A. Monreal-Ibero, S. Arribas, L. Colina, J. Rodríguez-Zaurín, A. Alonso-Herrero, M. García-Marín

Ionization mechanisms in the extra-nuclear regions of LIRGs

Luminous Infrared Galaxies (LIRGs) are an important class of objects in the low-z universe, bridging the gap between normal spirals and the Ultraluminous Infrared Galaxies. LIRGs are also relevant in a high-z context as a large fraction of the stars in the Universe were formed in these objects. Here, we present a study aiming to understand the nature and origin of the ionization mechanisms operating in the extranuclear regions of LIRGs as a function of the interaction phase and infrared luminosity. The study is based on Integral Field Spectroscopy data obtained with the VIMOS instrument of 32 LIRGs covering all types of morphologies (isolated galaxies, interacting pairs, and advanced mergers), and the entire 10^{11}-10^{12} L_{sun} infrared luminosity range.

We found strong evidence for shock ionization, with a clear trend with the dynamical status of the system. Specifically, we quantified the variation with interaction phase of several line ratios indicative of the excitation degree. In particular, while the [NII]/Ha ratio does not show any significant change, the [SII]/Ha and [OI]/Ha ratios are higher for more advanced interaction stages. Also, we constrained the main mechanisms causing the ionization in the extra-nuclear regions using diagnostic diagrams. Isolated systems are mainly consistent with ionization caused by young stars while large fractions of the extra-nuclear regions in interacting pairs and more advanced mergers are consistent with ionization caused by shocks. The relation between the excitation degree and the velocity dispersion of the ionized gas supports this result. We interpret both results as evidence for shock ionization in interacting galaxies and advanced mergers but not in isolated galaxies.

A deeper discussion about these results as well as about the dependence of the velocity dispersion – excitation relation with the luminosity of the system can be found in Monreal-Ibero et al. 2010, A&A, in press (arXiv:1004.3933).

Ionization mechanisms in the extranuclear regions of LIRGs

Ana Monreal Ibero

Santiago Arribas, Luis Colina,
Javier Rodríguez-Zaurín,
Almudena Alonso-Herrero, and
Macarena García-Marín

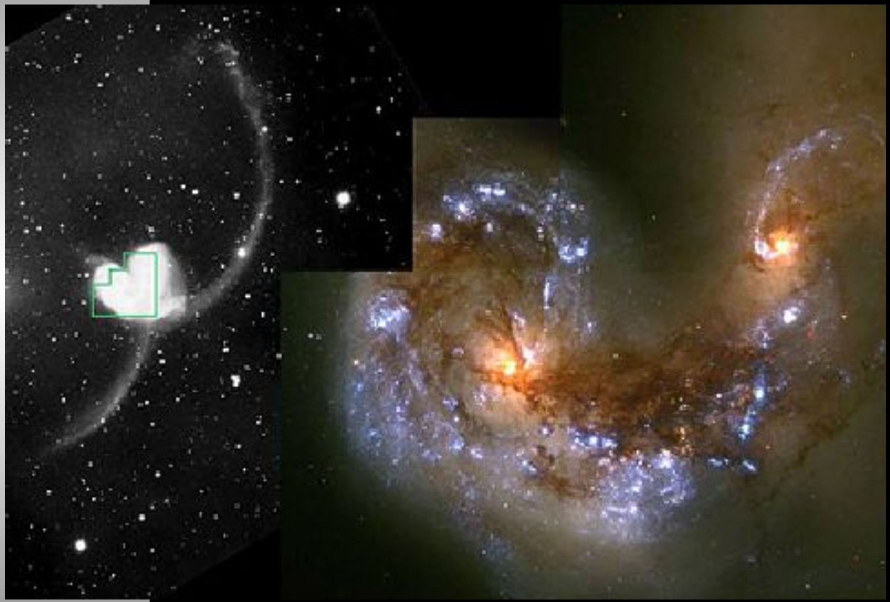
(based on Monreal-Ibero et al. 2010, in press)

(Ultra)luminous Infrared Galaxies

LIRGs: $L_{IR} = 10^{11} - 10^{12}\ L_{\odot}$

ULIRGs: $L_{IR} > 10^{12}\ L_{\odot}$

NGC4038/NGC4039



(Credit: B. Whitmore, STScI and NASA)

- Extreme starbursts: the episode of SF (and sometimes an AGN) is the cause of the IR luminosity
- Large quantities of gas and dust
- Interacting systems: more mergers and strongly interacting systems at higher luminosities

Strong evolution

- Locally: very few.
- At z~0.8-1.2: 2 orders of magnitude more

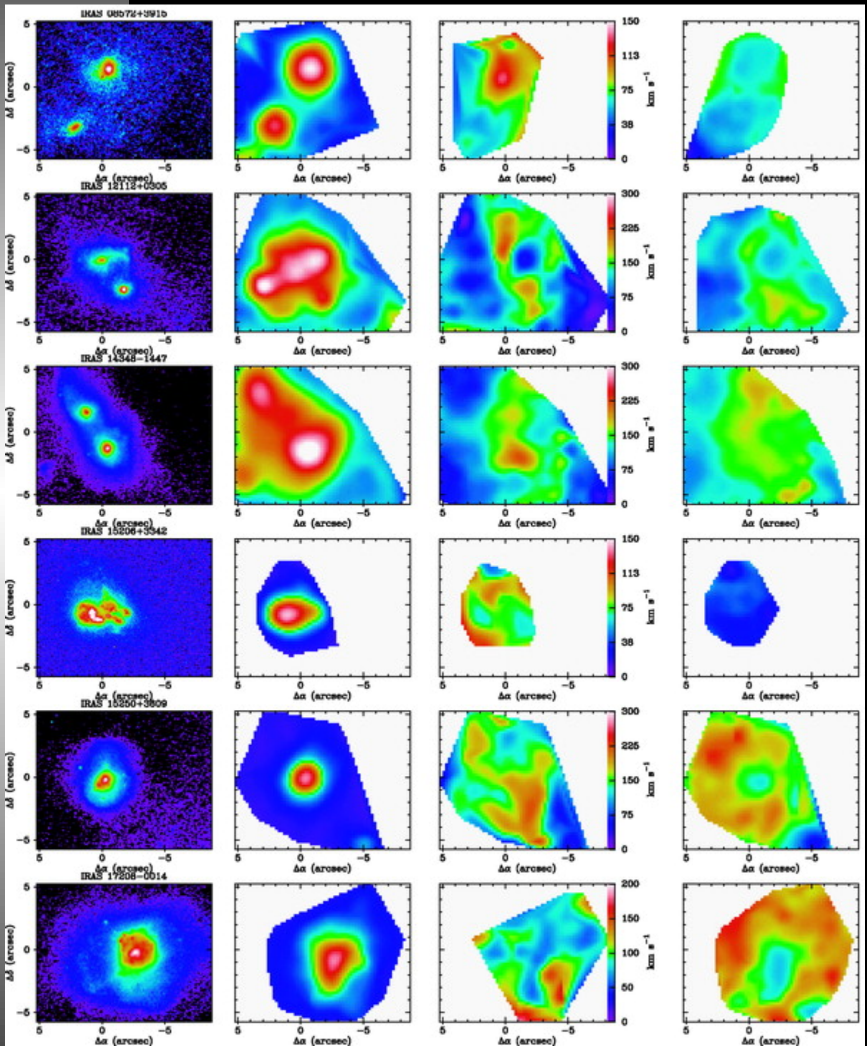
Why to study their ionization properties?

- To investigate the nature of the source causing the infrared luminosity
- To understand how the interaction/merger process and the release of energy and material affect the extended structure of the galaxy (in general) and of the interstellar medium (in particular).

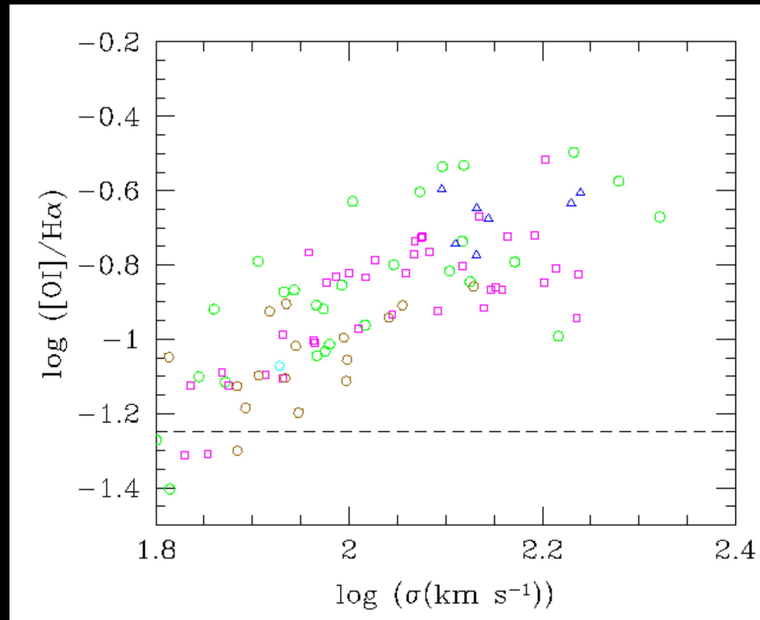
Complex structure: preferential direction difficult to select

We would like to have 2D unbiased spectroscopic information of the external parts of the galaxy.

Previous work: 6 ULIRGs

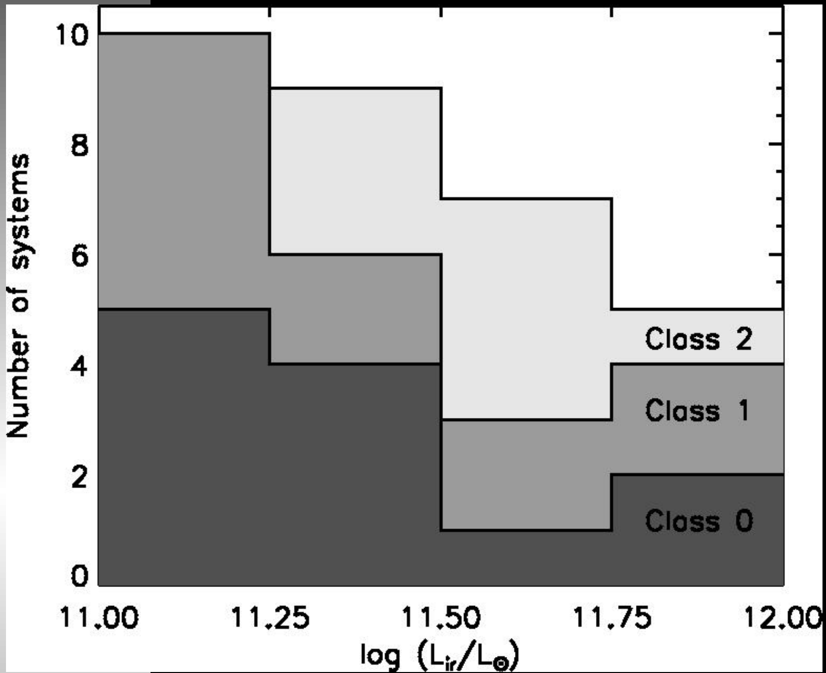


- Extended regions with line ratios typical of LINERs
- Local correlation between ionization degree and velocity dispersion

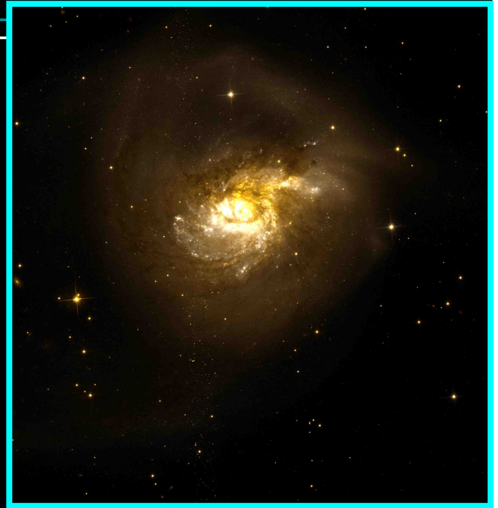


How does this extend to the LIRGs luminosity range?

The sample

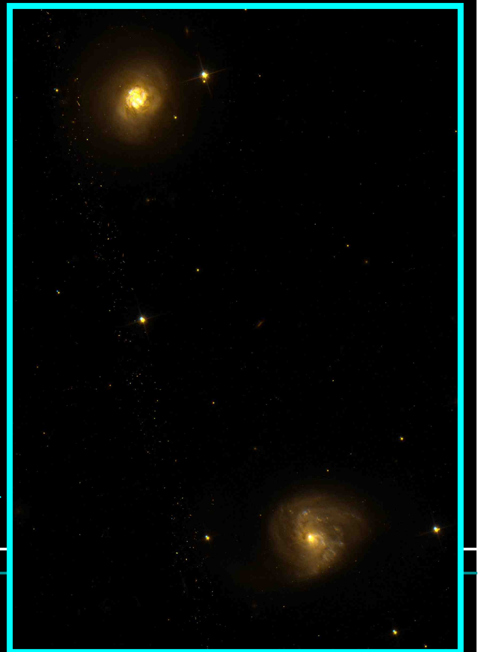


Class 2



Class 1

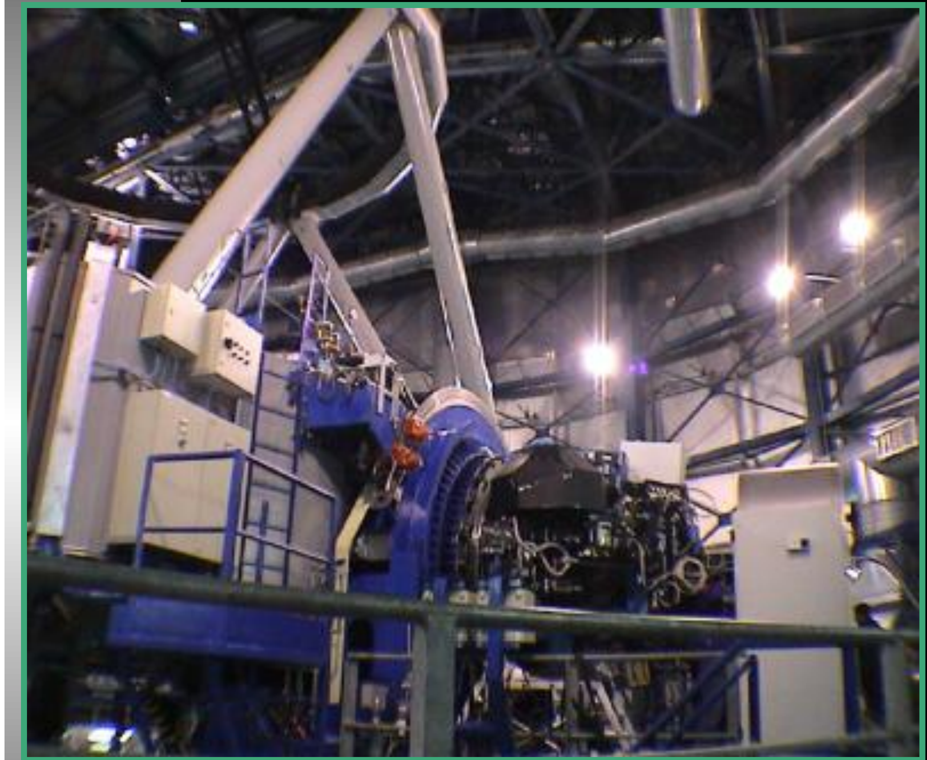
Class 0



- 13 isolated
- 11 interacting (9 pairs and 2 triple)
- 8 advanced

- <D> = 87 Mpc
- Scale ~400 pc / arcsec

VIMOS



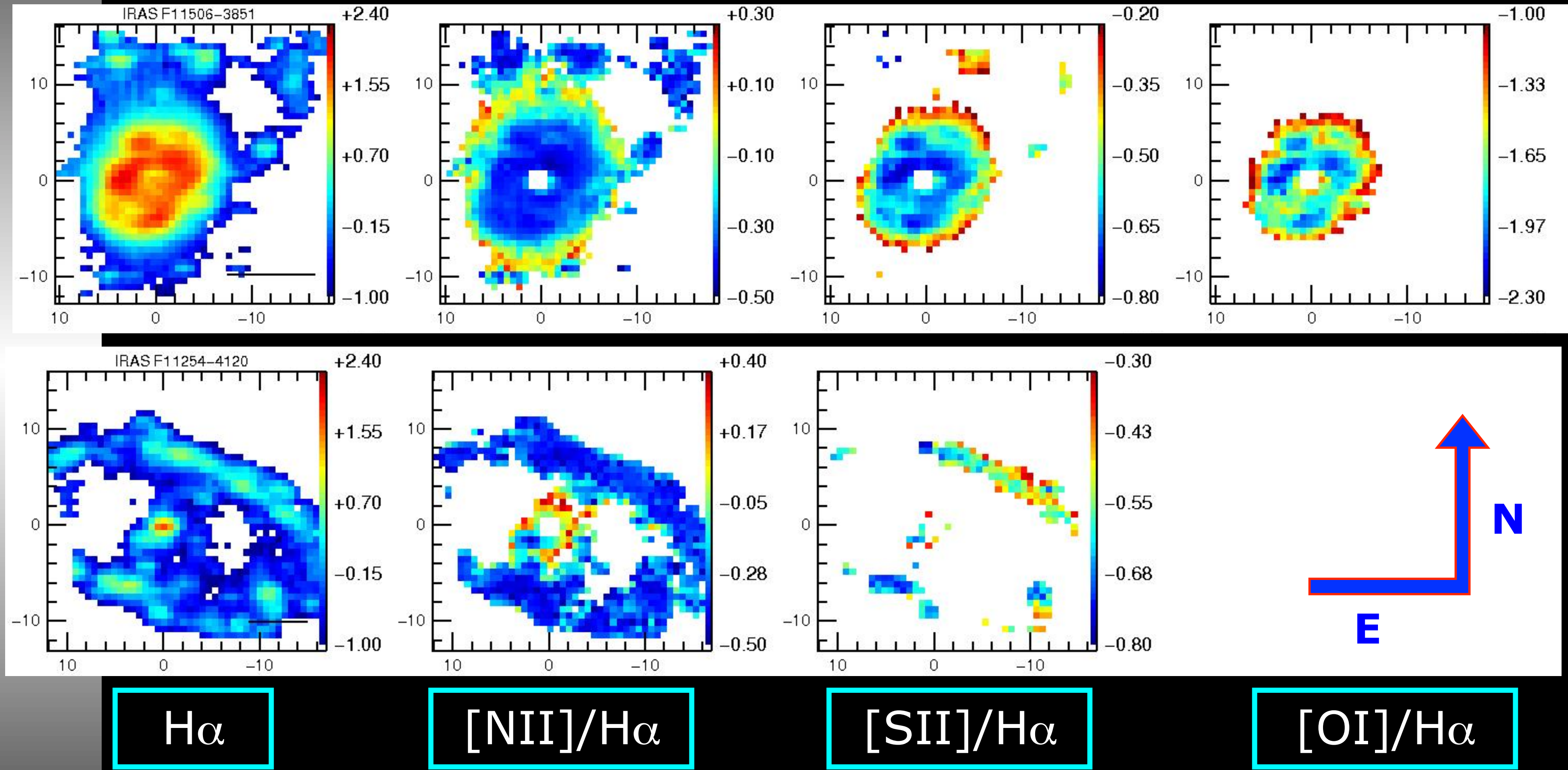
VIMOS @ UT3

Used configuration:

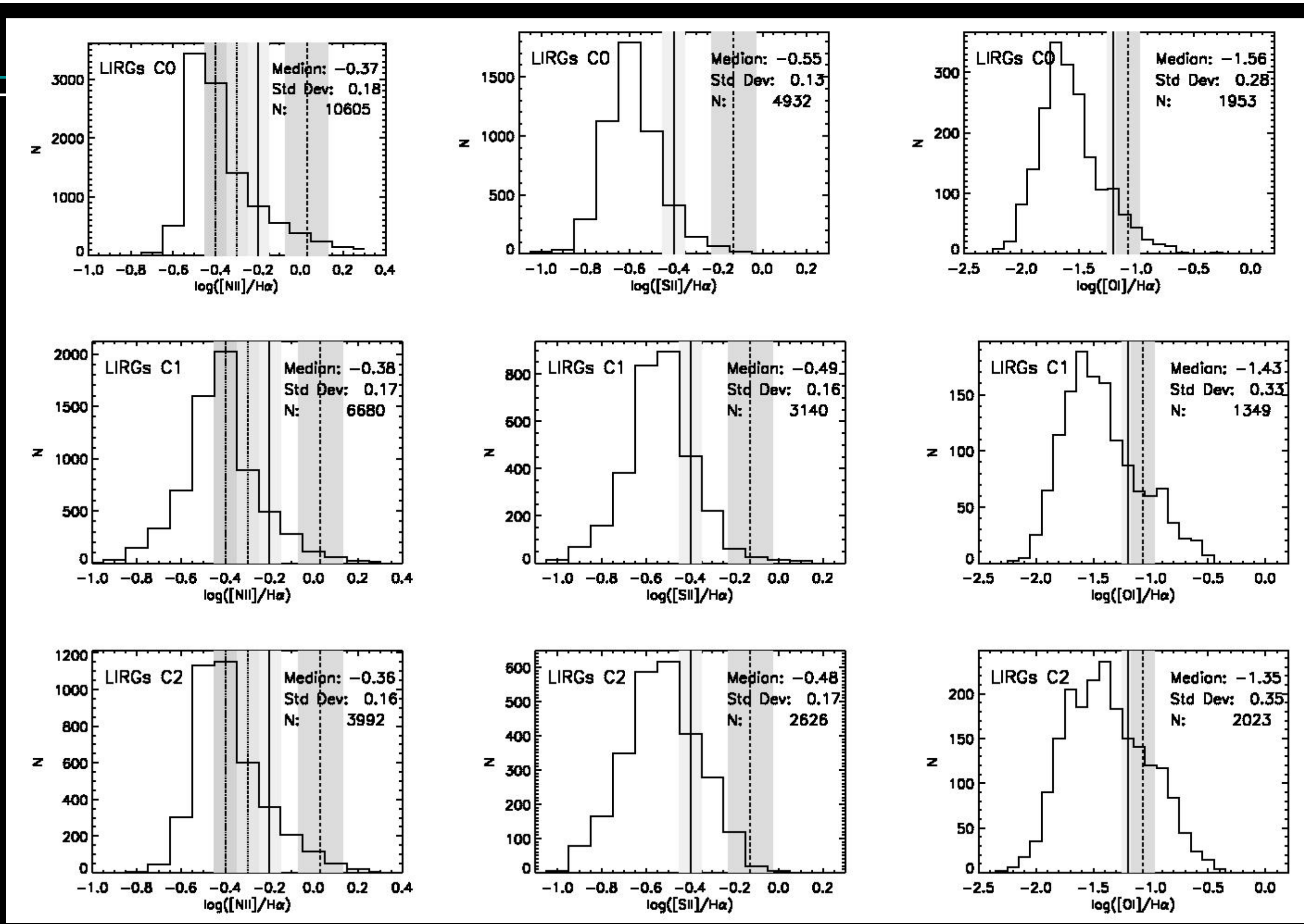
IFU-mode/HR_Orange

- scaling: 0.67"/spa
- f.o.v.: 27"x27"
- R~2650
- λ range: 5250-7400Å
- 4 pointings doing dither pattern
- texp = 4x750 s

Ex.: IRAS F11506-3851 and IRAS F11254-4120



Line ratio distribution

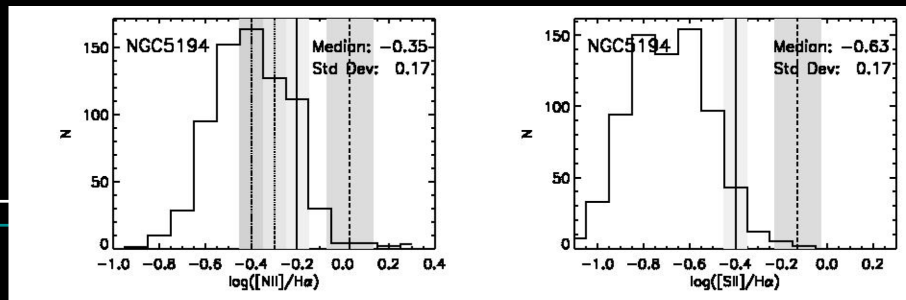


[NII]/Hα

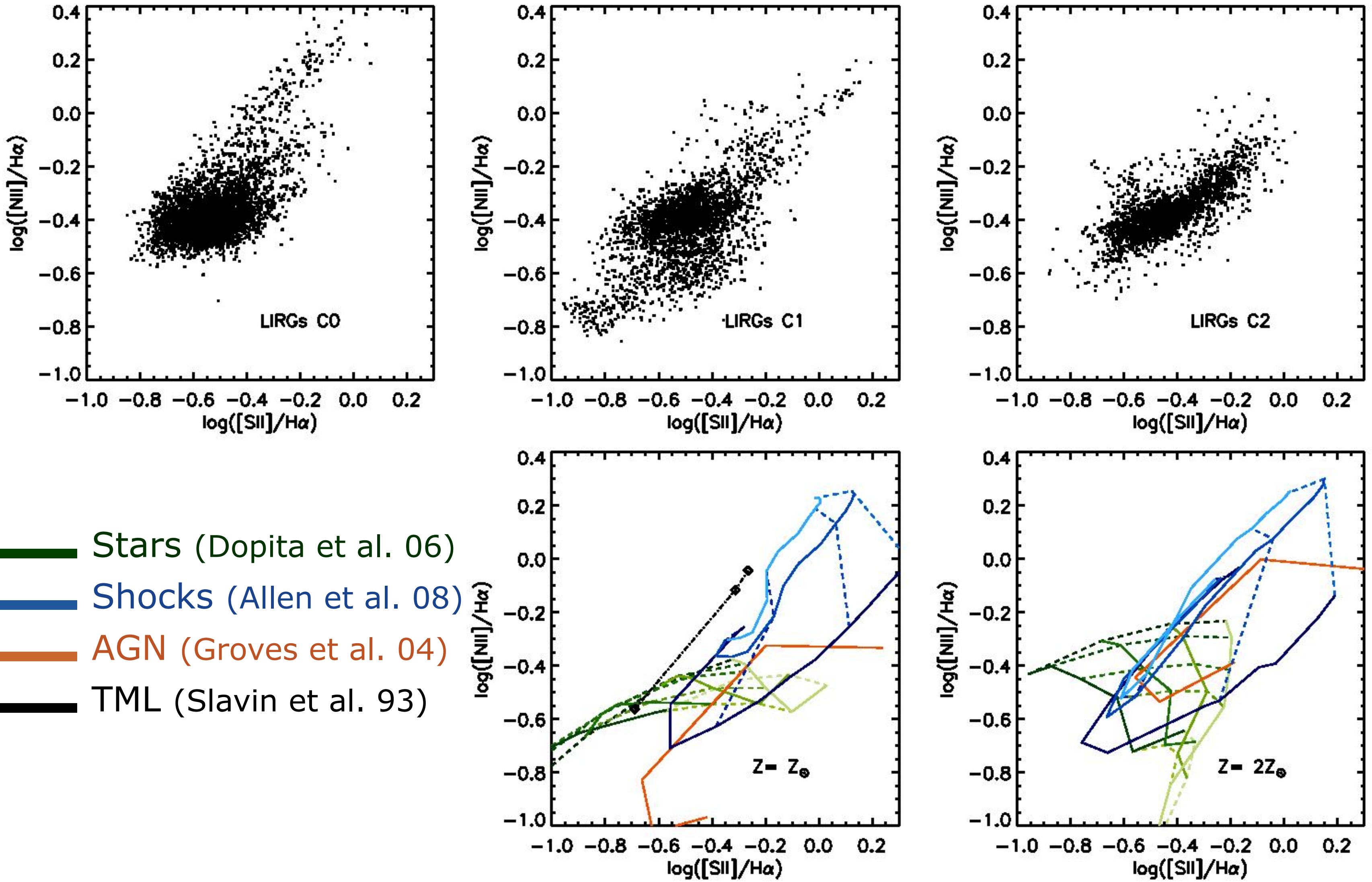
[SII]/Hα

[OI]/Hα

NGC5194: A more standard spiral



[SII]/Hα vs. [NII]/Hα



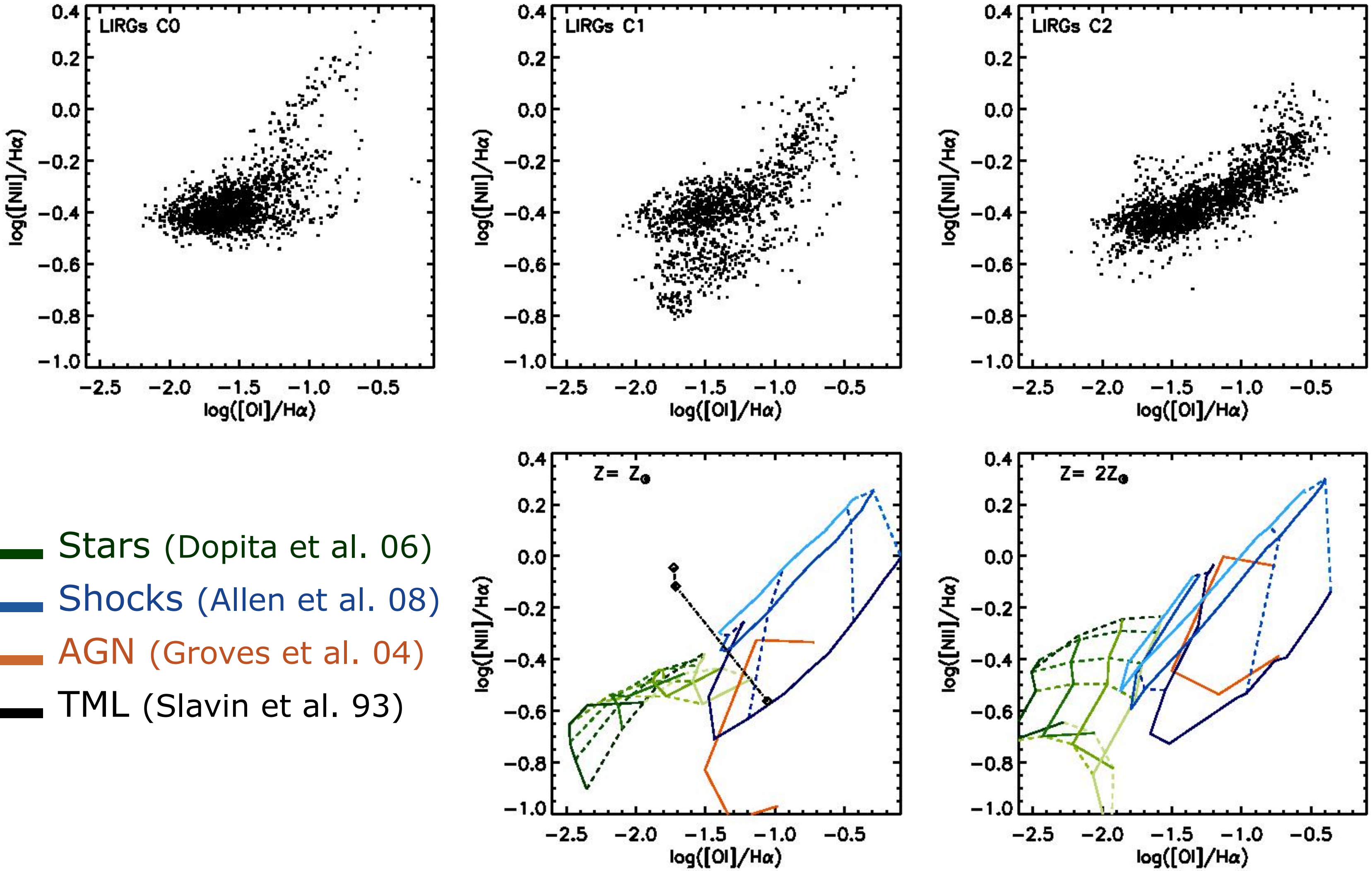
Stars (Dopita et al. 06)

Shocks (Allen et al. 08)

AGN (Groves et al. 04)

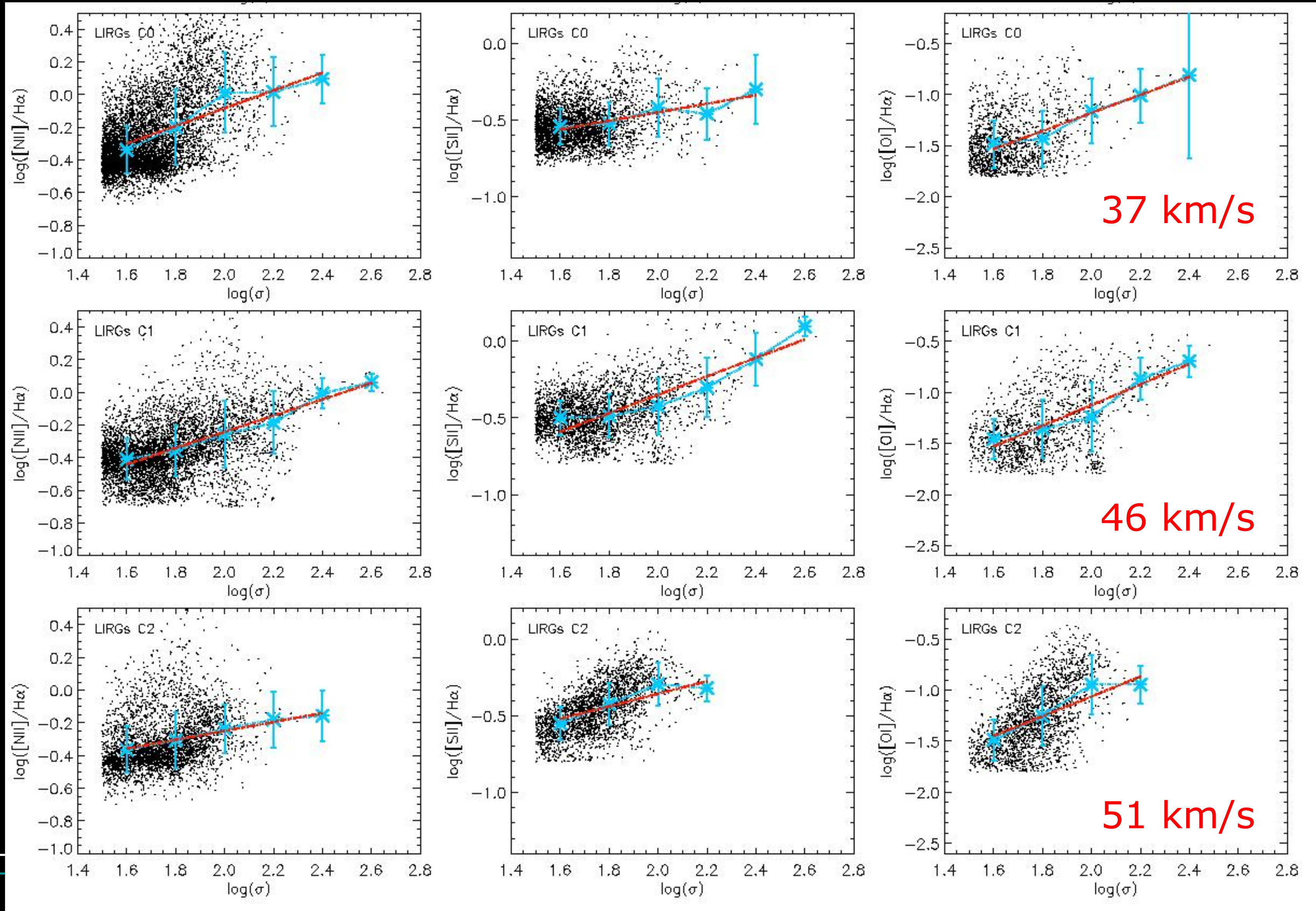
TML (Slavin et al. 93)

[OI]/Hα vs. [NII]/Hα



Stars (Dopita et al. 06)
Shocks (Allen et al. 08)
AGN (Groves et al. 04)
TML (Slavin et al. 93)

Velocity dispersion vs. ionization degree



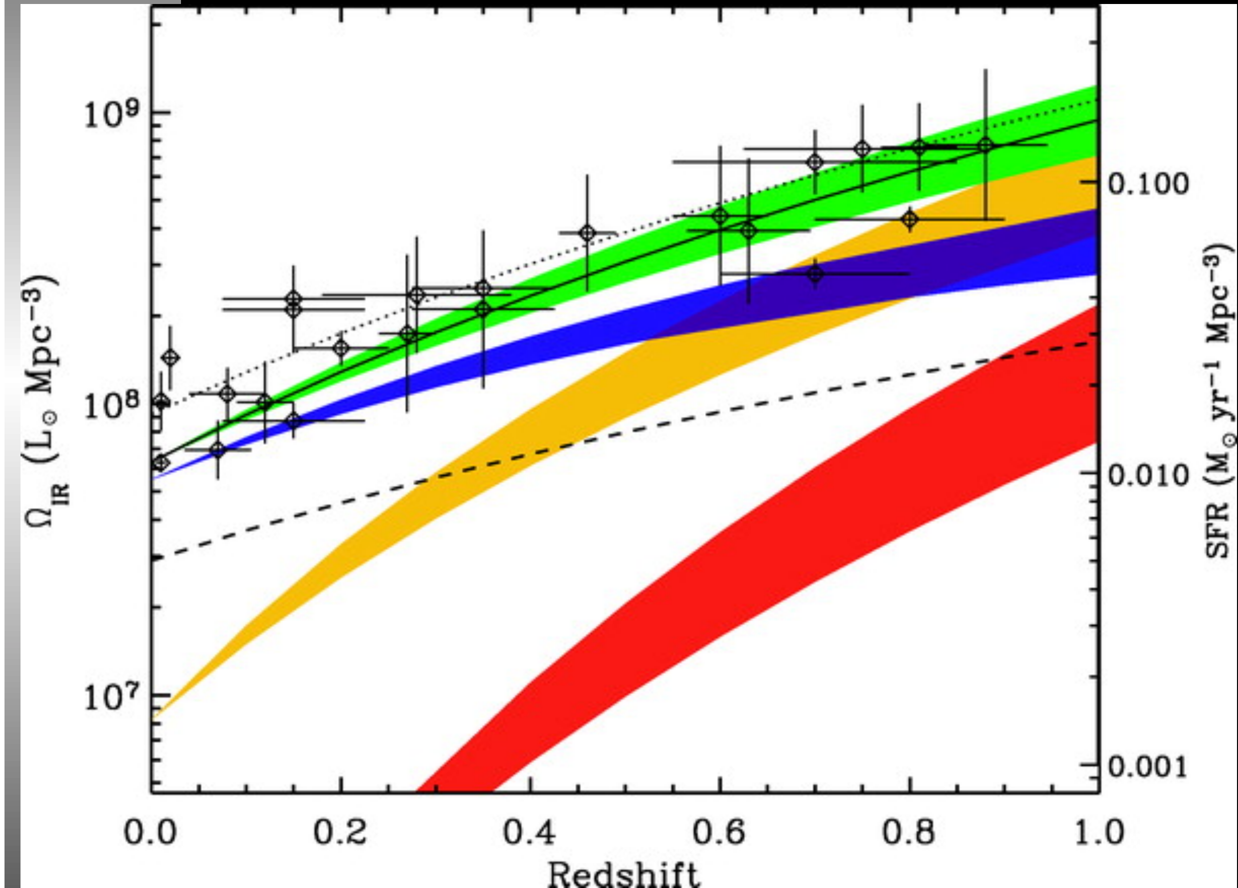
Summary

- [NII]/Hα distribution does not change with the interaction class. On the contrary, [SII]/Hα and [OI]/Hα show an extension towards higher line ratios in interacting systems and mergers.
- Line ratios in LIRGs can mostly be explained as caused by ionization due to young stars. However, the ionization in a large fraction of regions in systems with some degree of interaction is better explained by shocks.
- There is a positive relation between the degree of excitation and the velocity dispersions in interacting systems supporting the scenario where ther relevance of shocks as ionizing sources increases when there is some interaction.

End

Evolution of starburst galaxies:

Most of the stars were formed in an starburst



All

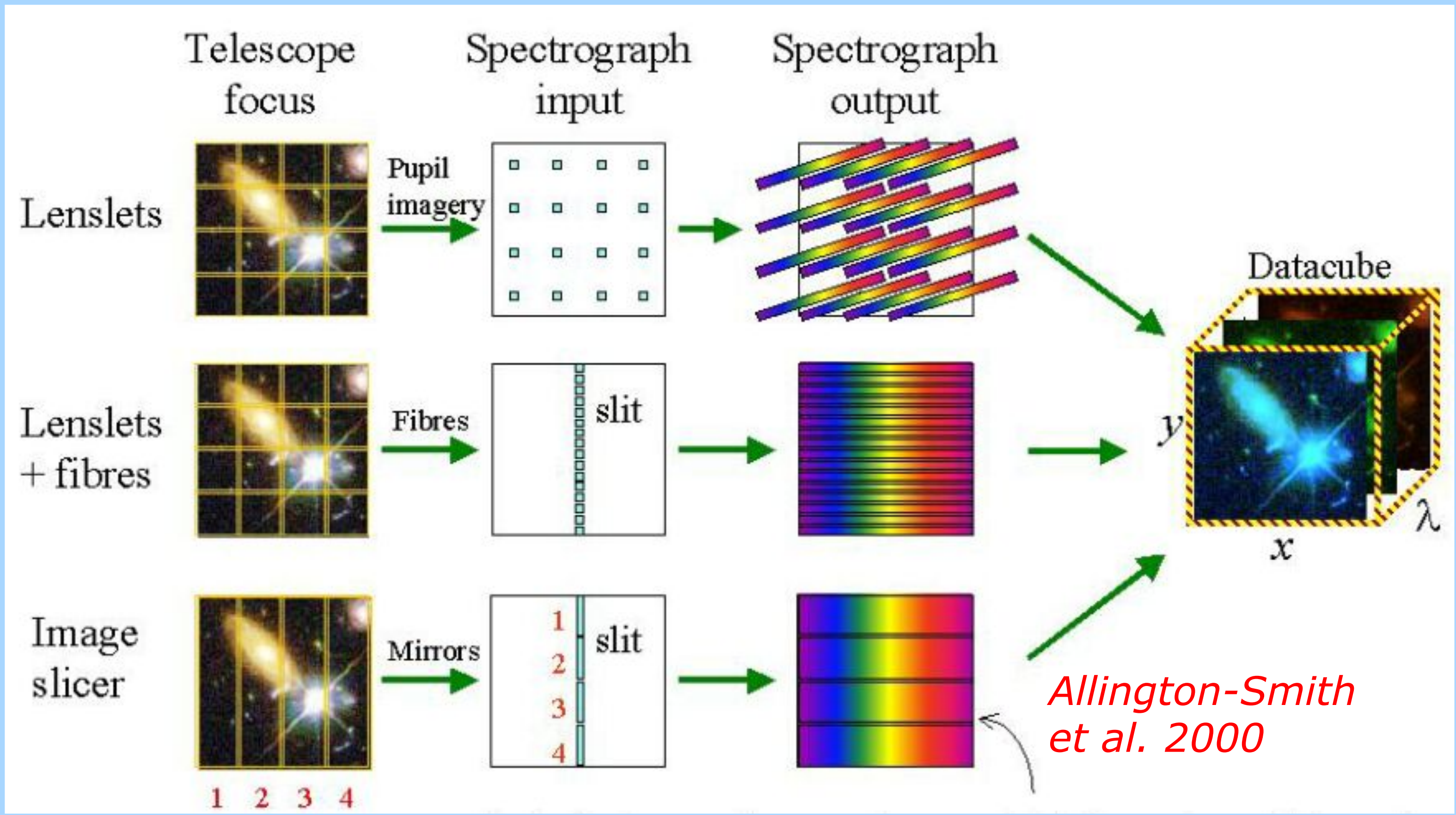
$L_{ir} < 10^{11}\ L_\odot$

$10^{11}\ L_\odot < L_{ir} < 10^{12}\ L_\odot$

$10^{12}\ L_\odot < L_{ir}$

(Le Floch et al. 2005)

Integral Field Spectroscopy



Records simultaneously three variables (α, β and λ) in two dimensions (x and y)

- Homogeneity
- Shorter exposure times

Velocity dispersion vs. ionization degree (II)