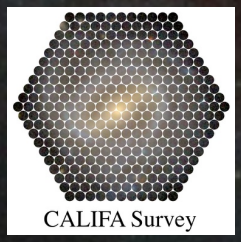
Inner and outer star forming regions over the disks of spiral galaxies

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XI Estallidos Workshop
Madrid, 6th June 2018









Motivation and objectives

Context:

- **Abundance distributions** in galaxies are fundamental to know their chemical evolution and star formation histories, which are central to guiding theoretical models of the **formation and evolution of galaxies**.

- There are **differences between regions** depending on the distance to the centre of the galaxies. Inner regions seem to show lower [OIII]λ5007/Hβ, higher [OII]λ3727/[OIII]λ5007 and [NII]λ6583/[OII]λ3727, higher electron densities and higher extinctions.

- The analysis of high excitation, low metallicity spectra from outer regions is easier, and the **applicability extent of the direct method** to derive abundances is larger.

- Additionally: **observational limitations**. Studies of a relative small number of objects and limited by the use of fixed aperture and/or long-slit spectroscopy.

➡ Despite any inferred different physical properties, most of the relations employed for estimation of abundances from strong emission lines are derived from the **outer disk regions,** and are **assumed to be valid** for all the ionized regions.

Motivation and objectives

Objective:

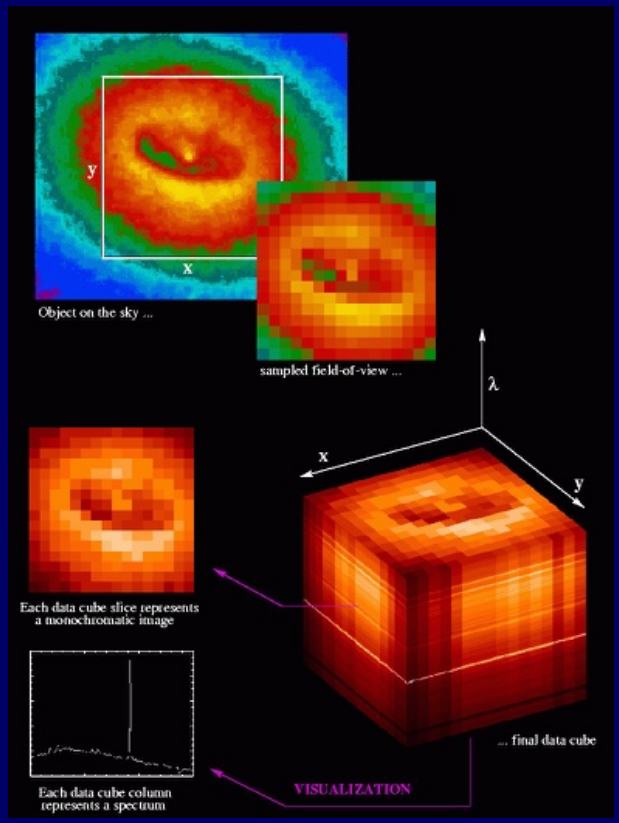
Exploring the existence of intrinsic differences in the star formation processes of inner and outer HII regions and their influence in derived properties of the regions, such as elemental abundances, ionization structure, evolutionary state, etc.

Methodology:

Integral Field Spectroscopy:

Complete spectroscopic mapping of the distributions of HII regions over the disks of spirals:

- High number of objects.
- Spatial resolution.
- Homogeneity and coherence of the observations.



First part: Sample characterization

Inner and outer star forming regions over the disks of spiral galaxies

I. Sample characterization*

M. Rodríguez-Baras[1], A. I. Díaz[1], F. F. Rosales-Ortega[2], and S. F. Sánchez[3]

Rodríguez-Baras et al. (2018)

Particular objectives:

- Description of observations and data reduction.
- Characterization of this work galaxy sample.
- Characterization of this work inner and outer HII regions samples.
- Systematic study and comparison of observational parameters.



Observations:

- 3.5m telescope, CAHA
- PMAS spectrograph, PPAK mode
- Wavelength range: 3745-7500 Å
- Spectral resolution: R~850 (low resolution setup)
- FoV: 74 x 65 arcsec^2 (hexagonal)
- Spatial resolution: ~3” → ~1 kpc

Sánchez et al. (2012a)

CALIFA galaxy sample:

- Diameter selection of the sample from SDSS images
- 667 galaxies
- Redshift: $0.005 < z < 0.03$
- Sizes: 1.7 kpc < r_{50} < 11.5 kpc
- Magnitudes: $-19.0 > M_{r,p} > -23.1$
- Morphological types: E0 - Irr

Walcher et al. (2014)

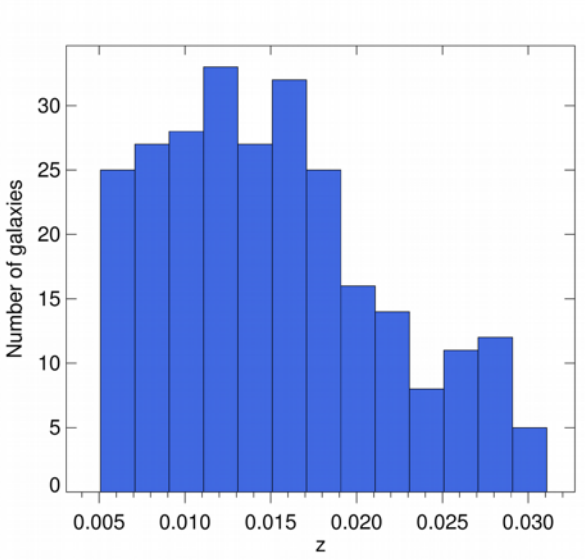
Galaxy sample

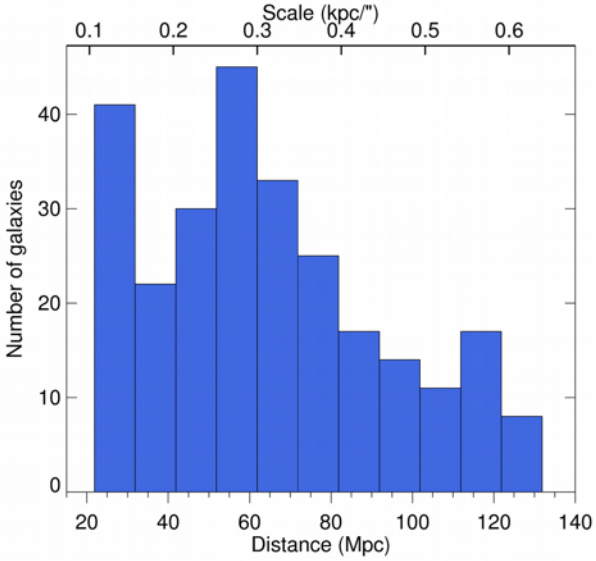
CALIFA Second Data Release (DR2)
García-Benito et al. (2015)

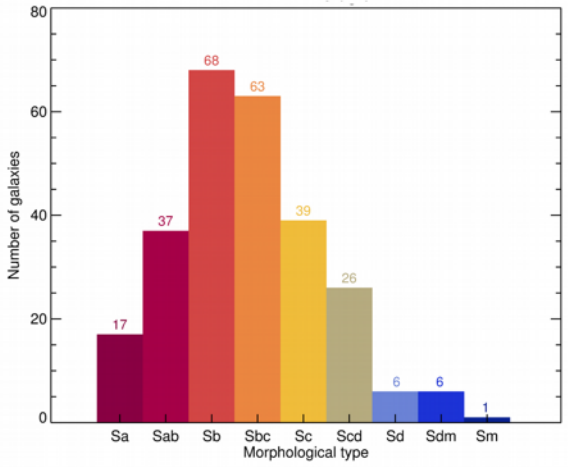
263 isolated spiral galaxies

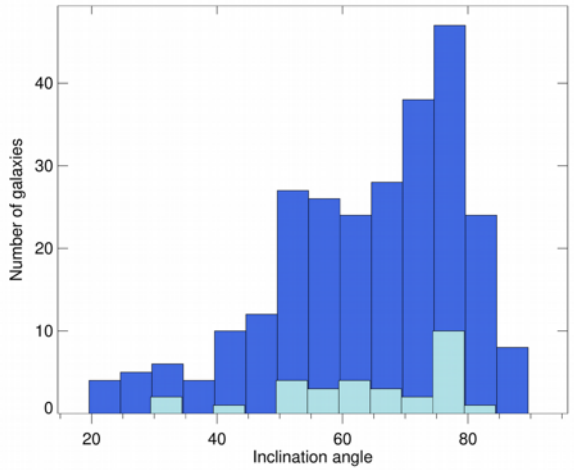
They fulfill the statistical properties of the whole CALIFA galaxy sample.

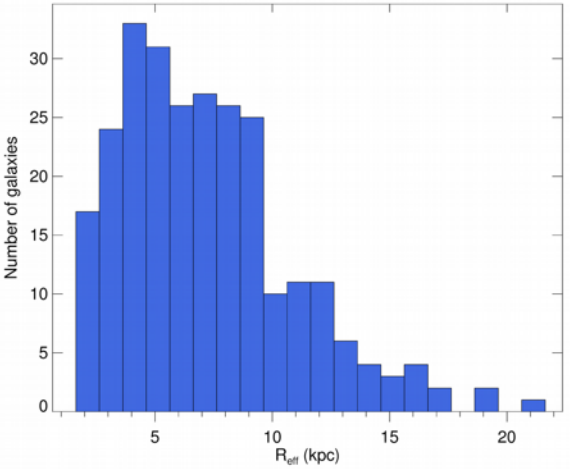
Rodríguez-Baras et al. (2018)

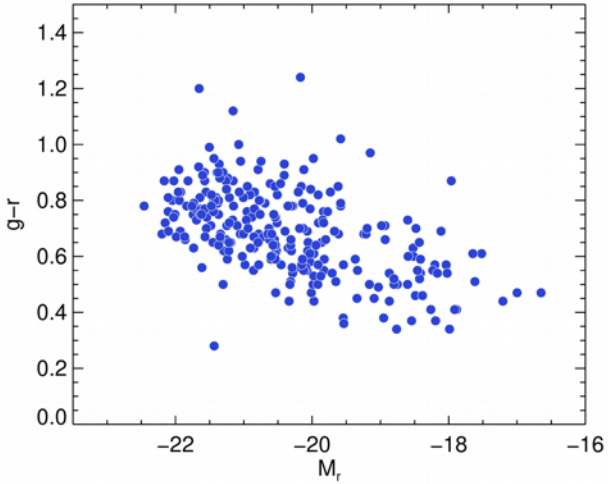












HII region samples

HII regions selection and extraction: HIIExplorer (Sánchez et al. (2012b)

Stellar continuum substraction and line fitting: FIT3D (Sánchez et al. (2016, 2011b)

Inner HII regions:

Located closer to the center than the distance defined by:

$$\log \mathrm{R(kpc)} = \text{-}0.204\ \mathrm{M}_B\ \text{-}\ 3.5$$

(Álvarez-Álvarez et al. 2015)

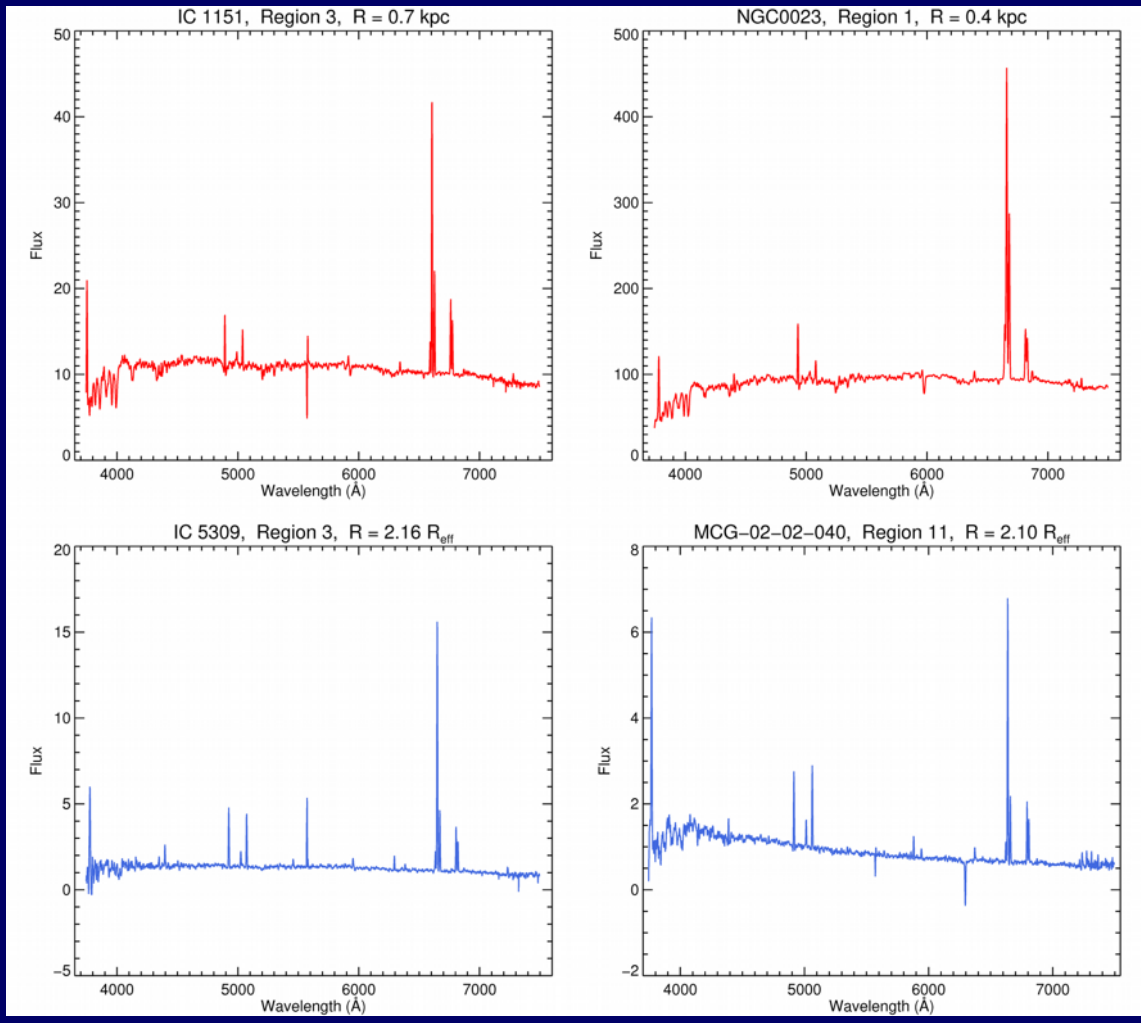
Total sample: 725 regions

Outer HII regions:

Located at a distance larger than 2 R_{eff} from the center of the galaxy.

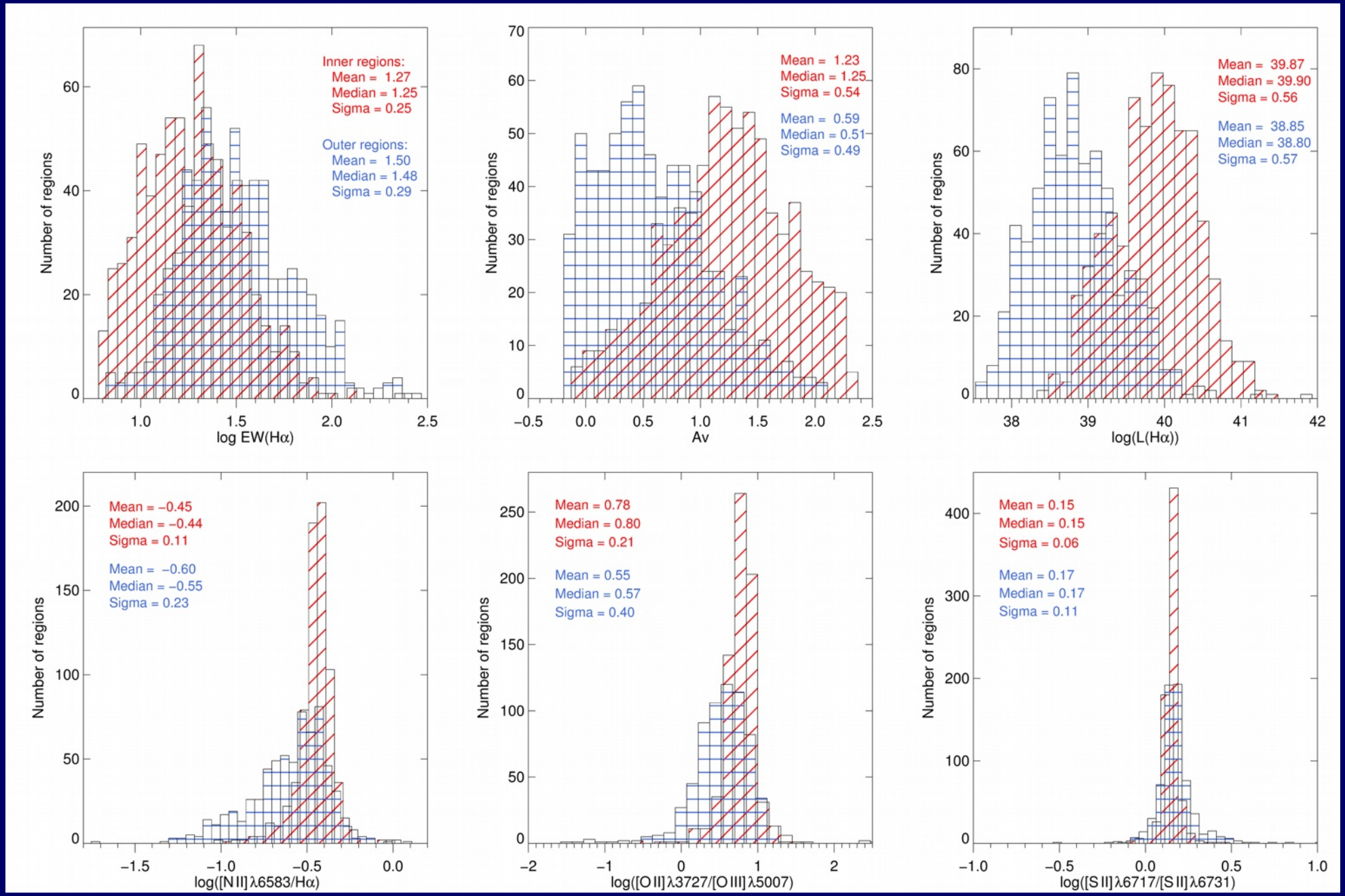
Total sample: 671 regions

Inner regions, outer regions



Rodríguez-Baras et al. (2018)

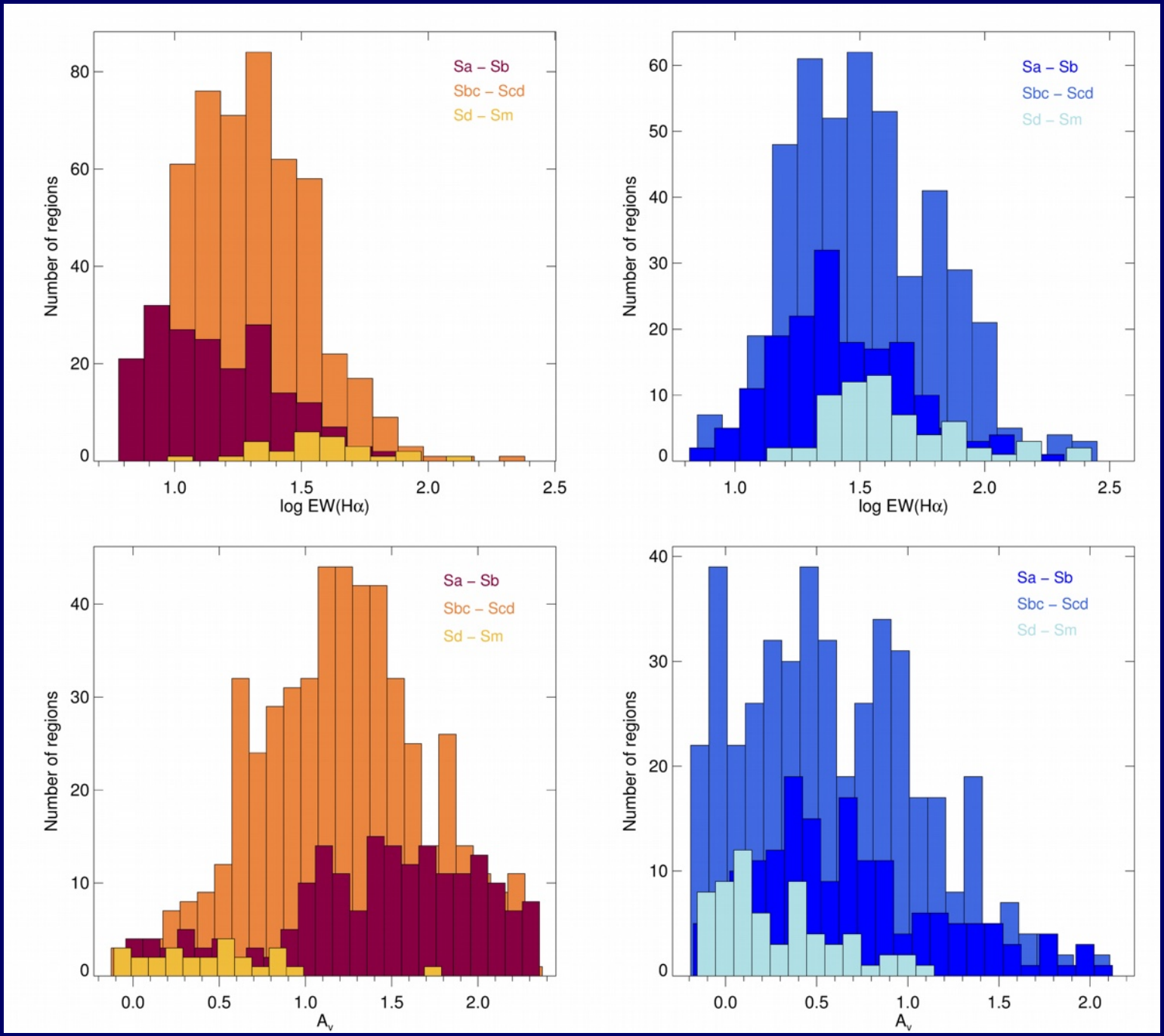
Observational parameters



Inner regions, outer regions

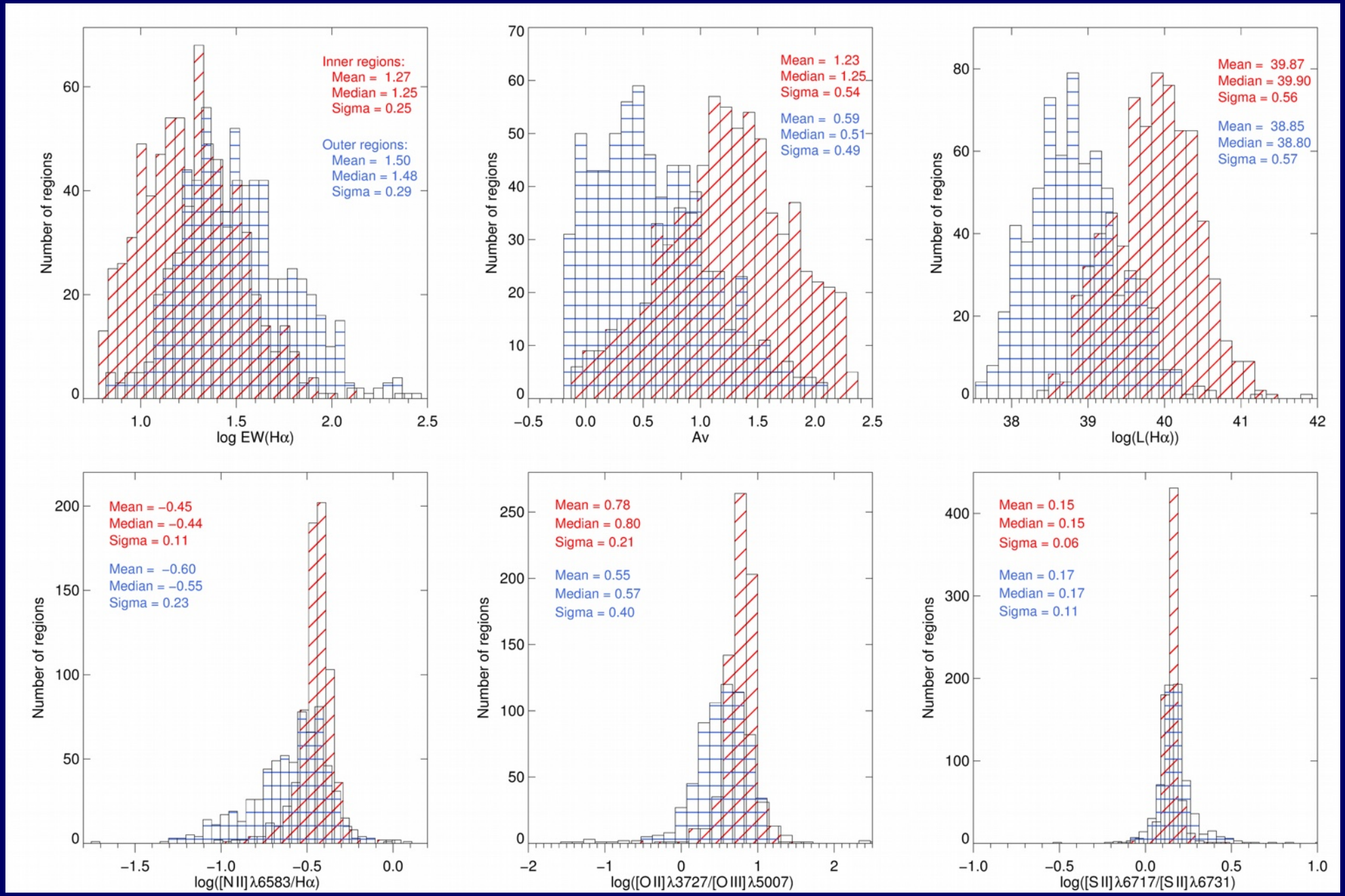
Rodríguez-Baras et al. (2018)

Observational parameters



Rodríguez-Baras et al. (2018)

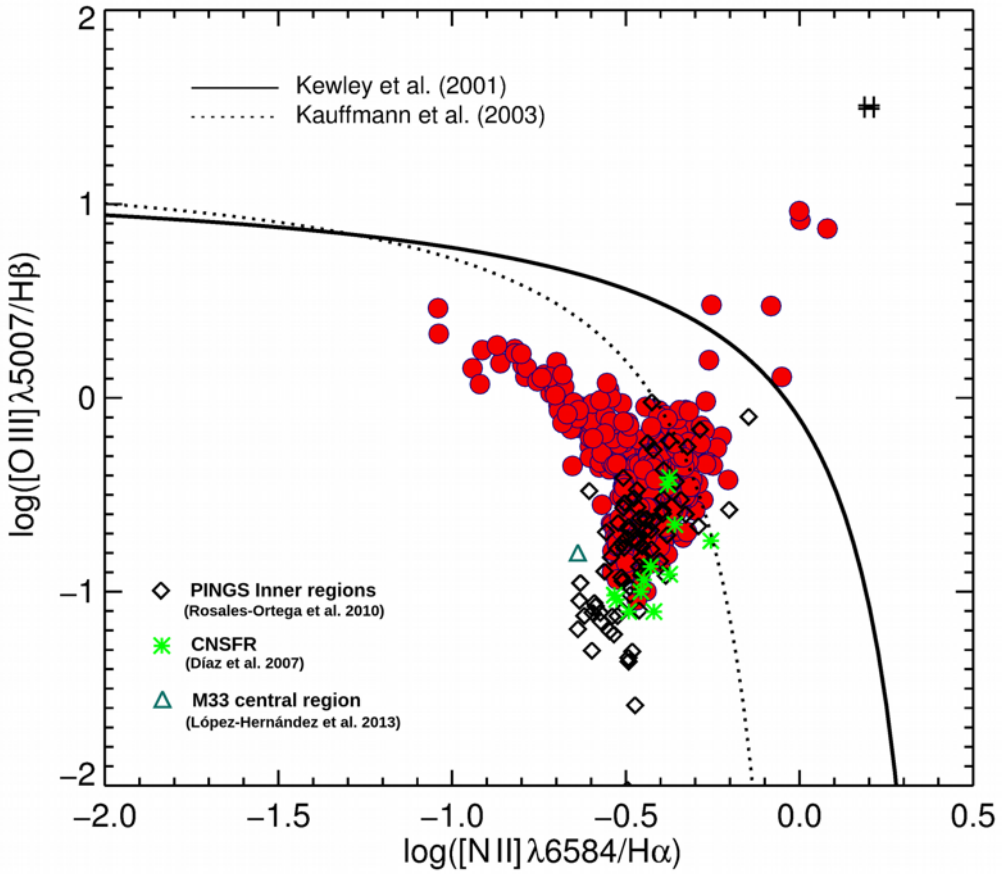
Observational parameters

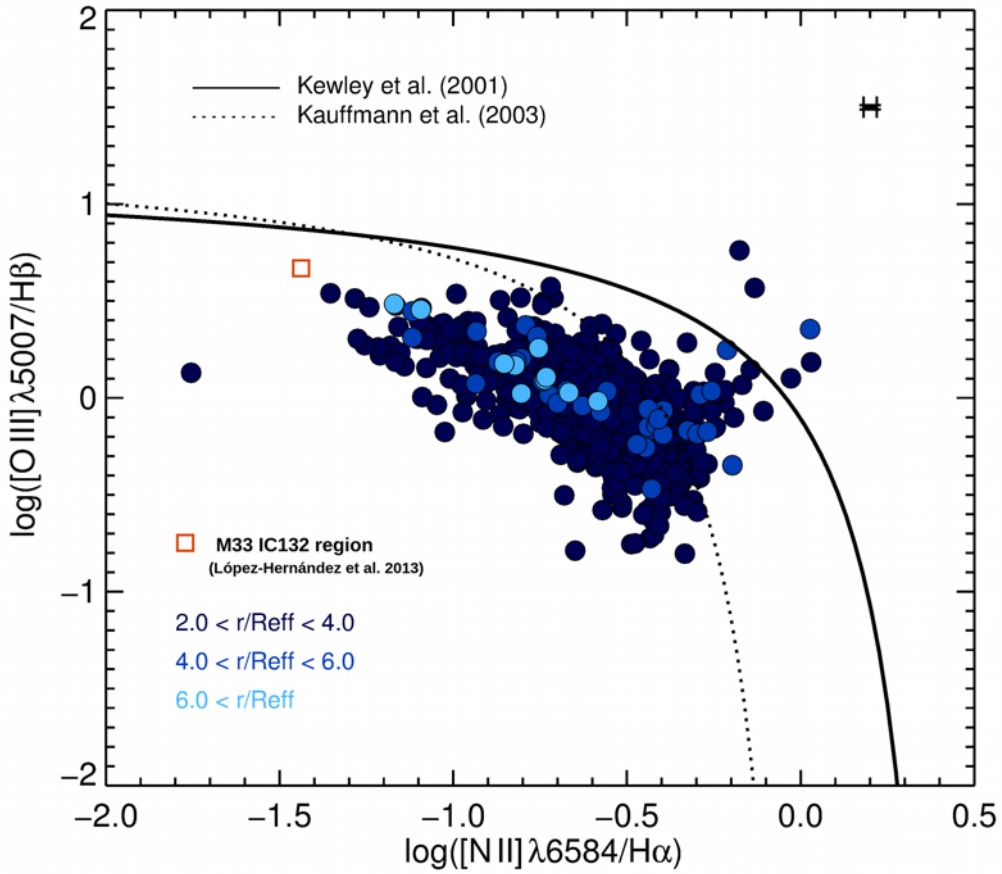


Inner regions, outer regions

Rodríguez-Baras et al. (2018)

Diagnostic diagrams

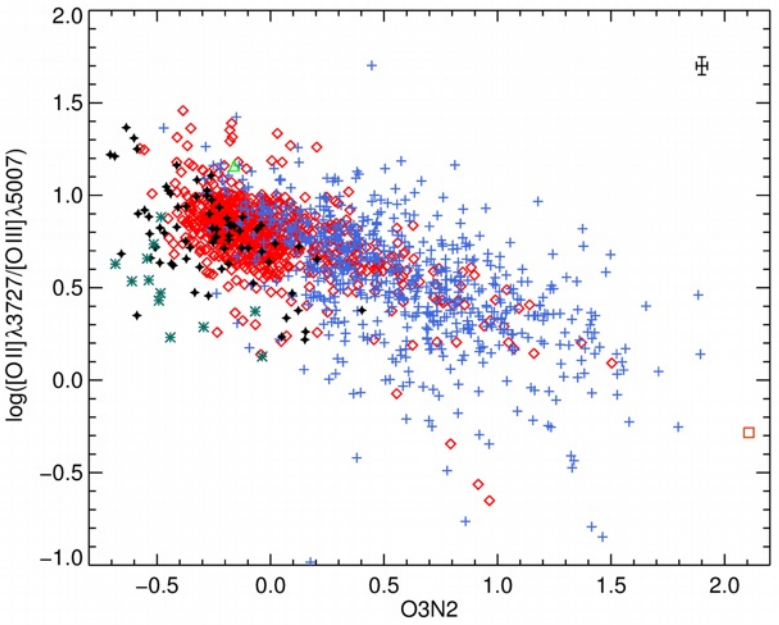


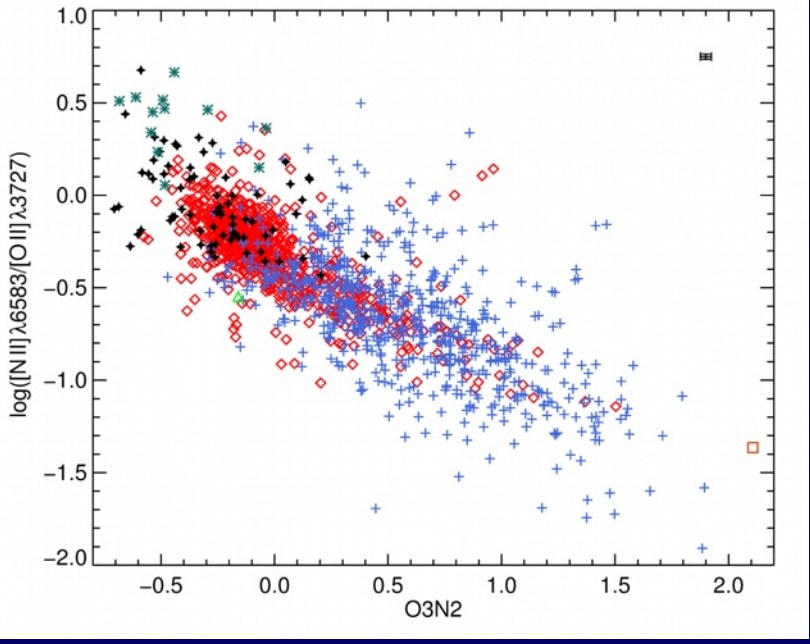


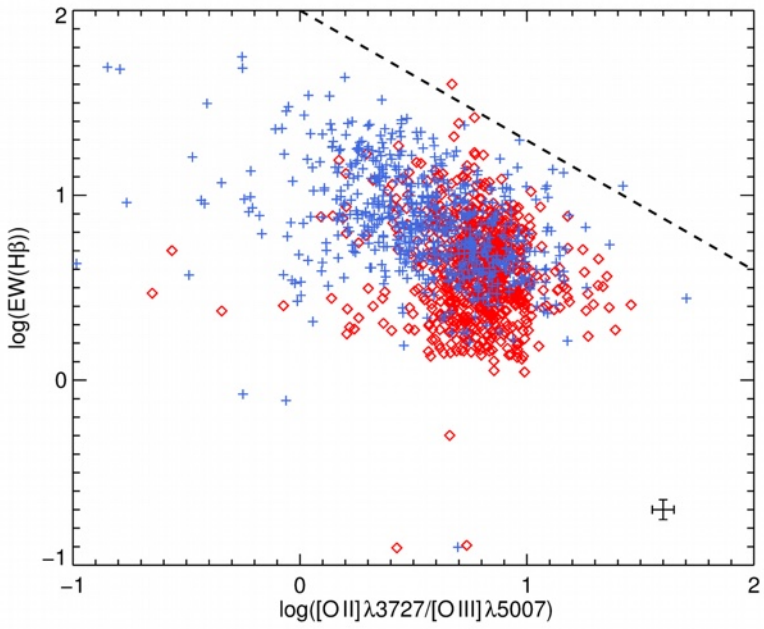
Rodríguez-Baras et al. (2018)

- **Inner HII regions** located to the **bottom-right corner of the classical star-forming branch**, implying higher metallicities and lower excitations. This also implies lower percentages of young stars for the inner HII regions (Sánchez et al. 2014 and 2015)

Diagnostic diagrams







Inner regions, outer regions

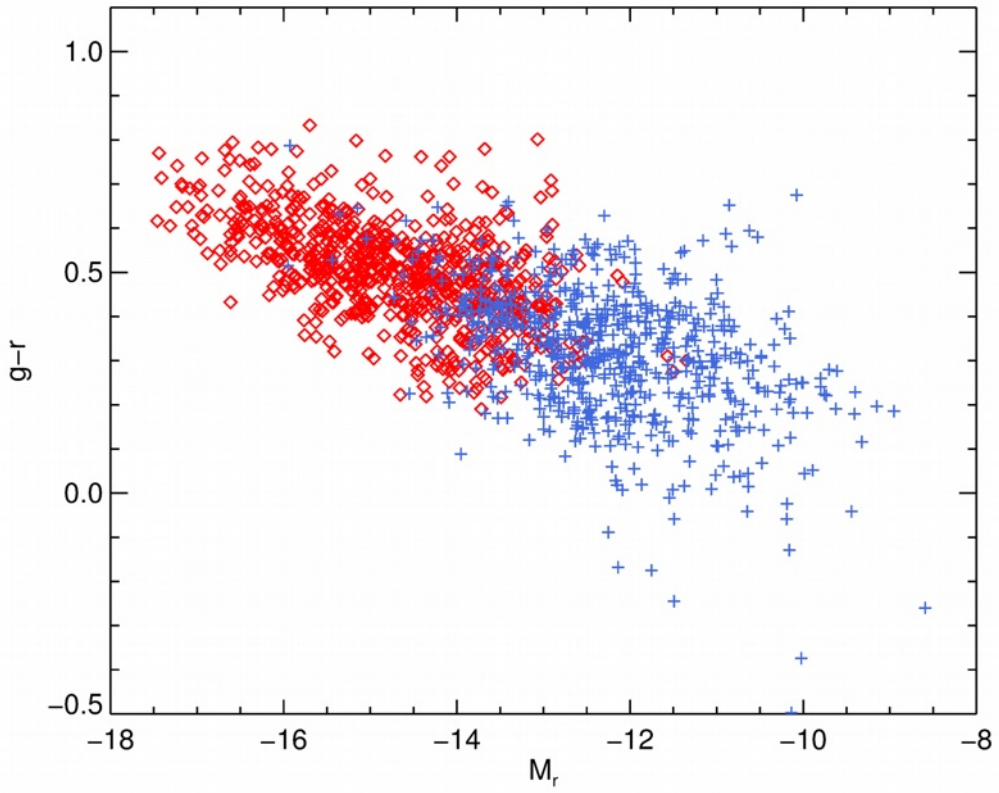
- [OII]/[OIII] vs O3N2. Same trend with one order of magnitude of difference. Inner regions show lower ionization and higher abundances.
- [NII]/[OII] vs O3N2. Confirms higher metallicities for inner regions.
- EW(Hβ) vs [OII]/[OIII]. Evolutionary diagram. Inner regions are ionized by more evolved clusters.

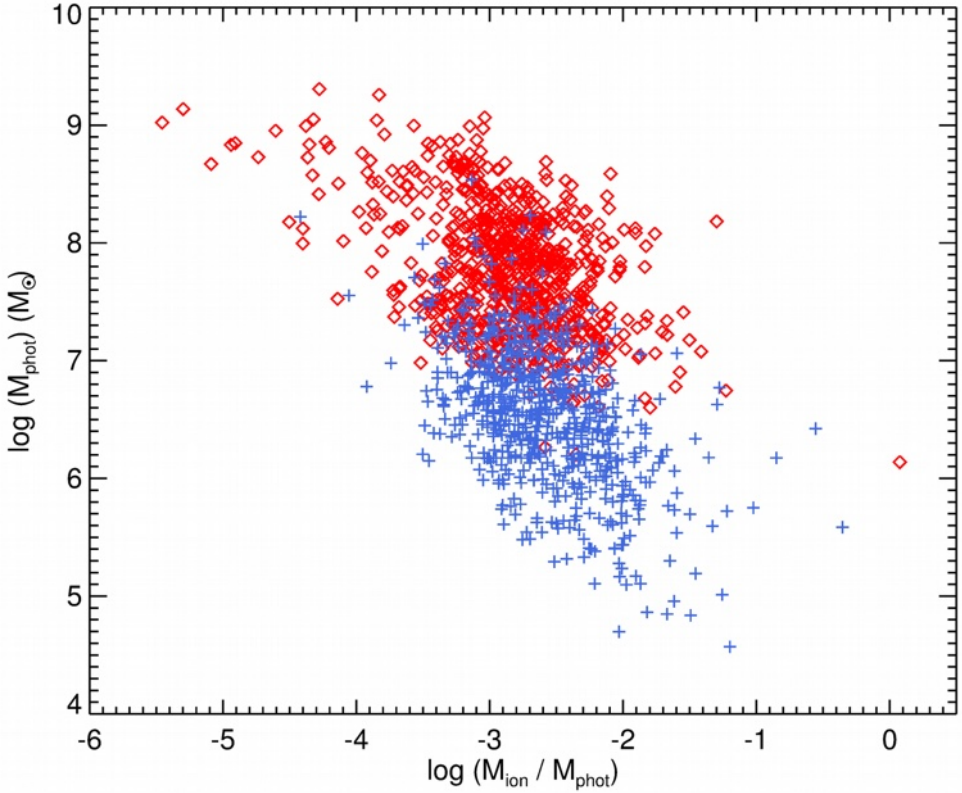
Rodríguez-Baras et al. (2018)

Colours, magnitudes and masses

Inner regions, outer regions

Rodríguez-Baras et al. (2018)





- Inner regions are redder and have higher luminosities than outer regions, as expected from older regions and with high metal content.
- Inner regions have photometric masses two orders of magnitude bigger than outer regions on average. Ratios between ionizing masses and photometric masses are similar for inner and outer regions, with outer regions' values being slightly higher.

Second part: Photoionization models

Inner and outer star forming regions over the disks of spiral galaxies

II. A comparative of physical properties and evolutionary stages

M. Rodríguez-Baras[1], A.I. Díaz[1], and F.F. Rosales-Ortega[2]

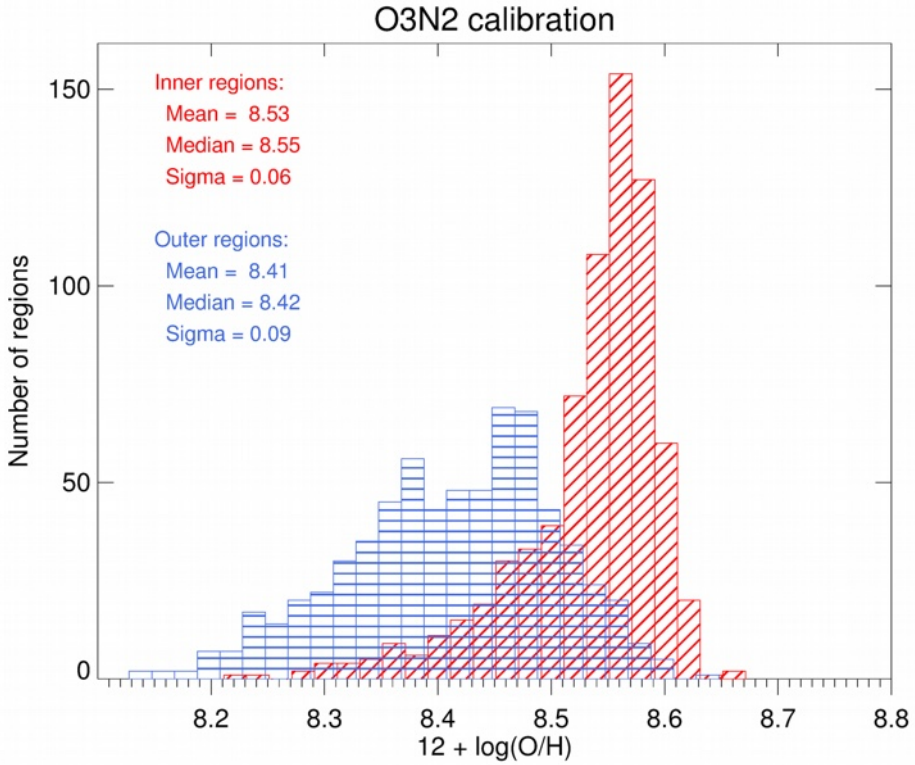
Rodríguez-Baras et al. (in prep.)

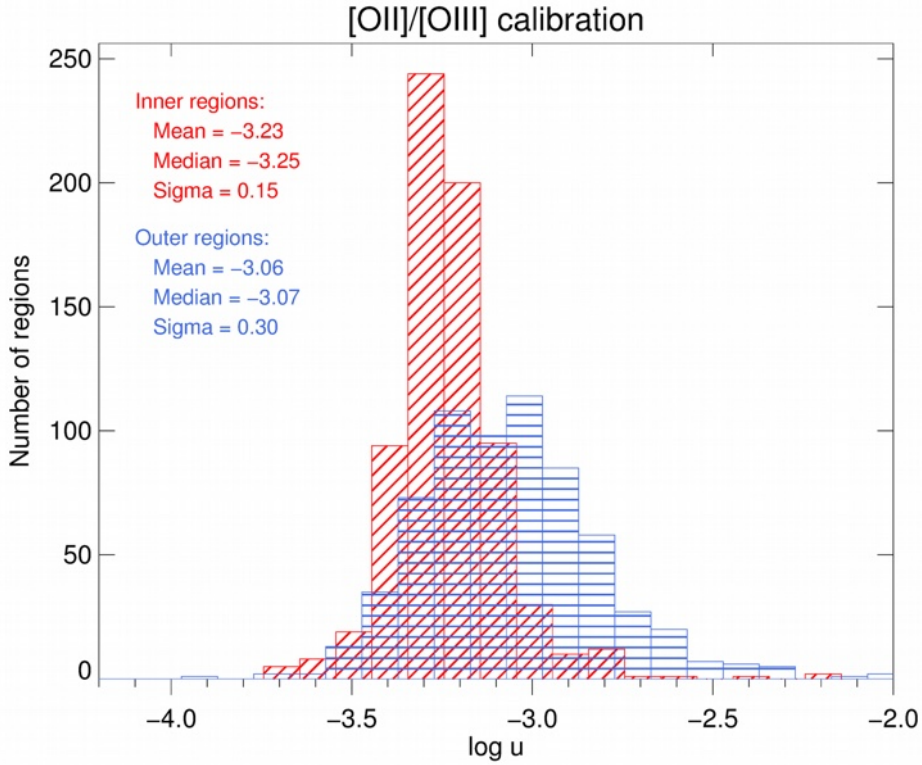
Particular objectives:

- Determination of functional parameter ranges of the observational HII region samples.
- Computation of photoionization models with a parameter grid compatible with the observational properties derived from the HII region samples.
- Comparative analysis of physical properties that provide information about evolutionary stages of inner and outer regions.

Functional parameters

- **Metallicity.** Oxygen abundance. Index O3N2. Calibration by Marino et al. (2013)
- **Ionization parameter.** Proxy: [OII]/[OIII]. Calibration by Díaz et al. (2000) and our models.
- **Effective temperature.**



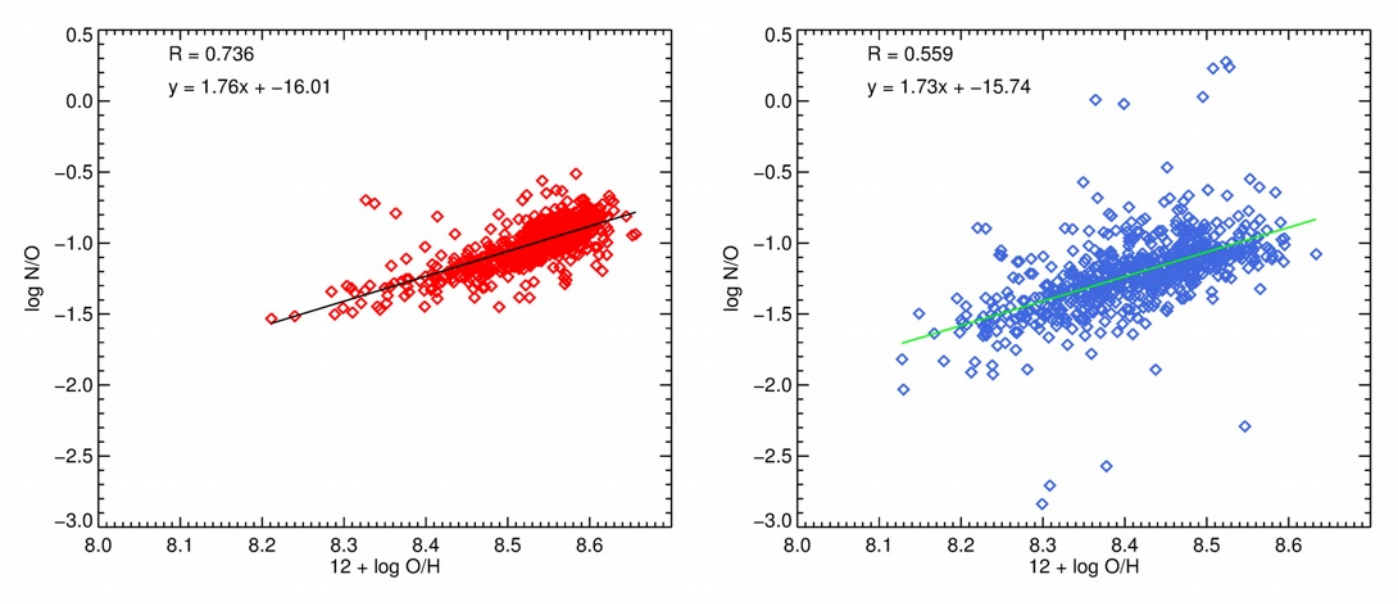


Rodríguez-Baras et al. (in prep.)

Photoionization models

Parameters grid:

- **Photoionization code:** Cloudy (version 17.01; Ferland et al. 2013)
- **SEDs:** PopStar evolutionary synthesis models (Mollá et al. 2009)
- **IMF:** Salpeter (1955), m_{low} = 0.15 $M_{\odot}$; m_{up} = 100 $M_{\odot}$
- **Abundances:** Grevesse et al. (2010), $Z_{\odot}$ = 0.018. Chemical evolution of N/O considered.
- **Electron densities:** 10 cm^{-3}
- **Ages:** from log t = 6.00 to log t = 6.72 in 17 steps of time.
- **Metallicities:** 0.006, 0.009, 0.012, 0.015 and 0.018.
- **Ionization parameter:** -3.75, -3.5, -3.25, -3.0, -2.75 and -2.5



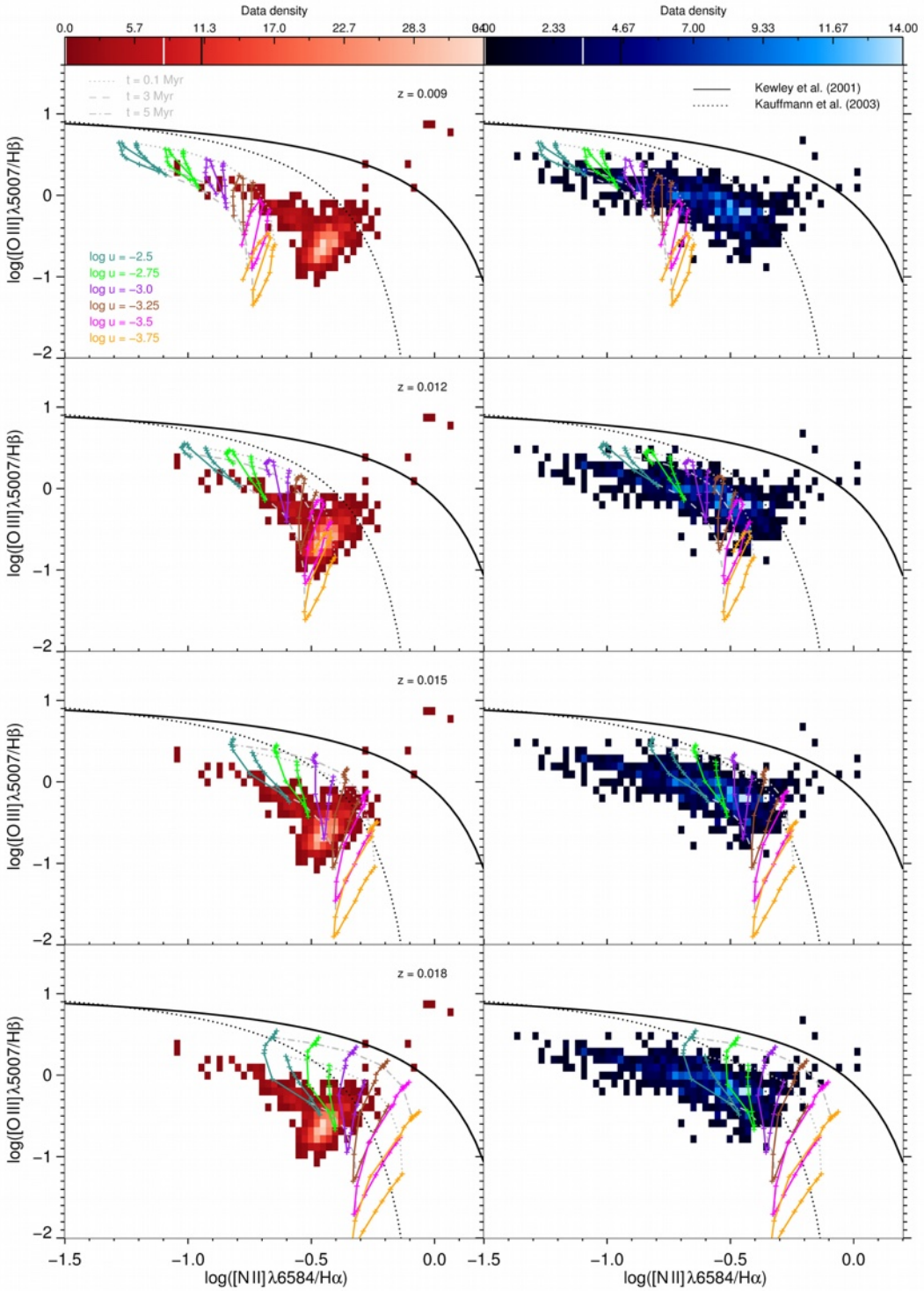
Inner regions,
outer regions

Rodríguez-Baras et al. (in prep.)

Diagnostic diagrams with photoionization models

[OIII]λ5007/Hβ vs [NII]λ6584/Hα

(fixed values of Z)

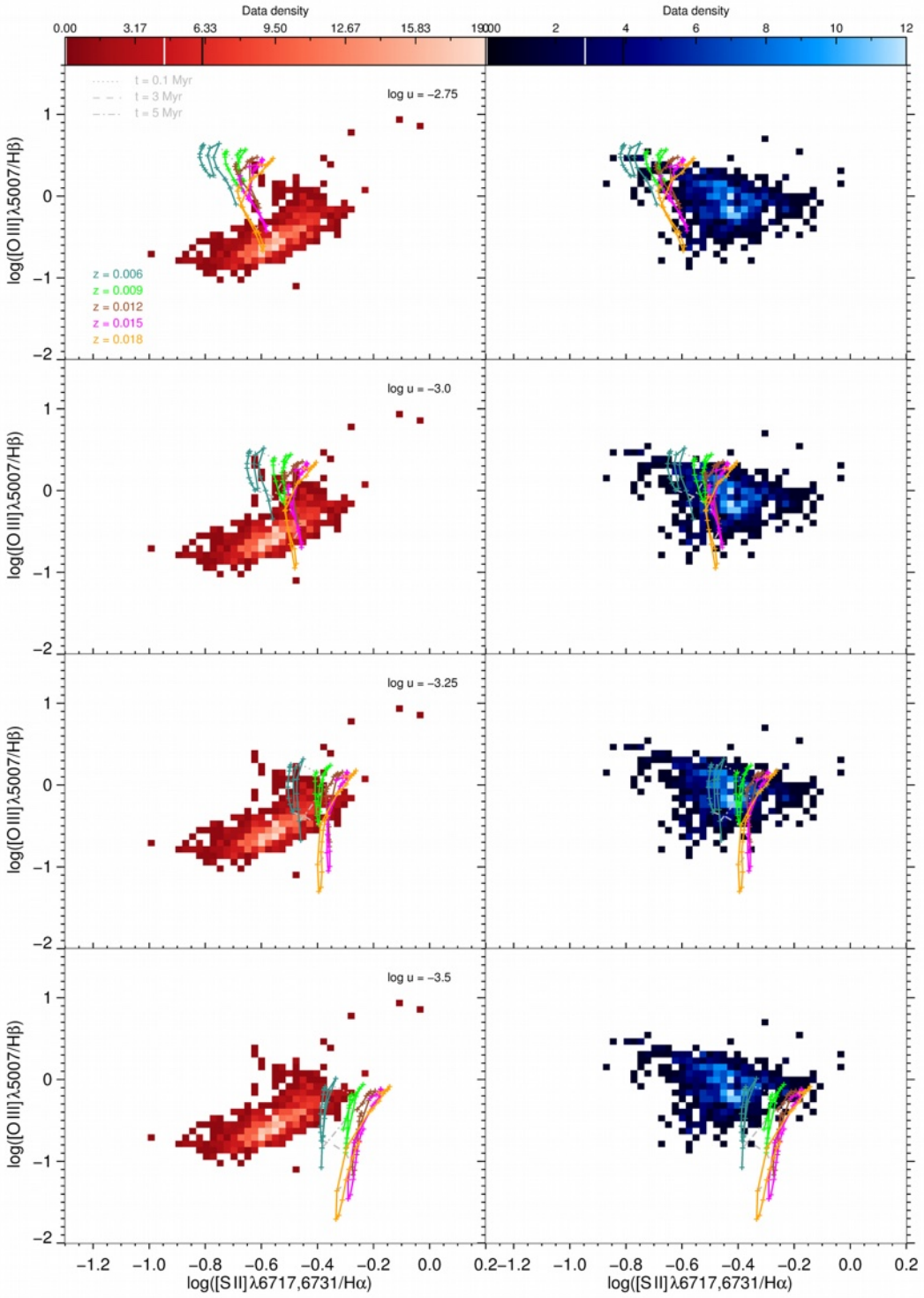


Rodríguez-Baras et al. (in prep.)

Diagnostic diagrams with photoionization models

[OIII]λ5007/Hβ vs [SII]λ6717,6731/Hα

(fixed values of log u)

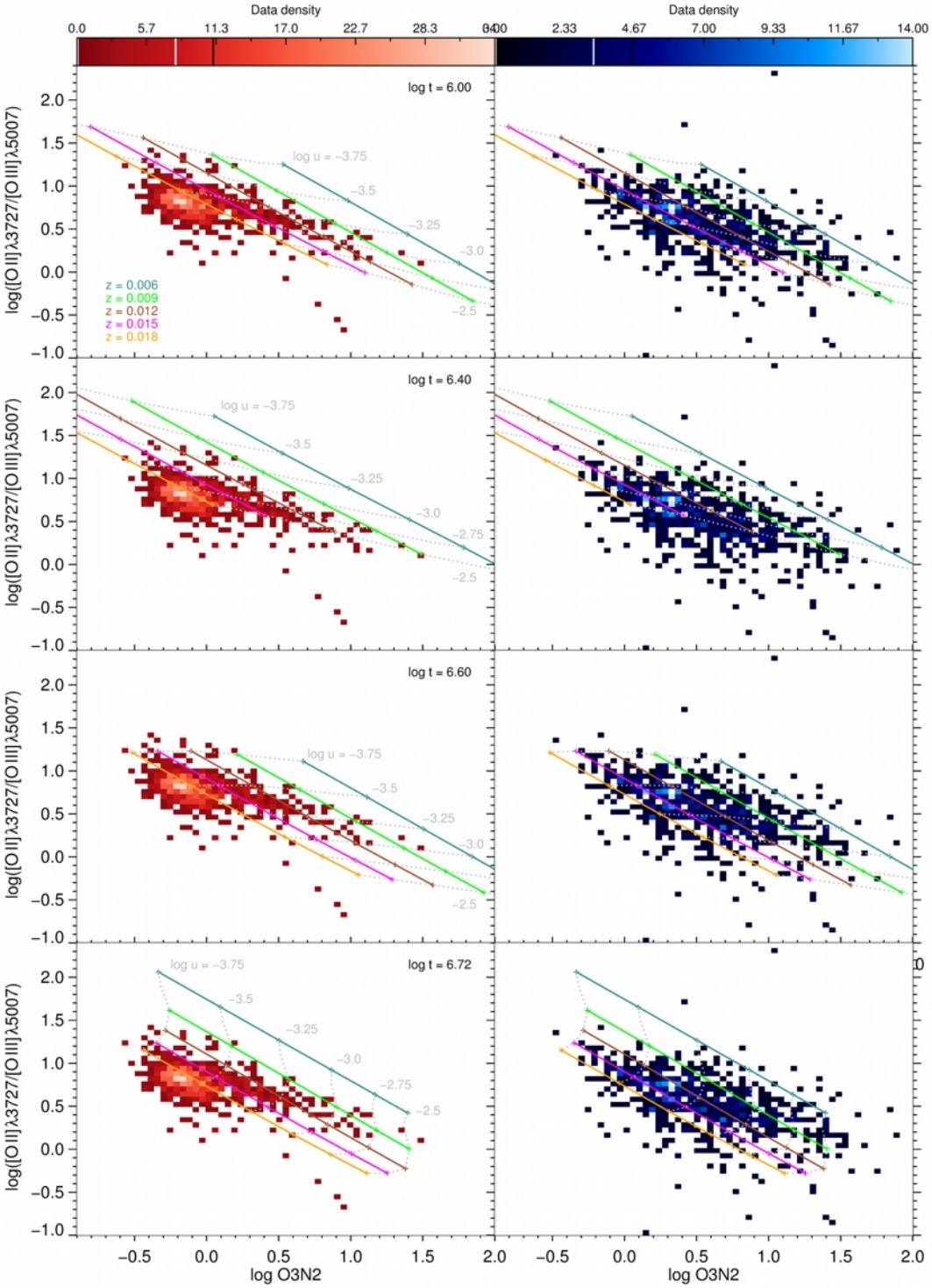


Rodríguez-Baras et al. (in prep.)

Diagnostic diagrams with photoionization models

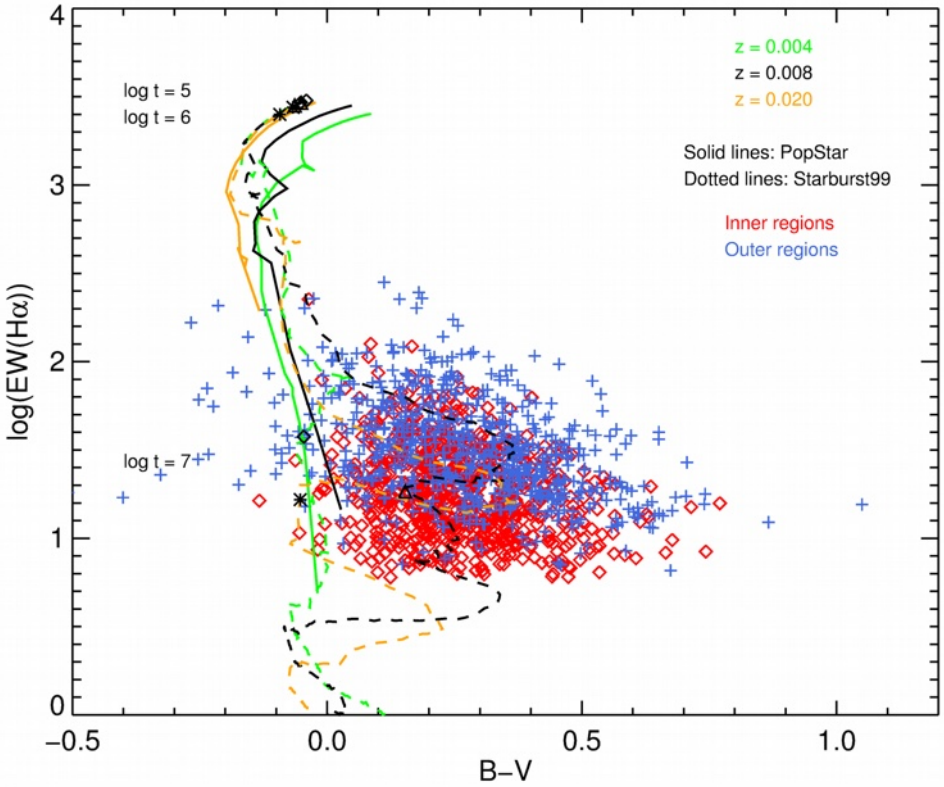
[OII]λ3727/[OIII]λ5007 vs O3N2

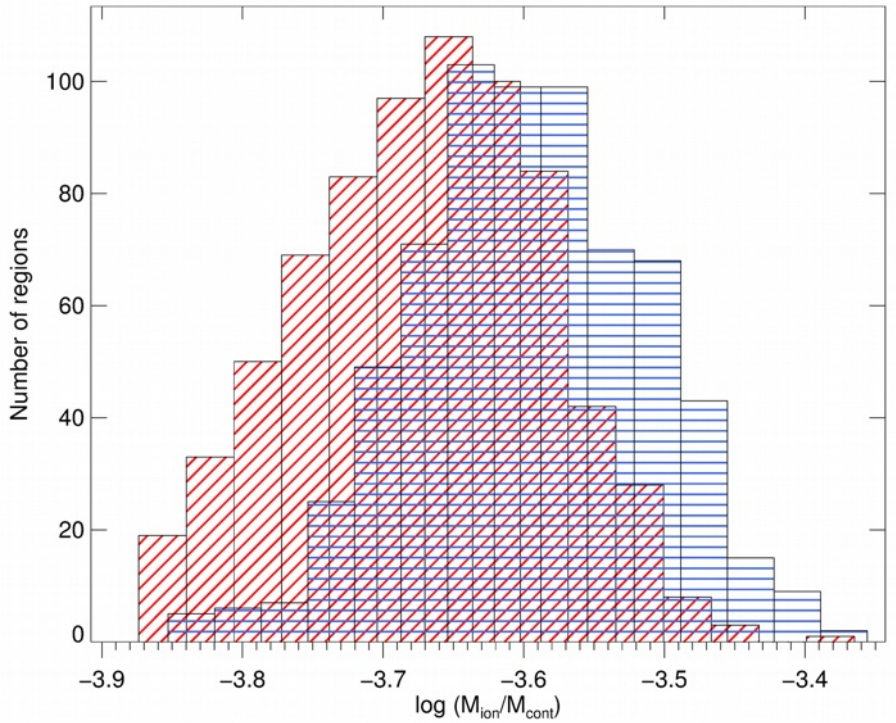
(fixed values of log t)



Rodríguez-Baras et al. (in prep.)

Equivalent widths





Inner regions, outer regions

Rodríguez-Baras et al. (in prep.)

- Inner regions show more evolved ionization clusters and a greater contribution of underlying population.

Work in progress

Detailed studies to characterise differences between physical properties of inner and outer HII regions.

Particular aspects:

- Bins of data that can be fitted with particular sets of models.
- Study of inner HII region subsample that may show an enhanced N/O ratio.
- Further study of equivalent widths in order to break the age degeneracy.
- Influence of electronic density variations (within the low density regime).

Thanks!

