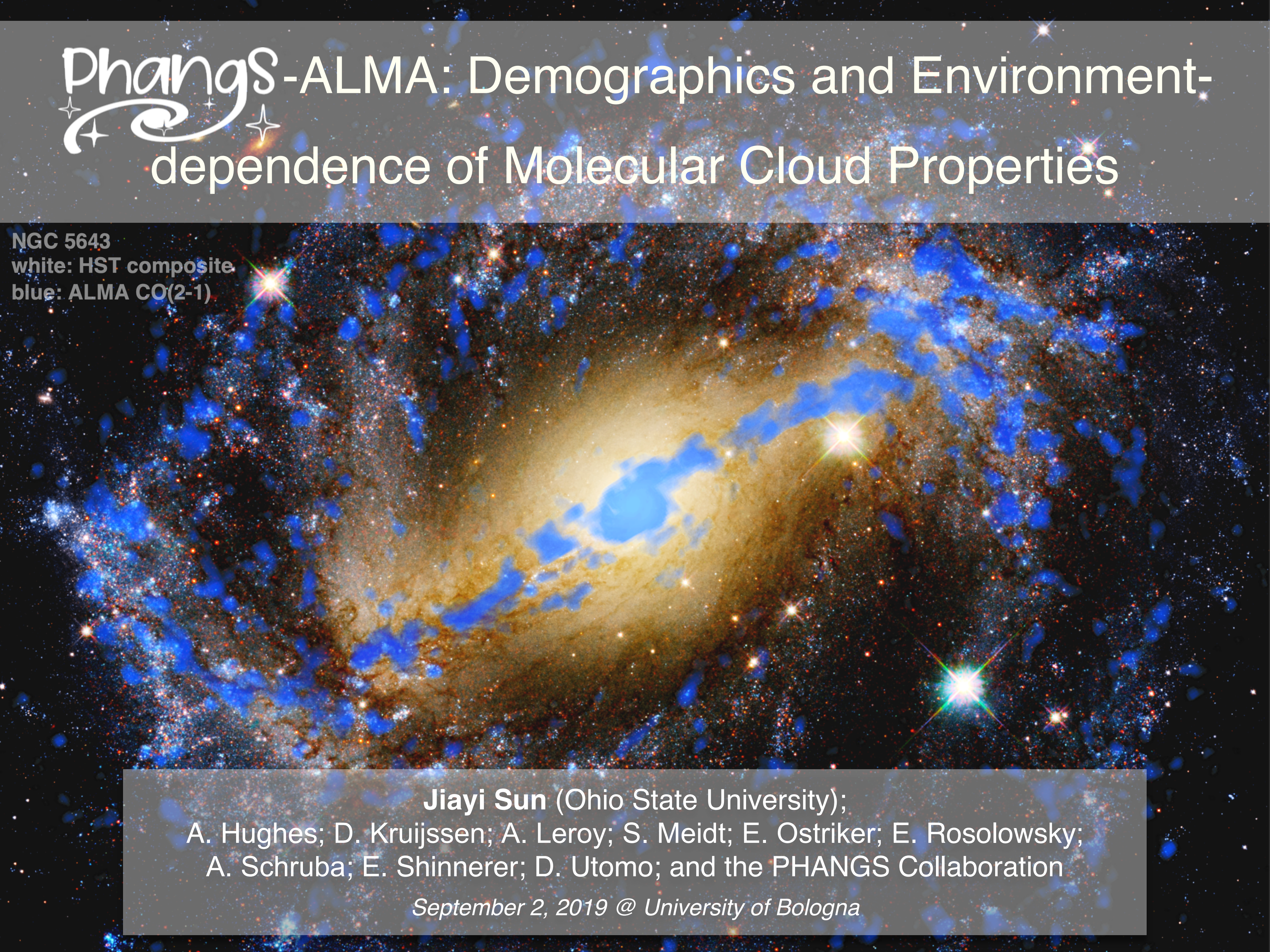
PHANGS-ALMA: Demographics and Environment-dependence of Molecular Cloud Properties



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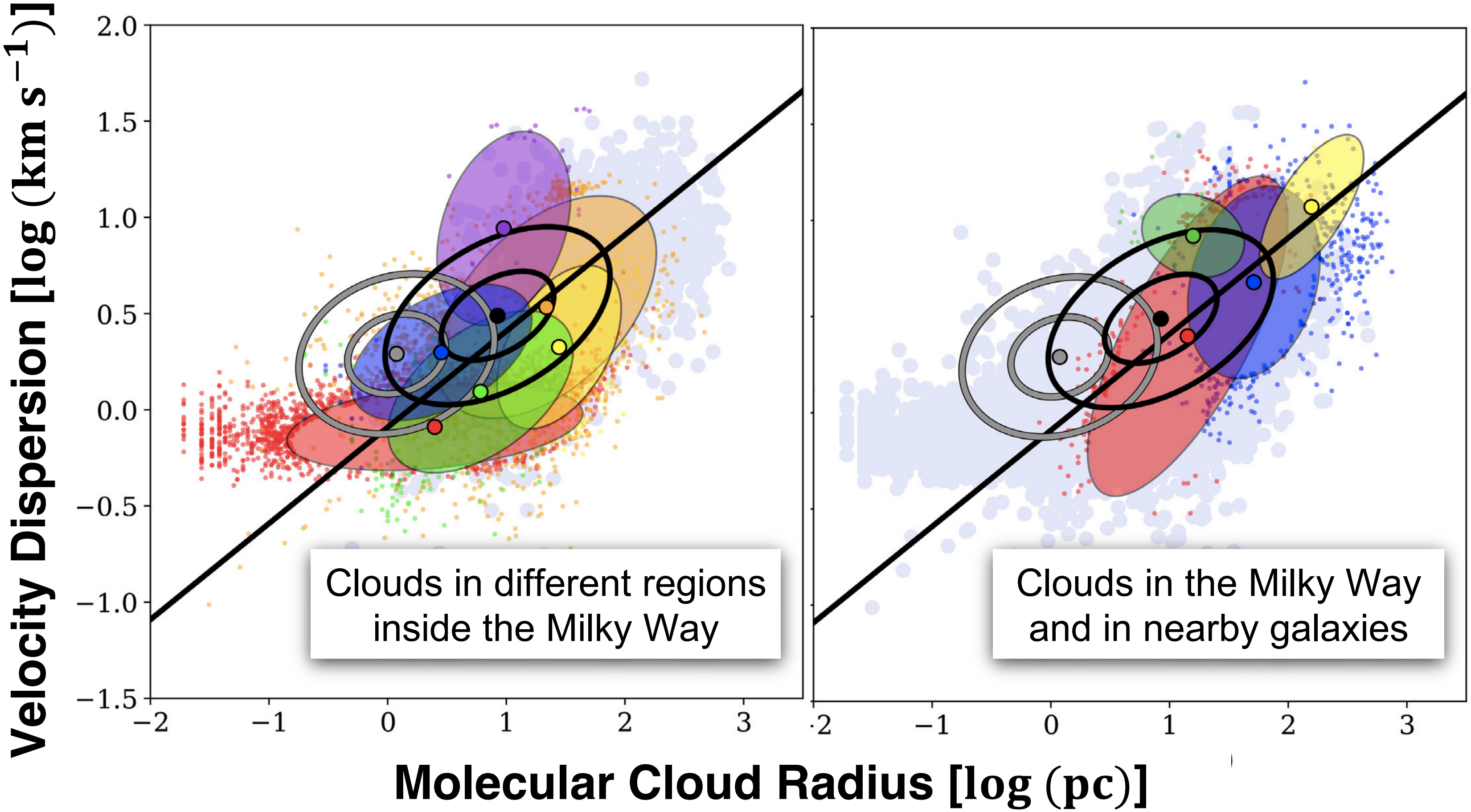
A. Hughes; D. Kruijssen; A. Leroy; S. Meidt; E. Ostriker; E. Rosolowsky;
A. Schruba; E. Shinnerer; D. Utomo; and the PHANGS Collaboration

September 2, 2019 @ University of Bologna

Molecular Clouds in Various Environments

Many comparative studies have shown that molecular clouds in different environments have systematically different properties (*Hughes et al. 2013, Leroy et al. 2016, Sun et al. 2018, Colombo et al. 2019, Schruba et al. 2019*)



Colombo et al. (2019)

Key Questions

- What is the typical range of molecular cloud surface density, velocity dispersion, virial parameter, and internal pressure in a local star-forming galaxy?

- How do these molecular cloud properties vary, within a galaxy and among galaxies?

- Do these cloud properties correlate with any local environment properties?

- What is the physical driver behind such correlations?

PI: E. Schinnerer (MPIA) *Image Credit: F. Santoro (MPIA), A. K. Leroy (OSU)*

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Sun et PHANGS 2018, ApJ, 860, 172 (pilot sample)
Sun et PHANGS 2020, in preparation (full sample)

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Methodology: Uniform, Non-parametric, Reproducible

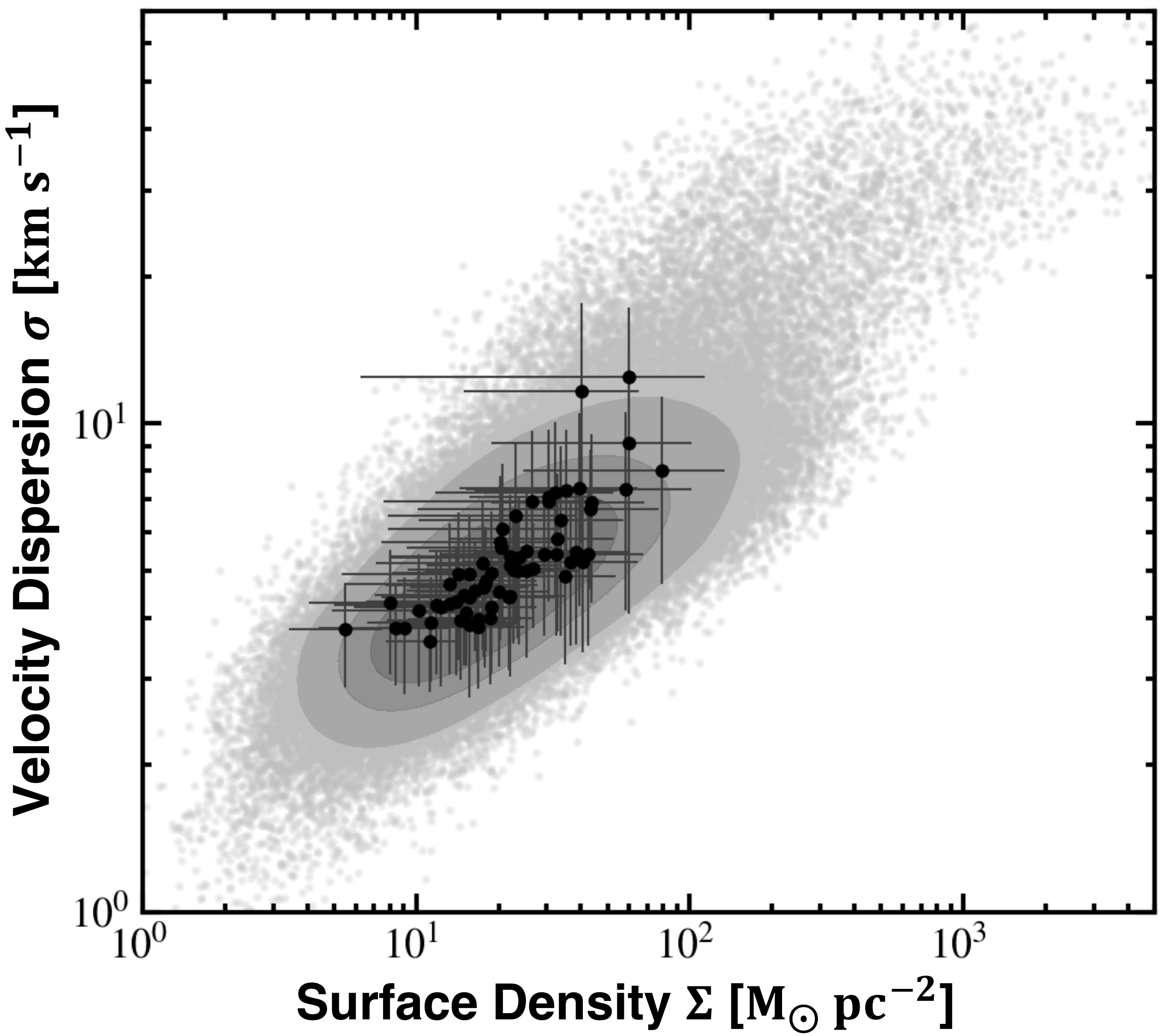
1. Convolve CO maps to a set of **common spatial resolutions** (i.e., beam FWHM => 60-150 pc)

2. Measure **CO line width** and **integrated intensity** for the gas structure **in each cloud-size beam**

3. CO line width => mol. gas **velocity dispersion**
   CO line intensity => mol. gas **surface density**
   (adopting either a constant, Galactic CO-to-H_2 conversion factor or a varying, Z'-dependent one)

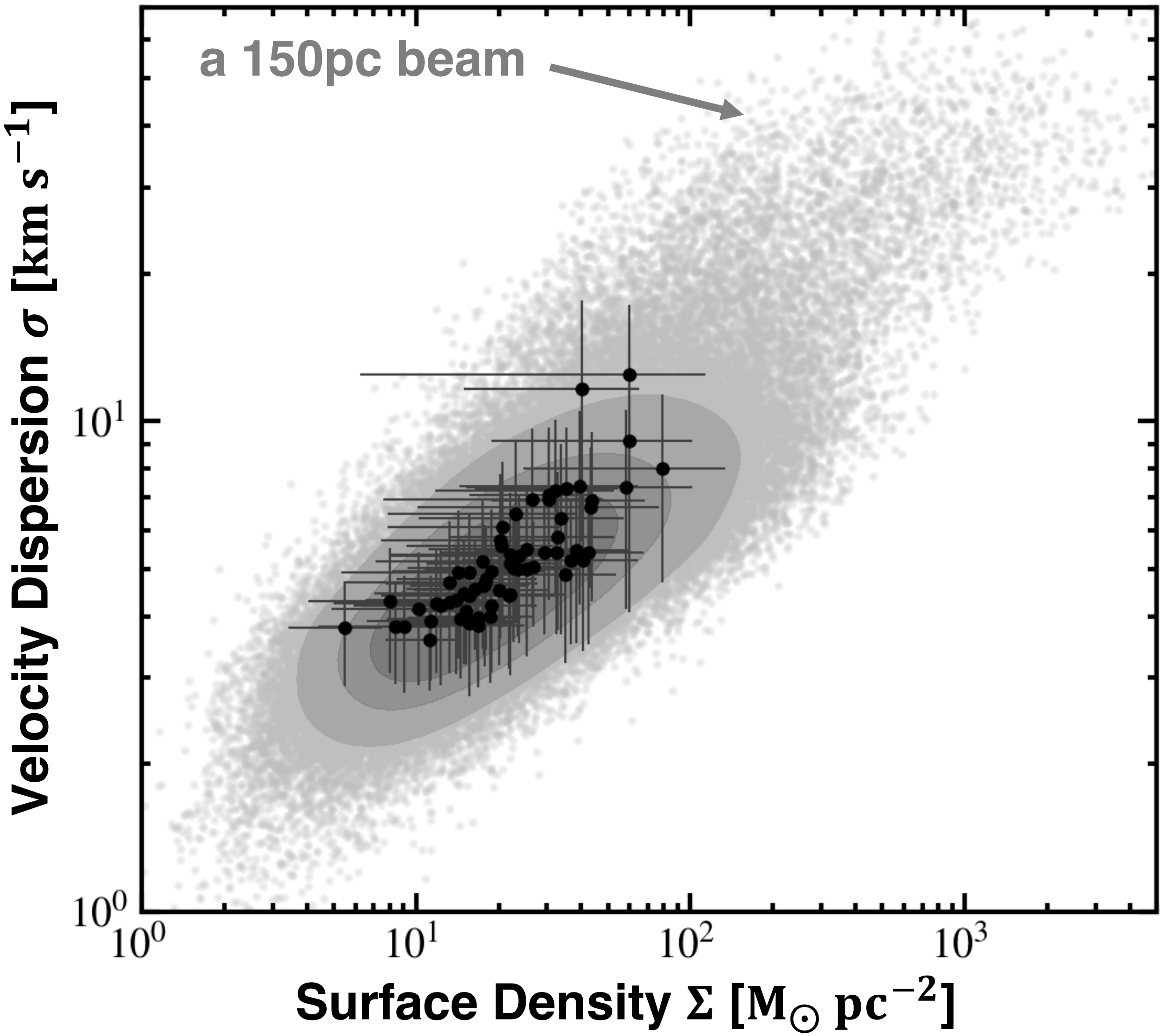
Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

Surface Density – Velocity Dispersion Relation



Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

Measurements on 60-150pc (GMC/GMA) Scale



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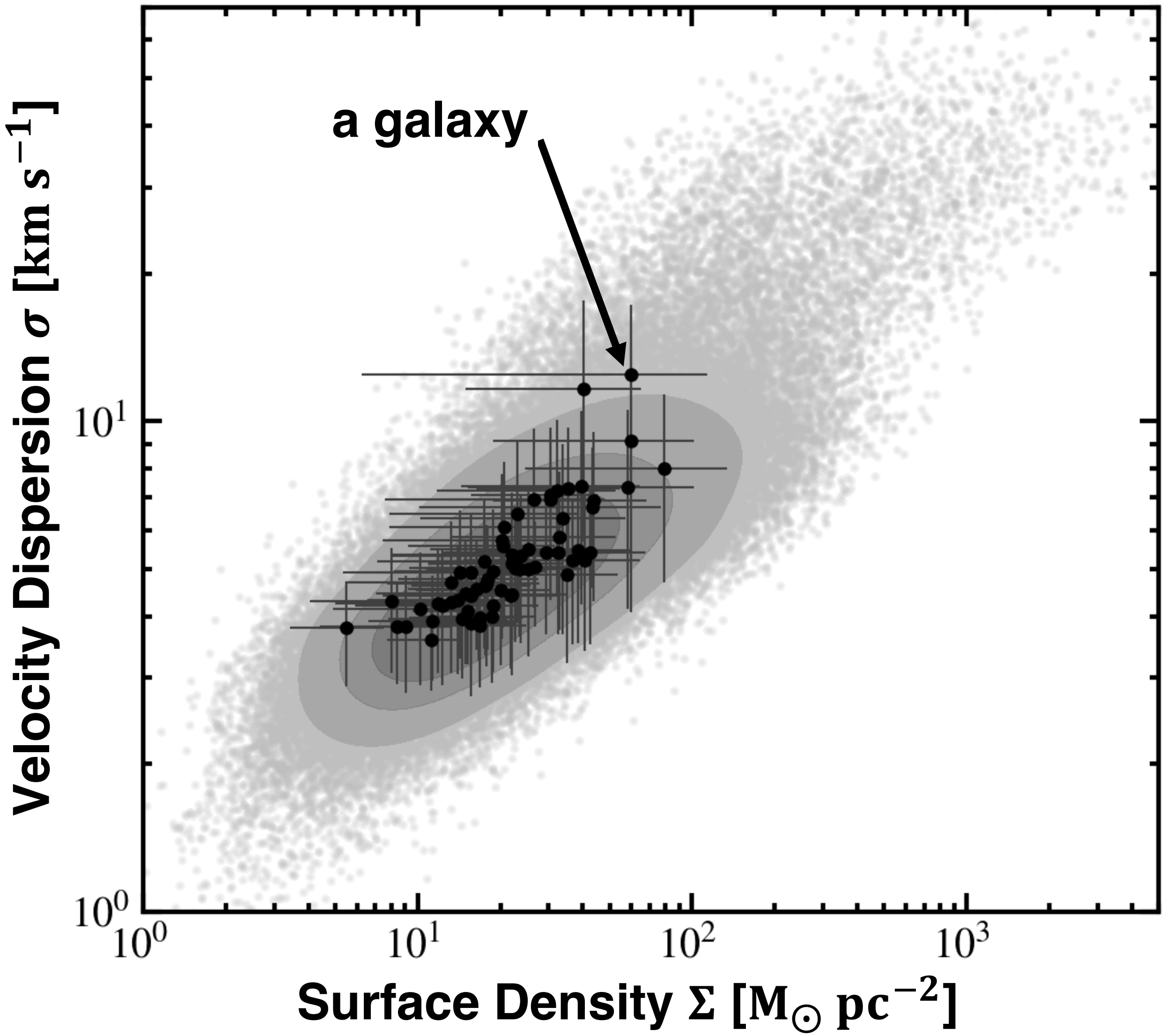
Median and 1σ Range within Each Galaxy



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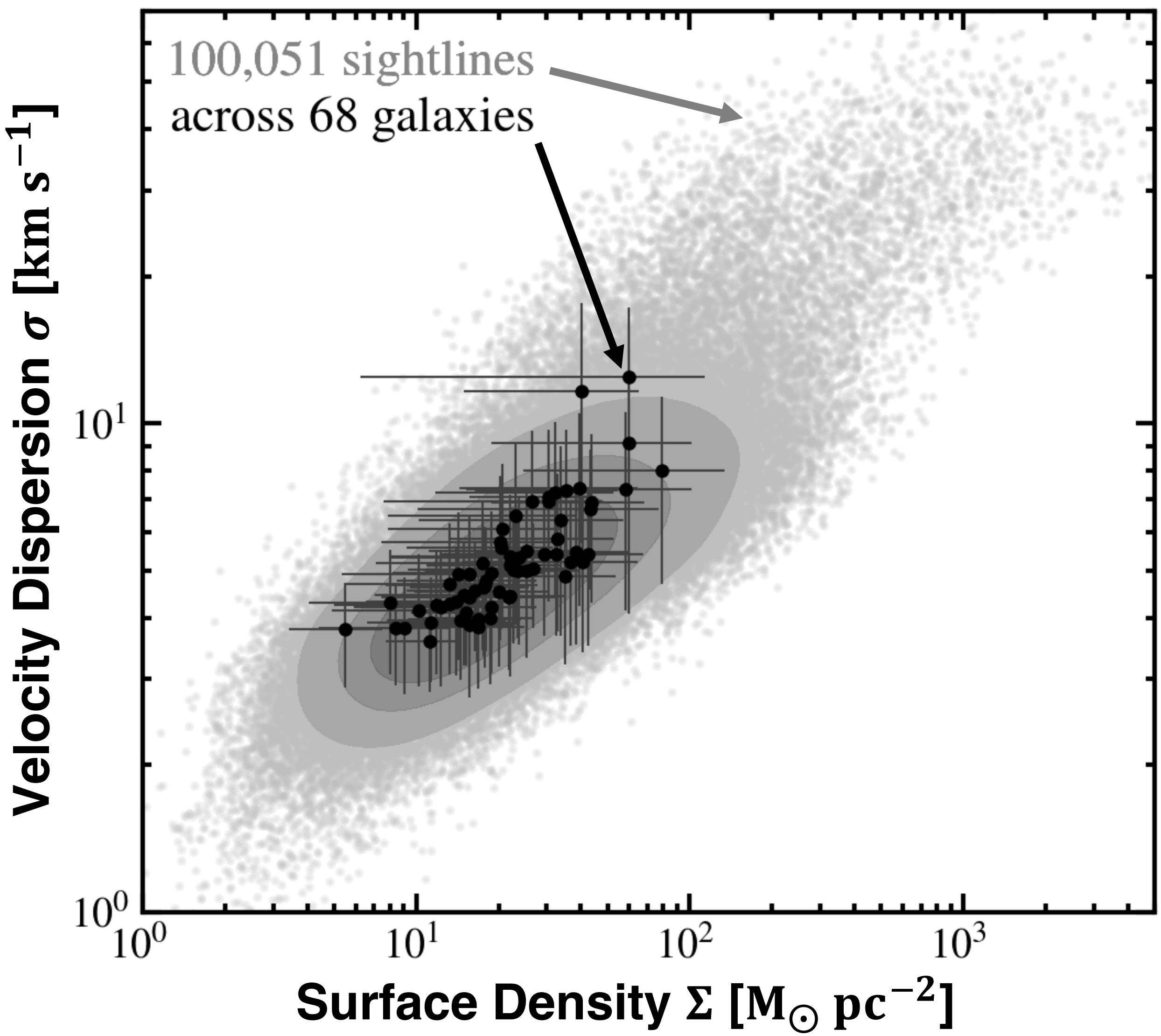
Huge Sample & Homogeneous Data



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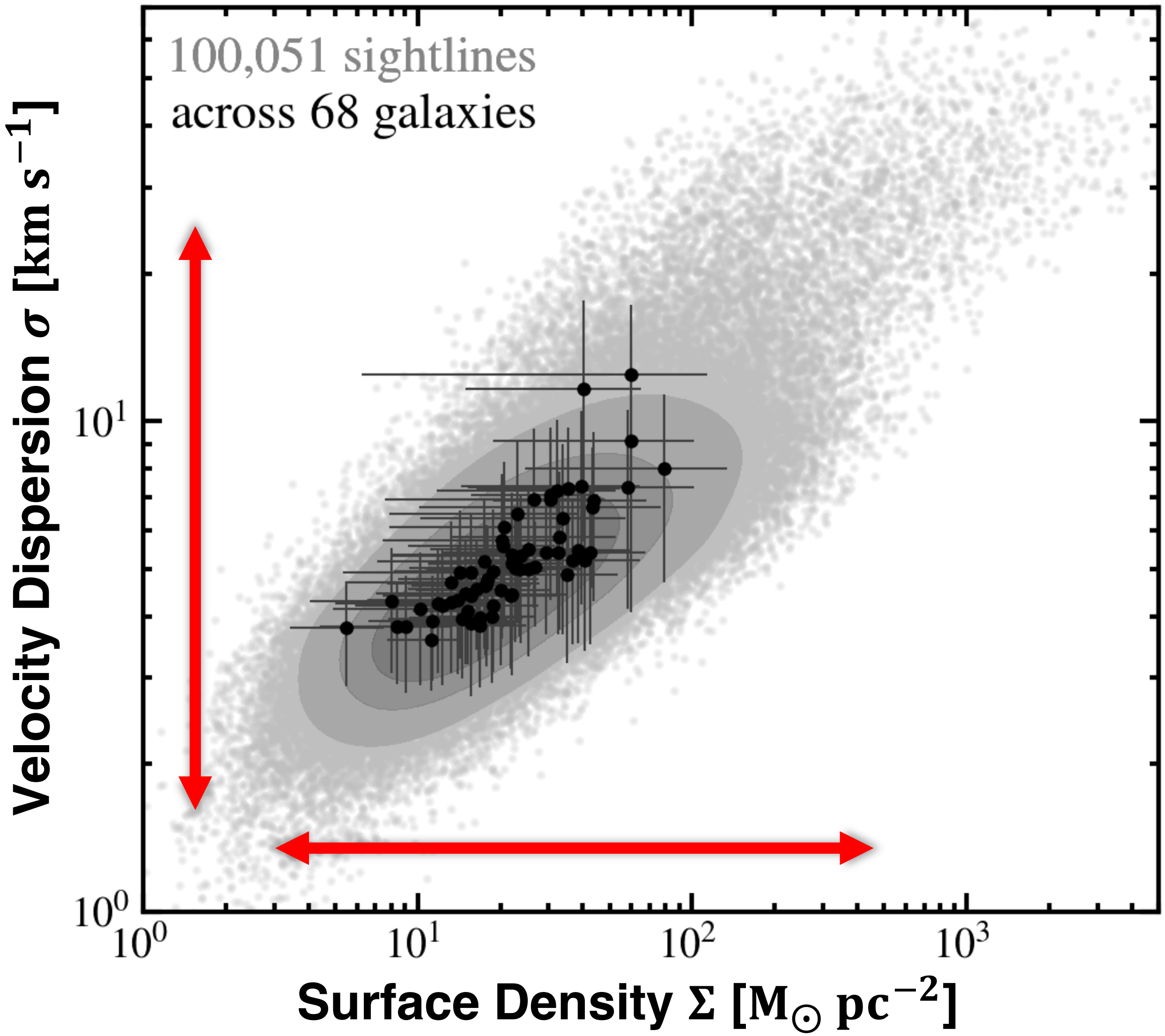
Clear Variations along Both Axes



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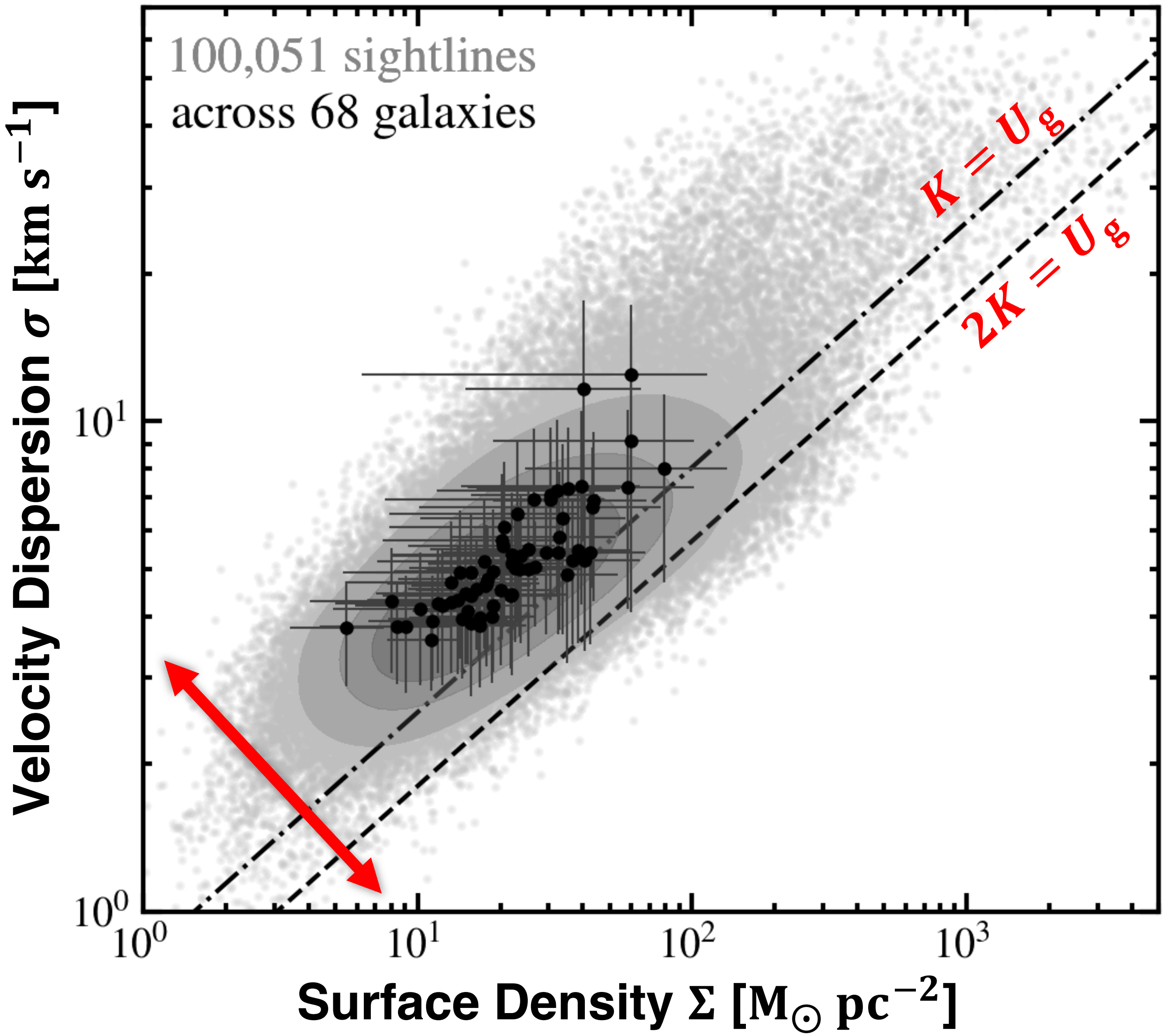
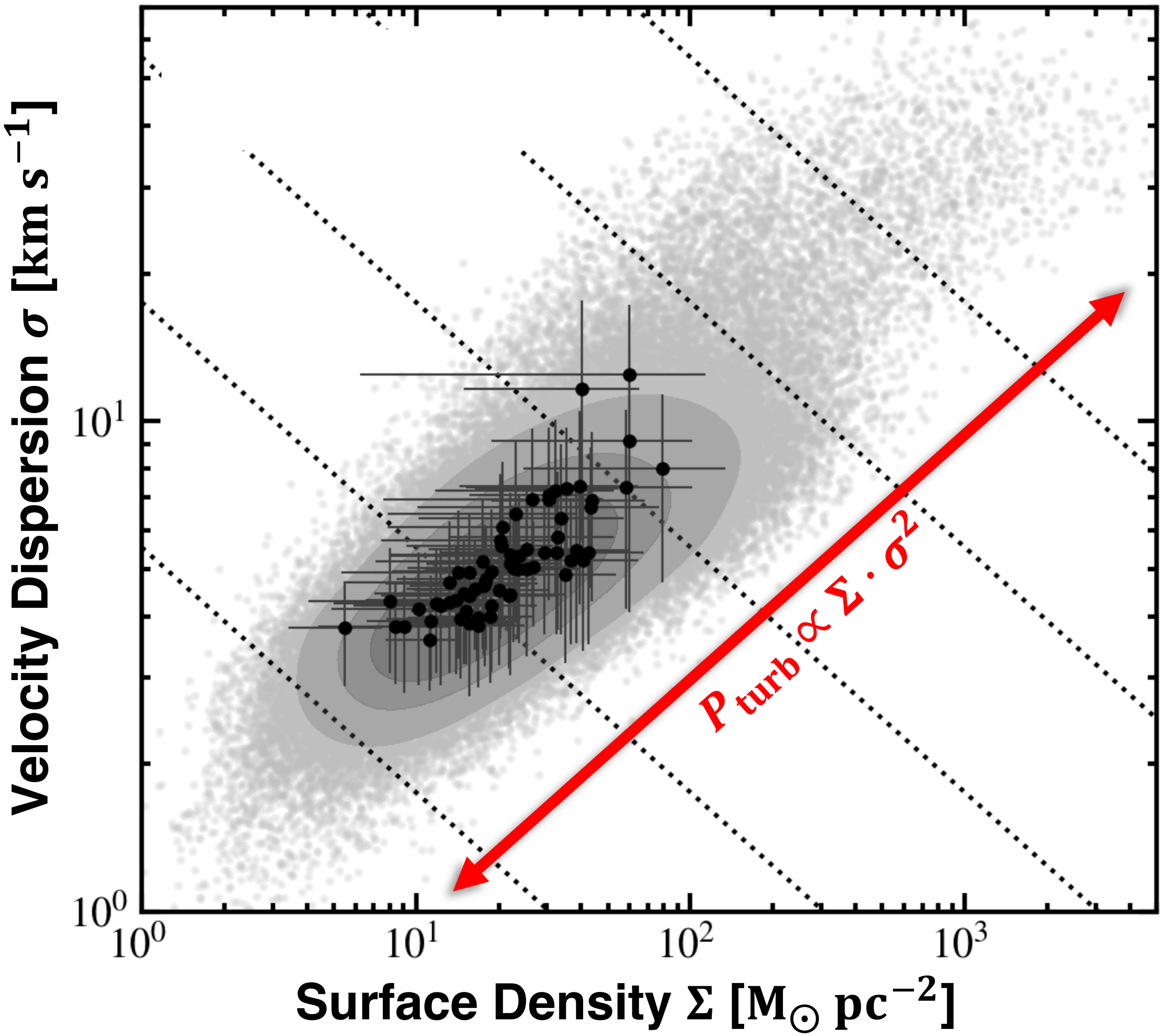
Most Points Locate just above Energy Equal-partition



Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

Wide Range of Gas (Internal) Turbulent Pressure



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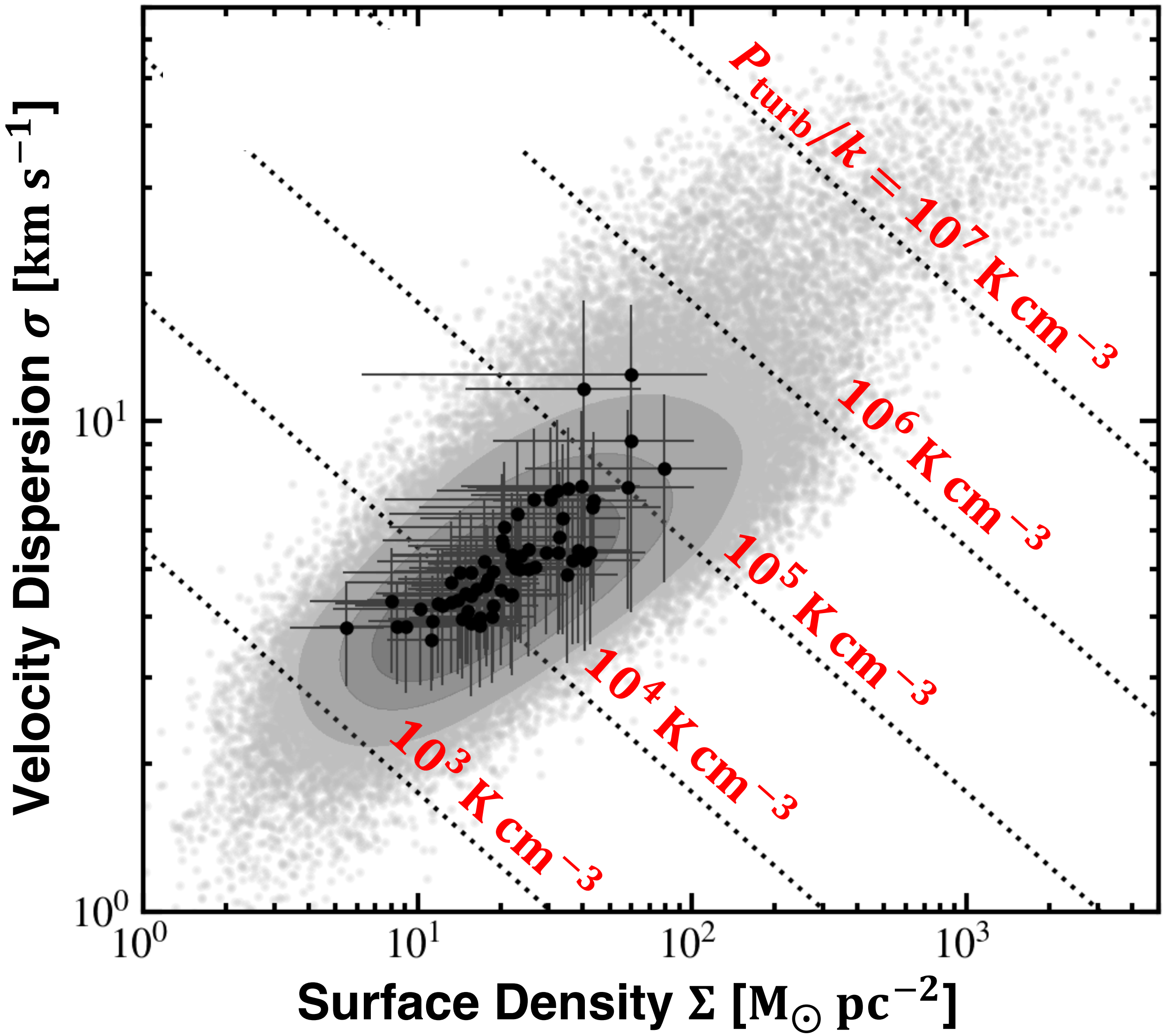
Variation in Turbulent Pressure > 4 dex



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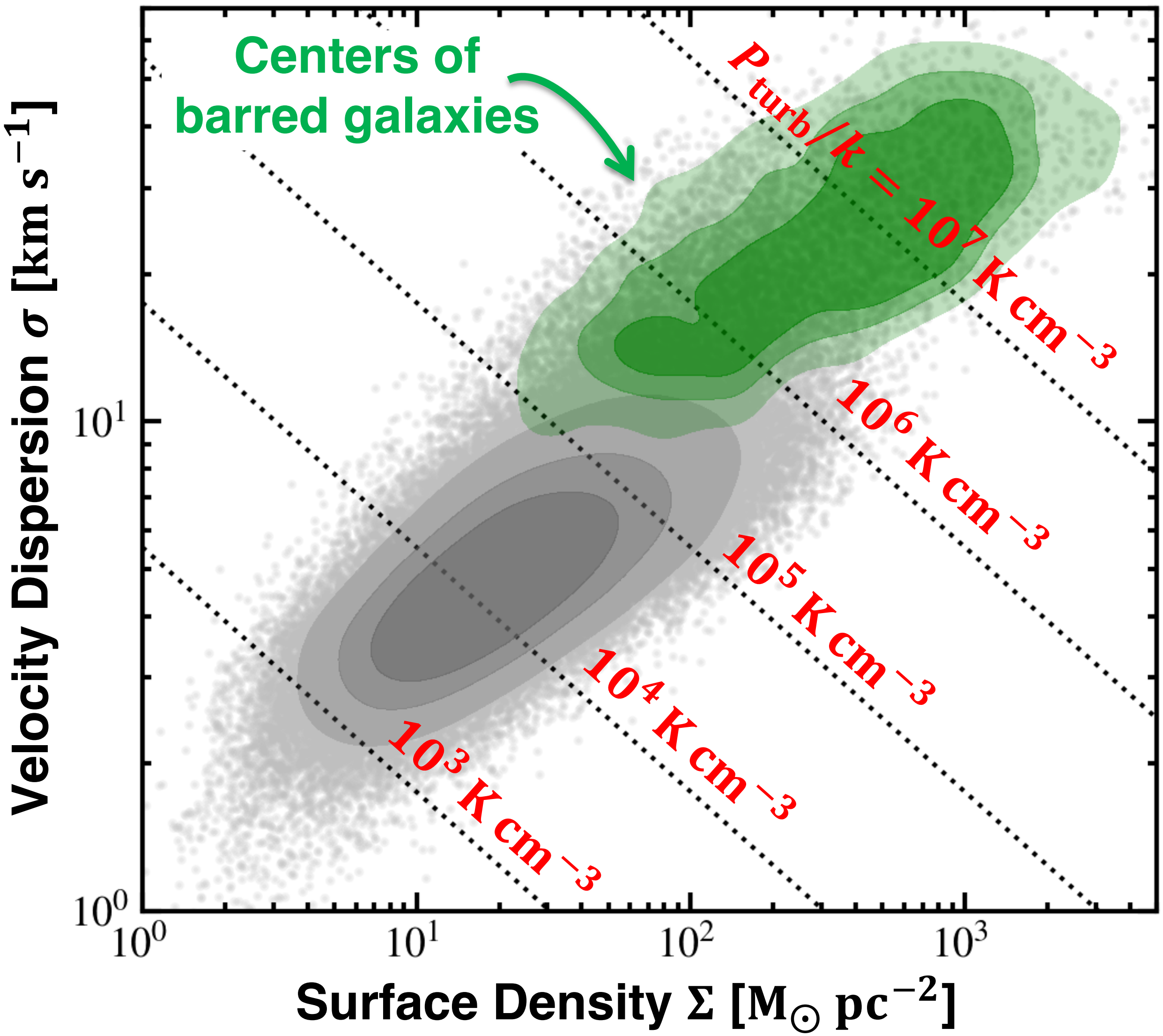
Higher Pressure Gas in the Centers of Barred Galaxies



Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

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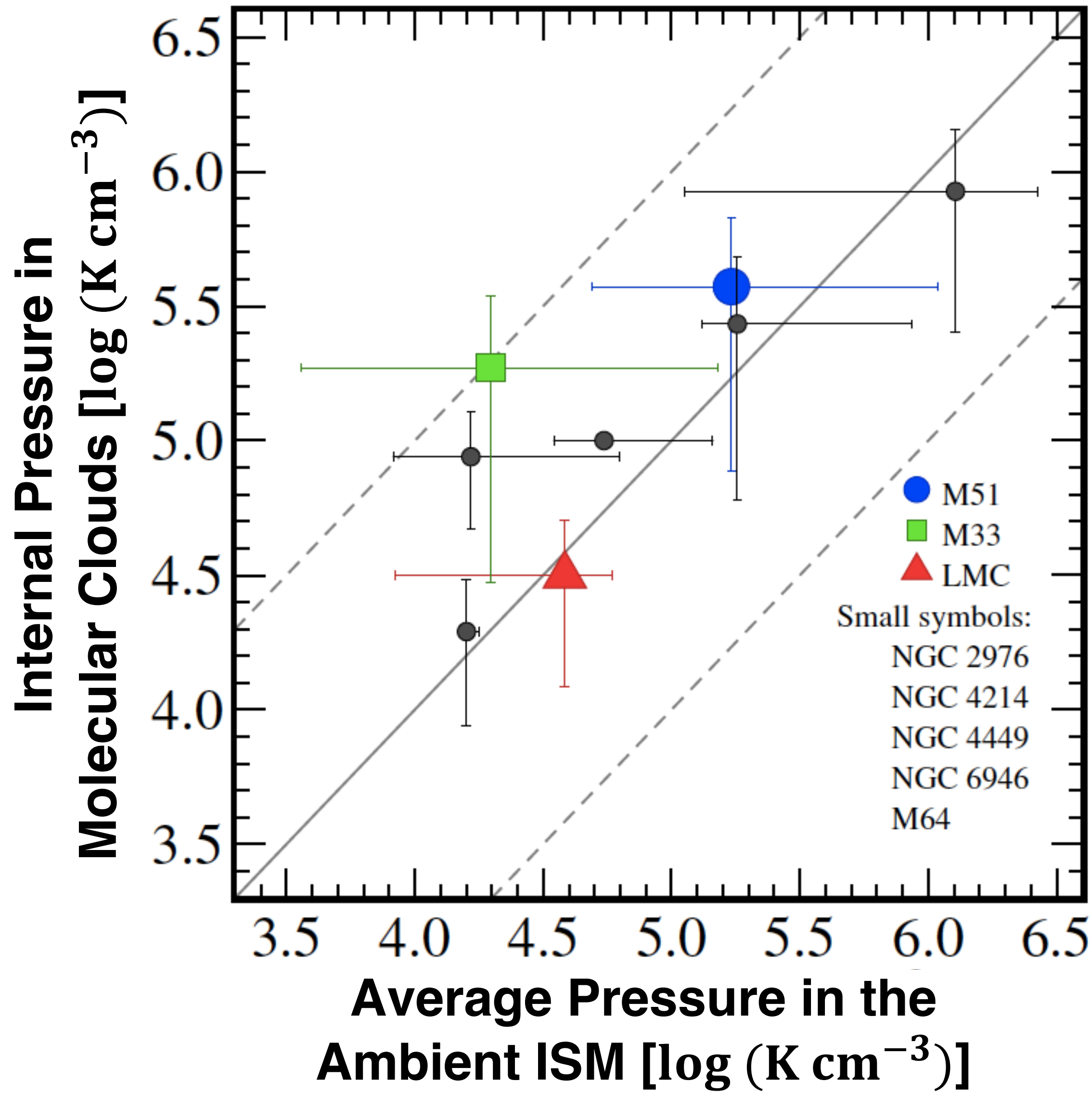
Sun et PHANGS (2019), to be submitted

Pressure in Clouds Correlates with Ambient Pressure

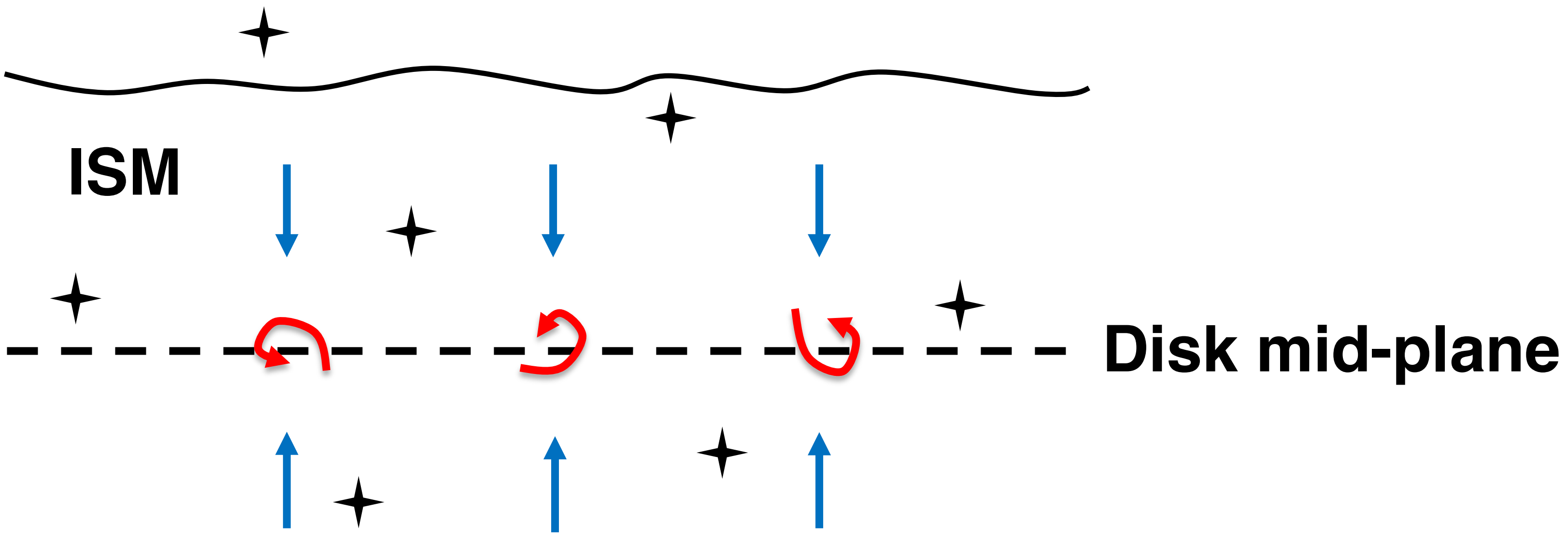


Hughes et al. (2013); also see Schruba et al. (2019)

Estimate Ambient Pressure from Dynamical Equilibrium

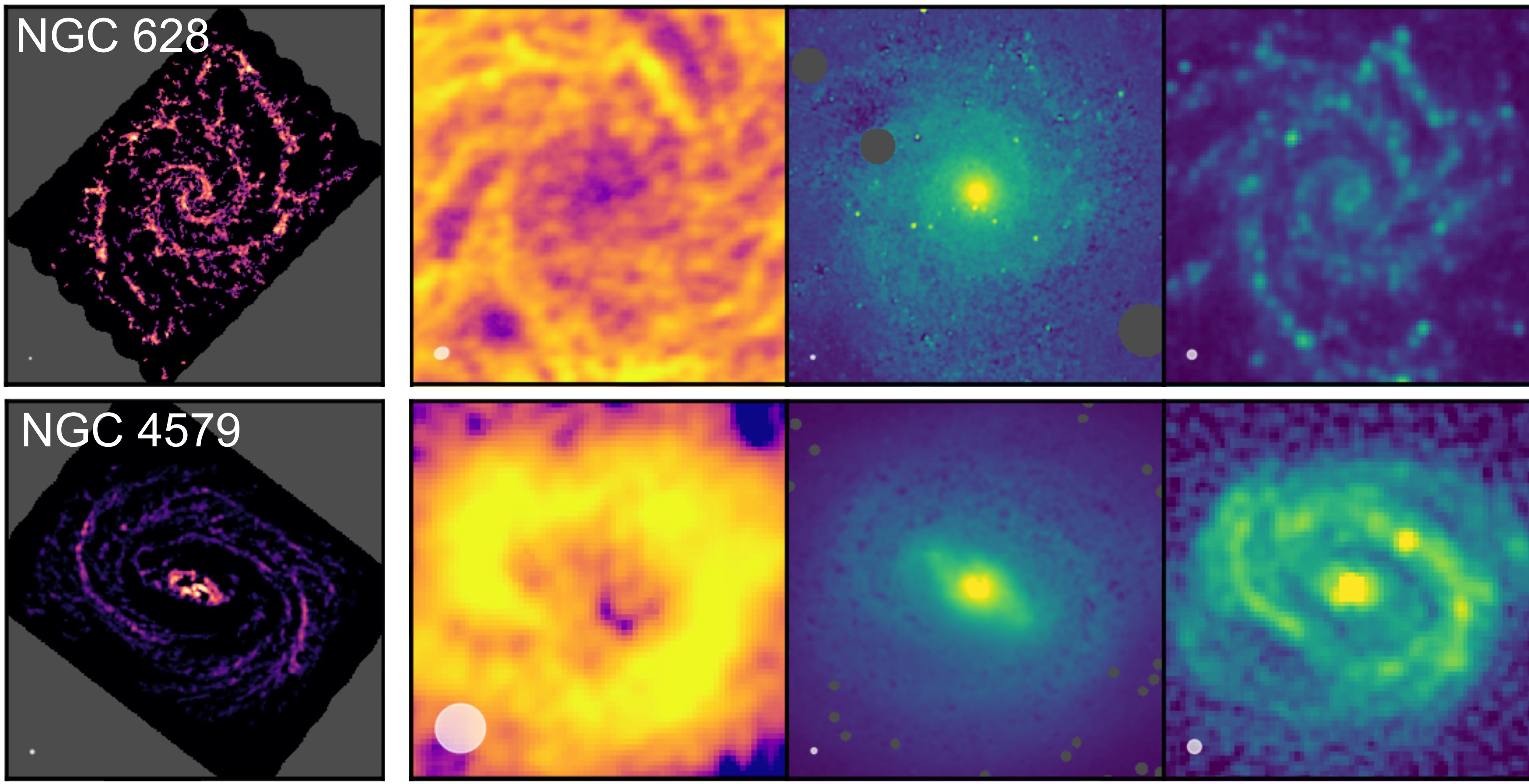
ISM in a steadily star-forming disk galaxy should achieve dynamical equilibrium *(Elmegreen 1989; Blitz & Rosolowsky 2004, 2006; Ostriker et al. 2010; Ostriker & Shetty 2011; Schruba et al. 2019)*

Mean ISM pressure near the disk mid-plane
≈ total weight of the ISM in the galaxy potential
(when averaged over large spatial/time scales)



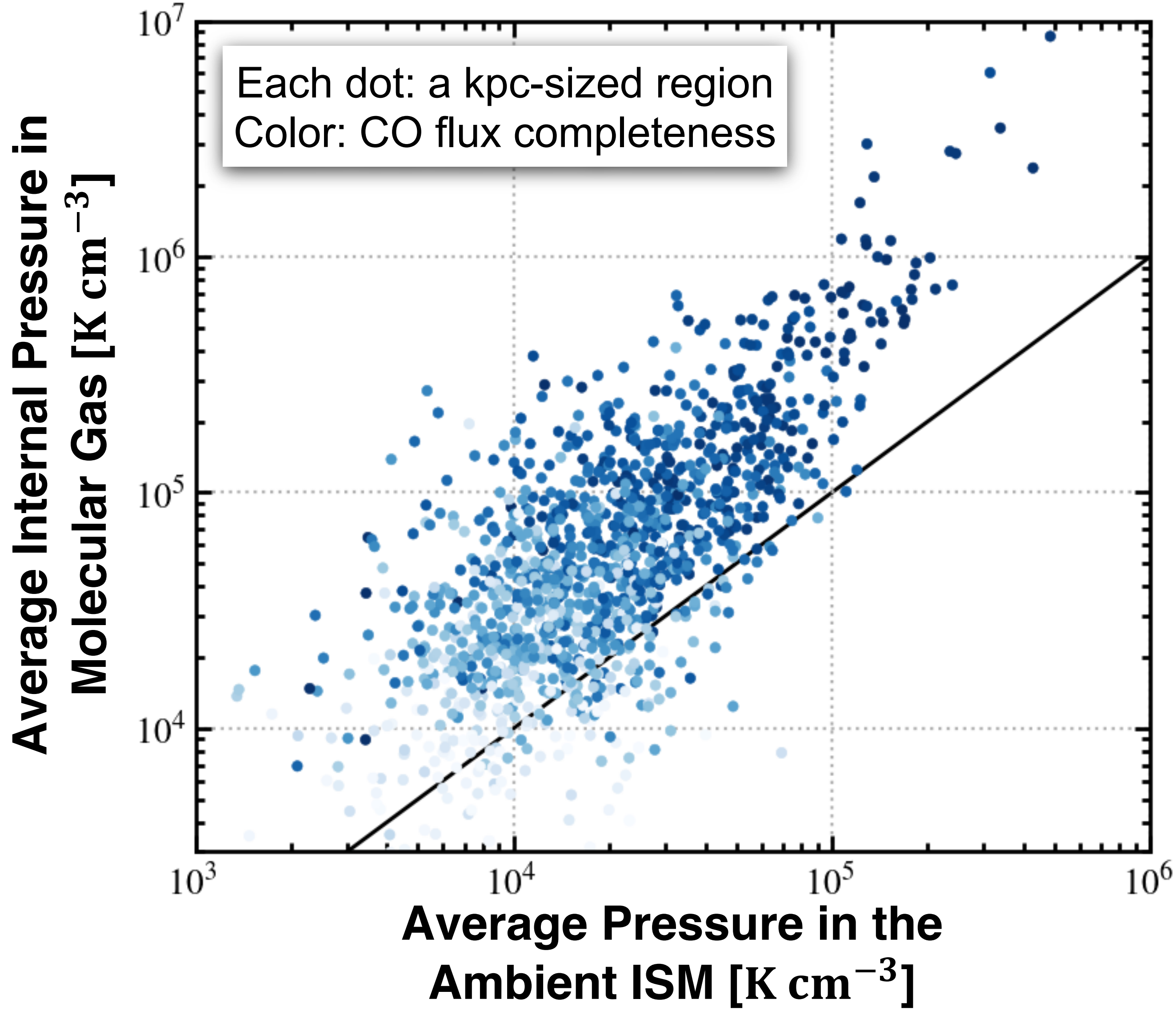
Gathering Multi-wavelength Data

CO (2-1)	**HI**	**NIR**	**UV + MIR**
PHANGS-ALMA (**Leroy, Schinnerer et al.**)	VLA obs (**D. Utomo**) + archival HI data	S^4G + new Spitzer data (**M. Querejeta**)	Z0MGS project (**Leroy+19 accepted**)



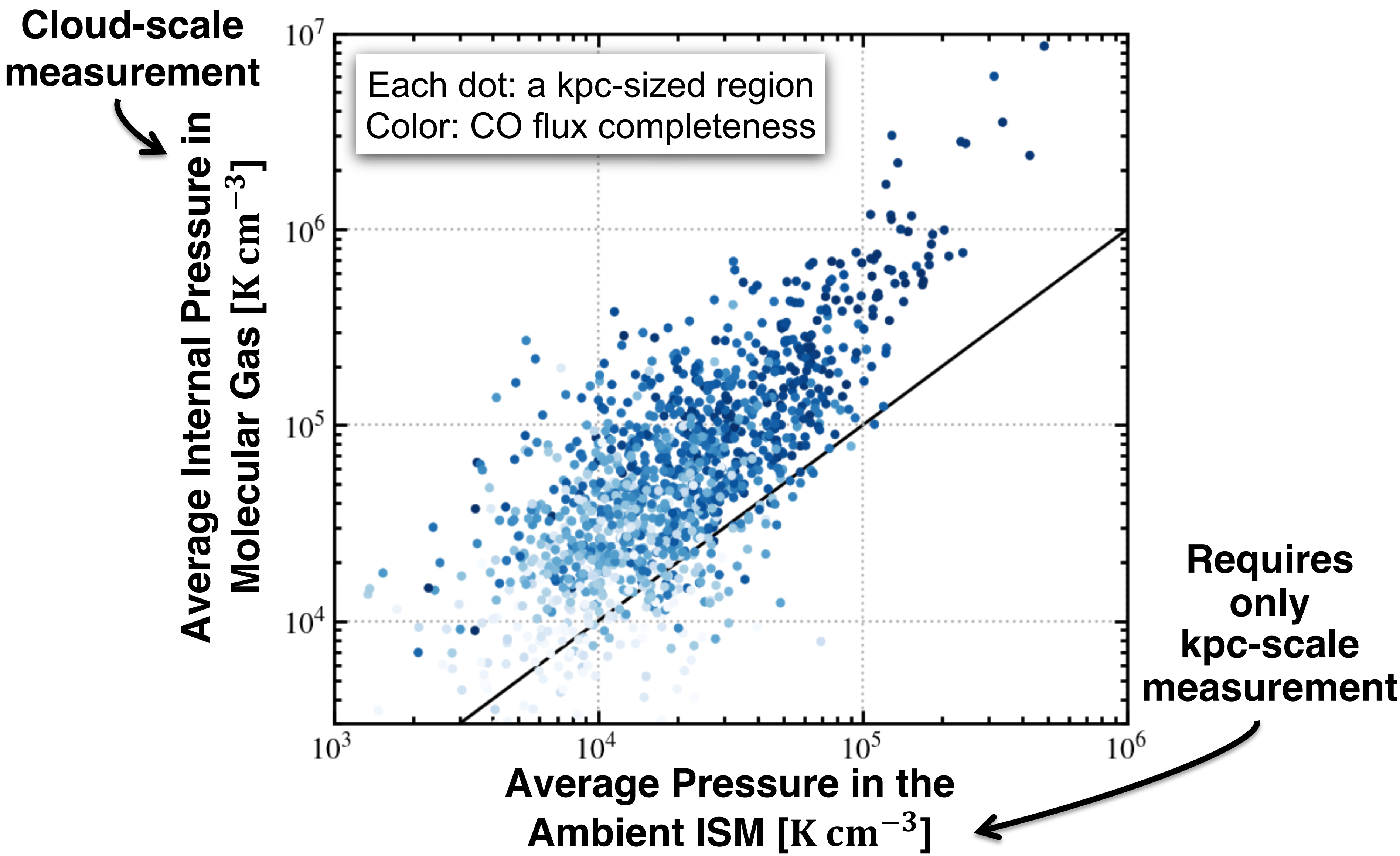
Sun et PHANGS (2019), to be submitted

Correlation between Internal & Ambient Pressure



Sun et PHANGS (2019), to be submitted

Could Use This Relation to Predict Internal Pressure



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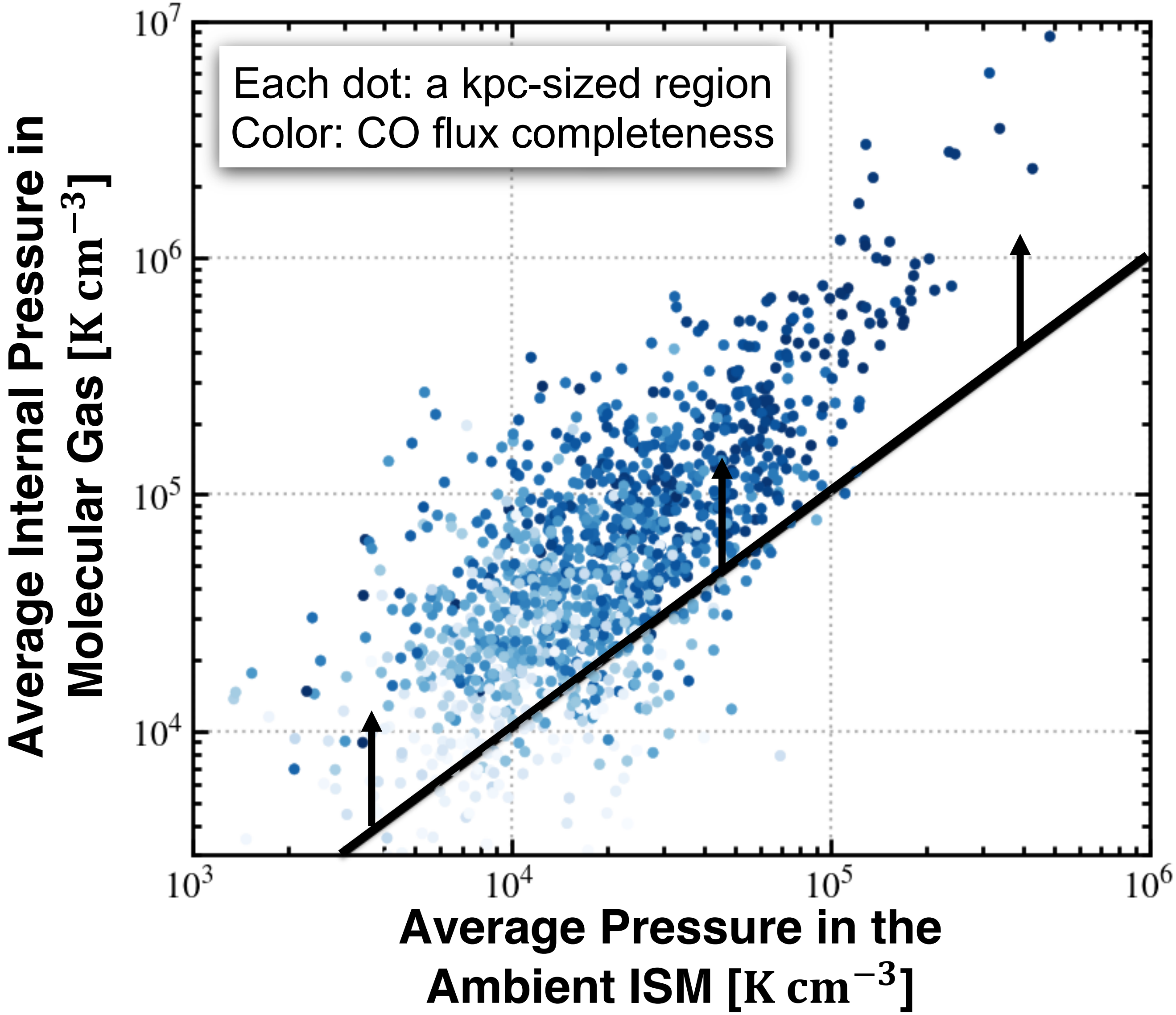
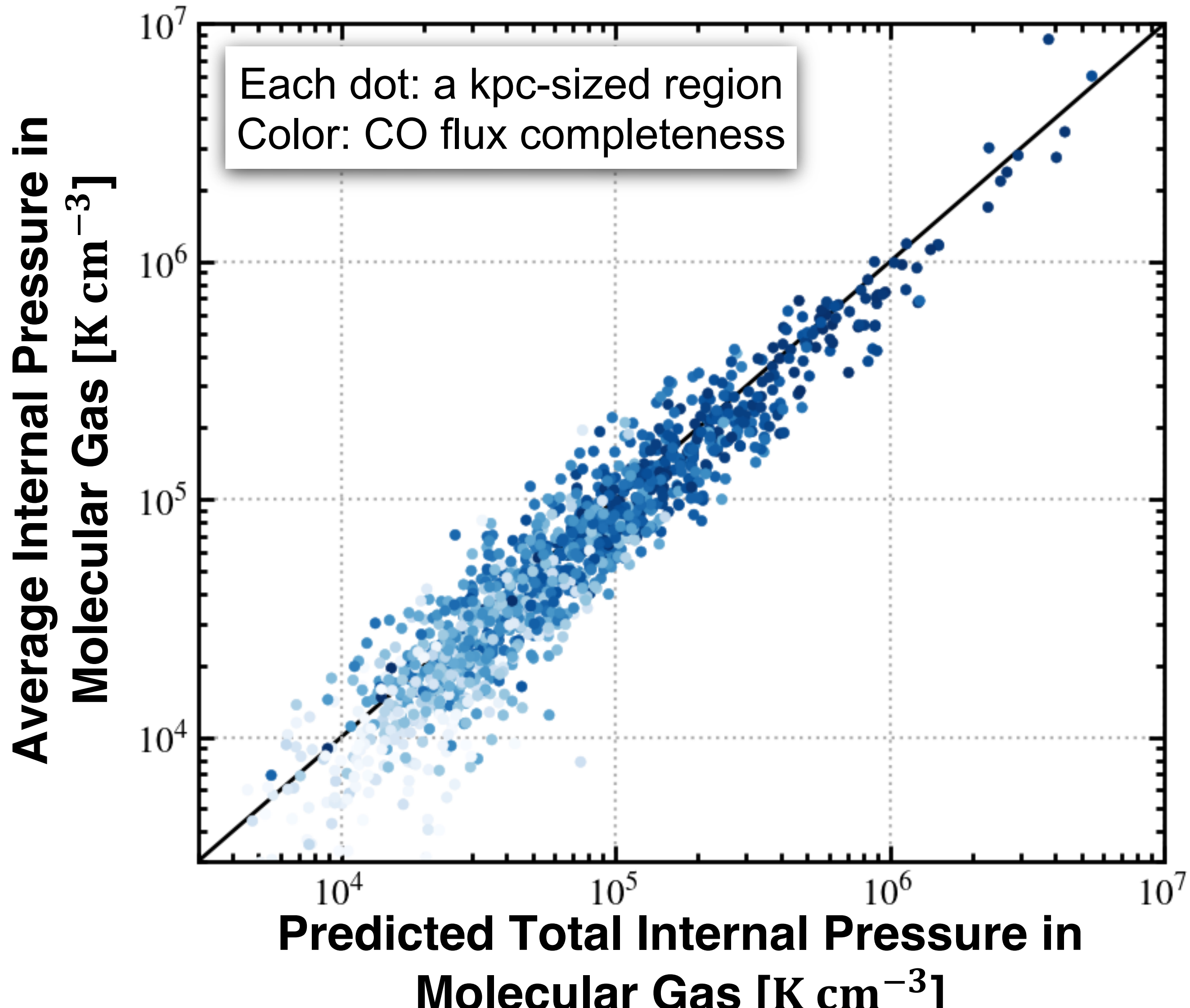
Molecular Gas is Over-pressurized w.r.t. Ambient ISM



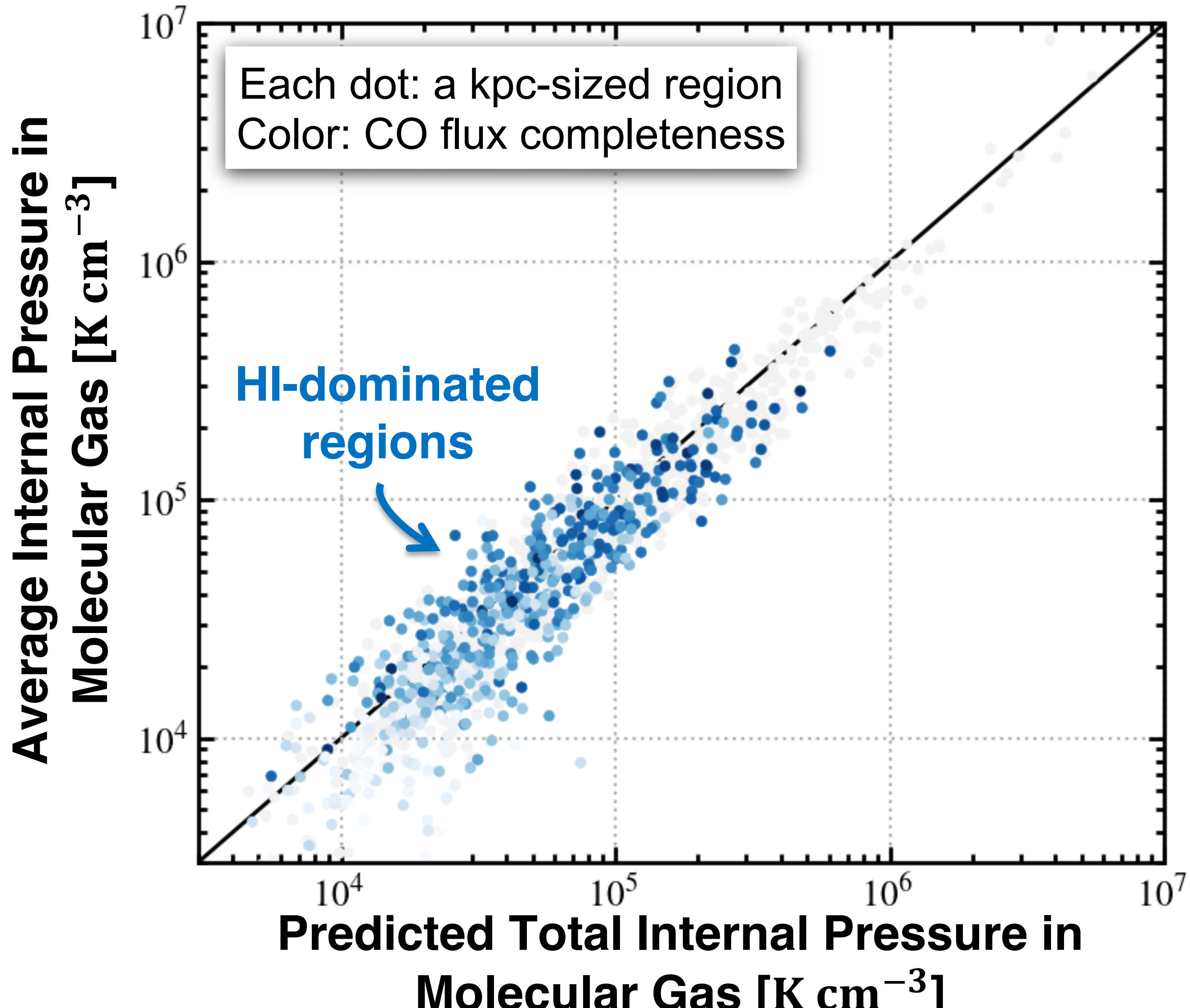
Sun et PHANGS (2019), to be submitted

Accounting for Excess in Molecular Gas Self-gravity



Sun et PHANGS (2019), to be submitted; also see Schruba et al. (2019)

Relation Holds in HI-dominated Regions



Sun et PHANGS (2019), to be submitted; also see Schruba et al. (2019)

Summary

- PHANGS-ALMA measures molecular gas properties on individual GMC scales across **> 70 nearby star-forming galaxies**. This is **a great local benchmark** to compare with other CO observations.

- We see **clear and location-dependent** variations in cloud-scale gas properties. We find **internal pressure** as the “principal component” of this variation (*Sun et PHANGS 2018; Sun et PHANGS 2020, in prep.*).

- Molecular gas internal pressure scales with the ambient pressure. This can be used to **predict small-scale molecular gas properties** from low resolution data (*Sun et PHANGS 2019, to be submitted*).

- Molecular gas internal pressure often exceeds the ambient pressure. The amount of **over-pressurization** is consistent with the required pressure to balance **the enhanced molecular gas self-gravity** on small scales (*Sun et PHANGS 2019, to be submitted*).

The PHANGS Collaboration

Schinnerer (PI); Bigiel, Blanc, Emsellem, Escala, Groves, Hughes, Kreckel, **Kruijssen**, Lee, **Leroy**, Meidt, Pety, Rosolowsky, Sanchez-Blazquez, Sandstrom, **Schruba**, Usero; Barnes, Belfiore, Bešlić, Cao, Chandar, Chatzigiannakis, **Chevance**, Congiu, Dale, Faesi, Gallagher, Garcia-Rodriguez, Glover, Grasha, Henshaw, Herrera, Ho, Hygate, Jimenez-Donaire, Kessler, Kim, Klessen, Koch, Lang, Larson, Le Reste, Liu, McElroy, Nofech, Ostriker, Pessa, Puschnig, Querejeta, Razza, Saito, Santoro, Stuber, **Sun**, Thilker, Turner, Ubeda, Utreras, Utomo, van Dyk, Ward, Whitmore