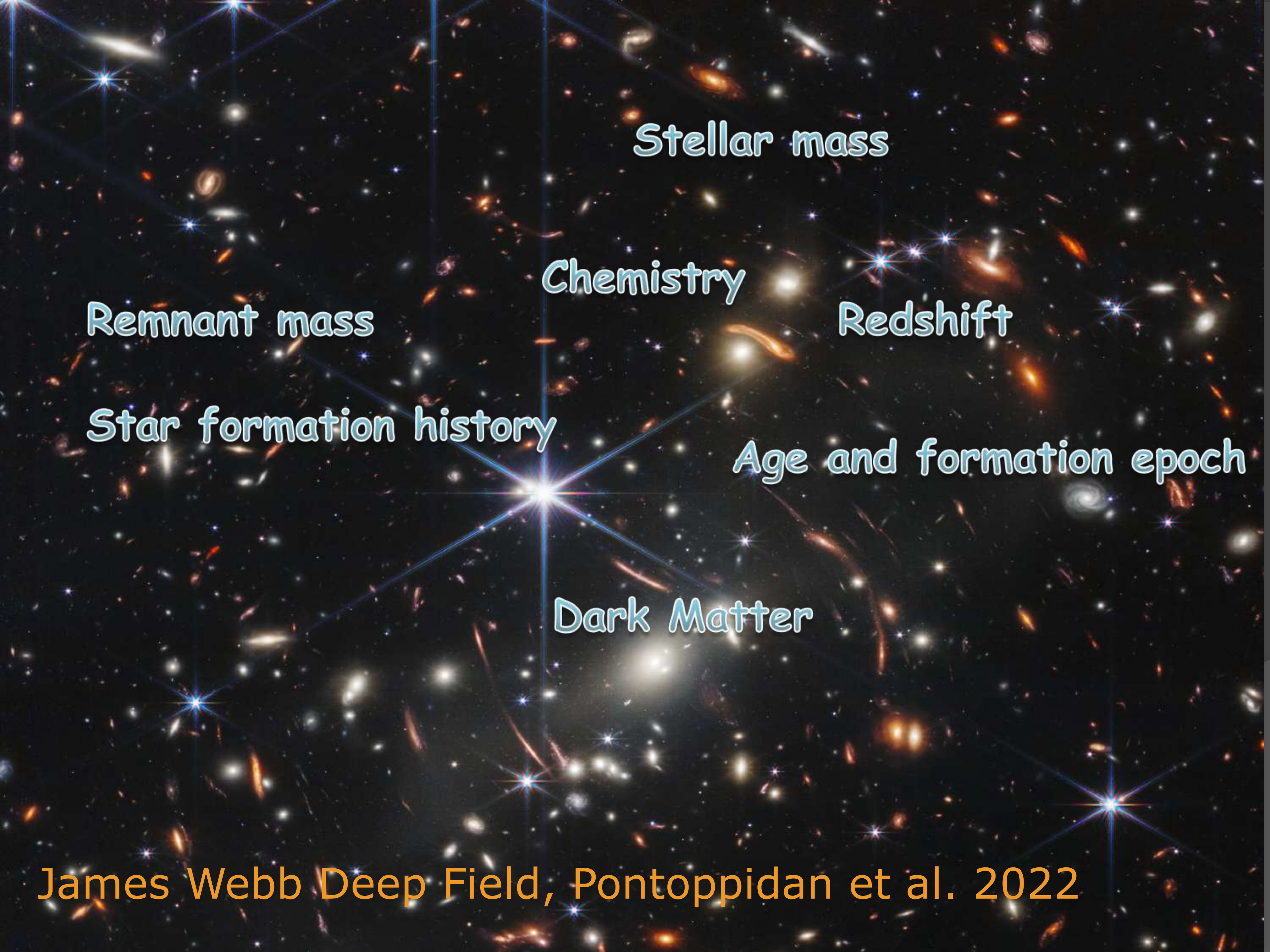
Claudia Maraston
University of Portsmouth
UK

Galaxy Scaling Relations through Stellar population models

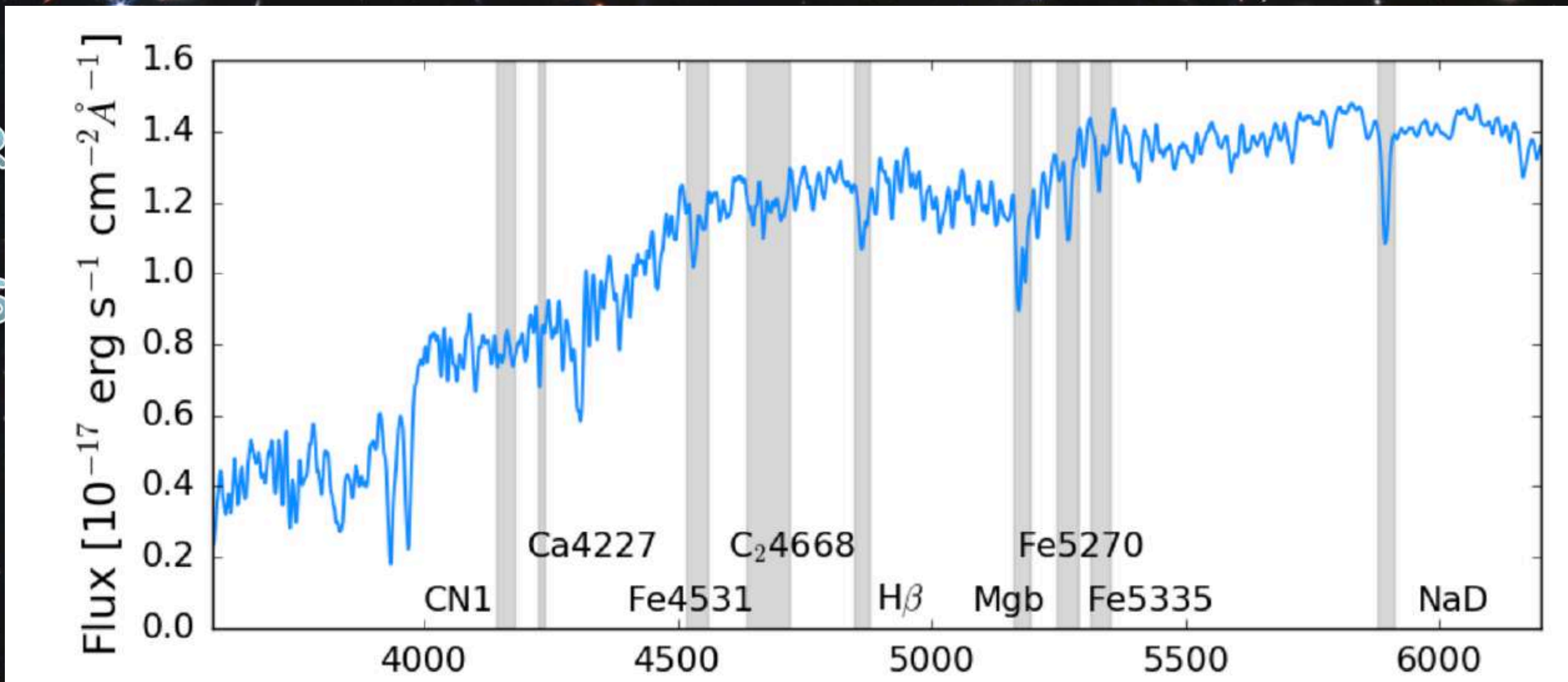
aka all what's outside the BH

Bid4Best - Southampton 2024



James Webb Deep Field, Pontoppidan et al. 2022

Stellar mass



Parikh et al. 2019,
MaNGA (Bundy et al. 16)

James Webb Deep Field, Pontoppidan et al. 2022

Outline

Galaxy physical properties from stellar population models

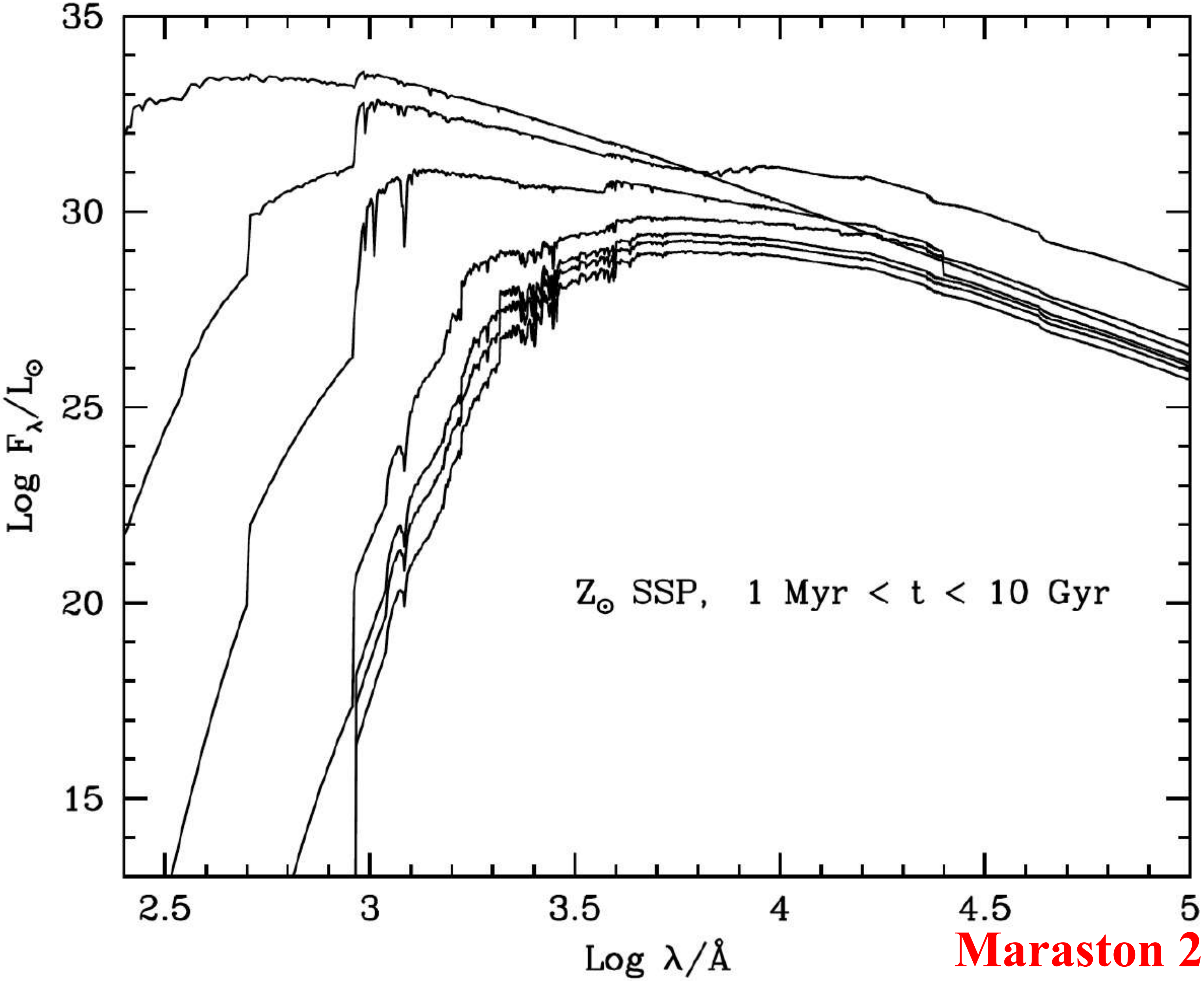
Degeneracies and iceberg effect

Derivation vs Prior

Applications:
- properties of real galaxies
- galaxy simulations
- linking the two

Stellar population model:

Theoretical SED of stellar generations as a function of the key population parameters t, [Z/H],[el/Fe],SFH,IMF,M*

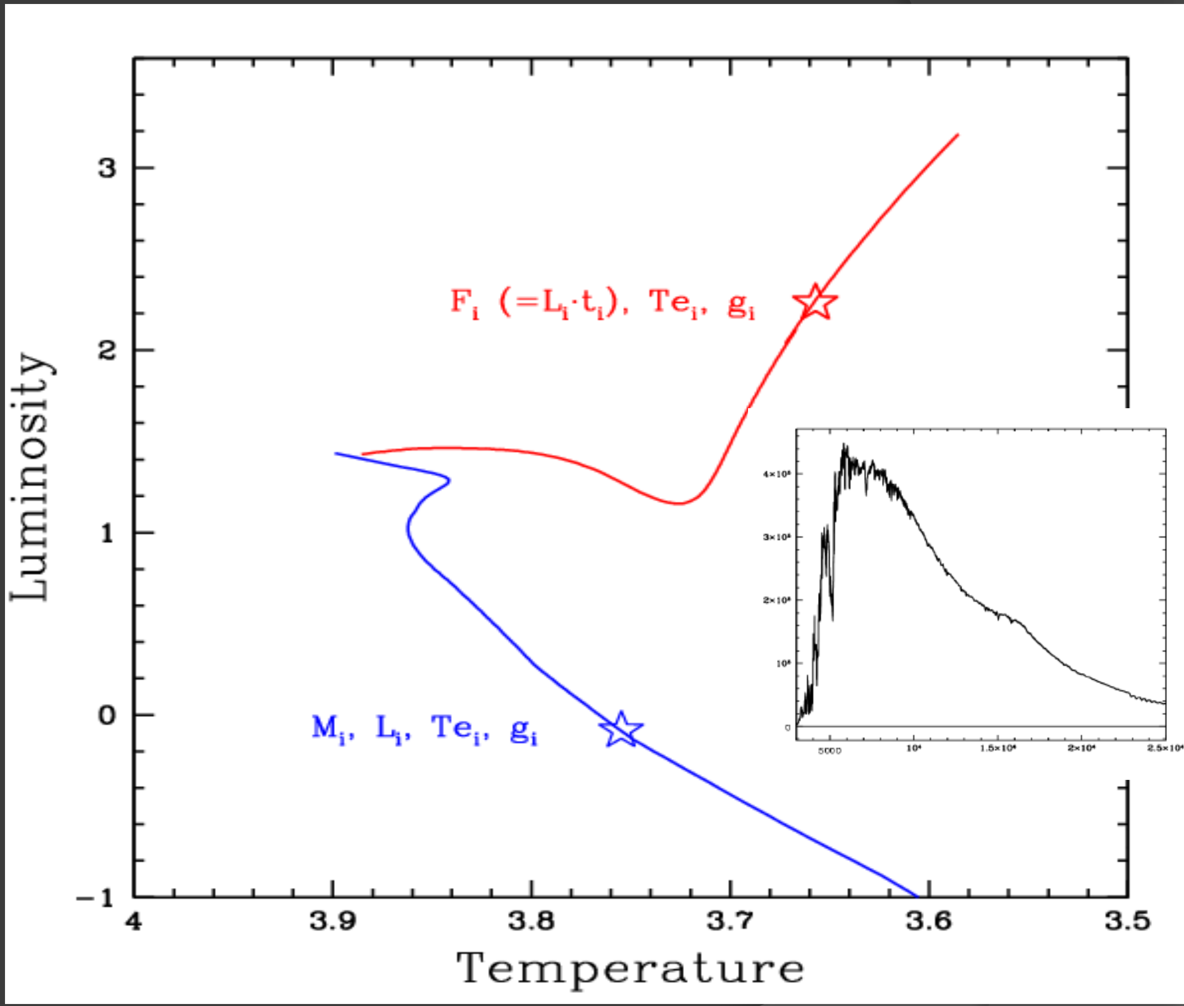


Maraston 2005

Model input physics

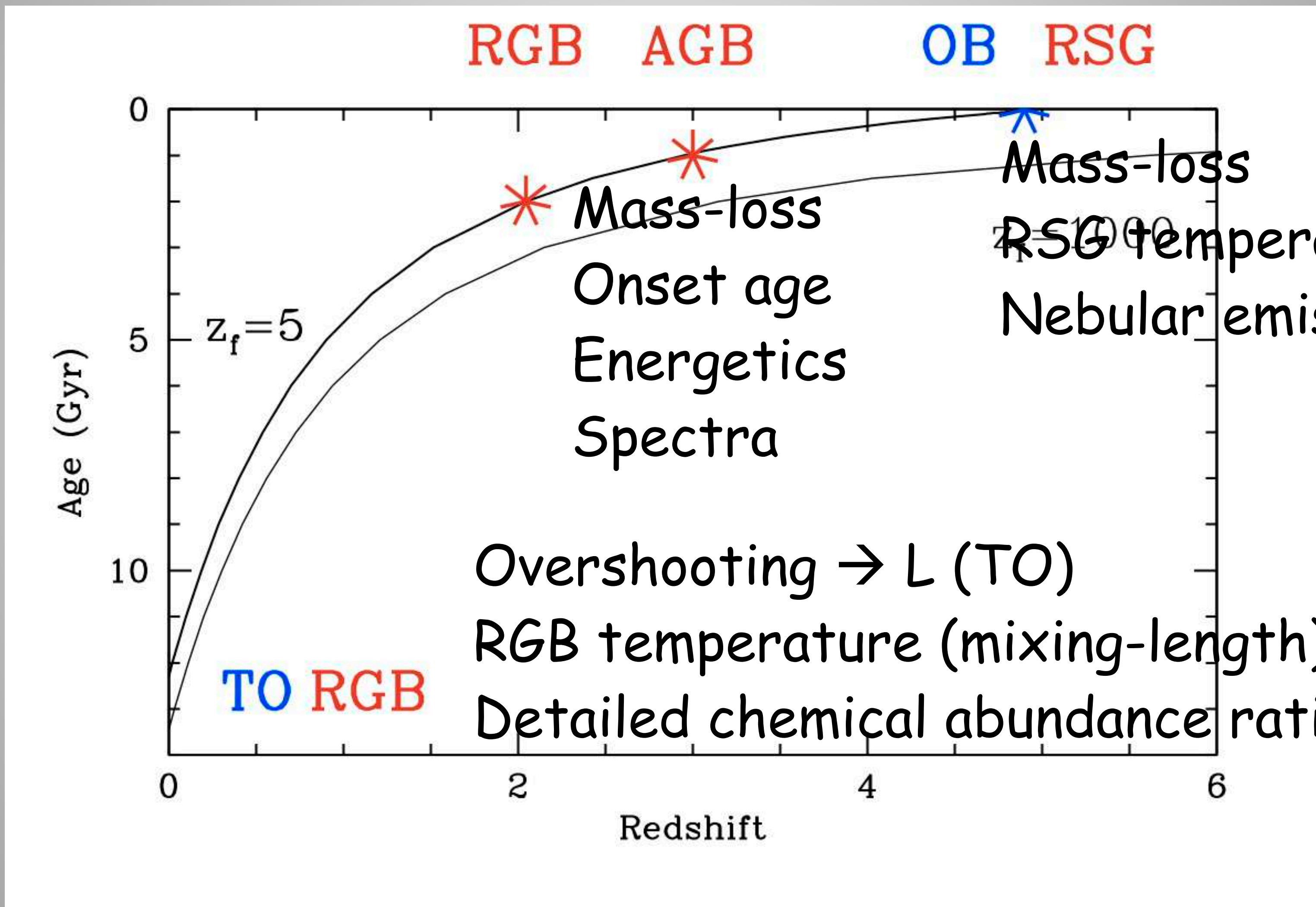
- ENERGY per star mass
- TIMESCALE
- SPECTRA
- Initial Mass Function   IMF
- Remnant Mass Distribution

mass and type of remnant



Extras: binaries, emission-lines/nebular continuum

Stellar evolution as a function of redshift



Mass-loss
Onset age
Energetics
Spectra

Mass-loss
RSG temperature
Nebular emission

Overshooting → L (TO)
RGB temperature (mixing-length)
Detailed chemical abundance ratios

C Maraston in "Galaxy ancestors", Burkina Faso 2010

Stellar Spectra - empirical libraries

MaStar: the MaNGA stellar library

Yan et al. 2019

- 60,000 spectra

(previously 900 spectra, MILES; XShooter-based, ~800)

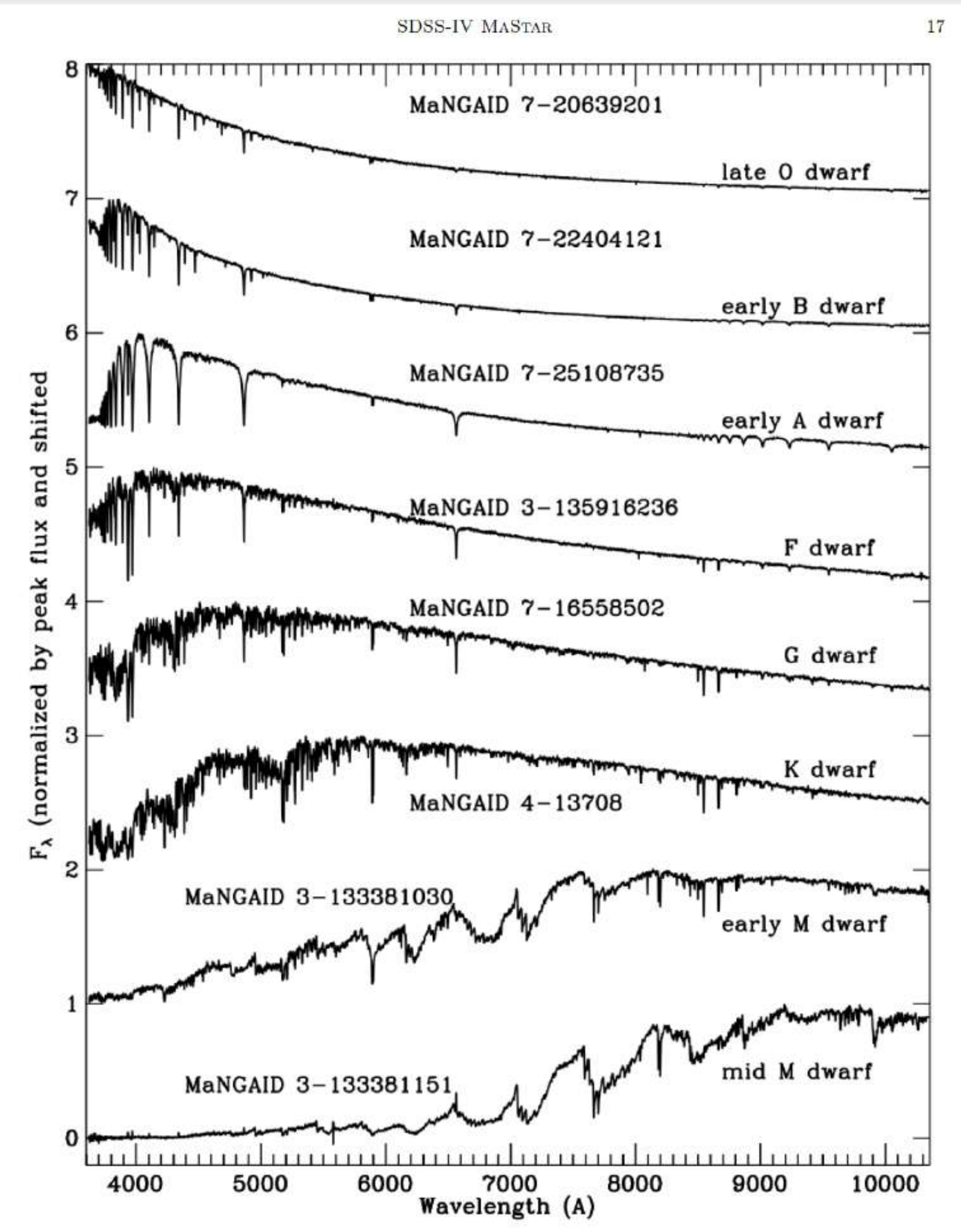
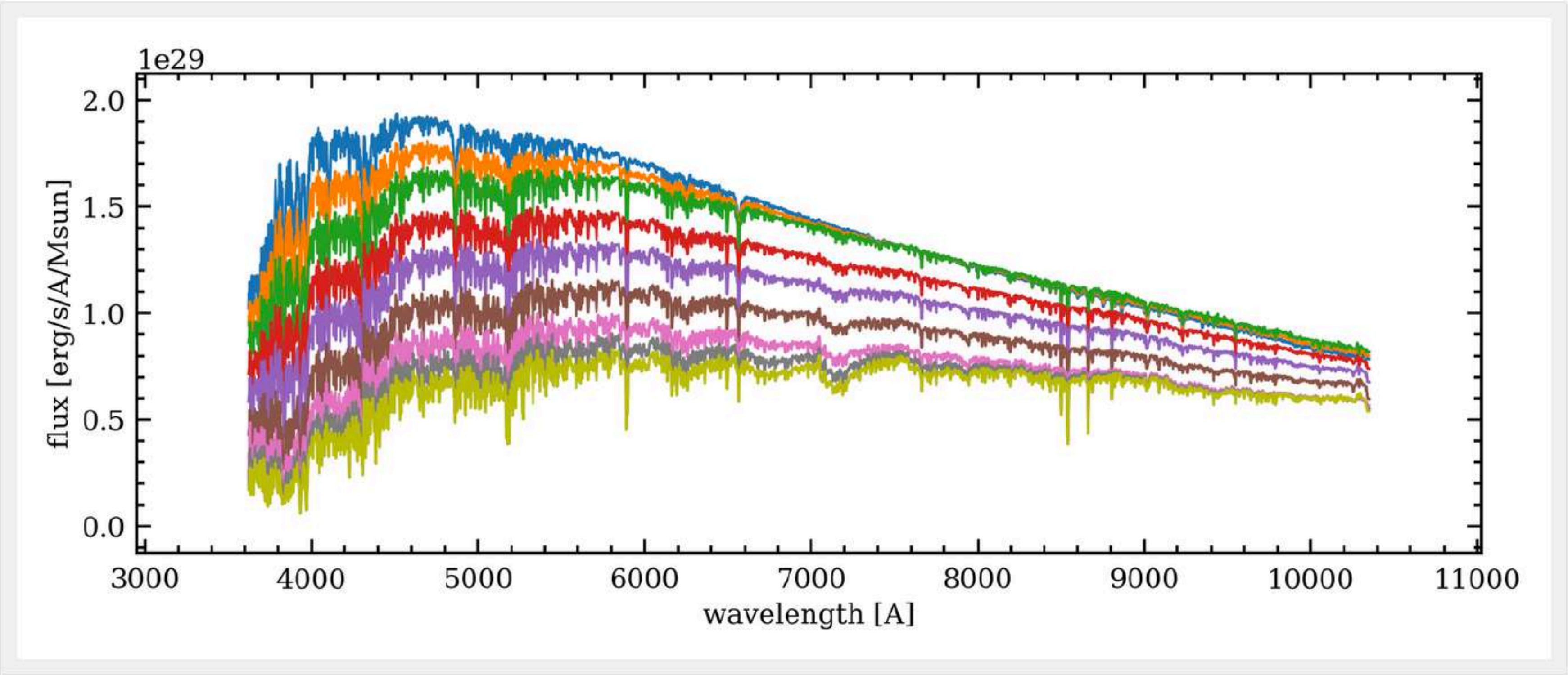


Figure 3. Example per-visit spectra for some main sequence stars in the MaStar Library.

www.icg.port.ac.uk/MaStar

MaStar
Stellar Population Models

12/06/2020: UPDATE to version v0.2

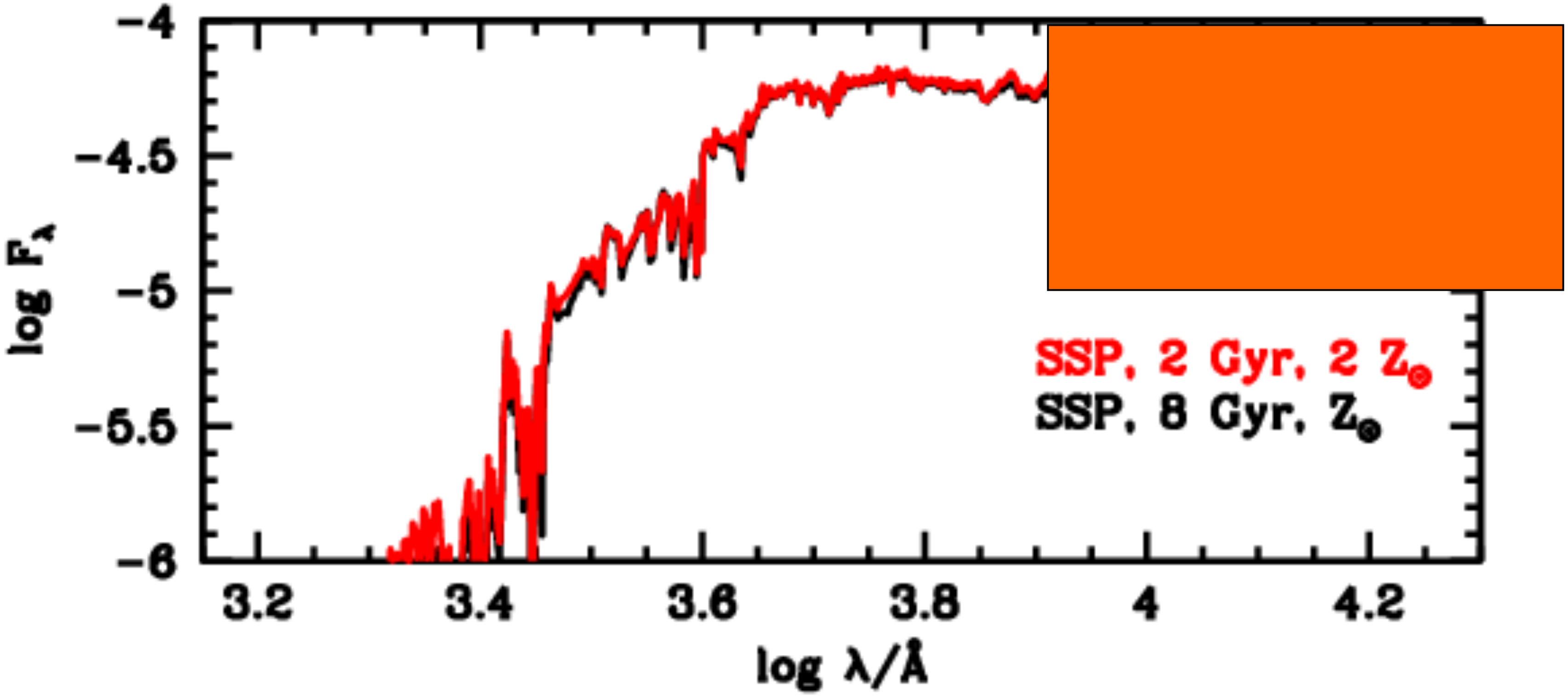


The MaStar Stellar Population Models (Maraston et al 2020) use the new SDSS-based stellar library MaStar (Yan et al 2019) to predict the spectral energy distributions of stellar population models with various chemical composition and age.

Maraston et al. 2020, 24 MNRAS

The age/metallicity degeneracy

Classically (Worthey94): **a metal-rich young SSP looks like a less metal-rich older one**



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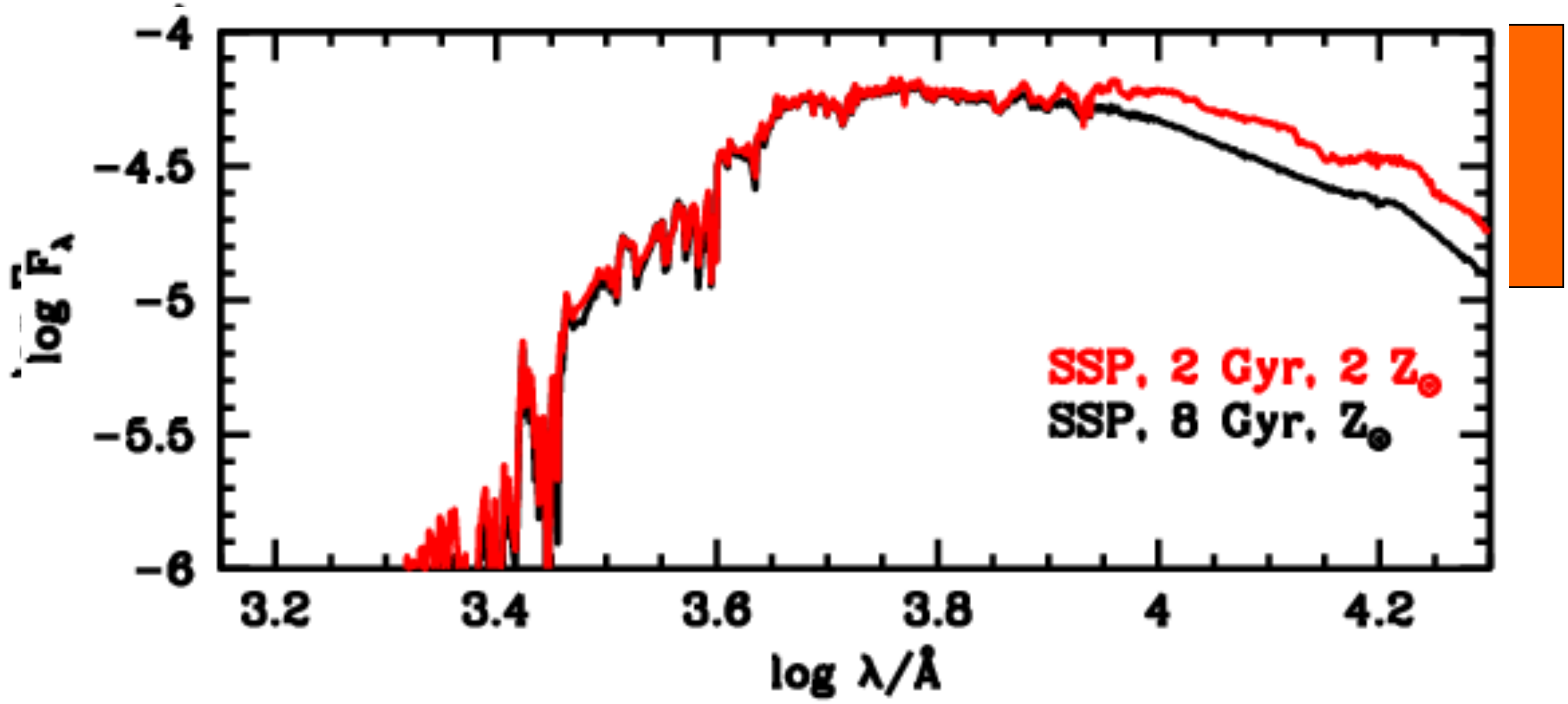
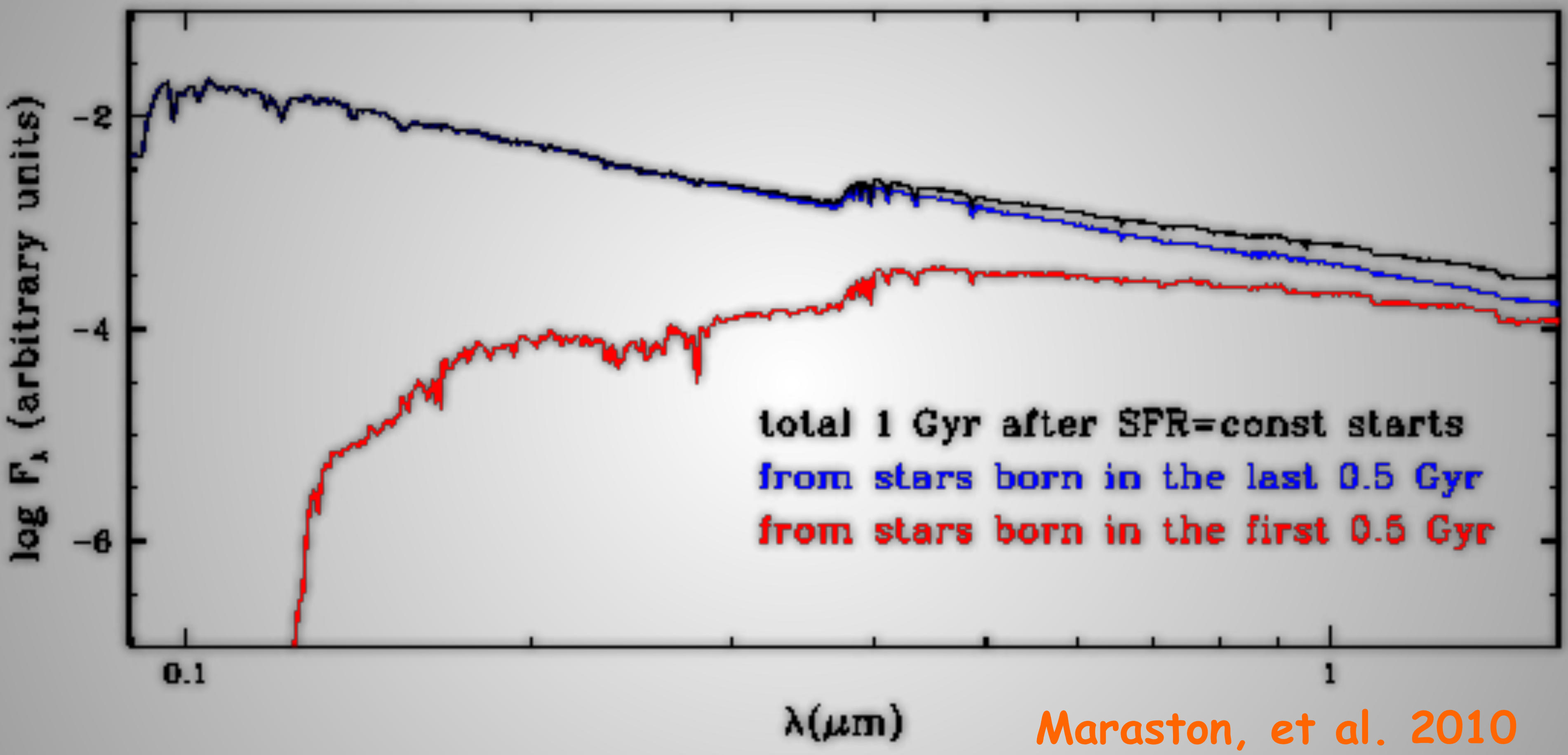


Revised (Maraston05): adding the **near-IR helps breaking the degeneracy** because of the AGB stars

The light average problem: Outshine from the youngest stellar generations



Maraston, et al. 2010

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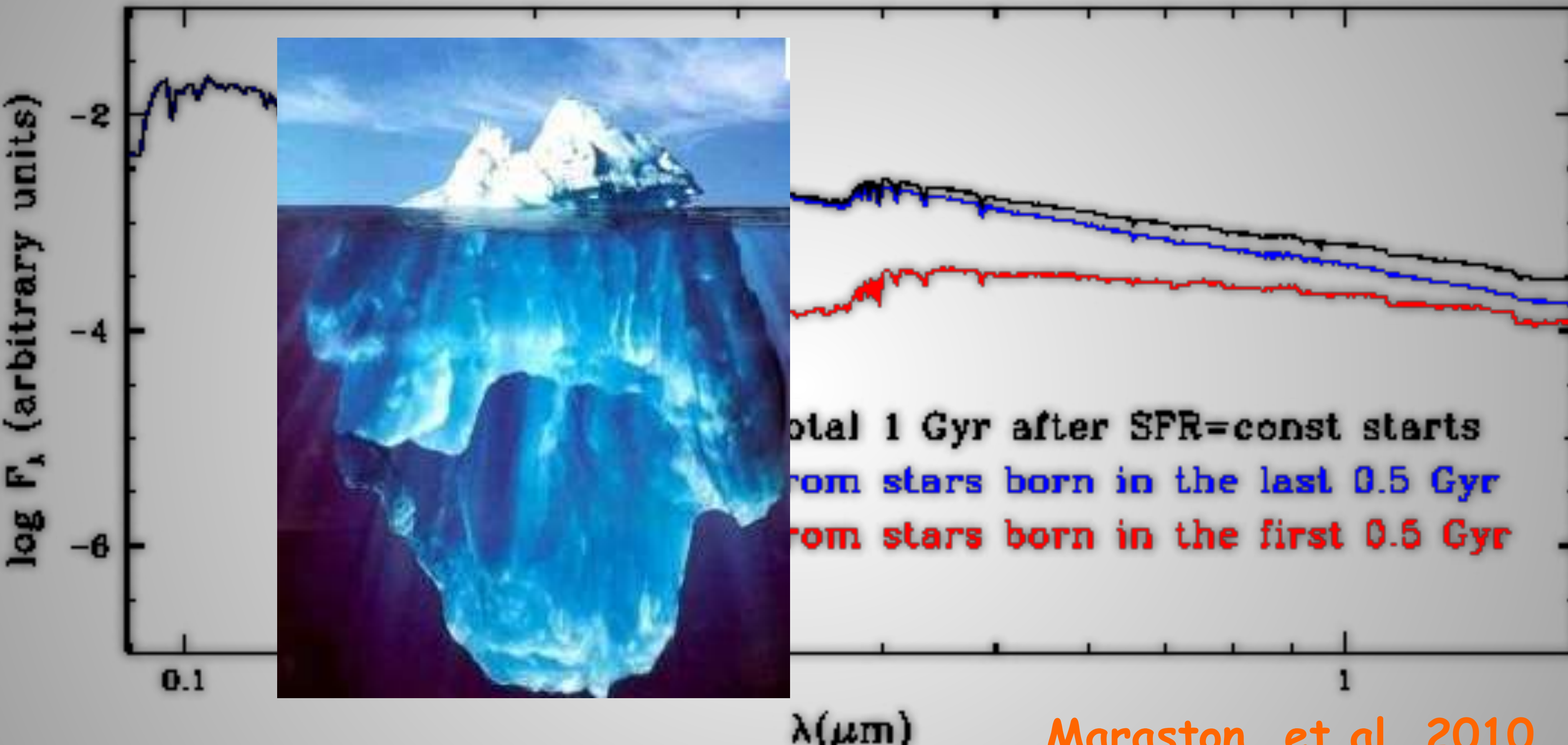


Maraston, et al. 2010

Galaxy mass or burst mass?

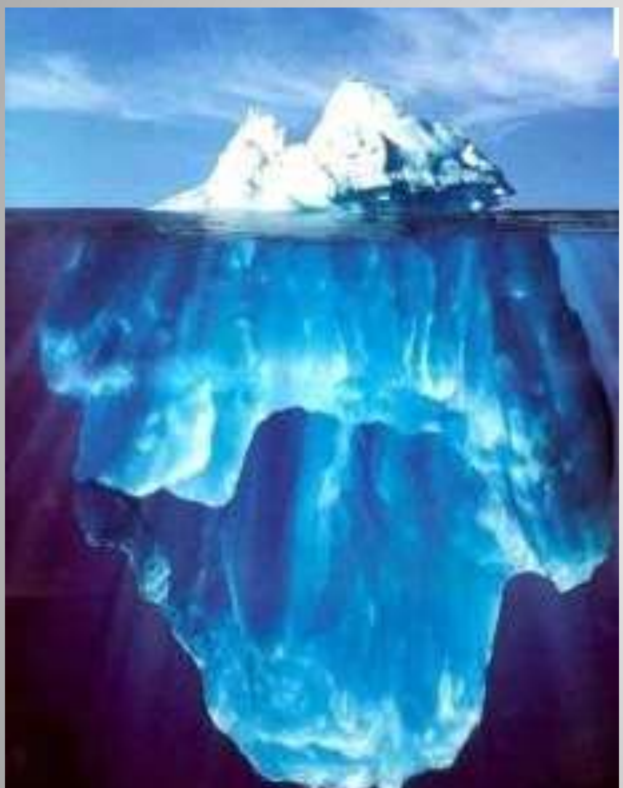


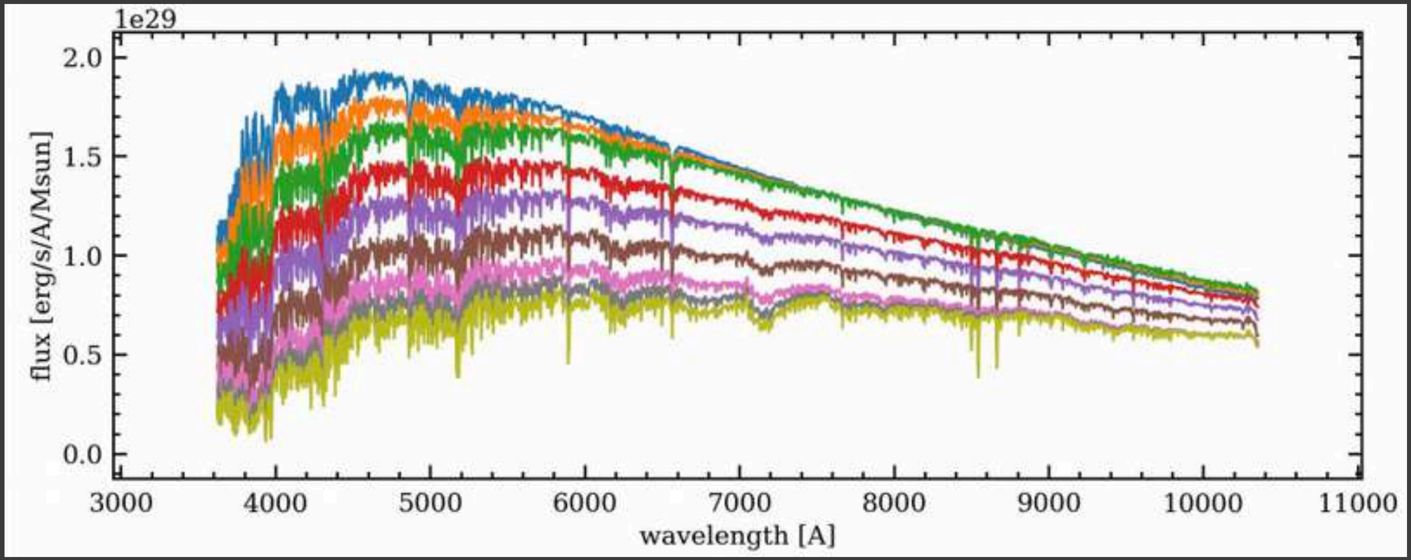
Table 2. Derived ages and stellar masses for a $10^{11}\,M_{\odot}$ galaxy composed of a 5 Gyr old population and a low percentage – 1 or 10 per cent – of a younger population. Burst characteristics are listed in the first column, while the second and third columns list the derived ages and masses.

Burst characteristics	Derived age	Derived M^* ($\log M_{\odot}$)
Burst no reddening		
1 per cent 1 Gyr	3.75 Gyr	10.85
1 per cent 100 Myr	4.5 Gyr	10.86
1 per cent 10 Myr	4.5 Gyr	10.74
1 per cent 1 Myr	15 Myr	9.23
10 per cent 1 Gyr	2.75 Gyr	10.83
10 per cent 100 Myr	404 Myr	10.42
10 per cent 10 Myr	8.7 Myr	9.91
10 per cent 1 Myr	6.6 Myr	9.93
Burst + reddening		
1 per cent 1 Gyr	3.5 Gyr	10.90
1 per cent 100 Myr	4.5 Gyr	10.86
1 per cent 10 Myr	7.9 Myr	9.28
1 per cent 1 Myr	13.8 Myr	9.30
10 per cent 1 Gyr	2.75 Gyr	10.83
10 per cent 100 Myr	6.3 Myr	9.69
10 per cent 10 Myr	8.7 Myr	9.91
10 per cent 1 Myr	6.6 Myr	9.93

Pforr, Maraston, Tonini 2012

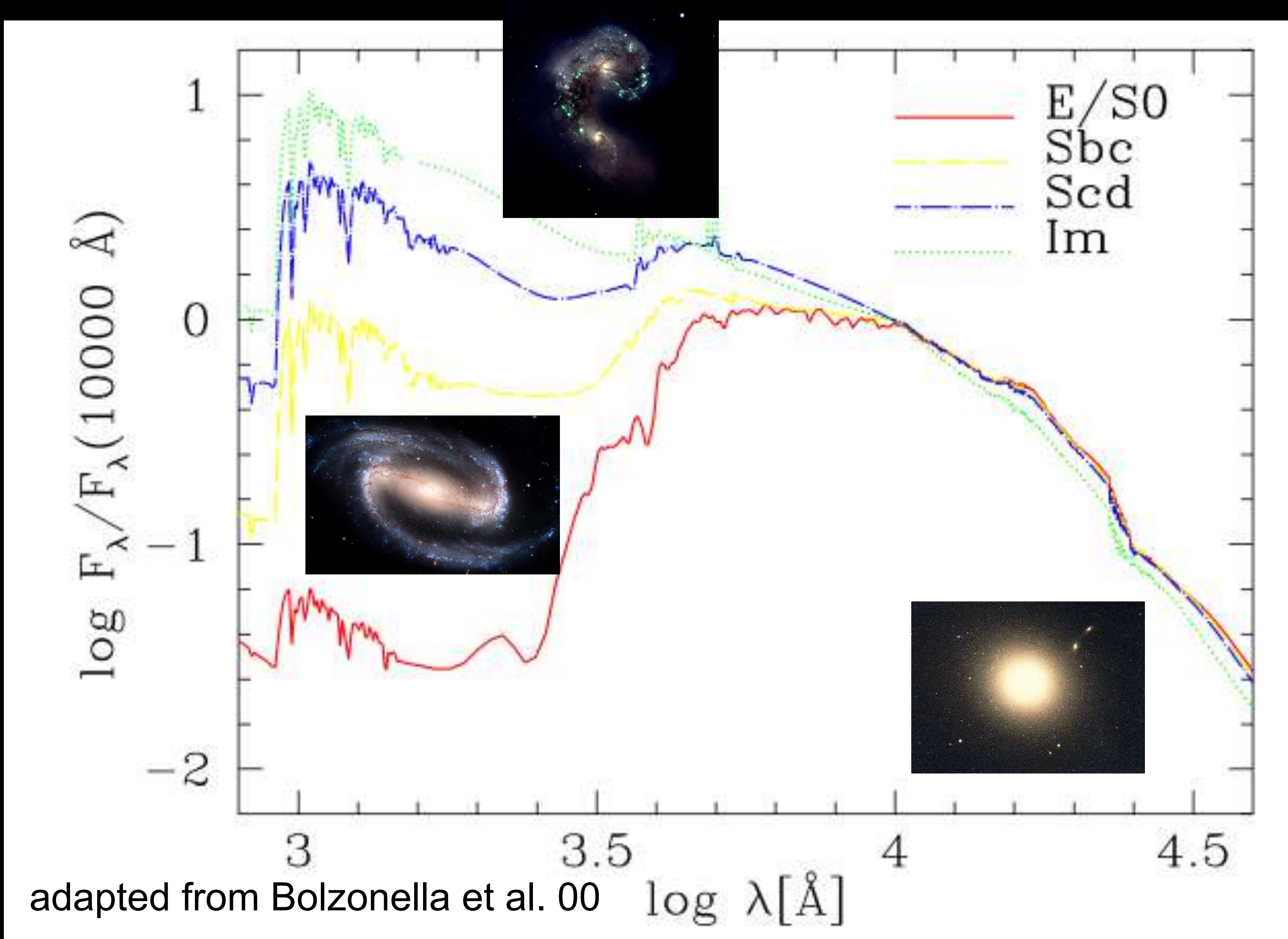
Applications

- Properties of real galaxies



- Theoretical spectra for model galaxies from galaxy formation simulations

What is the star formation history of a galaxy?



adapted from Bolzonella et al. 00

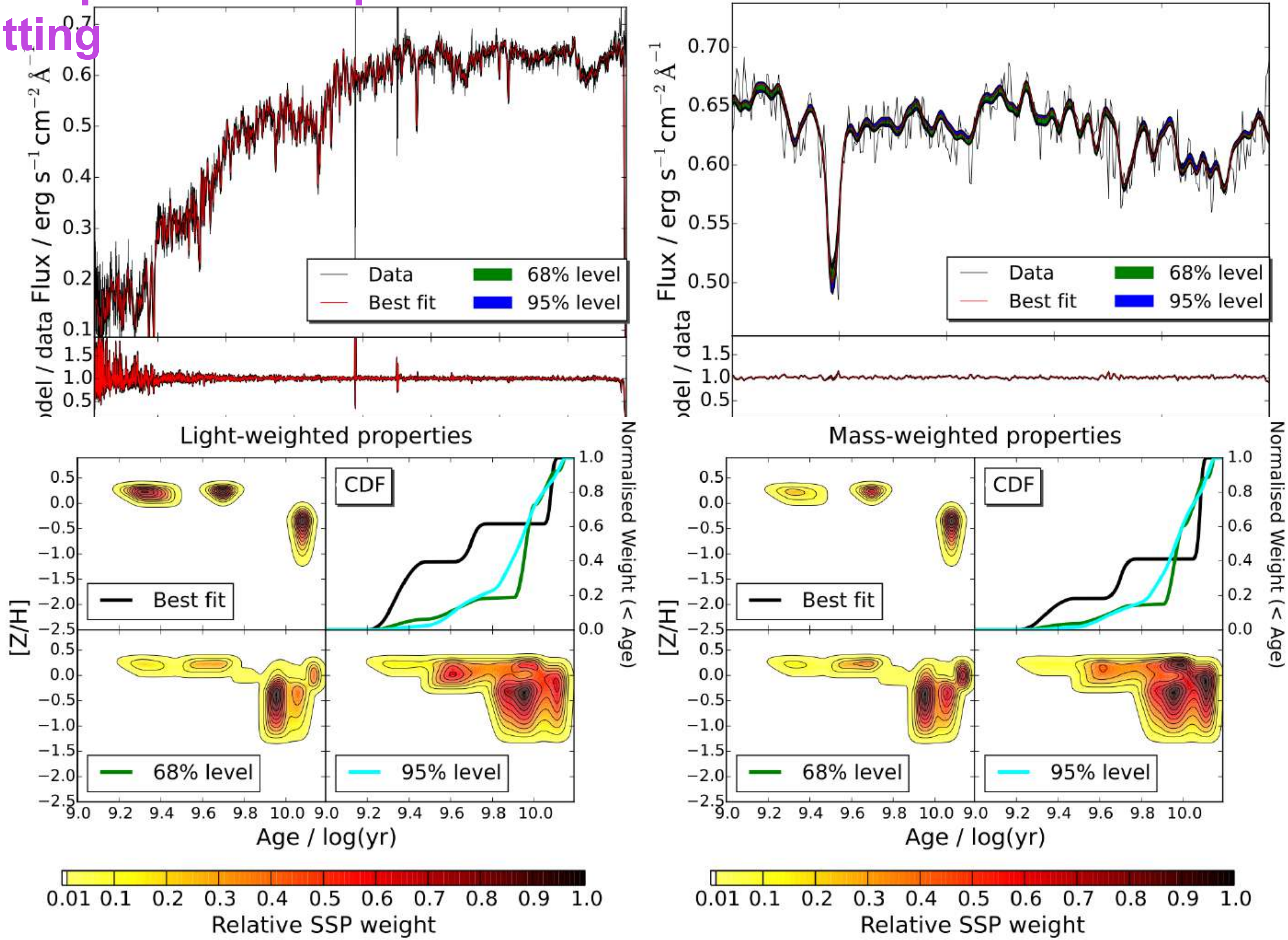
What is the star formation history of a galaxy?

Derivation vs prior

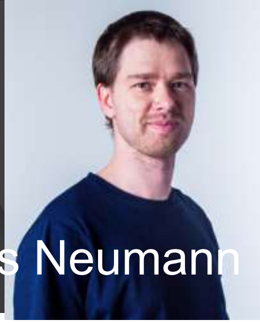
Non-parametric spectral fitting

Firefly - Fitting IteRativEly For Likelihood ana

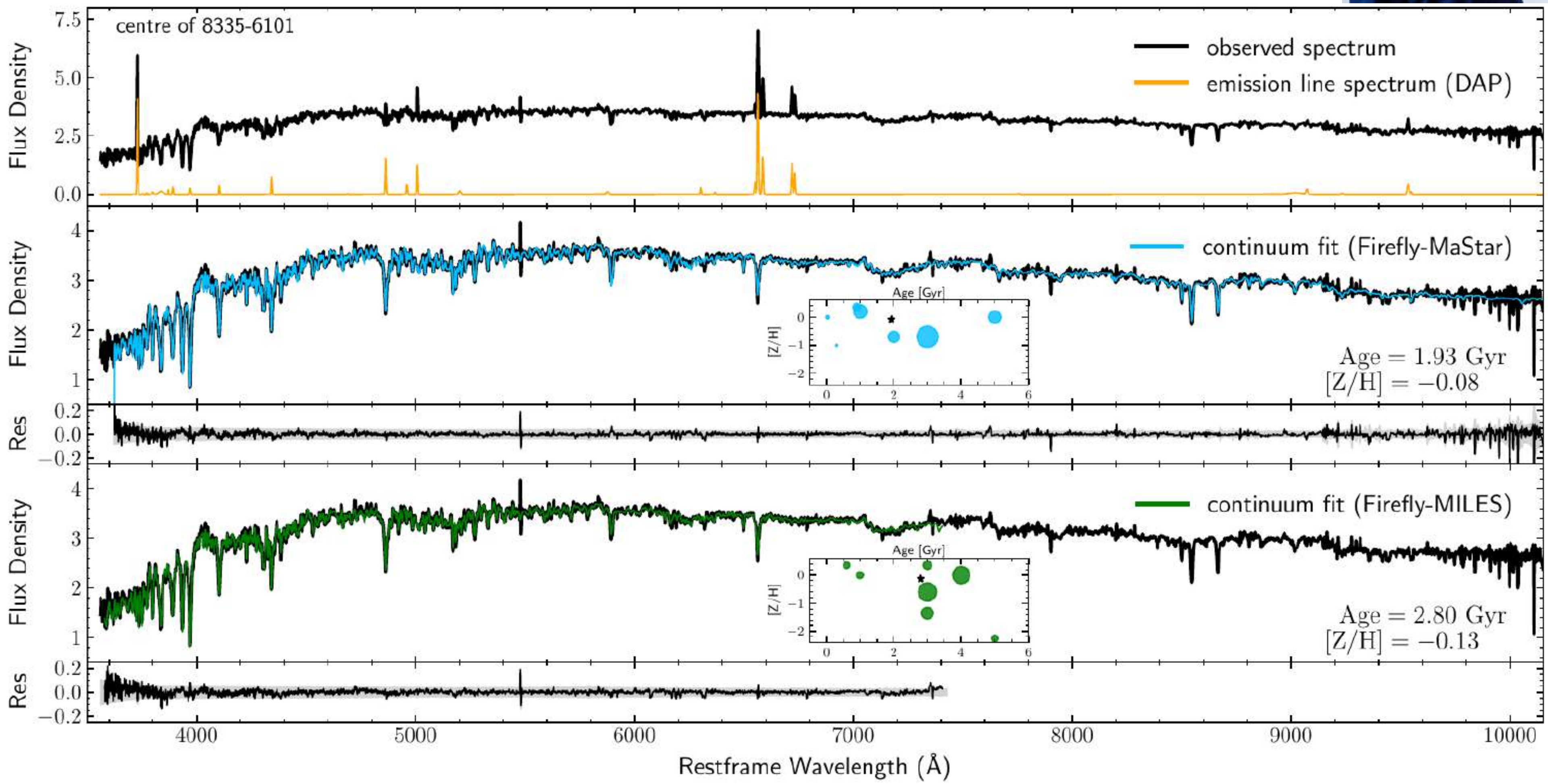
Wilkinson, Maraston et al. 2017



Portsmouth Value Added Catalogue – VAC Population model fit to SDSS-IV IFU galaxy spectra – Neumann et al. 2022, MNRAS



Dr. Justus Neumann



Full spectral fitting code Firefly, www.icg.port.ac.uk/firefly/

SDSS-IV/MaNGA data Bundy et al. 2016

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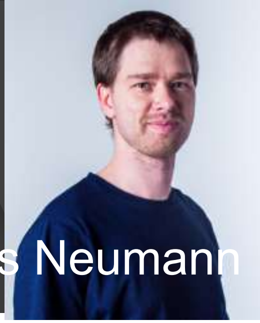

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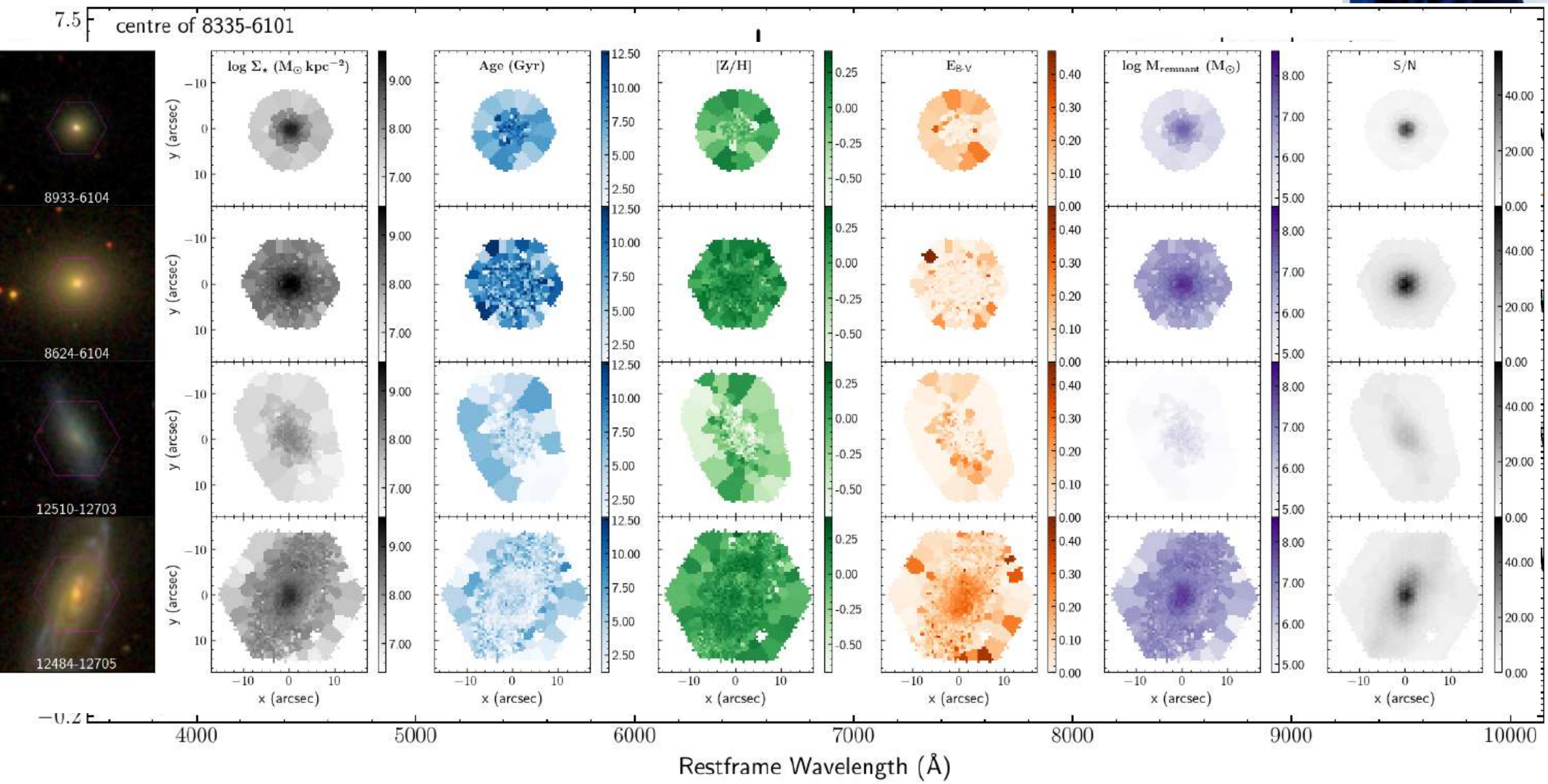

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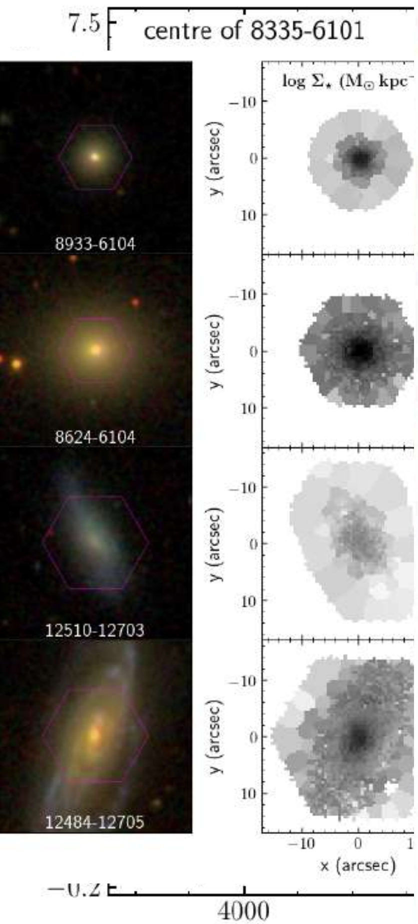
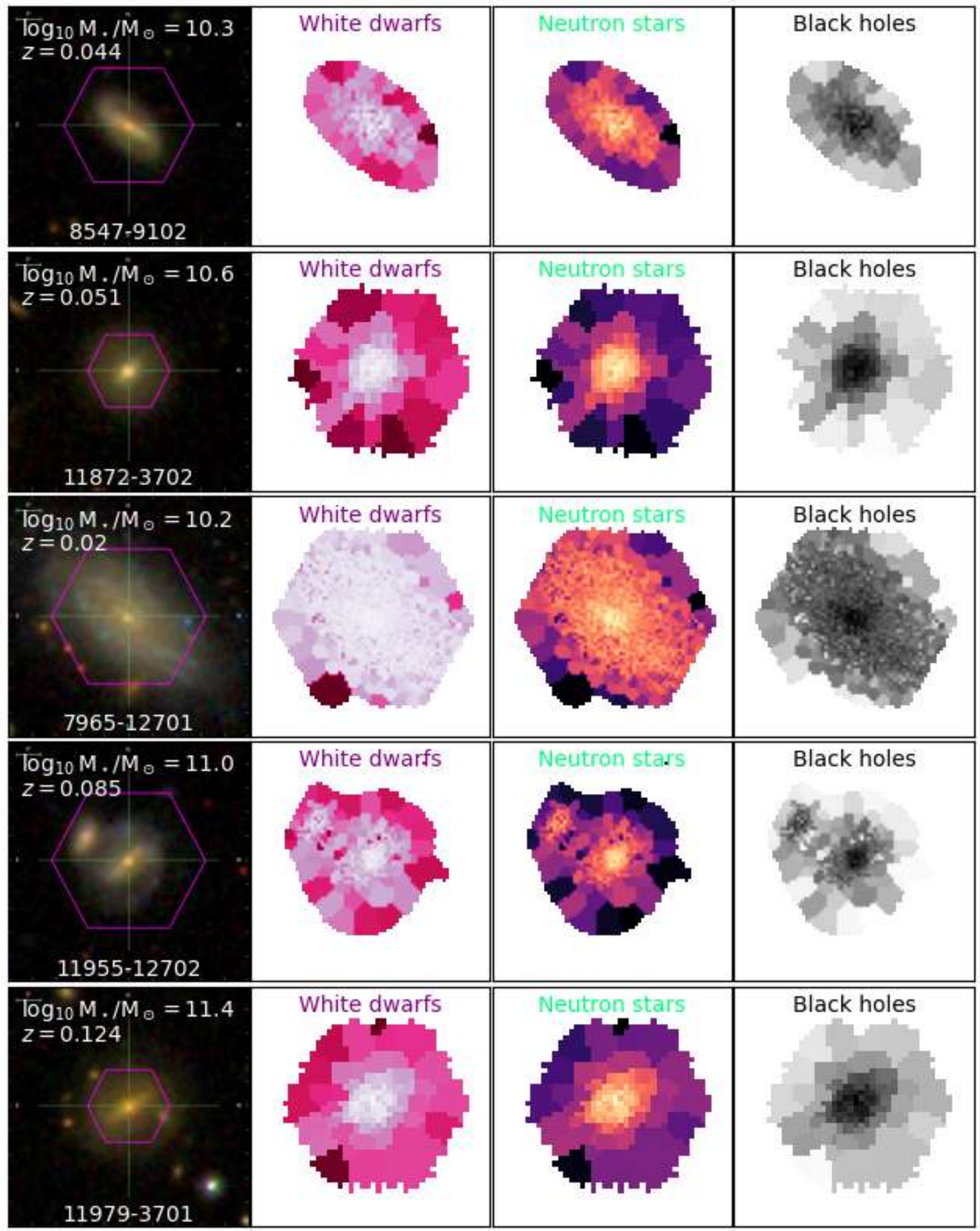
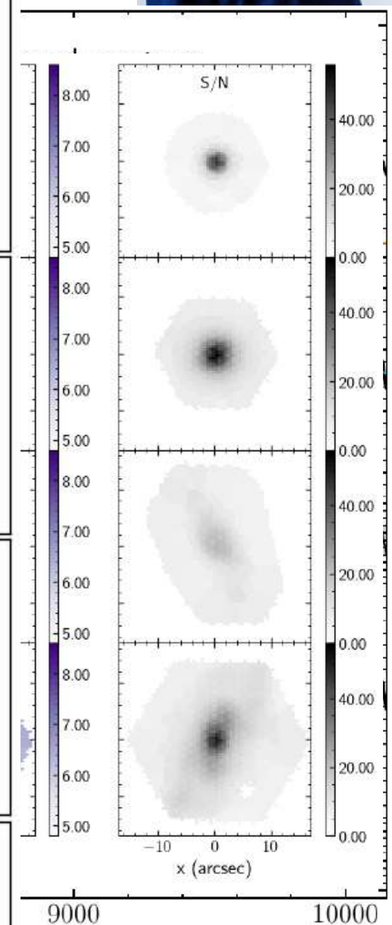
Population mode
spectra – Neumar

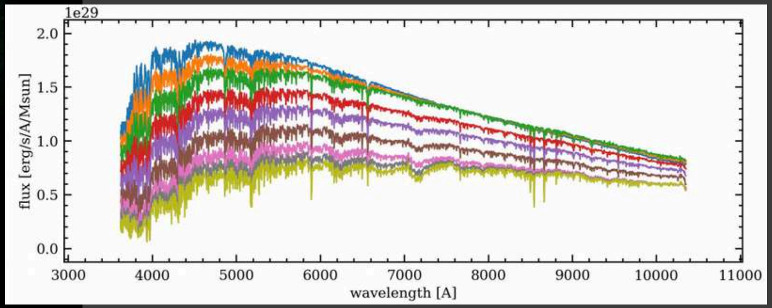




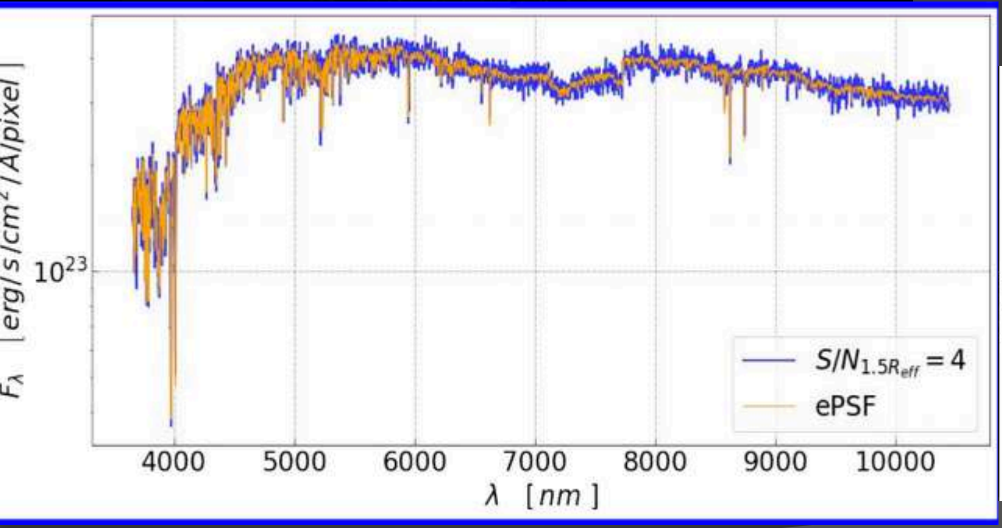


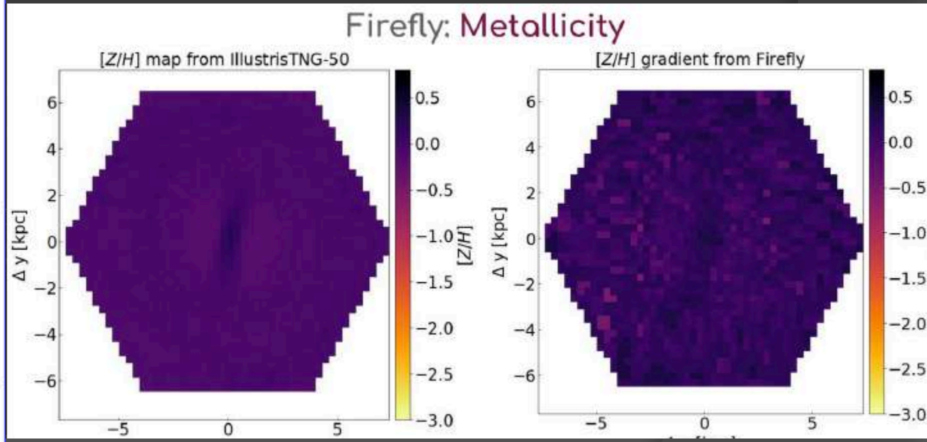
Full spectral fitti
SDSS-IV/MaNGA

IMaNGA: High-resolution spectra of galaxy models from cosmological, hydro-simulations Illustris-TNG50



Lorenza Nanni,
PhD, Portsmout

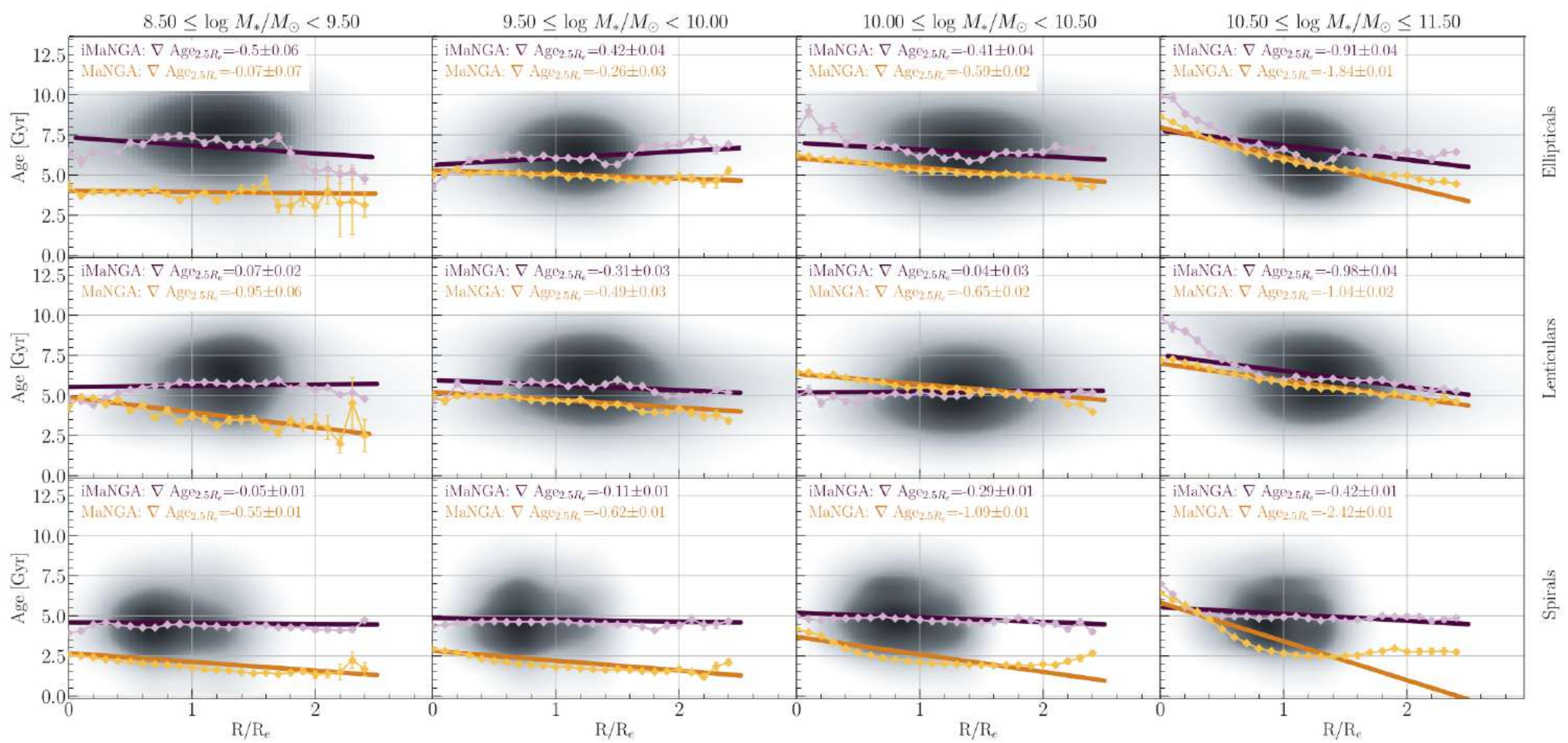




Nanni, Thomas, Trayford, Maraston, Piilepich, Yan et al. 2022; 2023, 2024

IMaNGA vs real MaNGA - aka mock-simulated vs real galaxies

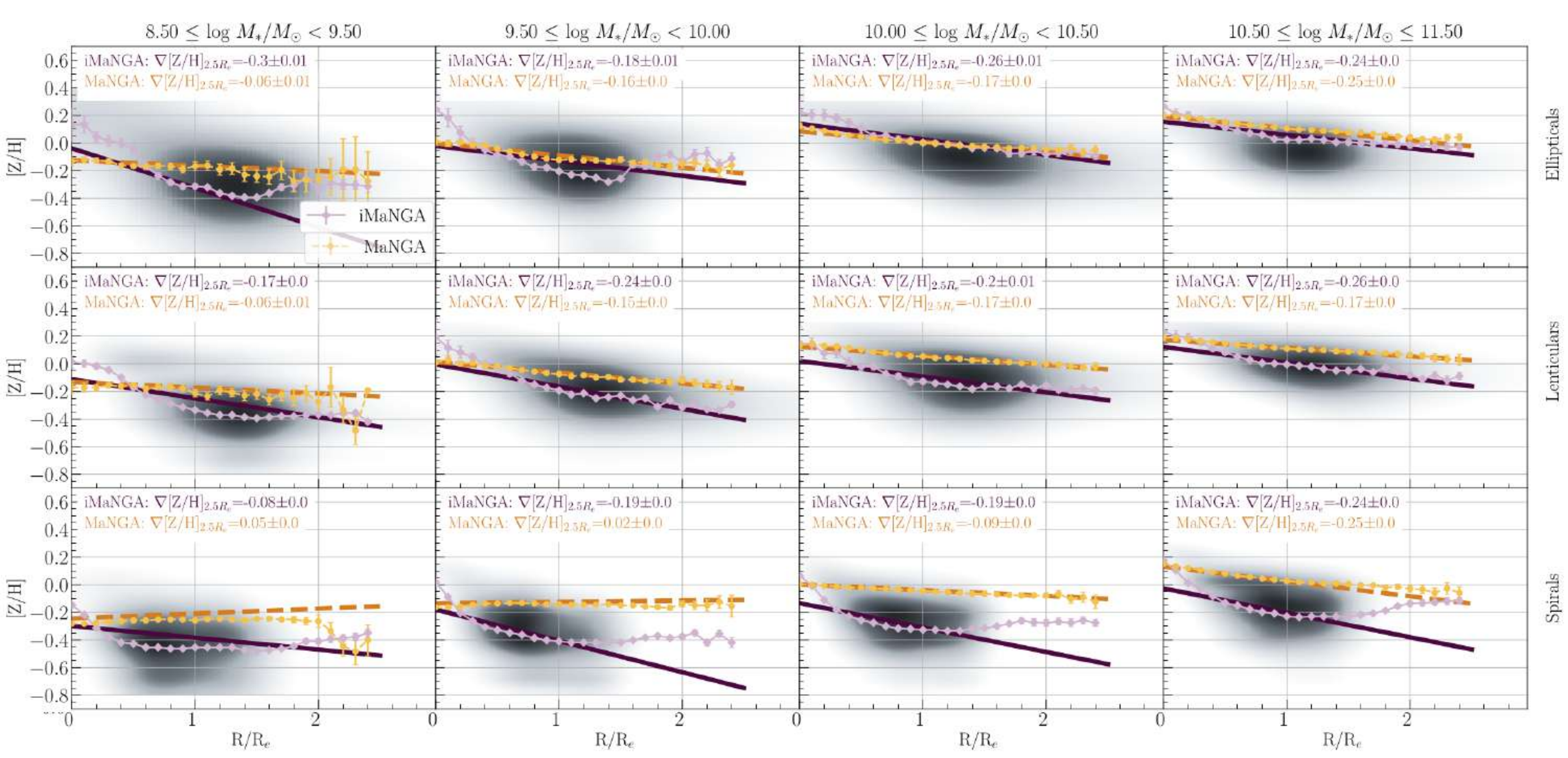
Age gradients: much flatter in simulations vs data, especially massive spirals and Es - lenticular do well



Nanni et al. 2024, MNRAS, 527, 6419

IMaNGA vs real MaNGA - aka mock-simulated vs real galaxies

Metallicity gradients: spot on for massive early types, steeper in spirals



Nanni et al. 2024, MNRAS, 527, 6419

Summary

- Stellar population models determine galaxy properties and scaling relations
- Age/dust degeneracy and iceberg effect insidious especially for AGN/QSO leads to underestimate M*
- Non parametric model fitting allows to derive a galaxy star formation history avoiding a template-bias approach
- Insights on galaxy evolution from cosmological simulations placed in the 'observer frame'