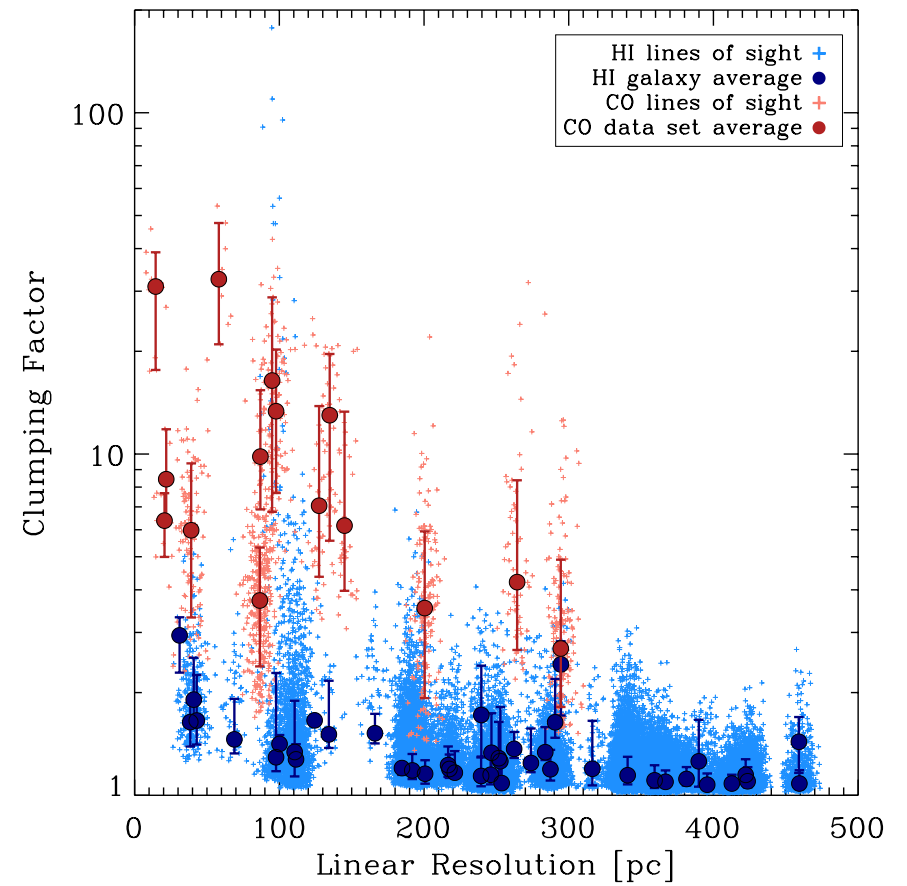
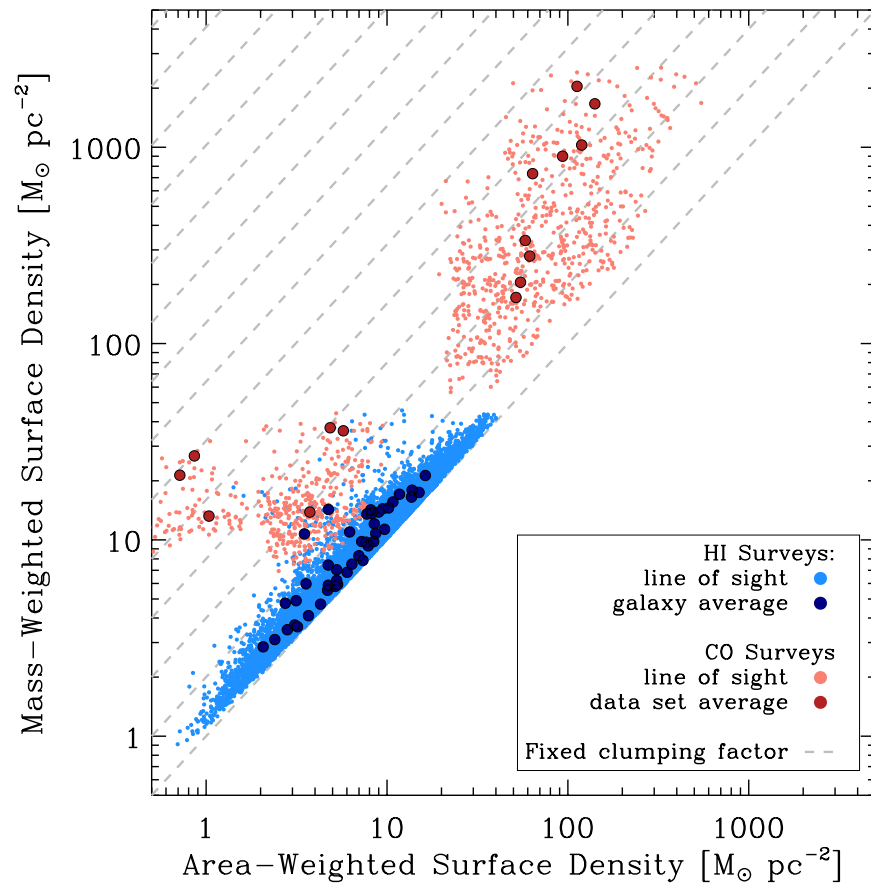


What is a kpc Surface Density?



Surface Densities Not Scale Invariant

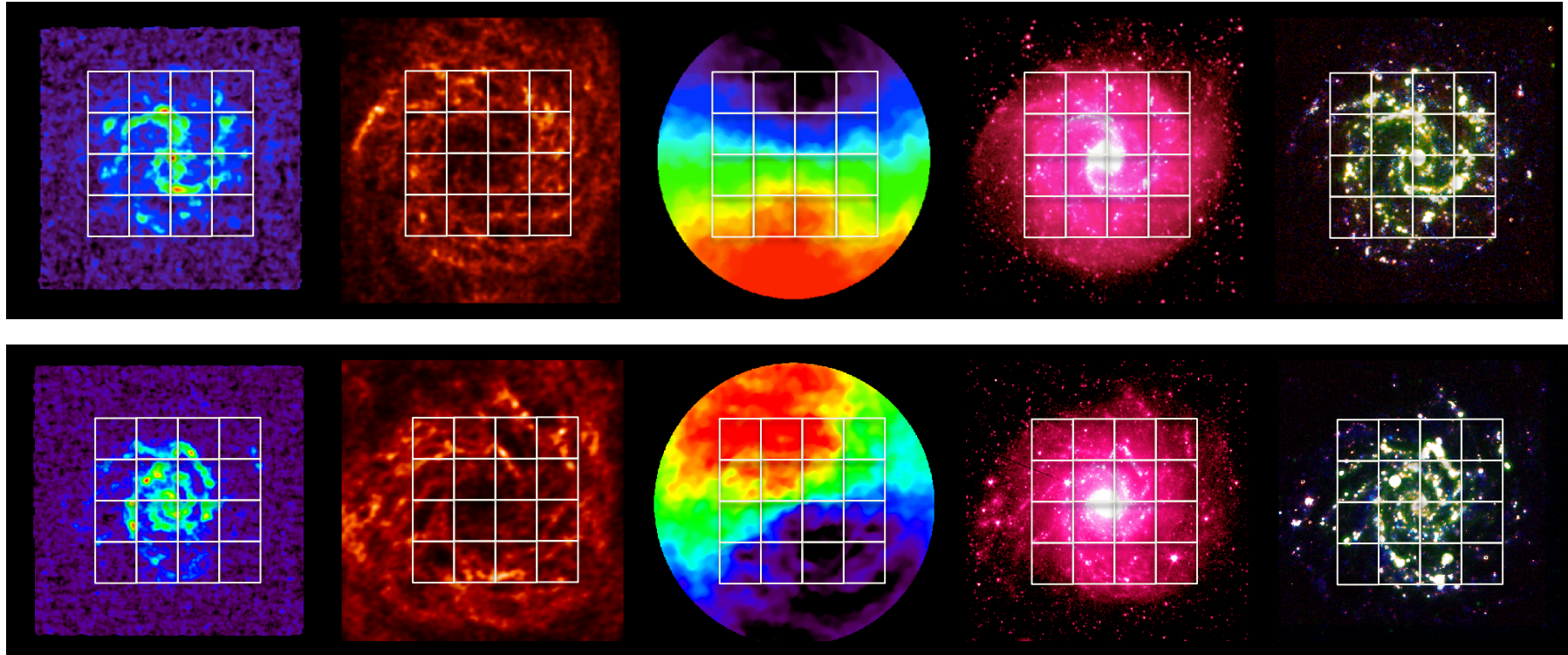


~~Four Legs
good
Two
Legs
Bad~~

Ratios

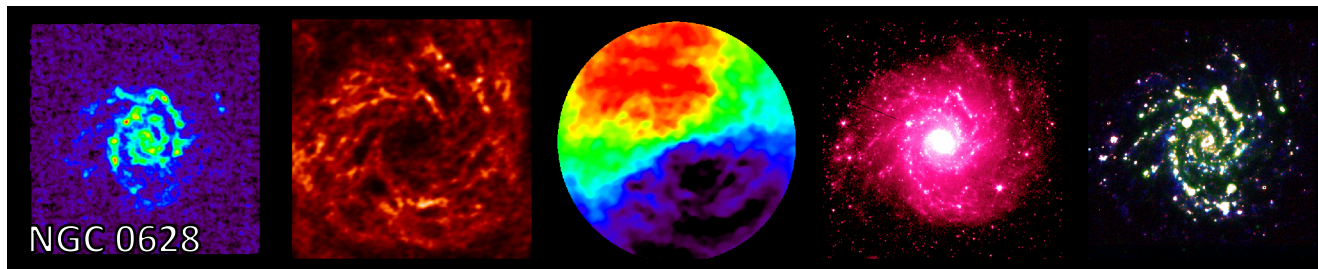
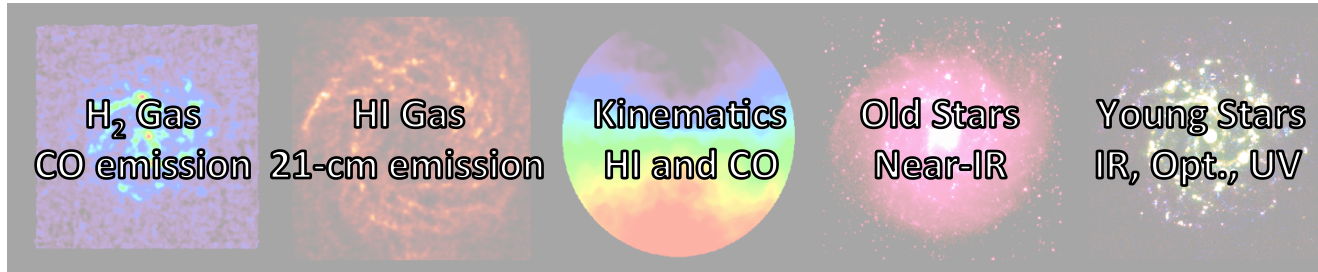
Surface
Densities

Kiloparsec+ Star Formation Scaling Relations

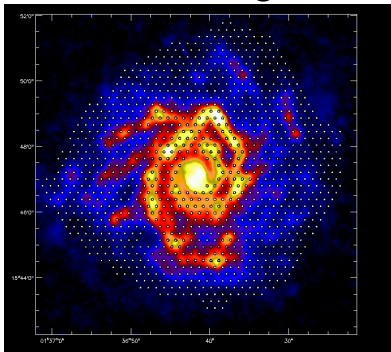


Adam Leroy (NRAO, Charlottesville), Fabian Walter (MPIA)
Andreas Schruba (CalTech), **Karin Sandstrom** (MPIA), **Antonio Usero** (OAN)
the HERACLES and THINGS Collaborations

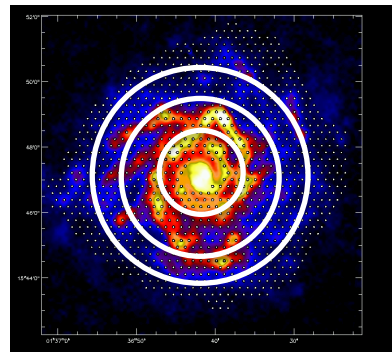
The HERACLES/THINGS++ View of Star Formation



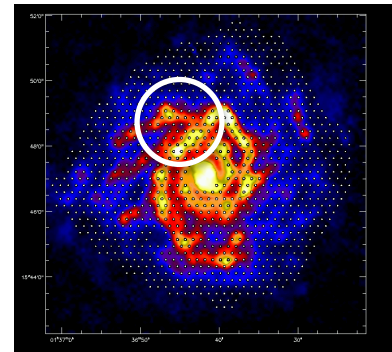
Lines of Sight



Azimuthal Averages

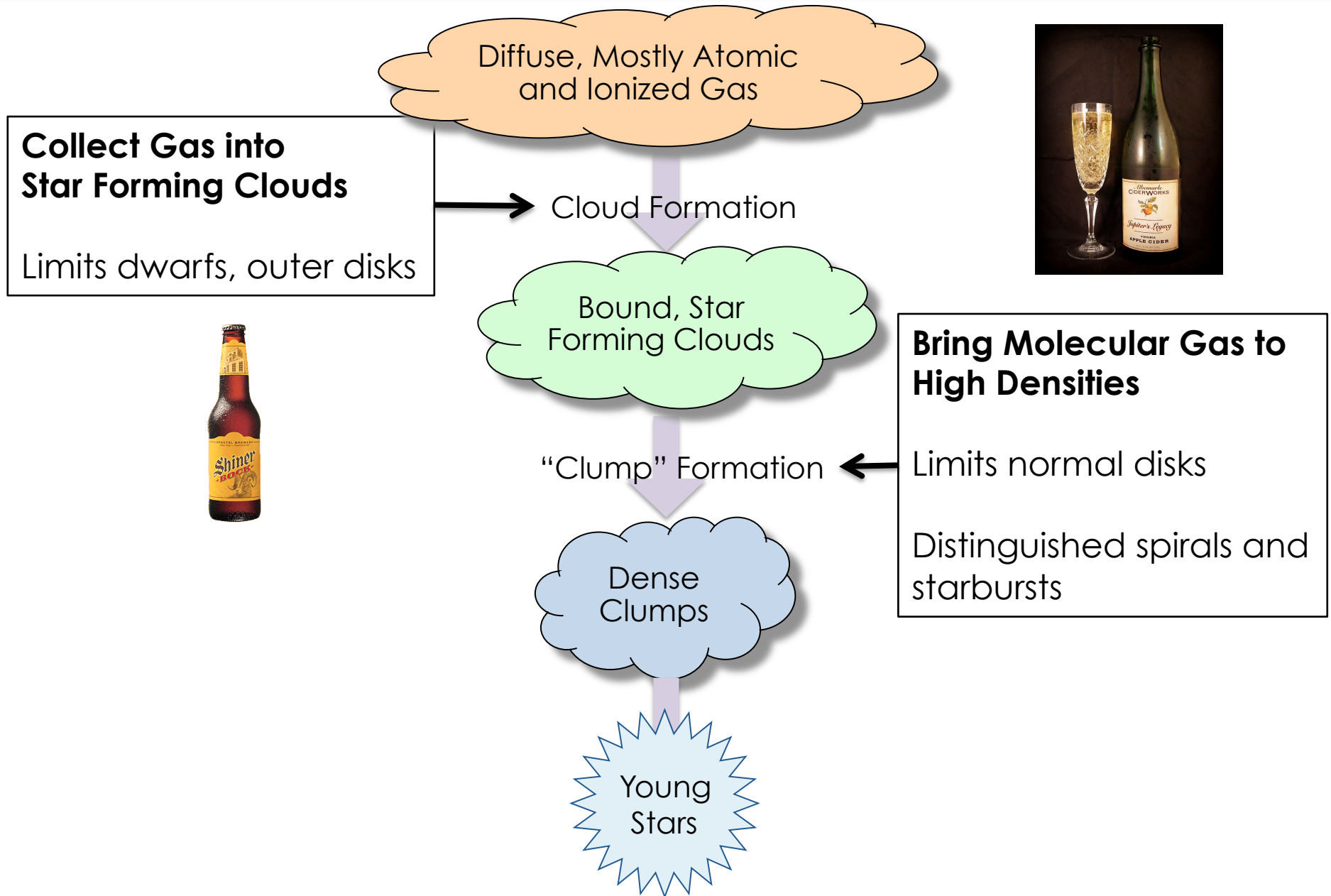


Selected Pointings



H₂ from CO (2-1)
 HI from 21-cm
 SFR from IR, H α , UV
 Dust from IR
 UV field from IR
 Stars from near-IR
 Rotation from HI
 Metallicity
 HCN (selected pts)

A Tale of Two Bottlenecks?



A Tale of Two Bottlenecks

- **WHY WE THINK THINGS ARE SEPARABLE.**

Clearly separable scalings of SFR, CO, HI at kpc scales.

- **OUR CURRENT VIEW OF MOLECULAR GAS-SFR SCALINGS.**

First order boring, second order variations with galaxy

- **THROWING A WRENCH AT THE DENSE GAS BOTTLENECK?**

HCN in galaxy disks doesn't give a tighter prediction for SFR.

- **(OBSERVATIONAL CONSTRAINTS OF THE H₂-HI BALANCE)**

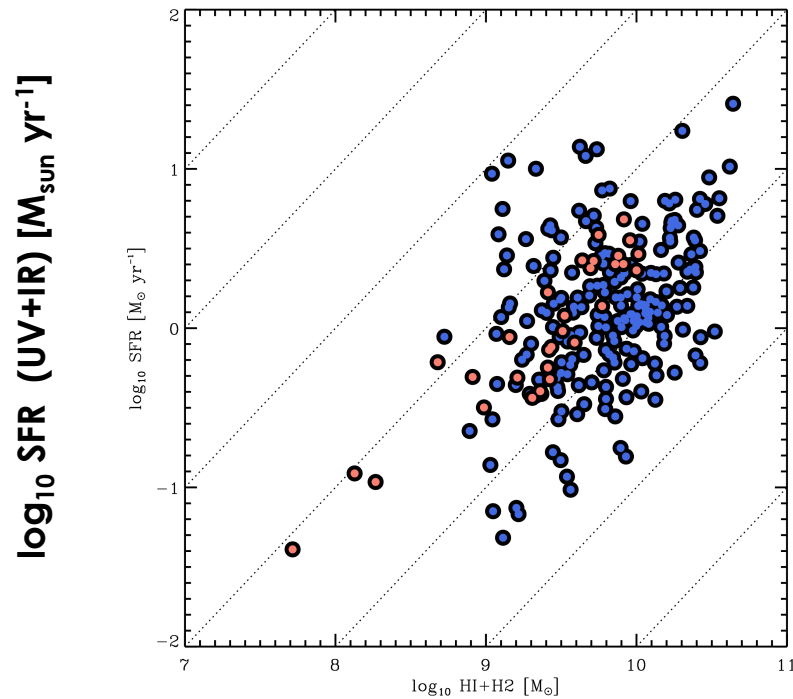
(Cloud formation is the bottleneck that matters in most local galaxies.)

- **A SNEAK PEAK AT ALMA'S VIEW OF STARBURST MOLECULAR CLOUDS.**

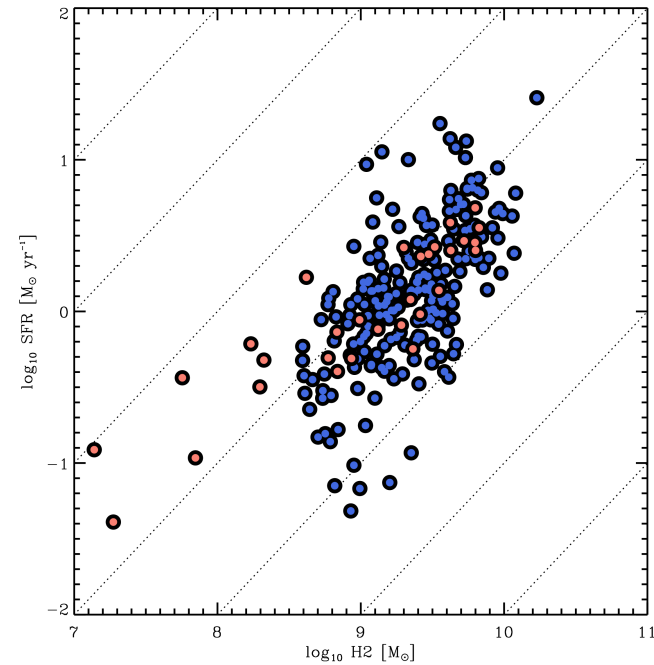
Cycle 0 views of NGC 253 and the Antennae Galaxies.

The Integrated Picture

Total HI+H₂ Gas



Total H₂ Gas



Gas Mass [M_{sun}]

COLDGASS

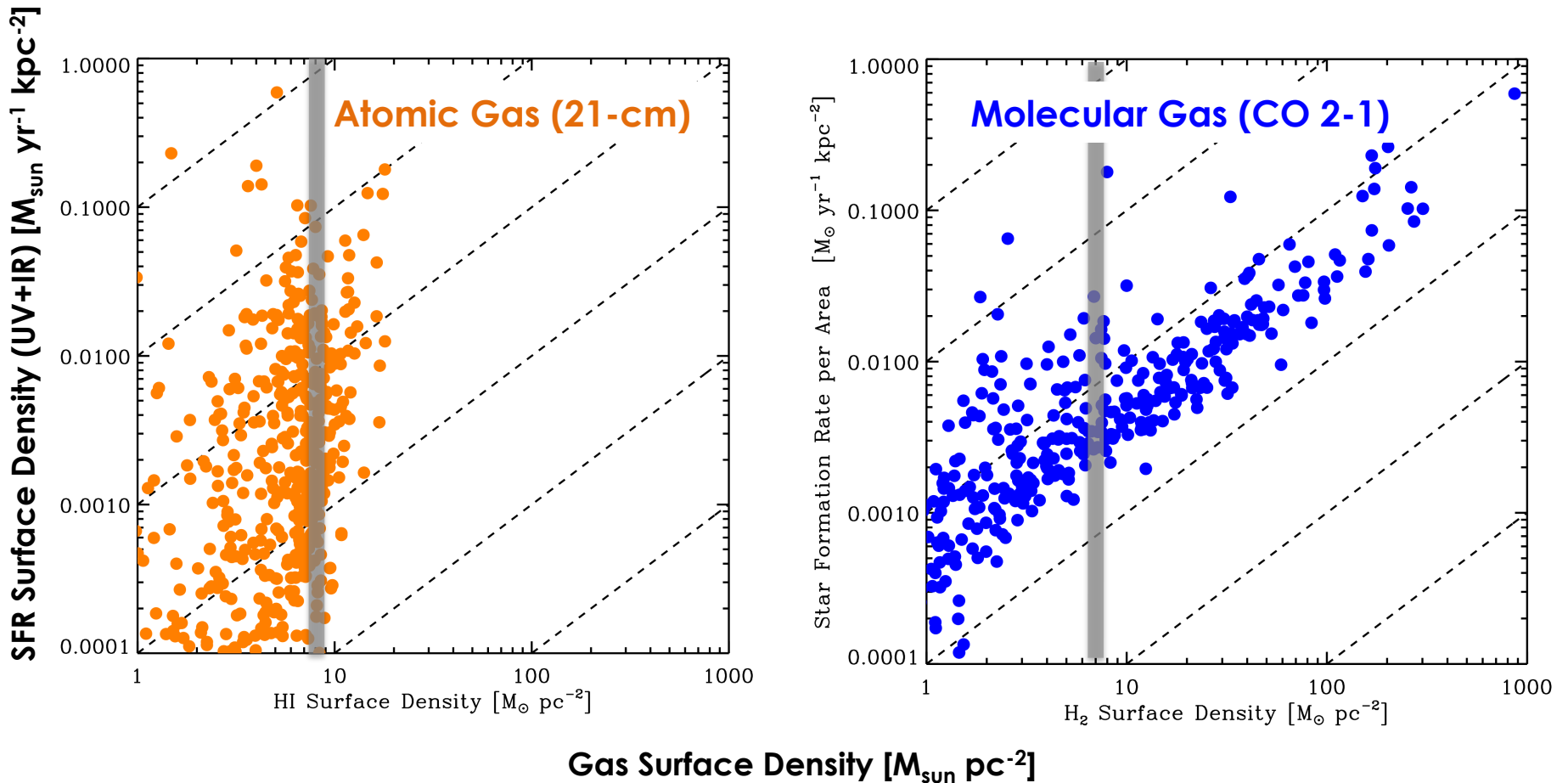
Saintonge+ '11, '12

HERACLES

Each Point:
Whole galaxy

kpc Resolution: Separable Relations for HI and CO

Scalings of SFR with HI and CO very different at kpc resolution.



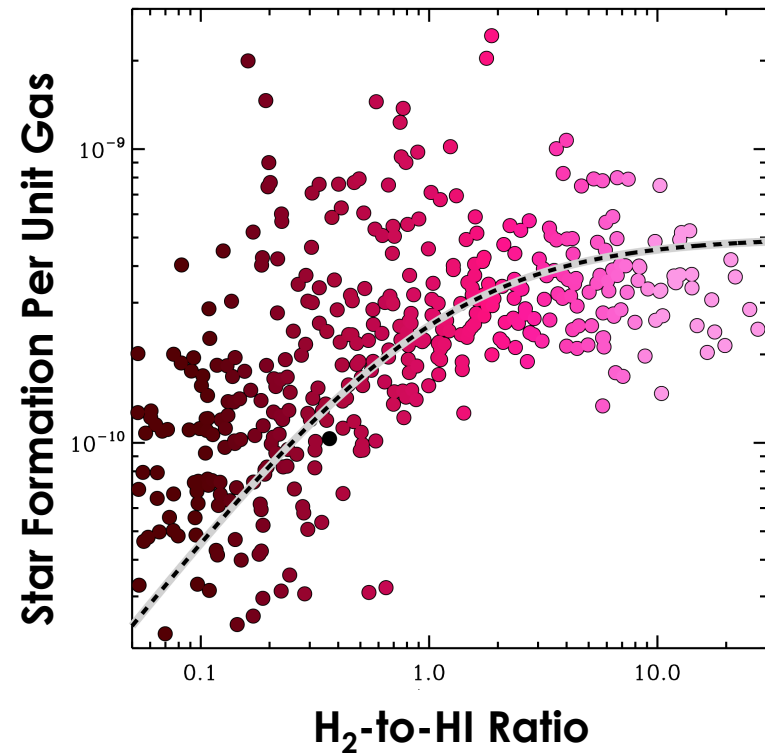
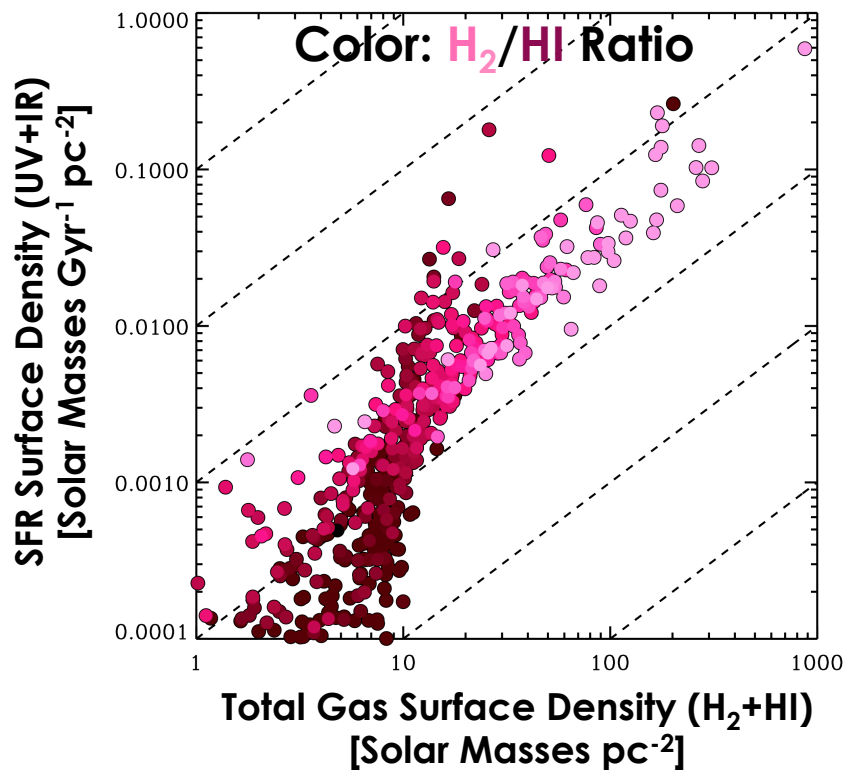
Each Point:

Azimuthal average (ring) in one galaxy, 30 galaxies combined

SCHRUBA ET AL. '11

The First Bottleneck

“Threshold” a product of changing molecular gas fraction



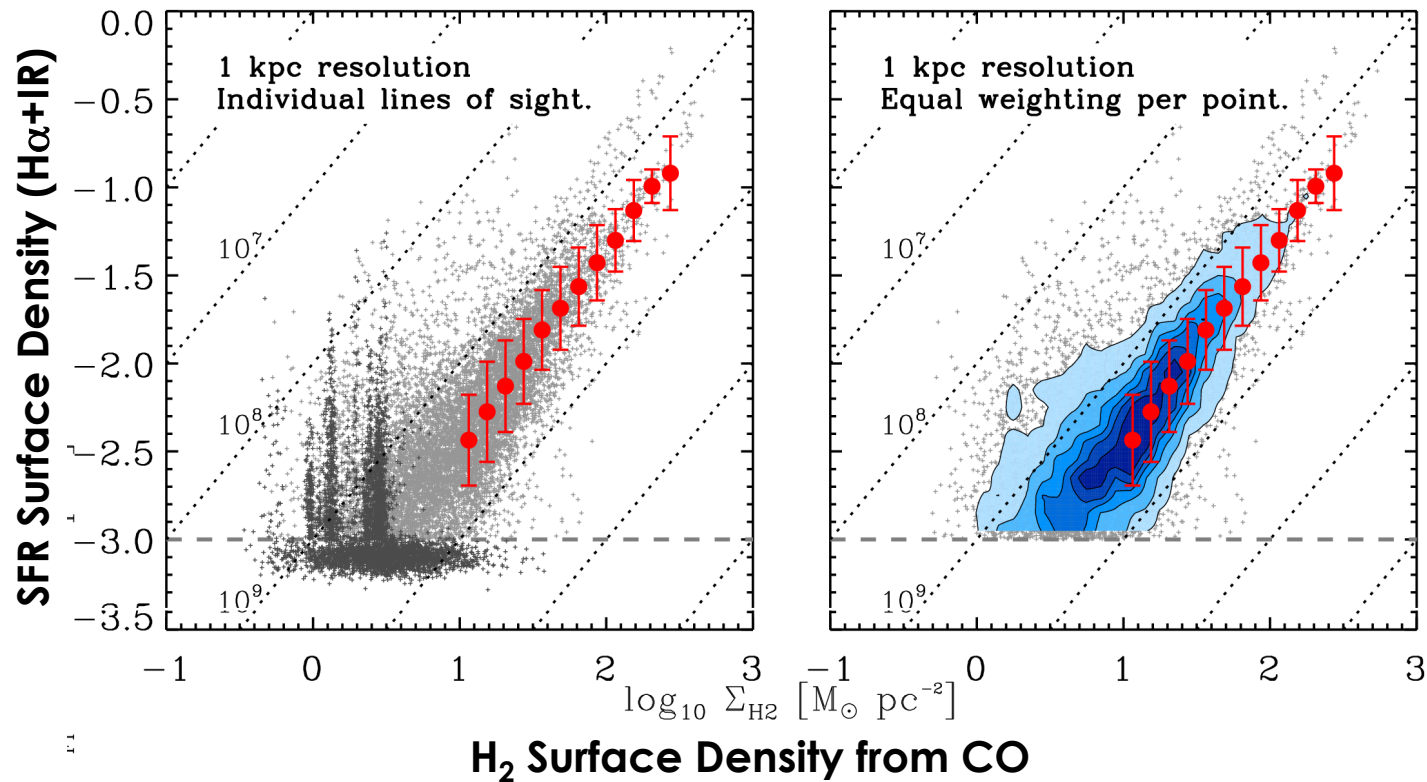
Each Point:

Azimuthal average (ring) in one galaxy, 30 galaxies combined

SCHRUBA ET AL. '11

Star Formation and H₂ – The Boring First Order View

Treating lines of sight equally, mostly see 1-to-1 scaling ...



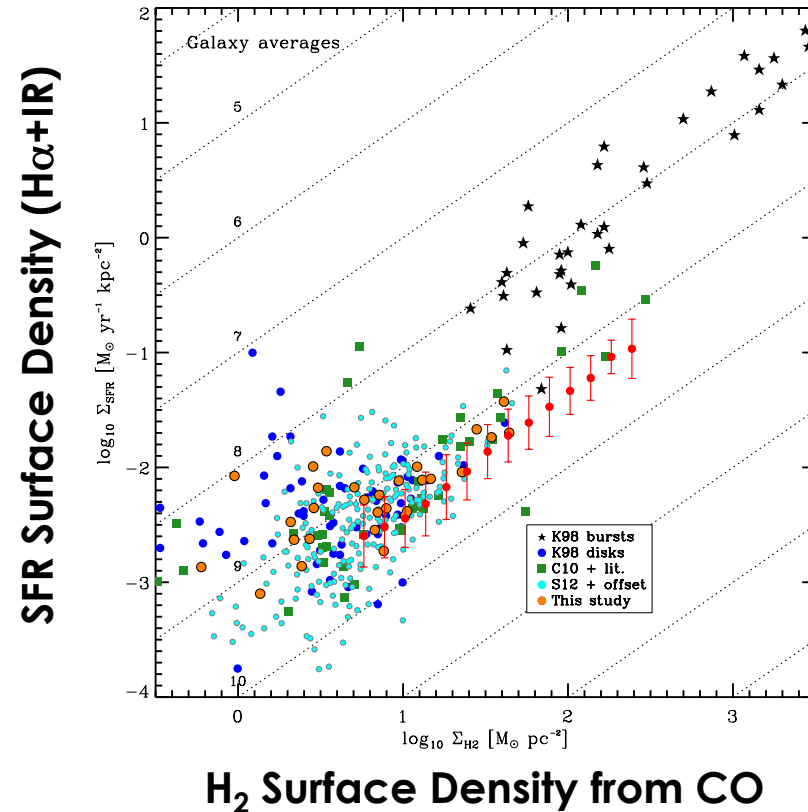
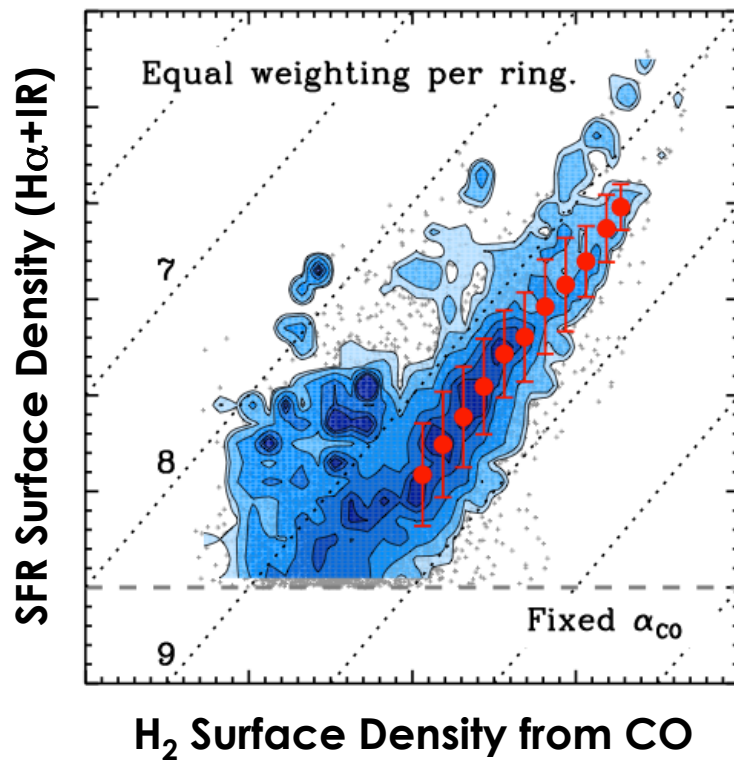
Each Point:

1 kpc resolution line of sight in a galaxy, 30 galaxies combined

Dark gray points – upper limits

Star Formation and H₂ – Teasing Out the Interesting Stuff

Emphasize small galaxies, centers, and starbursts: variations emerge.

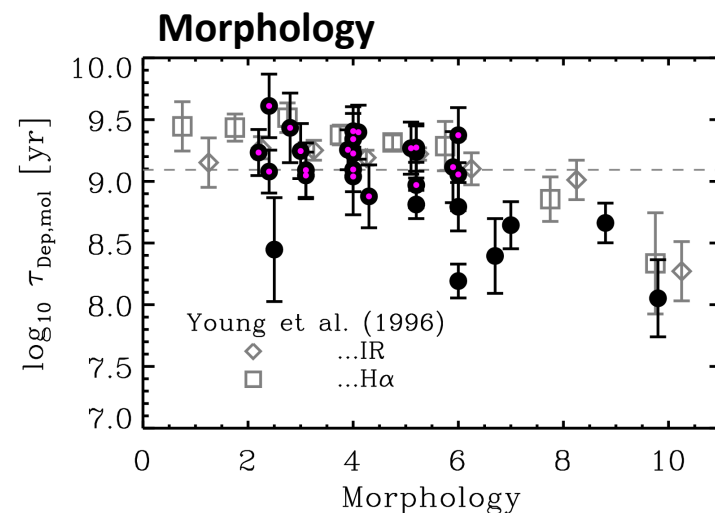
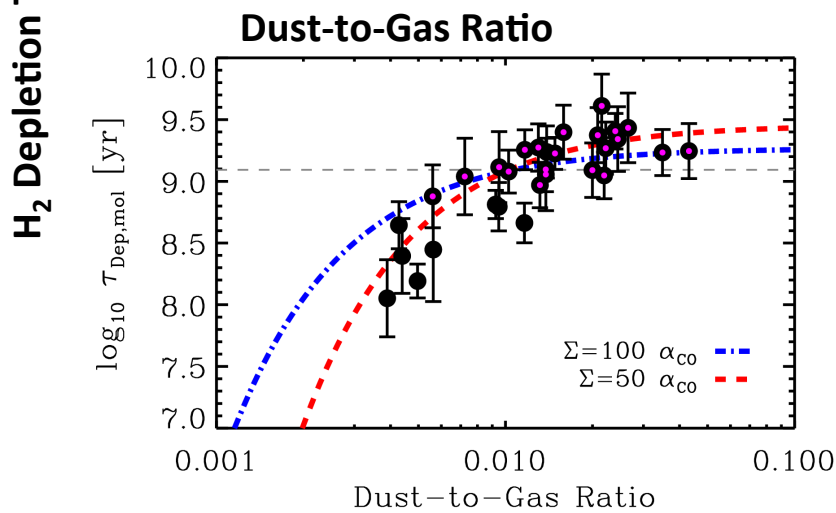
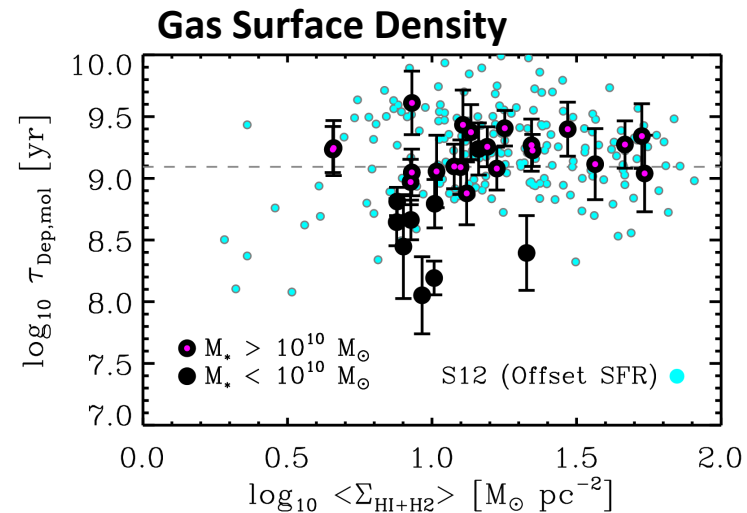
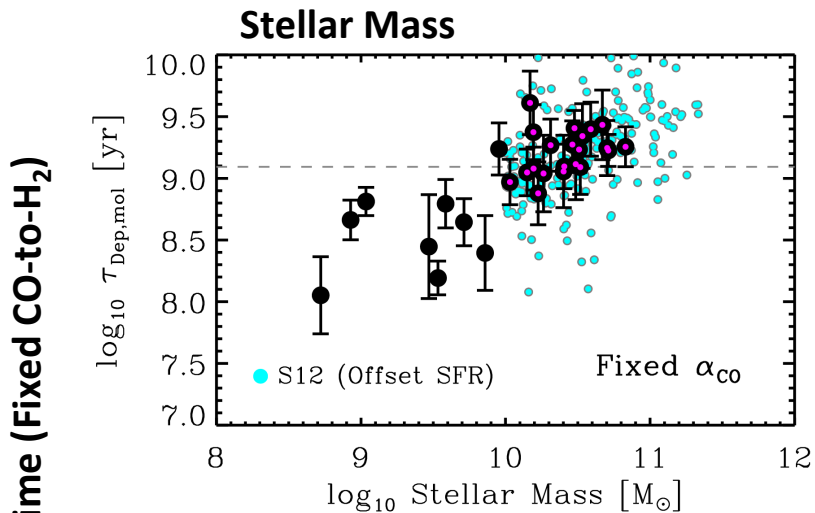


Each Point:

1 kpc resolution line of sight in a galaxy, 30 galaxies combined

Galaxy to Galaxy CO/SFR Variations

Low mass, late-type, low column galaxies show more SFR per CO.

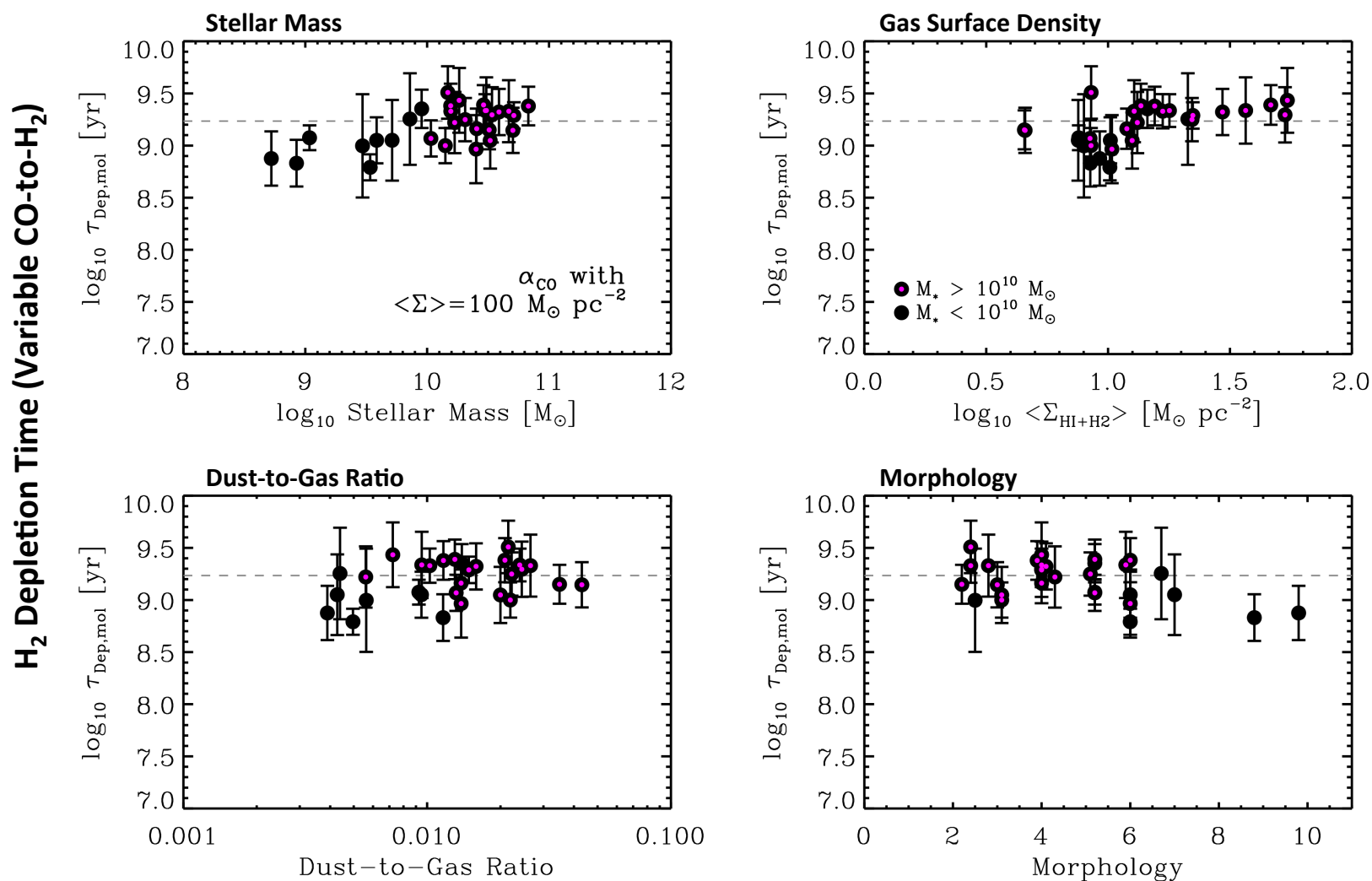


Each Point:
Whole-galaxy average

LEROY+ '13, SAINTONGE+ '12

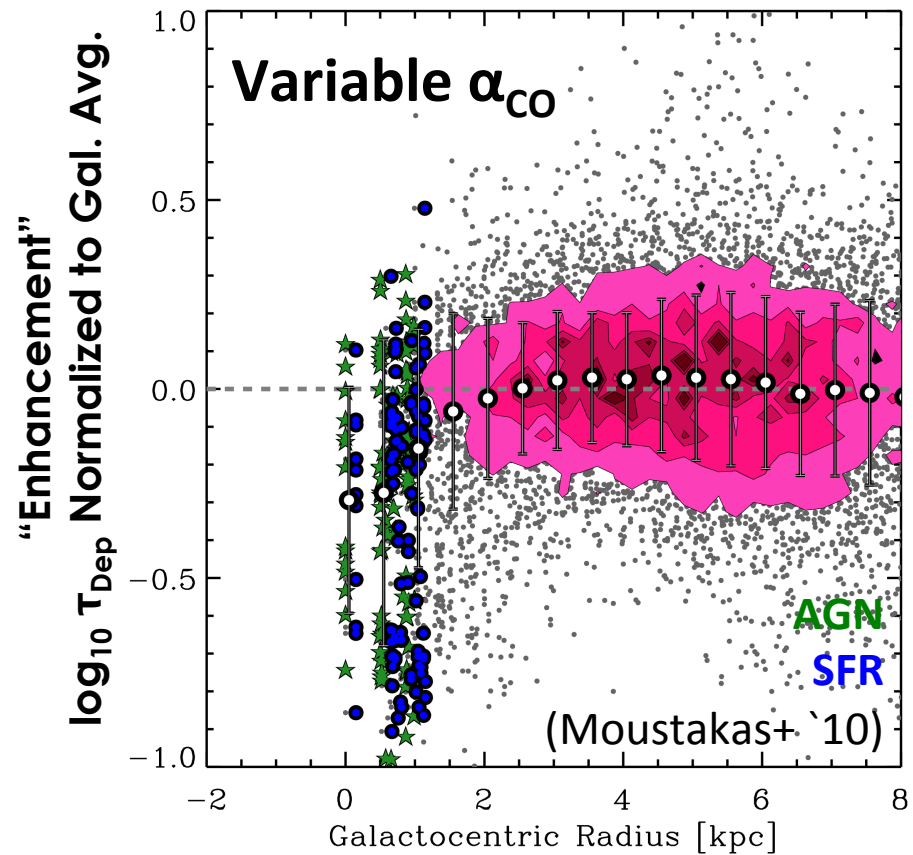
Conversion Factor?

Dust-dependent α_{CO} may explain CO/SFR variations



Each Point:
Whole-galaxy average

Star Formation and Gas

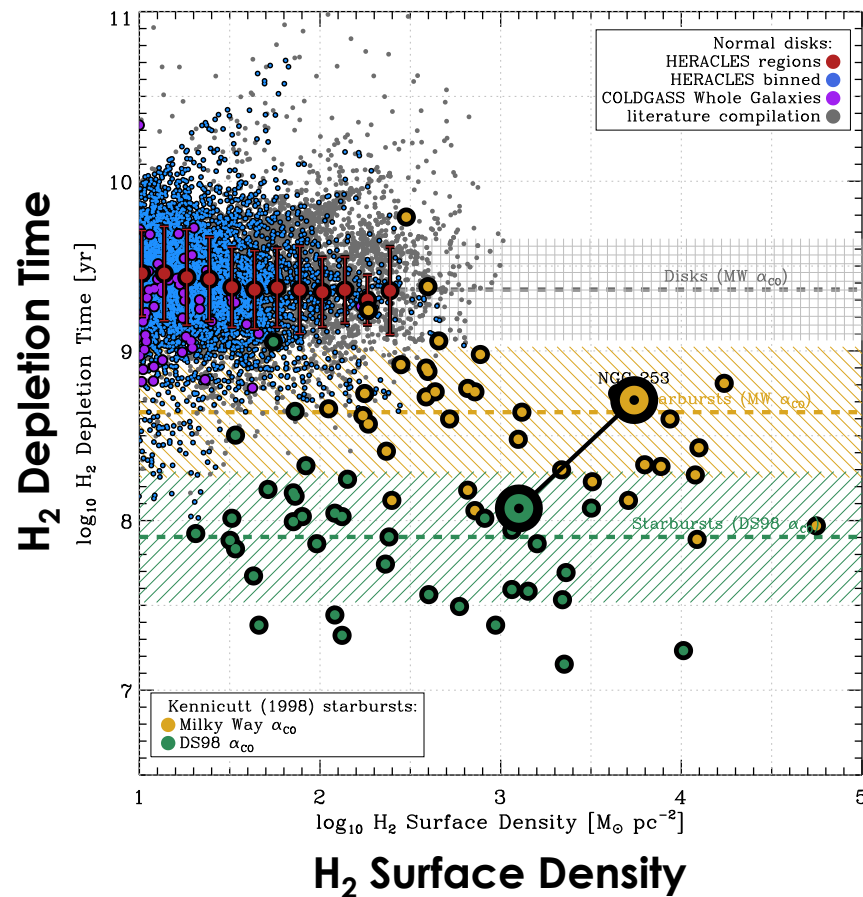


Each Point:

1 kpc resolution line of sight in a galaxy
30 galaxies combined

LEROY+ '13, SANDSTROM+ '13

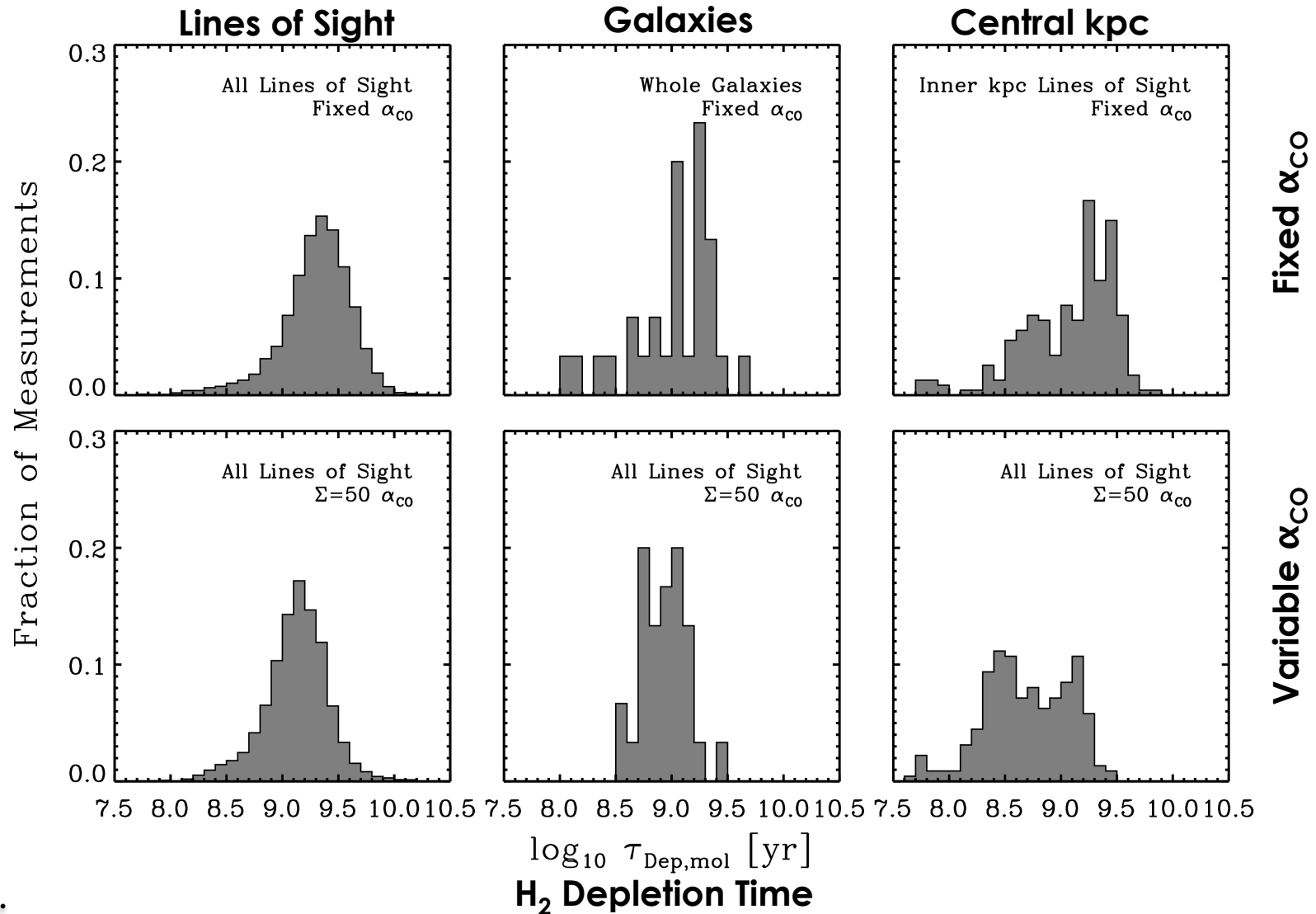
Enhanced Efficiency in Starbursts



Each Point:

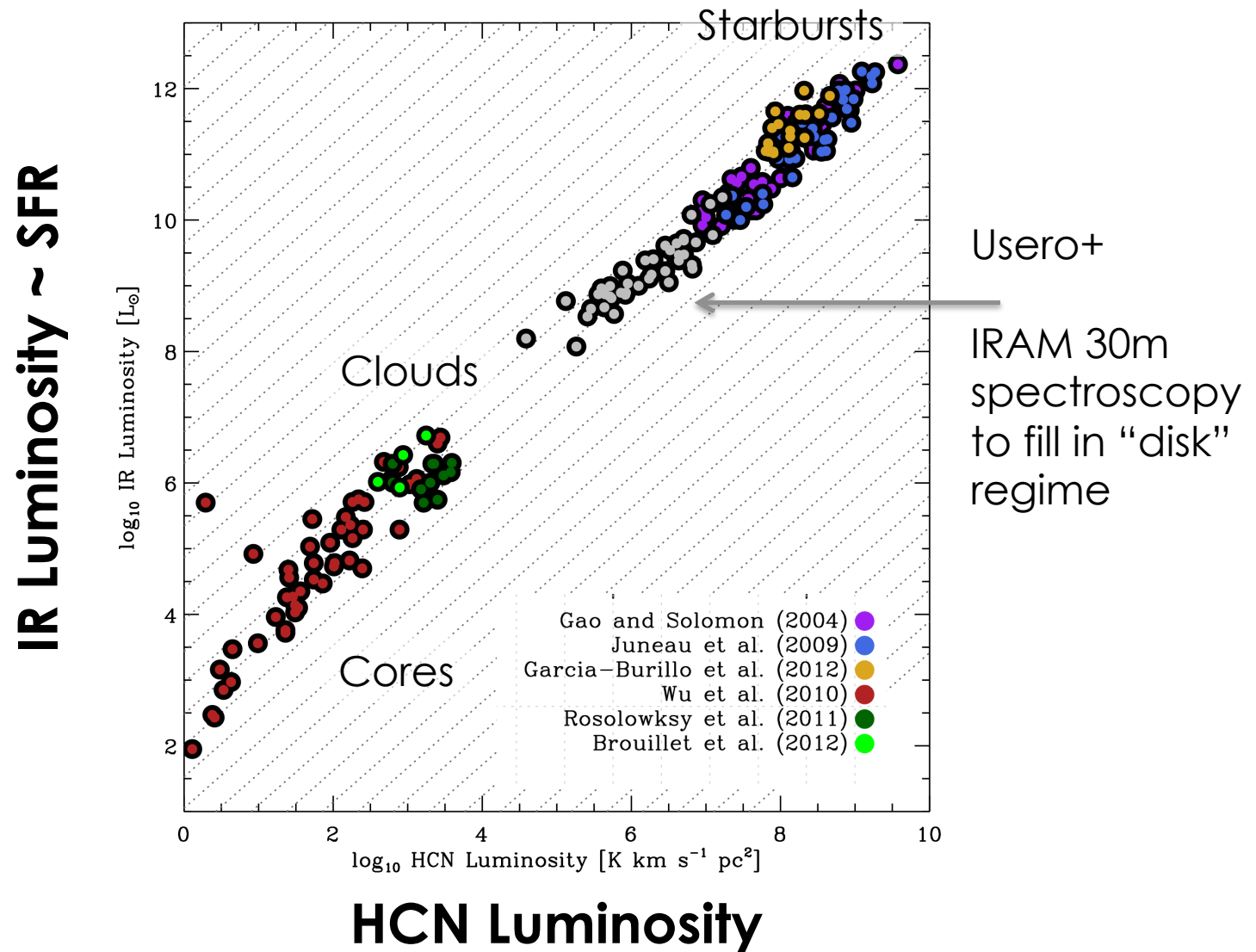
1 kpc resolution line of sight in a galaxy
COLDGASS, Kennicutt 98 Starbursts

The H₂ Depletion Time (CO/SFR) in Normal Disks



Each Point:
One literature measurement

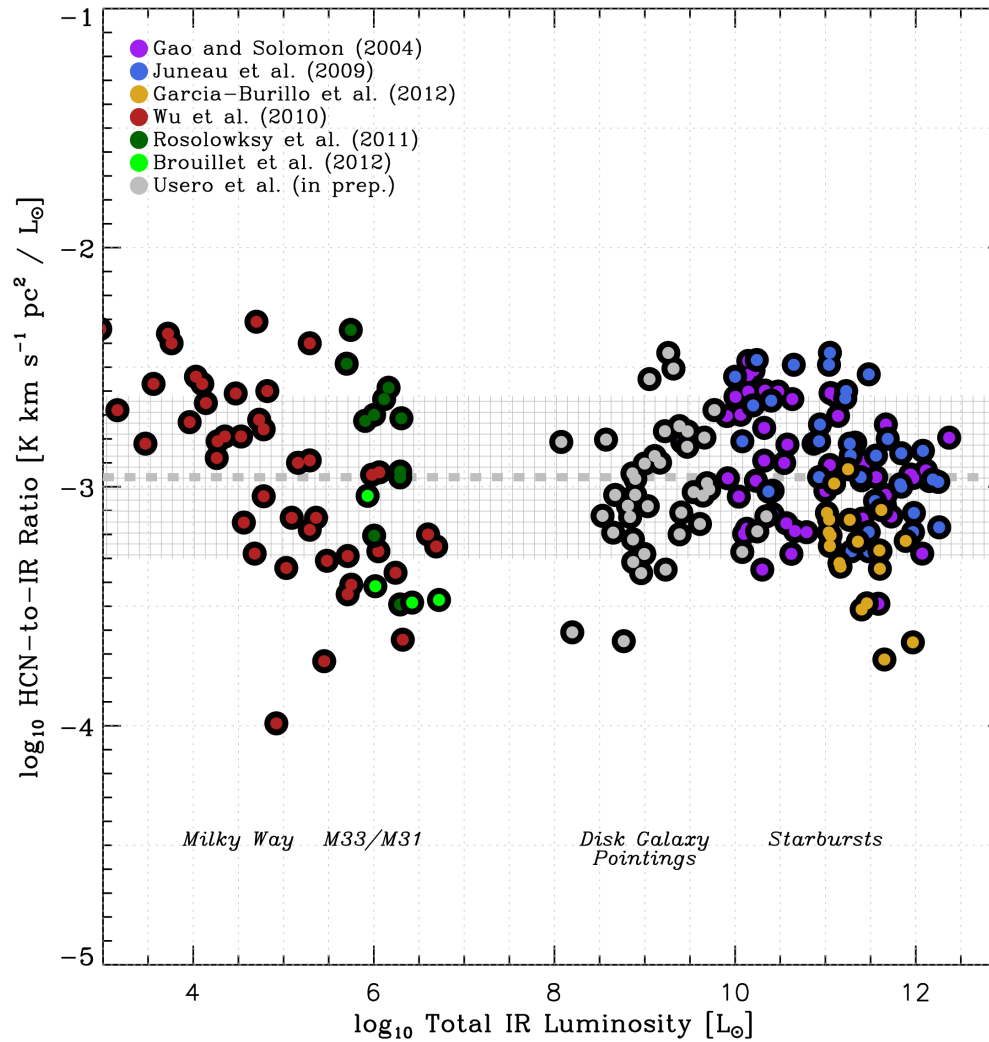
Star Formation and Dense Gas



USERO ET AL. (LEROY, SCHRUBA, GARCIA-BURILLO, SANDSTROM) IN PREP.

Dense Gas and SFR From Cores to Starbursts

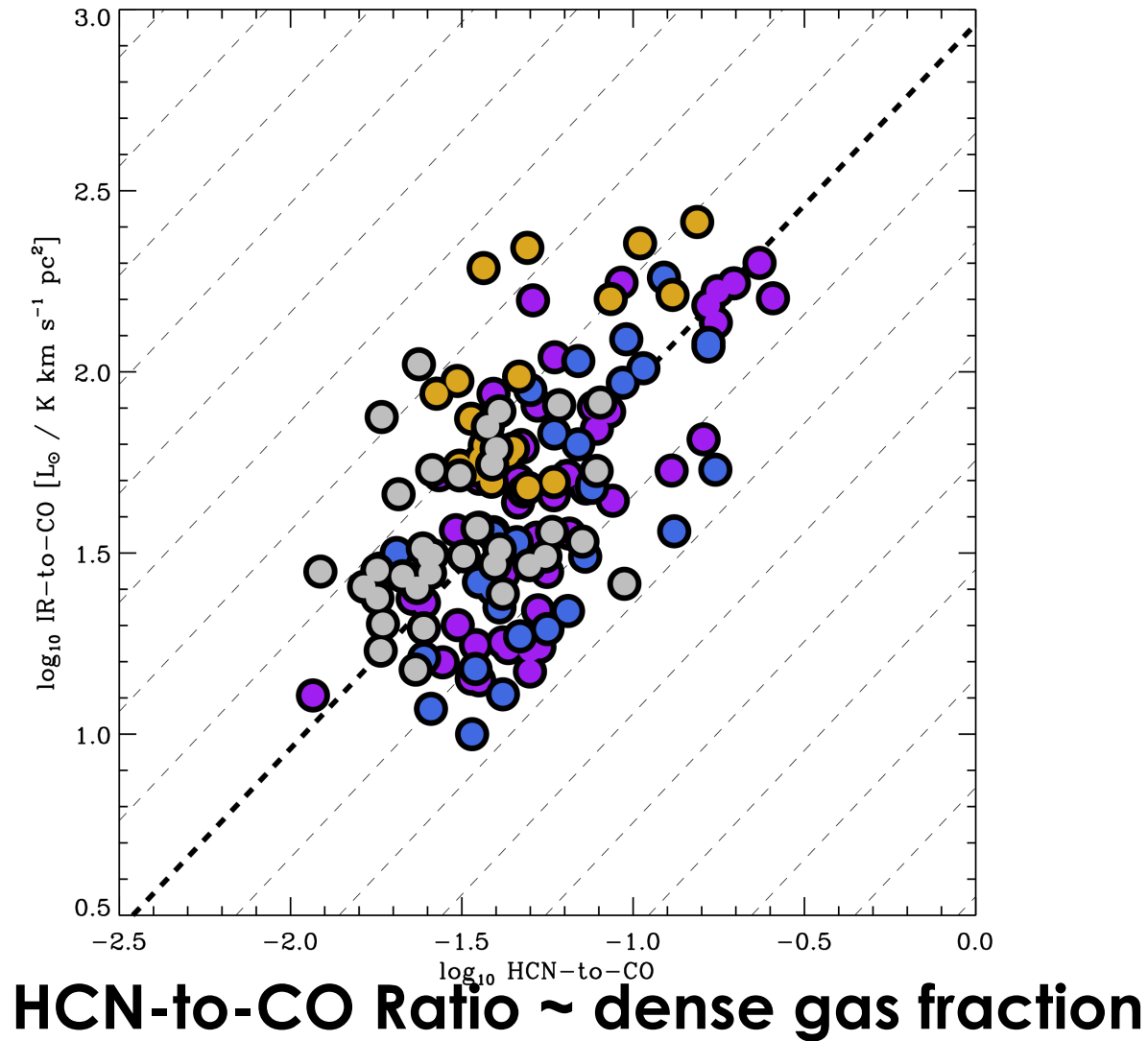
HCN-to-IR Ratio
~ dense gas efficiency



Total IR Luminosity

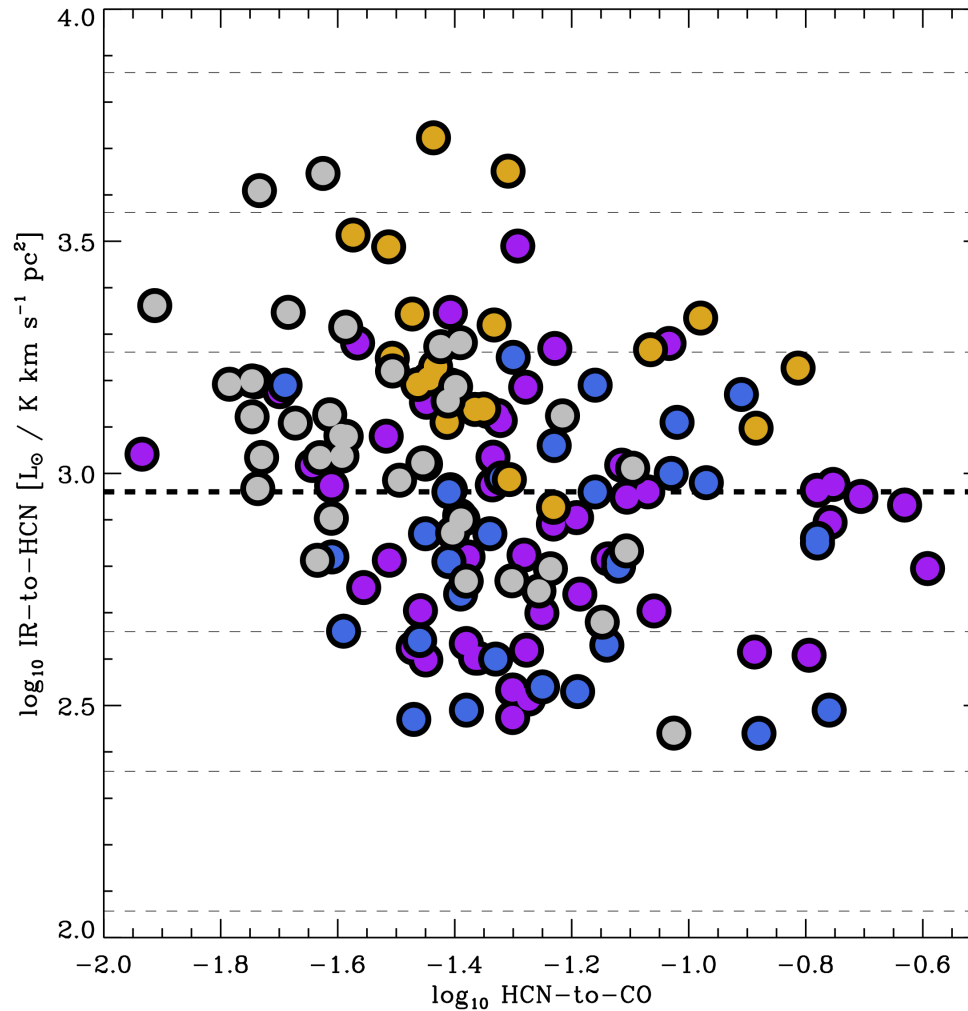
Dense Gas as the Controlling Parameter?

IR-to-CO Ratio
~ overall H₂ efficiency



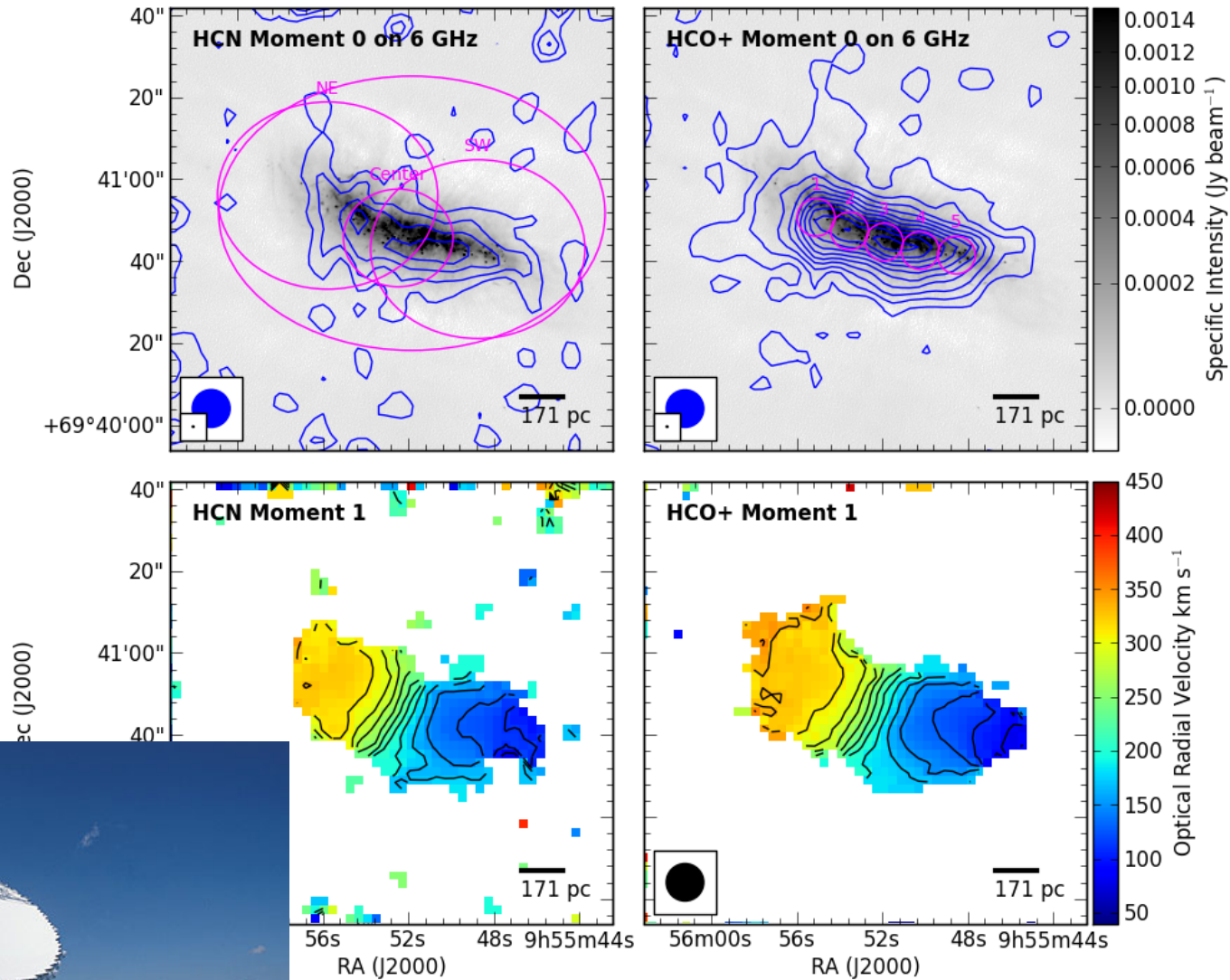
Star Formation and Dense Gas

IR-to-HCN Ratio
~ dense gas efficiency



HCN-to-CO Ratio ~ dense gas fraction

The GBT and High Critical Density Tracers



KEPLEY, LEROY, FRAYER, MARVIL TO BE SUBMITTED

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Cycle 0 views of NGC 253 and the Antennae Galaxies.

ALMA's First Look at the Nearest Starbursts



NGC 253:

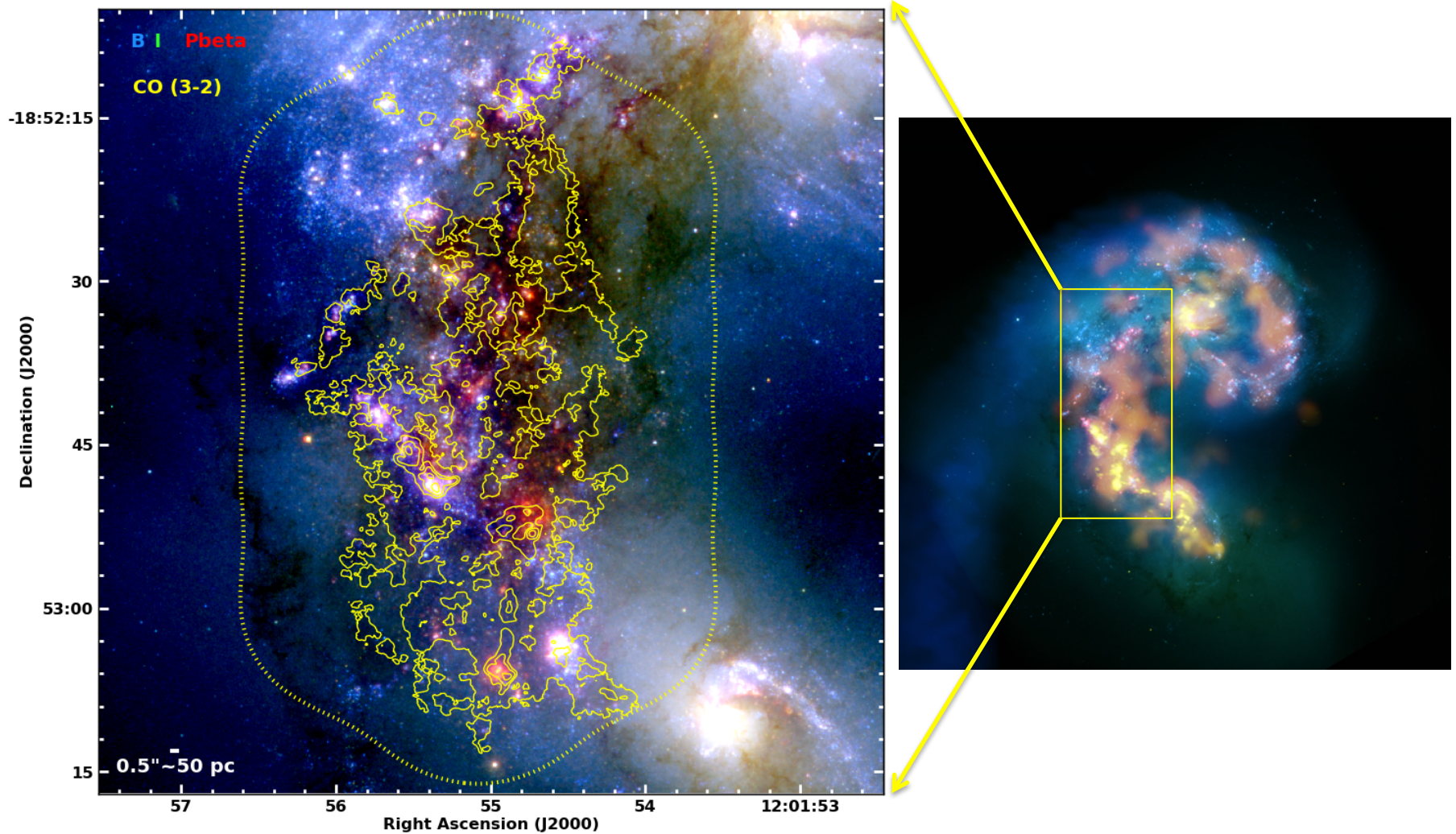
Nearest southern nuclear starburst
(PI Alberto Bolatto)

Antennae Galaxies:

Nearest major merger
(PI Brad Whitmore)

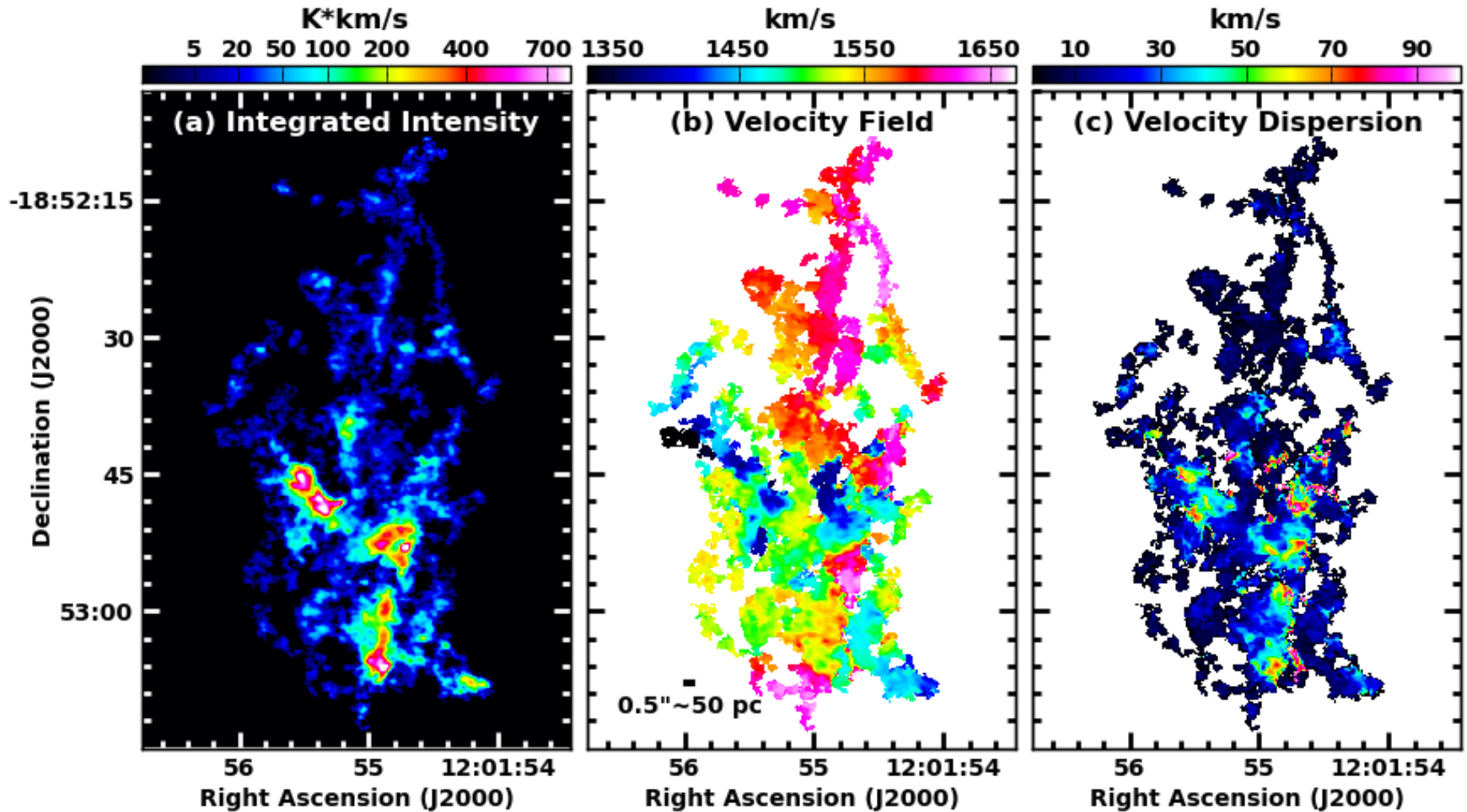


CO 3-2 in the Nearest Major Merger at 50 pc Resolution



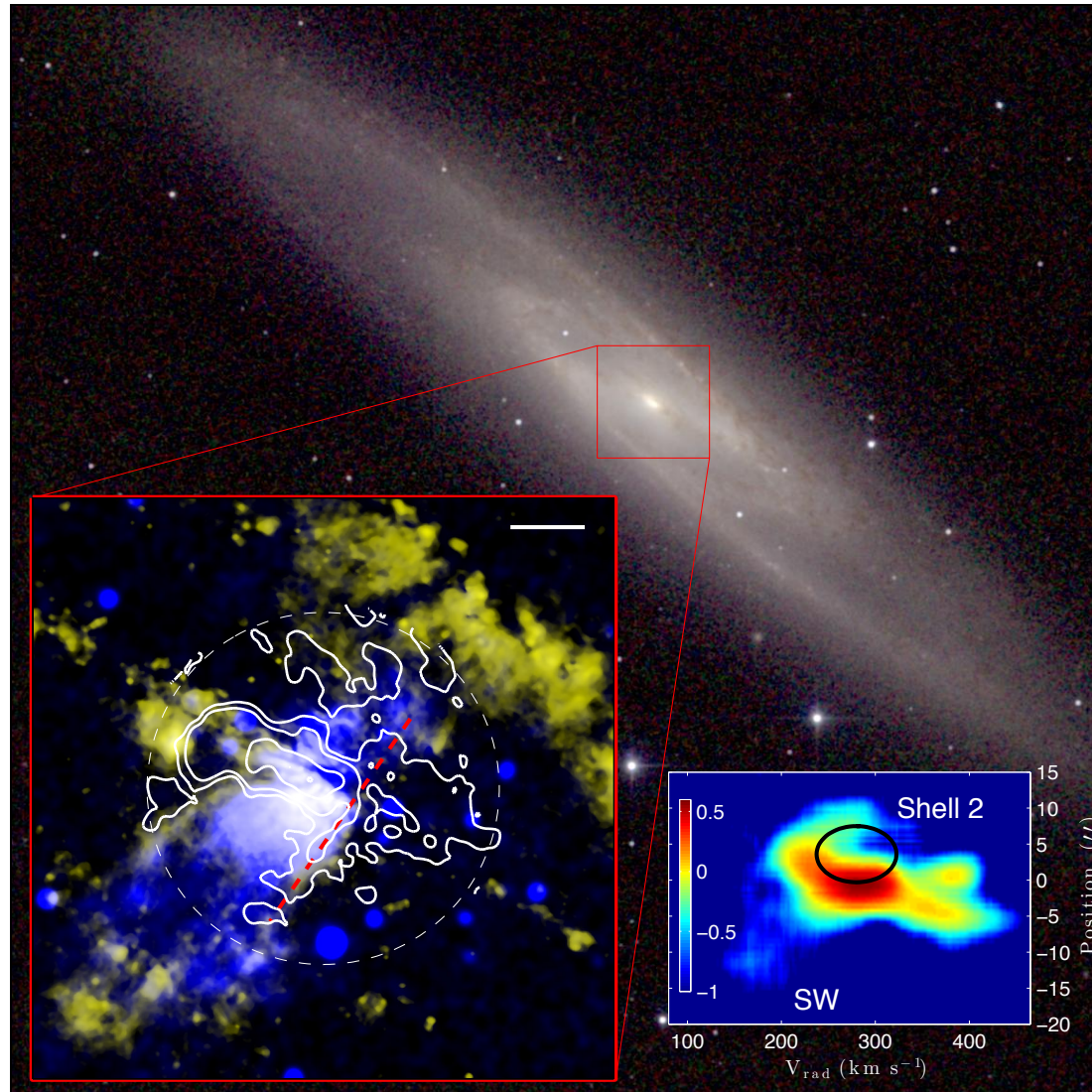
WHITMORE, BROGAN, EVANS, JOHNSON, HIBBARD, LEROY, SHETH ET AL. (IN PREP.)

CO 3-2 in the Nearest Major Merger at 50 pc Resolution



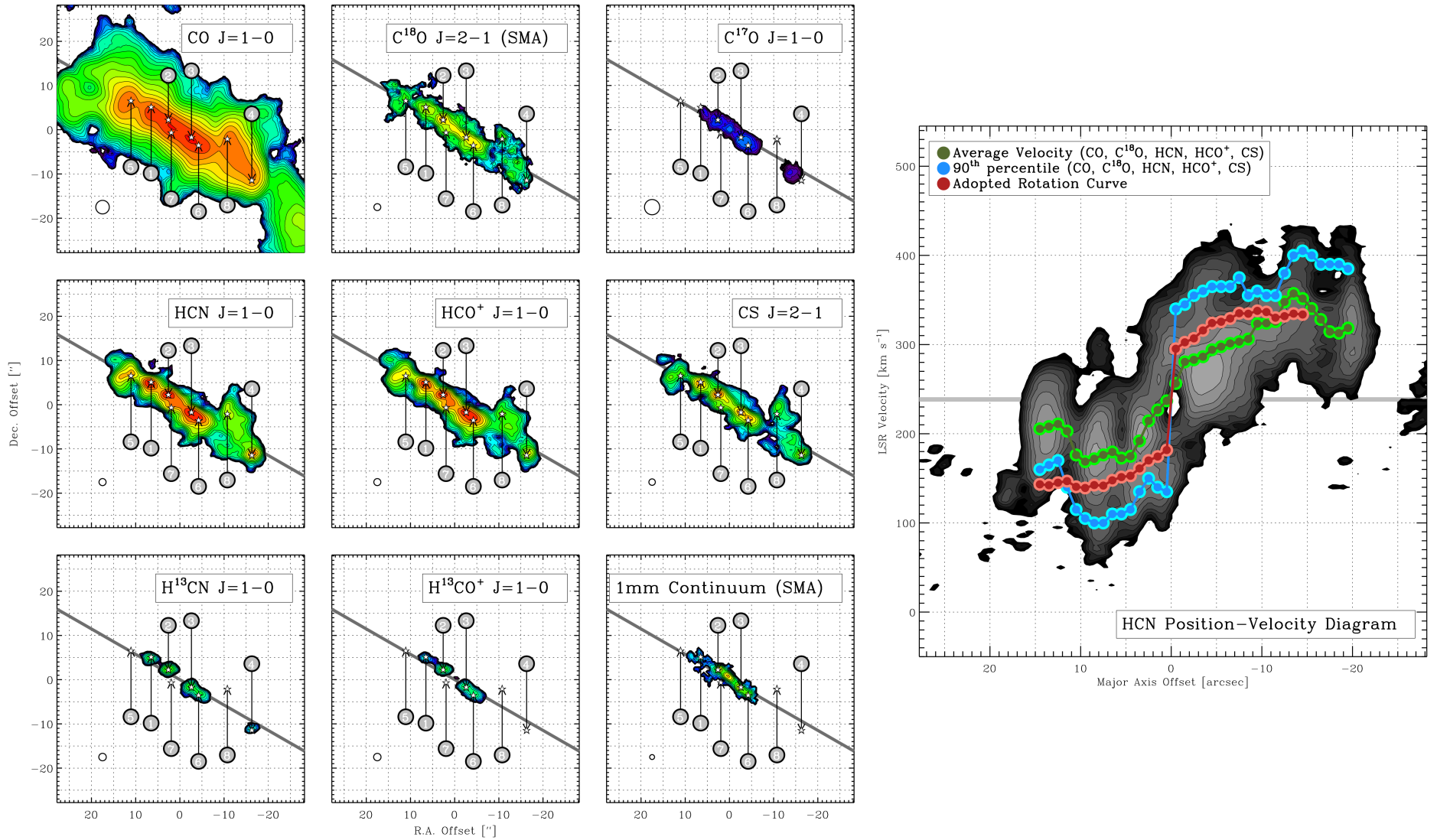
WHITMORE, BROGAN, EVANS, JOHNSON, HIBBARD, LEROY, SHETH ET AL. (IN PREP.)

The Inner kpc of NGC 253

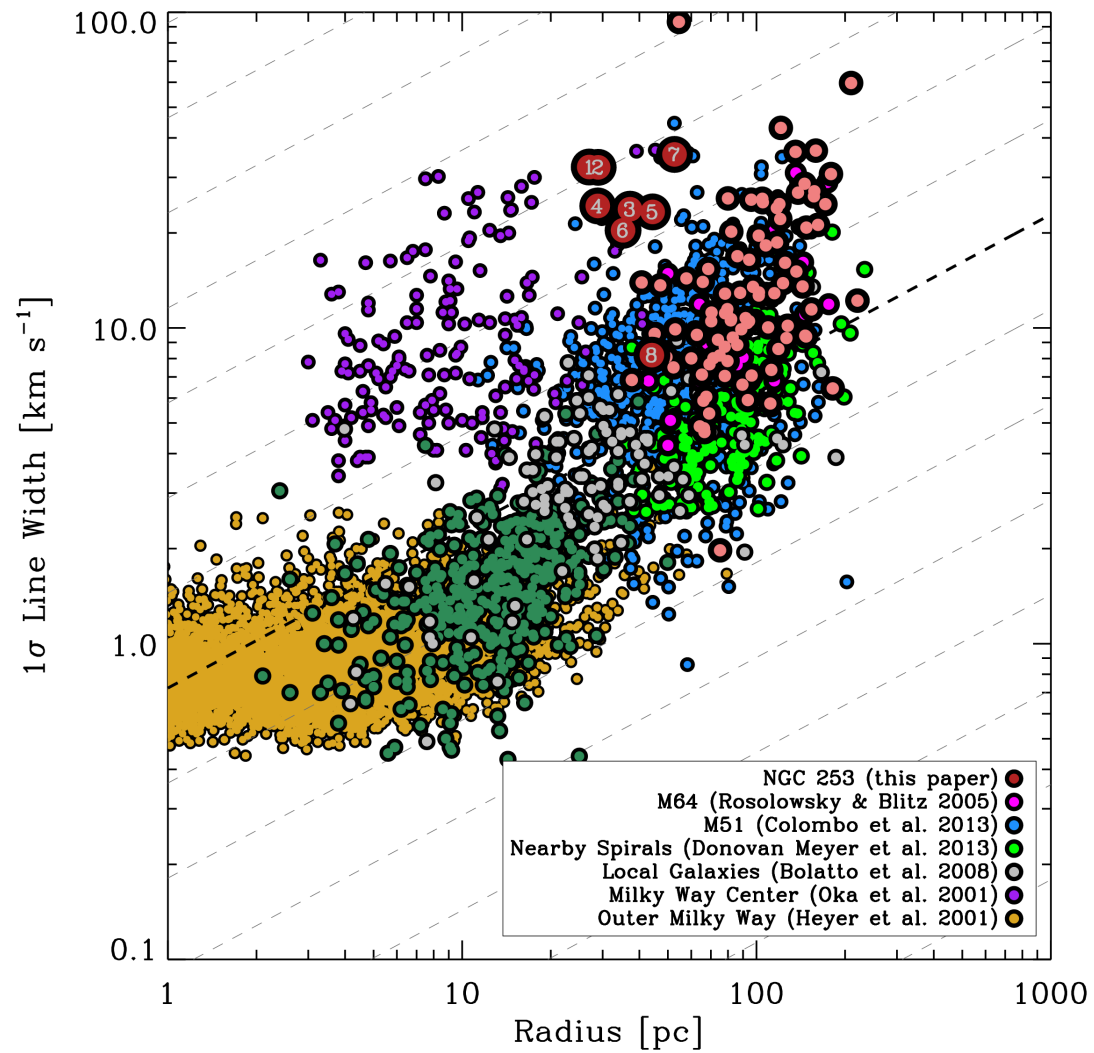


BOLATTO ET AL. (HERE LEROY, ROSOLOWSKY, OSTRIKER) – NATURE ACCEPTED

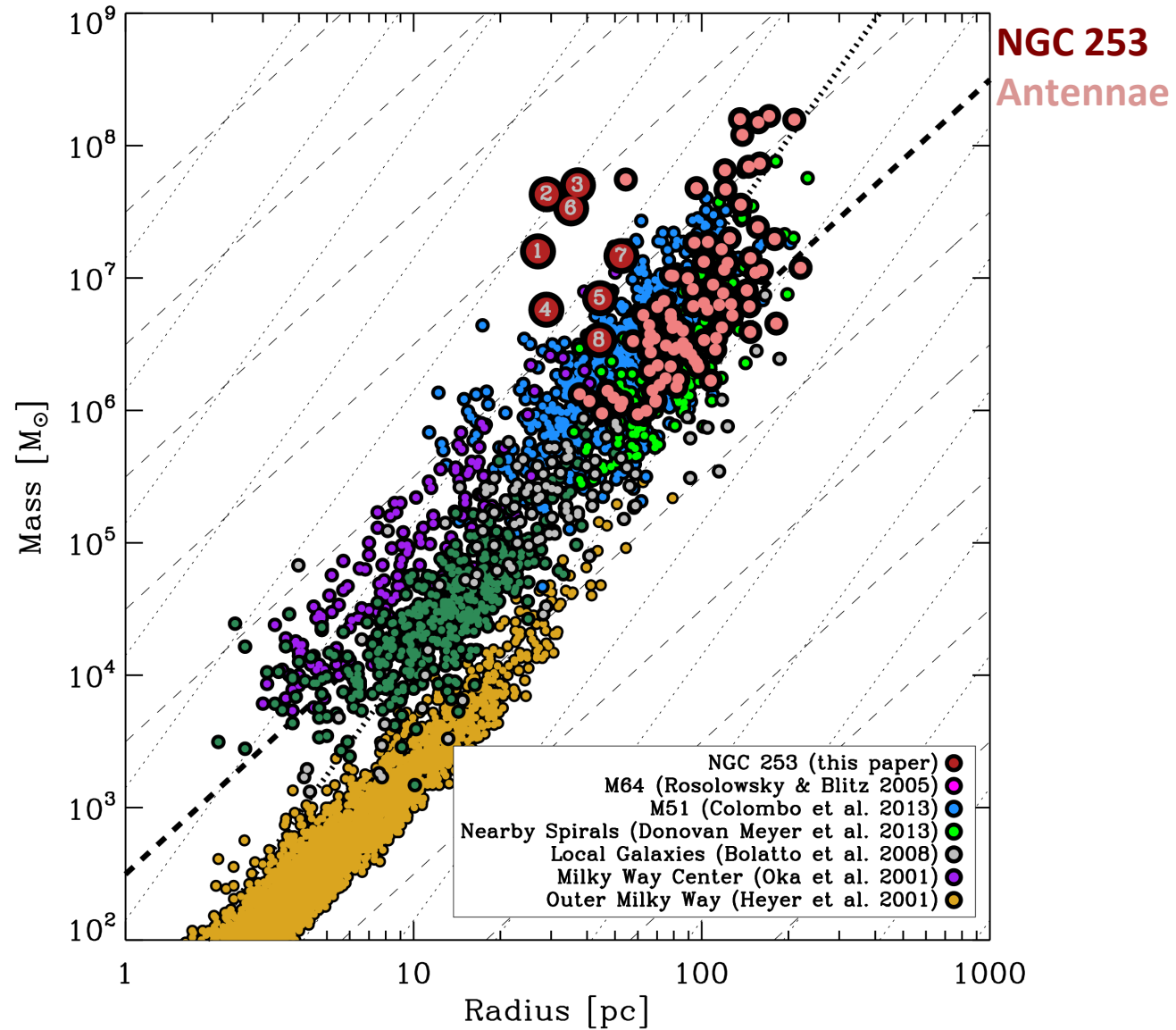
The Inner kpc of NGC 253



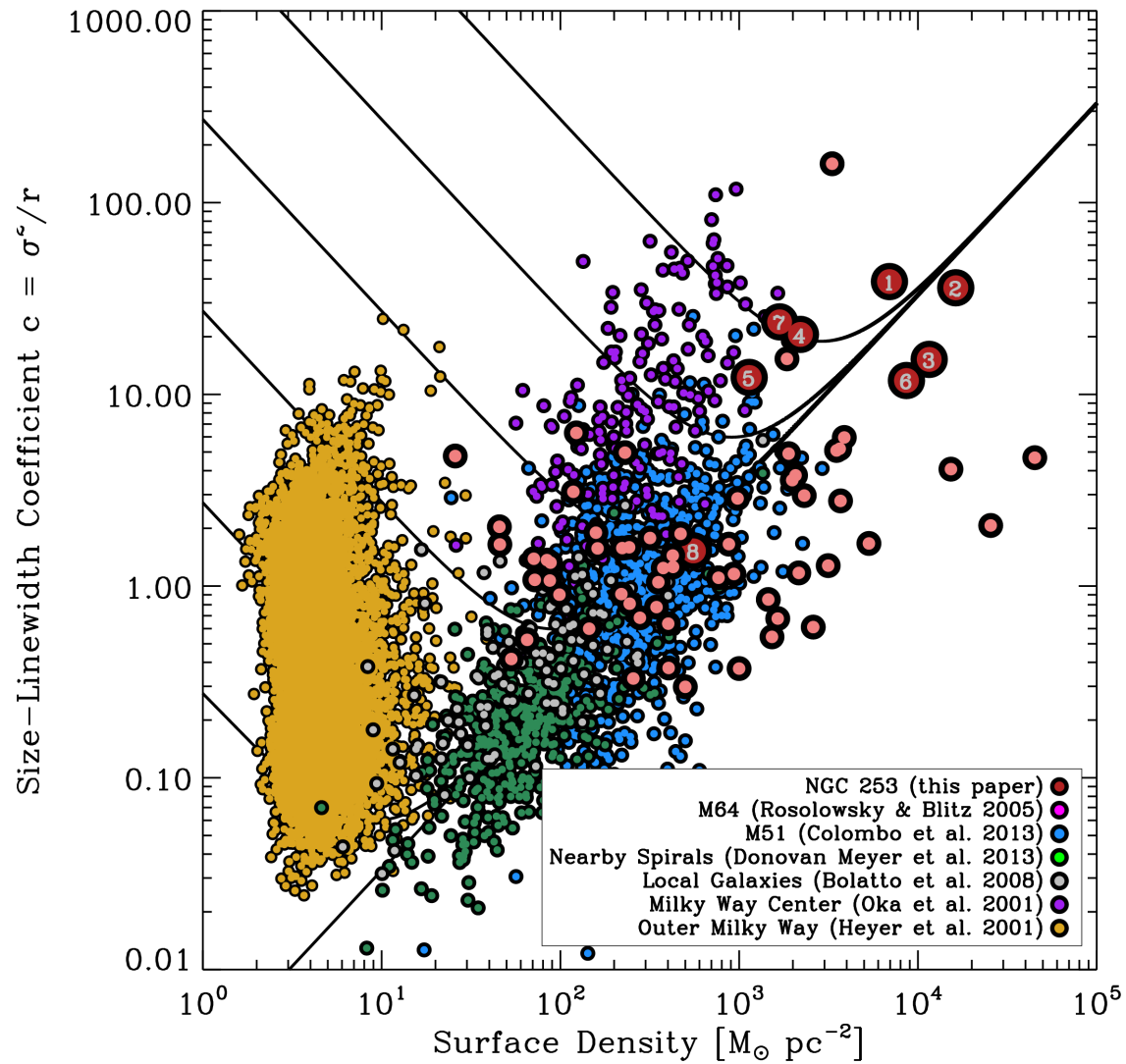
Very High Line Widths at GMC Scales



Very High Surface and Volume Densities



Very High Surface and Volume Densities



NGC 253
Antennae

NGC 253 in Context

