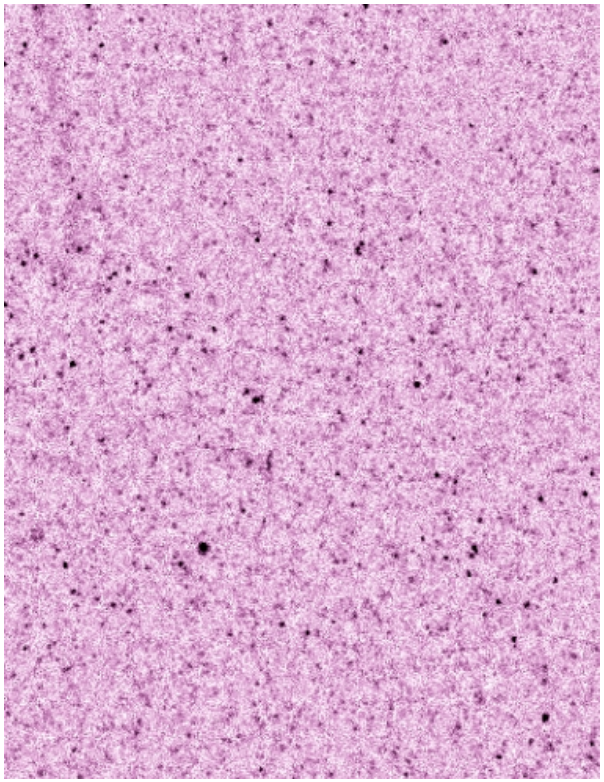
The VALES survey:
a new look to the molecular gas content in low-redshift galaxies

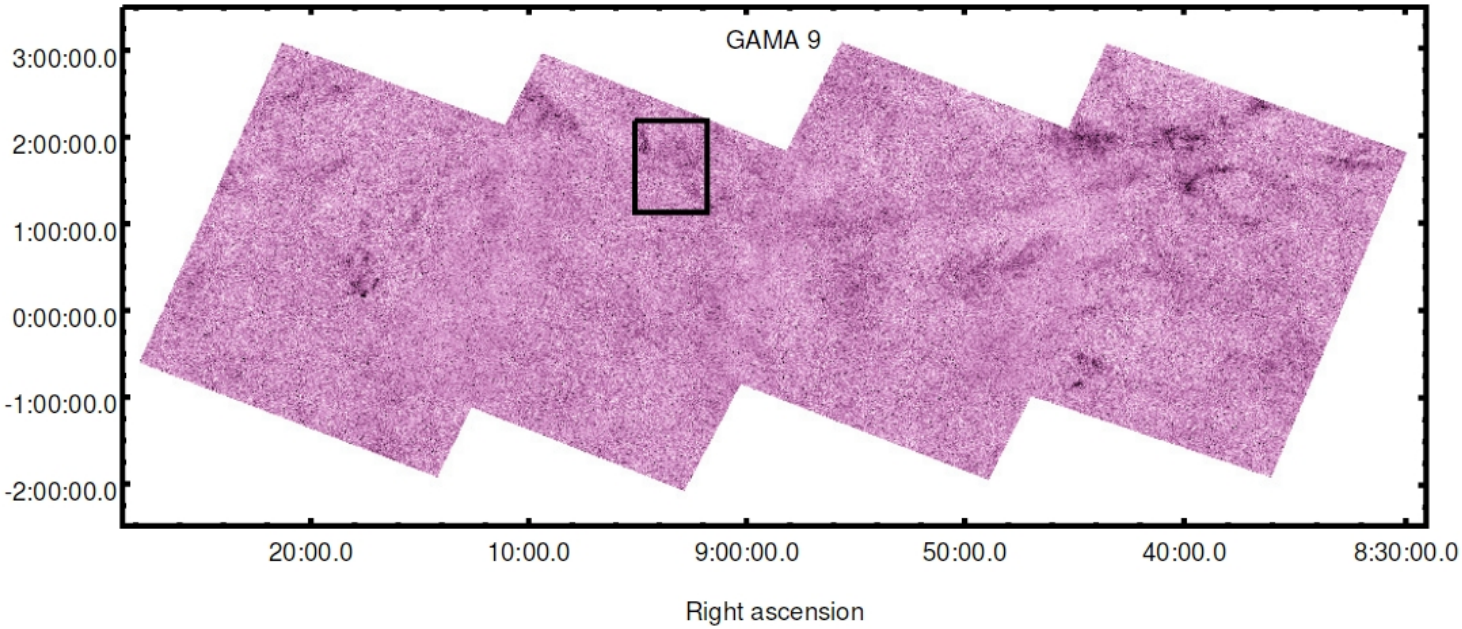
Edo Ibar

Thomas Hughes, Vicente Villanueva, Juan Molina, Cheng Cheng, Gustavo Orellana, & H-ATLAS folks

THE H-ATLAS SURVEY

The largest open time Key Project, with 600 hrs of time to survey a huge area of the sky: 600 square degrees.



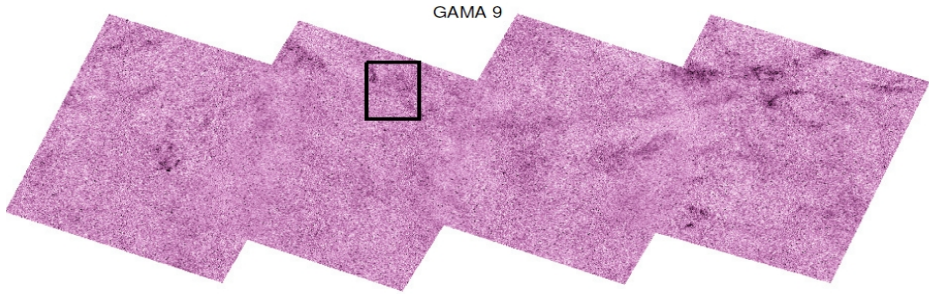


(Eales+10, Ibar+10, Pascale+11, Rigby+11, Valiante+16, Bourne+16, Smith+17, Maddox+17, Furlanetto+17)

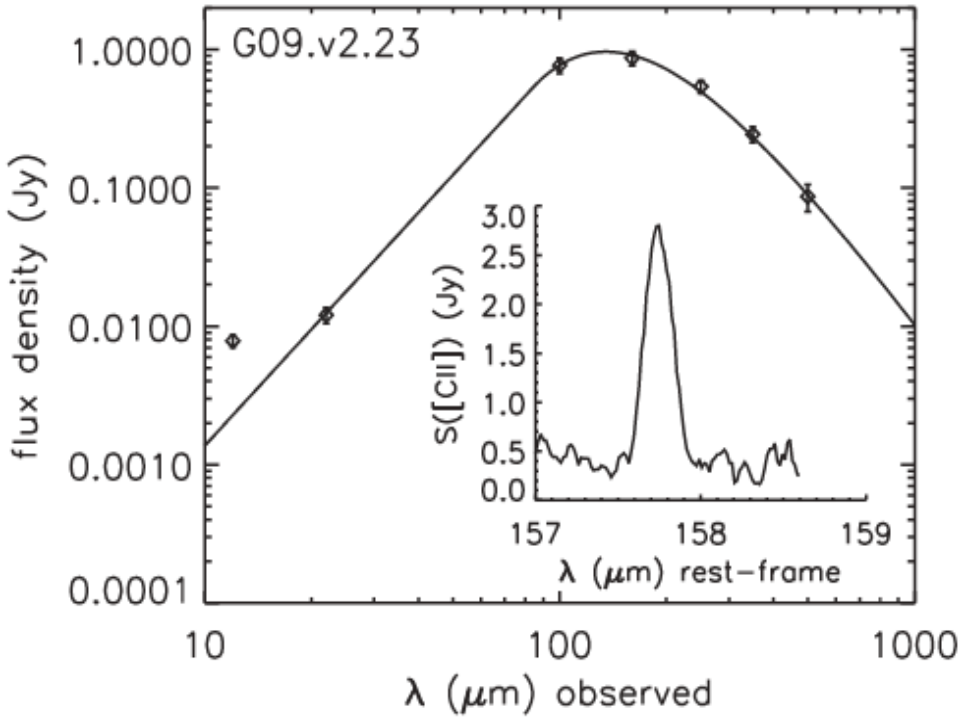
Over 400 thousand (>4σ) galaxies detected in at least one of the PACS or SPIRE bands. Rich multi-wavelength coverage.

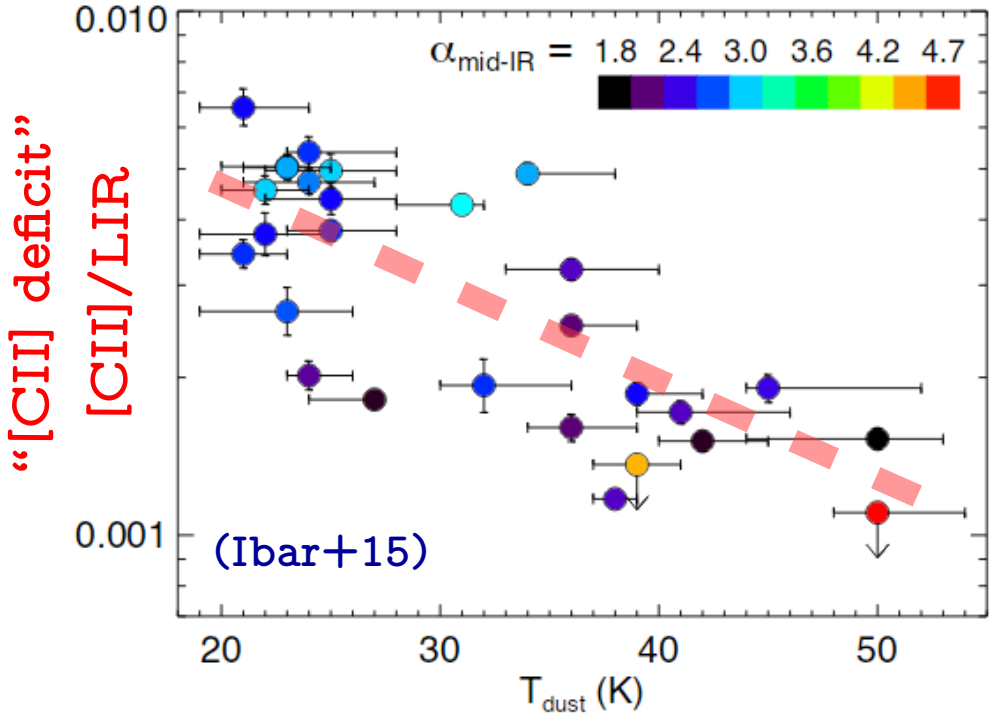
THE H-ATLAS SURVEY

We conducted a [CII]-158μm survey using the PACS spectrometer, detecting 27 galaxies at 0.02<z<0.2 in the GAMA-09hr field. (Ibar+15)



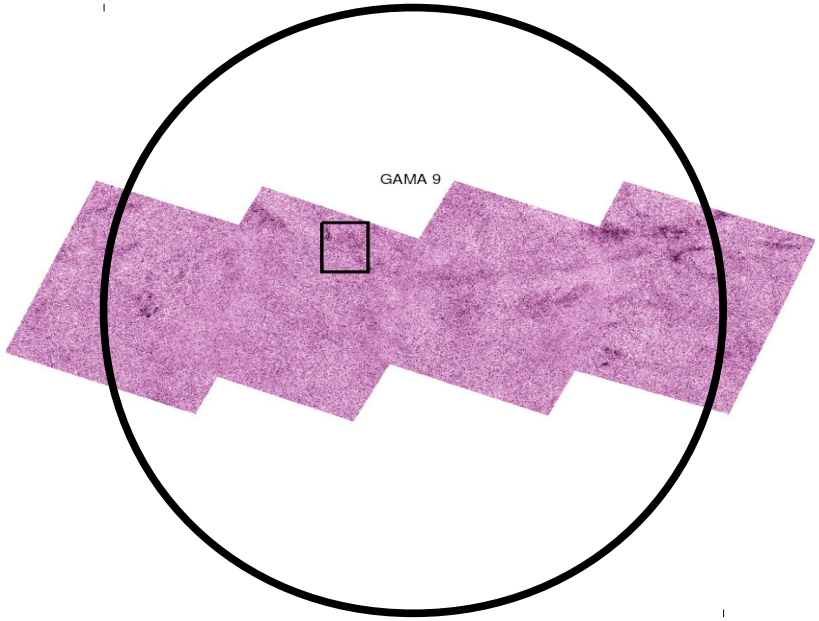
* Nice multi-wavelength SED
* Precise dust temperatures
* 10 < Log(LIR) < 12

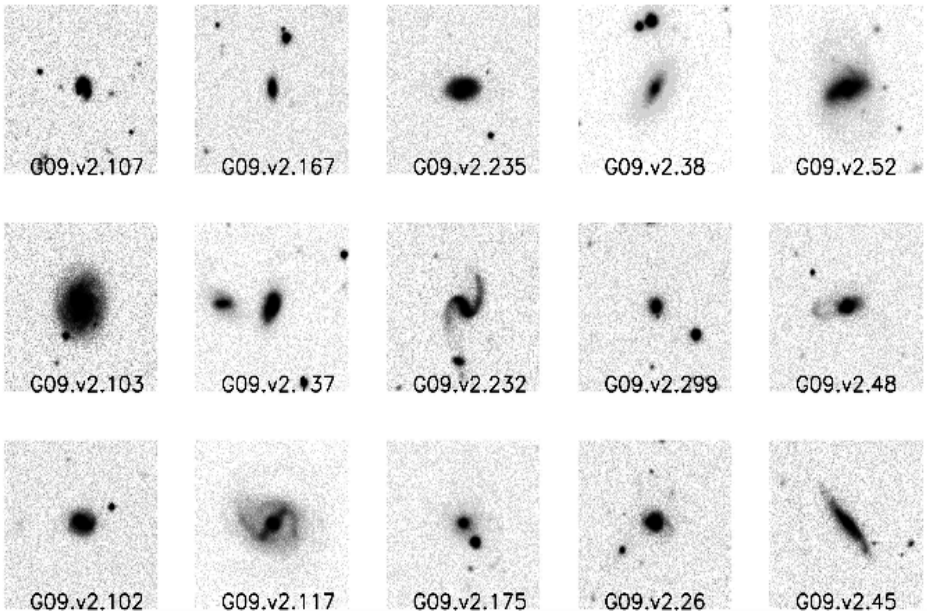




ALMA OBSERVATIONS

ALMA FOLLOW-UP





We targeted 67 H-ATLAS galaxies (inc. those with [CII]) with similar redshifts, so the CO(1-0)@115GHz line would fall into the ALMA Band-3 (z<0.35).

Main selection criteria:

* Detected by PACS at 160μm
* Reliable SDSS counterpart
* Reliable z-spec from GAMA

At low ~ 3.5" resolution became a perfect FILLER PROGRAM

ALMA FOLLOW-UP

We spectroscopically detected 49 galaxies (>5σ) and 12 others in stacked spectra.

Source Properties:

LIR ~ $10^{10\text{-}12}$Lo

Mstar ~ $10^{10\text{-}11}$Mo

z ~ 0.02-0.35

SFR ~ 1-80 Mo/yr

Observations:

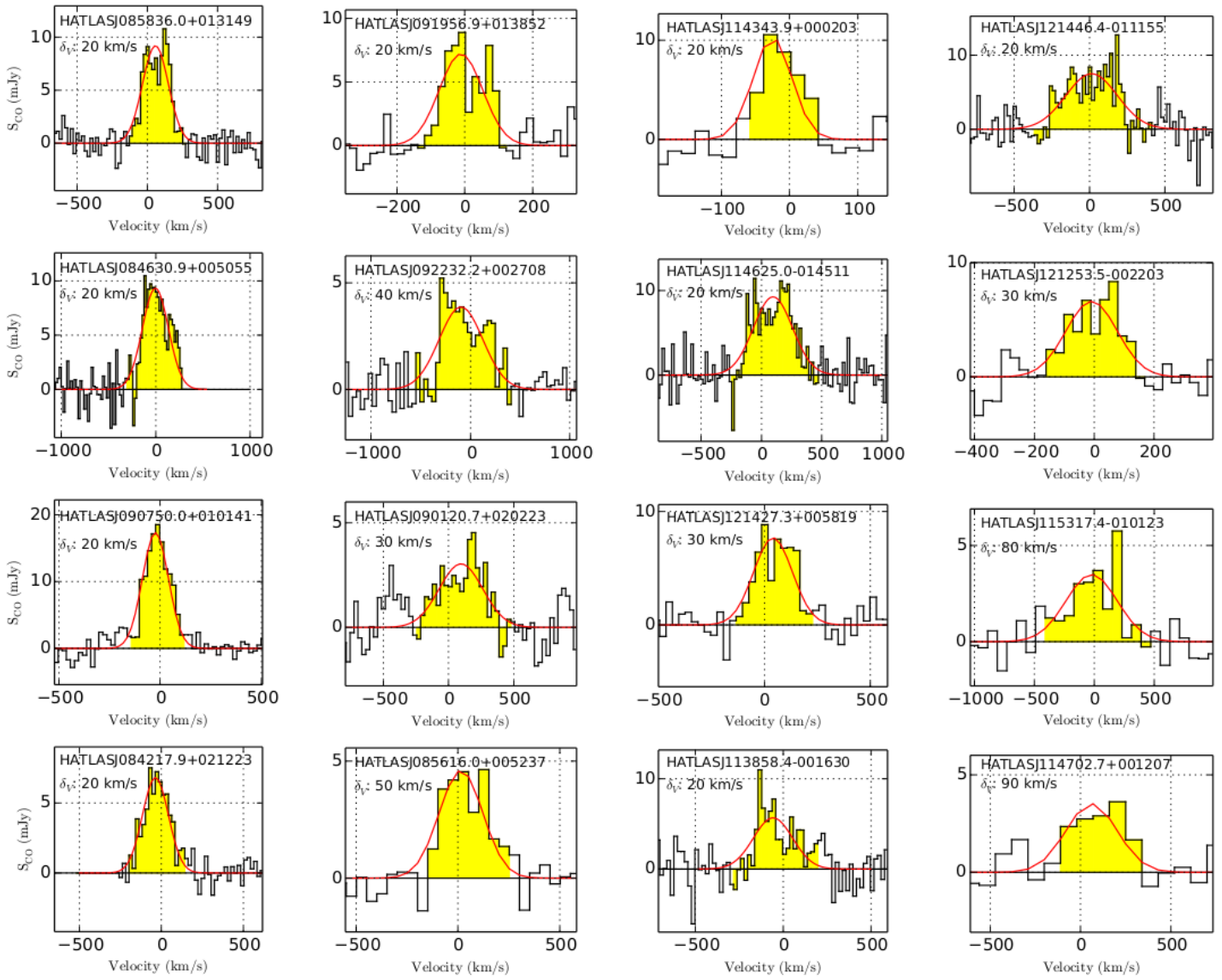
Resolution ~ 3-4”

Sco ~ 2-21 Jy km/s

L'co ~ (0.03-4)x10^{10} K km/s pc^2

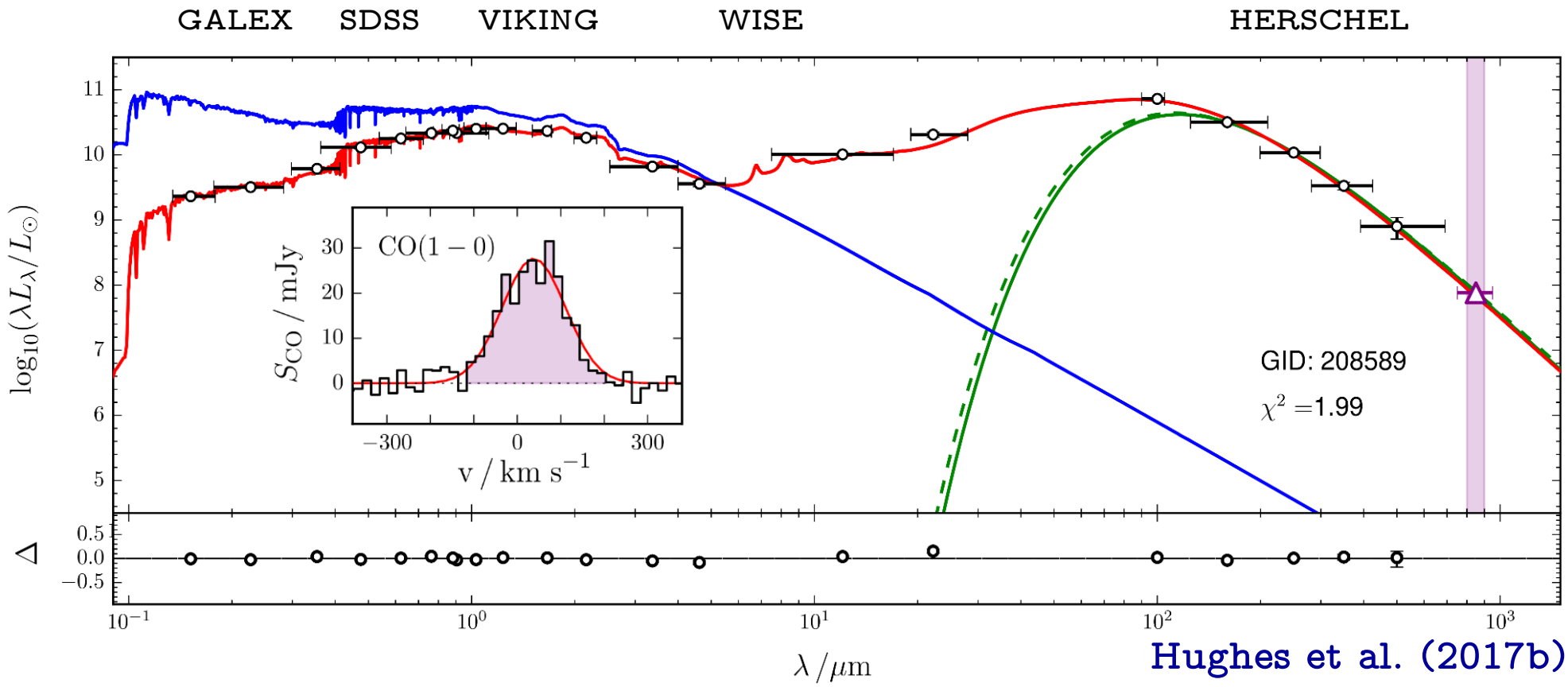
M(H2) ~ $10^{9\text{-}11}$Mo

FWHM~ 60-350 km/s



Villanueva et al. (2017)

Multi-wavelength coverage

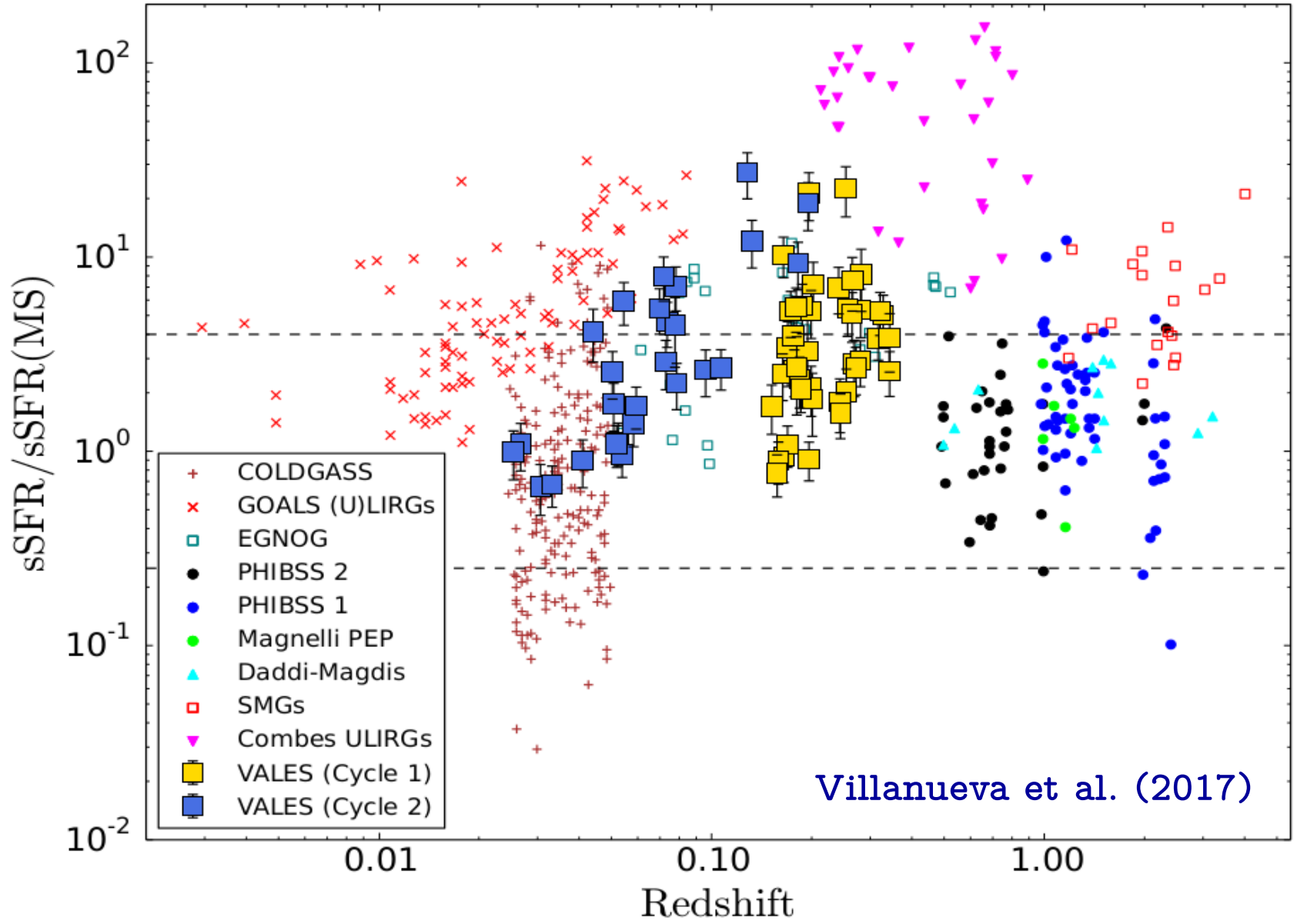


Hughes et al. (2017b)

We use MAGPHYS (Driver+in prep) on the full UV to far-IR emission to estimate the global galaxy properties.

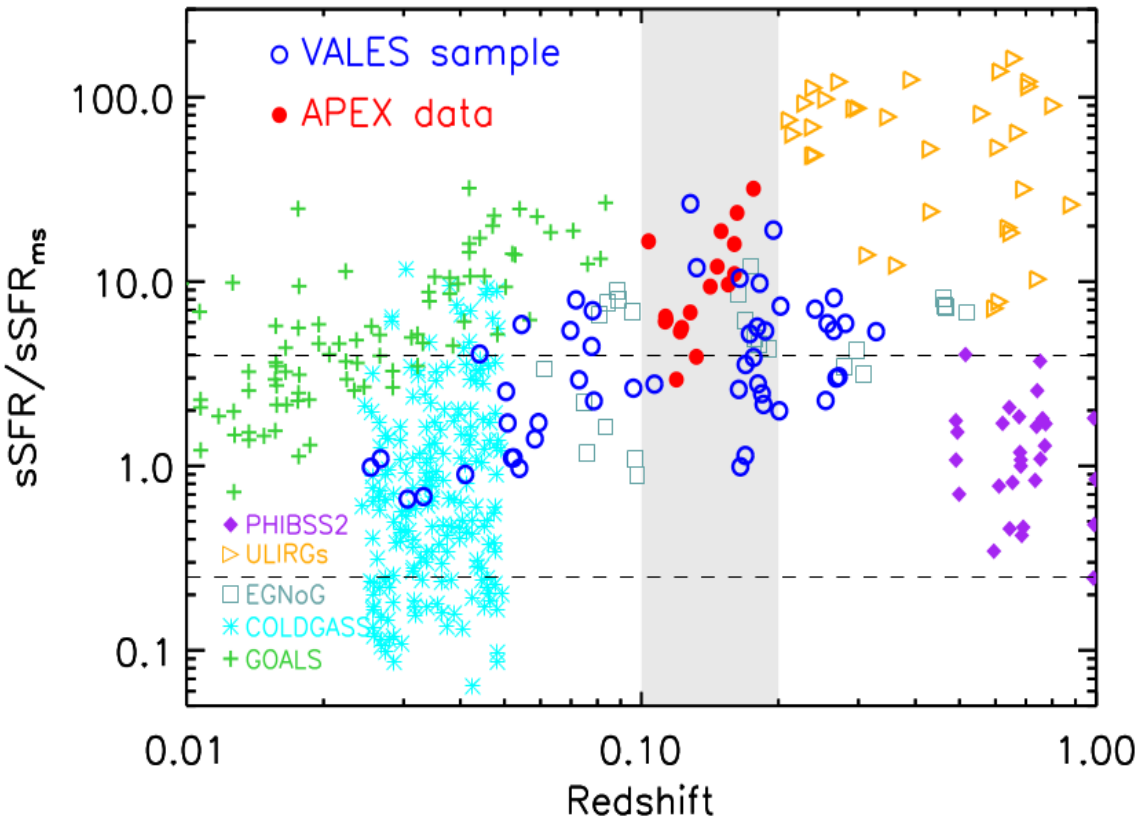
The specific Star Formation Rate

Normalised SFR/Mstar



APEX/SEPIA-B5 OBSERVATIONS

Extending the specific Star Formation Rate



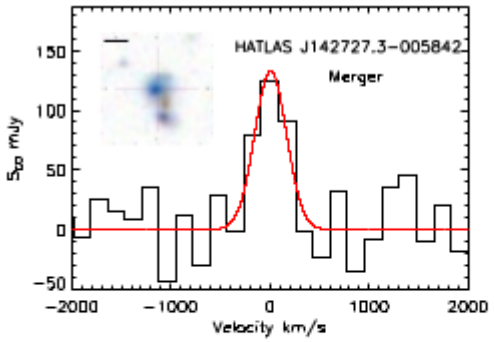
Main selection criteria:

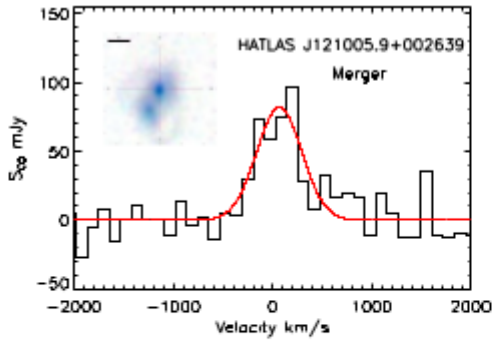
* 24 H-ATLASgalaxies
* starburst activity
* Reliable SDSS counterpart
* Reliable z-spec from GAMA

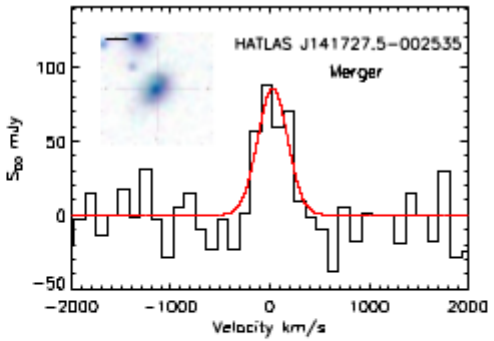
Cheng et al. (2018)

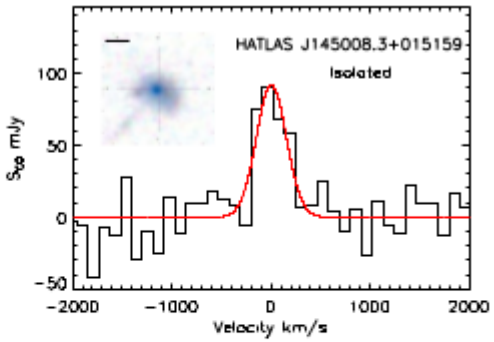
We targeted the CO(2-1)@230GHz emission line using the new SEPIA-B5 receiver for galaxies at 0.1<z<0.2. These observations perfectly complement with the ALMA data.

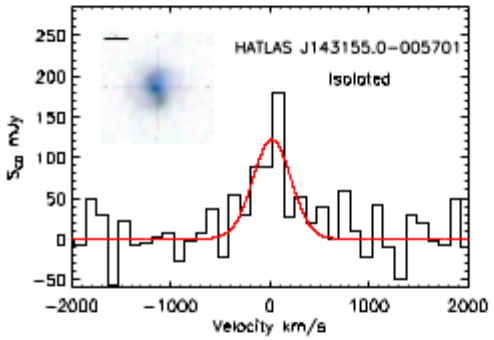
APEX SEPIA-B5 Spectra

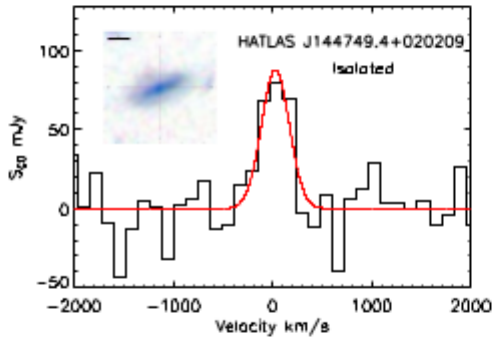


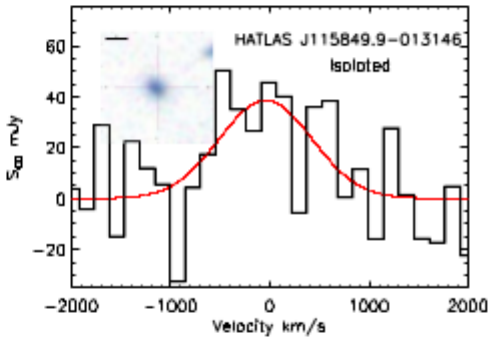


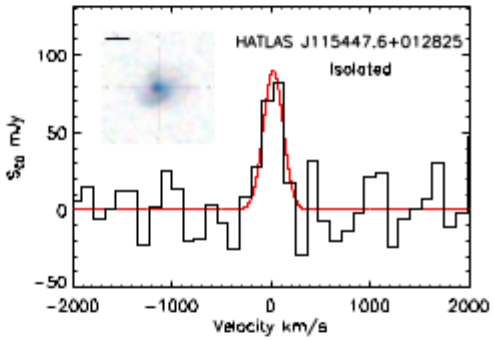


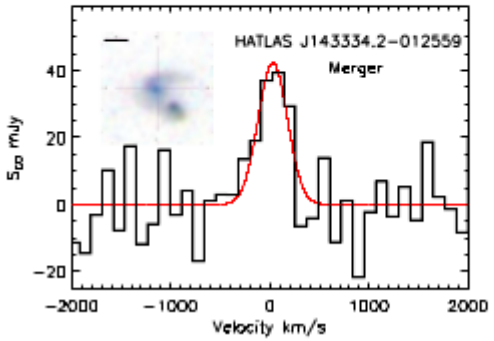


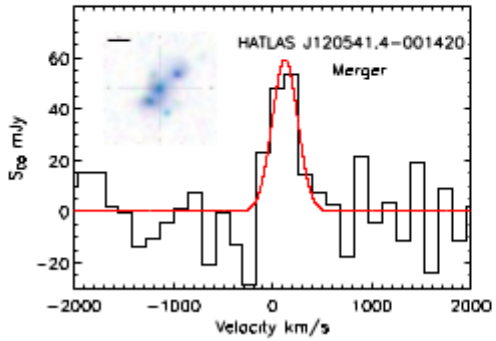


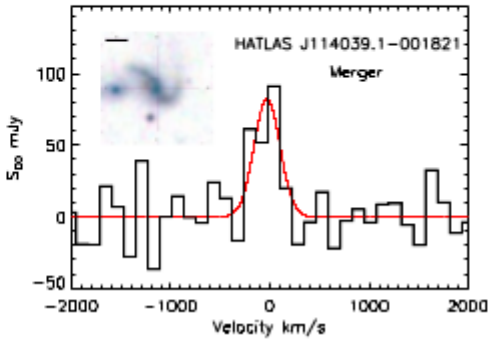


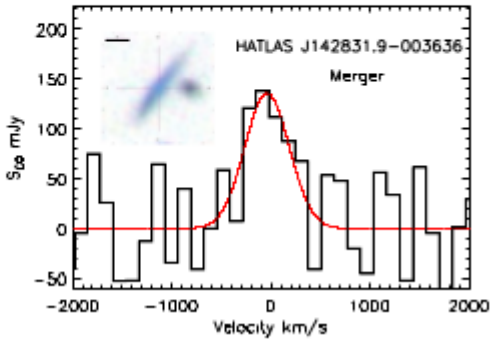












Cheng et al. (2018)

VALES:

The Valparaíso ALMA/APEX Line Emission Survey

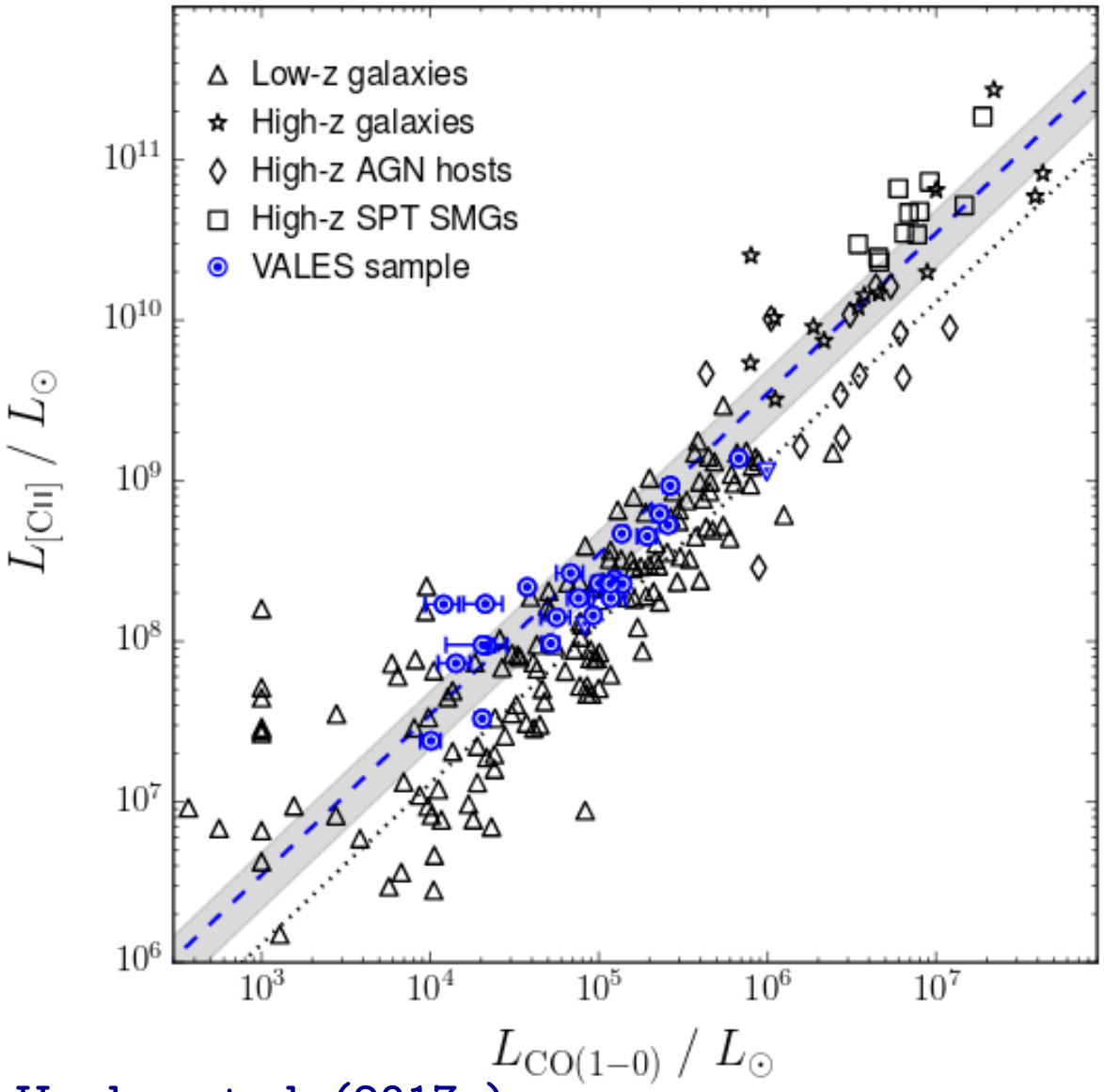
Summary:

* 67 galaxies at z<0.35 observed in CO(1-0) with ALMA Band-3:
    * 49 spectroscopically detected at >5σ
    * 29 spatially resolved

* 24 starburst galaxies at z~0.15 observed in CO(2-1) with APEX SEPIA Band-5

MAIN RESULTS

Photo-Dissociation Region Modeling



Hughes et al. (2017a)

The [CII] and CO(1-0) line emissions have a luminosity ratio of ~3500

This ratio can be explained by optically thin [CII] but optically thick CO(1-0) emission.

Photo-Dissociation Region Modeling

Considering:

* [CII] from 70% PDR
* 2x CO(1-0)

We find:

* <Go> = 10^2-10^3
* n = 10^4-$10^{5.5}$ cm^{-3}

Values similar to those seen in normal local galaxies

Hughes et al. (2017a)

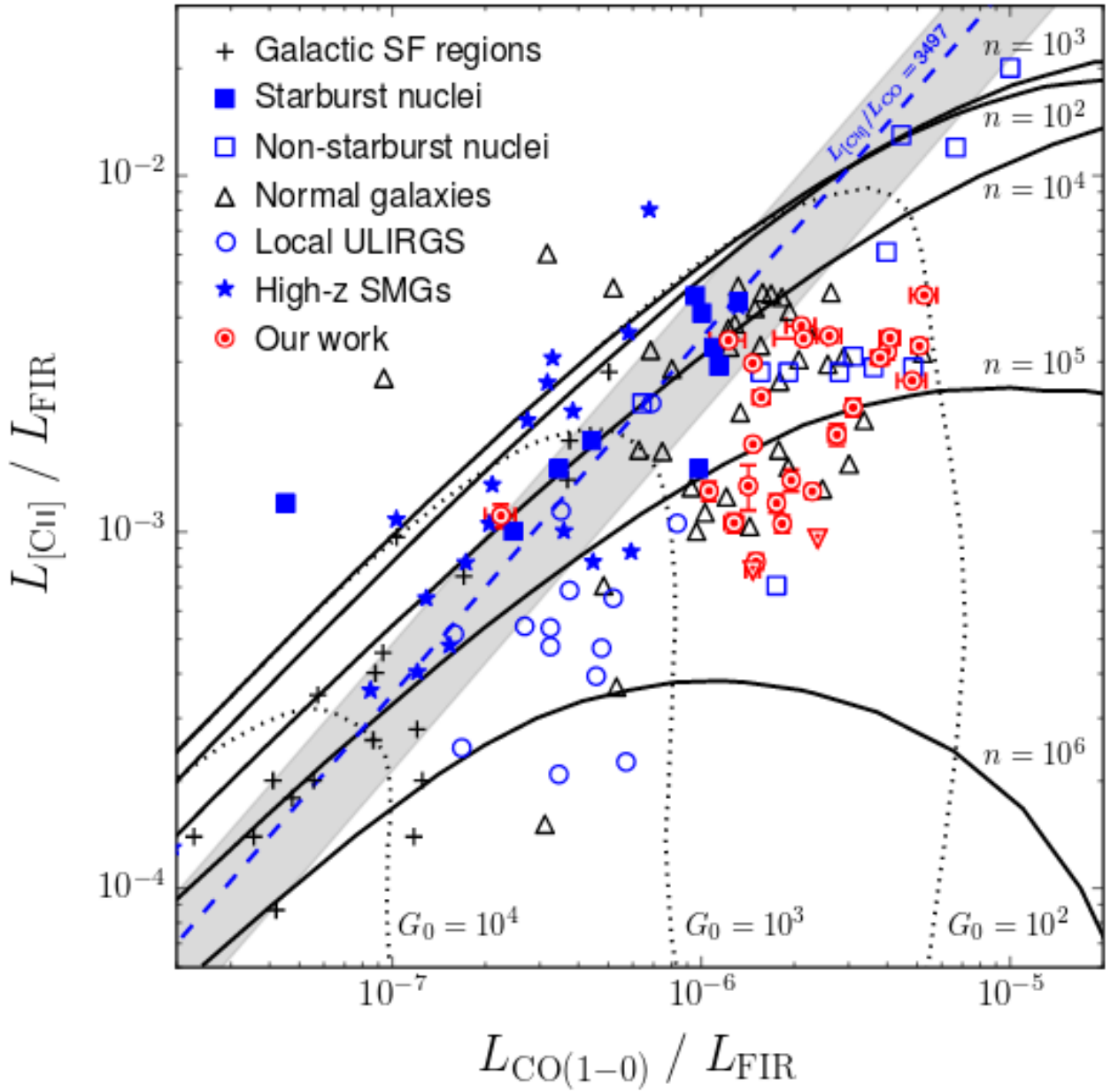
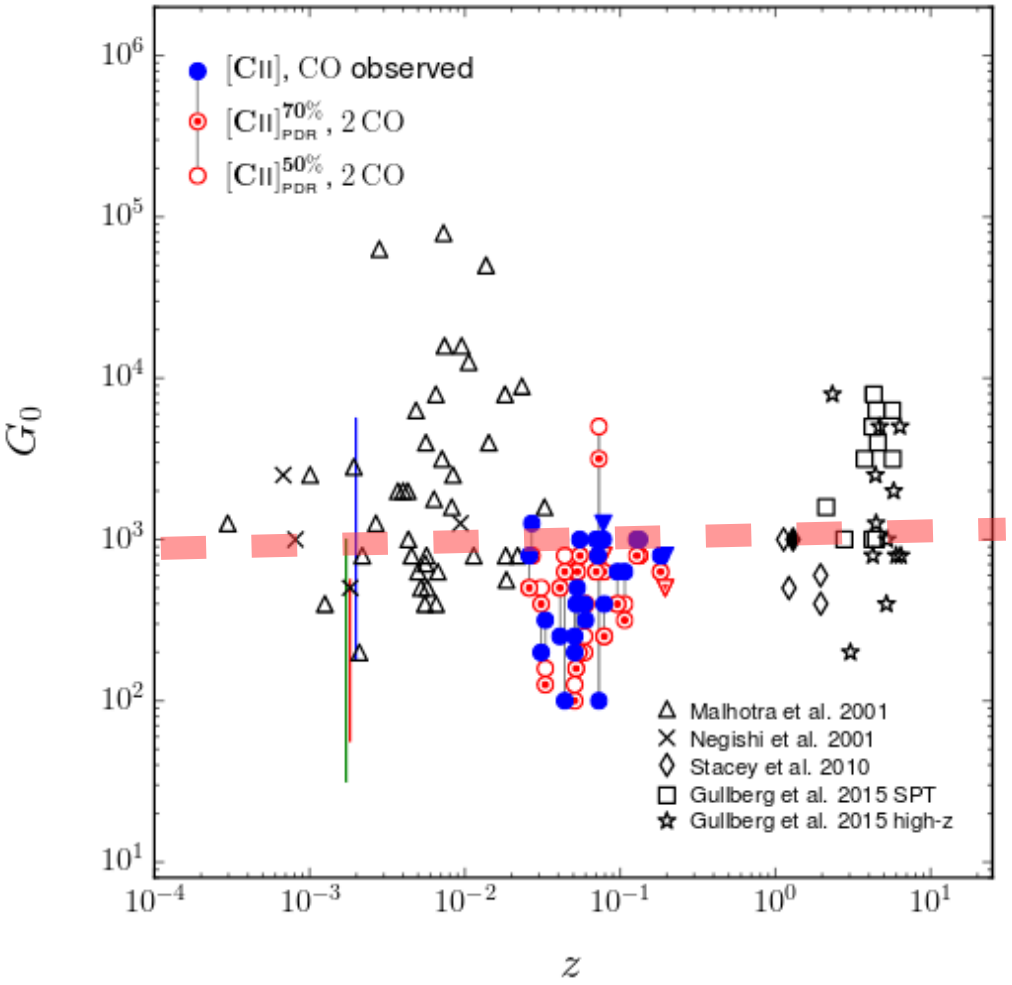
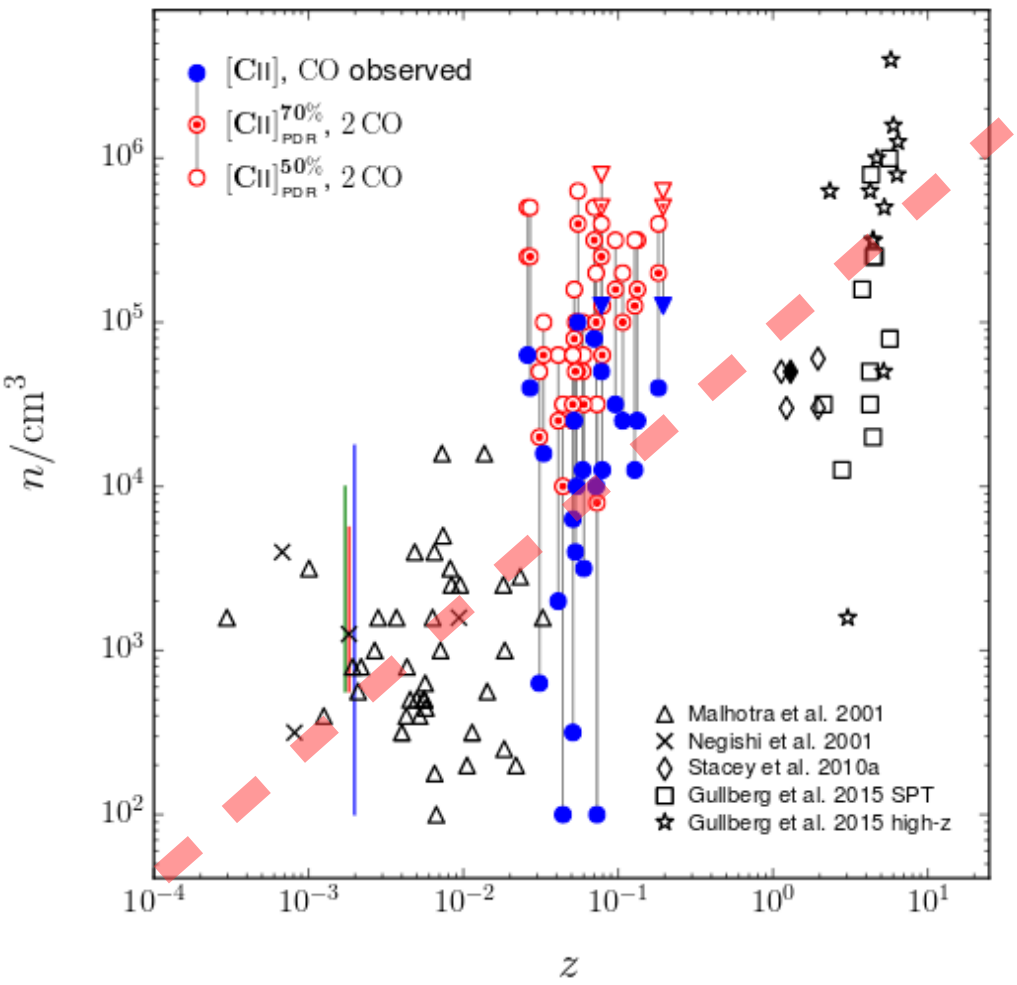


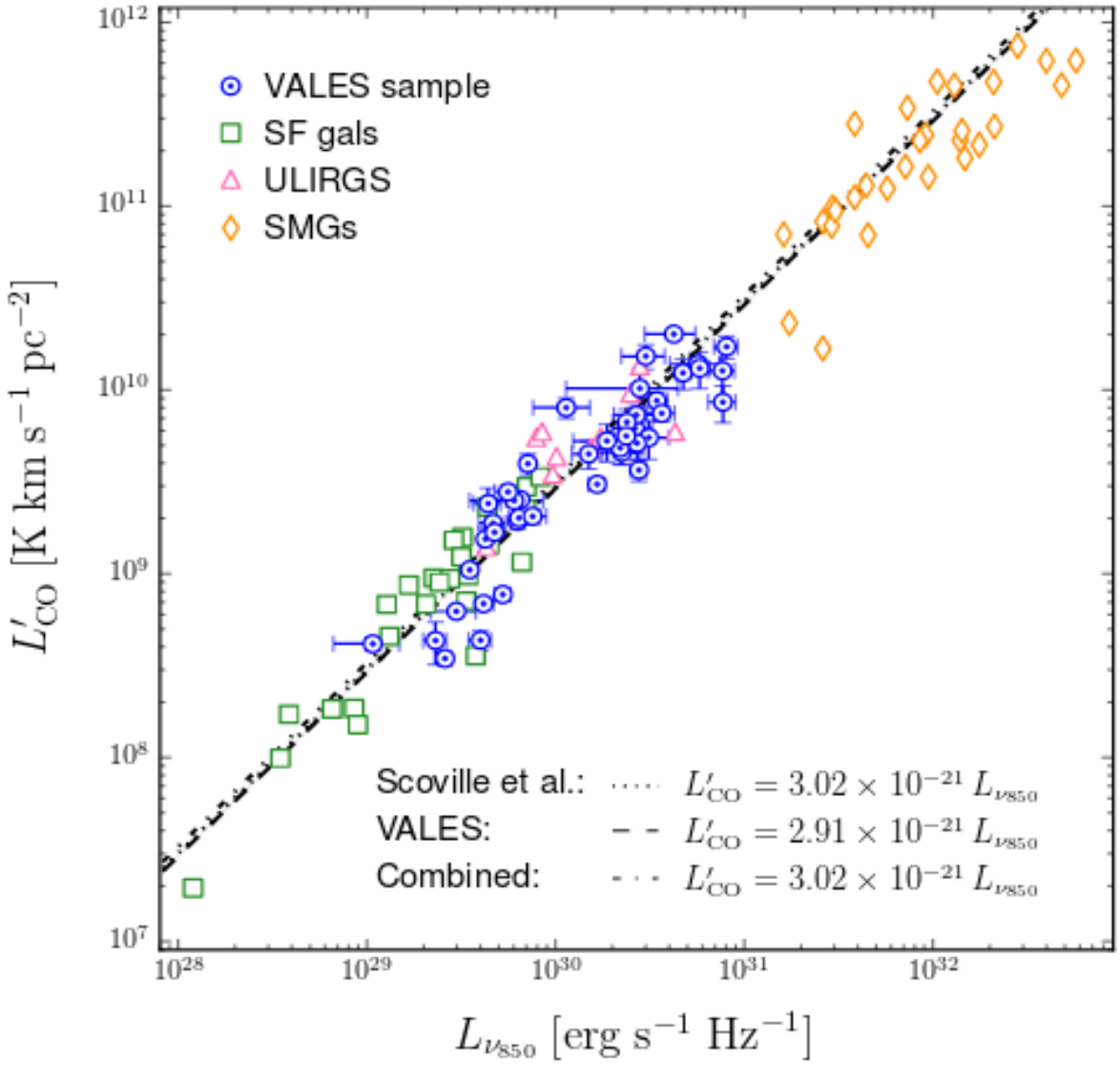
Photo-Dissociation Region Modeling



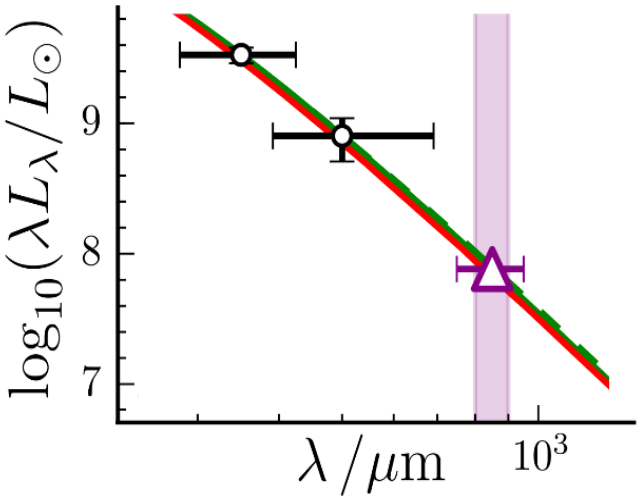


We fill the gap between low-z and high-z PDR analyses, finding a possible strong evolution in density. Hughes et al. (2017a)

The Molecular Gas to Dust Ratio



Hughes et al. (2017b)



The 850um emission (extrapolated) correlates with the observed CO(1-0) emission.

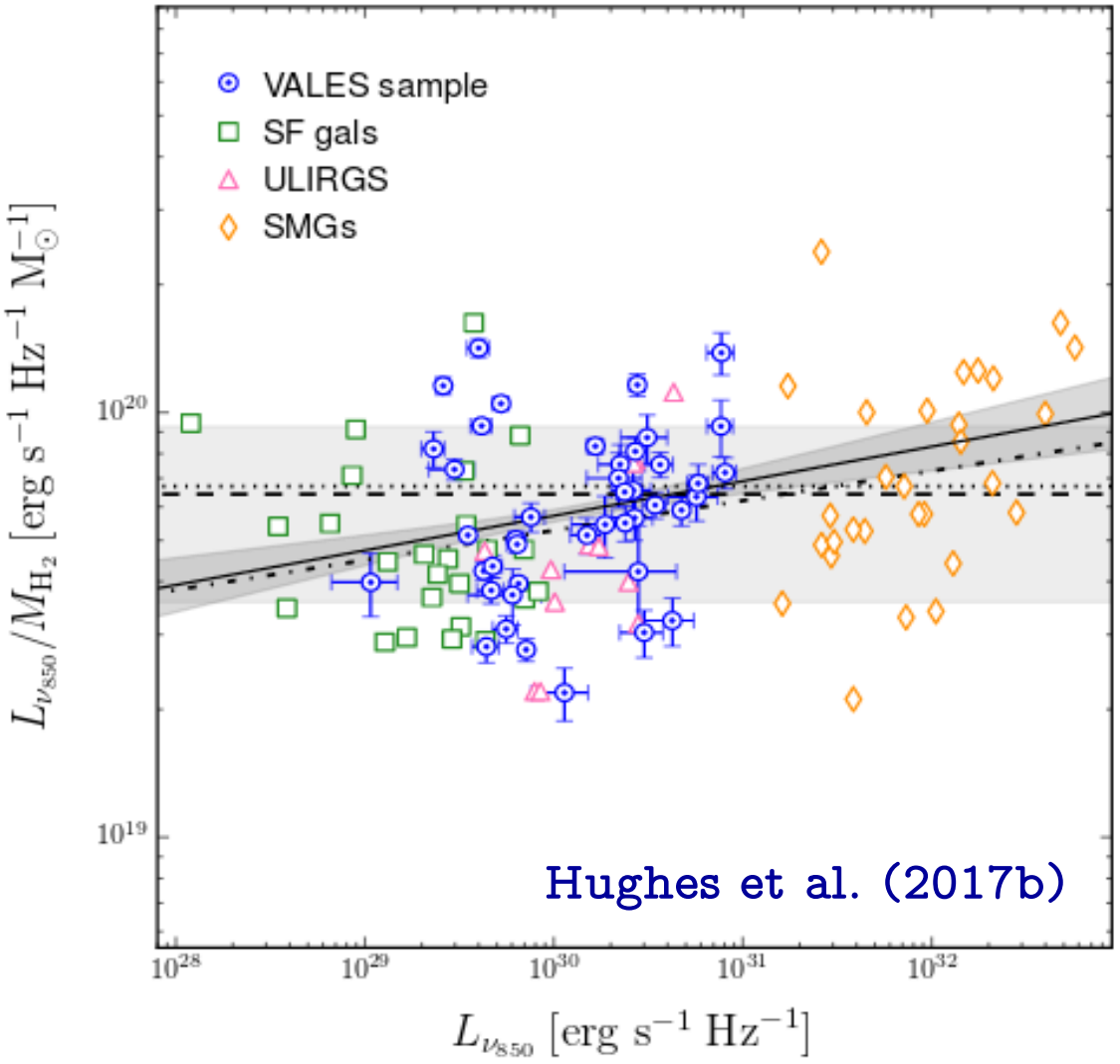
Scatter = 0.1dex

The Molecular Gas to Dust Ratio

$$\log_{10} M_{\mathrm{H_2}} = (0.93 \pm 0.01) \log_{10} L_{\nu_{850}} - (17.74 \pm 0.05)$$

Assuming an α(CO) conversion factor to get M(H2), we find a good agreement with previous work by Scoville et al. (2016).

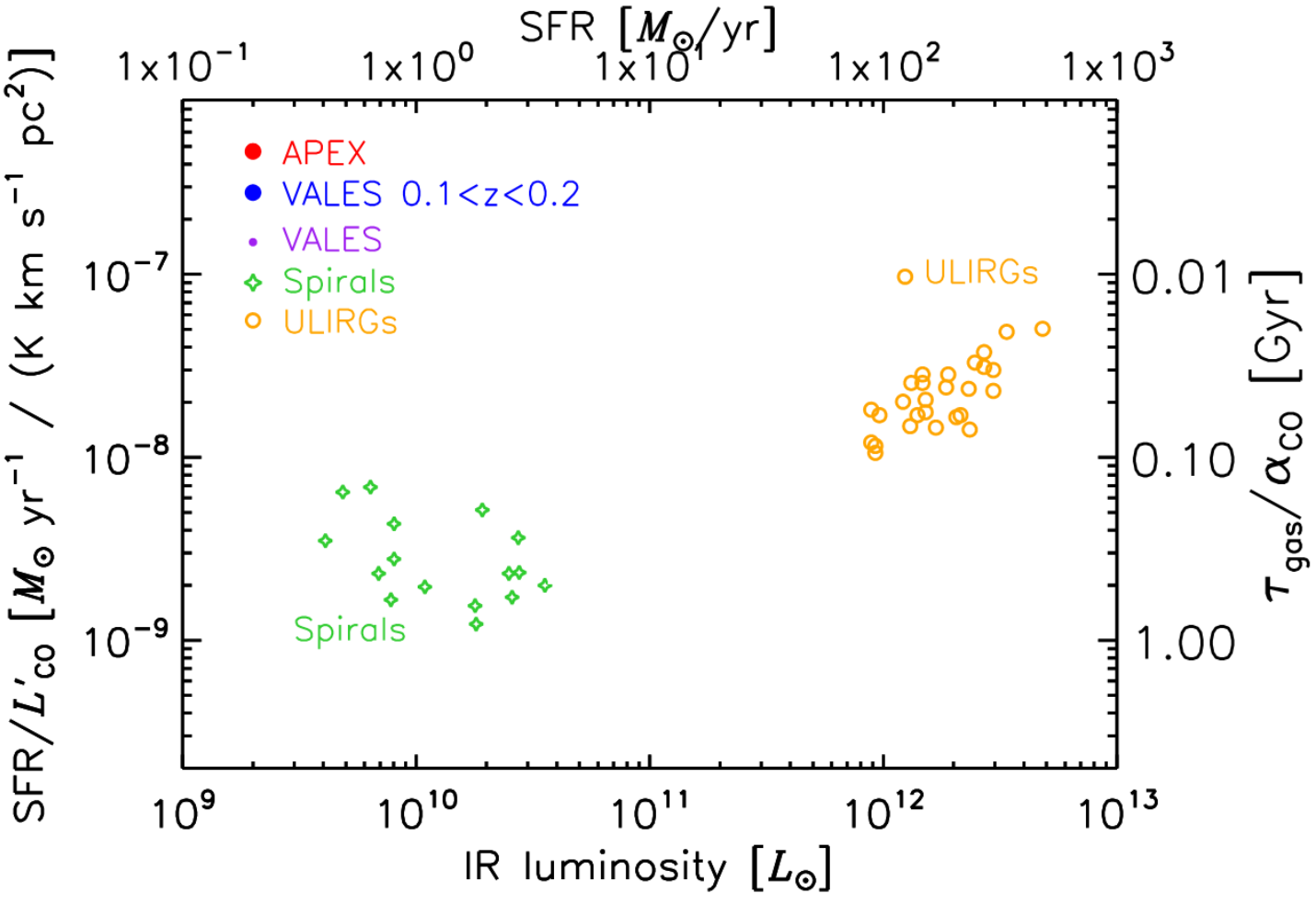
There is a mild dependency as a function of L(850μm).



The transition in Star Formation Efficiencies

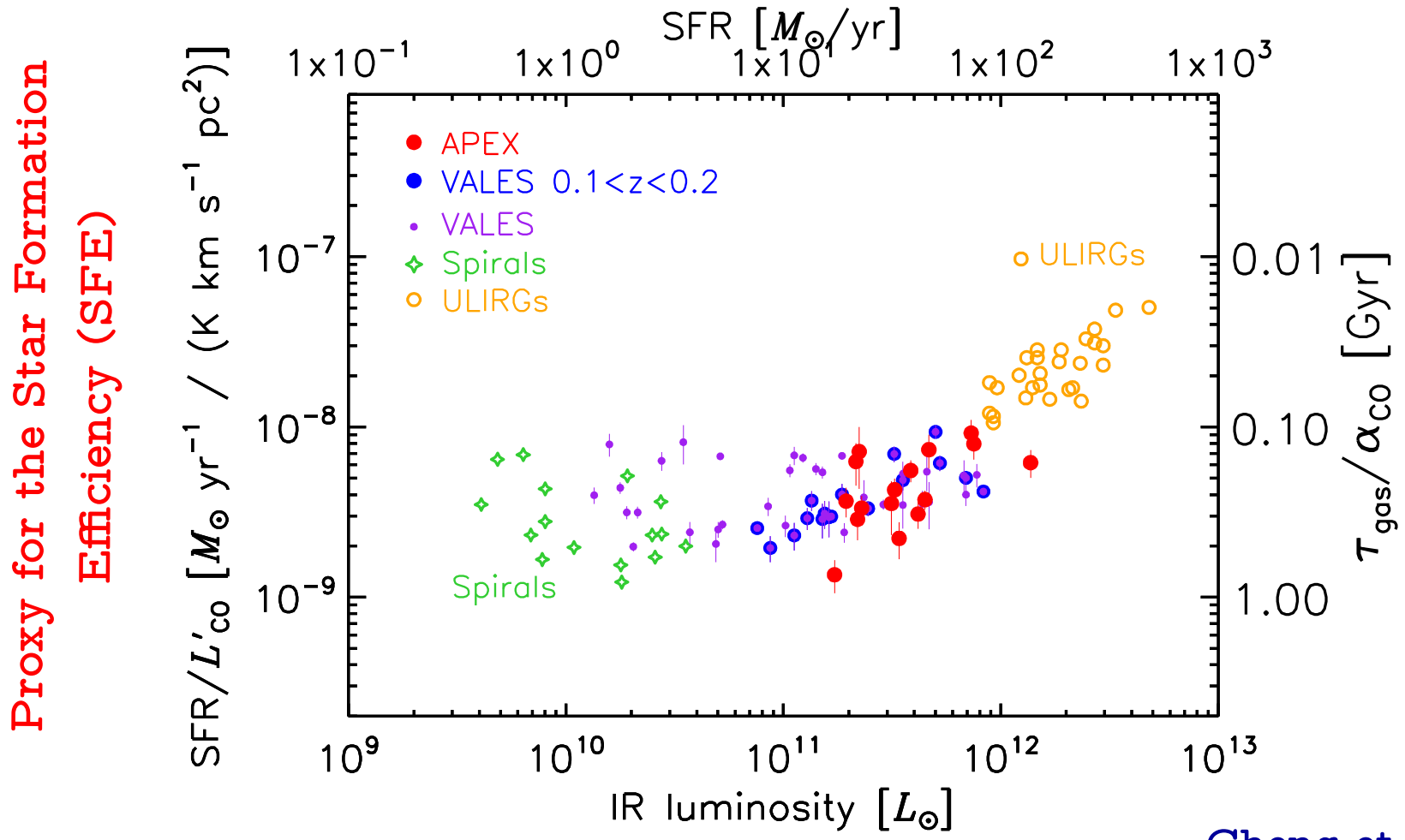
Two modes of star formation are proposed, one for normal and another for starburst galaxies

Proxy for the Star Formation Efficiency (SFE)



The transition in Star Formation Efficiencies

We cover the gap between both proposed star forming modes



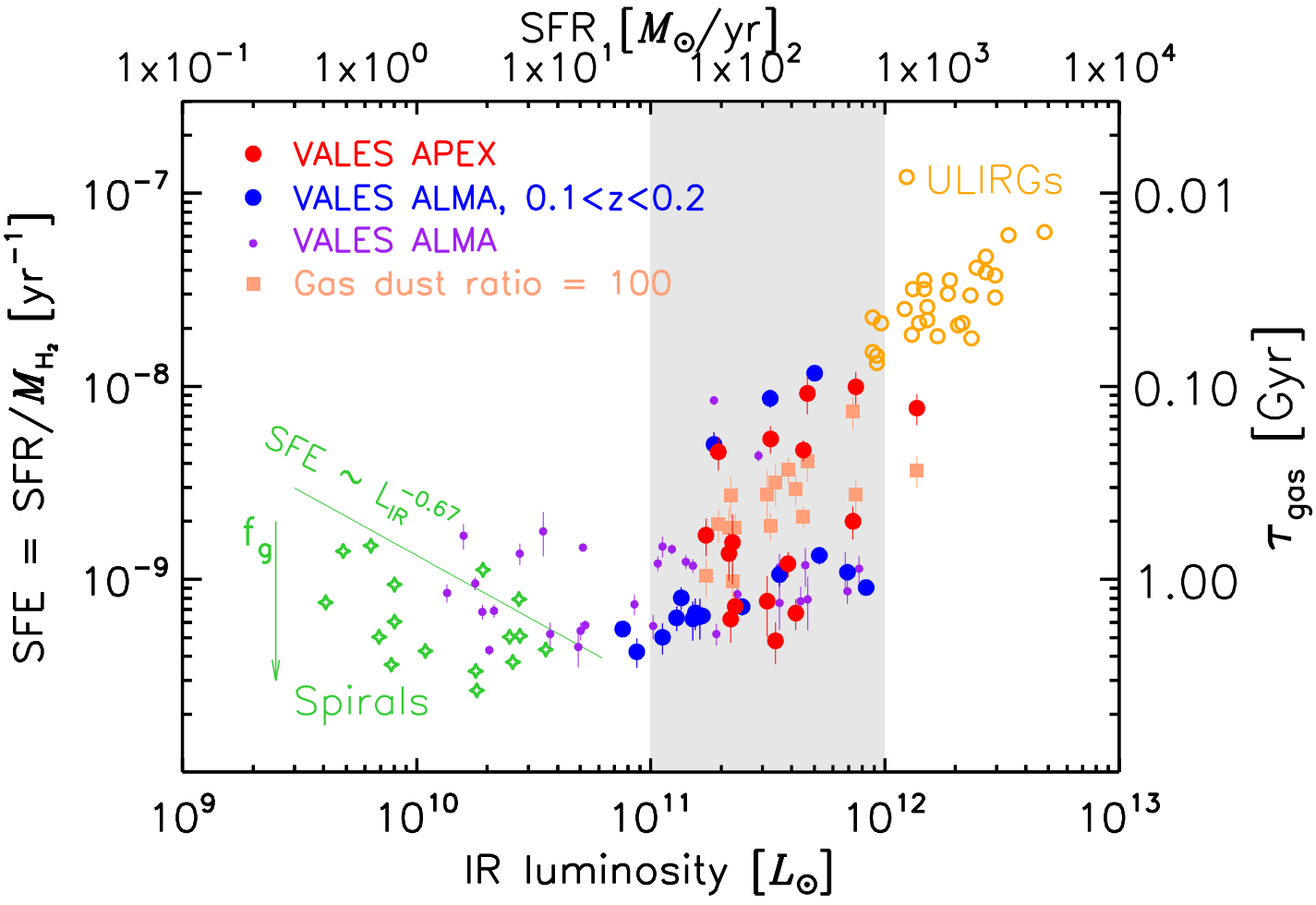
Cheng et al. (2018)

The transition in Star Formation Efficiencies

Is there really two modes of star formation?

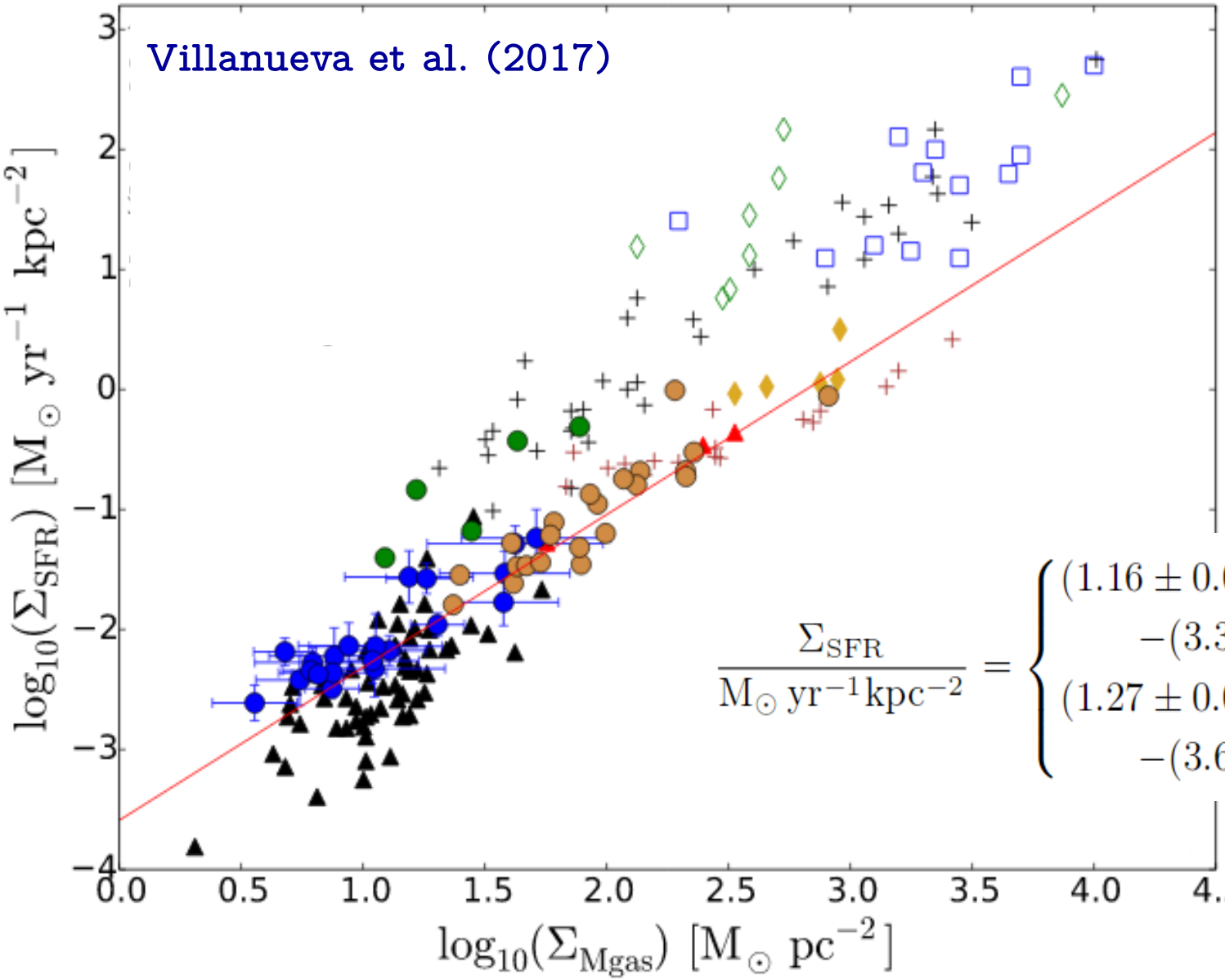
We find that the scatter is mainly controlled by:

* α(CO)
* f(gas)
* physical size



Cheng et al. (2018)

Resolved galaxies: The Schmidt-Kennicutt law

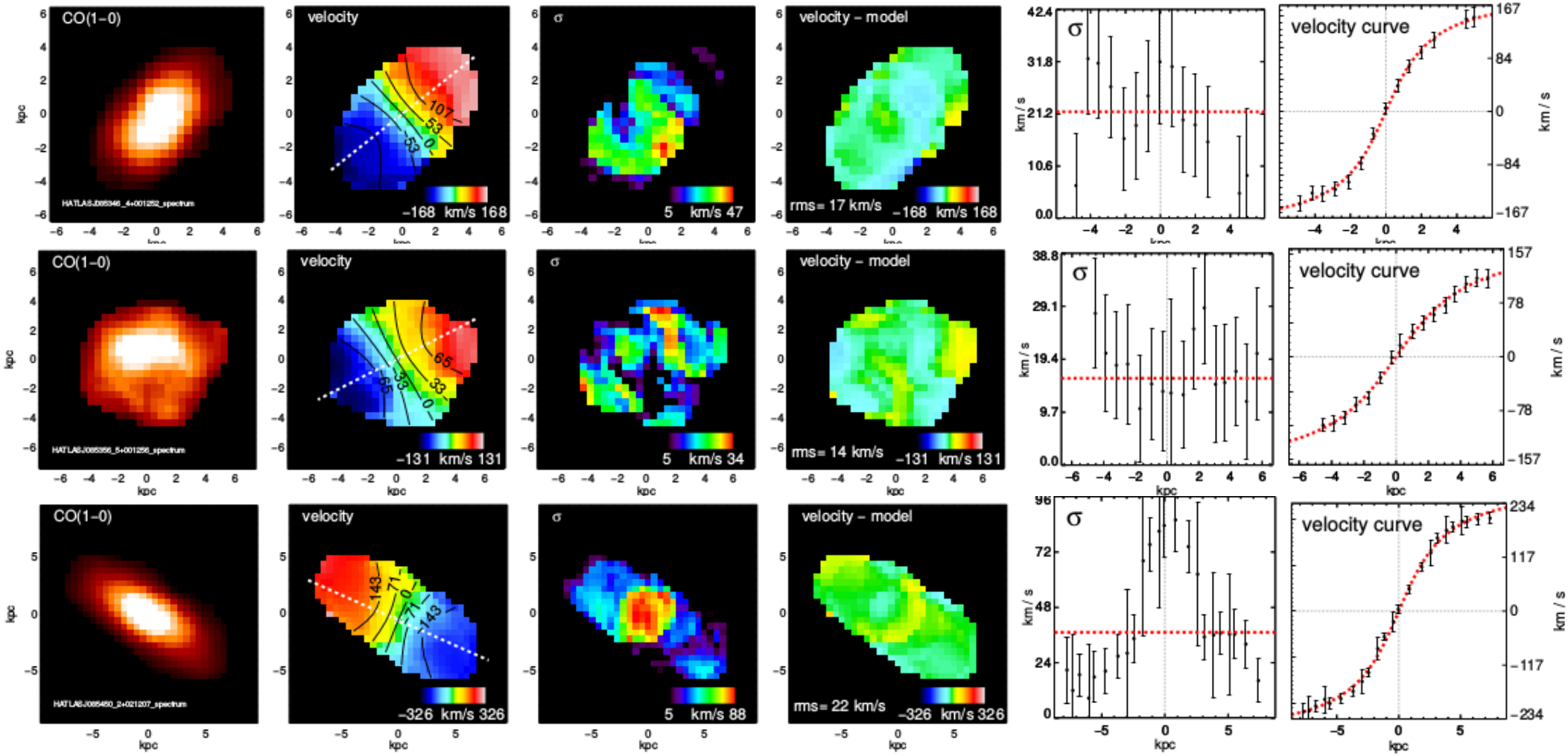


To get M(gas) we estimated M(HI) following Zhang et al. (2009).

$$\frac{\Sigma_{\rm SFR}}{M_\odot\,{\rm yr}^{-1}{\rm kpc}^{-2}} = \begin{cases} (1.16\pm0.05)\times\log[\Sigma_{M_{\rm gas}}/M_\odot\,{\rm pc}^{-2}] \\ \quad -(3.3\pm0.1) \\ (1.27\pm0.05)\times\log[\Sigma_{M_{\rm H2}}/M_\odot\,{\rm pc}^{-2}] \\ \quad -(3.6\pm0.1) \end{cases}$$

Resolved galaxies: CO dynamics

The ALMA observations resulted in 29 clearly resolved galaxies in CO. We describe their kinematic properties.



Molina et al. (submitted)

The VALES campaign

Villanueva et al. (2017), Hughes et al. (2017a, 2017b),
Cheng et al. (2018) & Molina et al. (submitted)

Upcoming soon:

A direct look to the gas to dust ratio:

* High-resolution CO(3-2) and 870μm continuum

Tackling the SFE and dynamics together:

* MUSE observations

Properties of gas rich galaxies:

* SINFONI Paschen-α and ALMA CO(1-0) emission at matched resolution