The Effect of the Virgo Environment on the Molecular Gas and Star Formation Efficiency in VERTICO Galaxies

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Credit: ALMA /S. Dagnello (NRAO)/Böhringer et al. (ROSAT All-Sky Survey)

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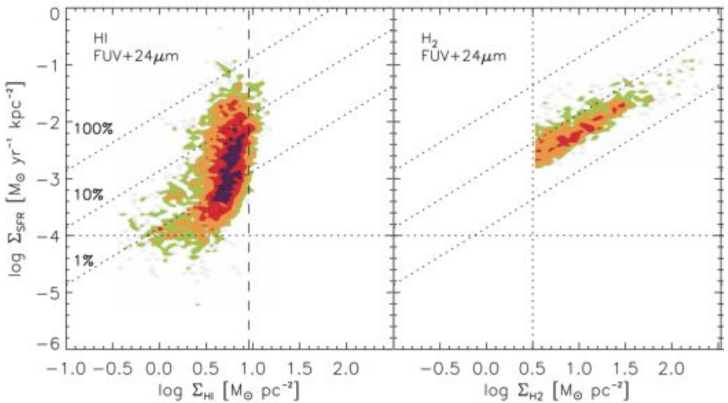
Galactic Ecosystem: Opportunities and Diagnostics in the Infrared and Beyond

Introduction

Star formation activity plays a key role in driving galaxy evolution.

- Stars form in Giant Molecular Clouds (GMCs) in which the molecular gas is the main constituent (e.g., Sanders et al. 1985).
- We use carbon monoxide molecule (CO) to trace the molecular gas (Σ_{mol}) through its low-J transitions.
- Increase of stellar mass is quantified through the star formation rate (SFR).
- The Kennicutt (1989, 1998) seminal studies shown a strong correlation between Σ_{SFR} and Σ_{gas}.



Bigiel et al. (2008)

Goals

We investigate the Star-Formation Efficiency of the molecular gas, $\mathbf{SFE_{mol}} = \Sigma_{SFR}/\Sigma_{mol}$, in the local universe.

- Almost constant $\mathbf{SFE_{mol}}$ as a function of galactocentric radius in field galaxies (e.g., Leroy et al. 2013; Villanueva et al. 2021).

In this work, we analyze the environmental effects of the Virgo cluster on:

1. The molecular and stellar exponential scale lengths.
2. $R_{mol} = \Sigma_{mol}/\Sigma_{atom}$ vs galactocentric radius.
3. $\mathbf{SFE_{mol}}$ vs galactocentric radius

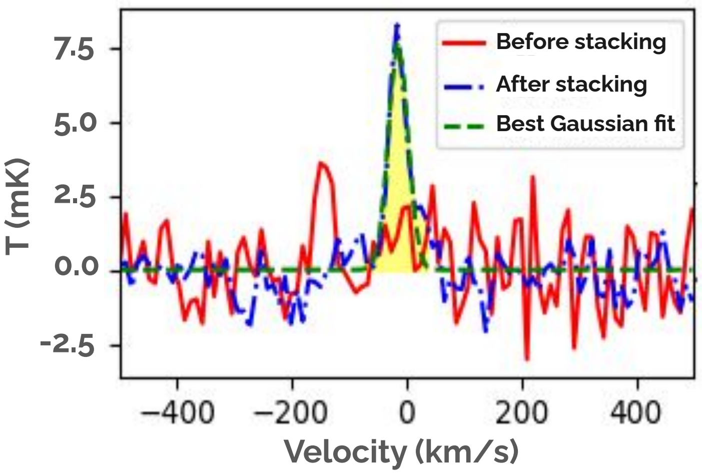
Methods

We focus on **the SFE as a function of basic quantities in galaxies selected from the Virgo Environment Traced In CO survey** (VERTICO; Brown et al. 2021).

- **VERTICO**: CO(J=2-1) ALMA ACA and TP data.
- **Plenty of ancillary data**: **HI** (VIVA survey), **SFR** (GALEX NUV + WISE band 4), and **stellar masses** (WISE band 1).
- **51 VERTICO** late-type galaxies.

- To increase SNR we do **spectral stacking of CO**, in radial bins using HI velocities from VIVA survey.
- Use only galaxies with ***i* < 75°** to minimize beam smearing effects.
- **34 galaxies** in total.

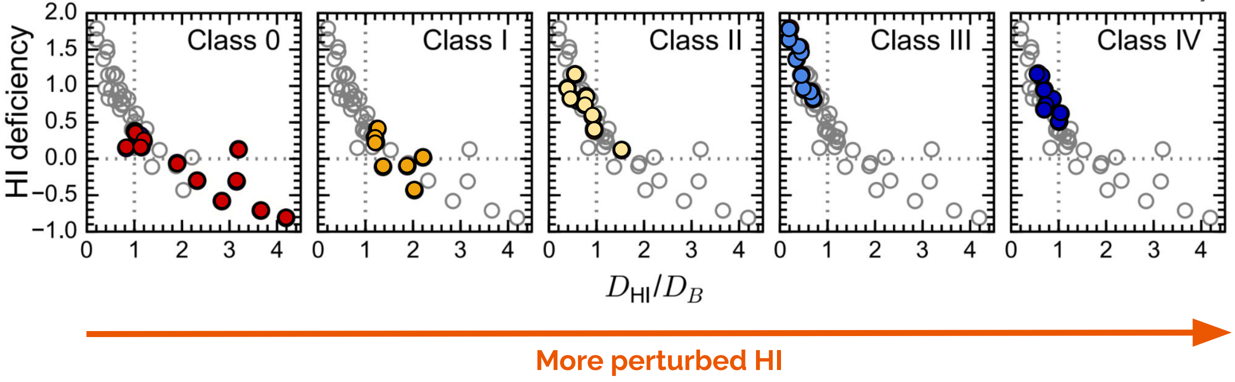
$0.6 < r < 0.7$ (r_{25}) NGC4189



Methods

We use the **classification of the HI-perturbation** (based **on morpho-kinematics**; Yoon et al. 2017), to analyze the **34 selected galaxies**:

Yoon et al. (2017)



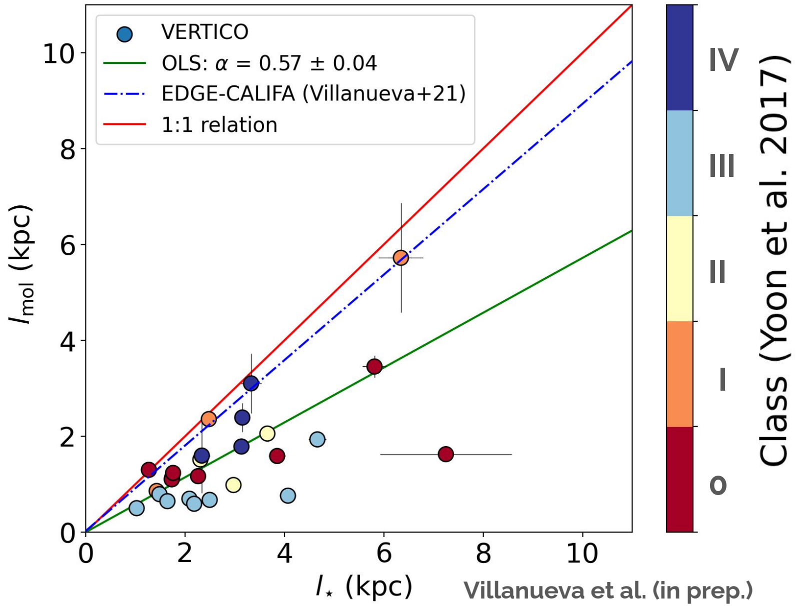
For quantities derived from the CO line emission data:

- We assume $I_{CO(1-0)}/I_{CO(2-1)}$ **= 0.7** (Brown et al. 2021).
- We obtain radial profiles for Σ_{mol}, Σ_{atom}, $\Sigma_\star$, and Σ_{SFR} (α_{CO} = 4.3 $M_\odot$ [K km s^{-1} $pc^{-2}]^{-1}$).

Results: Exponential Scale Lengths

We compute the exponential scale lengths for the molecular gas and stars :

- We **fit exponential profiles**, when possible, to the **molecular** and **stellar radial profiles**.
- We get the exponential scale lengths, l_{mol} and $l_{\star}$.
- **Close to 1:2 relation between them.**



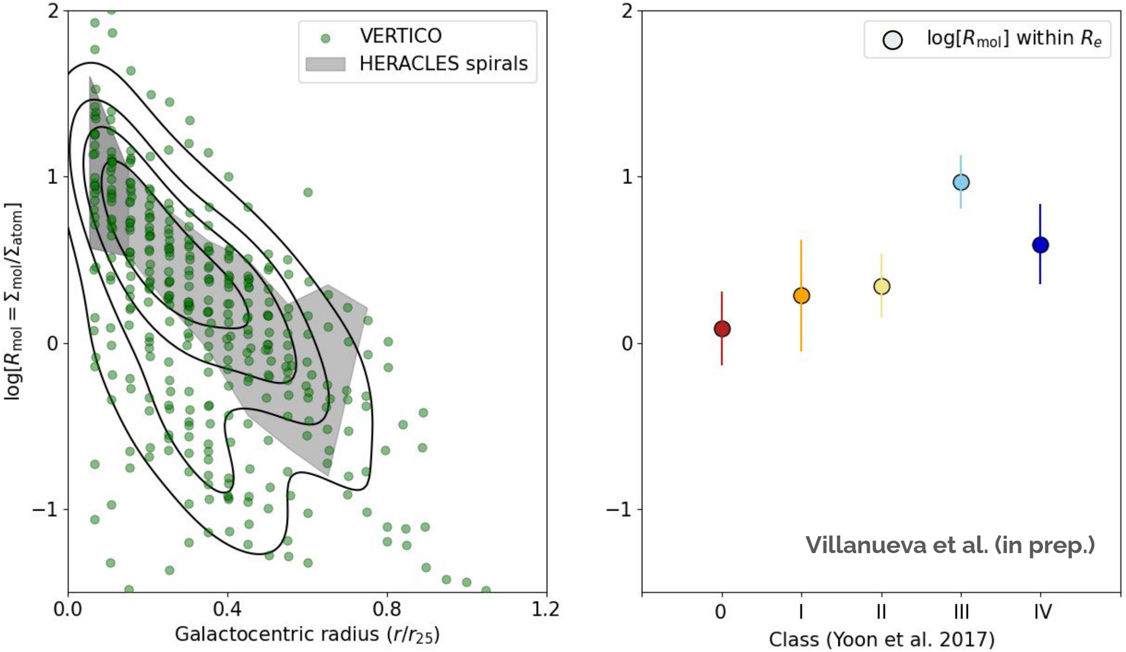
Villanueva et al. (in prep.)

1. H_2 is noticeably **more centrally concentrated than stars** when compared to **field galaxies** (e.g. EDGE-CALIFA)
2. Higher-classes tend to have shorter l_{mol} than lower-classes.
3. The **more perturbed the HI**, the **more centrally concentrated the H_2** .

Results: *R*mol vs Galactocentric Radius-CLASS

We analyze the molecular-to-atomic gas ratio, $R_{mol} = \Sigma_{mol}/\Sigma_{atom}$, for:

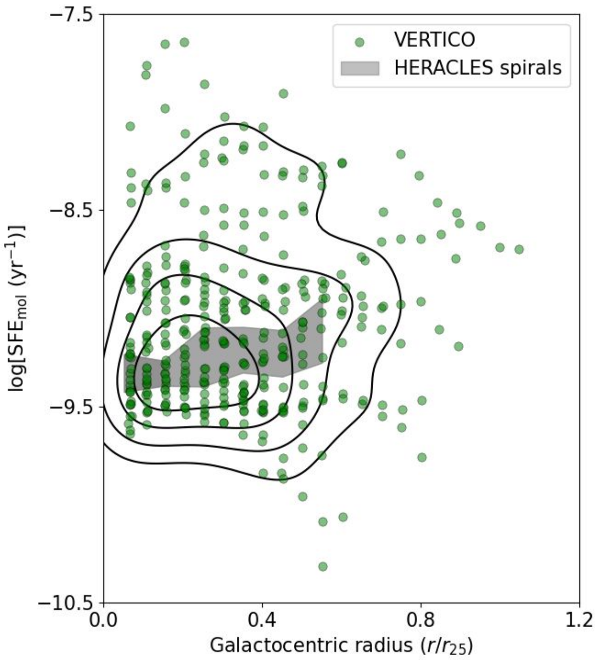
- Annuli (left panel).
- Galaxies by computing the integrated molecular and atomic gas masses within one effective radius, ***R*e** (right panel).

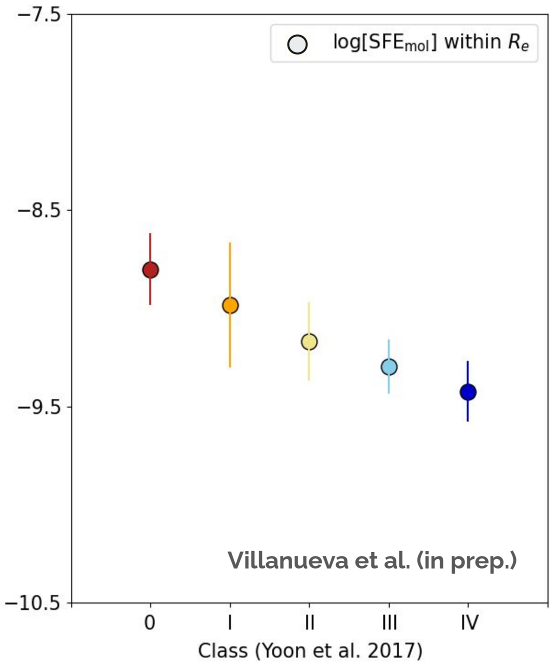


1. ***R*mol**, in the aggregate, decreases systematically with radius.
2. Most ***R*mol** are within the range for normal spirals (e.g. HERACLES).
3. Global ***R*mol** systematically increases with class.
4. The **more perturbed the HI**, the larger the ***R*mol** is.

Results: SFE_{mol} vs Galactocentric Radius-CLASS

We compute the Star-Formation Efficiency of the molecular gas, **$SFE_{mol} = \Sigma_{SFR} / \Sigma_{mol}$**, for the two prior cases.





1. Similarly to ***R_{mol}***, most of the **SFE_{mol}** are within the range of normal spirals (e.g. HERACLES).
2. **Global SFE_{mol} systematically decreases** with class..
3. The **more perturbed the HI**, the **less efficient H_2 is** at forming stars.

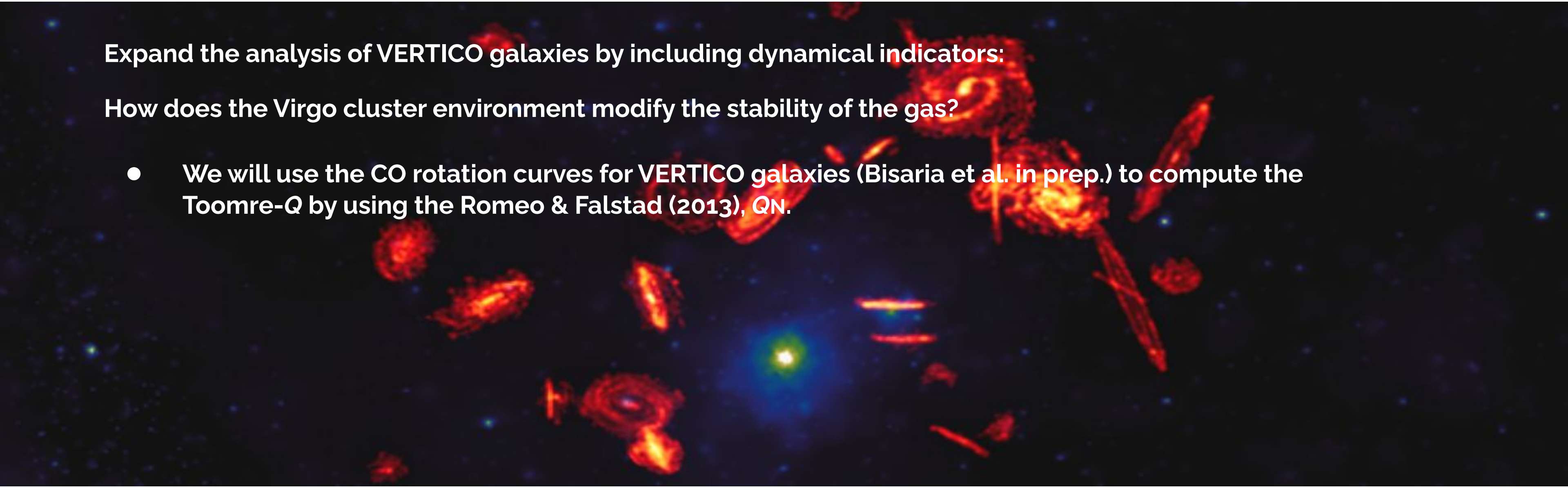
Summary to date

i) We find a close to **1:2 relation between the molecular and stellar exponential scale lengths.** On average, **H_2 in VERTICO galaxies** is **more centrally concentrated than stars** when compared to **field galaxies.**

ii) There is a **systematic increase of the global molecular-to-atomic gas ratio** from lower- to higher-classes. In general, the more perturb in HI a galaxy is, then the larger the R_{mol} is.

iii) There is also a **systematic decrease** of global **SFE_{mol}** from lower- to higher-classes; the more perturb in HI a galaxy is, then the less efficient in forming stars the **H_2** is.

Future work

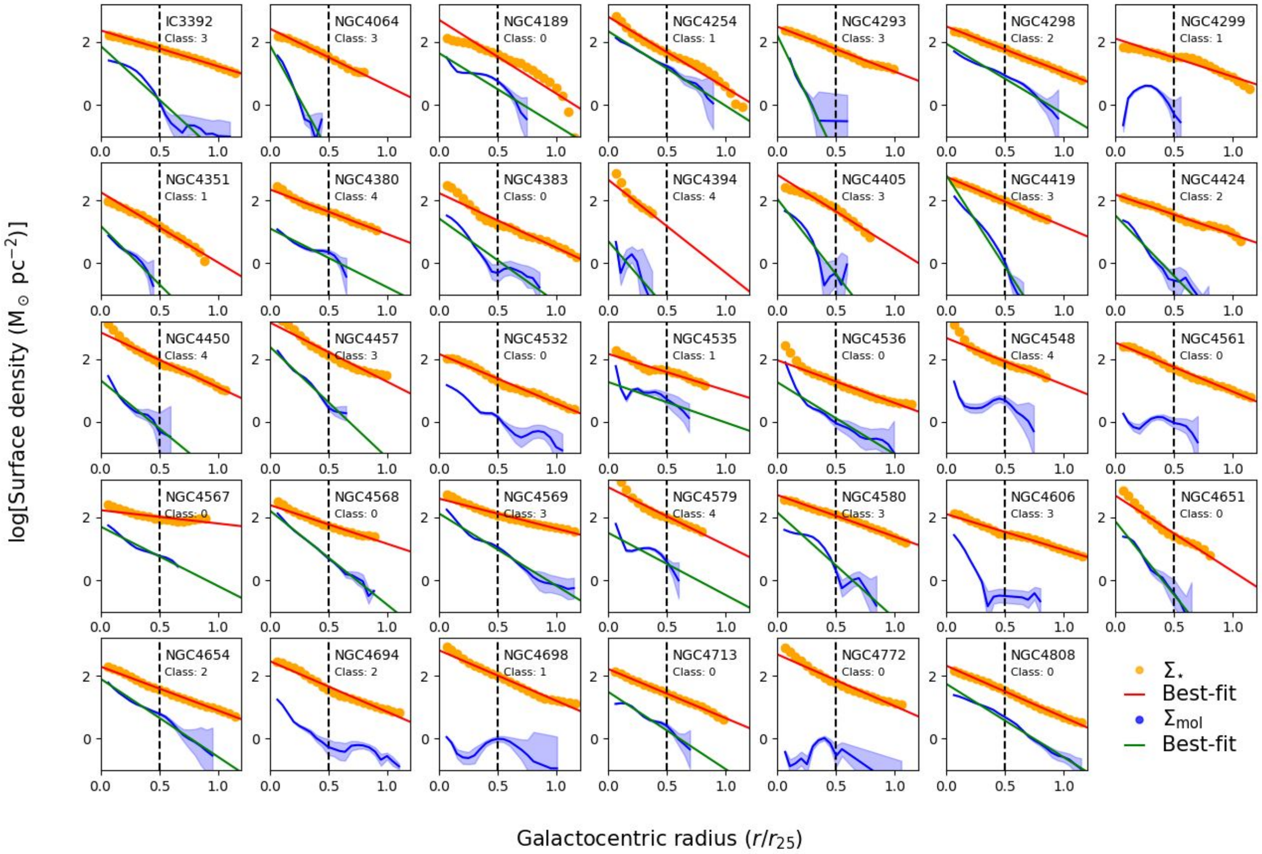


Expand the analysis of VERTICO galaxies by including dynamical indicators:

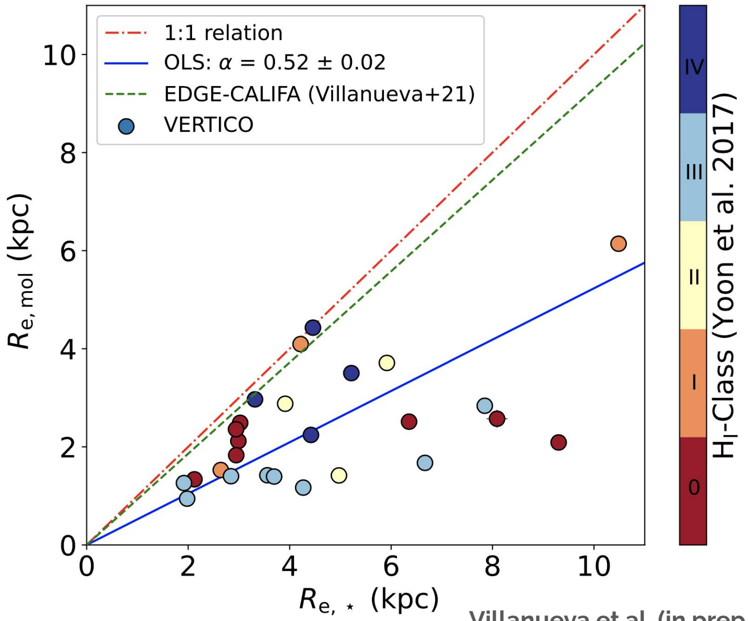
How does the Virgo cluster environment modify the stability of the gas?

- We will use the CO rotation curves for VERTICO galaxies (Bisaria et al. in prep.) to compute the Toomre-Q by using the Romeo & Falstad (2013), Q_N.

Results: Radial profiles



Results: Molecular and stellar effective radii



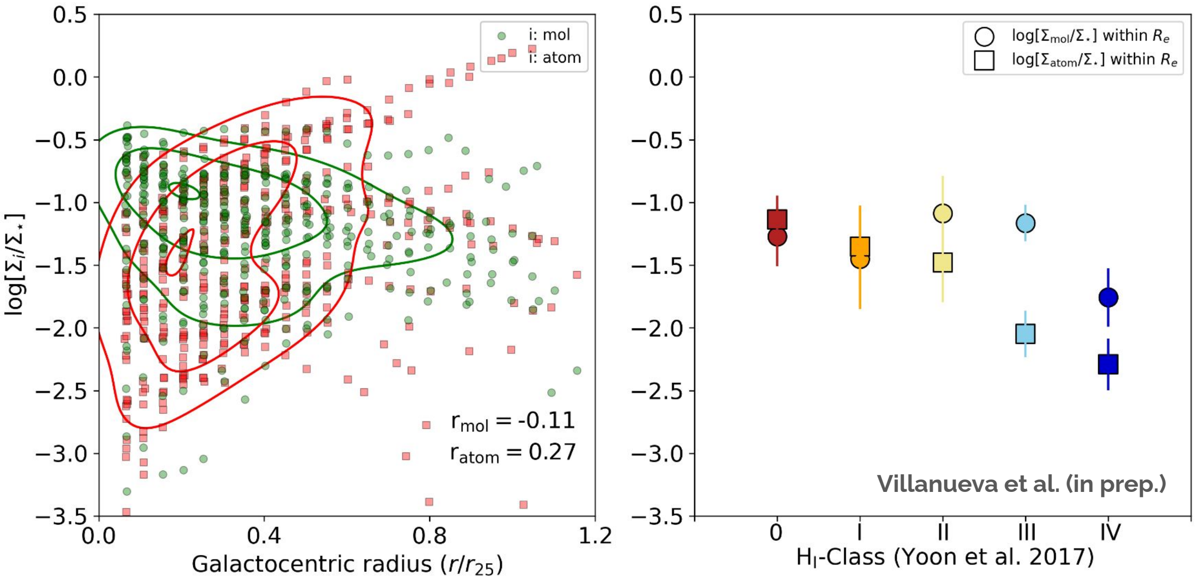
Villanueva et al. (in prep.)

<u>As for exponential scale lengths:</u>

1. **H_2** is noticeably **more centrally concentrated than stars** when compared to **field galaxies** (e.g. EDGE-CALIFA)
2. Higher-classes tend to have shorter ***l_{mol}*** than lower-classes.
3. The **more perturbed the HI**, the **more centrally concentrated the H_2** .

Results: $R_{mol,\star}$ and $R_{atom,\star}$ vs Galactocentric Radius

We analyze the molecular-to-stellar, $R_{mol,\star} = \Sigma_{mol}/\Sigma_\star$, and the atomic-to-stellar, $R_{atom,\star} = \Sigma_{atom}/\Sigma_\star$.



1. Almost constant global $R_{mol,\star}$ with HI-Class.
2. $R_{atom,\star}$ decreases systematically with HI-Class.