Gas metallicity gradients and age profiles in face-on disk galaxies

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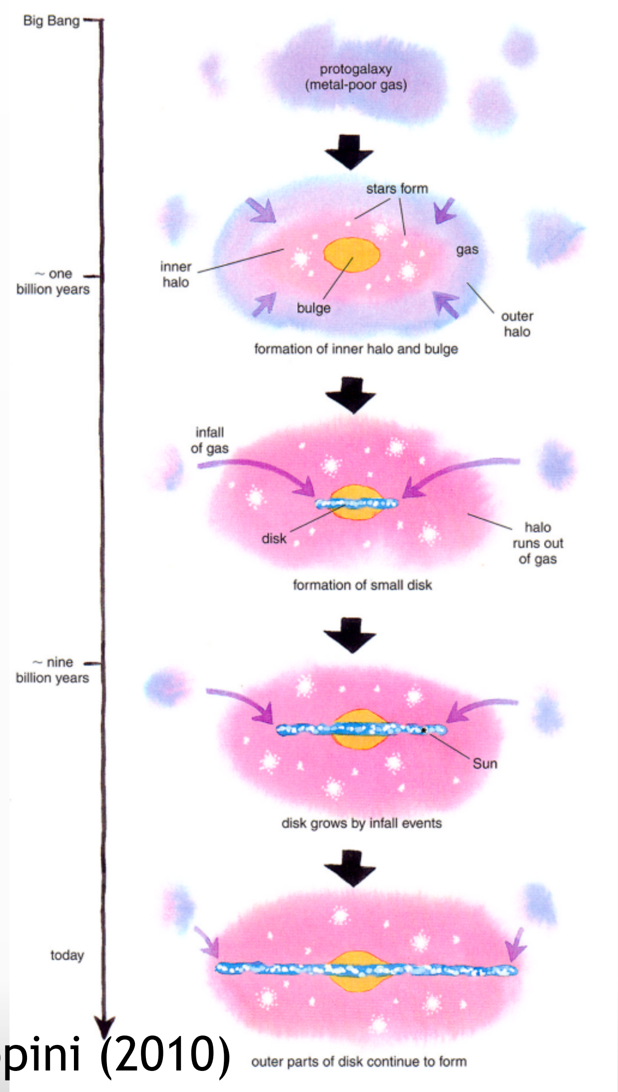
Why to study metal and age distributions?



Chiappini (2010)

In the current paradigm for disk formation, disks form inside out

Age and metallicity gradients are direct consequence of an inside-out growing.

- Chemical abundance gradients are affected by the combined action of *inflows*, *outflows*, *secular evolution*, *mergers and interactions*, *gas stripping*.
- In the current cosmological paradigm these processes take place as galaxies are *assembled in a non-linear way*
- As a consequence: the imprint chemical patterns in the stellar population and the ISM store valuable information for galaxy formation studies.

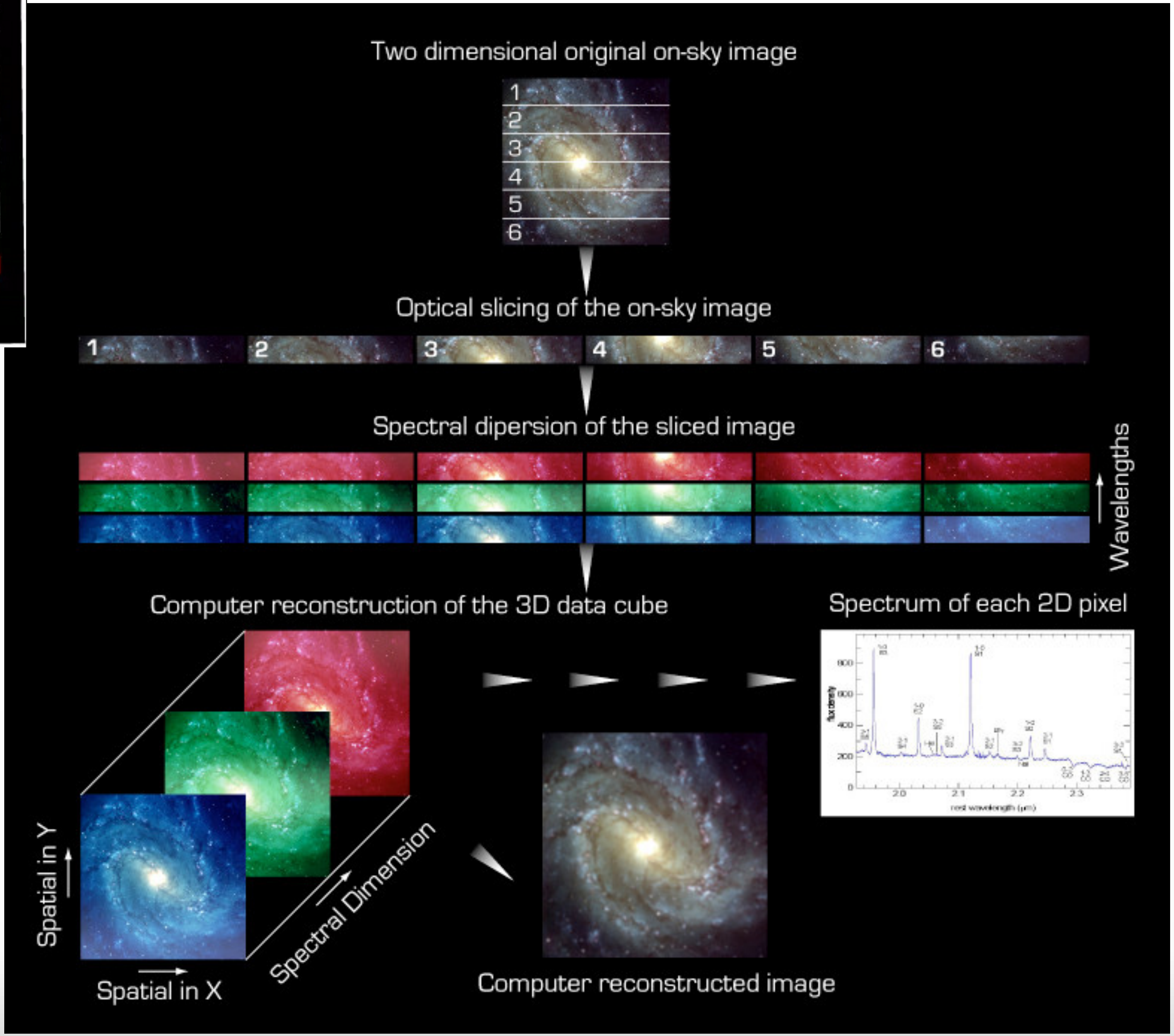
Abundance gradients in disk galaxies

- Most observational studies are devoted to the **gas-phase** abundances in discs traced by HII regions (Shields 1974; Zaritsky et al. 1994; Bresolin+2012; Sanchez+2012, 2014)

- However, an important fraction of the synthesized chemical elements is locked into stellar populations as the gas is transformed into stars

- Hence the chemical abundances of the SPs provide complementary information to understand the **chemical loop between the gas-phase medium and the SPs within a context of galaxy formation**


y
x
wavelength


Two dimensional original on-sky image
1
2
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6
Optical slicing of the on-sky image
1
2
3
4
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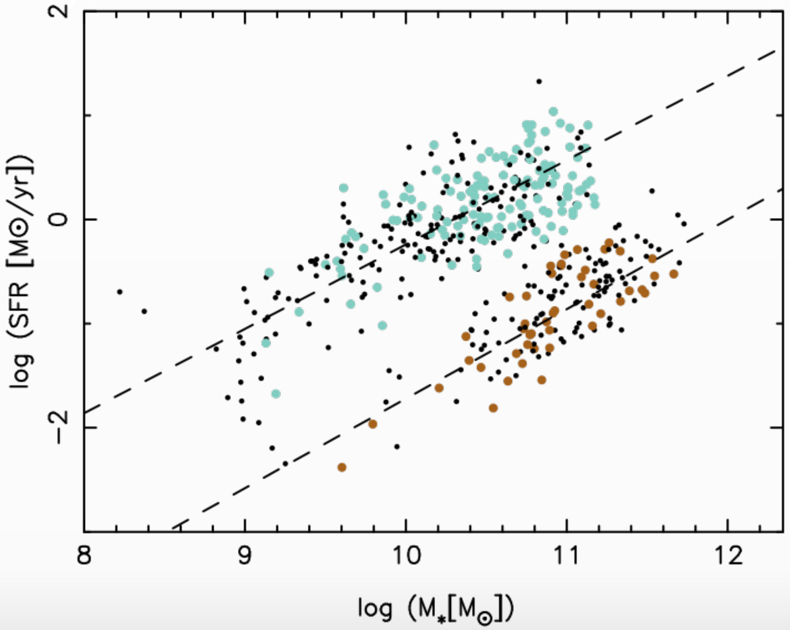
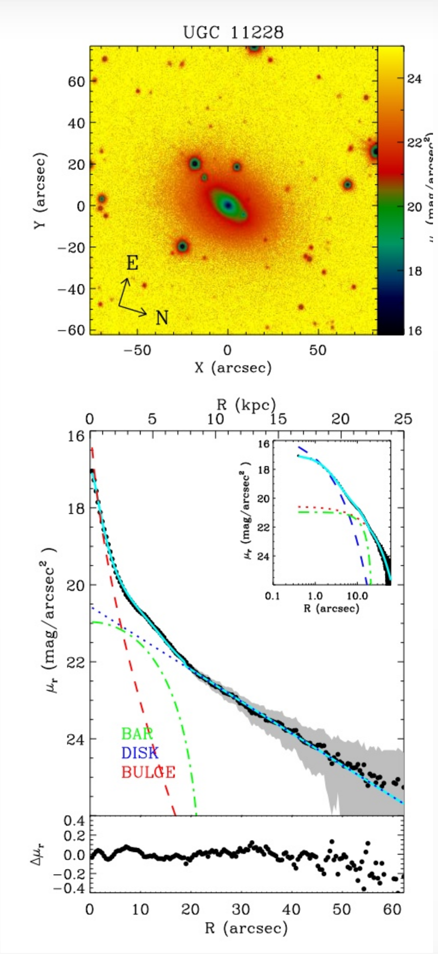
6
Spectral dipersion of the sliced image
Wavelengths
Computer reconstruction of the 3D data cube
Spectrum of each 2D pixel
Spatial in Y
Spatial in X
Spectral Dimension
Computer reconstructed image

The sample



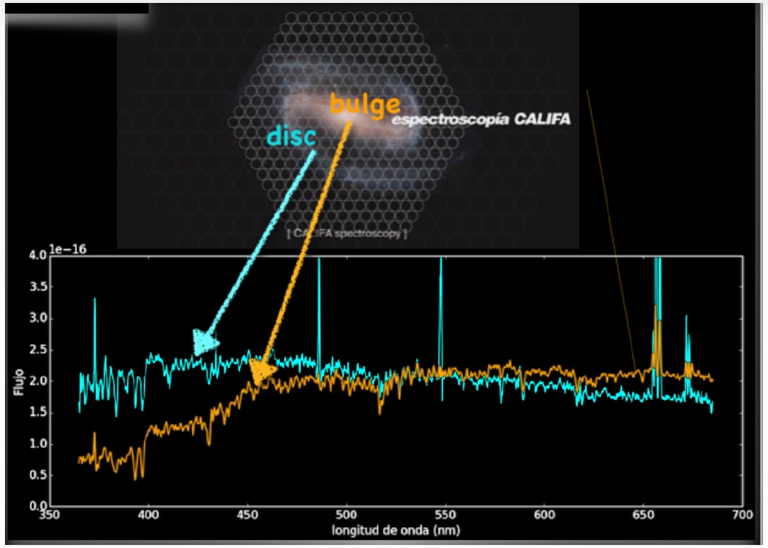


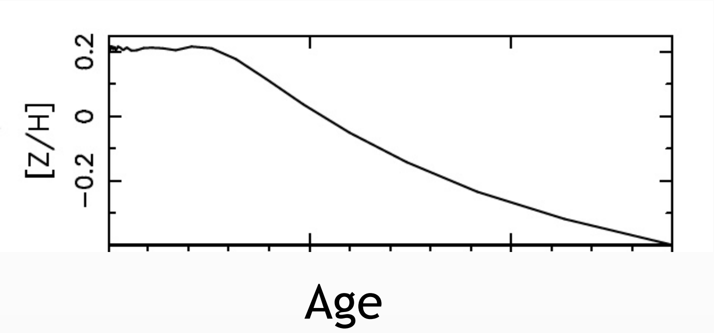
255 disk galaxies galaxies from the CALIFA survey with inclinations < 60

Disk galaxies → it does have a disk in the photometric decomposition

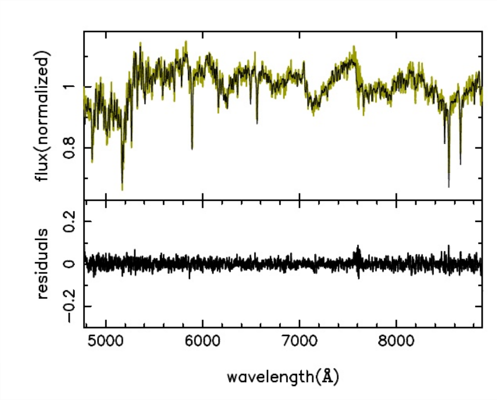
Mendez-Abreu et al. (2017)

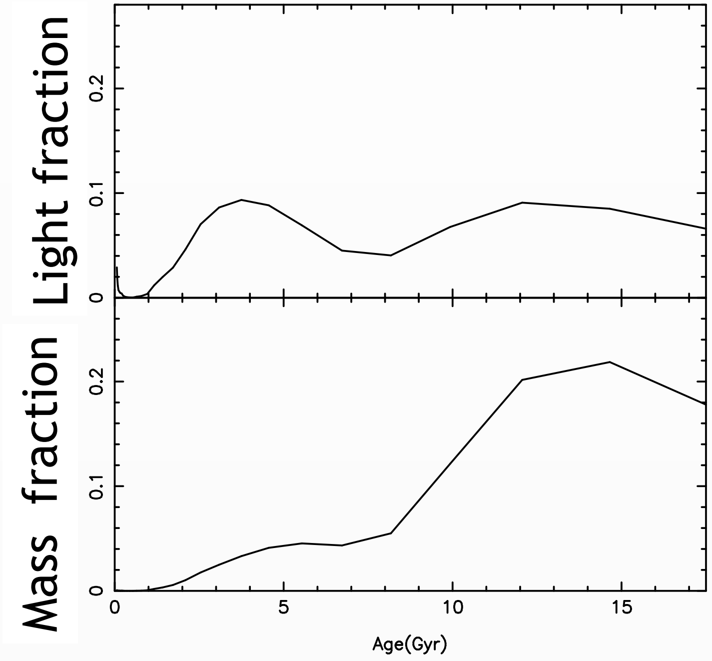
Stellar Population gradients in disk galaxies





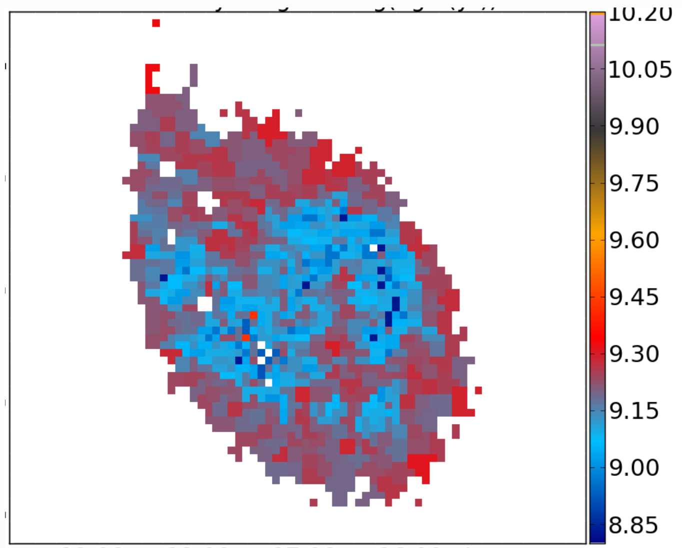
Inversion algorithm
(stecmap,
Ocvirk+2016ab)





Age (LW)

Age (MW)



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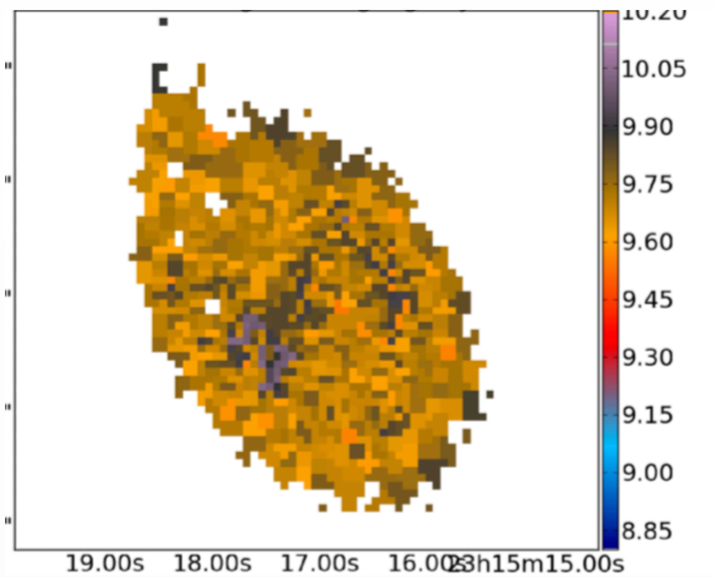

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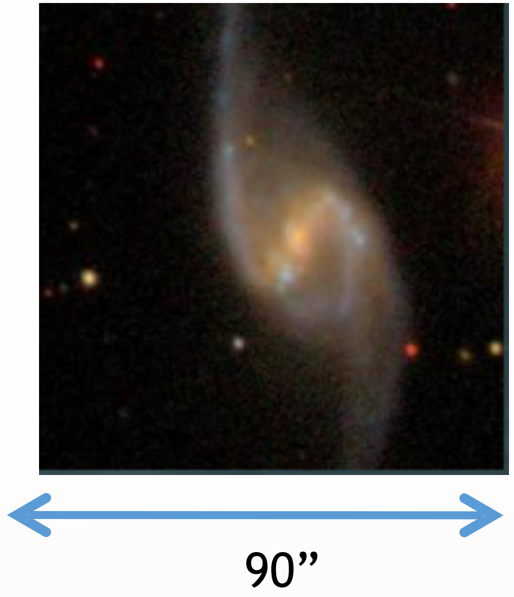
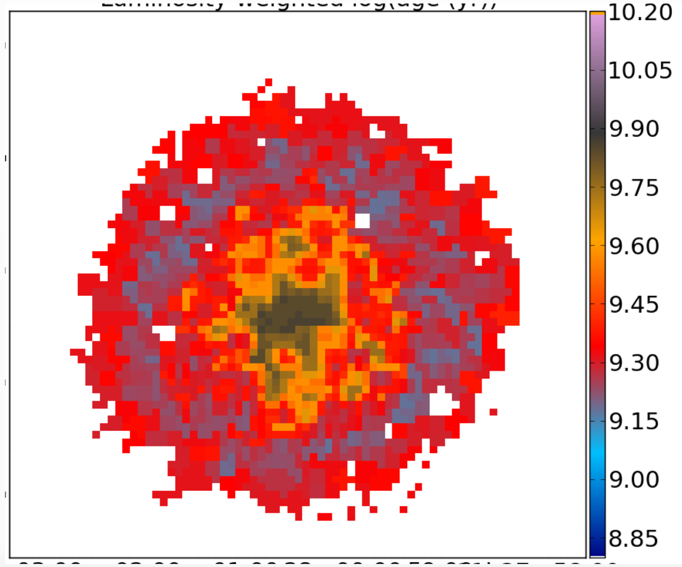


90”



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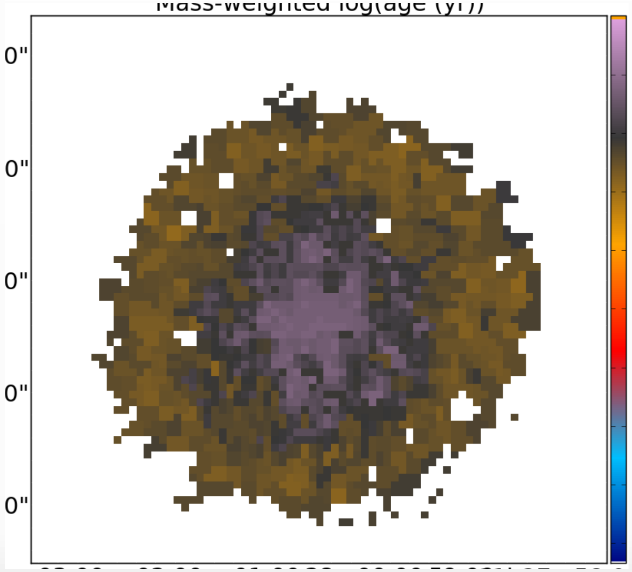

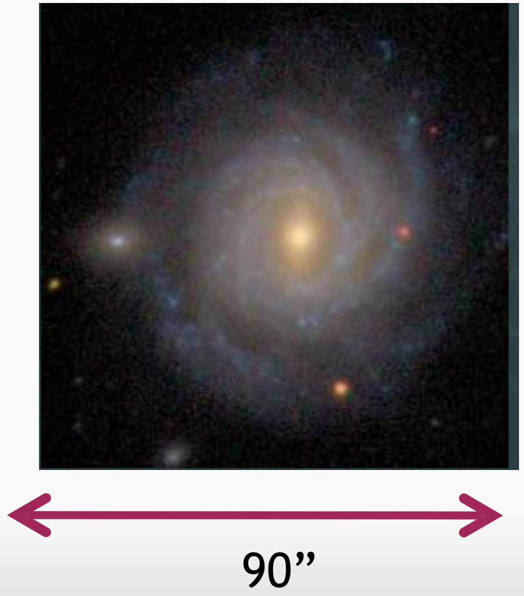

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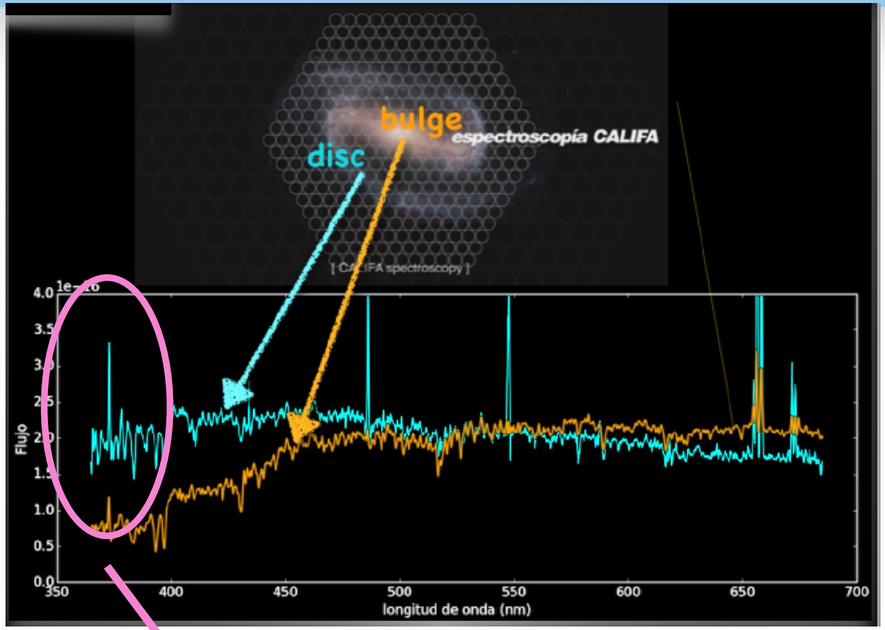
Abundance gradients in disk galaxies

Gas phase metallicities with different calibrations (M13, PP04, P12):

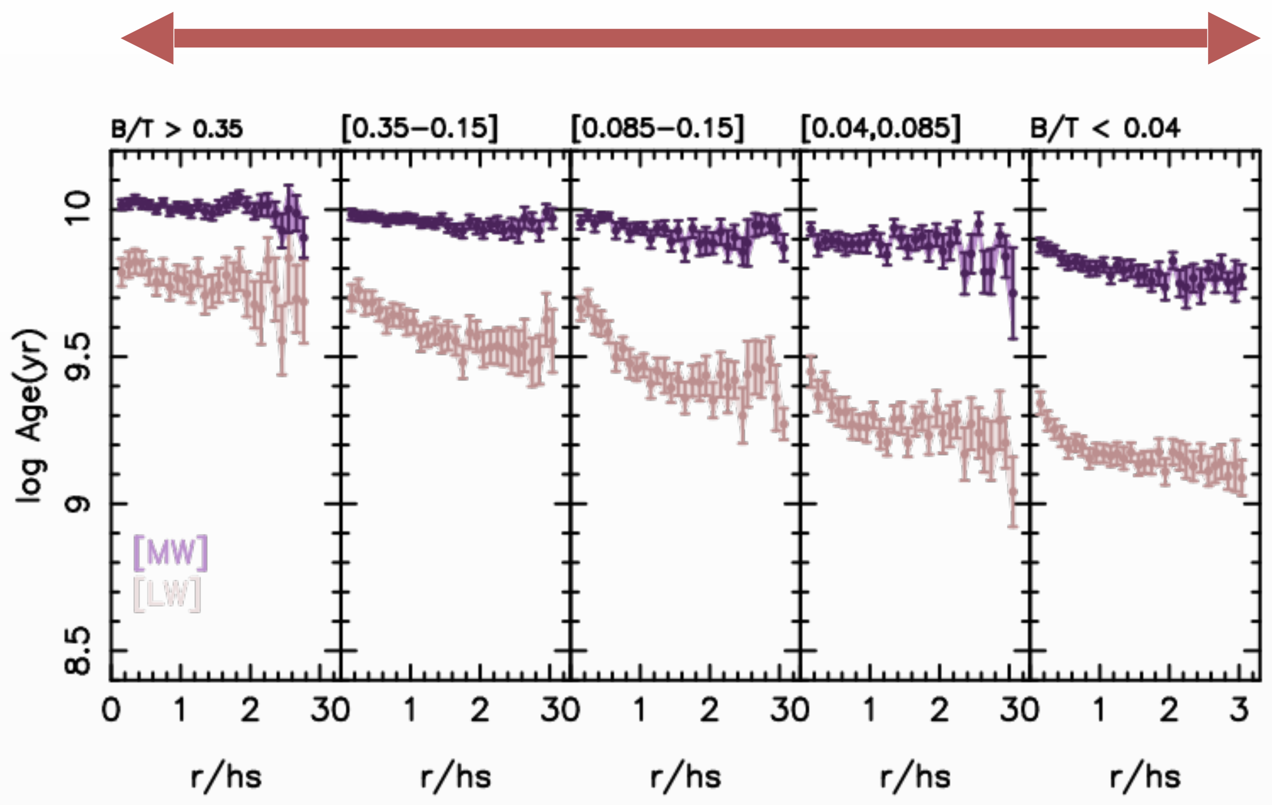


warm gas metallicities

Mean gradients in B/T bins

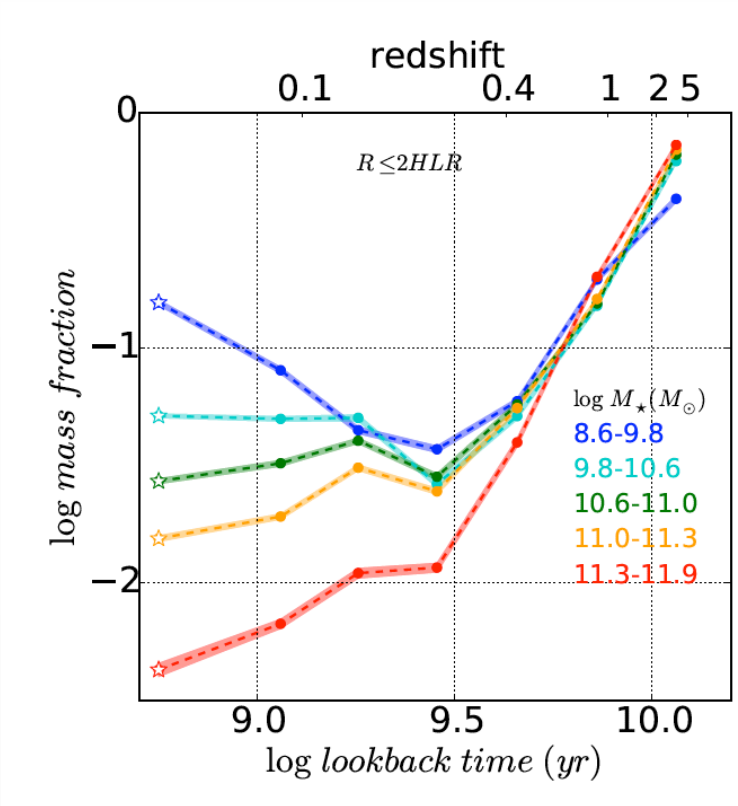
prominent bulge

disk dominated



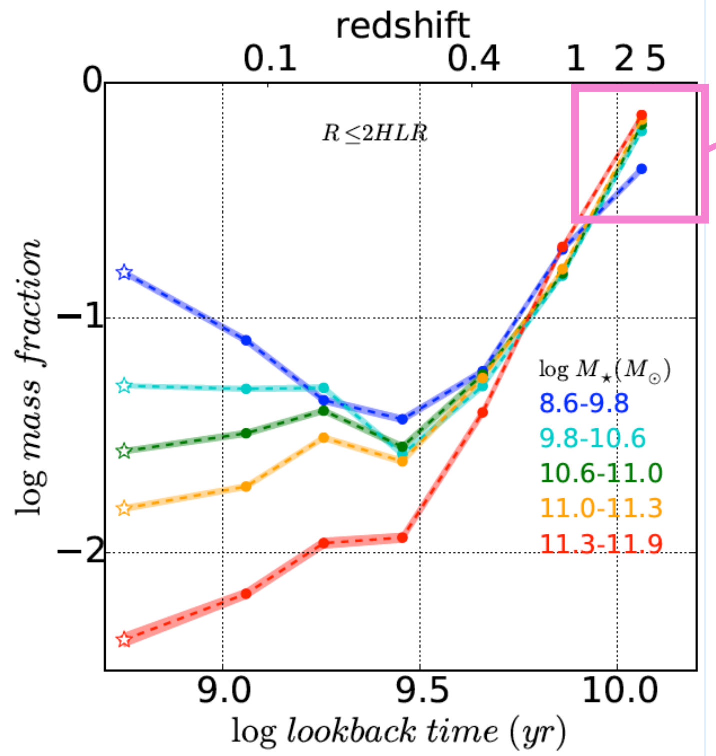
- Flat mass-weighed age profiles → all disks dominated (in mass) by old stars, even at large distances.
- Mild, negative Luminosity-weighed age profiles

"SFH" as a function of mass



Global

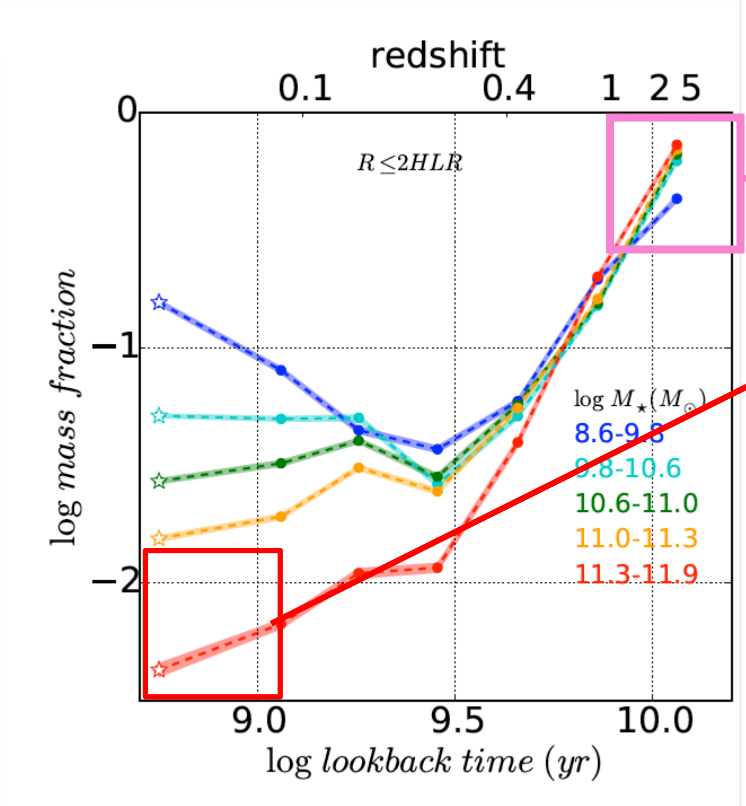
"SFH" as a function of mass



Global

Independently of the mass, disk galaxies formed ½ of their total mass before z~1

"SFH" as a function of mass

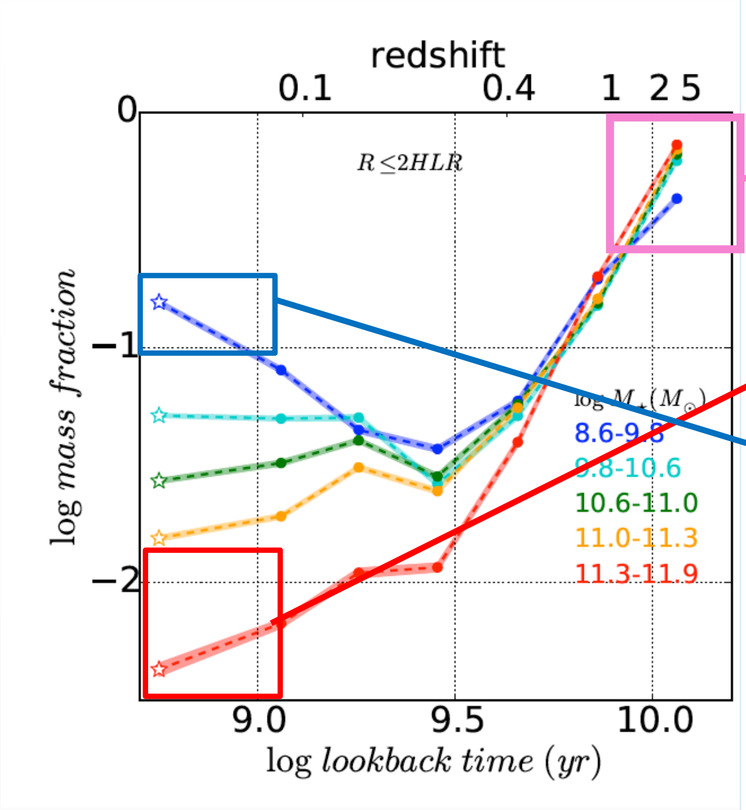


Global

Independently of the mass, disk galaxies formed ½ of their total mass before z~1

More massive galaxies 'quench' earlier

"SFH" as a function of mass



Global

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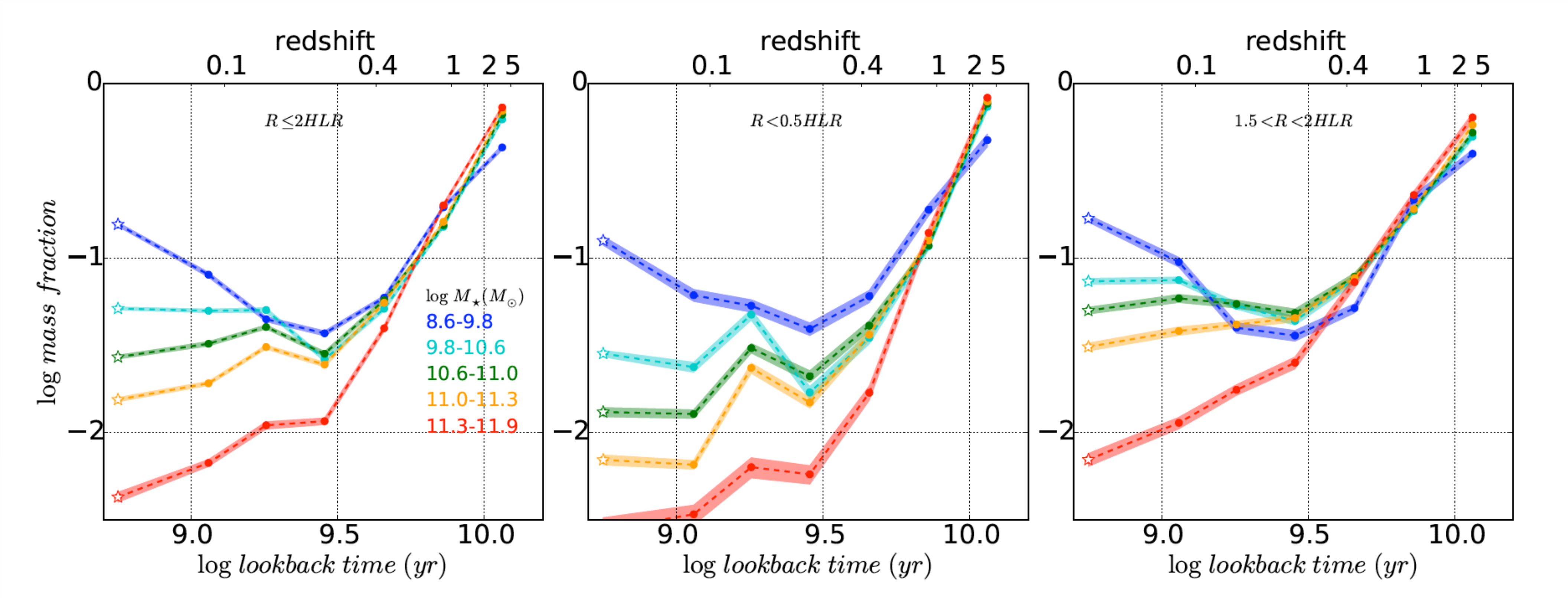
More massive galaxies 'quench' earlier

Less massive galaxies have a epoch of 'rejuvenation'

"SFH" as a function of mass

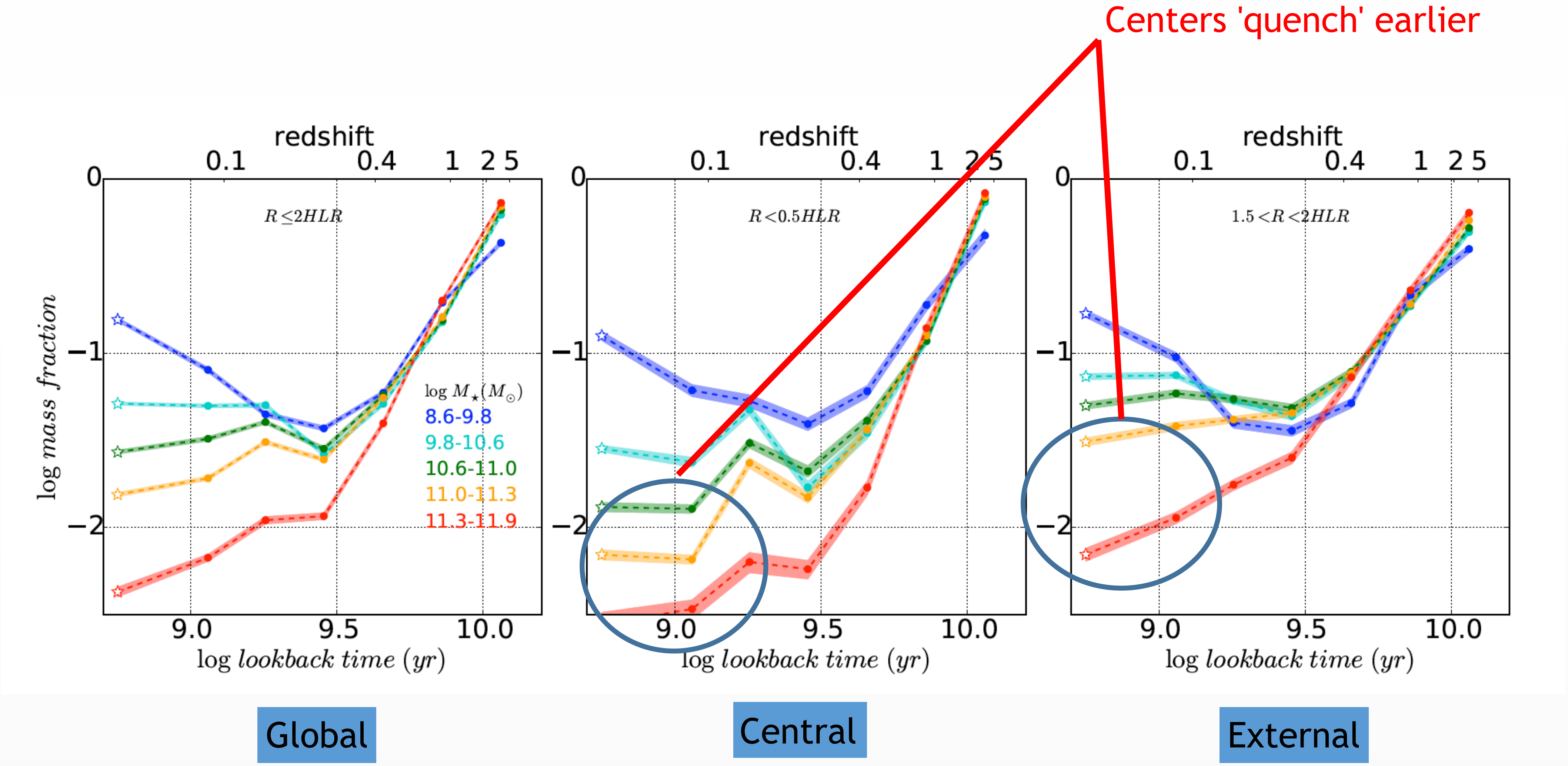


Global

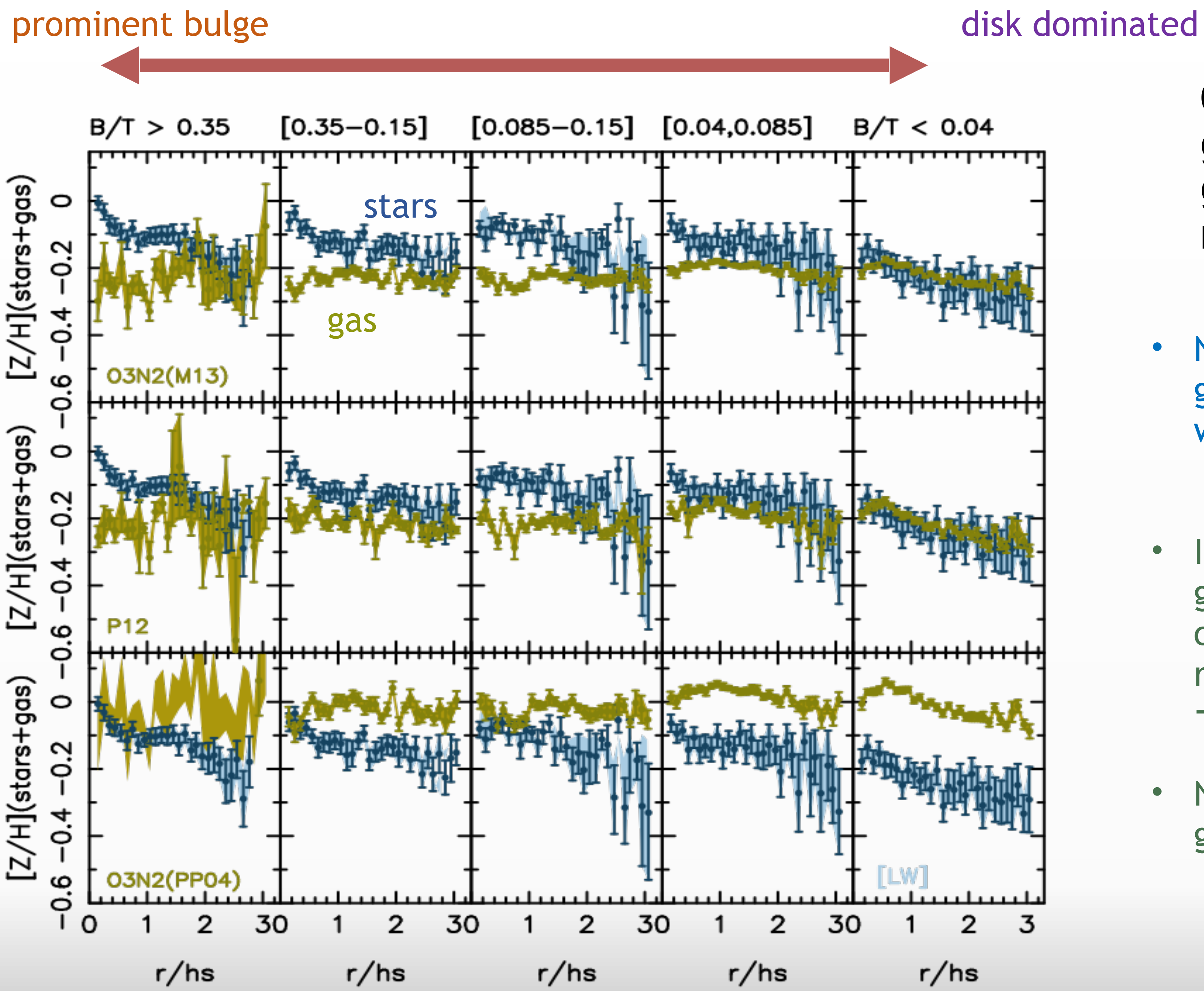
Central

External

"SFH" as a function of mass



Contrary to what happen in E galaxies → centers growth in mass (a factor of ~3.5 for a MW-type galaxy between z=2.5 and z~1)

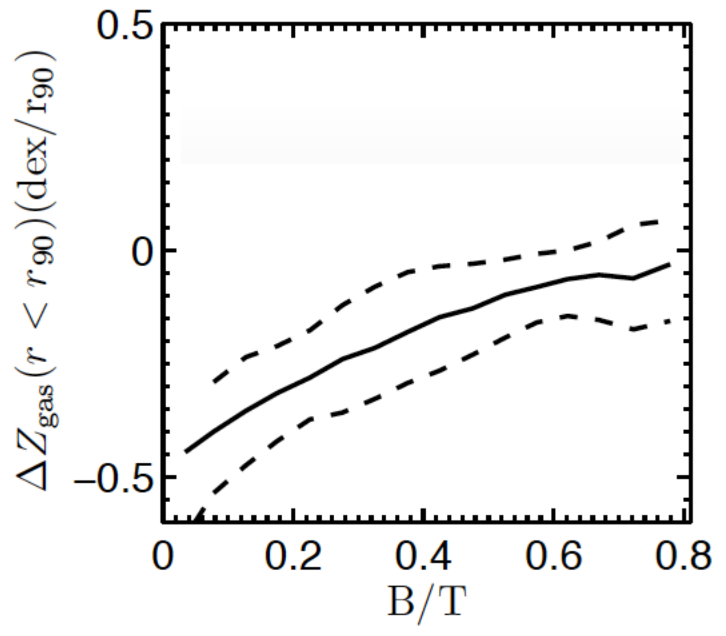


Comparison of stellar and gas-phase metallicity gradients in bins of B/T ratio

- Negative stellar metallicity gradient → compatible again with *inside-out*
- In general, gas-phase metallicity gradients are flatter than stellar ones → difficult to obtain in a regular chemical evolution model →
- Need a process that flattens the gas-phase metallicity gradient

gas-phase metallicity gradient vs B/T

If gas is consumed when the bulge forms during galaxy mergers →
a correlation between metallicity gradient and B/T is expected



Fu et al. (2013)

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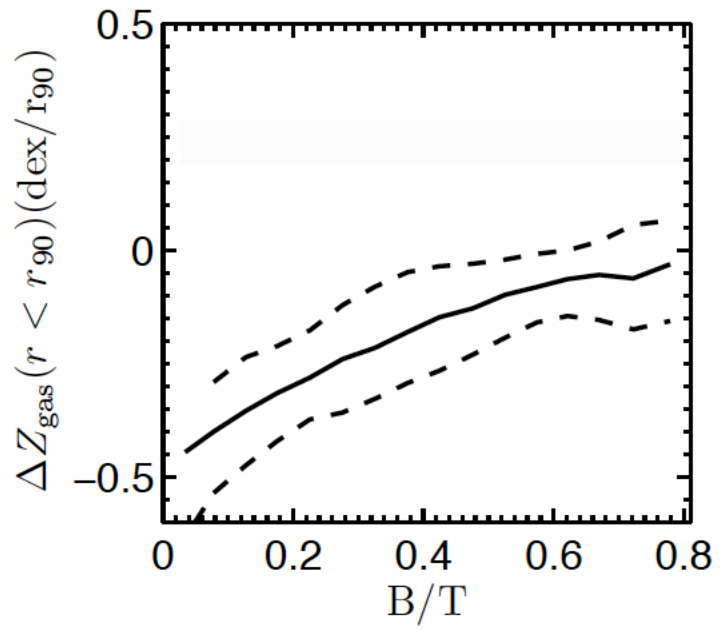

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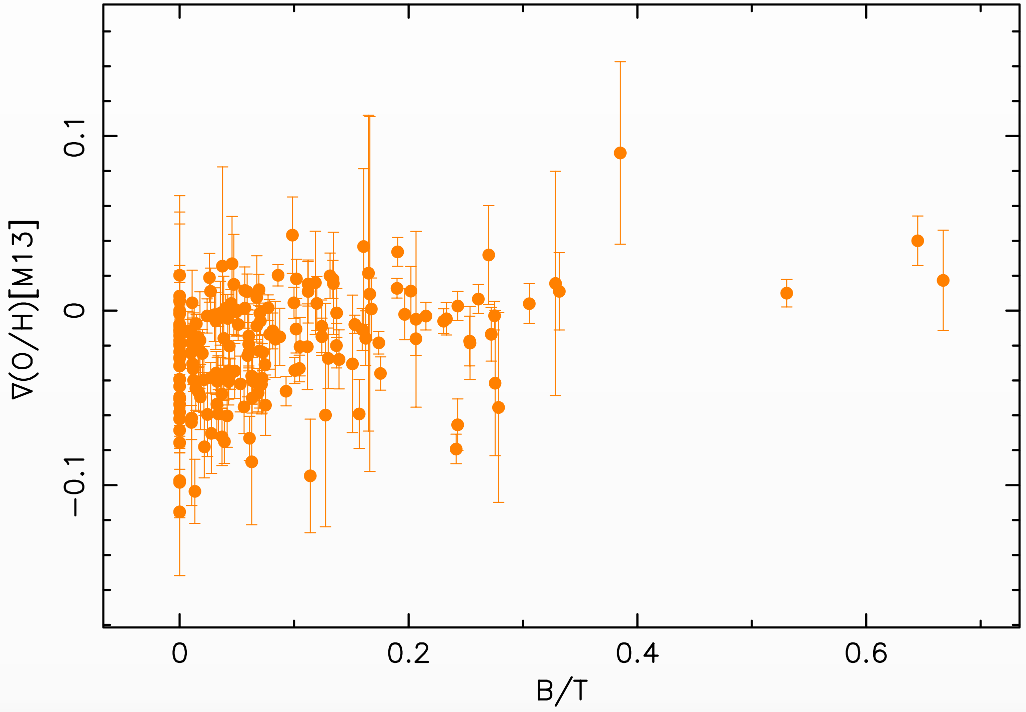

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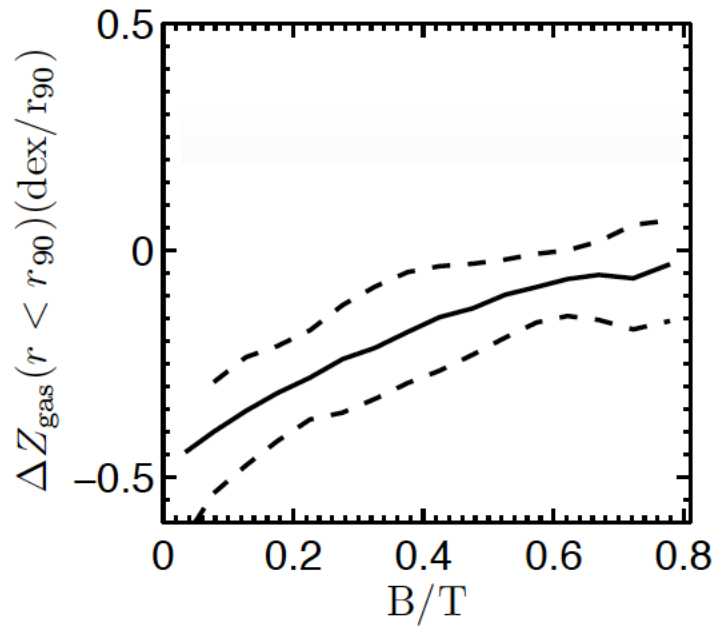
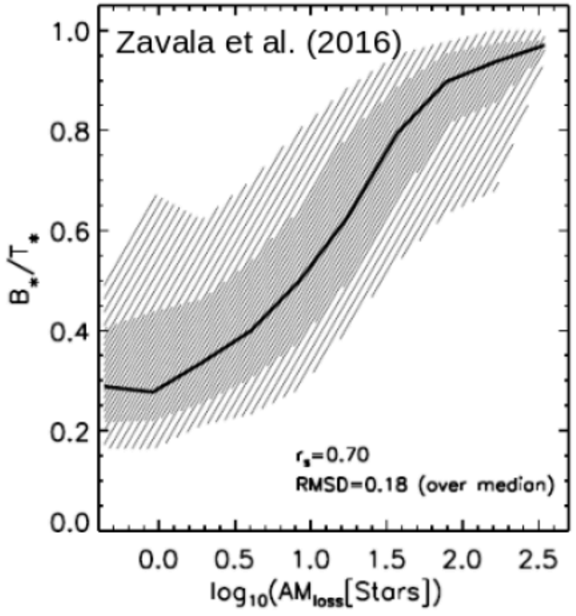
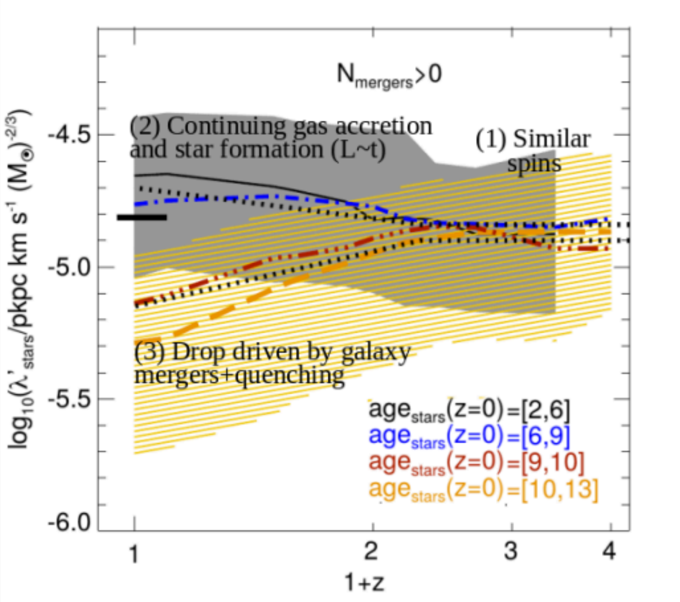


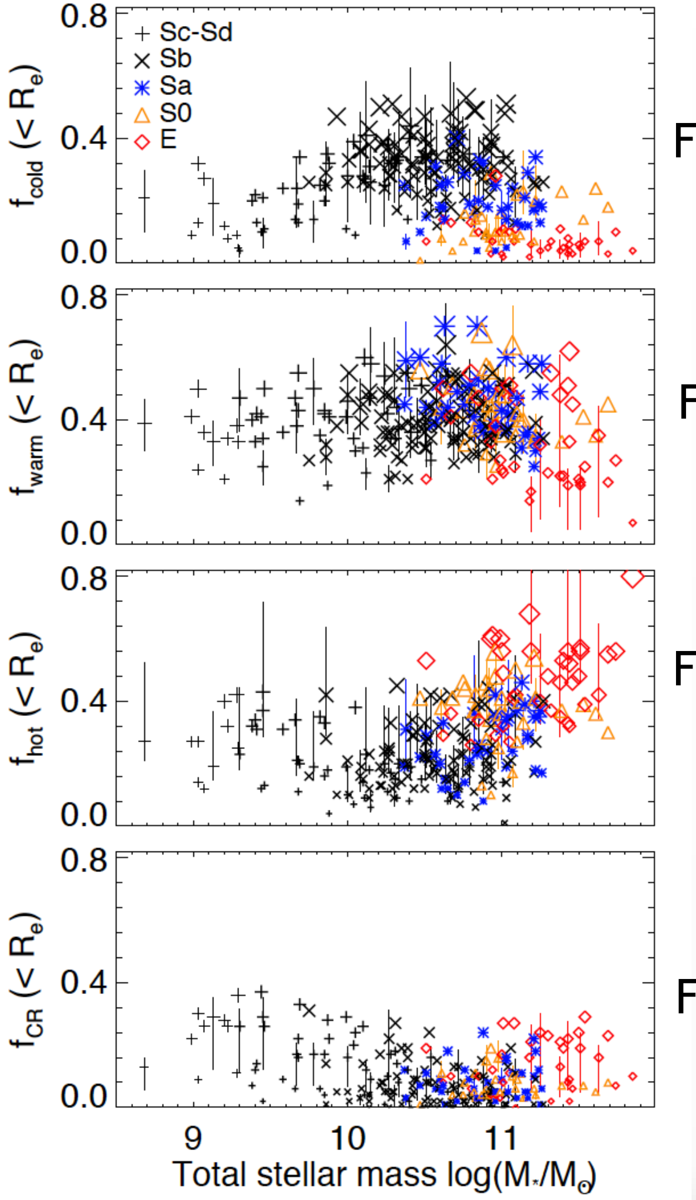




Fu et al. (2013)

Lagos et al. (2017)

Orbit superpositions (Schwarzschild models)



Fraction of cold orbits

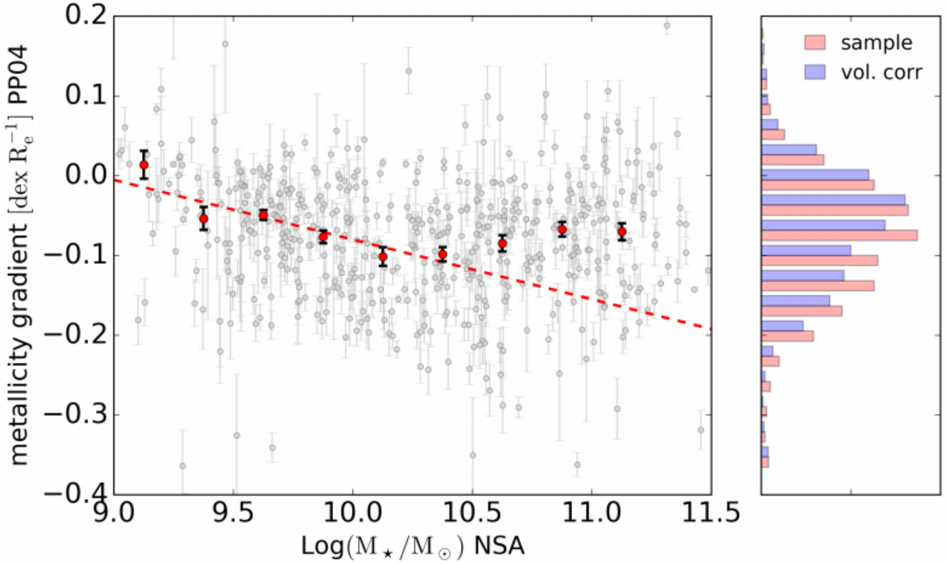
Fraction of warm orbits

Fraction of hot orbits

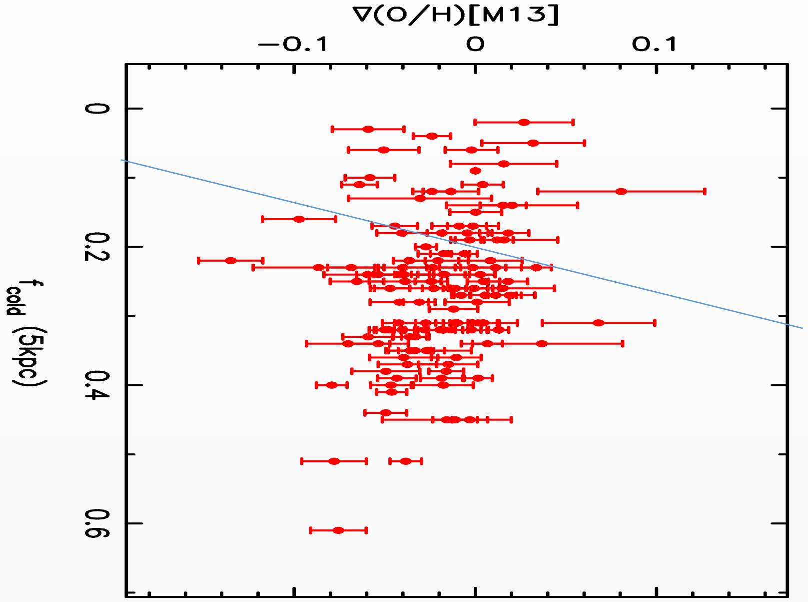
Fraction of counter-rotating

Zhu et al. (2018)

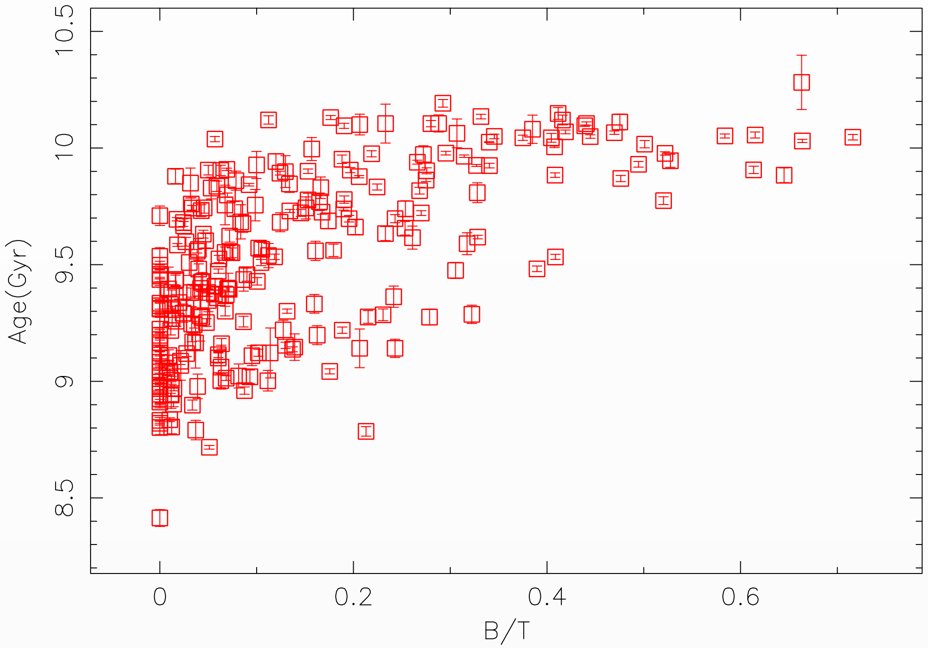
Belfiore et al.

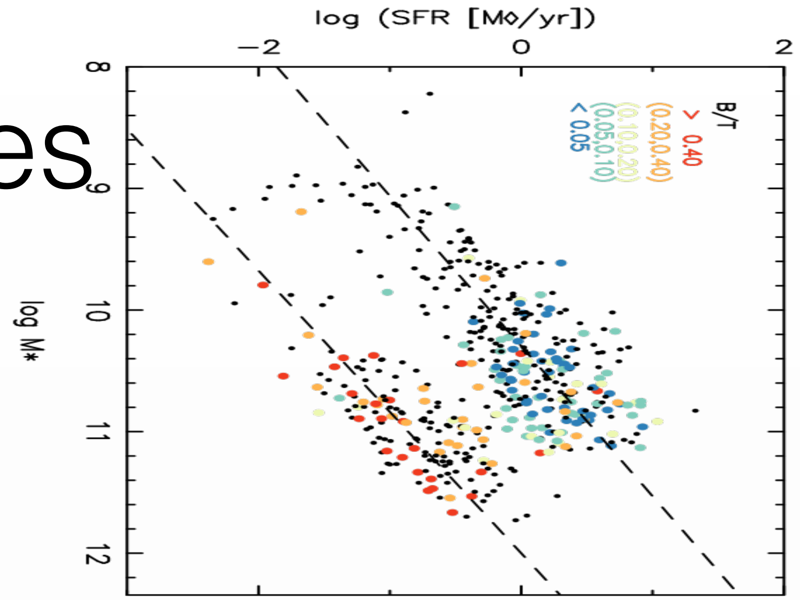


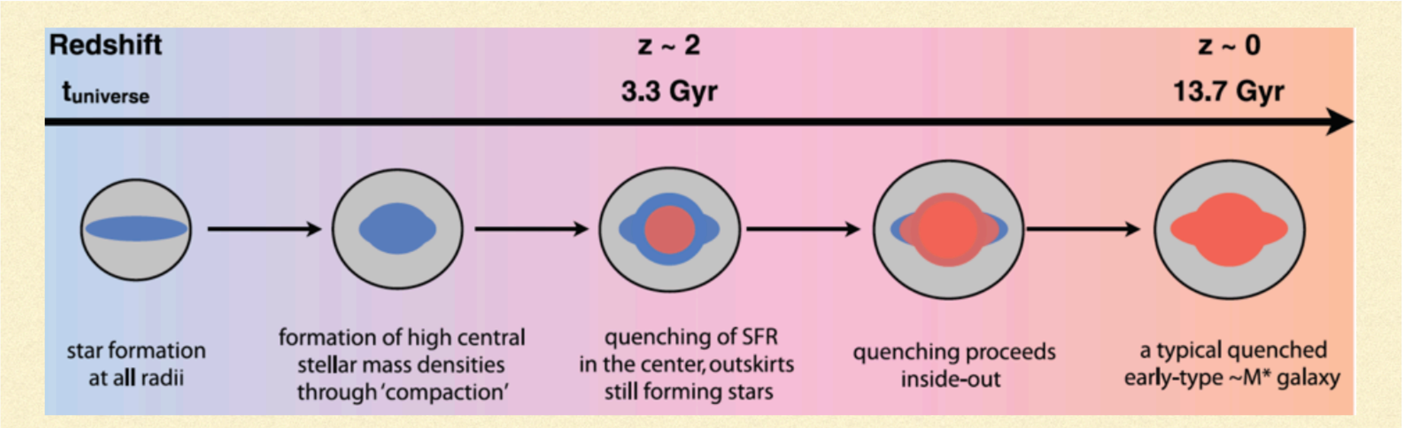
Slope of the gas-phase metallicity gradient vs fraction of cold orbits in galaxies



The formation of disk galaxies







Tacchella+2016

Summary

- **Old stellar populations dominate the mass budget in disks**; small negative (younger outside) LW age gradient – galaxies growth *inside-out*
- Contrary to what happen in elliptical galaxies, stellar mass growth in the center occurs at all times with outer growth being only mildly more efficient at late times (see also Patel+2013; van Dokkum+2013)
- Metallicity gradients correlate with B/T, central density and fraction of cold orbits → Higher AM the steepest the metallicity (dissipational process redistributing AM and producing 'compaction' flattens the gradients and 'quench' SF)
- Correlation compatible with a scenario where the galaxies stop forming stars after a 'compaction' process (e.g. Barro+2013; Tacchella+2016).