Variation of the radio spectral slopes on and off the Main Sequence: new constraints on internal galaxies physical processes

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DIPARTIMENTO
DI FISICA
E ASTRONOMIA
"GALILEO GALILEI"

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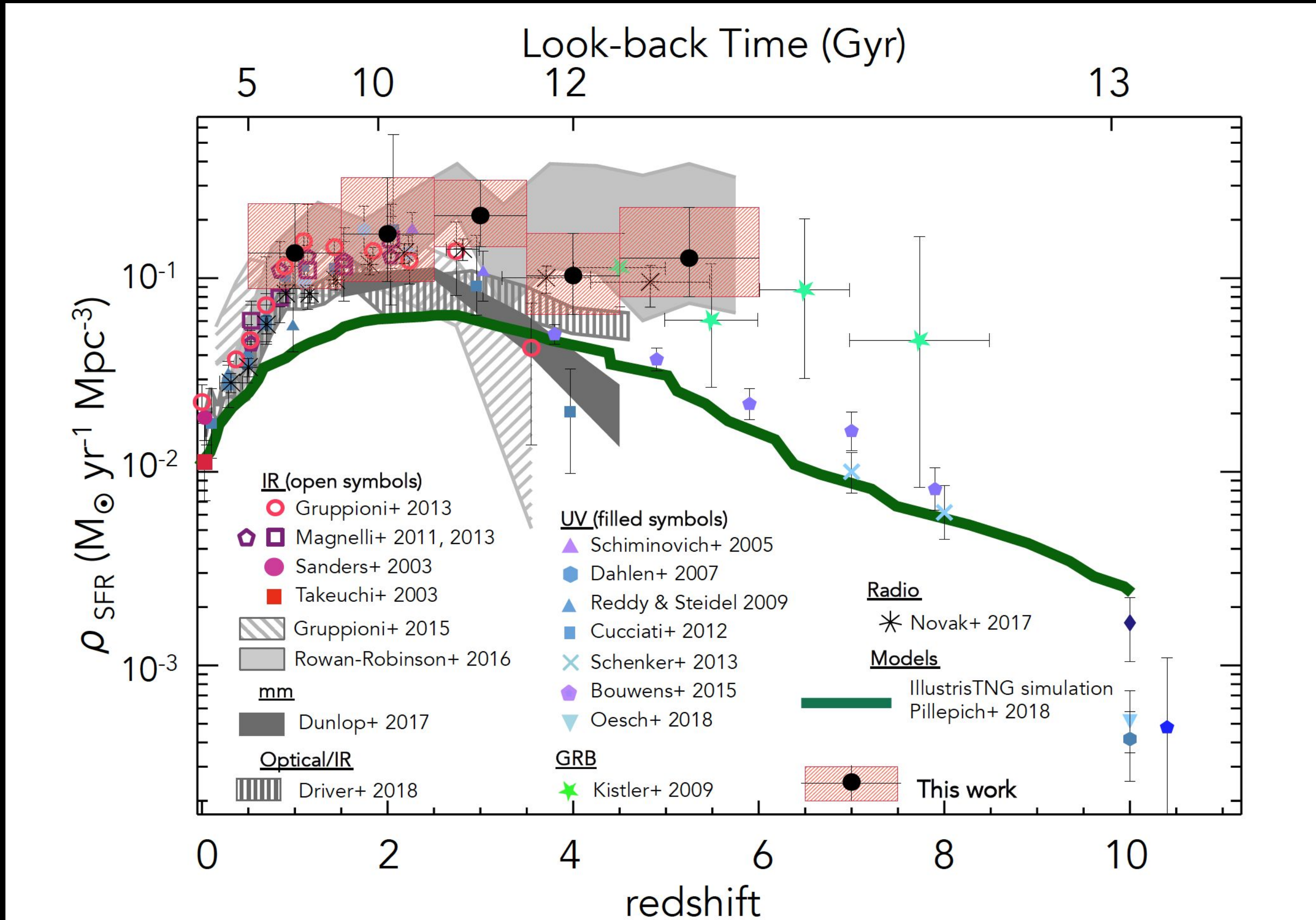
MCCXXII

Outline:

- a brief recap from the last decade
- motivation for new observational constraints

The cosmic SFR density in the *JWST* era



Credits: The ALPINE collaboration (Gruppioni+2020)

The main triggering mechanism of Star Formation in galaxies

Smooth accretion of pristine gas from the cosmic Web

Secular processes?

(Keres+2005, Bower+2006, Dekel+2009)

Galaxy mergers

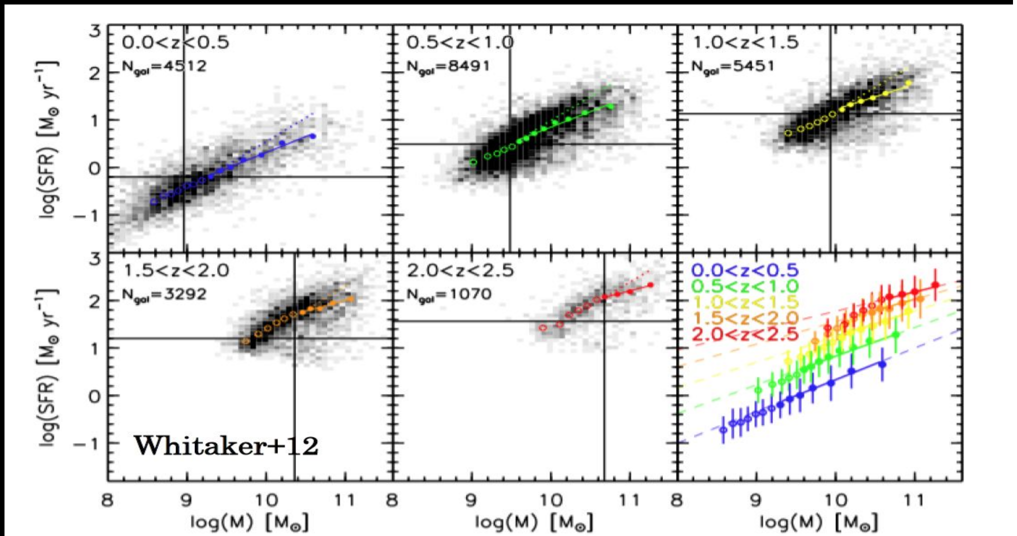
Major? Minor?

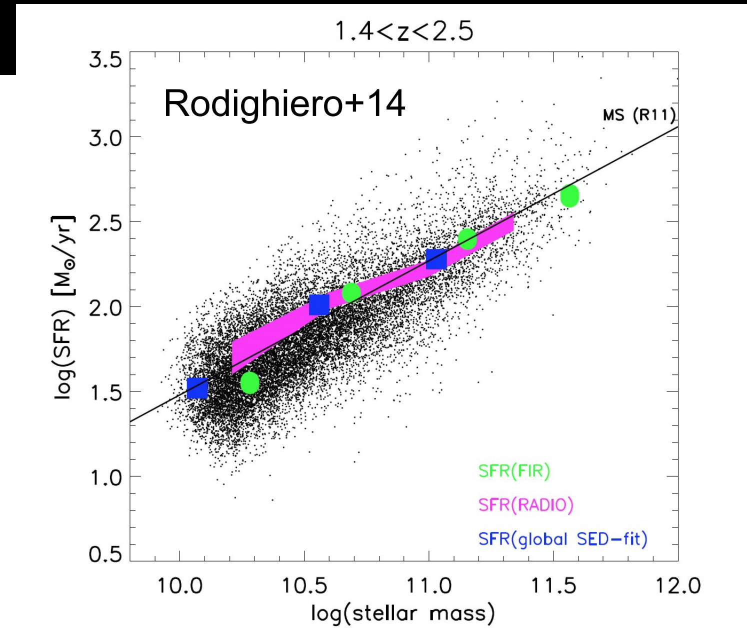
(e.g. Somerville+2001, Conselice+2008)

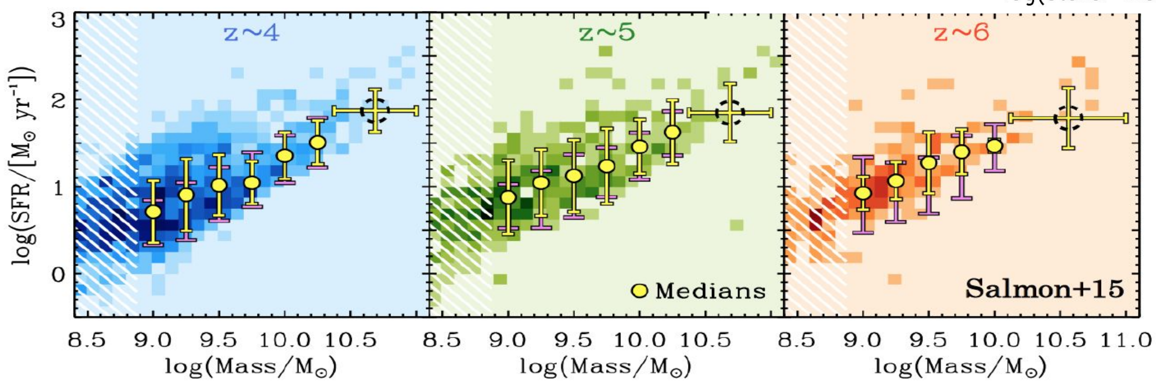
The big question: *What drives the life of galaxies?*

- What is the dominant mode of star formation in Universe ?
- What are the processes that regulate galactic scale star formation ?
- Is there a universal star formation law ?
- What drives the decline of the SFRD from z=2 to the present day ?
- It’s all about quenching?

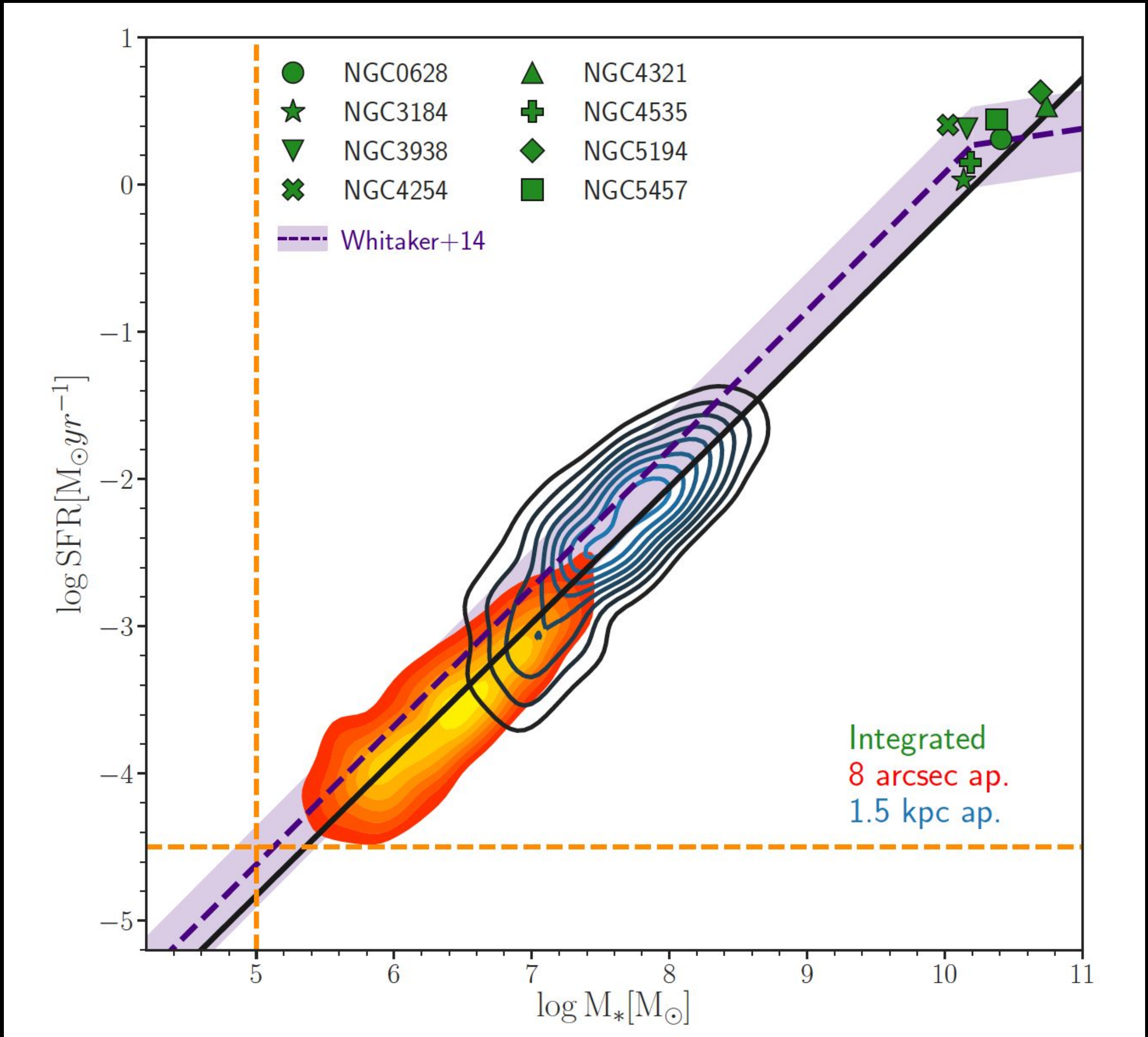
The **Main Sequence**: Connection of star formation to stellar mass assembly with redshift





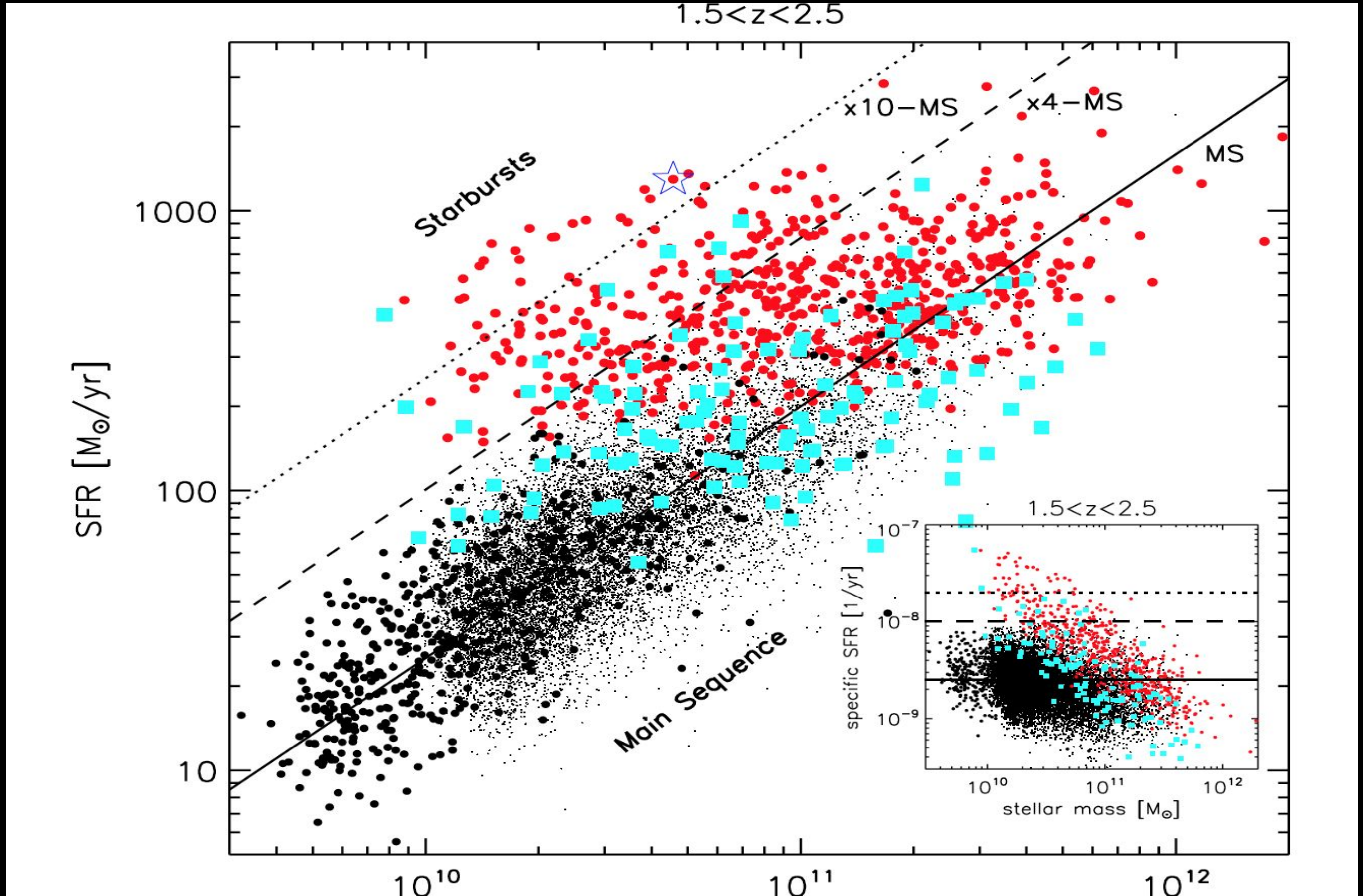


The MS holds on all spatial scales, from 0.5 Kpc up to the integrated galaxy sizes



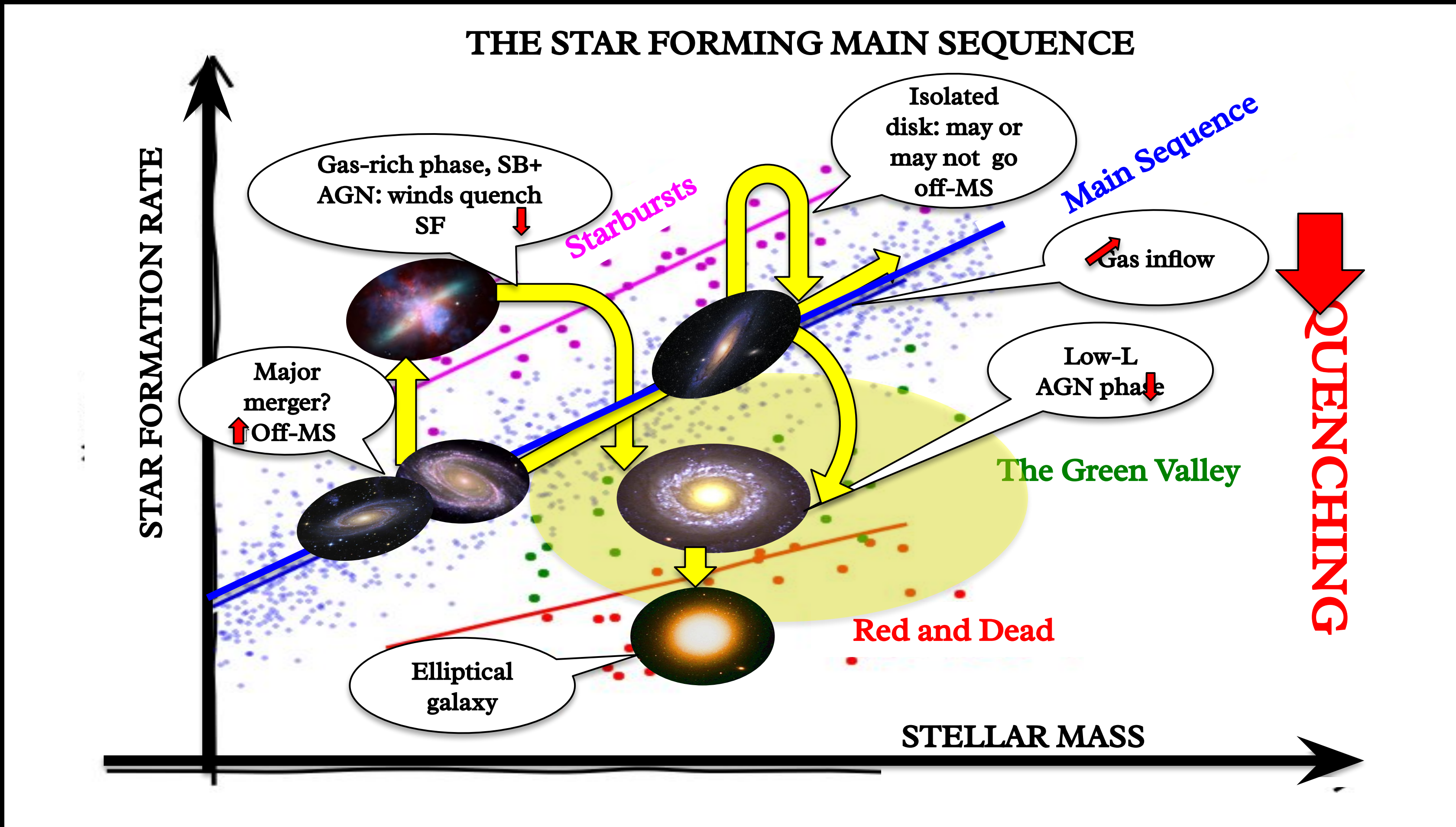
Enia, GR et al. 2020

Main Sequence “Liers” and Outliers



Rodighiero+2011

An evolutionary scenario driven by quenching mechanisms?



What have we learnt in the last decade?

The bulk of the stellar mass in galaxies is assembled along the Main Sequence in secular (disk like) processes, at all cosmic epochs (at least at $z<3$) supporting the need of gas replenishment from the cosmic web

What differences have we observed up to now in MS and SBs galaxies?

- SBs have a higher merger fraction (Calabro'+18, Cibinel+19)

- SBs are more compact, in particular for the dusty/star-forming component (Elbaz+18, but see Puglisi+19)

- SBs are more obscured and metal rich (Puglisi+17)

- SBs host powerful obscured AGN (Rodighiero+19, Carraro+20)

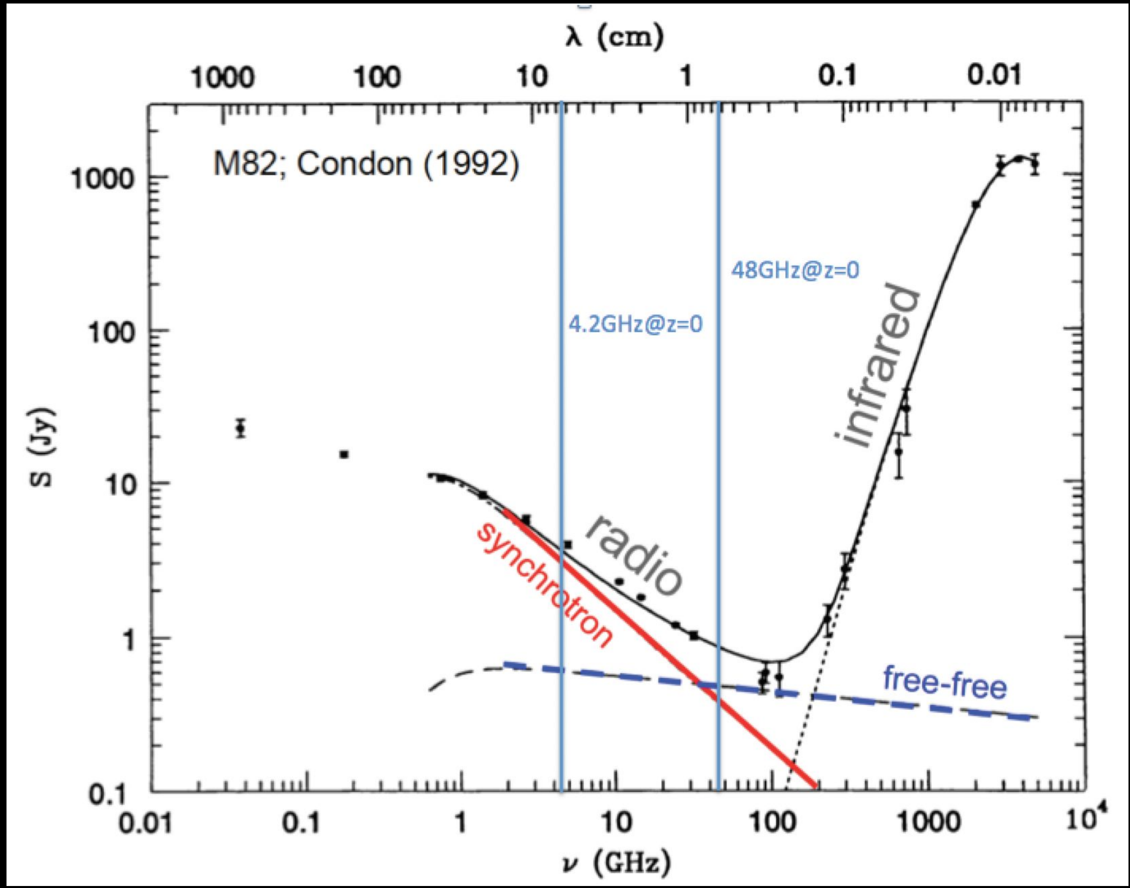
- SBs have a higher SF efficiency (shorter depletion times, Silverman+18)

Any missing observational constraint?
Looking for systematic variations of the radio spectral slope on-off/MS

A VLA continuum 15 GHz survey in COSMOS:

probing the free-free emission with 45 GHz rest-frame at *z~2 (2" beam)*
+
4.2 GHz rest-frame to track the synchrotron *(2" beam)*

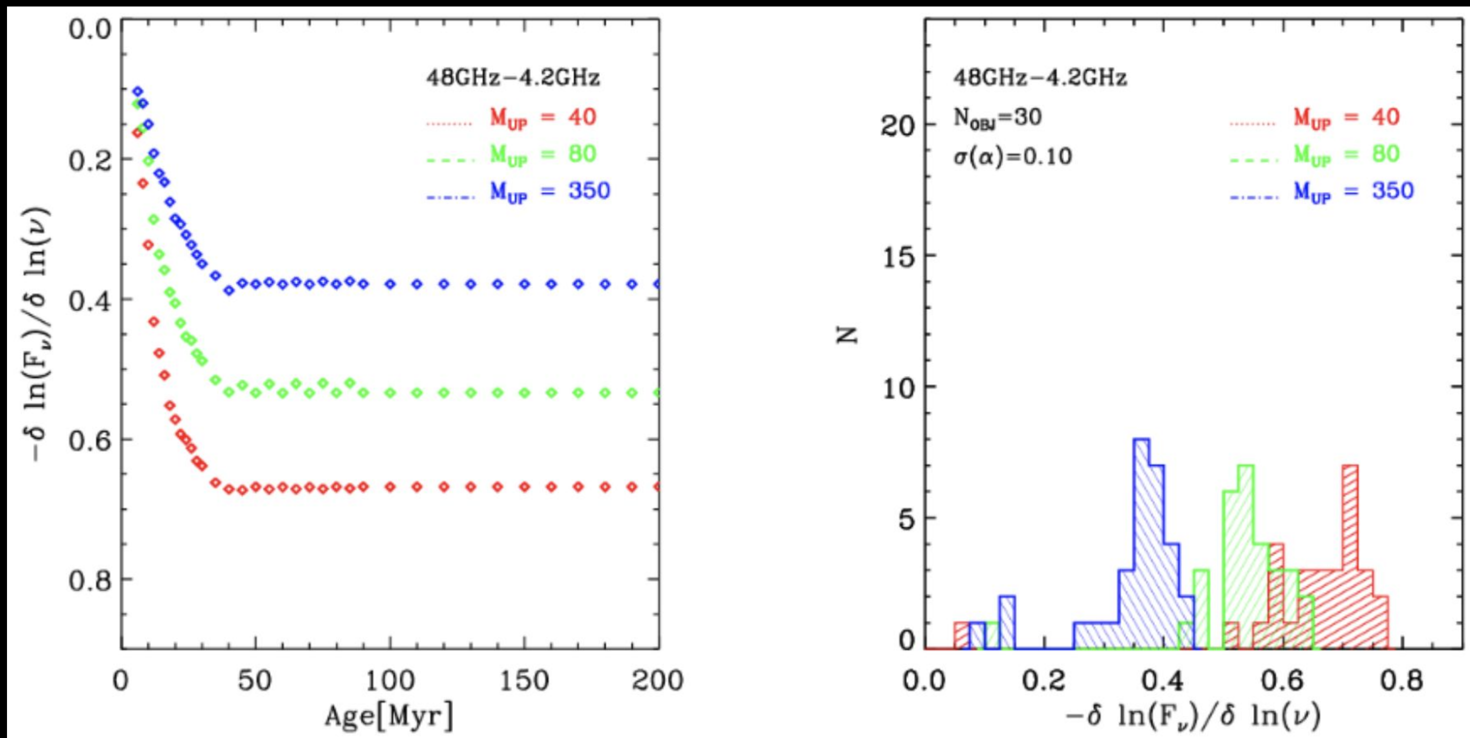
(P.I. G. Rodighiero)



Insights from stellar evolution models:

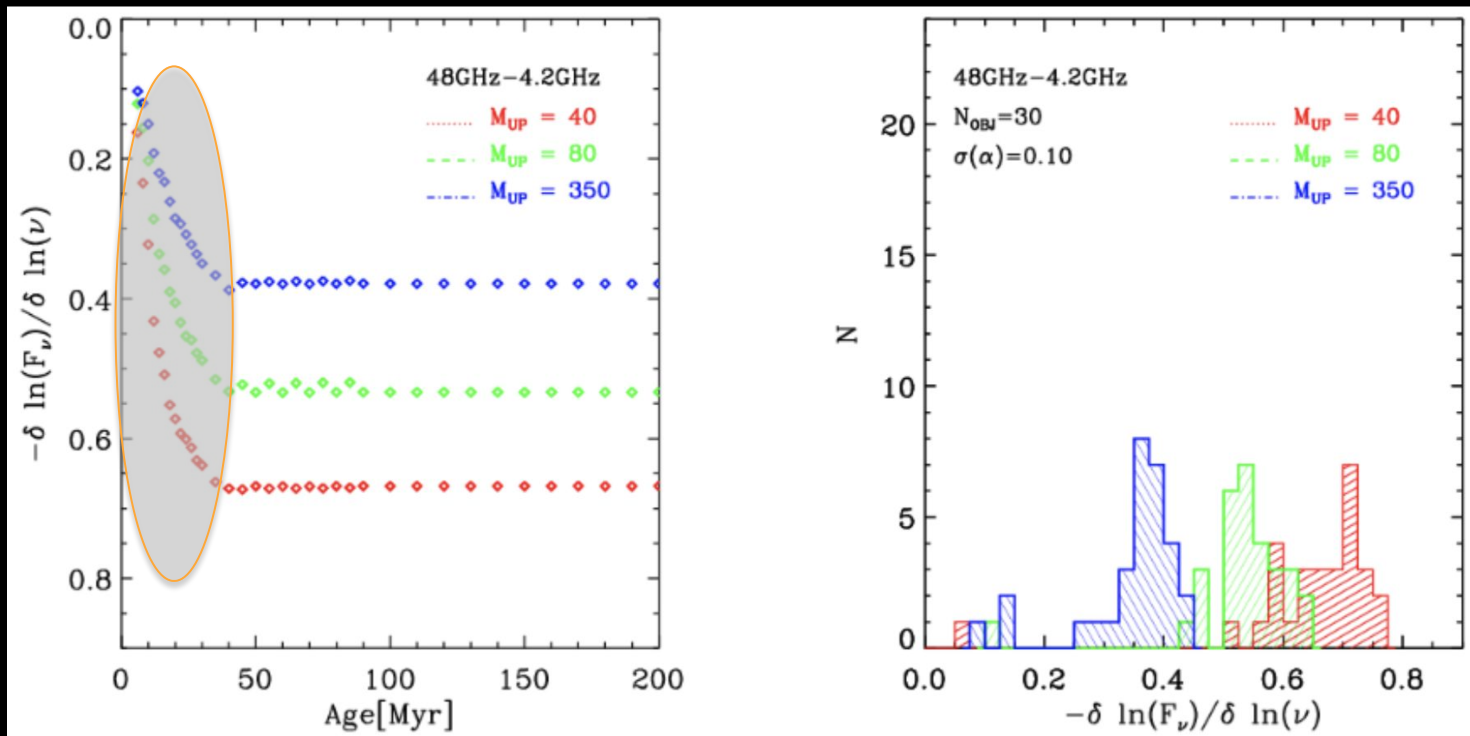
clues on Initial Mass Function (IMF) upper stellar mass variations

(based on Sandro Bressan predictions, *Obi et al. in prep*.)



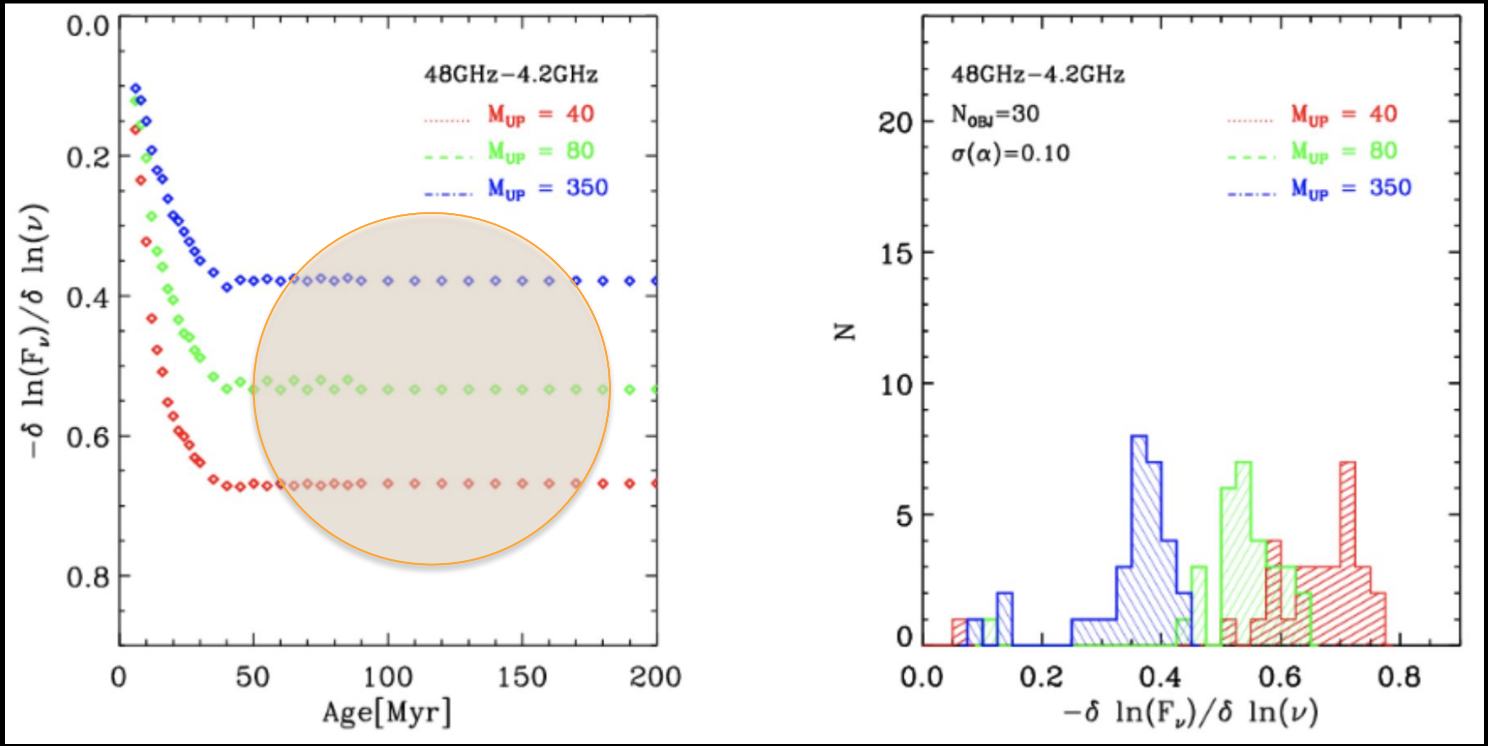
Example of time evolution of the 48GHz-4.2GHz rest-frame radio-emission slope for starburst models with constant SF histories for a metallicity of Z=0.008 (Kroupa IMF)

The slope is very flat in the first few Myr, due to the lack of non-thermal emission.



Example of time evolution of the 48GHz-4.2GHz rest-frame radio-emission slope for starburst models with constant SF histories for a metallicity of Z=0.008 (Kroupa IMF)

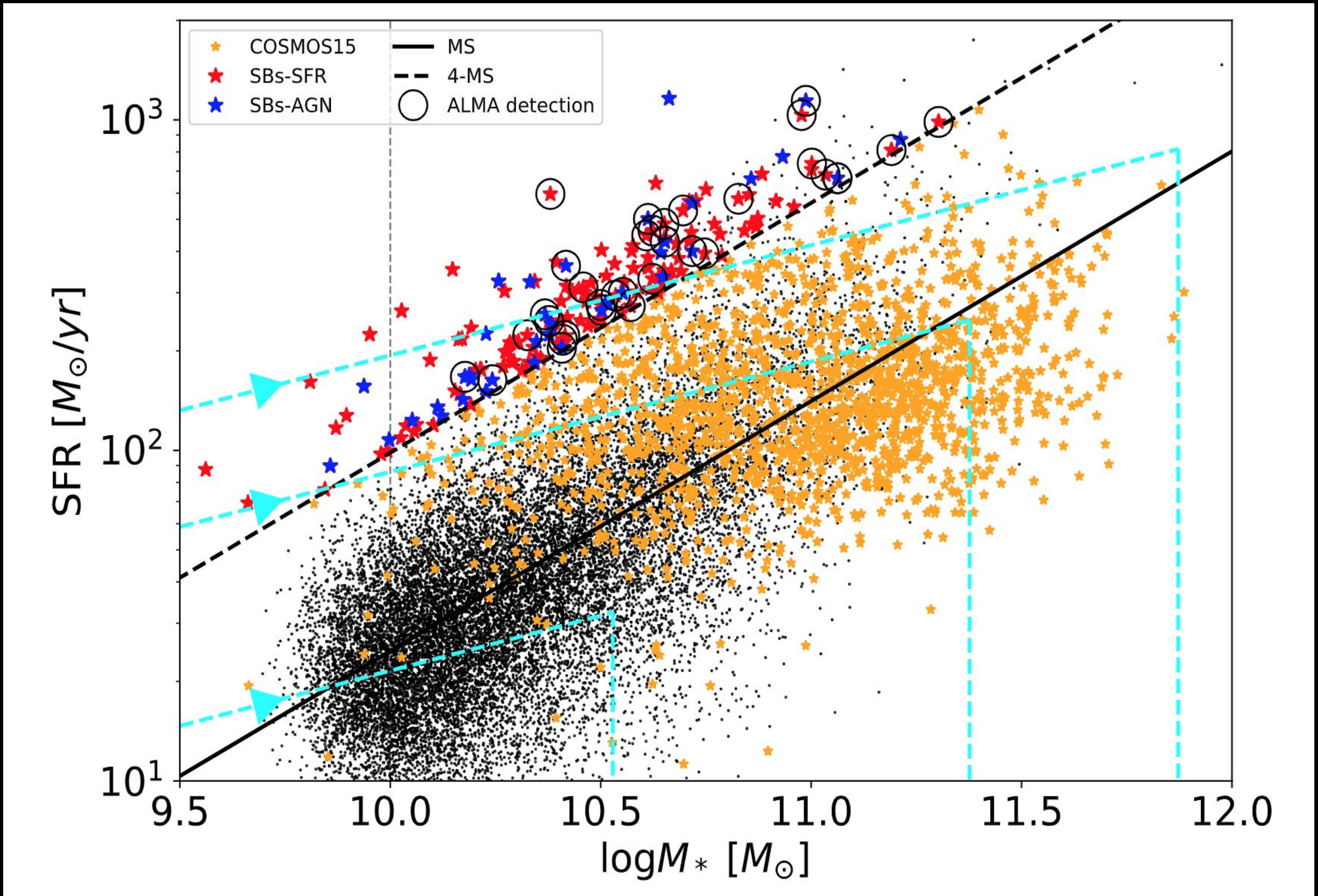
the slope steepens due to the rising of the non-thermal emission from successfully exploding supernovae



Example of time evolution of the 48GHz-4.2GHz rest-frame radio-emission slope for starburst models with constant SF histories for a metallicity of Z=0.008 (Kroupa IMF)

The relative proportion of free-free and synchrotron emission is clearly a very good proxy for the initial mass function in massive stars and in particular for the upper mass limit: Mup

Starbursts as primordial galaxies

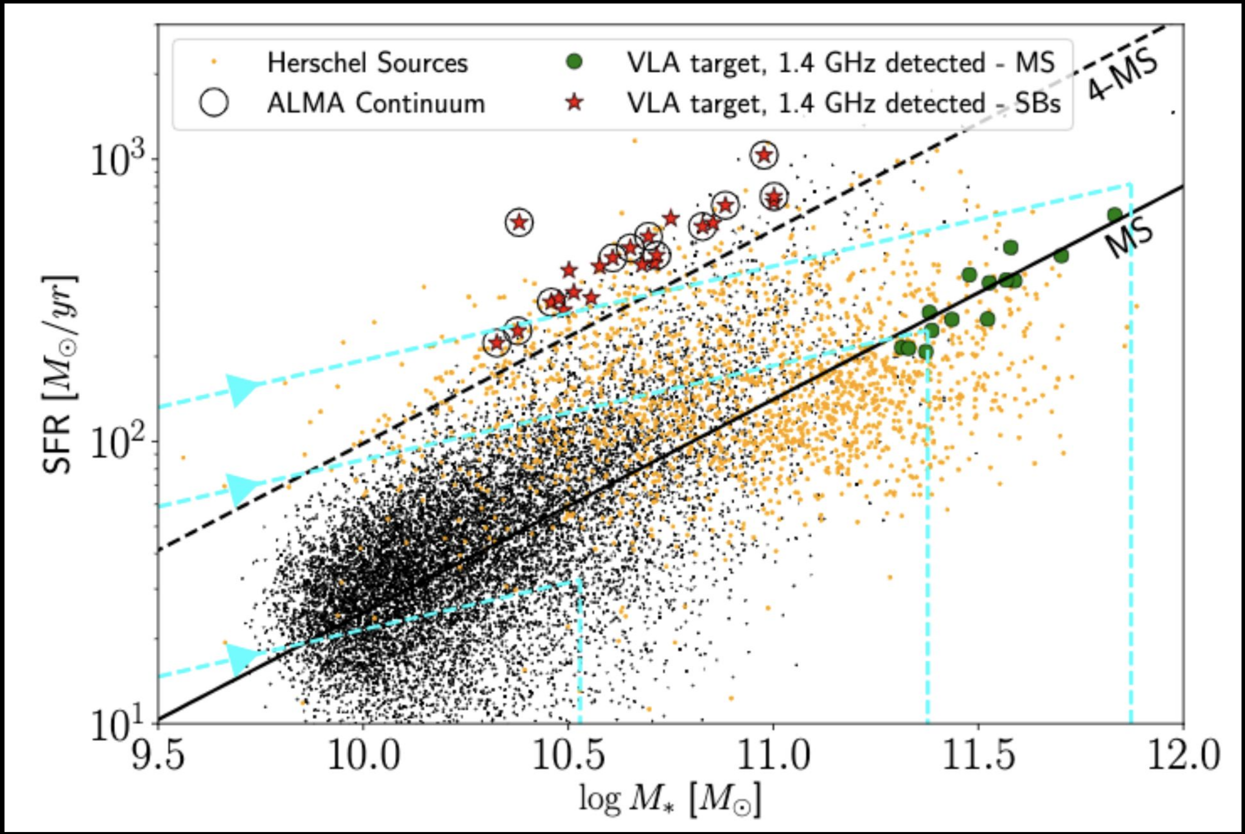


z=2 sources with SFR>a few 10^2 Msun constitute the progenitors of local massive spheroids with stellar mass M*>10^{11}Msun (Lapi+18, Rodighiero+19)

During their star-forming phase, lasting some 10^8 yr, these galaxies feature a nearly constant SFR and a linearly increasing stellar mass

Sample selection at 1.5<z<2.5:

1) mature evolved, massive MS sources
2) Herschel Starbursts 4x above the MS



Constraints for targets:

-being already detected at 1.4 GHz
-no AGN contamination

Observed in total 47 targets

SBs: mass weighted ages older then~50Myr and younger then~300Myr
(to maximize the identification of genuinely young sources)

Preliminary results on alpha(1.4GHz/15GHz) for:
-detections
-detections +stacking@15GHz

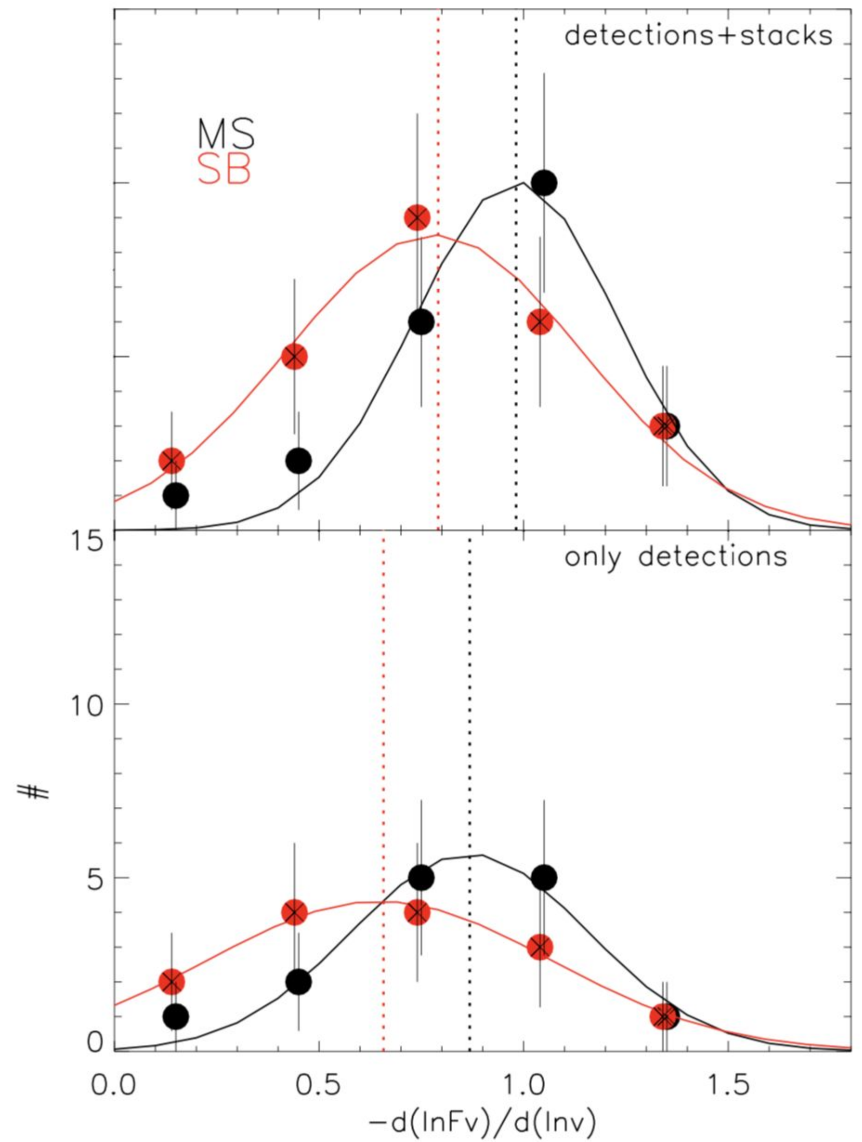
Detection Rate:

14 SBs detected
11 SBs undetected

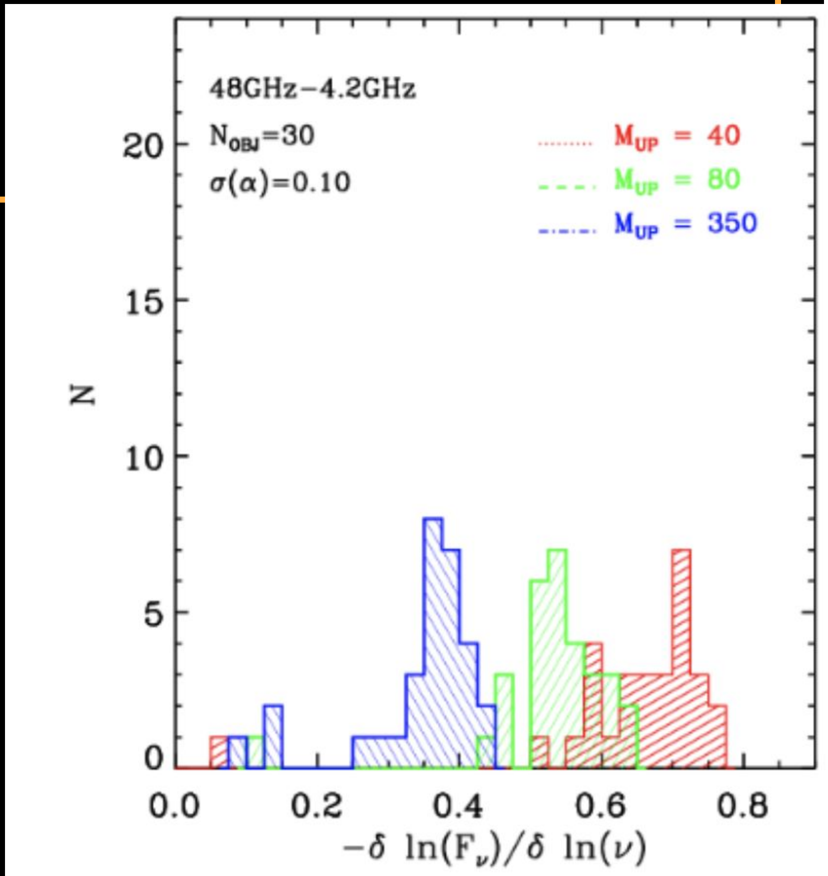
14 MS detected
8 MS undetected

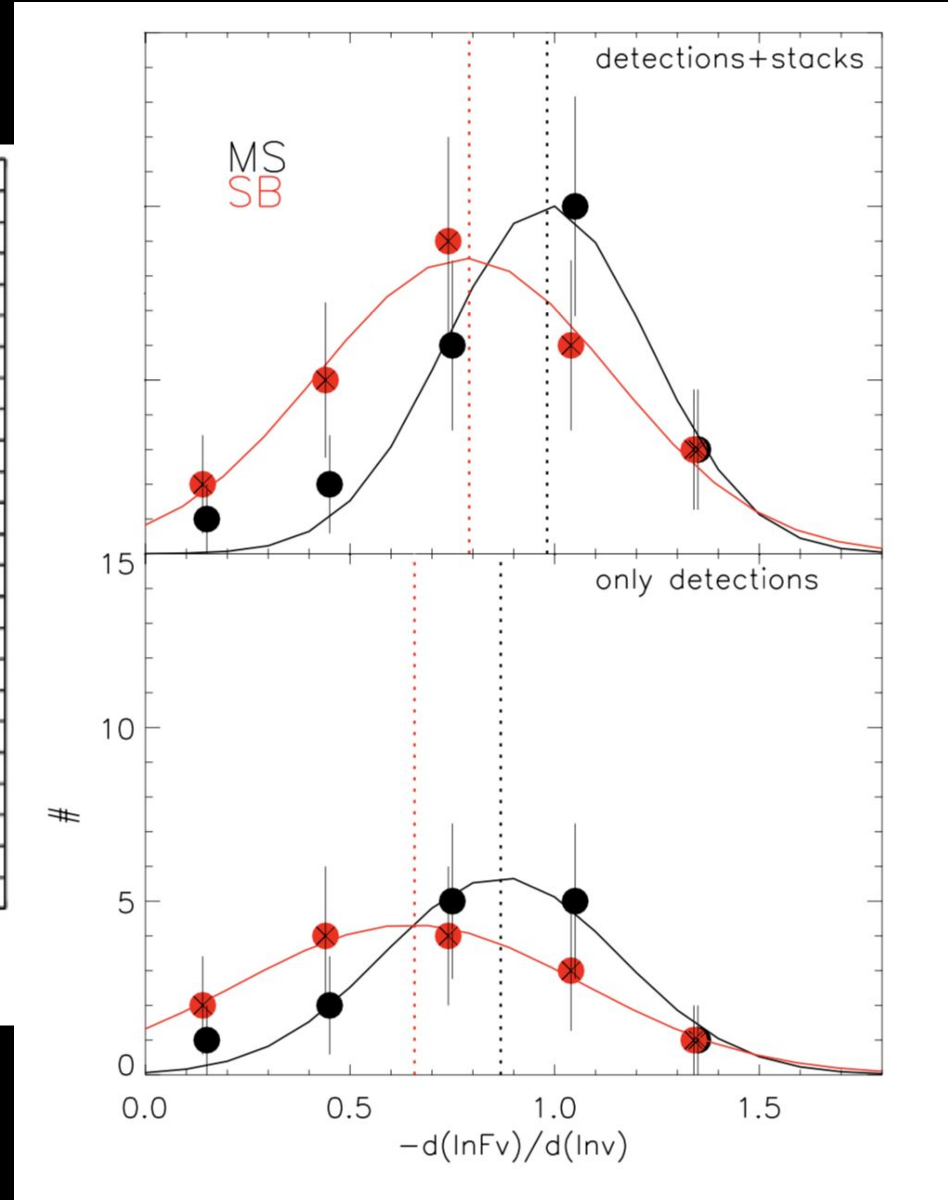
MS sources show statistically steeper slopes than SBs

(but more statistics is needed to confirm the trend)



Preliminary results on





slopes than SBs
(but more statistics is needed to confirm the trend)

Conclusions:

1) Main sequence and Starburst galaxies have systematic differences in the radio spectral slope at z~2, adopting frequencies that maximize the contribution of thermal and synchrotron components.

2) Indication of a top-heavy IMF in starbursts? (As claimed by investigations of the isotopic abundances of CNO elements in starburst galaxies, e.g., Romano et al. 2017)

3) Differences could be explained by other mechanisms? Magnetic fields, turbulences, shocks…

4) More data are required! **A hot topic for SKA.**

A SFR calibration for the SKA

(in collaboration with W. Rujopakarn and K. Aroonrueang)

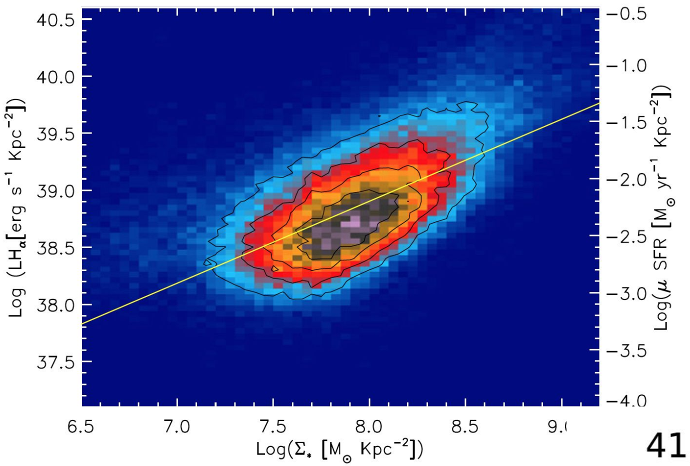
Our 15 GHz survey covers a total area of ~200 sq. arcmin

~100 serendipitous continuum detections (including targets), identified to lie at $0.5<z<2.5$, half of them at $z>1$

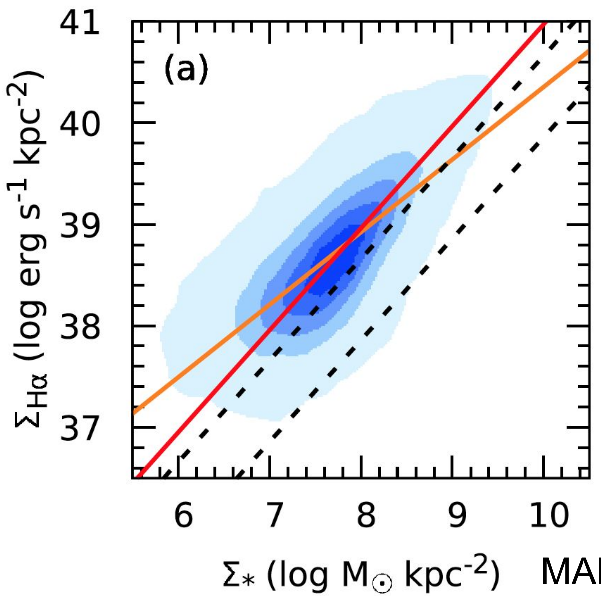
We are working on their multiwavelength properties (including far-IR and radio fluxes) to provide the first calibration of the rest-frame 30-to-45 GHz luminosities, as a SFR calibration that will be of common use in the SKA era.

Thank you for your attention!

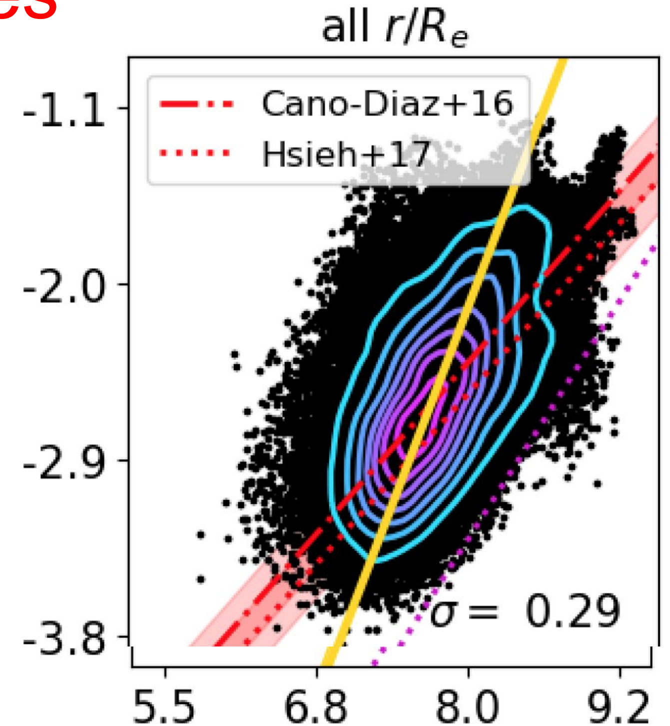
Spatially resolved MS in local galaxies



CALIFA – Cano-Diaz+16



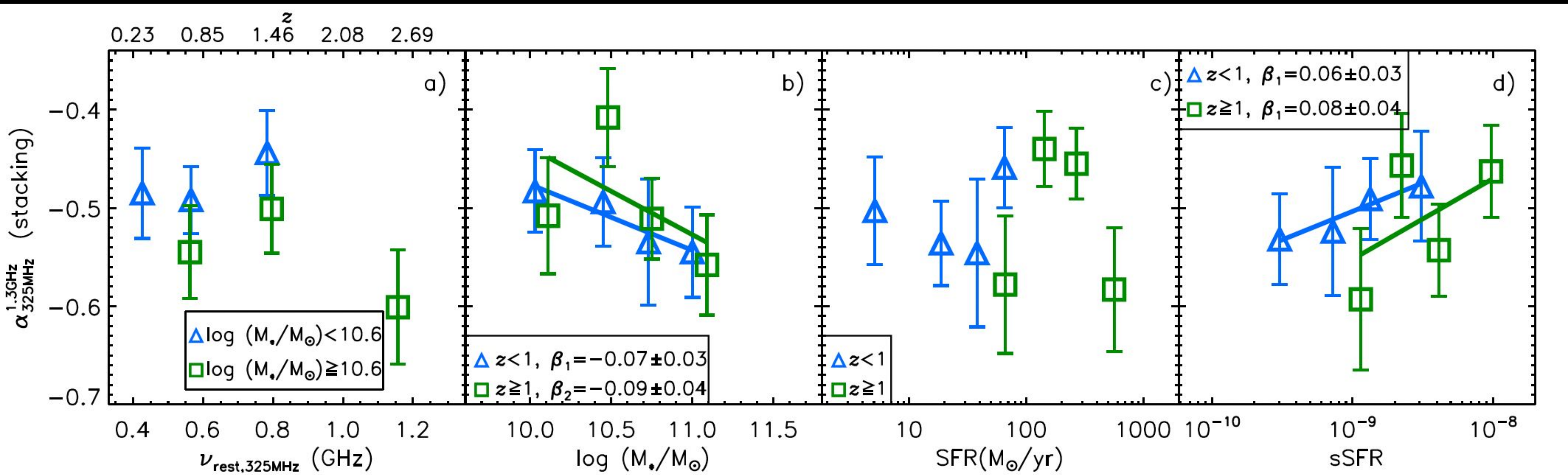
MANGA – Hsieh+17



MUSE – Vulcani+19

Mostly based on UV-to-optical SFR tracers!!

Recent similar trends from lower frequencies slopes:
VLA (3GHz) +MeerKat (1.4GHz) +GMRT (325MHz)



An+21

Mergers, what else? The in-situ co-evolutionary scenario

AGN bolometric luminosity against SFR