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Integrated spectroscopy of the *Herschel* Reference Survey

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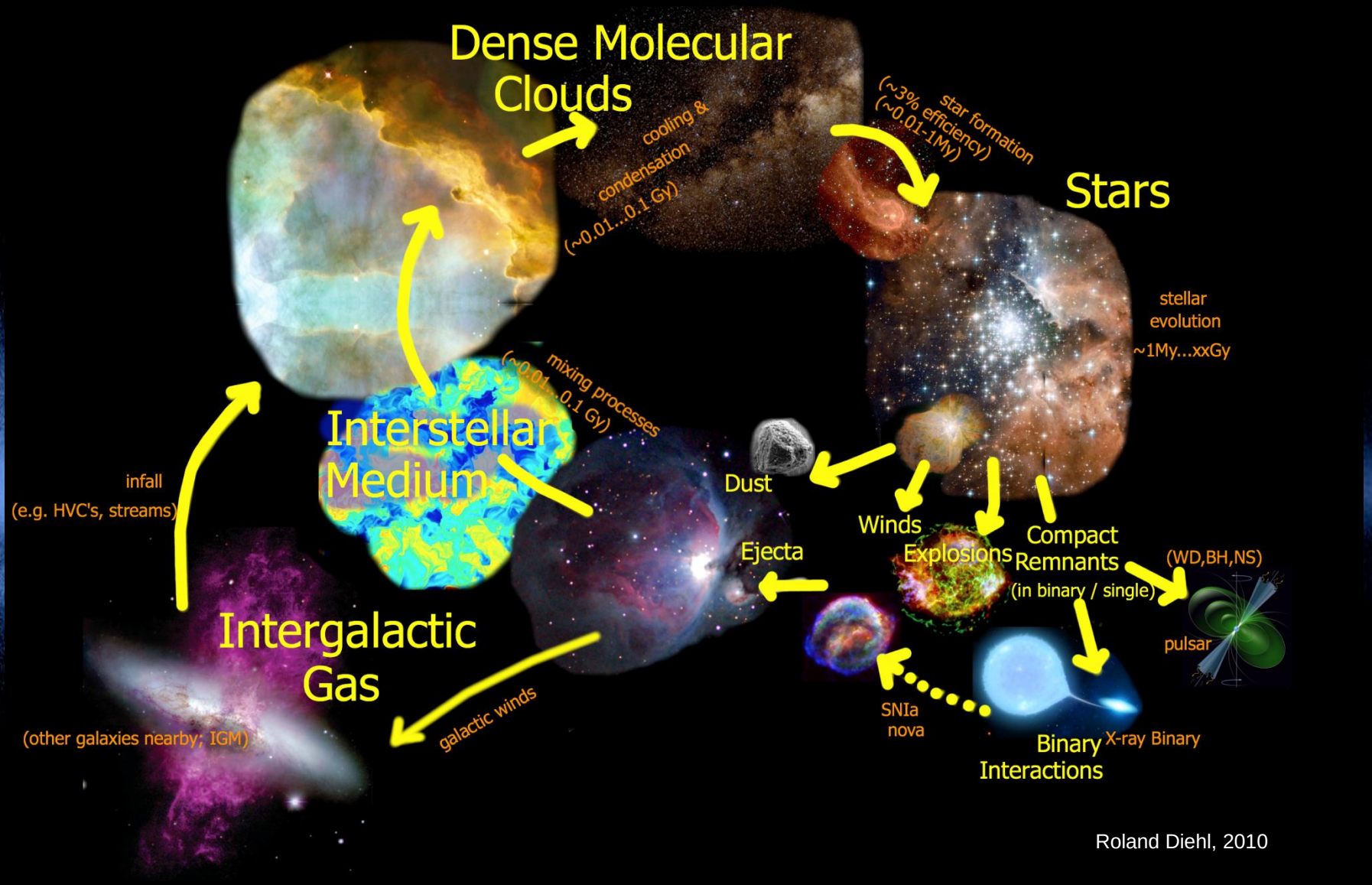
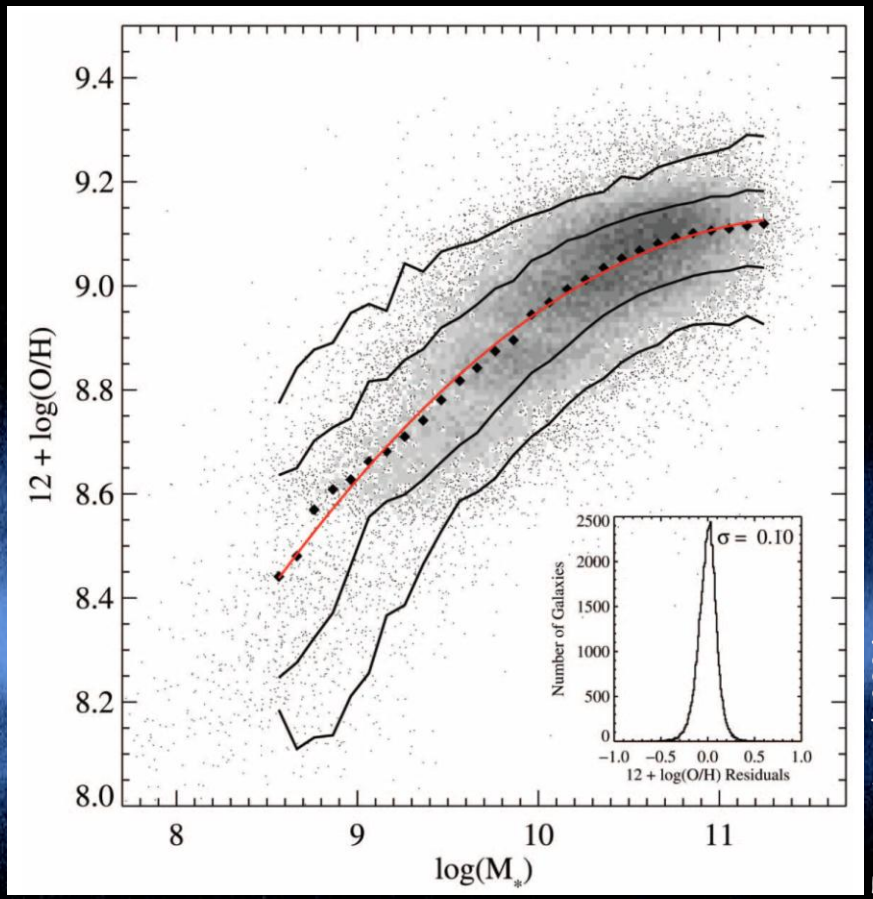
The star formation cycle



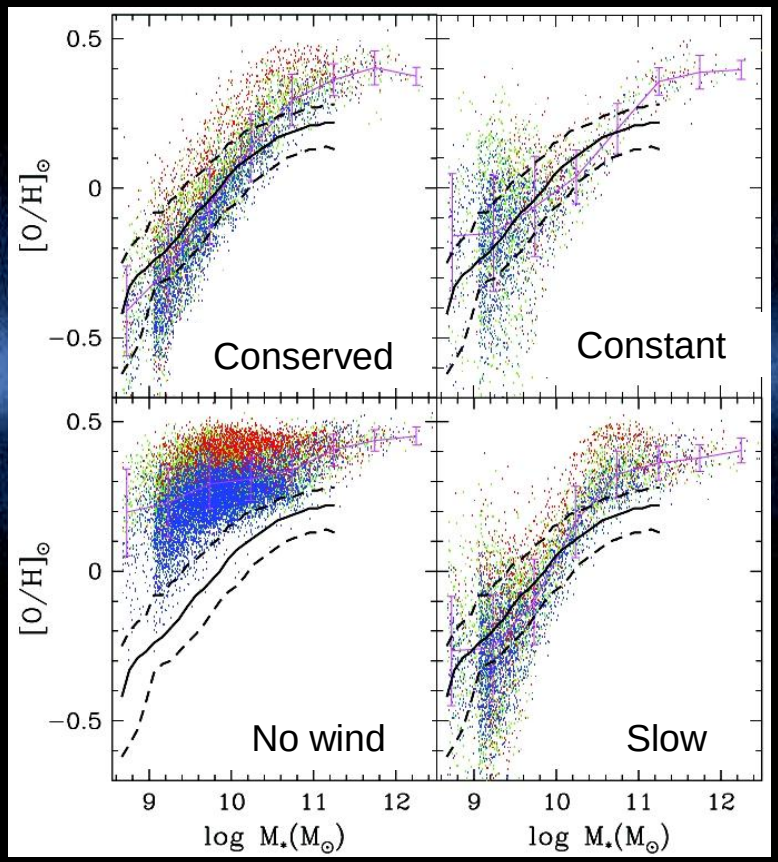
Roland Diehl, 2010

The Mass – Metallicity Relation



Tremonti et al. 2004

- **Origin?**: galactic scale winds
  variable SFR efficiency
  variable IMF



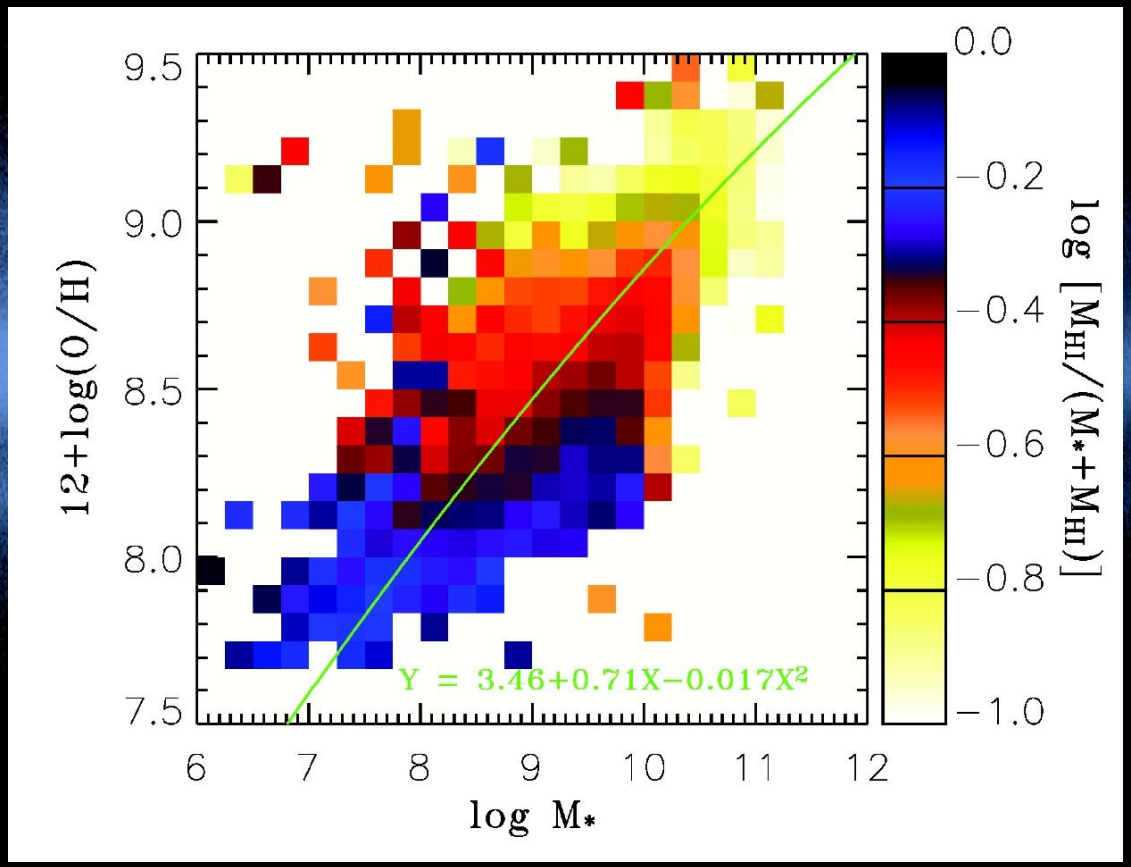
Dave et al. 2011

- useful for constraining galaxy evolution models

  e.g. De Lucia et al. 2004; Dave et al. 2007

Predicted role of gas content

Gas content so far **indirectly inferred** from:
Kennicutt-Schmitt Law (Tremonti et al. 2004),
HI Scaling relations (Zhang et al. 2009).



Zhang et al. 2009

Decreasing Z with increasing Gas Fraction **μ** predicted:

$Z = y \ln(1/\mu)$

(see e.g. Edmunds 2001)

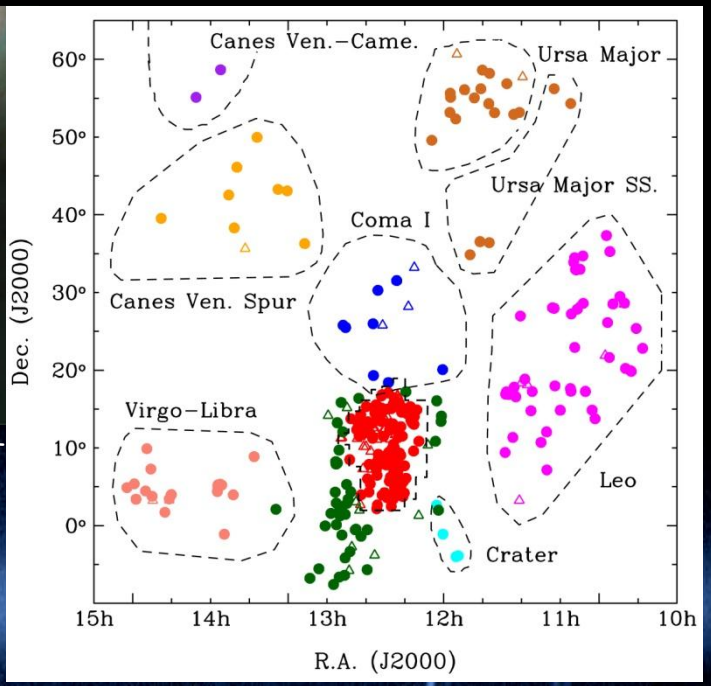
Herschel Reference Survey

Boselli et al. 2010

Magnitude &
Volume limited:

- 15-25 Mpc
- $K_{sTot} \leq 12$ mag
- $b > +55^{o}$
- $A_B < 0.2$

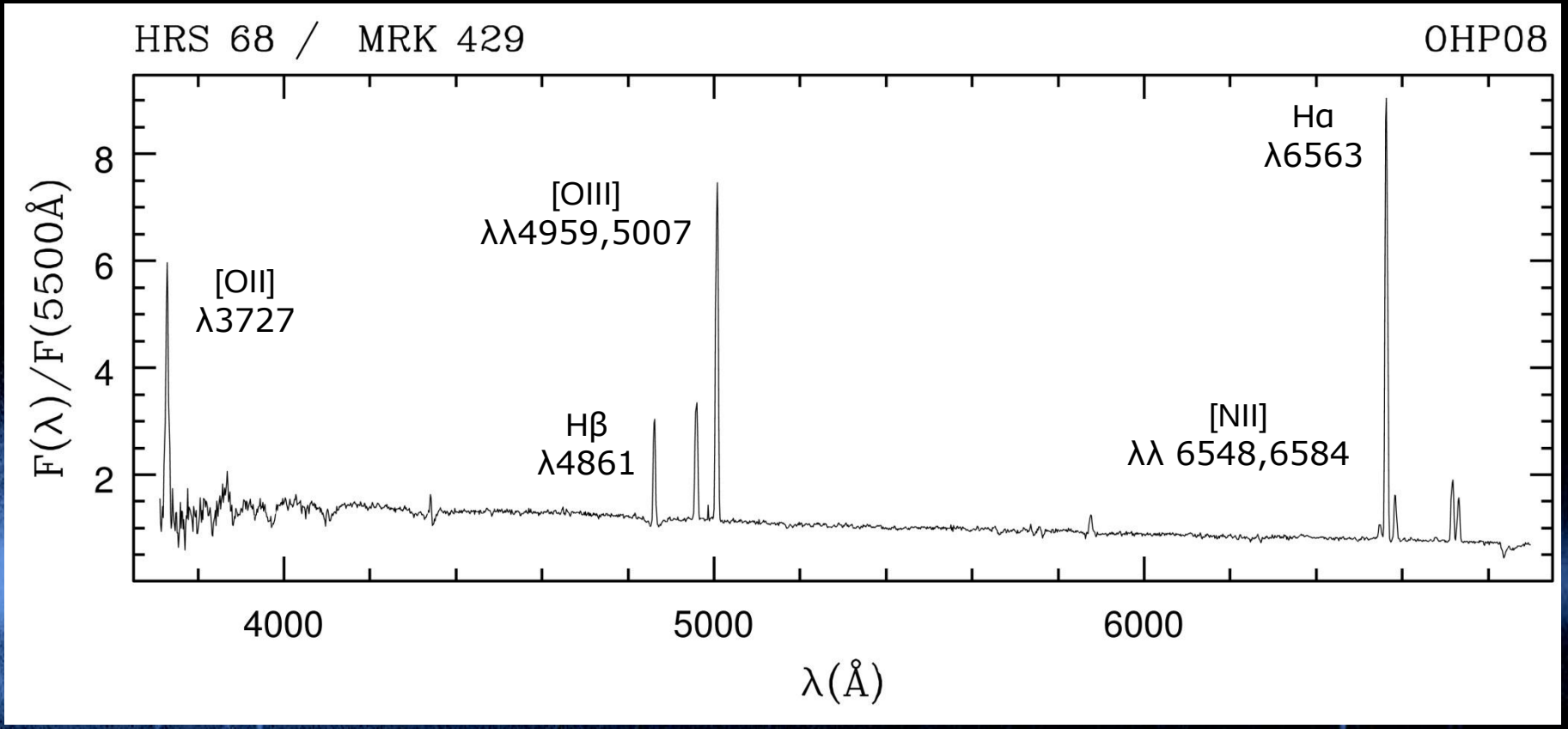
ESA/AOES/HST



= 260 late-types

Complete in H+B+V imaging: stellar mass
NUV imaging: SFR
HI 21cm: gas mass, Def(HI)
Optical spectra: metallicity

Optical spectroscopy



Line emission from nebulae, HII star-forming regions, AGN accretion disk.

Line ratios give nature of the ionising source.

237 drift-scan spectra; R~1000; mostly OHP 1.9m with CARELEC

Metallicity calibrations

Determine calibration between abundances and line ratios via:

1 / Direct measure of electron gas temperature

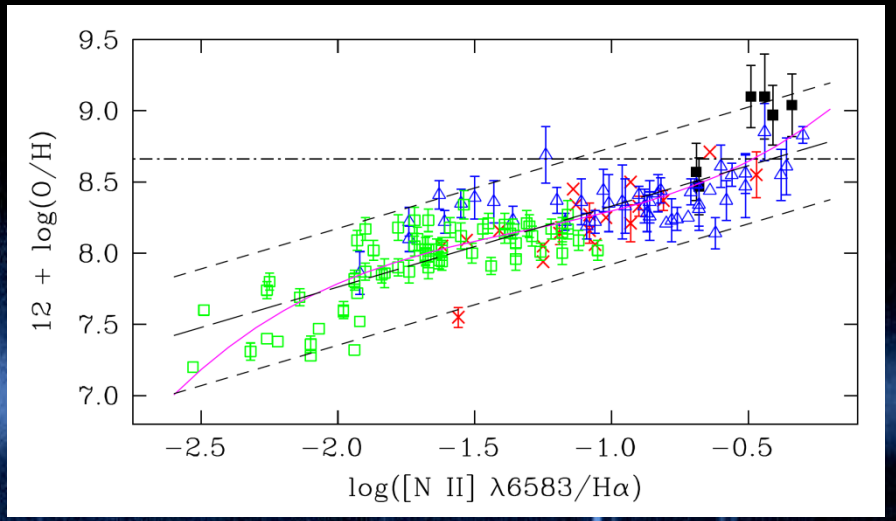
[OIII] λ4363 / [OIII] λ5007

2/ Empirical fits between ratios

[OII] + [OIII] / Hβ ... The R23 Method

[NII] λ6584 / Ha

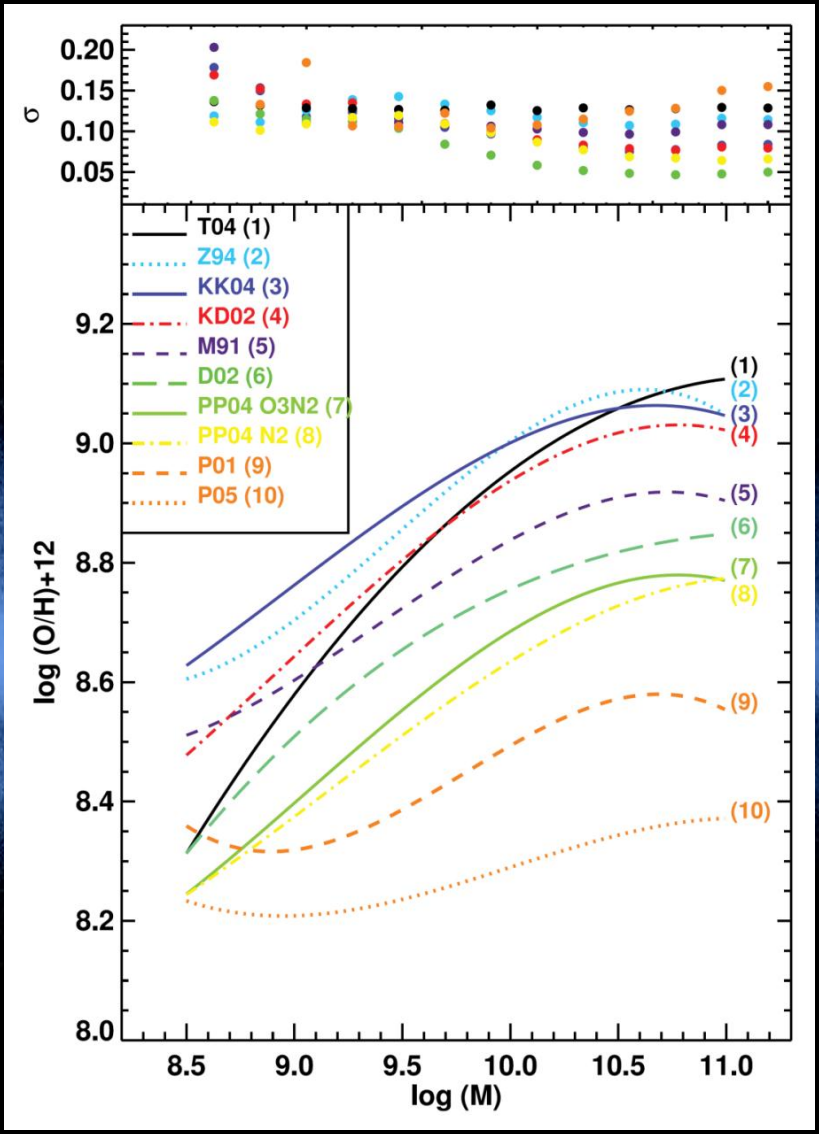
([OII] λ3727 / Hβ) / ([NII] λ6584 / Ha)



Pettini & Pagel 2004

3/ Theoretical methods based on photoionization codes (e.g. Starburst99).

Estimating oxygen abundance



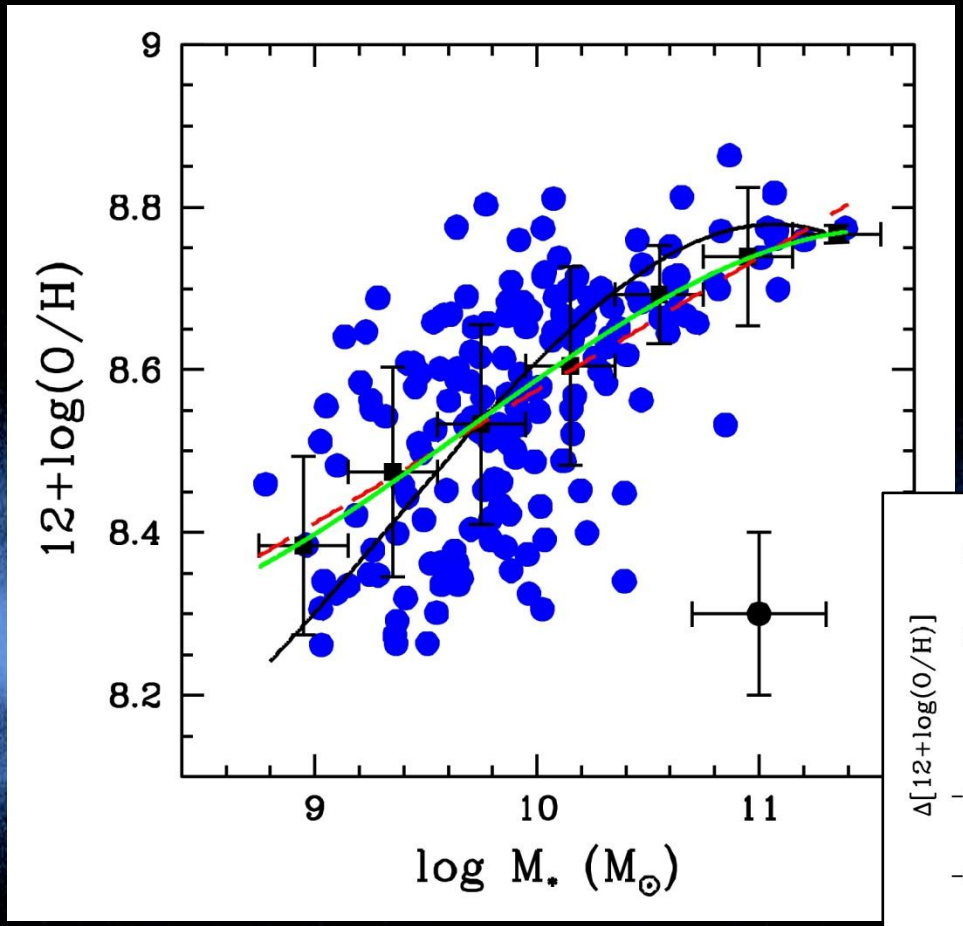
Kewley & Ellison 2008

1 / Examined a number of calibrations to maximize spectroscopic information to estimate 12+log(O/H)

2 / Use up to 5 methods to calibrate oxygen abundance from emission line intensities

3 / Convert to a base metallicity (PP04 O3N2) as in Kewley & Ellison 2008

Defining the M-Z relation

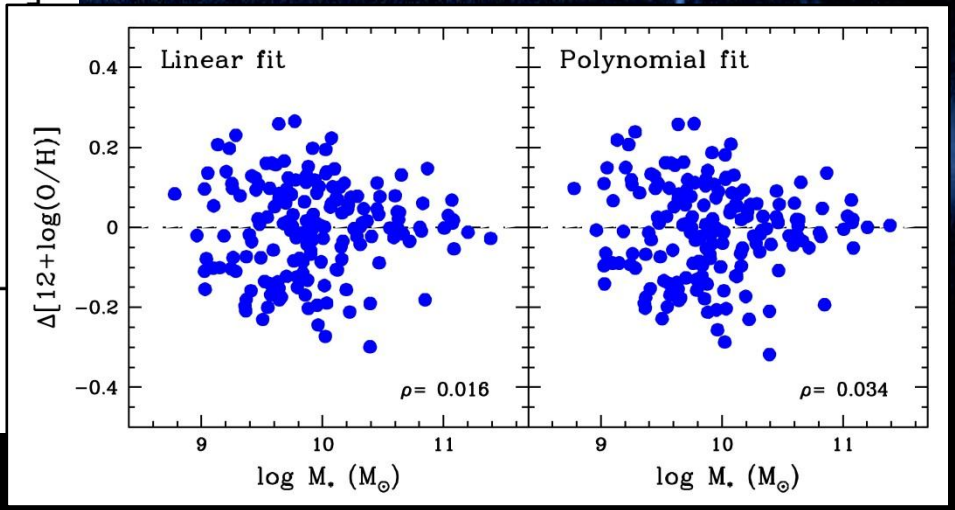


Hughes et al. 2013

- **M-Z shape and scatter consistent:**

  σ = 0.11 dex, rs = 0.57

  (c.f. Tremonti et al. 2004)



Residual oxygen abundance from polynomial fit

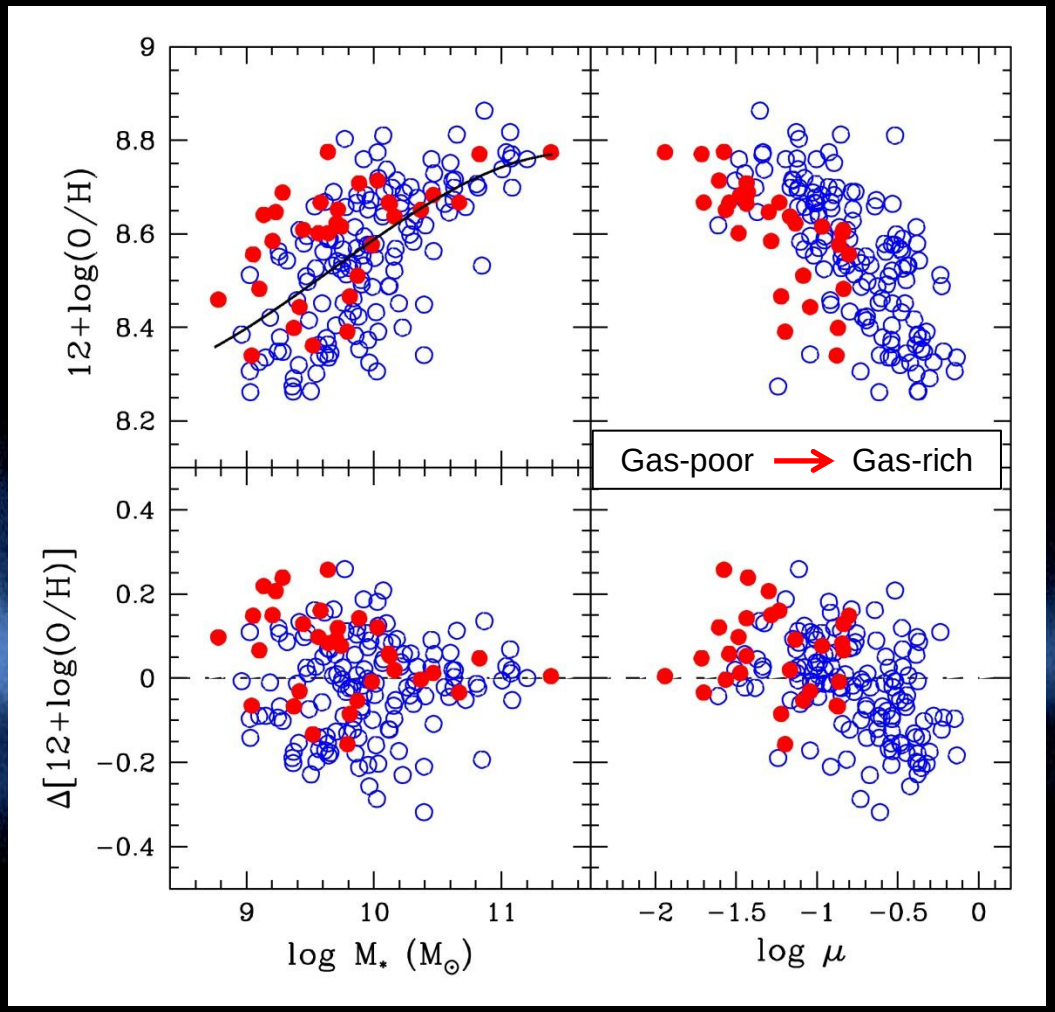
Observed role of gas content

- **Herschel Reference Survey of 323 nearby galaxies**
  (Boselli et al. 2010)
- **Integrated optical spectra for 238 objects**
  (Boselli et al. 2013)
- **HI deficiency defined as**

Def(HI) =
log M(HI) exp- log M(HI) obs

(Haynes & Giovanelli 1984)

Def(HI) > 0.5 : deficient
Def(HI) < 0.5 : normal gas



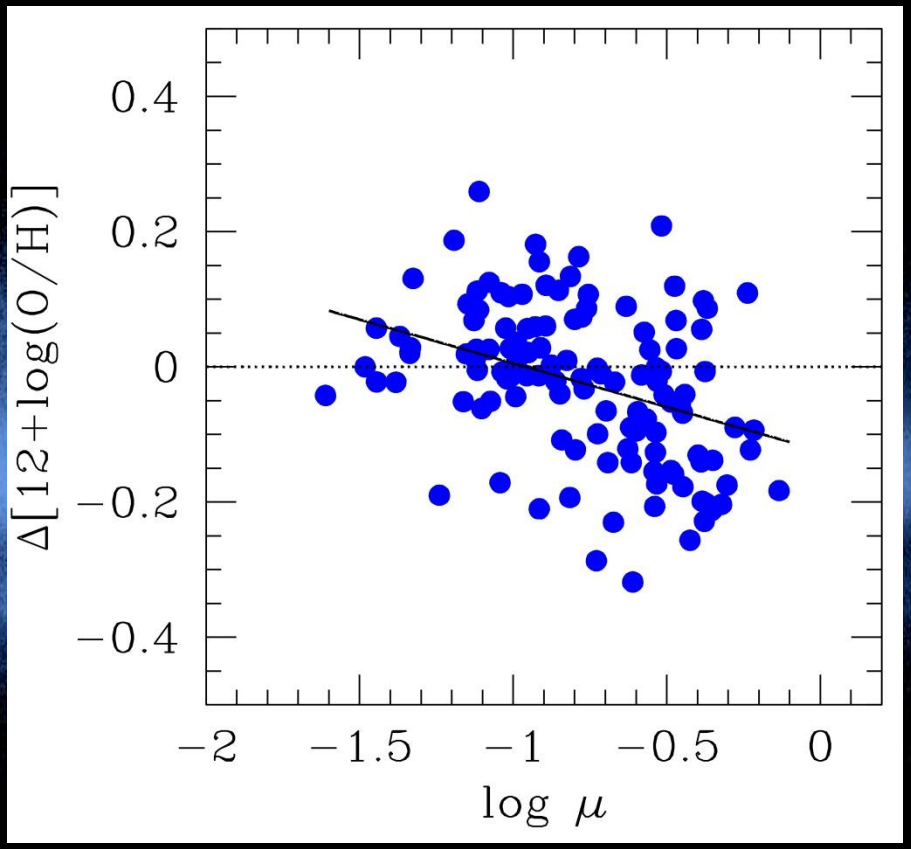
Hughes et al. 2013

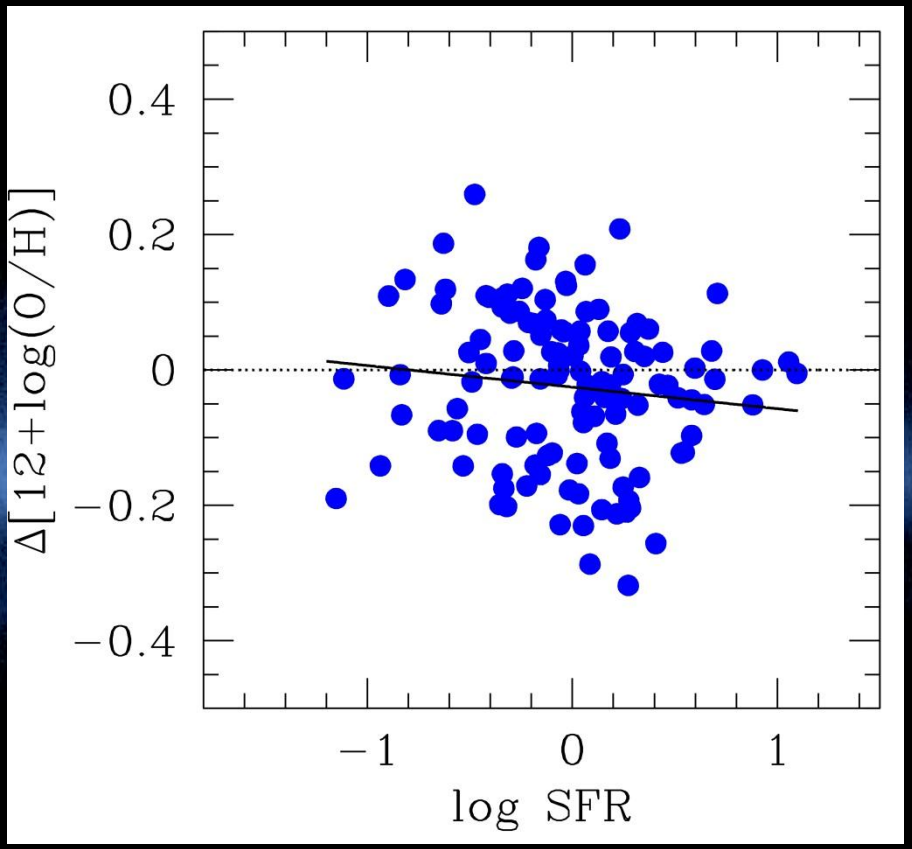
Clear correlation between metallicity and gas content

Comparison with SFR

Recently M-Z-SFR proposed as fundamental plane

See Manucci et al. 2011, Lara-Lopez et al. 2011

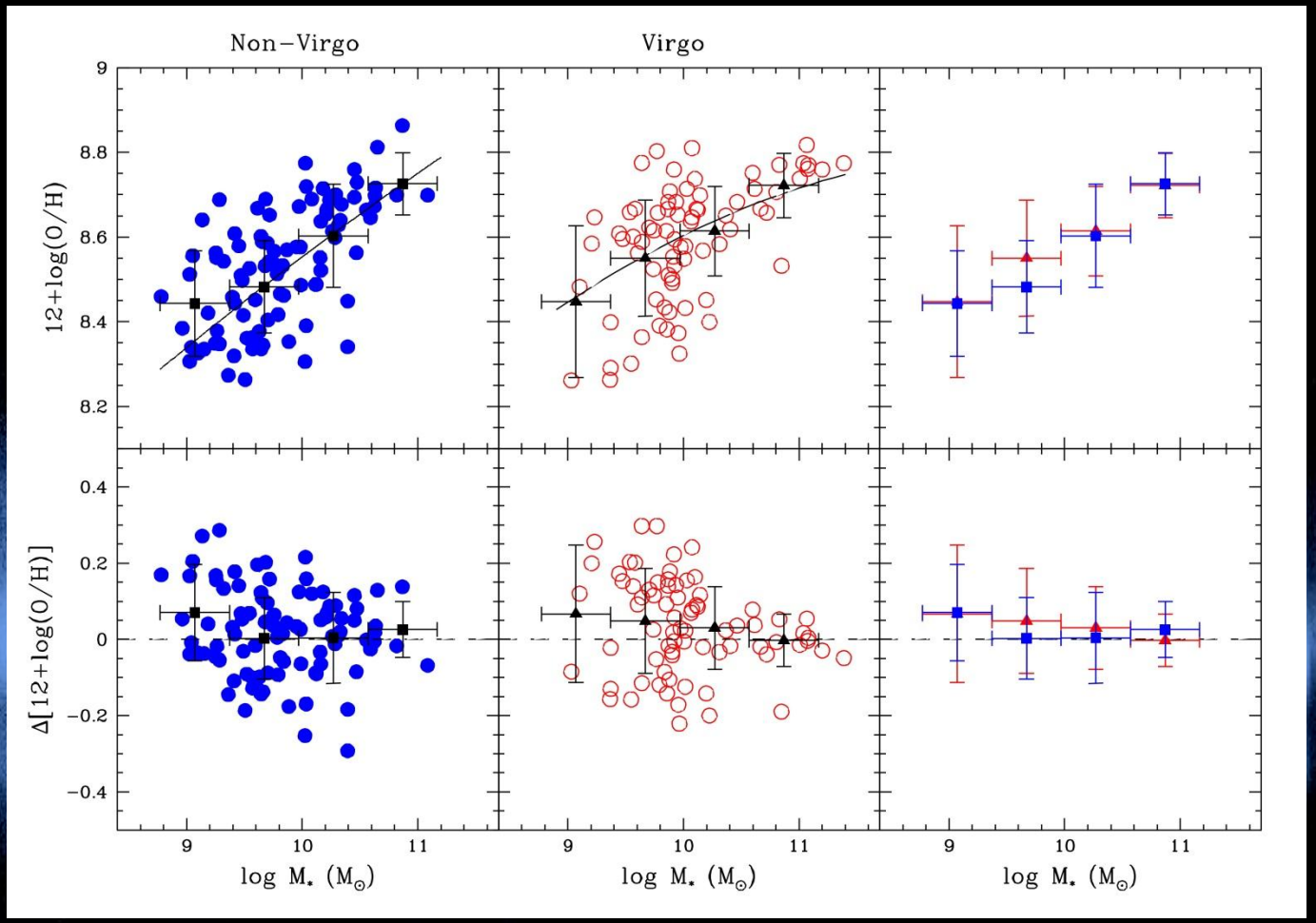




Hughes et al. 2013

Suggests scatter in MZR linked to gas content

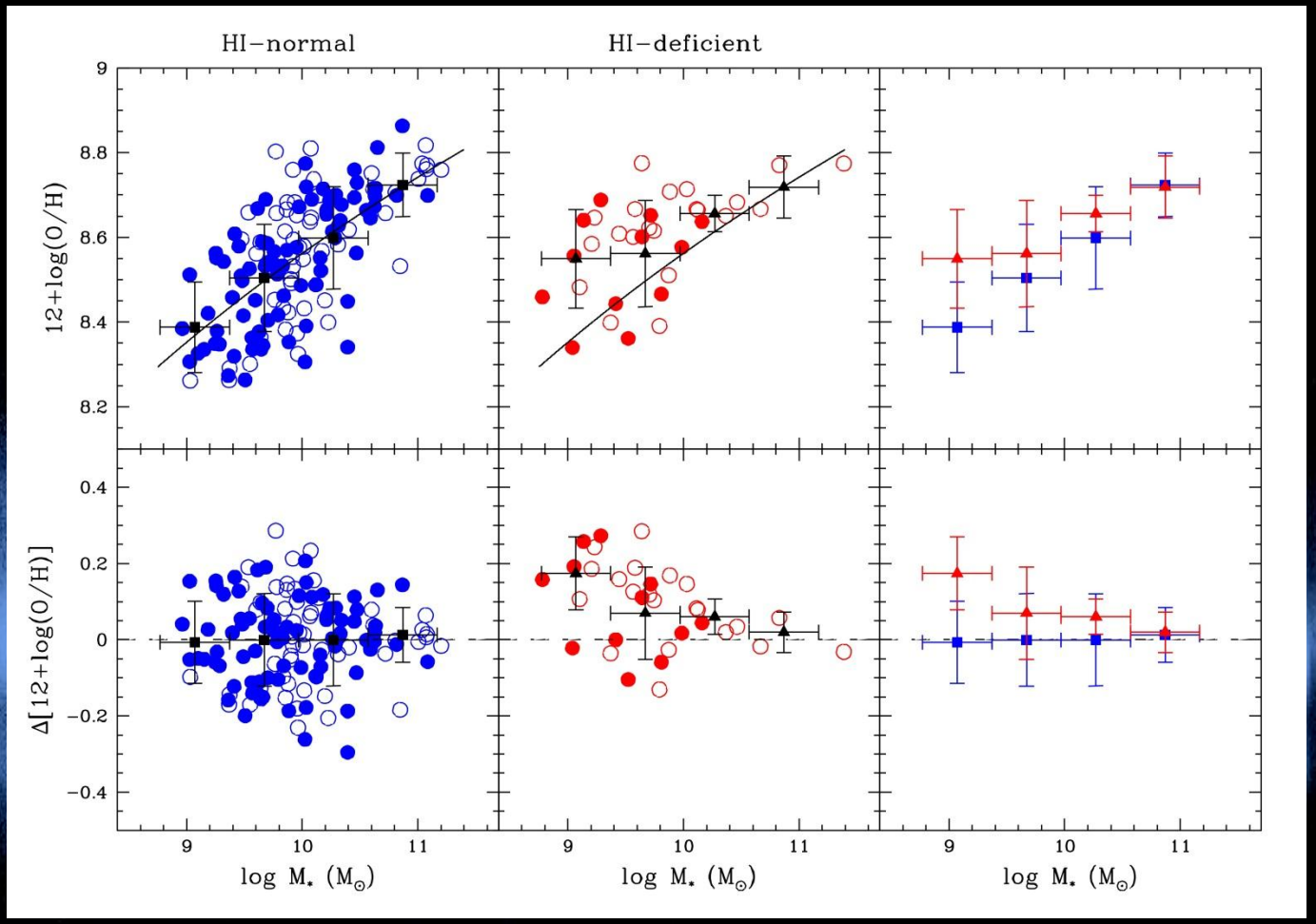
The role of environment



Hughes et al. 2013

No significant environmental dependence,
consistent with Ellison et al. 2009 + Mouhcine et al. 2007

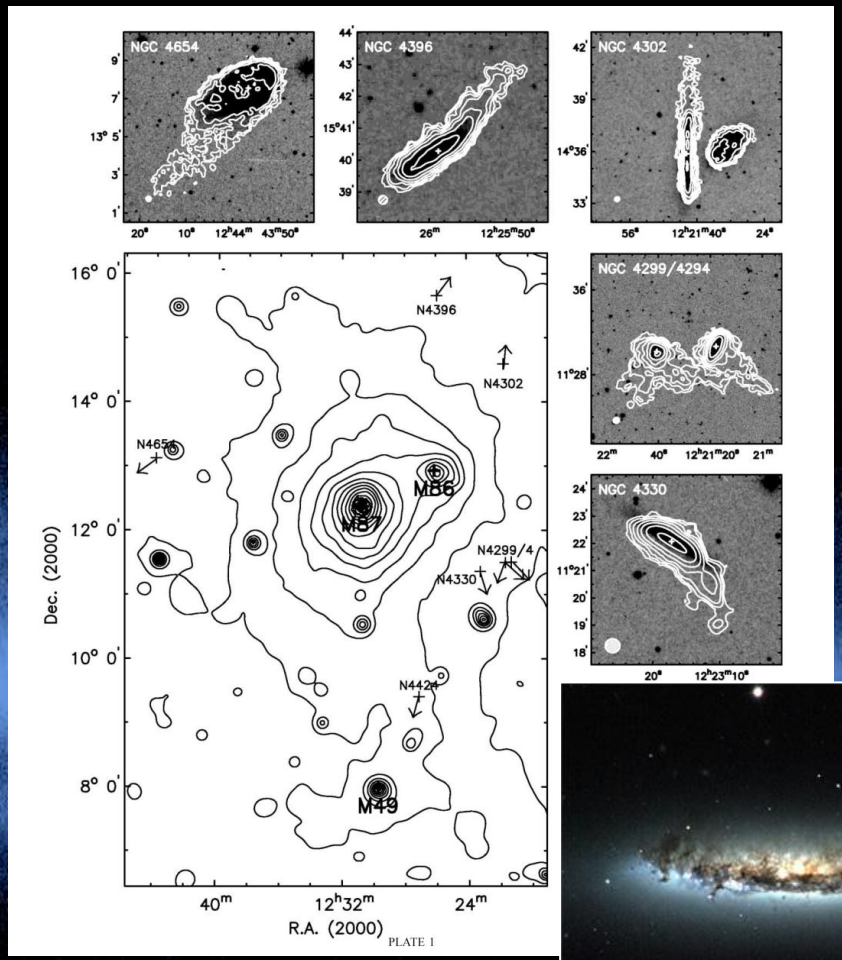
Back to the gas content



Hughes et al. 2013

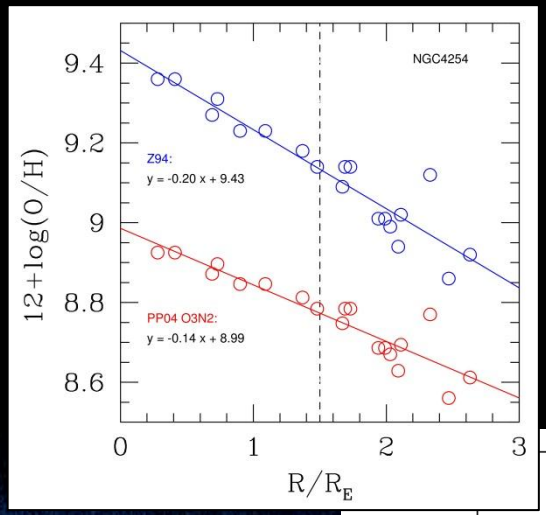
Dividing by gas content selects most perturbed systems, unlike dividing by cluster membership

A possible selection effect?

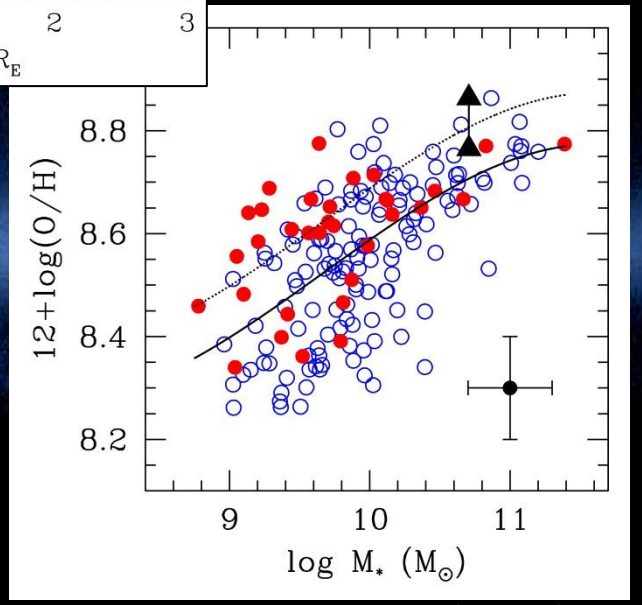


Chung et al, 2007

H.Crowl



NGC 4254 profile
(Skillman et al. 1996)



Hughes et al. 2013

HI deficient galaxies may just appear to be metal-rich

Most likely scenario

- **Environment:**
  Is there any dependence?

  No strong metallicity enhancement due to environment.

- **Scatter**:
  what governs the tight scatter?

  Metallicity and residuals well correlated with HI gas content

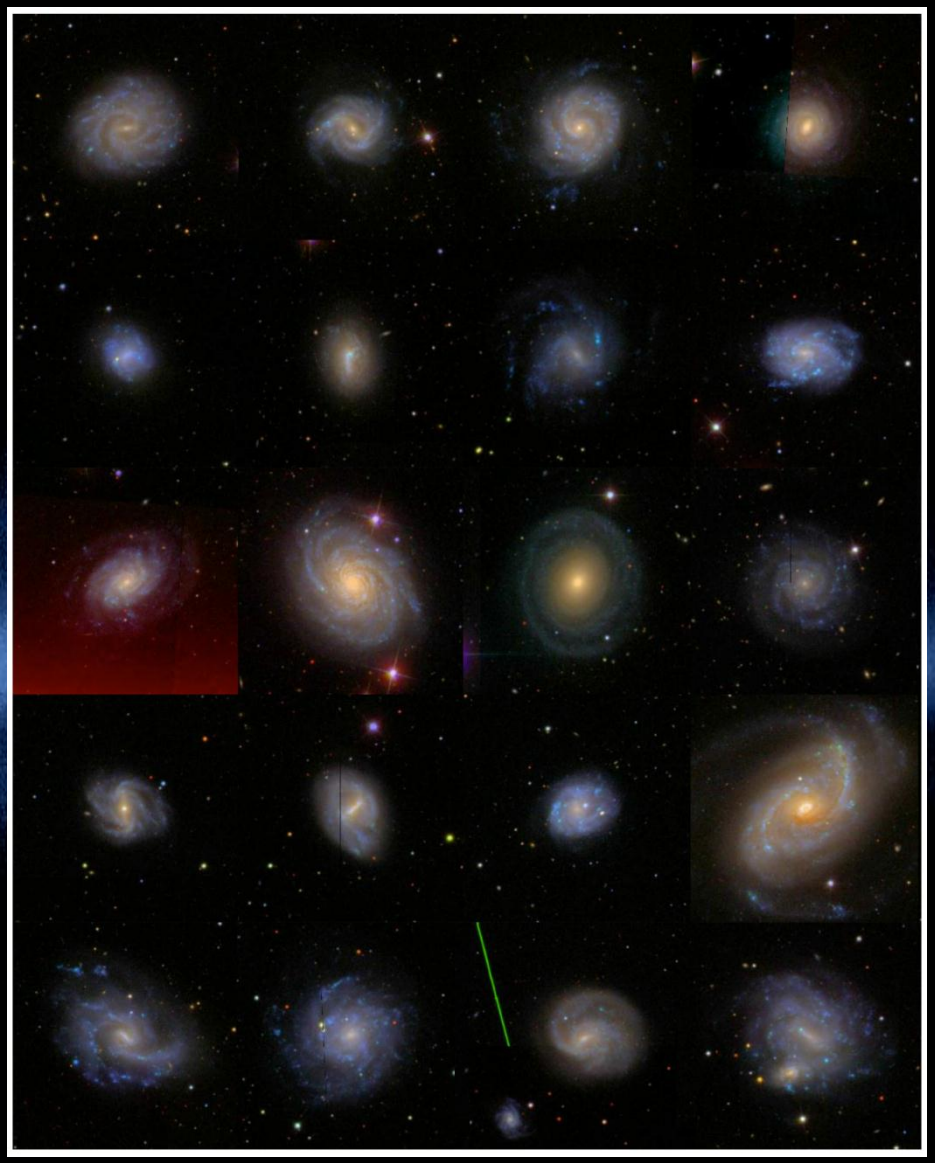
- **Origin**:
  what drives the shape?

  Relationships between mass, metallicity, gas content (and sSFR)

All evidence suggests a variation in efficiency of star formation with stellar mass (i.e. lower mass galaxies less efficient at converting gas to stars to metals).

HRS metallicity gradients

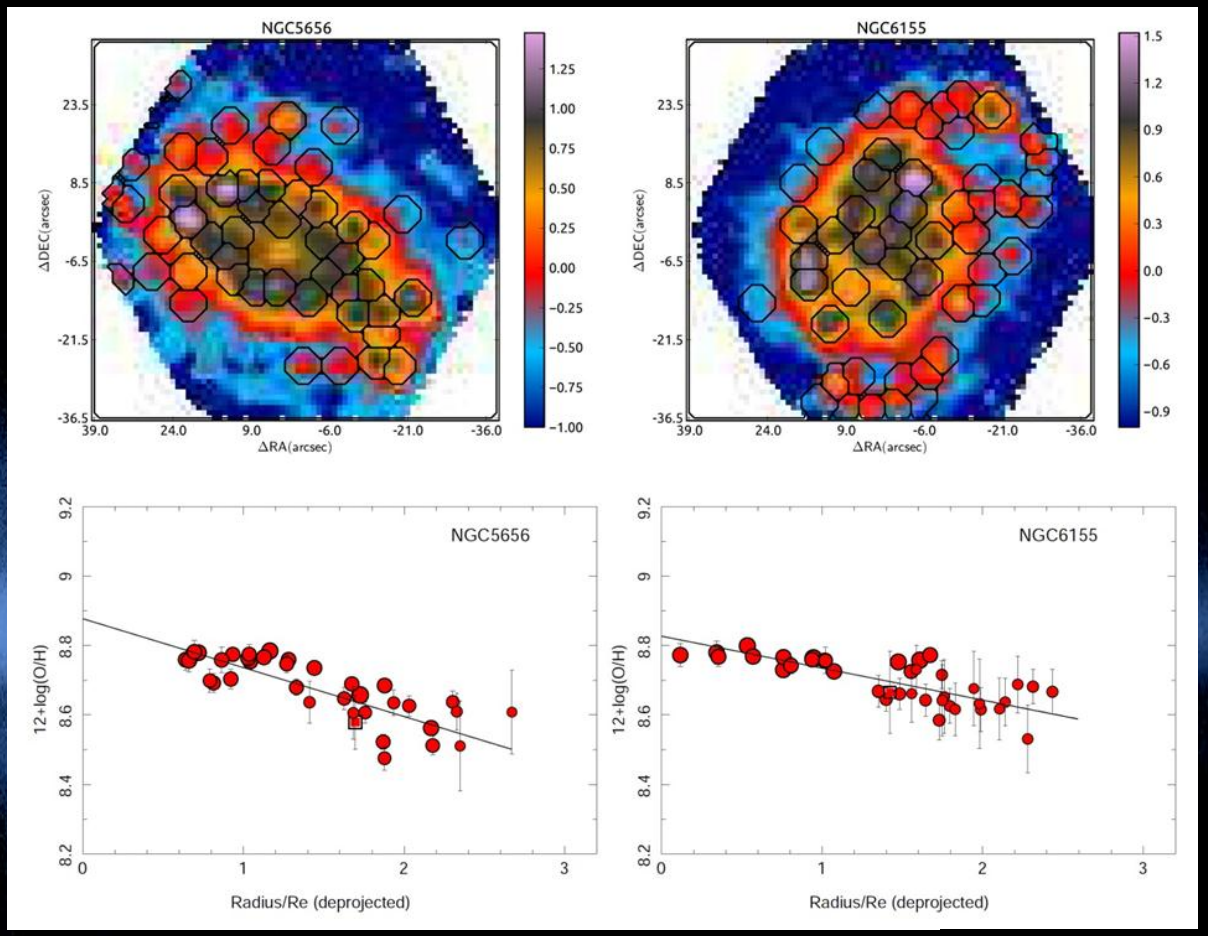
- Combined with dust maps, metallicity gradients provide a complete picture of enrichment across SF disks
- Very few gradients available in literature, biased towards Virgo
- Observing campaign using VLT/FORS2 low resolution spectrograph, completed observations for 20 HRS gals.
- Starting data reduction…



CALIFA metallicity gradients

- Calar Alto Legacy Integral Field Area survey
  (Sanchez et al. 2012)
- ~287 / 600 galaxies observed

Stefan Seip/Astromeeting.de/TWAN



Sanchez et al. 2013

Powerful dataset for spatially-resolved studies

Summary

- First time combined gas information with metallicities from drift-scan optical spectroscopy using new calibration techniques.

- **Gas content related to scatter of M-Z relation, environment of secondary importance.**

- Future work will examine the relations on spatial scales, and also push mass-metallicity studies into the dwarf / LSBG regime.

*See Boselli, **Hughes**, et al 2013: arXiv 1211.5262*
***Hughes**, Cortese, et al 2013: arXiv 1207.4191*