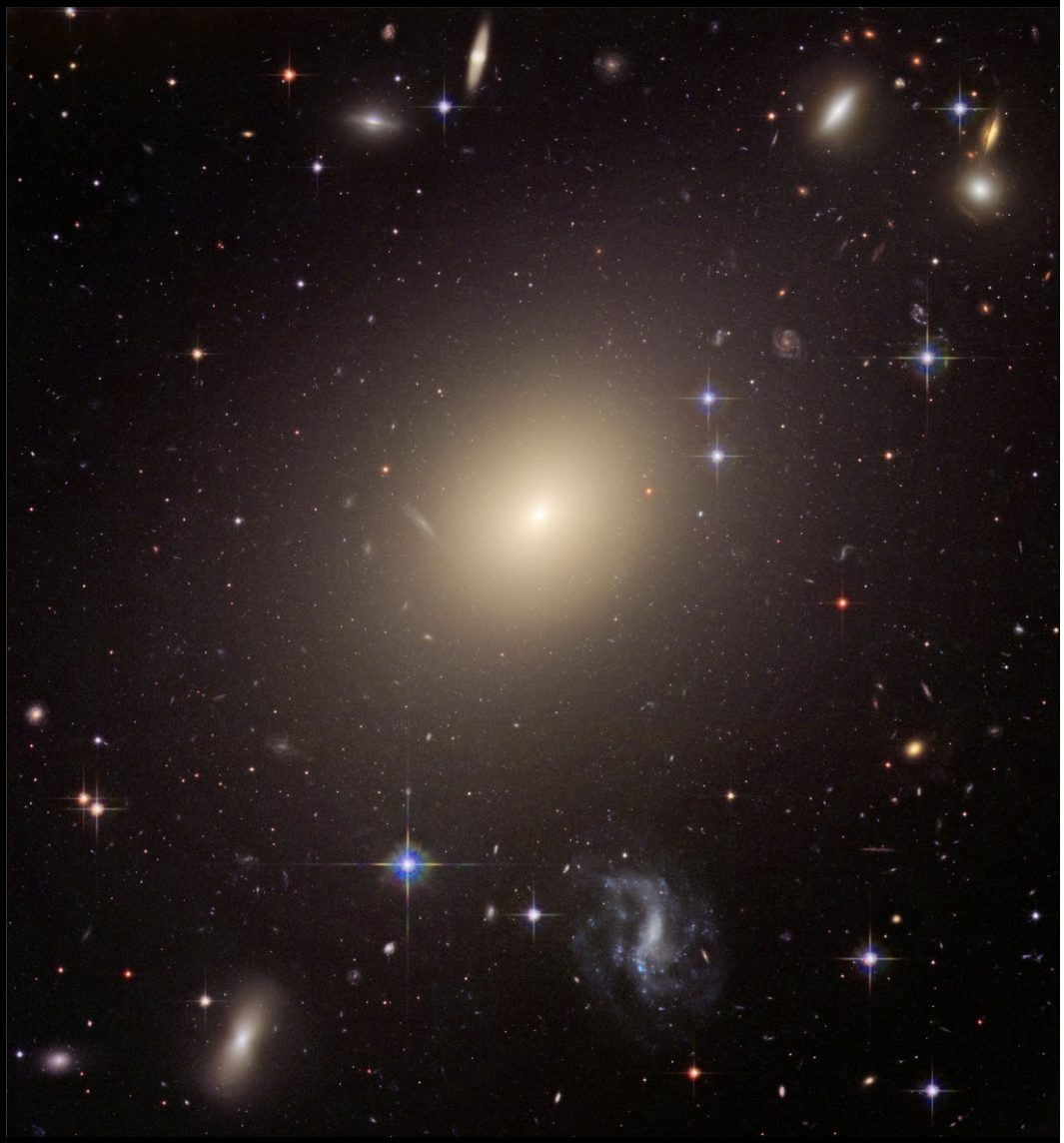
The Stellar Initial Mass Function at 0.9<z<1.5

Ignacio Martín-Navarro, P. Pérez Gonzalez,
Ignacio Trujillo, Pilar Esquej et al. (2015)

2015, ApJ, 798, L4

www.iac.es/project/traces

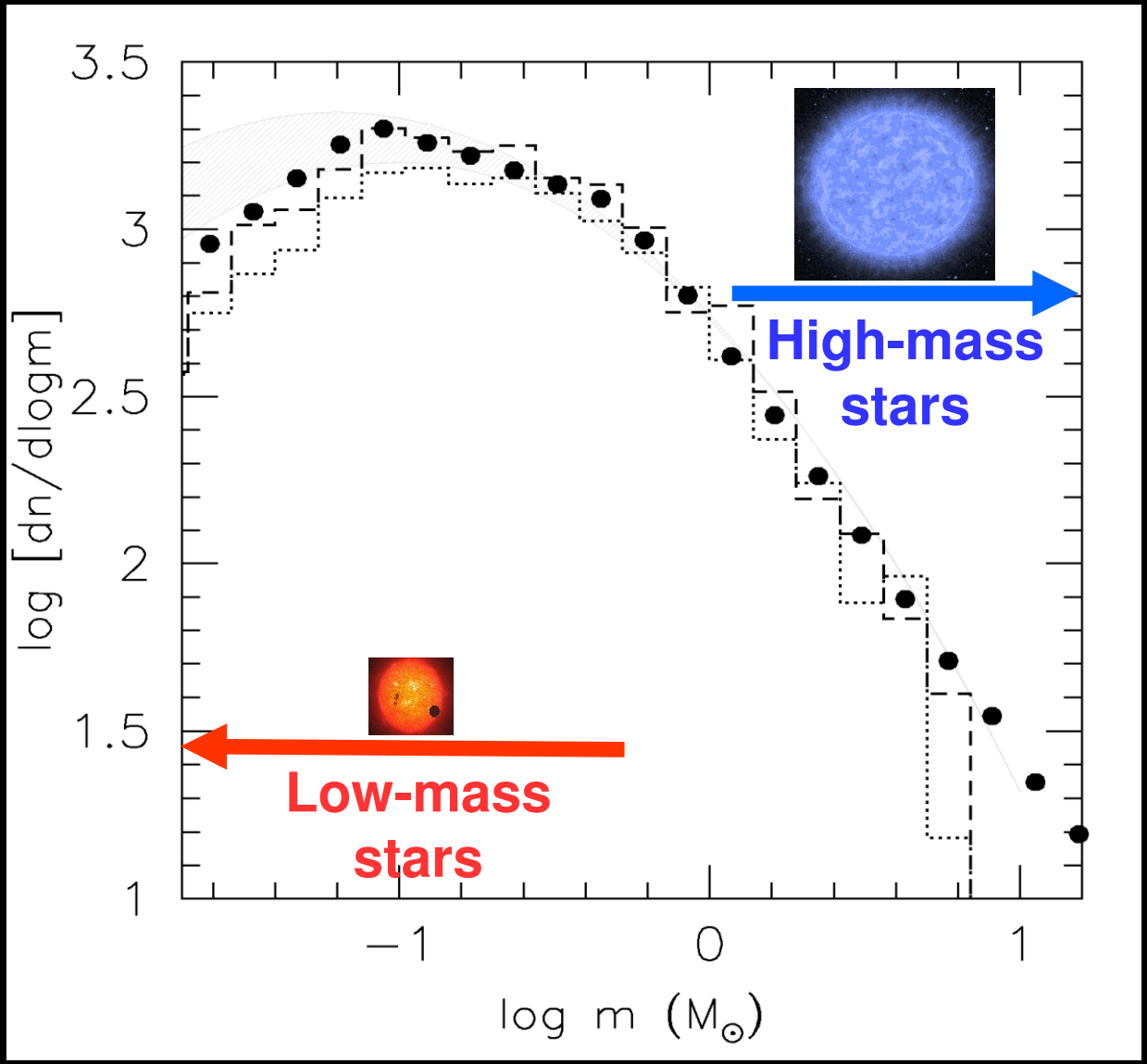
The importance of the Initial Mass Function



The distribution of stars at birth dictates the galaxy properties: age, metallicity, mass-to-light ratios…

The IMF in the MW galaxy

Moraux et al. 2004



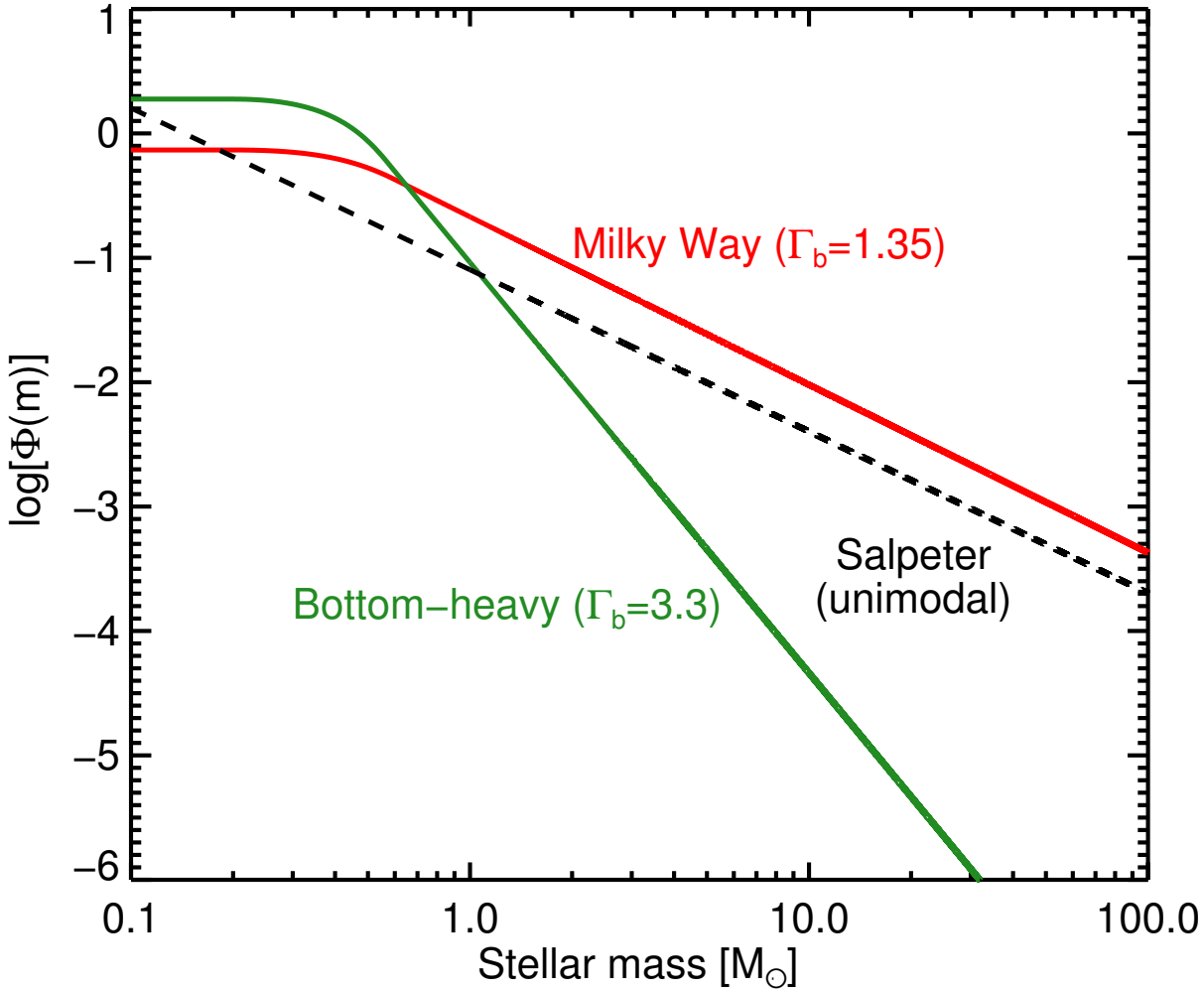
Characterizing the IMF

$$\phi(\log m) \stackrel{\text{def}}{=} \frac{\mathrm{d}\mathcal{N}}{\mathrm{d}\log m} \propto \begin{cases} m_{\mathrm{p}}^{-\Gamma_{\mathrm{b}}} & m \leqslant 0.2\,\mathrm{M}_{\odot} \\ p(m) & 0.2\,\mathrm{M}_{\odot} < m \leqslant 0.6\,\mathrm{M}_{\odot} \\ m^{-\Gamma_{\mathrm{b}}} & m > 0.6\,\mathrm{M}_{\odot} \end{cases}$$

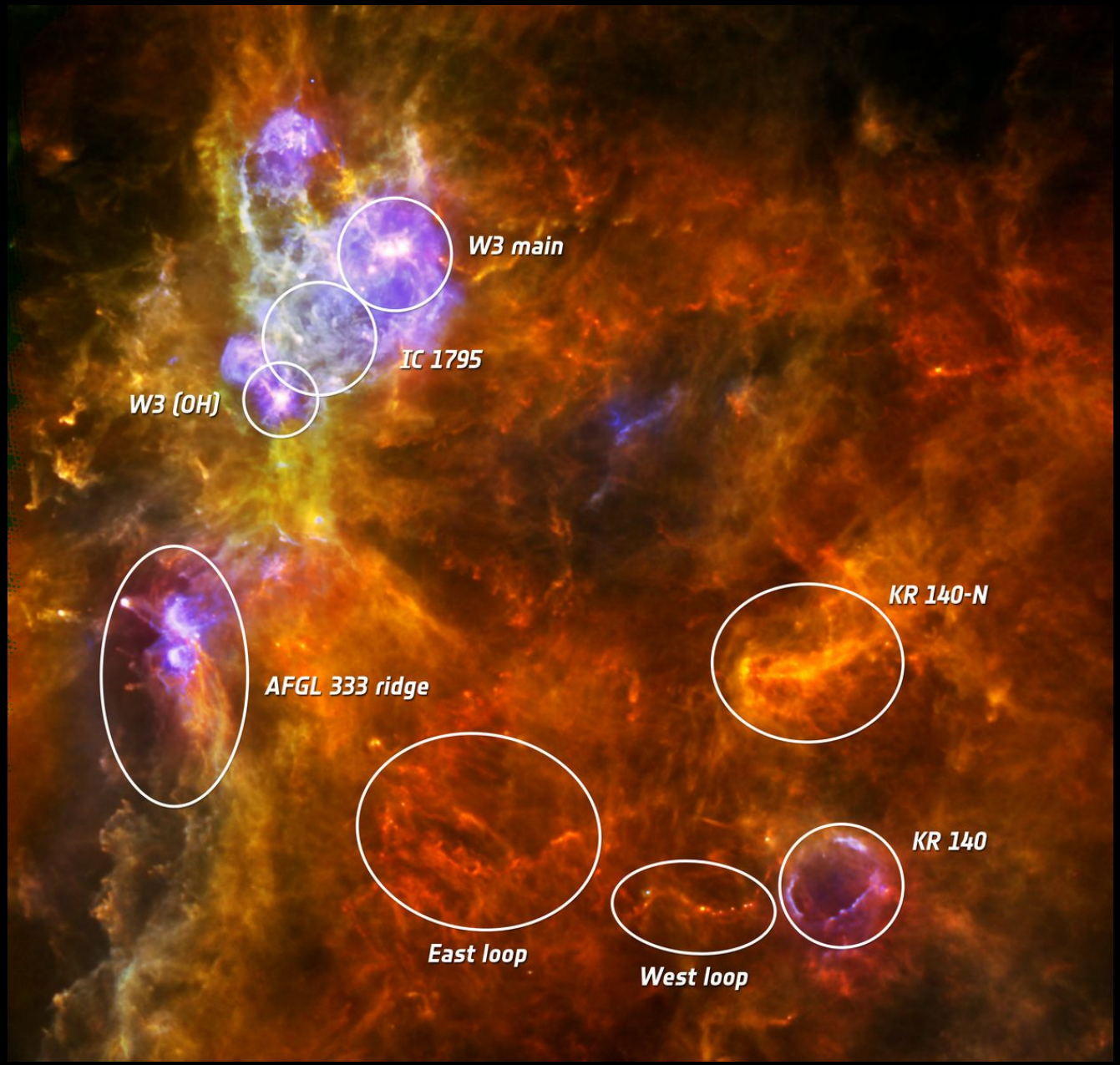
The bimodal IMF

The Kroupa IMF is characterized with Γ_b=1.3

Kroupa et al. 2002
Bastian et al. 2010
Kroupa et al. 2013



Is the IMF universal?

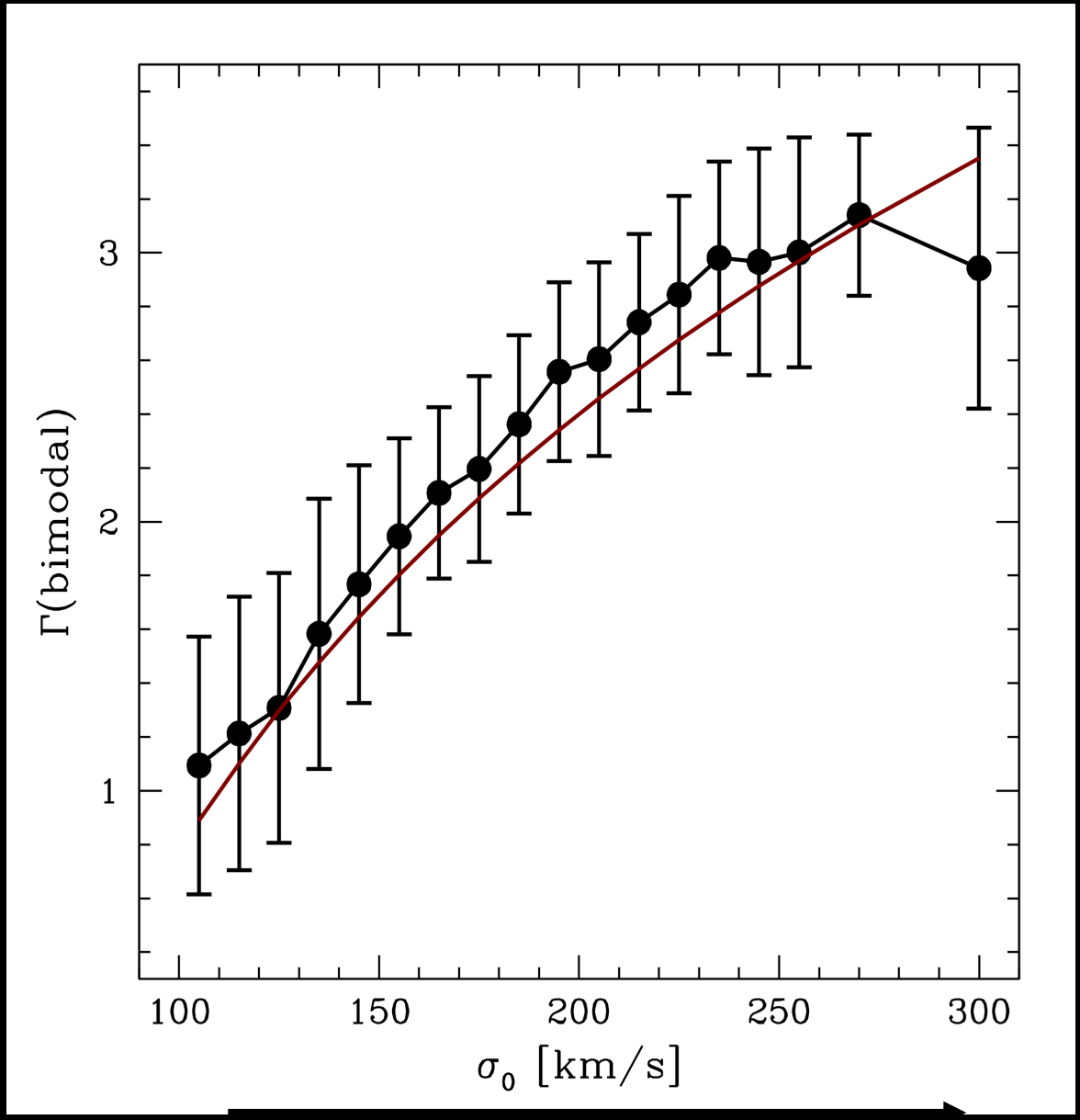


ESA/PACS & SPIRE consortia, A. Rivera-Ingraham & P.G. Martin, Univ. Toronto, HOBYS Key Programme

Is the IMF universal?

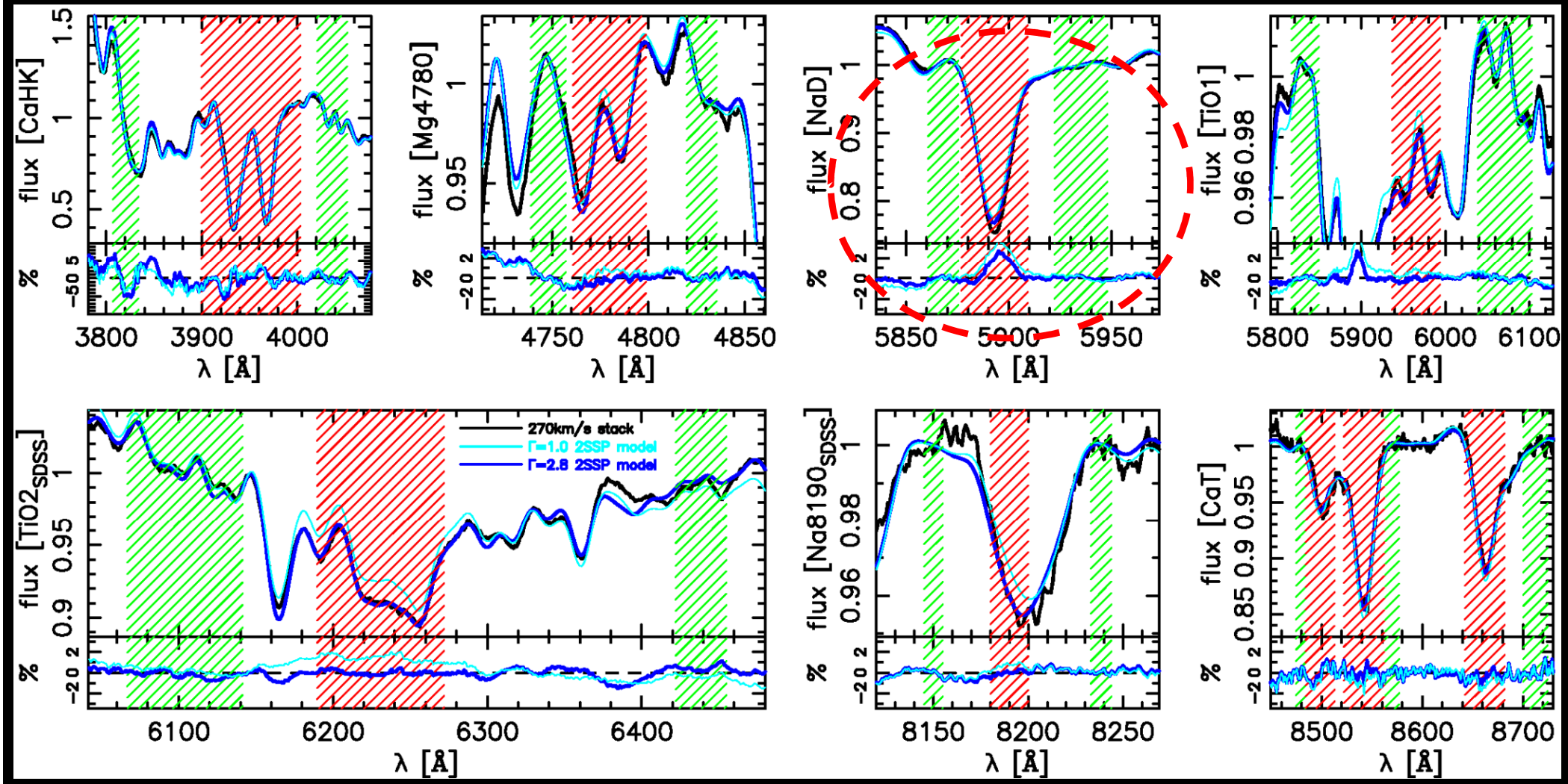
La Barbera et al (2013)

IMF slope



Central velocity dispersion

How to characterize the IMF?



La Barbera et al. (2013)

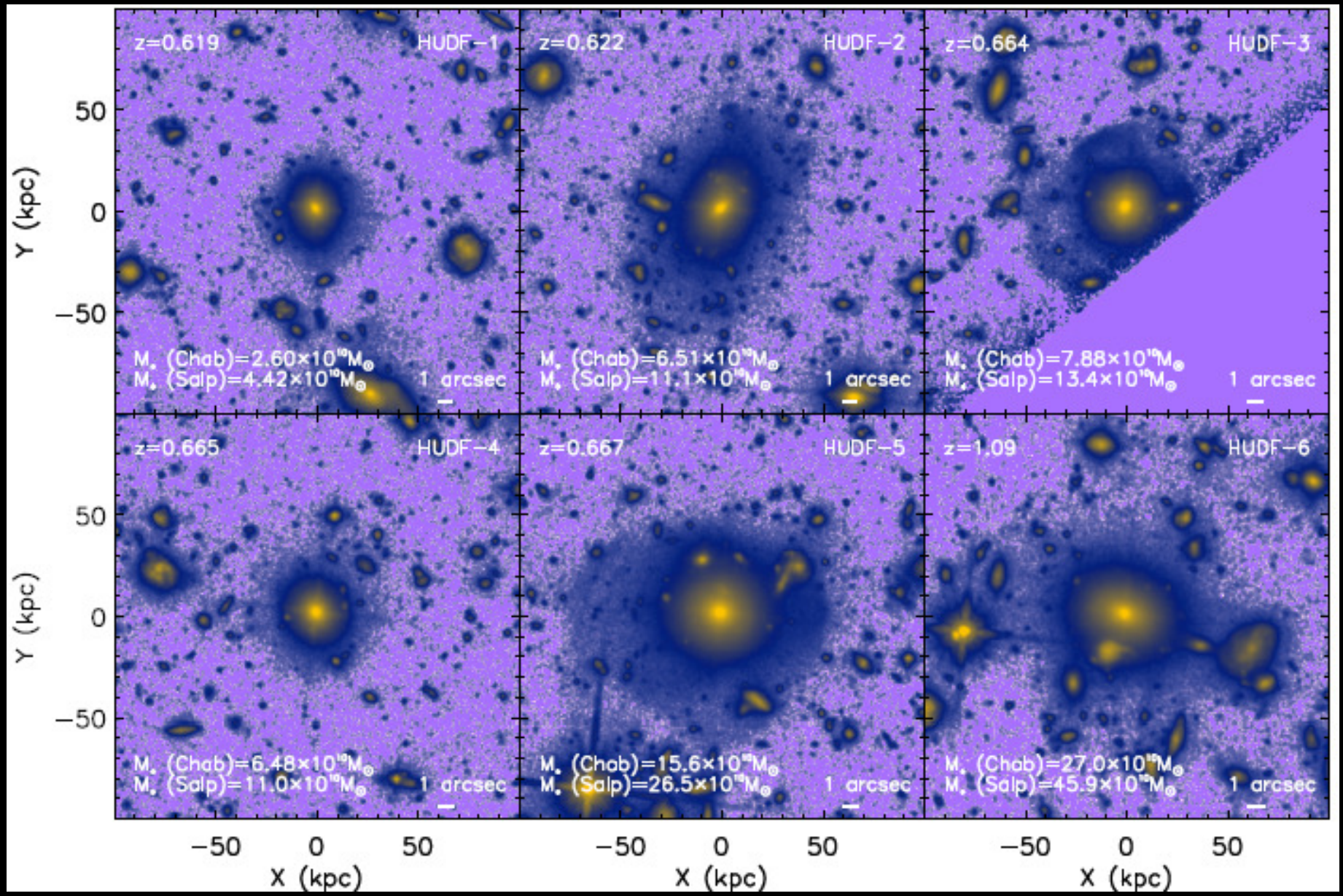
The IMF at the early Universe

Conditions in the early Universe were significantly different from present-day quiet star formation activity.

Exploring the early Universe in today's massive galaxies is not straightforward due to high merging activity

Merging activity on-going

Buitrago et al (2015)



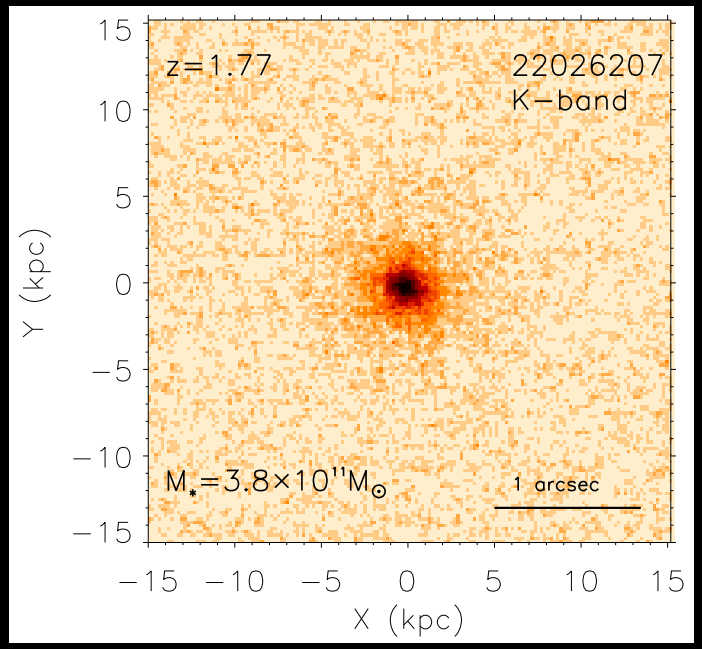
6 massive galaxies (M_{star}~10^{11} M_{sun}) at z~0.7 selected in the HUDF

How to access to the primordial IMF?

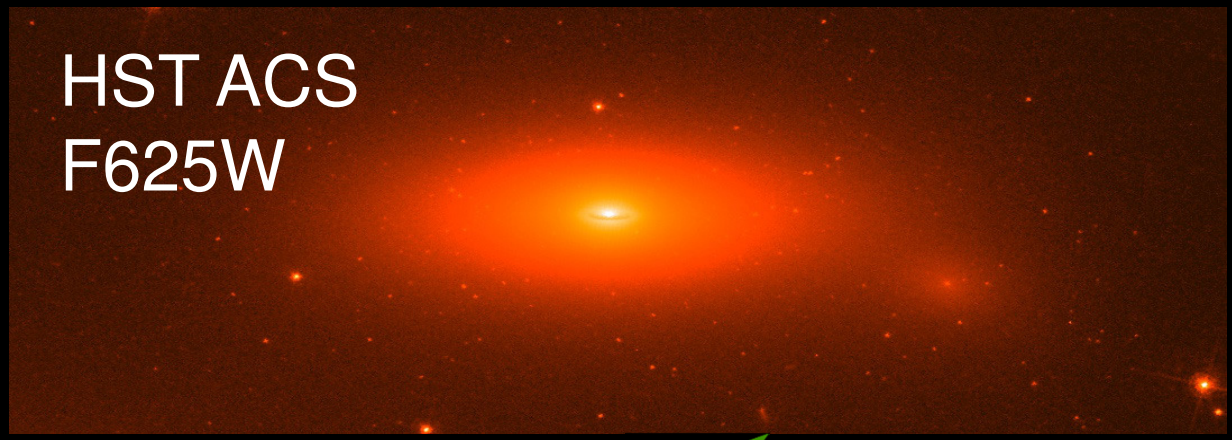
1. Exploring the stellar population properties of massive relic galaxies at z=0

2. Exploring the IMF at the highest possible redshifts

The IMF of a primordial massive relic galaxy: NGC1277



Carrasco et al. (2010; Gemini AO)

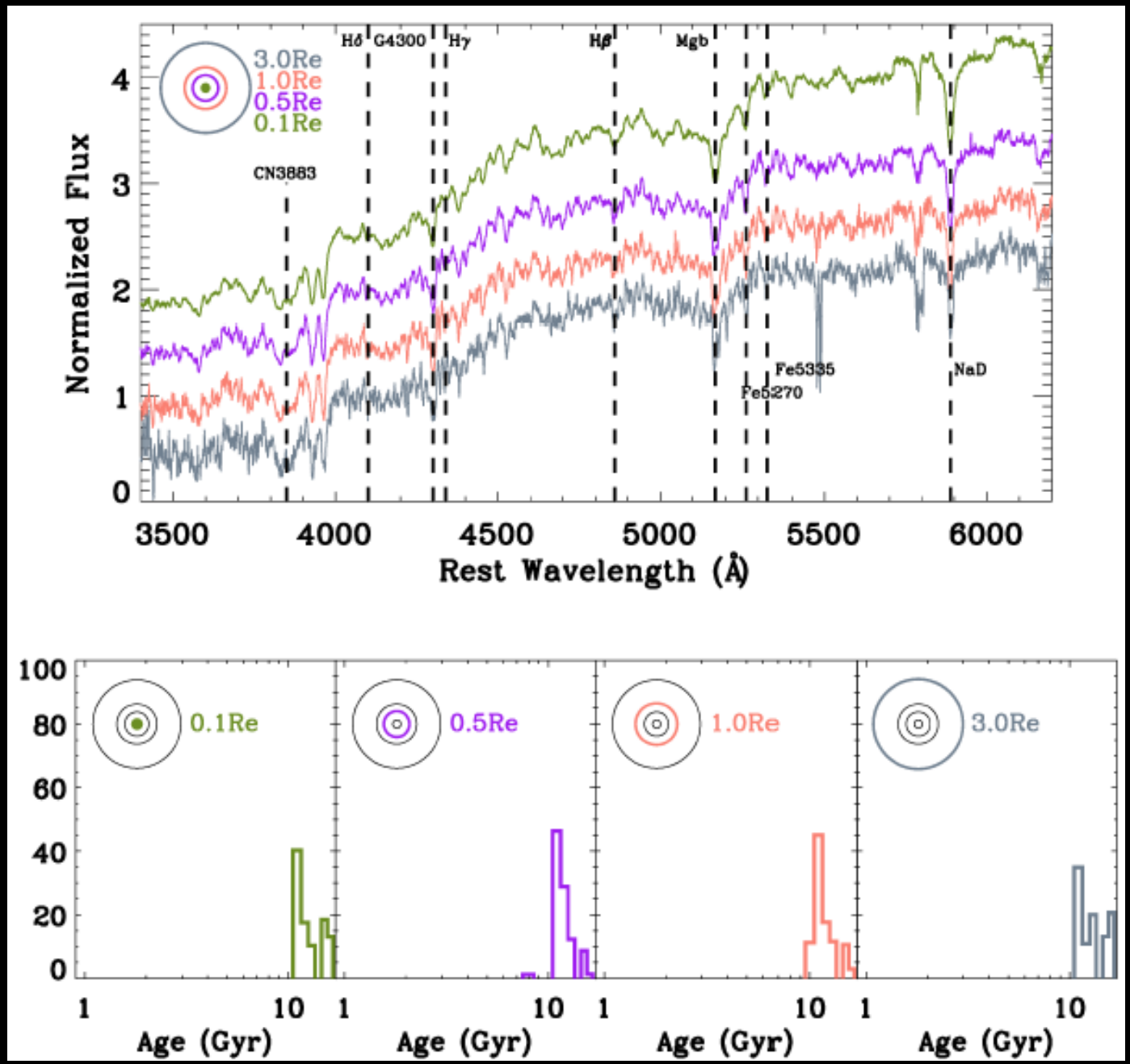


Old:
Age ~ 10 Gyr

Massive:
$M > 10^{11} M_{sun}$

Compact:
$R_e < 1.5$ kpc

The IMF of a primordial massive relic galaxy: NGC1277



Trujillo et al. (2014)

The IMF of a primordial massive relic galaxy: NGC1277

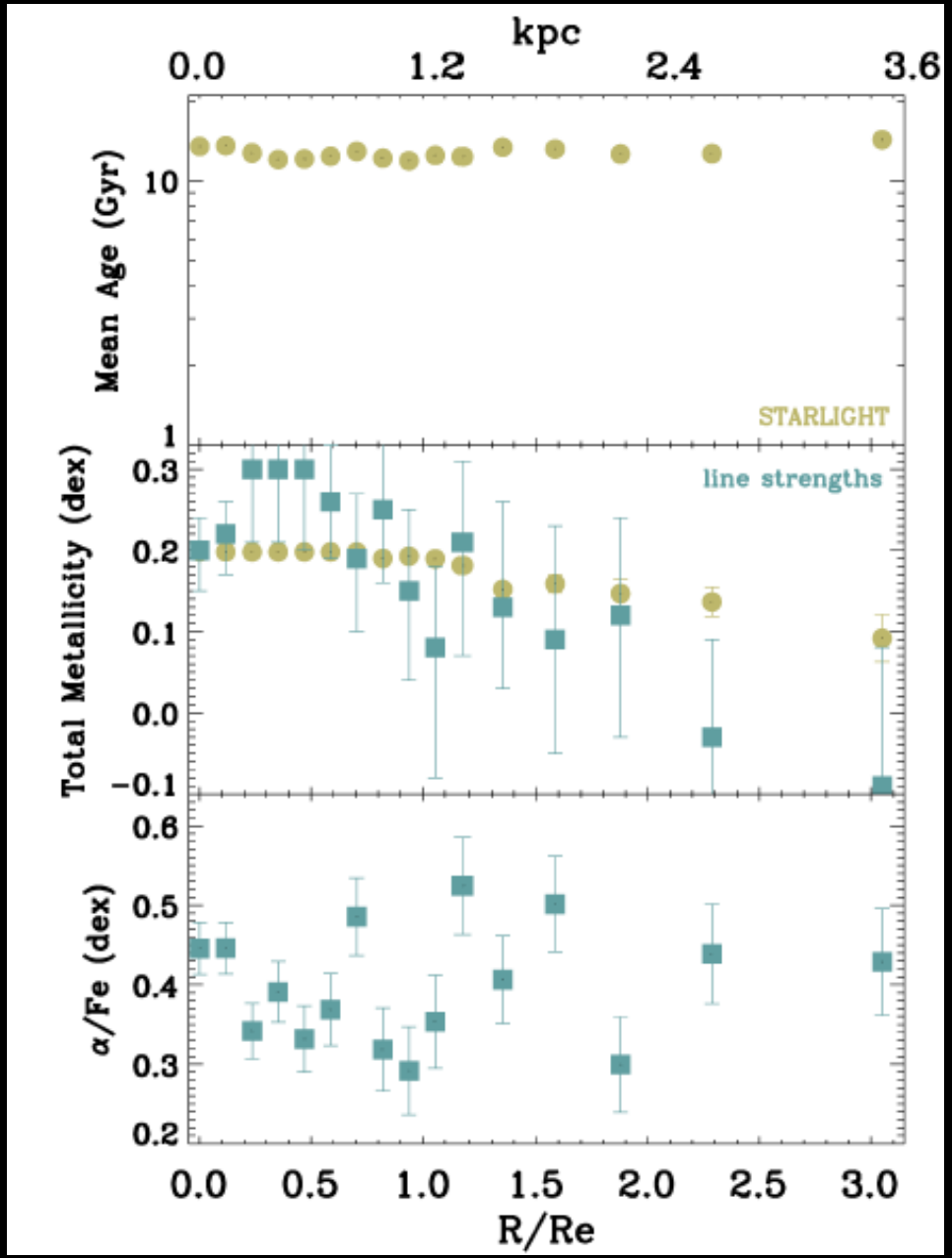
Properties:

Age, metallicity and α/Fe radial profiles are pretty homogenous…

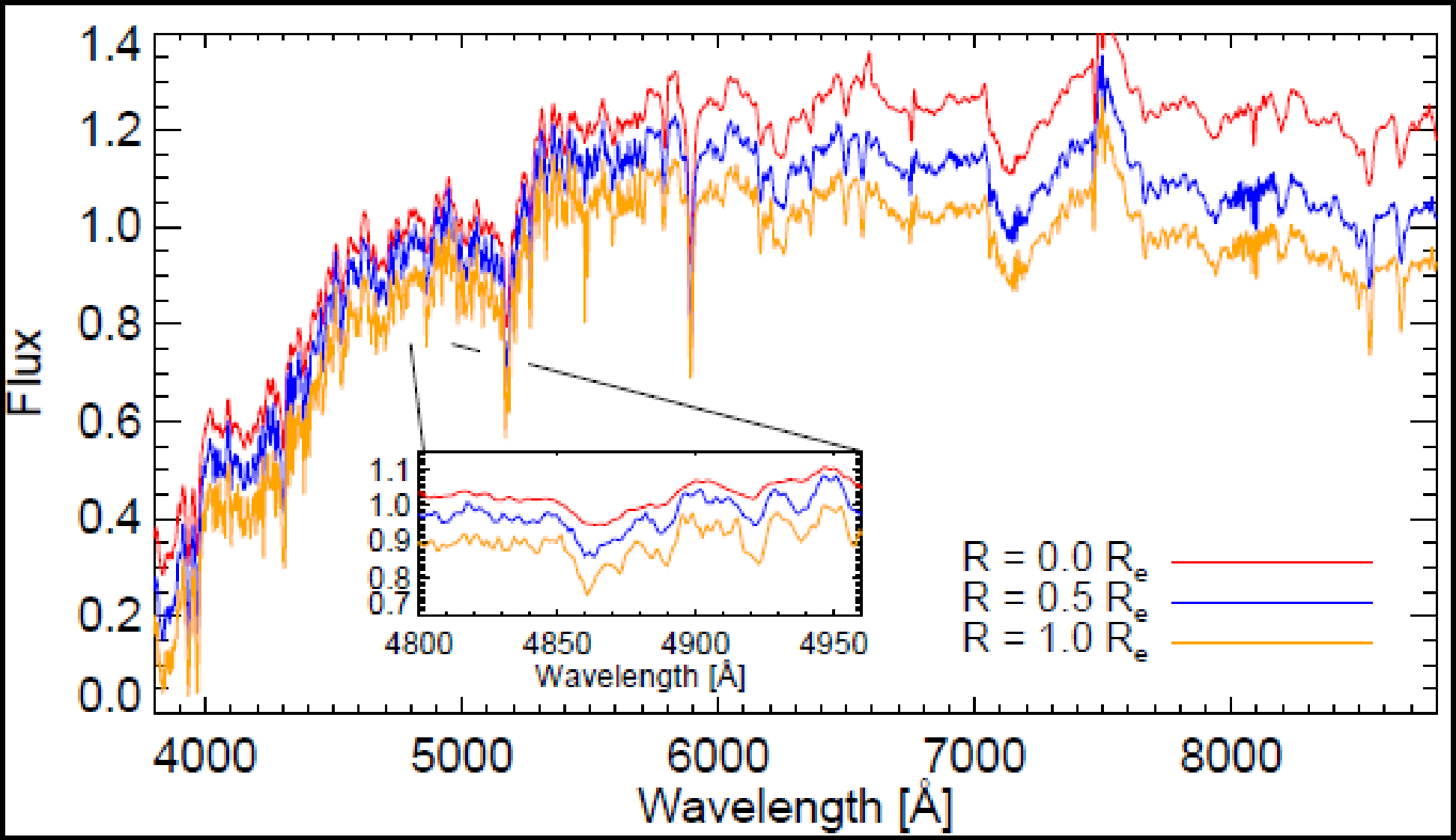
The large α/Fe>0.3 implies an extremely short formation time-scale: ~100 Myr !!!

Star Formation Rate: ~1000 M_{sun}/yr !!!

Trujillo et al. (2014)



The IMF of a primordial massive relic galaxy: NGC1277



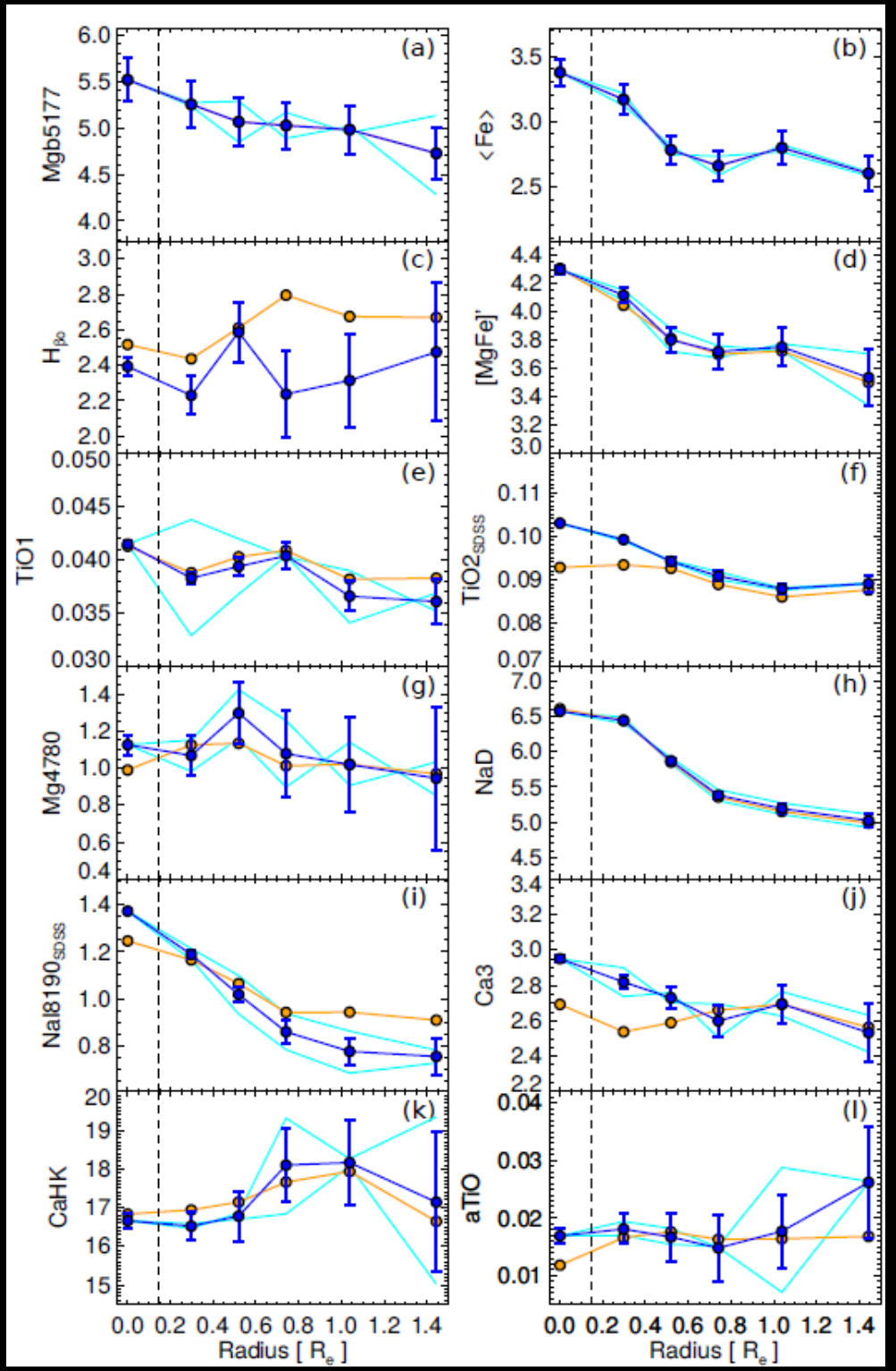
3h on source with WHT (λ<5700Å) and 1.5h on source with GTC (λ>5000Å)

S/N>80 at all radii

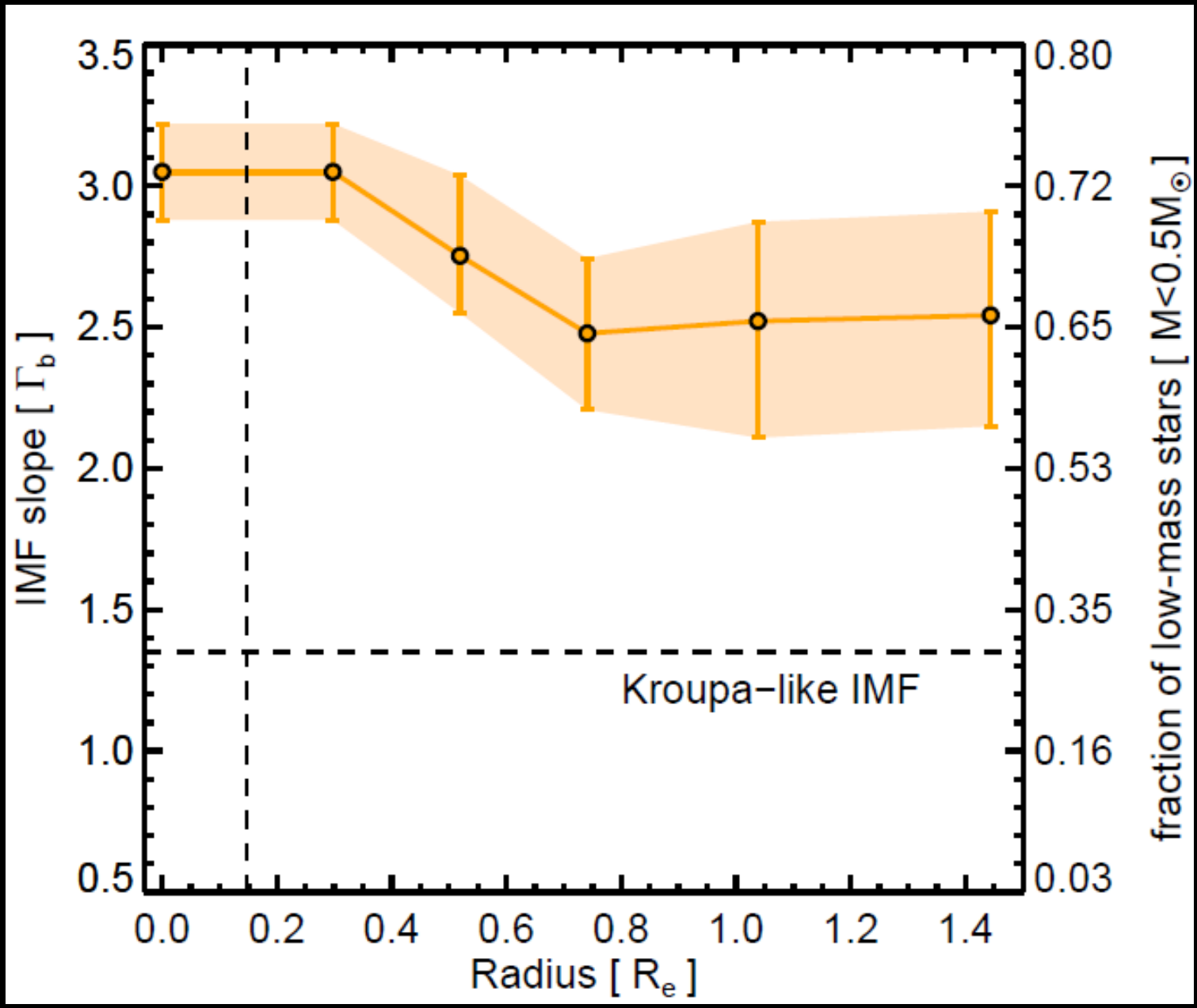
The IMF of a primordial massive relic galaxy: NGC1277

Martín-Navarro et al. (2015b)

Age, metallicity and IMF indices are fitted simultaneously



The IMF of a primordial massive relic galaxy: NGC1277



Martín-Navarro et al. (2015b)

The IMF at 0.9<z<1.5

Sample Selection:

Galaxies in the GOODS-North with:

1. No signs of recent star formation

a) UVJ diagram complemented with flux in the MIR/FIR

b) sSFR <0.2 Gyr^{-1}

2. SHARDS data was used to get very accurate photo-z

3. $M_{*}>2x10^{10}$ M_{sun} (Kroupa IMF)

124 sources in 112 $arcmin^2$

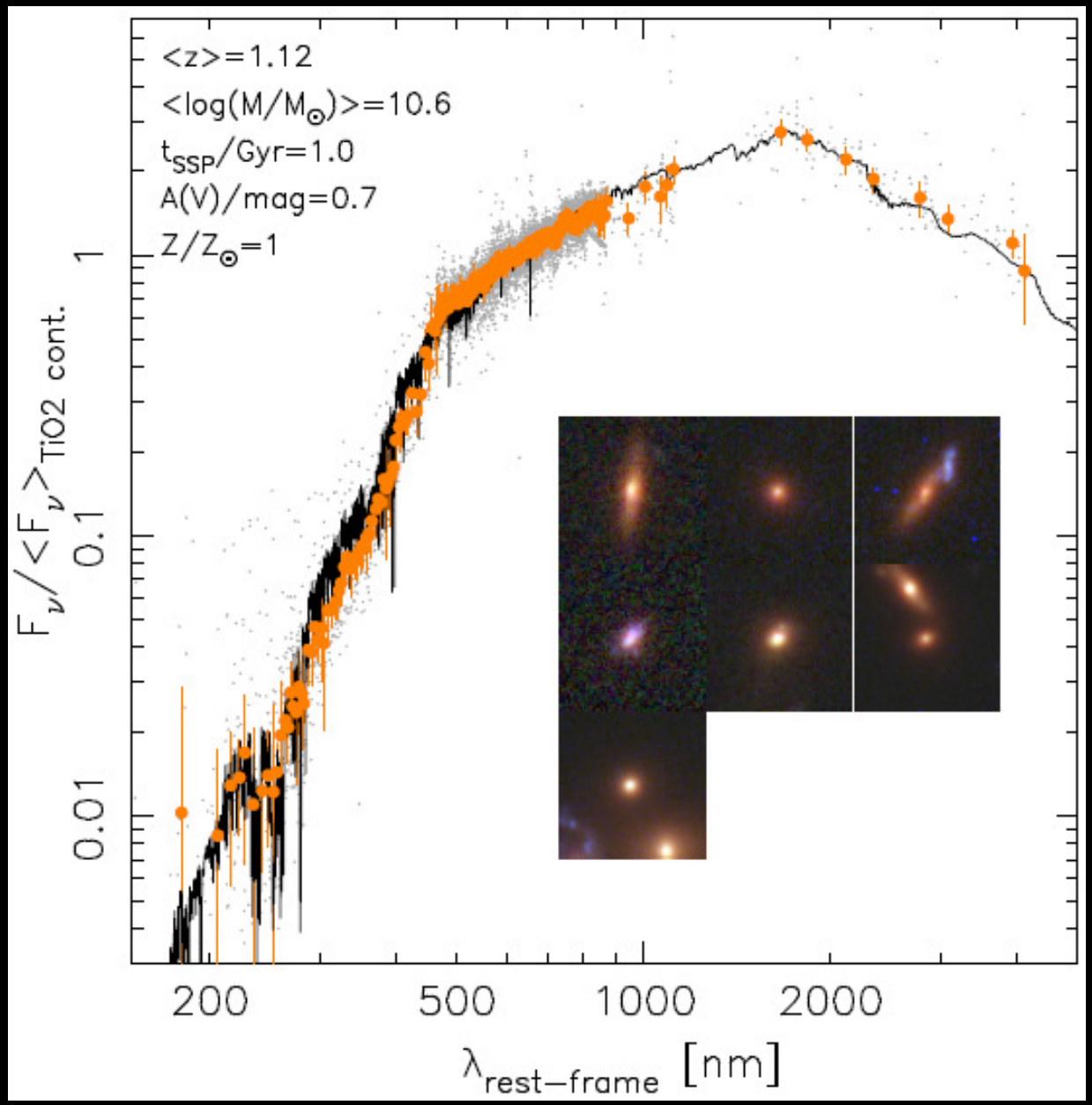
The IMF at 0.9<z<1.5

GRISM data for measuring TiO_2 spectral index (weakly dependent on [Z/H] and [α/Fe])

SHARDs data was complemented in the red (1.1<λ<1.6 μm) with:

WFC3/G141 grism data from AGHAST survey

The IMF at 0.9<z<1.5



Martín-Navarro et al. (2015a)

50 galaxies

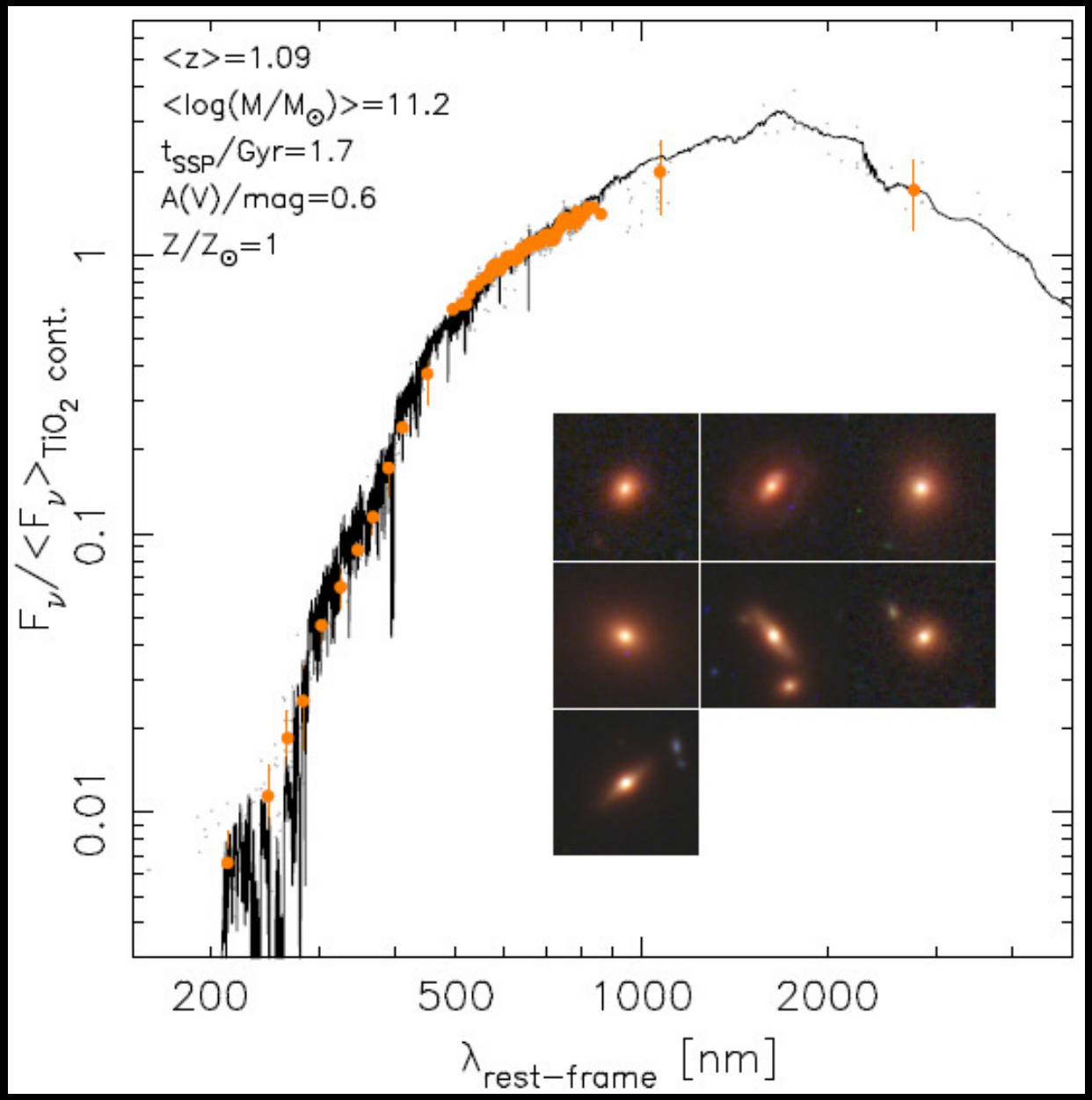
$M_* < 10^{11}\ M_{sun}$

$\Delta z/(1+z) = 0.0047$

The low mass sample

The IMF at 0.9<z<1.5

Martín-Navarro et al. (2015a)



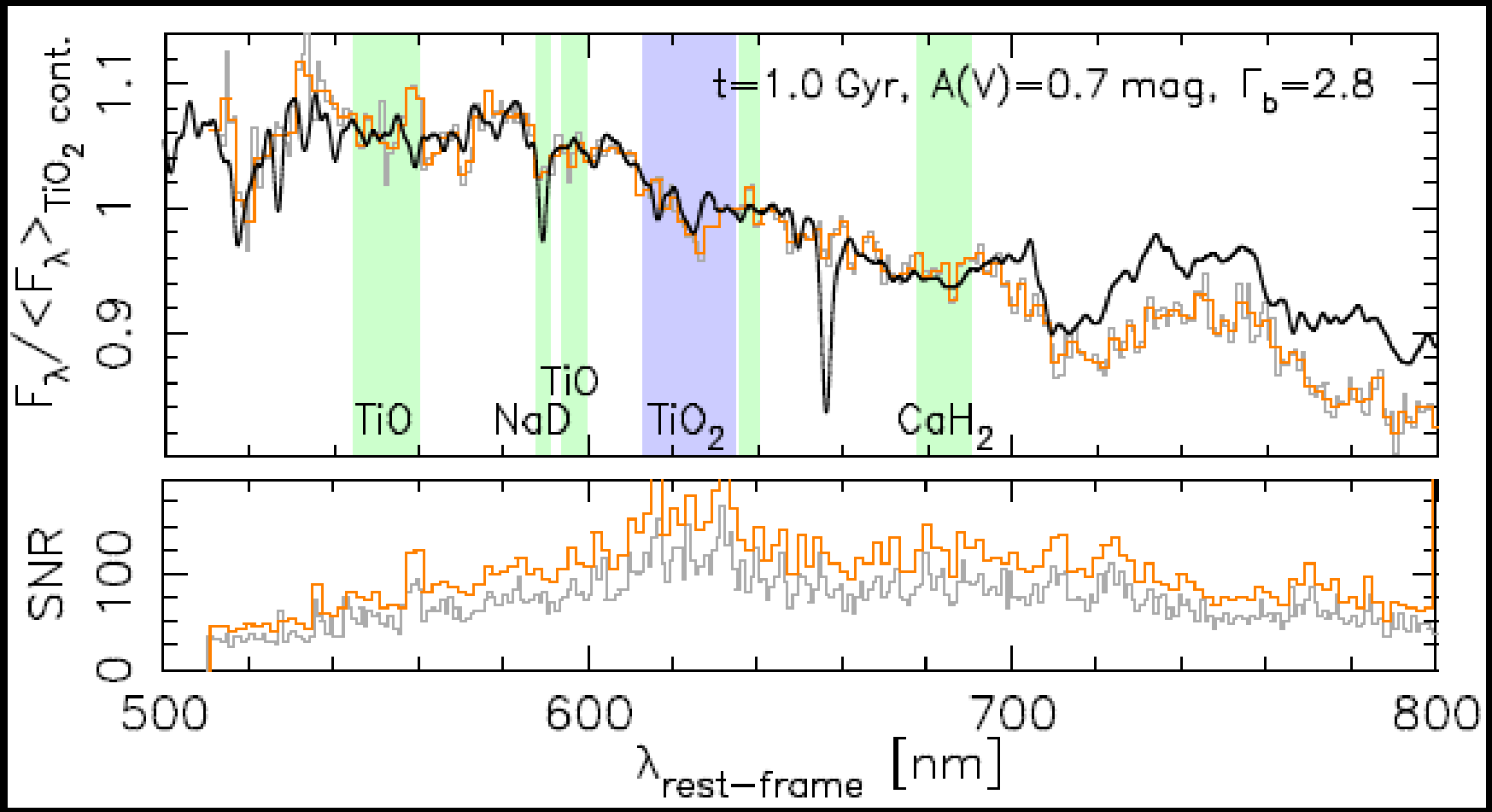
7 galaxies

$M_* > 10^{11}\ M_{sun}$

$\Delta z/(1+z) = 0.0047$

The high mass sample

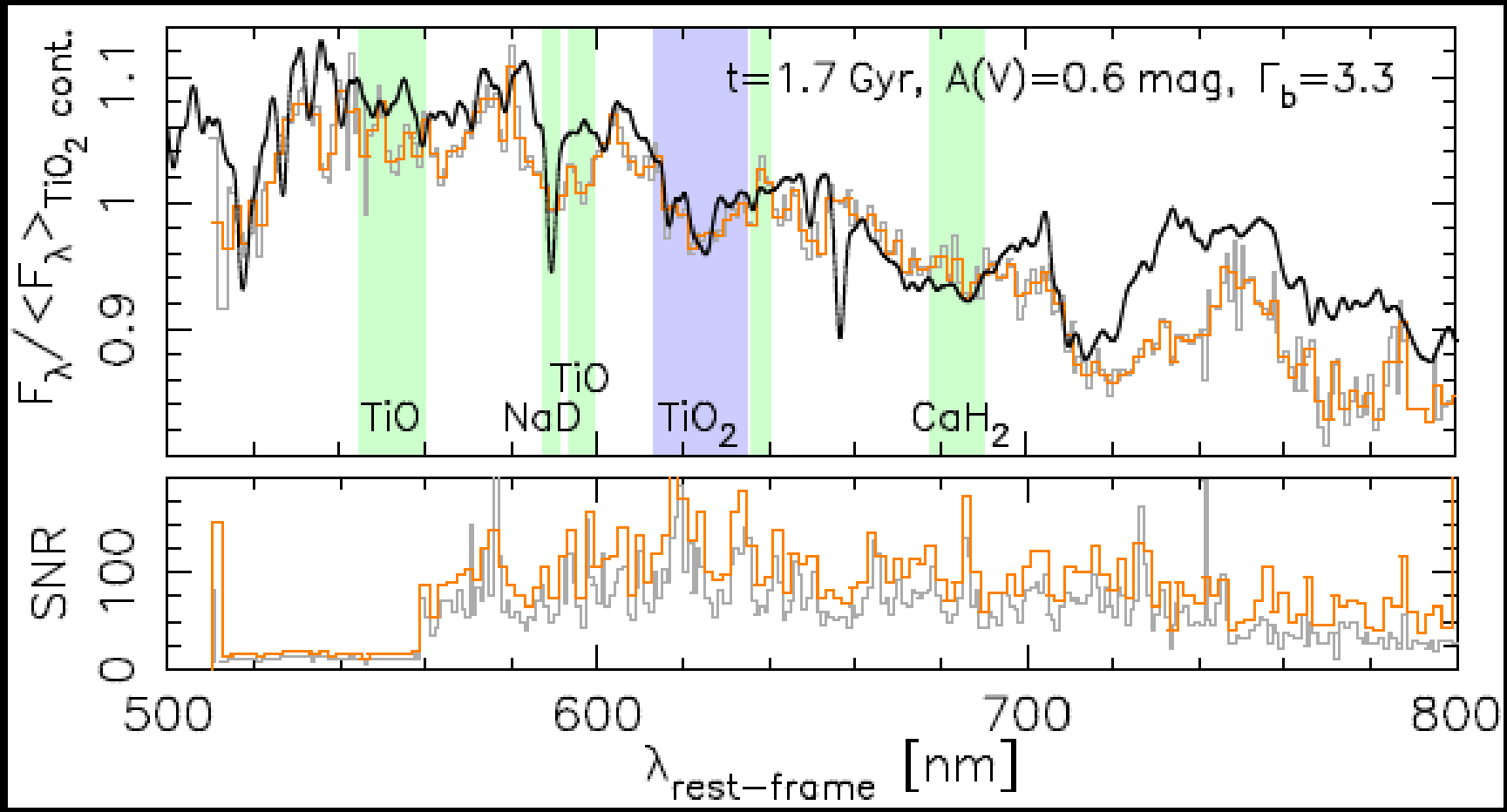
The IMF at 0.9<z<1.5



Martín-Navarro et al. (2015a)

The TiO_2 index: the low mass sample

The IMF at 0.9<z<1.5



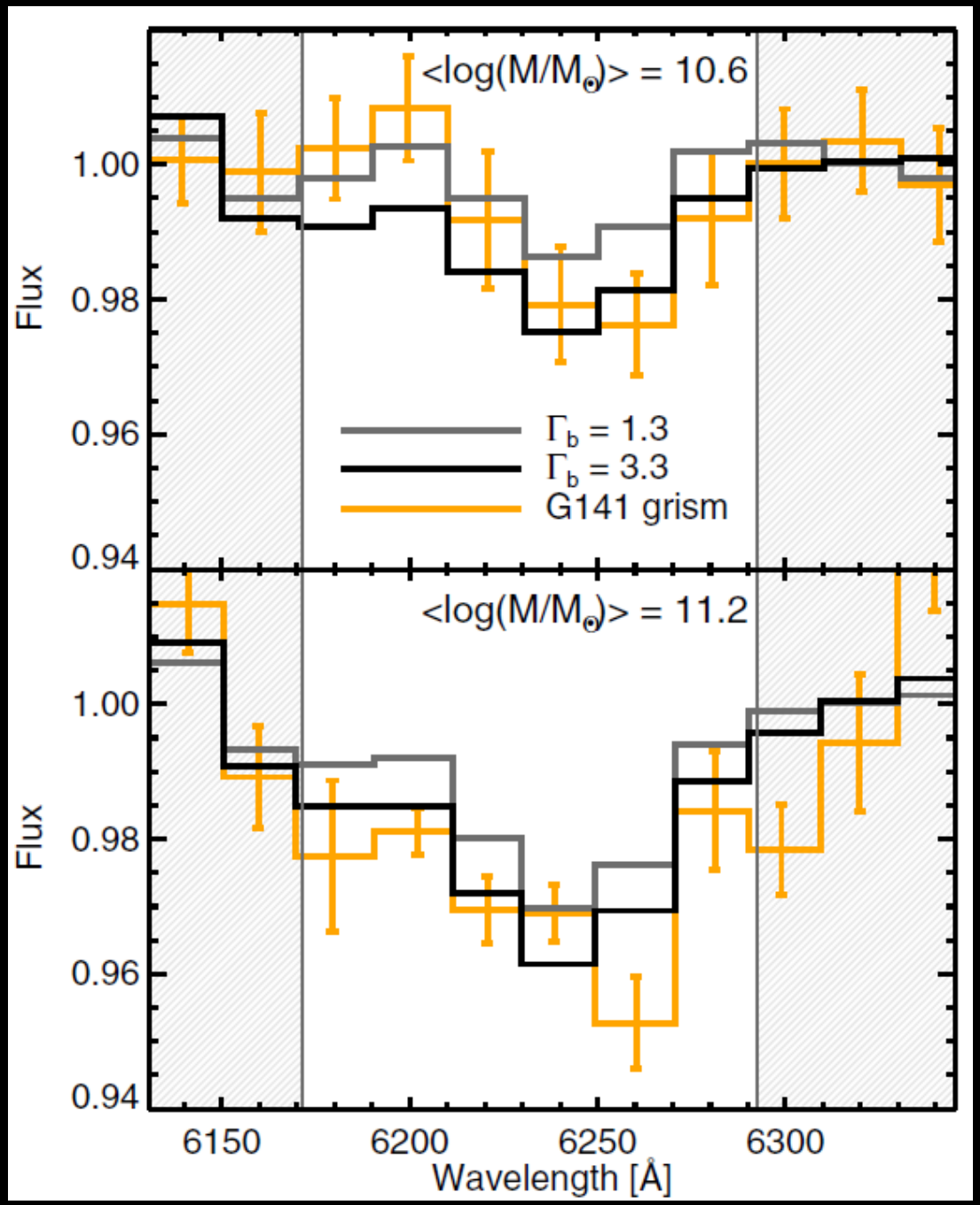
Martín-Navarro et al. (2015a)

The TiO_2 index: the high mass sample

The IMF at 0.9<z<1.5

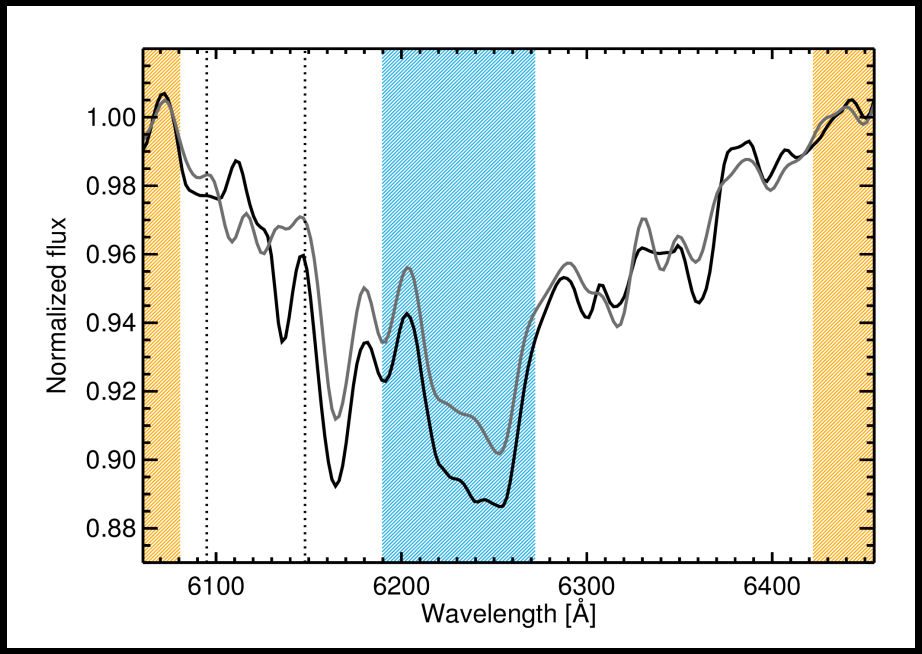
Martín-Navarro et al. (2015a)

The TiO_2 index: A molecular band dominated by cool-dwarf stars

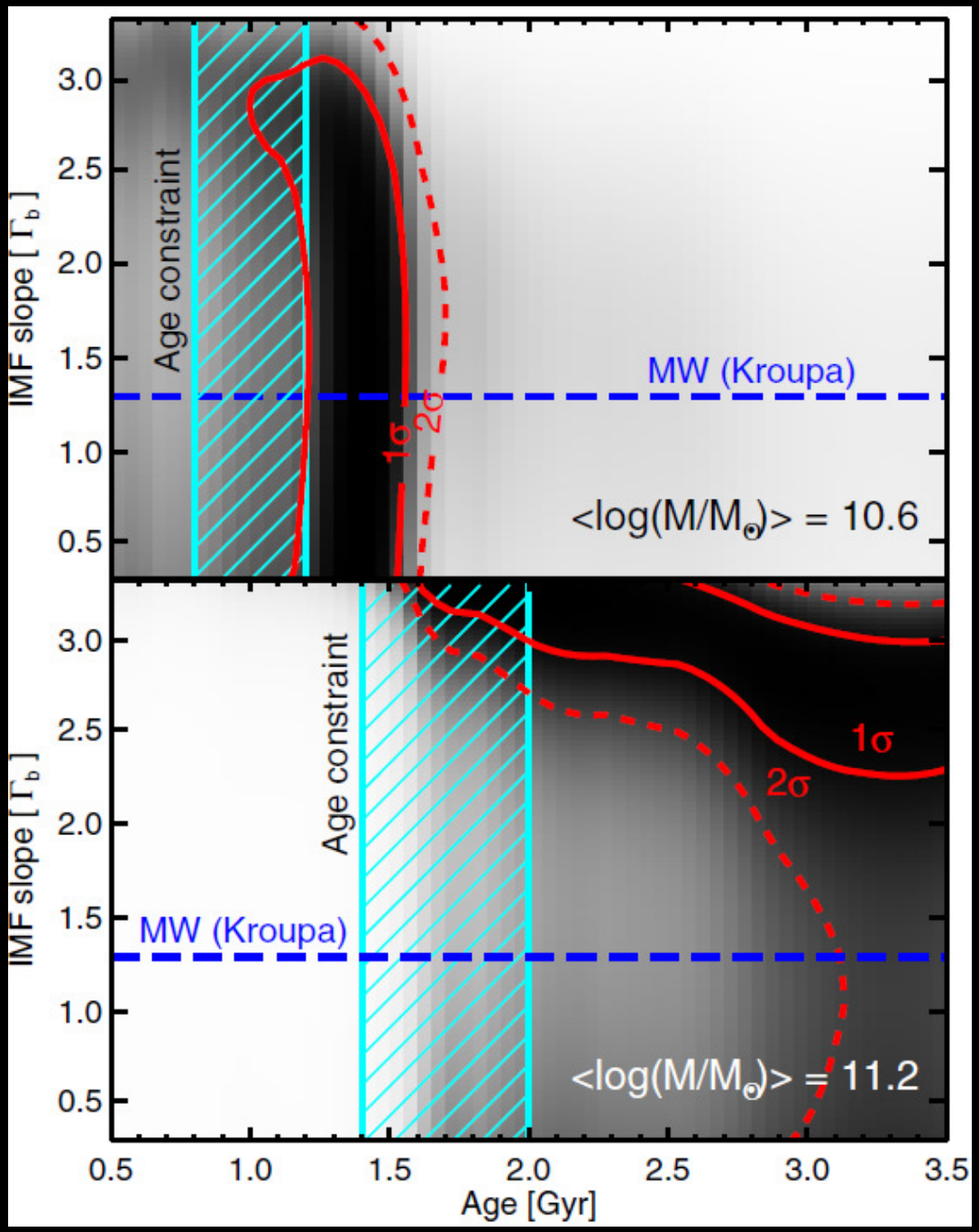


The IMF at 0.9<z<1.5

Martín-Navarro et al. (2015a)

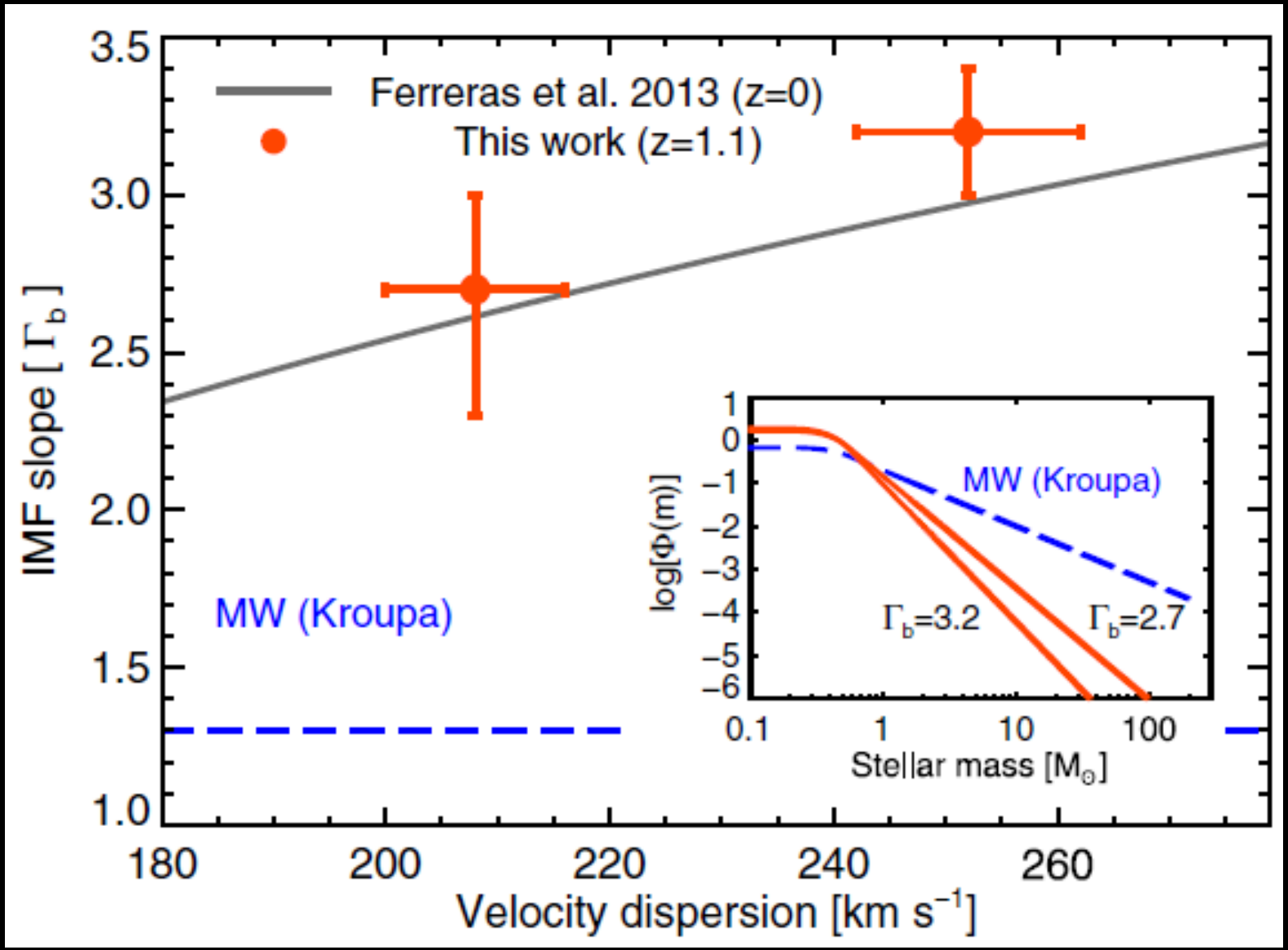


$$\chi^2(\Gamma_{\rm b}, {\rm age}, [{\rm M/H}]) = \sum_i \left[\frac{(EW_i - \Delta_{\alpha,i}) - EW_{M,i}}{\sigma_{EW_i}} \right]^2$$



The IMF at 0.9<z<1.5

Martín-Navarro et al. (2015a)



The IMF has not evolved in the last 8 Gyr

Summary

The IMF is:

Strongly dependent on the galaxy mass

- For MW-like galaxies follows a Kroupa law
- For massive galaxies is bottom-heavy (low mass stars $M_{*}<0.5\ M_{sun}$ are 2 times more abundant than in MW galaxies)

In massive and quiescent galaxy is already at place since z~1

- Supported by the observations of massive relic galaxies today
- Directly seen at z~1 in massive and red galaxies