GES Open Clusters as benchmarks for stellar evolutionary models

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Stellar models are good

- Predictions reliable, widely used, thoroughly tested, different chemistries implemented...
- Models of stellar interiors are widely used in different fields. Their predictive ability is used to derive properties up to extragalactic distances.
  - 1D models: simplified approched using free parameters that must be tuned using observations
    - rotation (magnetic braking, rotational mixing) still a new frontier
    - diffusion
    - mass loss
  - 3D hydrodynamical models are the state-of.the-art, but are still a challenge
    - (Viallet et al 2011, Freytag et al 1996, Bigot et al 2006)

Stellar models can be improved

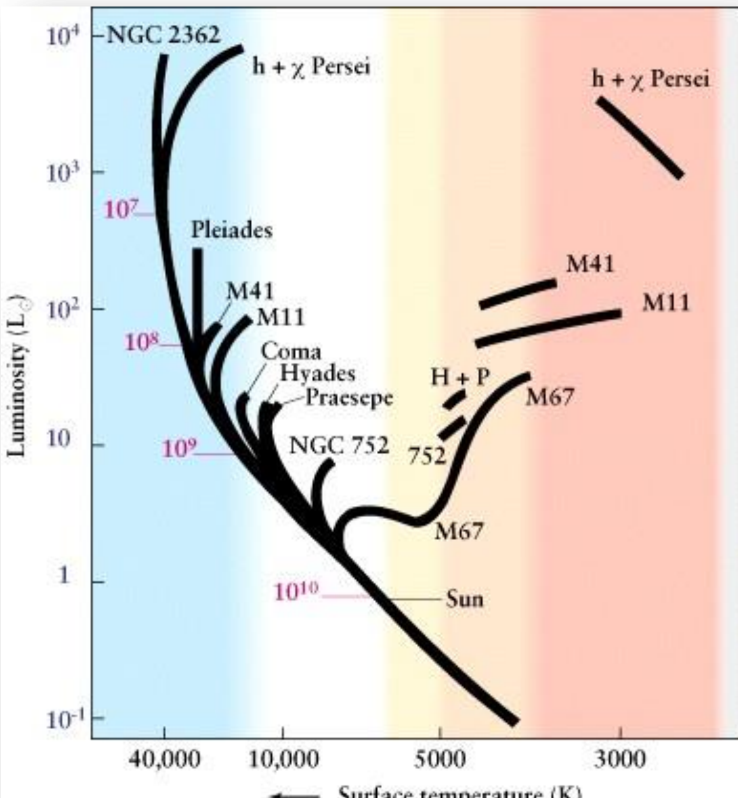
- Regions in the HR diagram difficult to model, prediction still not sufficiently accurate
- Under developement/recent changes:
  - Equation of State (critical for M<0.7 Mo)
  - nuclear reaction rates updates
    - LUNA collaboration (Bemmerer+ 06) fixes a lower $^{14}N(p, \gamma)^{15}O$ rate (bottle-neck of the CNO cycle), which has strong impact on critical phases of stellar evolution (Pietrinferni+10).
- Open issues:
  - Mixing (semiconvection,overshooting,diffusion,extra-mixing)
    - Mixing length parameter calibrated on solar model
    - Overshooting calibrated on few clusters
  - Mass loss
  - Color transformations via bolometric corrections (SEDs from ATLAS9, Phoenix...)
  - Definition of Zsun

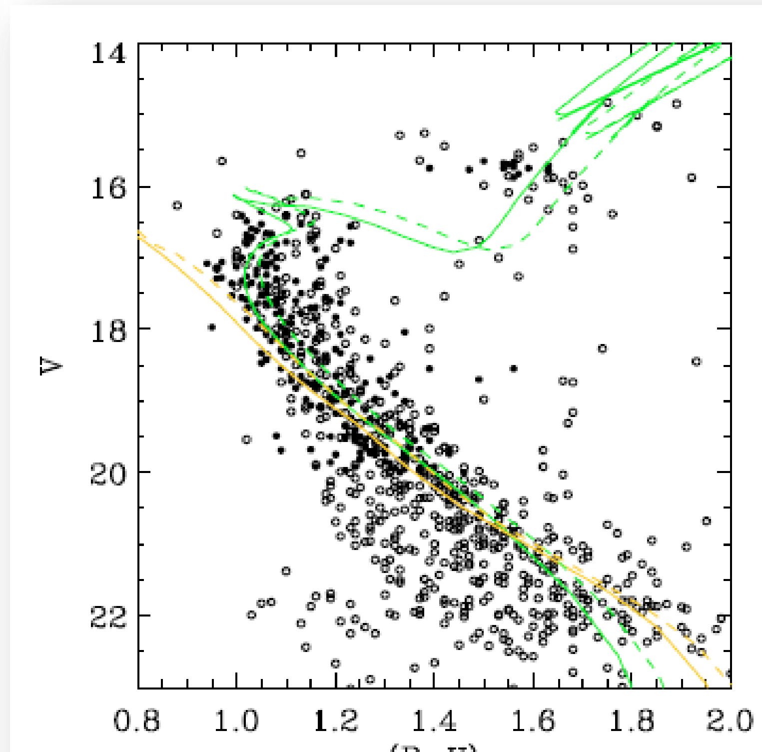
OC & stellar evolution

Gaia

Simple stellar population, easy to model... sure!
But reality is soo much interesting!

- foreground contamination, (differential) reddening, binaries, rotation, selection criteria, photometric errors, color calibrations.



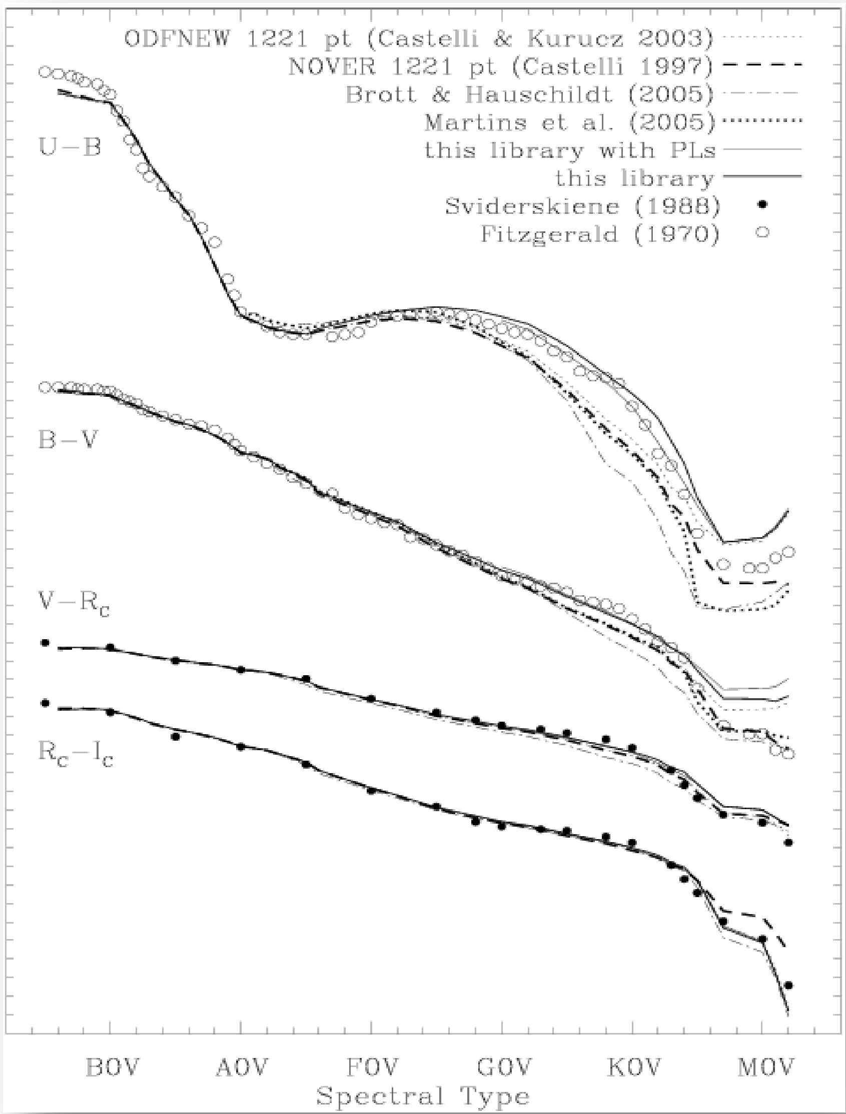


NGC7044 (Monteiro+ 2010)

OC & stellar evolution (II)

- OCs have 100-1000 stars
  - not well populated in the advanced stages (AGB)
  - Globulars have a better statistics
- But
  - Large range of ages, from very young (few tens Myr to several Gyr)
  - Different metallicities available (disk chemistry)
  - old OCs show: RC, sub-giant branch, RGB, upper MS.
  - Young ones have pre-MS stars (allows to test models in an homogeneous framework)
- Allow to:
  - calibrate models as function of metallicity AND age
  - Test EOS, opacities, convection throughout the whole cluster
  - Test the mass-loss
  - Availability of photometric CMD and (spectroscopic) Teff-logg-Fe/H diagrams allows much needed tests on color calibration.

Observed colors from spectra



This depend on how well a synthetic SED reproduce a real SED in the optical bands

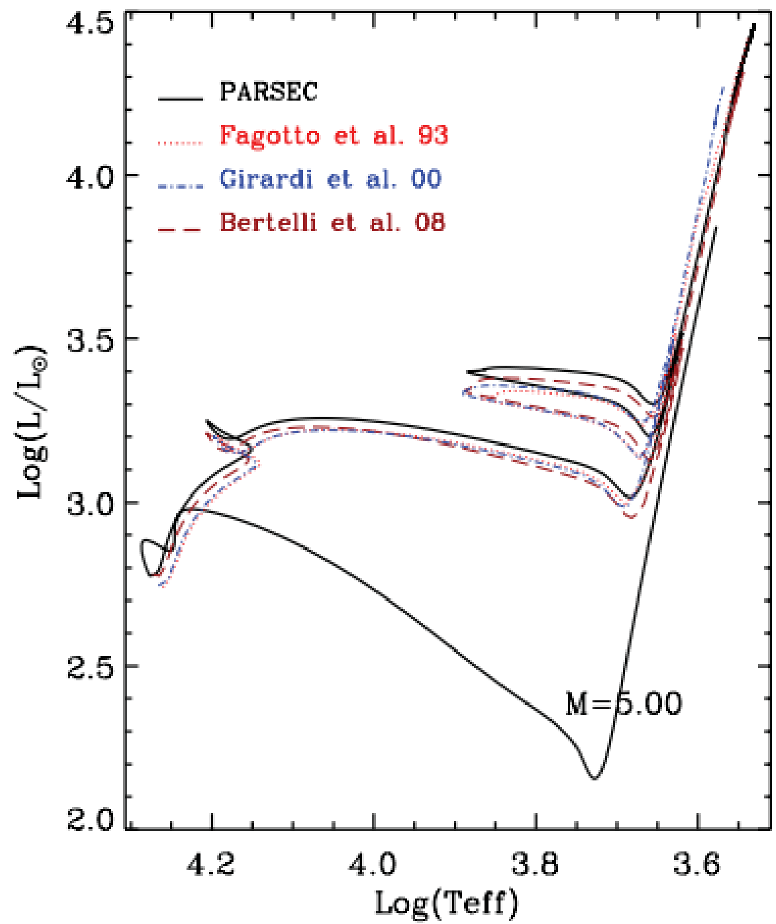
Bolometric corrections do depend on the way a synthetic SED reproduce a real SED on a very large wavelength range, including the difficult «blue» part.

Munari,Sordo+ 05

Comparison among tracks families

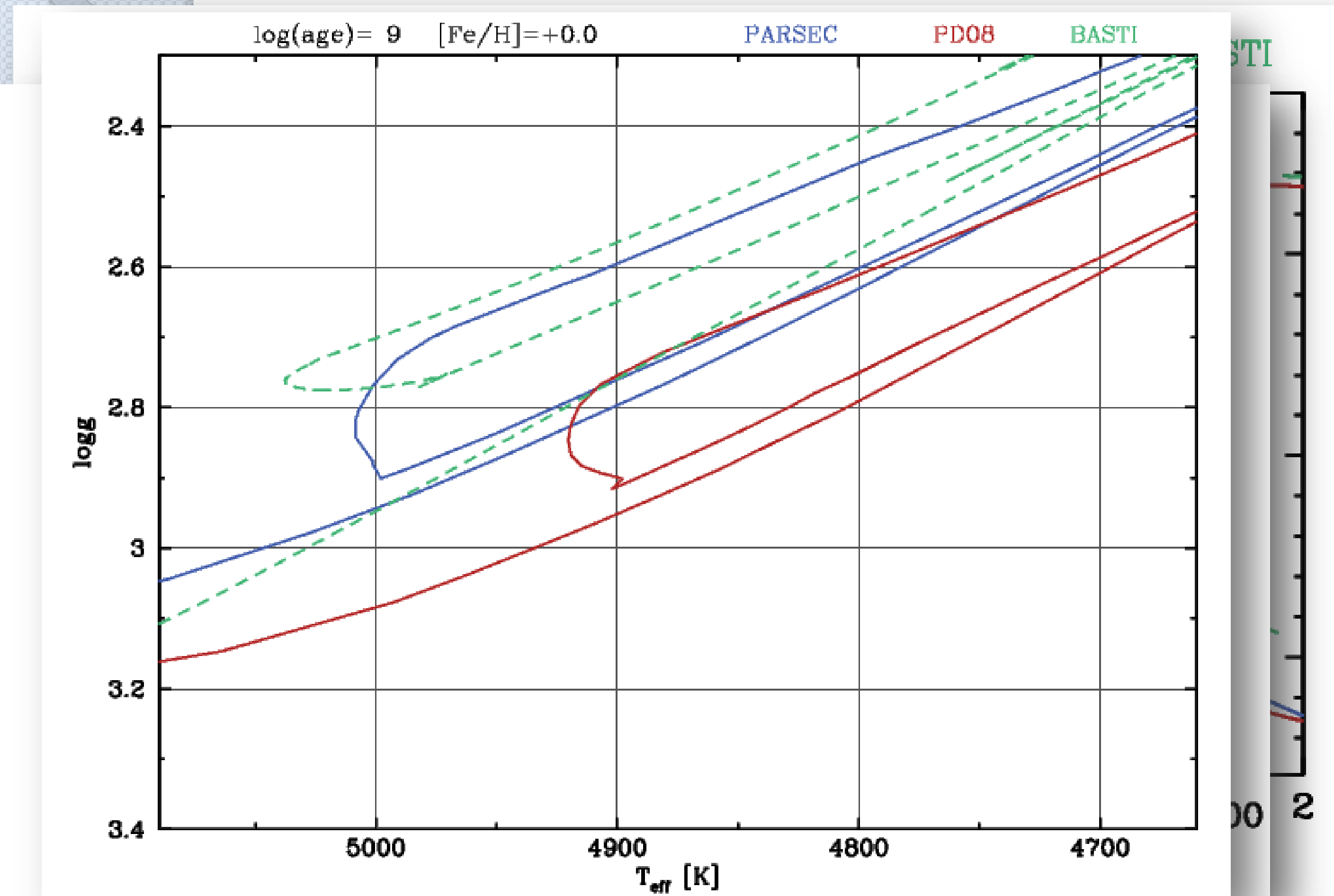
Differences (Z is fixed, similar parameter choice):

- new tracks more luminous, due to different assumptions on the temperature gradient in the overshoot region (mimick a larger overshooting parameter, larger mixed core).
- comparison with solar model (Basu+00) leads to fine-tuning of mixing length parameter (α_{MLT}=1.74)
  - affects the temperature of the RG stars!



Bressan+ 2012

Let's fix [Fe/H]



Usually compared at fixed Z!

Here, for a given [Fe/H] (no enhancement) →different Z due to different zero point

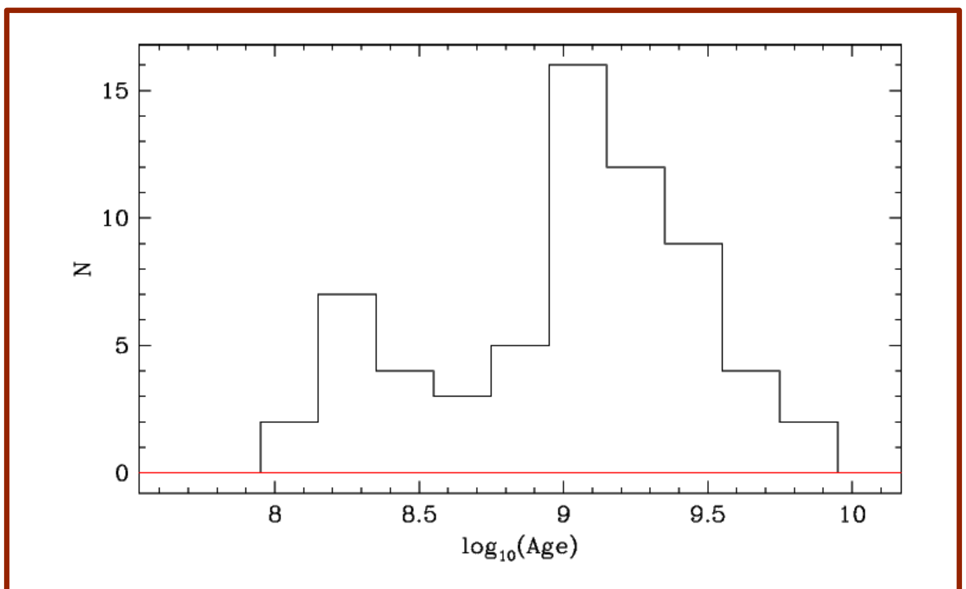
Differences in the turn-off location (different TO masses) and in the red clump position!

The Gaia-ESO Survey

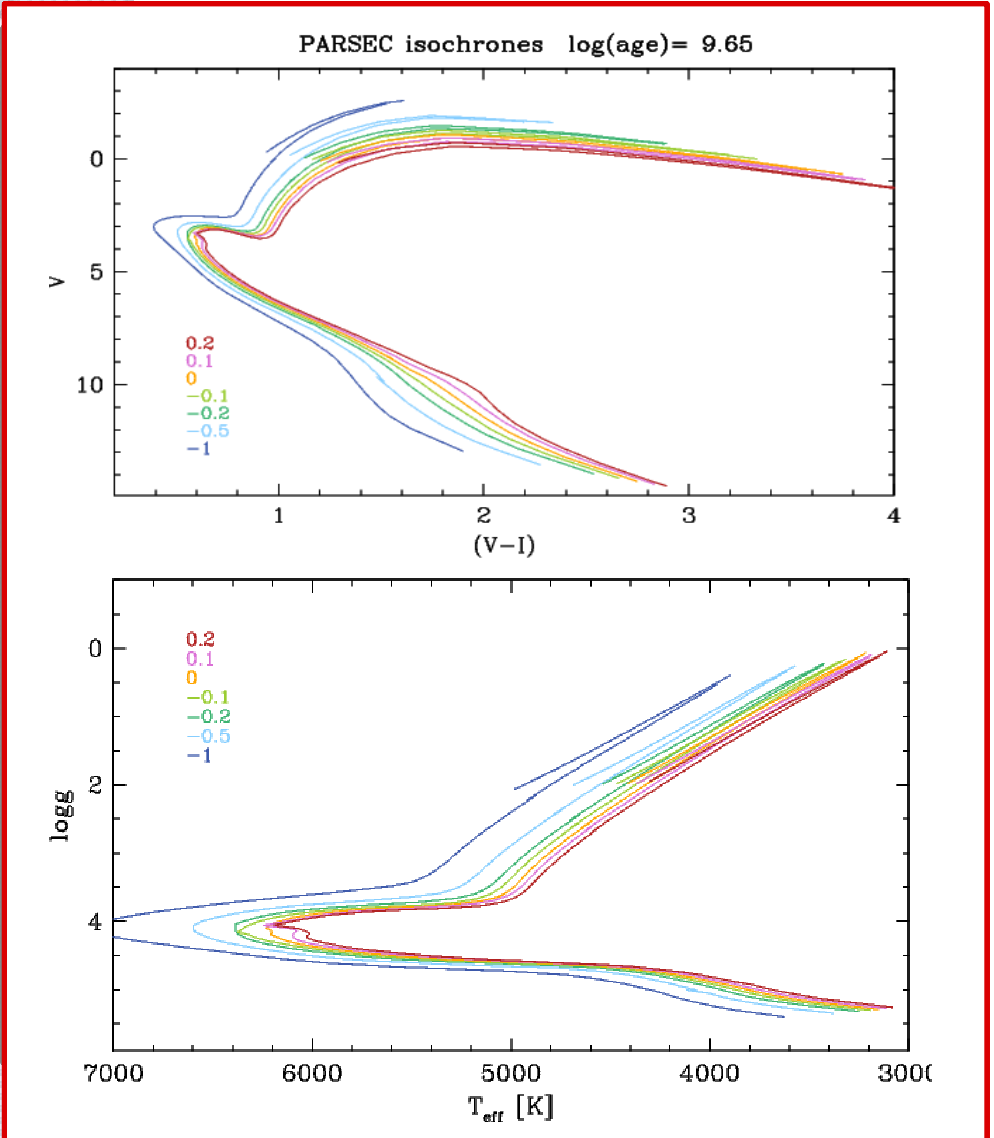
- Homogeneous spectroscopic survey of 10^5 stars in the Galaxy, in the field and in ~ 100 clusters
  - FLAMES@VLT: simultaneous GIRAFFE + UVES observations
- Homogeneous framework (data, data reduction, data analysis highly organized)
  - several methods for parameter determination, but…
  - same linelist
  - same set of model atmosphere/synthetic spectra
  - shared expertise in a collaborative framework
  - analysis of differences and systematics
  - homogenization
- result:
  - teff, logg, radial velocity
  - metallicity, as [Fe/H] but also alpha-enhancement and single element abundances → chemical composition!

GES OC sample

- A hundred target cluster, well distributed in age (Myr to Gyr) and metallicity
- Nearby (MS down to low Teff) and more distant (only UVES)
- Membership information
- Chemistry missing in literature (of course)

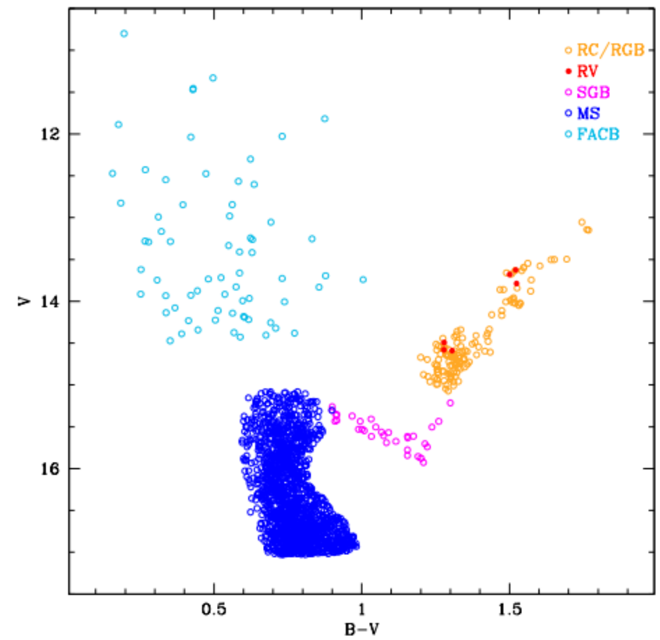


Overshooting calibration



- The transition zone definition do depend on the chemical composition (metallicity and helium content).
  - PARSEC: lower mass = 0.95-1.15 $M_{\odot}$
  - the calibration is uncertain due to lack of observational data in old and intermediate age open clusters (Bressan+12)
- The transition zone appears at solar metallicities at about 4.5 Gyr
- 10 OC in the GES OC master list have age determination close to that limit (given the uncertainties on age and metallicity)

Tr20



Literature:

- Age=1.4 Gyr (logAge=9.15)
- D= 3 Kpc
- E(B-V)= 0.35 to 0.45
- [Fe/H]=-0.11

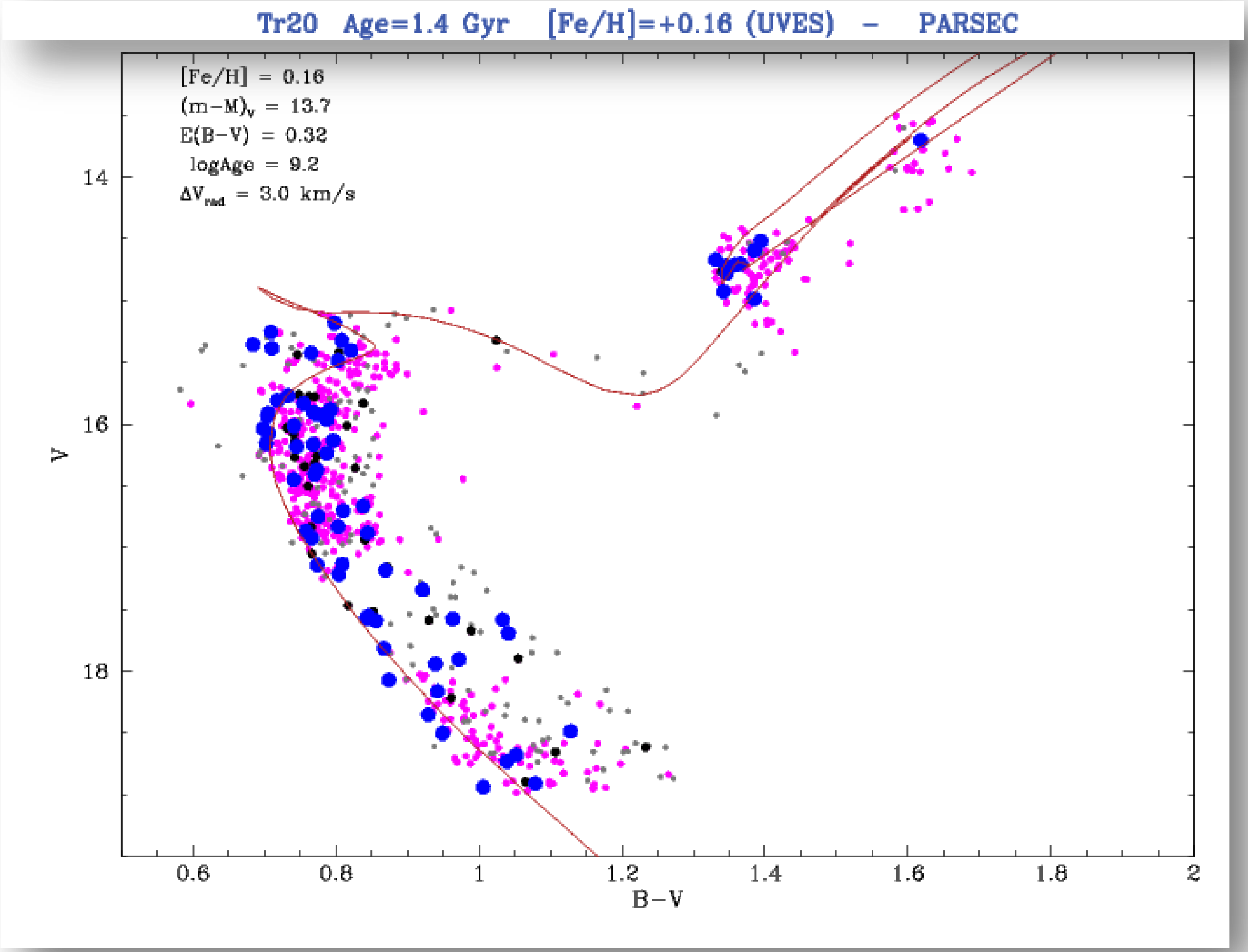
Ideal to test:

- the transition between non-degenerate and degenerate core He ignition (Girardi +09)
- overshooting, rotation, and mass loss effects (Girardi +00): Tr20 has a RC similar in luminosity extension to NGC2660, NGC752, and NGC7789.
- TO region confused: spread or split TO
  - rotation or
  - prolonged/bimodal star formation
  - mix of field contamination and unresolved binary systems (Carraro+10)

CMD degrees of freedom:

- age
- metallicity
- extinction
- distance modulus
- membership

hidden dependencies: color transformation for isochrones (ATLAS9)

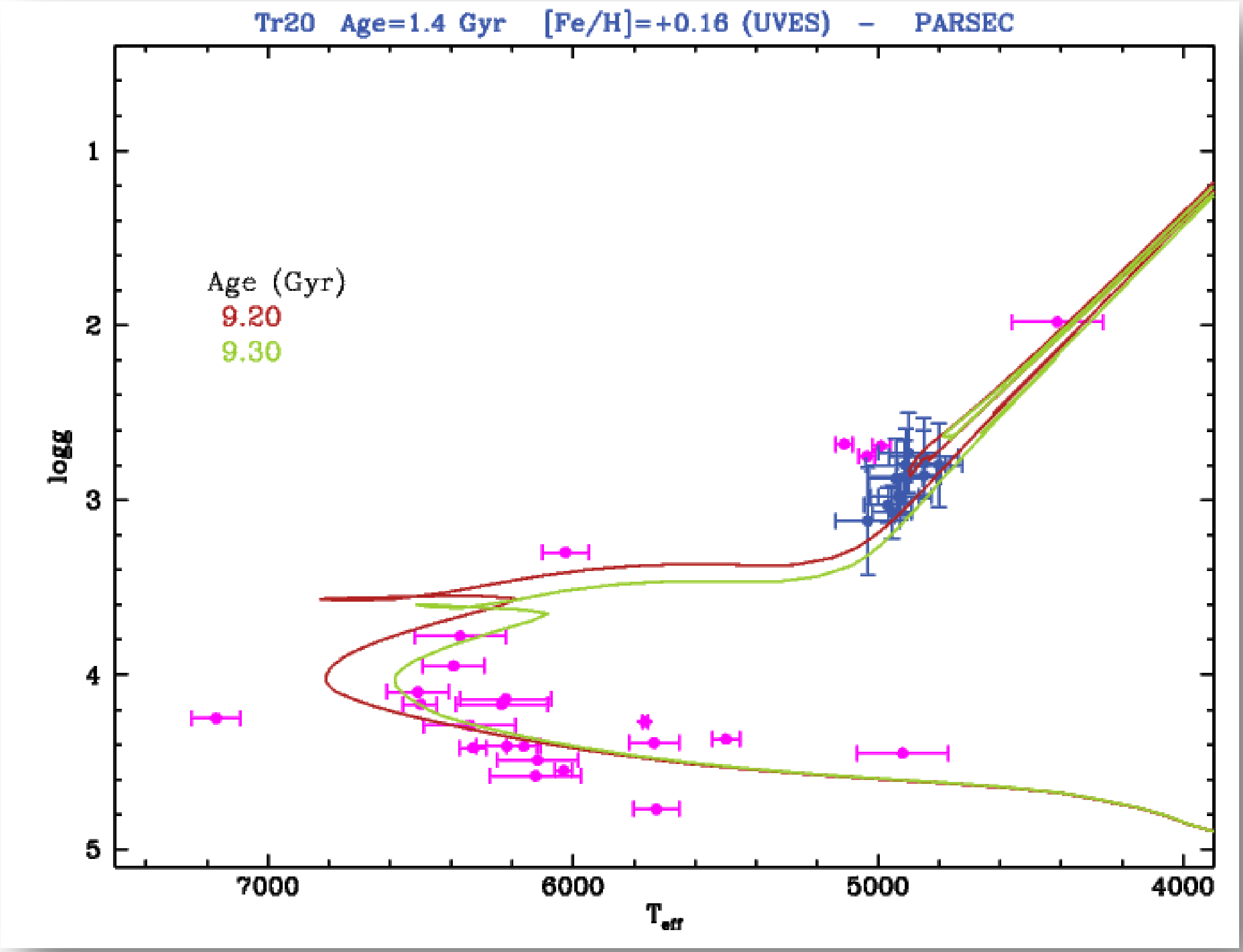


2 GES run pointings
+ extra-photometry

CMD degrees of freedom

- age
- metallicity

hidden dependency → spectroscopic determinations (linelist, methods)



only 1° GES run
soon more to come

Playing the Gaia card

- Gaia-ESO survey and Gaia do not share only the name!
- Gaia will provide homogeneity in the measures
  - astrometry: distance and proper motions (as) } clean CMD
  - photometry: (millimag up to G=20)
  - spectrophotometric determination of APs (from low resolution spectra)
- Gaia-ESO will provide homogeneity in the measures
  - ... will not repeat everything here } Teff, logg, Z, Vrad
- They will be homogeneous with each other:
  - same set of reference stars for parameters and metallicity!
  - Benchmarks:
    - Heiter+ 2013: set of 40 stars, spread all over HR diagram, parameters determination independent from spectroscopy
    - Jofré+ 2013: metellicity reference scale for them,