Ciências ULisboa

The Star formation history of galaxies in spectral synthesis methods

Ciro Pappalardo
IA – Lisbon (Portugal)
Cardoso, L. S. M. ; Gomes, J.M. ; Papaderos, P. ; Afonso, J. ; Breda, I. ; Humphrey, A. ; Scott, T. ; Amarantidis, S. ; Matute, I. ; Carvajal, R. ; Lorenzoni, S. ; Lagos, P. ; Paulino-Afonso, A. ; Miranda, H.

FCT Fundação para a Ciência e a Tecnologia

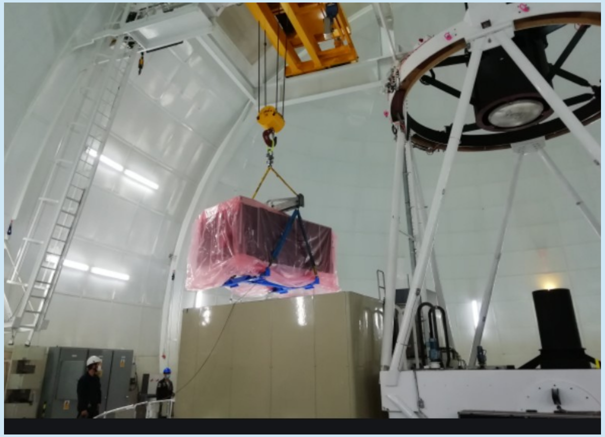
ia

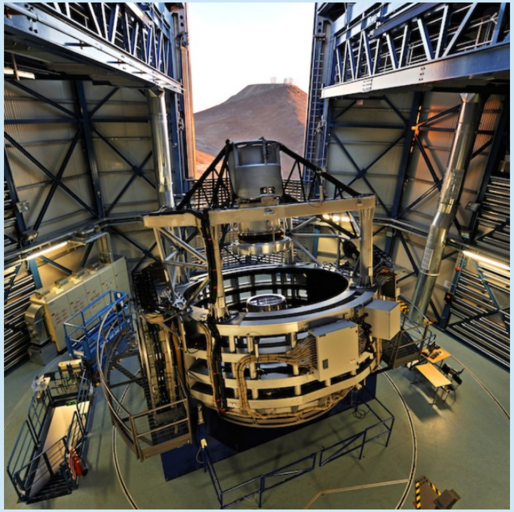
Work supported by FCT through grants PTDC/FIS-AST/29245/2017, UID/FIS/04434/2019, UIDB/04434/2020, UIDP/04434/2020

The future is in the MOS!

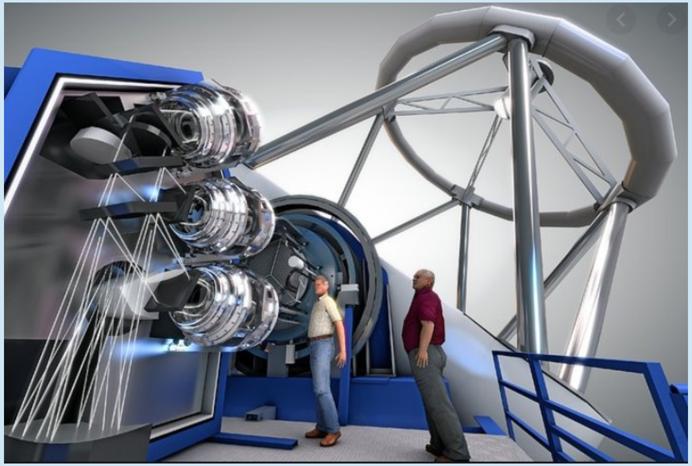
A new generation of MOS is coming!

WEAVE

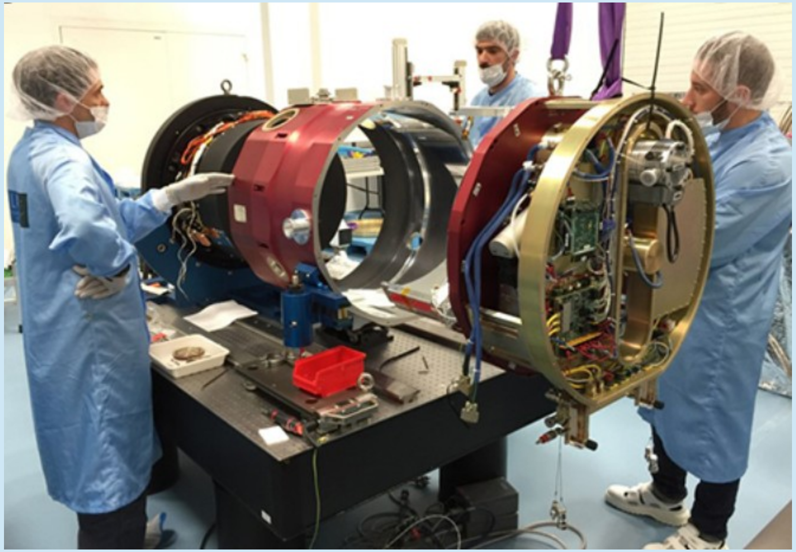




4MOST



MOONS

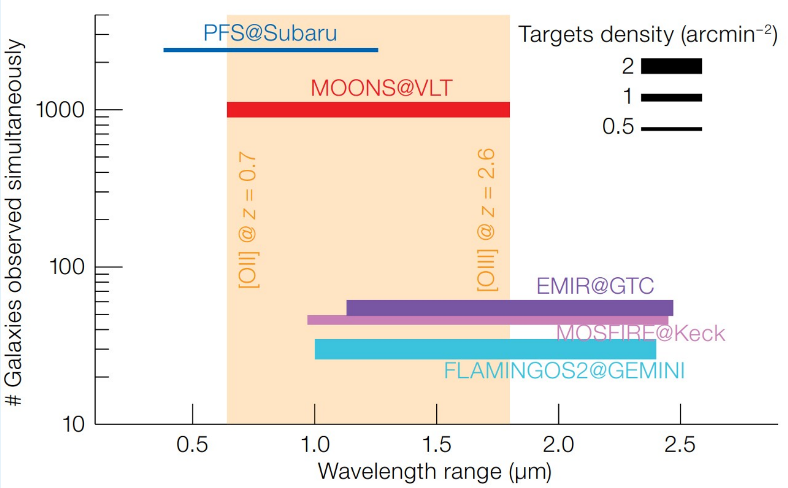


PFS

MOS for Extragalactic Astrophysics: MOONS as a test case

MOONS (Multi-Object Optical and Near-infrared Spectrograph) for the VLT:
- High Multiplex: 1000 fibres
- Extended wavelength range beyond optical: 0.64-1.8 μm

Maiolino+20



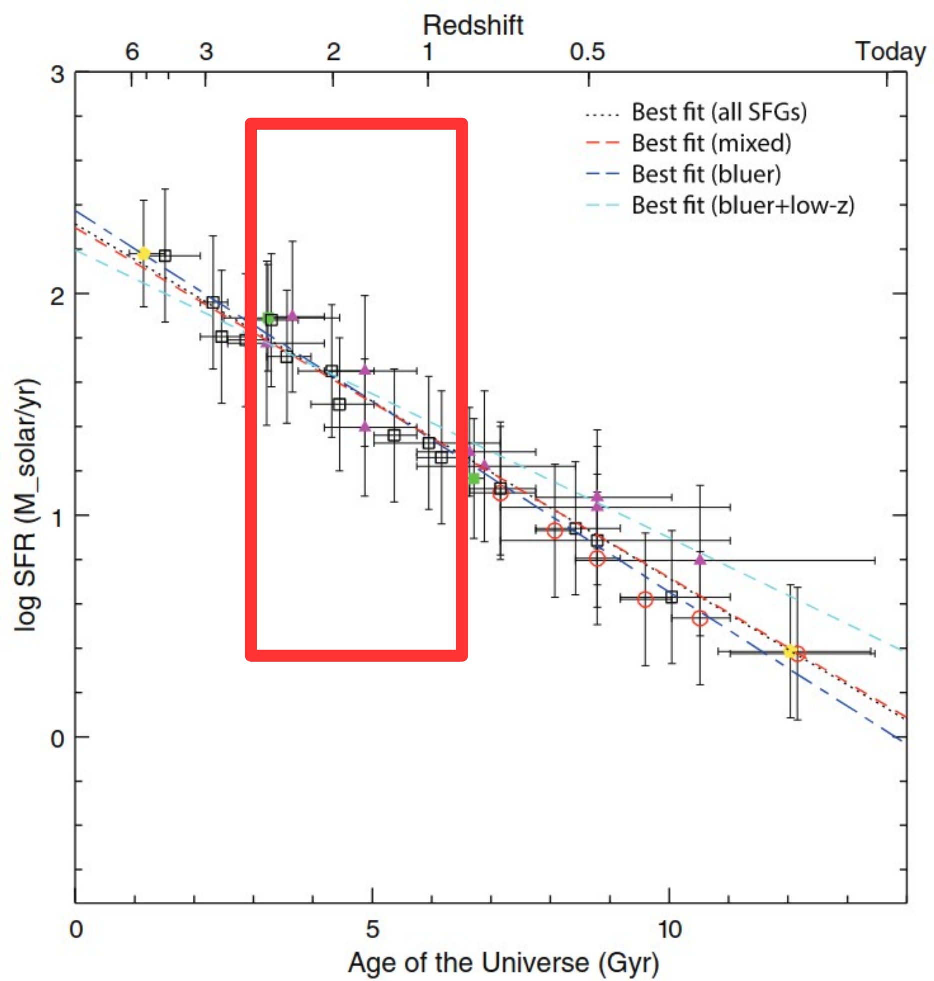
Science Goals:
a) The metallicity evolution of galaxies.
b) Active galactic nuclei and black hole demographics.
c) Kinematics.
d) **Passive galaxies, galaxy transformation and star formation histories.**
e) The role of the environment.

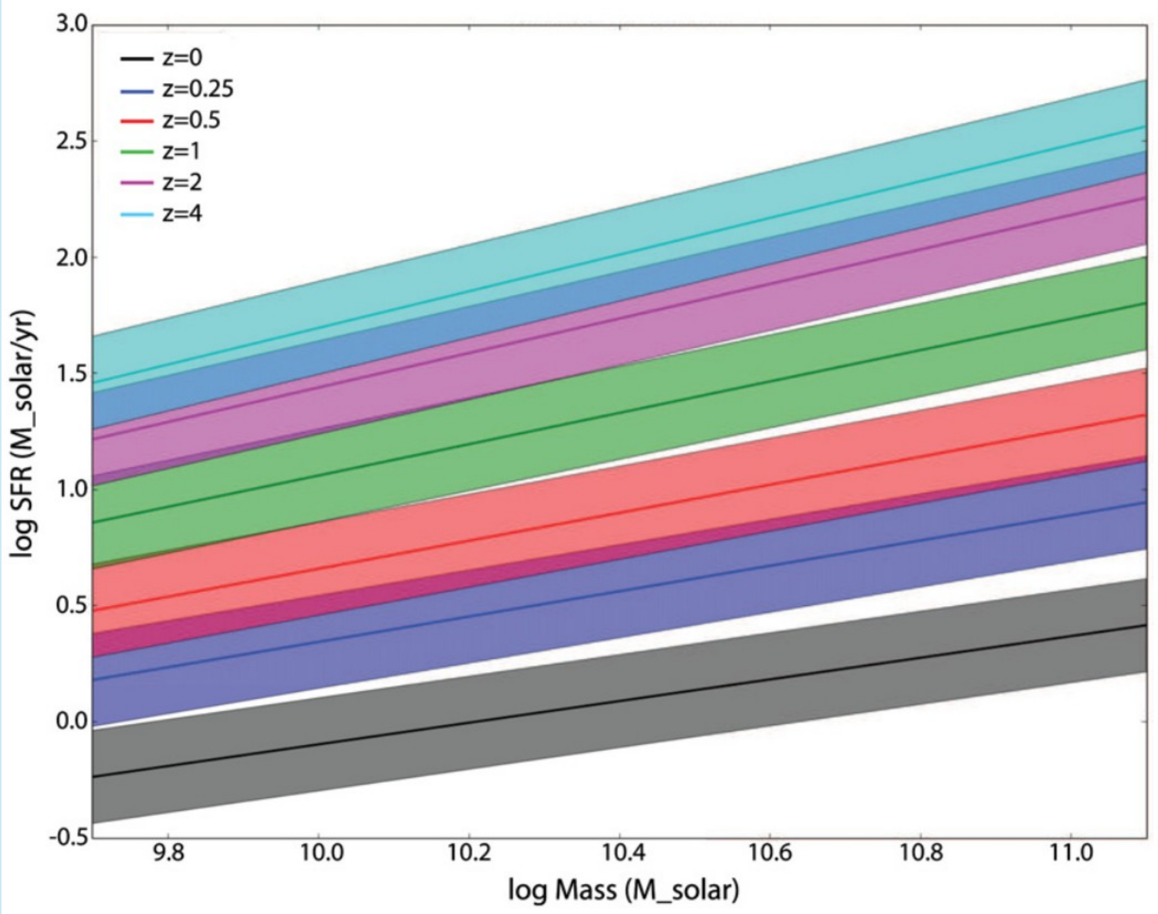
			Number of galaxies*	
Redshift range	Main spectral features	Selection	Xswitch (4 square degrees)	Stare (7 square degrees)
$0.9 < z < 1.1$	[OII], Hβ, [OIII], Hα, [NII], [SII] CaH+K, Hδ, Gb, Mgb, NaD, CaII	$H_{AB} < 23$ or $\log(M_*) > 9.5$	33900 12900	75300 28500
$1.2 < z < 1.7$	[OII], Hβ, [OIII], Hα, [NII], [SII] MgII, CaH+K, Hδ, Gb, Mgb, NaD	$H_{AB} < 23.5$ or $\log(M_*) > 9.5$	88700 13700	197100 30500
$2.0 < z < 2.6$	[OII], Hβ, [OIII] MgII, CaH+K, Hδ, Gb, Mgb	$H_{AB} < 24$ or $\log(M_*) > 10$	54500 2100	121100 4700
$5 < z$	Lyα, NV, HeII, CIV, CIII]	$H_{AB} < 26$	2000	4500
Total			207800	461700

Maiolino+20

MOS for Extragalactic Astrophysics: MOONS as a test case

What does it means?





Speagle+14

The quest for SFH: Spectral Synthesis Methods

Spectral-fitting codes deal with SFH with two approaches:

1. Parametric Methods: SFH is an analytic function

2. Non-Parametric Methods: fit with different age bins, allow for a discontinuous and ‘free’ SFH.

Advantages and disadvantages:

- Parametric fits are physically motivated and have fewer parameters to fit.
- Non-parametric fits have more parameters to fit, but more flexibility.

However:

$$F(\lambda, t) = \int_0^t \Phi(t - t') F_\lambda^{SSP}(t', Z) dt'$$

The quest for SFH: Spectral Synthesis Methods

Spectral-fitting codes deal with SFH with two approaches:

1. Parametric Methods: SFH is an analytic function

2. Non-Parametric Methods: fit with different age bins, allow for a discontinuous and ‘free’ SFH.

Advantages and disadvantages:

- Parametric fits are physically motivated and have fewer parameters to fit.
- Non-parametric fits have more parameters to fit, but more flexibility.

However:

$$F(\lambda, t) = \int_0^t \Phi(t - t')F_\lambda^{SSP}(t', Z)dt'$$

+

$$\frac{\gamma_{eff}(T_e)}{\alpha_B(T_e)} \int_0^t \Phi(t - t')q^{SSP}(t', Z)dt'$$

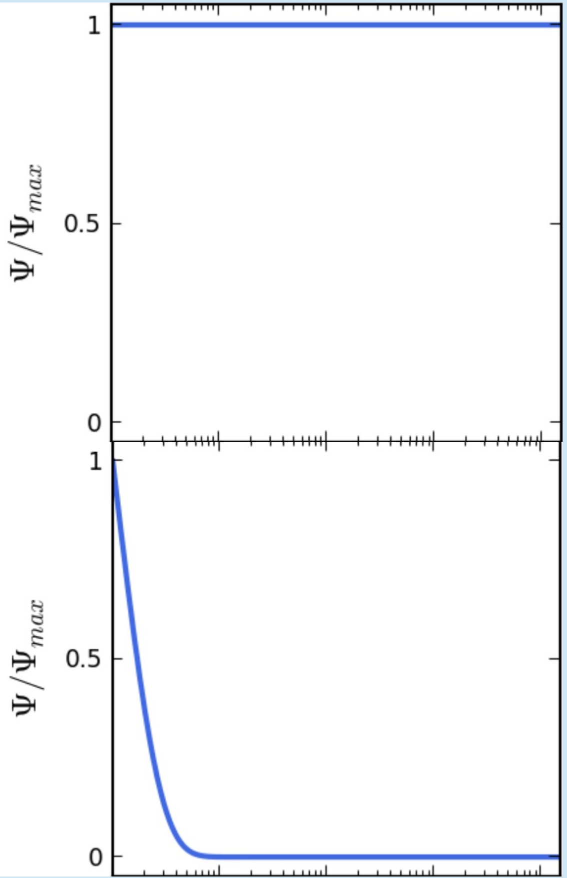
The importance of nebular emission

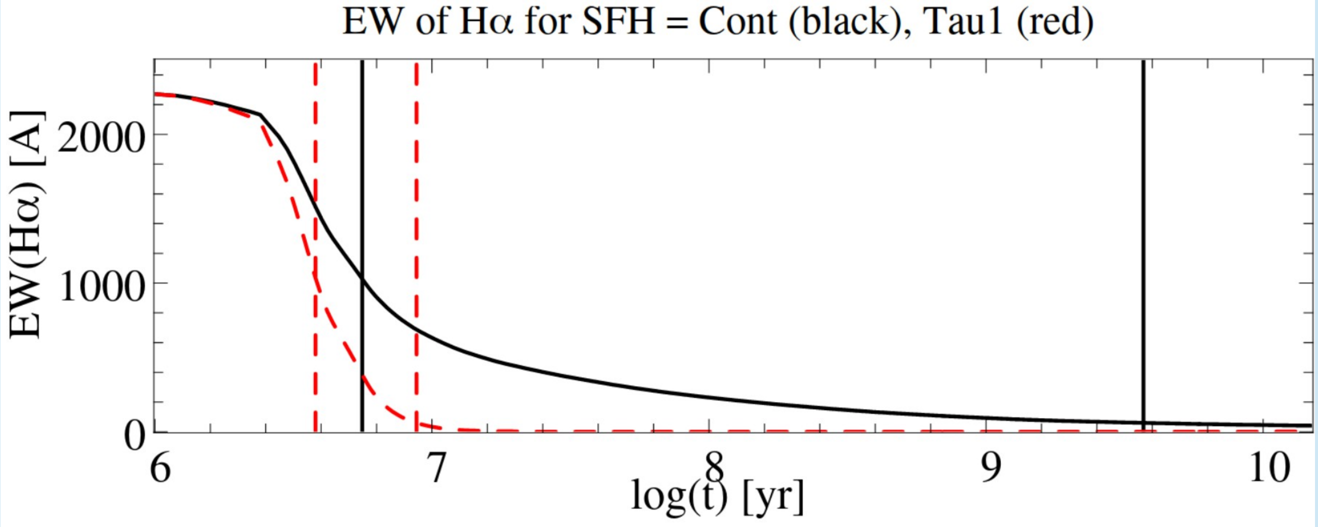
Assuming 2 limiting cases:
1 - continuous star formation
2 - single initial burst with an exponentially declining star formation law.

EW(Hα) indicates the contribution of the nebular emission to the total observed continuum.

EW(Hα) > 1000 Å at 5.6 Myr (CONT) and 3.8 Myr (TAU1)
EW(Hα) < 60 Å at 3.7 Gyr (CONT) and 8.8 Myr (TAU1)

Cardoso+19

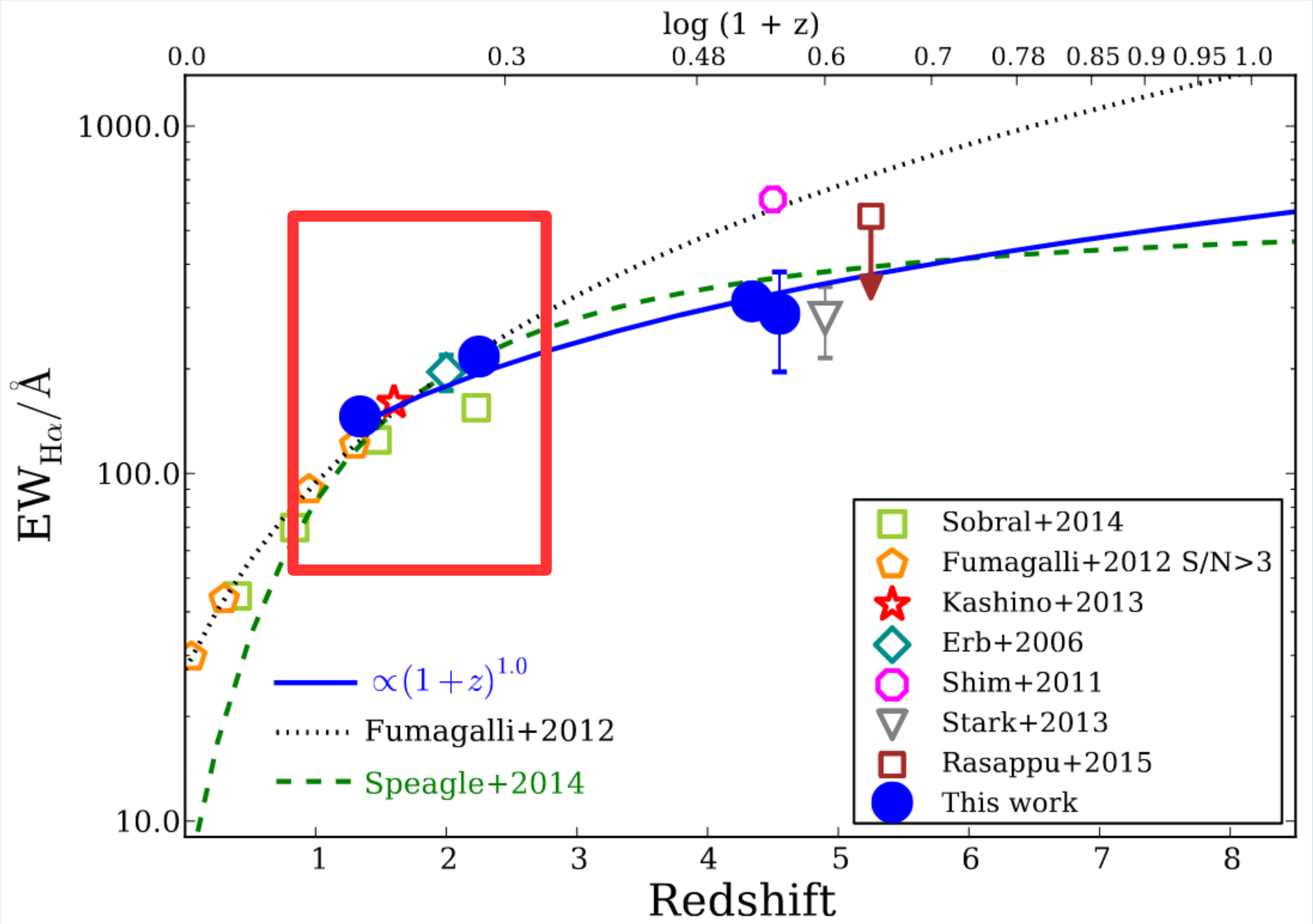




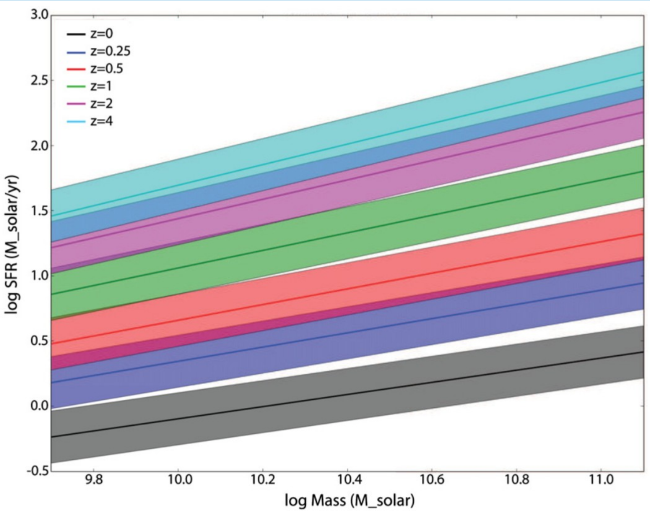
Pappalardo+21

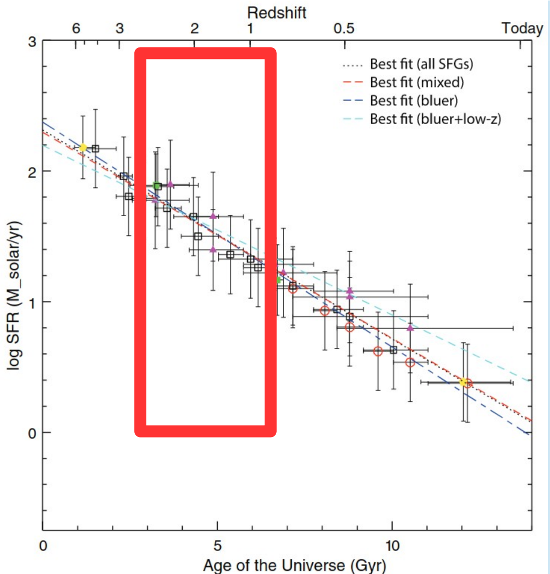
MOS for Extragalactic Astrophysics: MOONS as a test case

Marmol-Queralto+16



Speagle+14





Goals

a) to determine at which S/N the results for the parameters considered are still reliable

b) to identify which stellar ages the fitting tools are more sensitive to

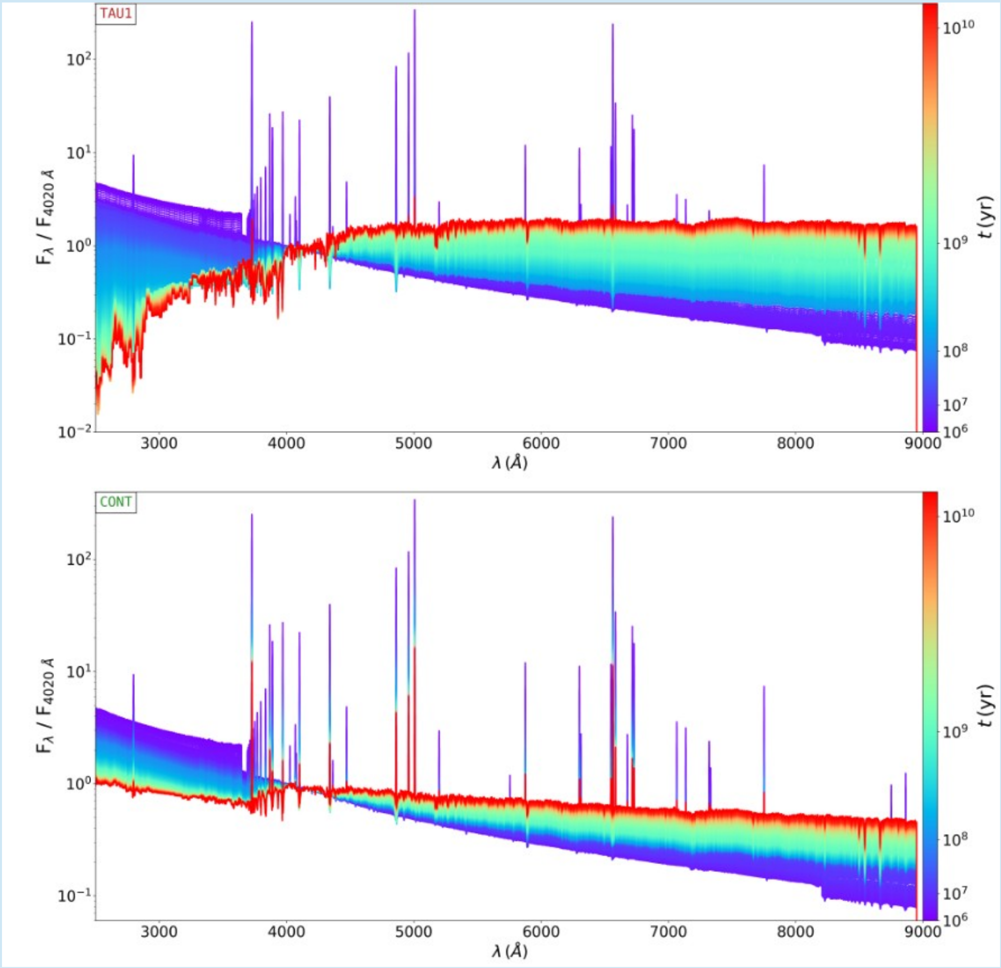
c) to quantify the effect of nebular emission on the physical quantities inferred for the stellar component in population synthesis codes

HOW?

We investigate the mean stellar ages recovered with 3 different spectral synthesis codes methods in a set of simulated spectra which includes nebular contribution.

Dancing Rebetiko 

Reckoning galaxy Emission By means of Evolutionary Tasks with Input Key Observables:



Two cases:

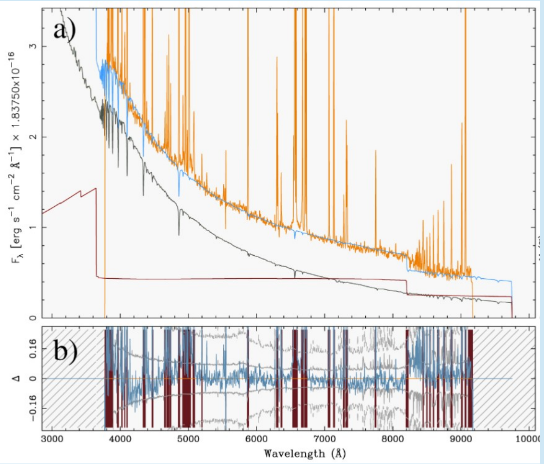
1. **Tau** model simulates a galaxy undergoing an initial instantaneous burst, followed by an exponentially declining SFR

2. **Cont**: simulates a galaxy undergoing a continuous accretion of gas, sustaining star formation at a constant rate.

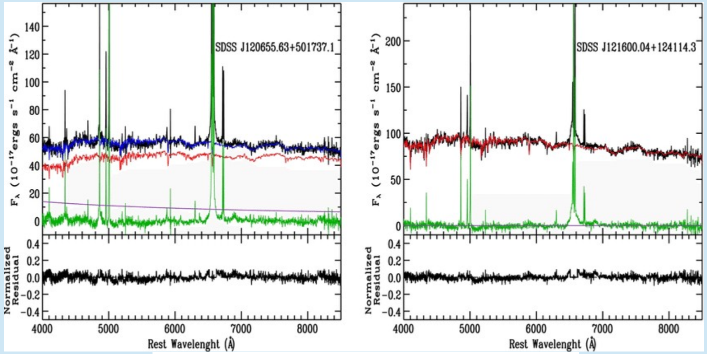
- Add to the input spectra random Gaussian noise, producing spectra with S/N values between 3-100.

Methods

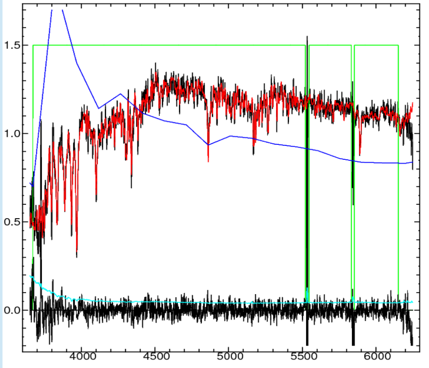
FADO: Nebular+Stellar code (Gomes & Papaderos 2017)
- Neb. Cont. estimated on the fly, together with electron density and temperature



STARLIGHT: Purely stellar (Cid Fernandes+05)
- Fits the observed spectrum with a linear combination of SSPs



STECKMAP: Hybrid (Ocvirk+06a,b)
- Non parametric inversion
- Regularisation through penalty functions in a Bayesian framework.



The spectral basis for the analysis is built from the ***BaseL:***
- 25 ages
- 4 metallicities: Z_o = 0.004, 0.008, 0.02, 0.05

Results for Cont, Tau SFHs

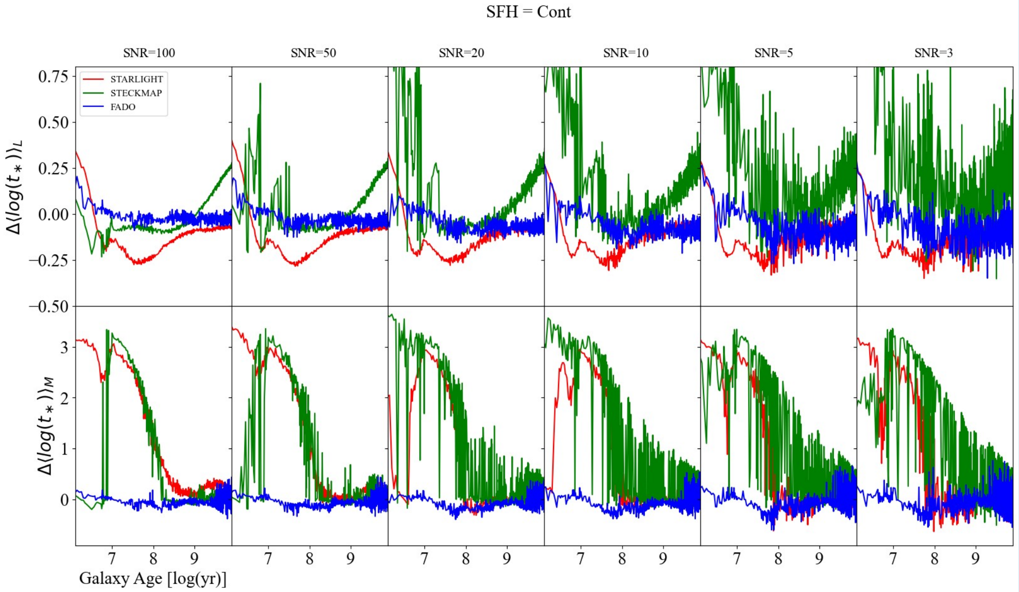
- At S/N = 3 all tools show large differences in the results, with median ΔlogtL of ~0.1 dex for Fado and Starlight, ~0.2 dex for STECKMAP

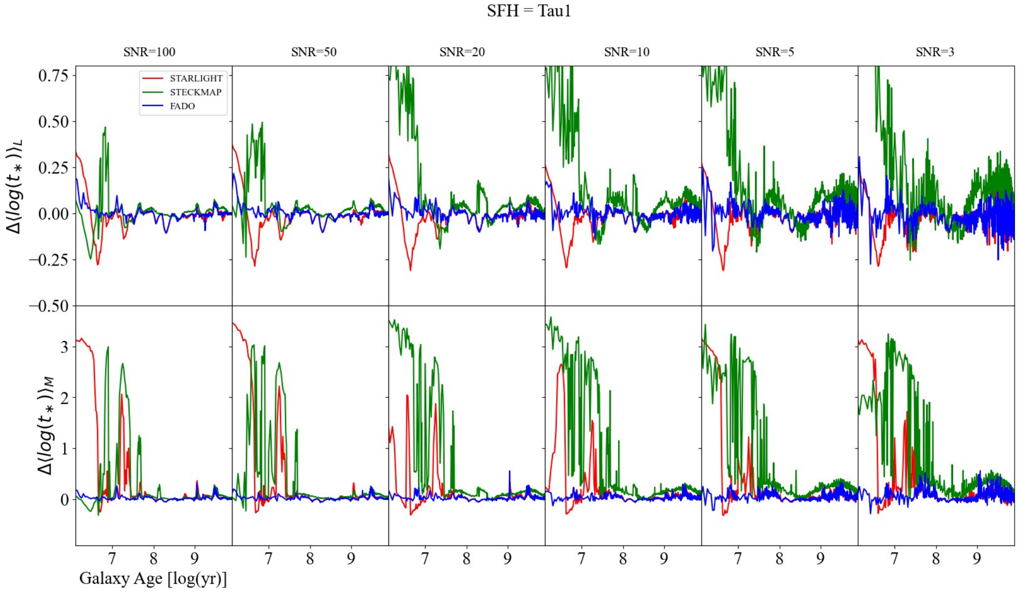
- For S/N>20:
  - FADO: ΔlogtL~ 0.03 dex (~7%)
  - STAR: ΔlogtL~ 0.08 dex (~20%)
  - STEC: ΔlogtL~ 0.11 dex (~30%)

- Mass-weighted fits are noisier:
  - FADO: ΔlogtM~0.08 dex (20%) at S/N ≥ 10
  - STAR and STEC: 0.13-0.19 dex (34-55% with no real trend with increasing S/N)

- Uncertainties at log(t/yr)~7, when nebular contributions are relevant.

- Nebular contribution for TAU1 models declines very rapidly: results show an overall consistency, with ΔlogtL~5% for Fado and Starlight already at S/N=5

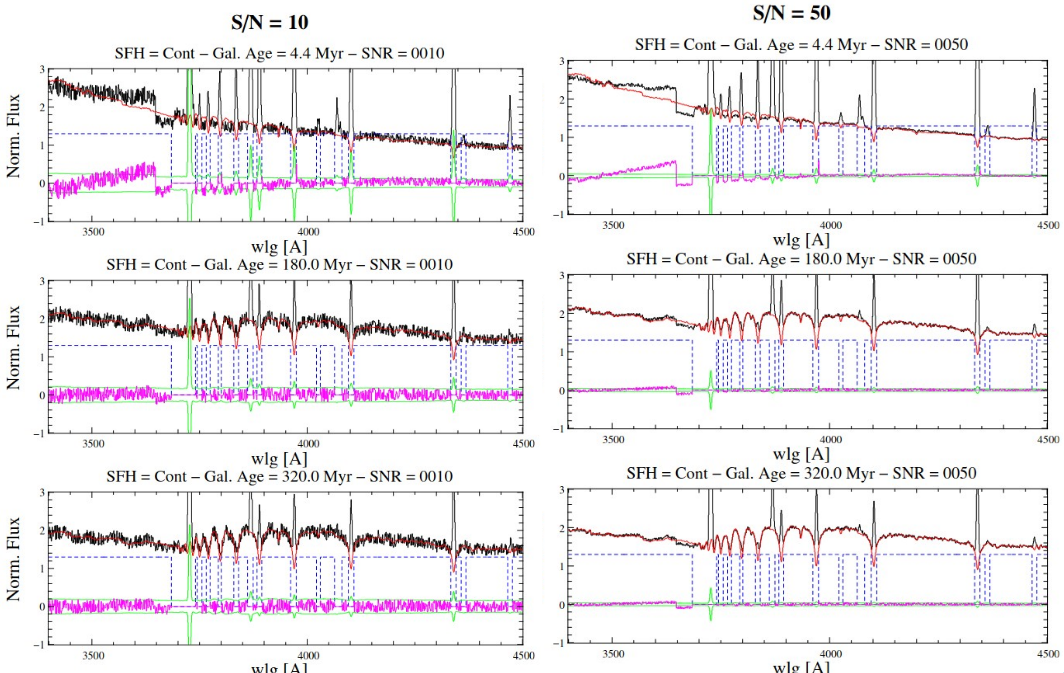


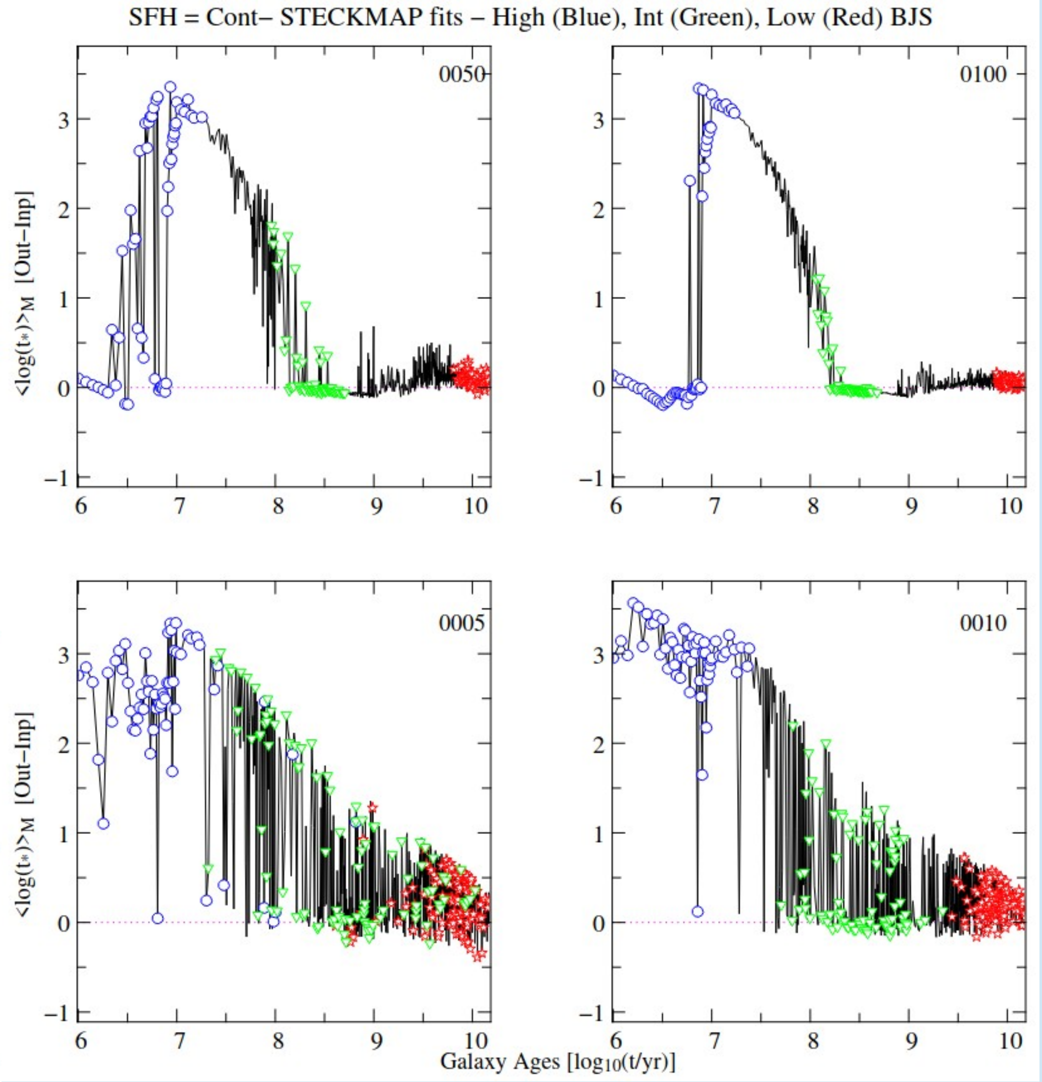


Origin of the observed discrepancies

$$\mathrm{BJS} = \frac{\int_{3580\text{Å}}^{3600\text{Å}} F(\lambda,t)d\lambda}{\int_{3660\text{Å}}^{3680\text{Å}} F(\lambda,t)d\lambda}$$

- *High BJS*: 1.2 < BJS < 2
- *Intermediate BJS*: 1.08 < BJS < 1.12
- *Low BJS*: 0.92 < BJS < 0.98 .





Conclusions

1. Code reliability depends not only on the SFH: also the S/N, the contribution of the nebular continuum, and the age coverage of the spectral basis play a role.

2. Larger discrepancies are associated with evolutionary phases where the nebular contribution to the continuum is not negligible.

3. Investigations of the best-fit spectrum in galaxies with overestimated ΔlogtM correlated the observed discrepancies with the difficulties of such methods to reproduce the Balmer jump at 3646 Å.

4. For galaxies with high BJS, neglecting the nebular emission in the fitting process has a strong impact on the estimation of the SFH. But even when a mild contribution from nebular continuum is present, there is still the possibility to misinterpret the data as a consequence of the poor quality of the observations.

If we want to extract reliable SFHs from future MOS spectra, we need to a) take into account nebular contribution, b) go to S/N above 10