SED fitting of unresolved stellar populations

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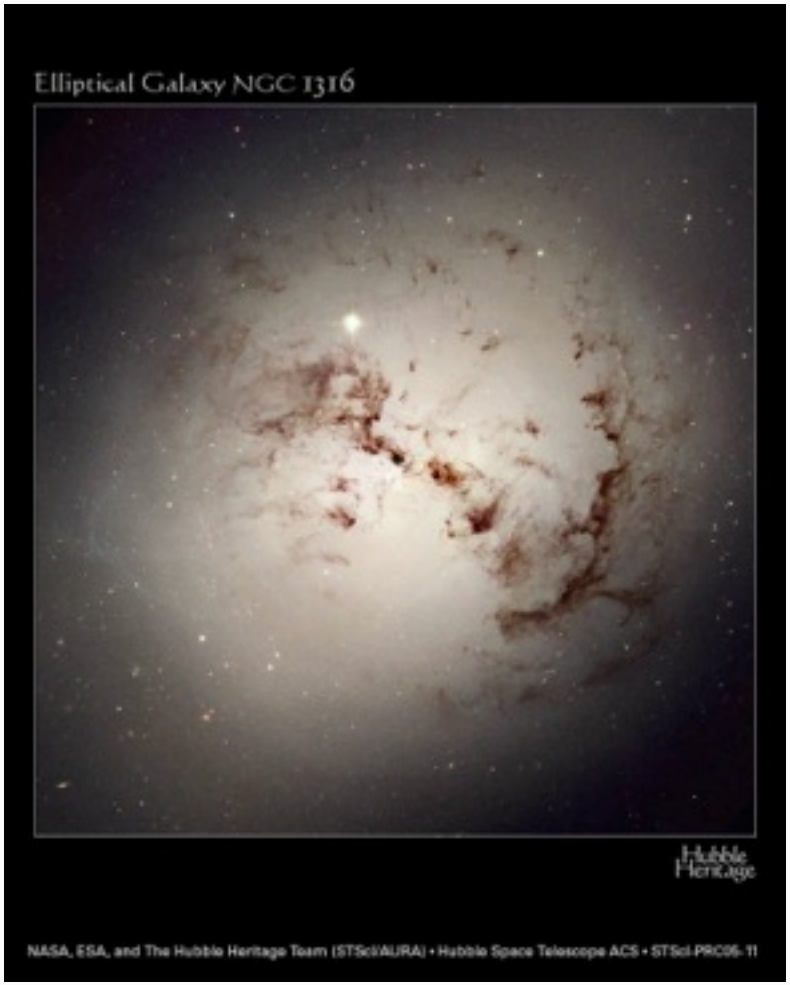
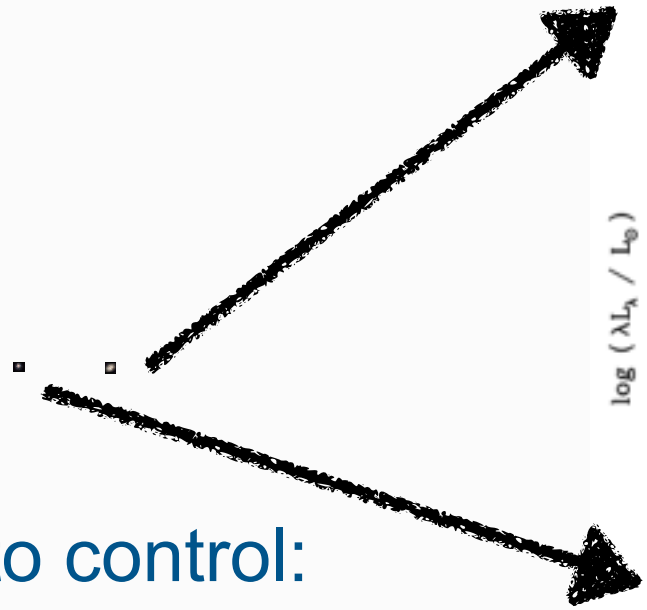
Resolved stellar populations

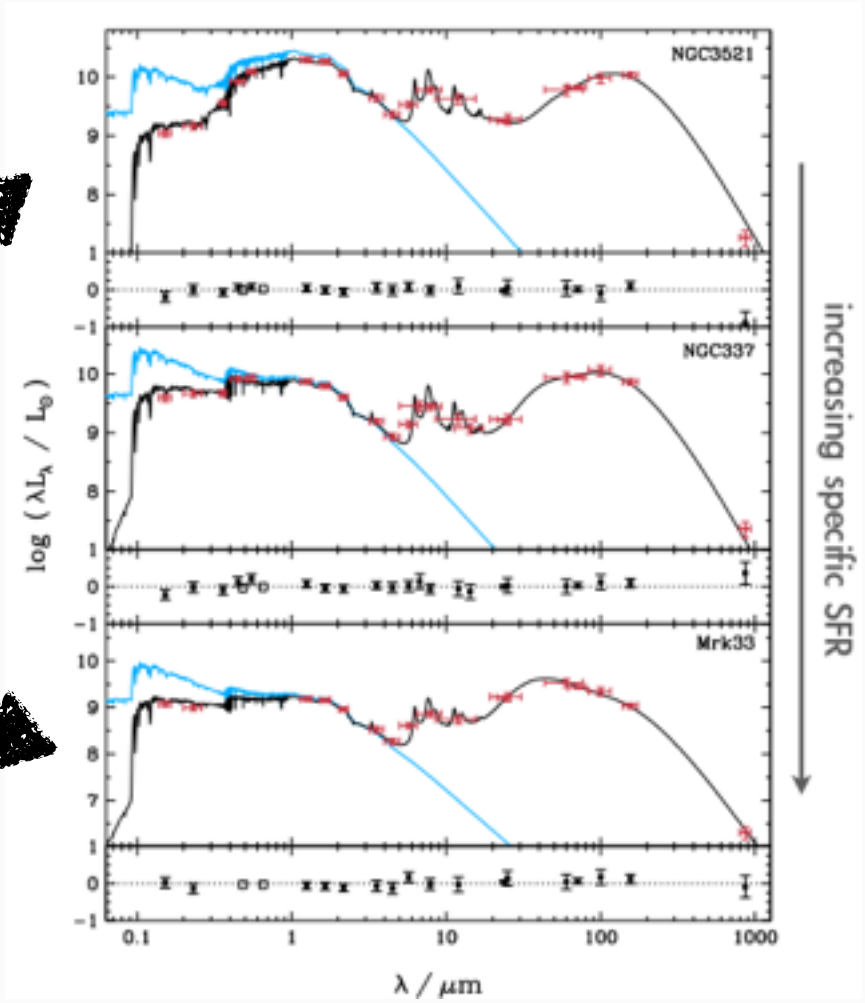
UNresolved stellar populations



UNresolved stellar populations

Spectral Energy Distributions





da Cunha et al., 2008

- Have to control:
  - sensitivity
  - spectral window
  - spatial window

Purpose of the exercise

Determine physical properties of a large quantity of "stuff" from its integrated light.

"Stuff" means stars, gas, dust, and more

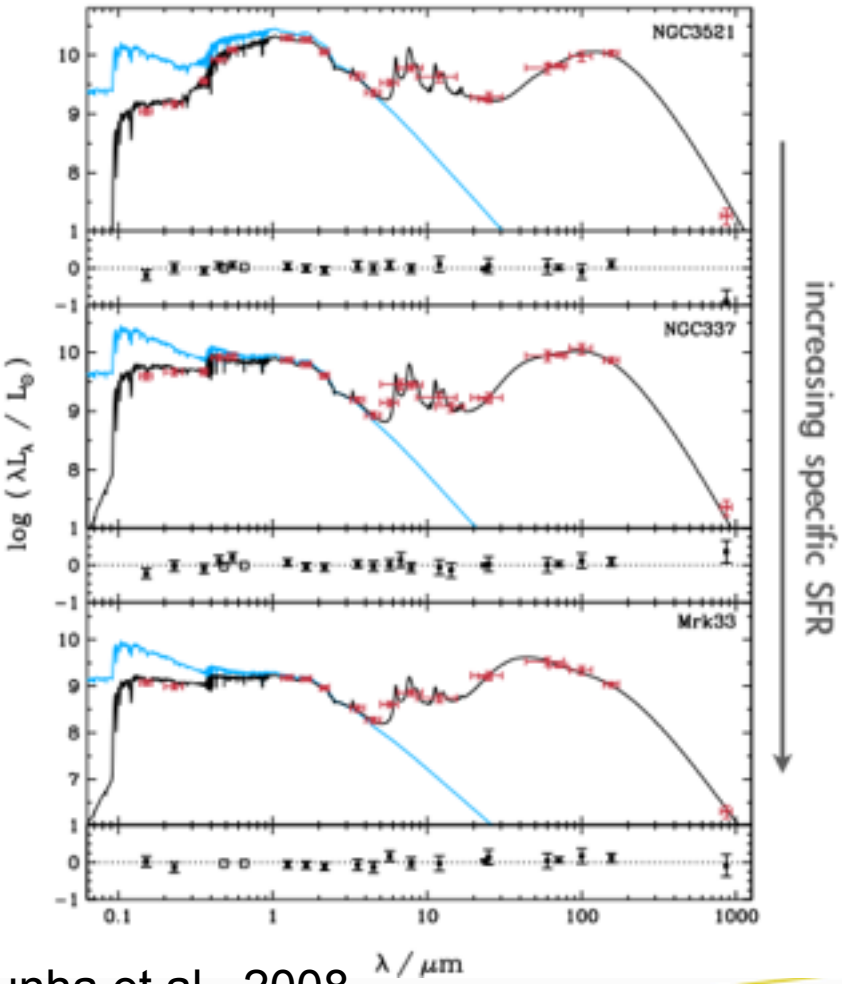
Walcher et al., 2011; Conroy et al., 2013

Physical properties

- Physics 101: A physical property is described by
  - a number
  - a unit
  - an errorbar
- Only well-defined quantities can be measured.
- The “Star Formation History” is not a well-defined quantity.
- The “contribution of stars aged between $1*10^9$ and $5*10^9$ yrs to the total luminosity in the V-band” IS a well-defined quantity.

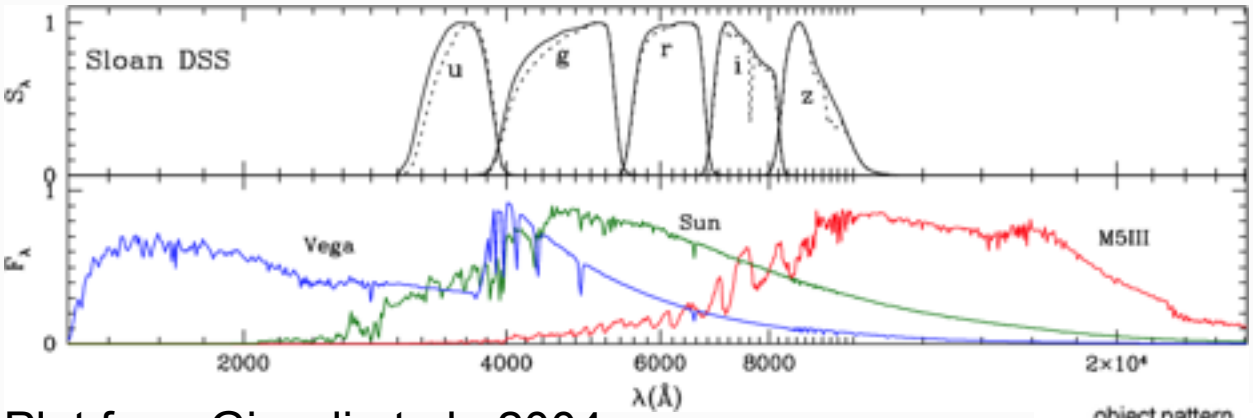
SEDs: two regimes

- Photometric SEDs (R<100): typically very accurate flux calibration.
- Spectroscopic SEDs (R>200): visibility of lines in absorption and emission.



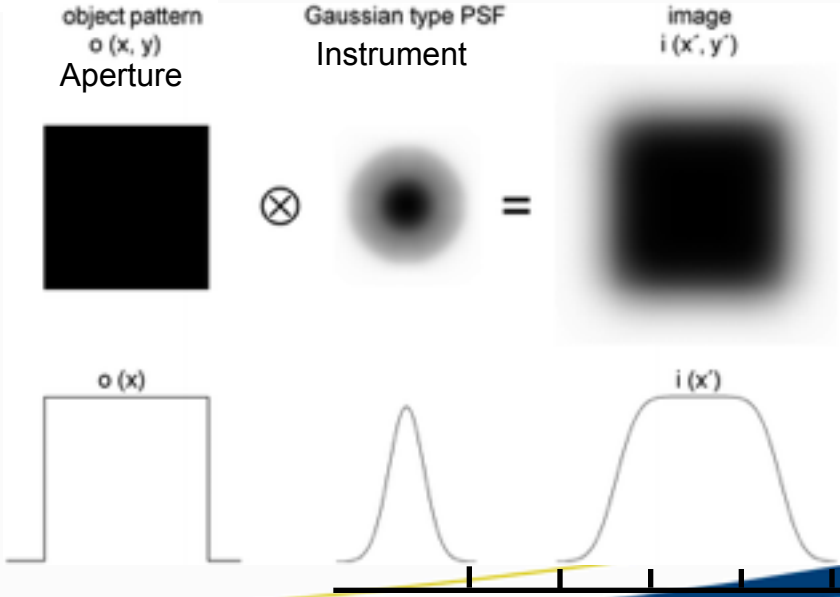
da Cunha et al., 2008

Spectral Energy Distributions and the spectral response curves



Plot from Girardi et al., 2004

Generation of LSF
Very sketchy example!



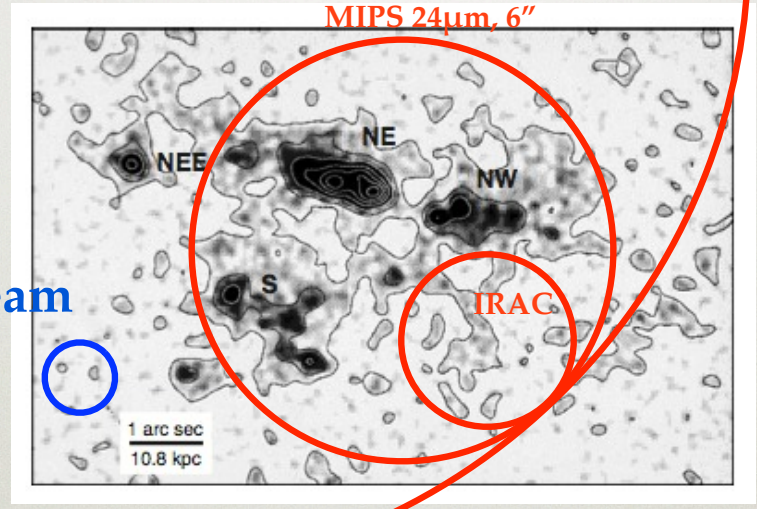
Sidenote: discrepancy between line spread functions may be reason why we never get the Balmer lines right in spectral fitting...

Spectral Energy Distributions and the spatial window

PB! RESOLUTION AT LONG WAVELENGTH

SPIRE 250μm, 18″

MIPS 24μm, 6″



ALMA beam

Cycle 1/2 ALMA program at ~1″ resolution (Gullberg et al., in prep)

The problem exists for spectroscopy as well (e.g. DAR on SDSS spectra)

Slide stolen from Drouard's talk

Fitting a photometric SED

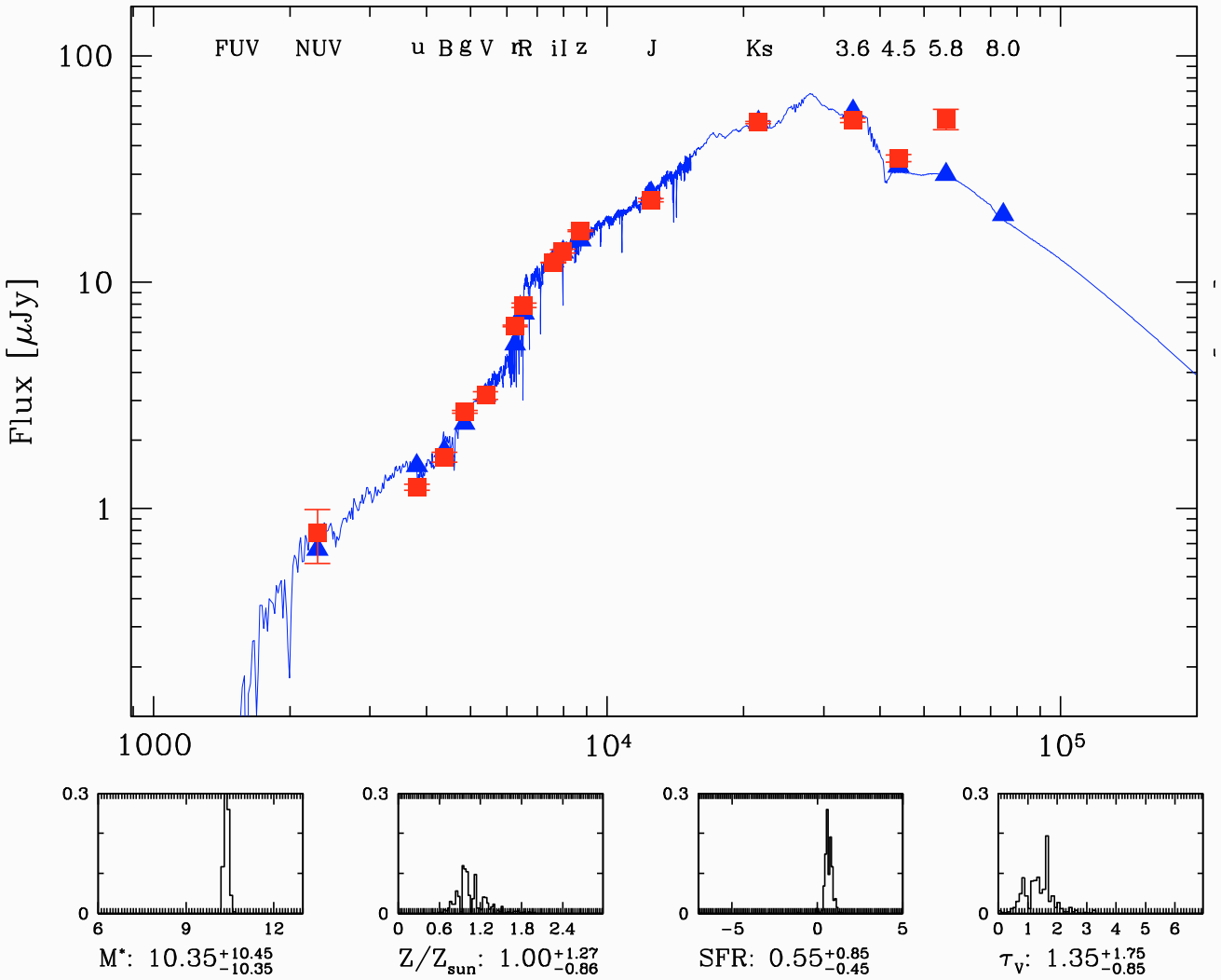
"Minimizing χ^2 is a maximum likelihood estimation of the fitted parameters if the measurement errors are independent and normally distributed." Press+, Numerical Recipes

χ^2 is a measure of probability:

$$P(D|M) \propto e^{-\chi^2/2}$$

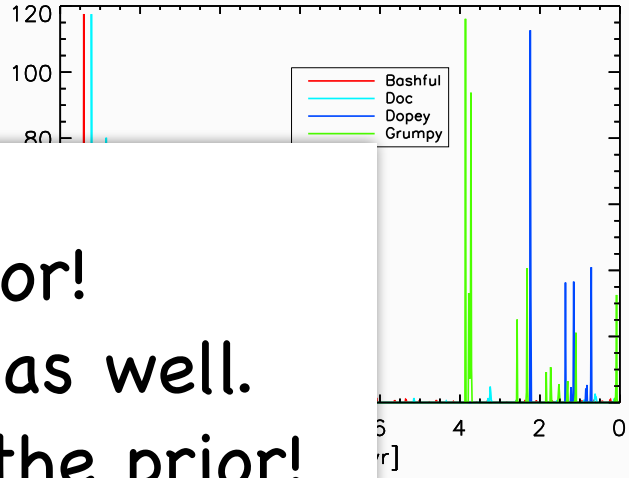
- One difference is in minimum χ^2 vs. "bayesian"
- Other difference is in the prior:
  SSP vs. pre-computed library vs. step-wise (MCMC)
- For codes check out http://www.sedfitting.org

Example SED fit



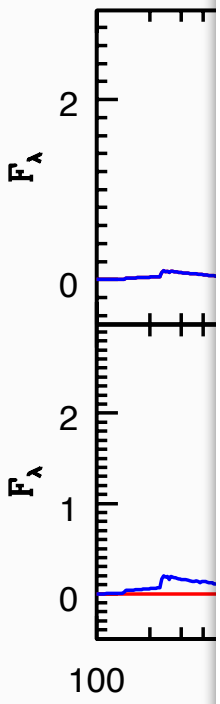
Walcher+08

Constructing libraries



$$L_\lambda(t) =$$

n et al., 2014

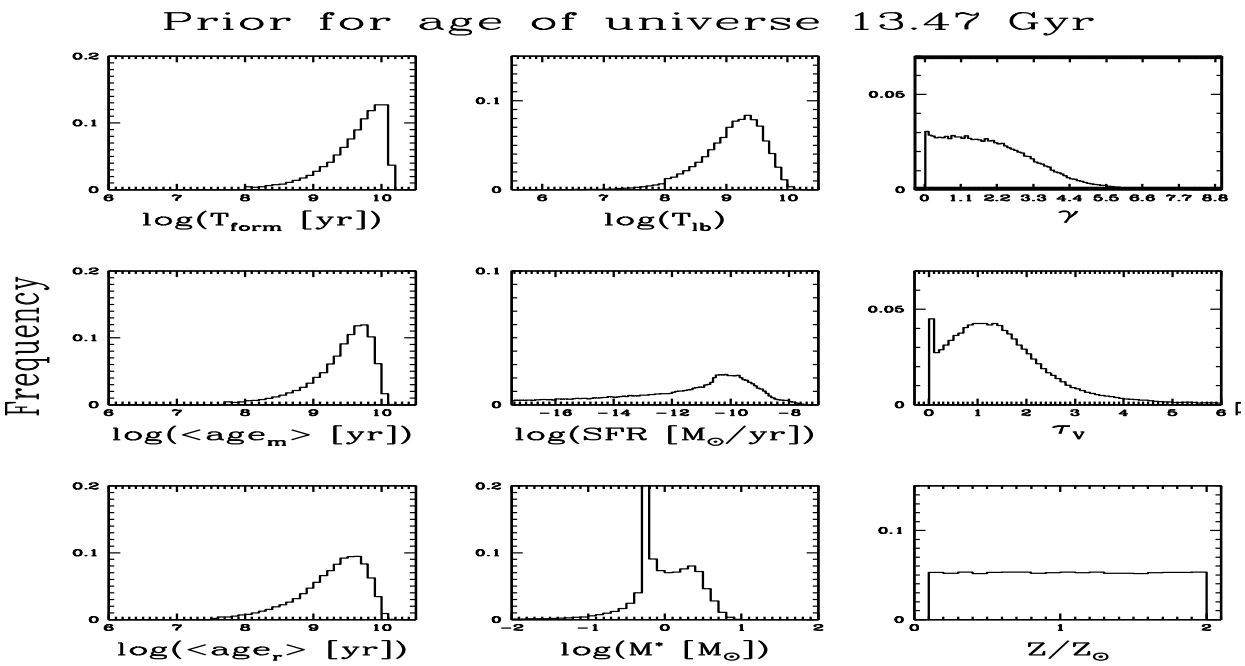


s the
l* by
x

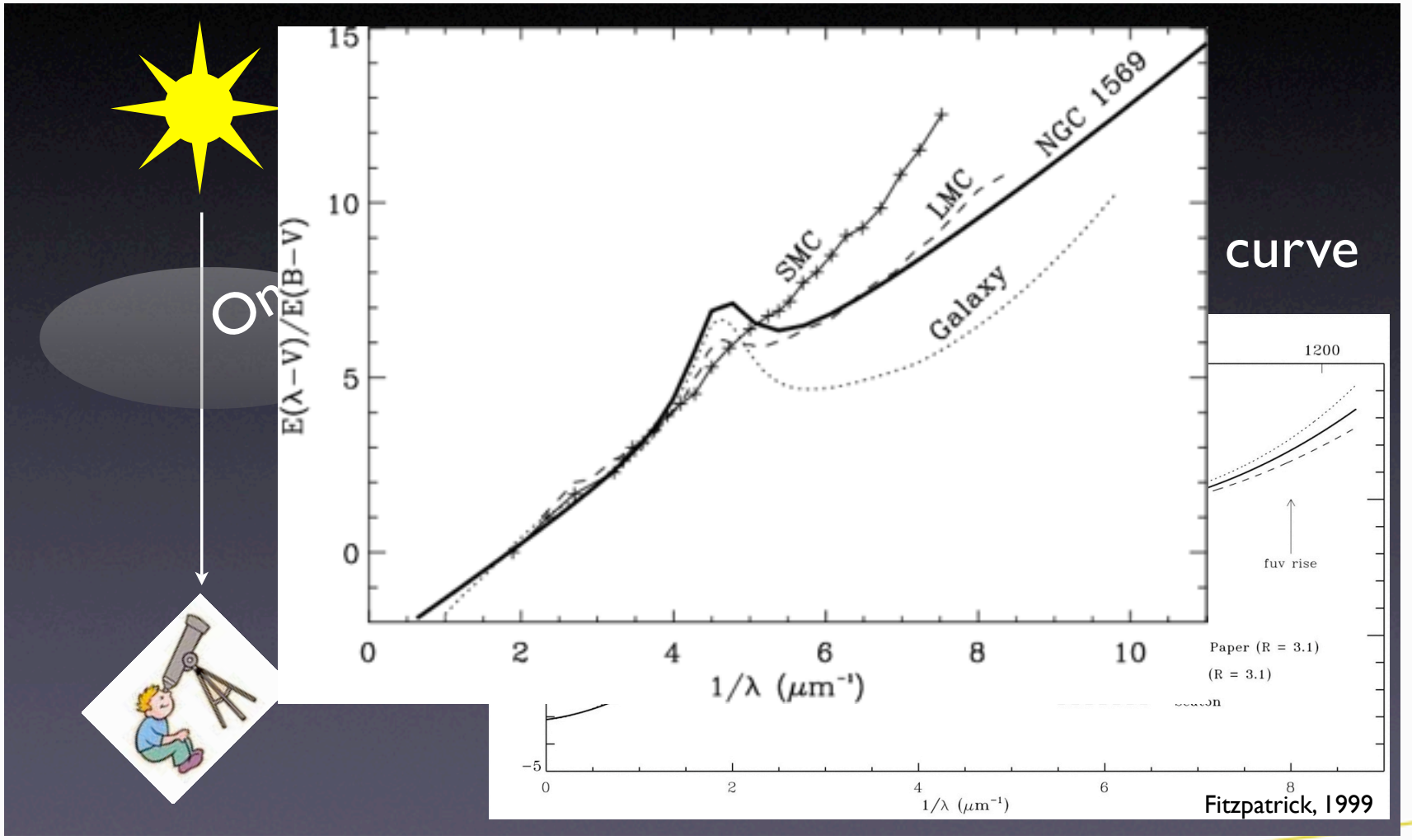
ablished by
ffmann+03

Re ls!

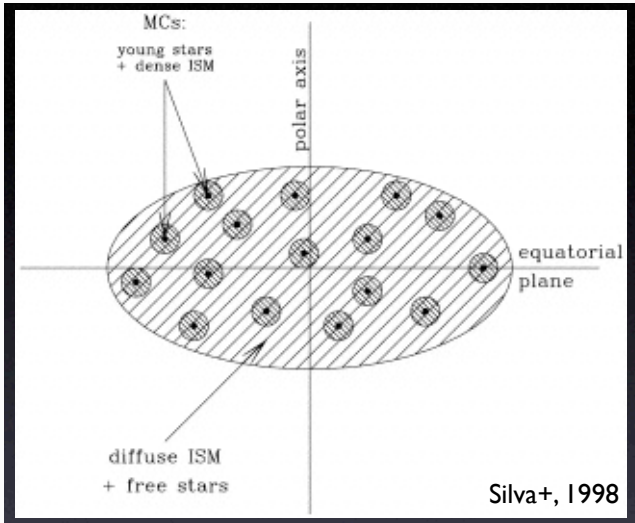
You always have a prior!
Only using SSPs is a prior as well.
At low S/N results tend to the prior!



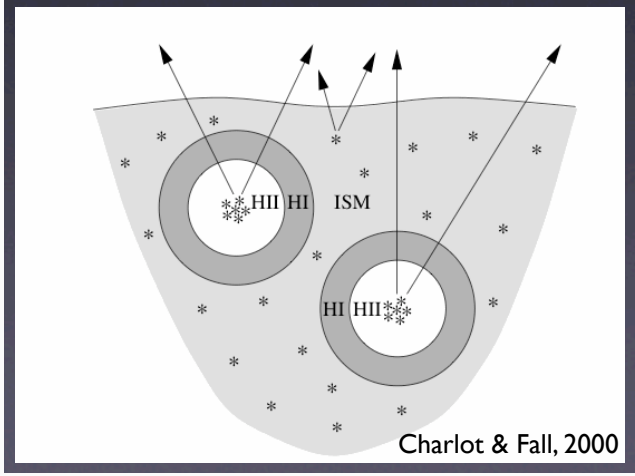
Dust extinction



Dust attenuation



Silva+, 1998



Charlot & Fall, 2000

The apparent attenuation law is a composite of the attenuation laws for the clumpy younger stars and for the diffuse older stars with a luminosity weight.

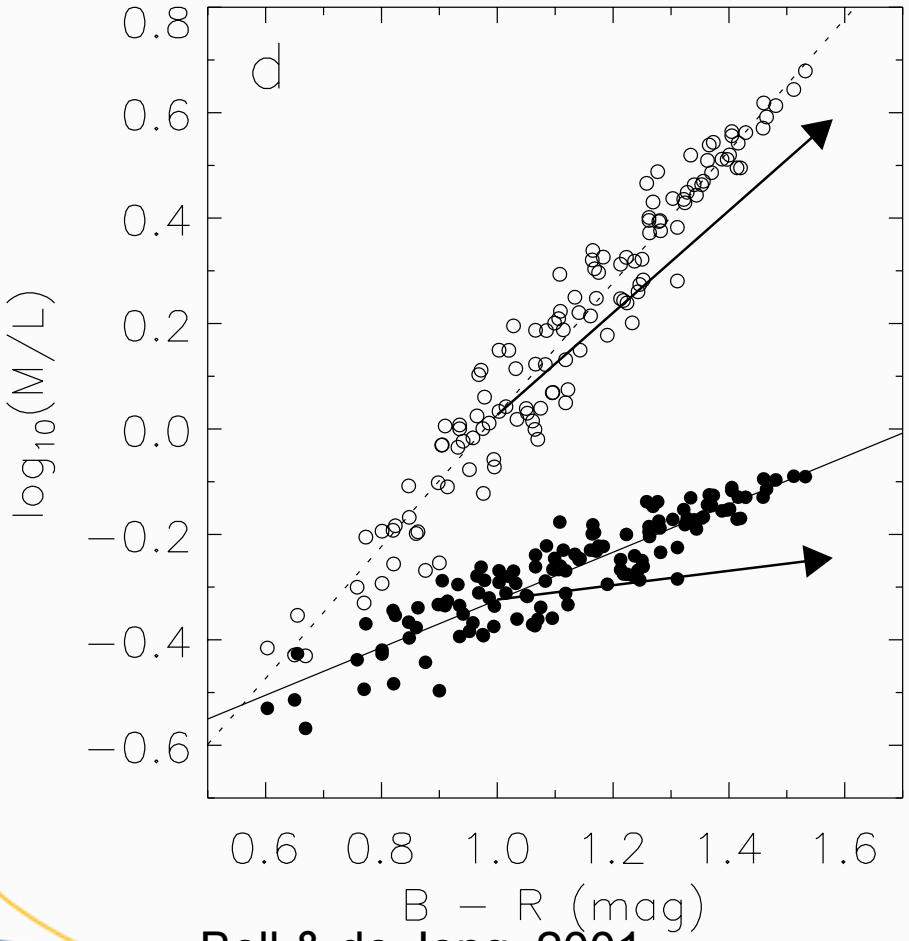
Inoue, 2005

Also: clumpiness

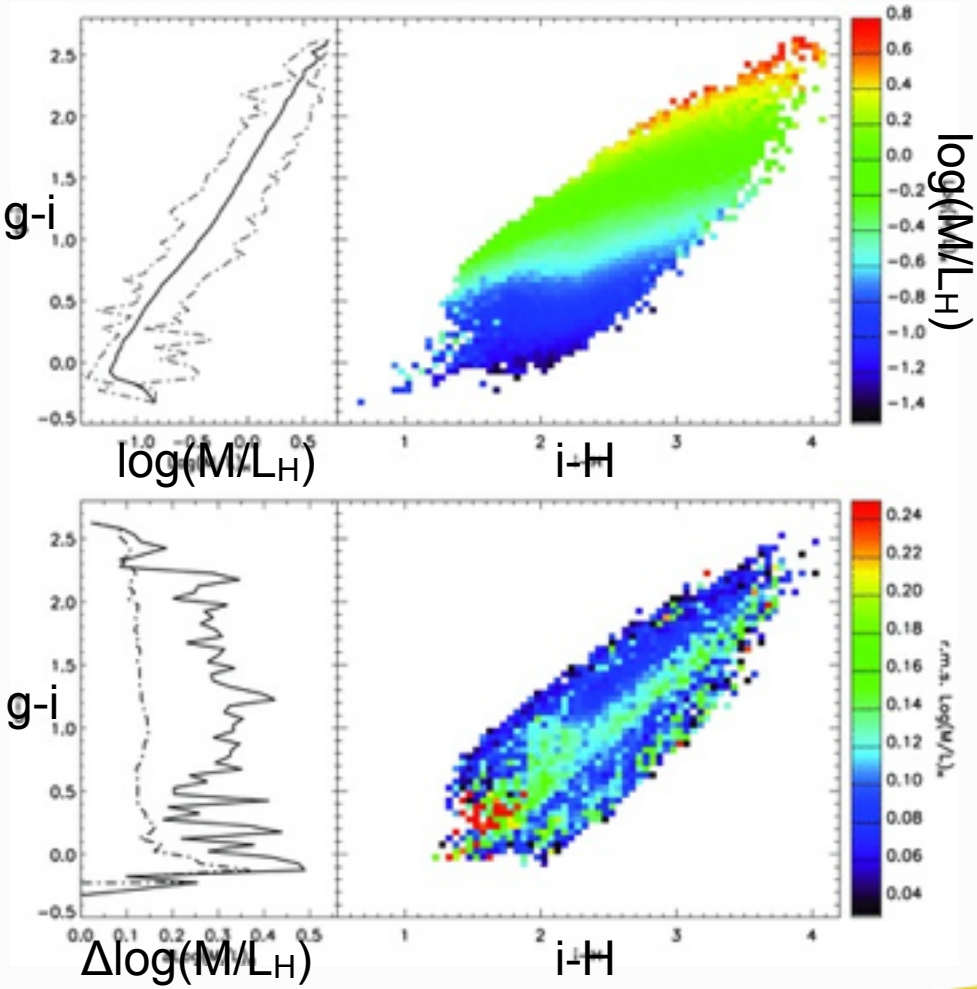
For attenuation slopes see Calzetti+ (1994) and Wild+ (2011)

Stellar masses and the “poor” mans SED fit

$M = M/L * L$



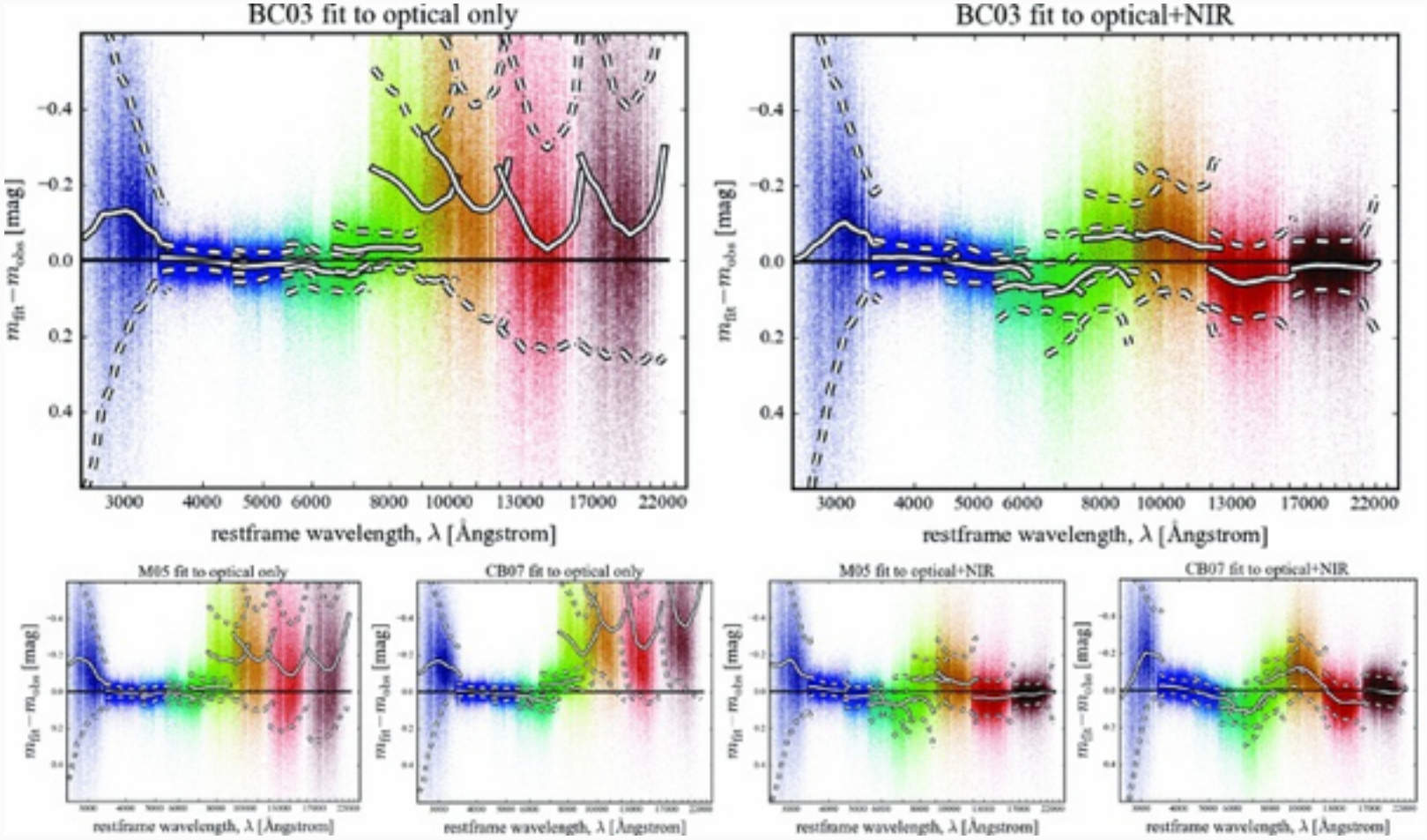
Bell & de Jong, 2001



Zibetti et al., 2009

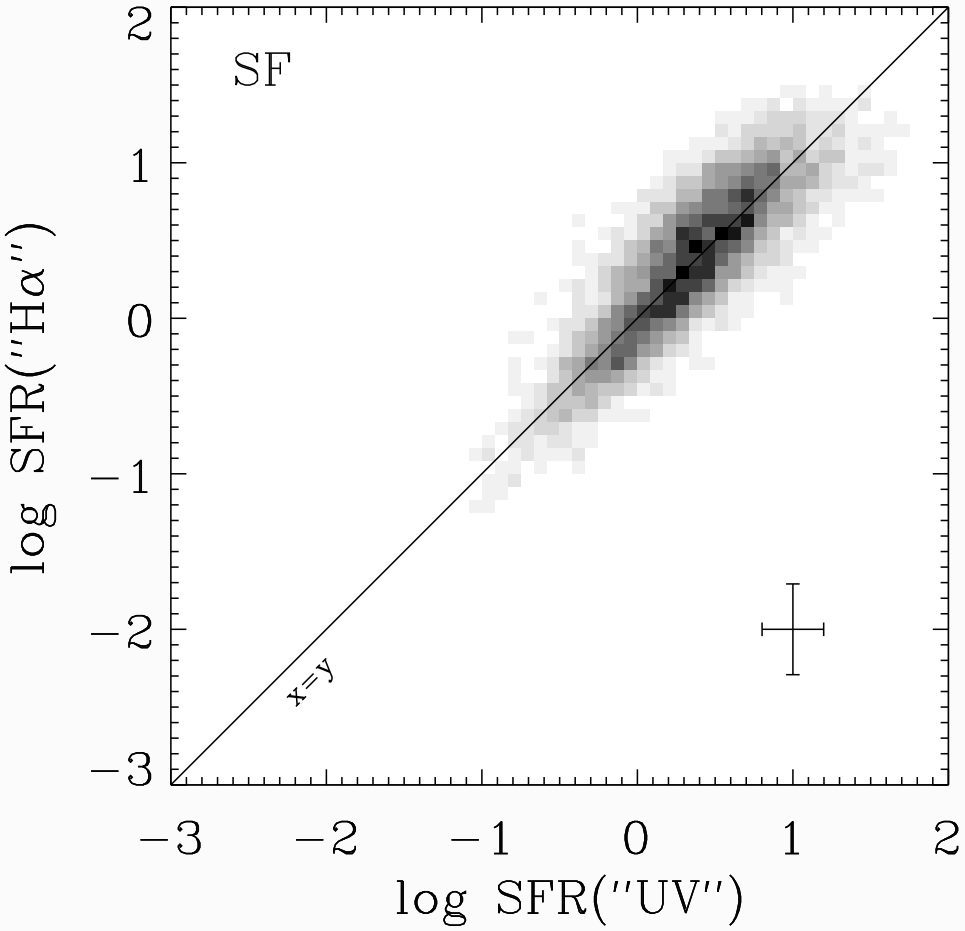
Residuals

"…these results strongly suggest inconsistencies between the observed optical-minus-NIR colours of real galaxies and those contained within our SPL."



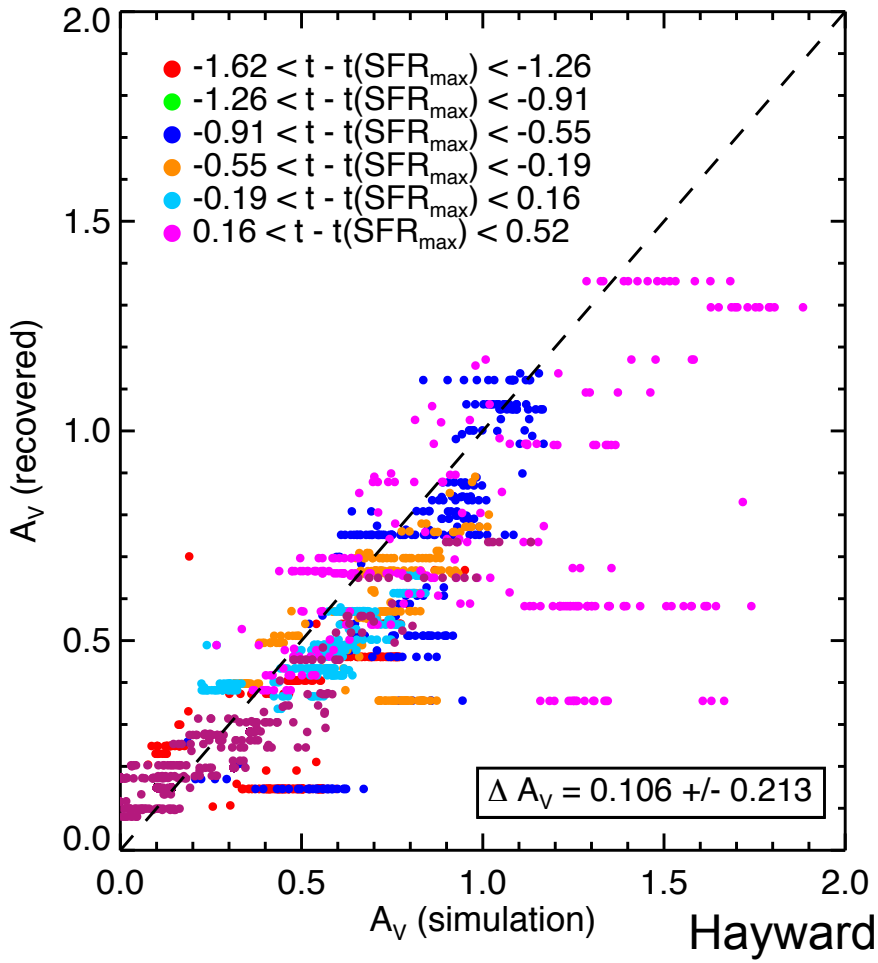
Taylor et al., 2011

SED fitting works …



Salim et al., 2007

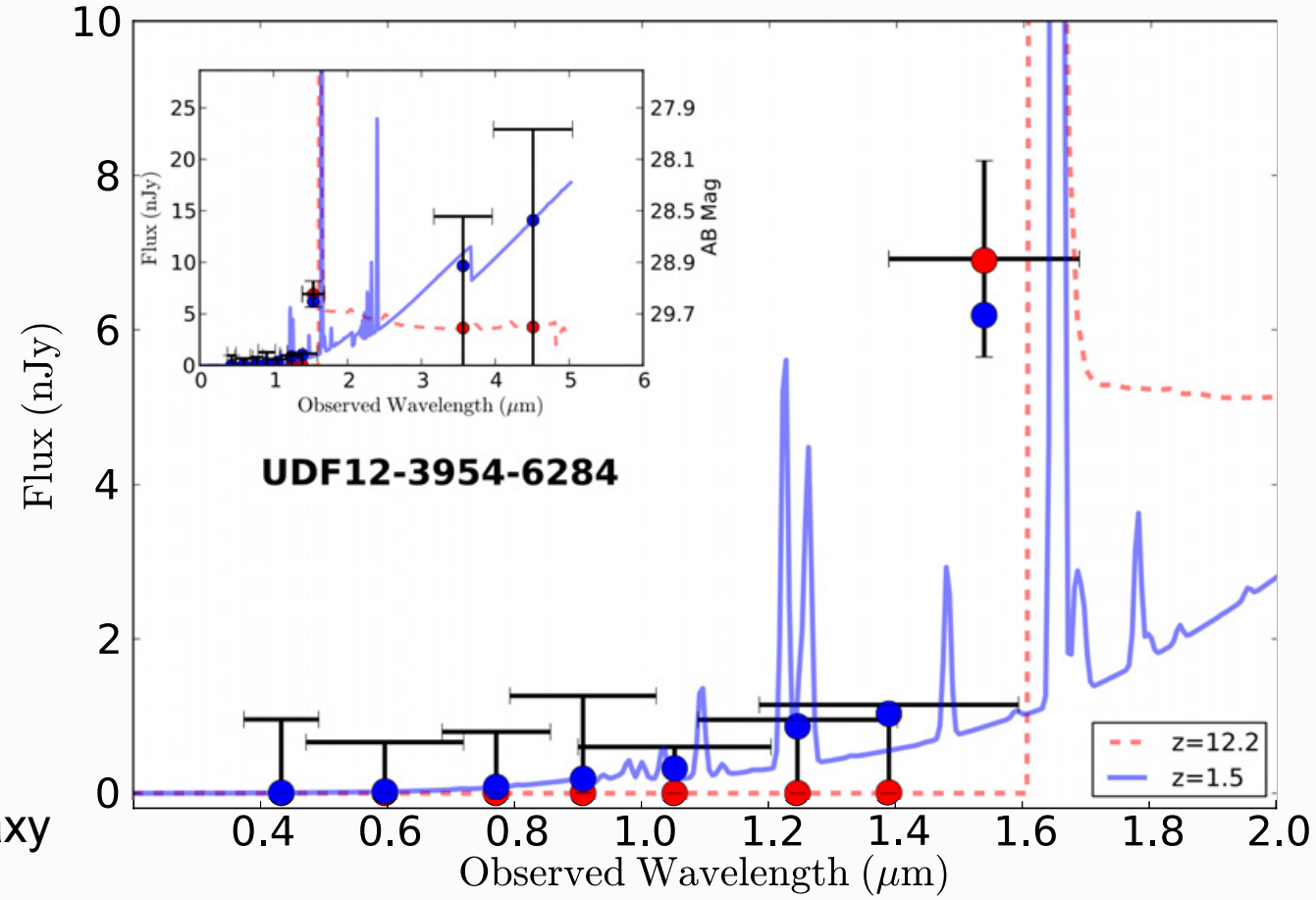
SED fitting works, but not all parameters are equal!



But IR data help - a lot!

Hayward et al., 2014

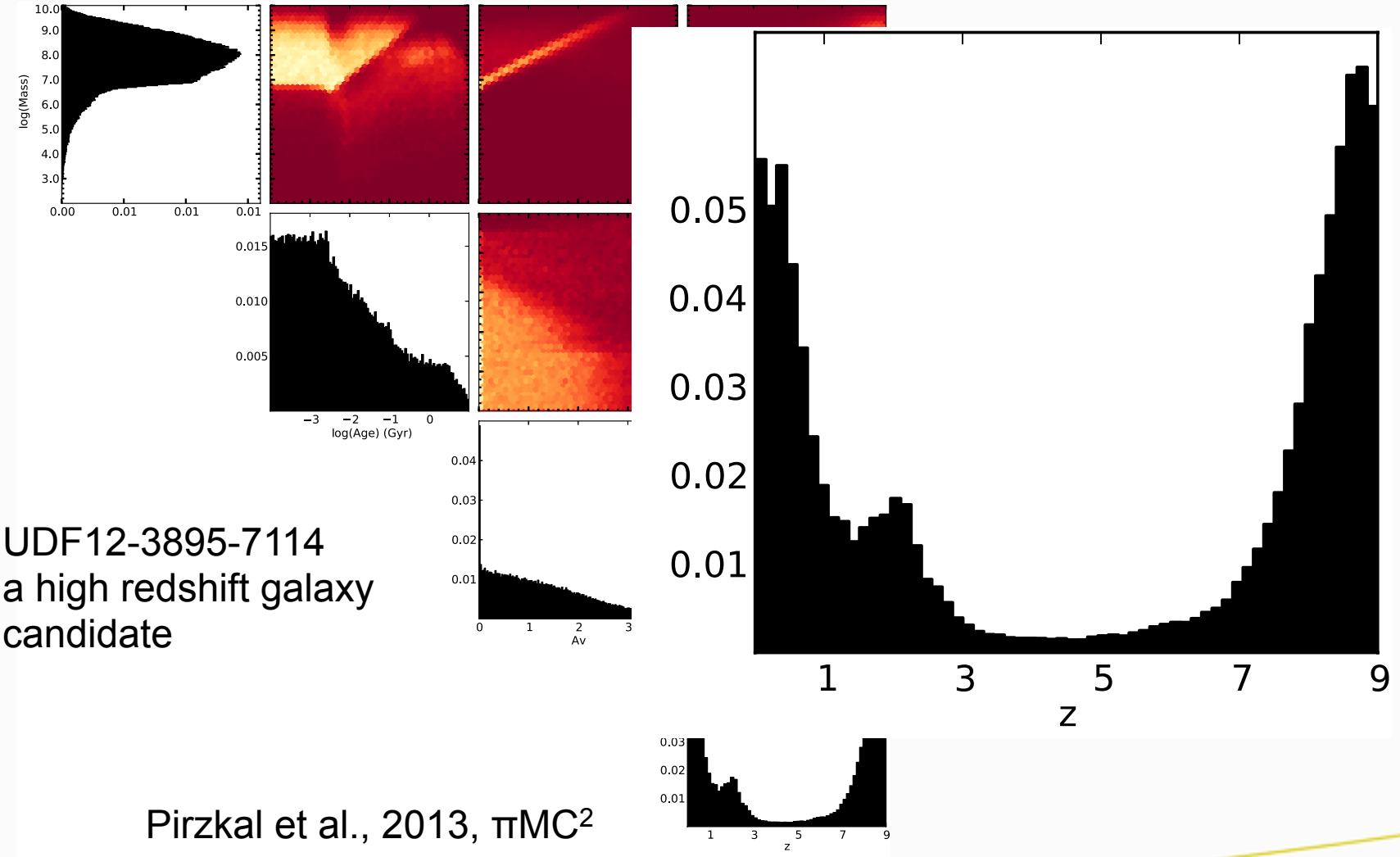
Example degeneracy problem



UDF12-3895-7114
a high redshift galaxy candidate

Pirzkal et al., 2013, πMC²

Example degeneracy problem



UDF12-3895-7114
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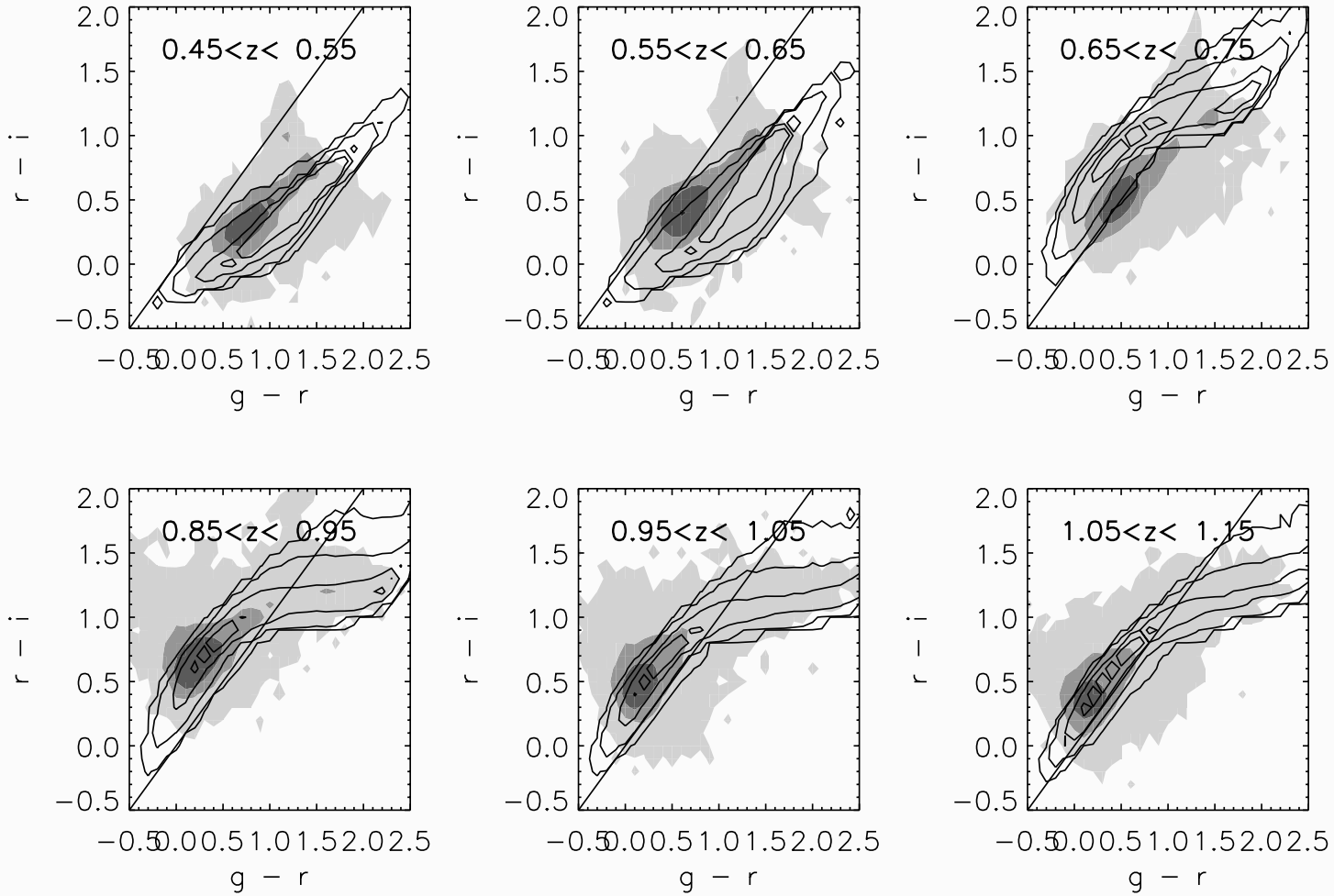
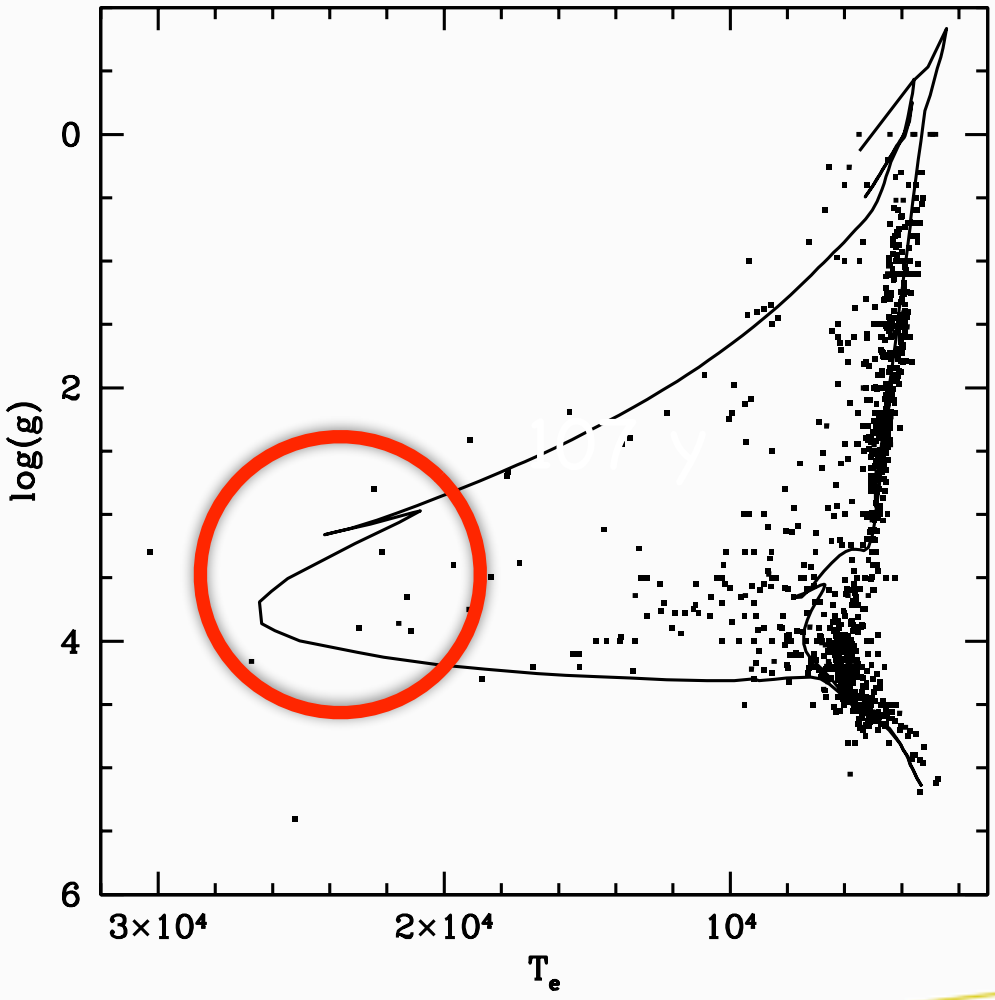
Example model problem



Walcher et al., 2008

Example model problem

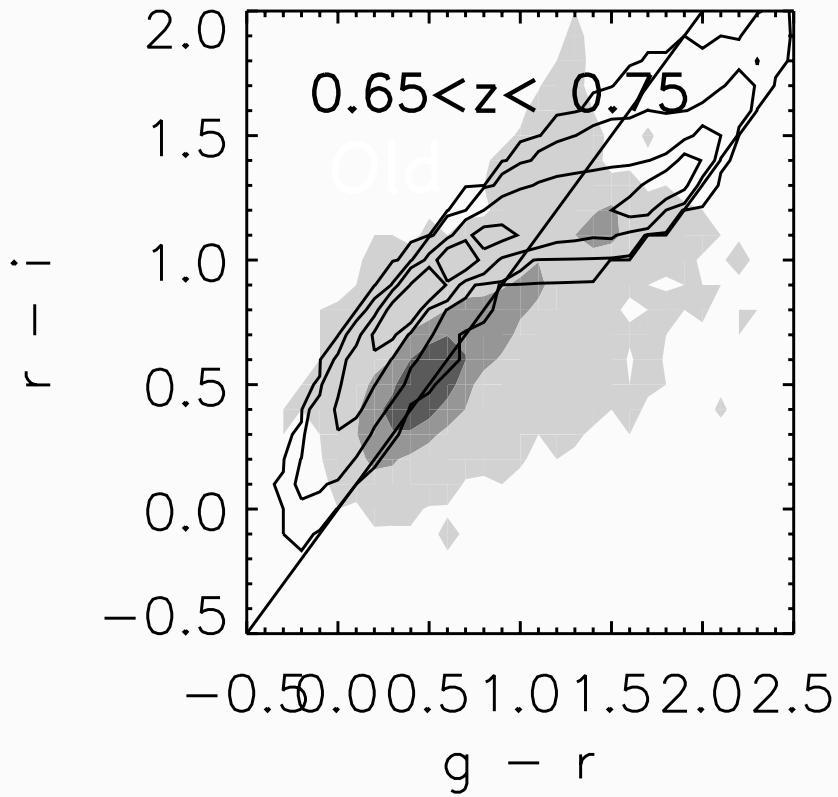
"Few" hot stars in the library



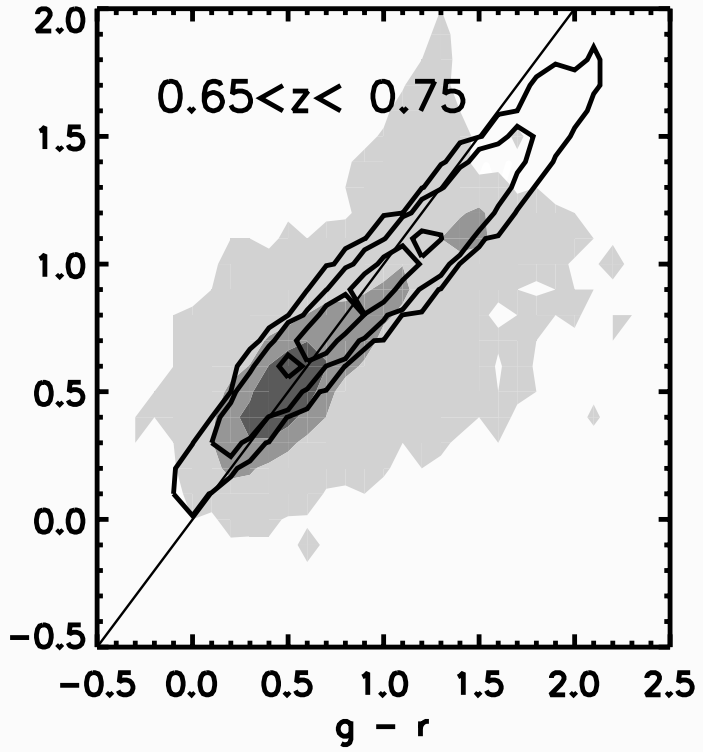
library: MILES
isochrone: Padova

Example model problem - solved

Old

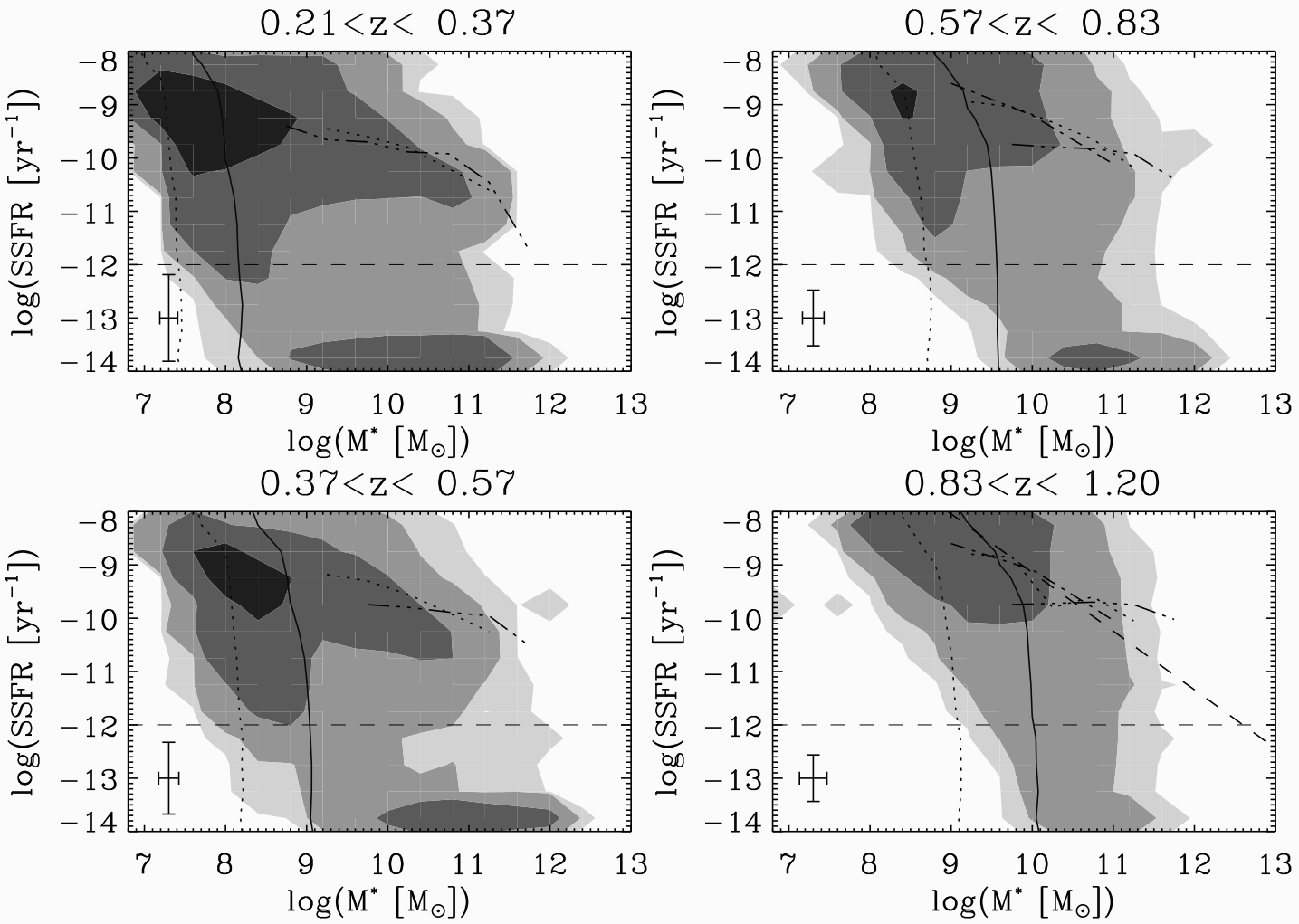


New



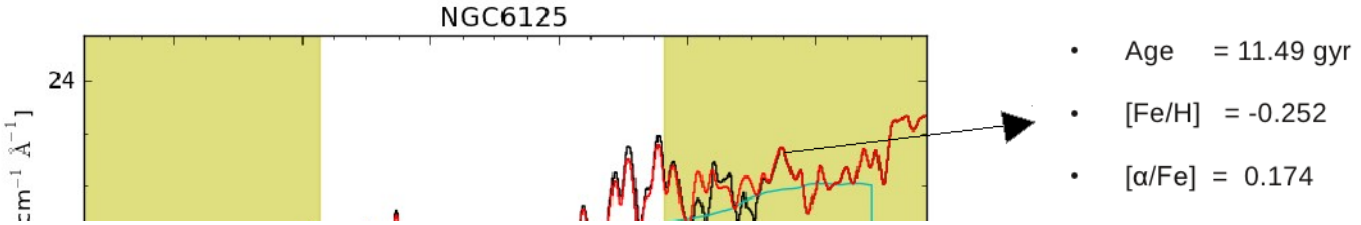
Based on test models by Bruzual & Charlot 2009 including theoretical hot stellar spectra

Space dens of gals & selection effects



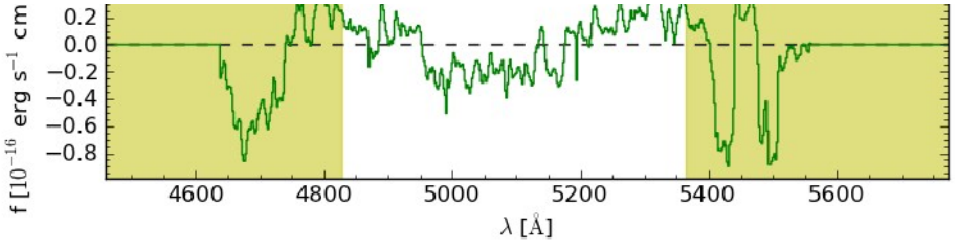
Walcher et al., 2008

Fitting a spectroscopic SED



Available codes (complete?):
ppxf, ulyss, starlight, steckmap, fit3D
(paradise, moped, platefit, nbursts, vespa)

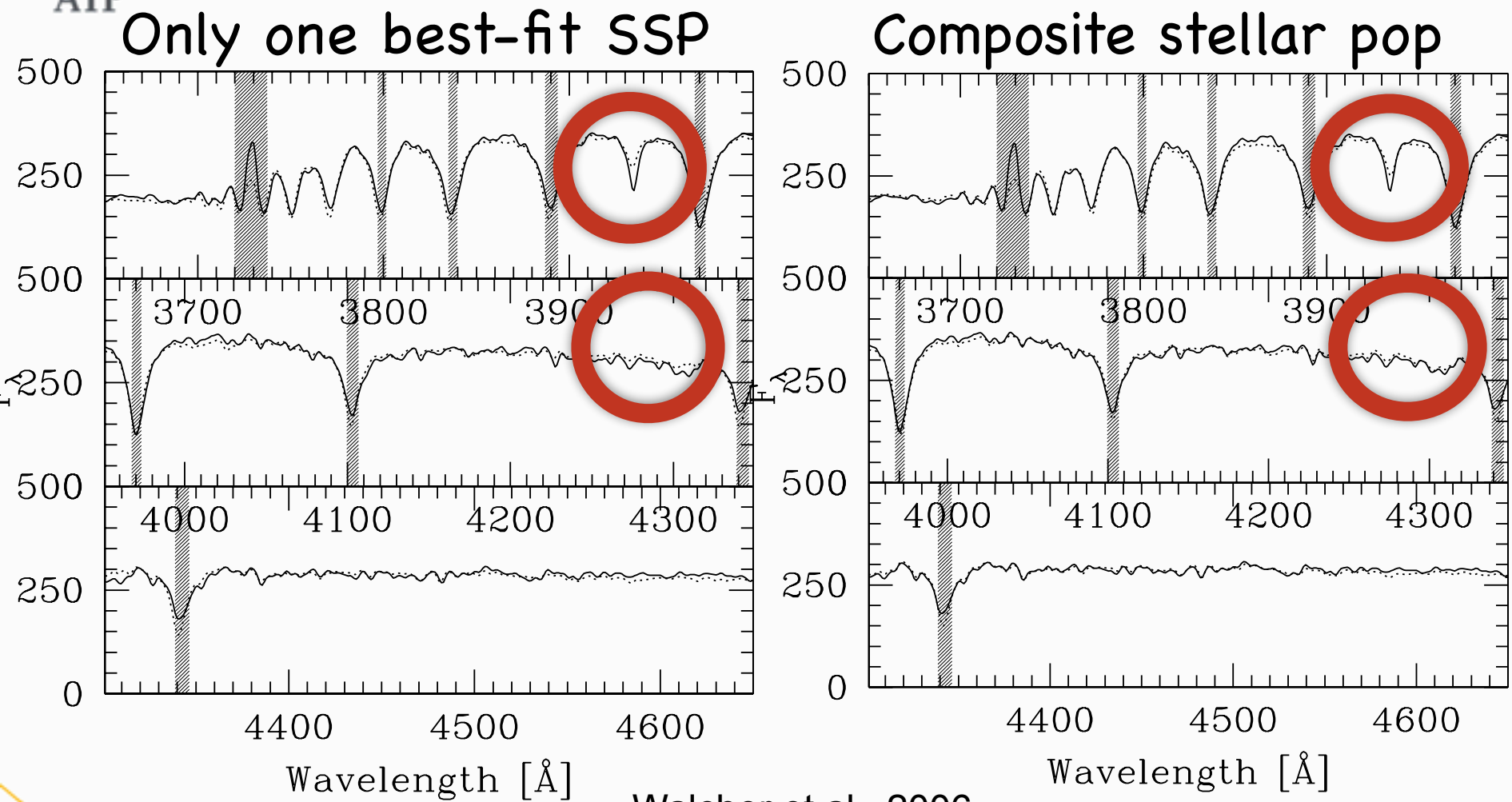
ill-
m!!



Dust and continuum slope!!

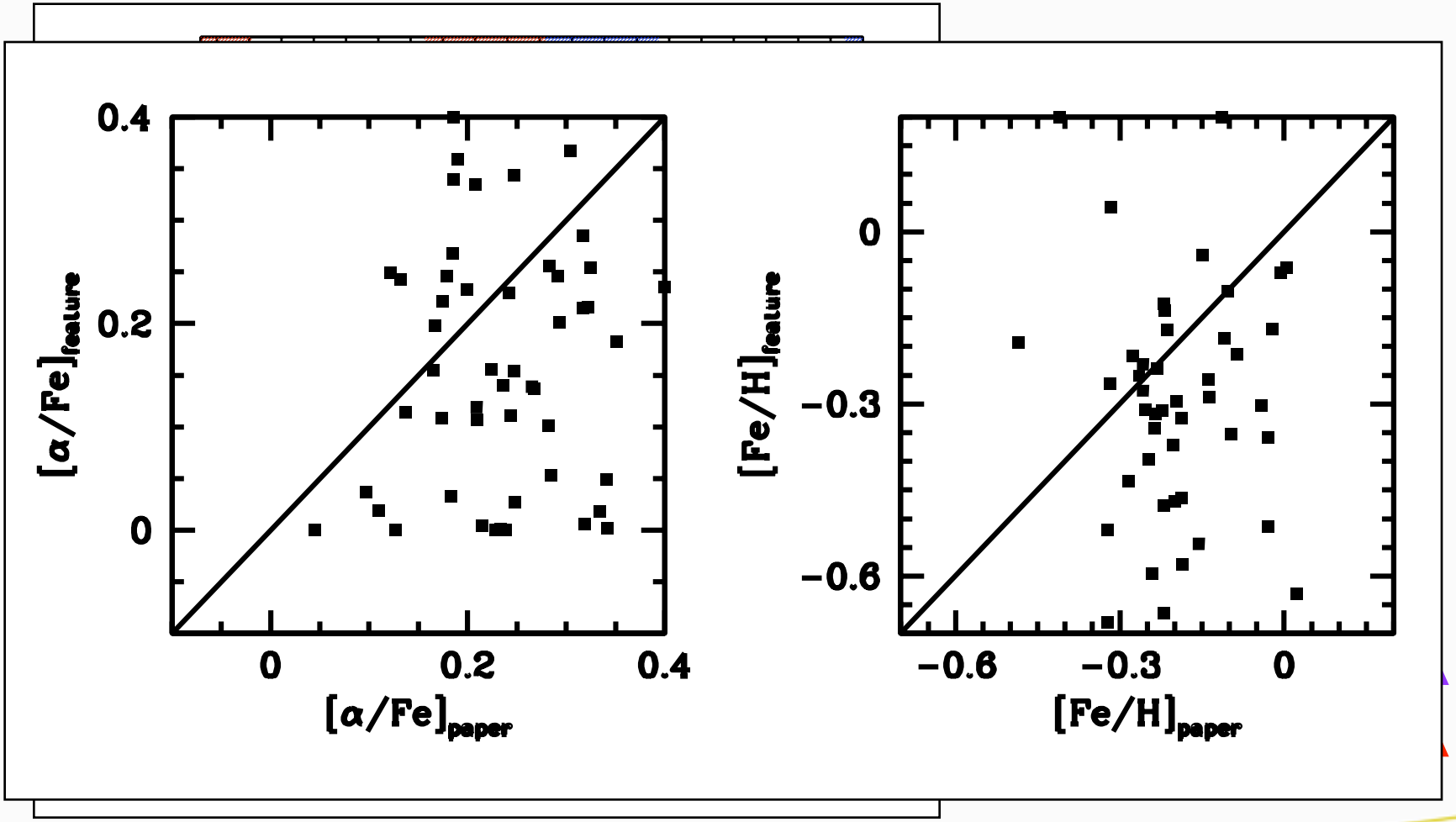
$$\chi^2 = \sum_{i=0}^{n} \left[\frac{F_i - \sum_{i=1}^{M} a_k S_i [t_k, Z^0, T^0]}{\sigma_i} \right]^2,$$

Why SSPs are not enough

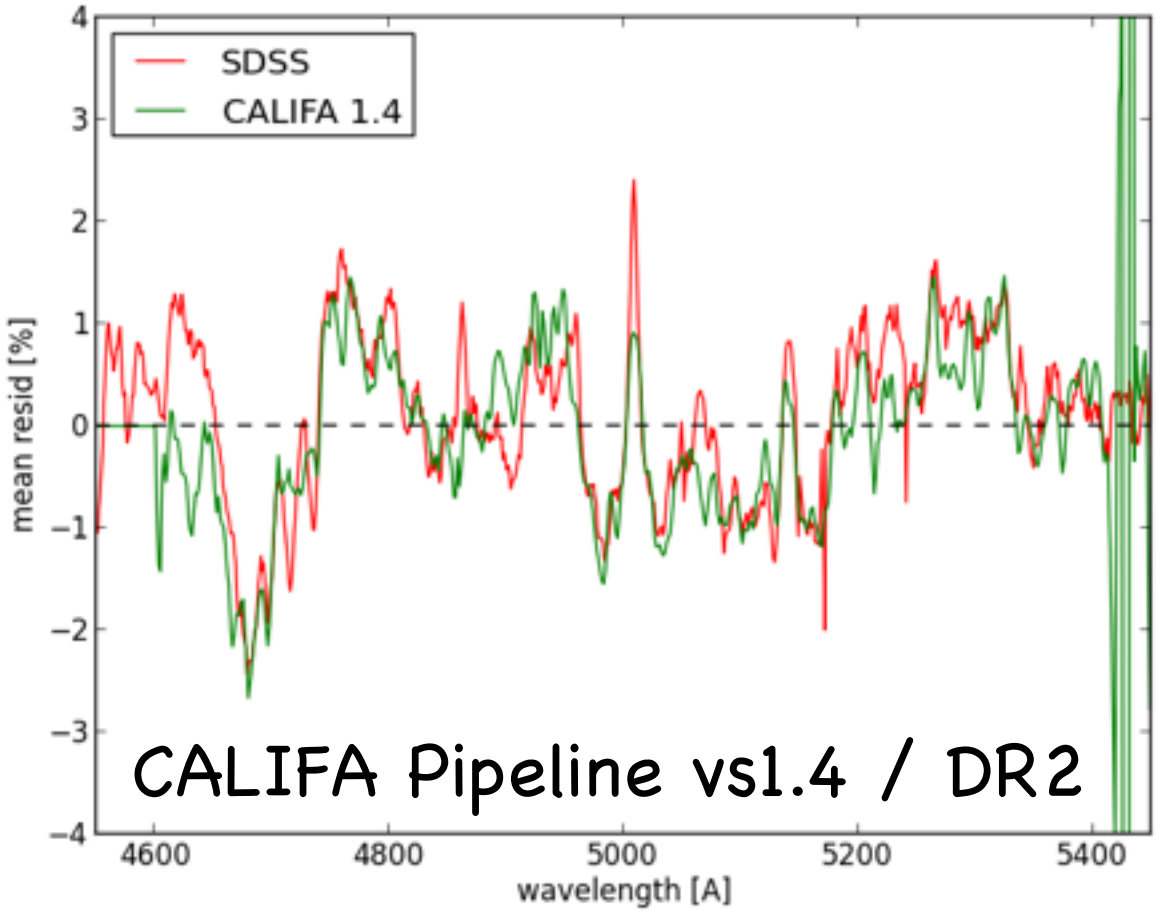


Walcher et al., 2006

Do not trust *good* fits!

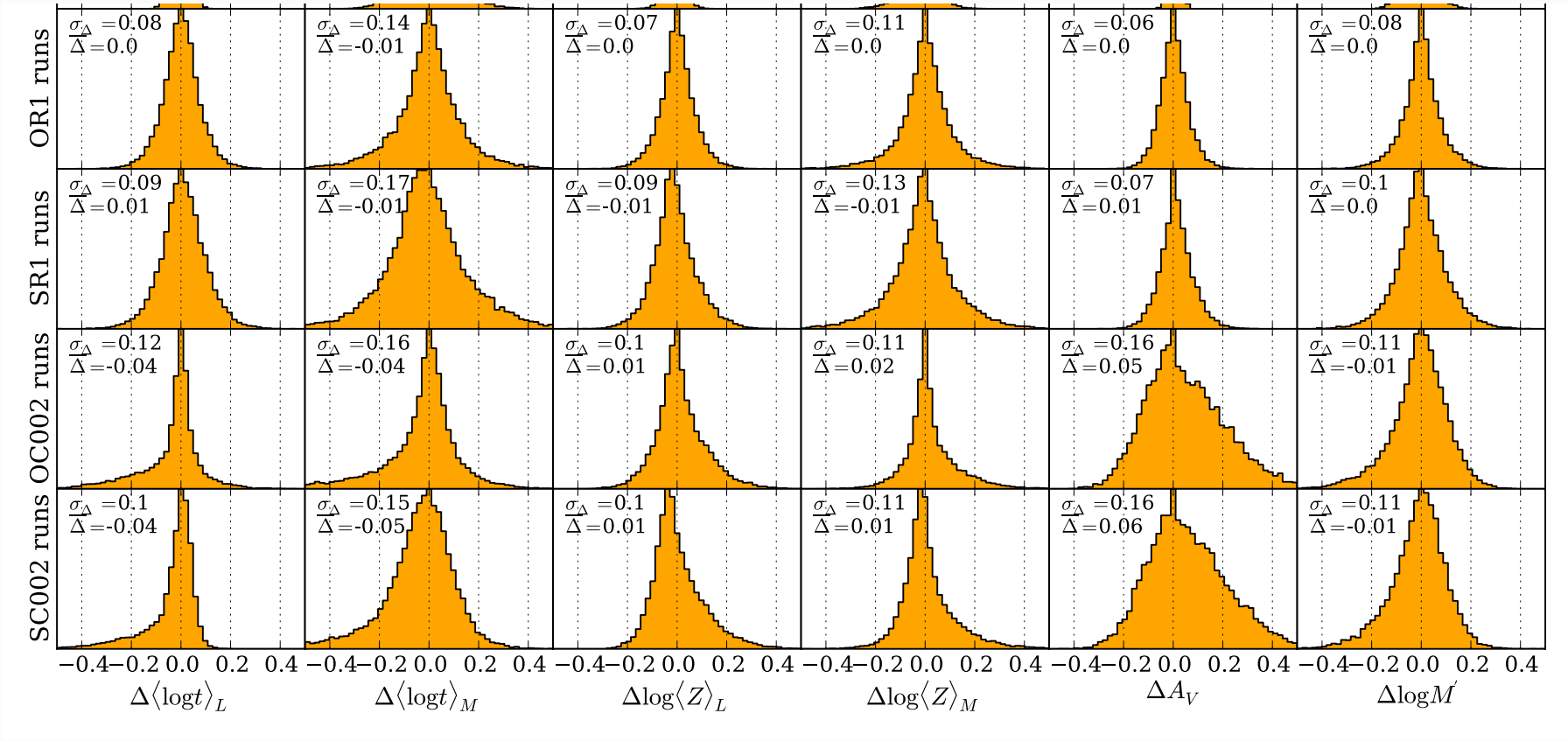


Residuals



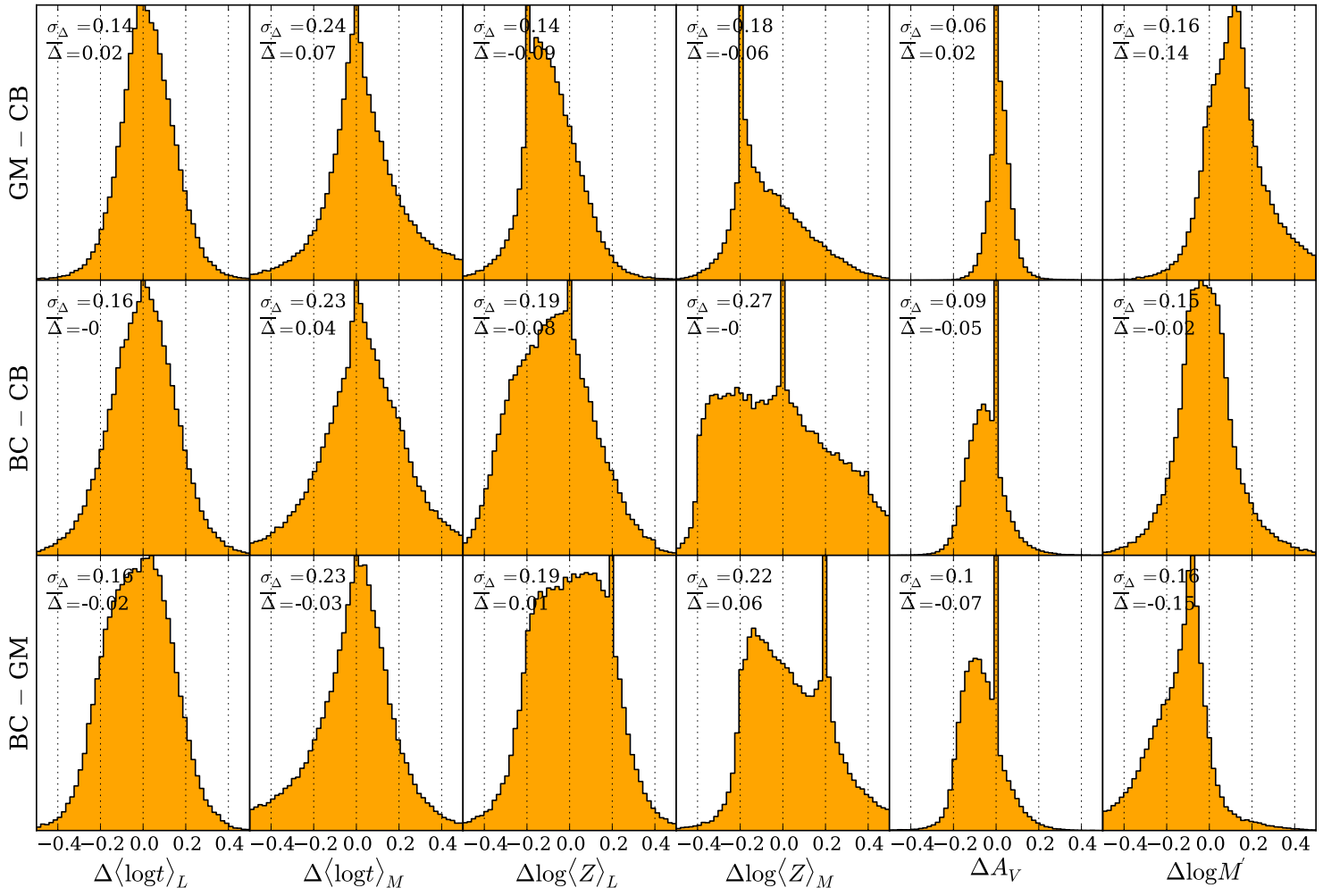
Template mismatch dominates!

Effect of noise



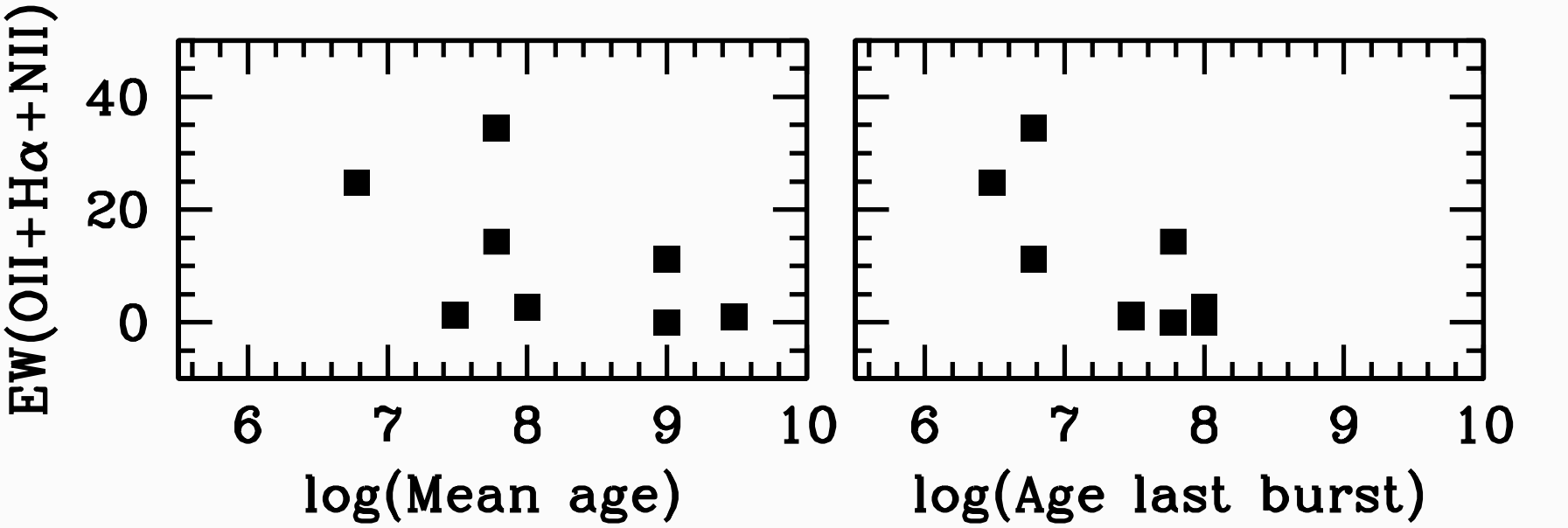
Cid-Fernandes et al. 2013, 2014

Effect of model



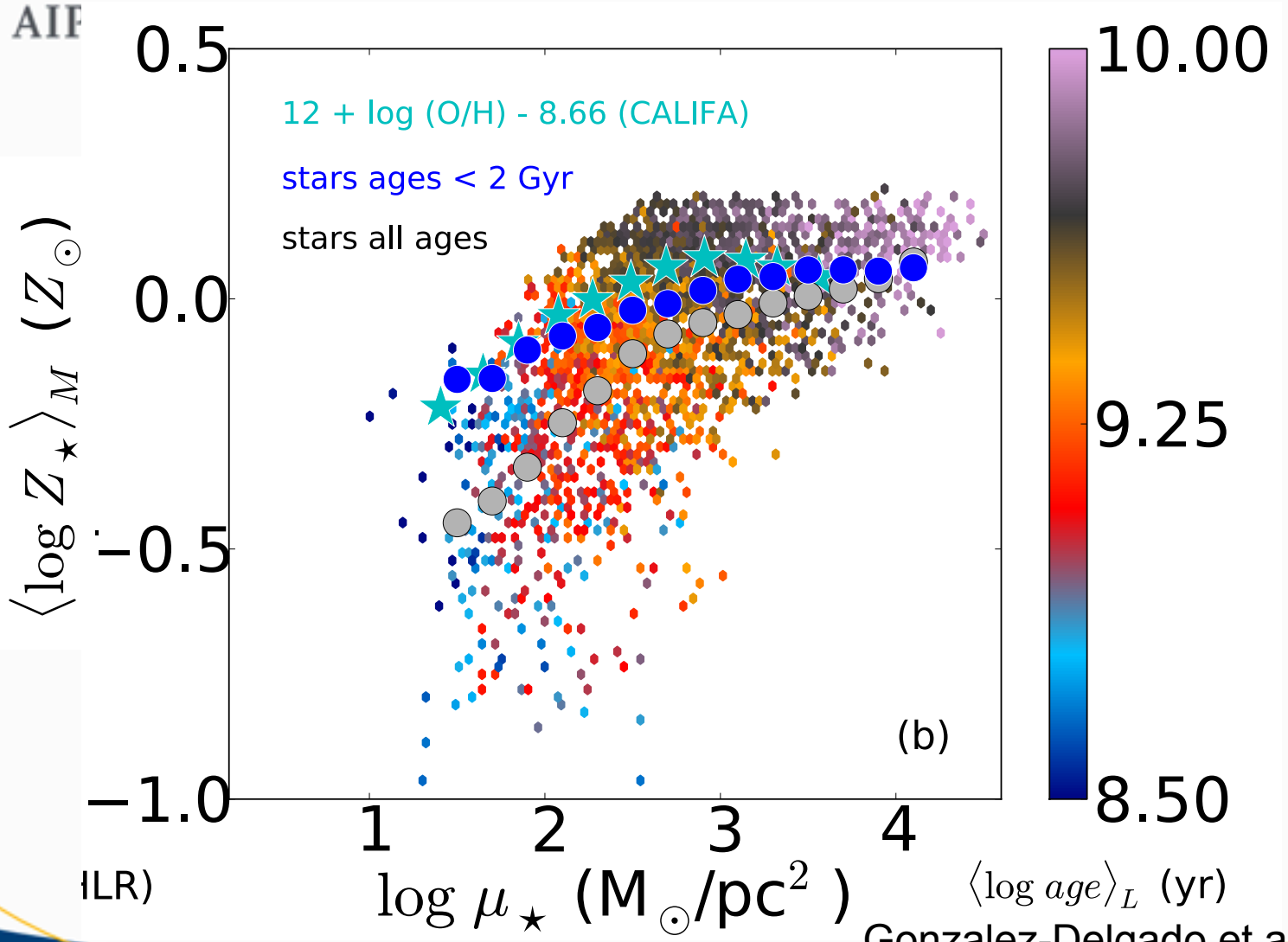
Cid-Fernandes et al. 2013, 2014

Young stellar populations in particular



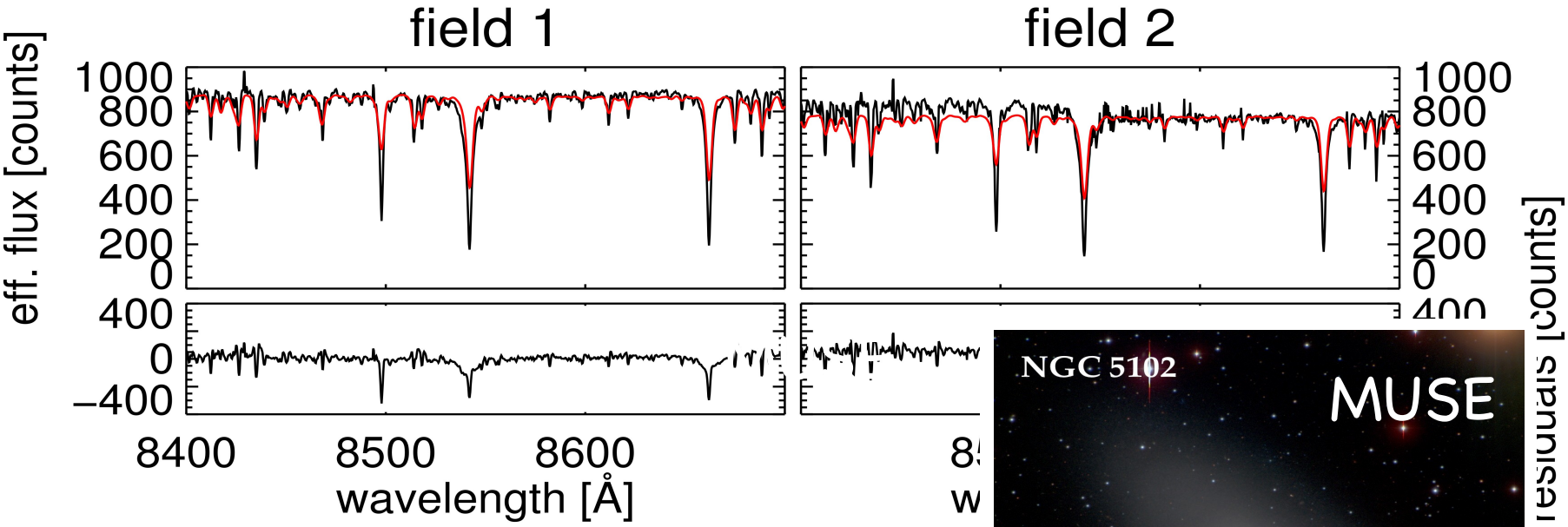
Walcher et al., 2011

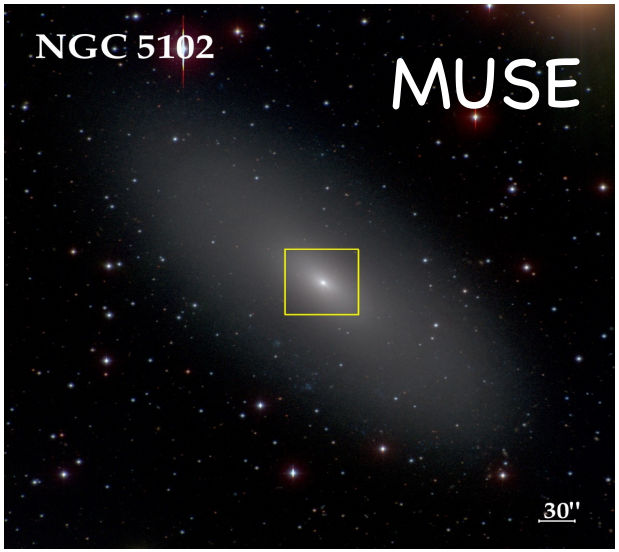
Σ-Z relation from CALIFA



Gonzalez-Delgado et al., 2014

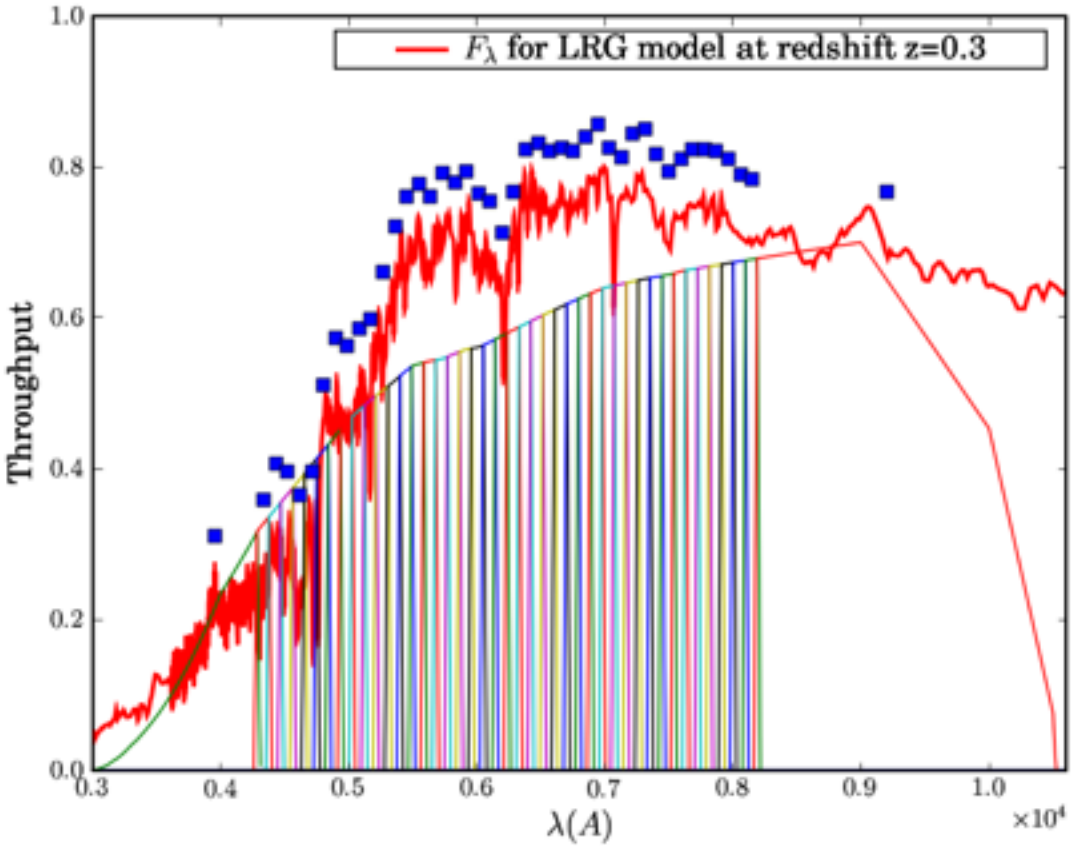
Blurring the boundaries: spectroscopic surface brightness fluct.





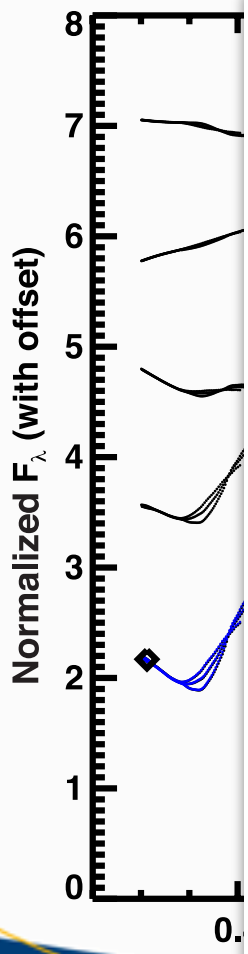
Martin Mitzkus et al., 2014

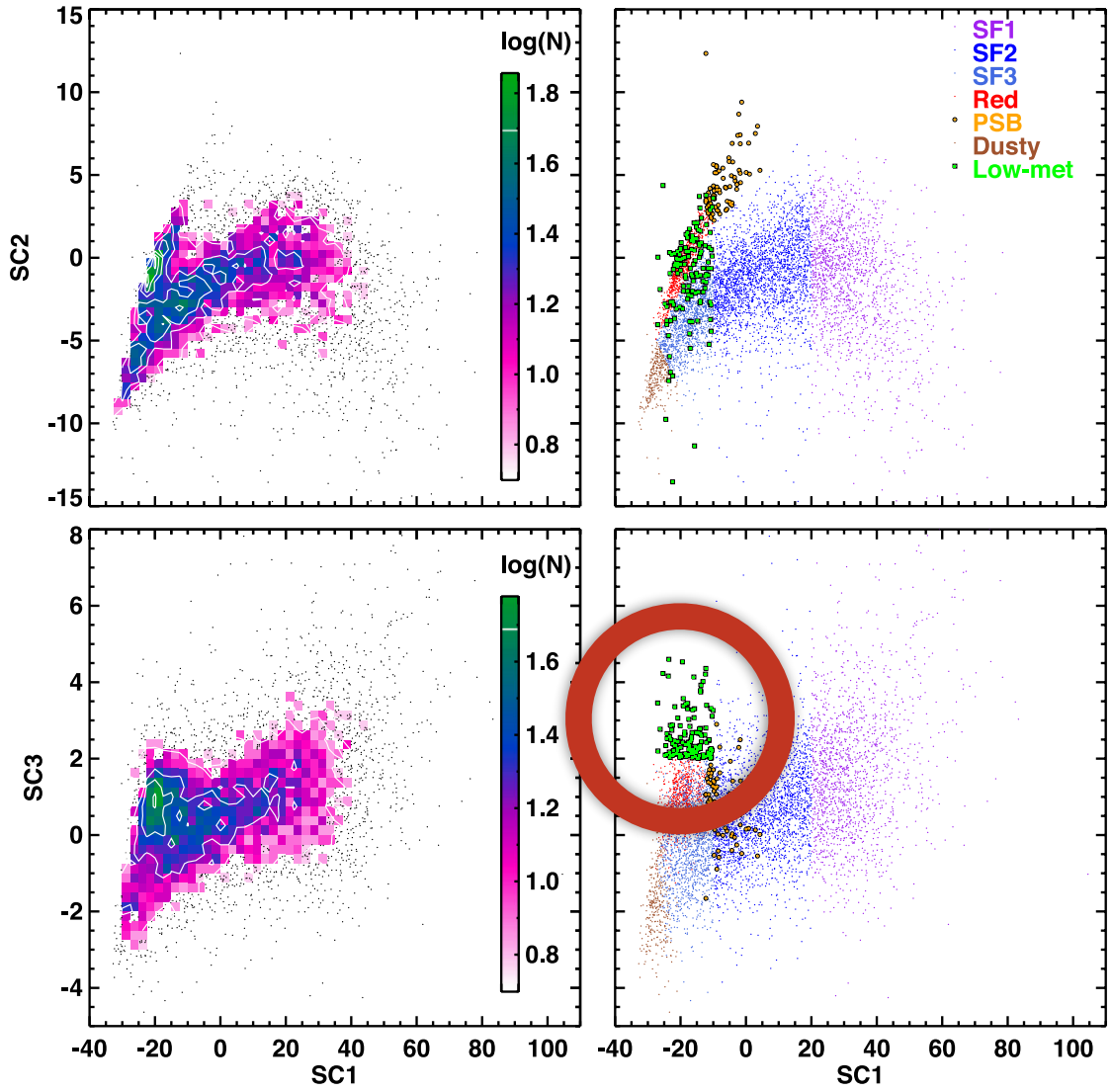
Blurring the boundaries: high R photometry



Javalambre observatory (Benitez et al.)
See also COMBO-17 and others

Blurring the boundaries: "spectroscopic" info from photoSEDs





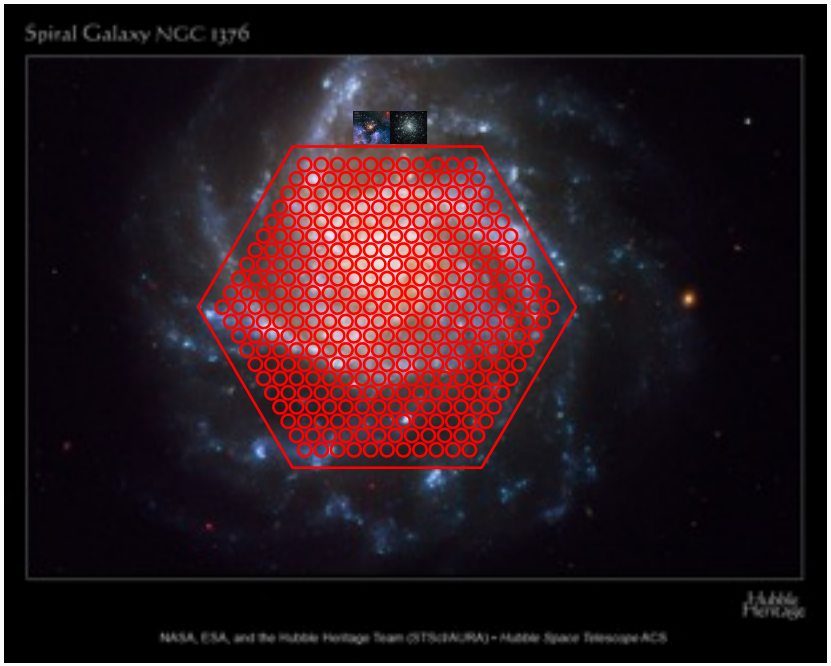
2014

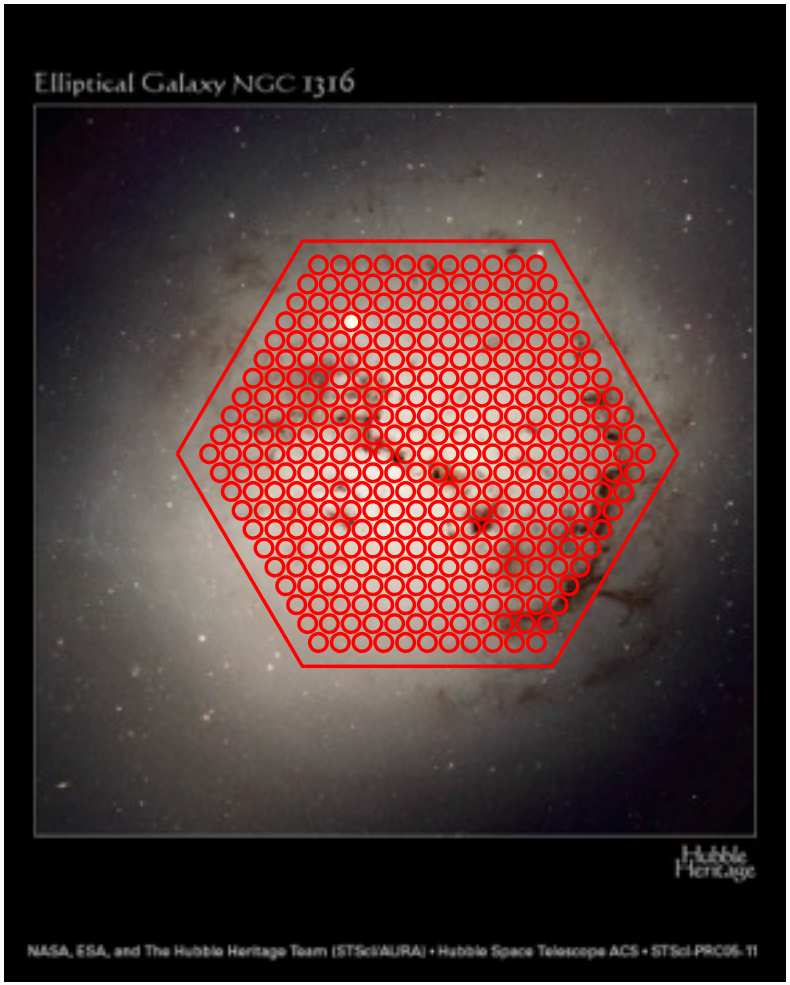
UNresolved stellar populations

- The (ongoing) future

UNresolved stellar populations, but resolved galaxies

Imaging spectroscopy: SAURON/A3D, CALIFA, VENGA, PINGS, SAMI, MANGA, MUSE, many more





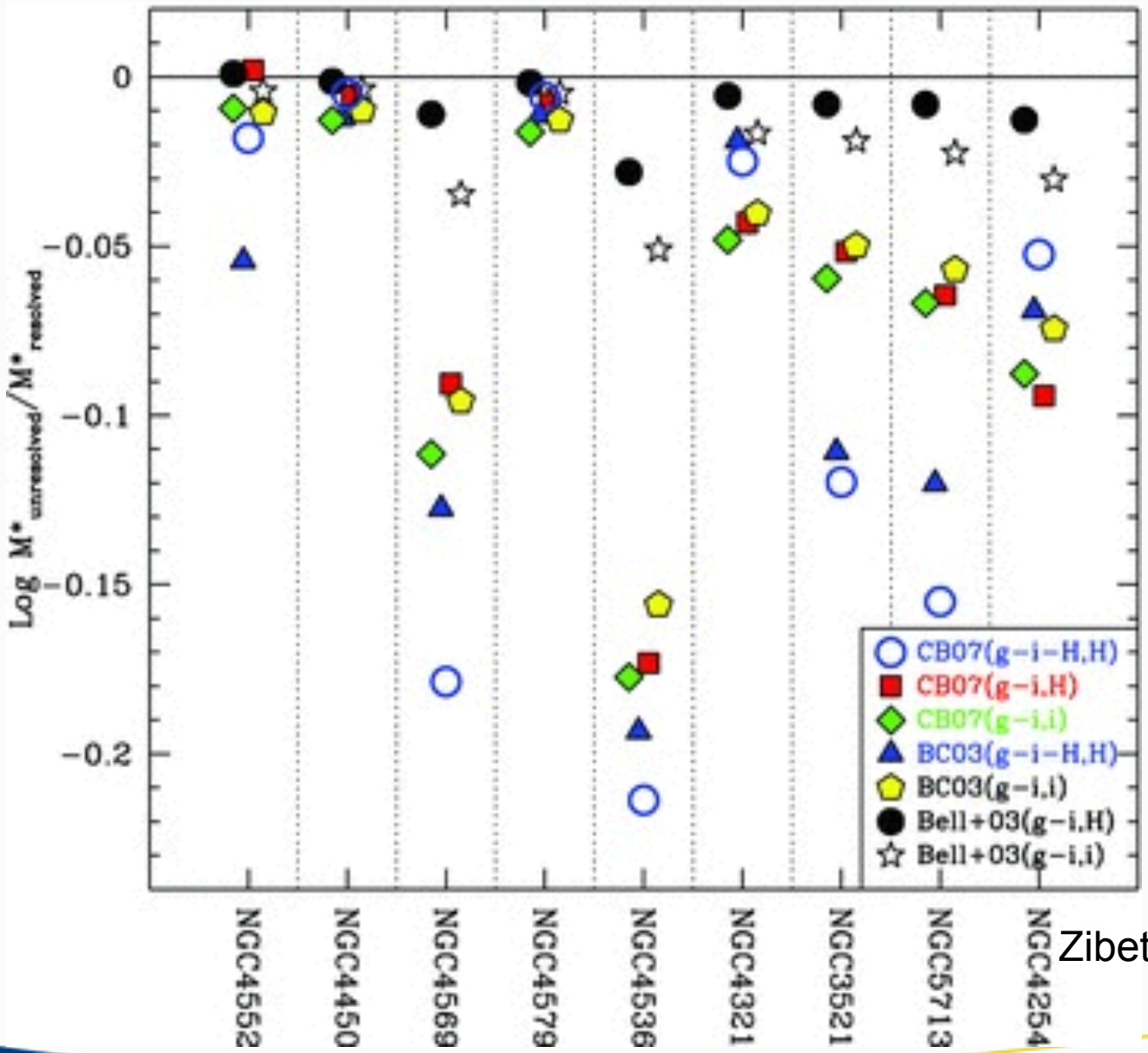
Resolved stellar populations

and resolved dust structures out to Virgo

Better, deeper, higher redshift …

Conclusions

- Without analyzing the integrated SEDs of galaxies we would know far less about the universe.
- Our dependance on the way we model the input physics clashes with the need for progress.
- Good practices exist that allow robust statements about galaxy physical properties *given the model*.
- To make best use of present and future instrumentation potential we need to emphasize:
  - Model development and verification
  - Rigorous sample selection
  - Discard old habits (e.g. fitting SSPs, calibrating to Lick system)



Zibetti et al., 2009

Extensive verification of spectral fitting

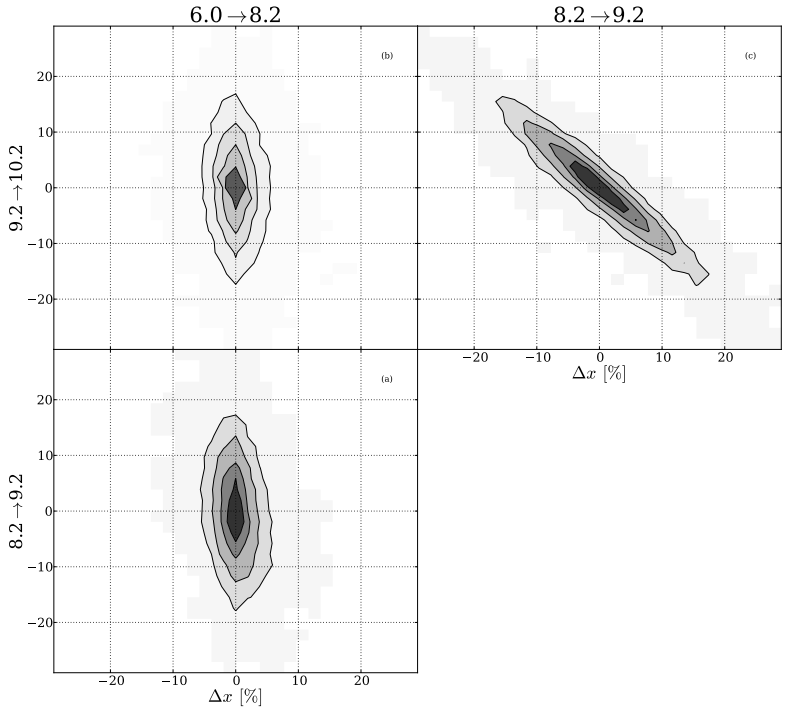


Fig. 5. Variations in the light fractions in Young, Intermediate and Old age groups (spanning log t = 6–8.2, 8.2–9.2 and 9.2–10.2, respectively) for OR1 simulations. Contours are drawn at 20, 40, 60 and 80% of enclosed points.

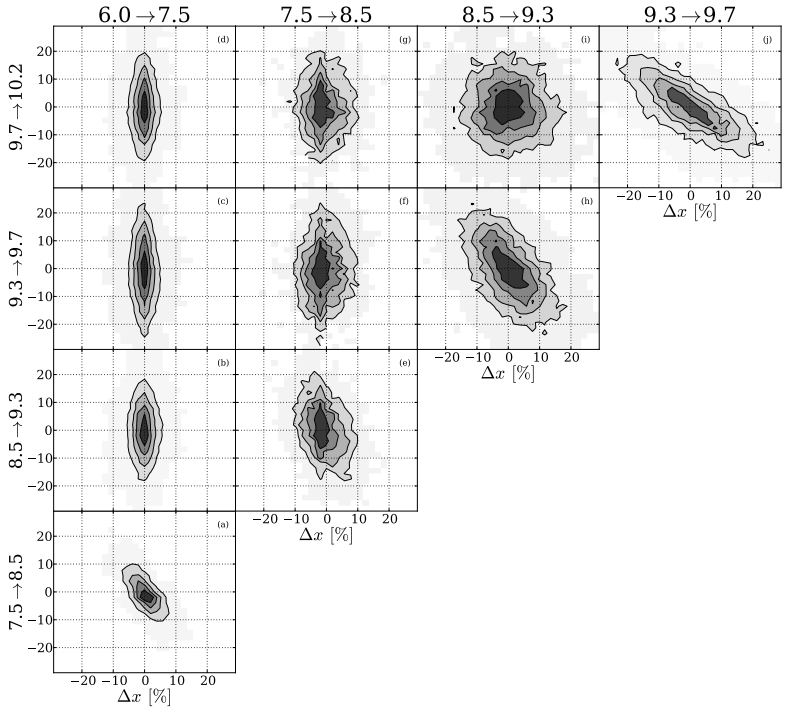
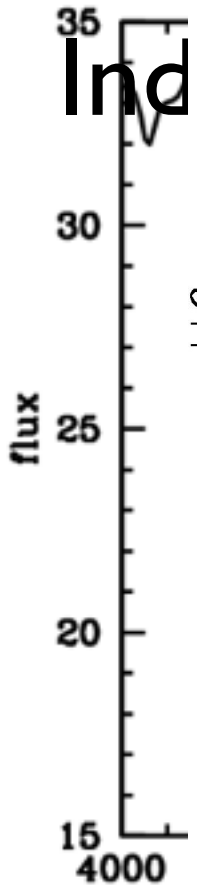
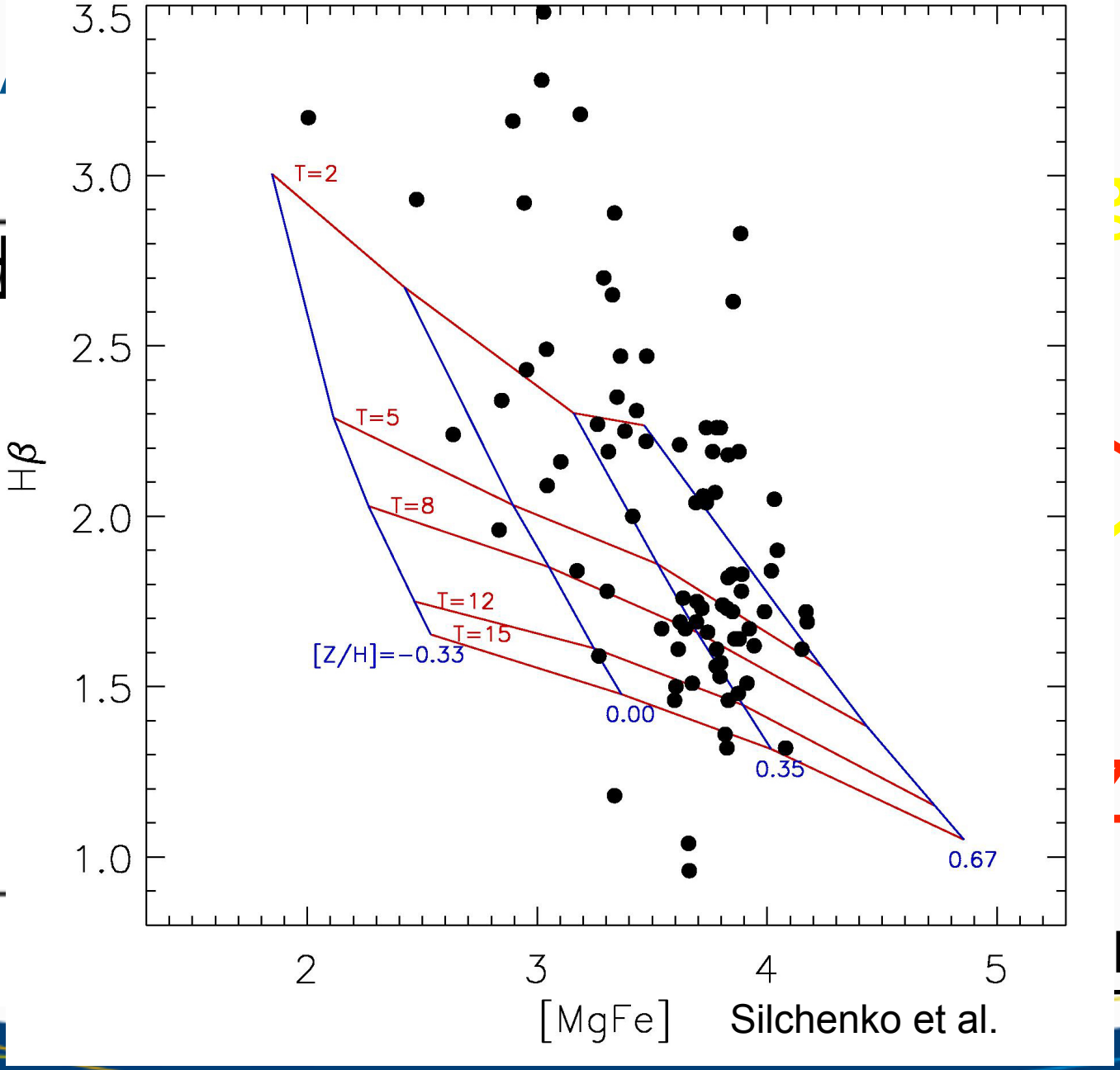


Fig. 6. As Fig.5, but for a finer graded description of the SFH in terms of 5 age groups.

Cid-Fernandes et al. 2013, 2014


35
30
25
20
15
flux
4000


3.5
3.0
2.5
2.0
1.5
1.0
Hβ
T=2
T=5
T=8
T=12
T=15
[Z/H]=−0.33
0.00
0.35
0.67
2
3
4
5
[MgFe]
Silchenko et al.