JOIN THE

DARK SIDE OF METALLICITY

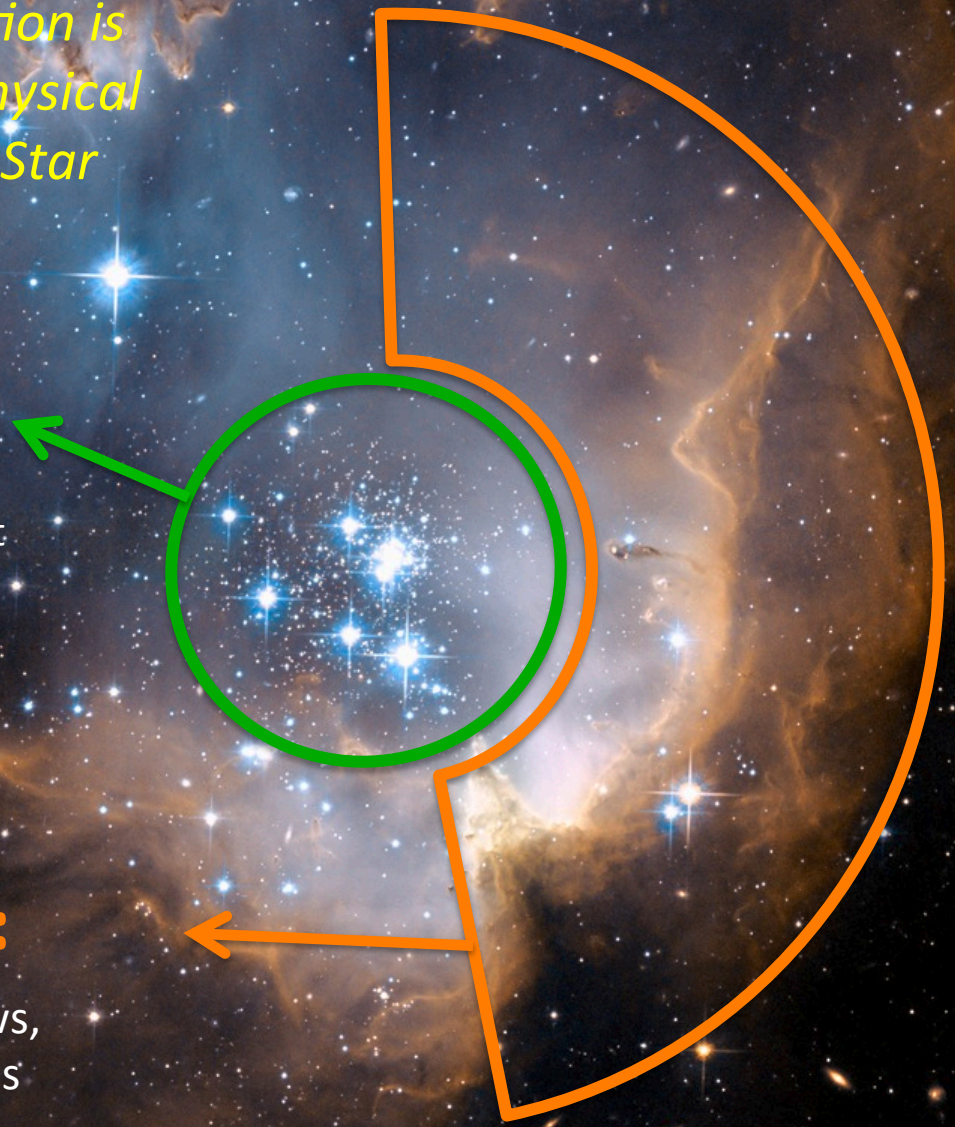
A long time ago in a dusty galaxy
far, far away....

Metallicity evolution probed by Spica
with rest-frame Mid- to Far-IR spectroscopy

G. CRESCI – ARCETRI OBSERVATORY

METALLICITY: A FUNDAMENTAL PARAMETER

Understanding its evolution is essential to isolate the physical mechanisms that drive Star Formation



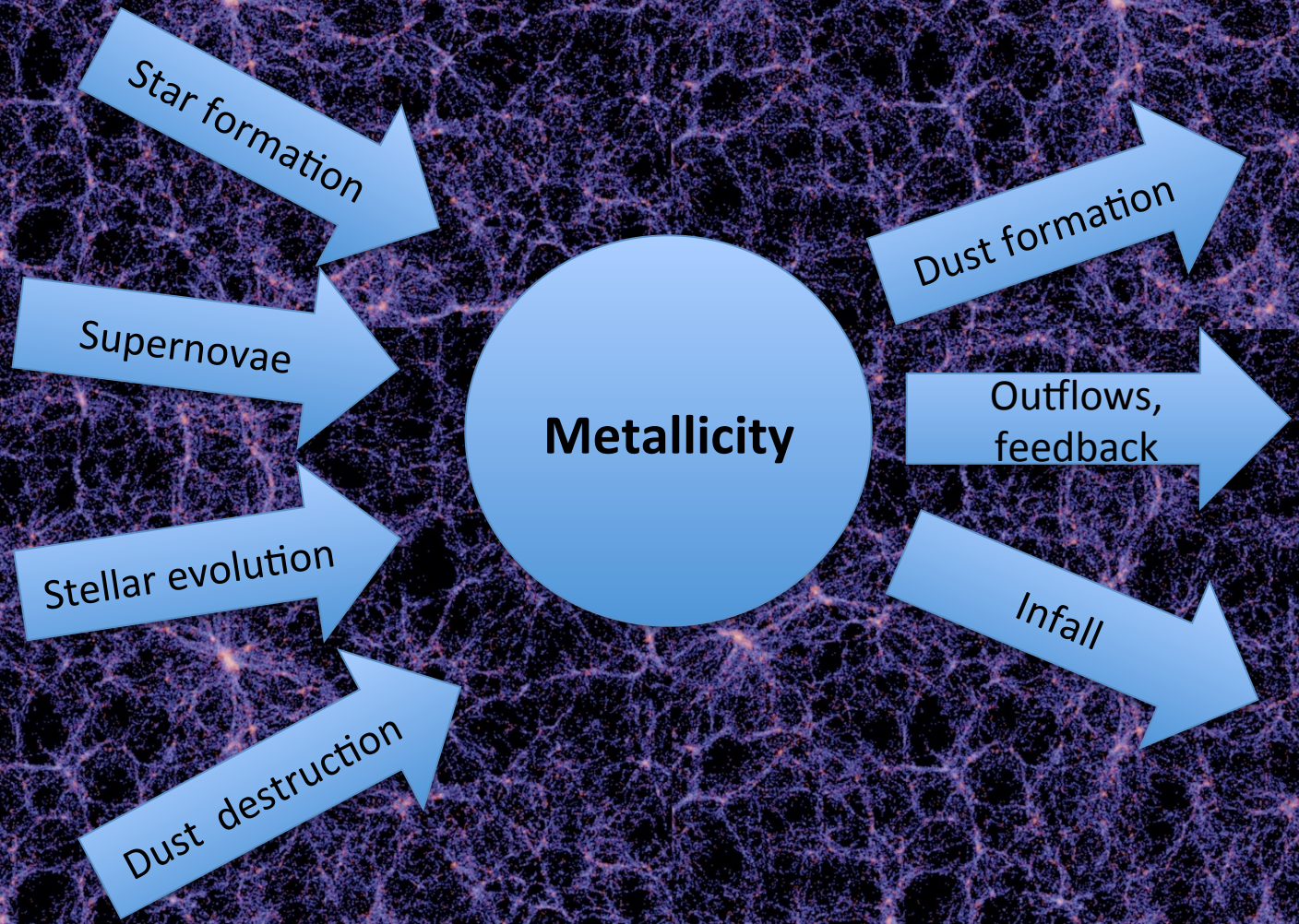
Stellar metallicity:

Represents an average over the entire star formation history of the galaxy, not only the current SFR: optical to UV absorption features

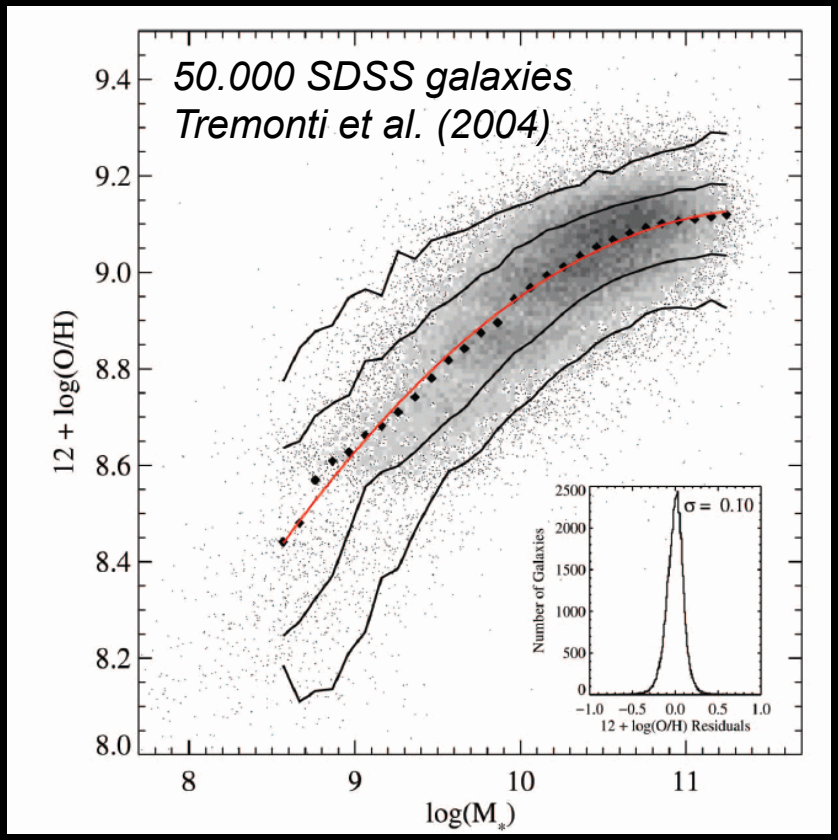
Gas-phase metallicity:

Also sensitive to infalls and outflows, cycling of gas: optical emission lines

METALLICITY: A FUNDAMENTAL PARAMETER

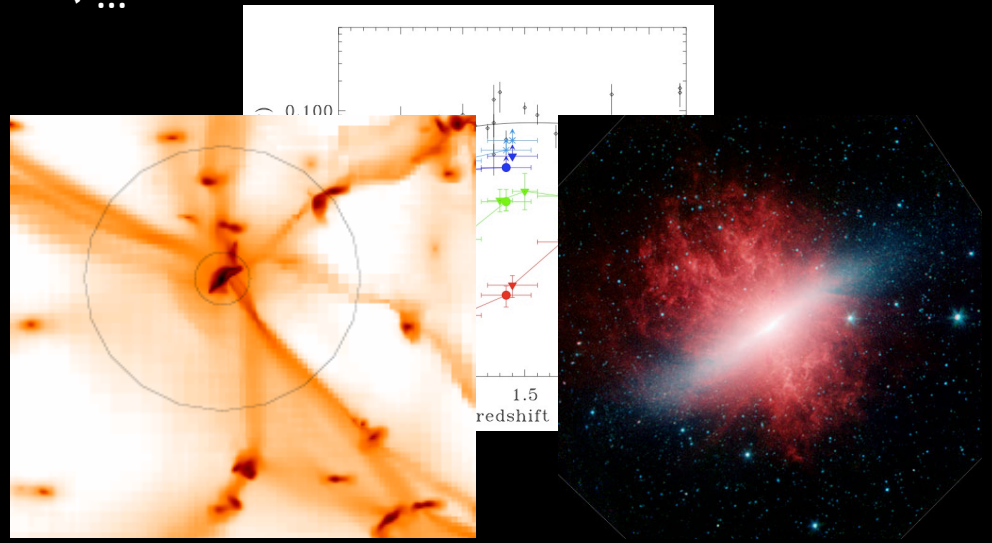


THE MASS-METALLICITY RELATION



Possible Drivers:

- ✓ star formation history and mass lost
- ✓ downsizing
- ✓ outflows and feedback (AGN, SNe)
- ✓ evolution in IMF
- ✓…

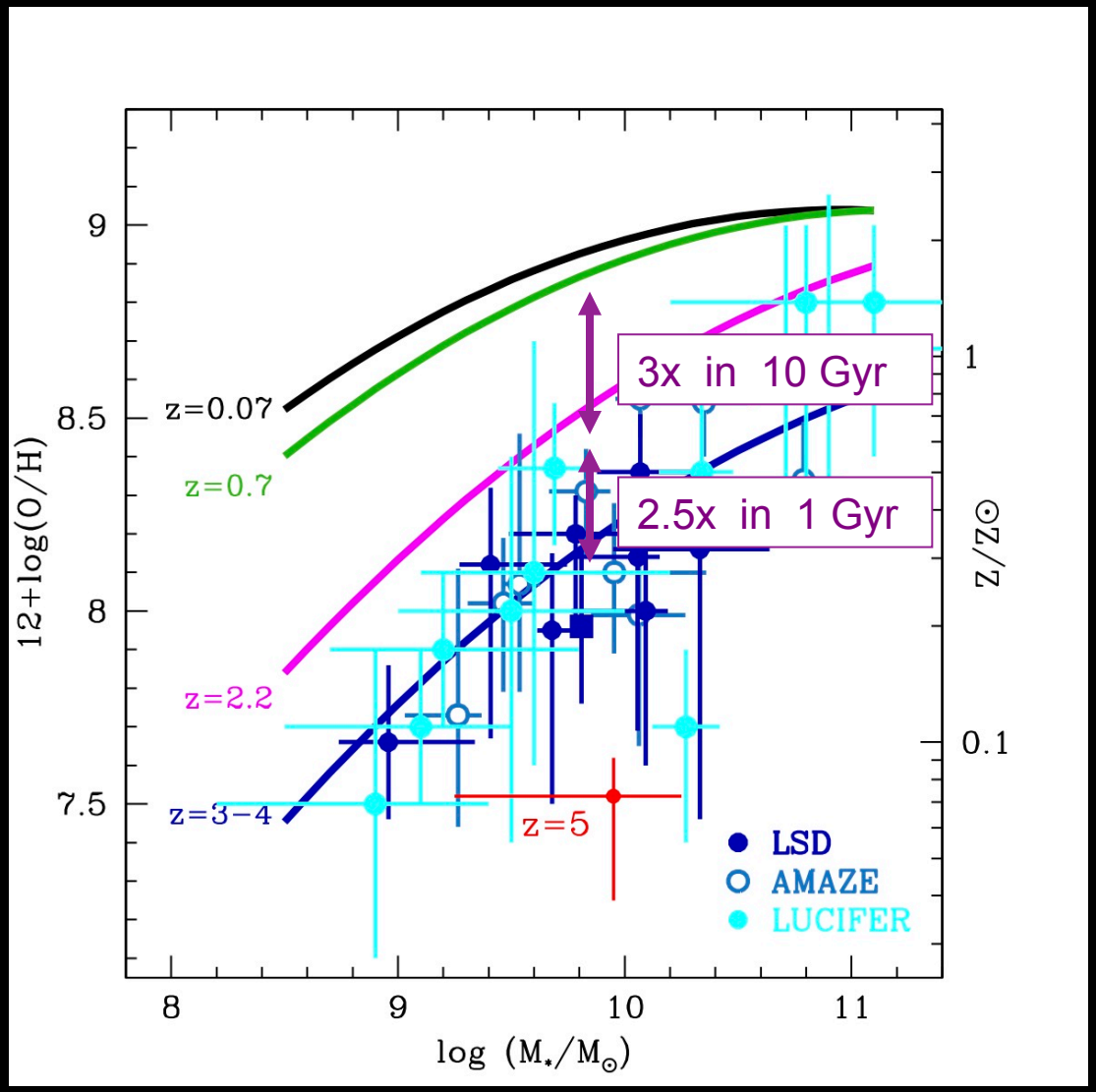


Crucial test for models

Expecially at high-z, where the predictions of different models diverge more

See Kobayashi+ 2007; Brooks+ 2007; de Rossi+ 2007;Dave' & Oppenheimer 2007; Dalcanton, 2007; De Lucia+ 2004; Tissera+ 2005; Koppen+ 2007; Cid Fernandes+ 2007; Finlator & Dave', 2008, Panter+ 2008, Governato+ 2008, Sakstein+ 2009; Calura+ 2009, Save', Finlator & Oppenheimer 2011, etc

EVOLUTION OF THE MASS-GAS METALLICITY RELATION



z~0.07 SDSS

z~0.8-1 GDSS+CFRS (Savaglio+05), GOODS (Cowie & Barger 09) VVDS (Lamareille+09, Perez-Monteiro+09)) IMAGES (Rodrigues+08) DEEP2 (Zahid+10)

z~2.2 LBG (Shapley+04, Erb+06) BzK (Hayashi+11) Lenses (Richard+10)

z~3.3 ○ AMAZE (Maiolino+08, Troncoso+13)

● LSD (Mannucci +09)

● LUCI (Cresci+16)

M-Z relation already in place at z~3.5

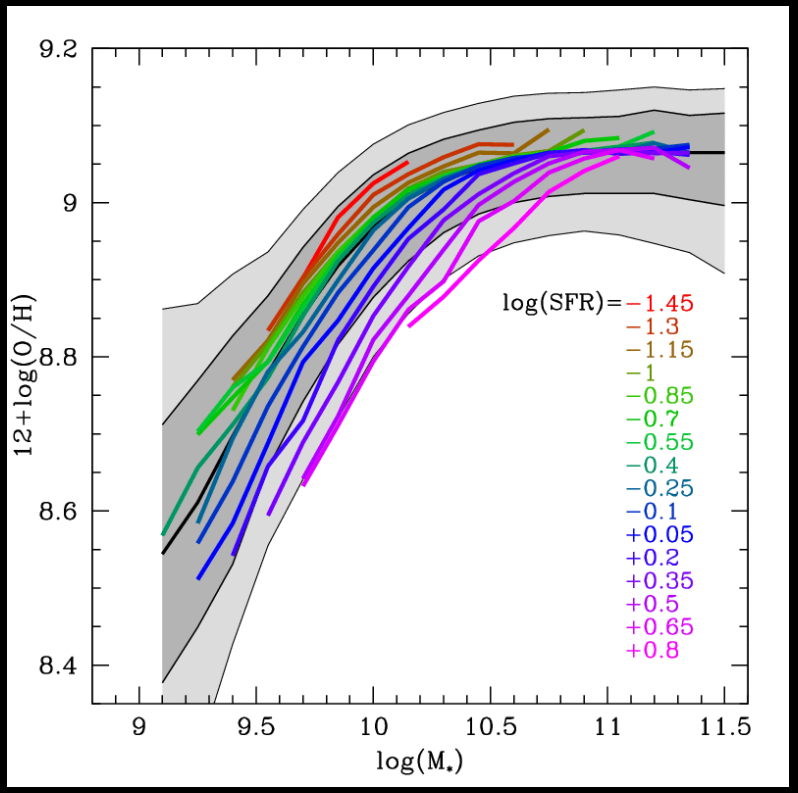
Strong and fast evolution of the M-Z relation beyond z~2

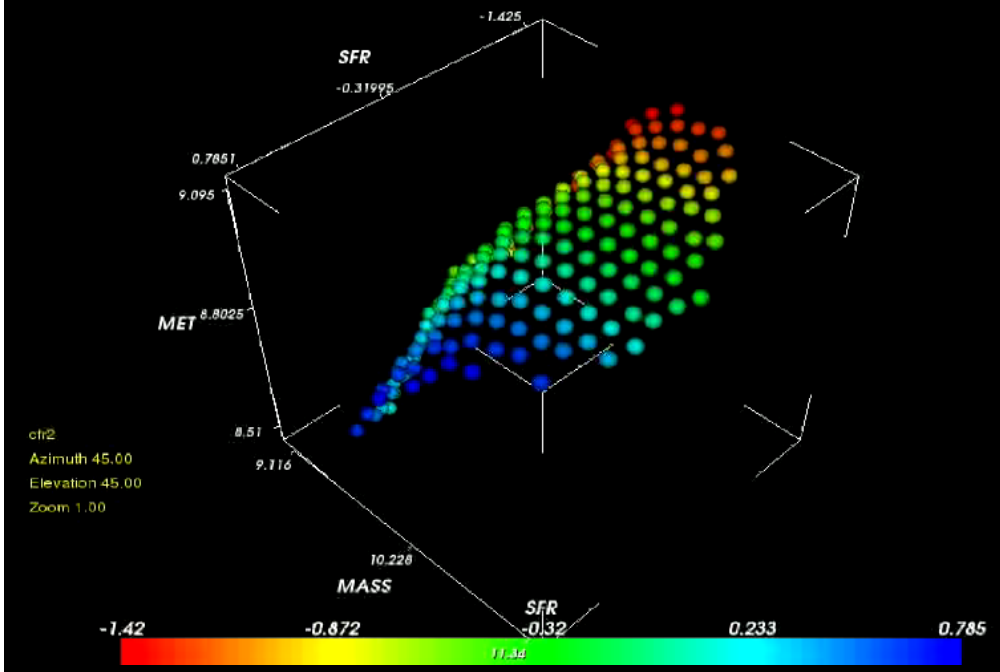
THE FUNDAMENTAL METALLICITY RELATION

Gas Metallicity depends on Mass but also on SFR

Spread ~0.05dex (12%)

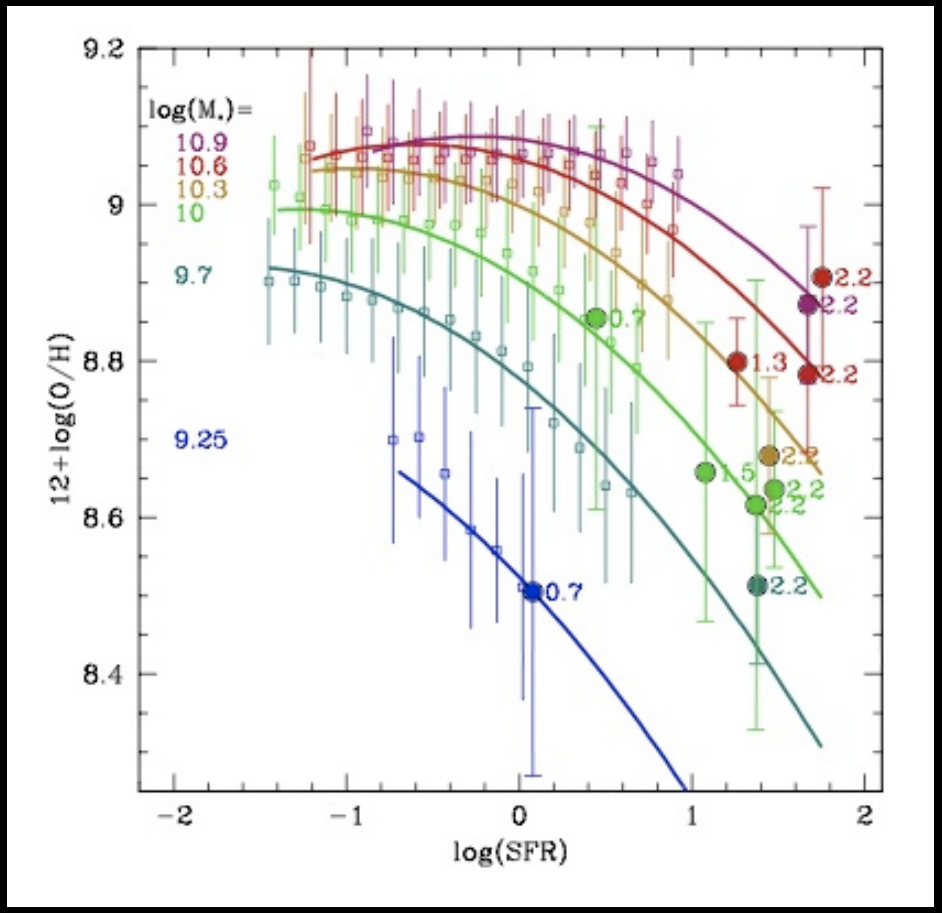
→ half dispersion of the original M-Z due to SFR

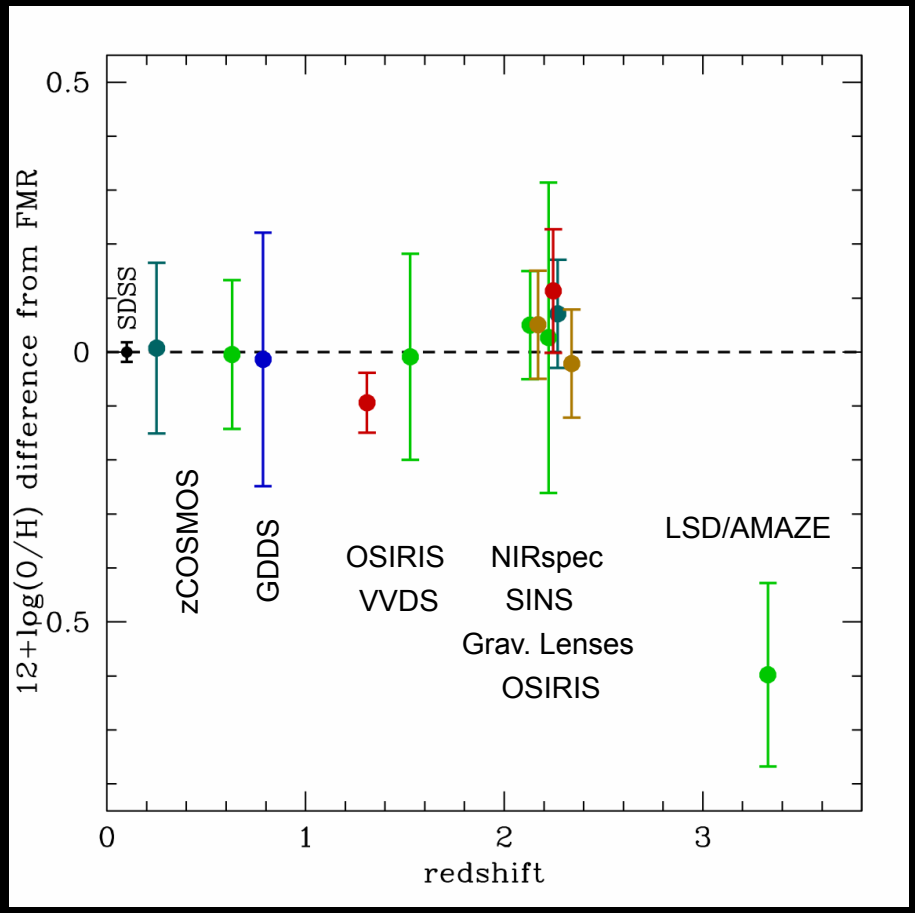




Mannucci, Cresci et al. 2010

REDSHIFT EVOLUTION OF THE FMR

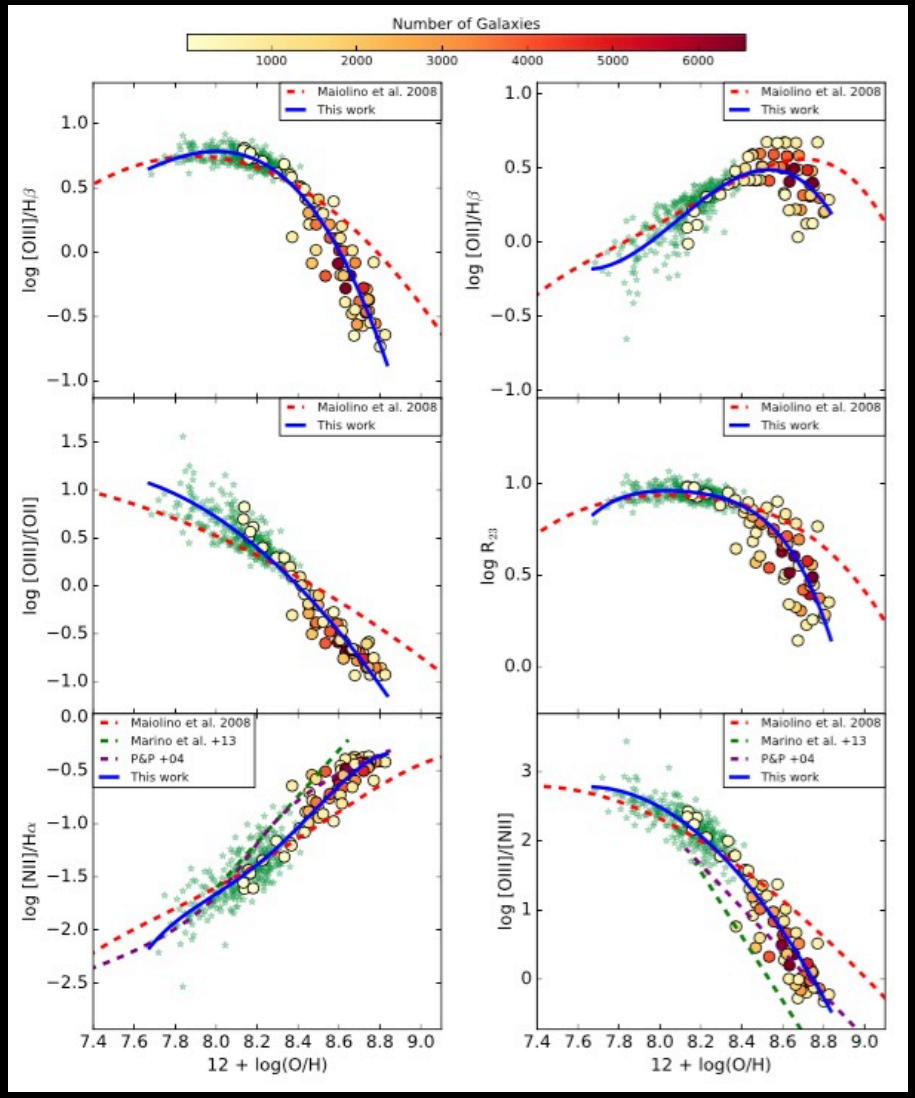




- **No evolution up to z=2.5**
- 0.6 dex of evolution at z=3.3?

Mannucci et al. 2010, Cresci et al. 2012, Cresci et al. 2016

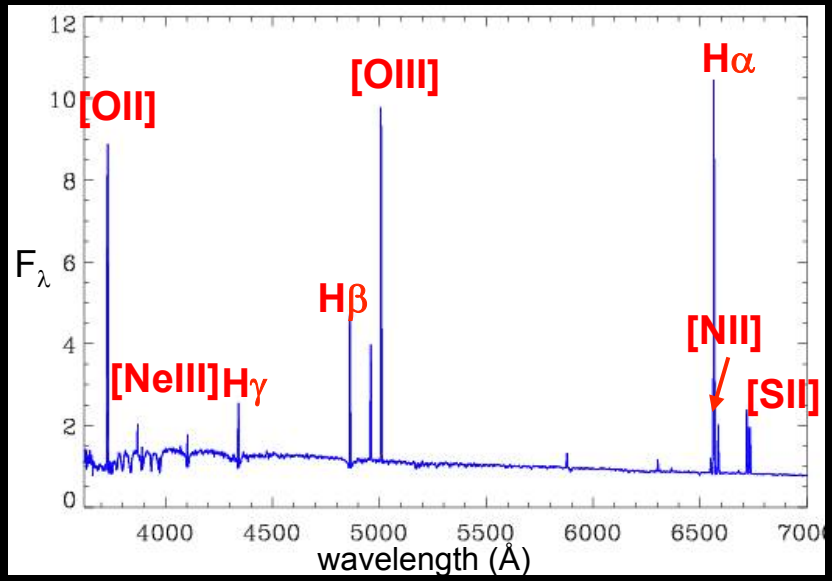
SHORT-WAVELENGTH OBSERVATIONS



Curti, Cresci et al. 2016

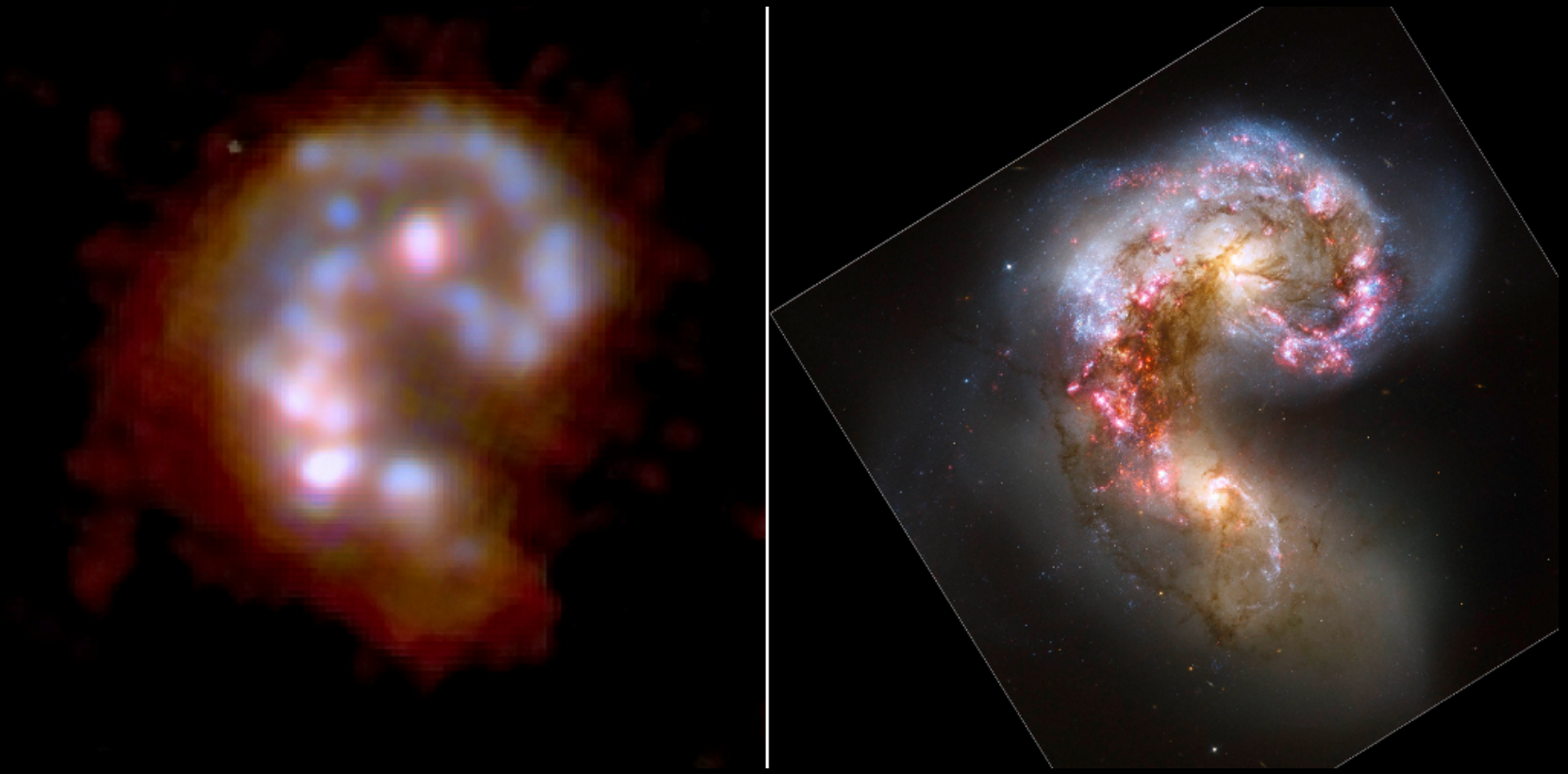
Gas phase metallicity:

- direct electron temperature measuraments (Pilyugin+01,10, Izotov+06, etc.)
- from strong emission lines ([OII], [OIII], Hβ, [NII], Hα.....) calibrated empirically (Pettini & Pagel 04, Liang+06, Andrews&Martini 16 etc.)
- or through photoionization models (Kewley&Dopita 02, Tremonti+04, Dopita+06,16 etc.)



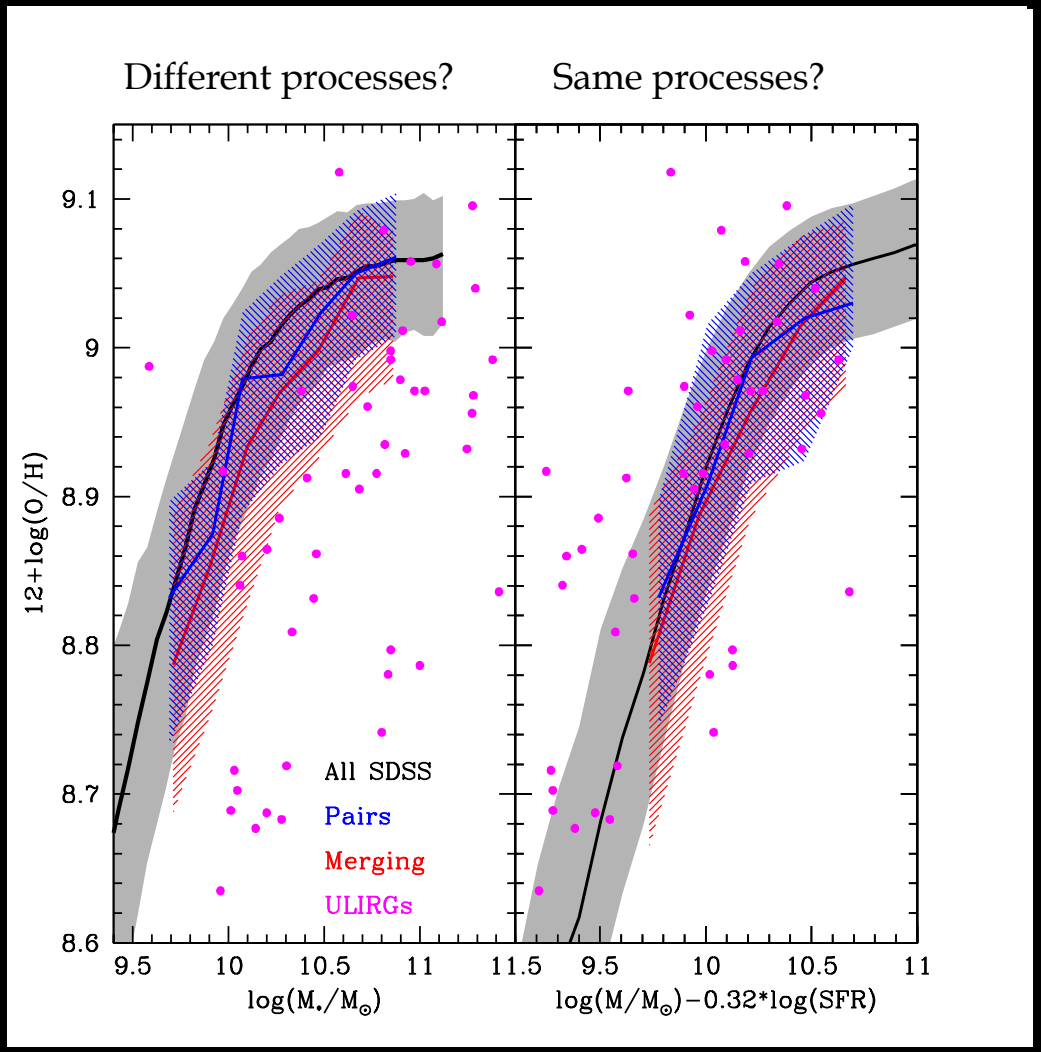
OBSCURED GALAXIES

- Metallicity is often unknown
- When observed, refers to the outskirt only

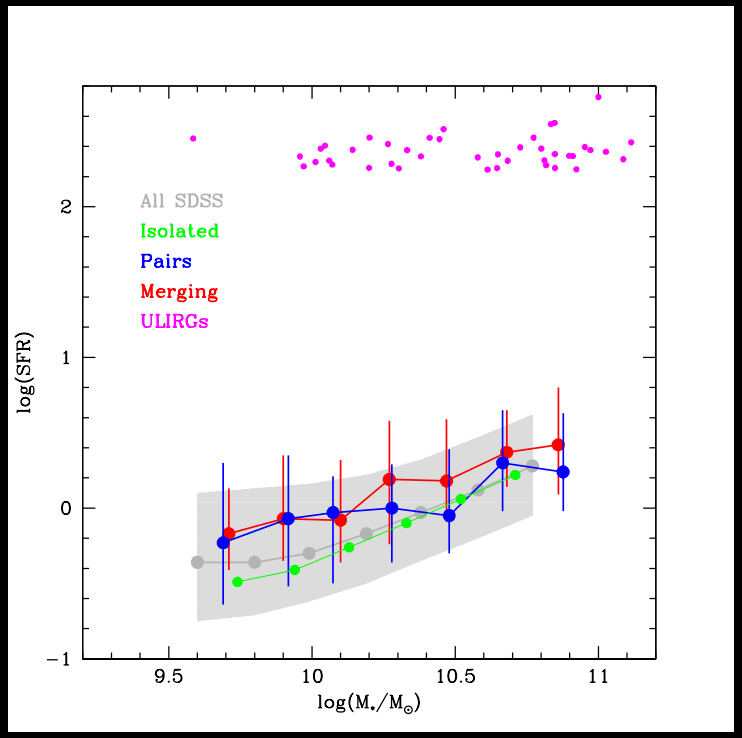


ESA / PACS / SHINING / U. Klaas & M. Nielbock, MPIA.

FMR IN OBSCURED GALAXIES



- Spectroscopic pairs in SDSS (Ellison et al. 2008)
- Merging galaxies from the Galaxy Zoo sample
- ULIRGs (Hou et al. 2009)



Cresci et al. 2025

Lower metallicities than M-Z, but higher SFR

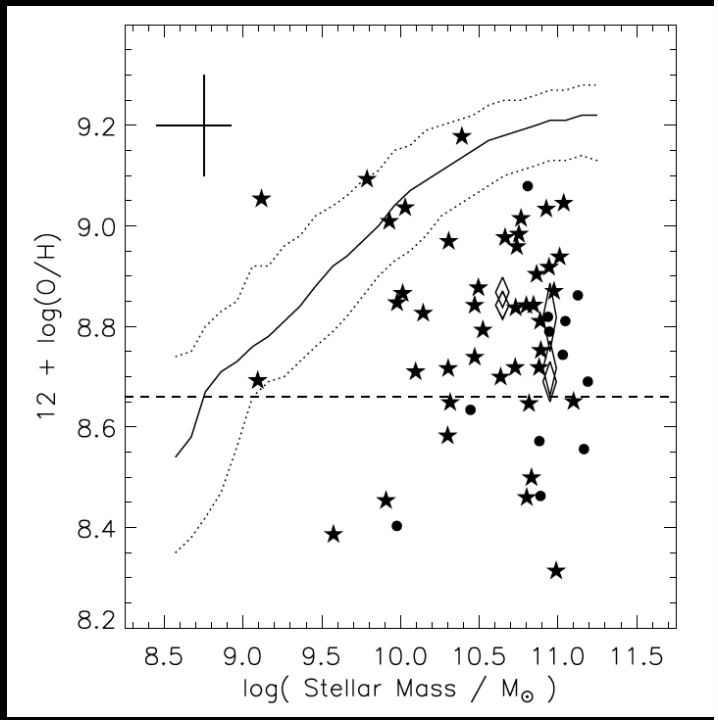
SFR from FIR luminosity needed in obscured sources, or just a skin effect?

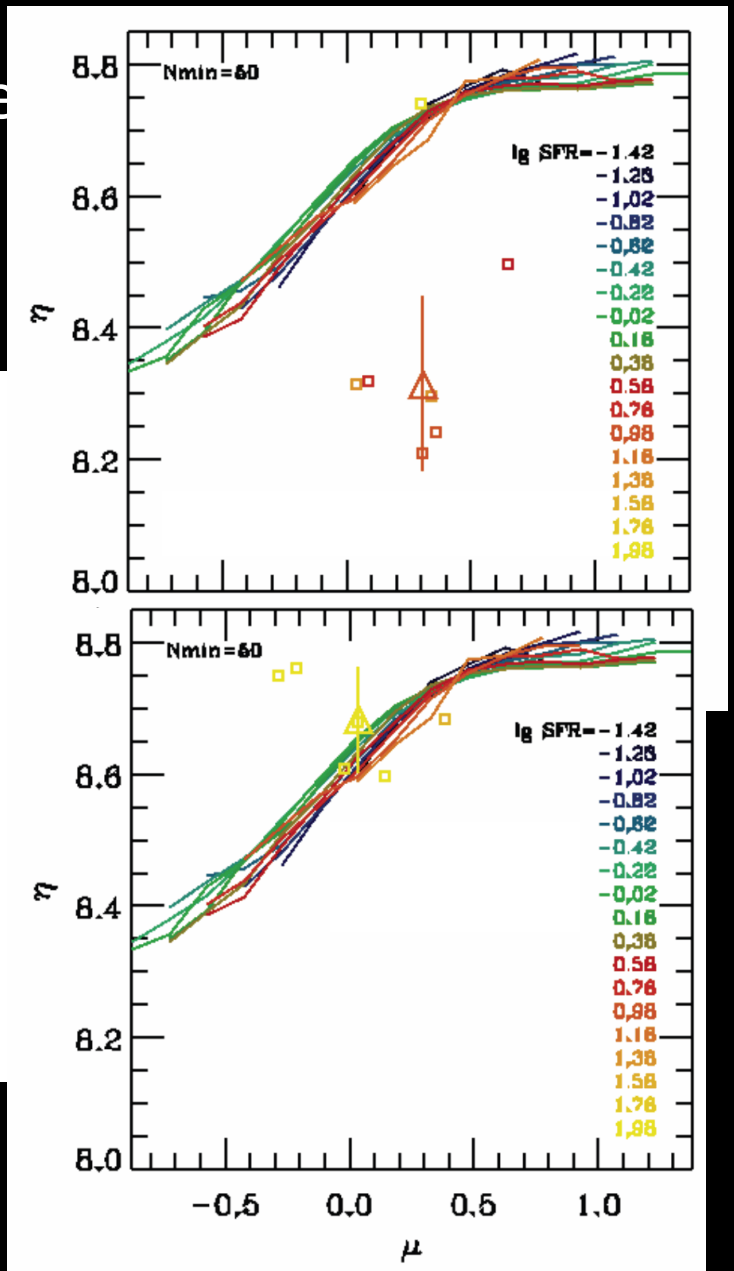
SPICA: both SFR and metallicity from FIR

OBSCURED GALAXIES

- Do ULIRG follow the same relations?

Rupke et al. 2008





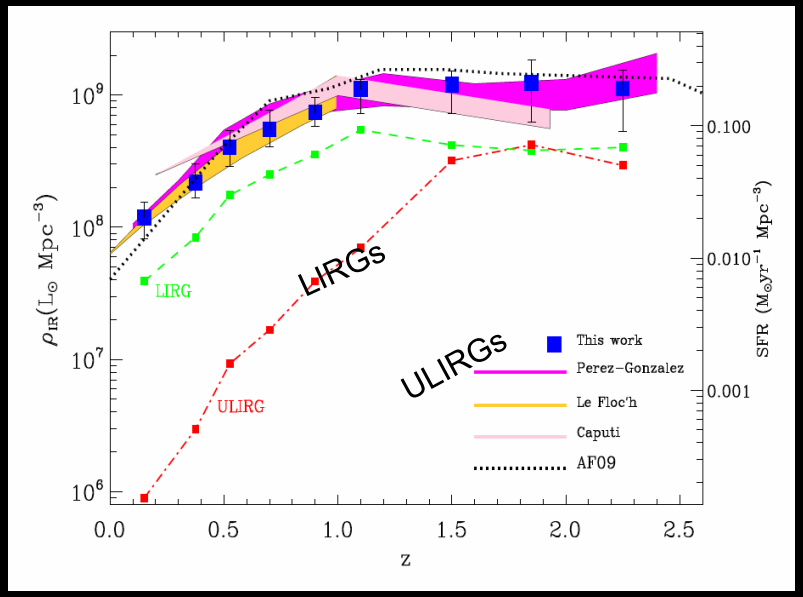
Maiolino+ in prep.

Different processes?

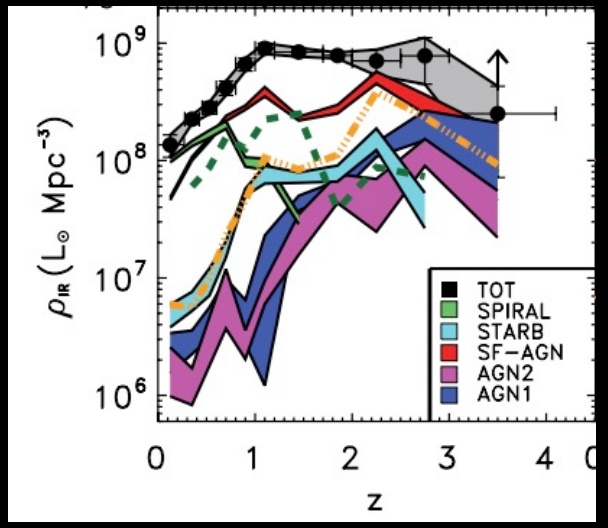
Same processes?

SPICA: both SFR and metallicity from FIR

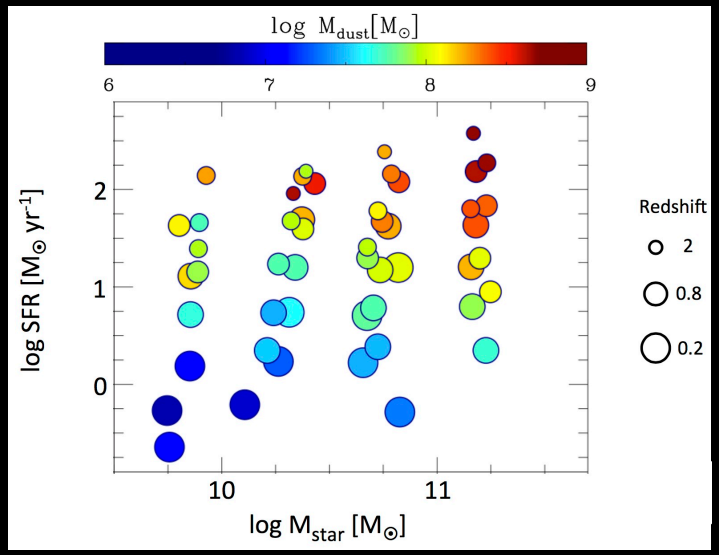
THE DARK SIDE AT HIGH-z



Rodighiero et al. 2010



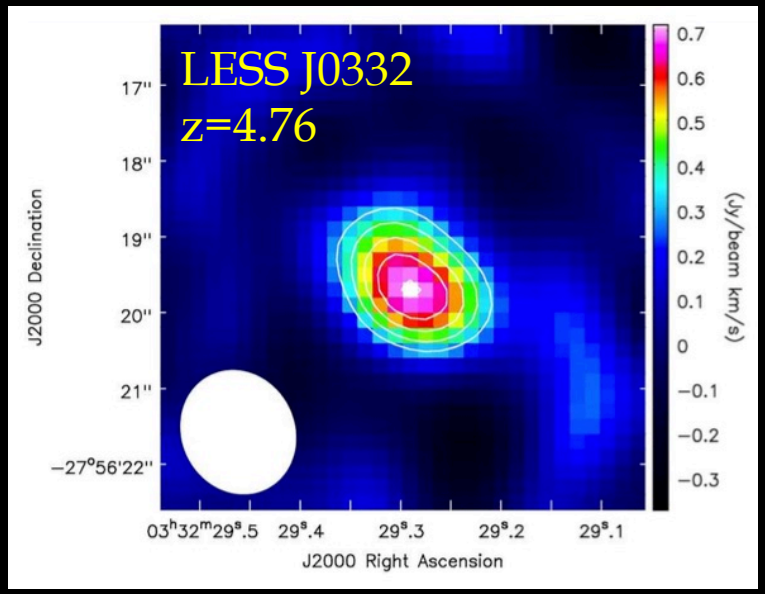
Gruppioni et al 2013



Santini et al. 2013

The fraction of obscured star formation increases with redshift, SFR and mass

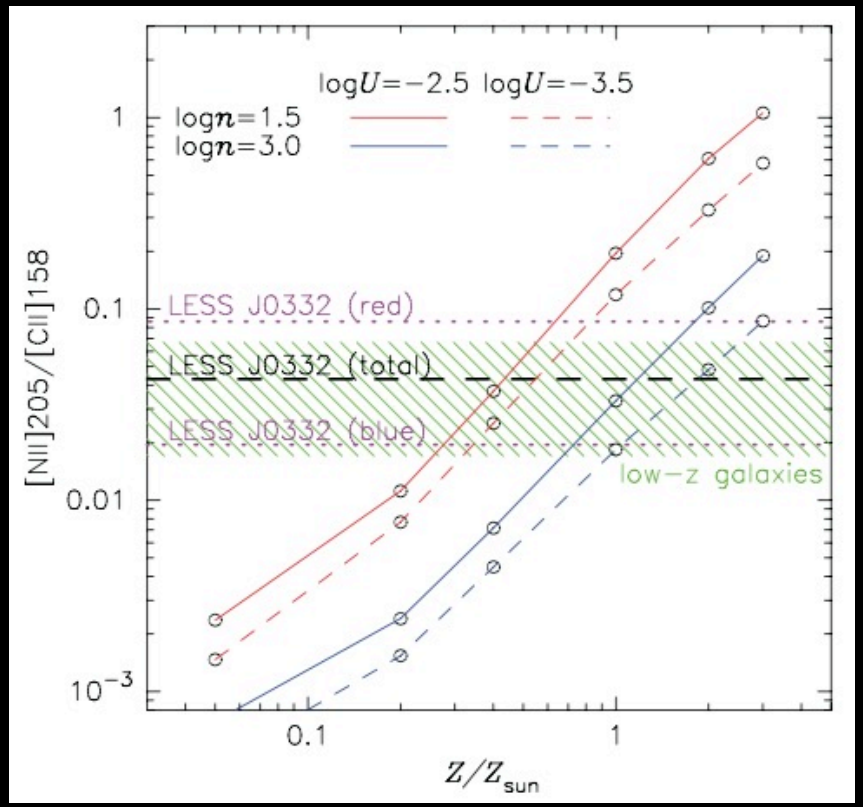
LONGER WAVELENGTHS



Nagao+12

Pioneer ALMA metallicity measurement!

$$\frac{\text{[NII]205μm}}{\text{[CII]158μm}}$$



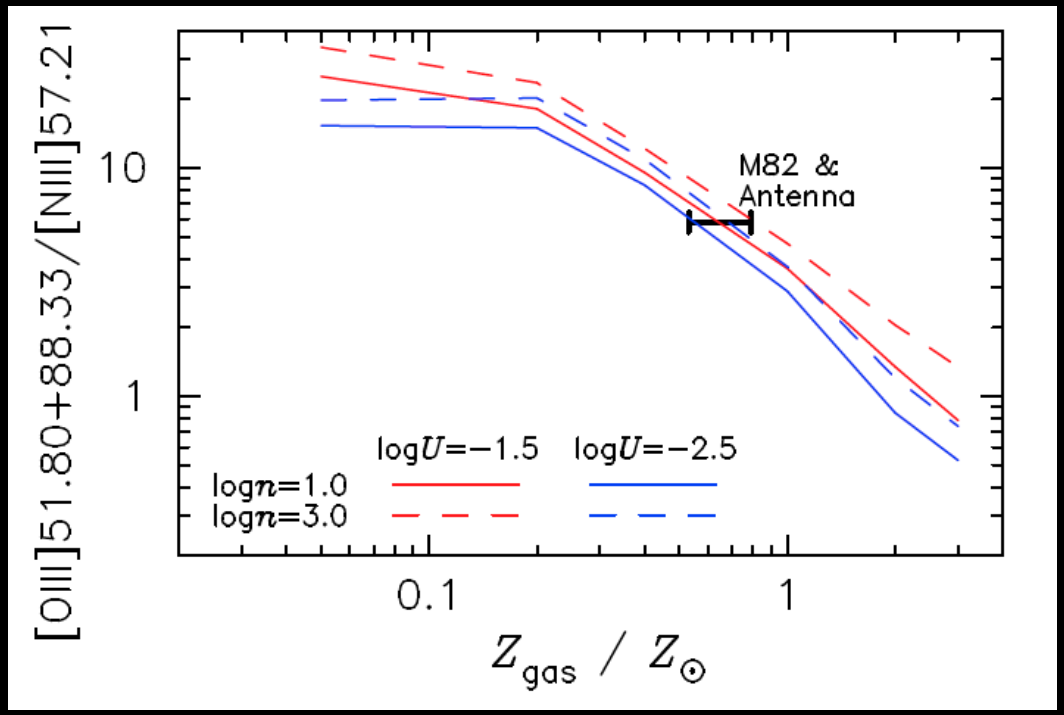
But only very high-z, and only 1-2 far-IR lines in good atmospheric window with ALMA

Need to calibrate empirically with local galaxies

LONGER WAVELENGTHS

Extinction-free lines

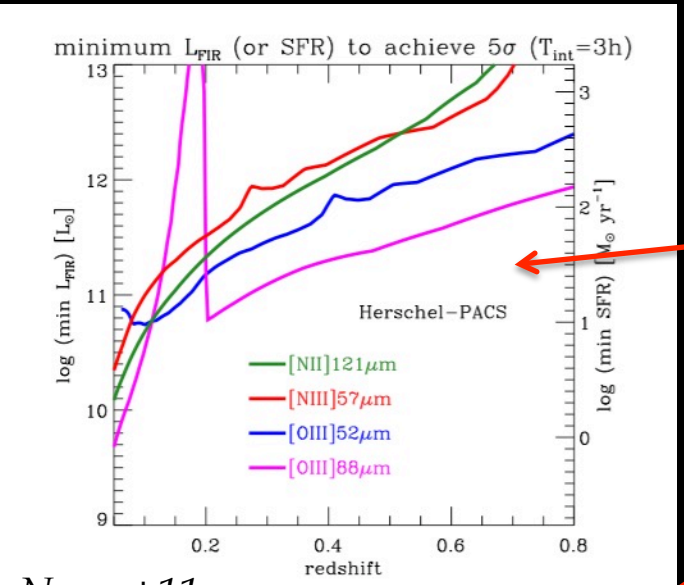
Exploring the chemical enrichment of dust embedded SF with Mid IR “strong” line



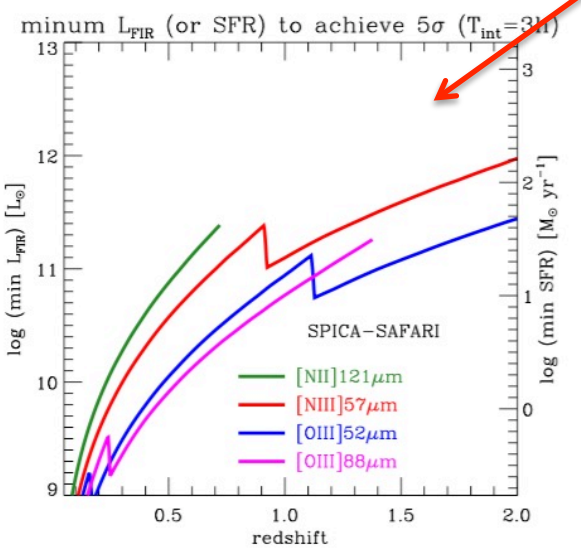
$$\frac{\text{[OIII]52+88μm}}{\text{[NIII]57μm}}$$

Nagao+11, calibrated with photoionization models

LONGER WAVELENGTHS

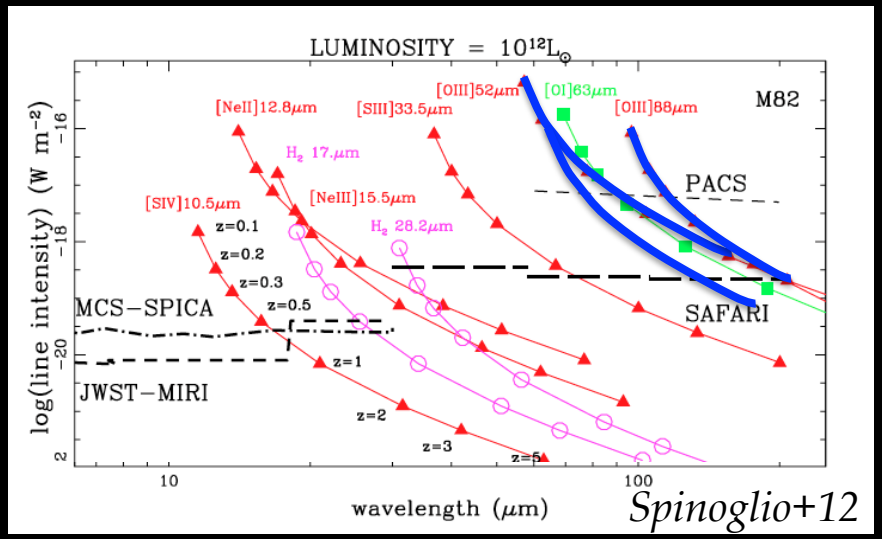


Nagao+11



With Herschel, barely feasible for just an handful of local galaxies

Massive surveys possible with SPICA at high-z!

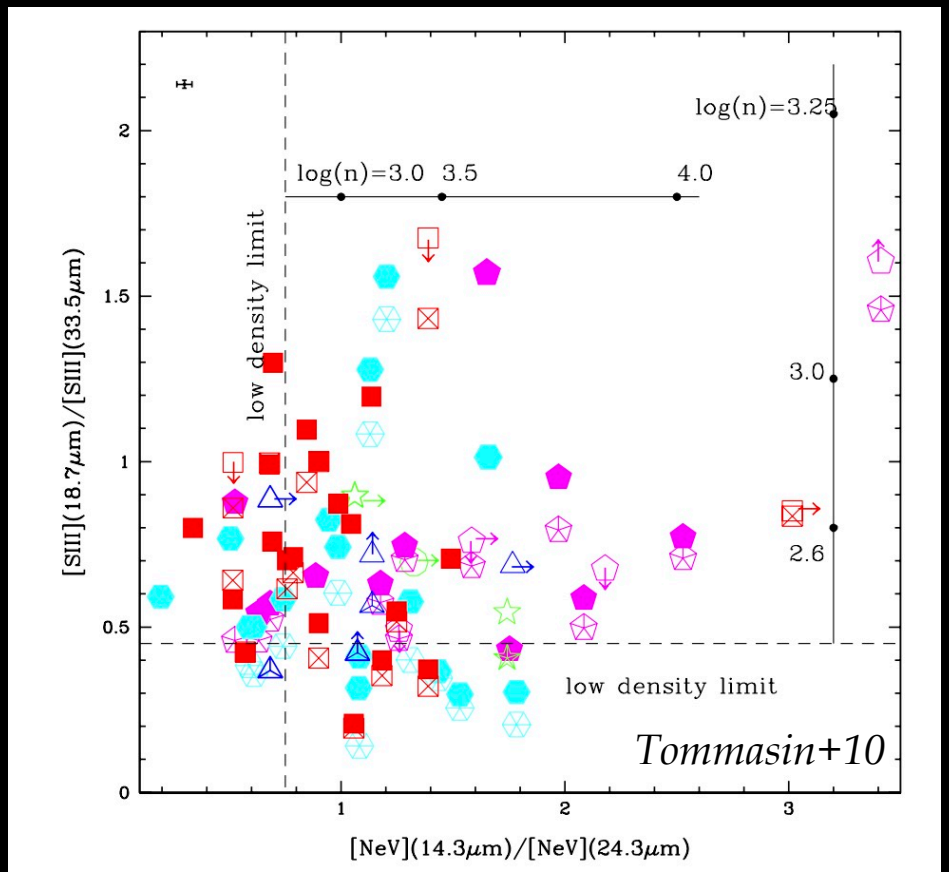


Spinoglio+12

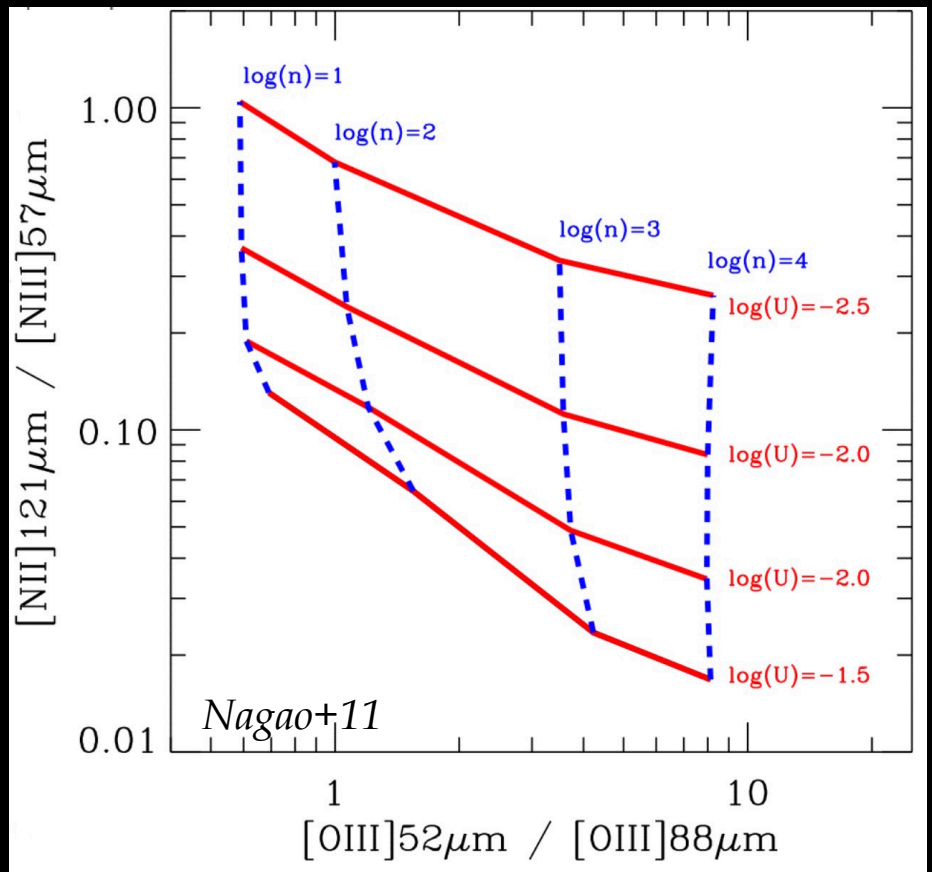
LONGER WAVELENGTHS

Not only metallicities…
…other physical quantities:

Electron densities



Ionization parameter



CONCLUSIONS

A long time ago in a dusty galaxy
far, far away....

It is crucial but still really hard to measure metallicities
in very dusty environments

This can only be done by using extinction-free
lines in the Mid/Far IR

SPICA will finally allow these studies
in a sensible sample of galaxies
up to high-z

THE DARK SIDE OF METALLICITY
IS STRONG WITH SPICA/SAFARI ...