Stellar populations and masses of high redshift galaxies

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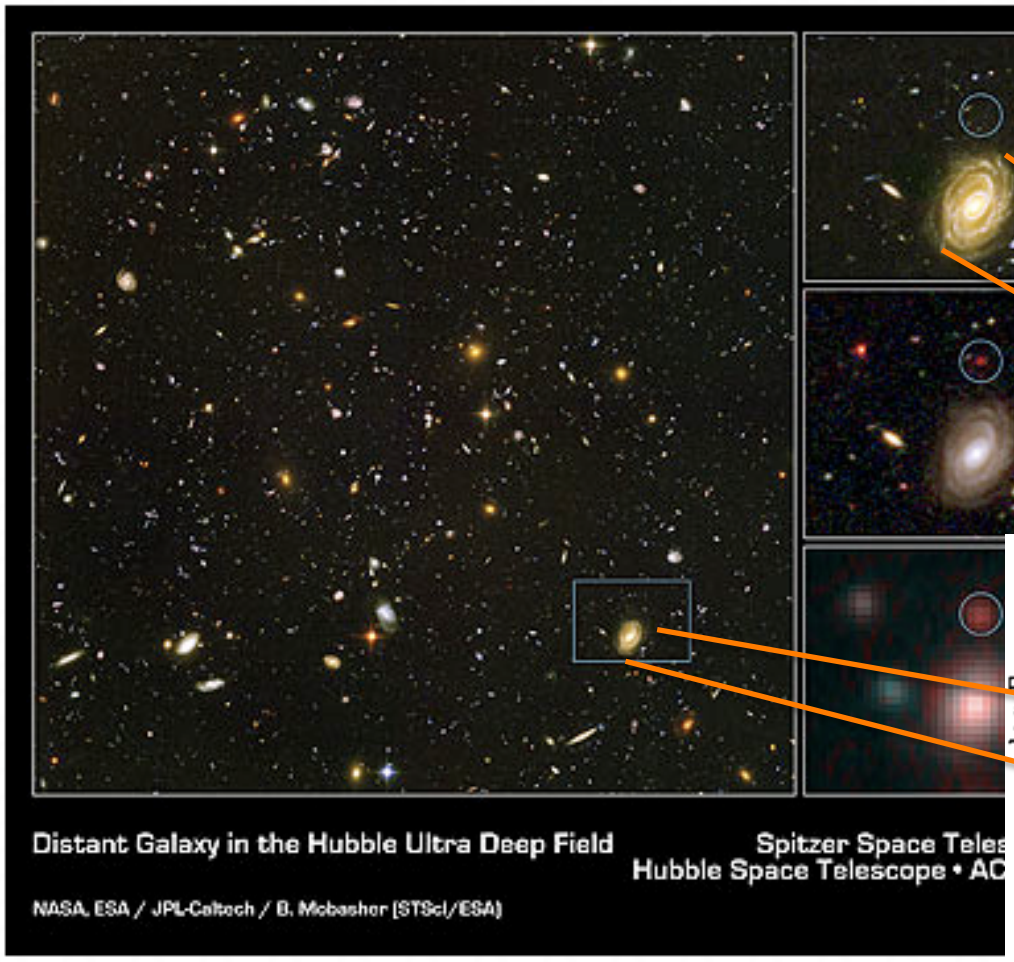
From Galaxies to Exo-Planets – the Spitzer growing legacy
Pasadena – 26-28 October 2009

Outline

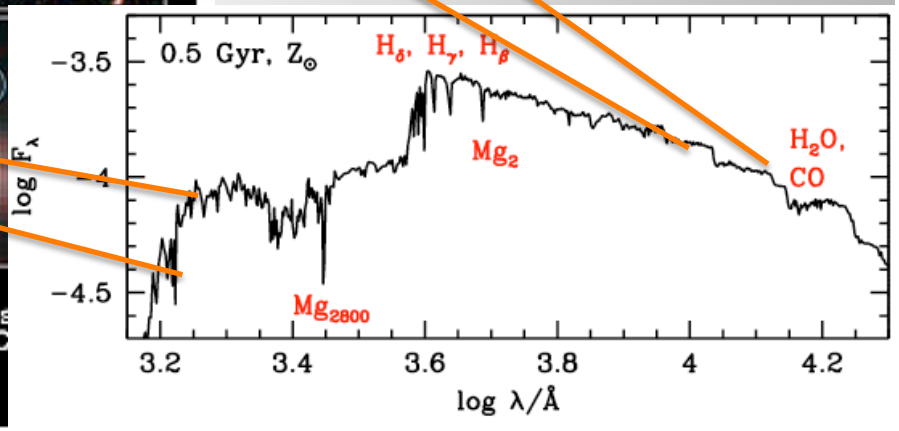
- Stellar populations and masses of high-z galaxies
  - Interpretative models
  - The role of Spitzer data
- Decoding galaxy evolution: a new mode of star formation
- Predicting galaxy evolution: semi-analytic models with TP-AGB stars

From light to galaxy physics



NASA, ESA/JPL-Caltech/B. Moba

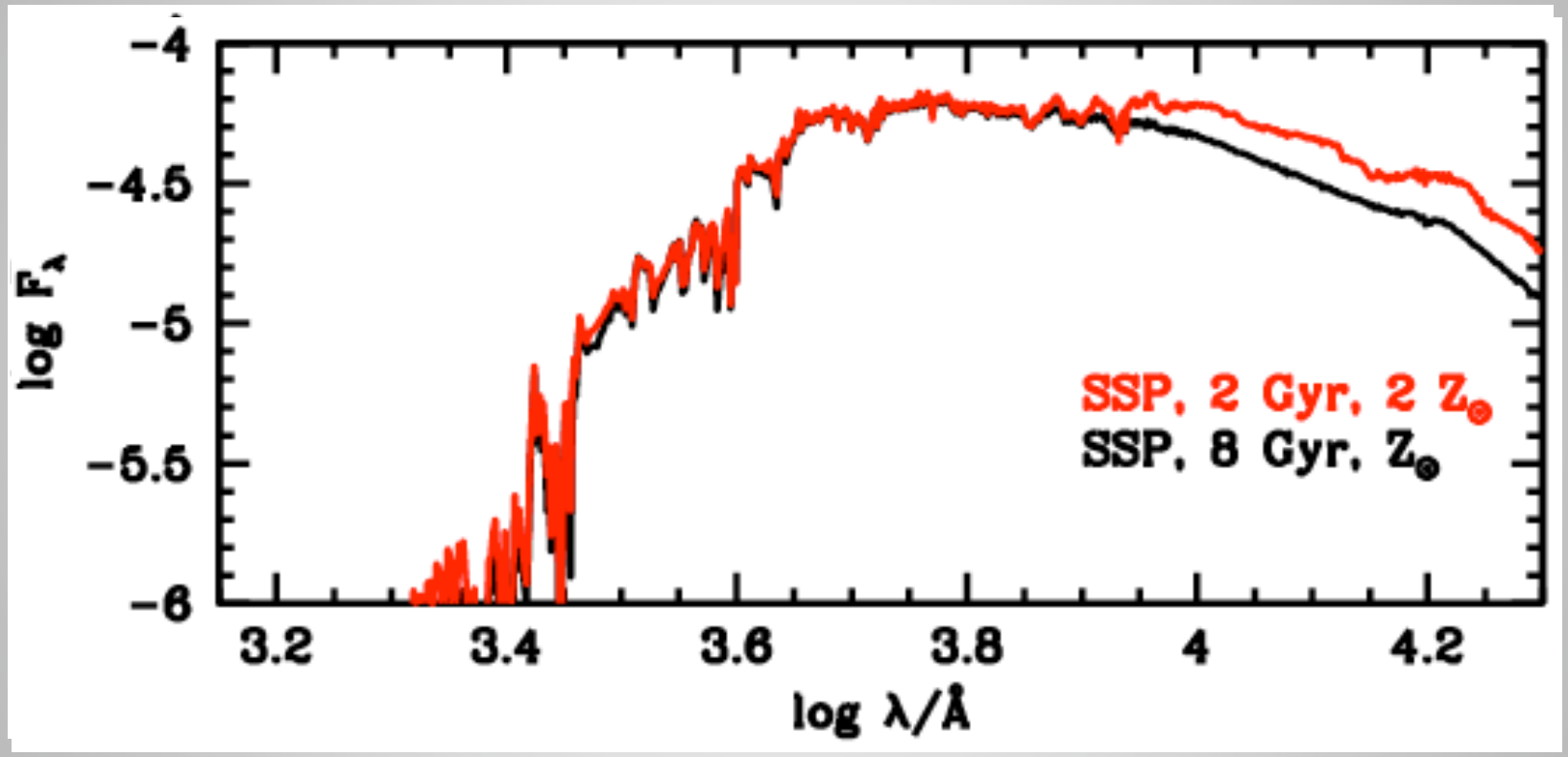
Stellar Population model



age, star formation history, chemical composition
stellar mass, photometric redshift

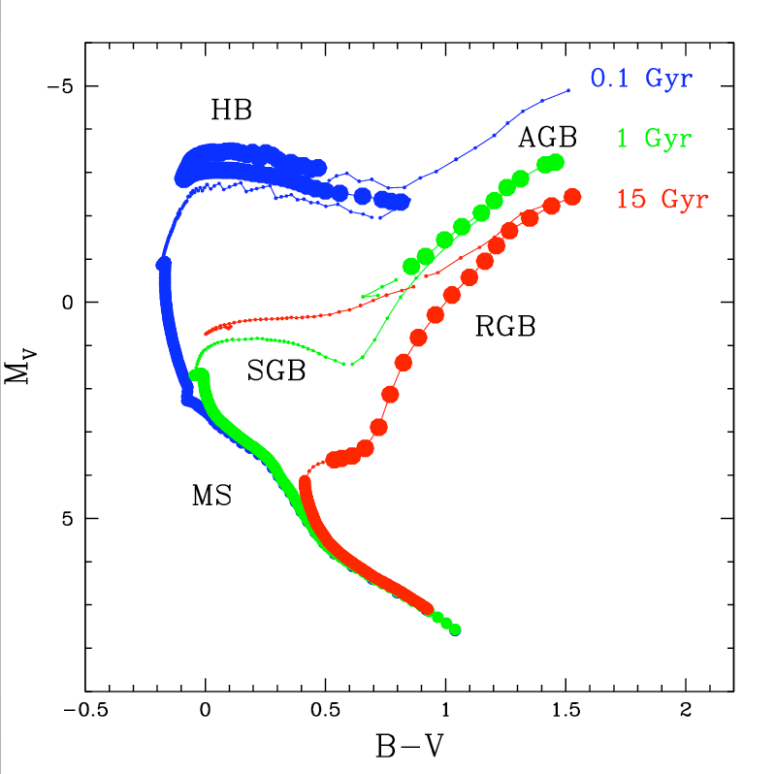
Decoding integrated light is not simple

Age/metallicity degeneracy in the optical (e.g. Worthey 94)



Can be alleviated (Maraston05) **near-IR helps breaking the degeneracy because of TP-AGB stars**

Energetics of Stellar Populations: Three Ages Three Phases



Main Sequence plus

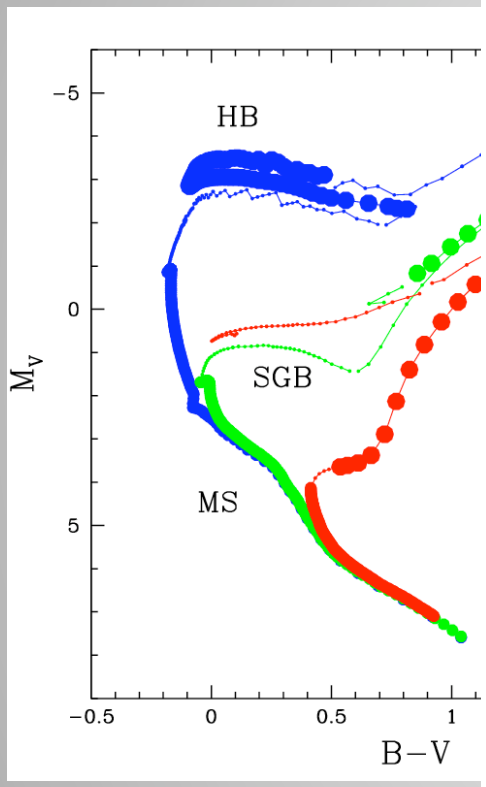
He-burning stars dominate the light of young stellar populations

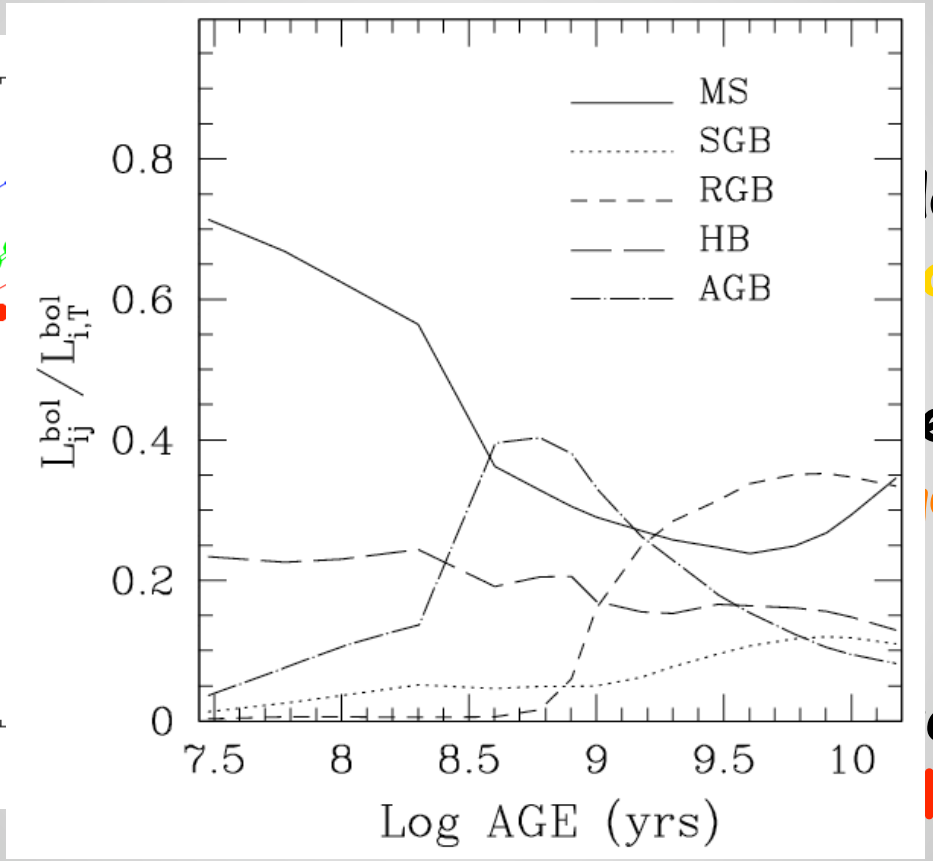
AGB stars dominate the light of intermediate-age stellar populations

RGB stars dominate the light of old stellar populations

Maraston1998

Energetics of Stellar Populations: Three Ages Three Phases





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Maraston1998

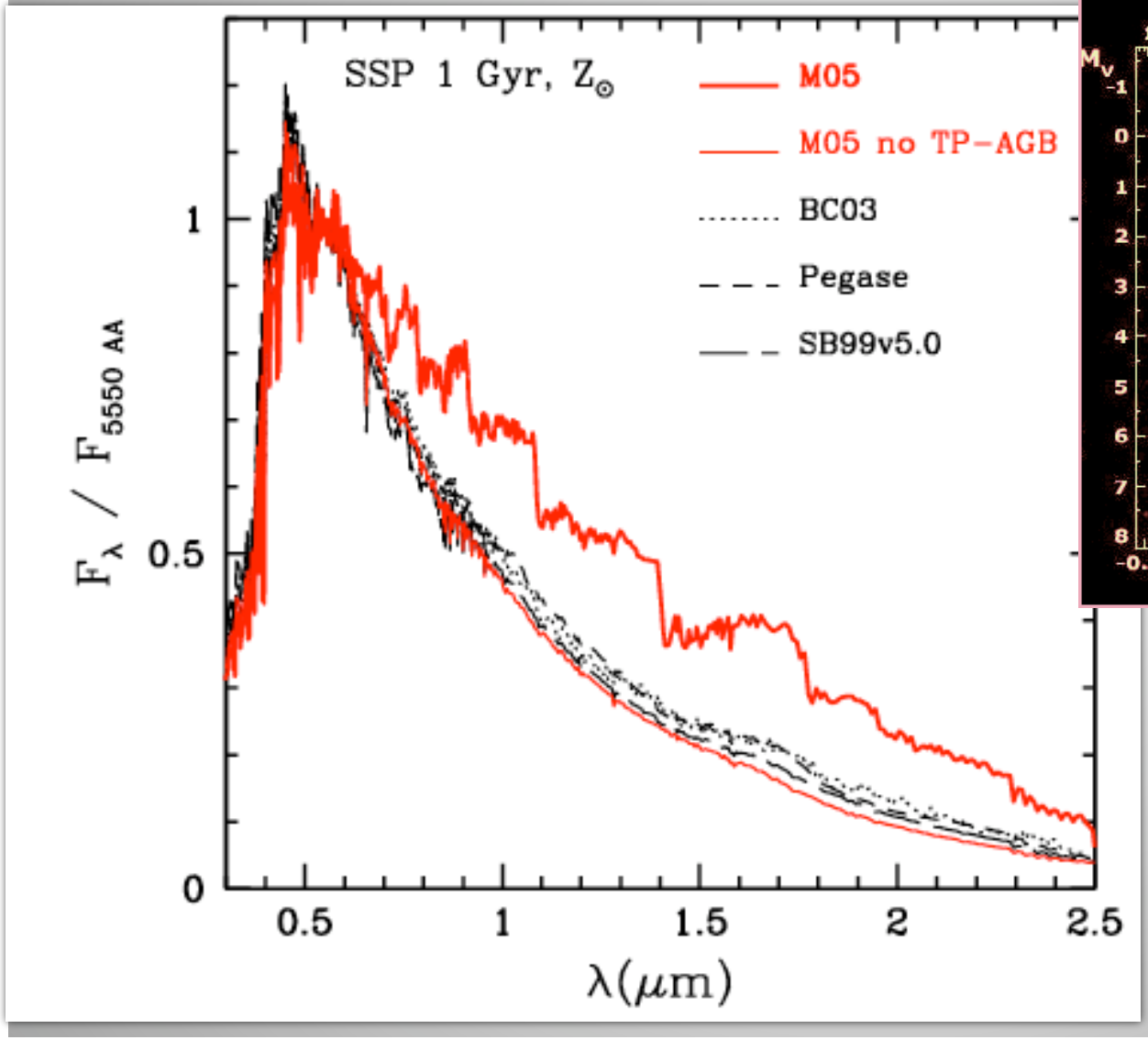
Spitzer crucial for exploiting the new models

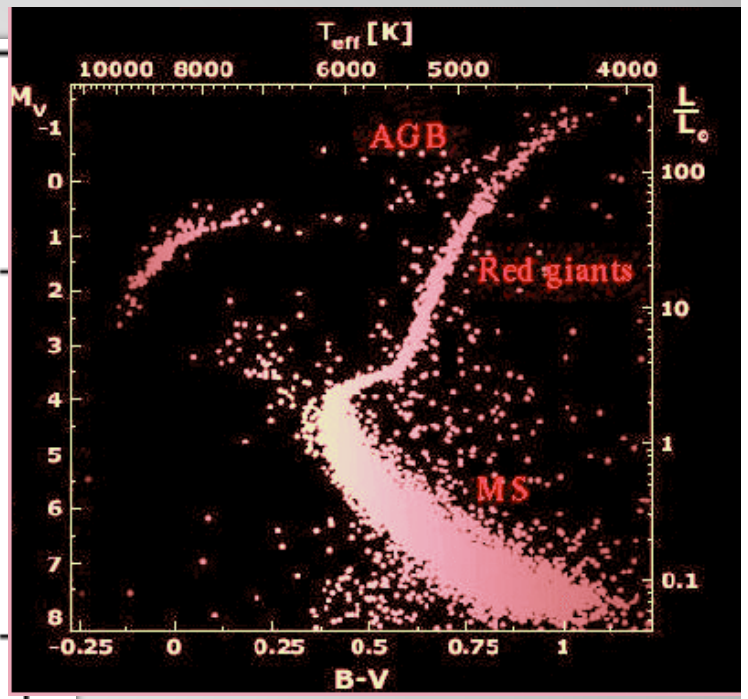
- TP-AGB stars to date high-redshift galaxies with the Spitzer Space telescope

C. Maraston in

"Multiwavelength mapping of galaxy formation and evolution", eds. A. Renzini and R. Bender, ESO Astrophysics Symposia, Springer 2003

2005: Inclusion of Thermally-Pulsing Asymptotic Giant Branch in the models



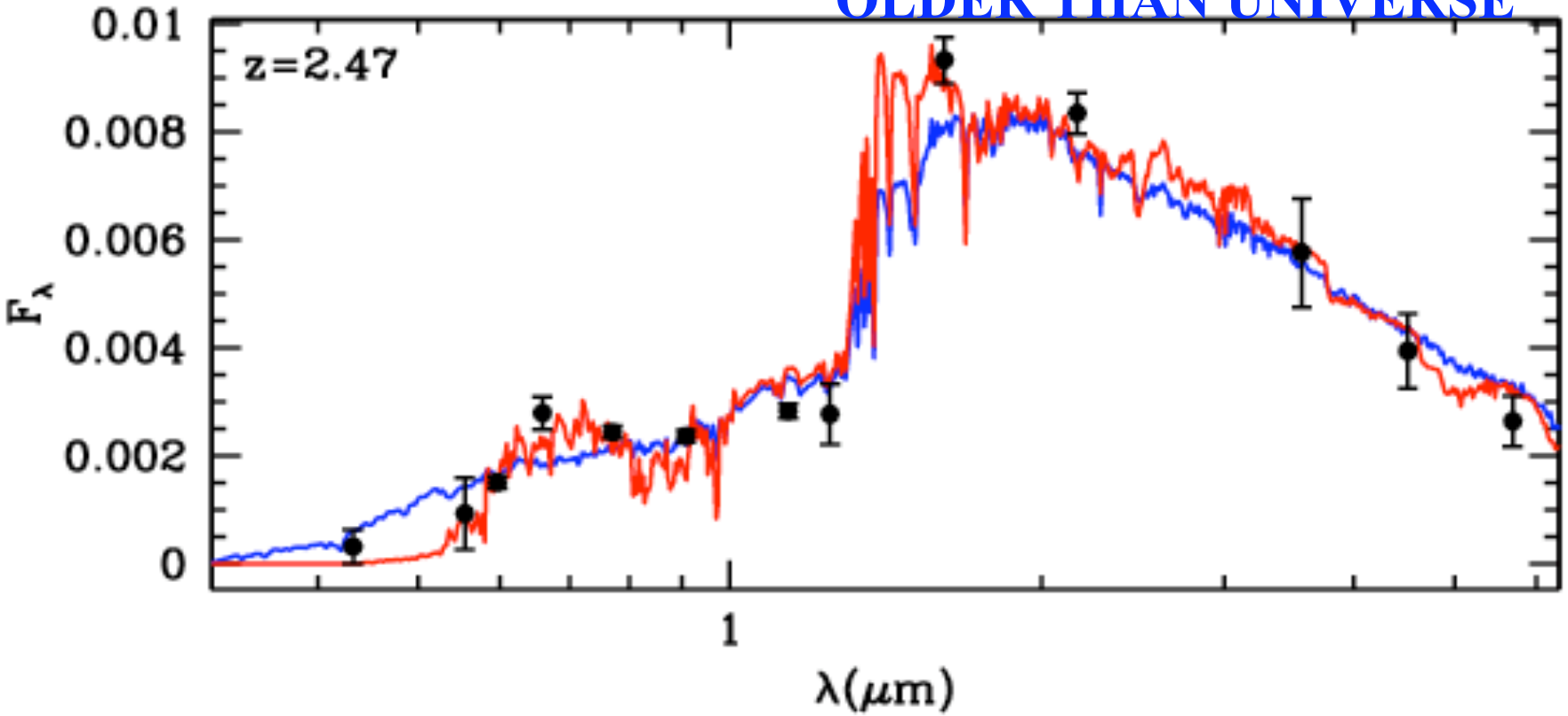


Models aid the interpretation of Spitzer data

t=0.4 Gyr; SFH: SSP; Z=2 $Z_\odot$; E(B−V)=0. (Maraston05)

t=2.6 Gyr; SFH: $e^{-t/1\ Gyr}$; $Z=Z_\odot/2.5$; Calzetti's law E(B−V)=0.3 (BC03)

OLDER THAN UNIVERSE



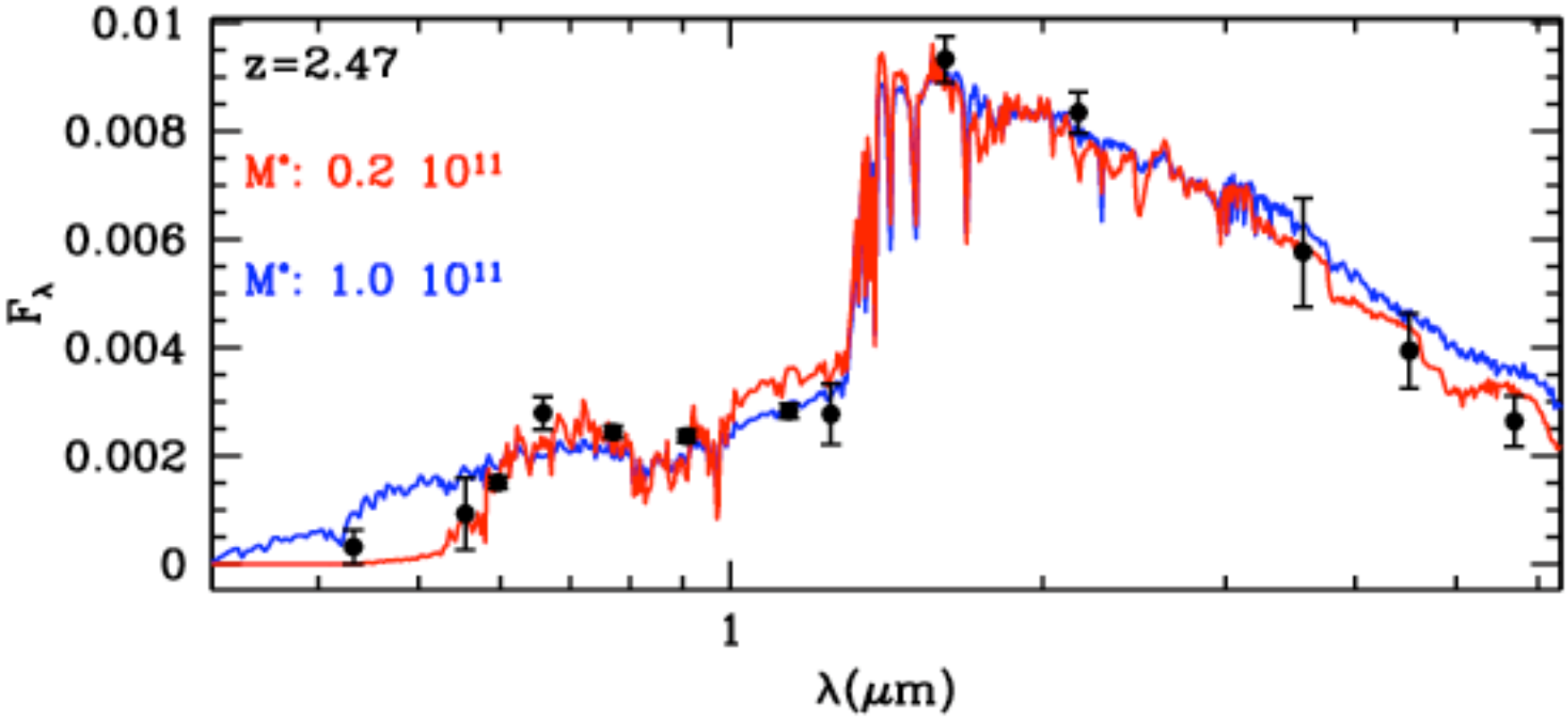
Maraston, Daddi + 06

Models aid the interpretation of Spitzer data

t=0.4 Gyr; SFH: SSP; Z=2 $Z_\odot$; E(B−V)=0. (Maraston05)

Undetected in MIPS!

t=1 Gyr; SFH: $e^{-t/0.1\ Gyr}$; $Z=Z_\odot$; Calzetti's law E(B−V)=0.35 (BC03)



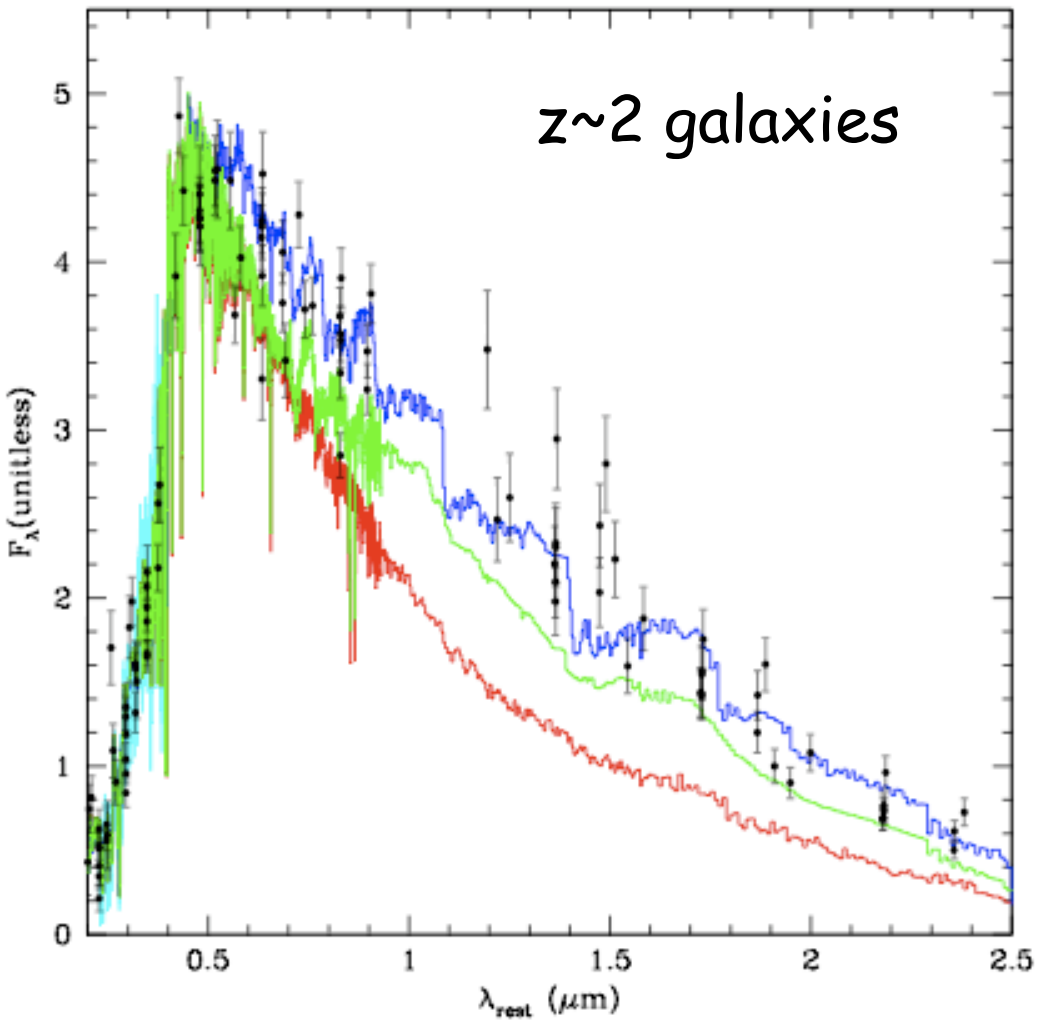
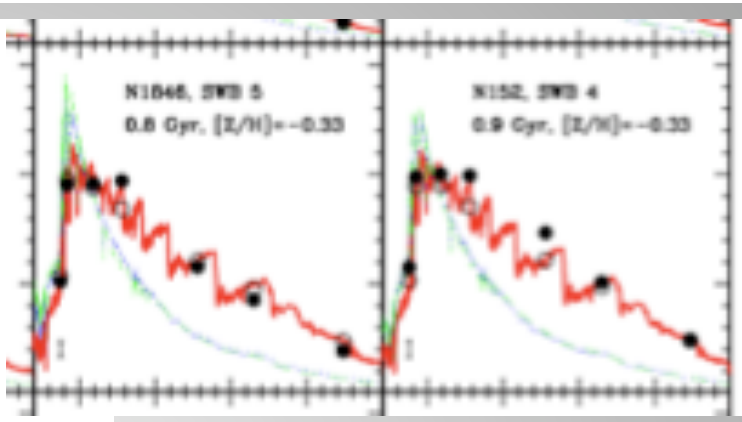


Fig. 5. Same as in Fig. 4, but including also the CB07 best fitting spectrum (green) and showing how the templates differ with each other at longer wavelengths. The observed stacked spectrum is shown in cyan. The black dots are the rest–frame photometry of the galaxies normalized at $\lambda_{rest} = 0.5\mu$m (see text for more details).



LMC GCs , Maraston 05

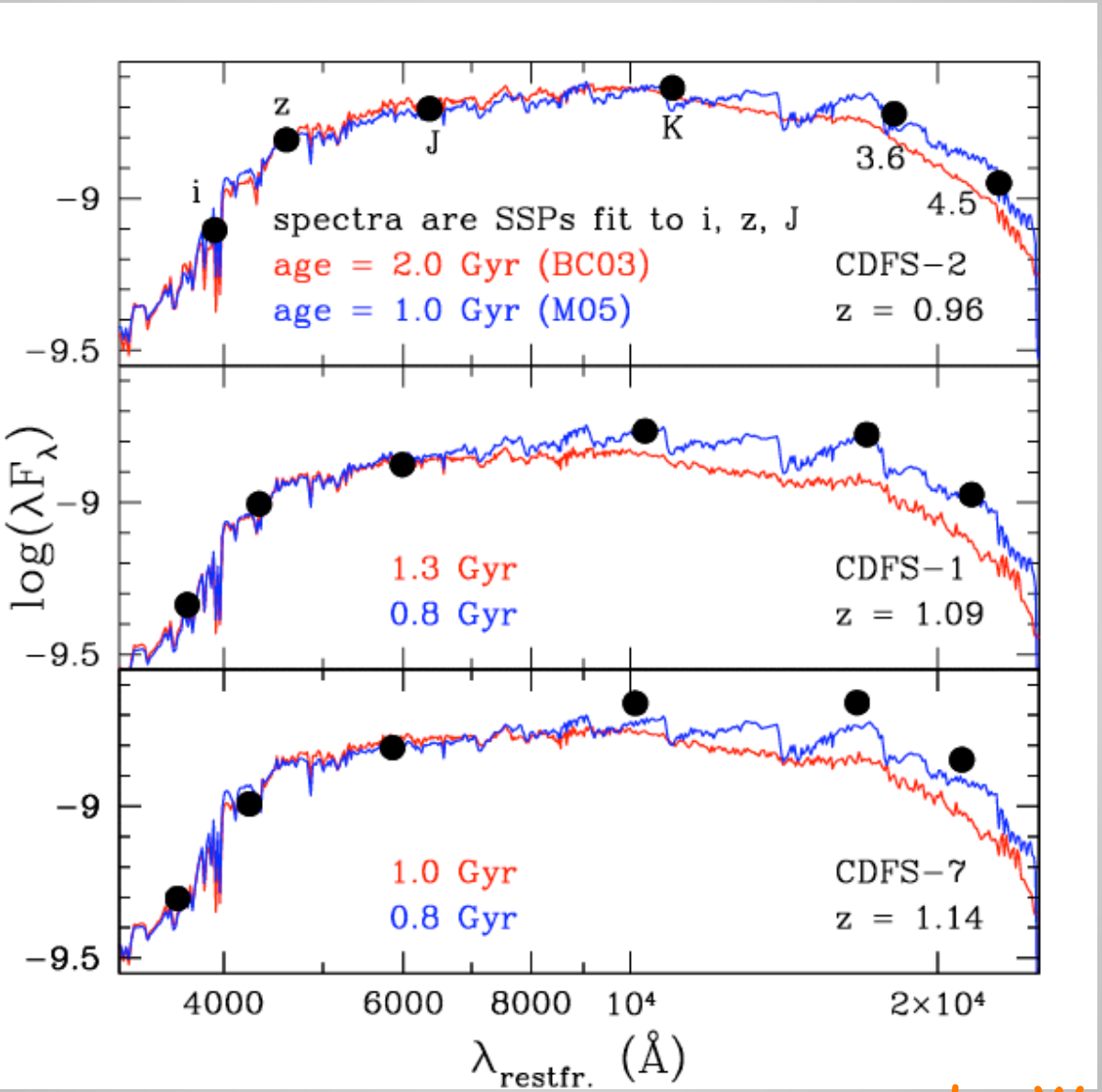
GMASS 480-hour spectrum

BC03, 1.0 Gyr
SSP, $A_V=0$, $Z=Z_\odot$

M05, 1.0 Gyr,
SSP, $A_V=0$, $Z=Z_\odot$

Cimatti et al. 2008

Down the redshift ladder



van der Wel et al. 06

Spitzer data and new models have modified our view of galaxy evolution

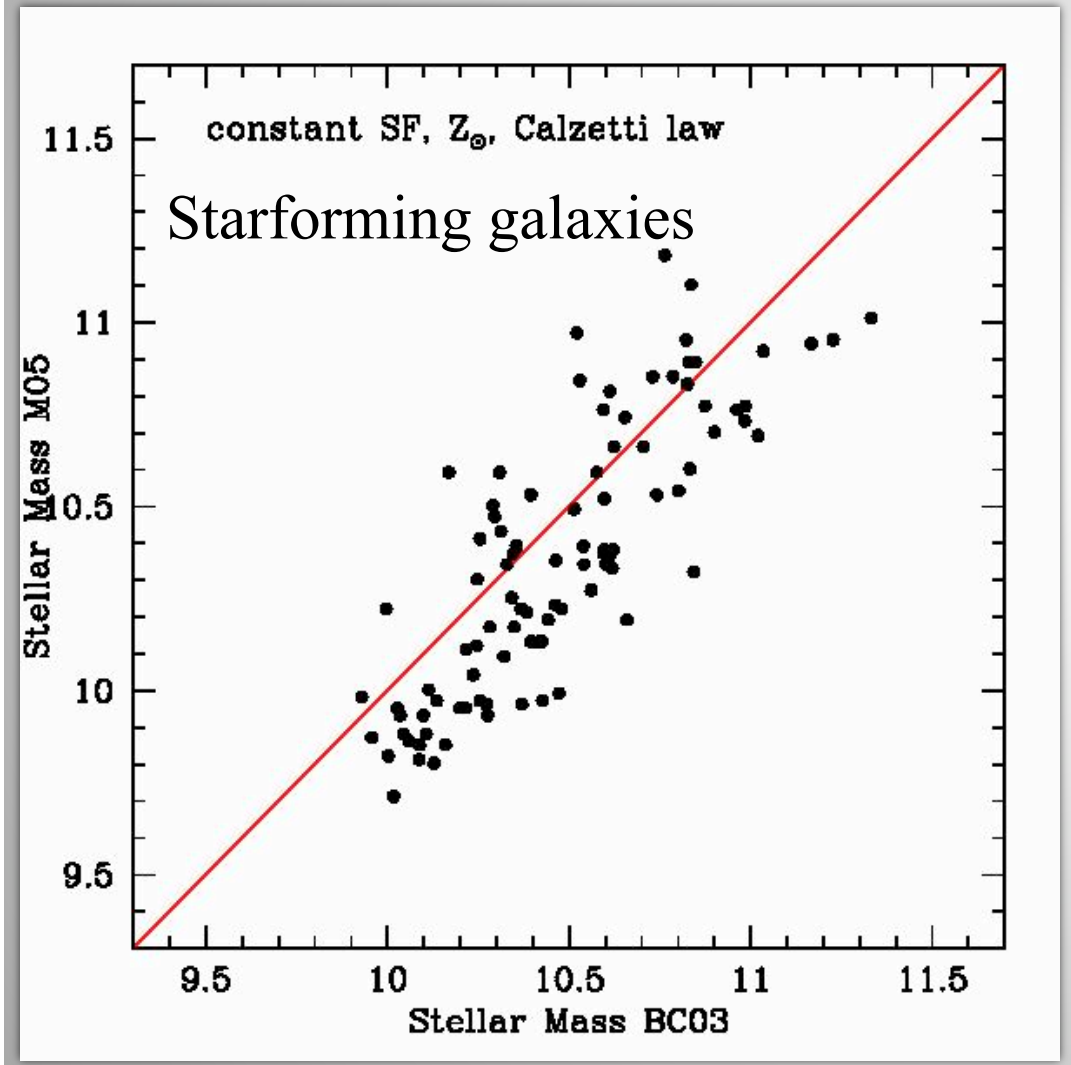
- TP-AGB: lower ages/ lower stellar masses/lower dust content

  Maraston et al. 06, van der Wel 05.06; Wyuts et al. 07; Rodighiero et al. 07; Bruzual 07; Cimatti et al. 08; Franx et al. 08; Zibetti, Charlot, Rix 09

- non overshooting RGB onset: same effect

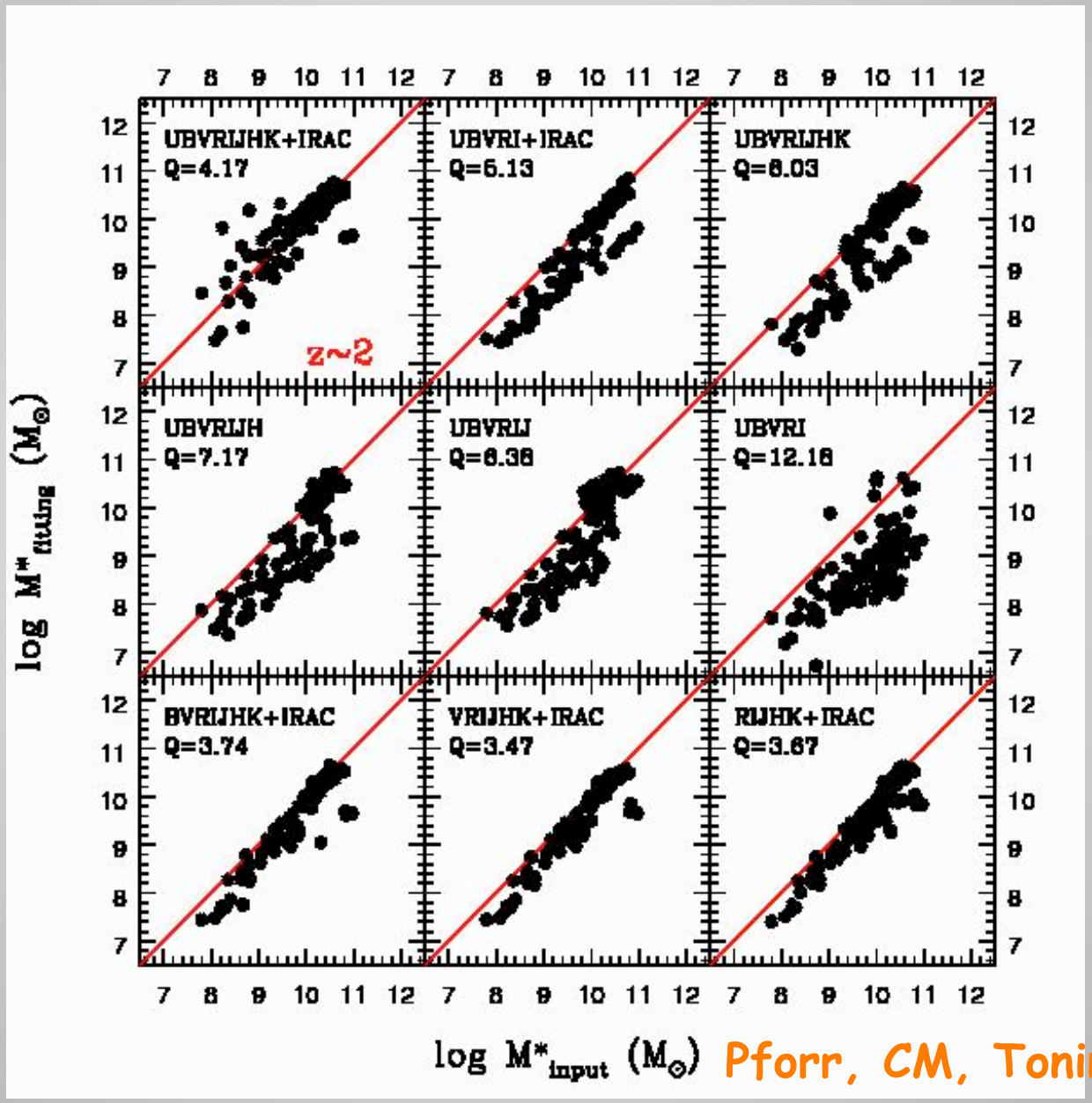
  Maraston et al. 2006

Spitzer helps both passive as well as starforming galaxies



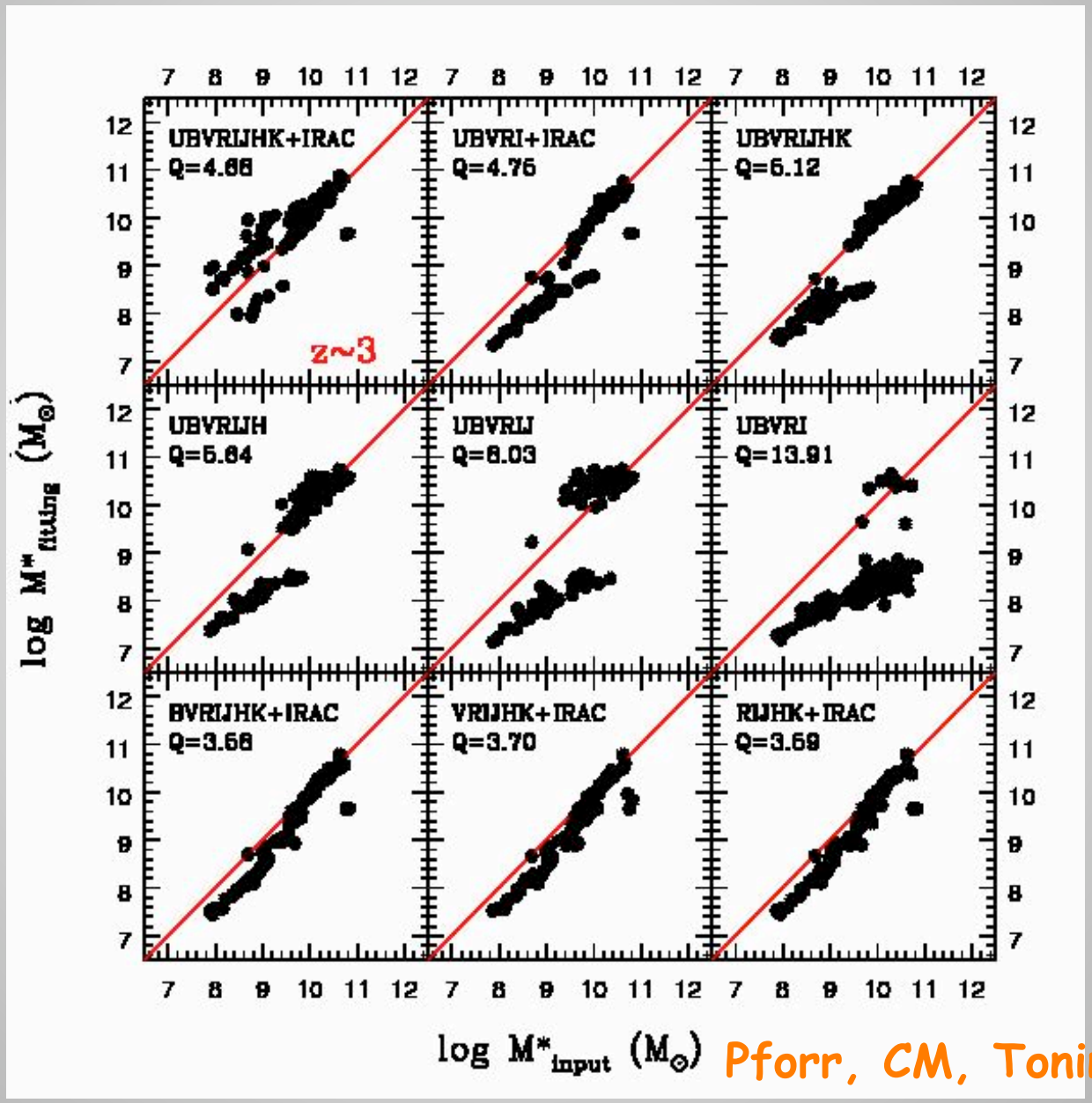
Shapley et al. 05 concluded that IRAC did not help because of their use of models without TP-AGB

Spitzer pin down galaxy masses



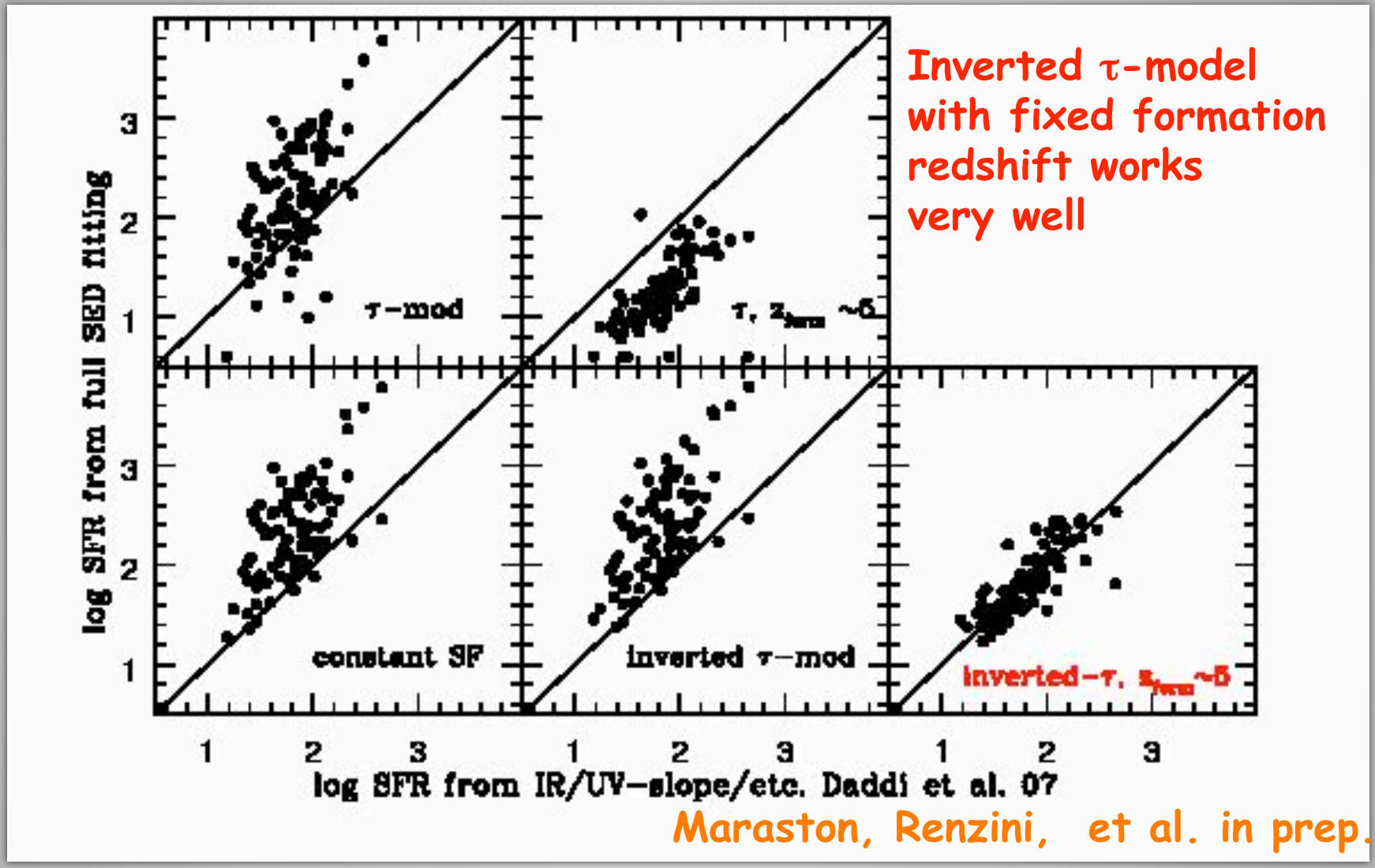
Pforr, CM, Tonini, in prep.

Spitzer pin down galaxy masses



Pforr, CM, Tonini, in prep.

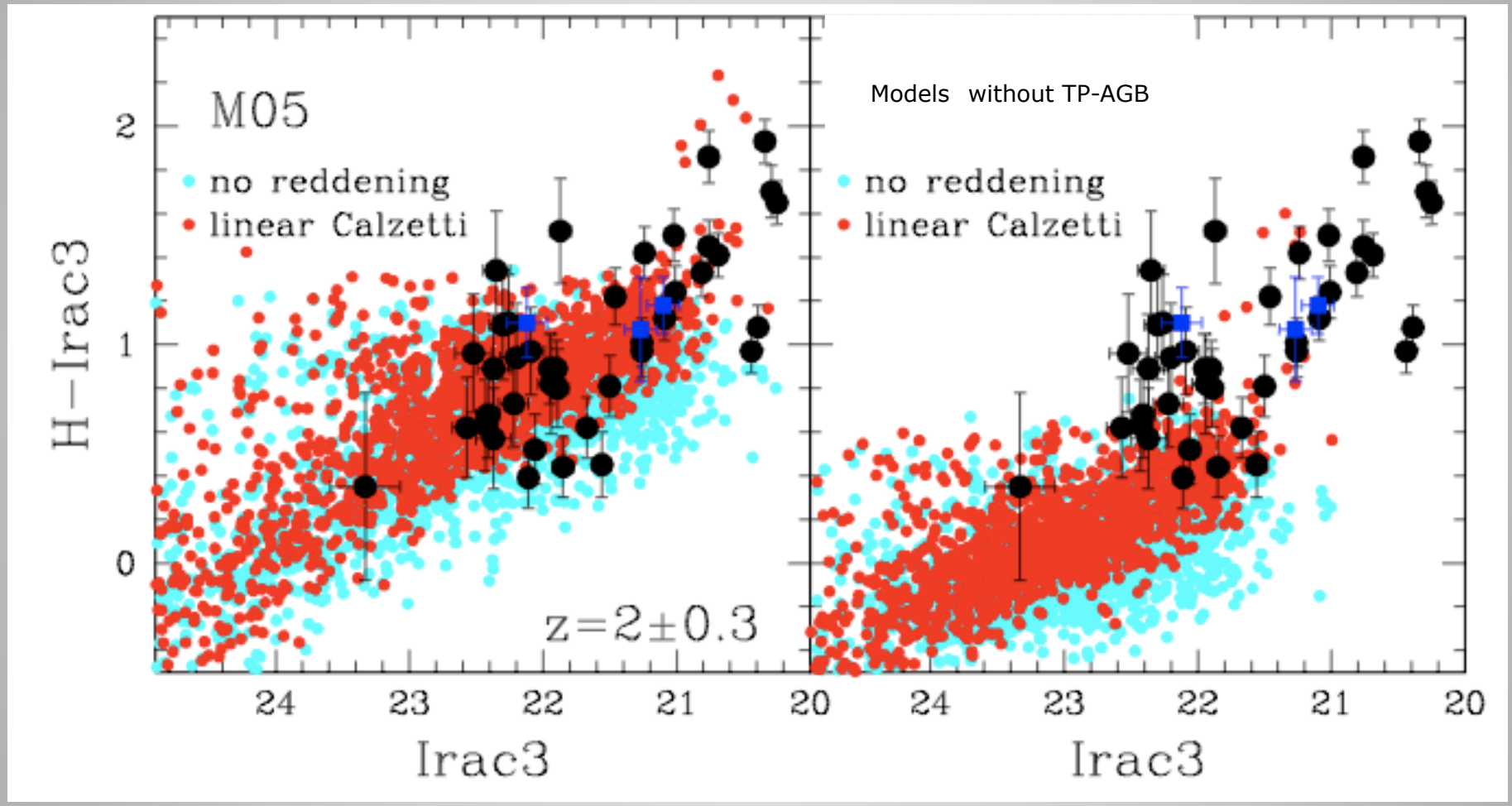
The star formation history of z ~ 2 galaxies



Inverted τ-model with fixed formation redshift works very well

Maraston, Renzini, et al. in prep.

Spitzer constrain hierarchical models



Tonini, Maraston, Thomas, Devriendt & Silk, 2009a, MNRAS-L, 177

Tonini, Maraston, Thomas, Devriendt & Silk, 2009b, MNRAS, *subm.*

Summary

- For tracing galaxy evolution is necessary to sample the relevant stellar evolutionary phases MS, HB, AGB, RGB
- The Spitzer Space Telescope has enabled us to detect the signature of Red Giant cool phases at high-redshift
- Spitzer data and last generation models are able to constrain ages and masses of high-z galaxies

  Warm Mission will keep doing good work (e.g. SERVS)
- The star formation history of z~2 galaxies follow an inverted tau-model starting from z~5
- Semi-analytic models can match the IRAC colors of z ~ 2 galaxies