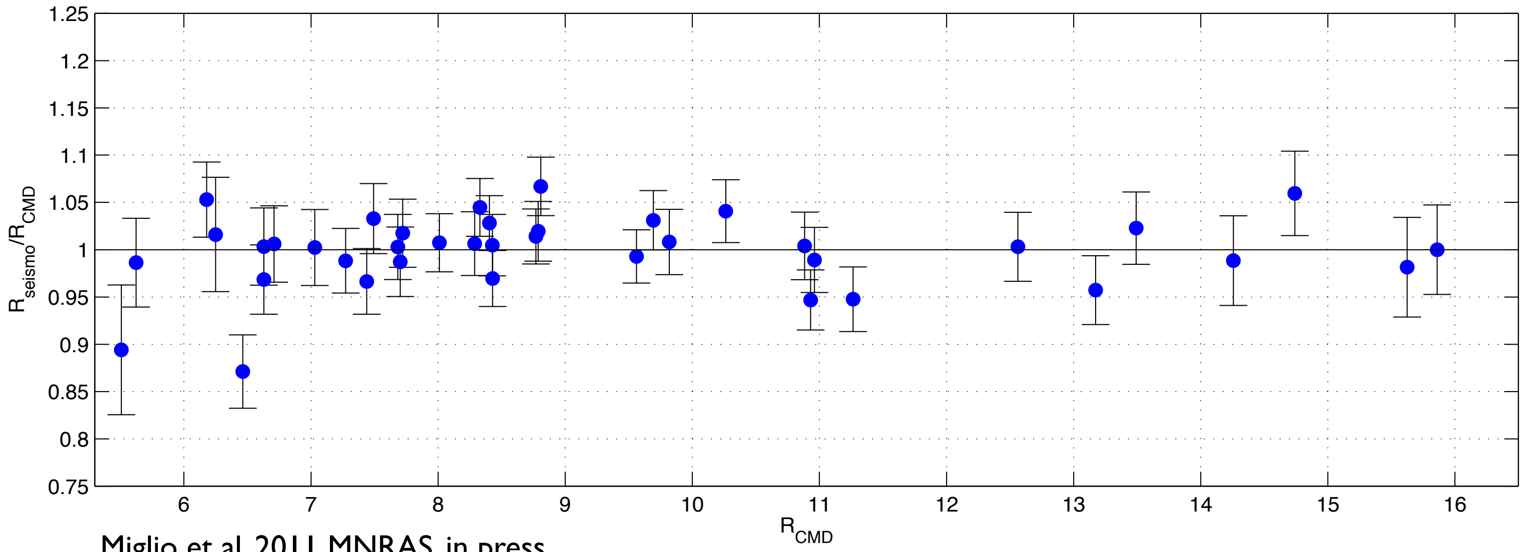
*Kepler* clusters e.g. NGC6791

Basu et al. 2011, Stello et al. 2011




Miglio et al. 2011, MNRAS in press

# Testing scaling relations




Miglio et al. 2011 MNRAS, in press

$R_{CMD}$ using distance modulus from EB: $(m\text{-}M)_V = 13.51 \pm 0.06$

Brogaard et al. 2011

warning: need for 2-3% relative correction on $\Delta\nu$ scaling RGB vs RC stars

# Distances

Radii + $T_{eff}$ → L

+ BC, de-reddened Ks apparent mag

↓

Distances (err ~15%)

# Distances

Radii + $T_{eff}$ ➜ L

+ BC, de-reddened Ks apparent mag

⬇

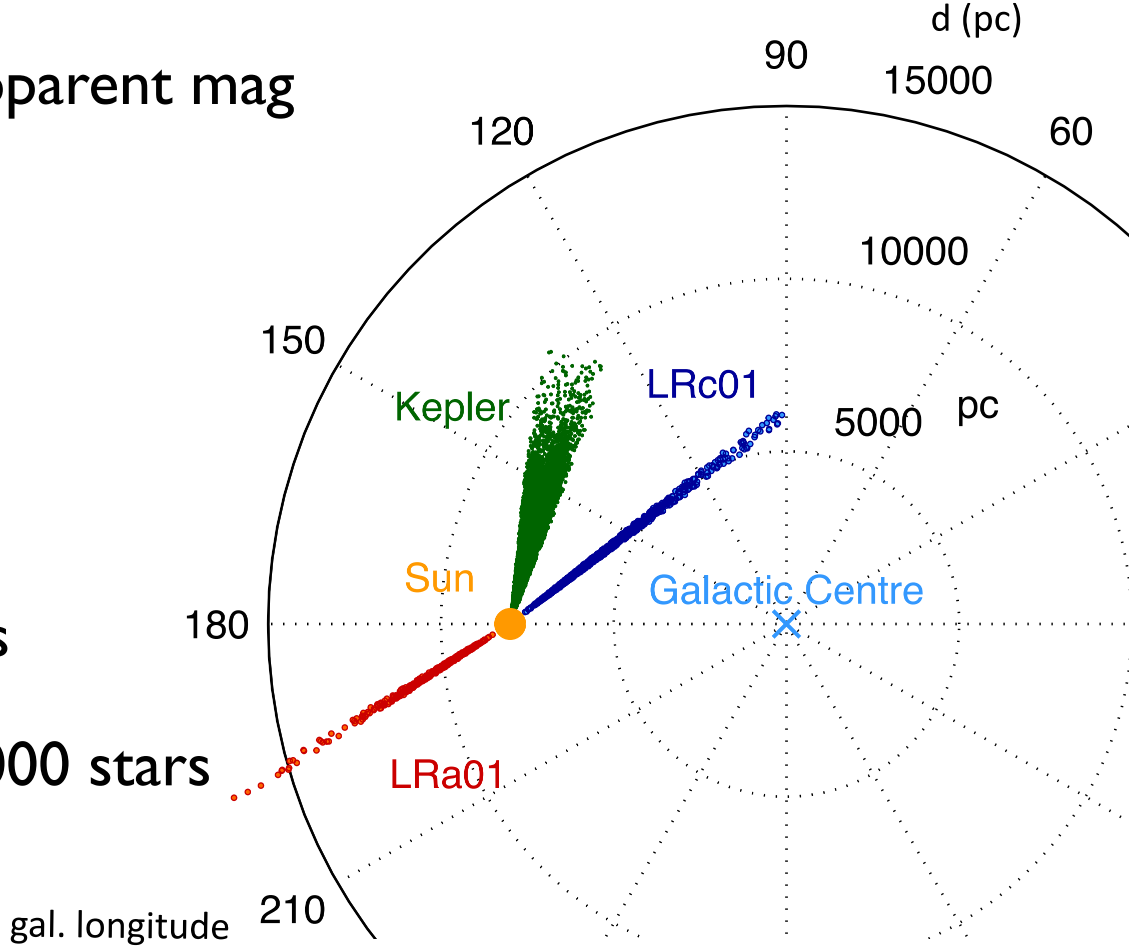
Distances (err ~15%)

LRc01, a01: ~ 2000 stars

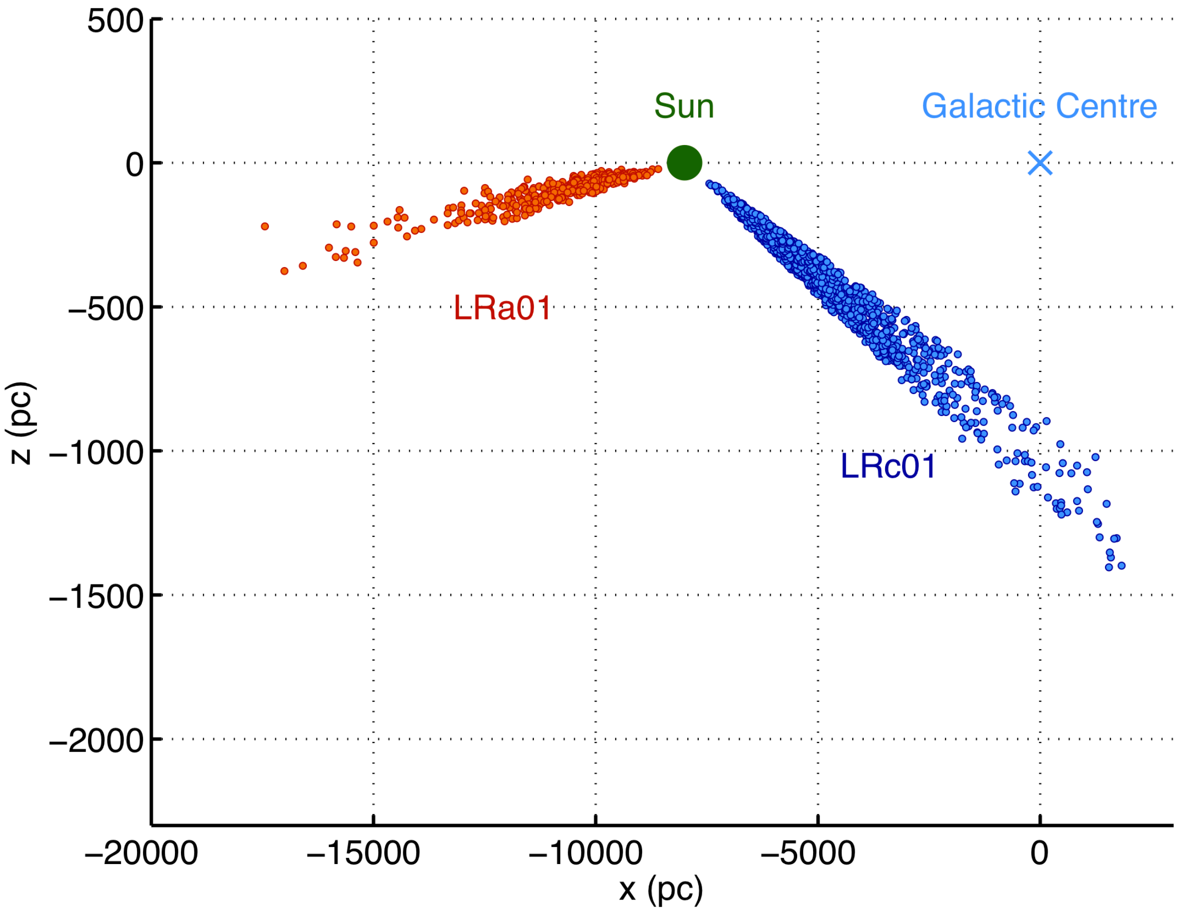
Mosser et al. 2010

*Kepler* public data: ~ 10000 stars

Hekker et al. 2011

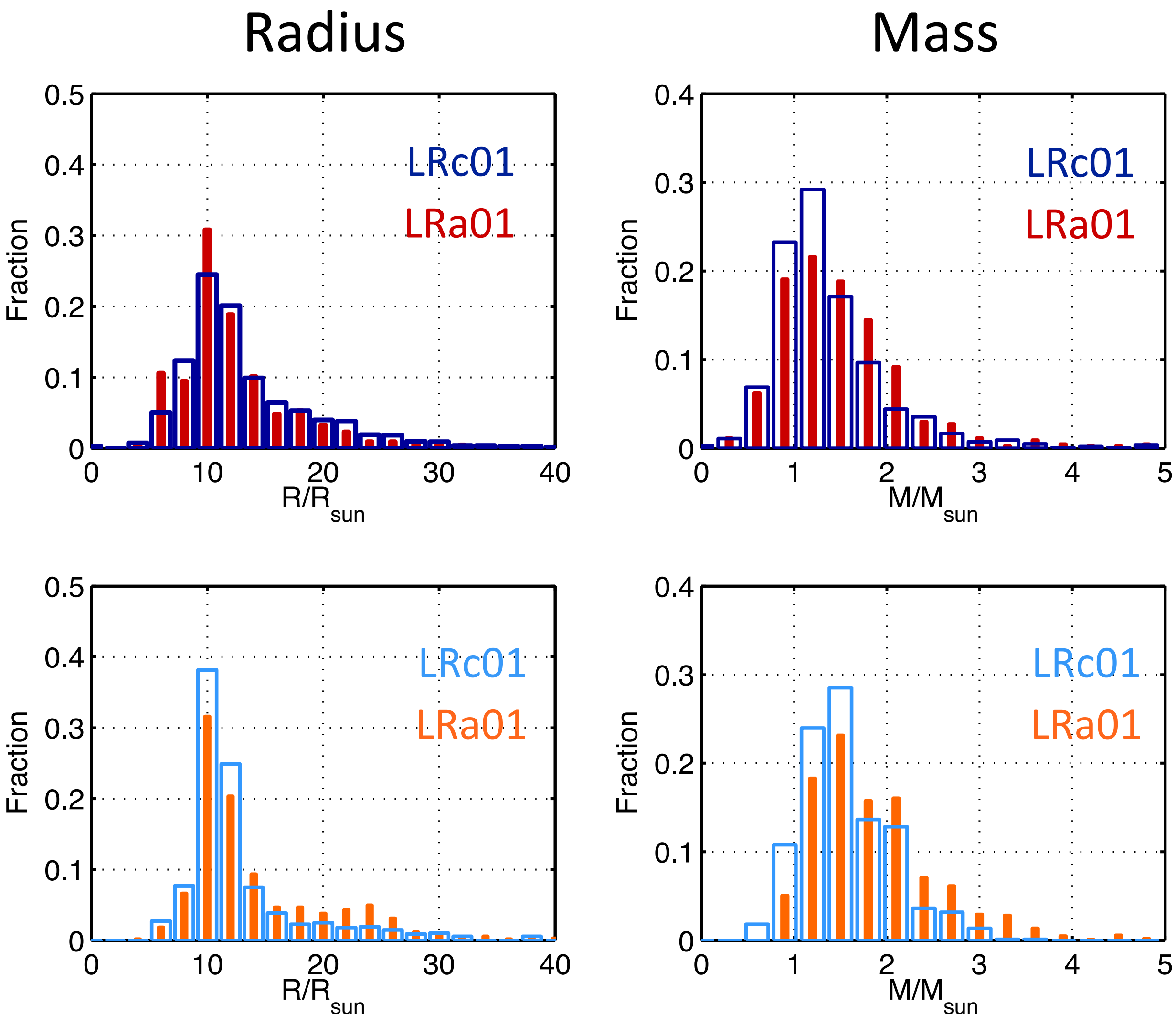


# Distances




Miglio et al. 2011, in preparation

# CoRoT LRa01 vs. LRc01

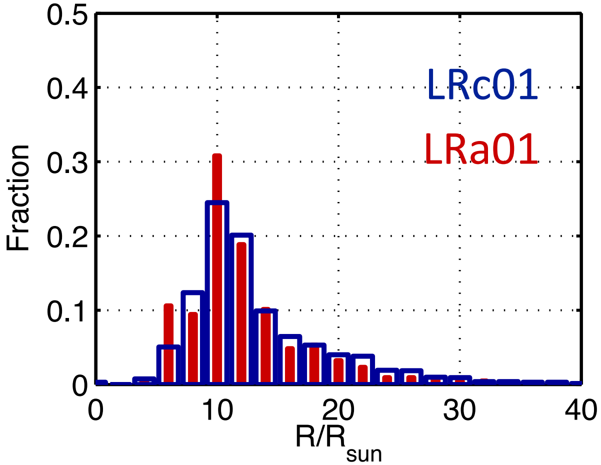



observed

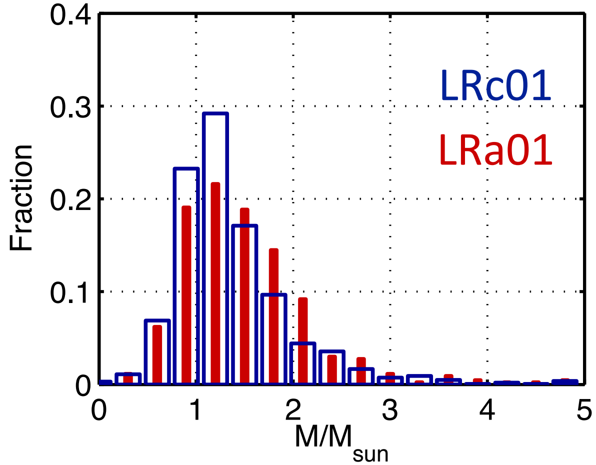
simulated TRILEGAL

# CoRoT LRa01 vs. LRc01

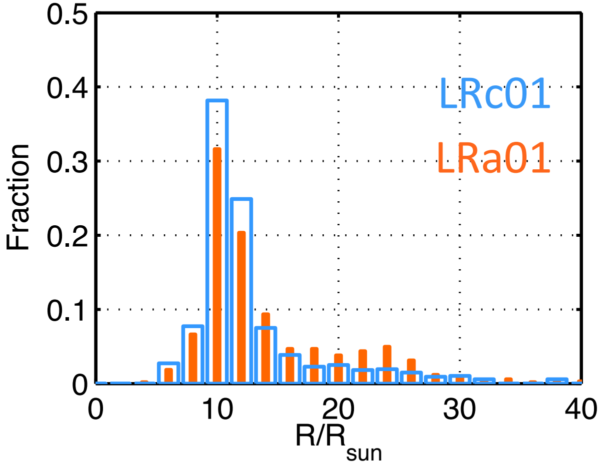
## Radius

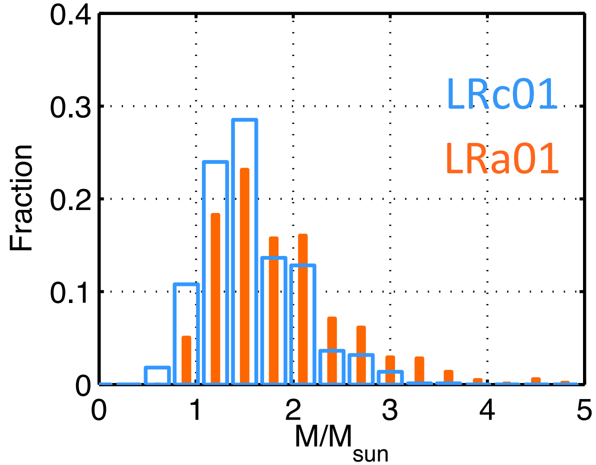



## Mass

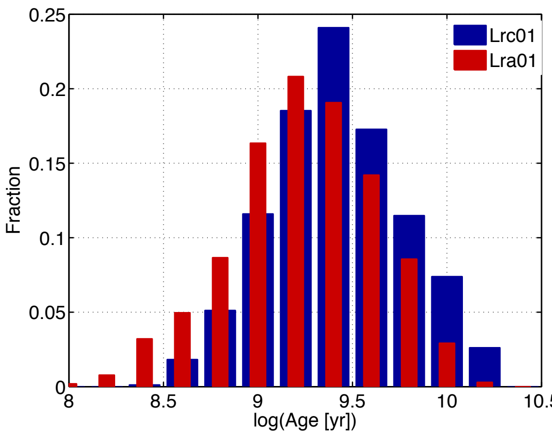



observed

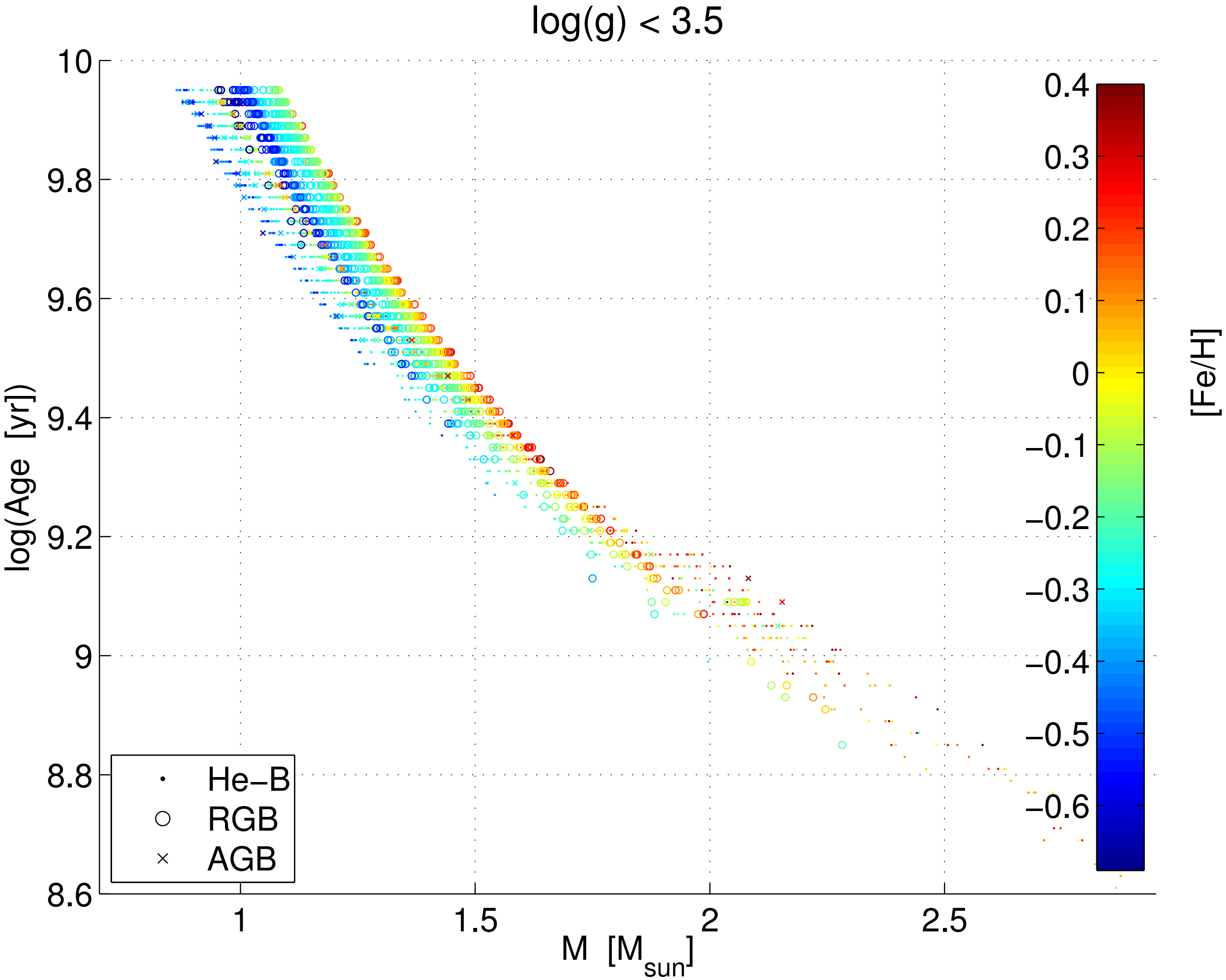



## Age



# from Mass to Age



# from Mass to Age

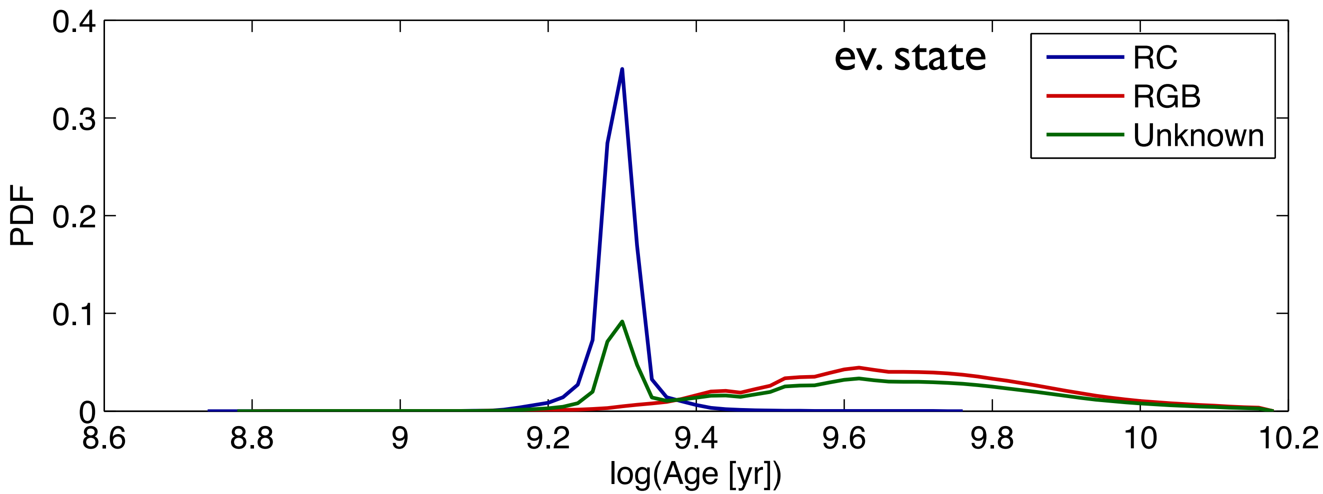
why is it relevant to determine ev. state of a ~10 Rsun giant ?

# from Mass to Age

why is it relevant to determine ev. state of a ~10 Rsun giant ?

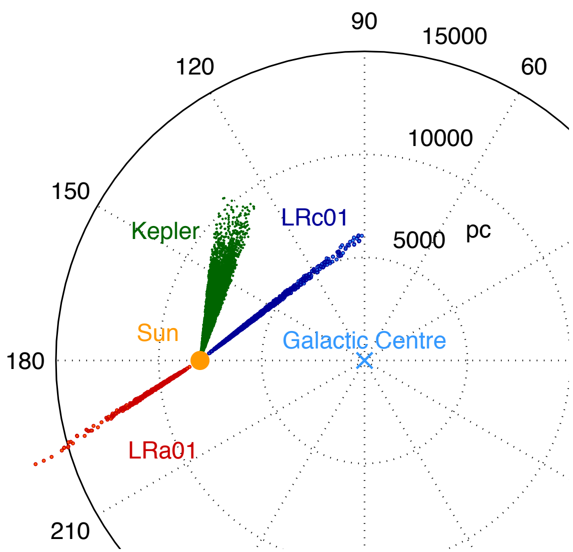
constraints: [Fe/H], Teff, $\Delta\nu$, $\nu_{\mathrm{max}}$, ev. state from $\Delta P$

age estimates using PARAM (as in Da Silva et al. 2006, Nordstrom et al. 2004)



# asteroseismic diagnostics in red giants

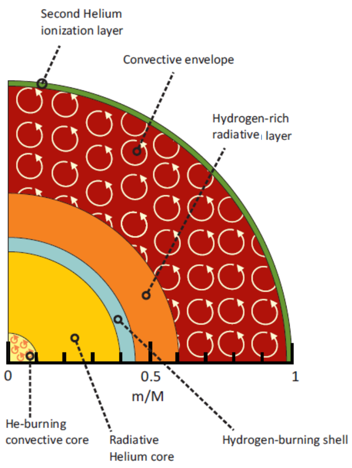
global parameters
M, R, ev. state (age)




local features in stellar interior

e.g.

- signature of He ionisation
- info on detailed properties of the g-mode cavity



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- G. Verner, London
- KASC WG 2, 8