Integral Field Spectroscopic Survey of Luminous and Ultraluminous Infrared Galaxies

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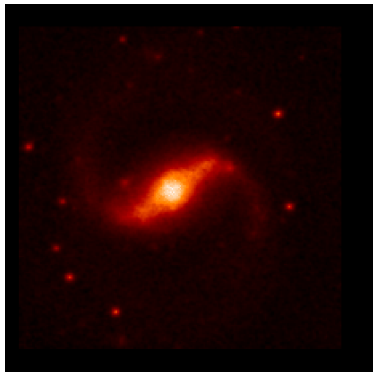
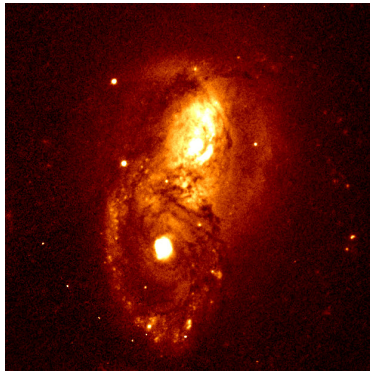
A. Bedregal (UCM)

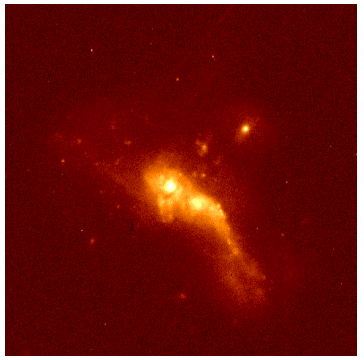
Outline

- Introduction
  - (U)LIRGs
- IFS Survey of (U)LIRGs
  - Why IFS ?
  - Instruments
  - Sample
- Some VLT / VIMOS data & recent/preliminary results
  - Structure
  - Kinematics
  - Excitation
- Prospects with ELT

INTRODUCTION-I: (U)LIRGs







LIRGS $(10^{11}\ L_\odot < L_{IR} < 10^{12}\ L_\odot)$

ULIRGS $(L_{IR} > 10^{12}\ L_\odot)$

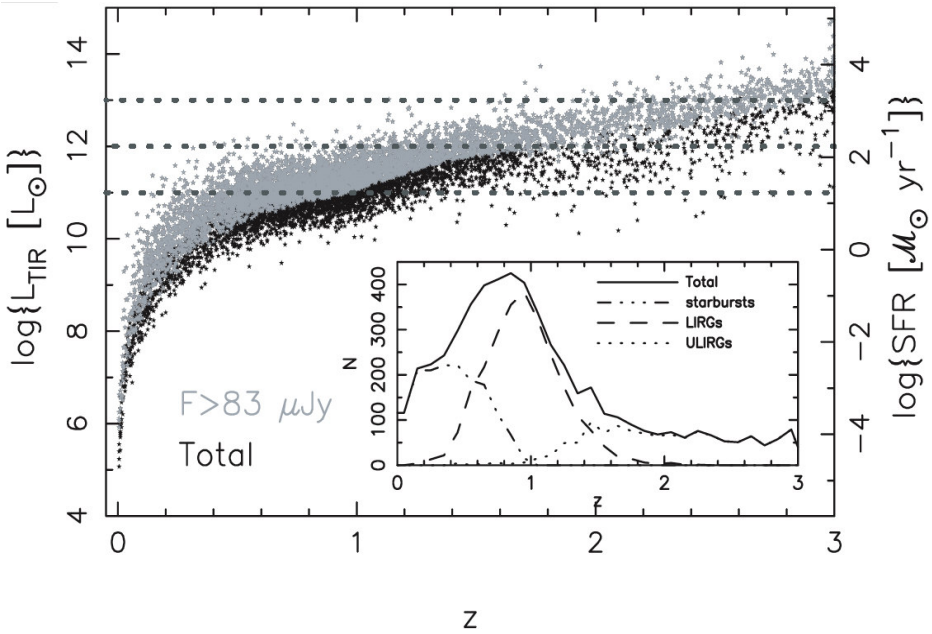
- **Objects with a wide range in morphologies: from regular star-forming spiral galaxies to interacting and mergers of gas-rich galaxies**
- **Sites of massive star formation**
- **Extreme cases to study the AGN-starburst connection**
- **(ULIRGs) can be in an early, dust-enshrouded, phase of QSOs**
- **(ULIRGs) seem to form ellipticals**
- **Sites of tidal-induced dwarf galaxies formation**
- **Sites of IGM metal enrichment**

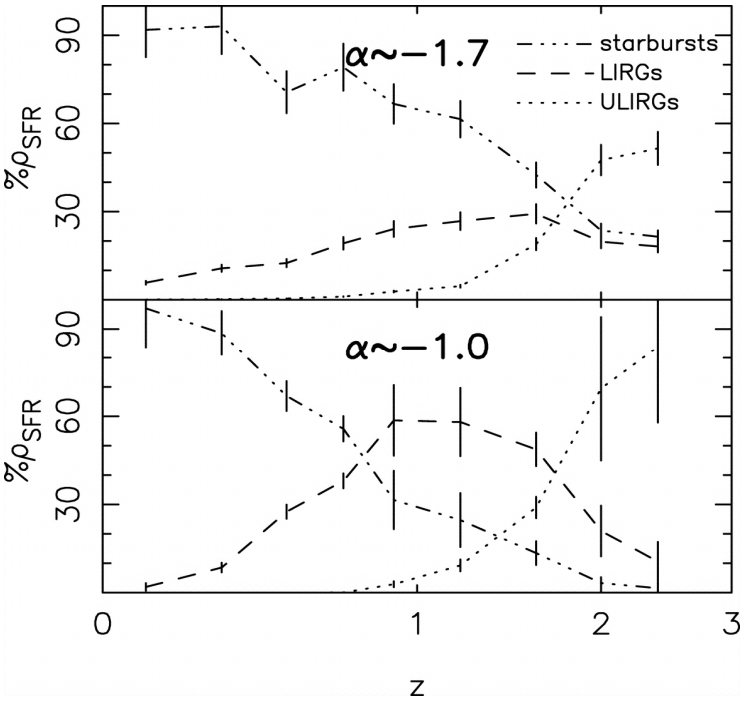
Local (U)LIRGs show an extreme behavior and are ideal astrophysical labs to study some key physical processes

INTRODUCTION-I: (U)LIRGs

At high-z (U)LIRGs

- **much more numerous (SPITZER)**
- **a large fraction of stars have been formed in (U)LIRGs**





Pérez-González et al. 2005

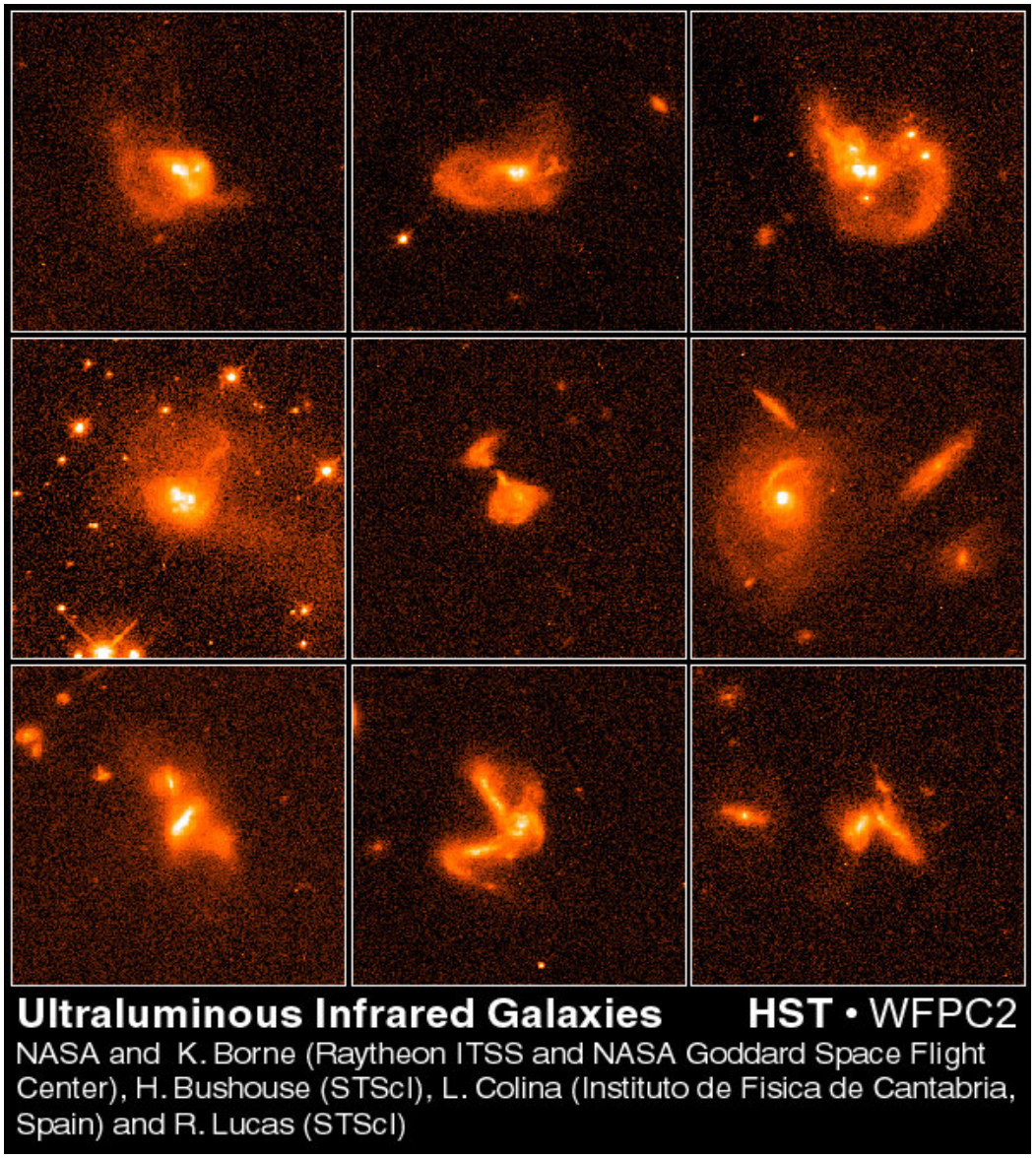
(U)LIRGs are key populations for studies of galaxy formation and evolution

Our project is aimed at studying in detail the internal physical and kinematic structure of (U)LIRGs at low-z

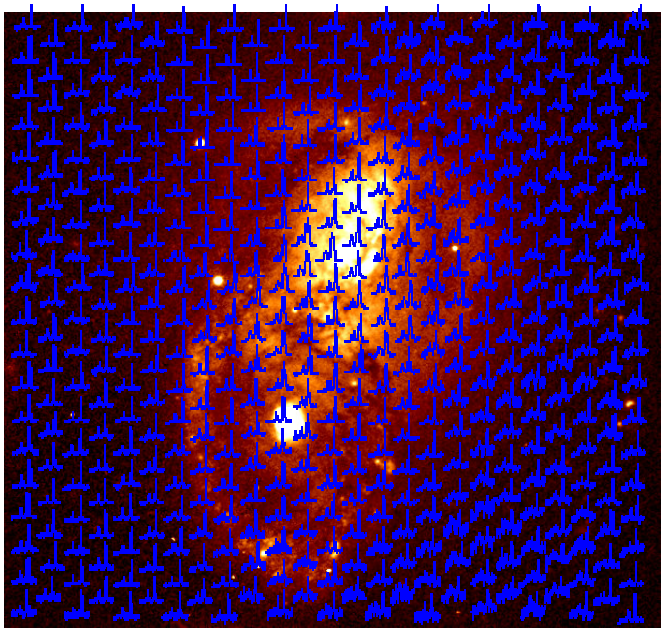
INTRODUCTION-II: IFS of (U)LIRGs

- (U)LIRGs are structurally complex
  - morphology (cont.)
  - complex velocity fields
  - complex 2D ionized gas comp.
  - complex ionization

- They require 2D spectroscopy
  - L-S ---> obvious difficulties
  - F-P ---> large range in V, need large scans in lambda.
  - **IFS ---> ideal approach**



INTRODUCTION-III: IFS of (U)LIRGs



QuickTime™ and a
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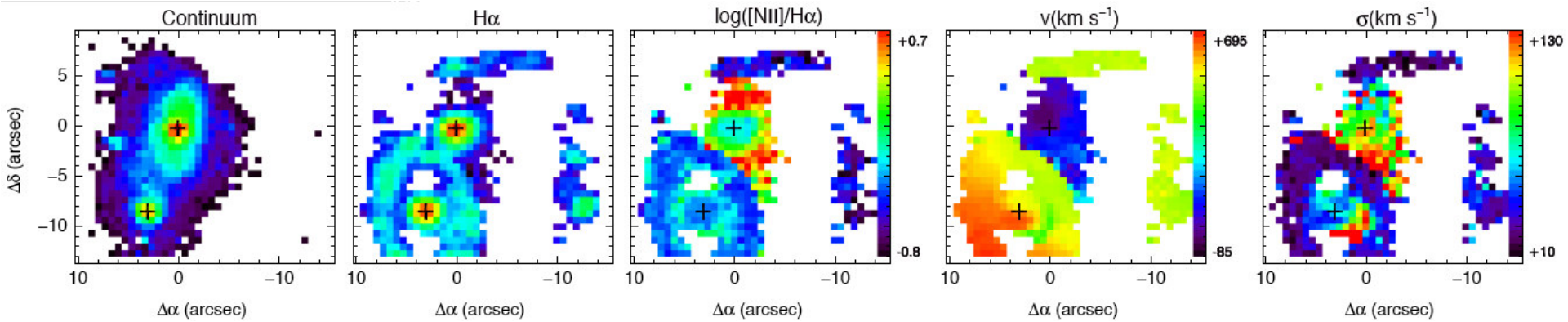


IFS provides simultaneous 2D spectroscopy in a very efficient and homogeneous way

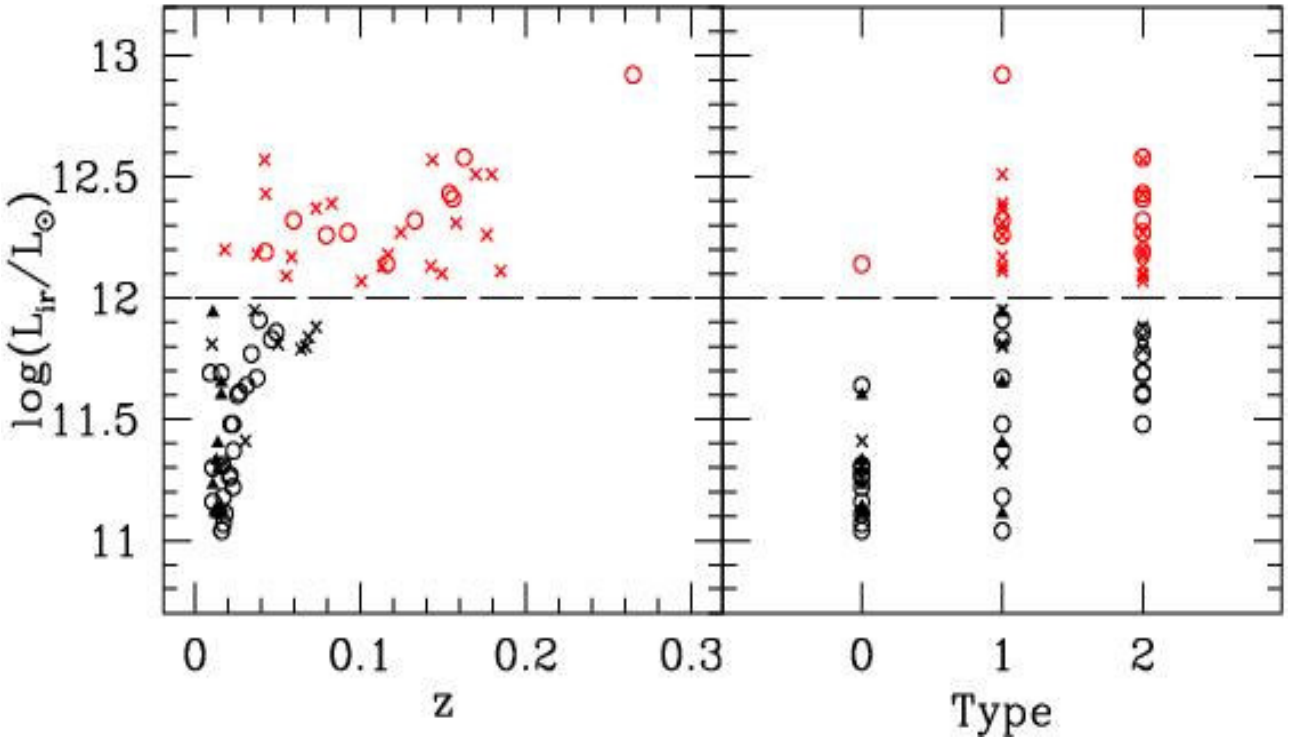
IFS SURVEY of (U)LIRGs: INSTRUMENTATION

TELESCOPE	IFS	FoV (arcsec)	Angular R. (´´/spaxel)	λ Range (μm)	Spectral Resolution (R)	Number of Targets
4.2m/WHT	INTEGRAL	12x16	0.90	0.49-0.82	1400	18
3.5m/CAHA	PMAS	16x16	1.00	0.36-0.70	1200	14
8.2m/VLT	VIMOS	27x27	0.67	0.52-0.74	2650	42
8.2m/VLT	SINFONI	8x8	0.25	H, K	3000-4000	16

INTEGRAL (ULIRGs): Garcia-Marin et al (2009) Astro-ph 0907.2408
PMAS (Low L LIRGs) : Alonso-Herrero et al (2009, submitted)
VIMOS Arribas et al. 2008, A&A, 479, 687
SINFONI (NGC5135) Bedregal et al. 2009, ApJ, 698, 1852

IFS SURVEY OF (U)LIRGS: The SAMPLE

~ 70 (U)LIRGs
- **Z < 0.2**
- **11.0 < log($L_{IR}/L_{\odot}$) < 12.6**
- **HII - Sy1**
- **EARLY/LATE**



Type
0= isolated
1= interacting
2= merger remants

Arribas et al. 2008; Alonso-Herrero et al. 2006, ApJ 650, 835

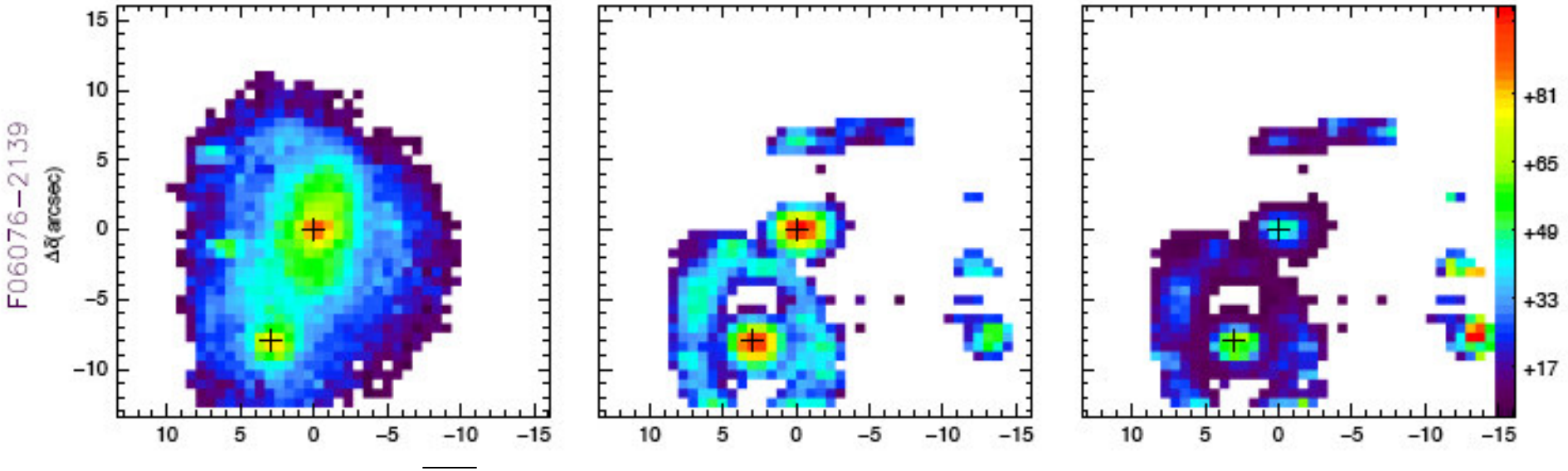
VLT / VIMOS data
and recent/preliminary results

Structural differences among galaxy components

Red continuum
(Old stellar comp.)

Hα emission
(Ionized gas)

Hα EW
(Young stellar comp.)



Rodriguez-Zaurin et al. 2009, in prep.

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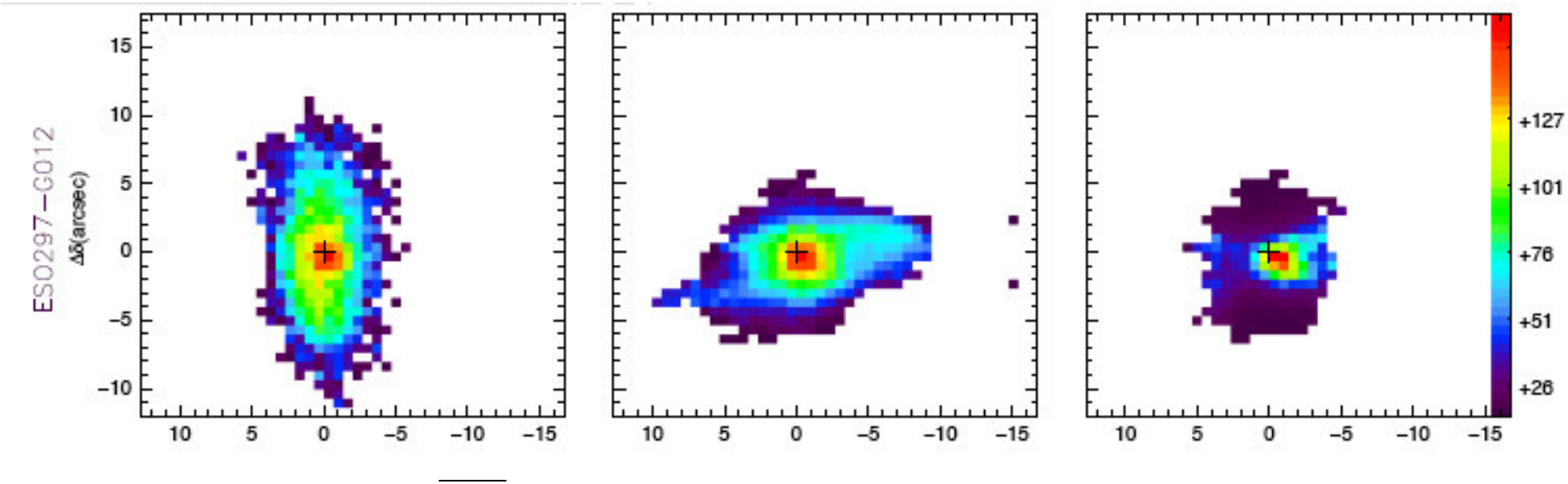

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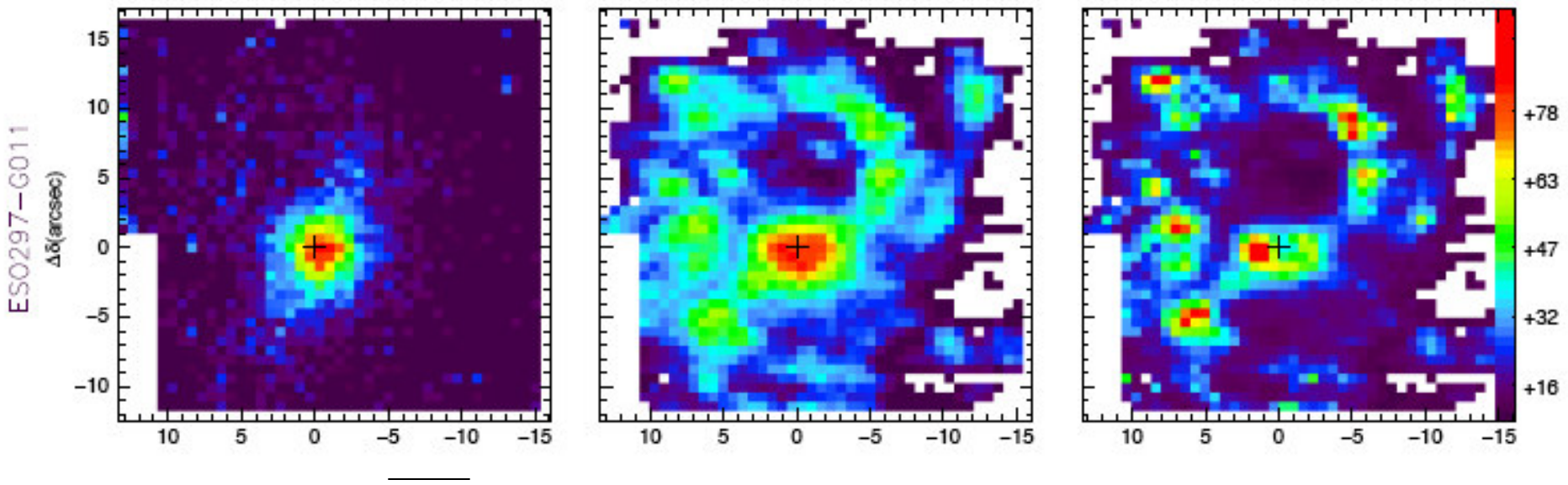

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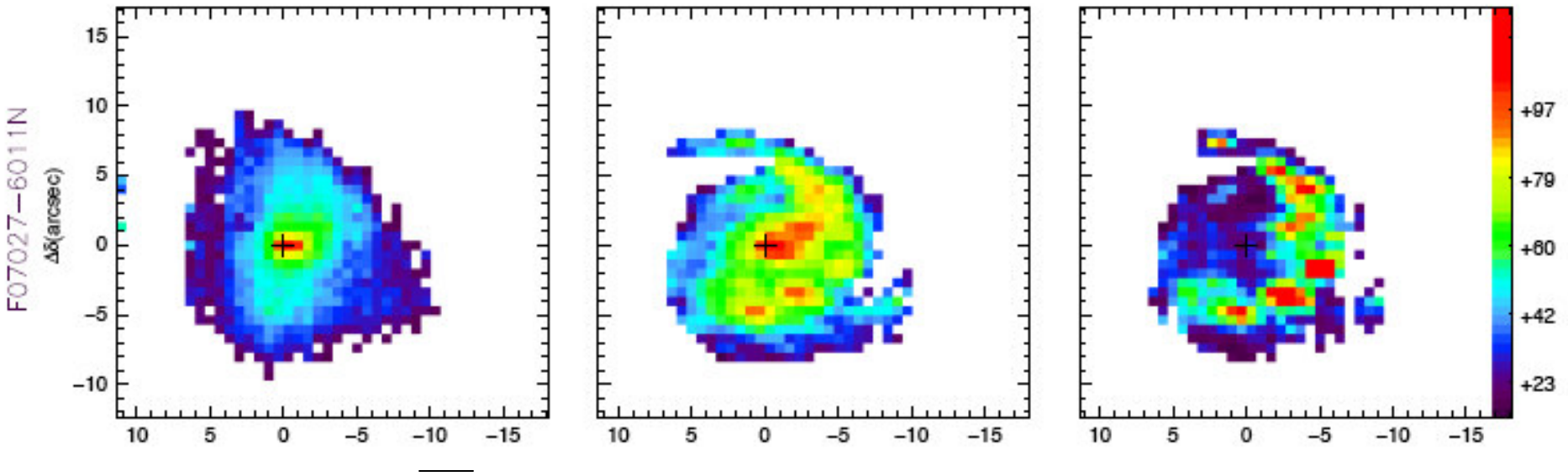

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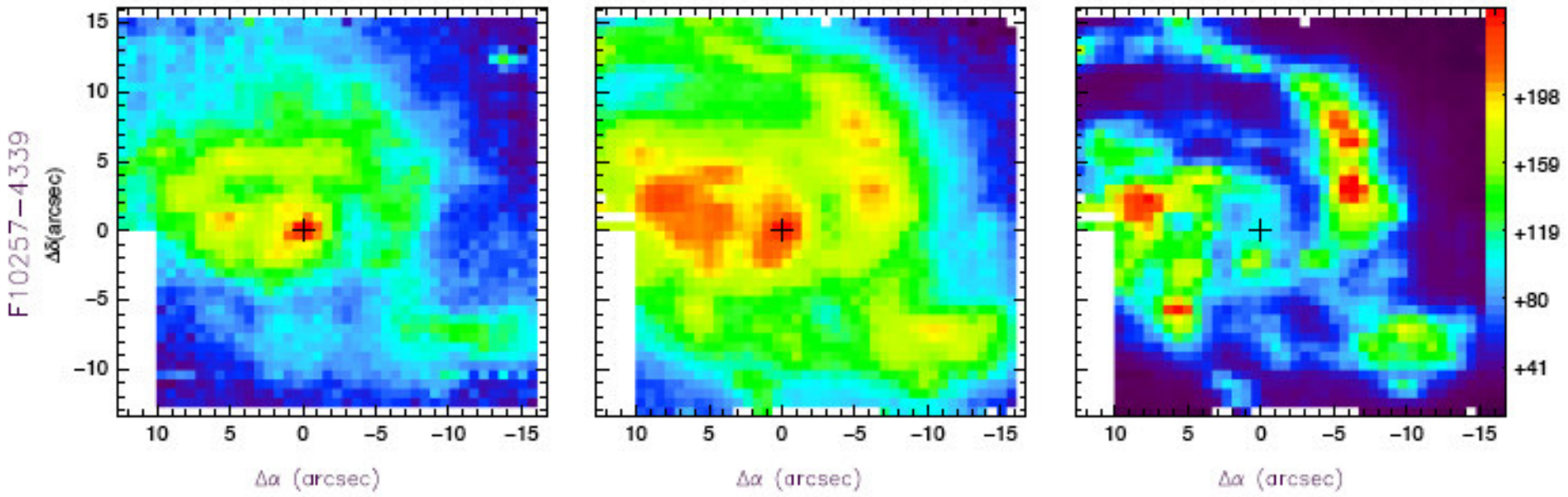

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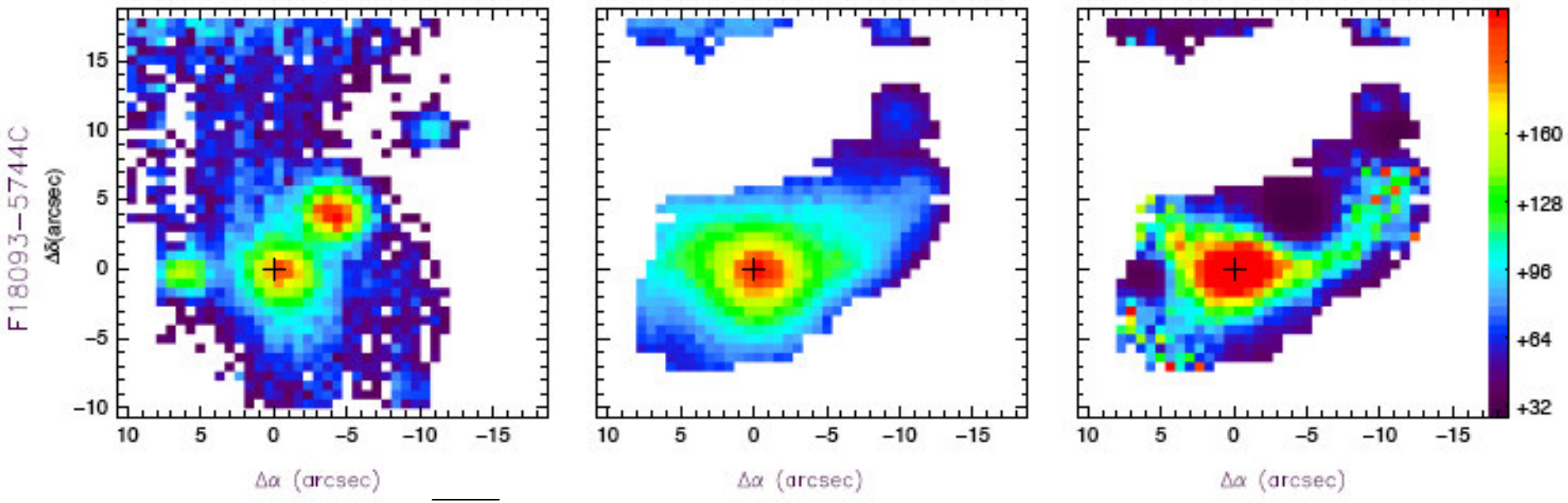
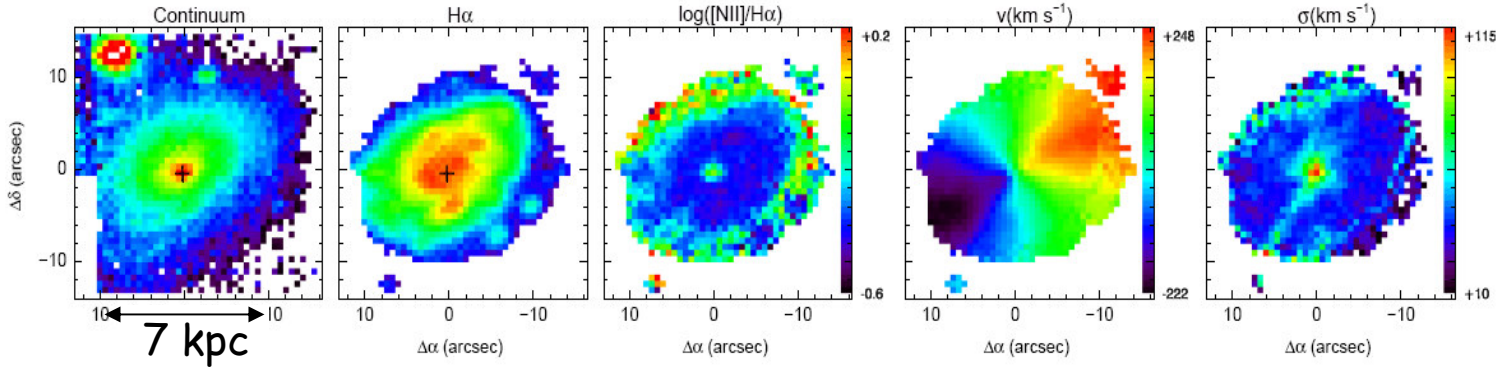


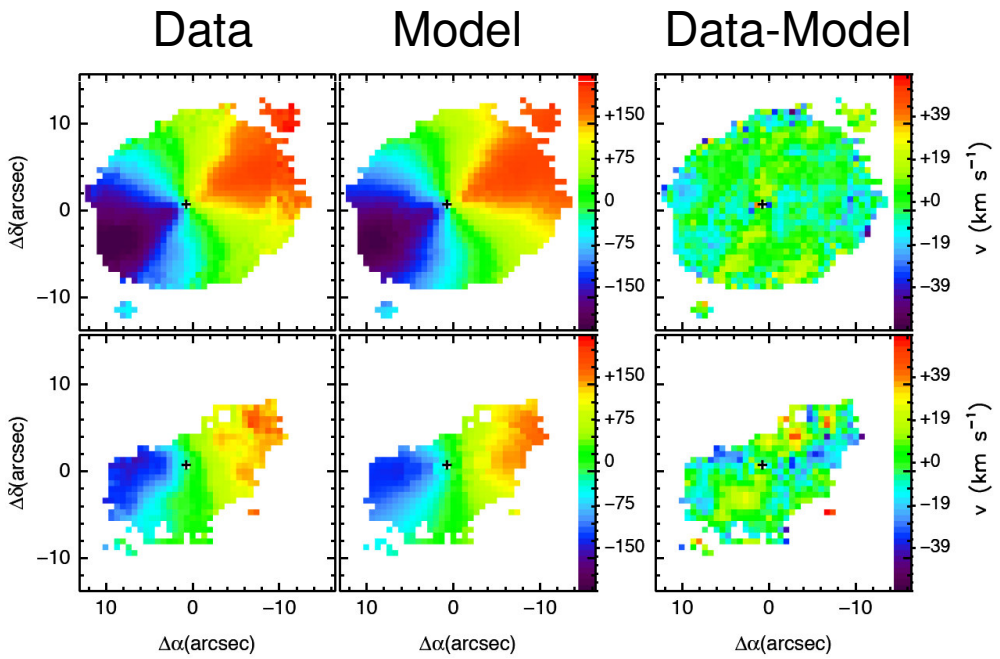
Rodriguez-Zaurin et al. 2009, in prep.

2D Ionized and Neutral gas Kinematics in IRAS12115-4656

IFS OF (U)LIRGS: NEUTRAL vs. IONIZED GAS KINEMATICS

The case of IRAS12115-4656 (a weakly interacting LIRG)





Ionized gas (Ha)

Neutral gas (Na)

$M_{dyn} = 8.7 \times 10^{10} M_{\odot}$

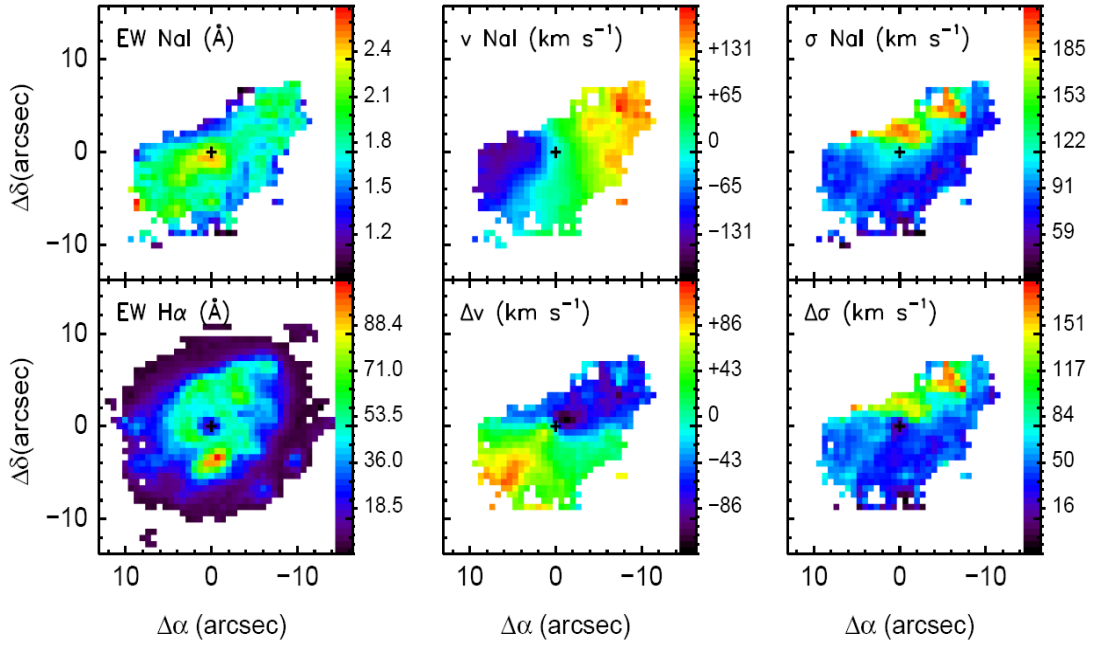
Radius = 6 kpc

V_{max} = 250 km/s

Arribas et al. 2008

IFS OF (U)LIRGS: NEUTRAL vs. IONIZED GAS KINEMATICS

The case of IRAS12115-4656, a weakly interacting LIRG of log Lir =11.16



Ionized Gas
- Disk + circumnuclear starburst ring
- Central σ peak
- Massive rotating disk ($V/\sigma \geq 3$)

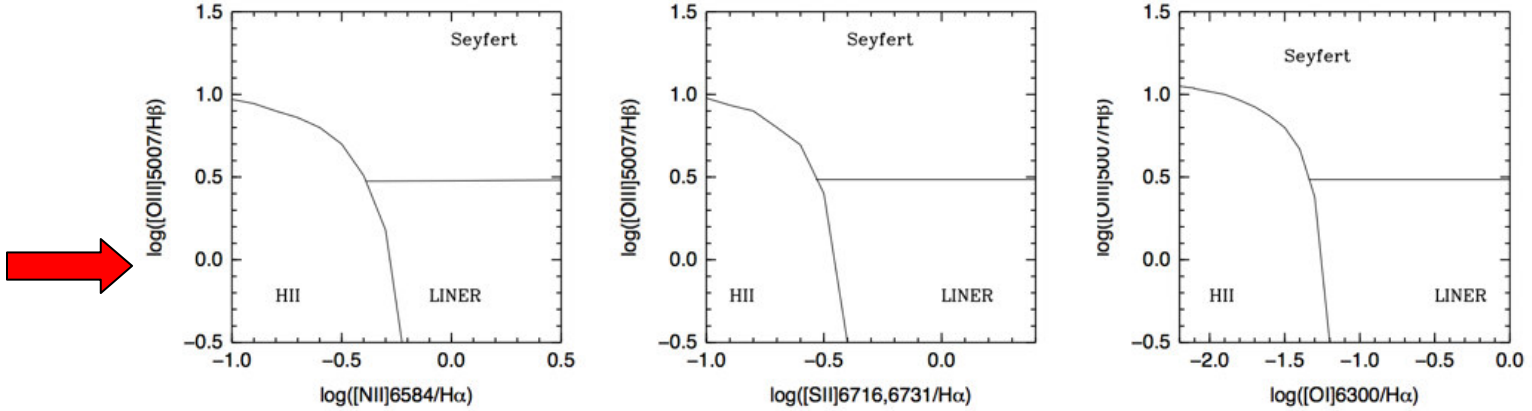
Neutral Gas
- Nuclear concentration
- Follow stellar distribution
- Extranuclear σ peak
- Rotating slower than ionized gas
- Dynamically hotter ($V/\sigma \leq 1$)

Arribas et al. 2008

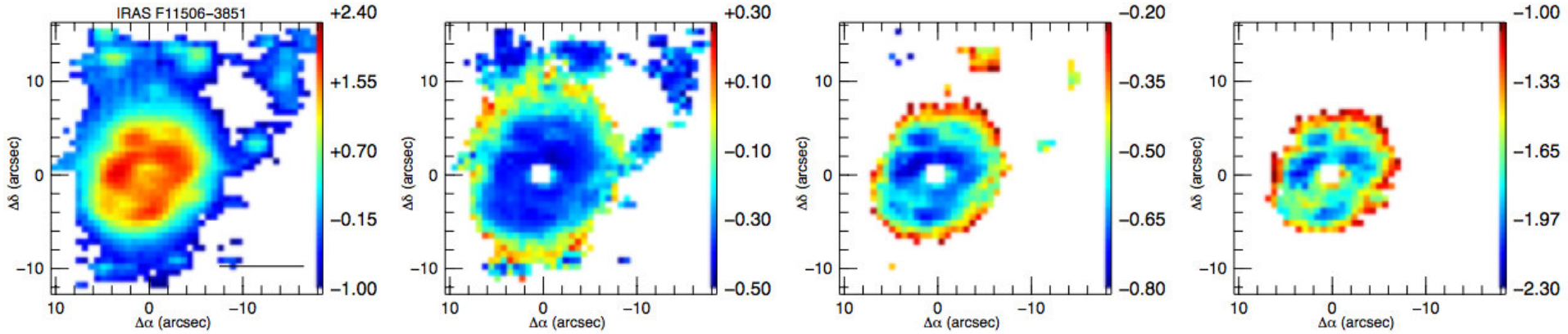
Neutral and Ionized gas trace different dynamics:

- seem associated to different stellar populations
- which is the best dynamical mass tracers?

2D Extra-nuclear excitation in LIRGs



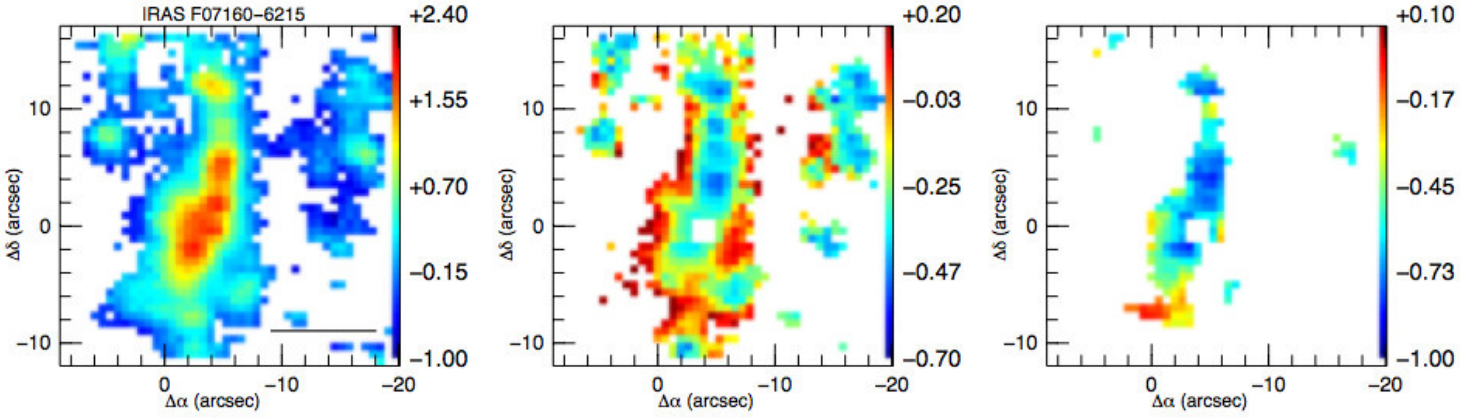
H_alpha [NII]/Ha [SII]/Ha [OI]/Ha



Monreal-Ibero et al. (in prep.)

Excitation Maps

H_alpha [NII]/Ha [SII]/Ha [OI]/Ha



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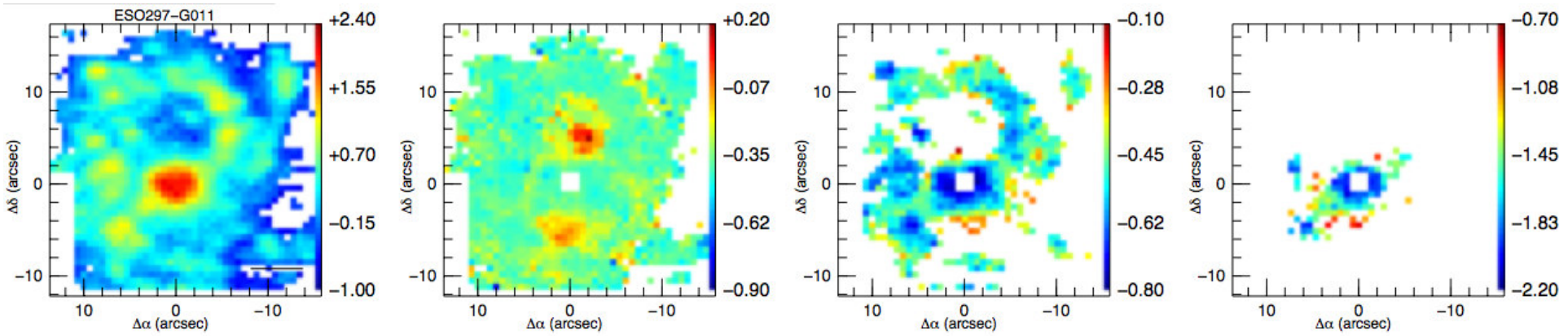

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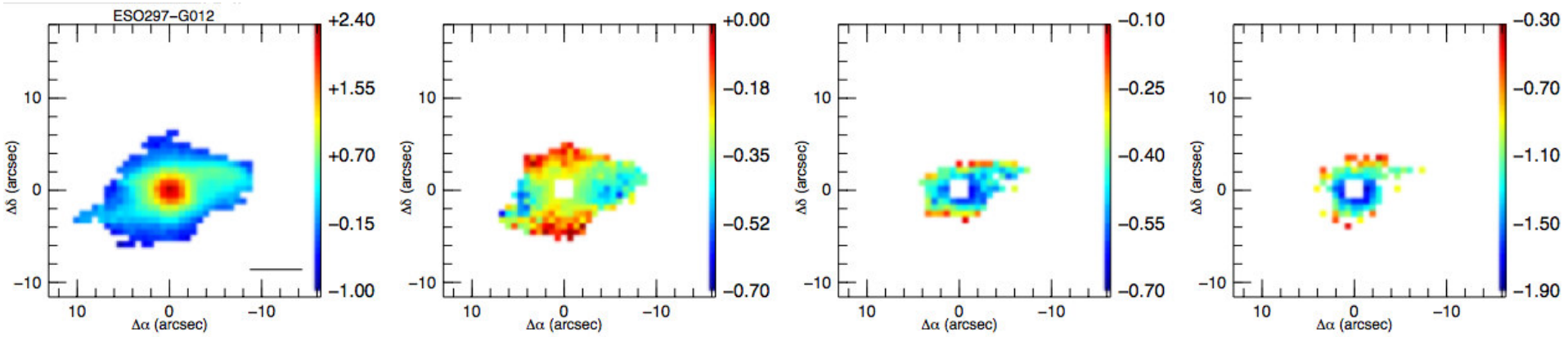

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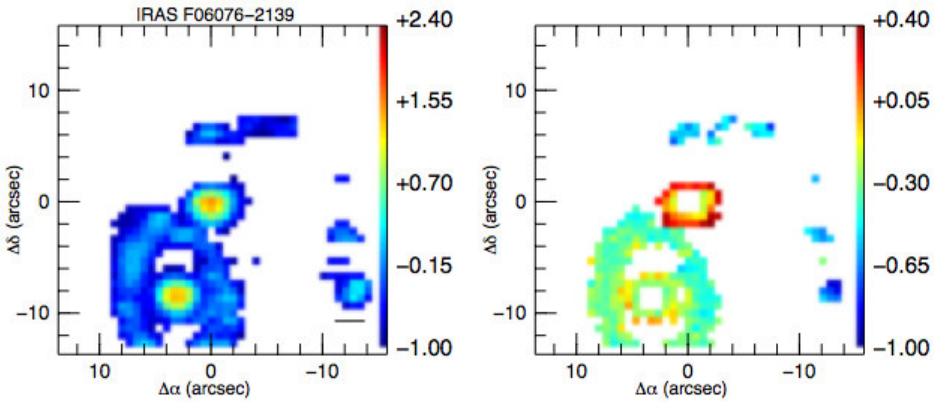
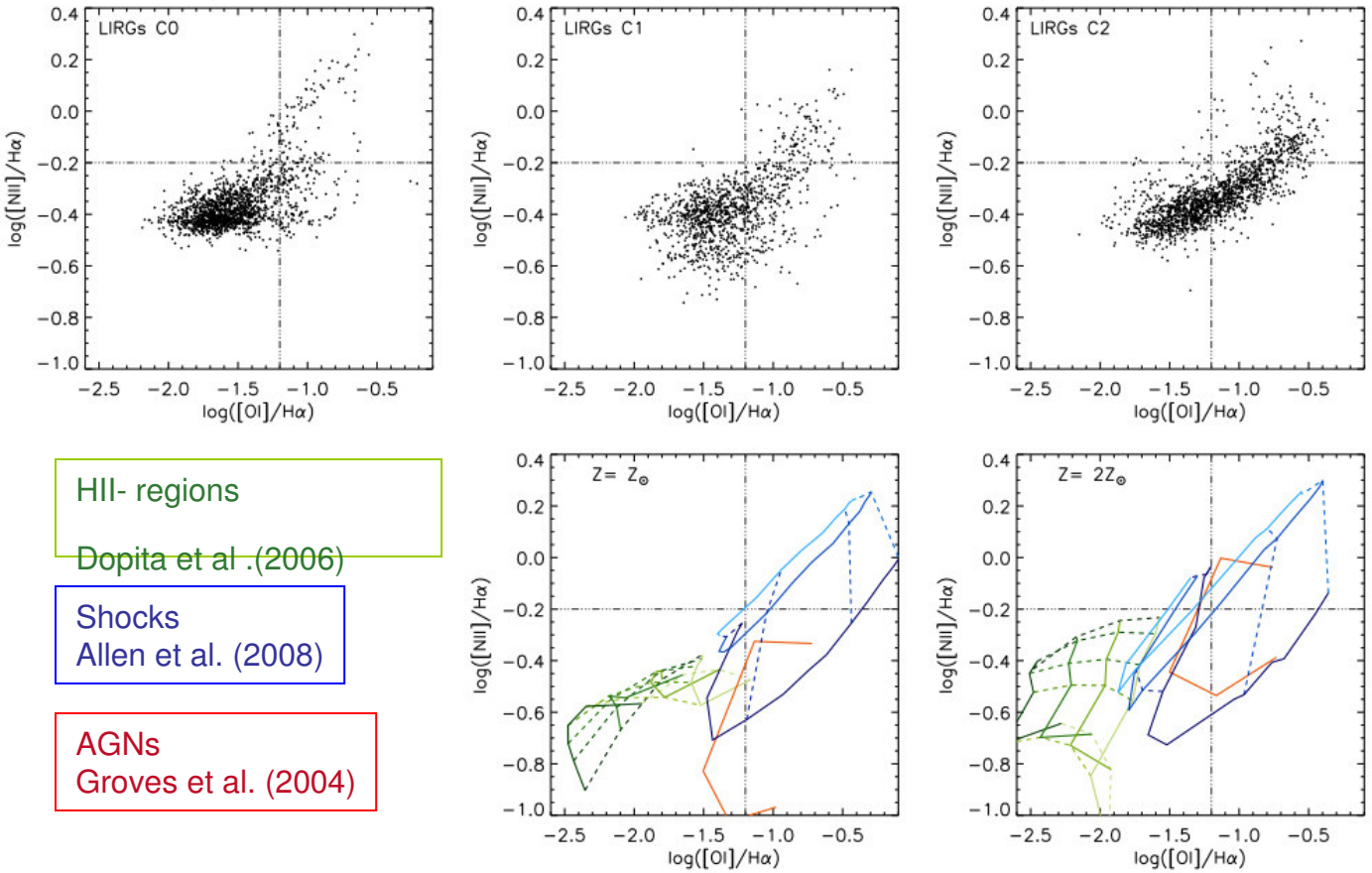


Monreal-Ibero et al. (in prep.)

Extra-nuclear excitation in LIRGs

Isolated | interacting | merger remnants



HII- regions

Dopita et al .(2006)

Shocks
Allen et al. (2008)

AGNs
Groves et al. (2004)

Higher fraction of shocks for interacting and merger systems

The presence of shocks seems to correlate better with the dynamical class than with the IR luminosity

Monreal-Ibero et al (sub.)

Fig. 6. [O I]λ6300/Hα vs. [N II]λ6584/Hα diagrams. *First row:* Line ratios for the different LIRGs groups in our sample. *Second row:* Theoretical models used for comparison where the ones in the middle column have solar metallicity and those in the right twice solar metallicity. The utilized color/symbol code is the same as in Figure 5.

ELT / HARMONI Observations of ULIRGs

HST /ACS @50 mas
z=0.04 (160Mpc)

40 pc/ px

ELT/LTAO/HARMONI @ 4mas
z=2 (>5200 Mpc)

40 pc/spx

$\Delta\lambda$ = 0.5- 2.5µ
R = 3000-20000
4, 10, 20, 40mas/spx

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Summary

We are carrying out a program to study the internal structure of (U)LIRGs with several IFS facilities.

Preliminary results show that the different galaxy components (neutral gas, ionized gas, old stellar component, young stellar component) have different structures/morphologies and kinematics.

In the particular case of IRAS 12115-4656 we found that the neutral gas seems more concentrated (similarly to the continuum) and is rotating slower than the ionized gas

The excitation conditions in the extra-nuclear extended regions of LIRGs seem to indicate a higher presence of shocks in interacting and mergers remnants. The presence of shocks does not seem to correlate so well with Lir.