Stellar models for population studies: some sticking points

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Maurizio Salaris

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OUTLINE

1. Efficiency of atomic diffusion
2. RGB mass loss
3. AGB evolution
4. Conclusions

ATOMIC DIFFUSION AND RADIATIVE LEVITATION

Element transport processes in radiative regions driven by P, T and chemical composition gradients , and by radiative pressure on individual ions

P (or g) gradient → Favours flow of heavier elements towards the centre

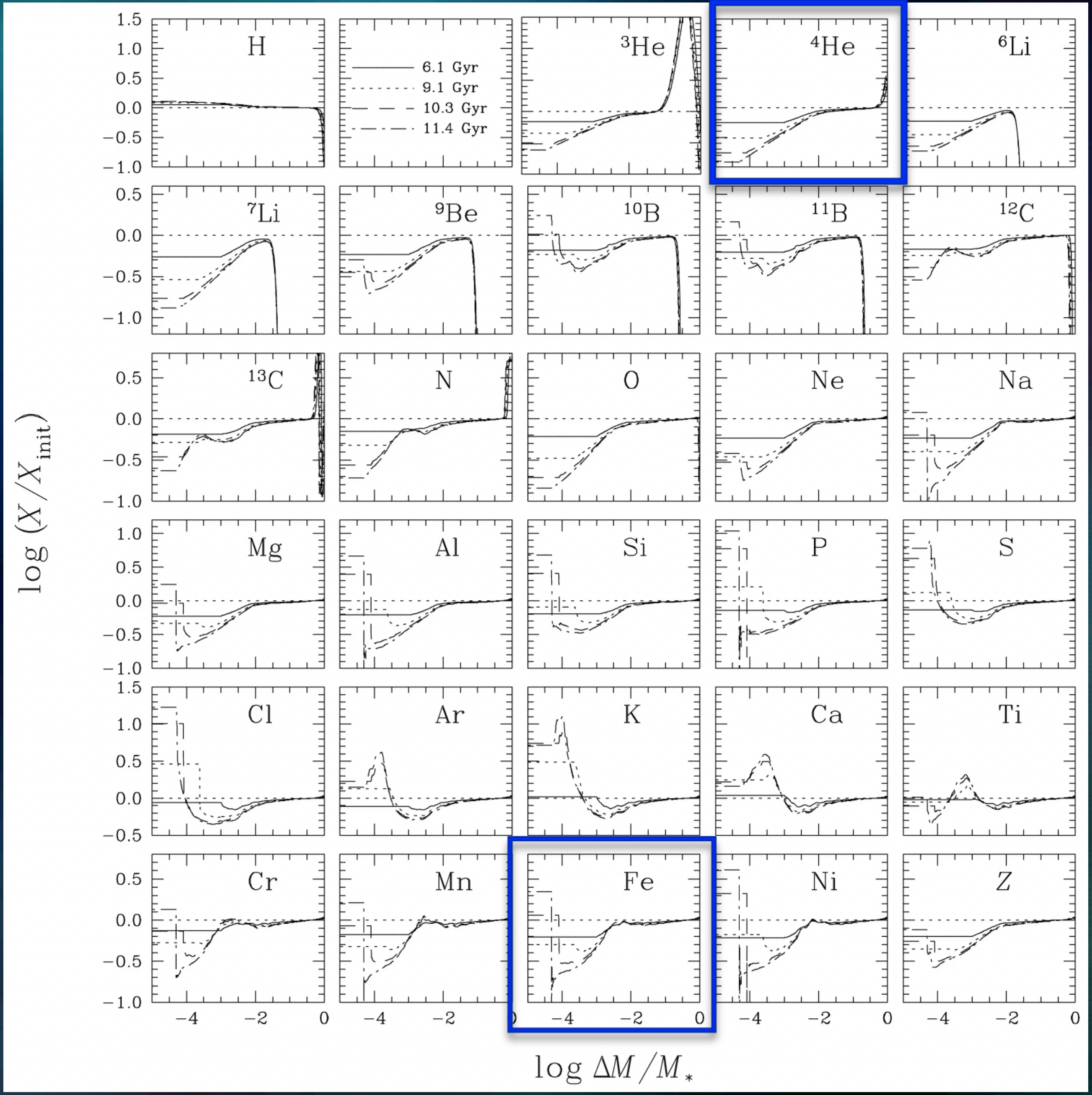
T gradient → Favours flow of heavier, higher charge elements towards the centre

Chemical composition gradients → Favour flow of elements in the direction of erasing the chemical gradients (essentially works in the opposite direction of the previous two effects)

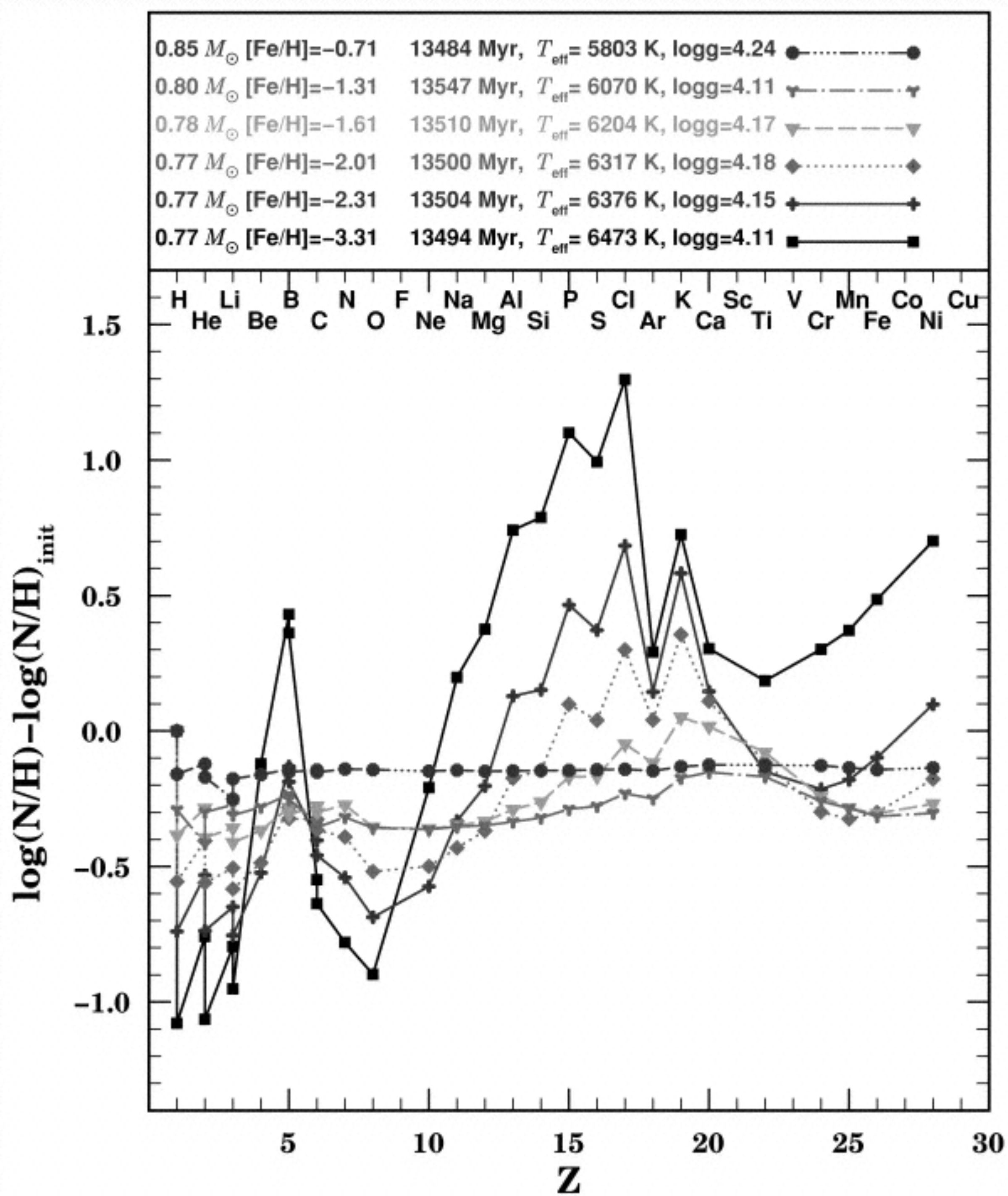
Radiative levitation → Pushes upwards individual elements whenever the acceleration imparted by the outgoing photon radiation is higher than the local gravity

The speed of the diffusive flow depends on the collisions with the surrounding particles as they share randomly the acquired momentum

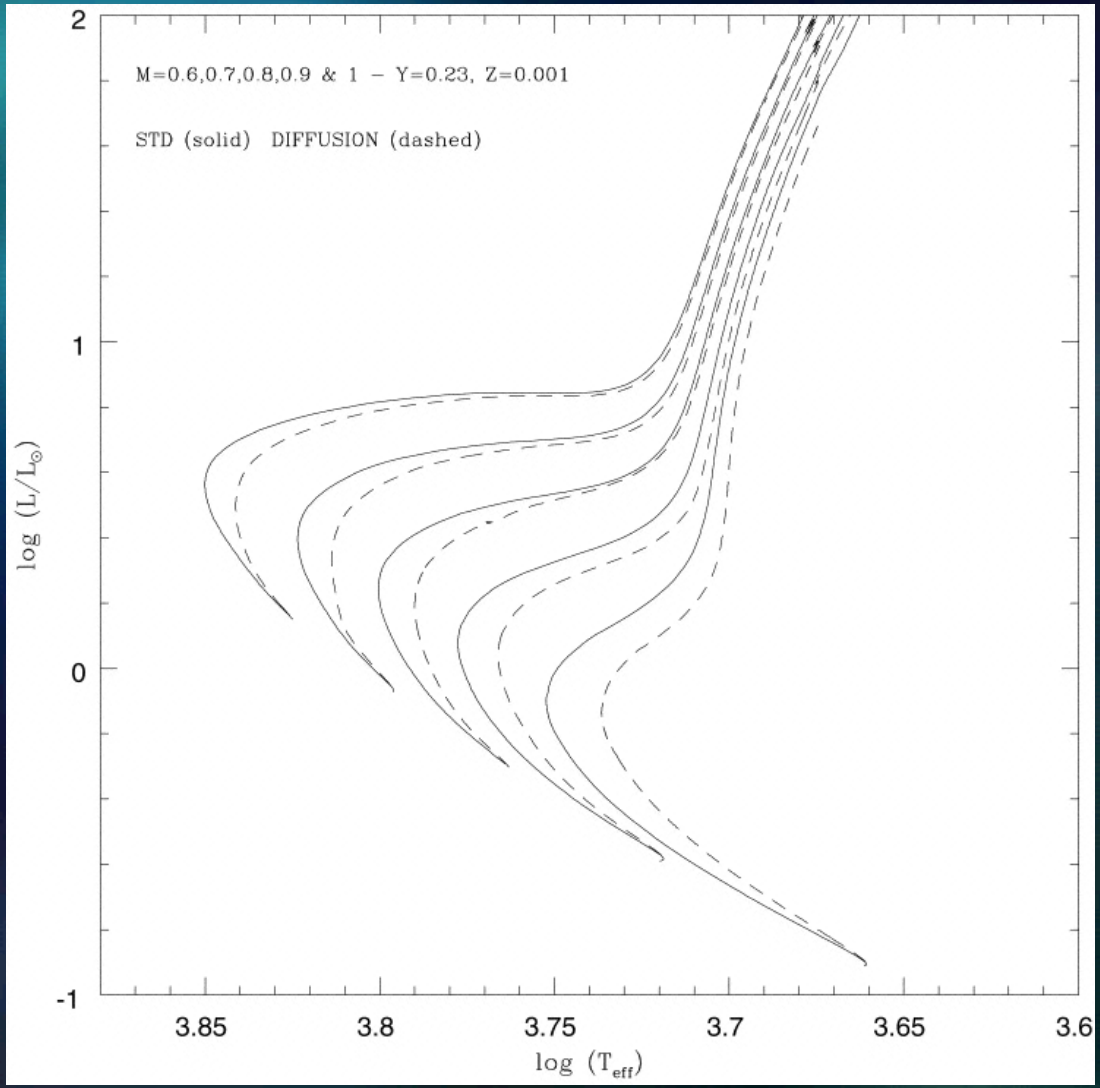
Internal abundance variations in a Population II star of 0.8 $M_\odot$ with [Fe/H] = -2.31



Richard et al. (2002)

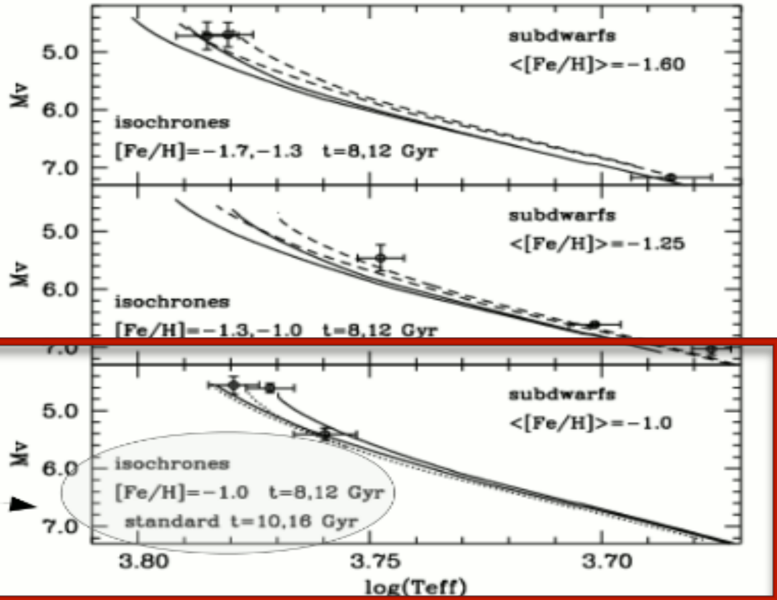


Predicted Turn off surface abundances as a function of initial (or RGB) [Fe/H] at 13.5 Gyr


M=0.6,0.7,0.8,0.9 & 1 – Y=0.23, Z=0.001
STD (solid) DIFFUSION (dashed)
log (L/L$_\odot$)
log (T$_{eff}$)
2
1
0
-1
3.85
3.8
3.75
3.7
3.65
3.6

Field star ages

Hipparcos parallaxes and IRFM effective temperatures



upper/middle panel: calibrated isochrones with two different [Fe/H]

lower panel: dotted: standard isochrones

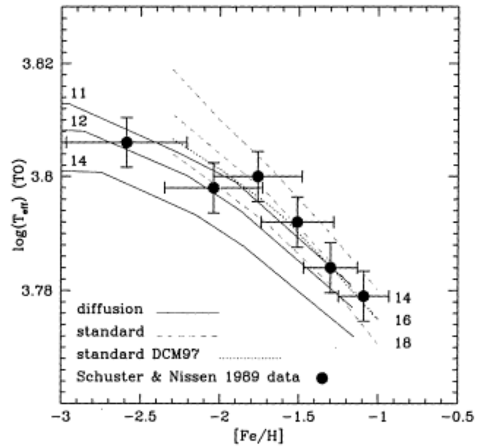
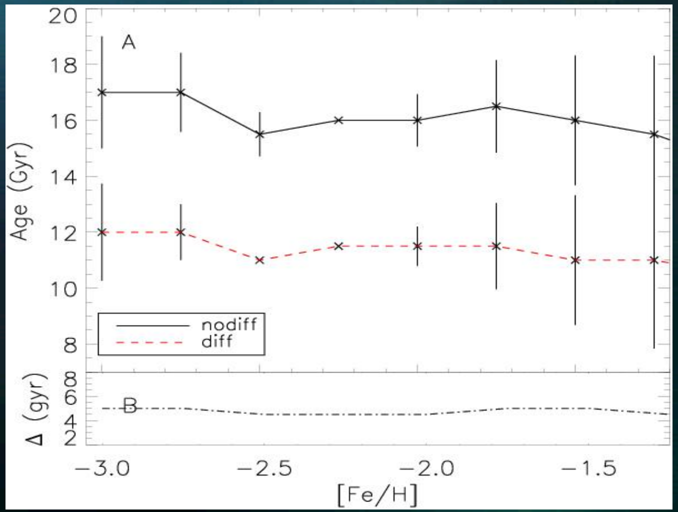


Figure 2. Age determination of the field halo population by comparing the $T_{\rm eff}$ of turnoff stars with the predictions of theoretical isochrones, with and without diffusion. The isochrone ages are in Gyr.

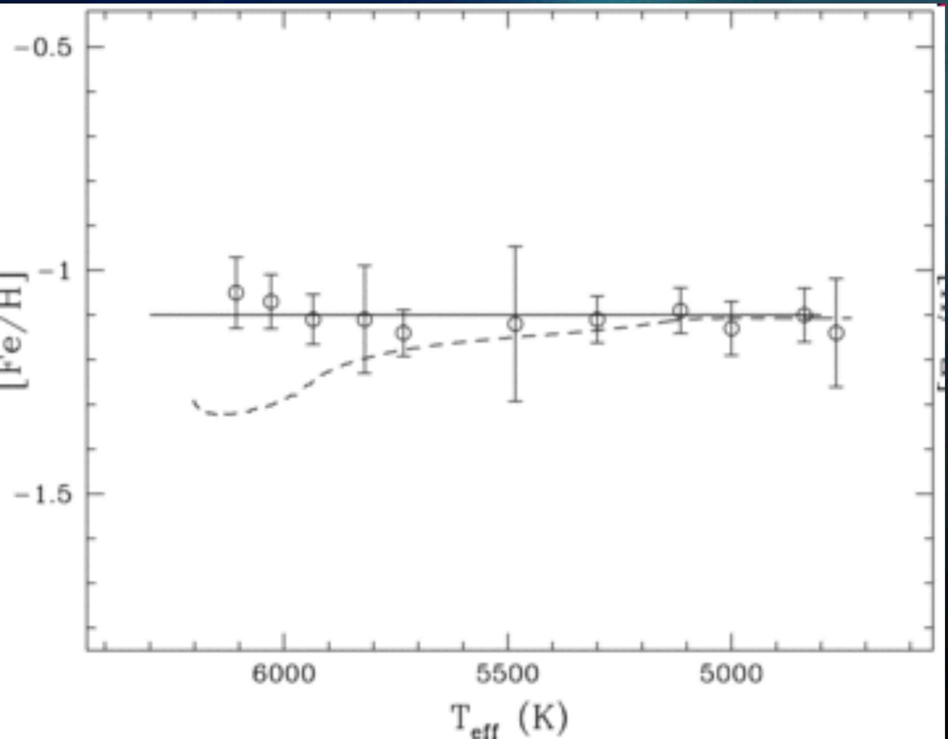
Salaris & Weiss (2001)



Jofre & Weiss (2011)

Observationally diffusion (at least from convective envelopes) seems to be less efficient than predicted

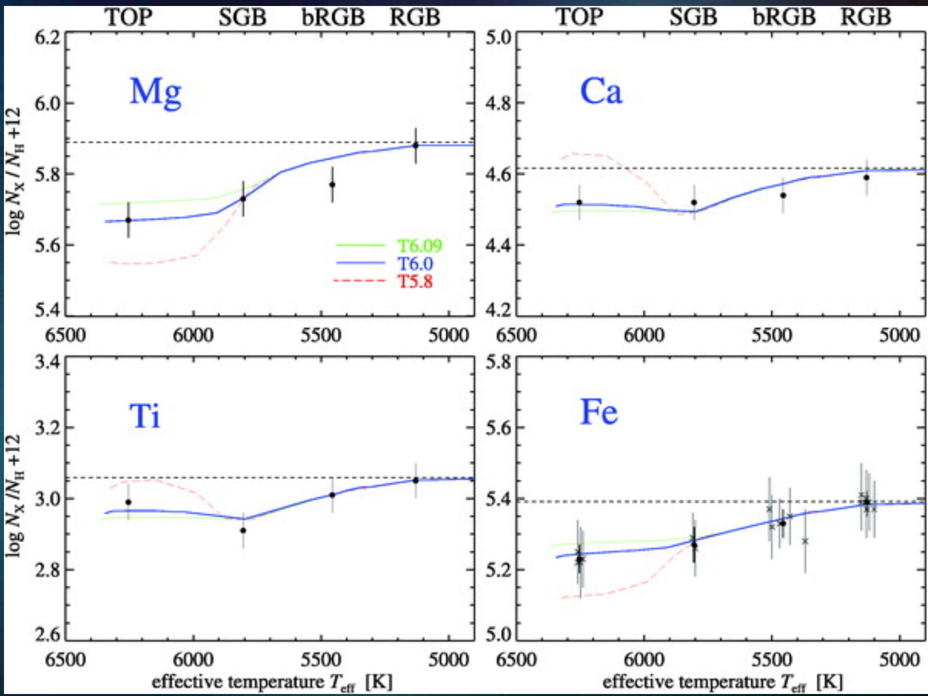
M4 Mucciarelli et al. (2011)



NGC6397

Korn et al. (2006, 2007)

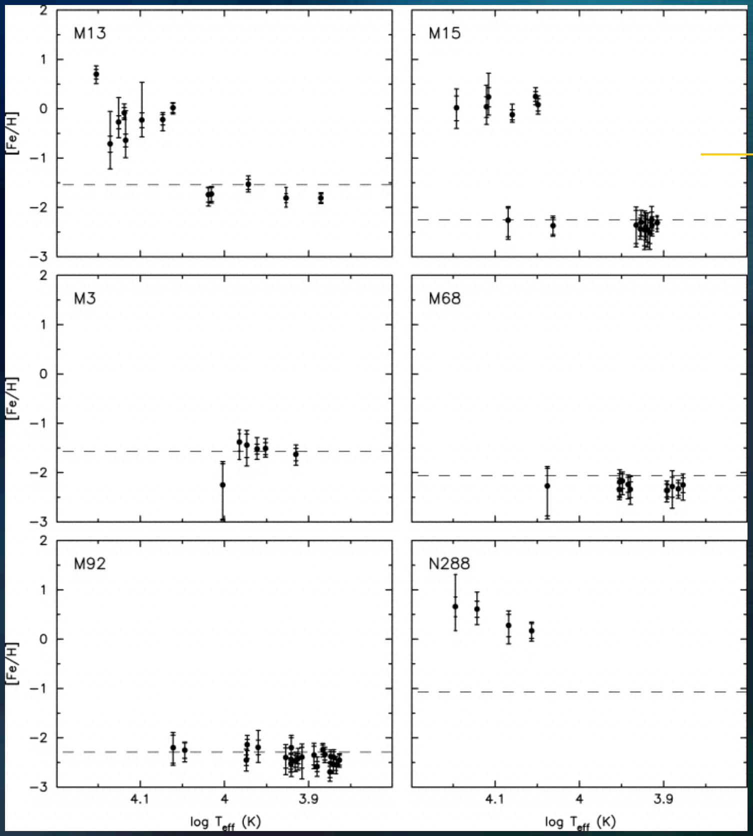
Models by Richard et al. (2005)

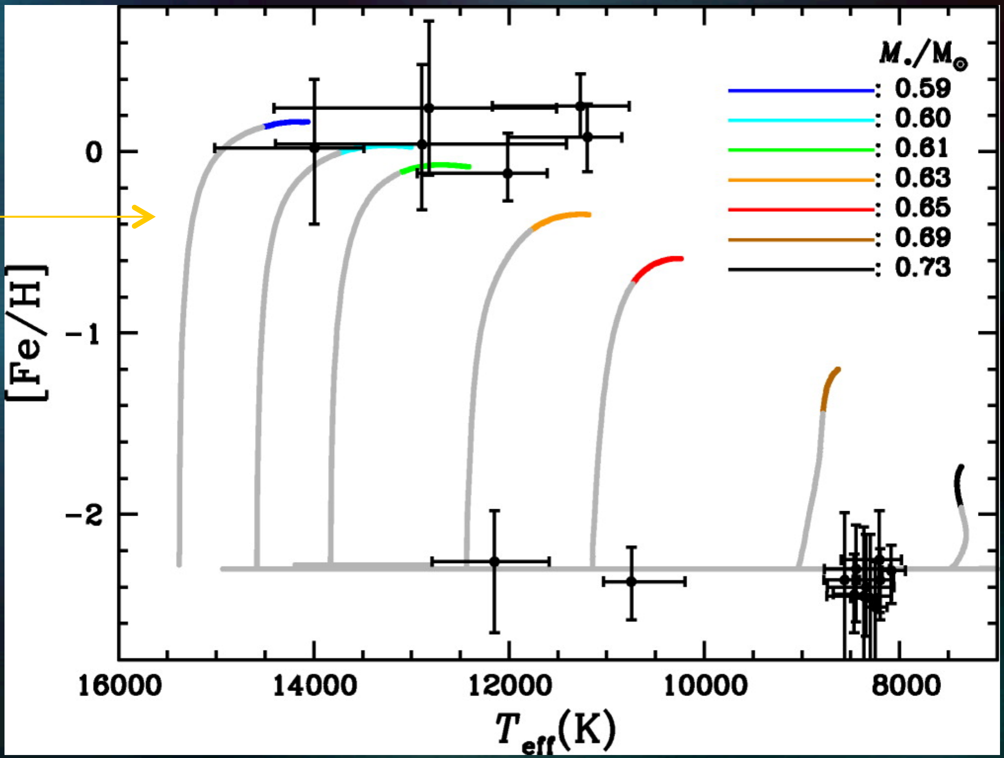


Diffusion + levitation on the hot HB

Elements like Mg and Si remain nearly invariant all along the HB (with the same RGB abundances) while above 11500 K He is underabundant and Fe, Ti, P, Cr, Mn, Ni are enhanced by factors ≈100.

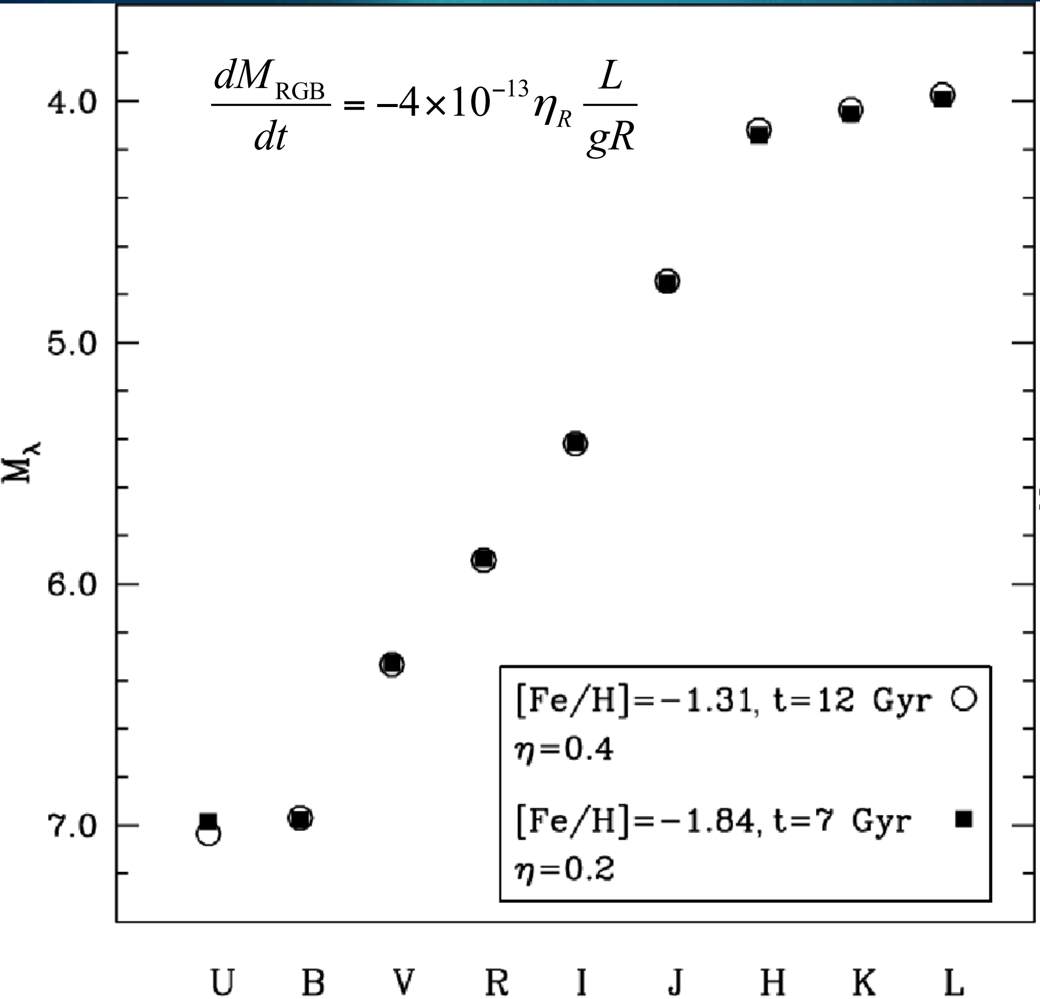
Behr (2003)

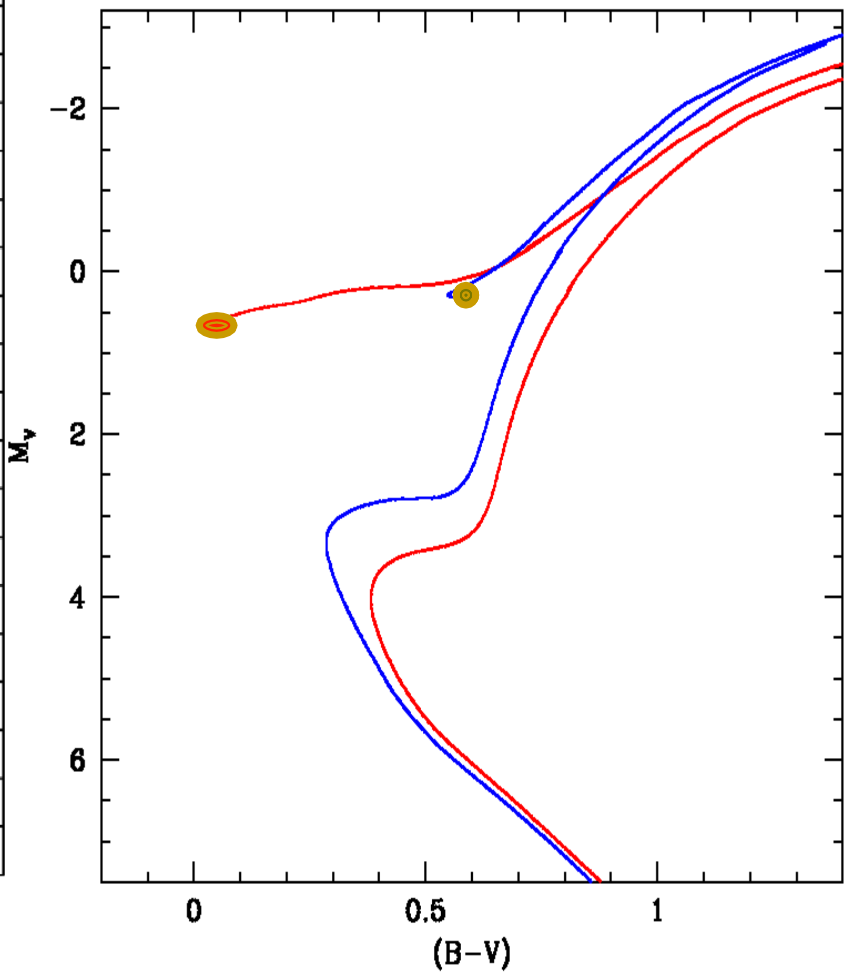




Michaud et al. (2008)

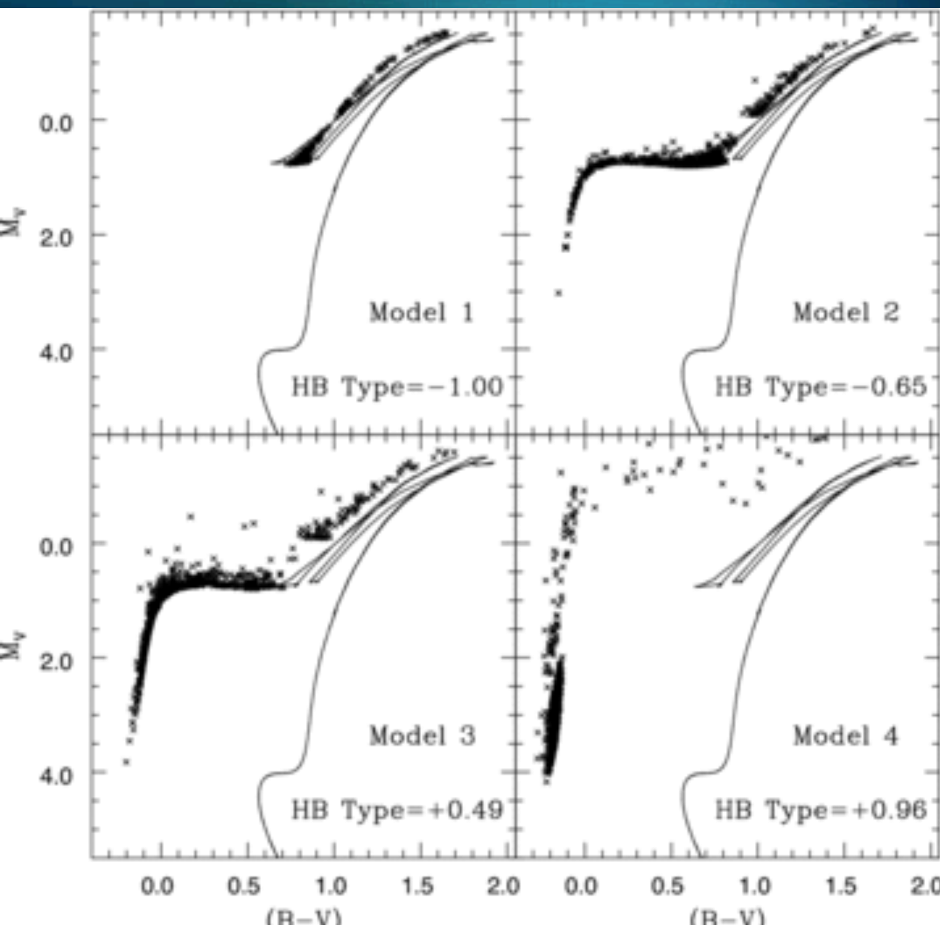
Mass loss on the RGB

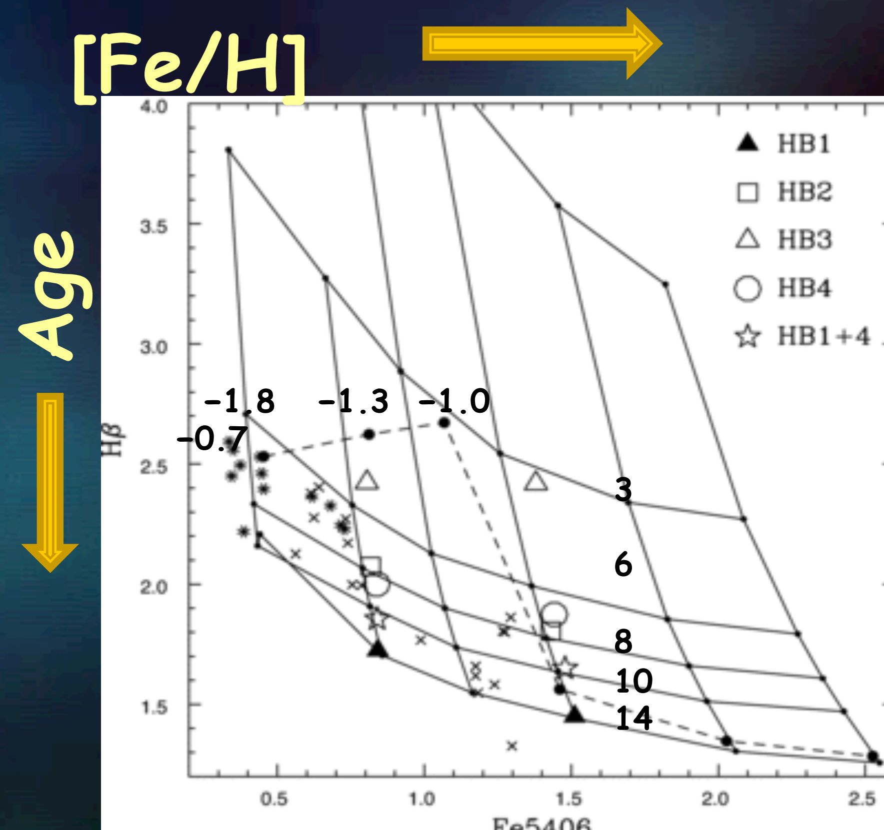




HB and spectral indices

[Fe/H]=-0.70





η= 0.2 reference grid

Percival et al. (2011)

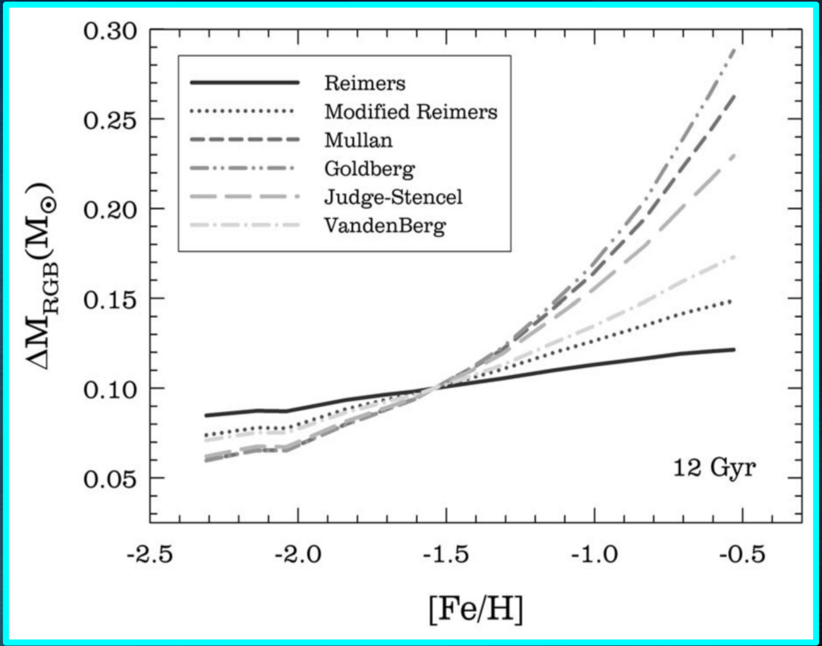
Crosses and asterisks are observational data for Galactic GCs from Schiavon et al. (2005)- the asterisks denote clusters with HB type > 0.8 (i.e. predominantly blue)

Parametrization of the RGB mass loss

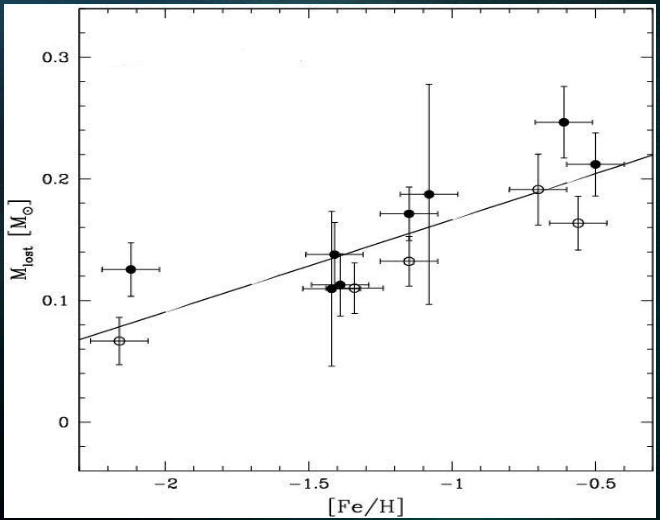
Reimers' law

$$\frac{dM_{\mathrm{RGB}}}{dt} = -4\times10^{-13}\,\eta_R\,\frac{L}{gR}$$

free parameter



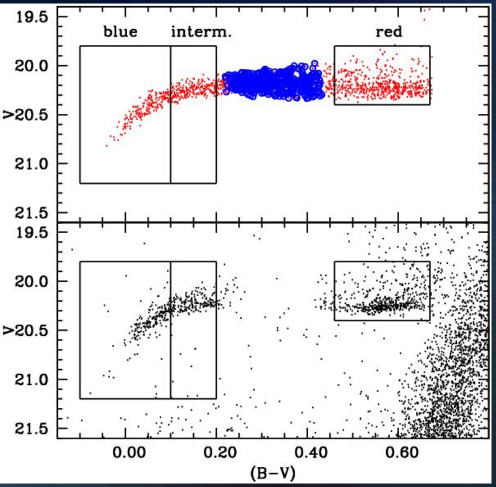
Origlia et al. (2014)

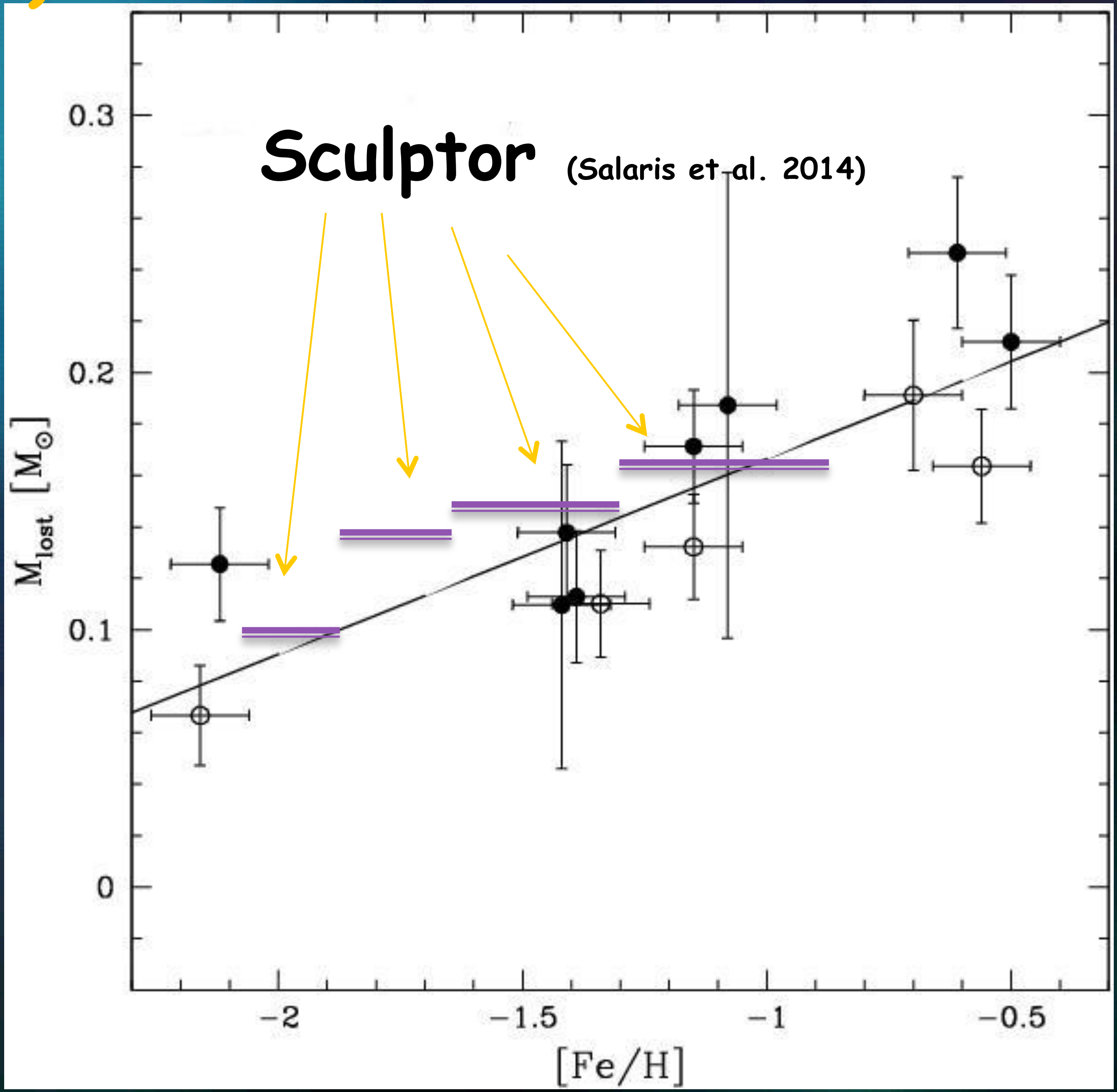


From excess of mid-infrared light due to dust formation in the mass flowing from the photosphere

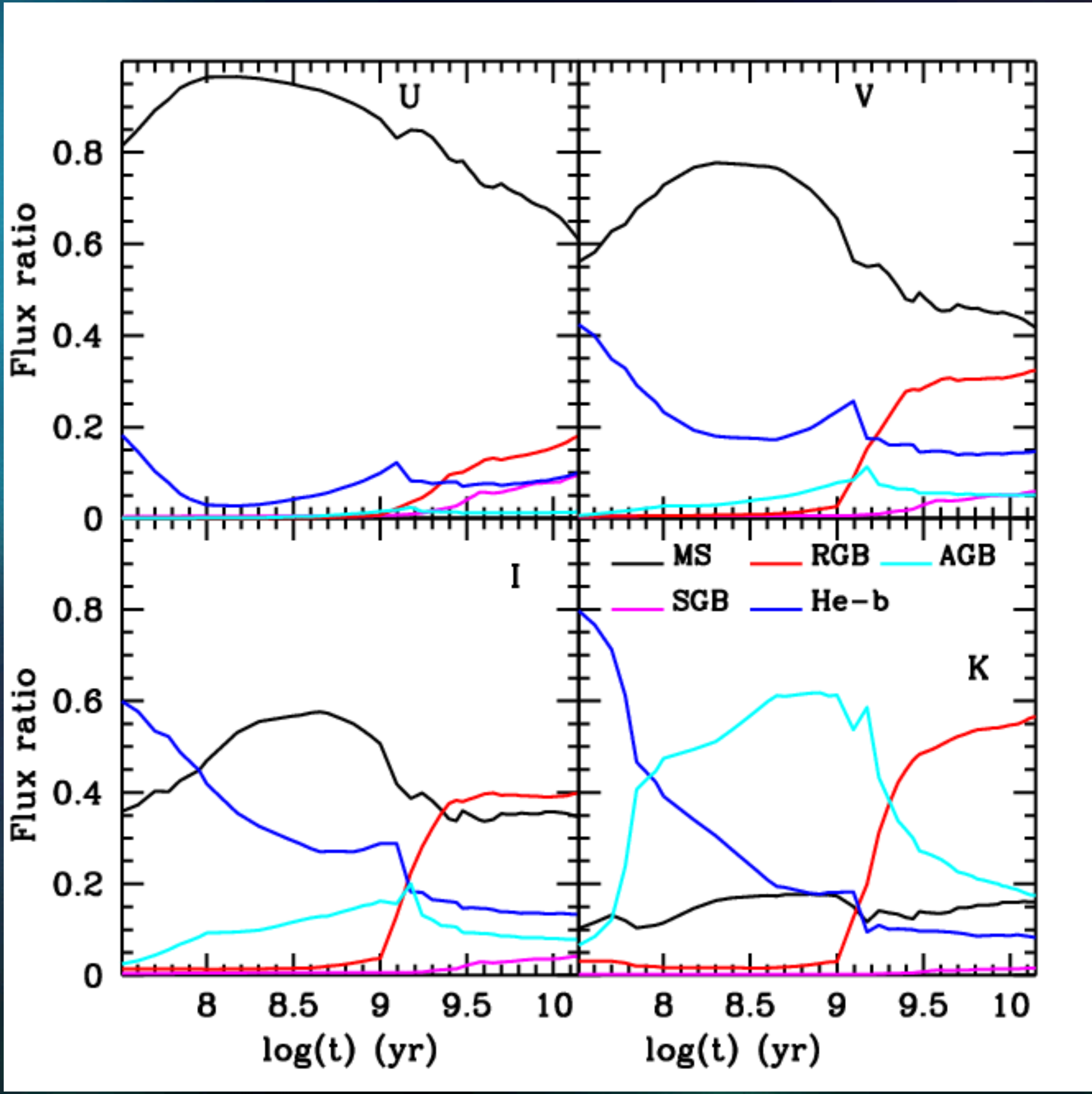
Empirical (GGCs) vs Estimates from HB morphology (dwarf galaxies)

Sculptor
HB



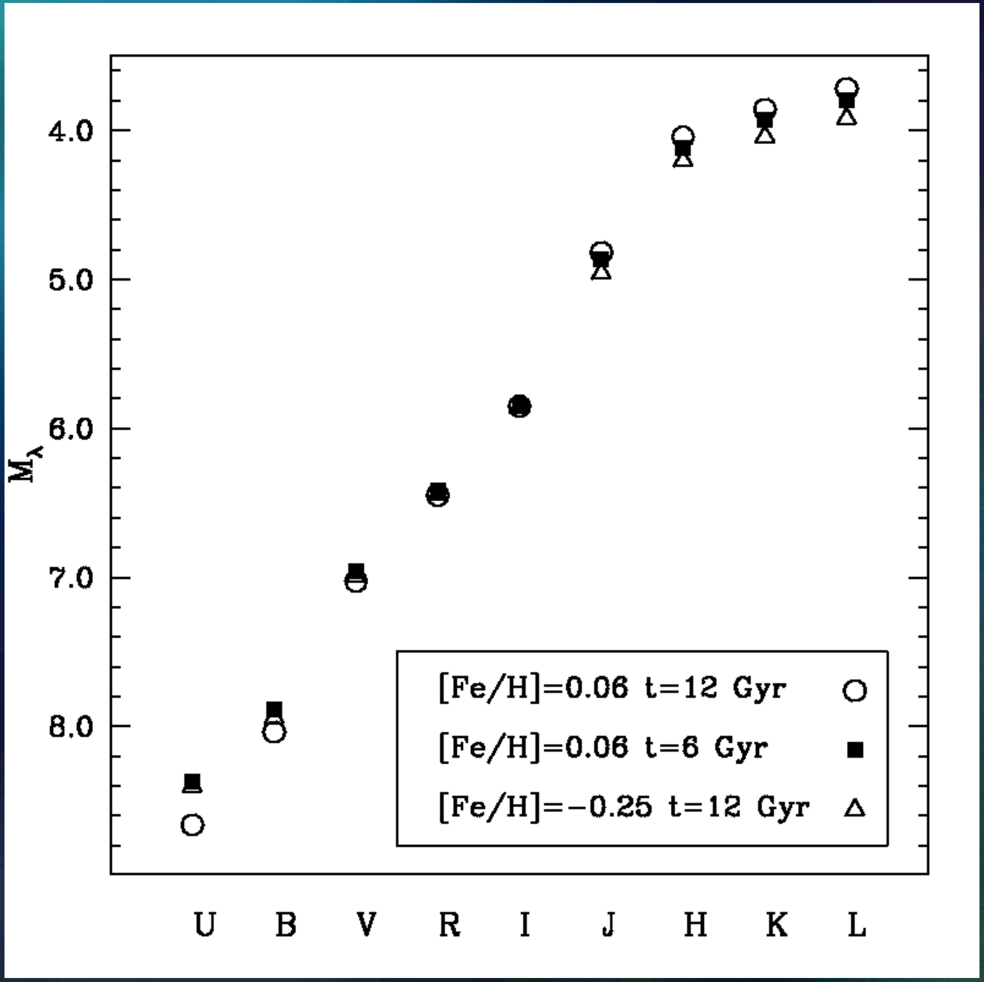


AGB



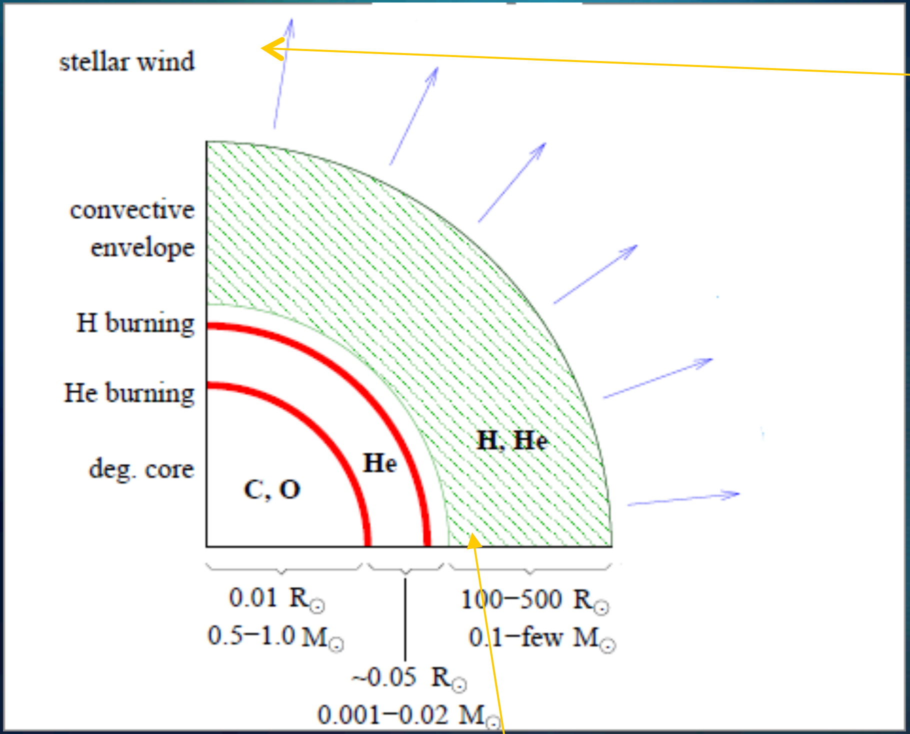
U
V
I
K
Flux ratio
0
0.2
0.4
0.6
0.8
8
8.5
9
9.5
10
log(t) (yr)
MS
RGB
AGB
SGB
He-b

Age-metallicity degeneracy

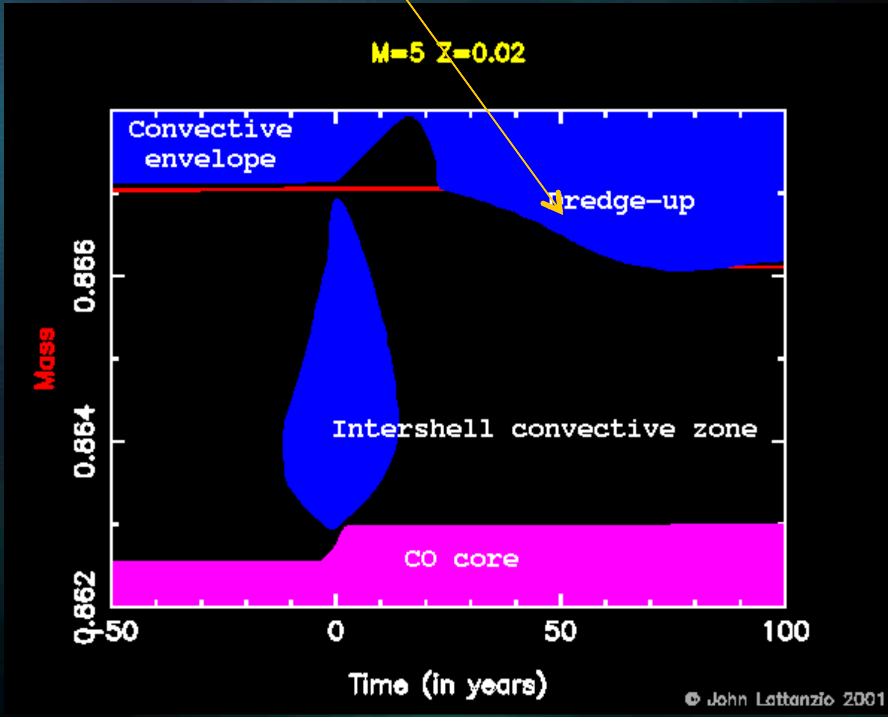


One needs to use jointly blue-visible and near-IR magnitudes to minimize the age-metallicity degeneracy

Structure of an AGB star

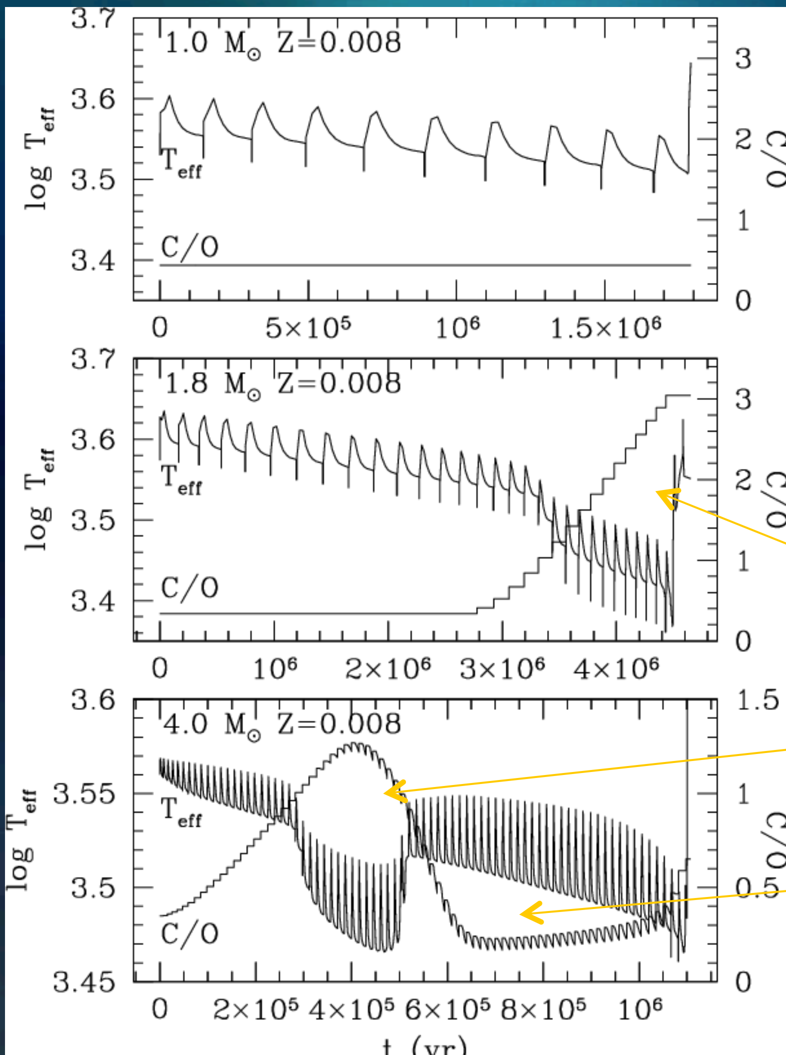


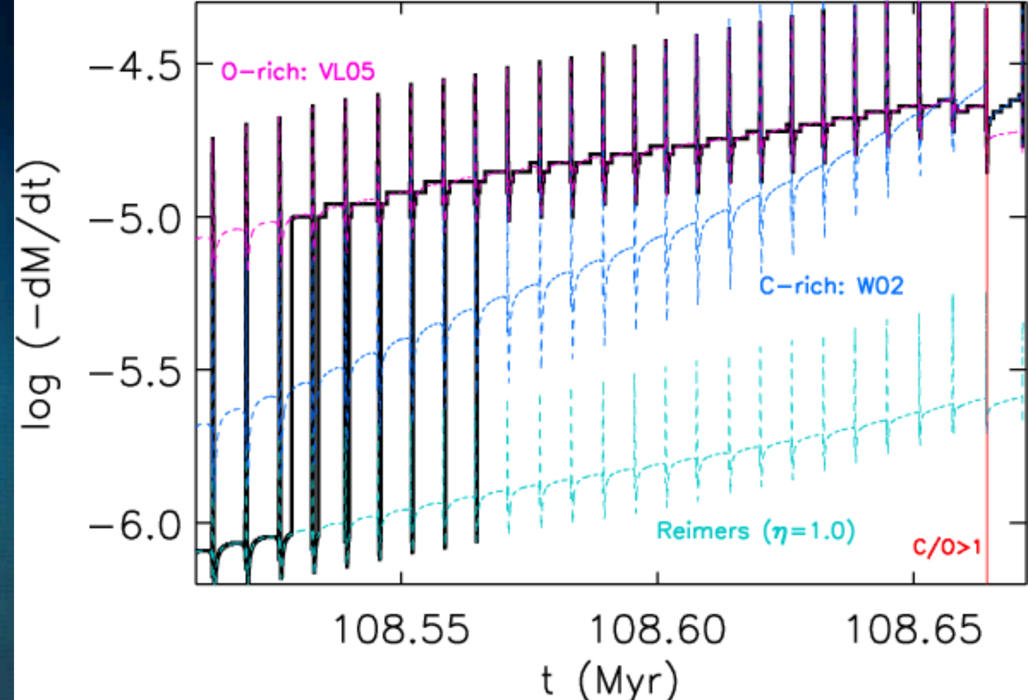
uncertain



Hot Bottom Burning (for large enough masses)

Weiss & Ferguson (2009)





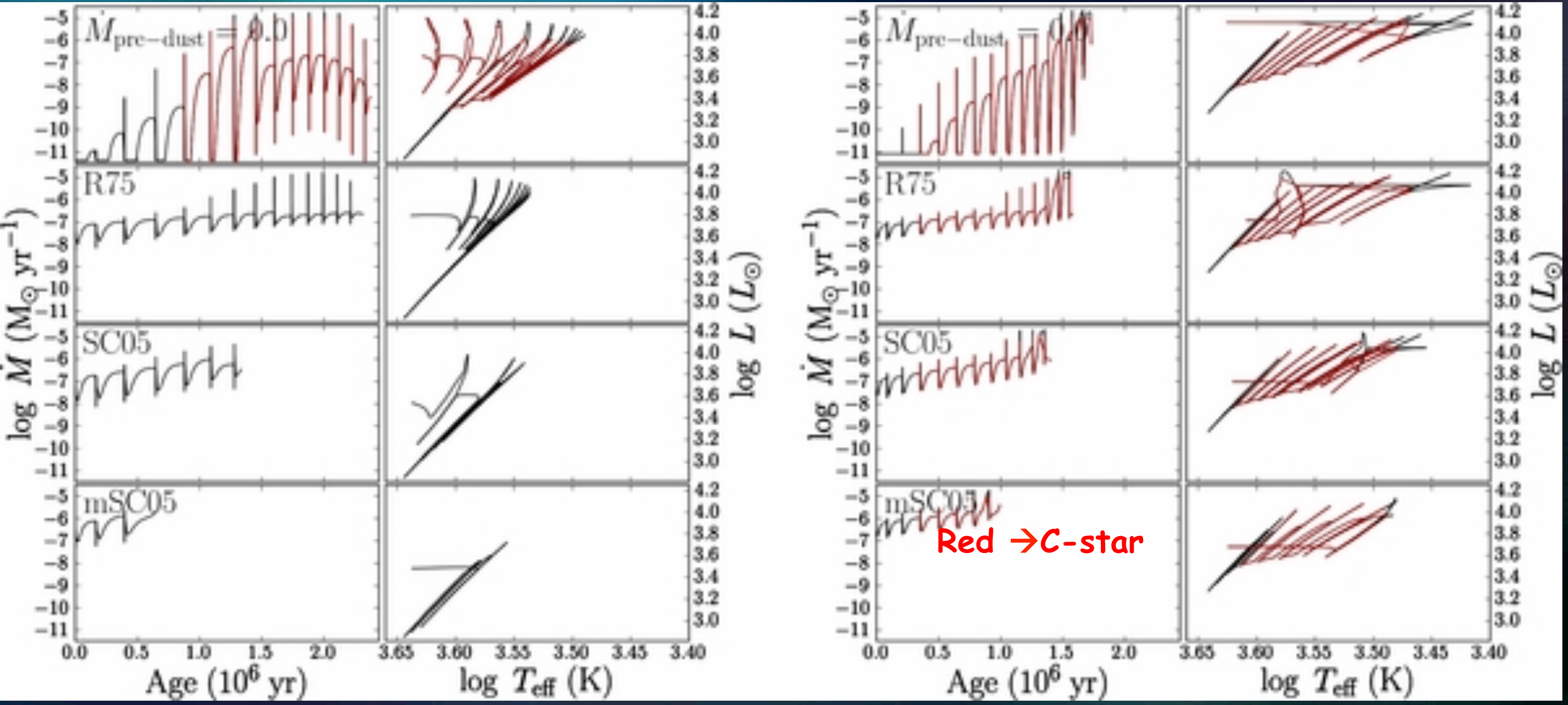
Importance of mass loss choice

Importance of 3rd dredge up efficiency

Importance of hot bottom burning efficiency

Marigo & Girardi (2007)

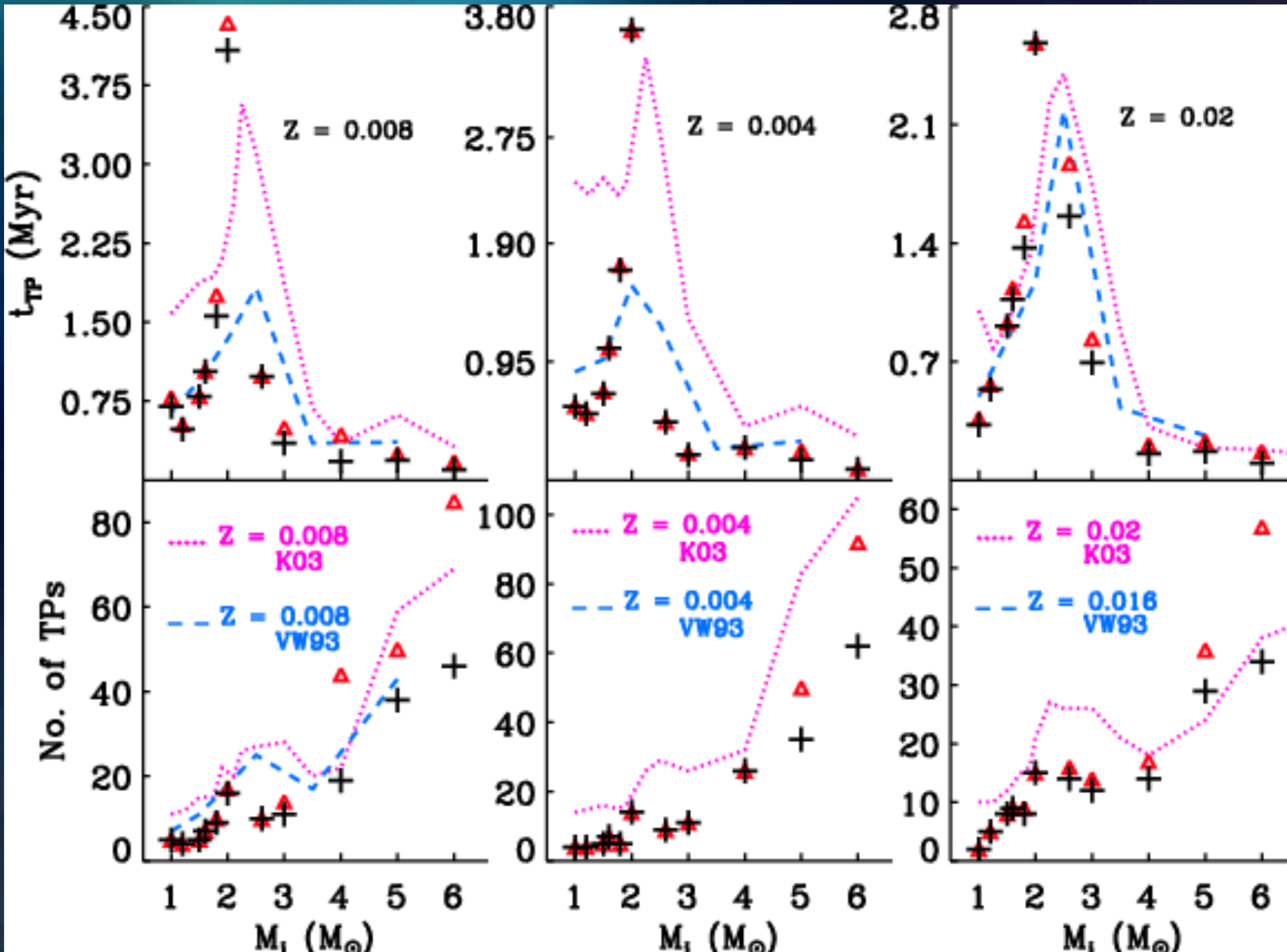
Mass loss



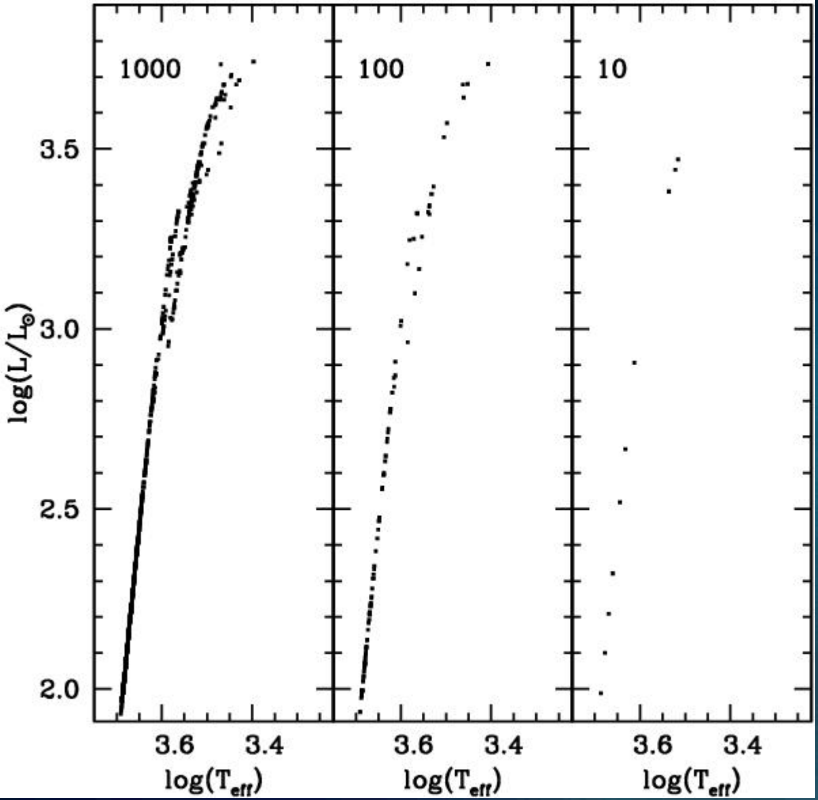
Rosenfield et al (2014)

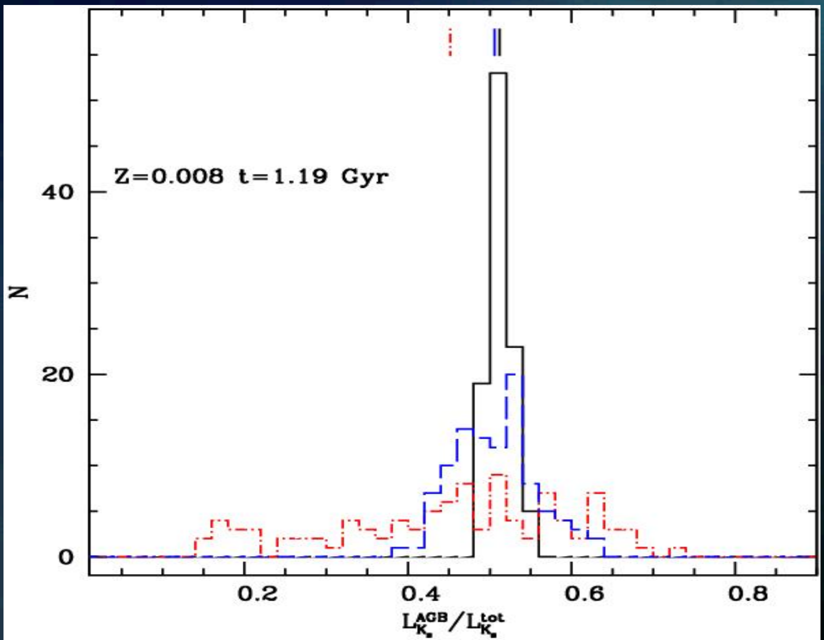
Four different prescriptions for mass loss before the TPs (1 and 2 $M_\odot$ models) (Z=0.001)

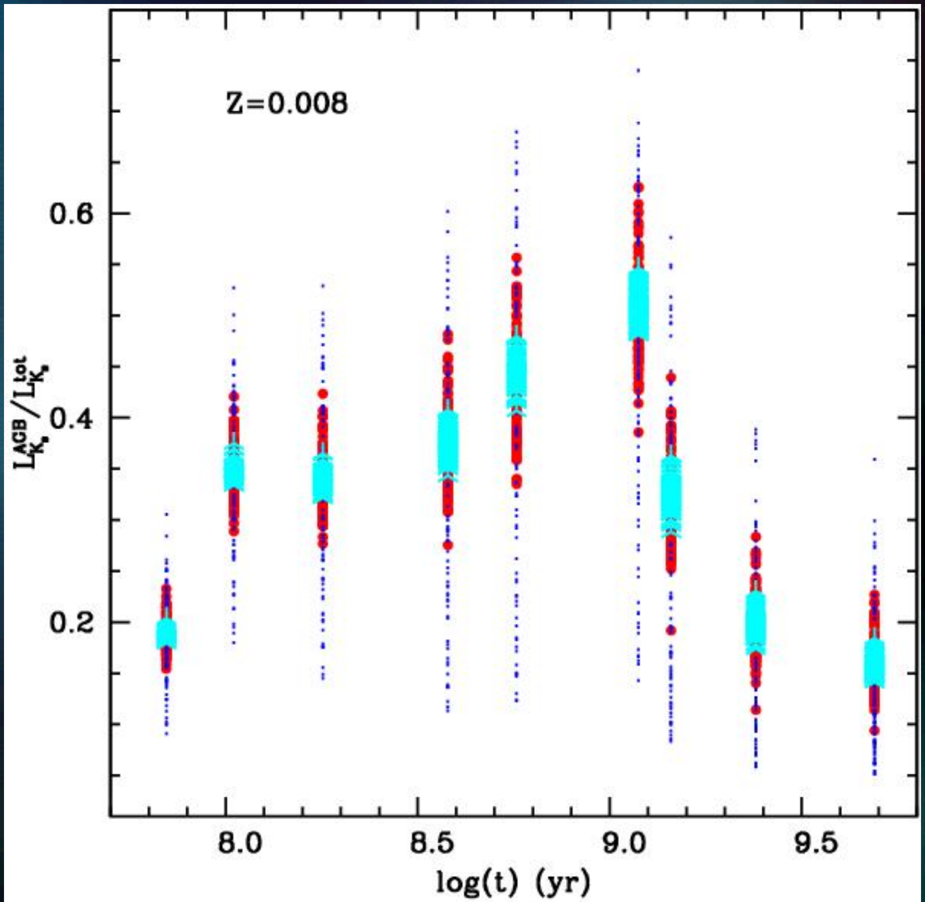
Weiss & Ferguson (2009)



Calibration on star clusters: Stochastic fluctuations

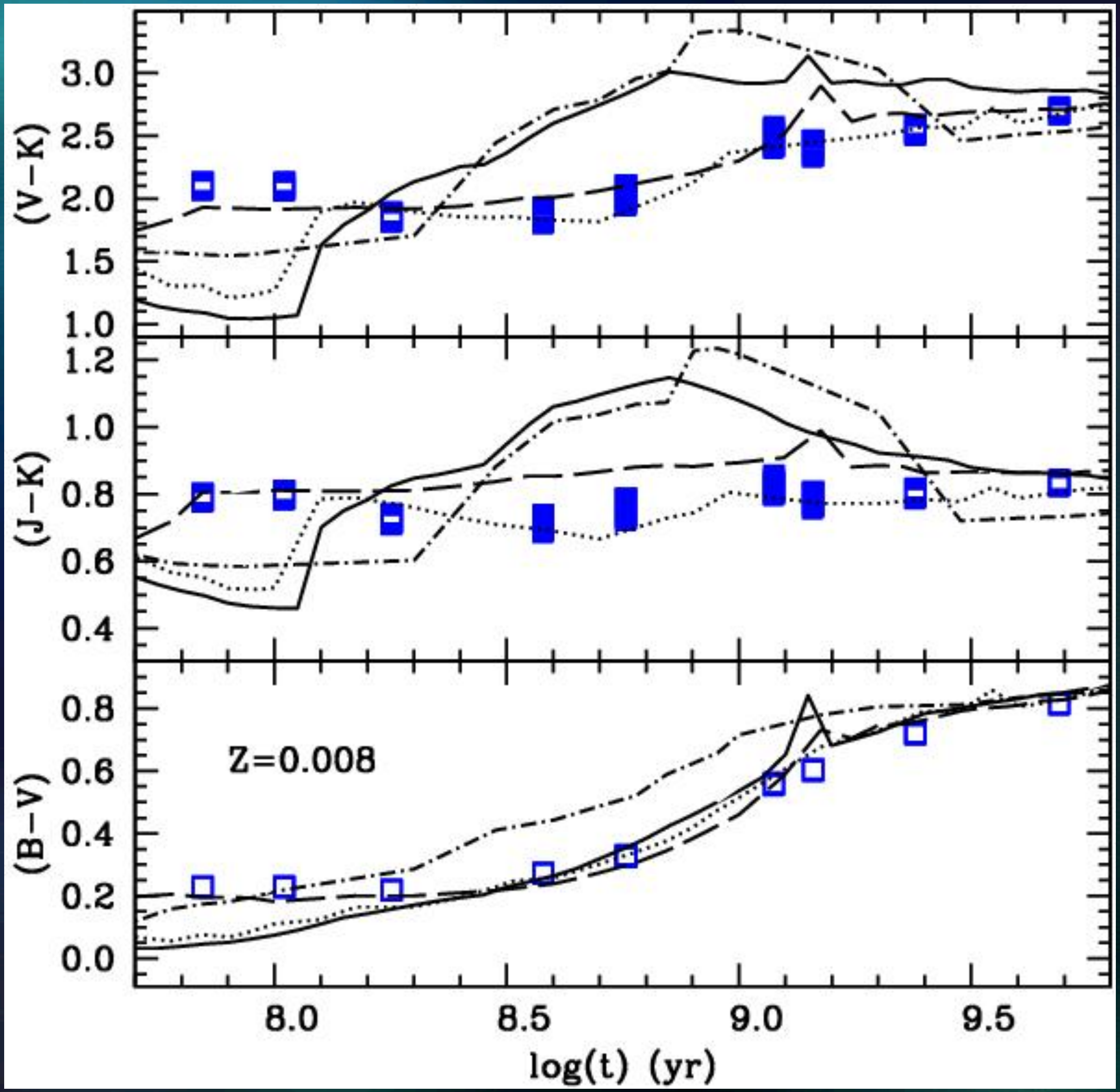




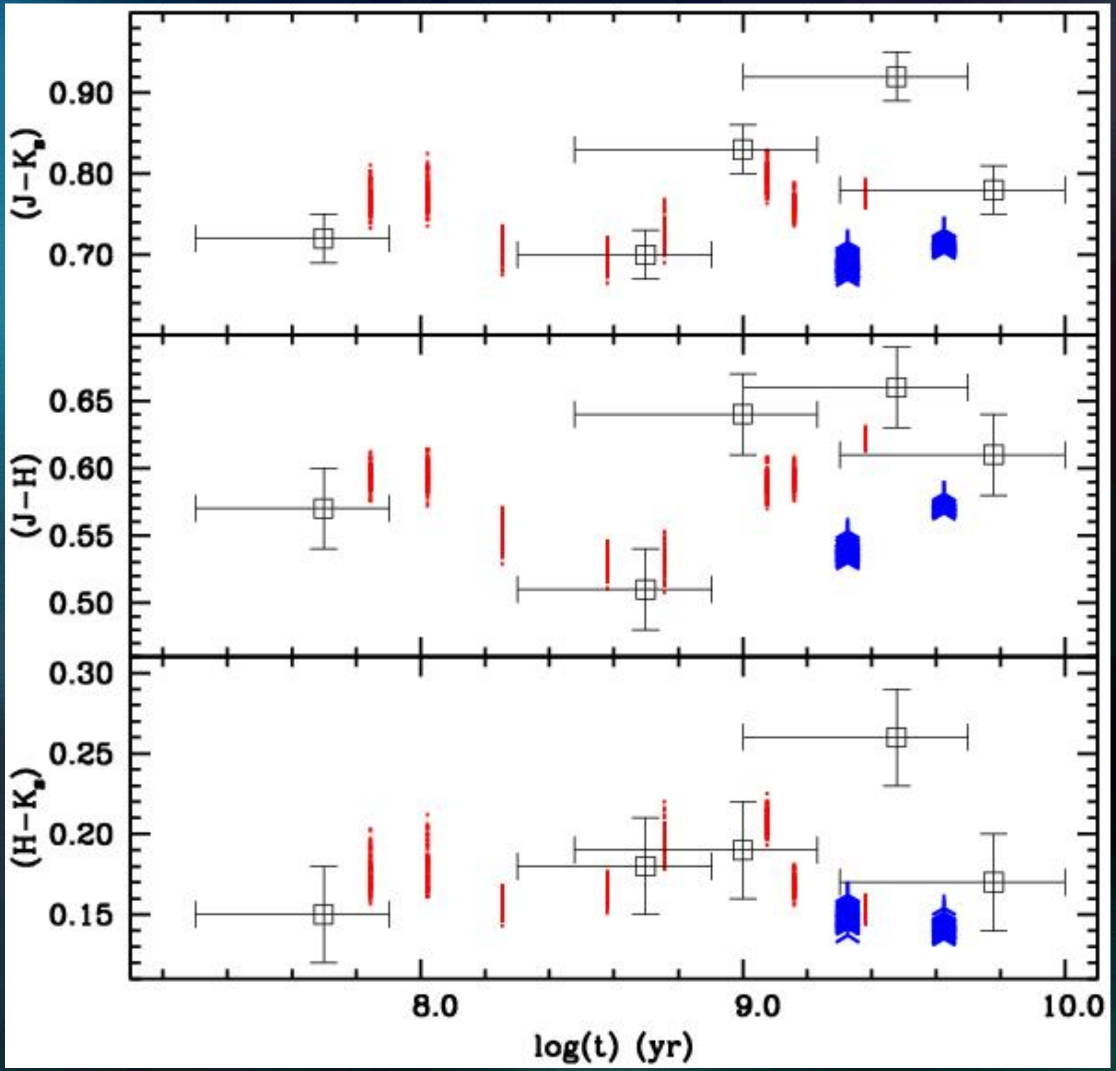


Salaris et al. (2014)

Different predictions of integrated colours



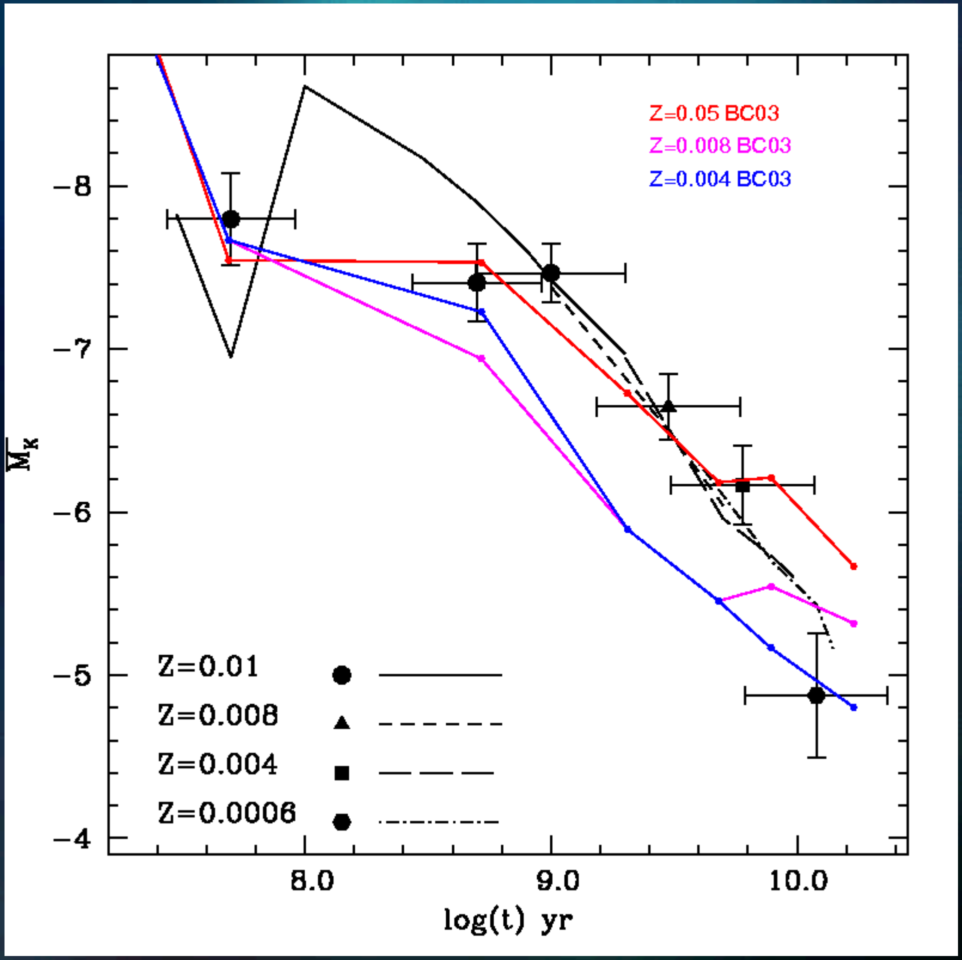
LMC and SMC superclusters



Salaris et al. (2014)

Use SBF for calibration/test of models ?

Distance fixed



Definition of fluctuation luminosity

$$\bar{L} \equiv \frac{\Sigma n_i L_i^2}{\Sigma n_i L_i}$$

Data from Gonzalez et al. (2004)

Reproducing the AGB star counts in resolved galaxies with known SFH

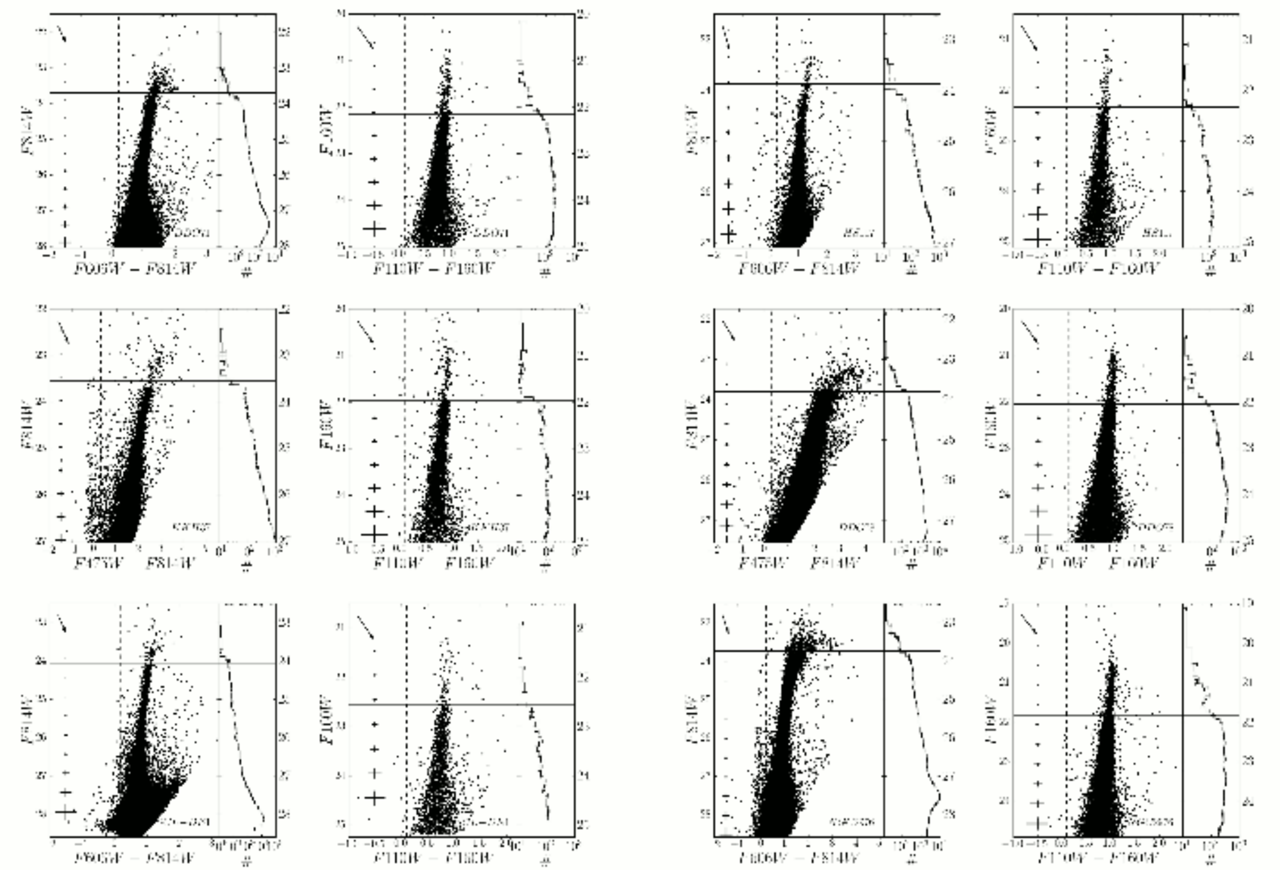
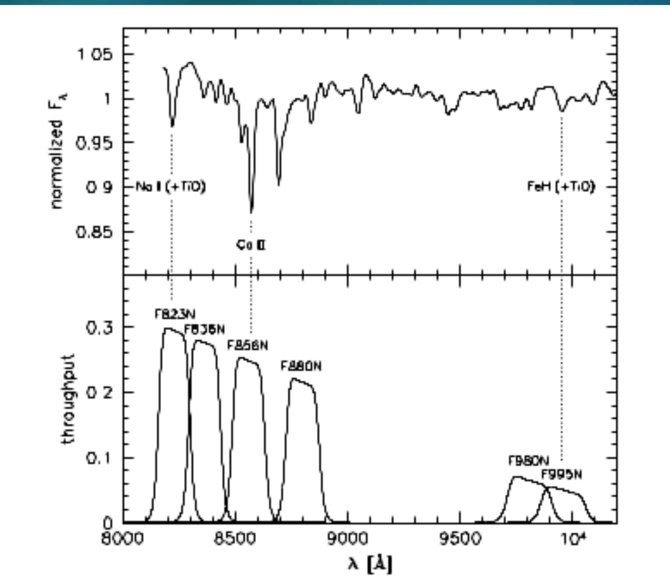


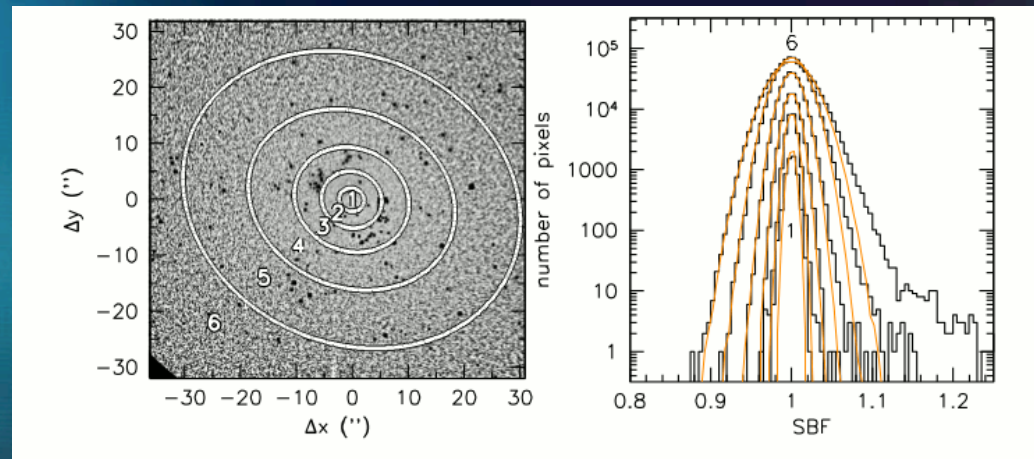
Figure 1. Color magnitude diagrams and luminosity functions of the galaxy sample. Each CMD shows typical photometric uncertainties as a function of magnitude and each LF shows Poisson uncertainty in each bin. Reddening arrows for 0.5 mag extinction are shown in the upper left of each CMD. Horizontal lines mark the TRGB (Dalcanton et al. 2009) and vertical lines mark the color cut discussed in Section 2.3.

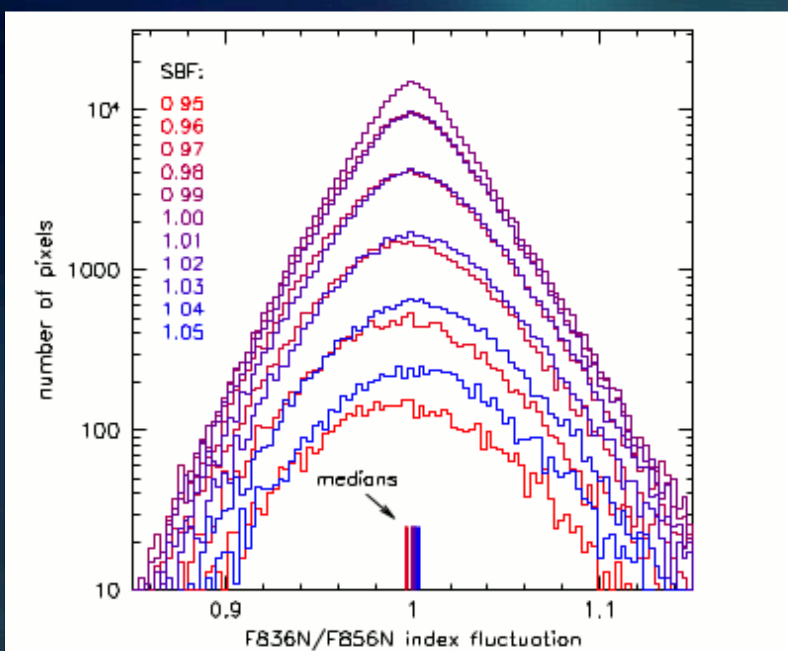
Rosenfield et al. (2014)

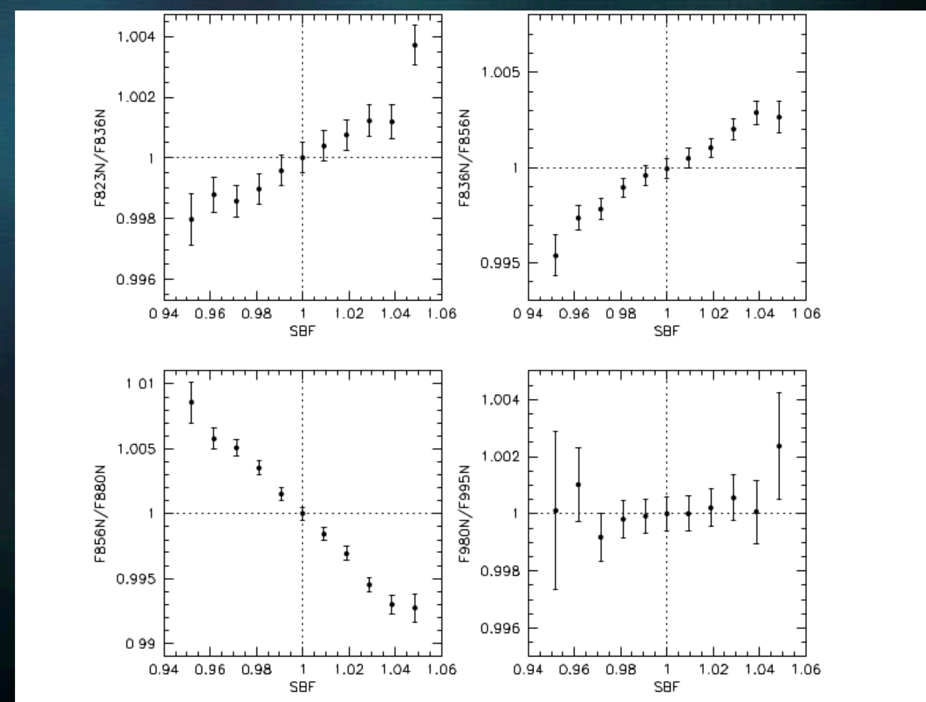
Spectral fluctuations

Van Dokkum & Conroy (2014)









CONCLUSIONS IN A NUTSHELL

EFFICIENCY OF ATOMIC DIFFUSION →

spectroscopy from the MS well below the TO to the RGB (HIRES)

RGB MASS LOSS →

dusty circumstellar envelopes (METIS)

asymmetries chromospheric lines (HIRES)

SFH determination dwarf galaxies and HB modelling (MICADO)

AGB CALIBRATION →

Spectral fluctuations (HARMONY)

SFH plus synthetic AGB modelling (MICADO)