To Ba or not to Ba:
Observational constraints to the evolution of barium stars

Ana Escorza - ImBaSE 2017

+ H. Van Winckel, L. Siess, A. Jorissen, H. Boffin, S. Van Eck ...

Barium stars

Barium (Ba) stars

G- and K-type giants which present overabundances of s-process elements (e.g., Ba) on their surface. → They could not have synthesised them

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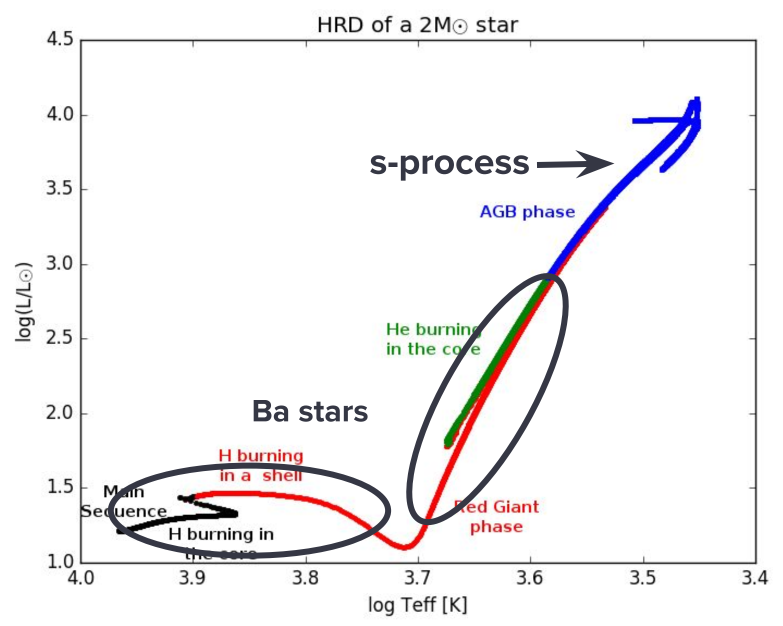
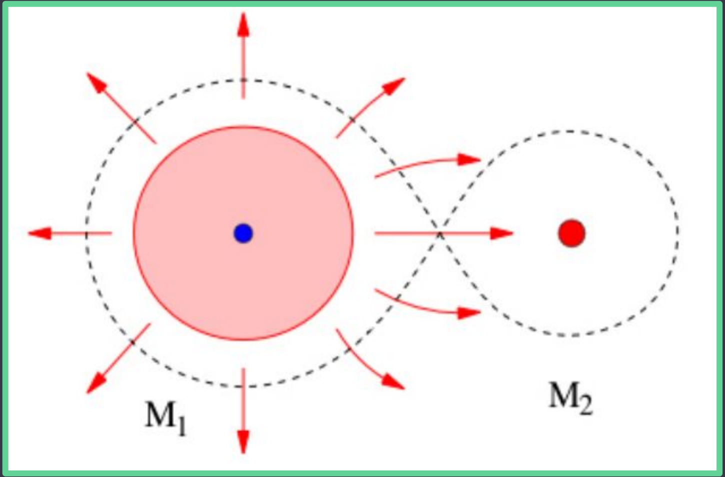
The slow-neutron-capture (s-) process of nucleosynthesis takes place in the AGB phase.



Barium (Ba) stars

Formed through binary interaction in a low- or intermediate-mass binary.

The less evolved secondary gets polluted with AGB products via wind and/or RLOF.



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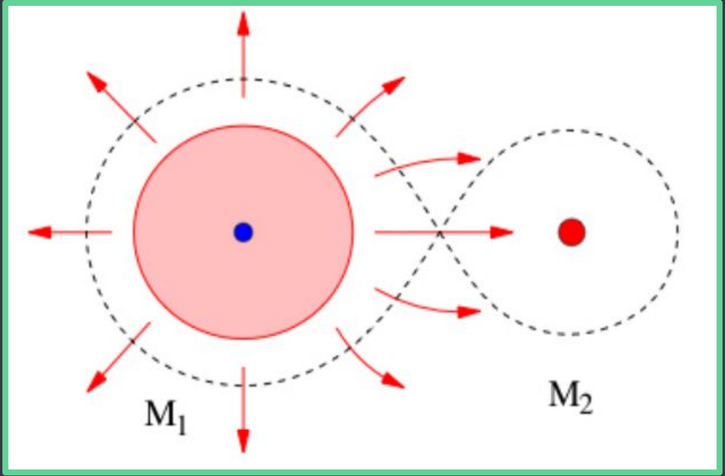

Remaining uncertainties:

- ★ Initial conditions
- ★ Mass-transfer scenario
- ★ Evolutionary links
- ★ …

Talks by H.M.J.Boffin, O.Pols

Goal of our research

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Observational vs. theoretical
HR and e-logP diagrams

Improving models & increase our understanding of evolution and interaction in low- and intermediate-mass binaries.

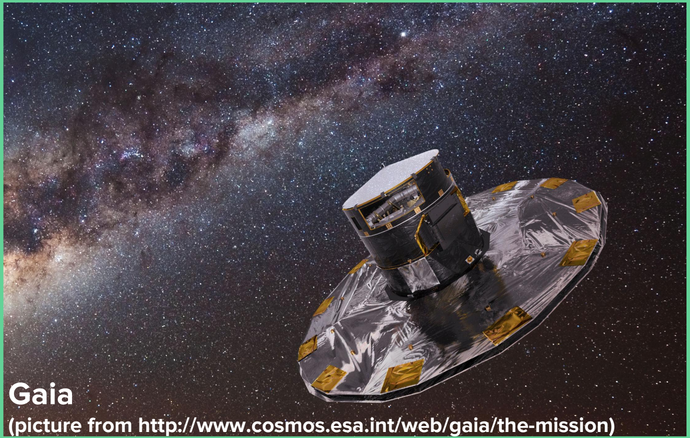
Why barium stars?

- Known to be formed by binary interaction with a former AGB companion
- We can use both observed orbital parameters and chemical abundances to put constraints on the models.

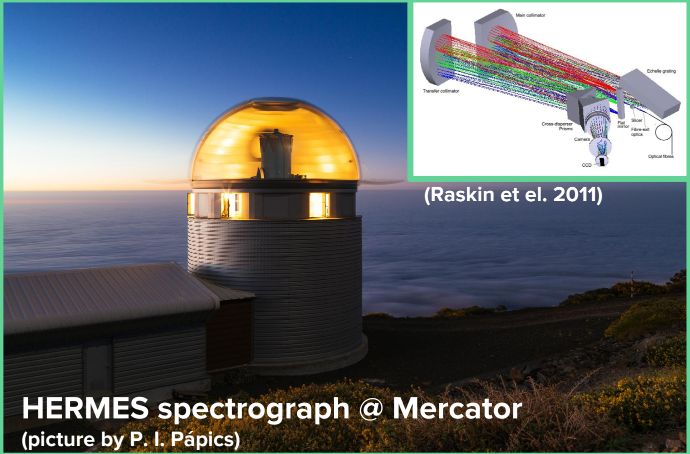
Goal of our research

Observational vs. theoretical
HR and e-logP diagrams

Improving models & increase our understanding of evolution and interaction in low- and intermediate-mass binaries.



Gaia
(picture from http://www.cosmos.esa.int/web/gaia/the-mission)

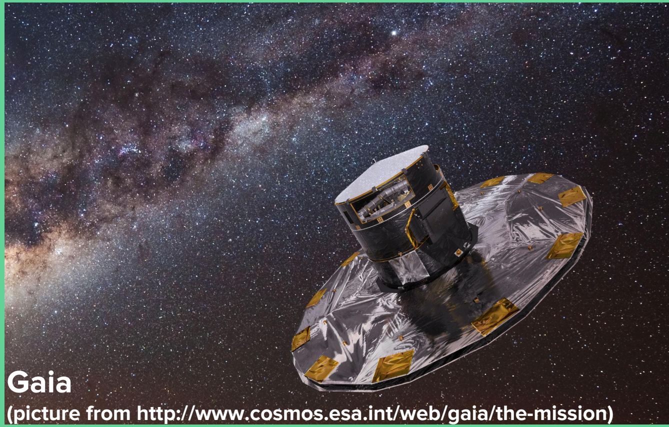


(Raskin et el. 2011)

HERMES spectrograph @ Mercator
(picture by P. I. Pápics)

The TGAS HR diagram of Ba stars

Escorza et al., in prep



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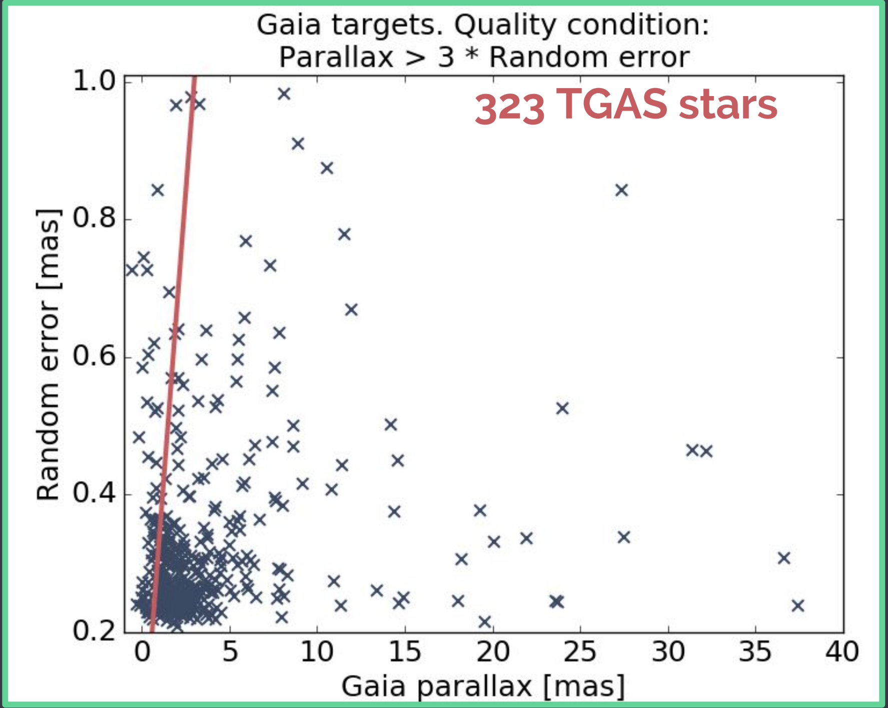
Sample selection



Ba and related star samples from

- Lu et al. (1983 & 1991)
- Bartkevicius (1983)
- North et al. (2000)

Part of the Tycho2 catalogue.

Part of TGAS (Tycho-Gaia Astrometric Solution)

Error(parallax) < ⅓ parallax.

DR1, Gaia Collaboration et al. (2016a)
TGAS, Lindegren et al. (2016)

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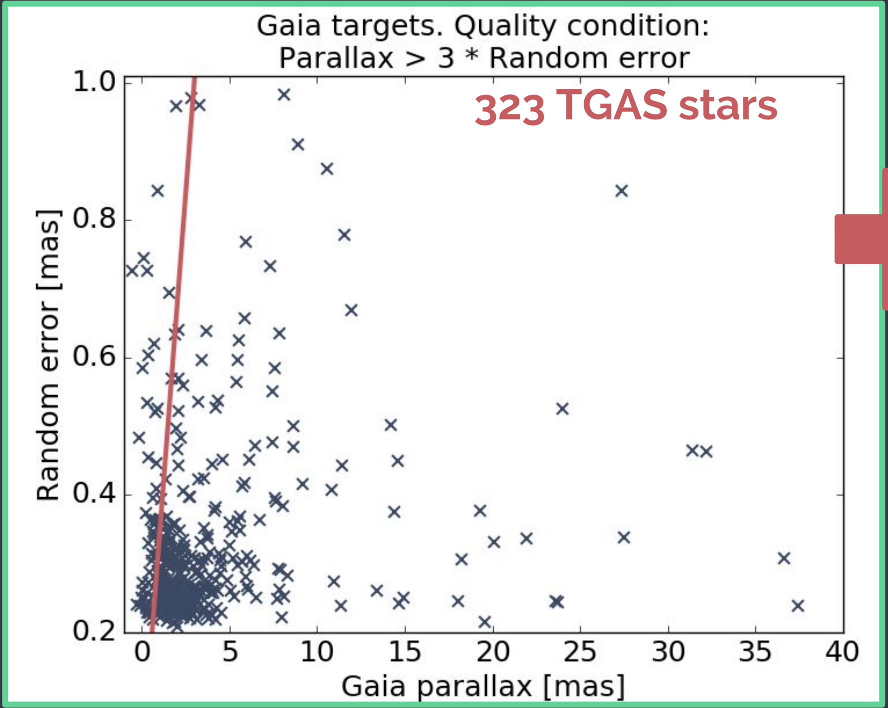
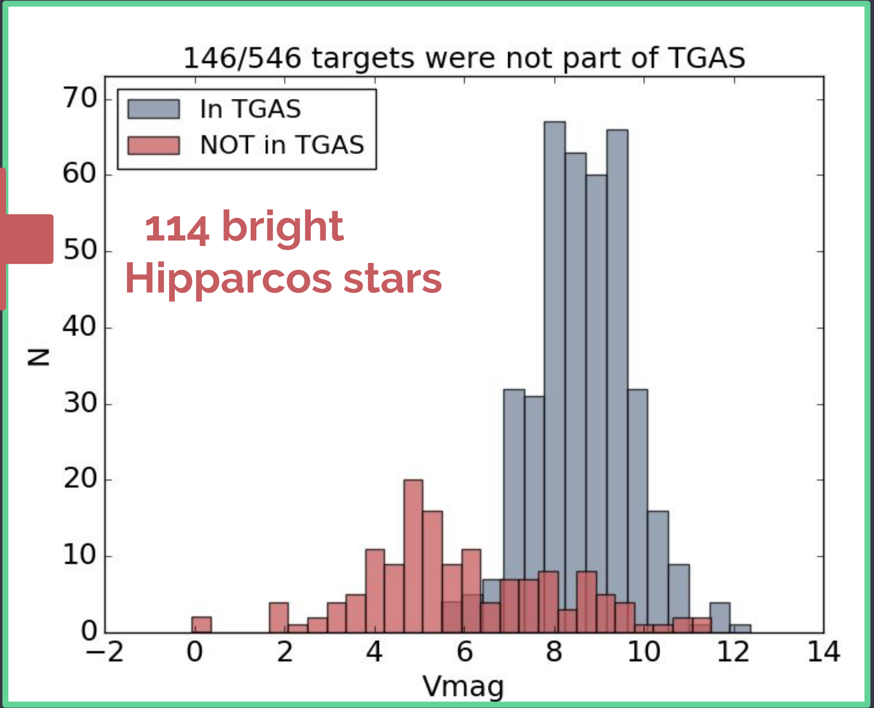




DR1, Gaia Collaboration et al. (2016a)
TGAS, Lindegren et al. (2016)

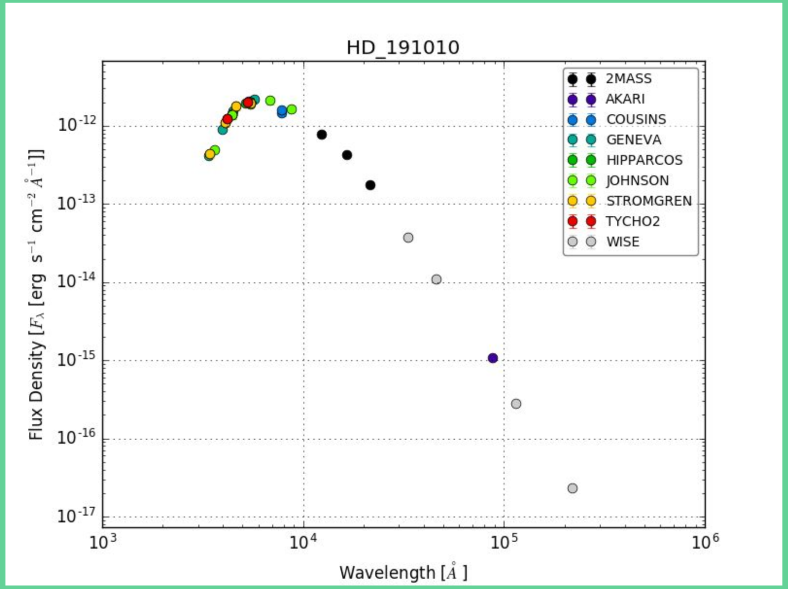
Hipparcos, ESA (1997)

Determination of Teff and L

Spectral energy distribution (SED) fitting

We retrieve available photometry from SIMBAD → $\chi 2$ minimization over a grid of MARCS model atmospheres

Gustafsson et al. (2008)



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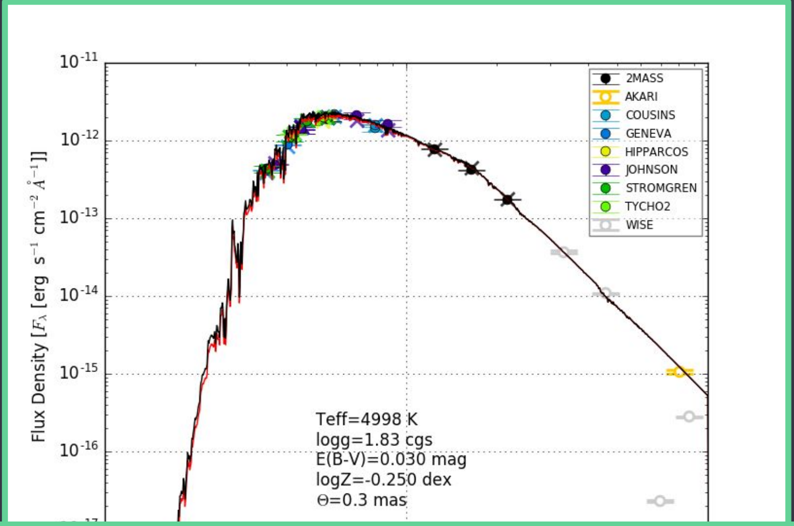
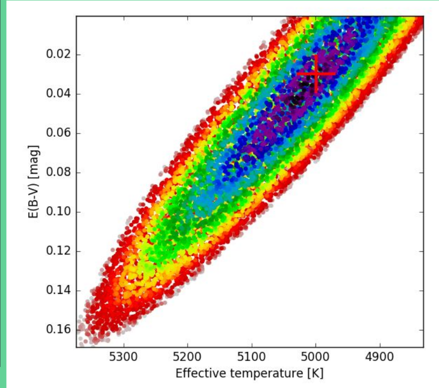
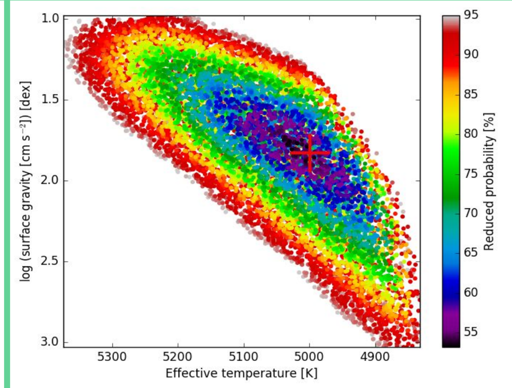


Teff, logg, metallicity and E(B-V)





Fitting tool by P. Degroote

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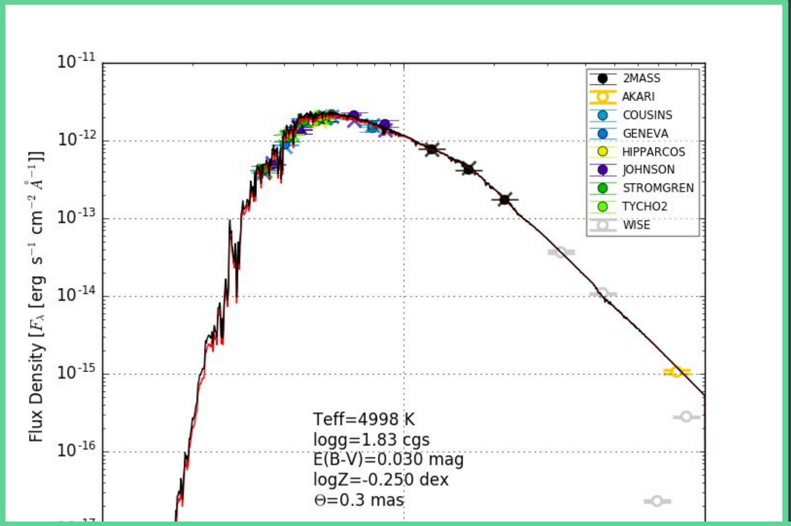
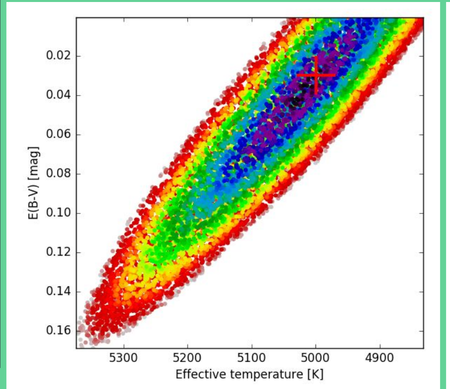
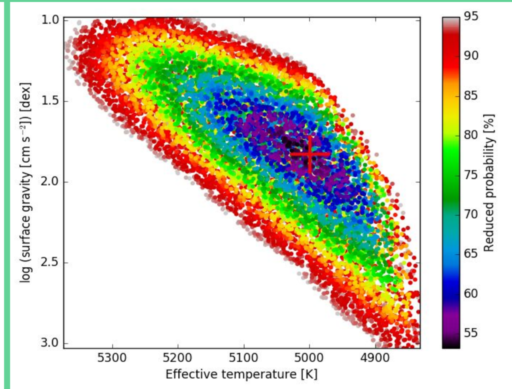


Too many free parameters:
Teff, logg, metallicity and E(B-V)

Fixed [Fe/H] = -0.25, where the distribution of known metallicities for Ba stars peaks

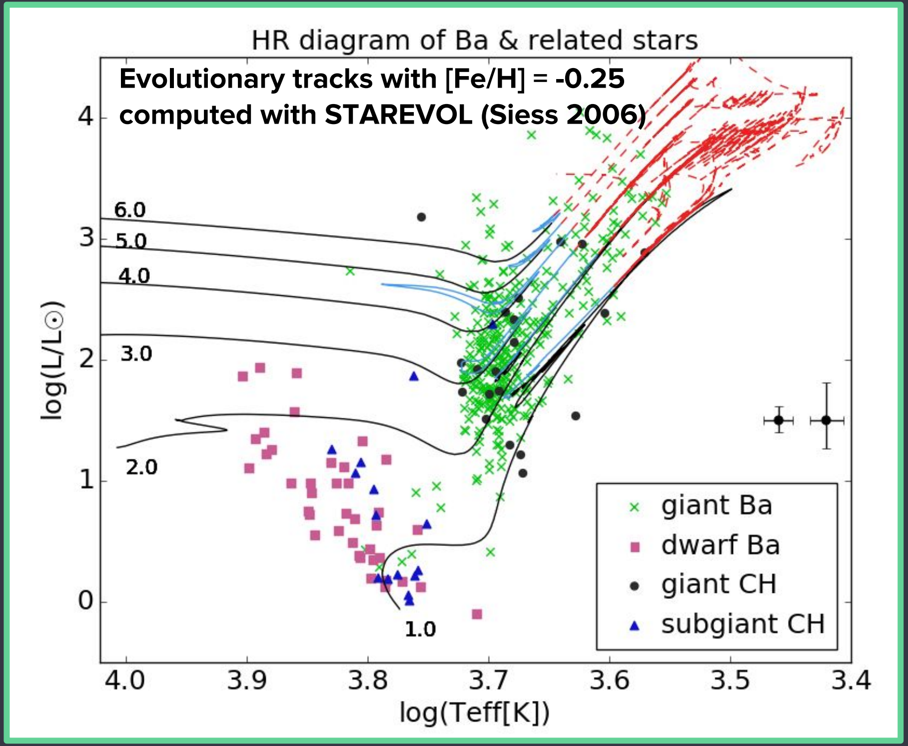
Galactic 3D extinction maps from Gontcharov et al. (2012)





Fitting tool by P. Degroote

HR diagram of Ba stars



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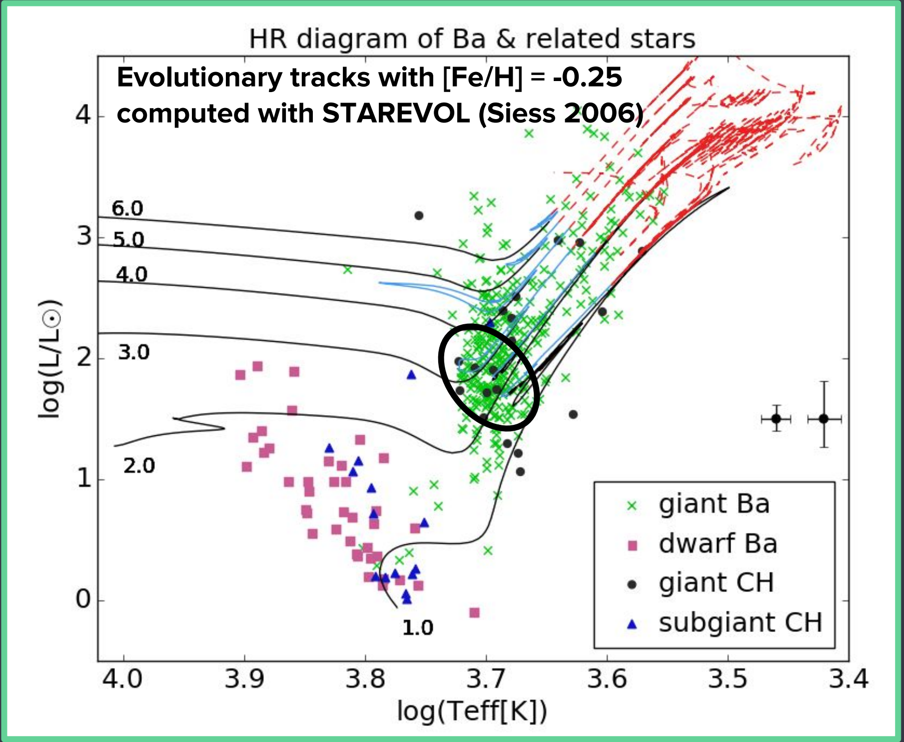


- sgCH stars occupy the same region on the HRD that dBa stars.
- Some targets appear at high masses.
- Strong concentration of Ba stars in the red clump.

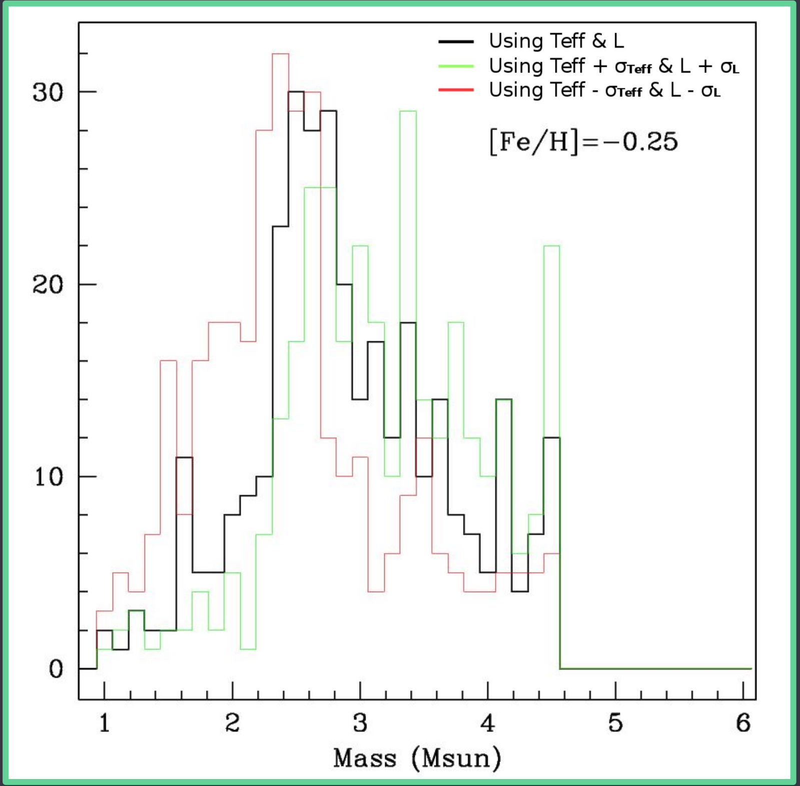
What can we learn from this?

Mass distribution of Ba stars

Mass estimated by interpolating in the theoretical tracks.

Grid with 17×10^6 points characterised by a value of T, L and $M_{T,L}$

We take into account the time that a star spends at a given location of the HRD.



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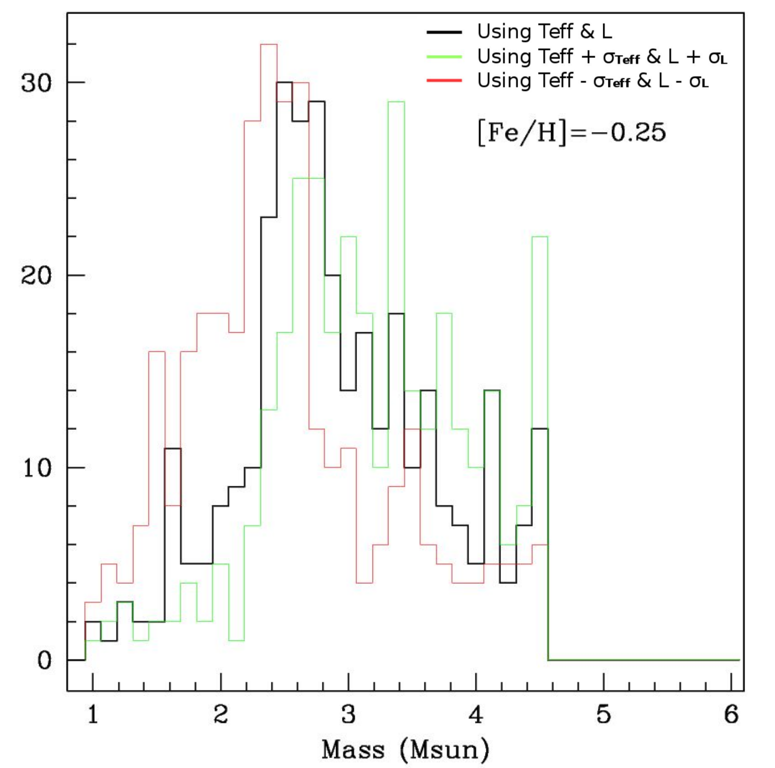
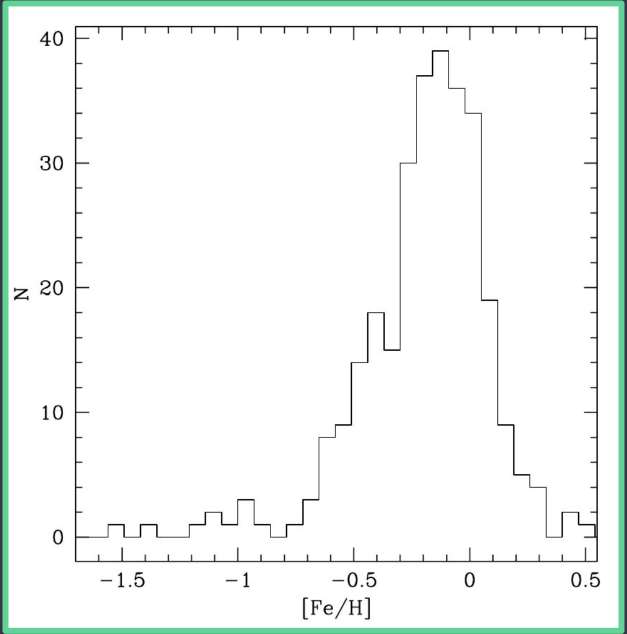
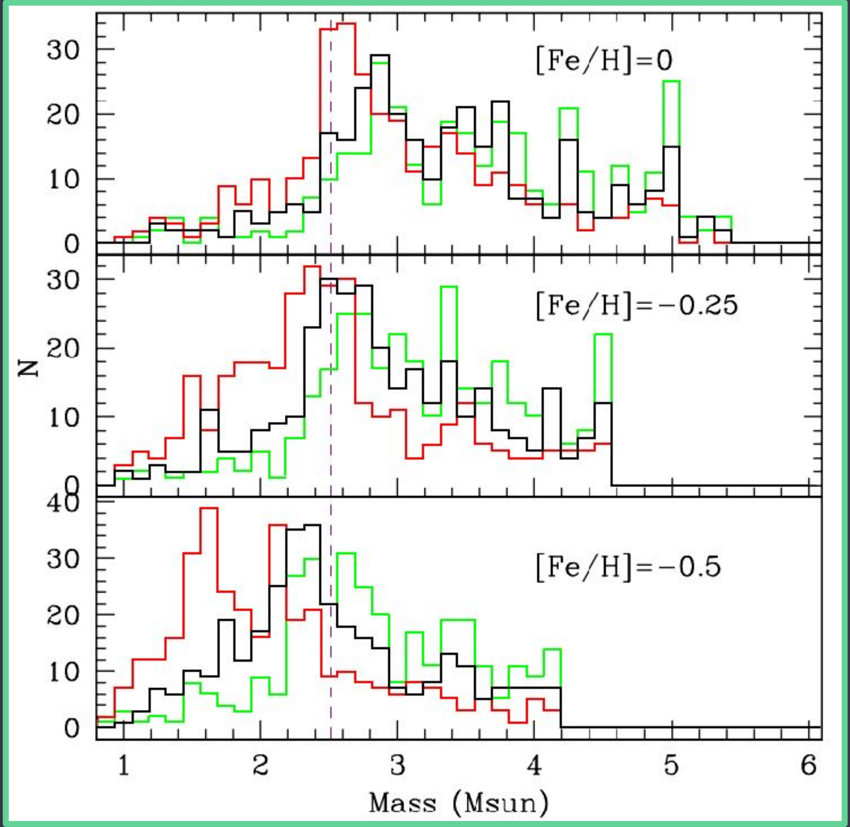
Uncertainties in Teff and L have a strong effect



Mass distribution of Ba stars: metallicity

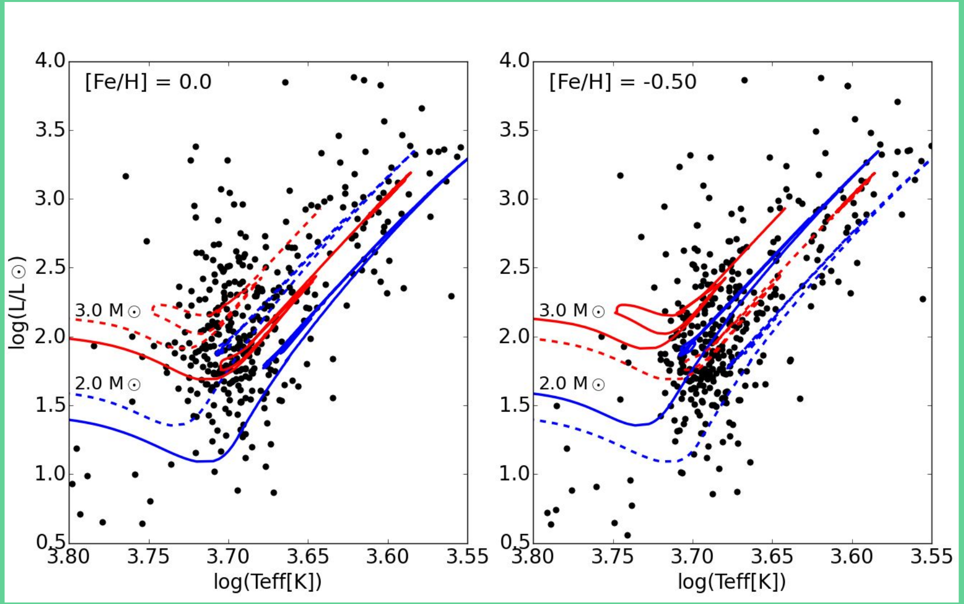
Distribution of metallicities if Ba stars found in the literature

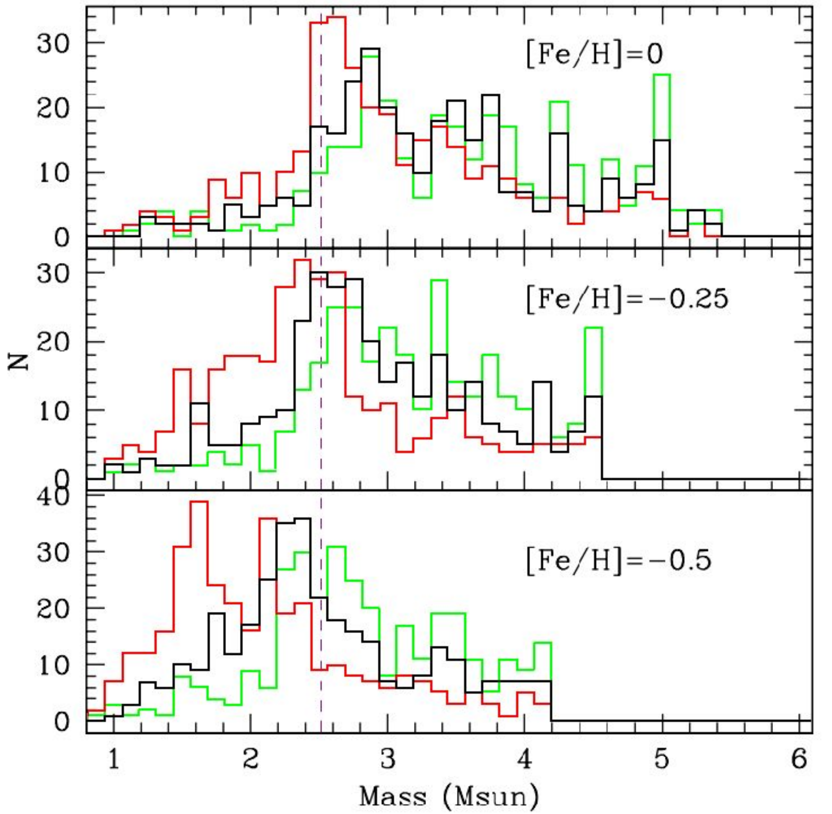




Mass distribution of Ba stars: metallicity

Mass-metallicity degeneracy





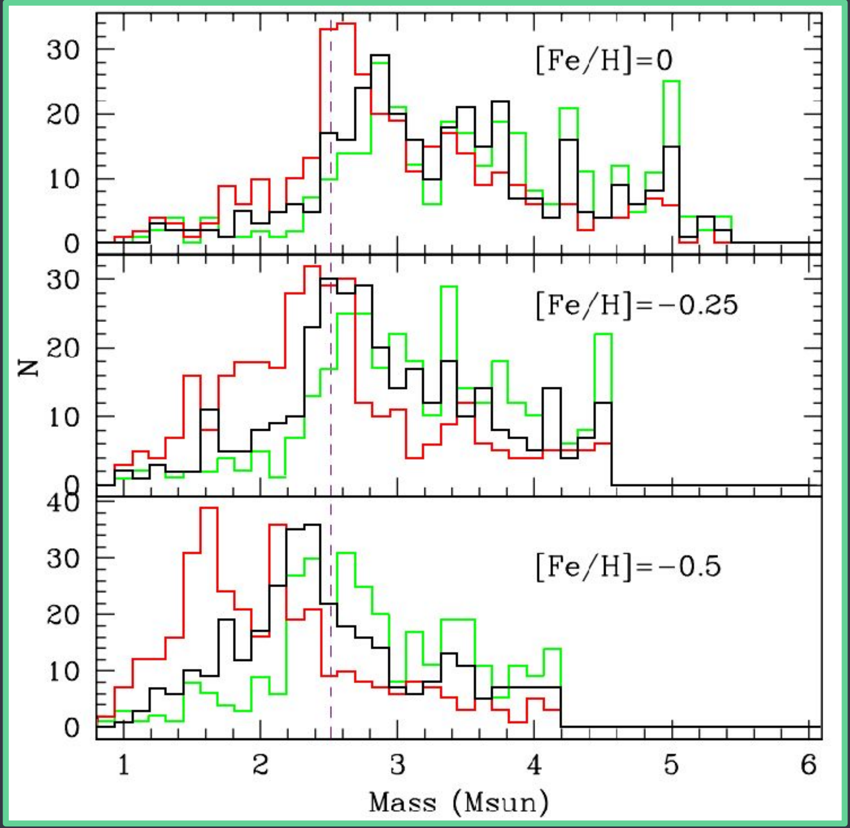
Mass distribution of Ba stars: metallicity

The effect of metallicity is also very important

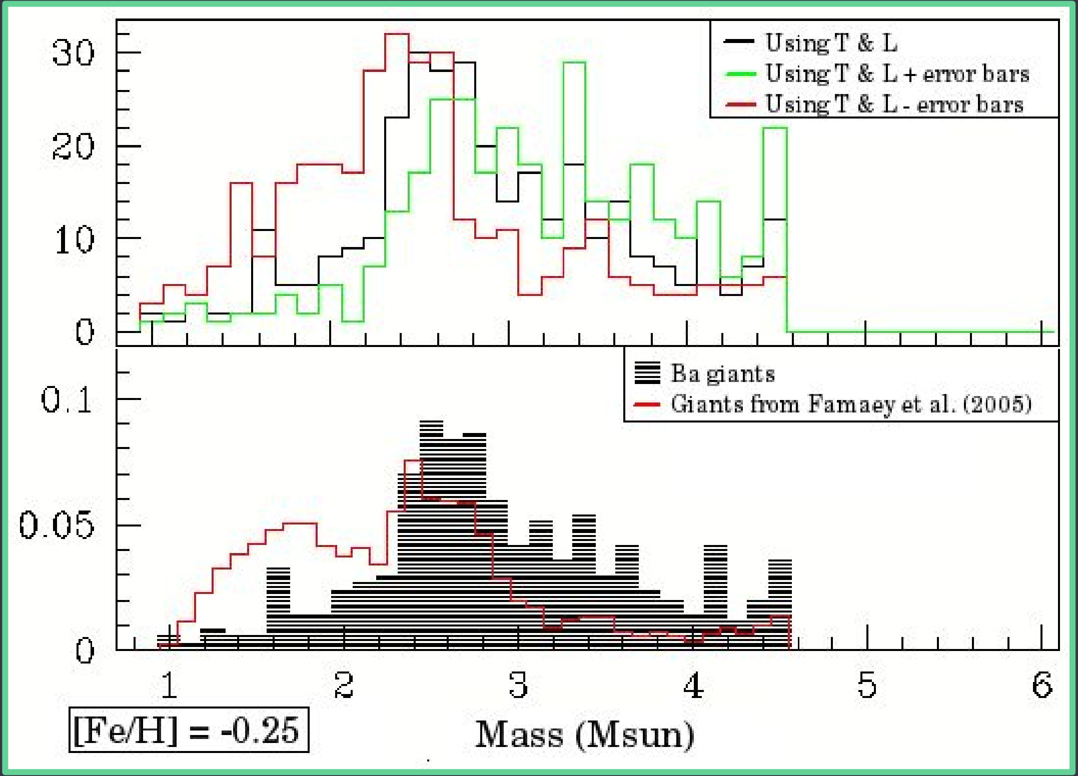
Spectroscopically determined metallicities are a requirement to get information about individual masses.

Data for 330 stars of the sample is available in the literature (+ we have HERMES !)

Talk by D.Karinkuzhi



Mass distribution of Ba stars: normal giants?



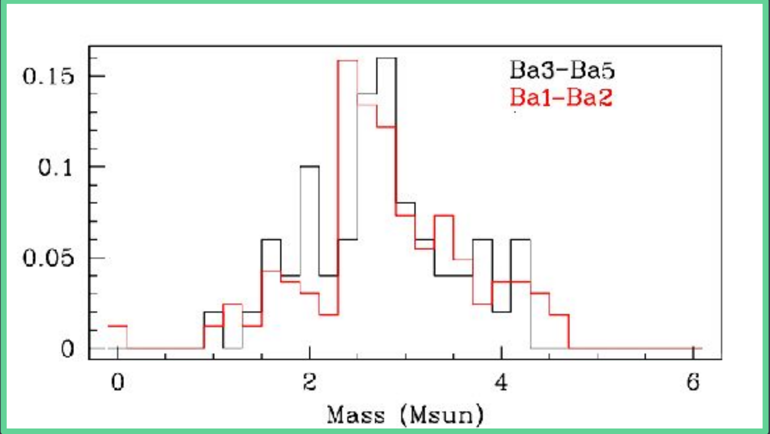
- Both distributions peak at similar values.
  Accumulation in the clump does not seem to be specific to Ba stars.
- Deficit of low mass Ba stars.
  Probably early shrinkage of the orbit.
- Excess of high mass Ba stars.
  Pollution of the sample.

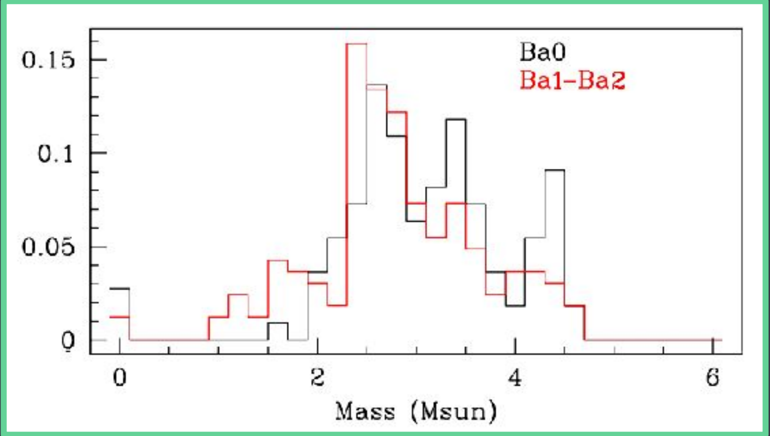
Mass distribution of Ba stars: Populations

Barium index (Warner, 1965) reflects the strength of the Ba lines, based on visual inspection, on a scale from Ba1 to Ba5.

No significant difference between mild (Ba1 - Ba2) and strong (Ba3 - Ba5) barium stars.

Lü (1991) introduced some stars with **"Ba < 1"**, which happen to populate the high mass tail.





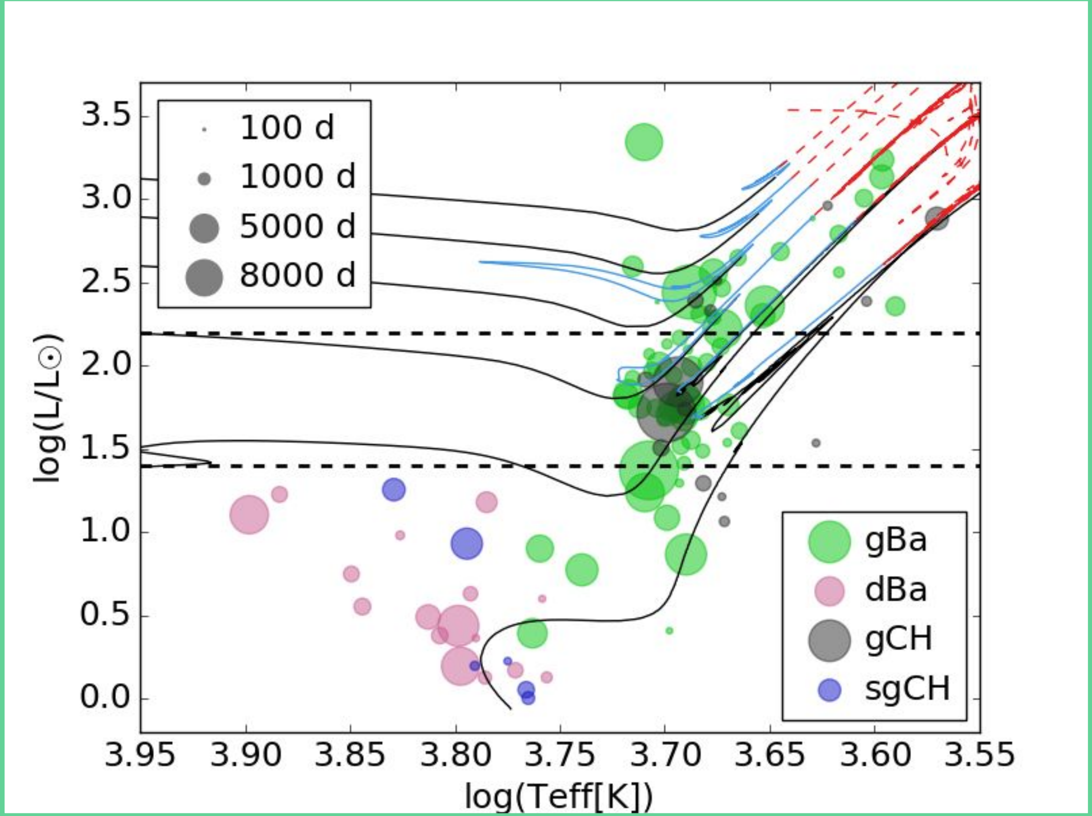
Location in the HRD and orbital period

HRD and orbital period

Orbital elements from Jorissen et al. (1998), Jorissen et al. (2016) and Escorza et al. (2017; in prep.)

Two subsamples:

- Pre-RGB: log L/L⊙ ≤ 1.4
- Red clump: 1.4 < log L/L⊙ ≤ 2.2



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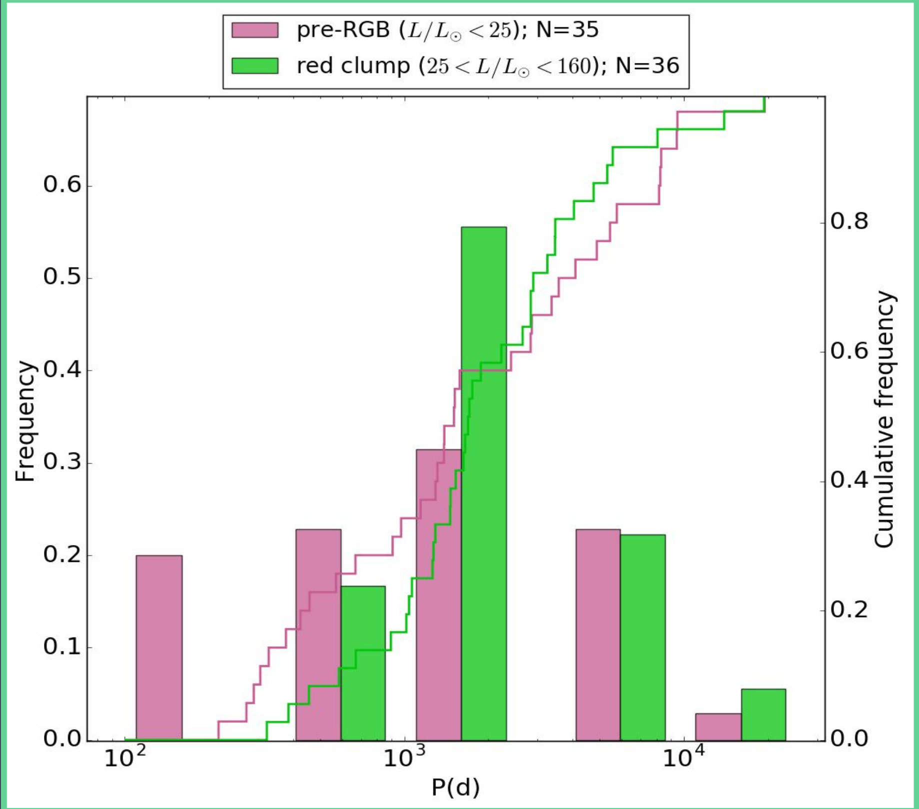

Tendency for larger periods in the red clump, as compared to systems lying below.

Conclusions

Conclusions

HR diagram for barium stars → **Mass distribution.**

- The effects of the **uncertainties** and of the metallicity prevent us from getting information about individual objects. Don't forget the uncertainties in evolutionary models!

- Ba giants seem to evolve as **normal red giants**.

- Subgiant CH and dwarf Ba stars occupy the **same region of the HRD**.

- Strong and mild barium stars have **similar mass distributions**.

- **Correlation** between the location in the HRD and the **orbital period** of Ba stars. Tendency for larger periods in the core He burning phase.

Thank you for your attention

KU LEUVEN
ULB UNIVERSITÉ LIBRE DE BRUXELLES