Using Current Population Synthesis Models to Their Limits

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Fine-Tuning Stellar Population Models, Leiden, 26-30 June 2006

Stellar Population Models

Goal:

Use our knowledge about how stars form, evolve, and shine, to build models which allow as to make quantitative predictions of the observable properties of stellar populations (star clusters and galaxies) as a function of time and other astrophysical parameters (Z, IMF, SFR).

Stellar Population Models

Very Basic Ingredients:

Stellar evolutionary tracks

Stellar spectra

Models cannot be better than these data sets

Most talks in this conference discuss these points

Where are the limits?

Stellar libraries limit models by their:

- Spectral wavelength coverage
- Coverage of HRD or CMD
- Flux calibration or lack of it
- Metallicity coverage
- Uncertainties in theoretical model atmospheres

How to fill the gaps? (model dependent trick)

Where are the limits?

Stellar tracks limit models by the:

- Coverage of all or some evolutionary phases
- Input physics (opacities)
- Metallicity: X, Y, Z, Fe/H, alpha enhancement
- Accuracy of numerical codes

How to fill the gaps and join disjoint data sets?
(model dependent trick)

Recent empirical spectral libraries

Indo–US Library:

A library of KPNO Coudé feed stellar spectra (Valdes et al. 2004) for 1273 stars from 3460 to 9464 Å at a resolution of ~ 1Å.

MILES:

Flux calibrated spectra for ~ 1000 stars with 2.4 Å resolution in the range from 3500 to 7500 Å (Sánchez-Blázquez et al. 2006).

Recent empirical spectral libraries

HNGSL:

Hubble's New Generation Stellar Library (Heap and Lanz 2003): 2000 to 10,000 Å for close to 400 stars. Low resolution, but UV coverage.

UVES POP Library:

UVES Paranal Observatory Project – a Library of High-Resolution Spectra of Stars across the HRD (Bagnulo et al. 2004) . High SNR spectra from 3040 to 10,400 Å for over 400 stars, with R = 80,000.

Theoretical spectral libraries

Chávez, Bertone, Buzzoni, Rodríguez-Merino:

Atlas from 850 to 4750 Å for same parameters as Kurucz model atmospheres. Designed to study UV spectral indices.

González-Delgado & Cerviño:

Atlas from 3000 to 7000 Å for an ample range of parameters. Evolutionary models already available.

Theoretical spectral libraries

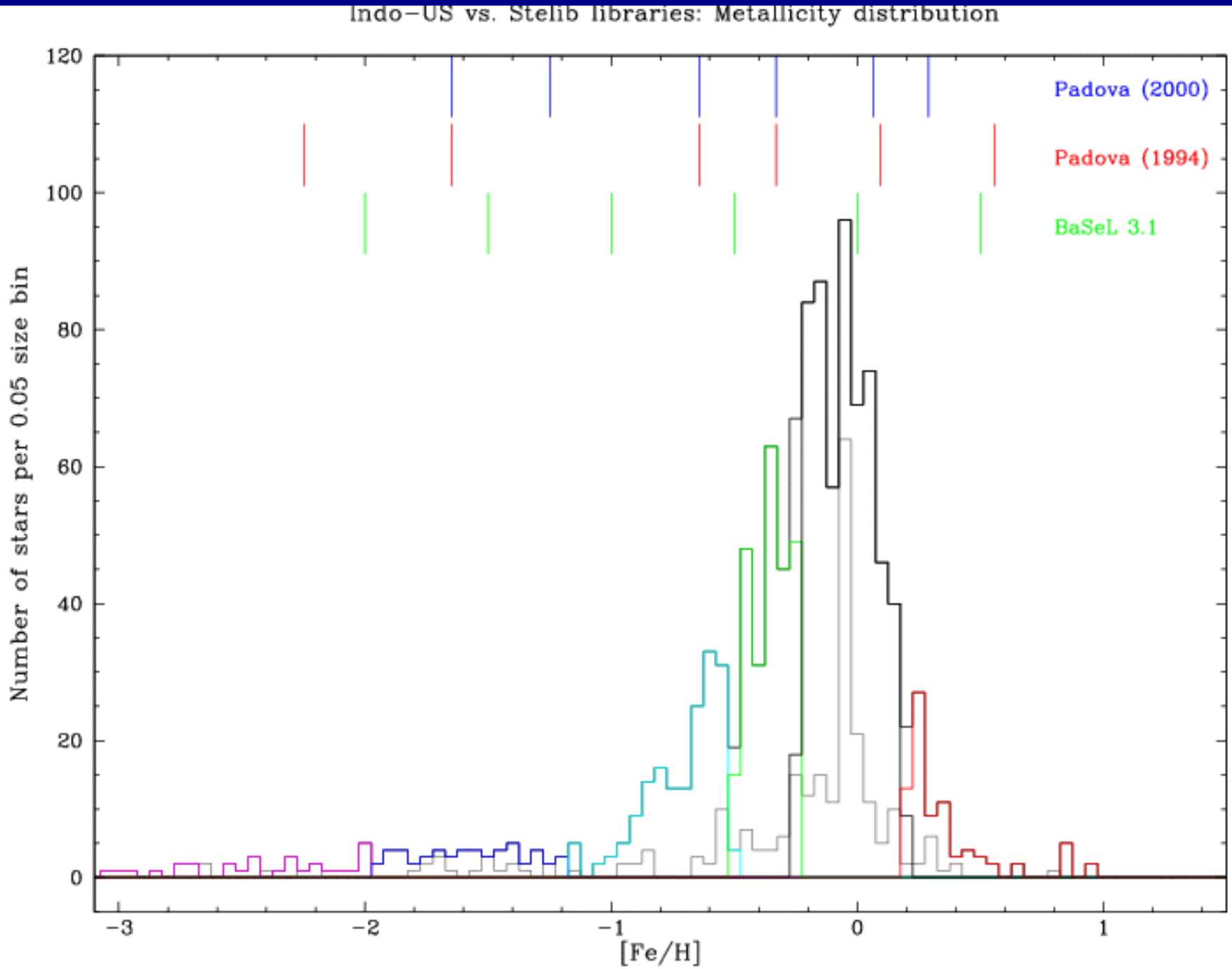
Munari & Castelli:

include effects of alpha enhancement in an atlas from 3000 to 10000 Å at high resolution.

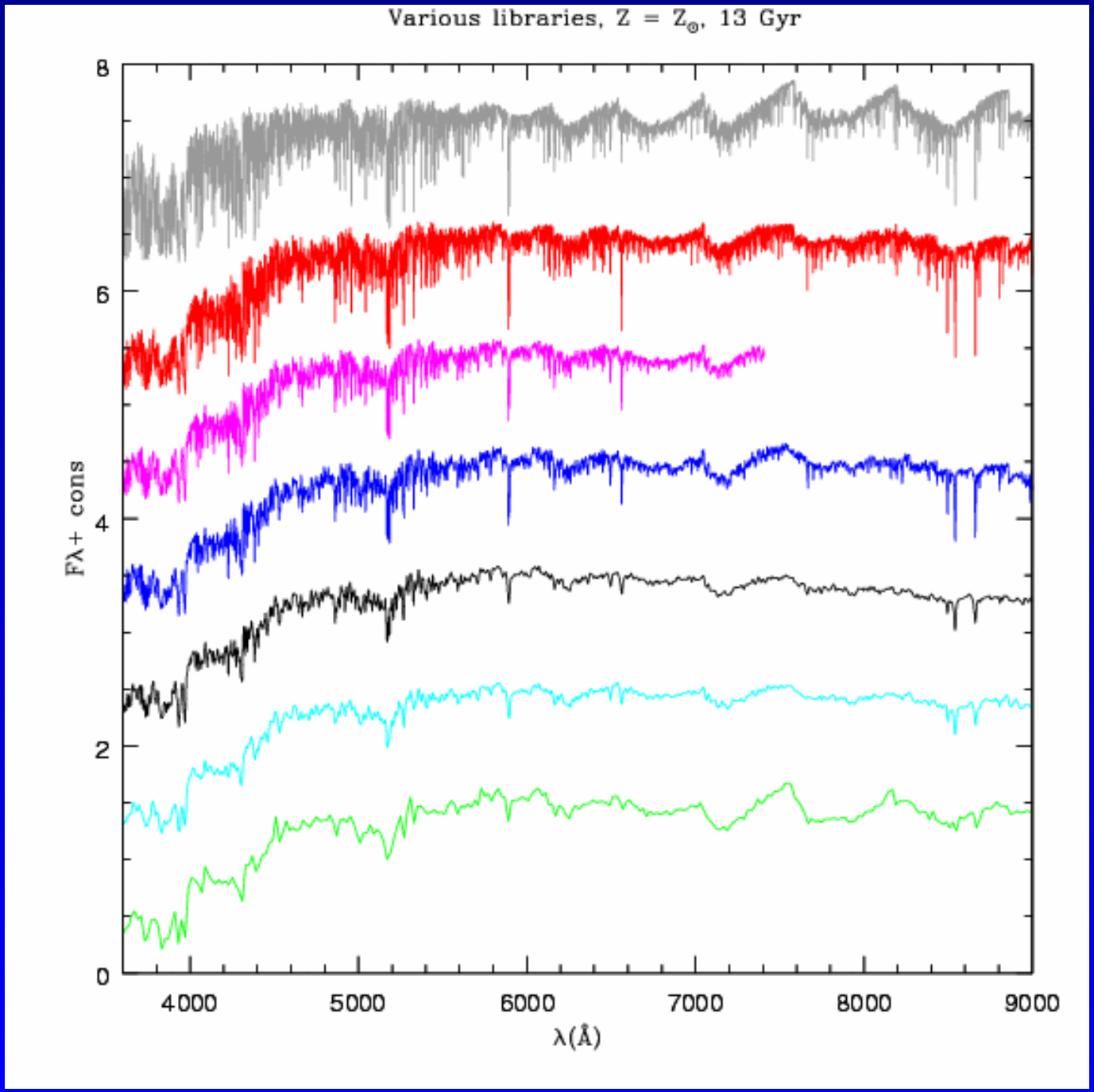
Coelho et al. theoretical model atmospheres:

long term project by Barbuy, Coelho and collaborators to compute a grid of theoretical model atmospheres based on Kurucz original models but at high resolution (0.1 Å) in the optical and IR. (see Coelho et al. 2004) including alpha enhancement.

IndoUS vs STELIB



Improving spectral resolution

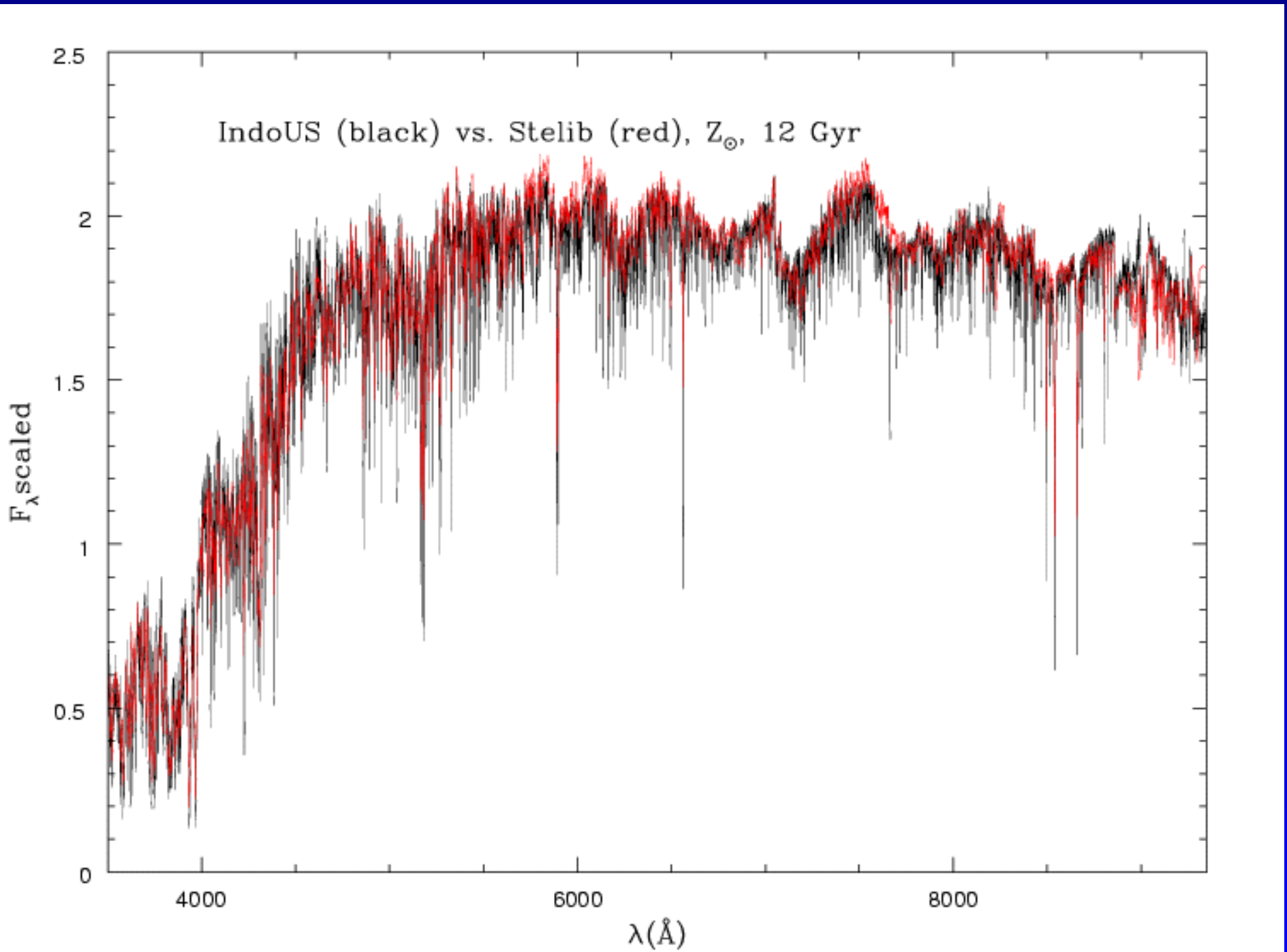


- IAG (< 1Å)
- IndoUS (~ 1Å)
- Miles (2.4 Å)

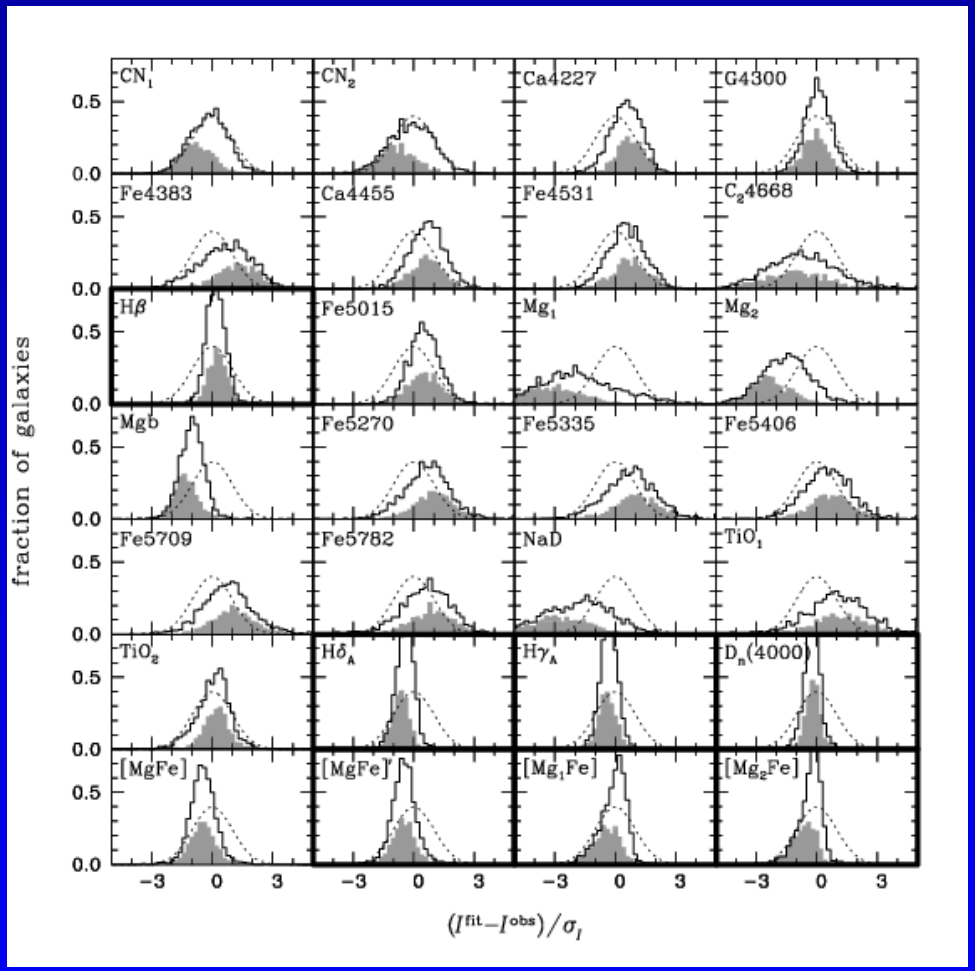
- Stelib (3 Å)
- HNGSL (~ 5Å)
- Pickles (5 Å)
- Kurucz (20 Å)

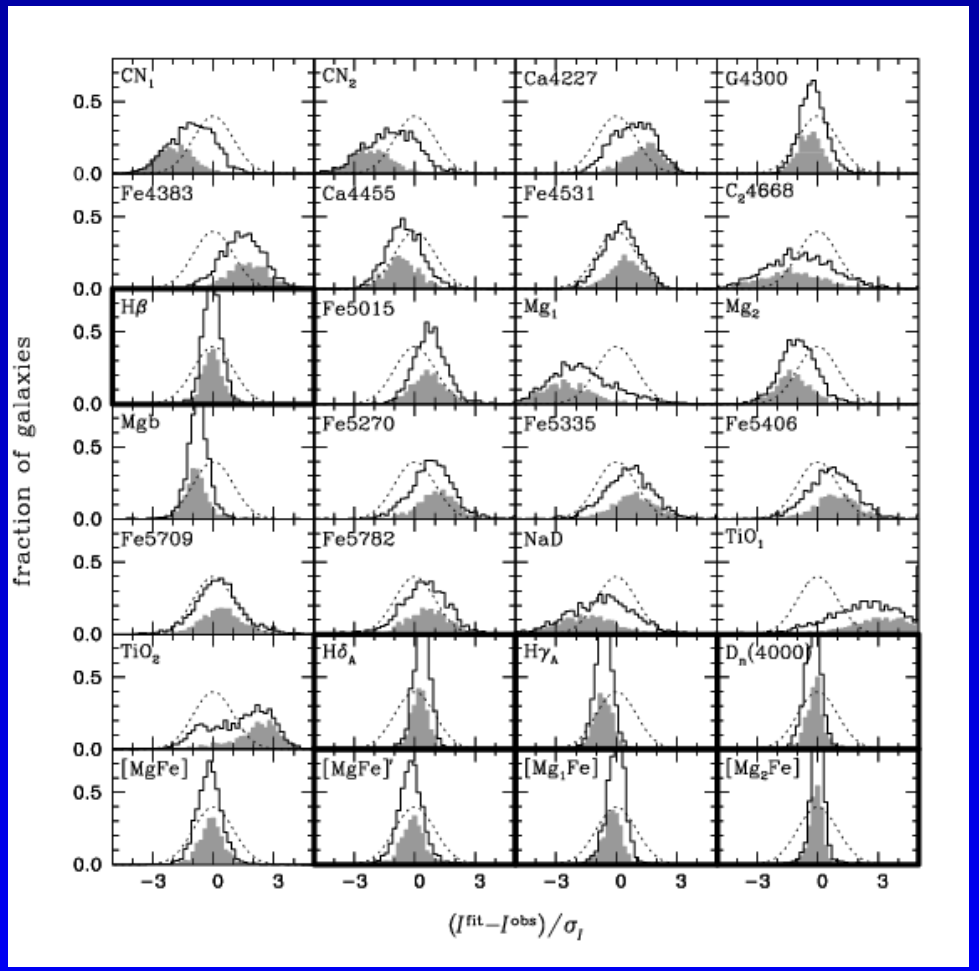
Padova 94 tracks

IndoUS vs Stelib models

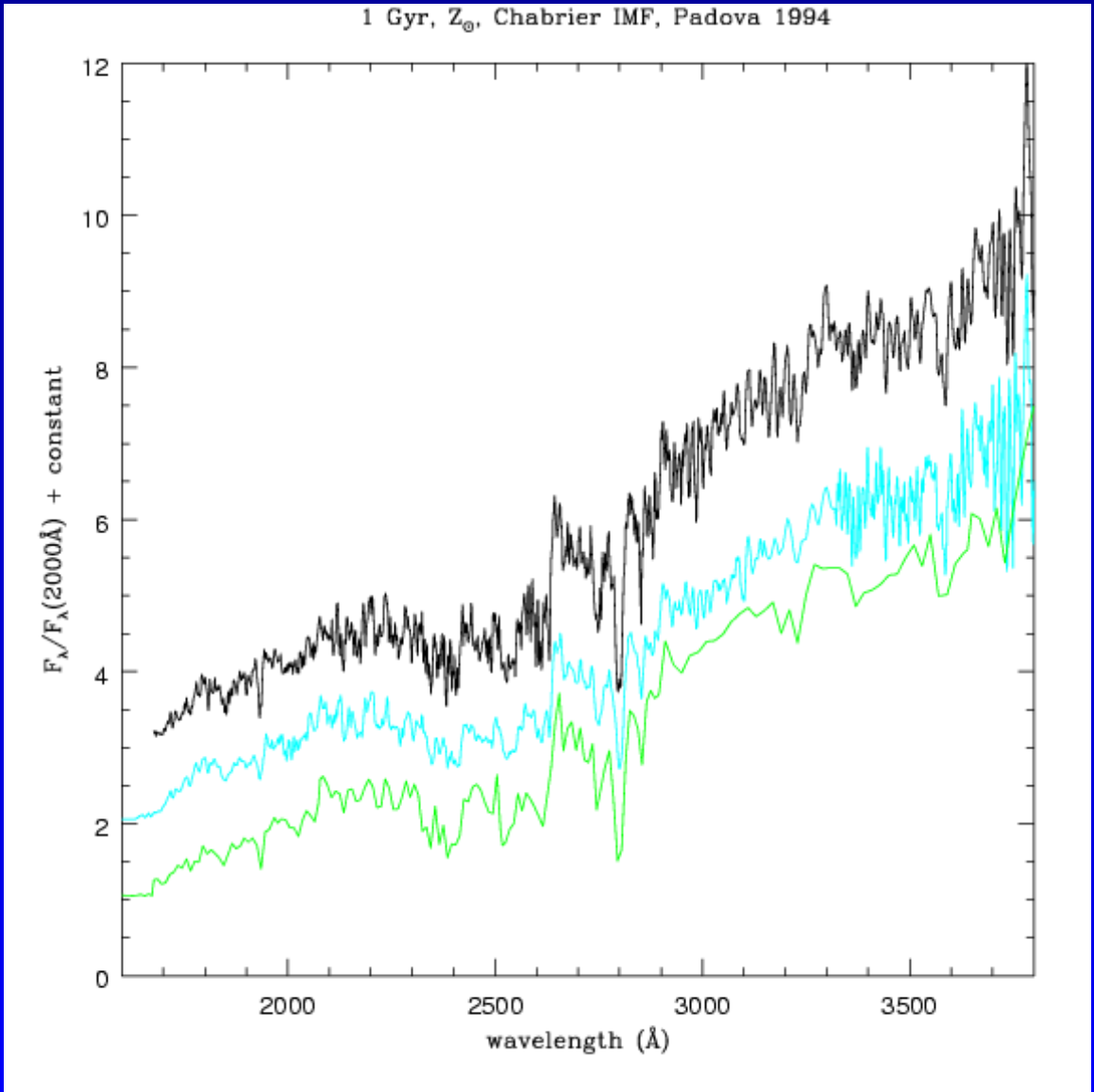


Update using IndoUS library (lhs)



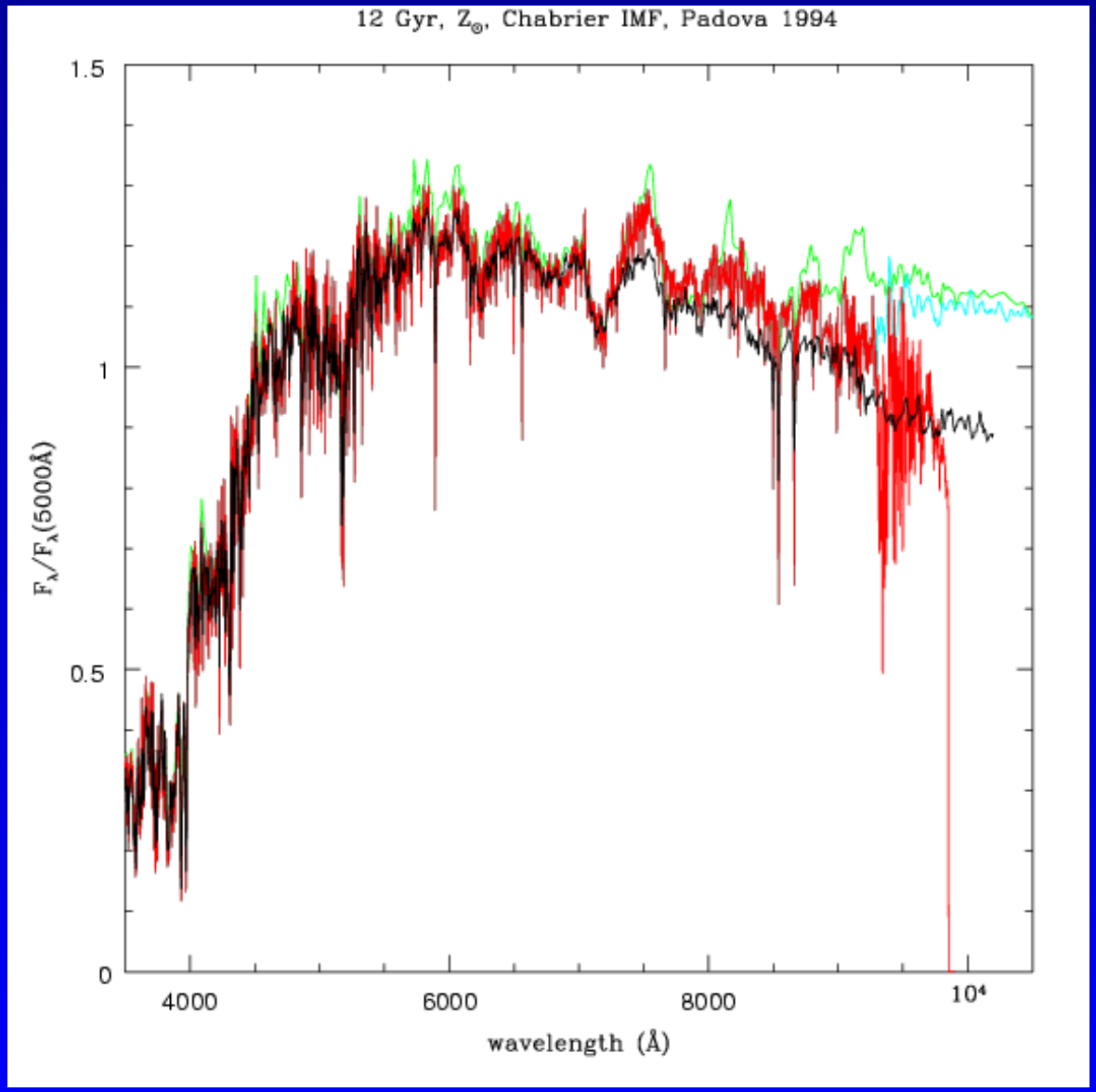


HNGSL UV coverage



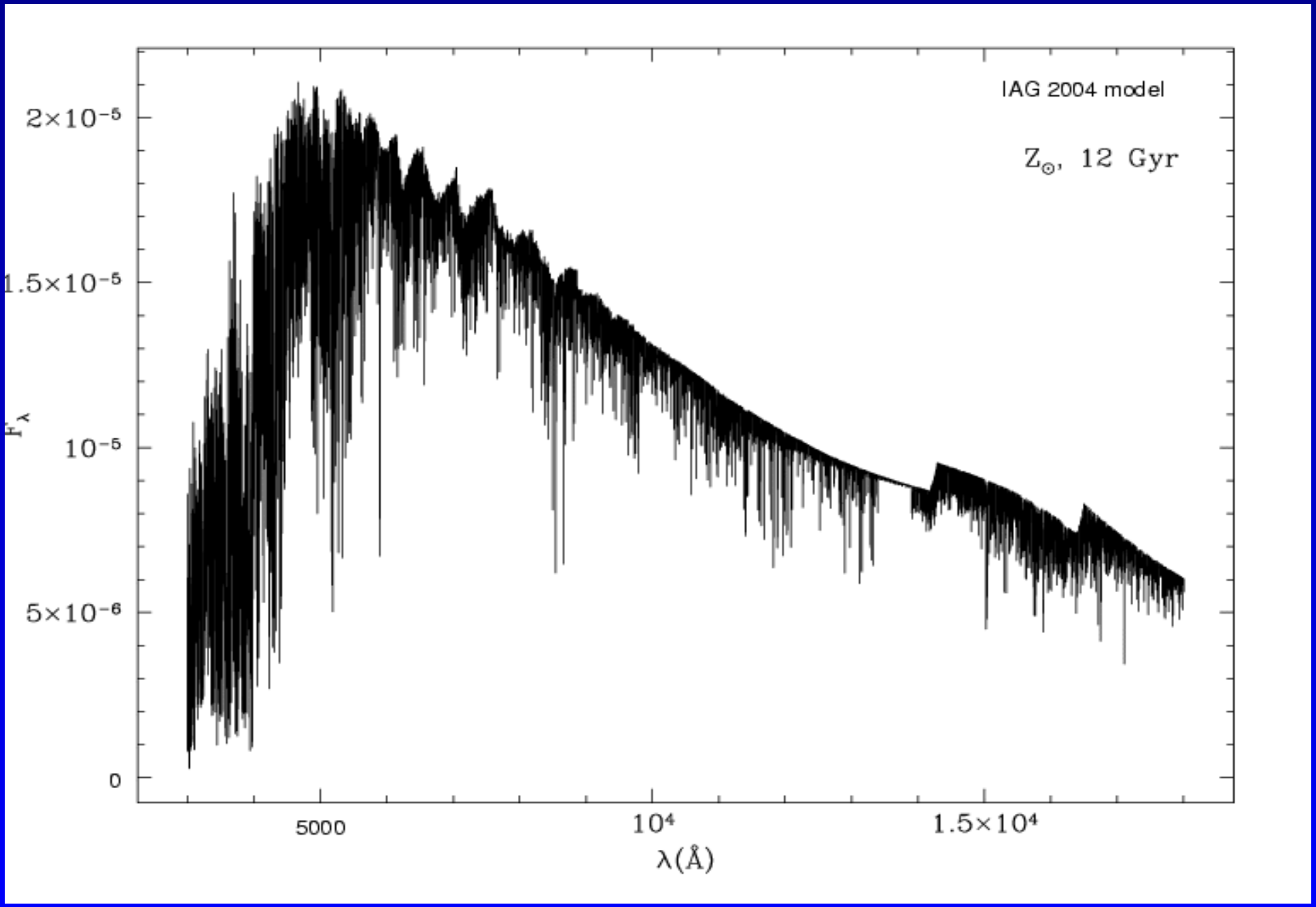
- HNGSL (*black*) vs IUE (*cyan*) and Kurucz models (*green*)
- Solar metallicity
- 1 Gyr SSP
- Chabrier IMF
- Padova 94 tracks

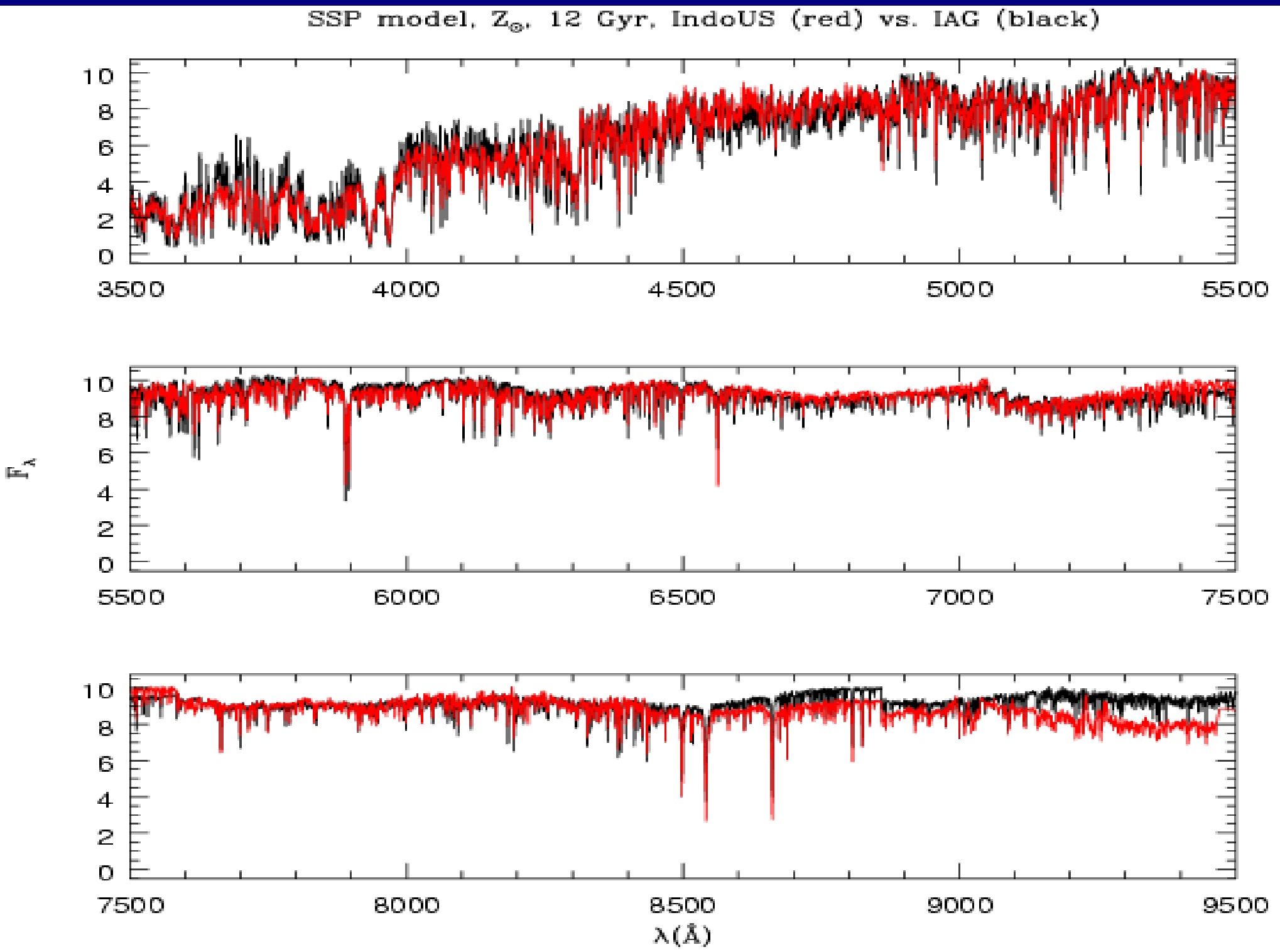
HNGSL in the visible range



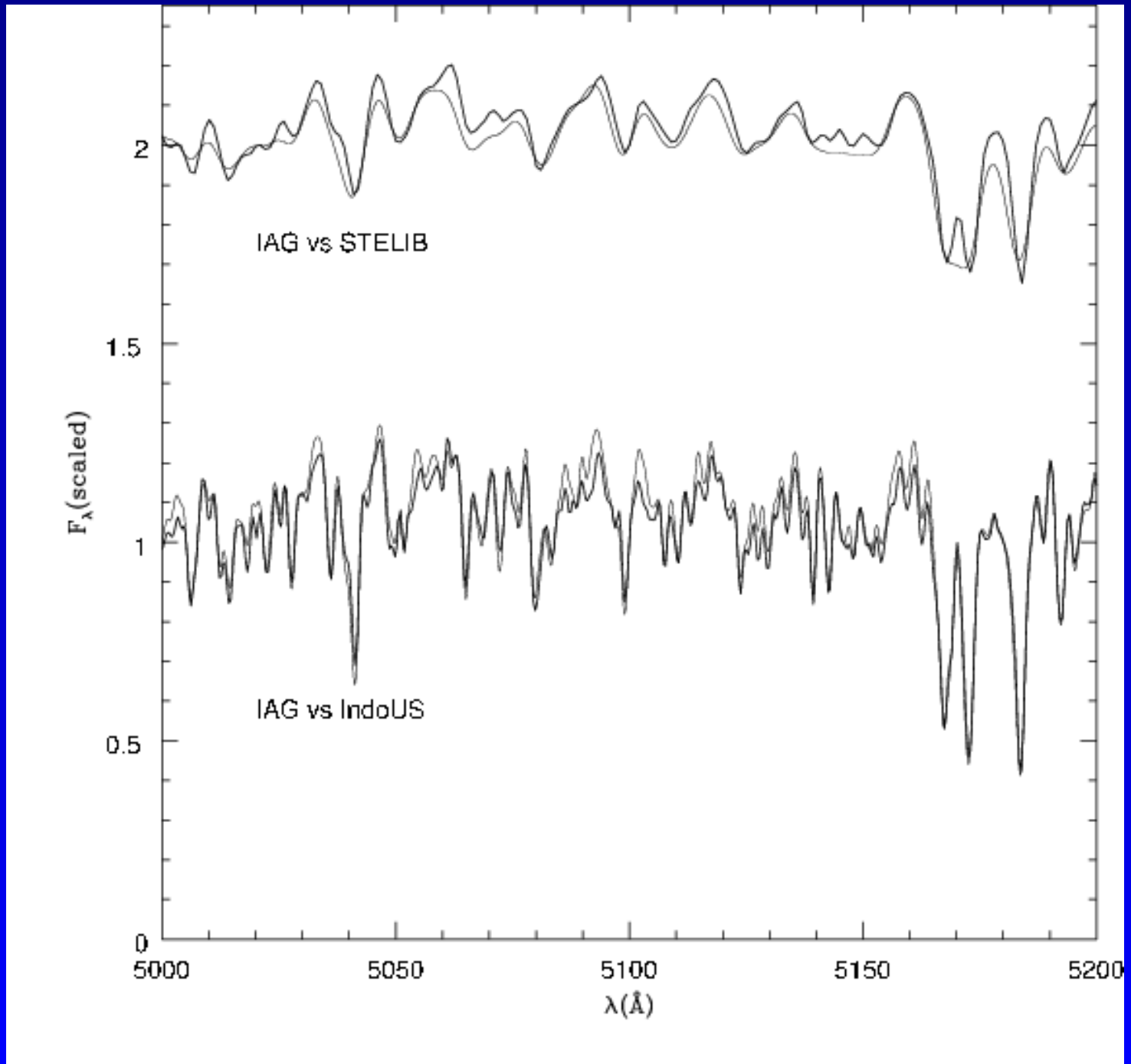
- HNGSL (*black*) vs STELIB (*red*), Kurucz models (*green*), and Pickles library (*cyan*)
- Solar metallicity
- 12 Gyr SSP
- Chabrier IMF
- Padova 94 tracks

Pop Syn model using Coelho et al.




SSP model, $Z_\odot$, 12 Gyr, IndoUS (red) vs. IAG (black)
F_λ
λ(Å)
0
2
4
6
8
10
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500

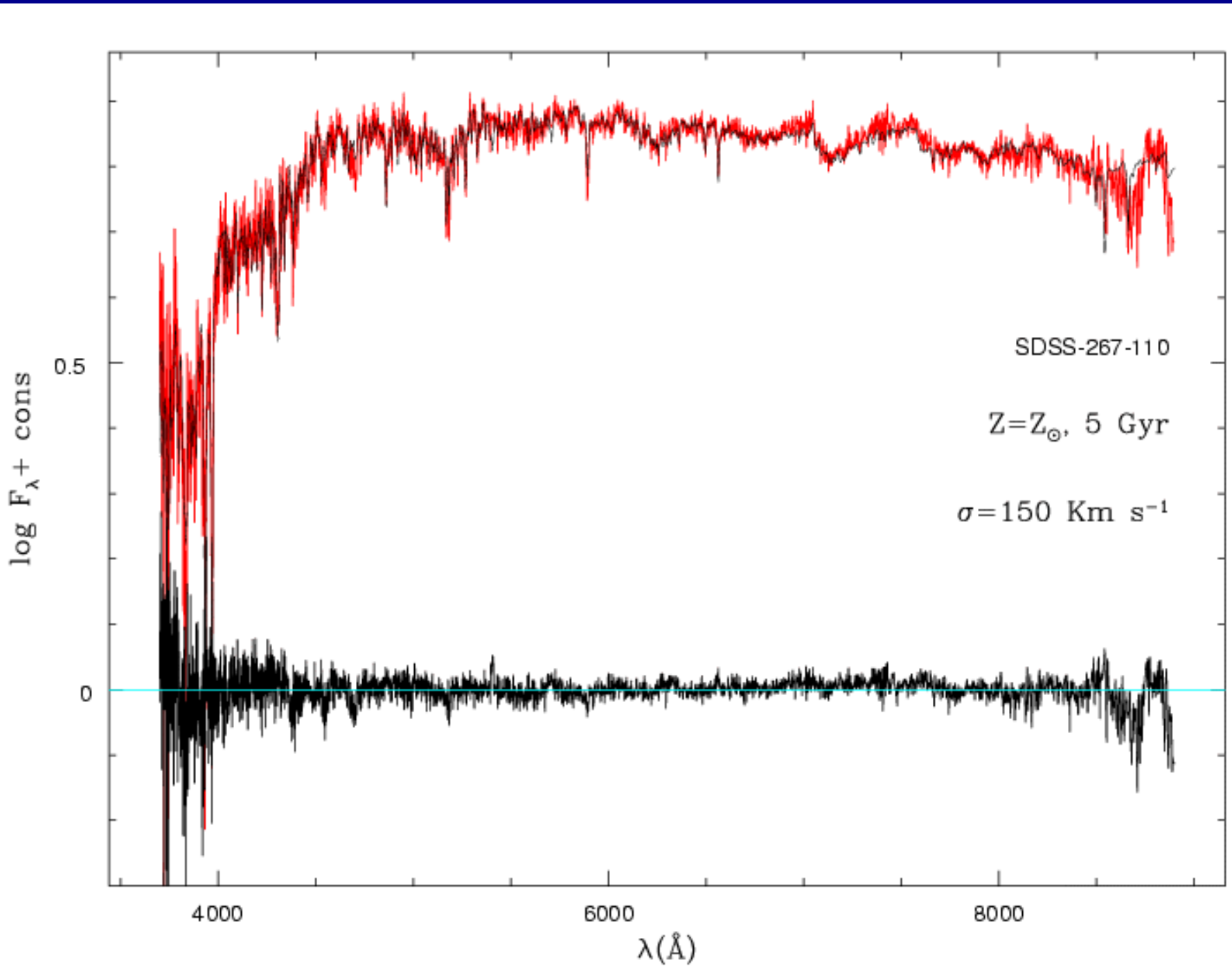
Coelho et al. vs IndoUS and STELIB



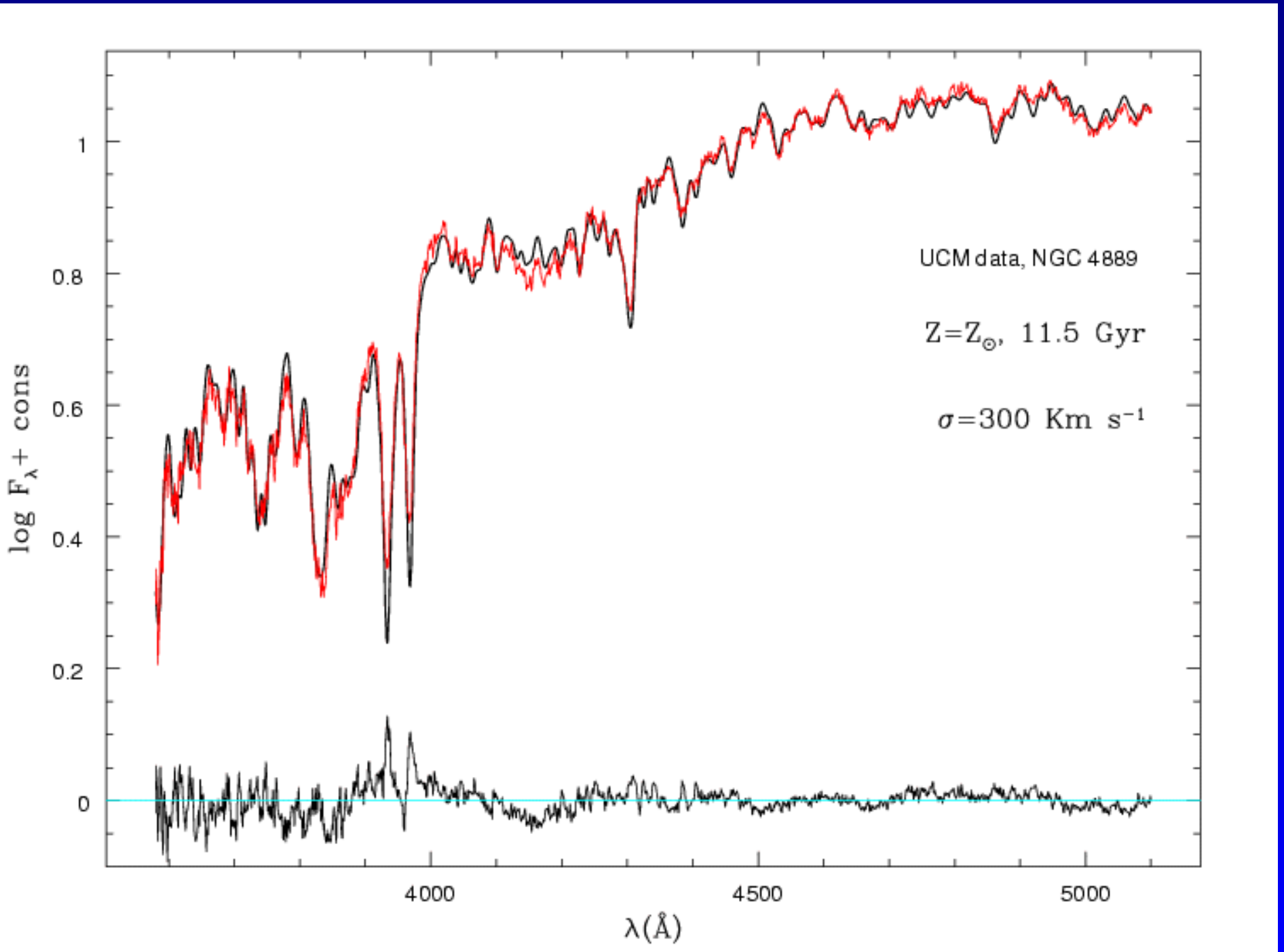
Applications

- SSP fitting to galaxy sed’s
- CSP fitting to galaxy sed’s (=> SFH)
- Defining new spectral indices

SSP fit


SDSS-267-110
Z=Z⊙, 5 Gyr
σ=150 Km s⁻¹
log F_λ + cons
0.5
0
4000
6000
8000
λ(Å)

SSP fit

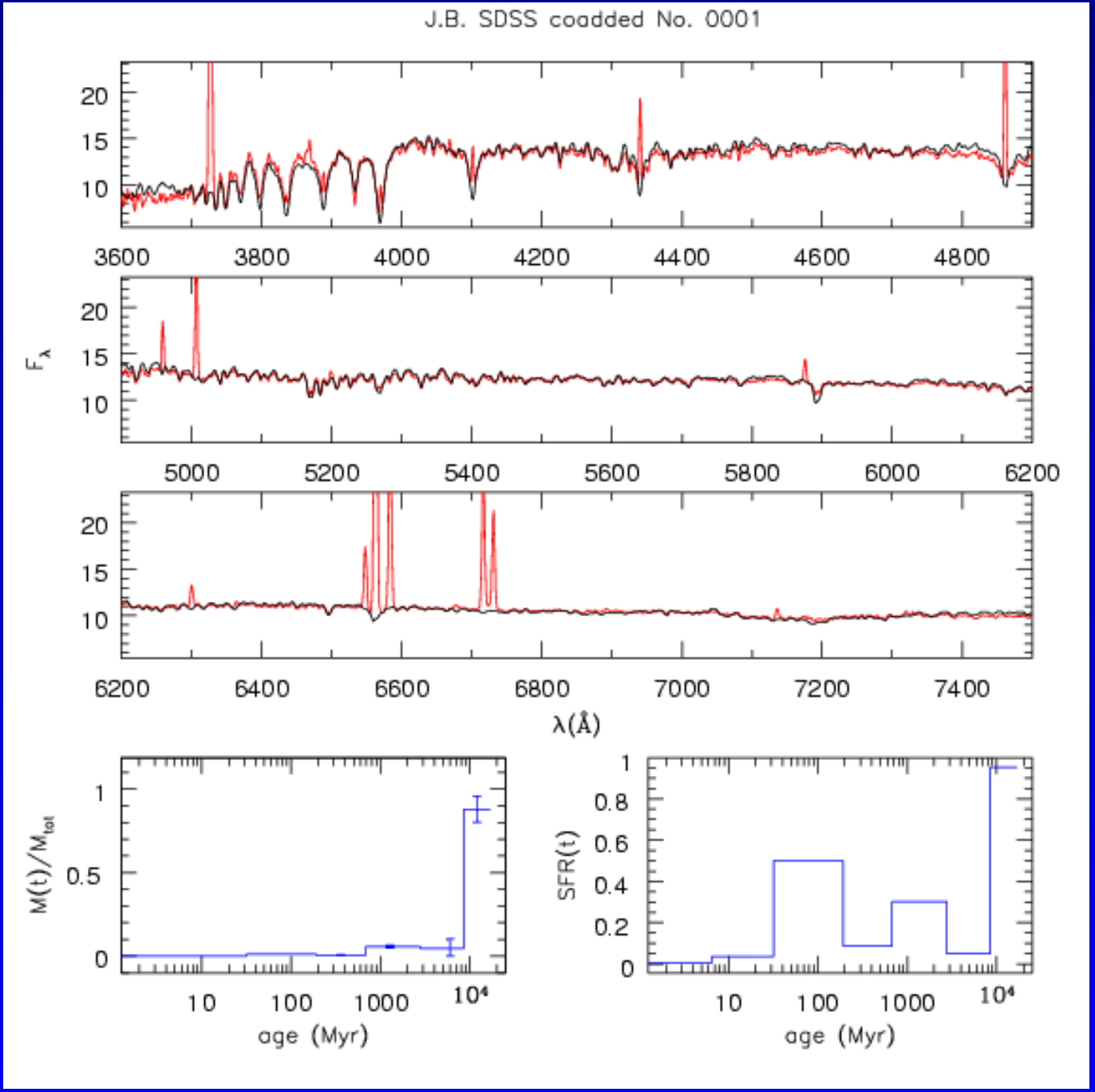

UCM data, NGC 4889
Z=Z⊙, 11.5 Gyr
σ=300 Km s⁻¹
log F_λ + cons
λ(Å)
1
0.8
0.6
0.4
0.2
0
4000
4500
5000

CSP fitting

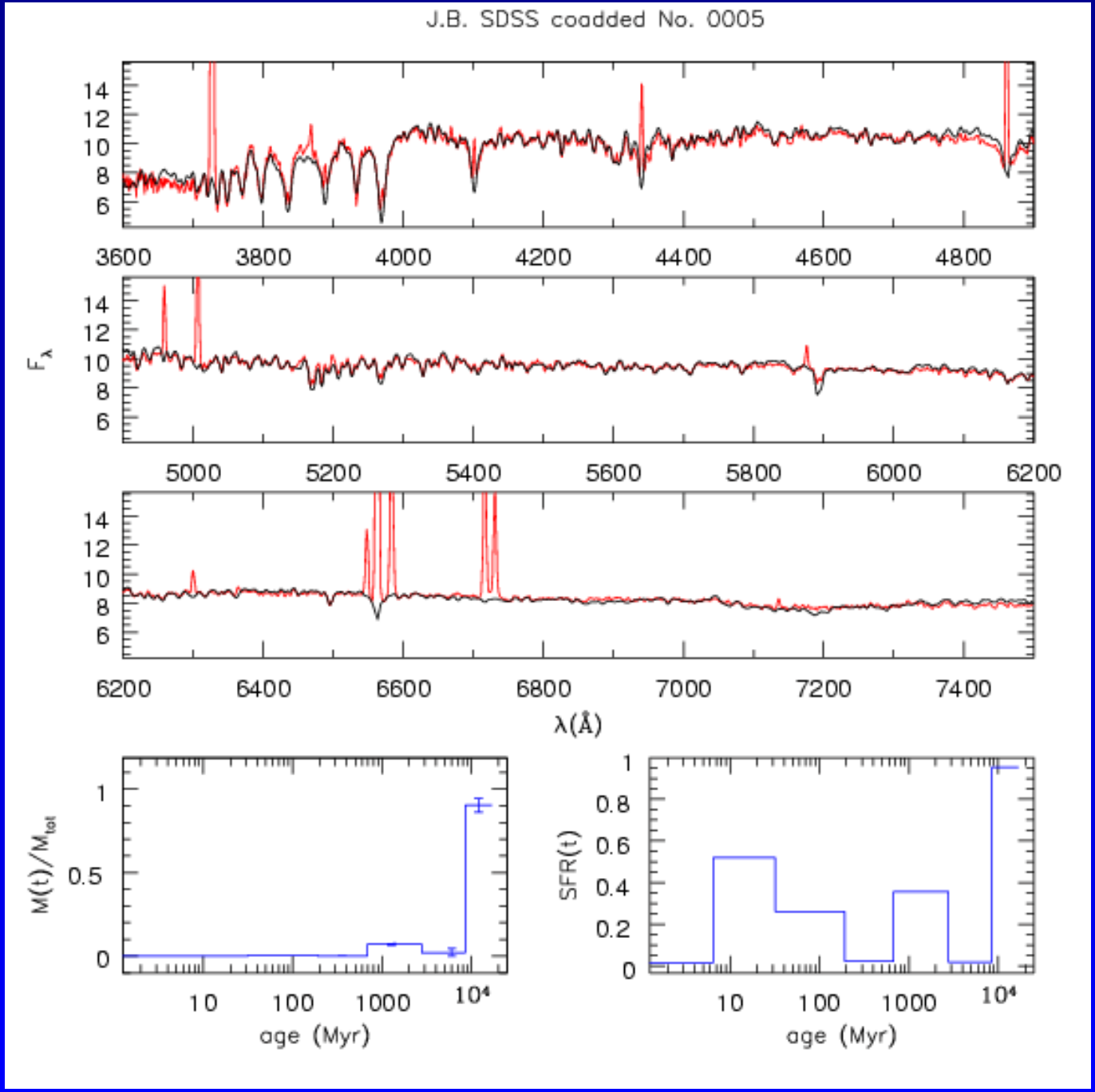
Several groups working on this:

- Mateus, Cid Fernandes, Sodré, et al. (2005, 2006)
- Mathis, Charlot, & Brinchmann (2006)
- Mateu, Magris, & Bruzual (2006)
- Ben Panter & the Moped collaboration.

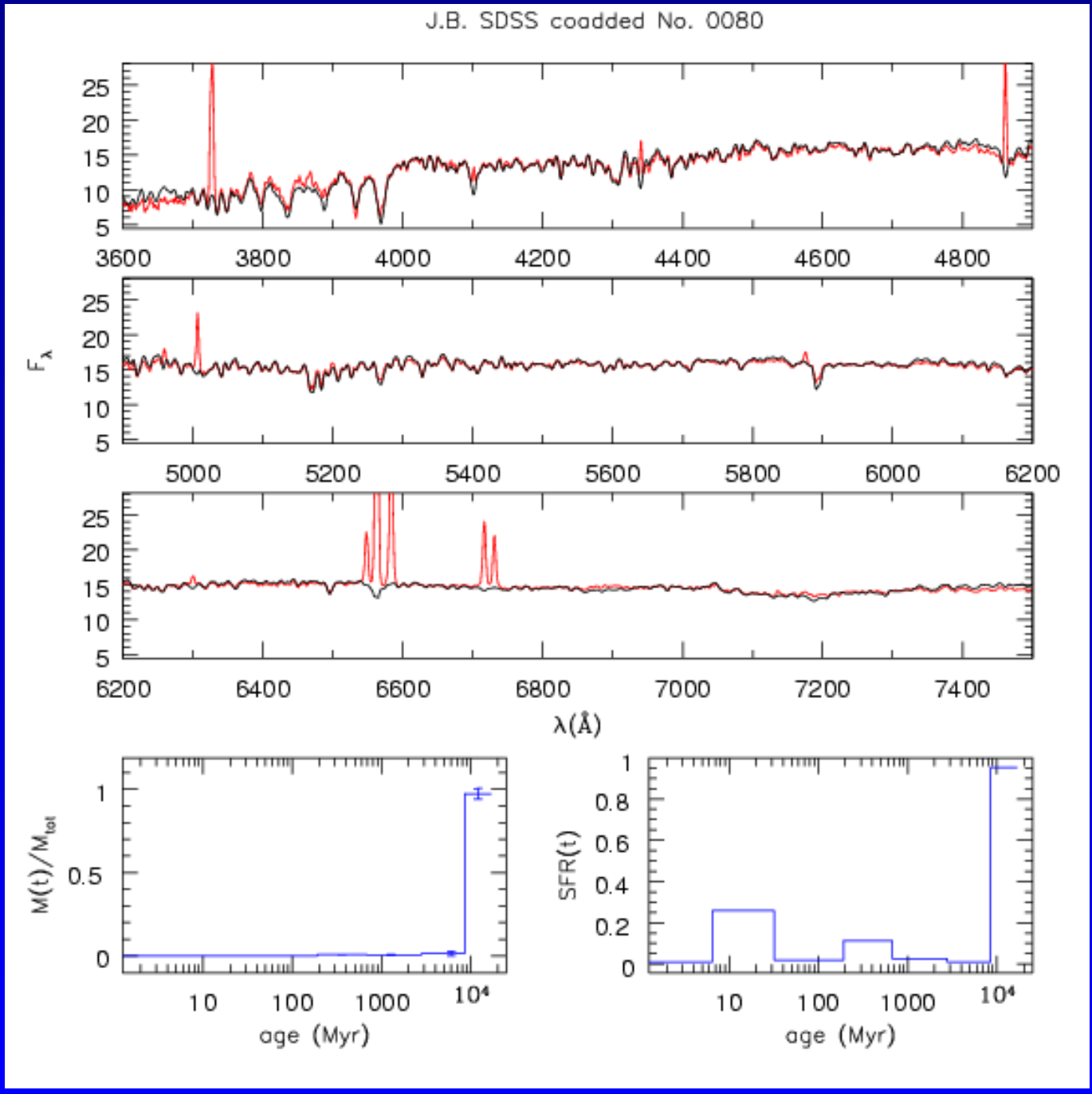
CSP fit, recovering the SFH



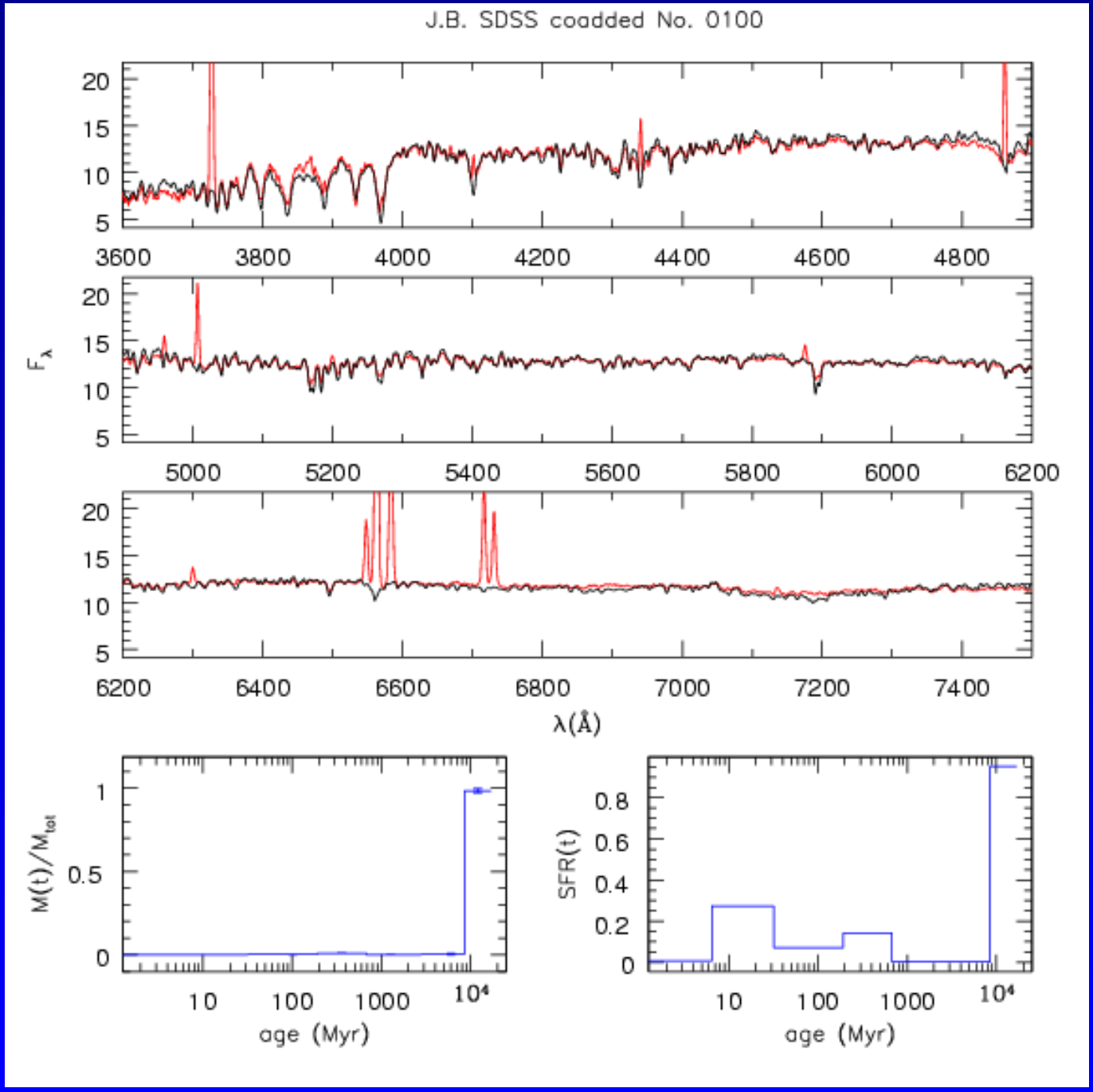
CSP fit, recovering the SFH



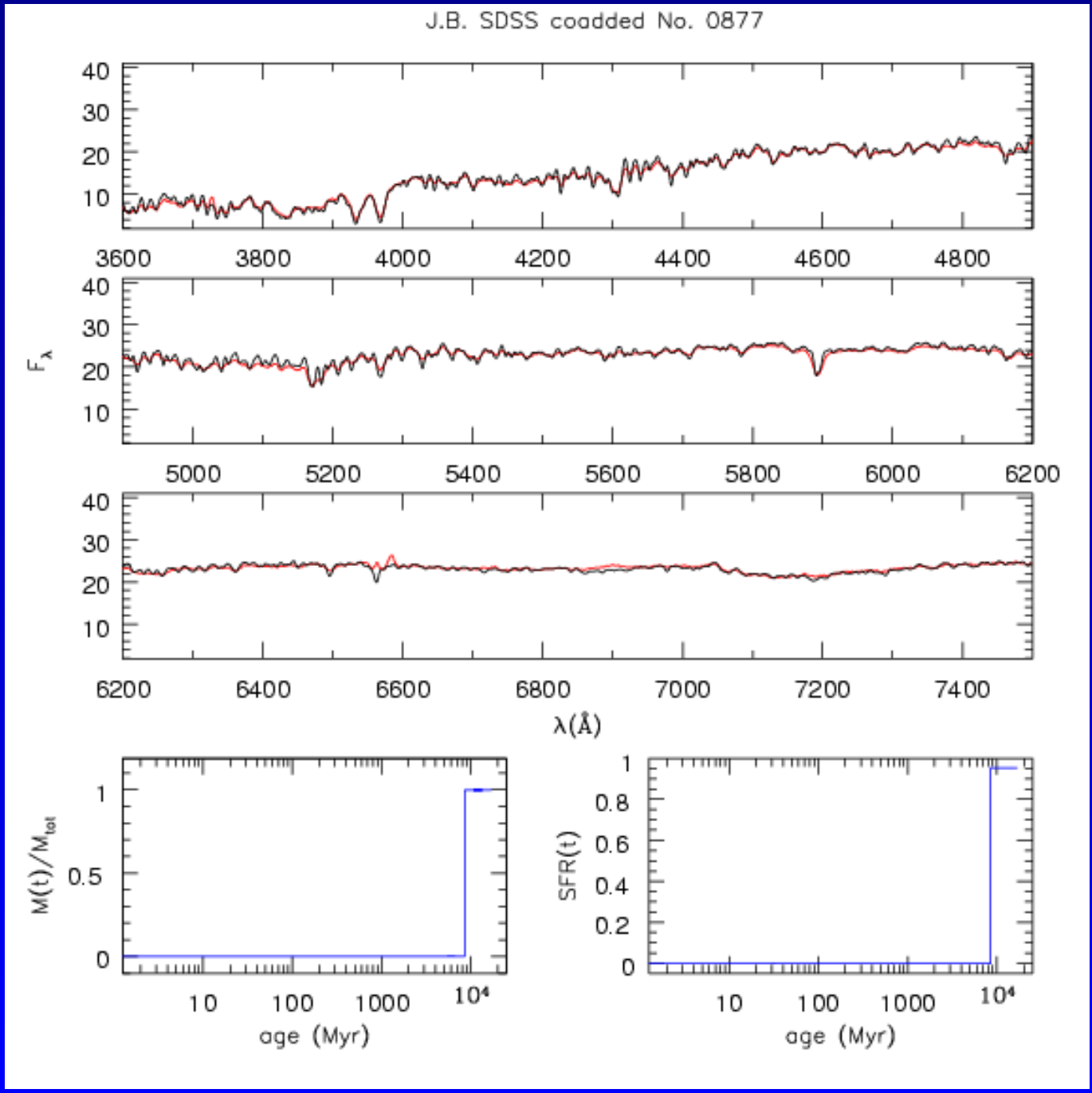
CSP fit, recovering the SFH



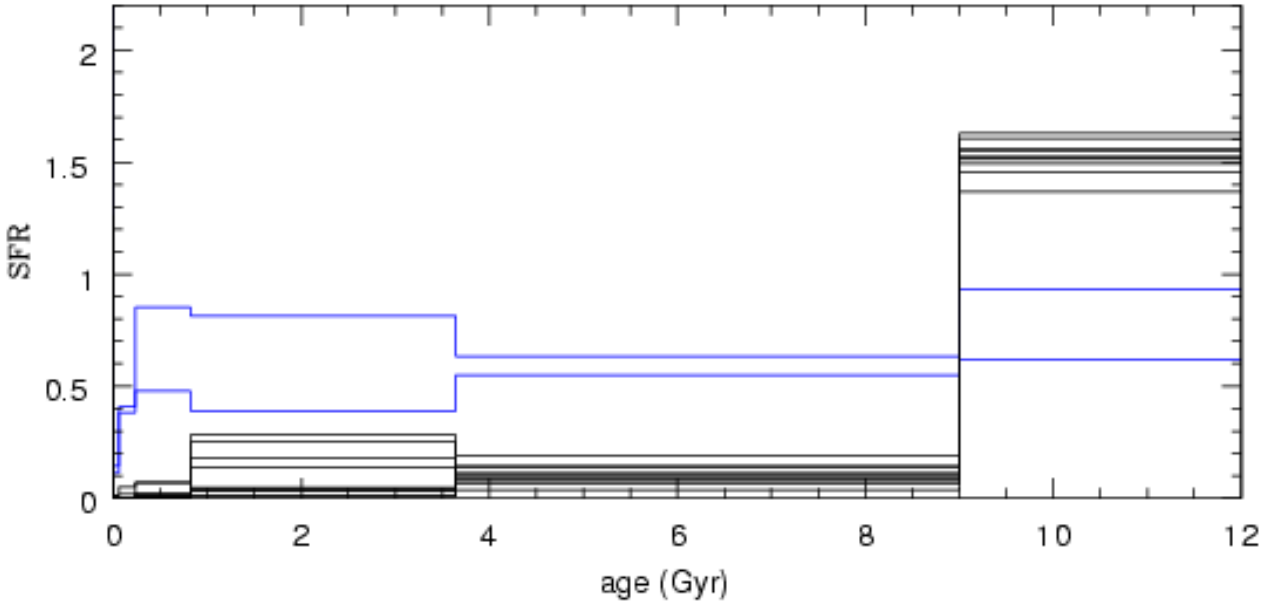
CSP fit, recovering the SFH

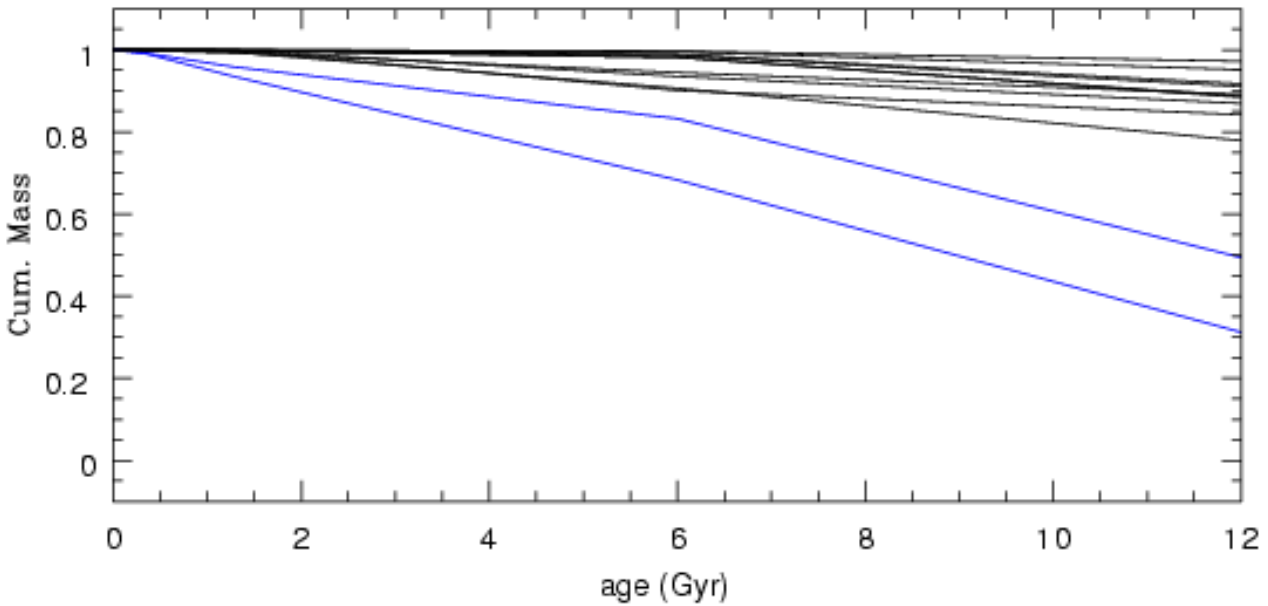


CSP fit, recovering the SFH



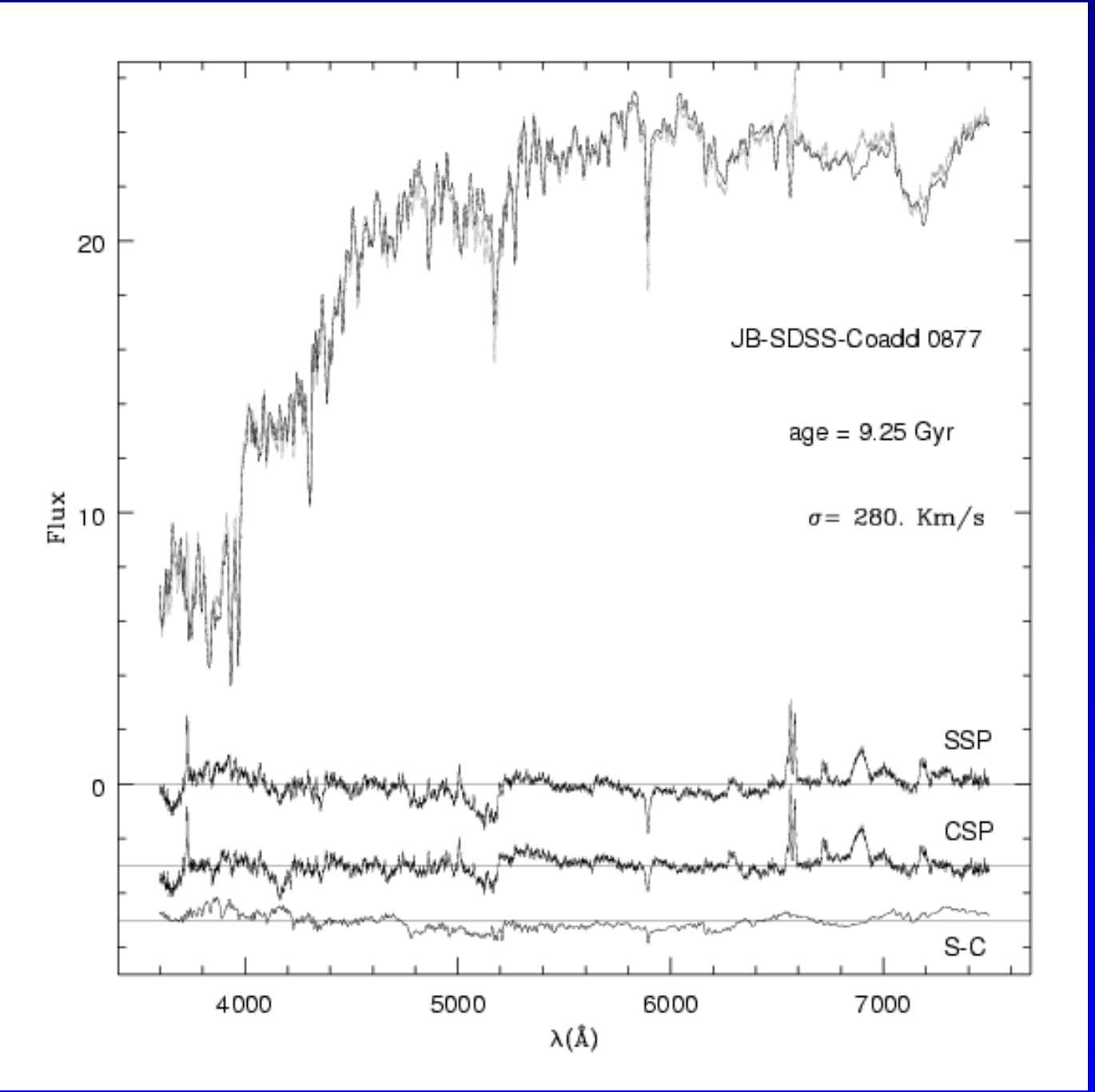
CSP fit, recovering the SFH



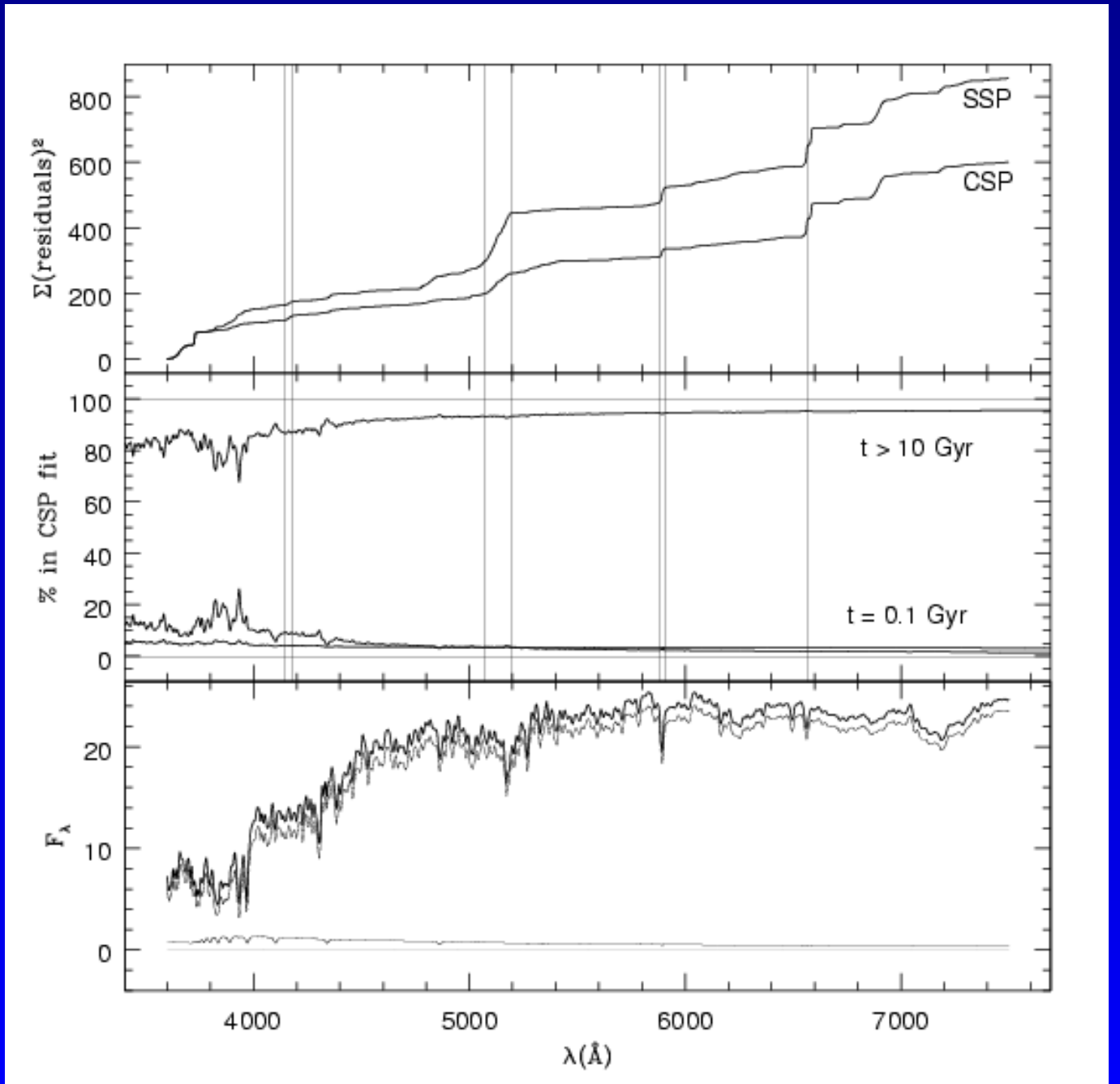


- SFH
- Cum. Mass

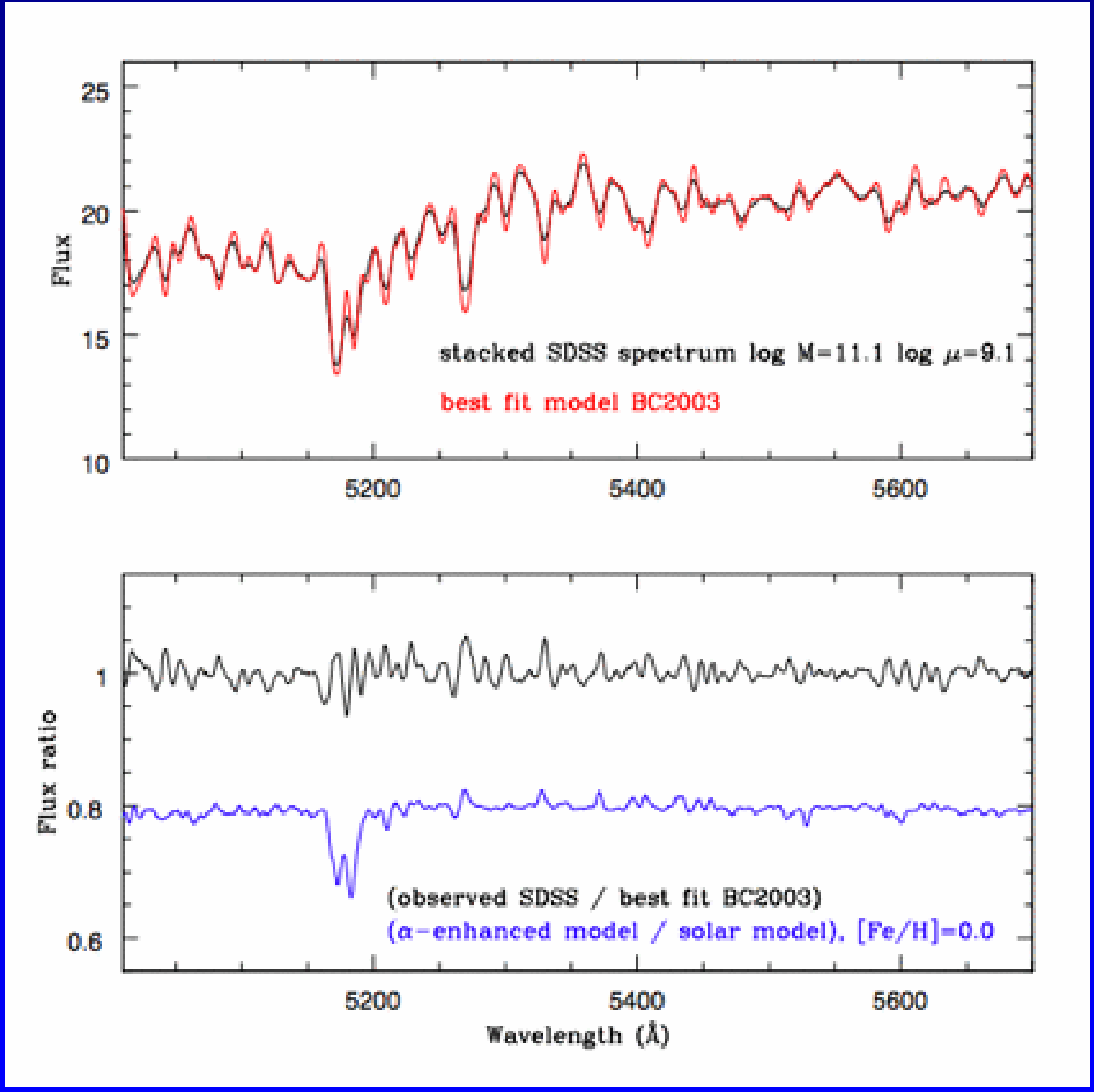
SSP vs CSP fitting



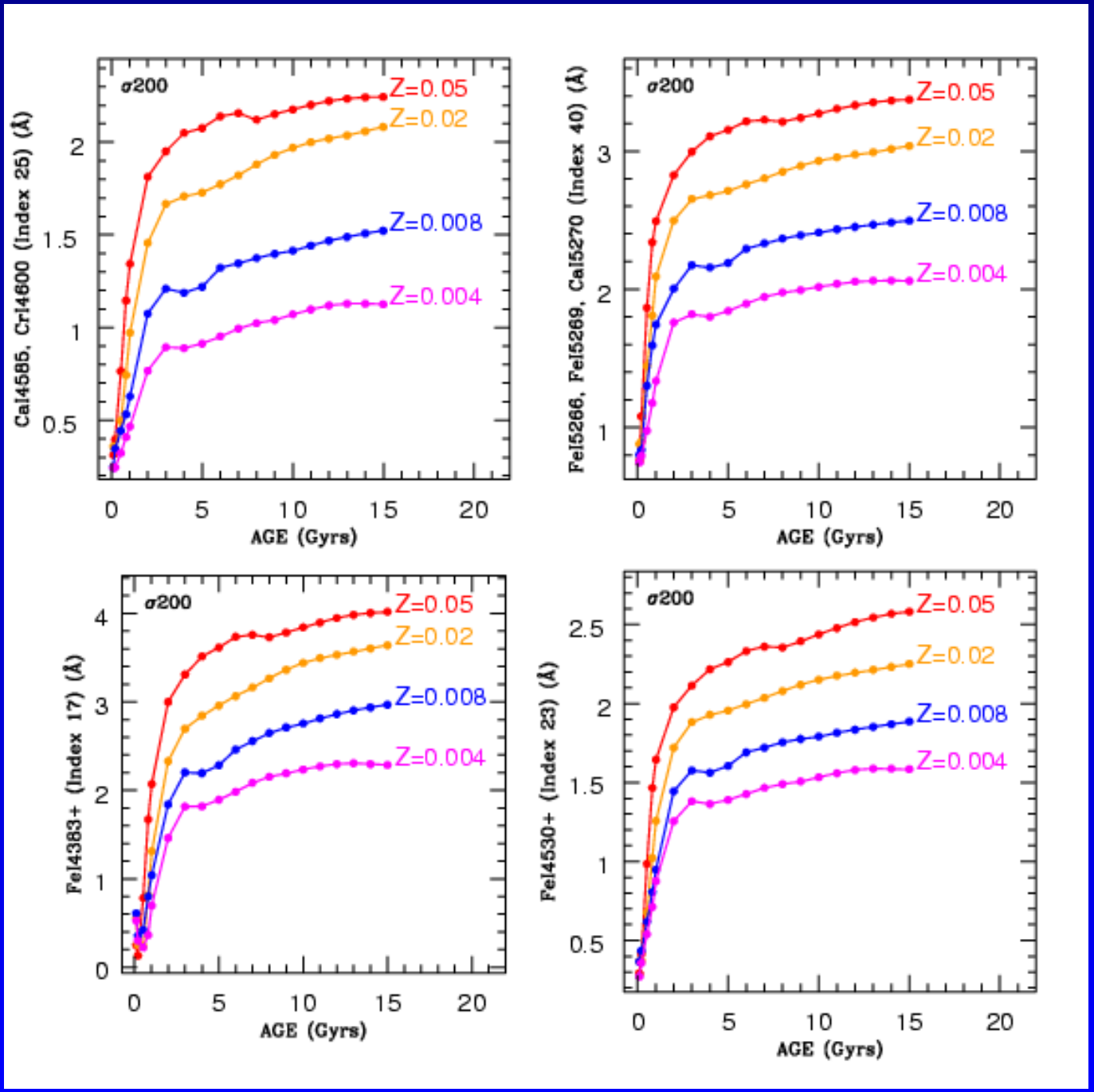
SSP vs CSP fitting



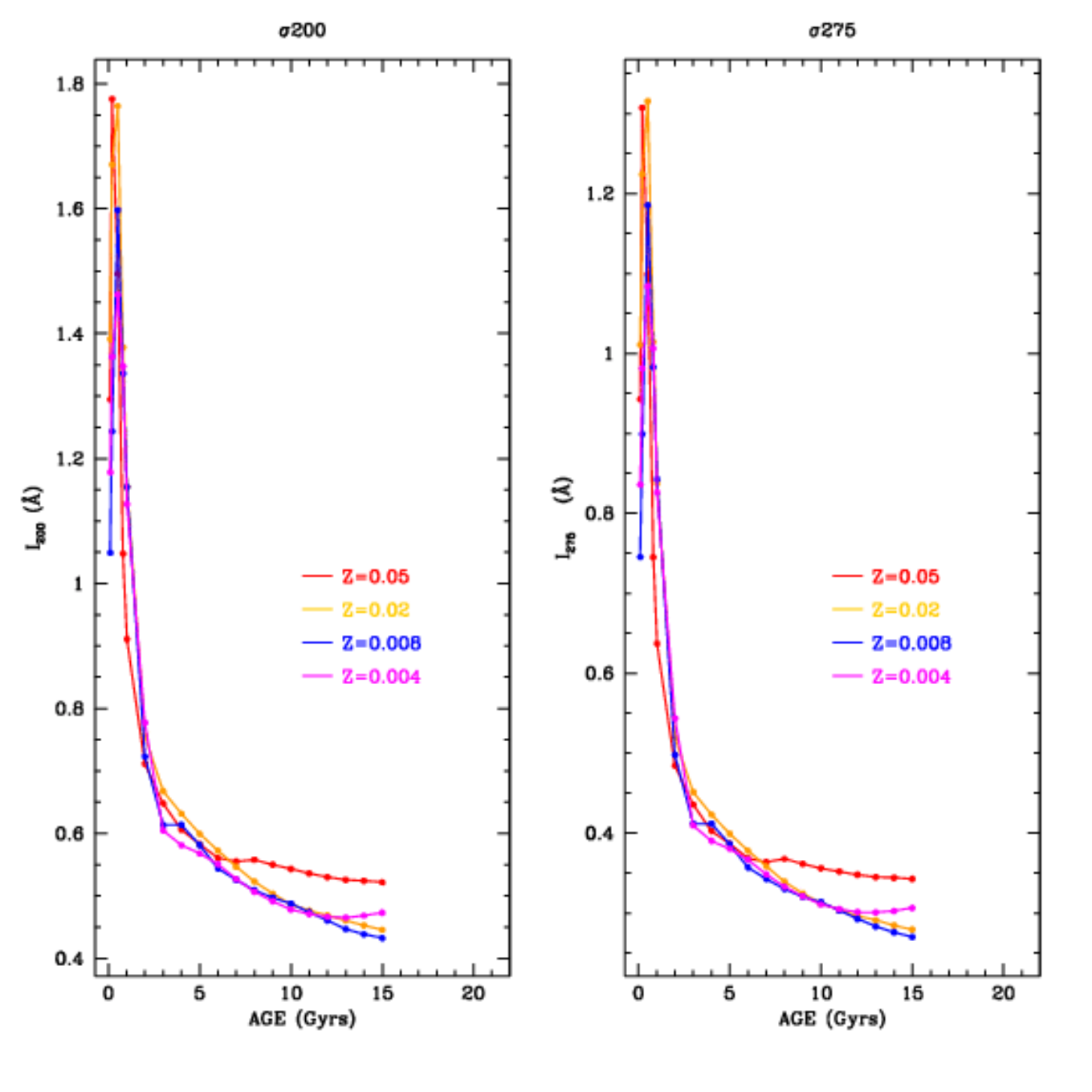
Need for alpha enhanced models



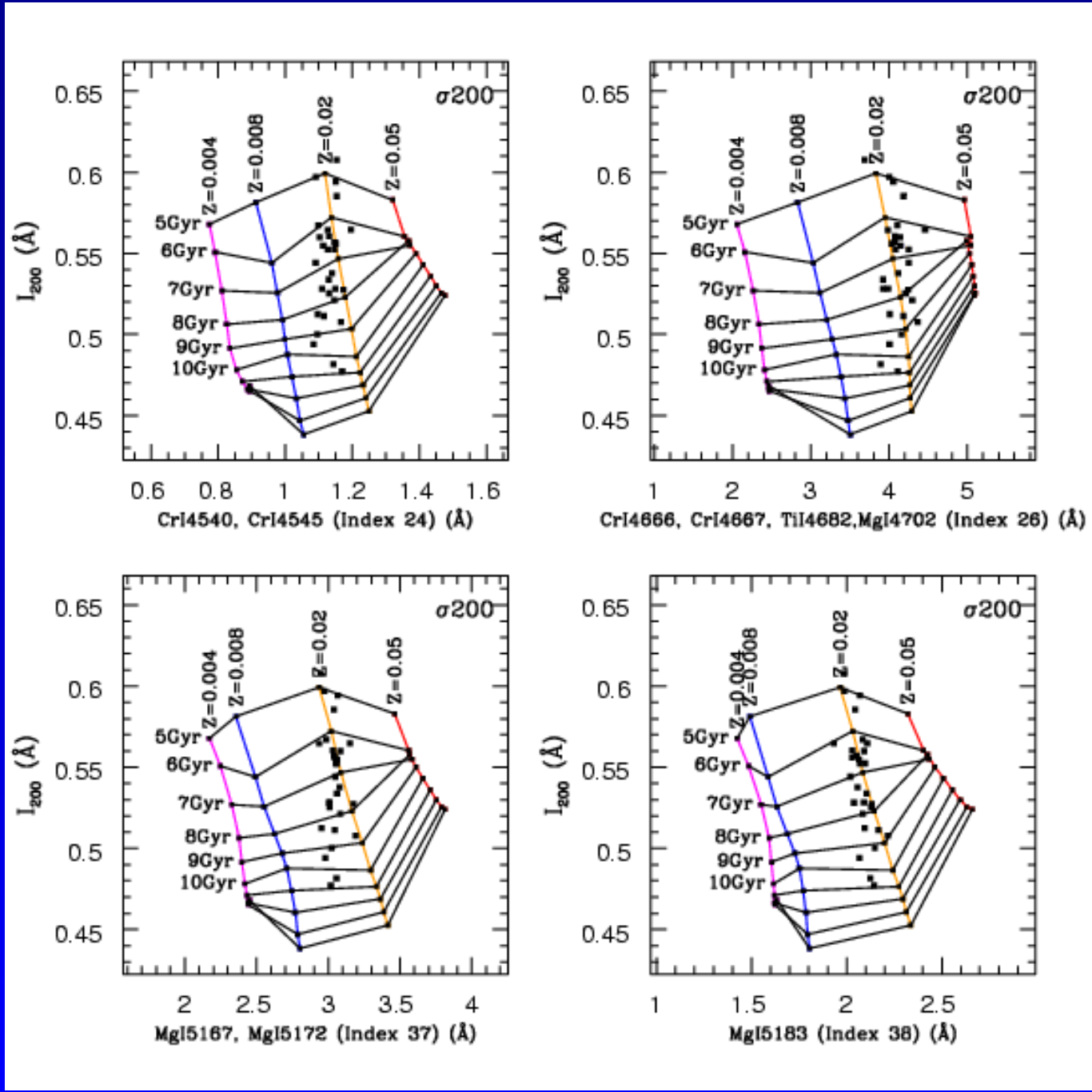
Line Strength Indices



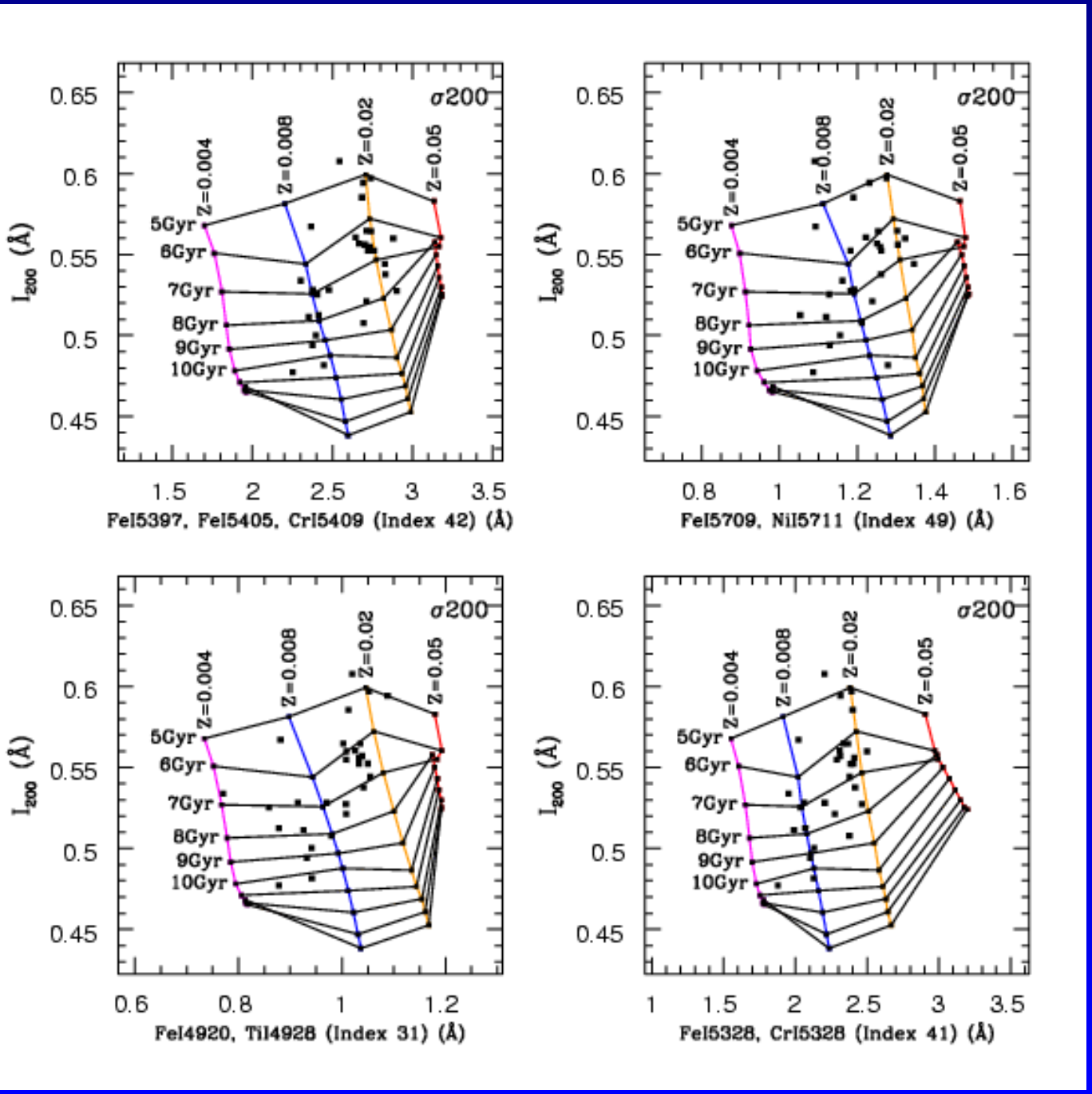
Line Strength Indices (V & A 99)



Line Strength Indices



Line Strength Indices



Conclusions

- Most stellar population models available today present large improvements over previous versions.
- There is still a lot of room for improvement in population synthesis models.
- We will be hearing in this workshop a lot on what must be improved and some ideas on how to do it.