The oxygen abundance in the IFU era

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)

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 (aggregations)

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 $R_{\odot}$

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

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
**Surface mass density**

- **B and V-band** surface brightness 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%

**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

$$\Sigma_{\text{Lum}} (M_\odot \text{ pc}^{-2})$$

- Mean value at bins $\sim0.15$ dex $\Sigma_{\text{Lum}}$
- Polynomial fit to the data
- Tremonti et al. 2004 fit ($\pm 0.1$ dex)

3 orders of magnitude in $\Sigma_{\text{Lum}}$
factor of $\sim 8$ 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 $\sim 20%$

Rosales-Ortega et al. (submitted)
The *local* mass-metallicity relation

HII regions: surface mass density vs. metallicity

Rosales-Ortega et al. (submitted)

The relation holds for individual galaxies!

There is also a relation with $|\text{EW}(\text{H}\alpha)|$ (emission)
The *local* mass-metallicity-EW(H\(\alpha\)) relation
The **local** mass-metallicity-\(\text{EW(H}\alpha)\) relation

\[ \text{EW(H}\alpha) \text{ vs surface mass density projection} \]

**EW(H\alpha)**

- 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)

Rosales-Ortega et al. (submitted)

lower (inner) values of \(|\text{EW(H}\alpha)|\) 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:**

\[-15 < M_B < -23\]

\[-0.4 < B-V < 1\]

**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 \(M_B + B-V\) + 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)

(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)**

★ 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 outstanding 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