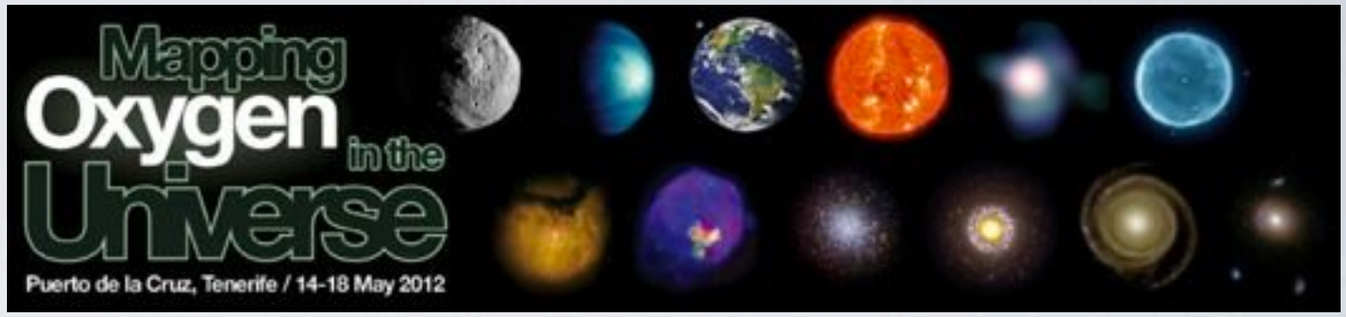


The oxygen abundance in the IFU era

F. F. Rosales-Ortega (UAM,CAHA), **S. F. Sánchez** (IAA/CAHA), **A. I. Díaz** (UAM), **J. Vílchez** (IAA), **J. Iglesias-Páramo** (IAA/CAHA), **R. Kennicutt** (IoA, Cambridge), **J. Bland-Hawthorn** (U. Sidney), **et al.**

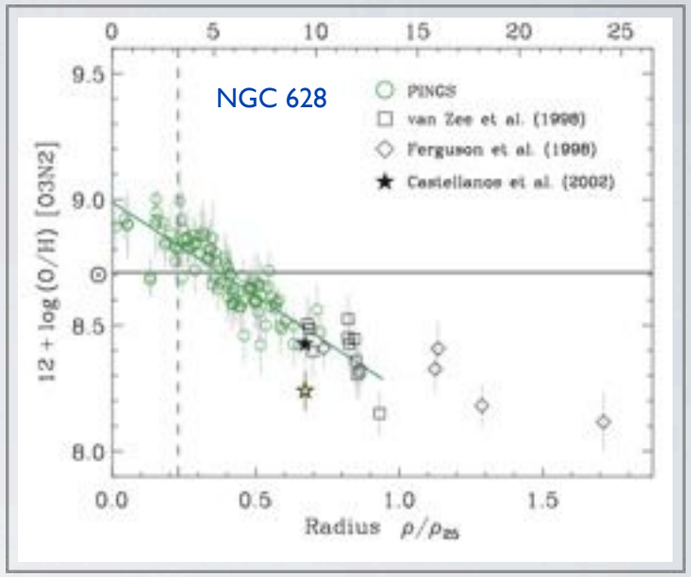
UAM UNIVERSIDAD AUTONOMA DE MADRID

ESTALLIDOS

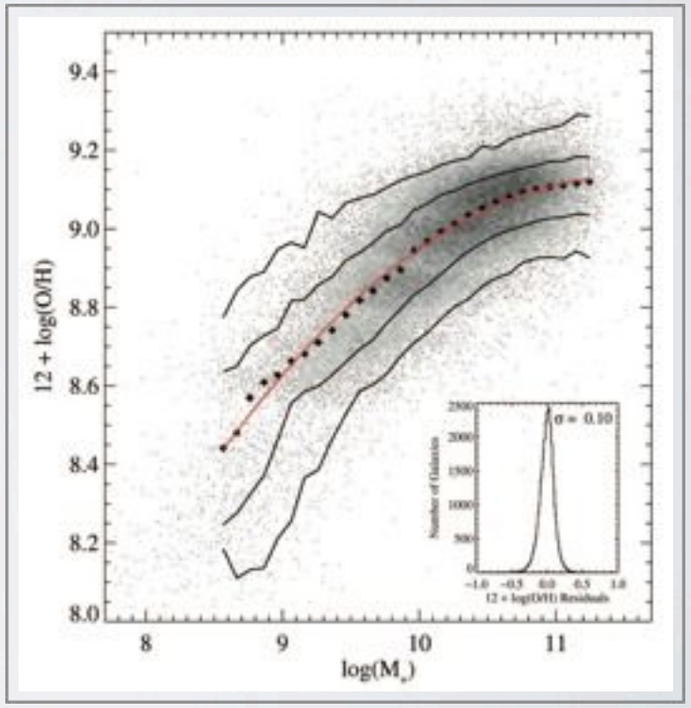
Calar Alto

Two highlights:

I. The IFS approach to abundance gradients

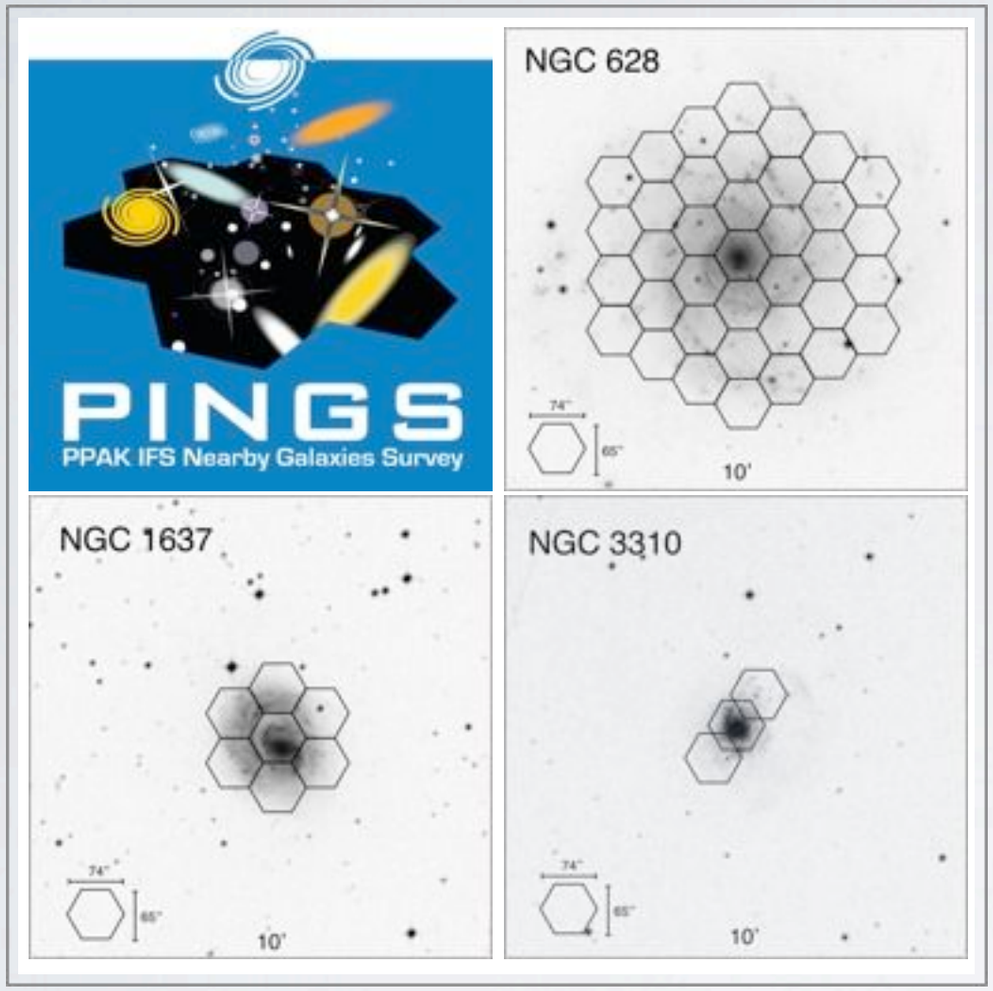


II. On the origin of the mass-metallicity relation

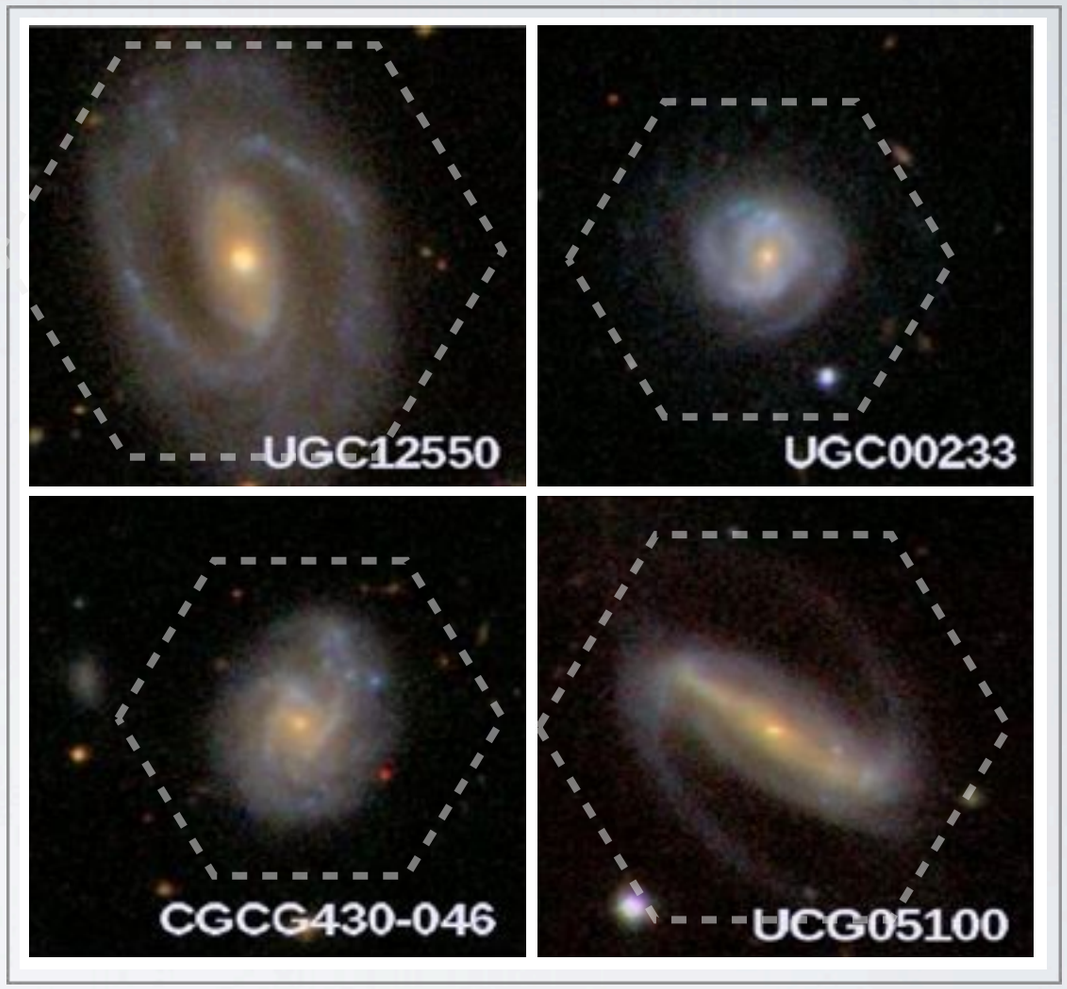


IFS nearby galaxies sample

3.5m telescope Calar Alto, Spain (PMAS/PPAK instrument)



Rosales-Ortega PhD 2009
Rosales-Ortega et al. 2010



Mármol-Queraltó et al. 2011

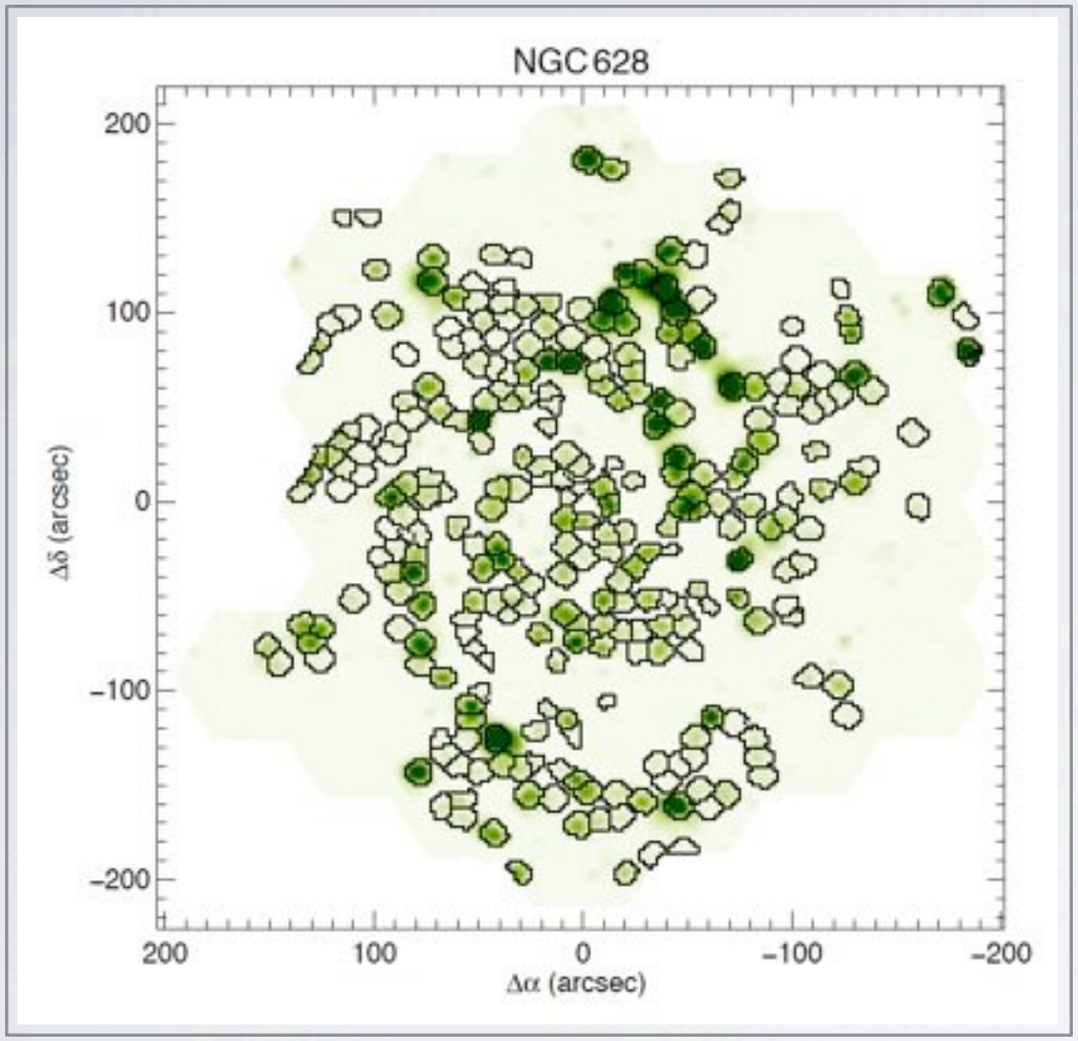
Feasibility study for the CALIFA survey (Sánchez et al. 2012)

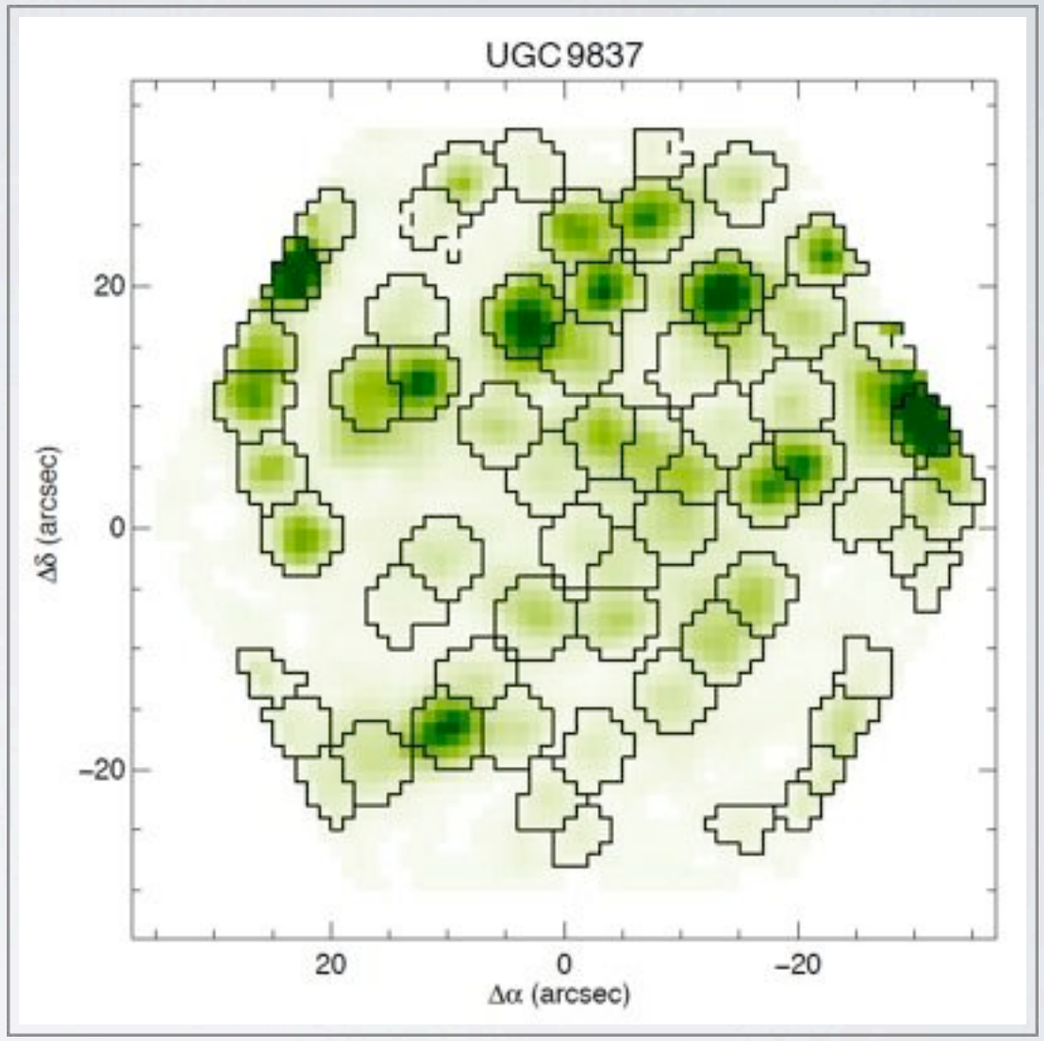
38 late-type galaxies in the local Universe (0.001 < z < 0.025)

Continuous coverage spectra ~3700−7000 Å

IFS-based HII region extraction

`HIIexplorer` (Sánchez et al. 2012; submitted)



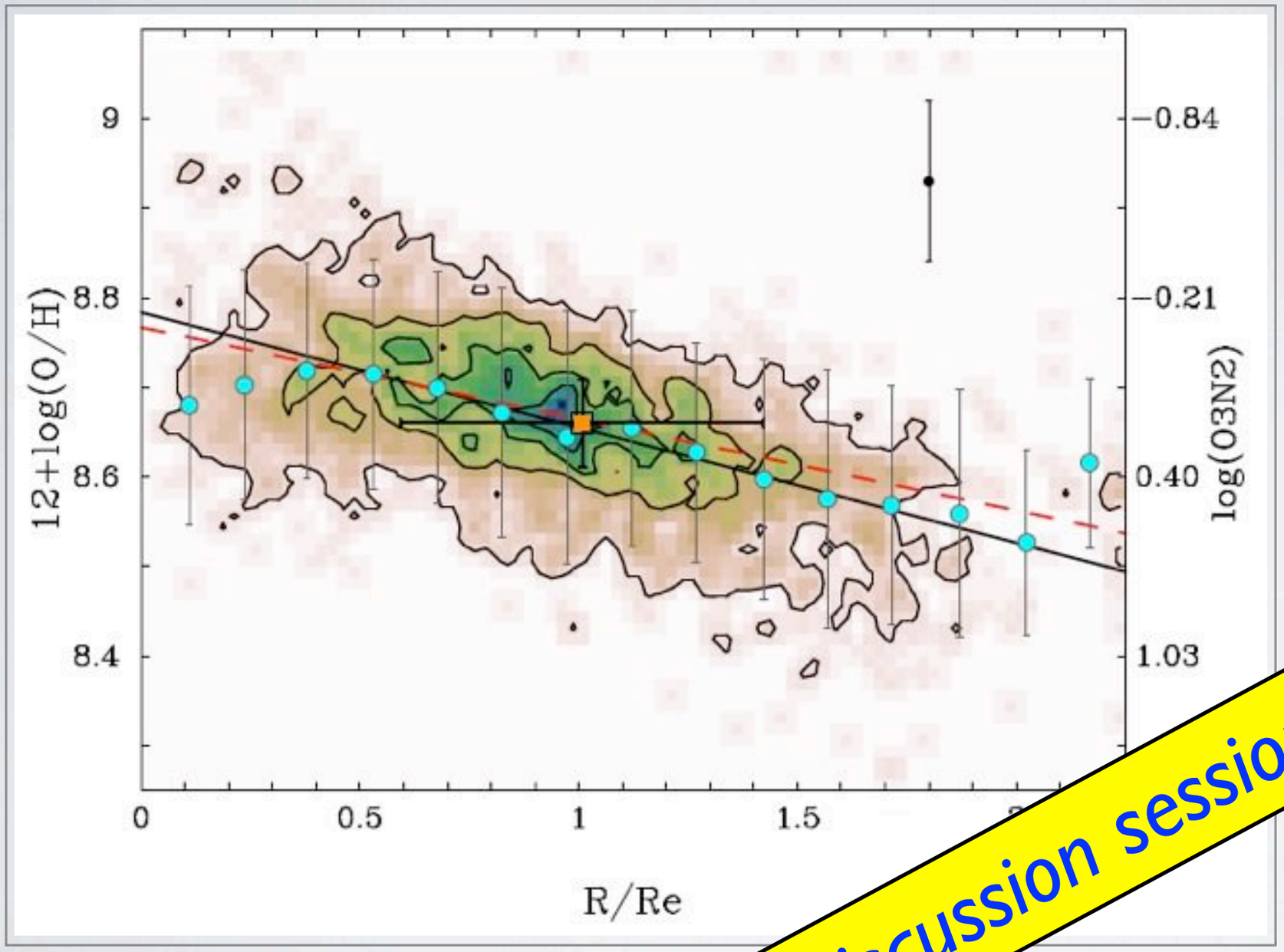


~2500 high S/N, spectra of HII regions (aggretations)

The largest spatially-resolved, nearby spectroscopic HII region survey ever accomplished

I. A statistical (IFS) approach to abundance gradients

Density of HII regions in normalized axes

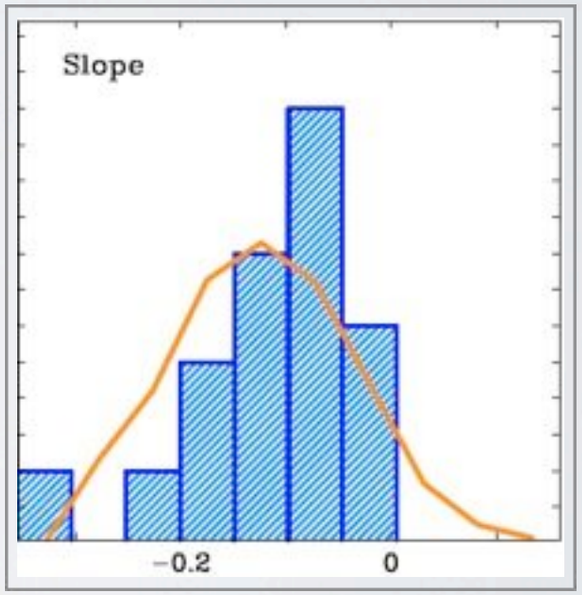


Average linear fit (all galaxies)
−0.12 dex/Re

Linear fit to all HII regions
−0.11 dex/Re

Mean value at radial bins ~0.15 Re

Average abundance of solar neighborhood at R_{Sun}



Discussion session!

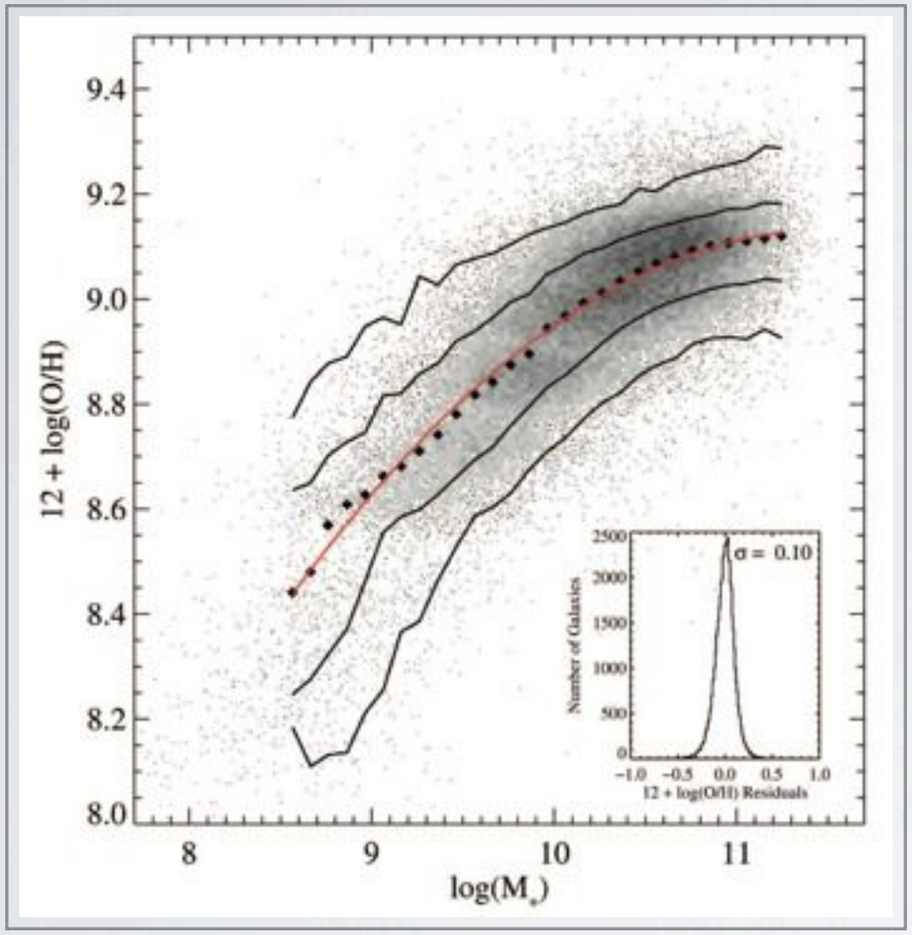
Sánchez et al. 2012 (submitted)

Characteristic value of the slope!

II. On the origin of the mass-metallicity relation

Lequeux et al. 1979: metallicity is strongly correlated with galaxy mass

Established observationally using 53,000 galaxies in the SDSS up to z ~0.1



Tremonti et al. 2004

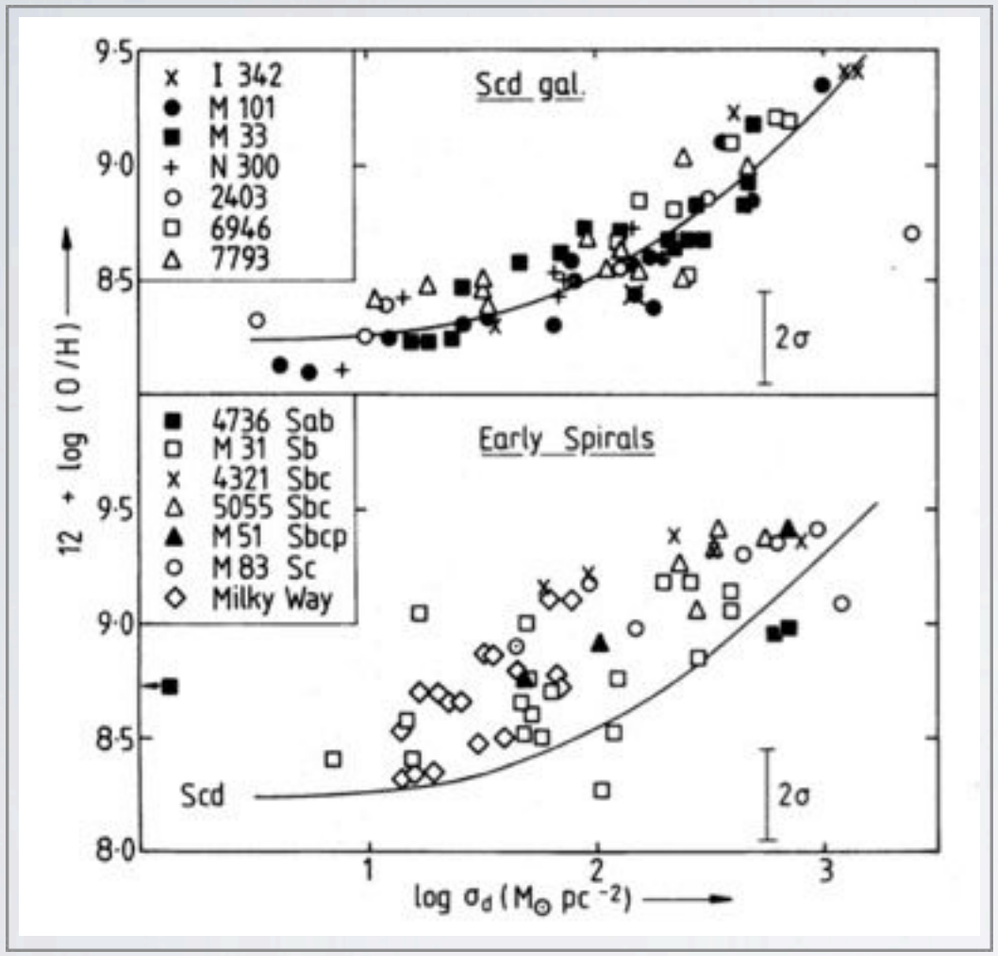
What is the physical mechanism underlying the M-Z relation?

- ★ Loss of enriched gas by outflows
  (e.g. Tremonti+ 2004, Kobayashi+ 2007, etc.)
- ★ Accretion of pristine gas by inflows
  (e.g. Finlandor & Davé 2008)
- ★ Variations in the initial mass function (IMF)
  (e.g. Köppen et al. 2007)
- ★ Selective star-formation efficiency or *downsizing*
  (e.g. Brooks+ 2007, Ellison+ 2008, Calura+ 2009, Vale Asari+ 2009)

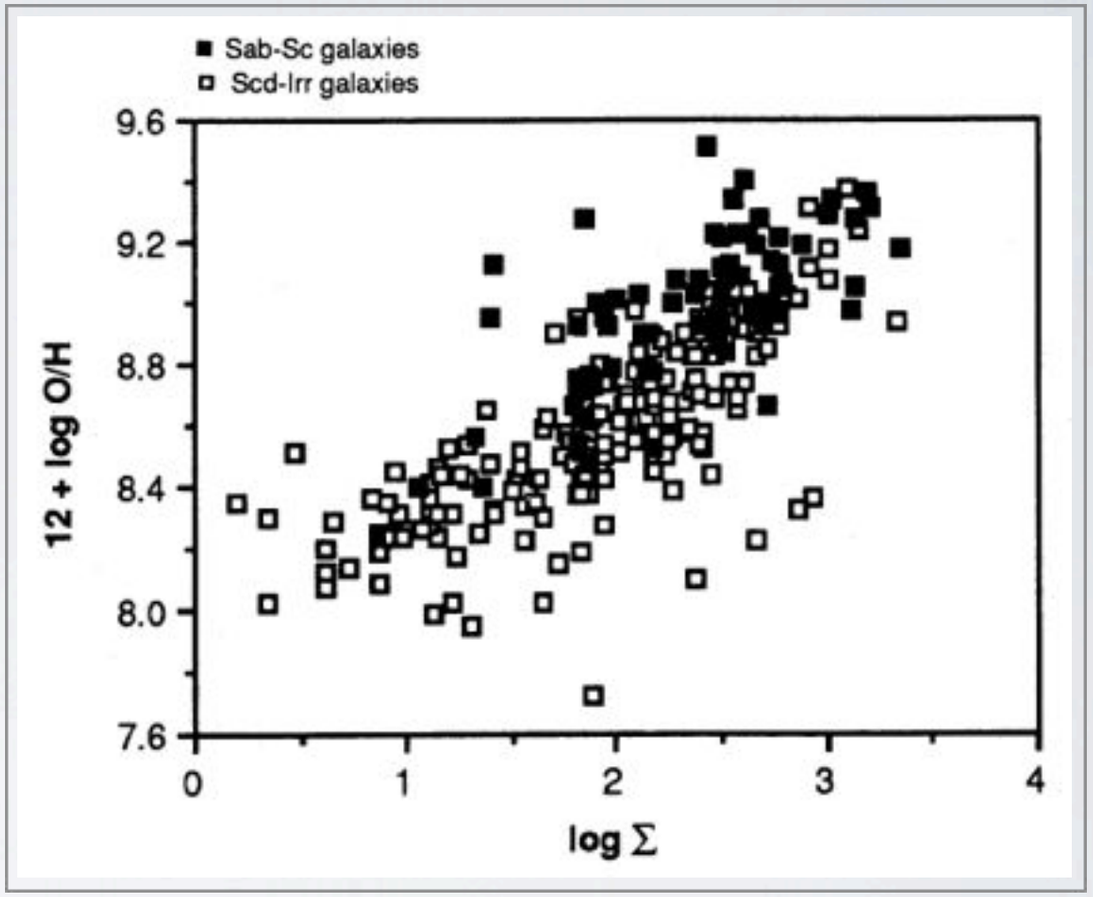
There has been no major effort to test the M-Z relation using spatially-resolved information

Literature background:

surface mass density vs. gas metallicity relation



McCall 1982, PhD
Edmunds & Pagel 1984



Vila-Costas & Edmunds 1992

Plus few other examples in the literature, but almost an overlooked relation

Σ_{Lum}

Surface mass density

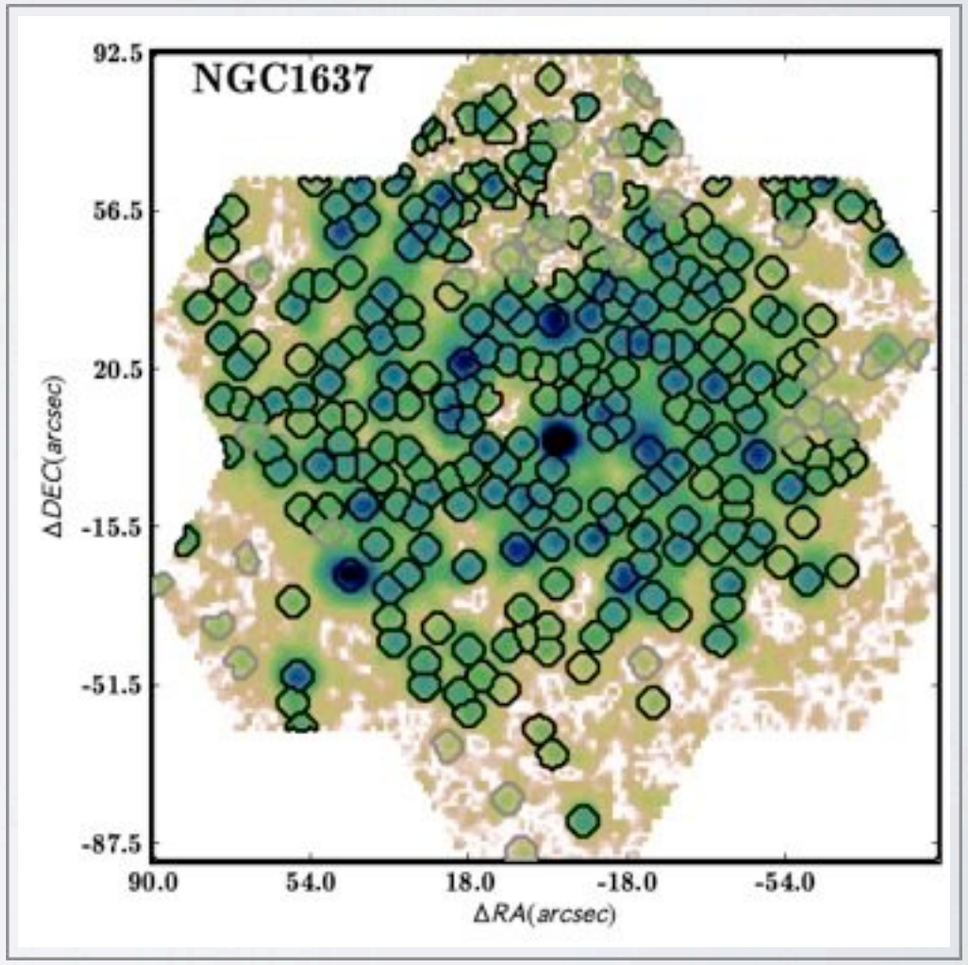
- **B** and **V**-band surface brigthness were extracted directly from the IFS data, within the area encompassed by our IFS-segmented HII regions (emission lines removed).
- Use **B−V** colors to **B**-band mass-to-light ratio to derive the (luminosity) *surface mass density* (Bell & de Jong 2001)
- Radial mass profiles compared with **K**-band profiles of common galaxies in our sample with the **DiskMass survey** (Bershady et al. 2010, Martinsson 2011 PhD).
  - Agreement within ~20%

12 + log(O/H)

- Gas-phase oxygen abundances:

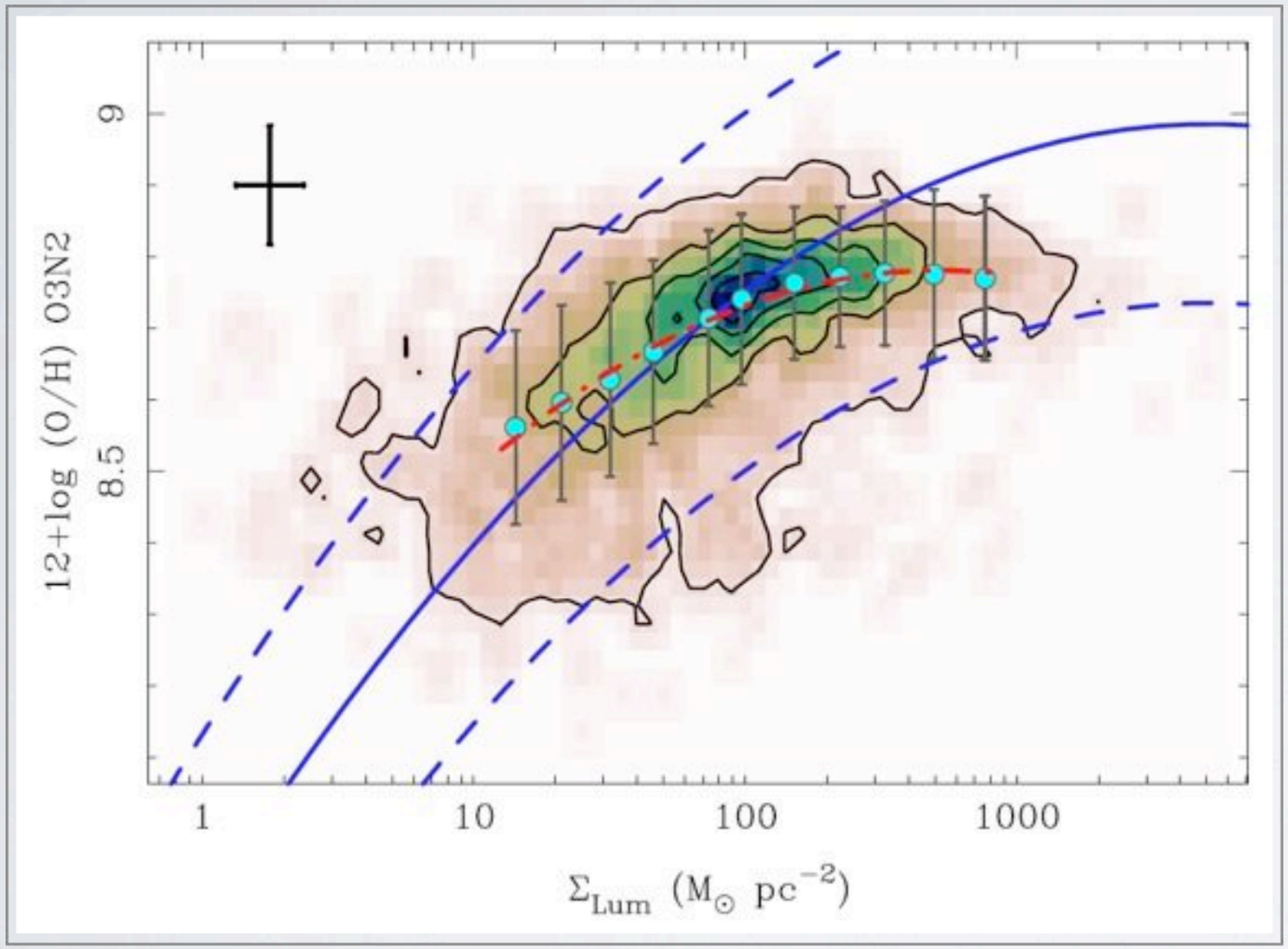
  O3N2 calibrator (Pettini & Pagel 2004)

  R_{23} for those regions with [OII] 3727



The ***local*** mass-metallicity relation

HII regions: surface mass density vs. metallicity



Rosales-Ortega et al. (submitted)

Mean value at bins ~0.15 dex Σ_{Lum}

Polynomial fit to the data

Tremonti et al. 2004 fit (± 0.1dex)

Z −0.15 dex

M −5.0 dex

3 orders of magnitude in Σ_{Lum}

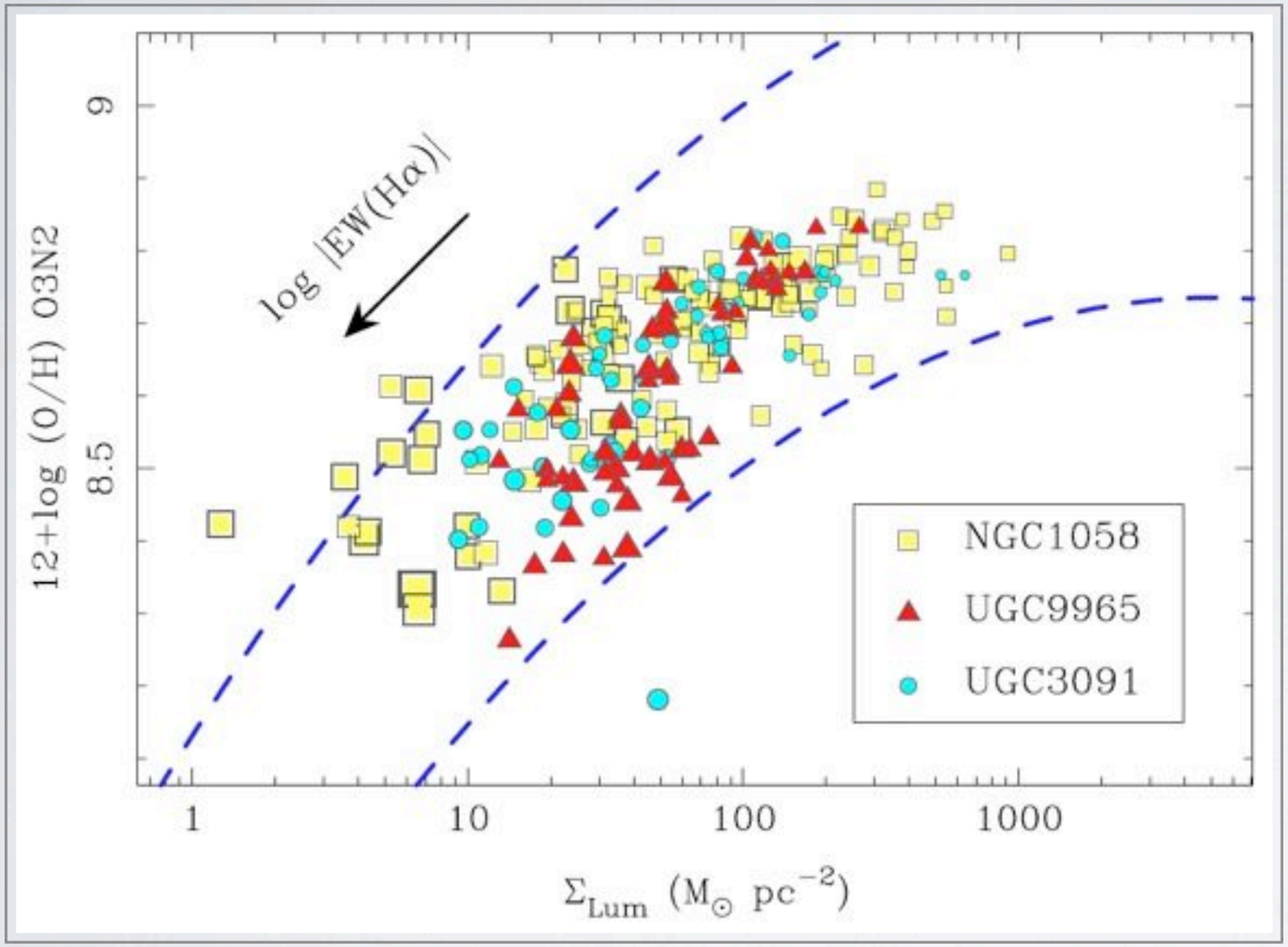
factor of ~ 8 in metallicity

The local M-Z relation stands with 90% within the 95% of the T04 relation

Same shape and fit for other calibrators (e.g. R_{23} by T04), but larger scatter ~20%

The ***local*** mass-metallicity relation

HII regions: surface mass density vs. metallicity



Tremonti et al. 2004 ± 0.1dex fit

Z −0.15 dex

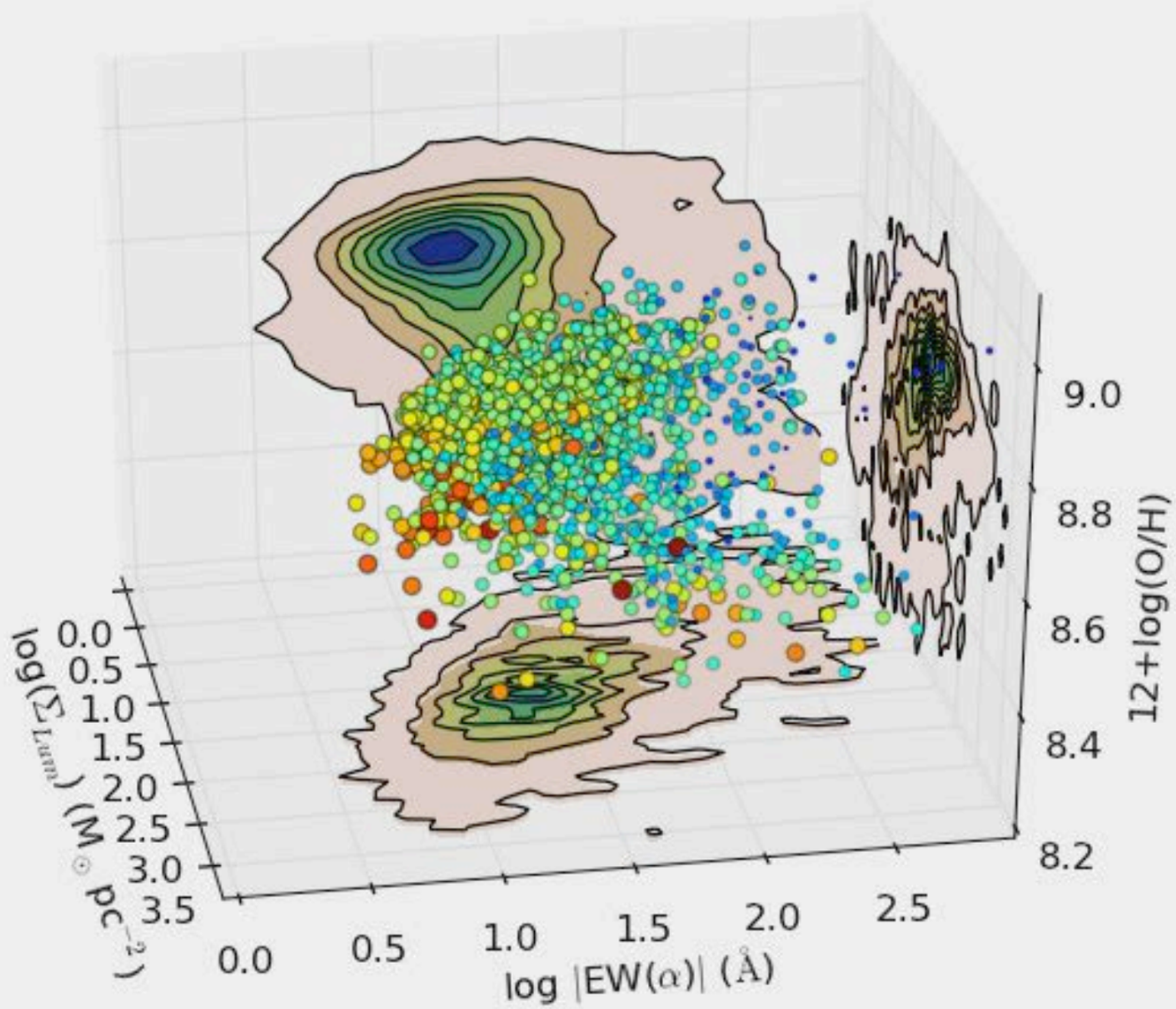
M −5.0 dex

The relation holds for individual galaxies!

There is also a relation with |EW(Hα)| (emission)

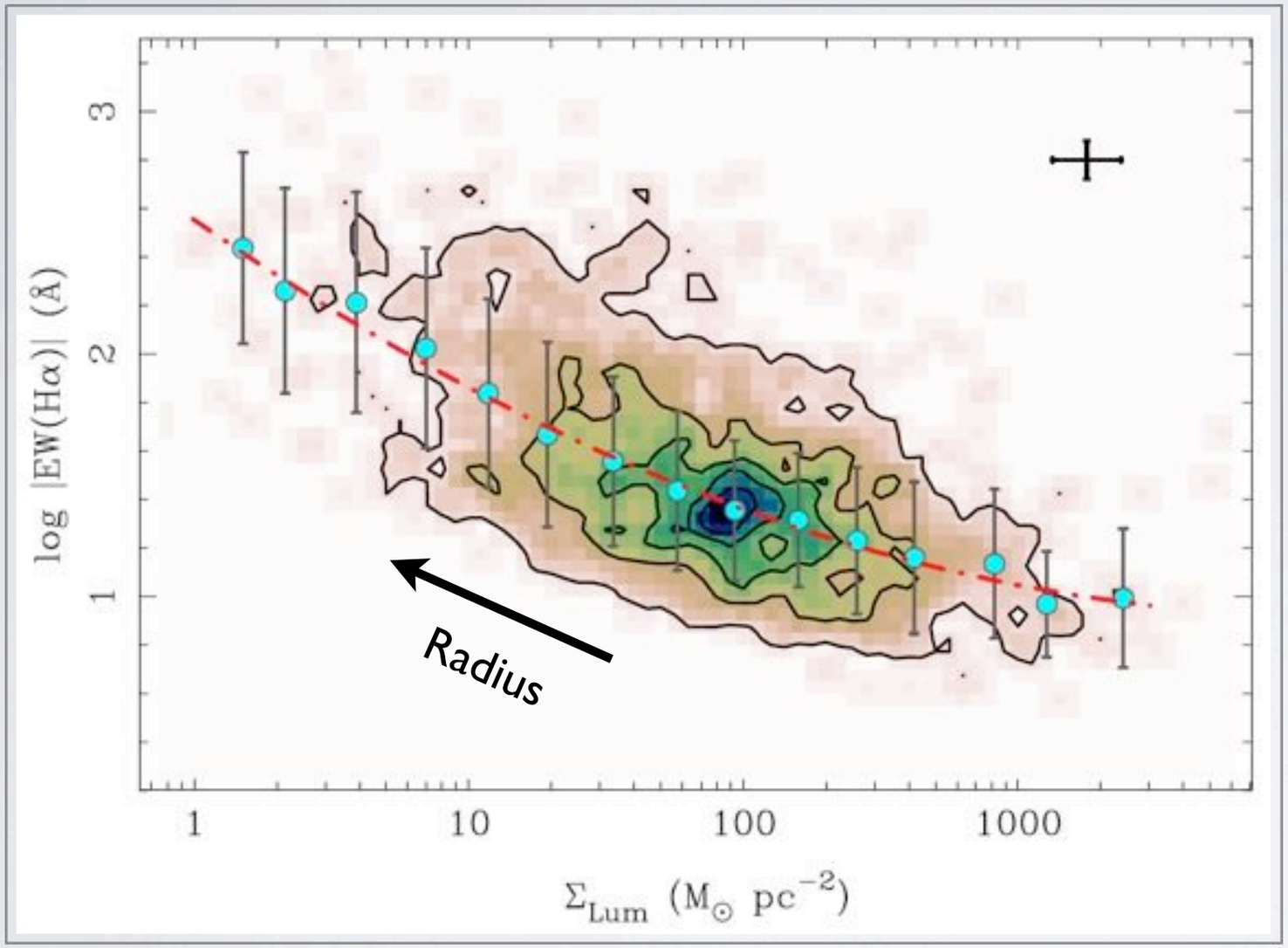
Rosales-Ortega et al. (submitted)

The ***local*** mass-metallicity-EW(Hα) relation



The ***local*** mass-metallicity-EW(Hα) relation

EW(Hα) vs surface mass density projection



Rosales-Ortega et al. (submitted)

EW(Hα)

- ⋆ Scales with the SFR per unit mass, i.e. the Specific SFR (SSFR)
- ⋆ Proxy of the stellar birthrate parameter or *b*-Scalo

$$b = \frac{SFR}{\langle SFR \rangle_{past}}$$

(Kennicutt et al.1994, Kennicutt 1998)

lower (inner) values of |EW(Hα)| → lower SSFR

and vice versa

Is the ***global*** M-Z relation a consequence of the ***local*** one?

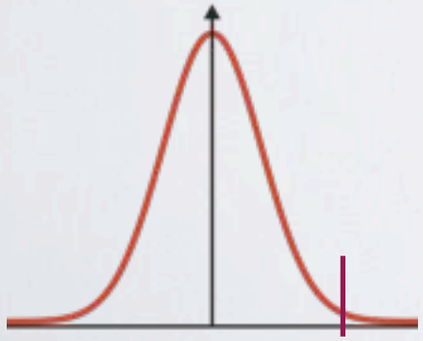
Test: simulate galaxies *assuming* the *local* M-Z relation and the SDSS aperture effect

Draw randomly:

$-15 < \mathbf{M_B} < -23$

$-0.4 < \mathbf{B-V} < 1$

redshift



$\mu \sim 0.1$ $\sigma = 0.05$ $z < 0.02$

Surface brightness

Exponential light distribution

Effective radius

Luminosity-scale relation

(e.g. Brooks et al. 2011)

assuming $\sigma = 0.3$ dex

(Shen et al. 2003)

Luminosity Mass

Integrated $\mathbf{M_B}$ + **B–V**

+

average **M/L**

(Bell & de Jong 2001)

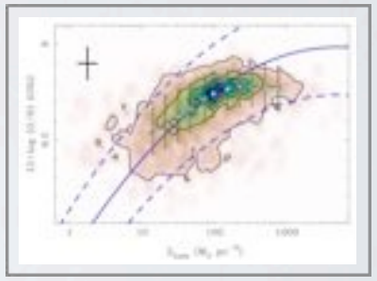
Surface mass density

Aperture equal to the SDSS fibre (3 arcsec)

Mock galaxy

Gas metallicity

local M-Z relation



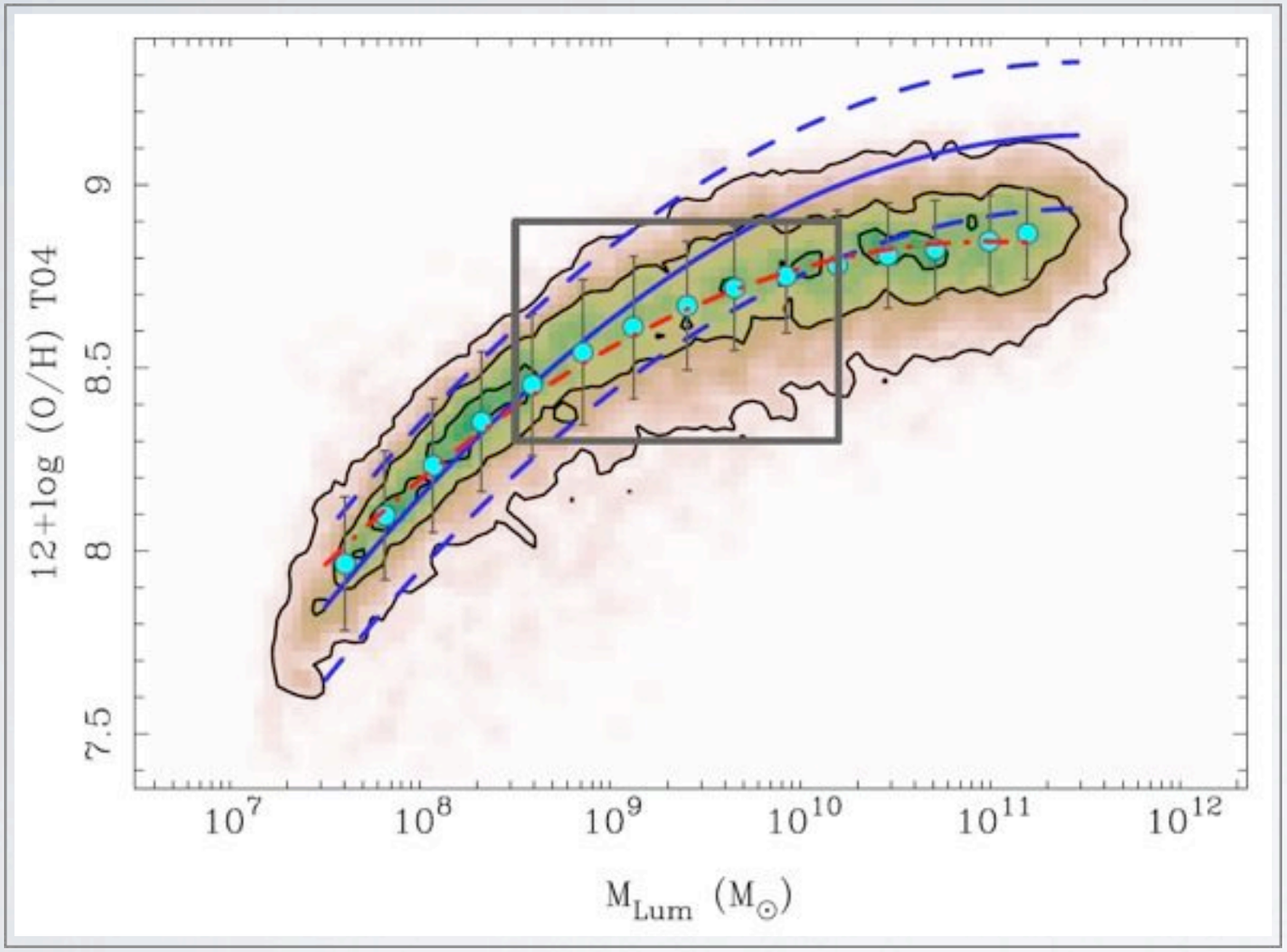
O3N2 conversion to the T04 base

(Kewley & Ellison 2008)

10,000 realizations

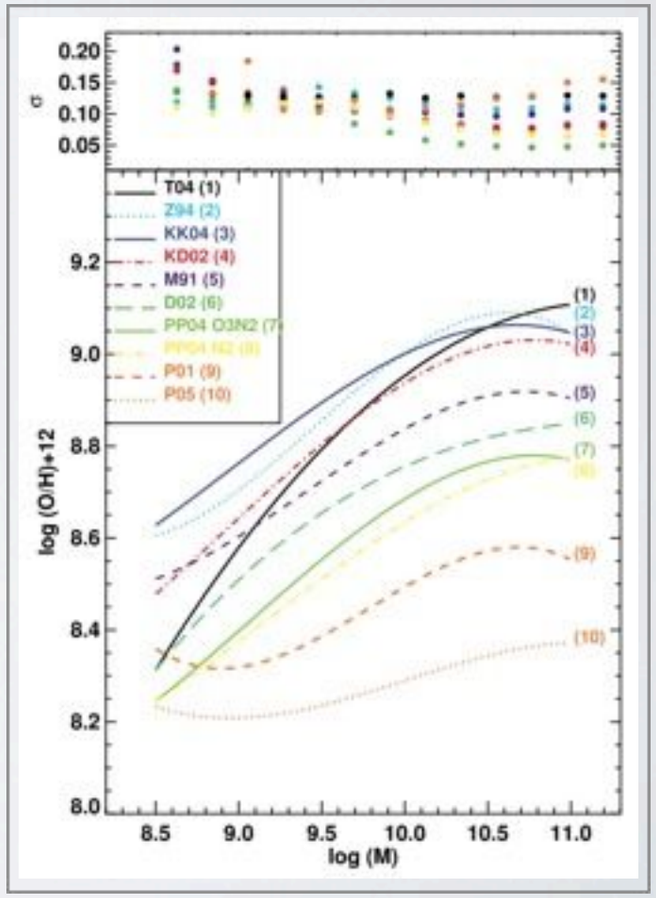
Simulated galaxies in the M-Z plane assuming a ***local*** M-Z relation

Outstanding agreement!



Rosales-Ortega et al. (submitted)

- Mean value at bins ~0.15 dex Σ_{Lum}
- Polynomial fit to the data
- Tremonti et al. 2004 fit (± 0.1dex)
- Range in mass and metallicity of our galaxy sample



(Kewley & Ellison 2008)

The origin of the ***local*** mass-metallicity-EW(Hα) relation

Natural consequence of the radial gradients in spiral galaxies

Mass

Metallicity vs. Radius

EW(Hα) (SSFR *proxy*)

"inside-out" galaxy disc growth

+

chemical evolution in discs

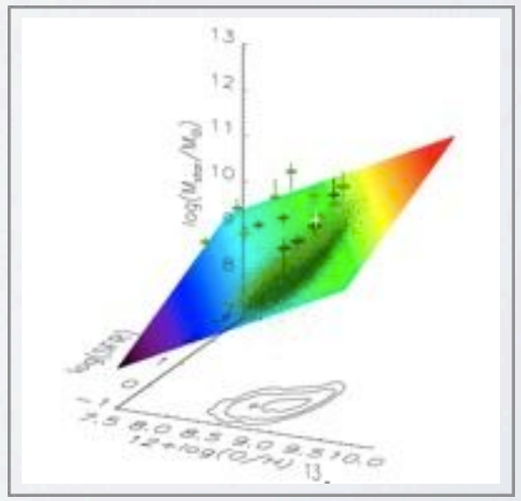
The origin of the ***global*** M-Z relation

- ★ Existence of the ***local*** M-Z relation
- ★ Aperture bias of SDSS

The existence of the fundamental M-Z-SFR

(Lara-López et al. 2010, Mannucci et al. 2010)

Follows naturally from of the existence of the ***local*** M-Z-SSFR relation

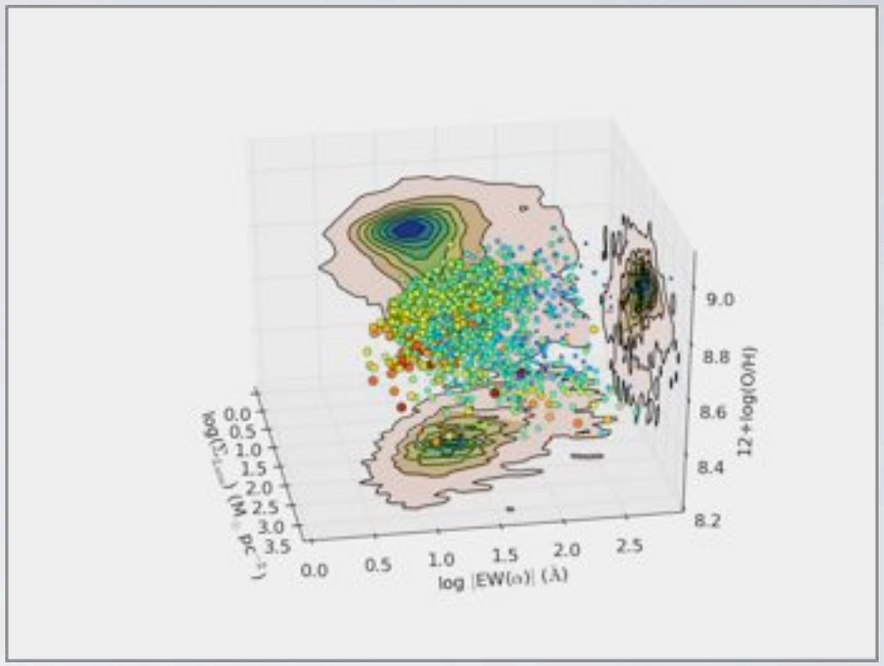


Conclusions

- ⋆ Using IFS ~2500 HII regions of the local Universe, we demonstrate the existence of a ***local*** relation between:

Surface mass density – Gas metallicity – EW(Hα)

local M-Z relation

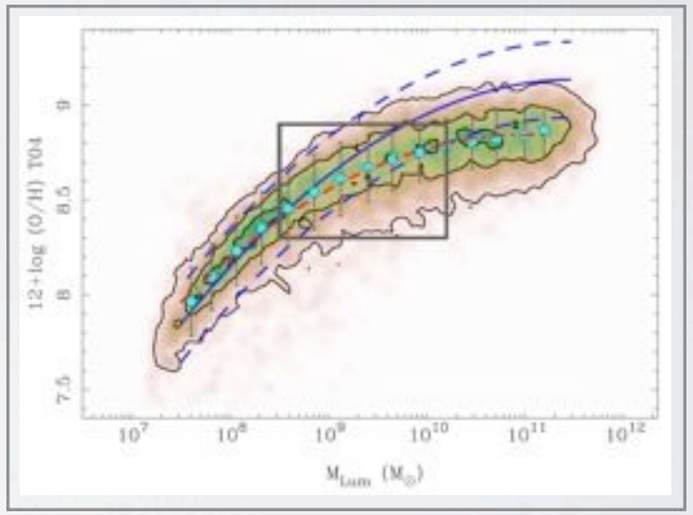


- ⋆ Explained as the combination of well-known physically-based relationships between **mass** and **metallicity** with their differential distributions in spiral discs

- ⋆ We reproduce –*with an oustanding agreement*– the ***global*** M-Z relation by means of a simple simulation assuming:

  1. **The local M-Z relation**
  2. **Aperture effect of the SDSS fibre**

- ⋆ The existence of a fundamental M-Z-SFR relation can be explained by the presence of the local M-Z-SSFR correlation



M-Z relation drivers:

Star formation history
+
downsizing