Gravity Binding and Pressure Bounding of HII Regions and Molecular Clouds in Interacting Galaxies

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Introduction

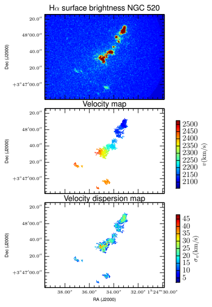
Motivation

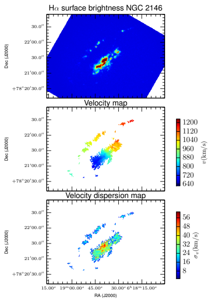
- Do galaxy mergers induce star formation? How?
- Are the most intense star forming galaxies at high redshifts, (U)LIRGS, SMGs, mainly driven by mergers?
- Since star formation occurs largely in molecular clouds, and HII regions trace massive star formation, kinematic properties of those regions are crucial to understand the connection between turbulence and star formation in interacting galaxies
- Larson (1981) found $M_{mol} \propto R^{1.8}$ for molecular clouds, while Terlevich & Melnick (1981) found $L_{H\beta} \propto R^{1.9}$
- Break in the mass function of molecular clouds in the Antennae galaxies (Wei et al., 2012) at $M_{mol} = 10^{6.5} M_{\odot}$.
- Break in the HII region luminosiy function at $L_{H\alpha} = 10^{38.6}$ erg/s (Kennicutt et al., 1989)

GHαFaS

Galaxy Hα Fabry-Perot system

- Circular FOV 3.4′ diameter, 0.2″ pixel size (seeing limited), 400km/s spectral range, 8km/s spectral resolution
- The data products are the Hα emission data cube, and the Hα surface brightness, velocity, and velocity dispersion maps

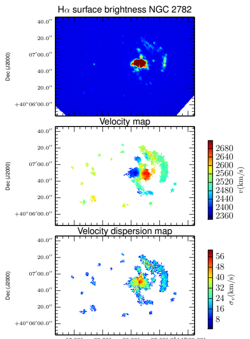


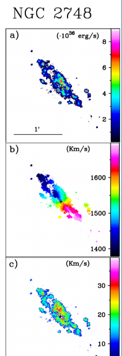


Kin. of interacting and isolated galaxies

Zaragoza-Cardiel et al. (2015)

- We have analyzed the properties of HII regions in 8 pairs of interacting galaxies using Astrodendro
- We have also analized a sample of 28 isolated galaxies using the data from Erroz-Ferrer et al. (2015)
- Analysis performed for 537 HII regions in interacting galaxies and 1018 HII regions in isolated galaxies

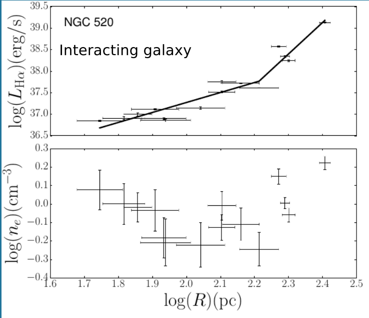


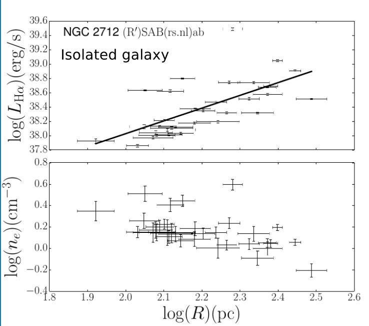


Kin. of interacting and isolated galaxies

Scaling relations

$$L_{H\alpha} = 10^{L_1} R^{N_1} \; ; \quad \text{for } R < R_1$$
$$L_{H\alpha} = 10^{L_2} R^{N_2} \; ; \quad \text{for } R > R_1$$

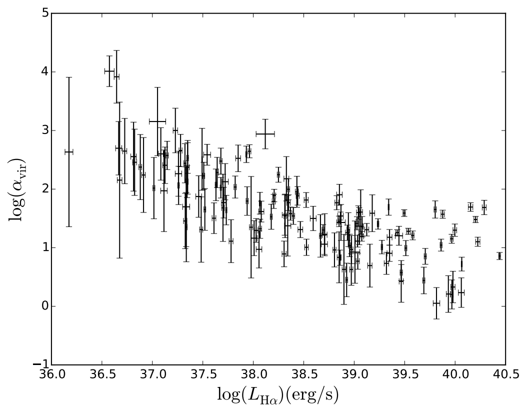




- 8 of the 12 interacting galaxies present an increasing density regime
- 6 of the 28 isolated galaxies present an increasing density regime

Kin. of interacting and isolated galaxies

Interacting galaxies



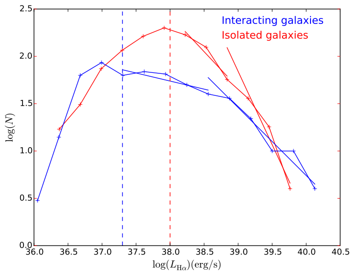
- $\alpha_{\rm vir} = 5\frac{\sigma_v^2 R}{GM} = \frac{a}{1-P_0/P}$ (Bertoldi & McKee, 1992)

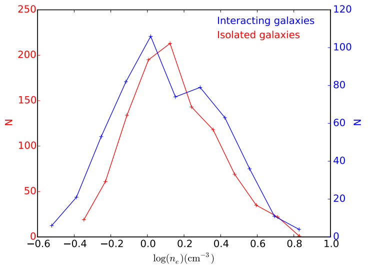
- The smaller $\alpha_{\rm vir}$, the more important is self gravity rather than external pressure $\longrightarrow$ Brightest star forming regions are dominated by gravity, thus, the star formation is enhanced

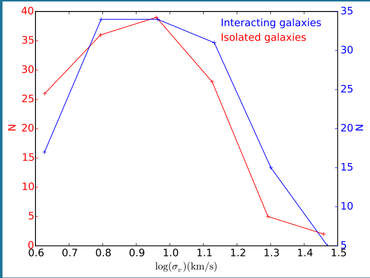
Kin. of interacting and isolated galaxies

Comparison

- Bright end of the luminosity function is flatter for the interacting galaxies sample
- More turbulent and denser HII regions in the interacting galaxies sample





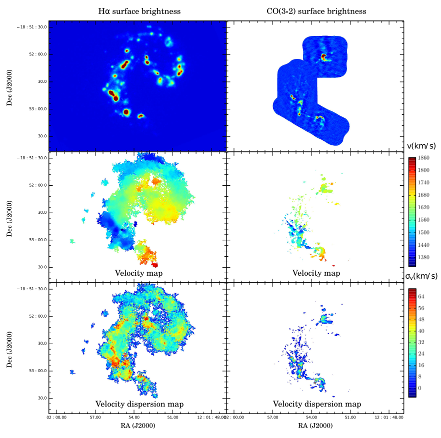


The Antennae galaxies

Zaragoza-Cardiel et al. (2014)

$L_{H\alpha}$, R_{HII}, σ_v

M_{HII}, $\alpha_{vir} = 5\frac{\sigma_v^2 R_{HII}}{G M_{HII}}$



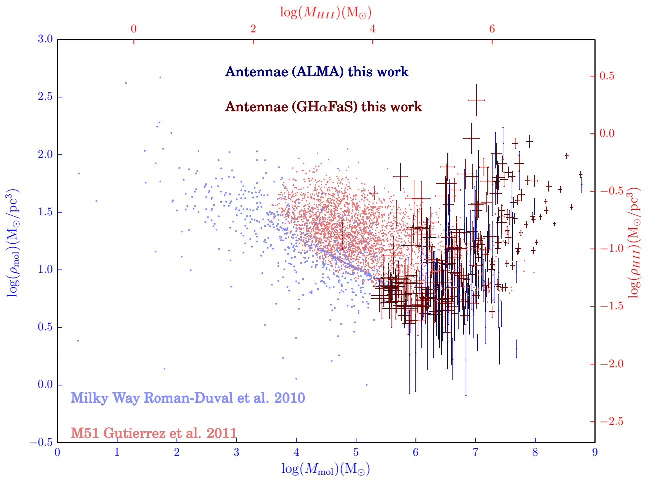
L_{CO}, R_{CO}, σ_v

$M_{H_{mol}}$,

$\alpha_{vir} = 5\frac{\sigma_v^2 R_{CO}}{G M_{H_{mol}}}$

The Antennae galaxies

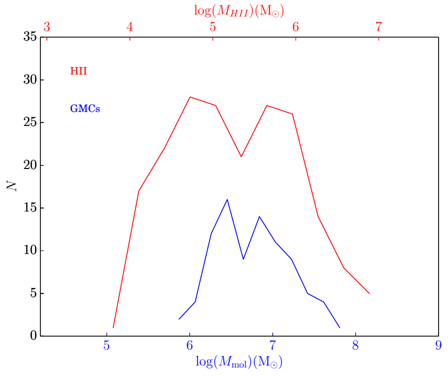
Results



- Increasing density regime ⟶ Triggered star formation!

The Antennae galaxies

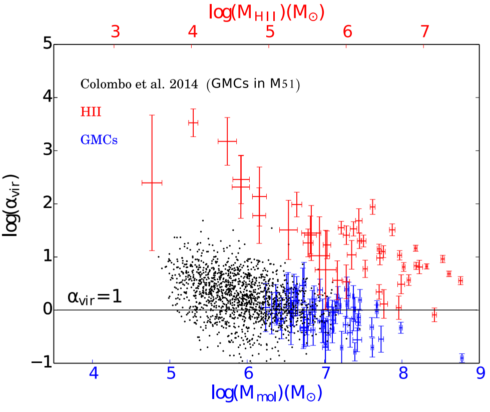
Results



- The ionized gas mass, M_{HII}, is 20 times smaller than the molecular gas mass, M_{mol}, because is a fraction of the total gas mass
- Break in the M_{mol} mass function at $\log(M_{mol}) \simeq 6.7$, near the value from Wei et al. (2012)
- Break in the M_{HII} mass function at $\log(M_{HII}) \simeq 5.4$, which corresponds to a break in the $H\alpha$ luminosity function at $L_{H\alpha} \simeq 38.6$dex as reported in previous studies

The Antennae galaxies

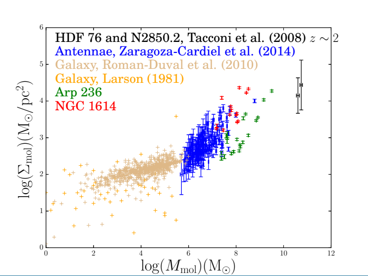
Results

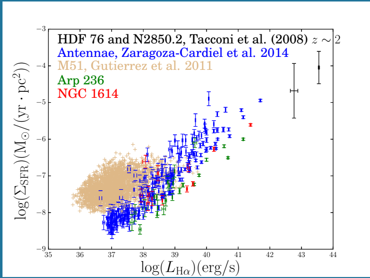


- The smaller α_{vir}, the more important is self gravity rather than external pressure $\longrightarrow$ More massive star forming regions are dominated by gravity, thus, the star formation is almost certainly enhanced

Intense star formation at high redshift

- We have analyzed GHαFaS data and used ALMA published data of Arp 236 (Saito et al., 2015) and NGC 1614 (Sliwa et al., 2014).





- The massive regime for the GMCs and HII regions found in the nearby Antennae galaxies could be a pointer to stronger star forming regions found at higher redshifts.
- Galaxy mergers are a plausible driver for extreme star formation at higher redshifts.

Conclusions

- The population of brighter HII regions is enhanced in the interacting galaxies, and presents a flatter slope at the bright end of the Hα luminosity function.
- The star formation rate is enhanced in the increasing density regime.
- The electron density and the velocity dispersion of HII regions is enhanced in the interacting galaxies.
- Two populations of HII regions and two populations of GMCs in the Antennae galaxies based on the luminosity-mass function, suggesting that the double population of HII regions is due to the double population of GMCs.
- We found that the mass size relation presents a different exponent, 2.62, in the Antennae galaxies. The gas surface density increases with mass and the gravity becomes more important for the more massive regions, eventually dominating the external pressure.
- The interaction induced star formation (seen in the Antennae galaxies, Arp 236, and NGC 1614) is a plausible driver for the extreme high star formation at higher redshifts.