Characterizing the MZR at global scales

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Abstract: We explore at the most suitable functional form of the mass metallicity relation using integrated properties from (~970 galaxies) from the extended version of the CALIFA integral field spectroscopy data. We explore different functional forms (linear, polynomial - 3rd grade - and exponential) as well as different statistical environments: (1) fixed size binning, (2) variable size binning, (3) not applying any binning, and (4) reducing scatter. We derive the ionized-gas metallicity for each galaxy, using the O3N2 strong-lines calibrator derived by Marino et al. (2013). To test the goodness of the fit to the MZR, we identify the function that yields the smallest scatter in its residuals. We use this residual to explore the secondary relation of the MZR with other observables (SFR, gas mass and gas fraction). Among other results, we identify the lack of strong correlation between these residuals and the SFR, in contrast to previous (e.g., Mannucci et al 2010). Our results suggest that the functional form and the presence of secondary relations may depend on statistical treatment

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Context of the research

➢ The stellar mass traces the previous gas available for star formation and the potential well.

➢ The metallicity measured from the ionized gas emission lines reflects the metal content produced in previous stars generations.

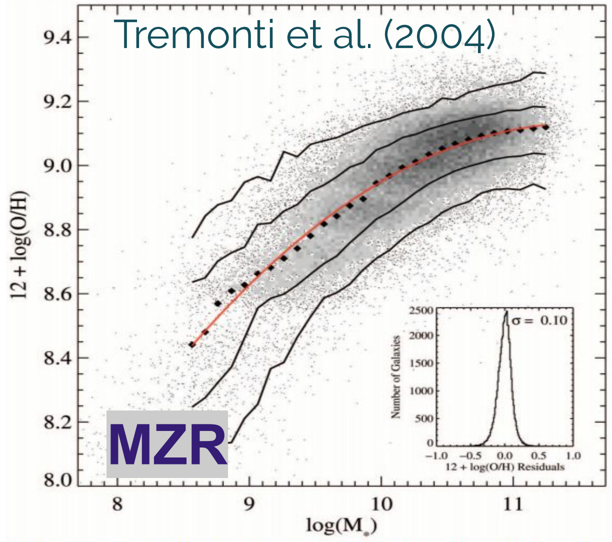
Correlation between both properties is known as **Mass-Metallicity Relation (MZR).**

New studies around MZR has been done using single-fiber spectroscopy data, granted by the SDSS:

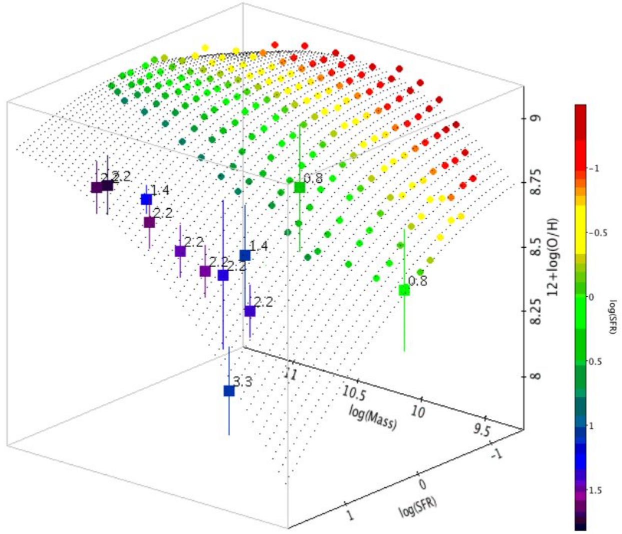
➢ **Tremonti et al (2004)** → First systematic exploration for more than 53,000 star-forming galaxies, showing a tight relation between stellar mass and metallicity.

➢ **Ellison et al (2008), Mannucci et al (2010)** → Strongly suggest that SFR plays an important role in shaping the MZR.

The related measurements from these studies come from the central 3'' → **aperture bias**



Mannucci et al. (2010)



Fundamental Mass-Metallicity Relation

To address these issues properly, we required spatially resolved spectroscopic information.

Single-fiber-spectroscopy: 3'' **Integral Field Spectroscopy: 1Re**

Credit: Robert Gendler (http://www.robgendlerastropics.com/)

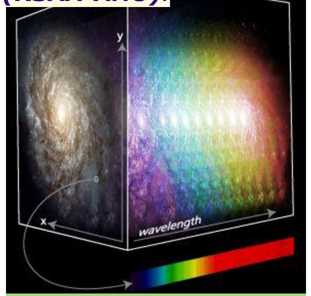
Project

I. Data and sample selection

We use data from integral-field spectroscopy (IFS) technique. Advantages:

- ➔ Obtaining spatially resolved spectra of extended objects
- ➔ Spatial and spectral information simultaneously.
- ➔ Datacube is obtained under the same instrumental and atmospheric conditions.

Credit: Marc White (RSAA-ANU).



DATACUBE
2 spatial coordinates
1 spectral coordinate

eCALIFA 974 galaxies
Sánchez et al. (2012)

- ➔ Spectral range: 3745 A - 7500 A
- ➔ Physical spatial resolution (kpc) 0.8 [0.3-1.5]
- ➔ IFU FoV 74''x64'' (usually covers 2.5Re)
- ➔ **$0.005<z<0.03$**
- ➔ Different Hubble types

Star-Forming galaxies selection criteria:
Kewley et al. (2001) & Sánchez et al. (2014)

Metallicities measured at 1Re using O3N2 calibrator derived by Marino et al (2013)

II. Methodology

1. We explore MZR behavior through functional forms:

- ➔ Linear
- ➔ Polynomial 3rd grade (max power: 3).
- ➔ Exponential

2. We apply different statistical techniques to fit the 3 functional forms:

- ➔ Binning:
  - ◆ Fixed-size binning (symmetrical intervals, 0.2 dex)
  - ◆ Variable-size binning (Intervals with the same number of elements, each interval presents a different size according to the subsample contained)
  - ◆ x-axis & y-axis
- ➔ OLS (not subject to error of any kind)
- ➔ ODR (taking into account for different variances of the observations)
- ➔ Reduce scatter (taking some percentage of the SFG in order to analyze the distribution behavior reducing the present scatter, and trying to avoid losing information on the total stellar mass range)

3. To quantify the coupling degree between the fittings and the M-Z distribution, we calculated the respective residuals. We expect that a reliable fit presents the least scattering around zero, i.e., that it does not show dependence on stellar mass.

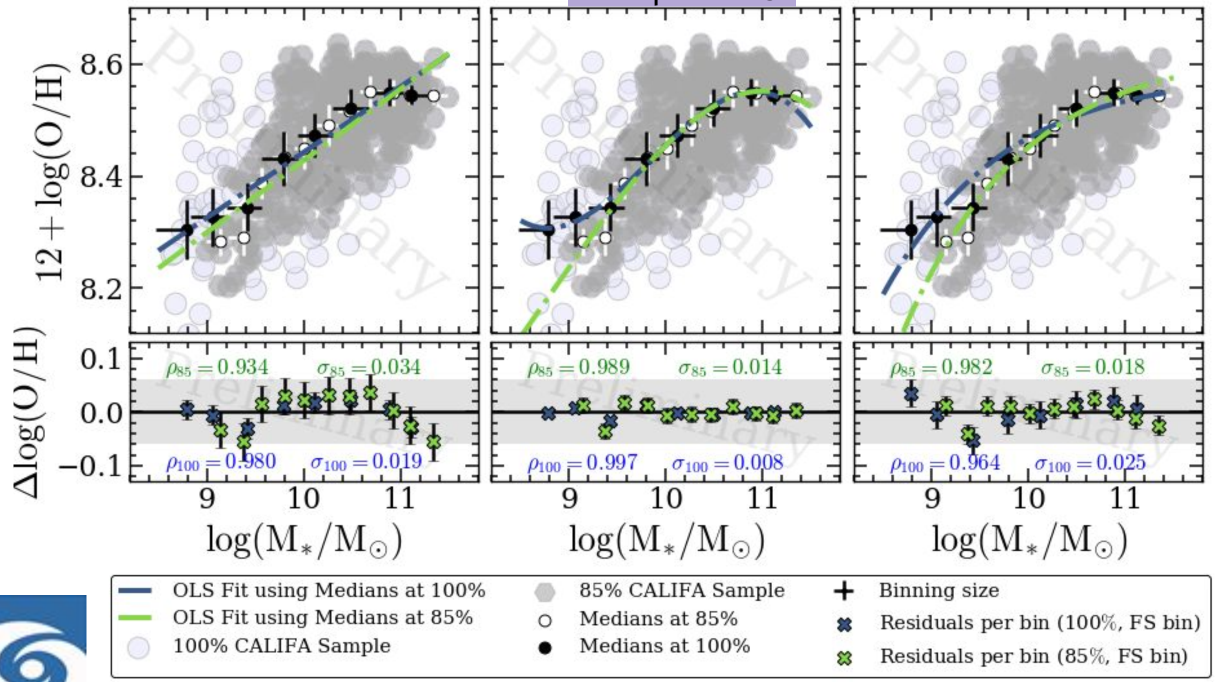
4. Once we have the best functional form that describes the MZR, the next step is to evaluate if there is a secondary dependency with other parameter.

Results (I)

A couple of fits tested are showed. If we observe carefully, we will notice that the polynomial fit taking the medians in a variable size binning gives the least scatter, since its residuals show the least variation around zero-line.

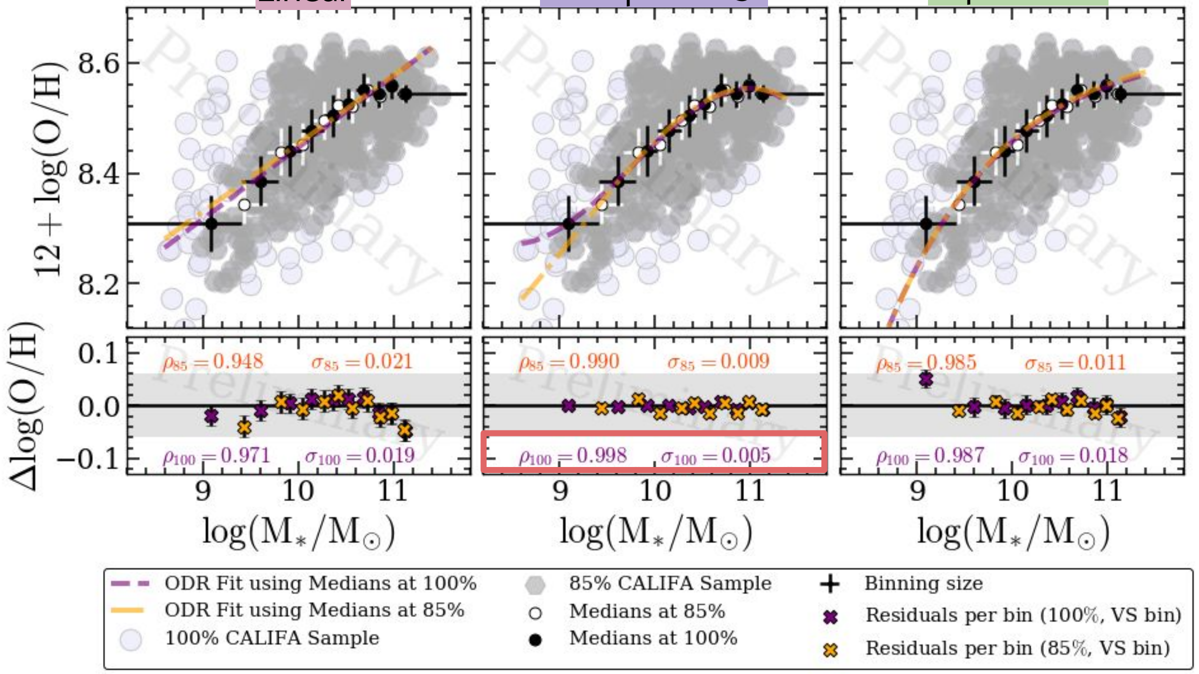
Fixed-size binning: fit through nOLS

Linear | Polynomial (max power: 3). | Exponential



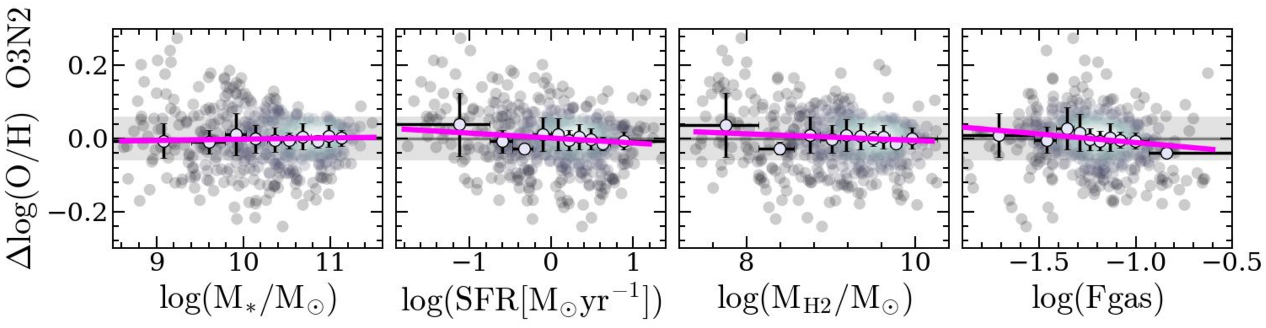
Variable-size binning: fit through nODR

Linear | Polynomial (max power: 3). | Exponential



Results (II)

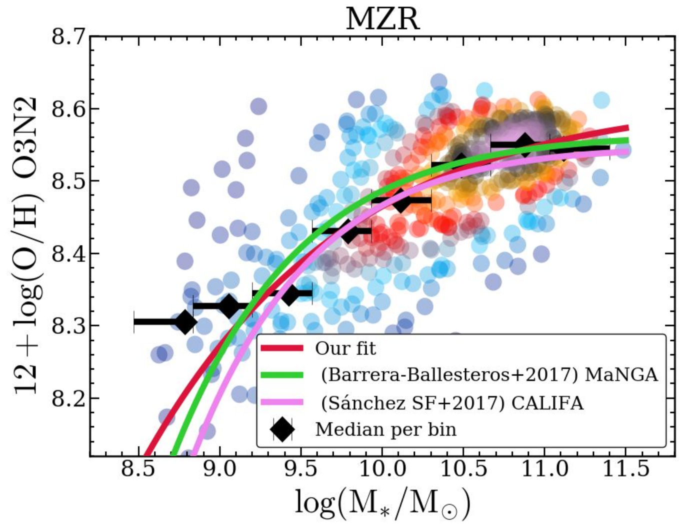
According to our exploration, the residuals from **the best polynomial fit does not show dependence on SFR, molecular mass** (using as proxy the optical extinction, Barrera-Ballesteros et al., 2020) **or gas fraction**. Since the scatter is not significant and is located below the intrinsic error associated with the measurement of metallicity (shaded region).

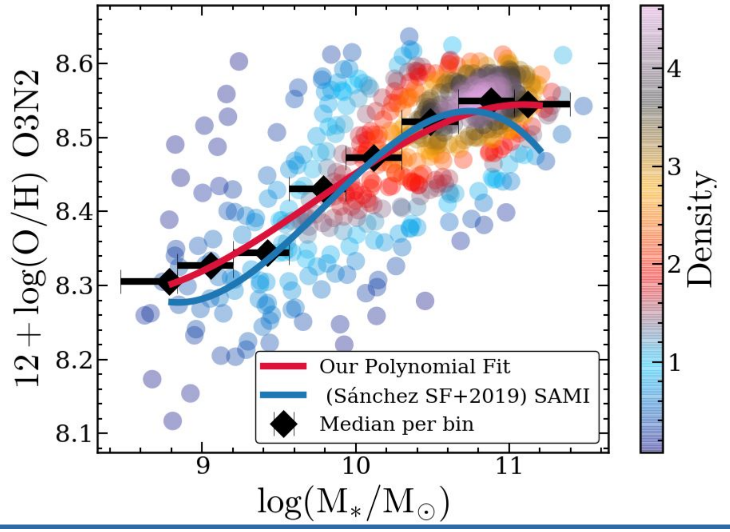


The magenta line traces the medians behavior of each residuals distribution. Note that these lines has a almost zero slope for each parameter, specially with SFR, indicating **a poor/non correlation between SFR and MZR.**

Functional forms for different surveys and statistical criteria.

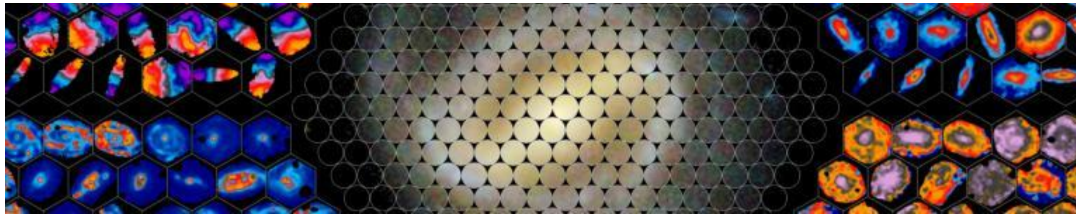
The green, pink and blue lines show the best fit curve for the MZR from Barrera-Ballesteros et al. (2017) for MaNGA survey, Sánchez et al. (2017) for a CALIFA sample and SAMI survey Sánchez et al. (2019), respectively. **We include our best polynomial and exponential nOLS fittings for comparison (red).**





Alvarez-Hurtado et al. in prep.

Impact, and prospects for the future



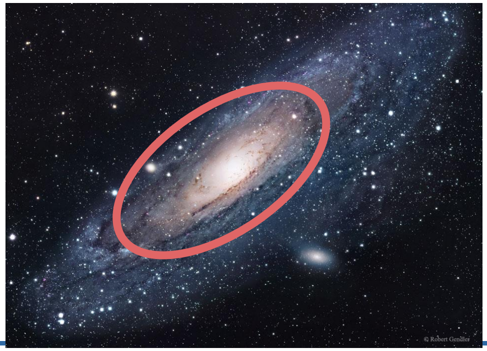
García-Benito et al. (2015)

Impact:

- ➔ This study provides **a characterization of the MZR at global scales** through spatially resolved data from eCALIFA survey.
- ➔ Use of **data truly characteristic of galaxies** in contrast with single fiber spectroscopy.
- ➔ According to the statistical analysis, a polynomial fit (max power: 3) **provides the best MZR description** (the residuals analysis provide the least scatter).
- ➔ **The MZR functional form depends** on statistical criteria which could generate non-existent secondary relationships (for example, a significant scatter in the sample could generate alternative results).

Integral Field Spectroscopy: 1Re

Credit: Robert Gendler



Future plan:

- ➔ *Further exploration of the residuals will allow us to explore the impact of other physical parameters the MZR.*
- ➔ *Continue studying of non-correlation results.*