Constraining the Star Formation History of unresolved stellar systems

Some techniques, uncertainties, calibrations

Maurizio Salaris

Astrophysics Research Institute,
Liverpool John Moores University

OUTLINE

- Constraining Star Formation Histories of galaxies:

  Ingredients

  Integrated magnitudes and methods for unresolved systems

  Problems in calibrating theory **(see also Santi and Achim talks)**

  Additional unpleasantries **(see also Santi and Achim talks)**

Theoretical tools to derive the SFH

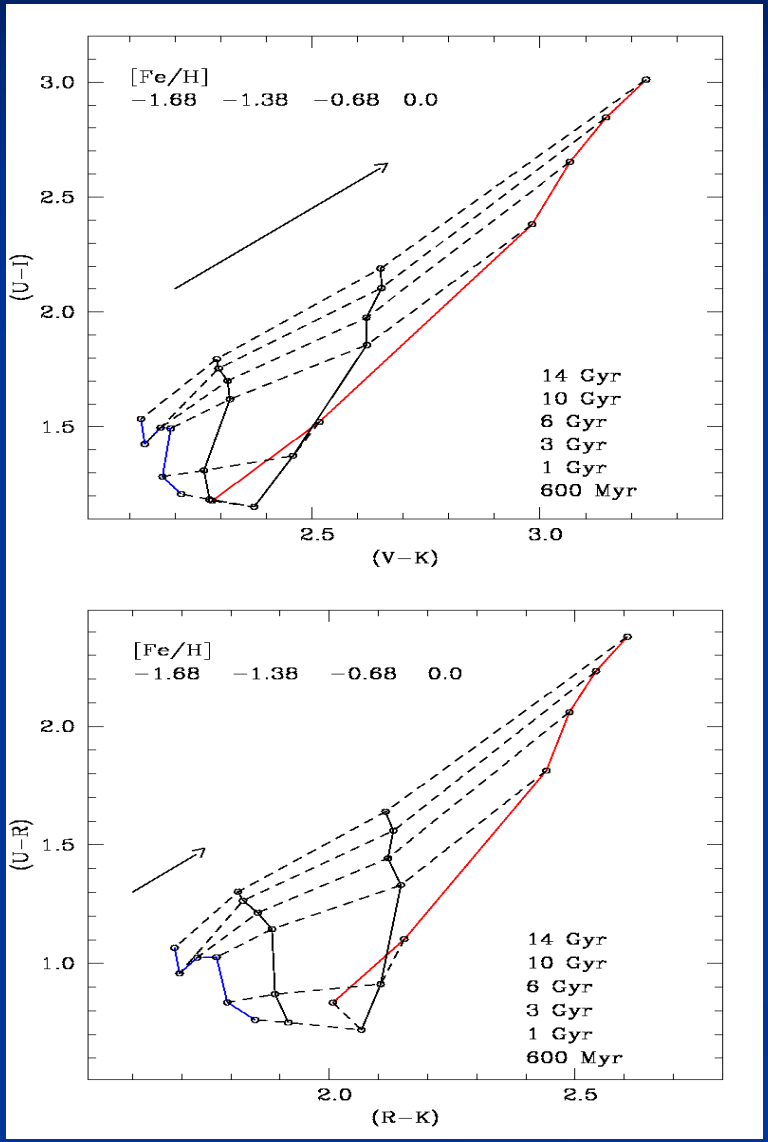
Input from stellar evolution theory

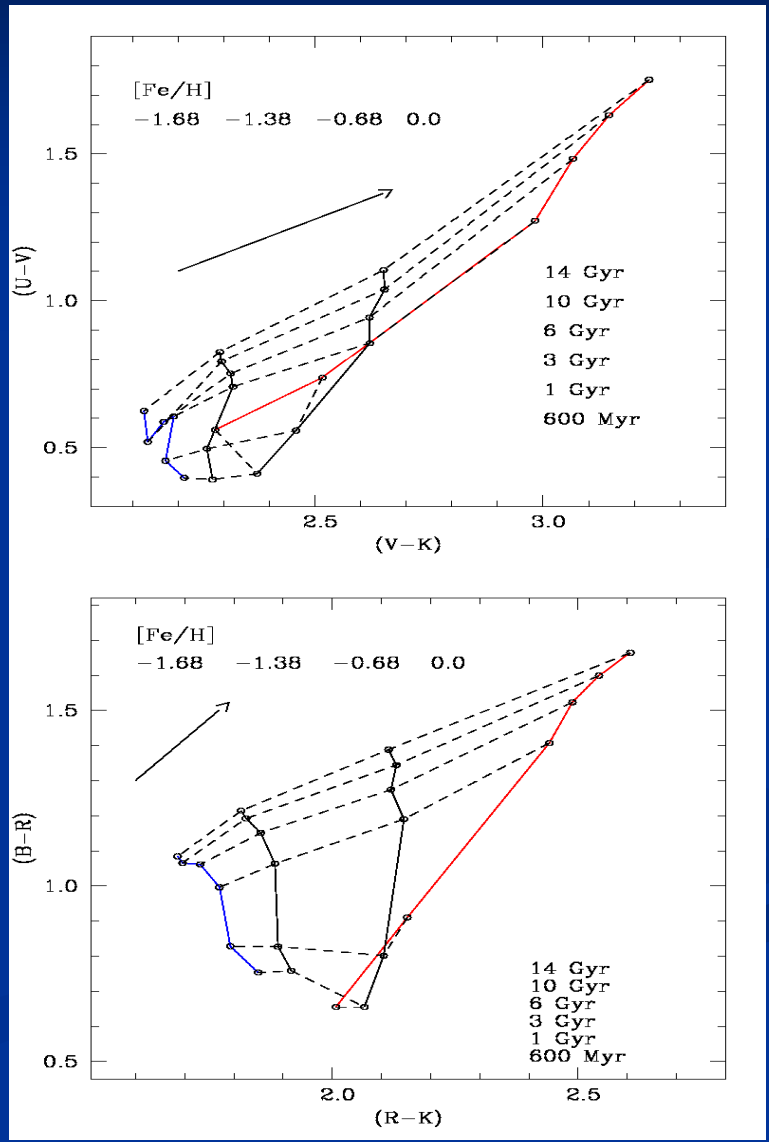
- Library of stellar models covering large ranges of mass and initial chemical composition (predict, among others, evolution of L,Teff).
- Theoretical isochrones (L,Teff, mass distribution)

Additional ingredients (not from stellar evolution calculations)

- Library of stellar spectra and bolometric corrections (either from model atmospheres or empirical or a mixture of both) to predict fluxes and magnitudes
- Initial Mass Function (IMF – usually empirical)

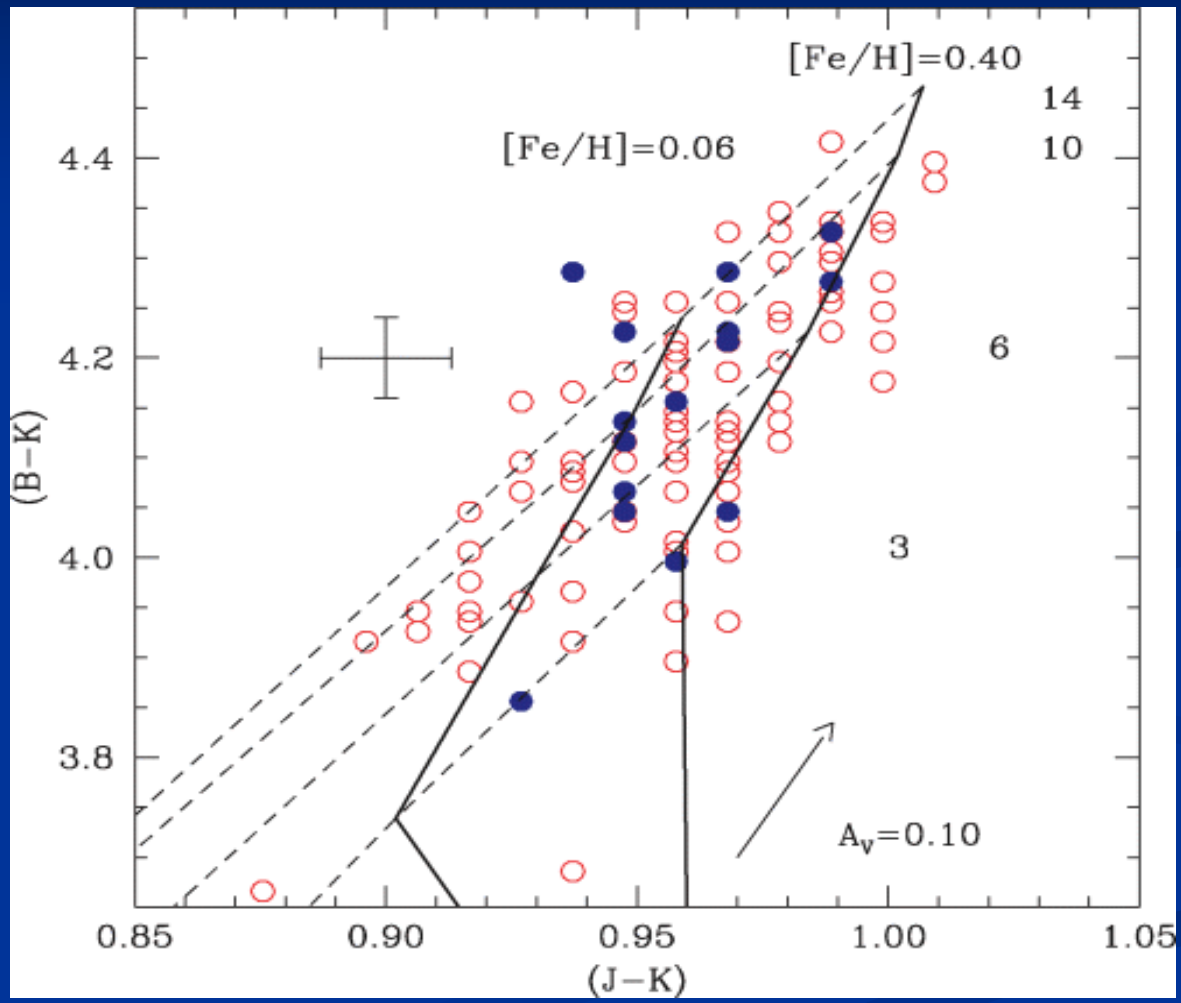
Breaking the age-metallicity degeneracy





Field and Virgo ellipticals

From James, Salaris, et al. (2006)



Broadband magnitudes and complex SFHs

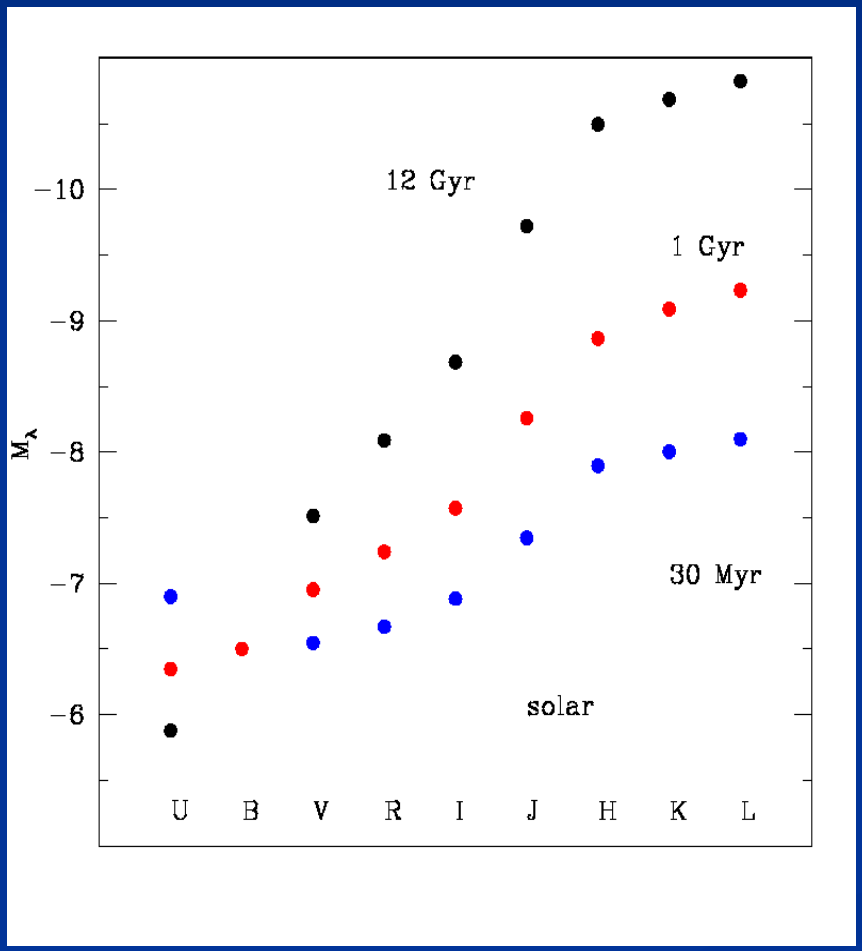
Luminosity weighted ages and metallicities provide only limited (albeit useful) constraints on the full galactic SFHs.

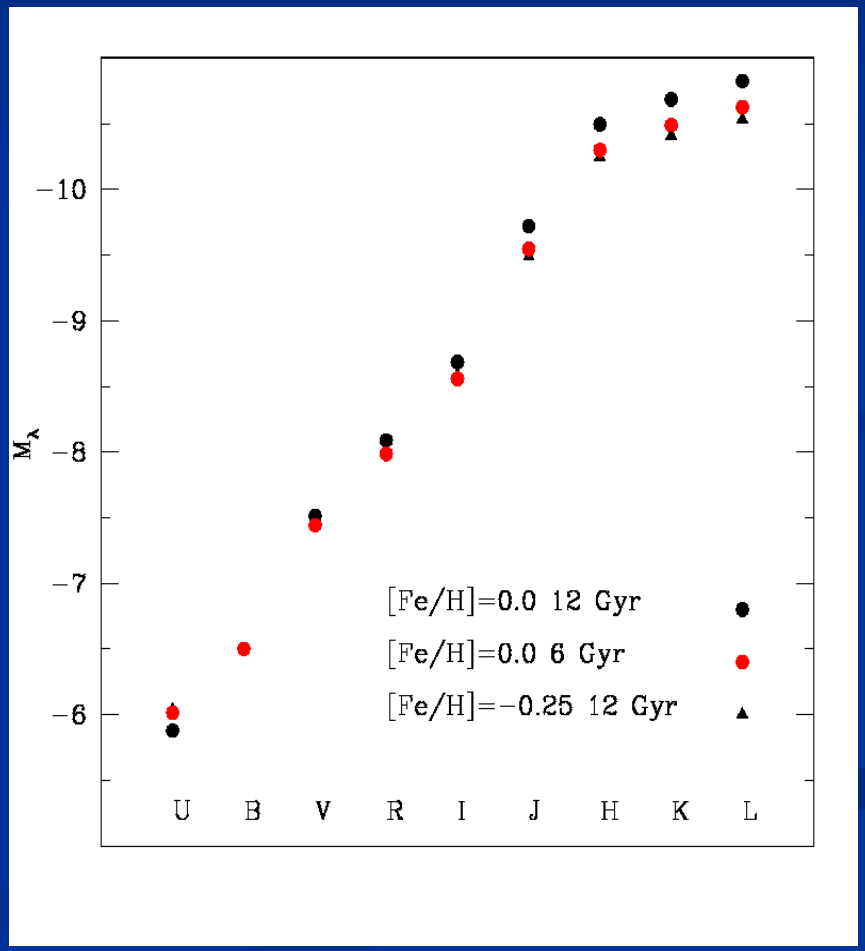
i) Could different SFHs produce the same observed pairs of integrated colours?

ii) If yes, is there any way to get some additional information about the true SFHs ?

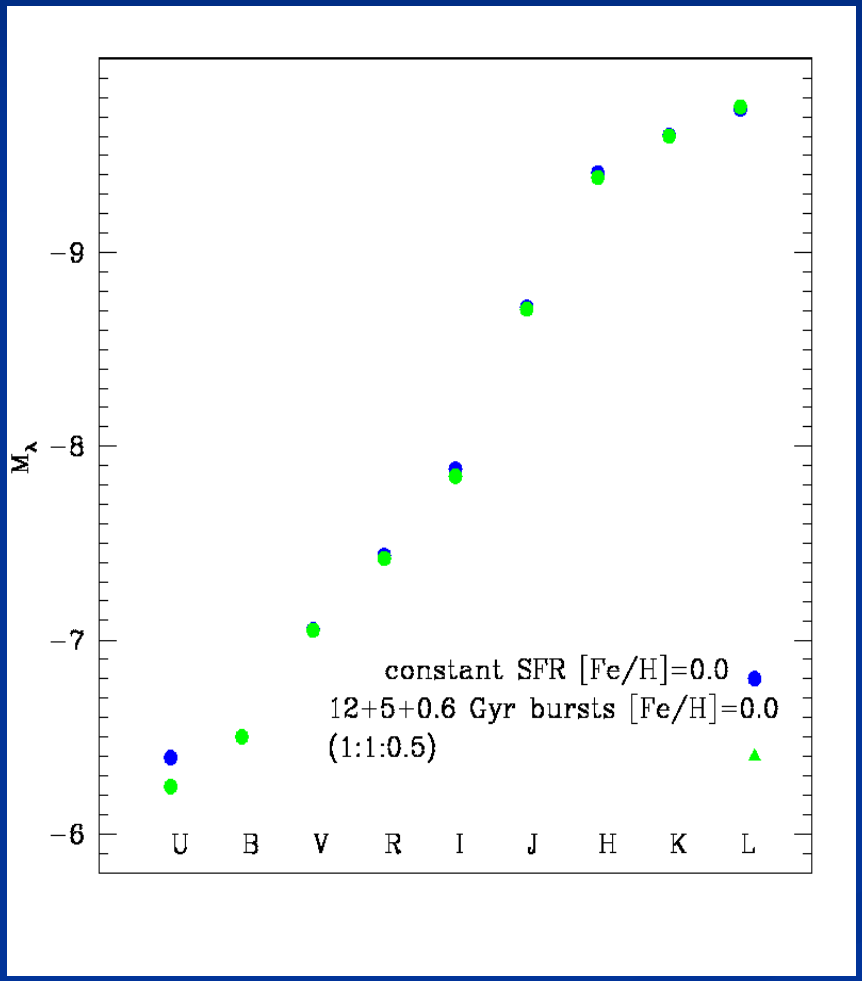
Low resolution SED properties

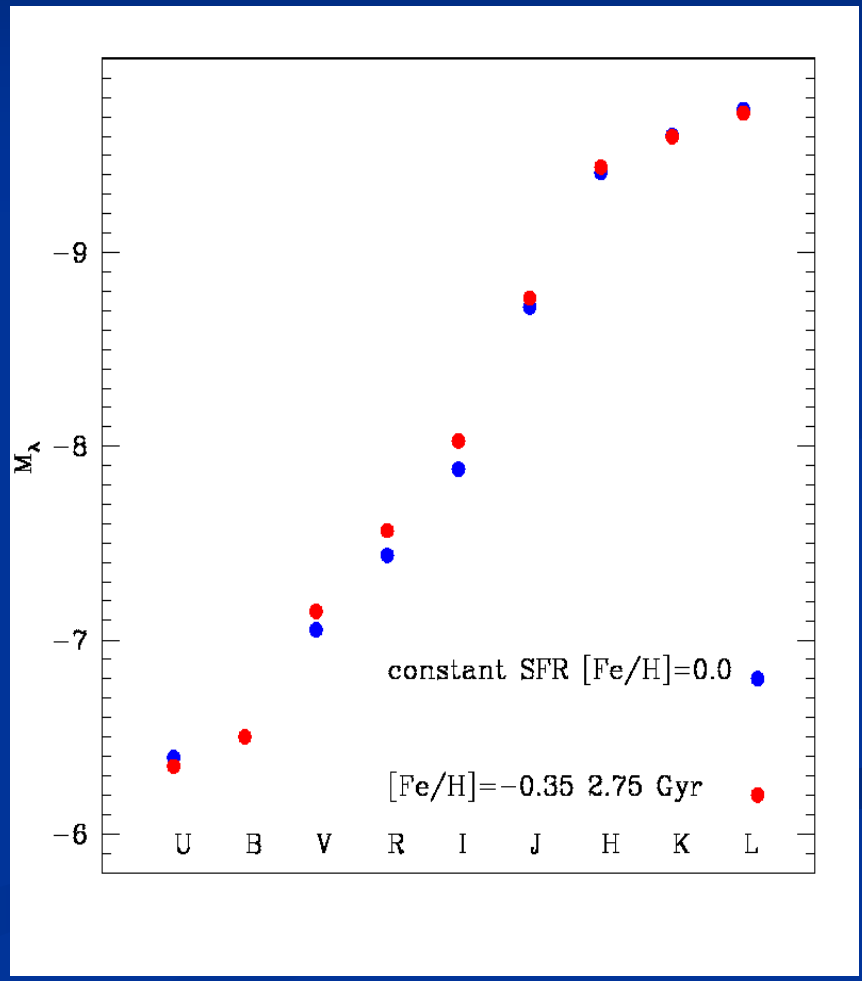
U~3500 A - K~22000 A



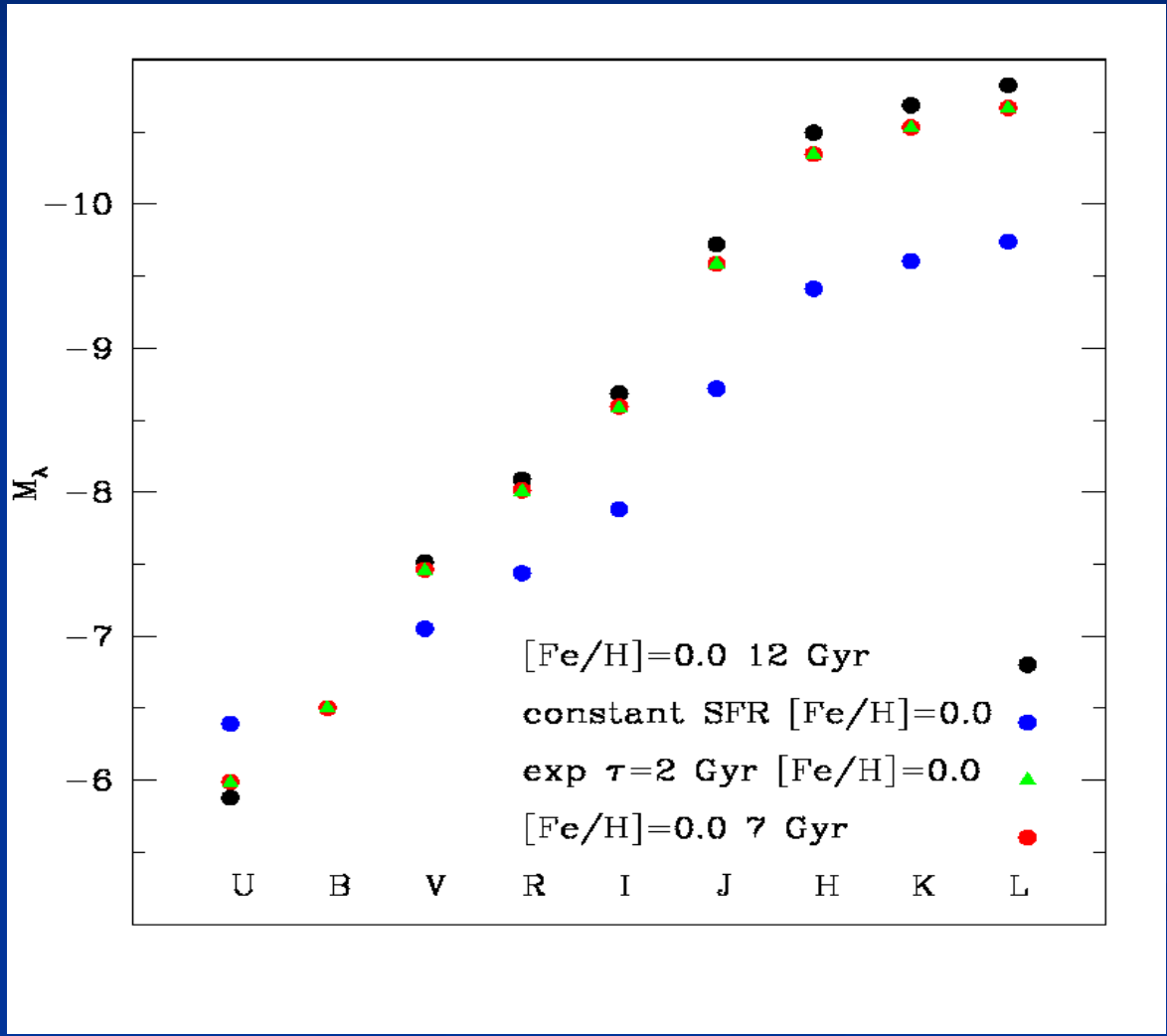


SED of complex SFHs: removing some degeneracies (i)



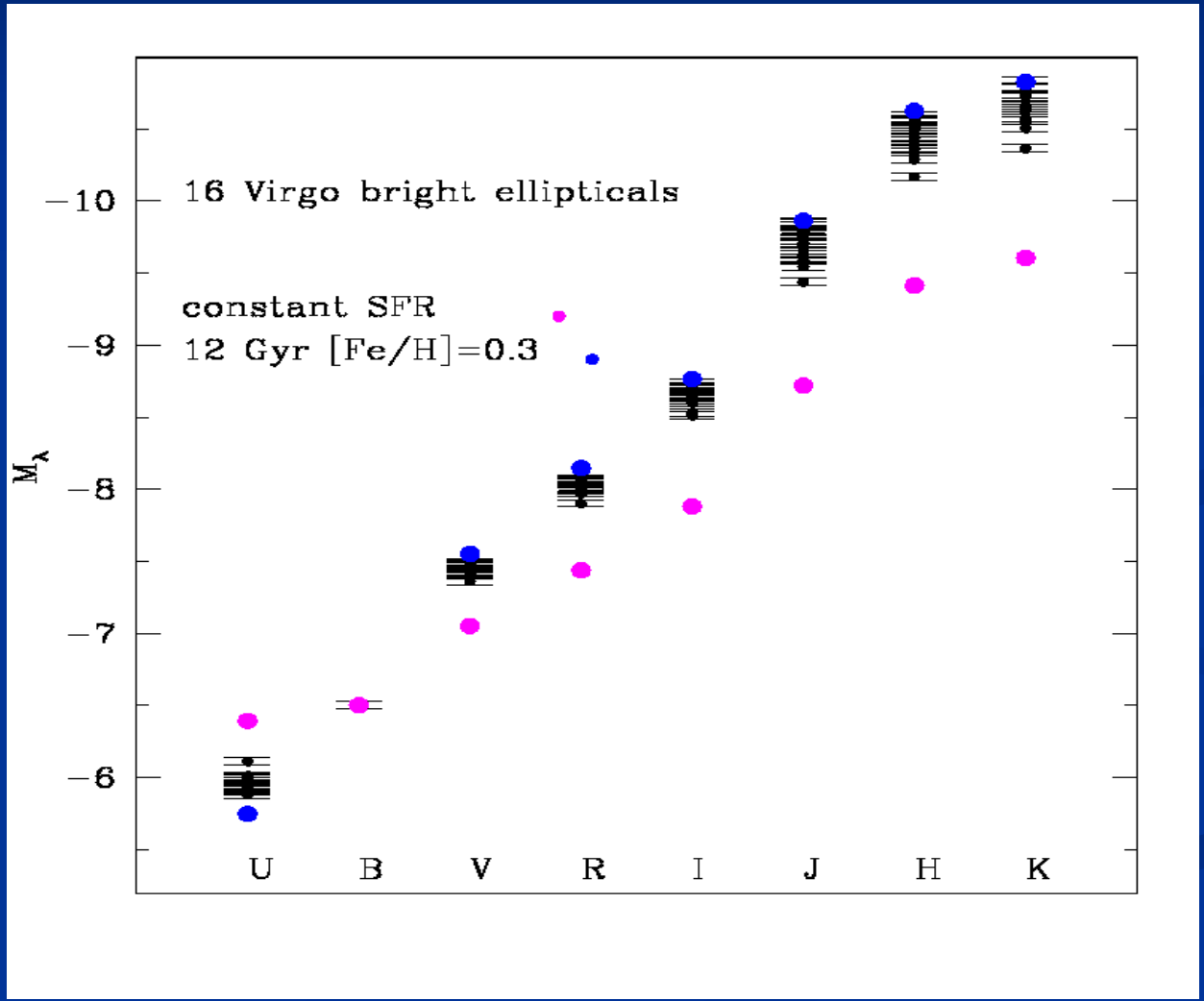


SED of complex SFHs: removing some degeneracies (ii)

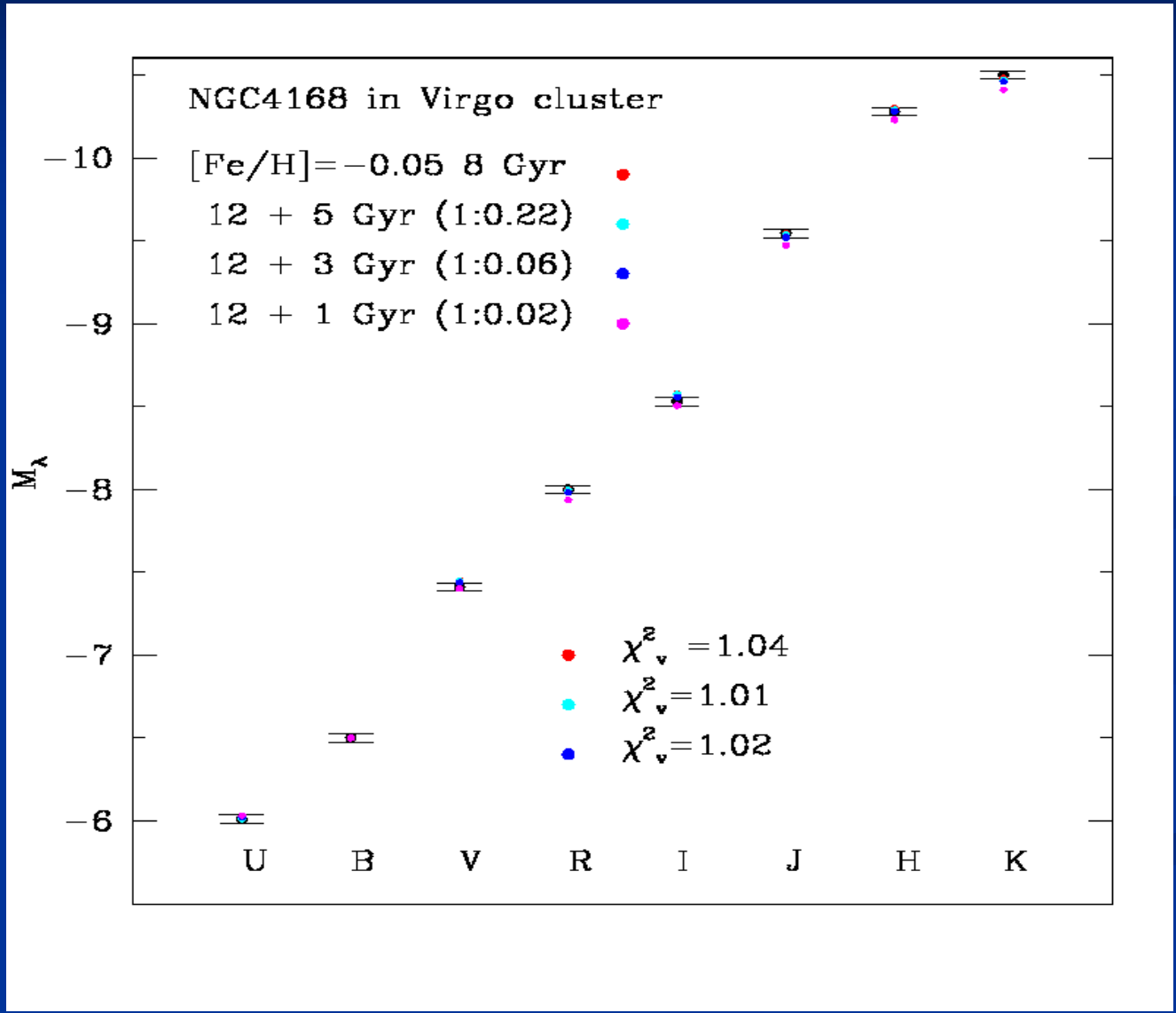


A practical case: A sample of bright ellipticals in Virgo

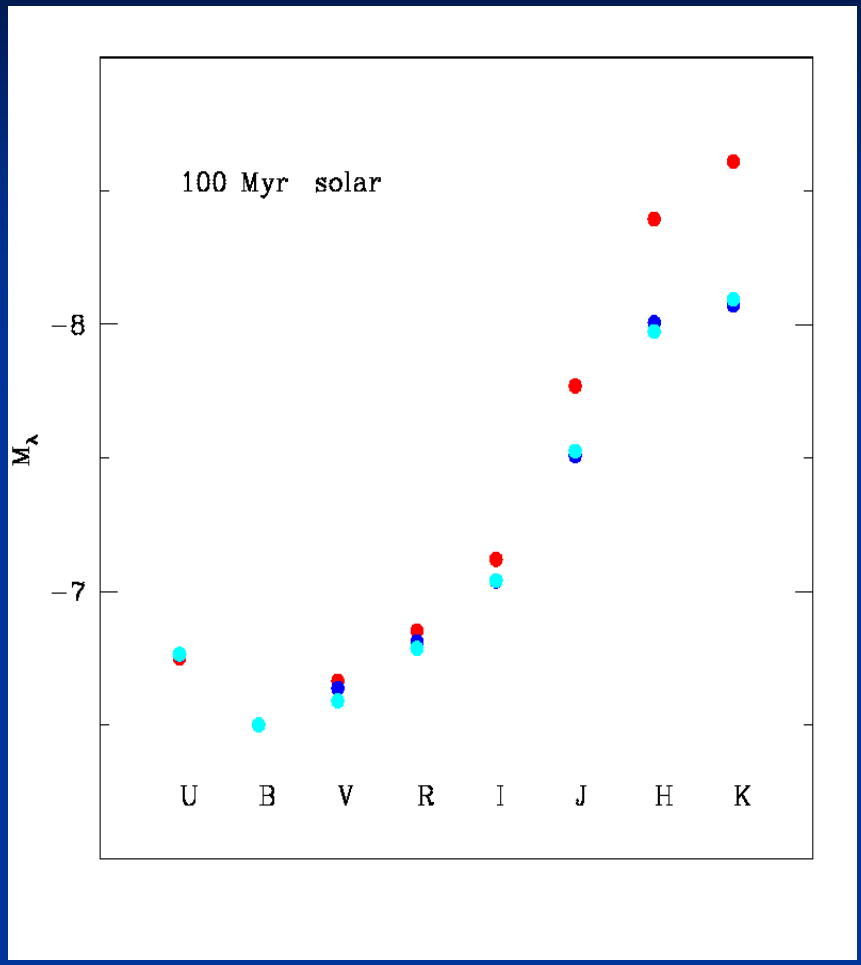
Data from Michard (2005)

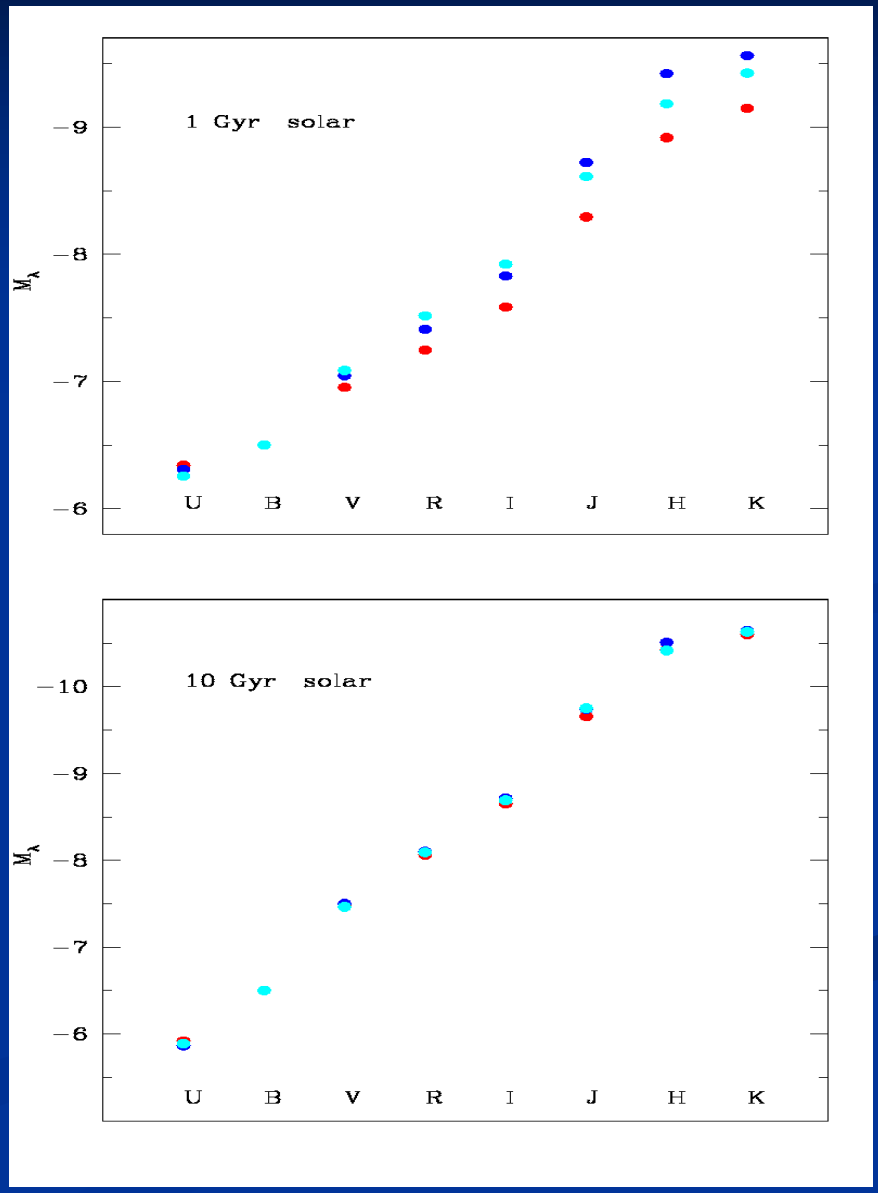


A specific example: NGC4168 in Virgo cluster



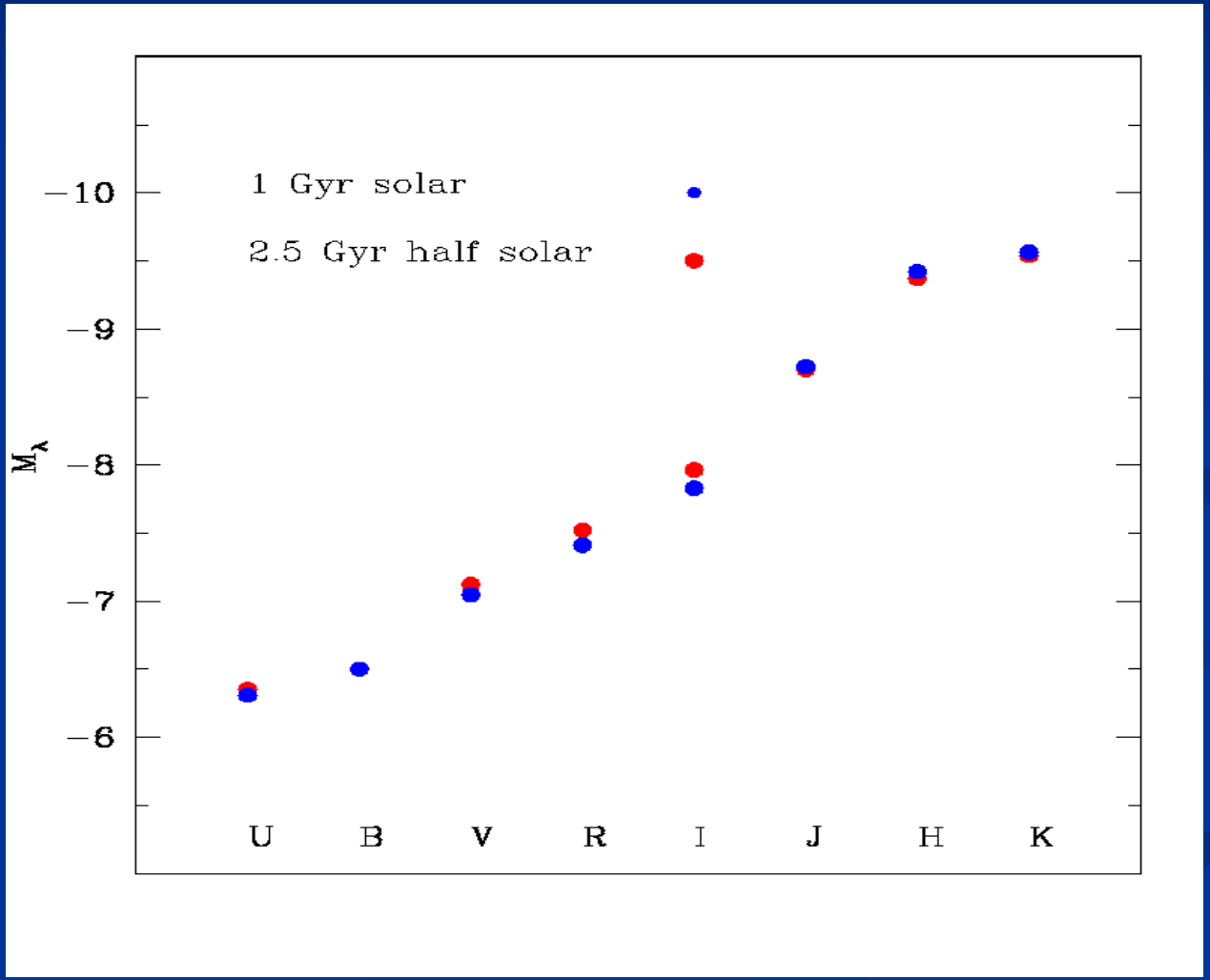
How uncertain are theoretical SEDs?





SEDs from BaSTI, Galadriel, BC03

More quantitative estimate of systematic uncertainties



Sources of SED differences

- Uncertainties in the theoretical models (predictions of L, Teff as a function of time for models of given mass and chemical composition)

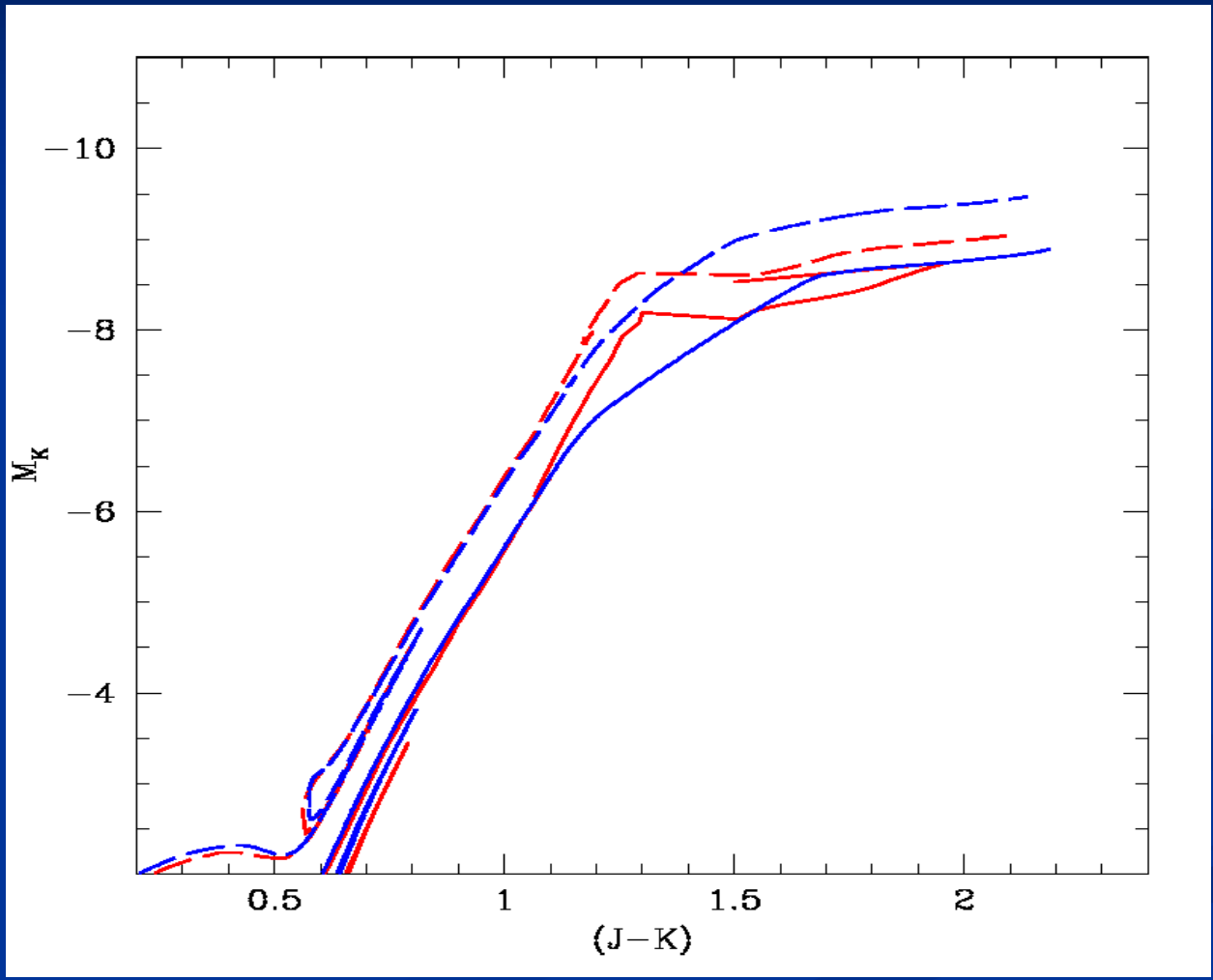
- Uncertainties in the spectral libraries and bolometric corrections (predictions of fluxes as a function of wavelength)

Comparison of AGB in near-IR

300 Myr, 1 Gyr

BaSTI

Cioni et al. (2006)

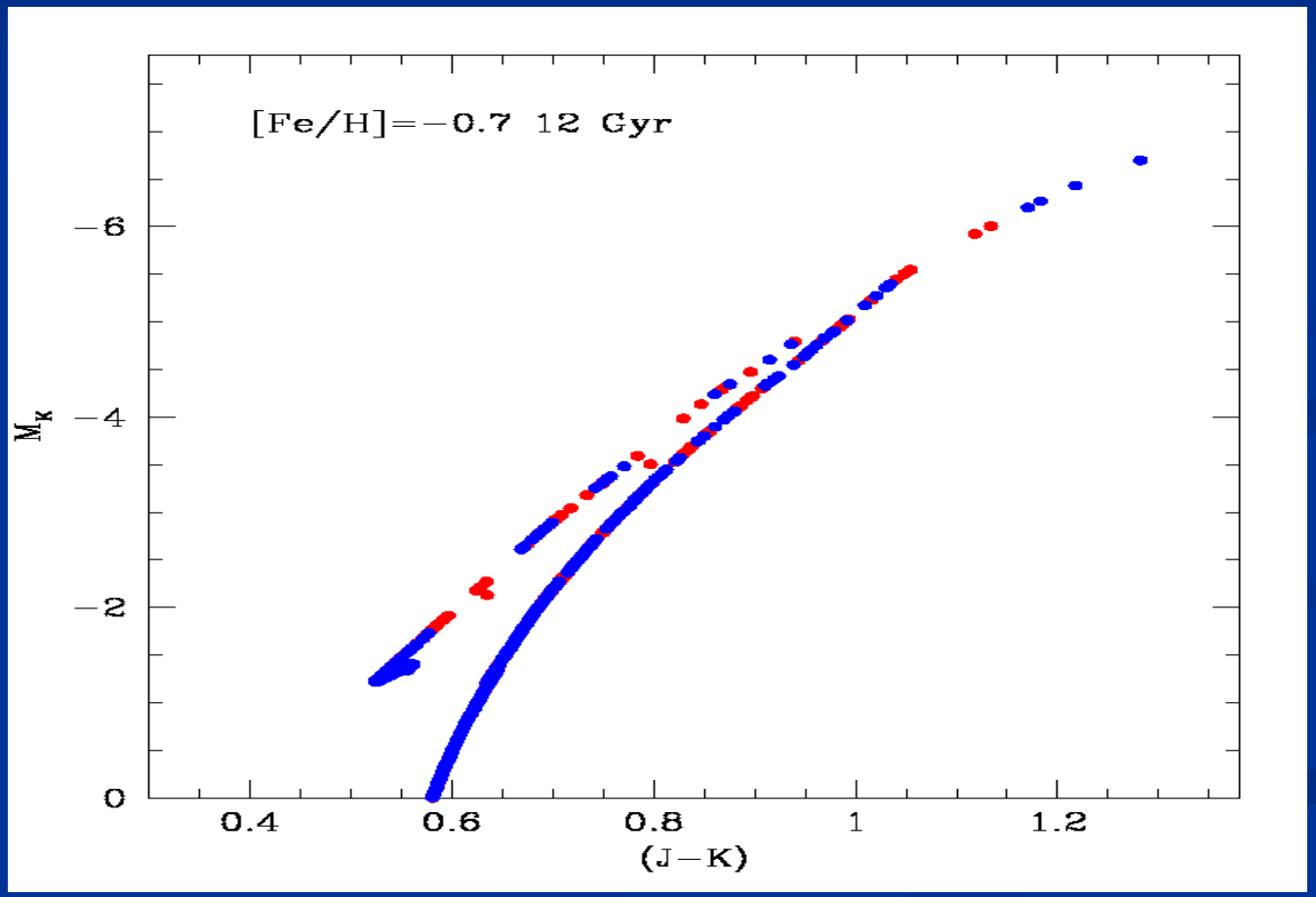


How do we calibrate ?

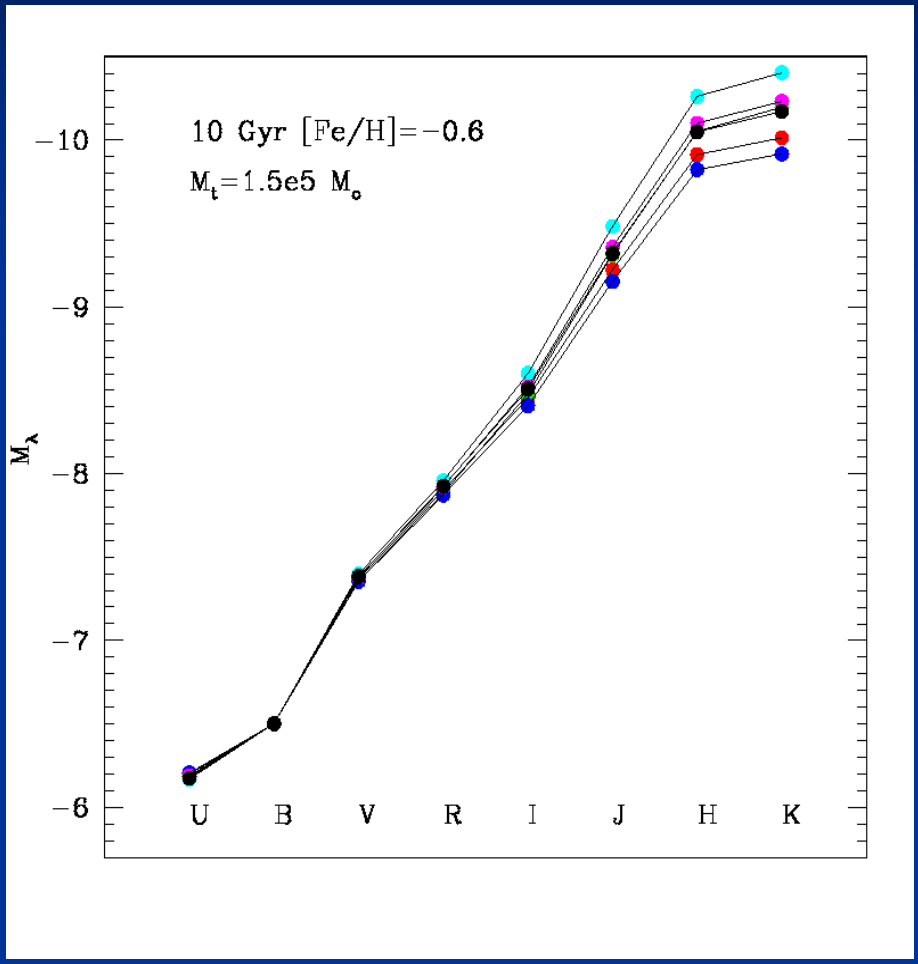
- Eclipsing binaries (R-M) – only few with accurate parameters (and generally only Main Sequence/Turn Off) uncertain chemical composition
- LF and CMDs of resolved star clusters in the Galaxy (very few AGB stars, if any) or LMC/SMC (often uncertain chemical composition)
- Integrated colours of star clusters in the Galaxy or LMC/SMC (magnitude fluctuations)

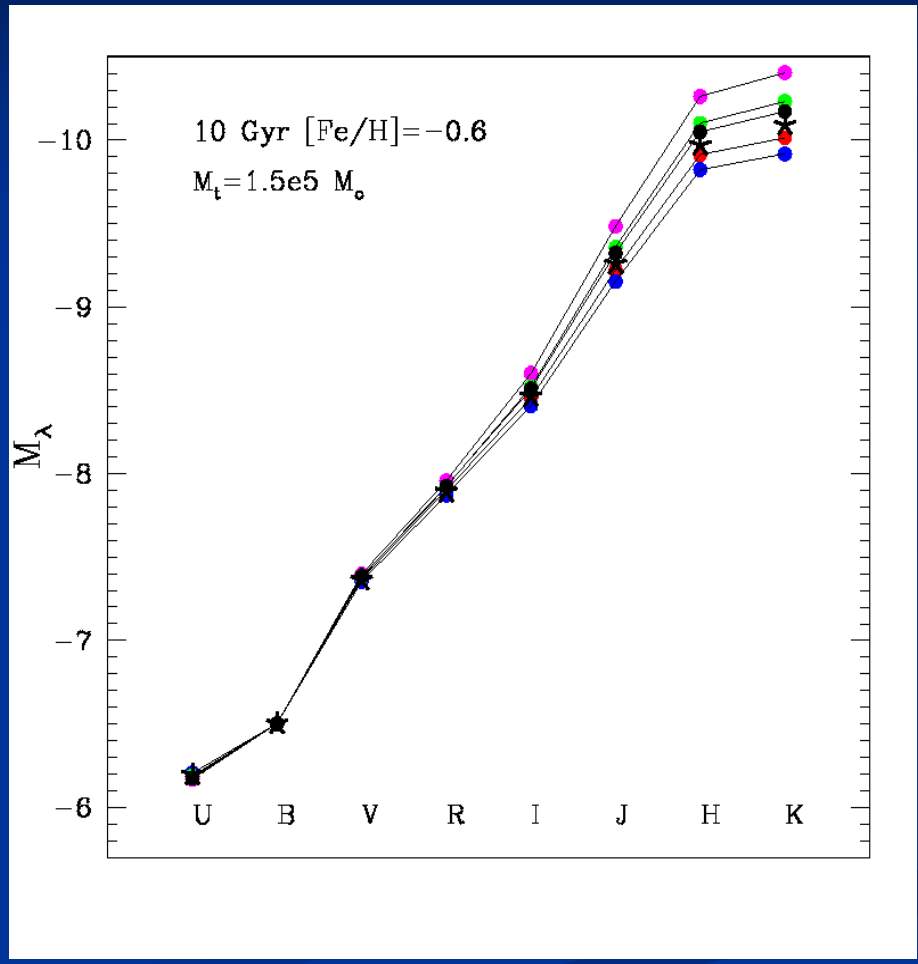
Fluctuations !!! (i)

Chiosi et al. (1988), Santos & Frogel (1997), Cervino & Valls-Gabaud (2003)



Fluctuations (ii)





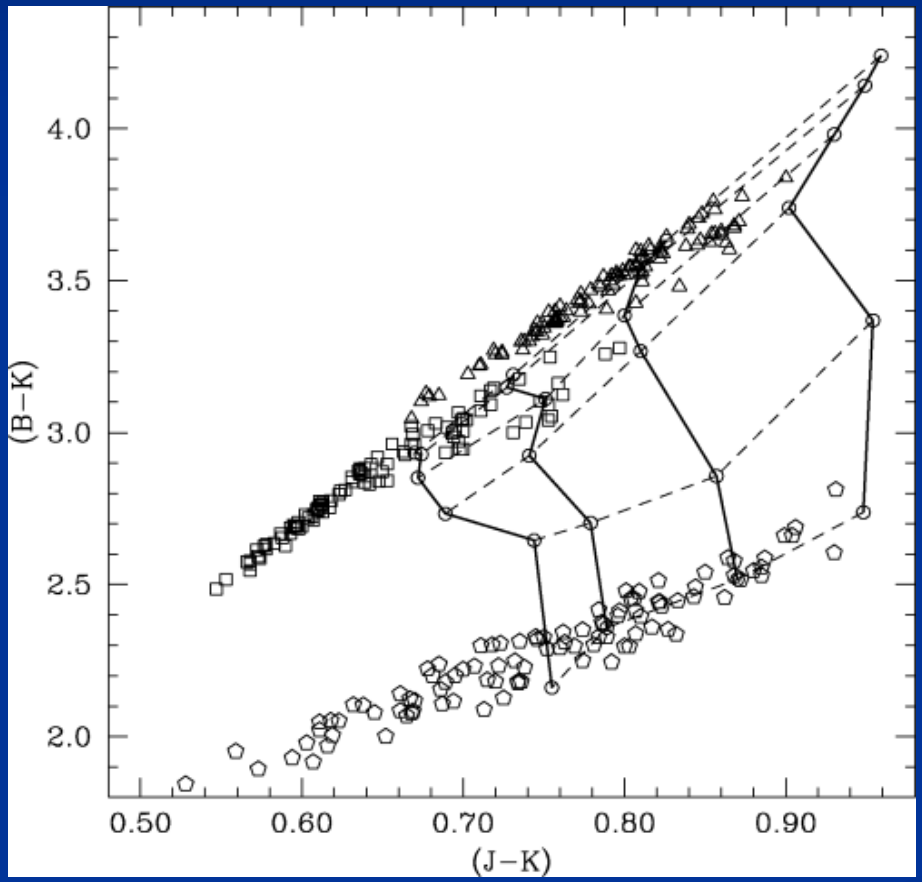
12 Gyr 1σ(K)=0.12 mag 1σ(V-K)=0.12 mag 1σ(V-I)=0.03 mag 1σ(J-K)=0.07 mag

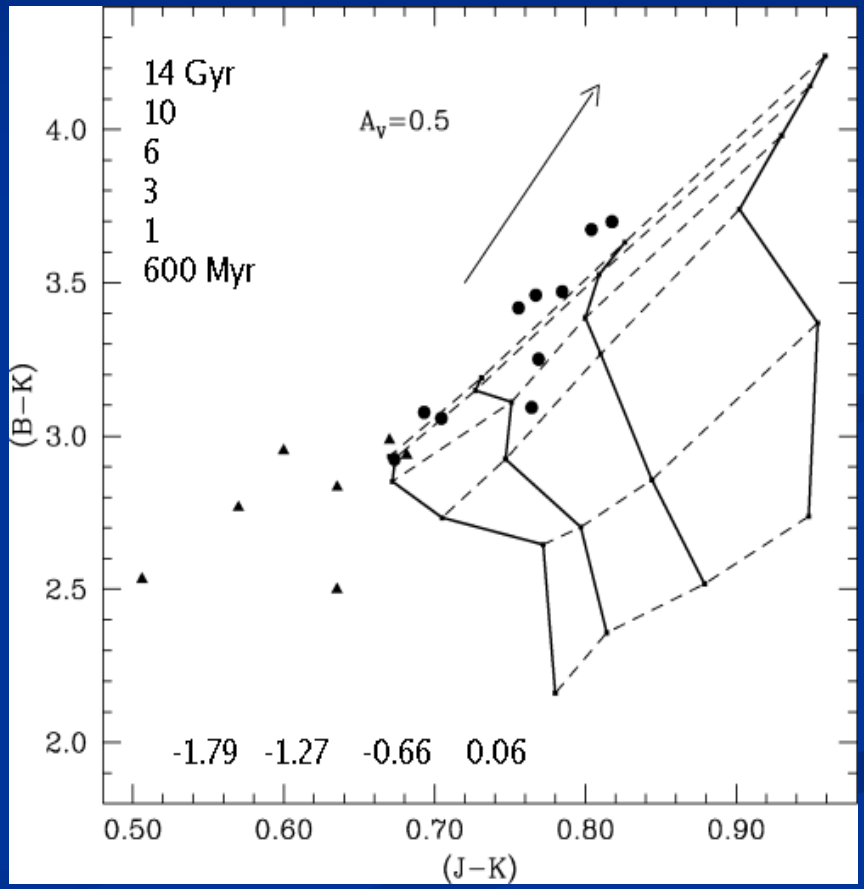
1 Gyr 1σ(K)=0.14 mag 1σ(V-K)=0.14 mag

Fluctuations (iii)

Dots → [Fe/H] –0.6 ÷ –1.6

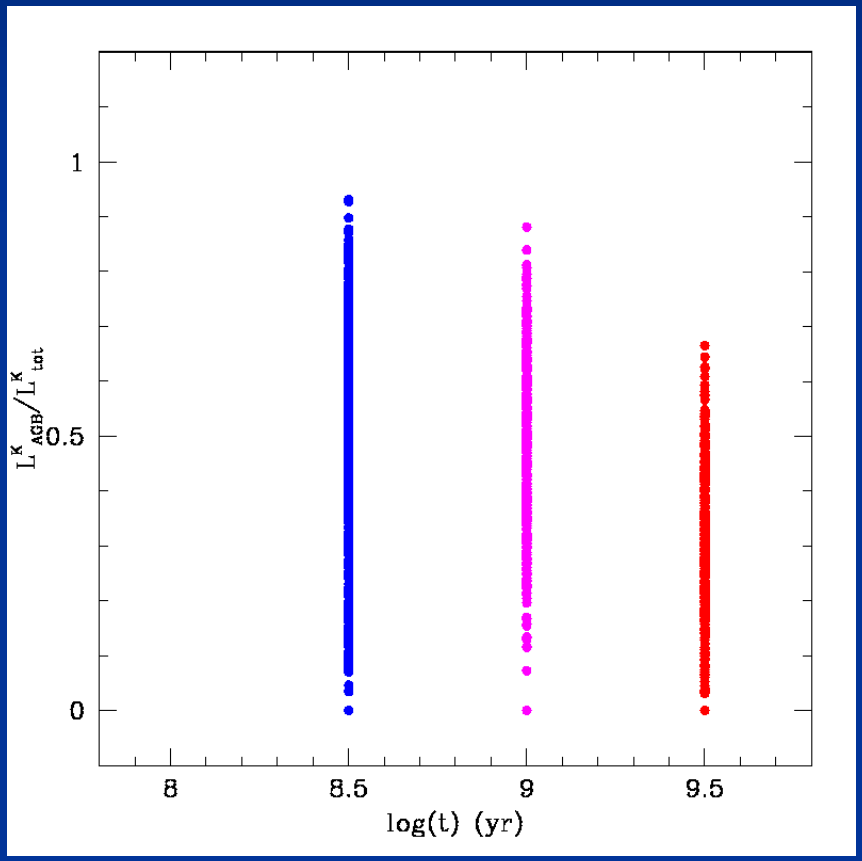
Triangles → [Fe/H] –1.6 ÷ –1.9

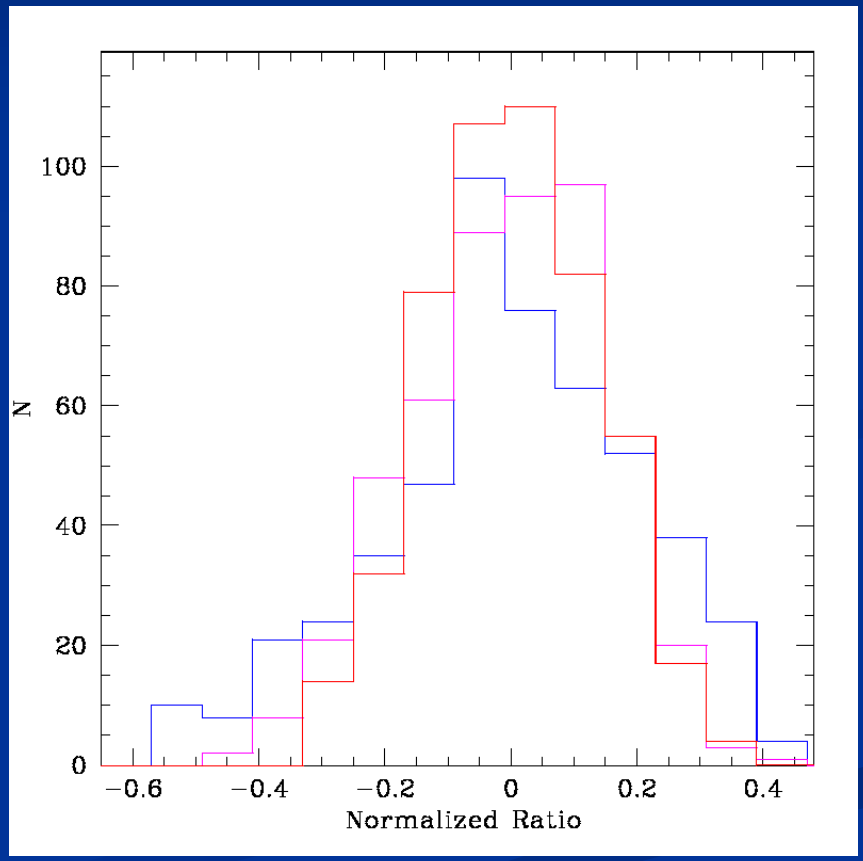


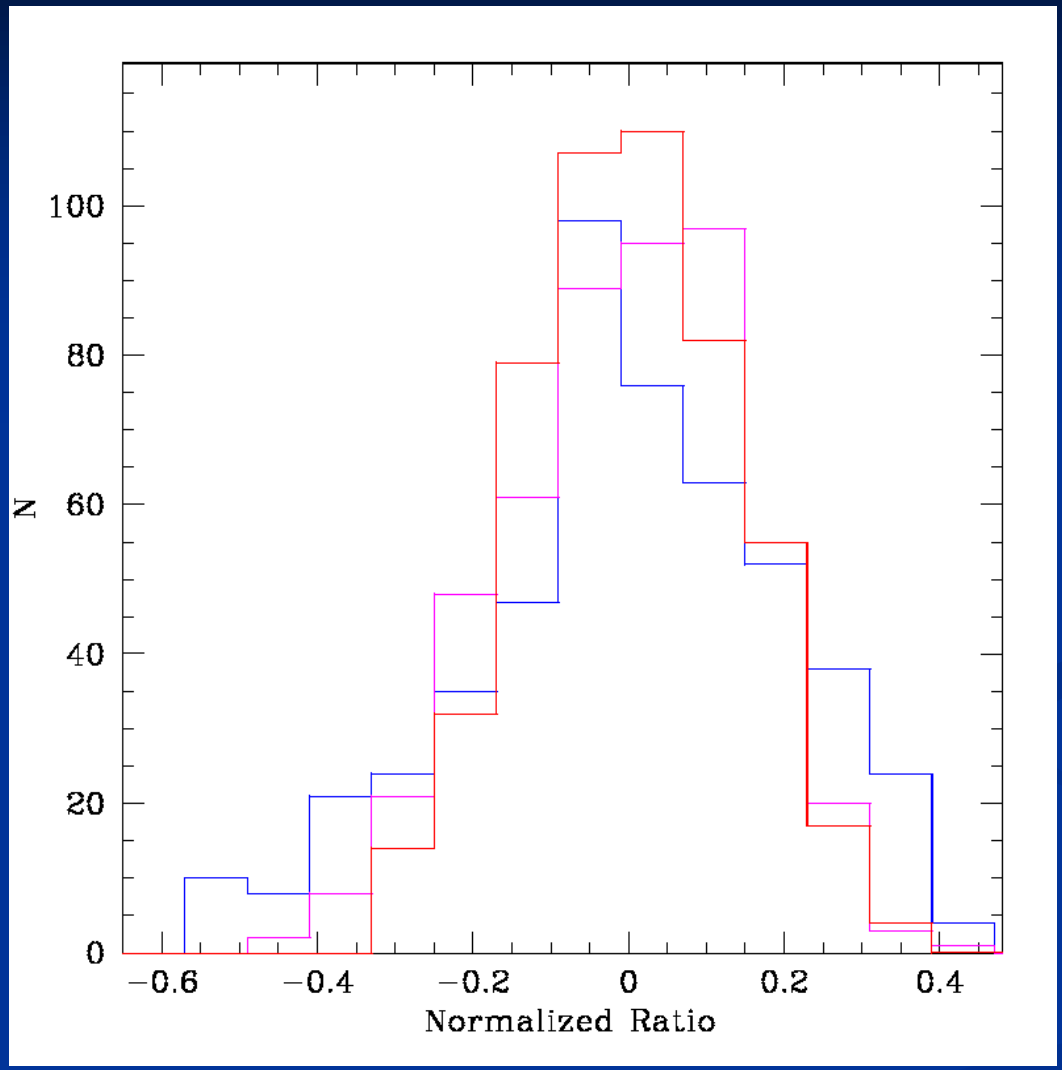


Simulations from James, Salaris et al. (2006), M31 globulars data from Galleti et al (2004)

Calibrating the AGB contribution to the total near-IR flux (fluctuations again)







300 Myr $1\sigma = 0.20$

1 Gyr $1\sigma = 0.15$

3 Gyr $1\sigma = 0.13$

Avoiding the fluctuations

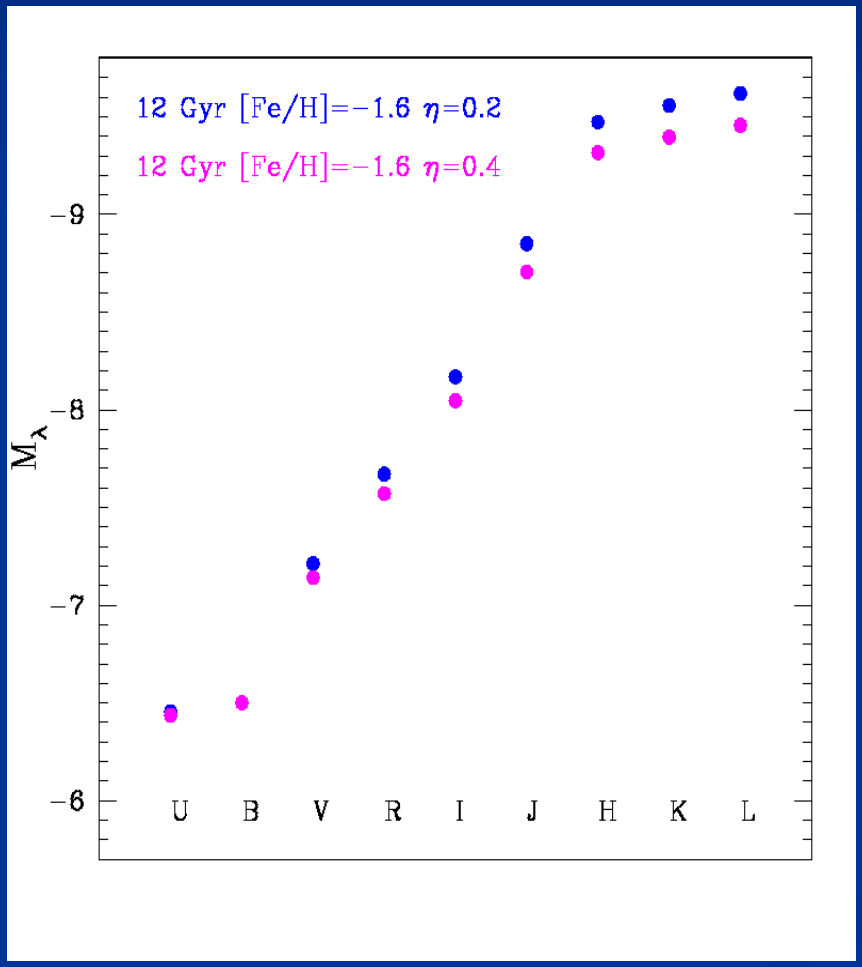
The effect of statistical fluctuations on integrated magnitudes, colours and flux ratios becomes negligible when $M_{pop} \sim 5\text{-}6\ 10^6\ M_o$

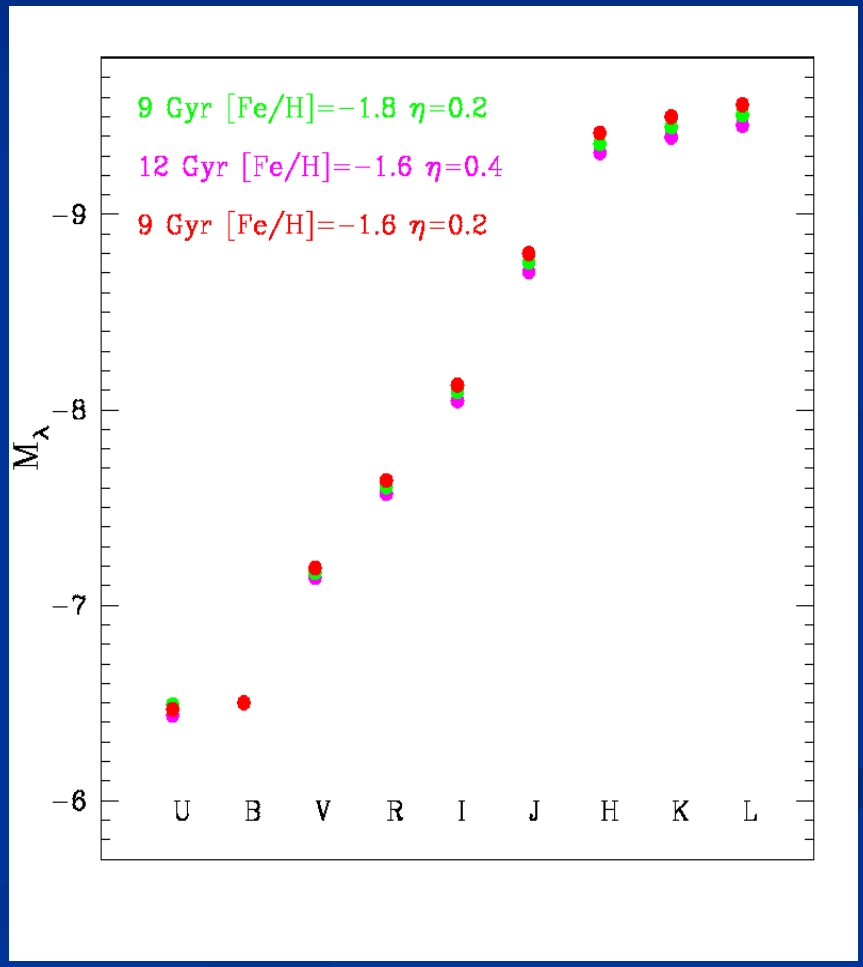
This is about 40 times the typical Galactic globular cluster mass.

We can co-add clusters within narrow t-Z ranges (Gonzalez et al. 2004).

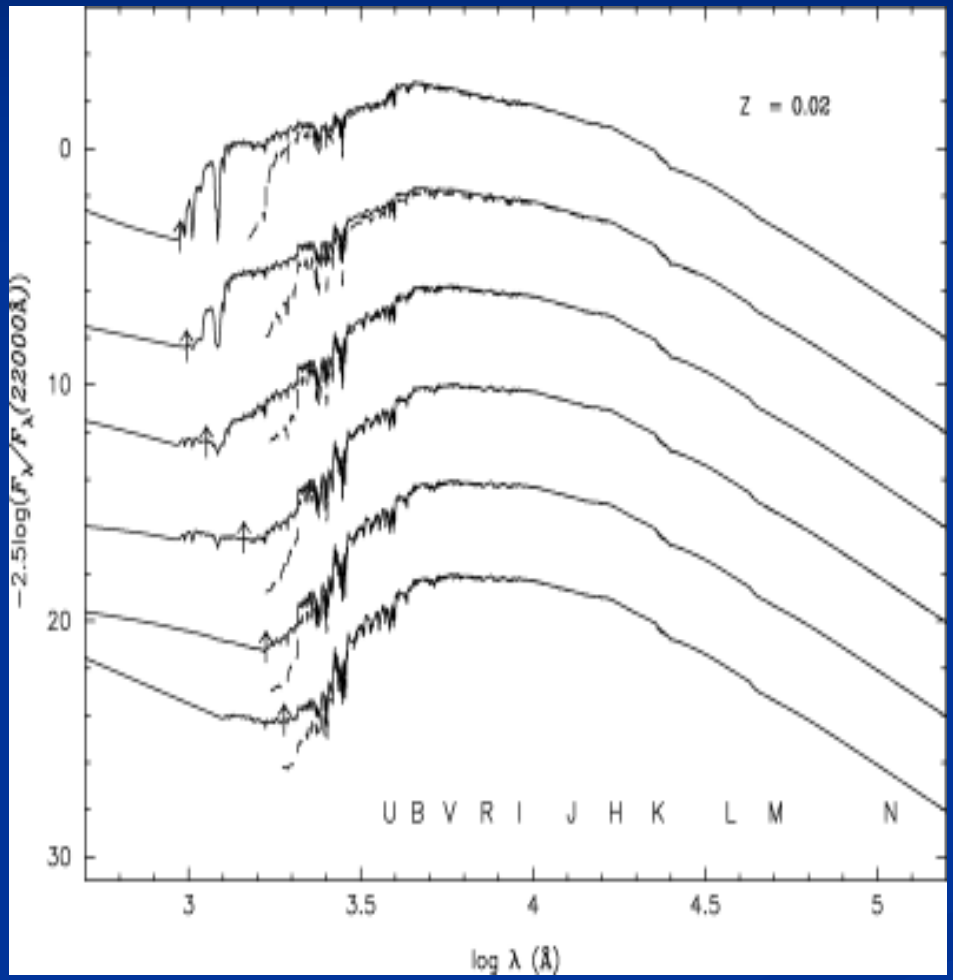
Do we have enough calibrating clusters for the full age/metallicity range covered by stellar populations in the universe?

Horizontal Branch colour





Hopefully this doesn't hurt too much: interacting binaries



- Interacting binaries may cause the appearance of 'exotic' objects like blue stragglers or very hot HB stars.
- SED is modified mainly shortward of the U-band

← results from Zhang et al. (2005)
(solid line – pure binary population
dashed line – single star population)

Conclusions: Some important issues to ponder

this is important for both photometric and spectroscopic methods !!!!

- *Find ways to calibrate/test properly the population synthesis models (especially the AGB phase).*
- *What about the HB colour (e.g. RGB mass loss)?*
- *What about α-enhancement at high metallicities ?*
- *Estimate/include effects related to the progeny of interacting binaries (blue stragglers ? Hot HB stars?…see works by Zhang et al.)*
- *Effect of interstellar dust (i.e. dust enshrouded AGB stars…. see e.g. works by Piovan et al.)*
- *IMF (universal, SFH dependent) ???*