



Dissecting massive galaxies @ high-z: new and future observing facilities and surveys

Pablo G. Pérez-González



In this talk...

Current paradigm for the formation of massive ($M \gtrsim M^*$) galaxies, i.e., **the modeler's perspective:**

- ◆ hierarchical evolution.
- ◆ SFHs of massive galaxies.
- ◆ SF efficiency, feedback.
- ◆ formation vs. assembly.

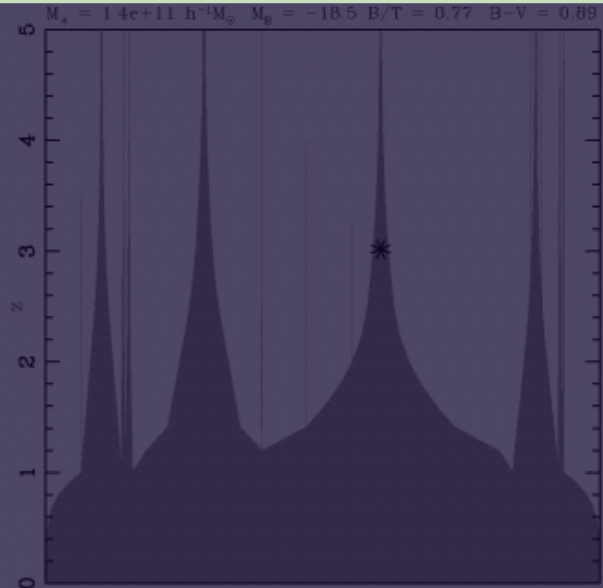
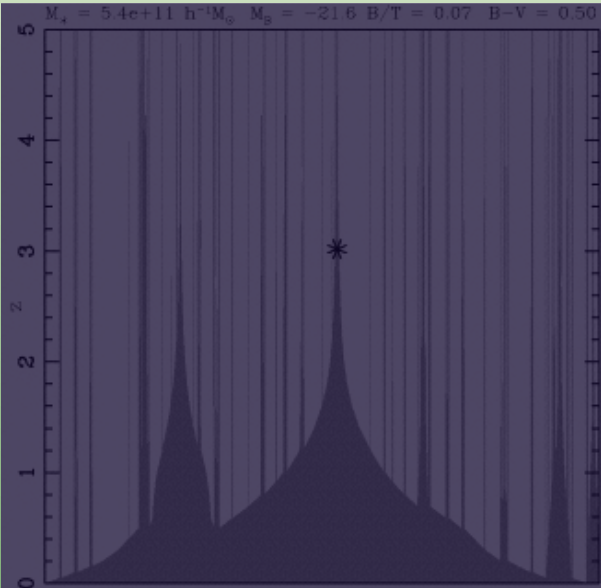
Some interesting results about high- z ($z=1-4$) massive galaxies, i.e., **observer's view:**

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- ◆ SFRs of massive galaxies at $z > 1$.
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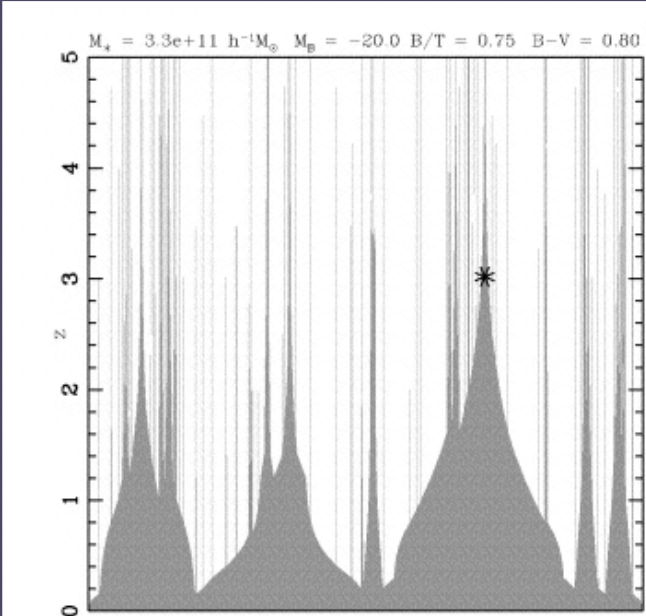
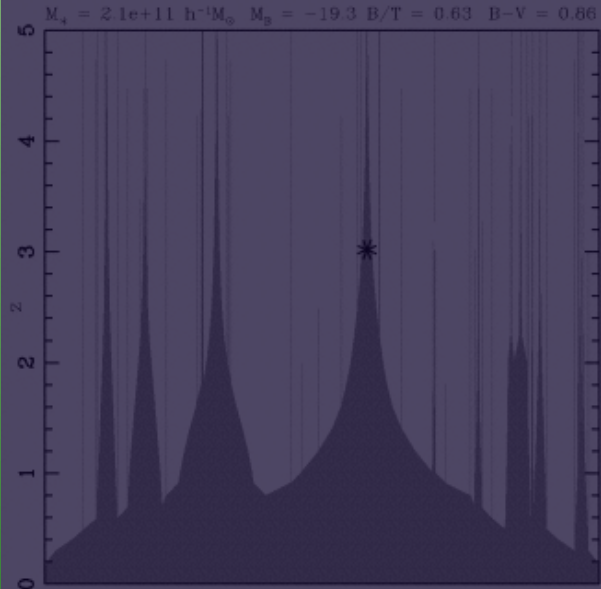
Open questions and (observational) paths to follow:

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- ◆ Robustly determining **dynamics** of stars and gas (sizes, gas/stars inflow) and **environment**: NIR (2D) spectroscopy and ALMA.

Modelers: "This is how you 'form' L* galaxies"

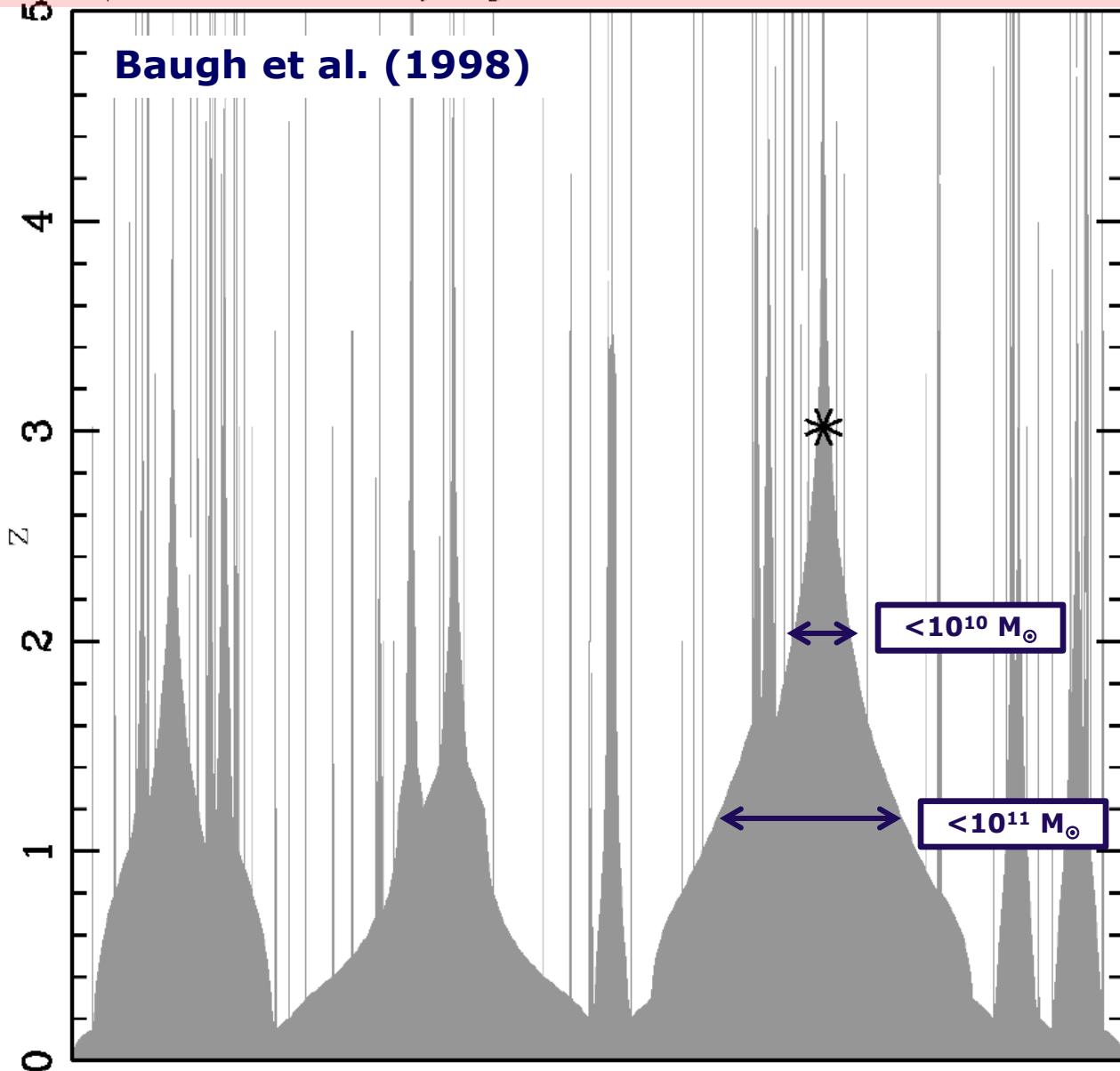


Baugh et al. (1998)



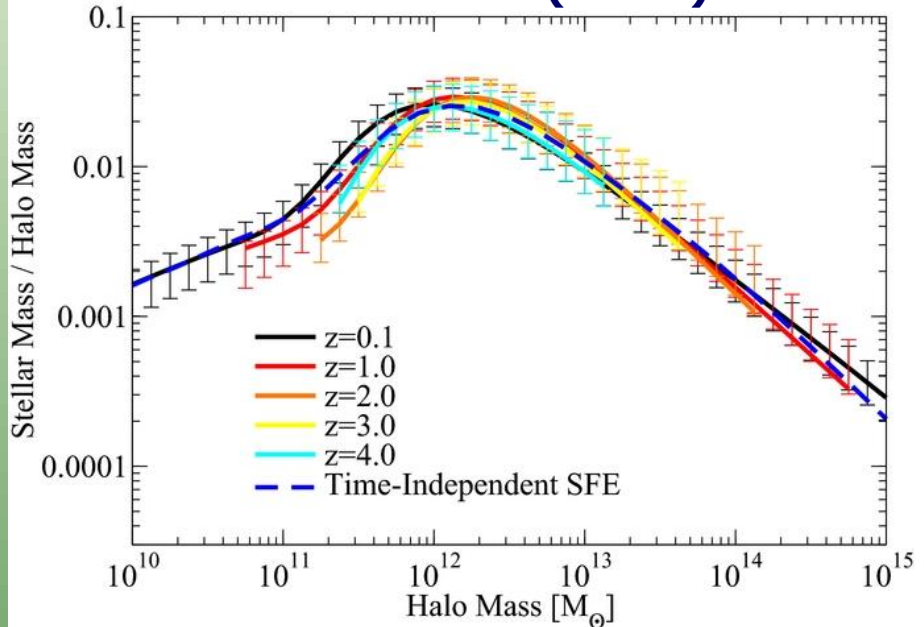
Modelers: "This is how you 'form' L* galaxies"

$M_* = 3.3e+11 h^{-1}M_\odot$ $M_B = -20.0$ $B/T = 0.75$ $B-V = 0.80$

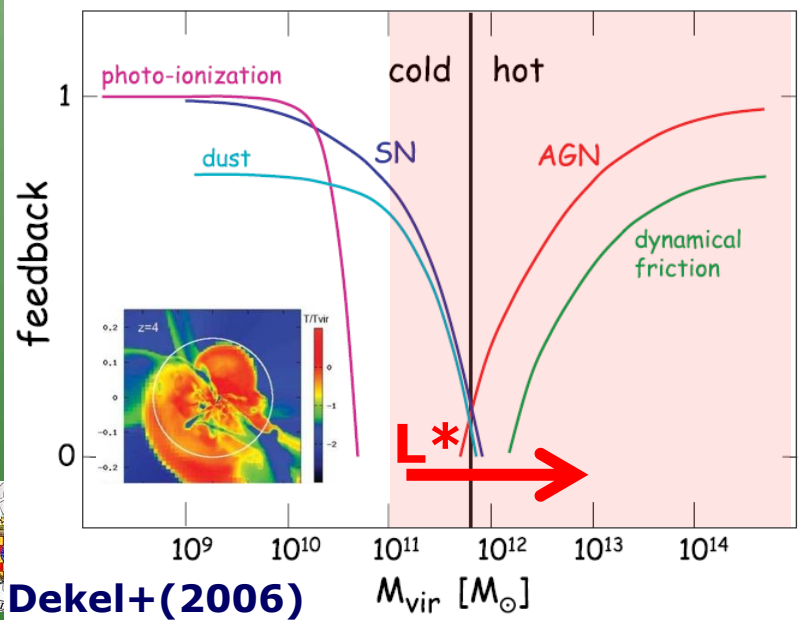
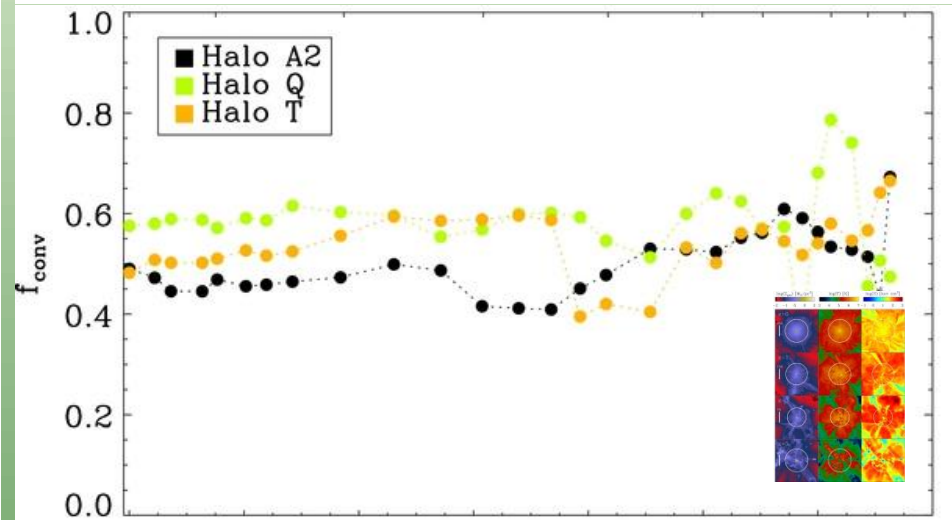


Quenching 'conspiracy' and SF efficiency

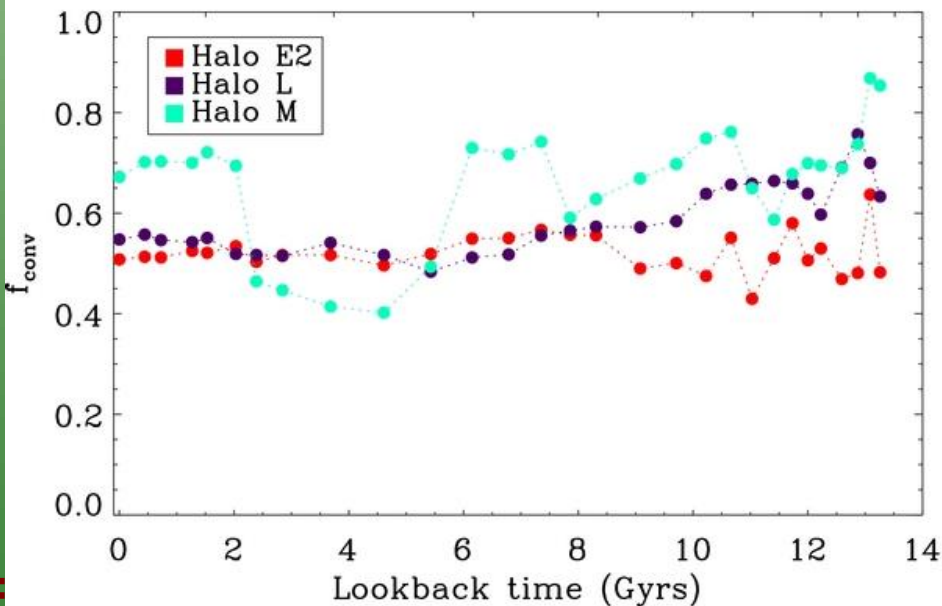
Behroozi+ (2013)



Also Shankar+ ('06), Conroy+ ('09), Moster+ ('10), Guo+ ('10), ...



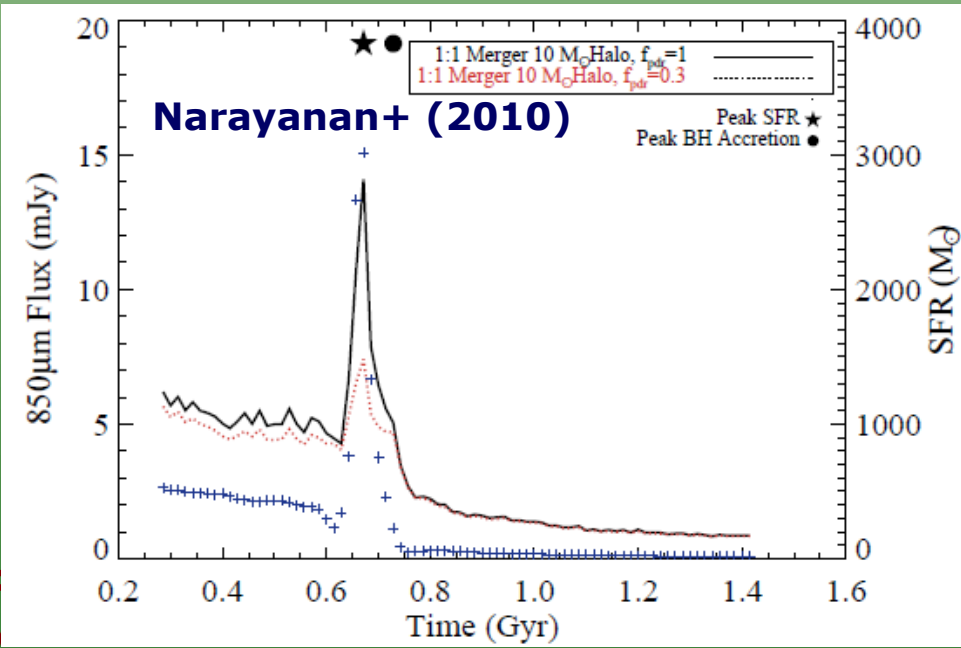
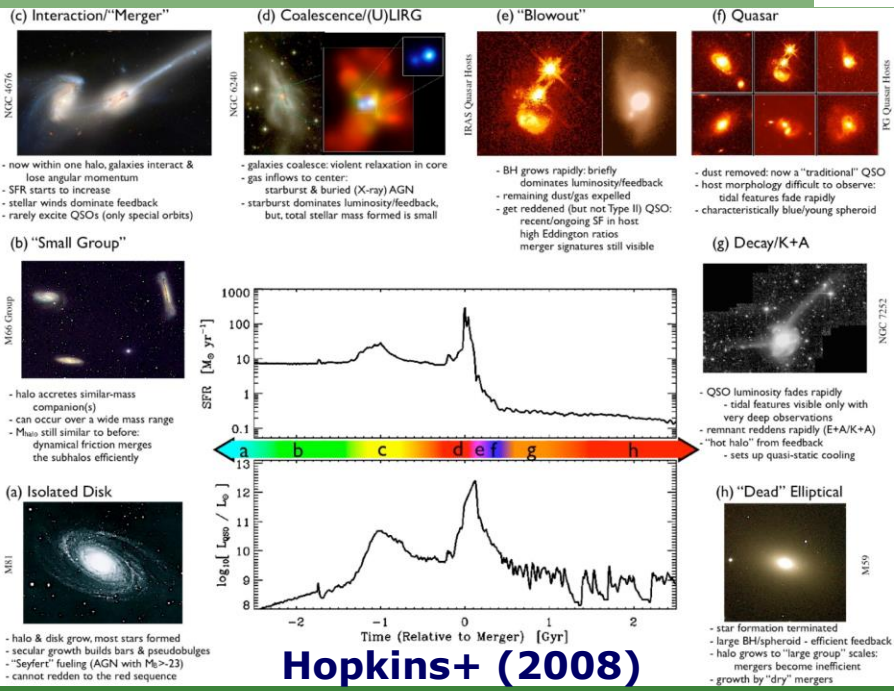
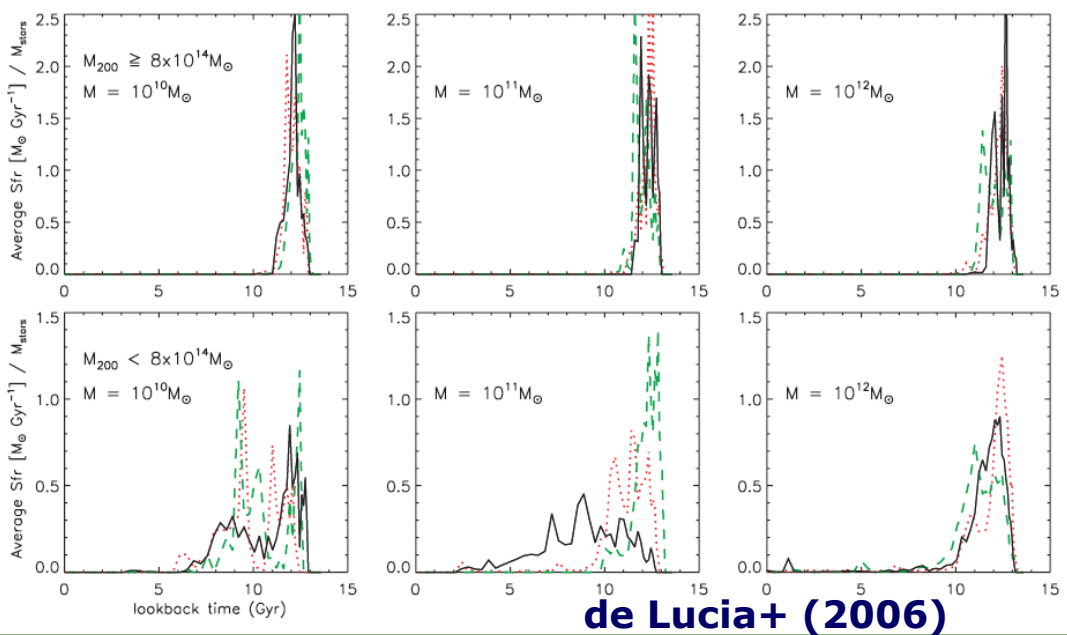
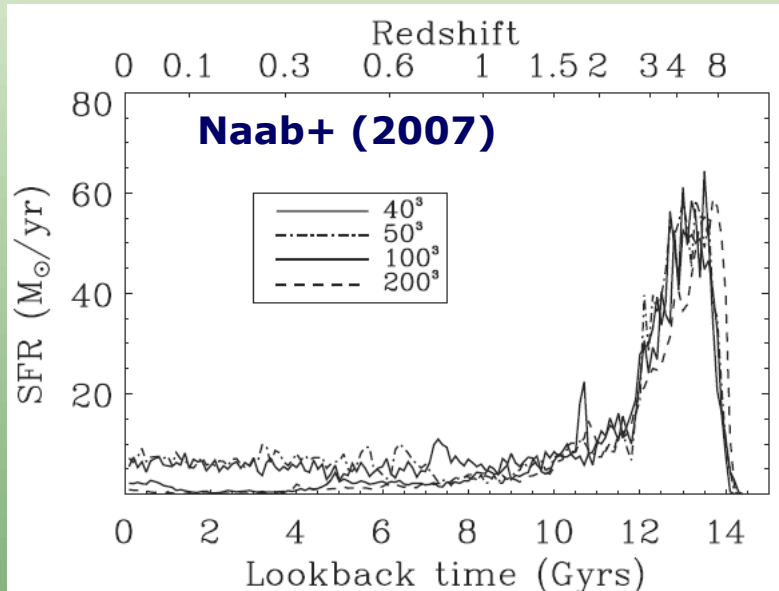
13: July 8-9, 2013



Johansson+ (2012)

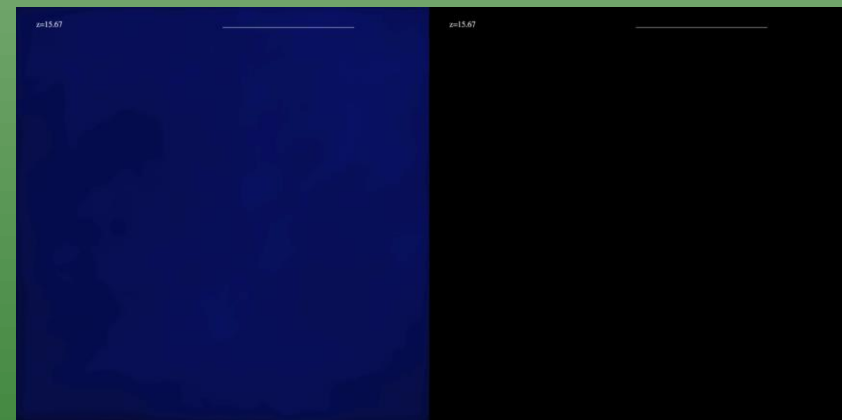
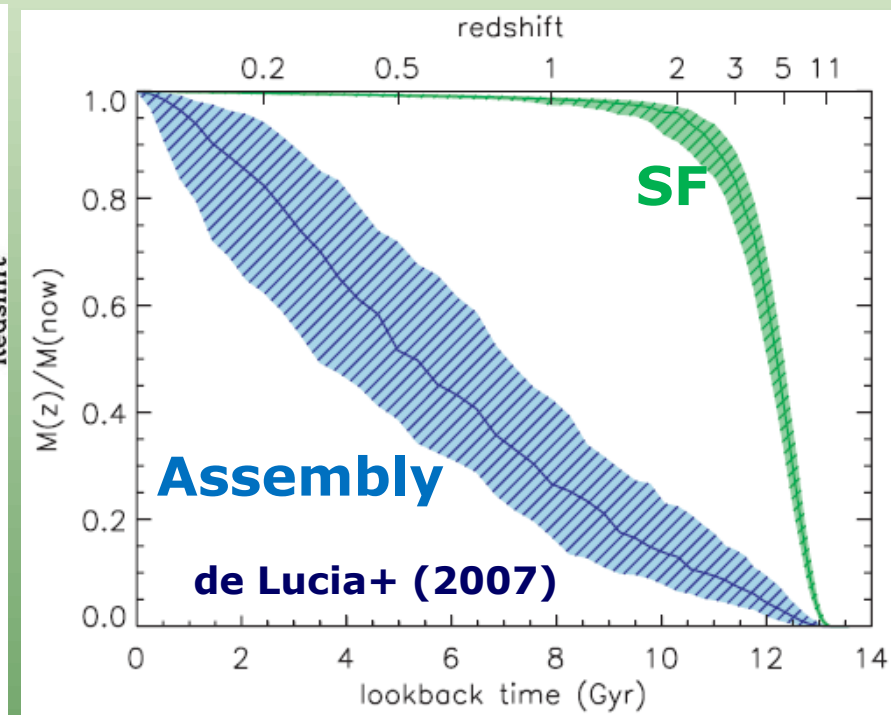
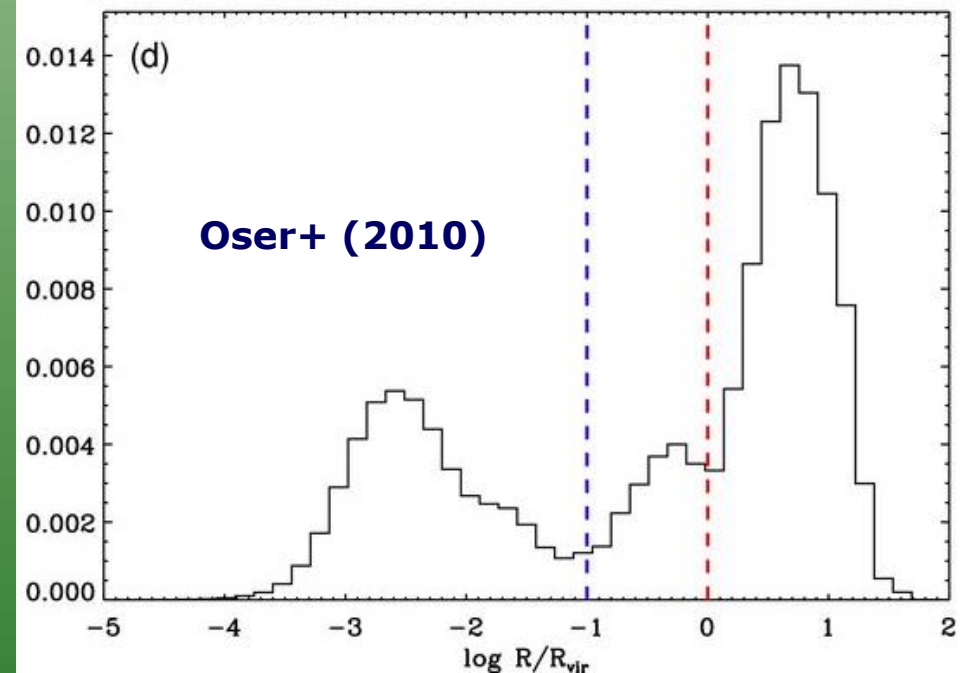
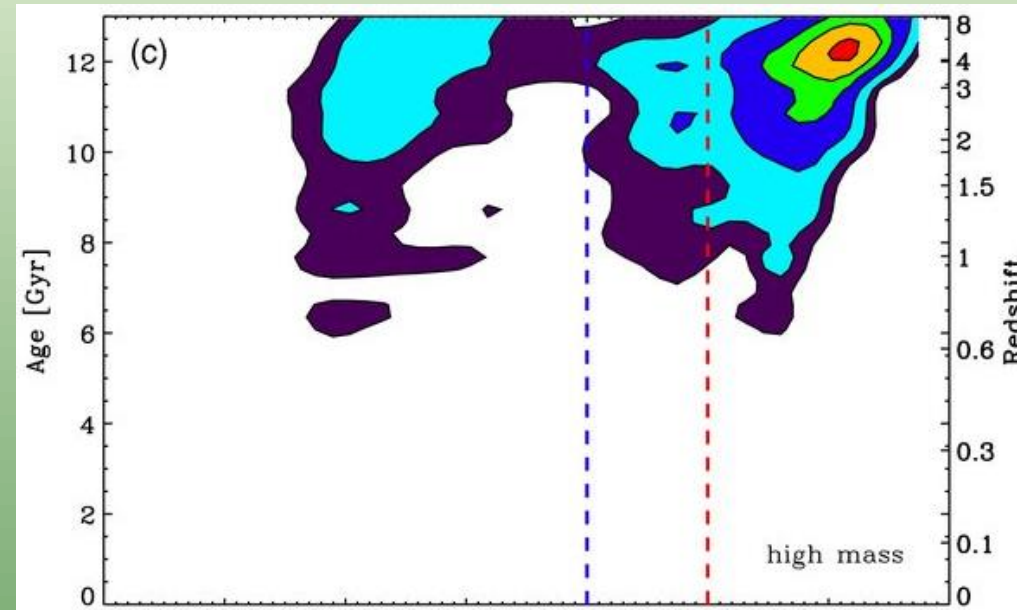


Formation vs. assembly



3 July

Formation vs. assembly



poslum 4
, 2013

Credits: Oser, Naab

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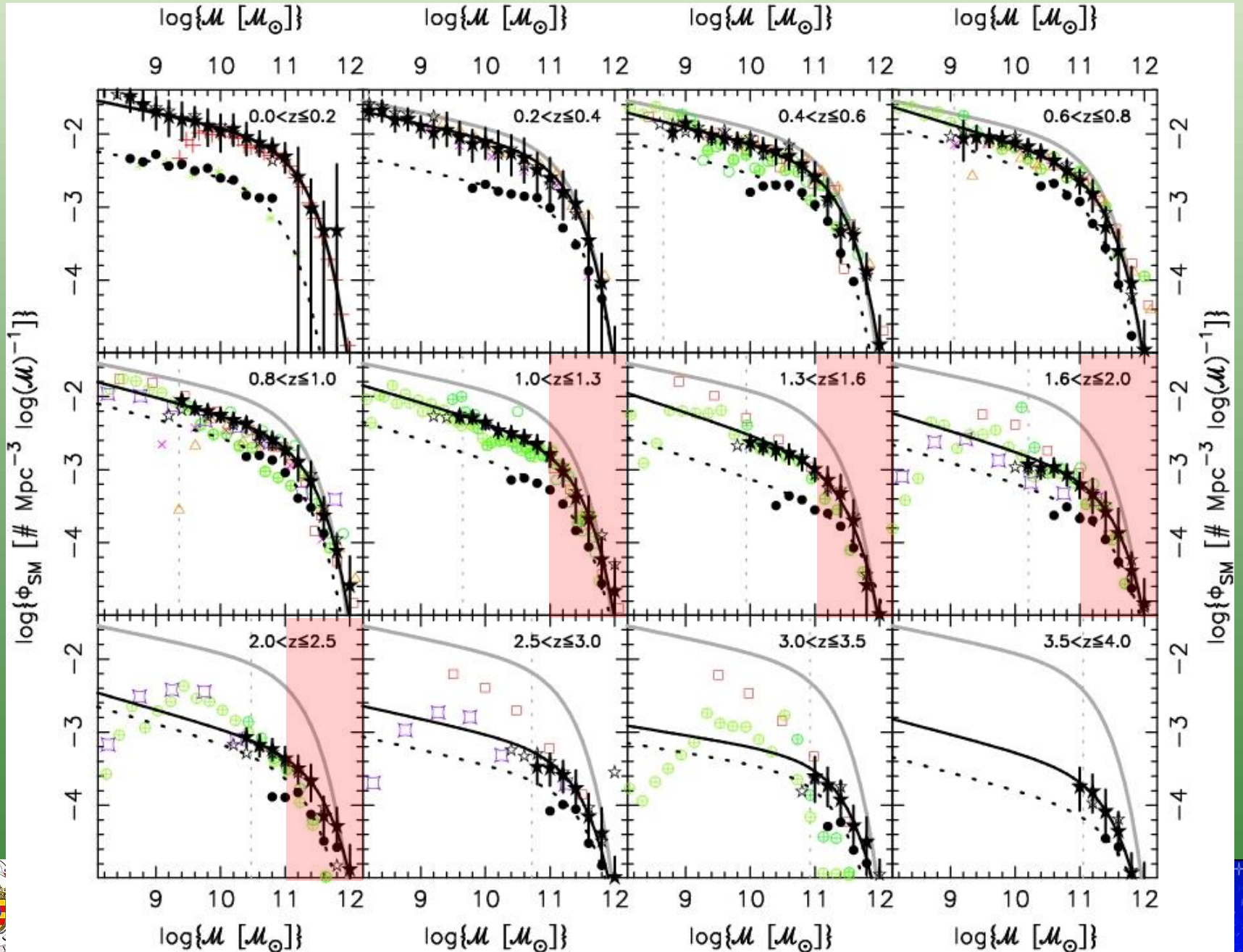
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Observers: "Uhhmm, we see downsizing..."

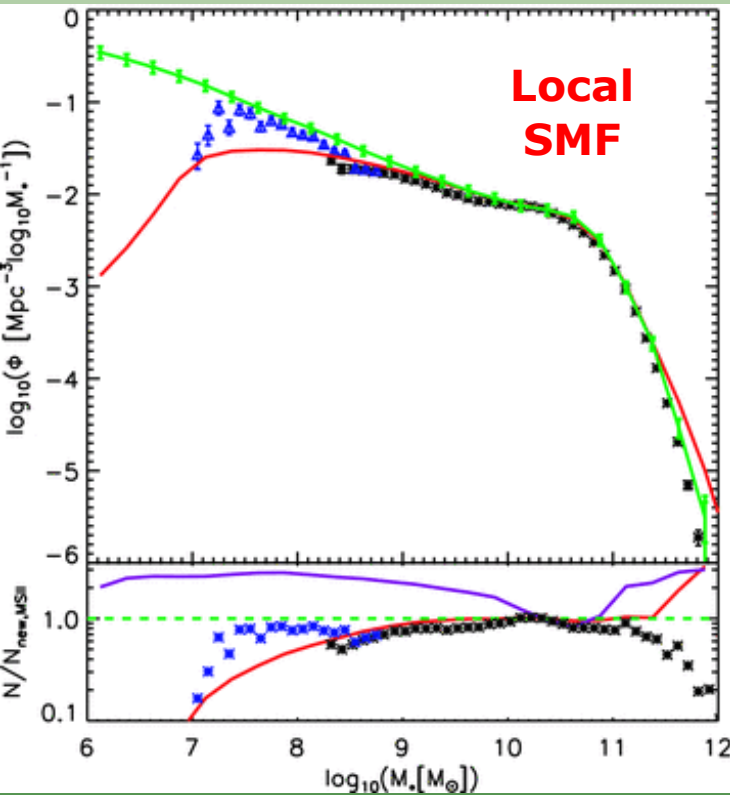


Pérez-González et al. (2008)

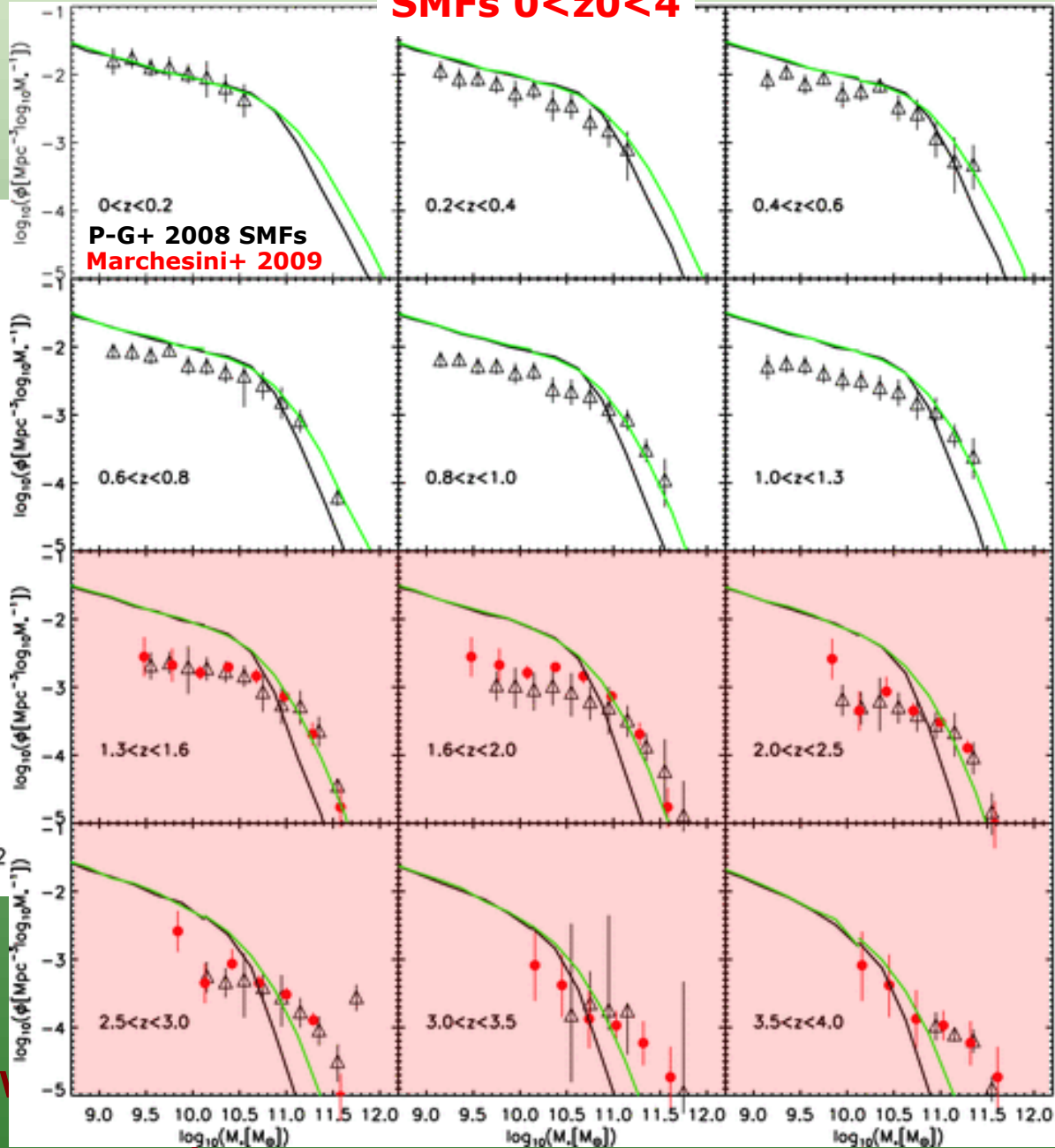


Tension between models and observations

Guo et al. (2012,2013)



SMFs $0 < z < 4$

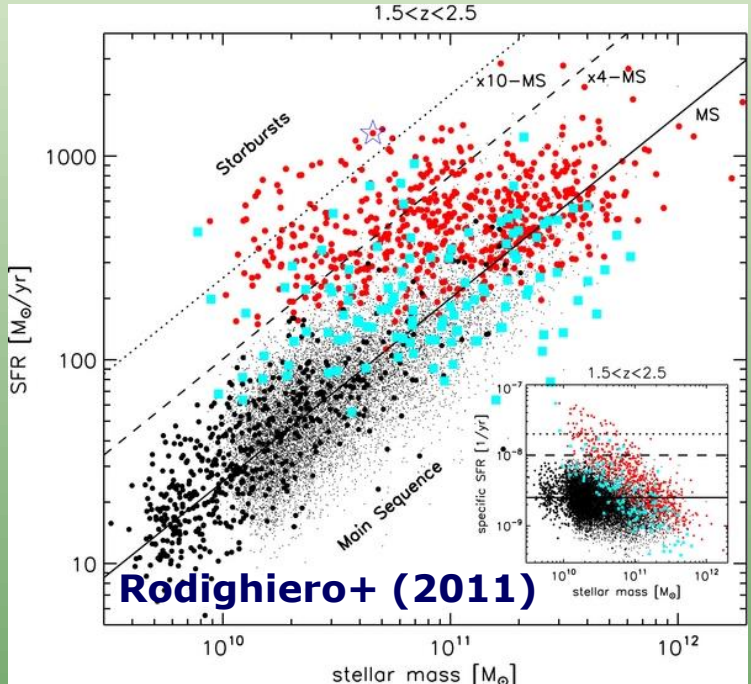
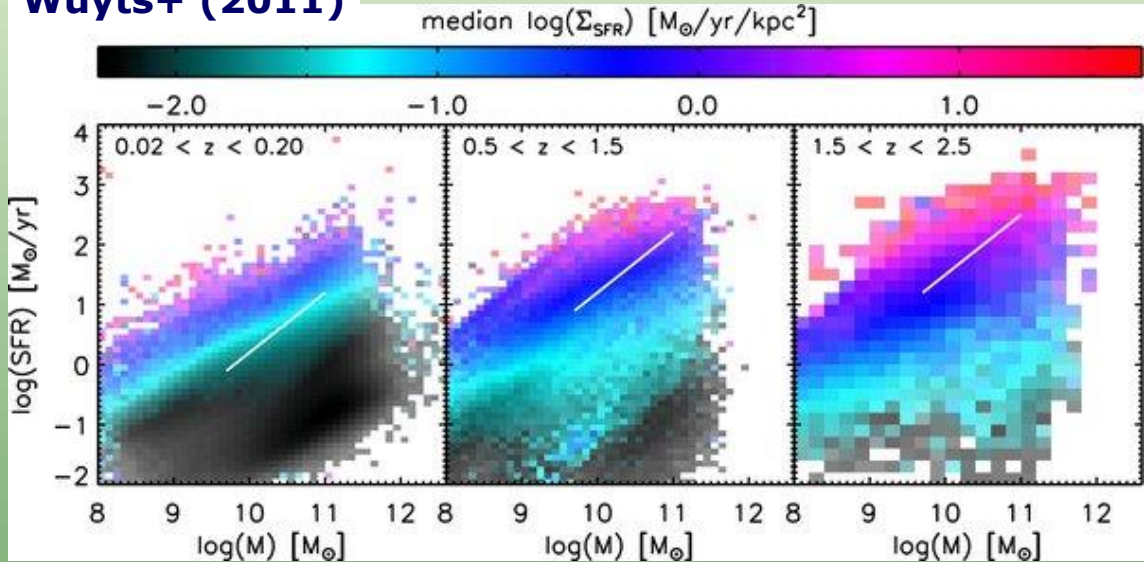


EV

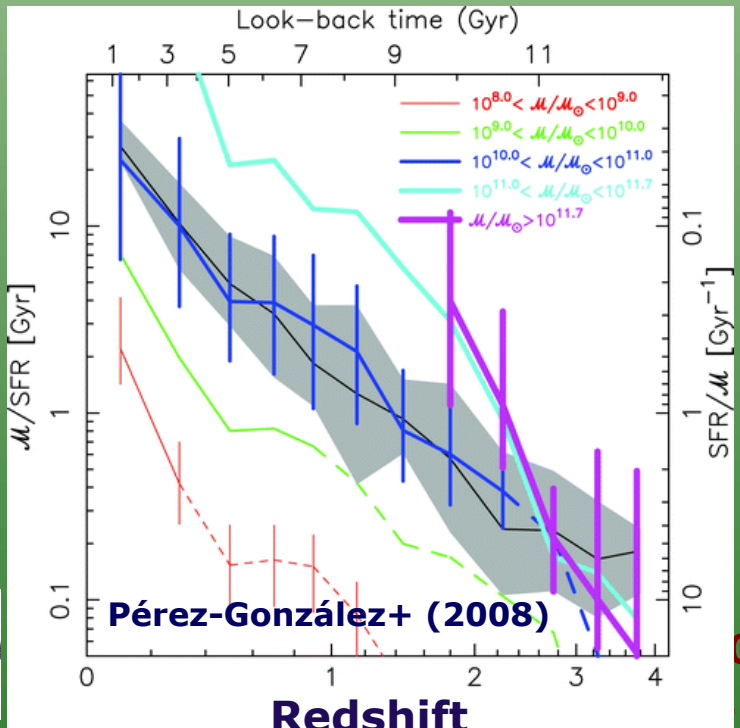


SFR, dust content & densities of $z > 1$ massive gal's

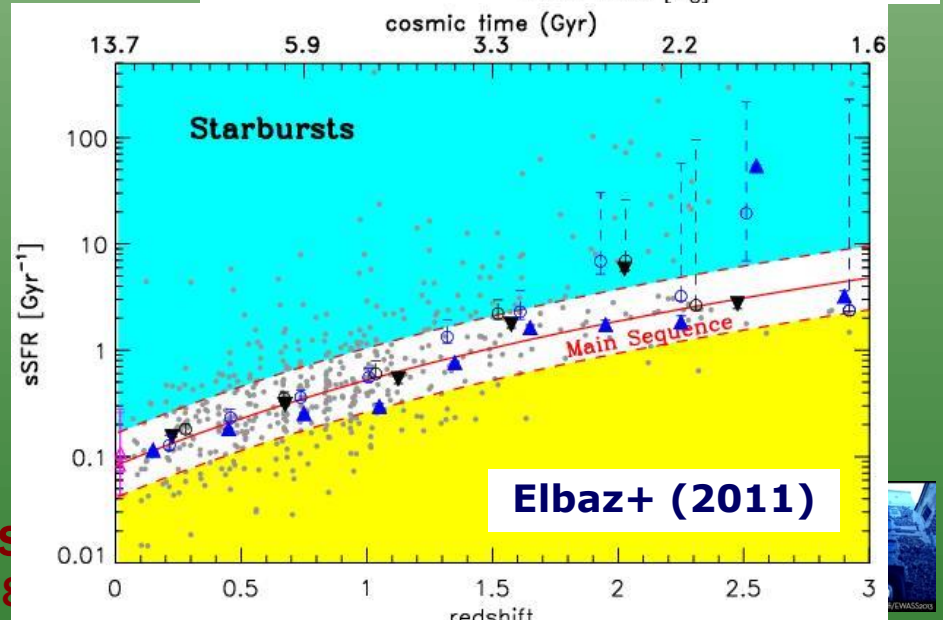
Wuyts+ (2011)



Rodighiero+ (2011)



Pérez-González+ (2008)



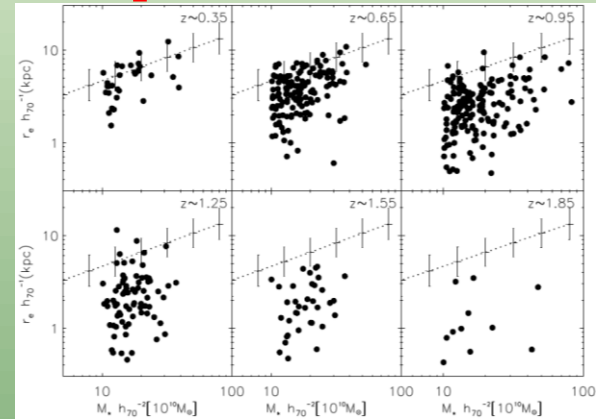
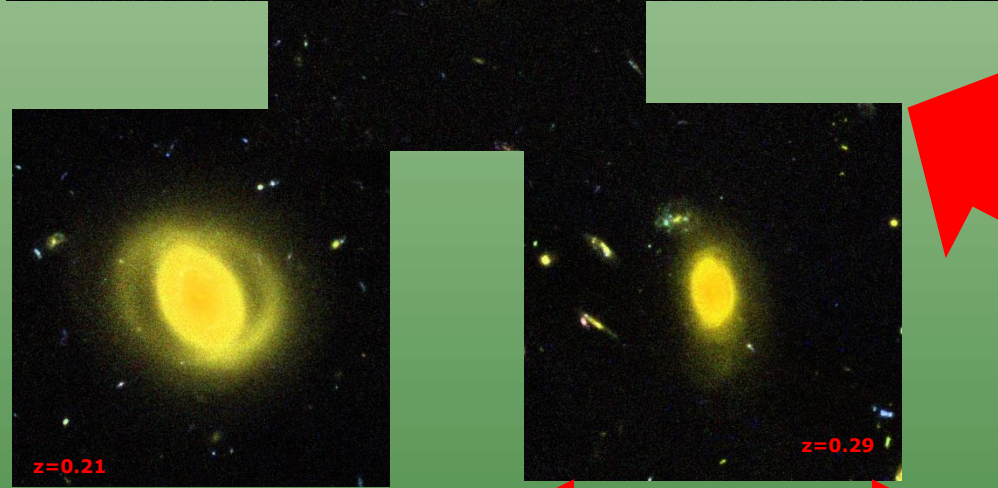
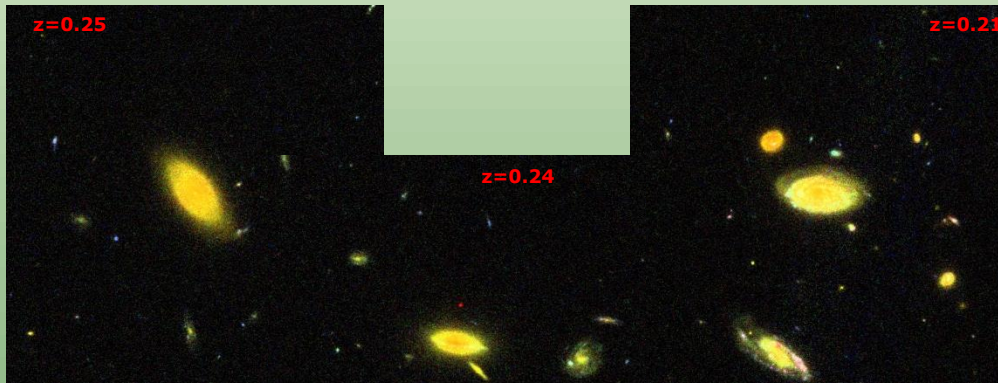
Elbaz+ (2011)



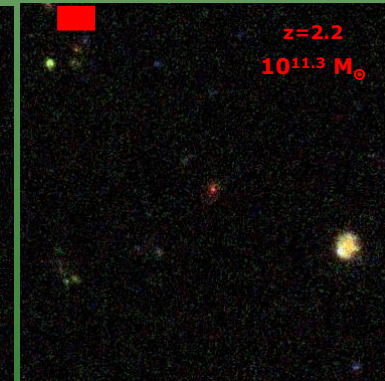
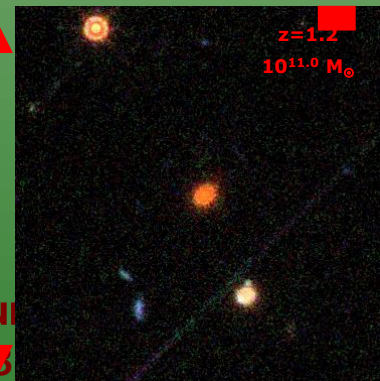
013: S
July 8



Observers: “(Many) Red & dead massive (compact) galaxies already in place @ $z \sim 2$ ”

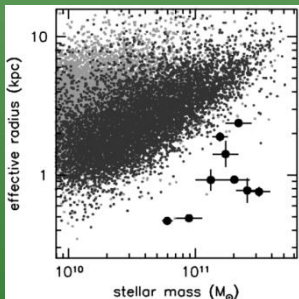


Trujillo et al. (2007)



90 kpc

90 kpc



van Dokkum et al. (2008)

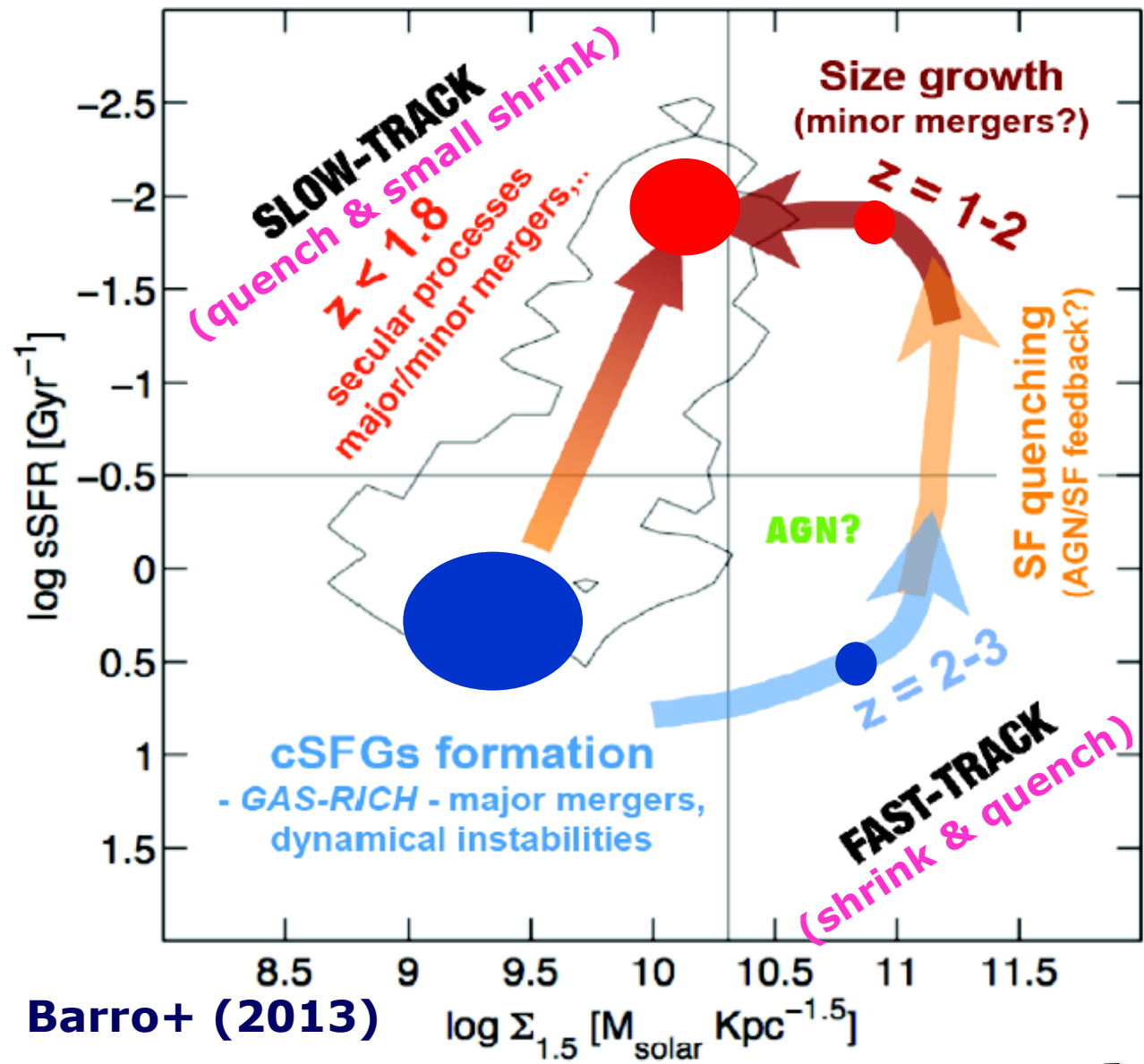


3: Symposium
Tartu, July 8-9, 2013



Combining redshift, mass, SFR, and size

SF suppression ↑



stellar mass 'density'



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Where are we and where should we go?

SCIENCE QUESTIONS ABOUT HIGH- z ($z=1-4^+$) MASSIVE GALAXIES

- ➔ Stellar masses seems OK now (they behave well). Now we need to move on and **ROBUSTLY** determine...
- ➔ What are their **ages**?
- ➔ More generally, how **are their SFHs**? (i.e., how fast did they die?)
- ➔ Why are they small (even very compact)? (i.e., their **assembly**)
- ➔ Why did they start forming stars so early and why/how did they quench?

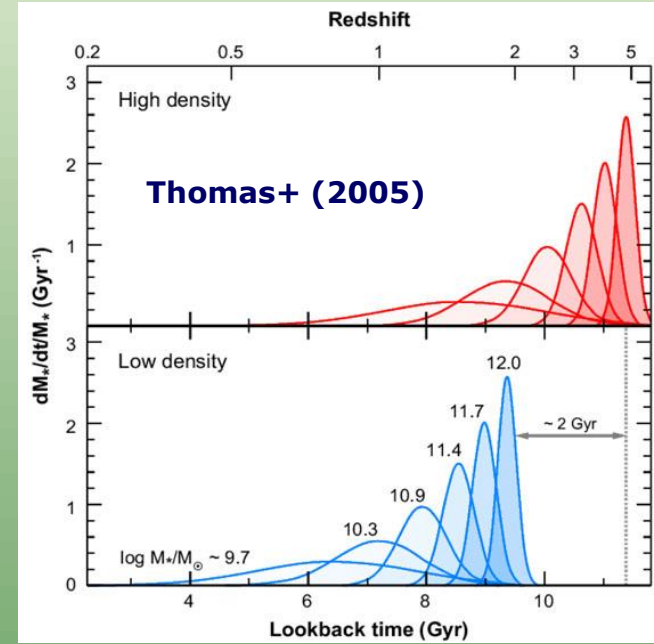
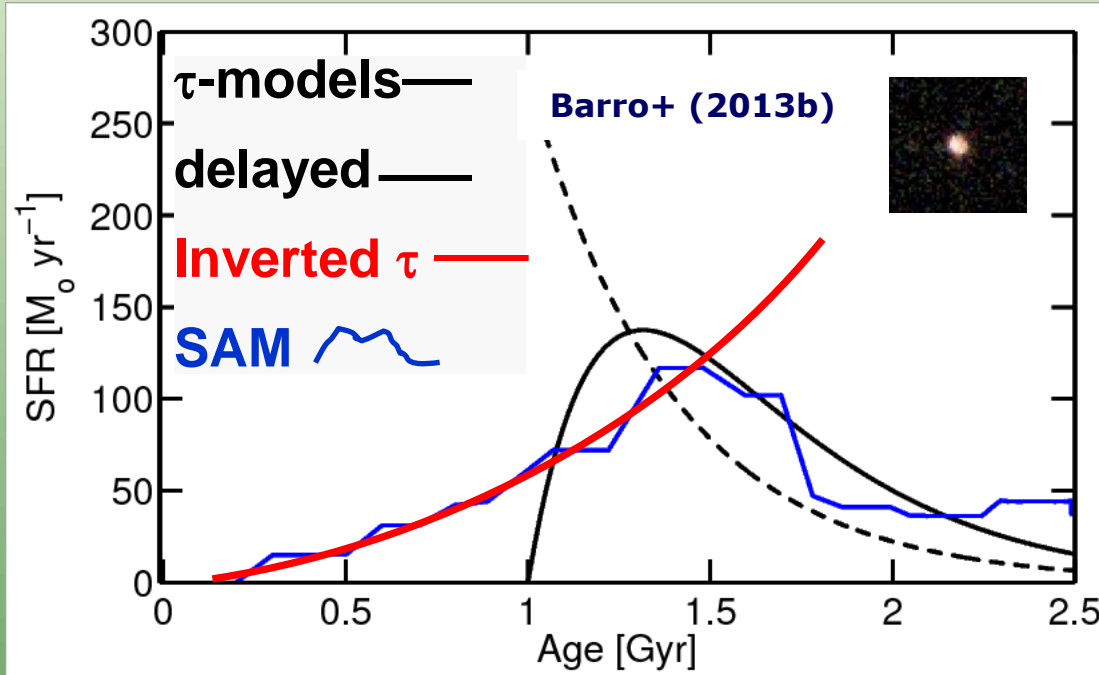
TECHNICAL ISSUES

- ➔ **SFH**: Can we trust the results from “classic” SED fitting (i.e., fits to broad-band data) in terms of mass, ages, extinctions, etc...?
- ➔ **SFH**: Do we have all degeneracies under control? What can we do about them?
- ➔ **Assembly mode**: How can we test assembly vs. formation scenarios?

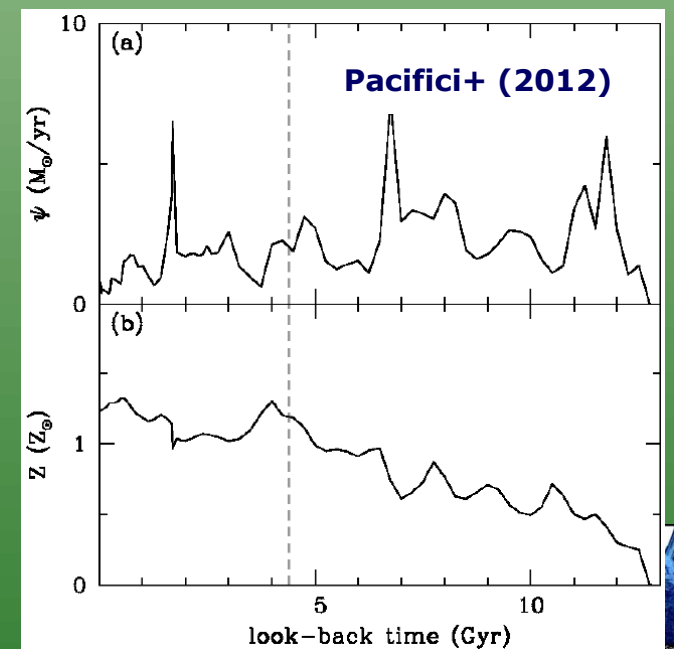
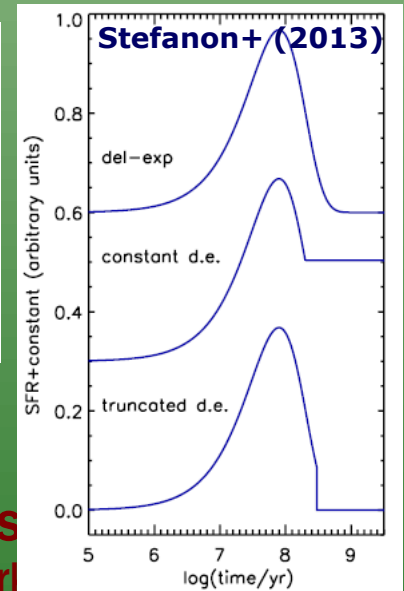
SOLVING THOSE ISSUES

- ➔ Using data with proved sensitivity to **SFH** parameters: spectral indices.
- ➔ Keeping track of degeneracies and “model dependent artifacts”.
- ➔ Systematic study of galaxies in different stages of evolution ($z < 4-6$).
- ➔ Study gas accretion and stellar **dynamics and environment**.
- ➔ Stellar population synthesis models should also be improved.
- ➔ Galaxy formation models should be revised according to new results.

Dissecting high-z massive galaxies: SFHs

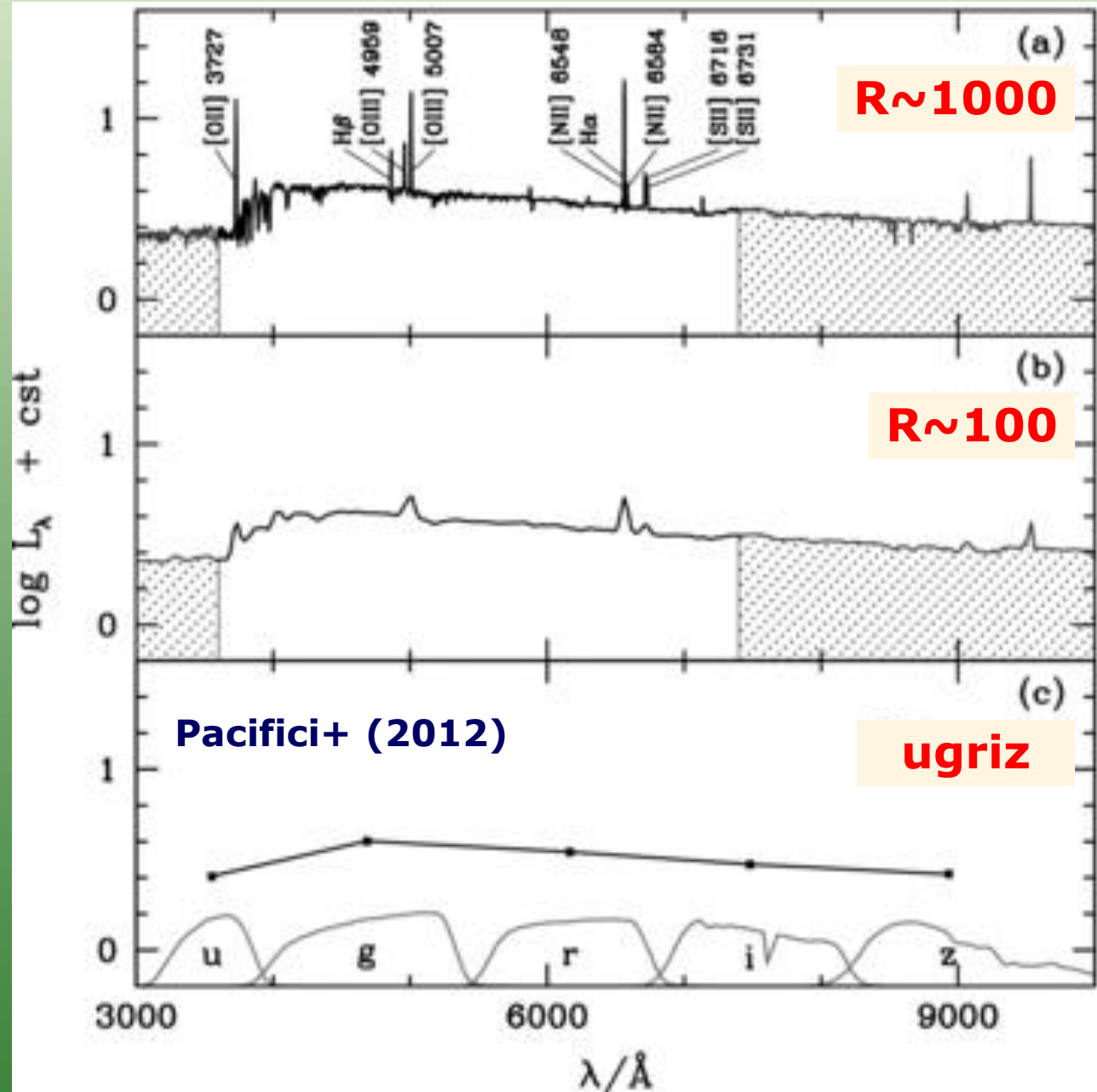


See Thomas+ (2005), Wuyts+ (2009), Maraston+ (2010), Pforr+ (2012), Pacifici+ (2012), Ferreras+ (2012), Schaerer+ (2013), Stefanon+ (2013), Barro+ (2013b),...



EWASS
Turl

Improving our estimations of stellar params



Turku, July 6-9, 2013

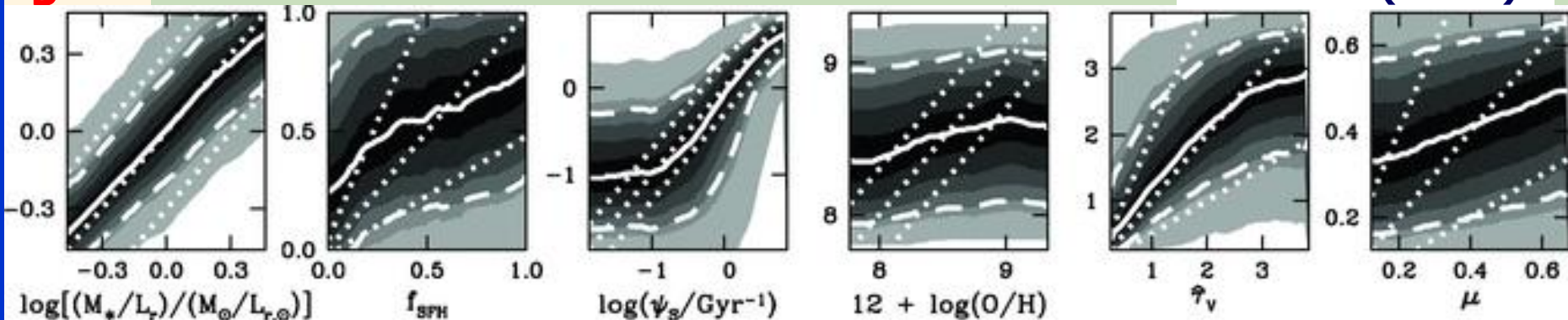


Improving our estimations of stellar params

ugriz

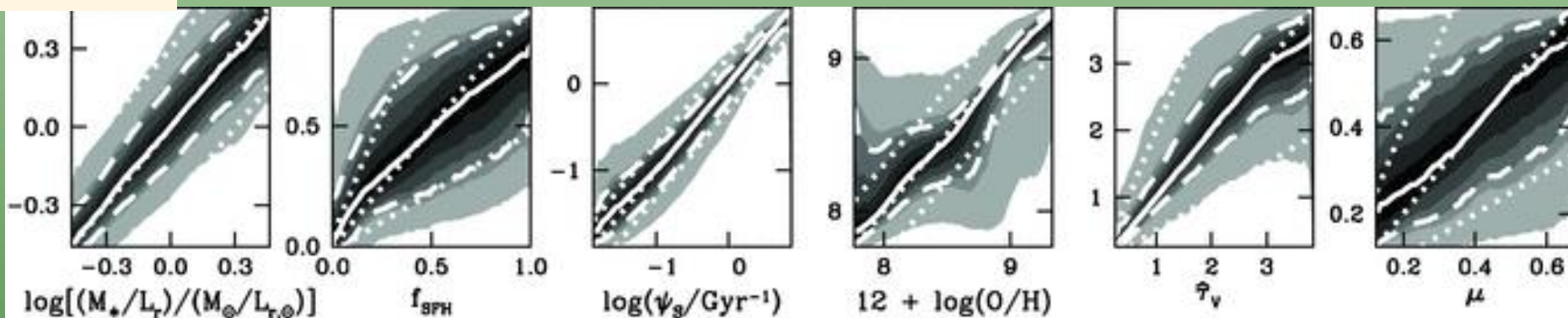
Pacifici+ (2012)

recovered values

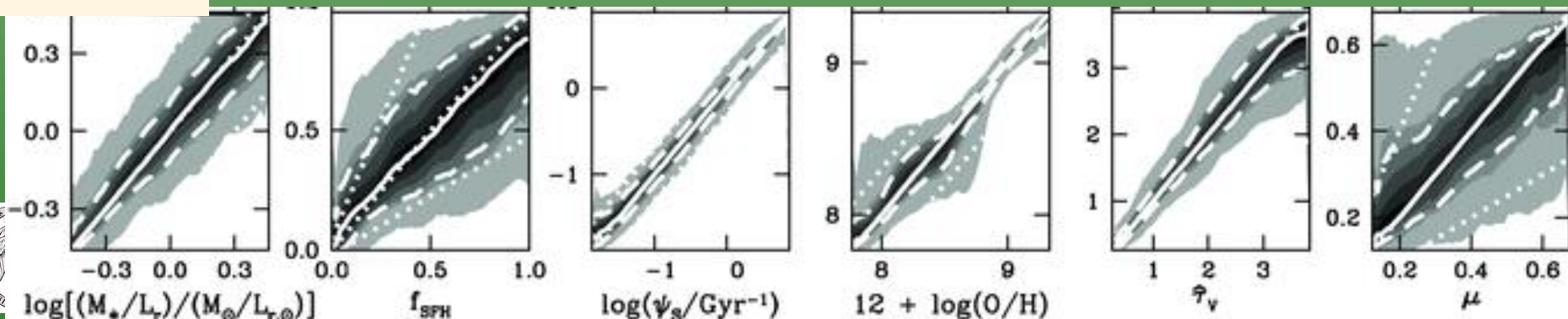


R ~ 100

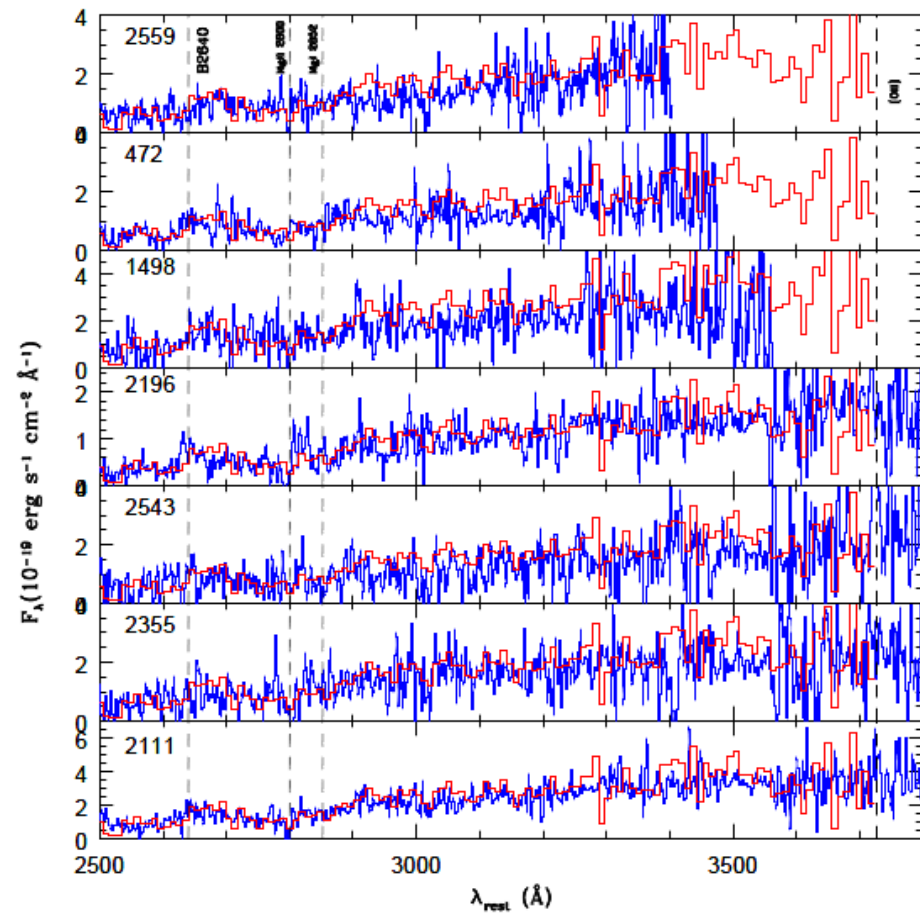
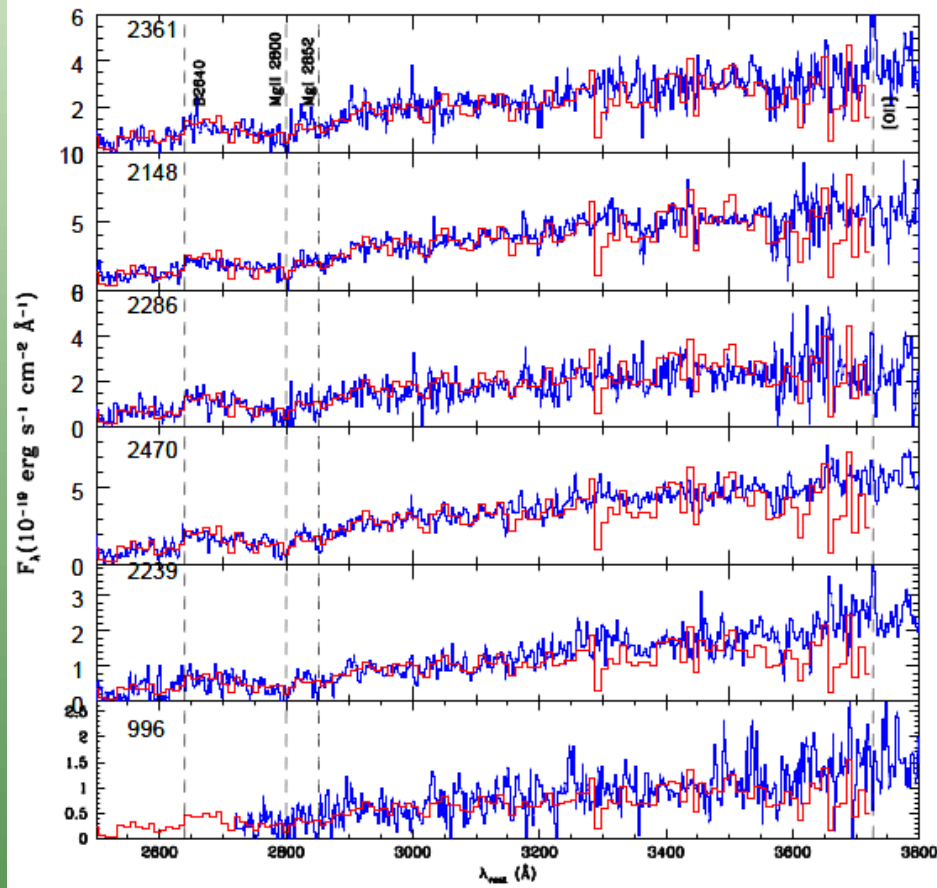
input values: mass, SFR, sSFR, Z, A(V), attenuation law



R ~ 1000



High-z red&dead galaxies in detail: spectra

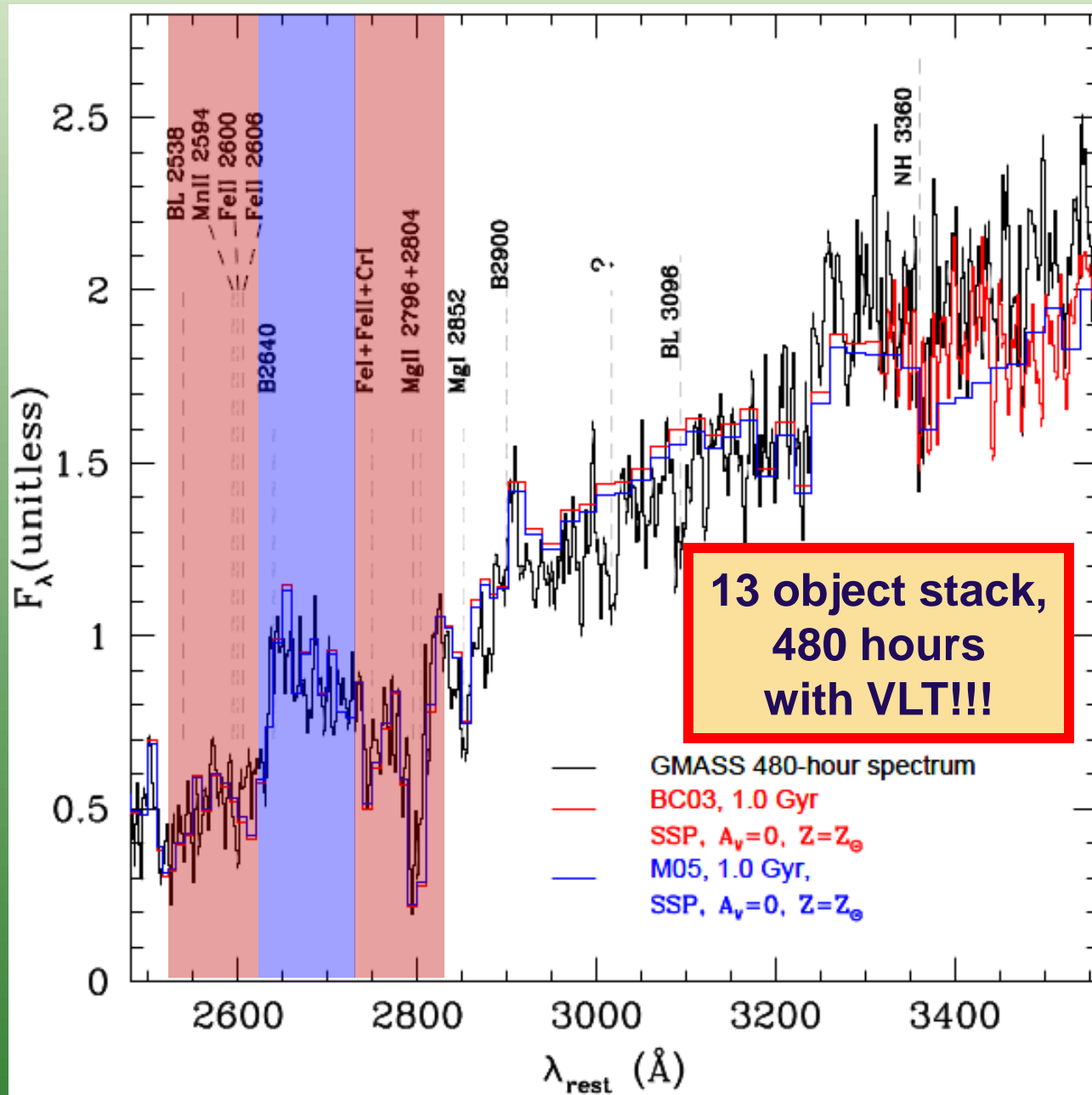


Cimatti et al. (2008)

EWASS 2013: Symposium 4
Turku, July 8-9, 2013



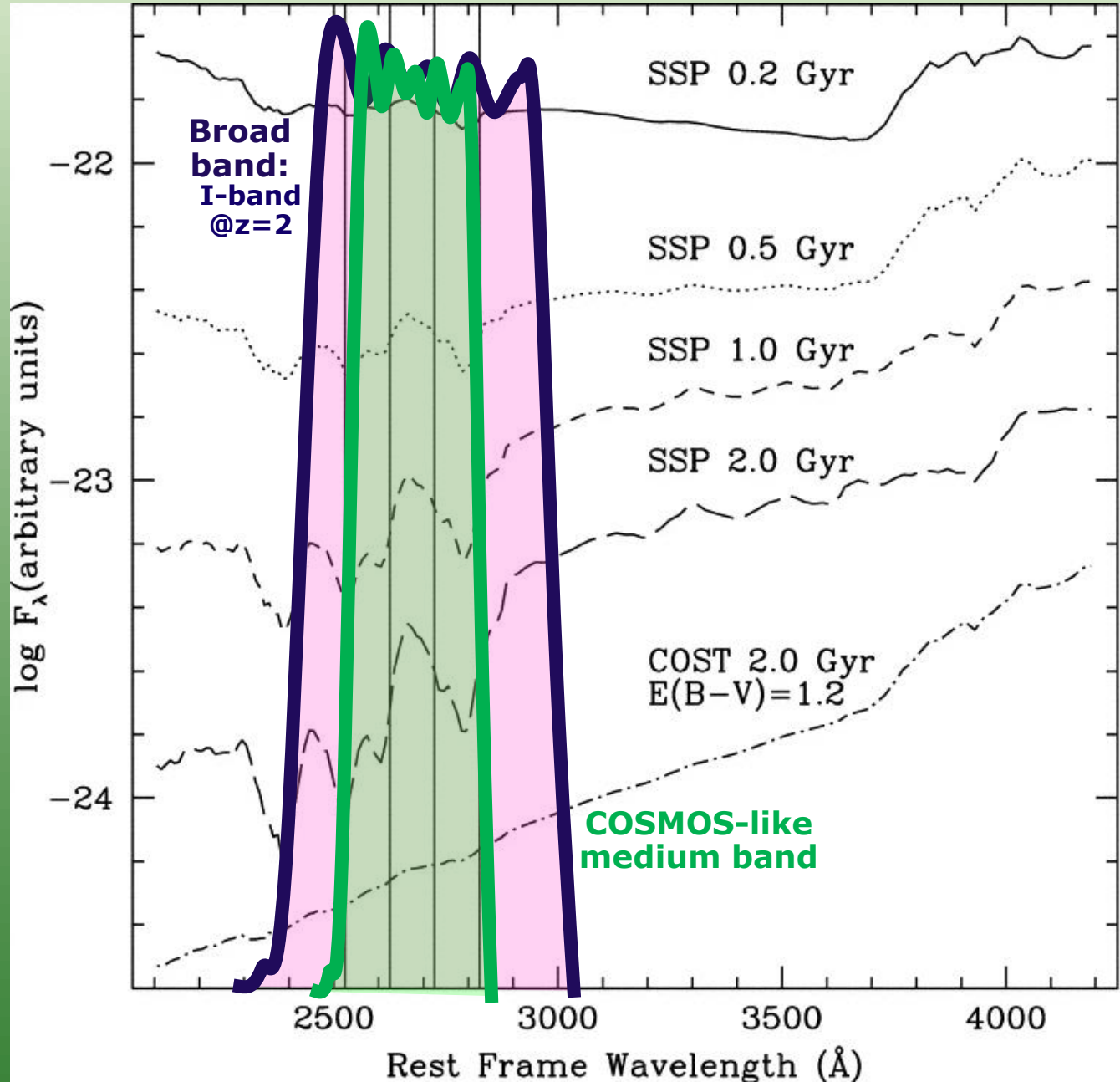
Accurate stellar population synthesis @high-z



Cimatti et al. (2008)



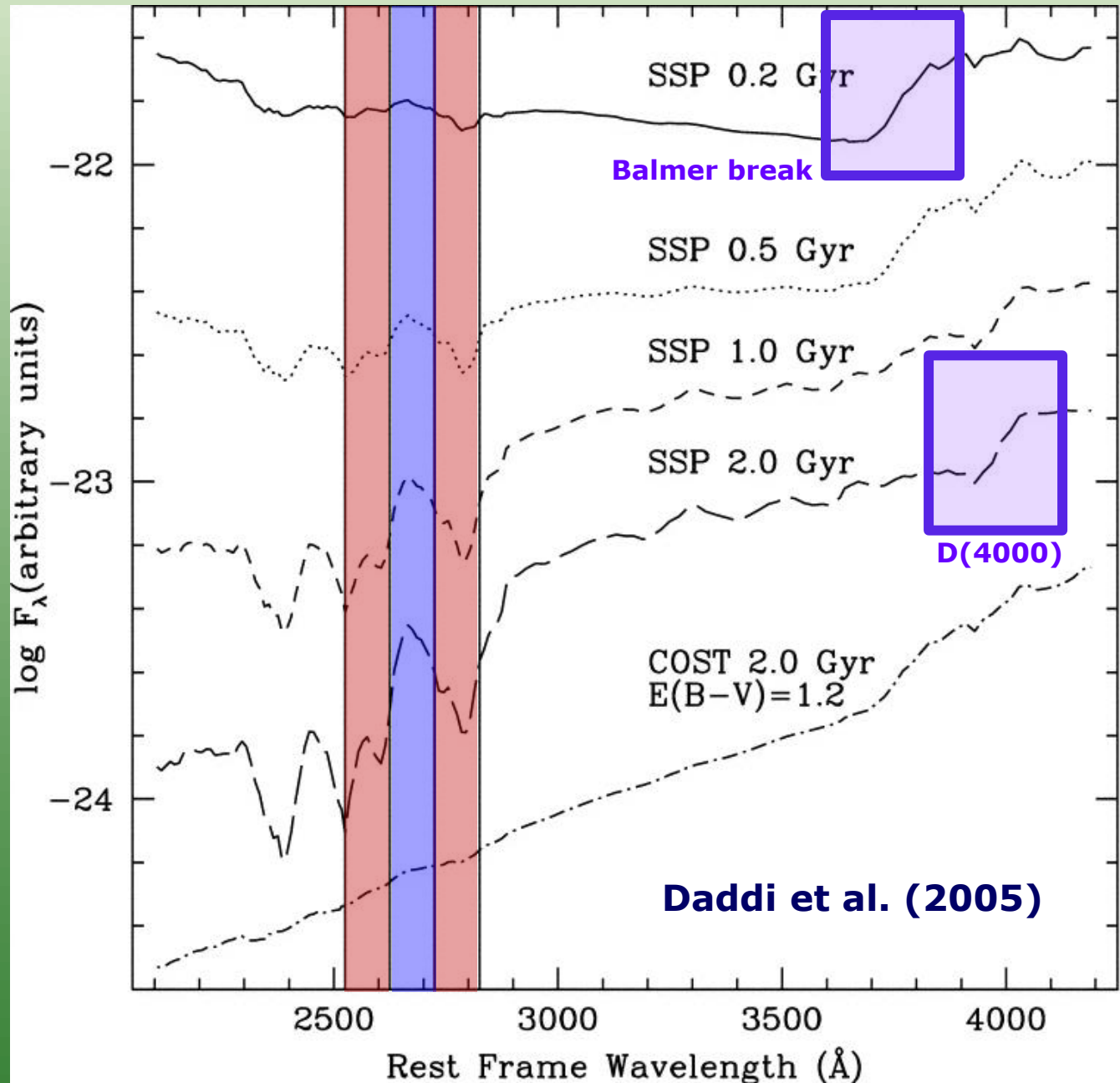
Robust characterization of SFHs: spectral indices



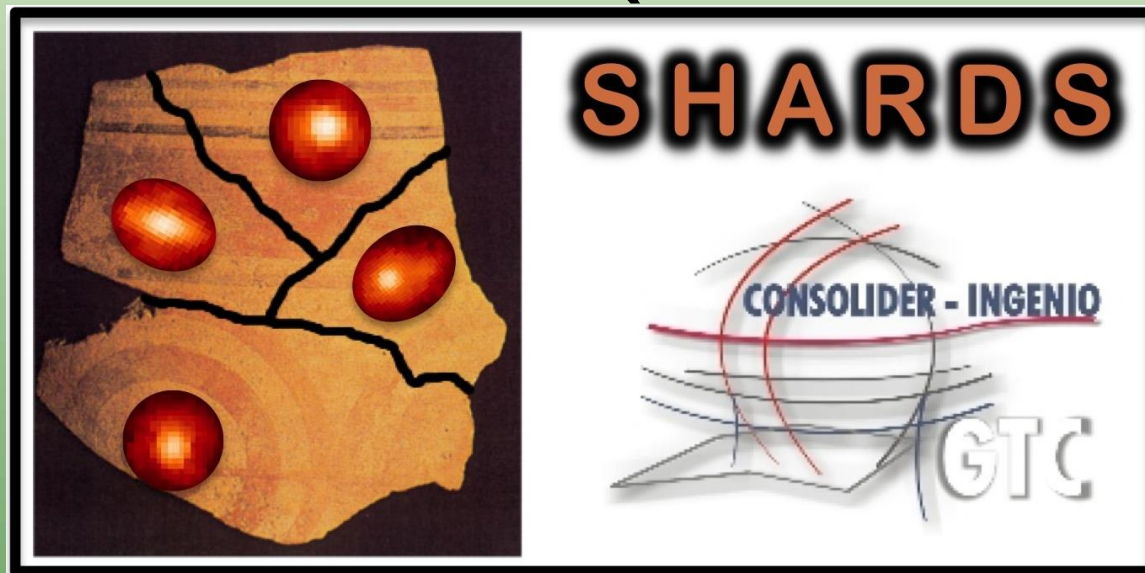
Daddi et al. (2005)



Robust characterization of SFHs: spectral indices



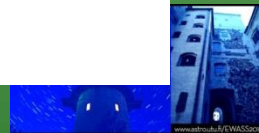
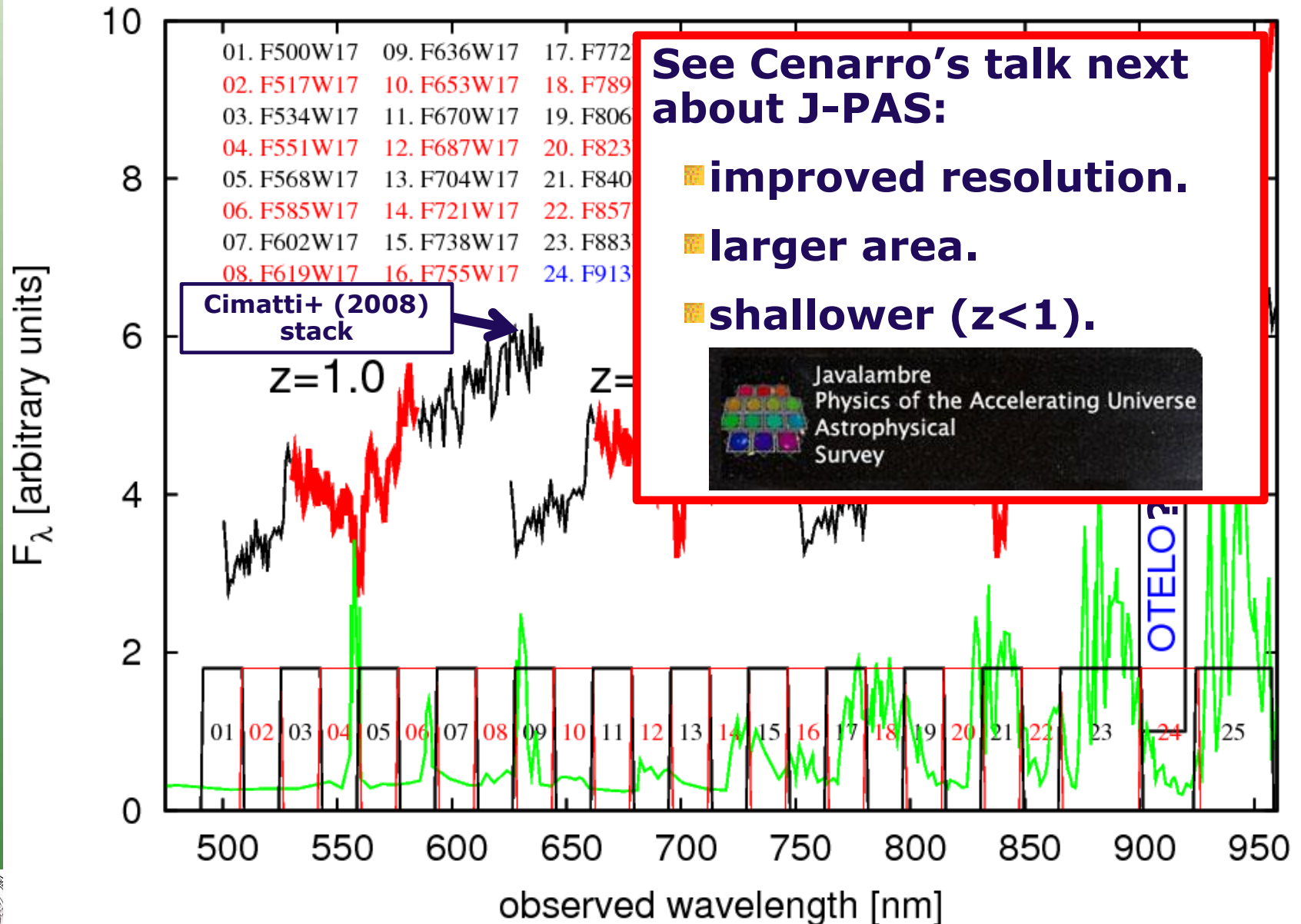
SHARDS: Survey for High-z Absorption Red and Dead Sources (in GOODS-N field)



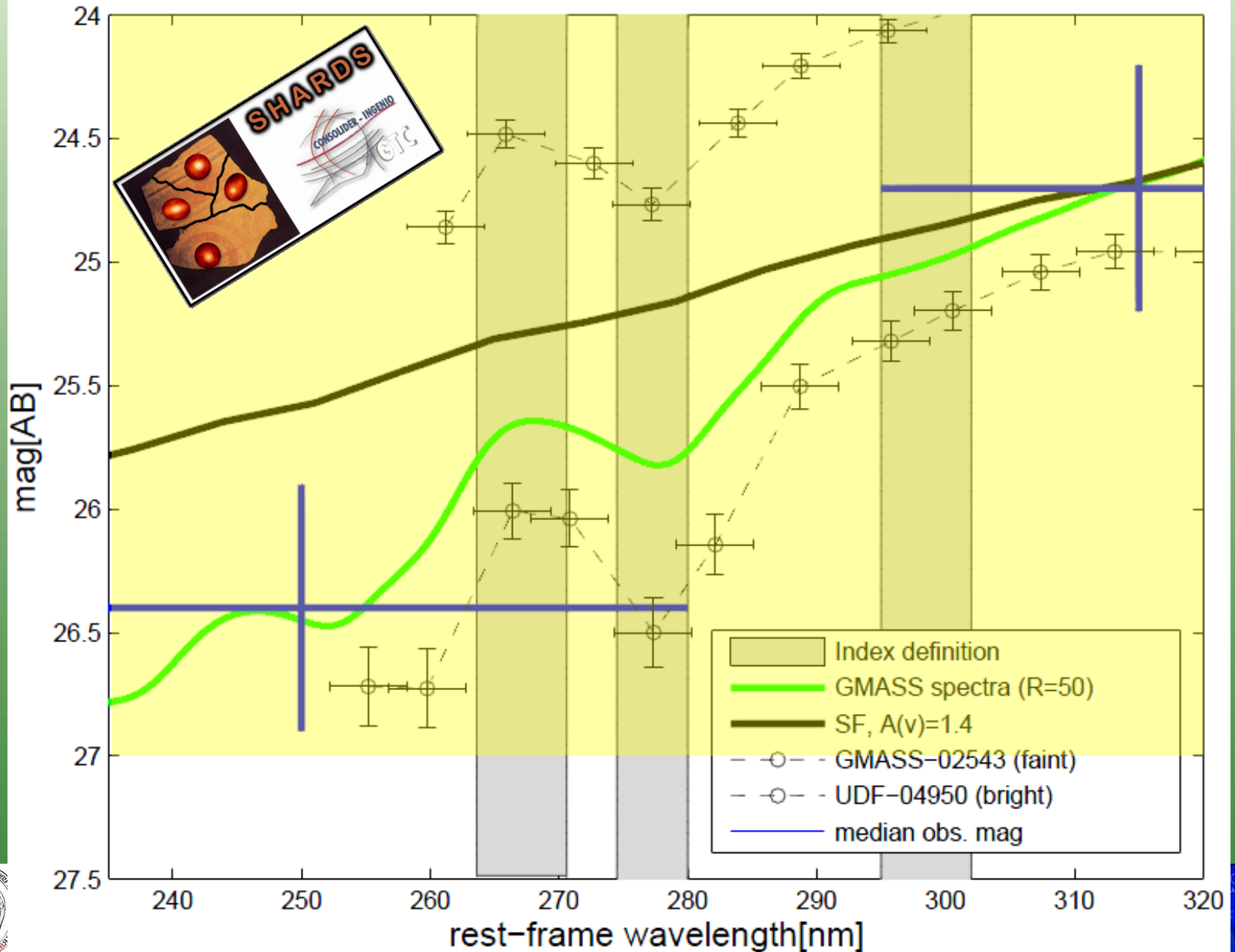
<http://guaix.fis.ucm.es/~pgperez/SHARDS>



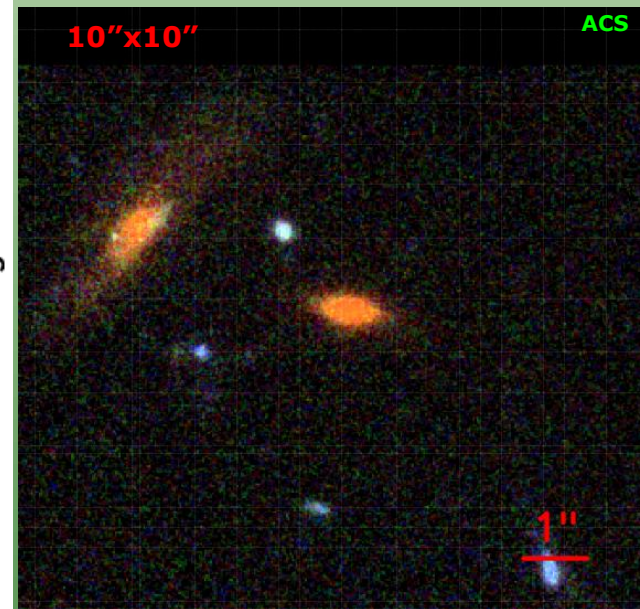
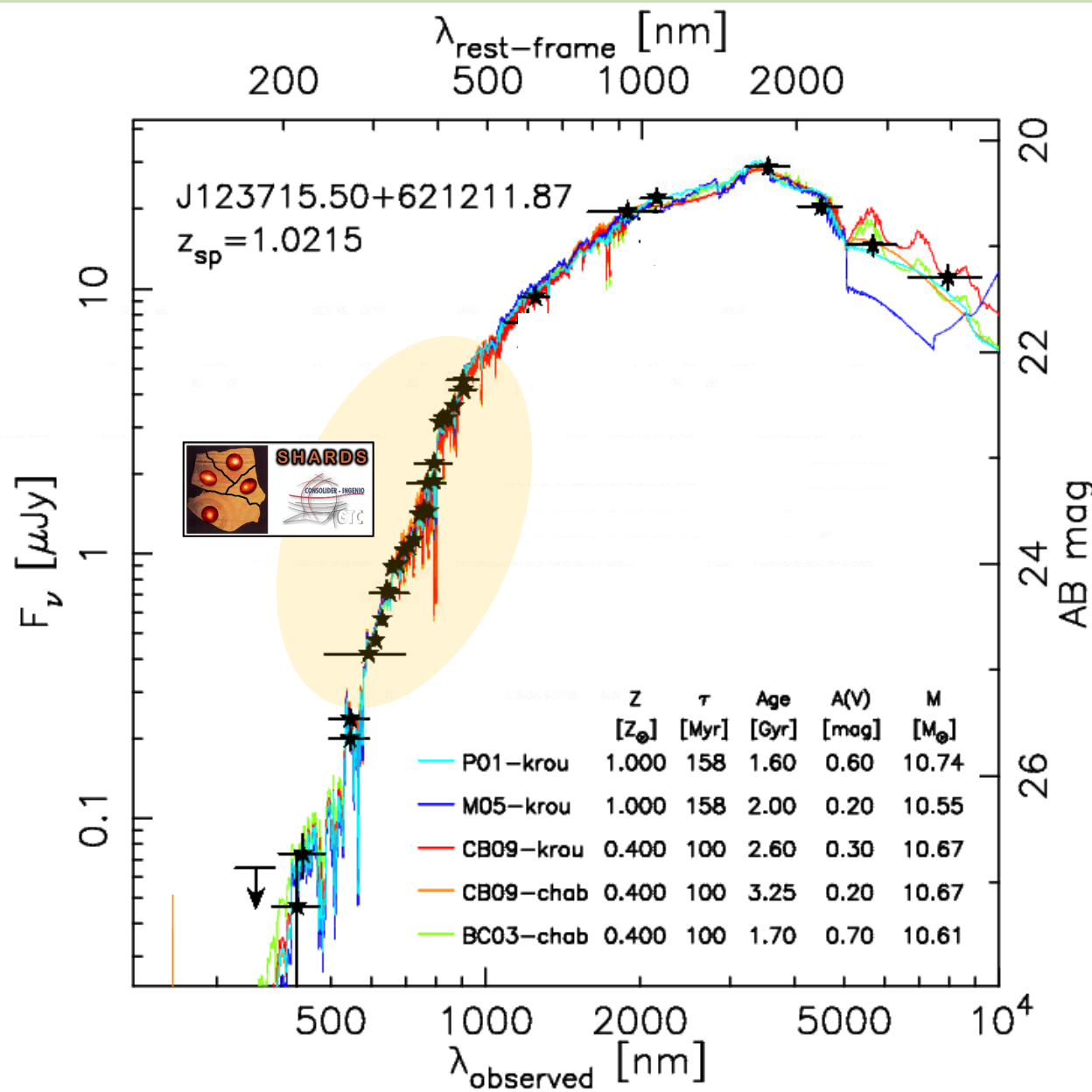
SHARDS: spectro-photometry in GOODS-N



SHARDS: Mg(UV) index with photometry



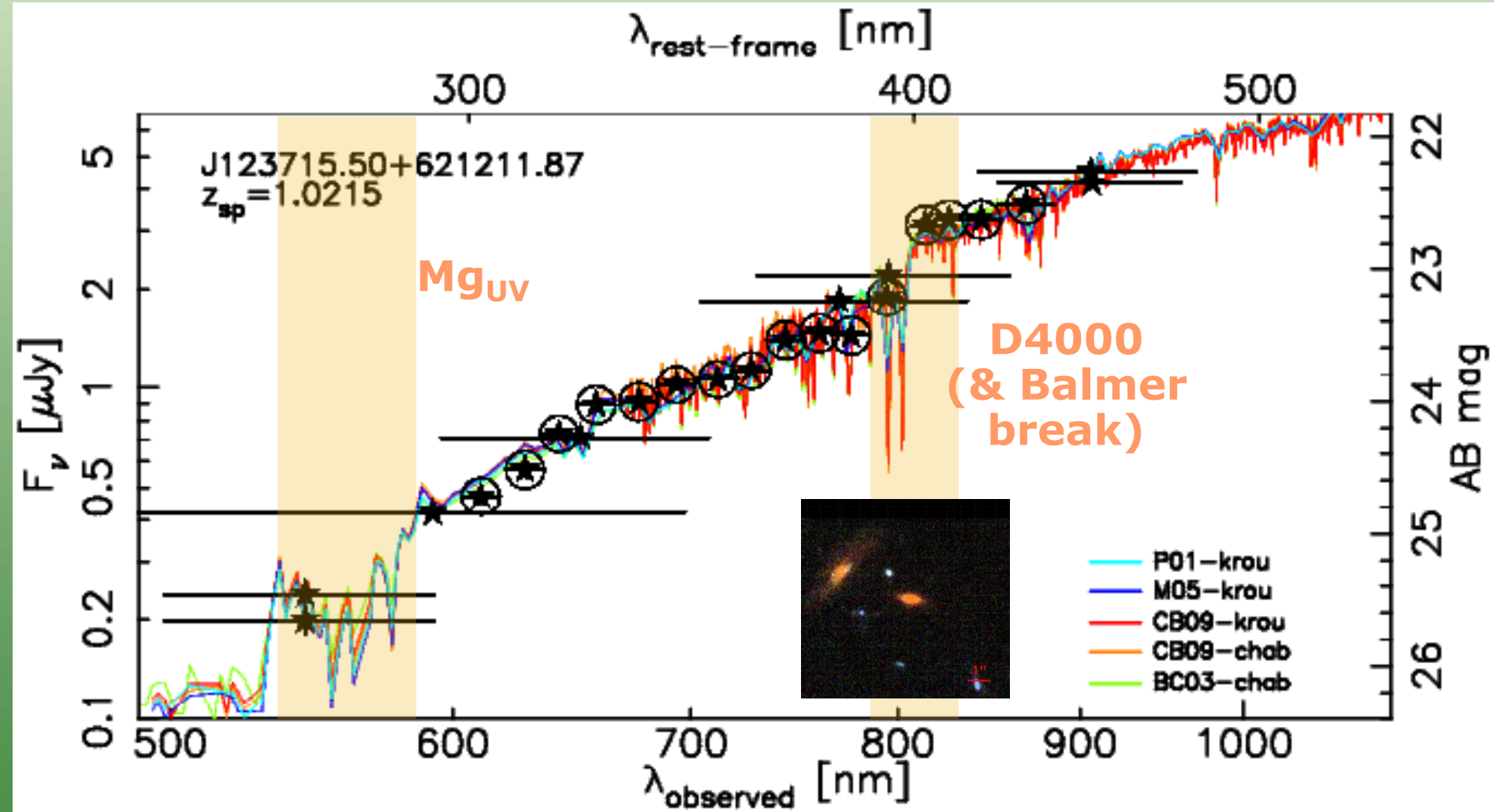
SHARDS: detailed SP synthesis



Pérez-González+ (2013)



SHARDS: detailed SP synthesis



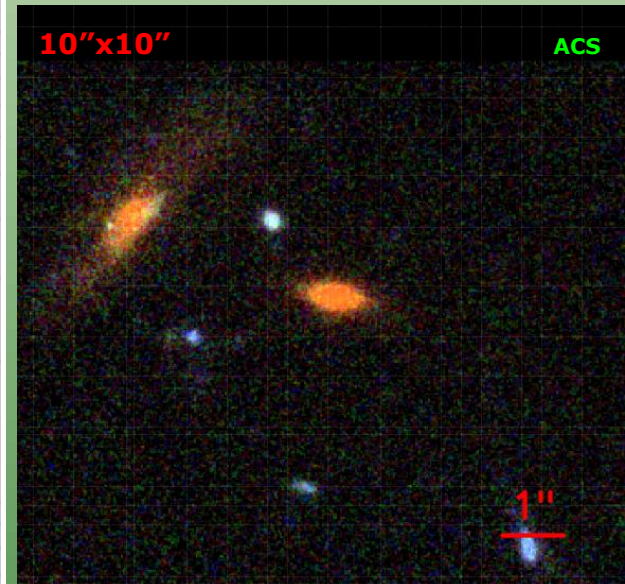
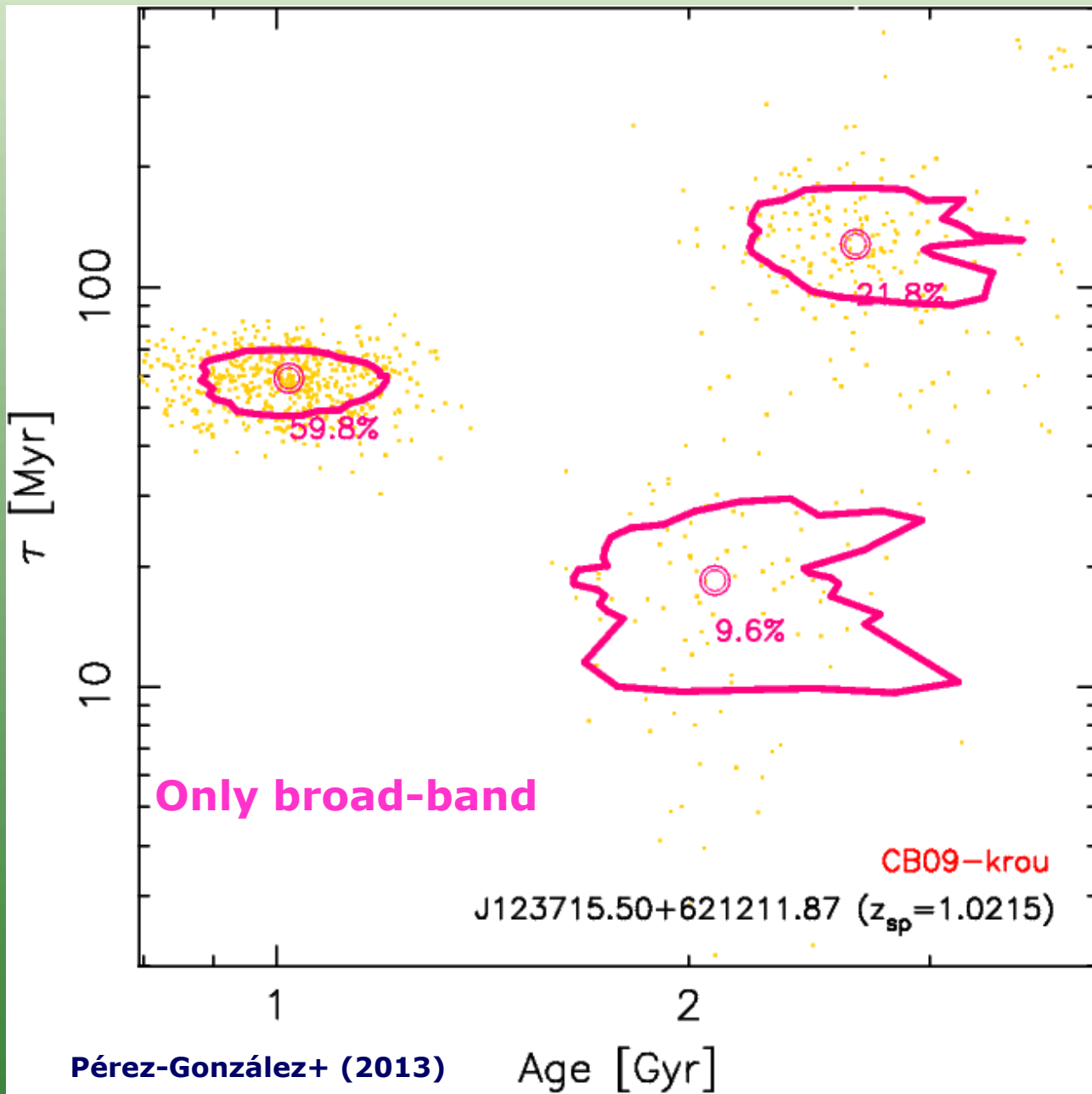
Pérez-González+ (2013),
see also **Hernán-Caballero+ (2013)**

2013: Symposium 4

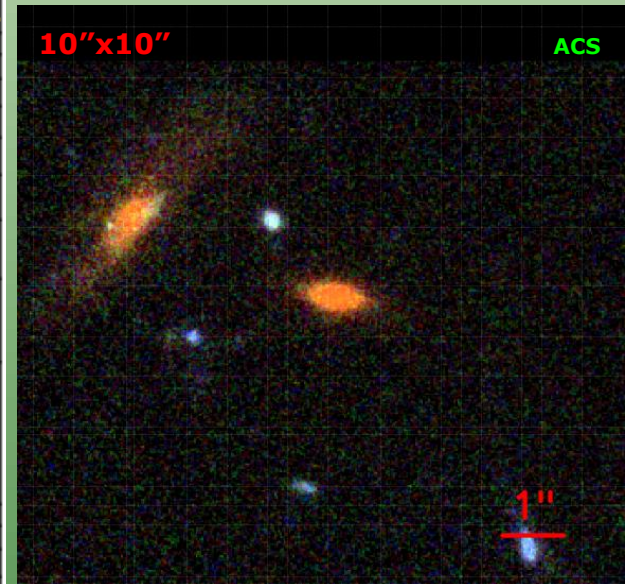
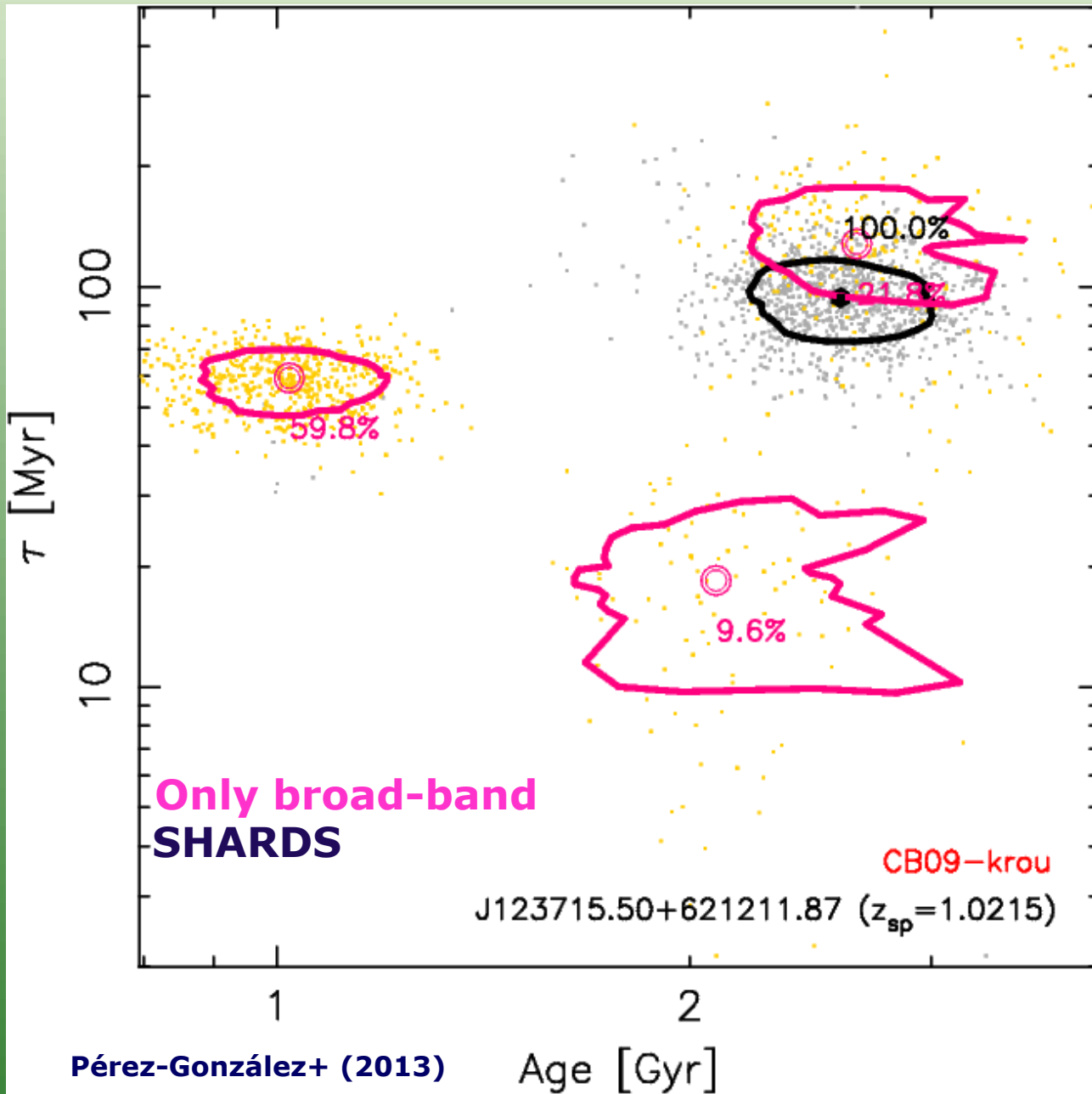
Turku, July 8-9, 2013



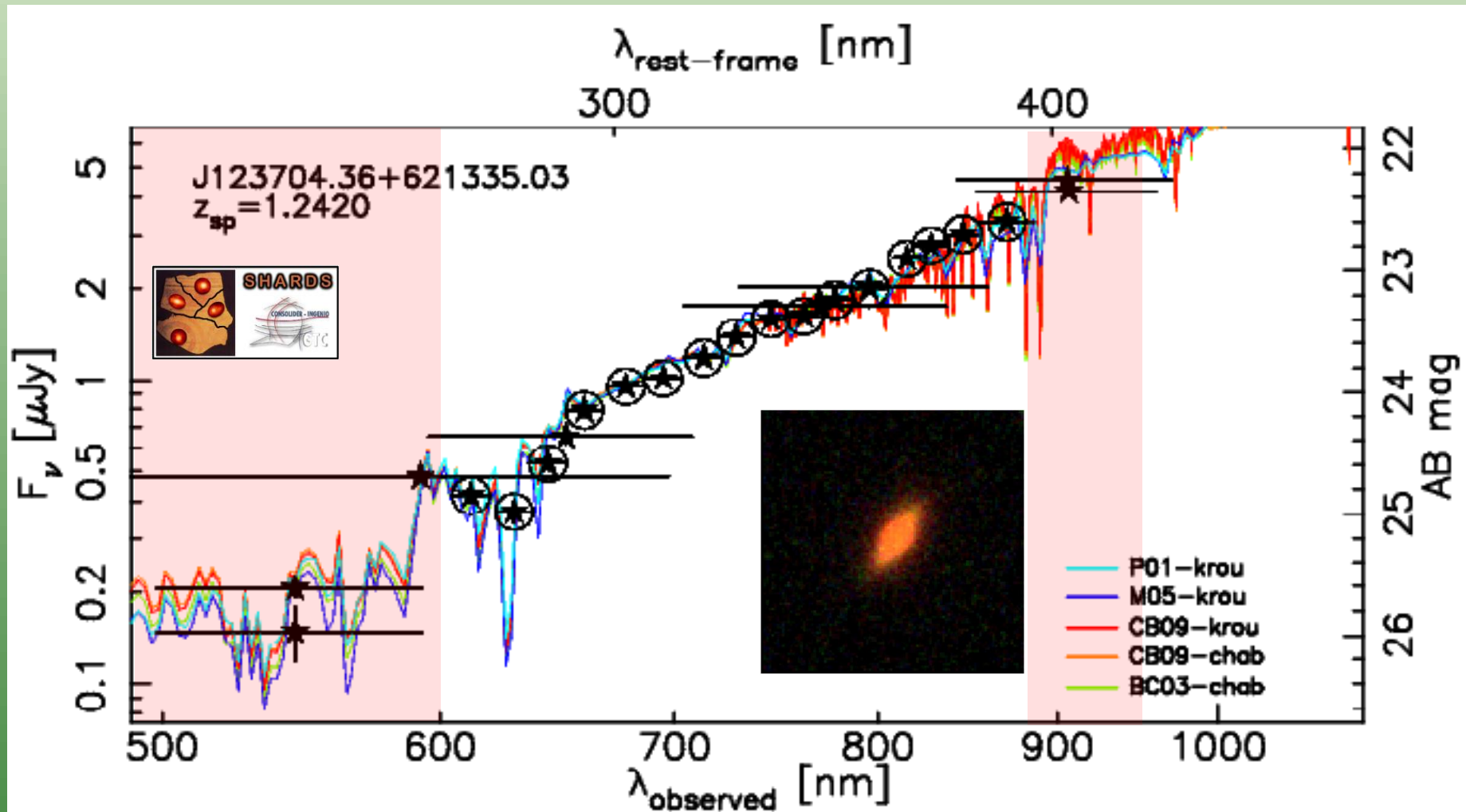
SHARDS: detailed SP synthesis



SHARDS: detailed SP synthesis



SHARDS: absorptions (red&dead, Ex. # 2/2)



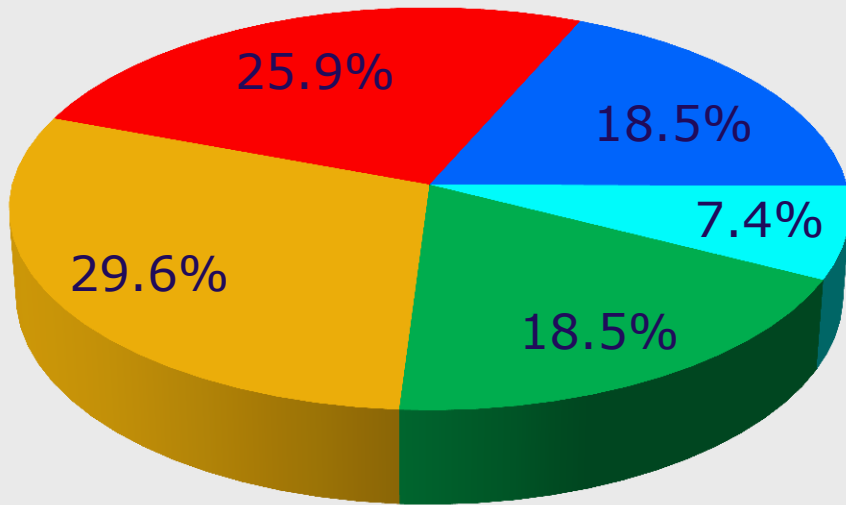
Pérez-González et al. (2013)

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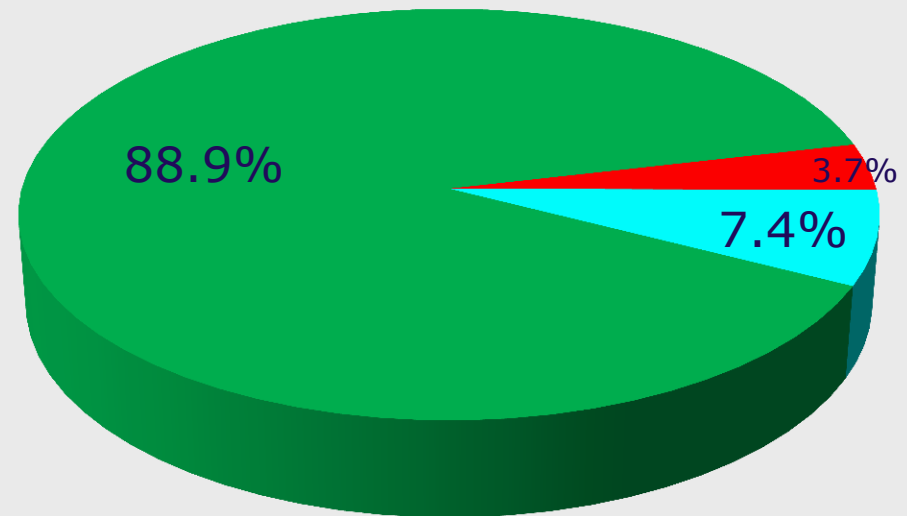
SHARDS (+BB+NIR grism): testing SP models @ $z > 1$

Best fits, only BB



■ BC03-chab ■ CB09-chab ■ CB09-krou
■ M05-krou ■ P01-krou

Best fits, BB+SHARDS



■ BC03-chab ■ CB09-chab ■ CB09-krou
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Pérez-González+ (2013)

EWASS 2013
Turku, Jul

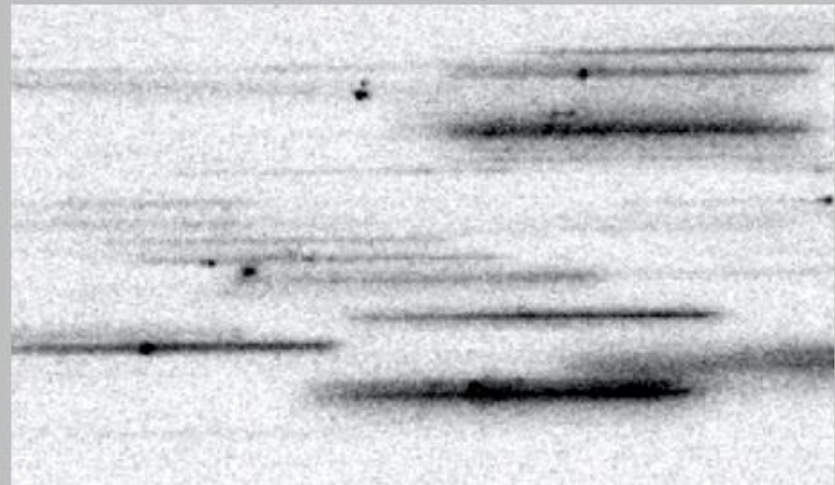
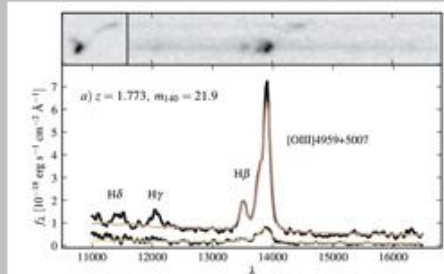
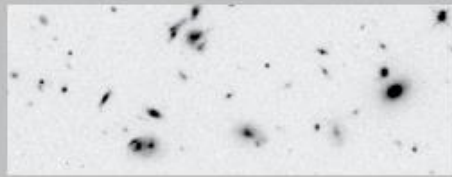


3D-HST: low resolution spectra in the NIR

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A Spectroscopic Galaxy Evolution Survey with the Hubble Space Telescope



Figures (clockwise from top left): F140W direct image within the GOOD-South field observed as part of 3D-HST; G141 grism spectra within the same GOOD-South pointing; an extracted spectrum of a star-forming galaxy at $z=1.733$ in GOODS-N, showing multiple line-emitting components (shown are the extractions for the main galaxy and the tail) from Brammer et al., 2012.

Brammer+ (2012)

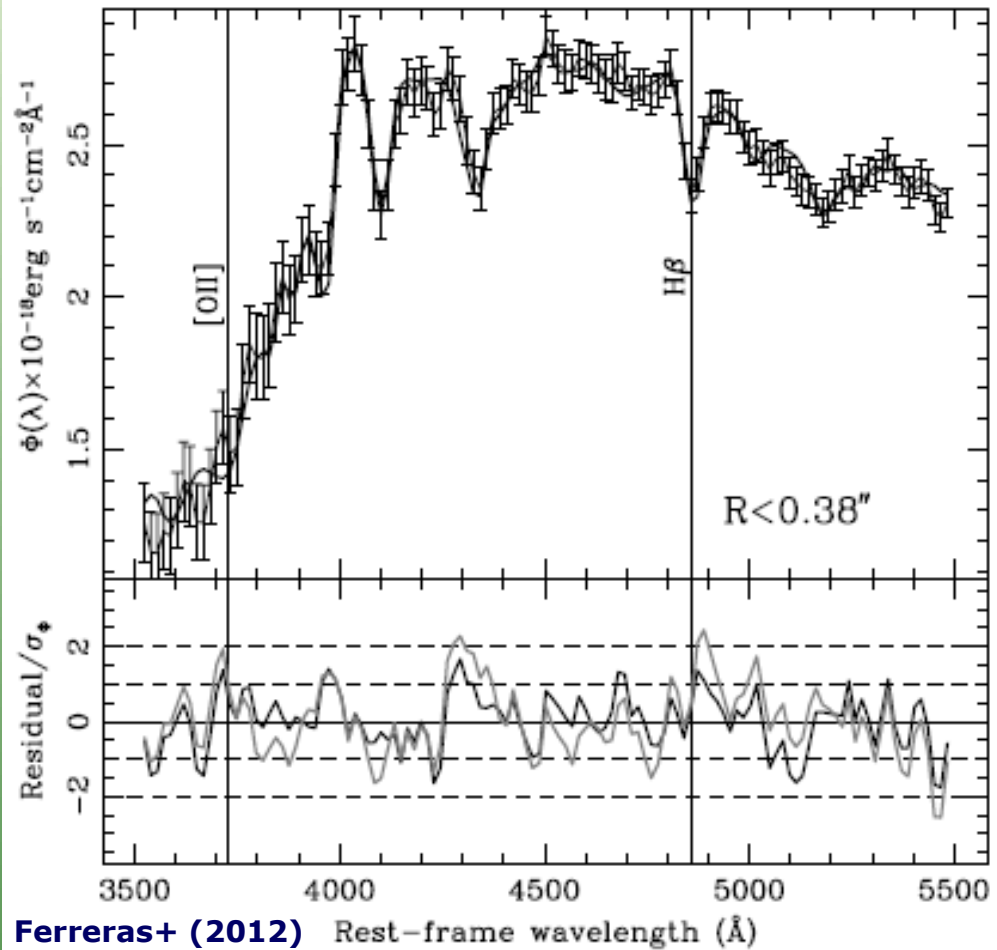
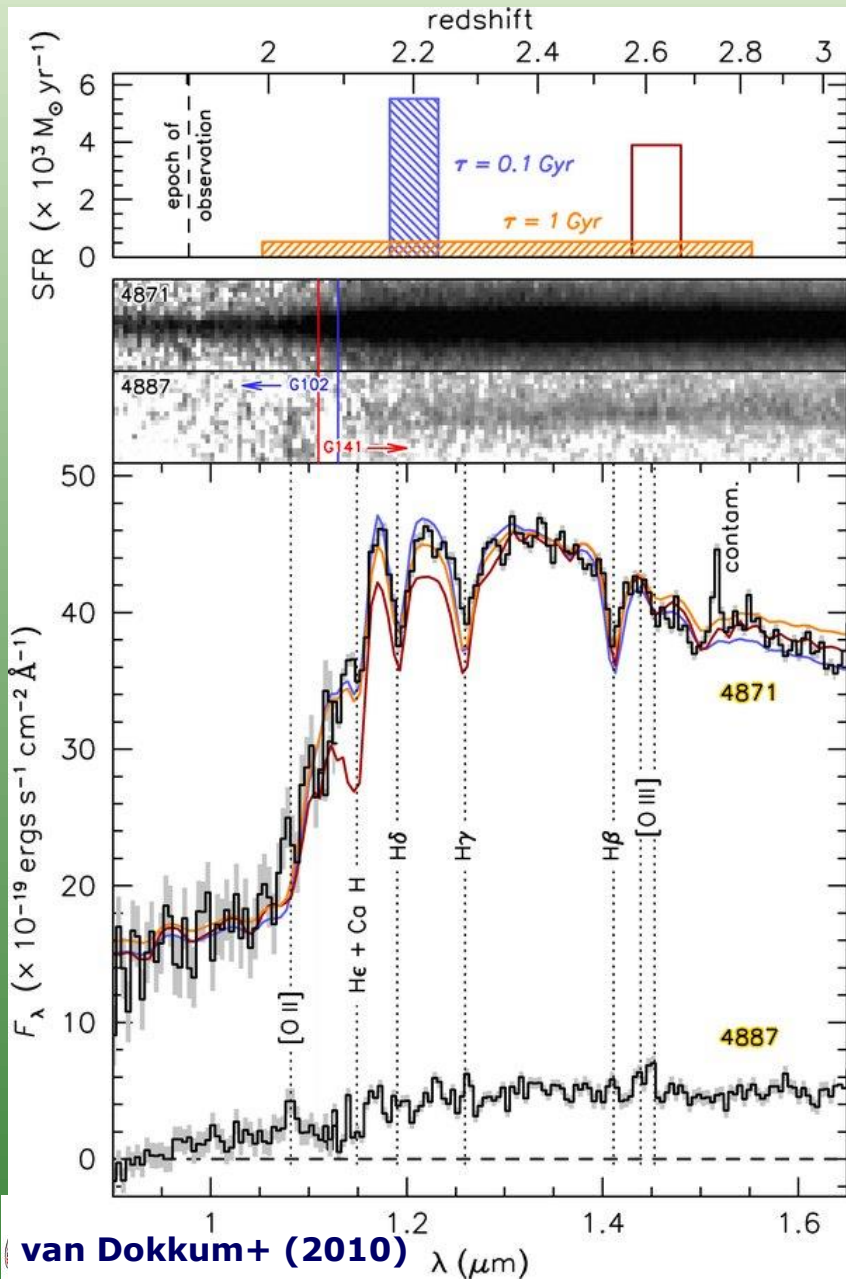
DATA RELEASE V3.0 IS NOW AVAILABLE

V3.0 includes WFC3 mosaics of GOODS-N, GOODS-S, AEGIS, COSMOS, and UDS; and deep grism spectra and redshifts in the Hubble Ultra Deep Field.

3D-HST is a near-infrared spectroscopic survey with the Hubble Space Telescope designed to study the physical processes that shape galaxies in the distant Universe. This Treasury program has been allocated 248 orbits of HST time during Cycles 18 and 19. 3D-HST is surveying ~600 square arcminutes of well-studied extragalactic survey fields (AEGIS, COSMOS, GOODS-S, UKIDSS-UDS) with two orbits of primary WFC3/G141 grism coverage and two to four orbits with ACS/G800L coverage. The short acquisition images, taken in the WFC3/F140W and ACS/F814W filters used for wavelength reference for the spectra, are also deeper than most ground-based observations. When completed, 3D-HST would provide the critical third dimension - redshift - for some ~10,000 galaxies at $z \geq 1$.



3D-HST: low resolution spectra in the NIR

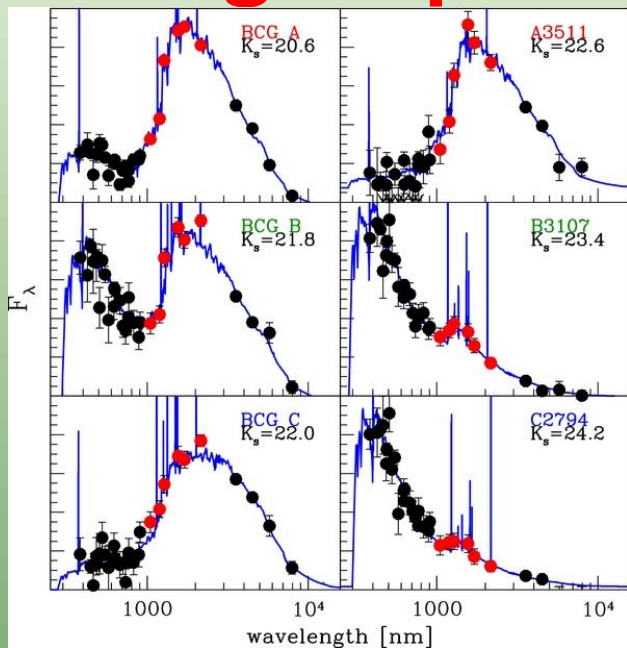


Low resolution spectroscopy with HST to be extended to other wavelengths (e.g., J-band) and deeper (H \sim 24?, Frontier Fields).

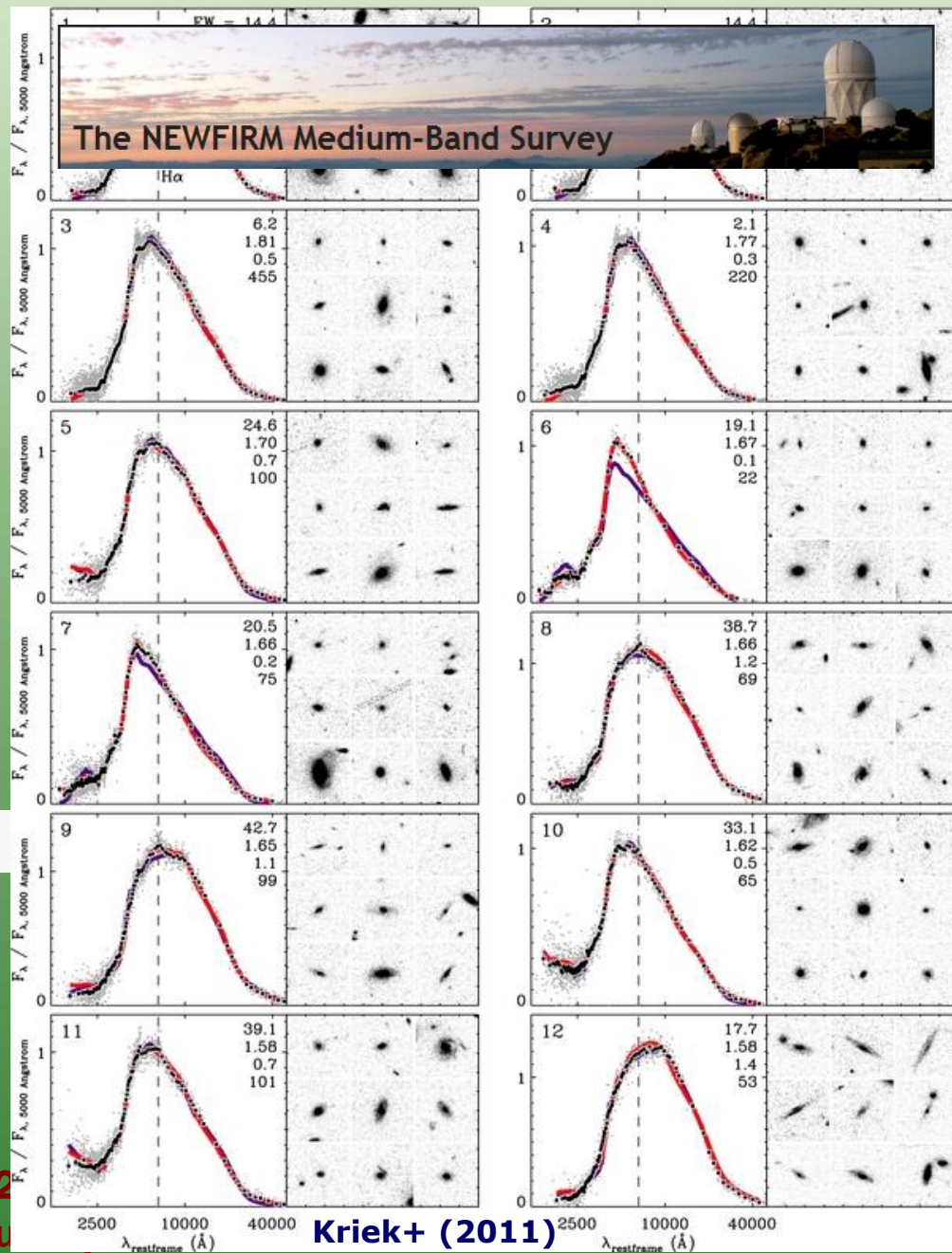
013 See Brammer+ (2012) Whitaker+ (2013), Trump+ (2013), Patel+ (2013), Domínguez+ (2013)...



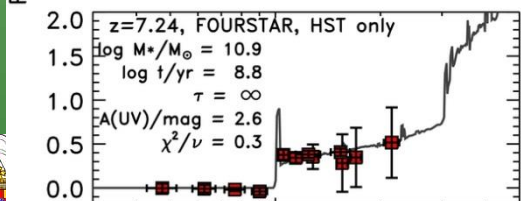
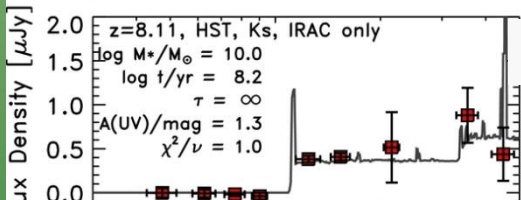
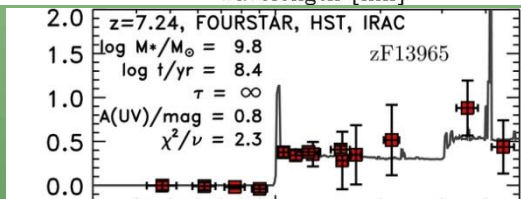
Going deeper: NIR medium resolution imaging



Spitzer+ (2012)



Kriek+ (2011)



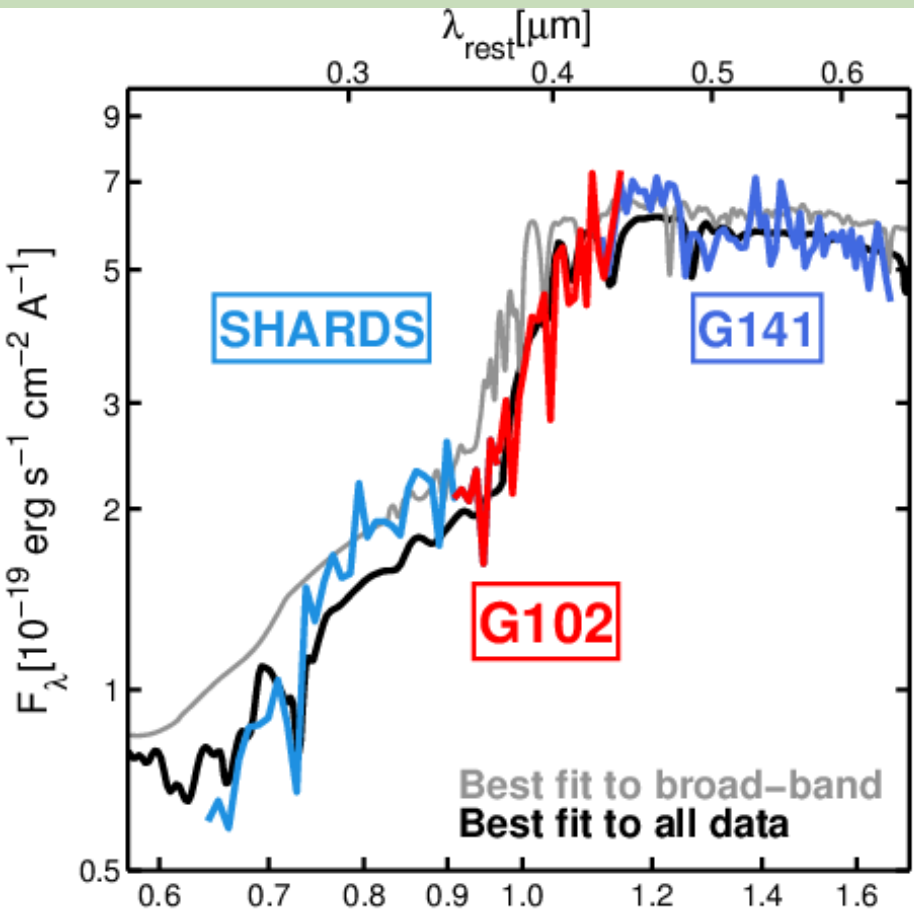
zFOURGE

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Turku

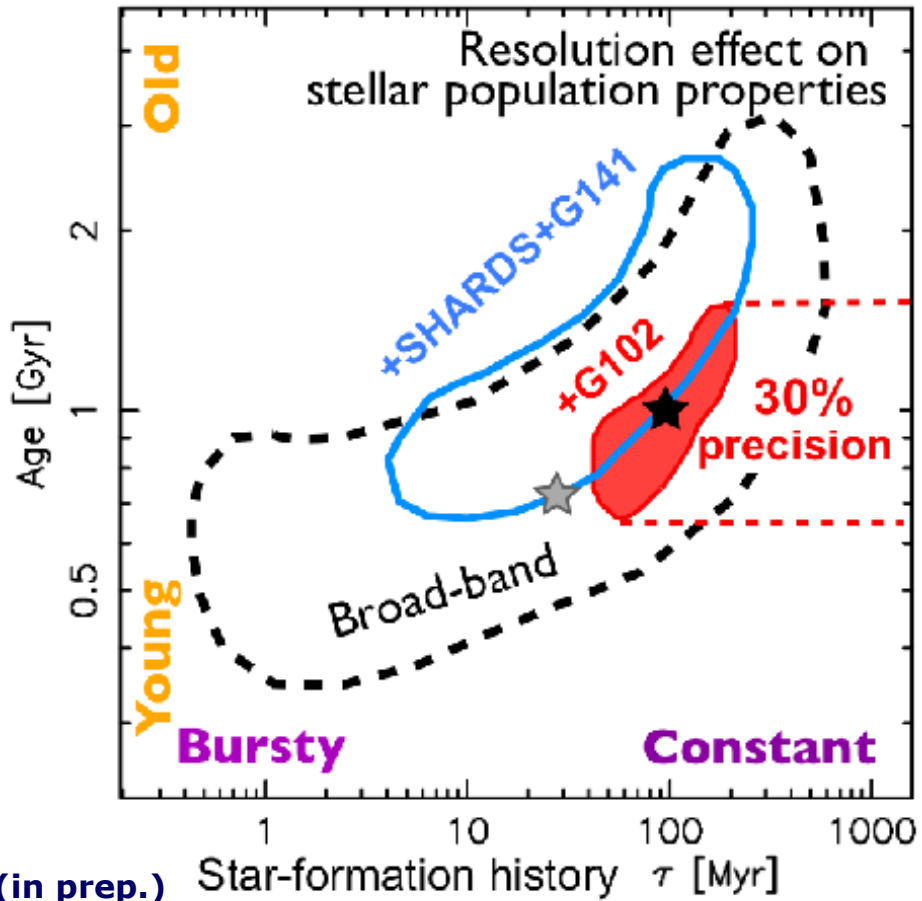
Tilvi+ (2013)



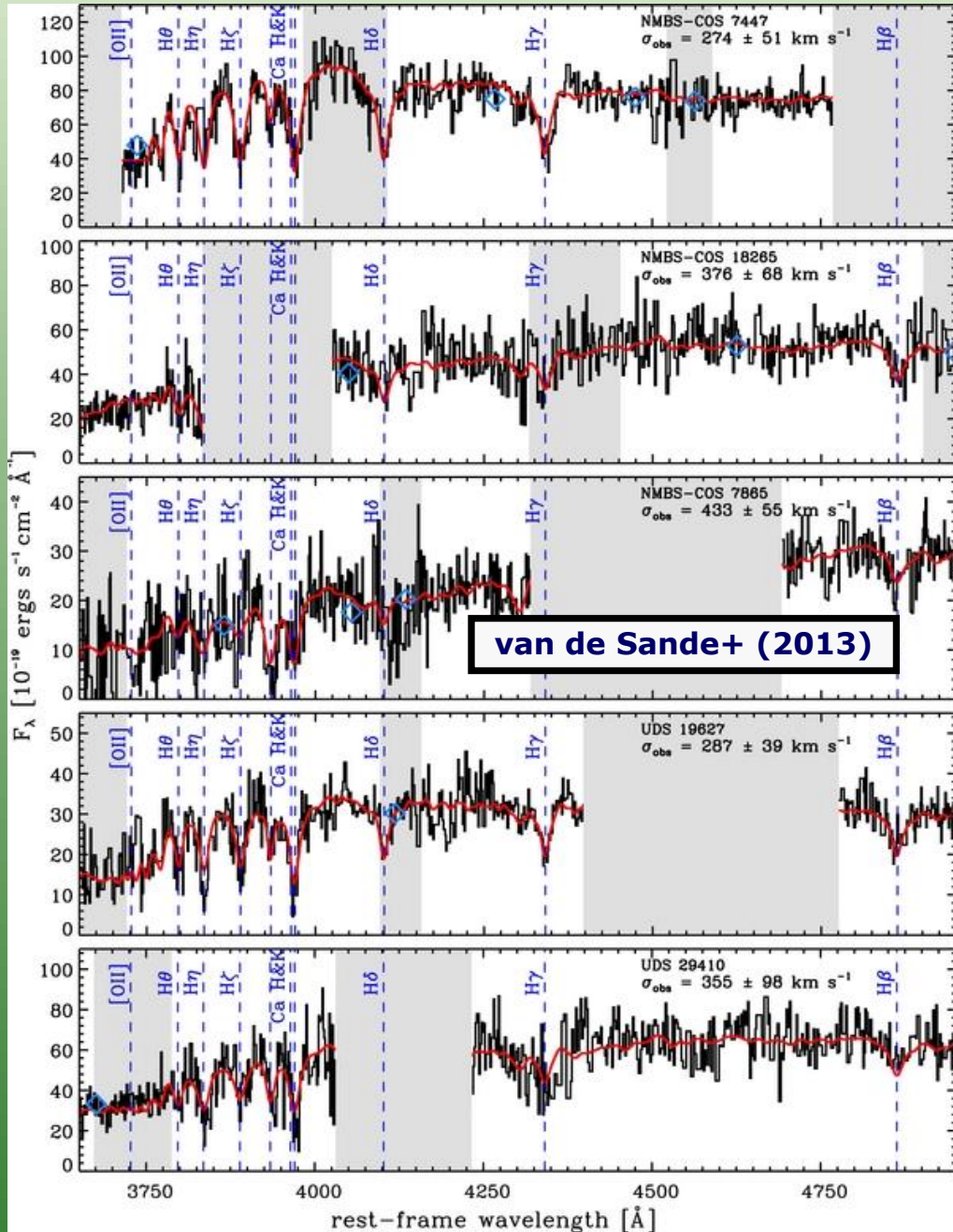
Optical/NIR spectrophotometry: best dataset ever!!



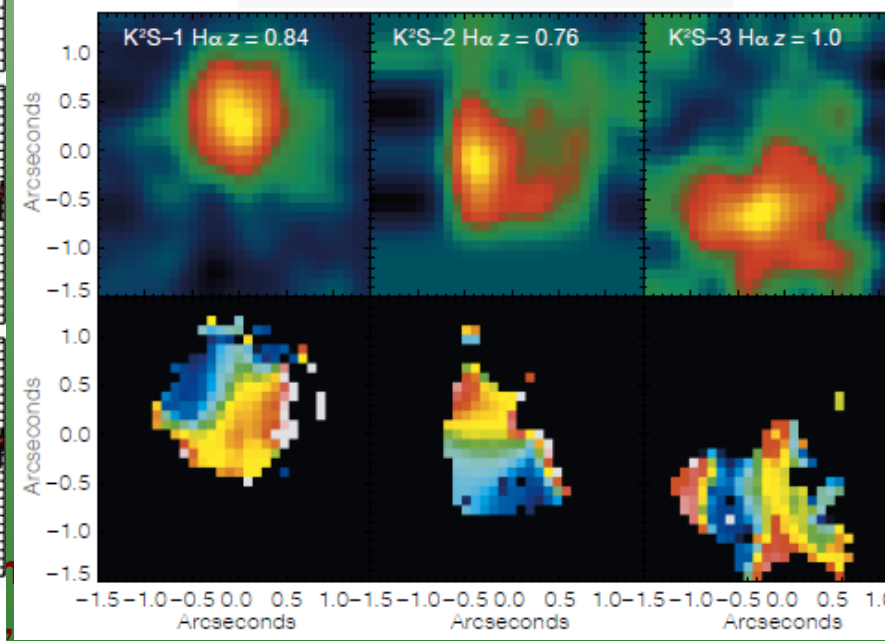
Barro, P-G+ (in prep.)



Higher res (R& θ): dynamics w/ NIR MOS/IFU spectroscopy



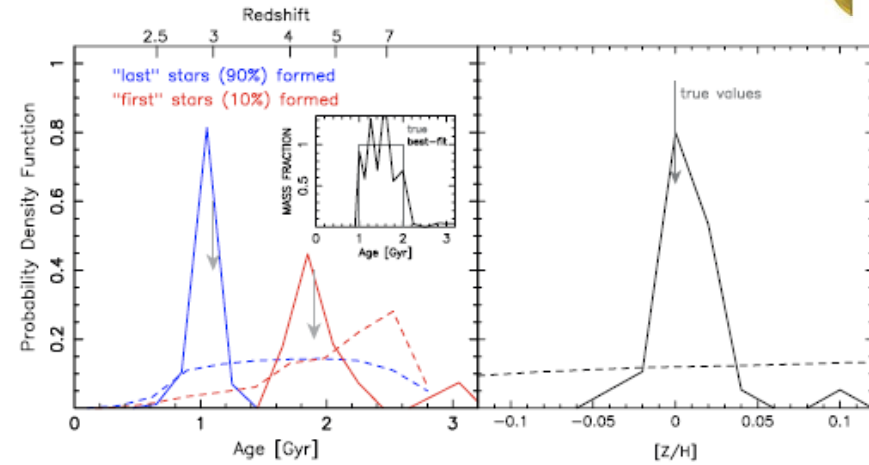
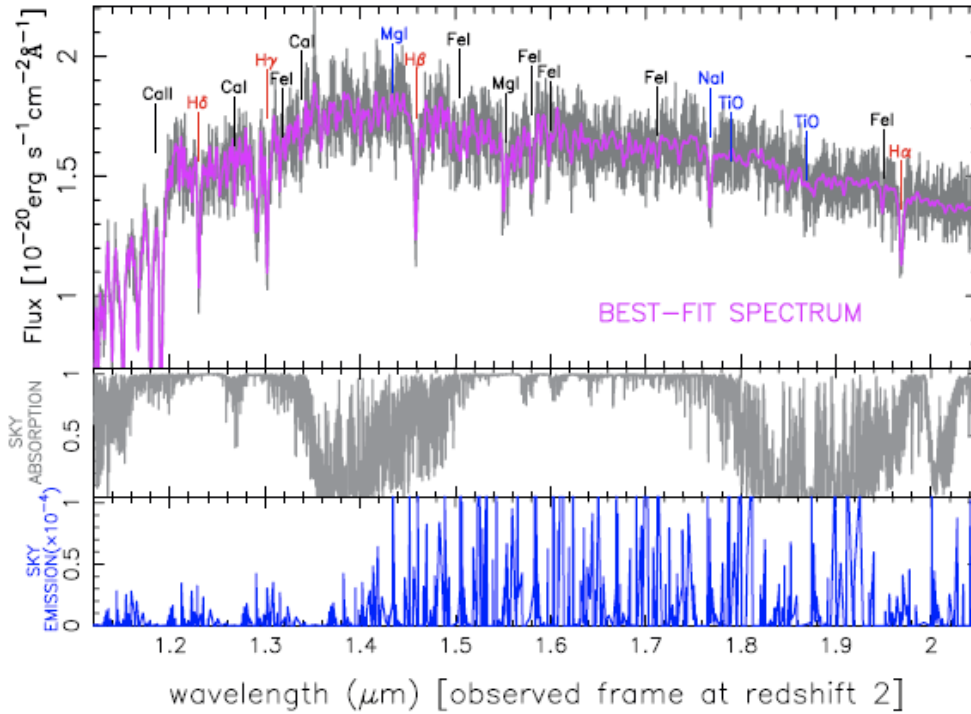
KMOS commissioning



The future of r-f optical SFHs&dynamics: Chronos

Ferreras, Sharples, *et al.* • *Chronos* • ESA L2-L3 white paper (May 2013)

H~26-27 R~1500 spectroscopy!!

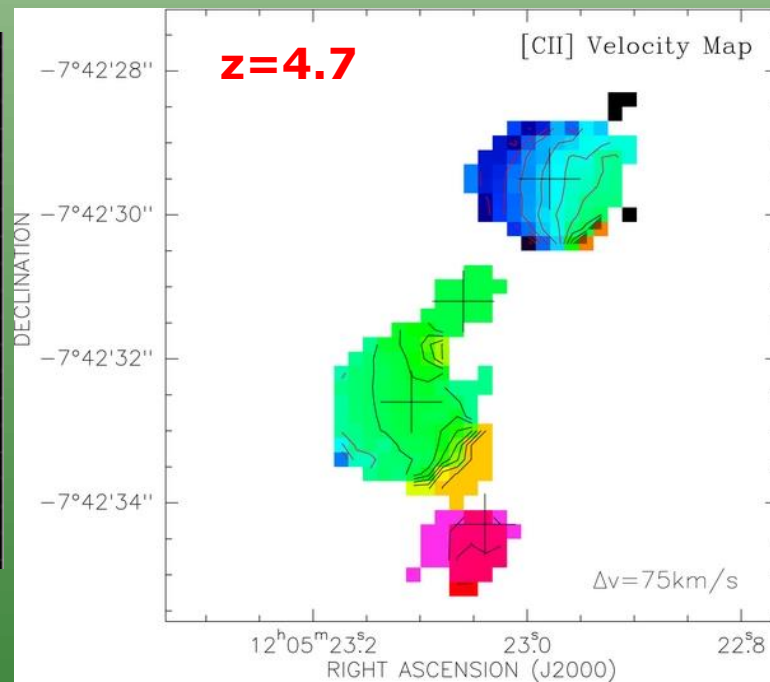
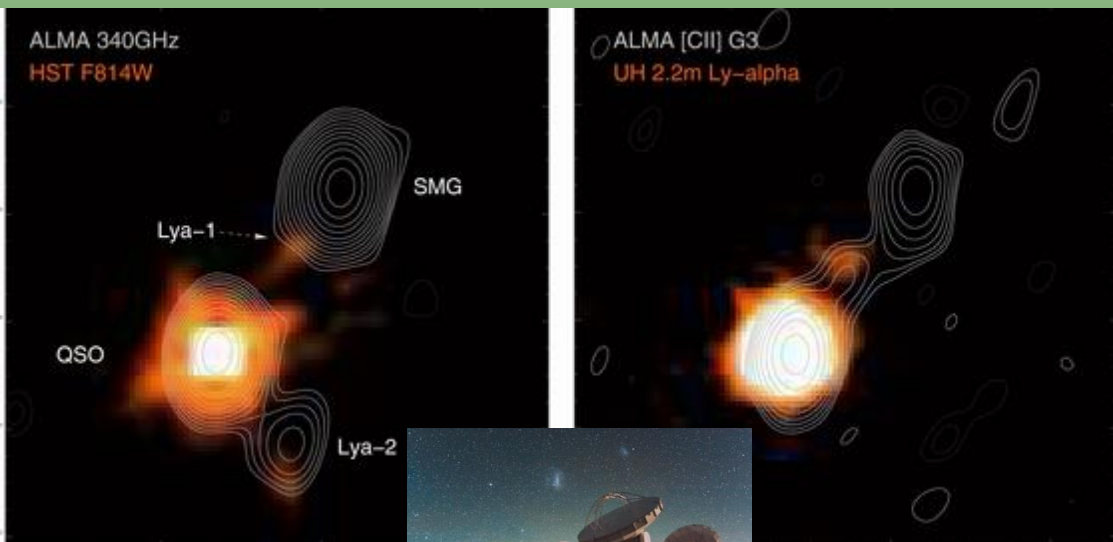
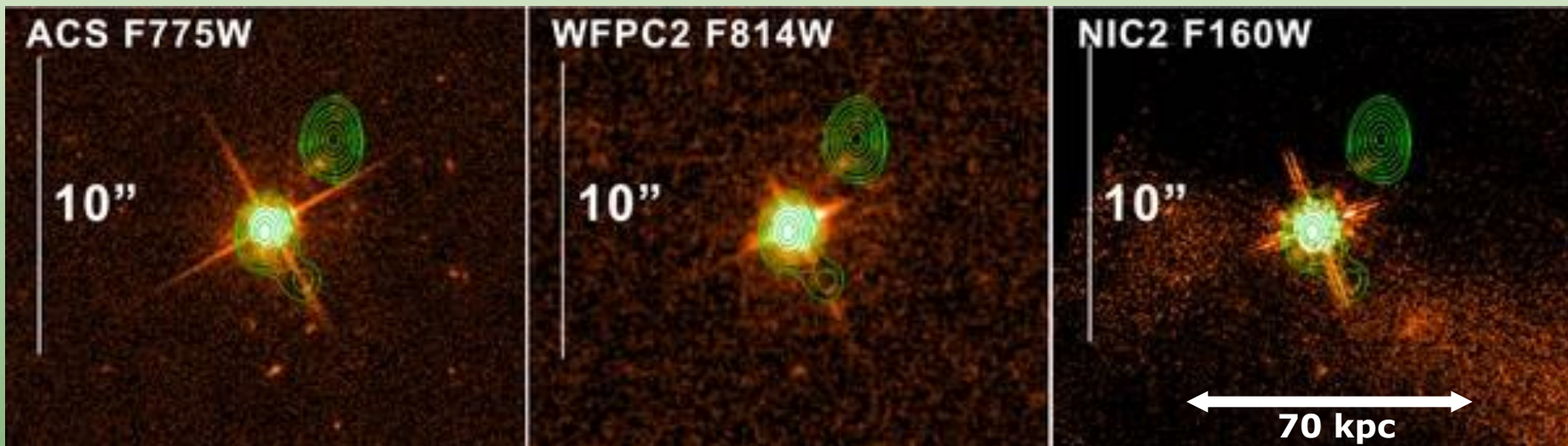


Ferreras & the Chronos collaboration(2013)

EWASS 2013: Symposium 4
Turku, July 8-9, 2013



Witnessing the build-up of massive galaxies with ALMA



Wagg+ (2012), Carilli+ (2013) in 20m with ALMA at 1/3 capabilities!!



Galaxy formation: where from and where to?

- Current paradigm of galaxy formation: (cold) baryons and star formation follow closely the Λ CDM skeleton.

And we (think we) know Λ CDM structure evolution very well.

- But... we see many more massive galaxies at high- z than predicted by models, they are compact and present huge (dusty) SFRs.

downsizing, upsizing, and lots of dust is (still?) a challenge for modelers!!!

- Roadmap for a reconciliation between observers and modelers:

- 1) carry out a detailed study of the stellar populations (mass, SFR, photo- z , age, SFH) in all kinds of $z=1-4$ galaxies (star-forming, post-SB, passive).

medium band optical/NIR imaging and low/high-res spectroscopy:

Current surveys: SHARDS, 3DHST, z-FOURGE, NMBS,...

Near Future: grism in Frontier Fields, MOSFIRE, EMIR, J-PAS, Chronos...

- 2) include (gas and stars) dynamics and environment in the study (to understand assembly mode –minor vs. major wet merger, disk instabilities, timing-).

2D optical/NIR/mm spectroscopy: Keck/MOSFIRE, KMOS, ALMA, MUSE,...

- 3) improve stellar populations models and fitting techniques.

- 4) revise evolution models according to new results from this observational effort.