Phangs-ALMA: Understanding Molecular Clouds across the Local Universe

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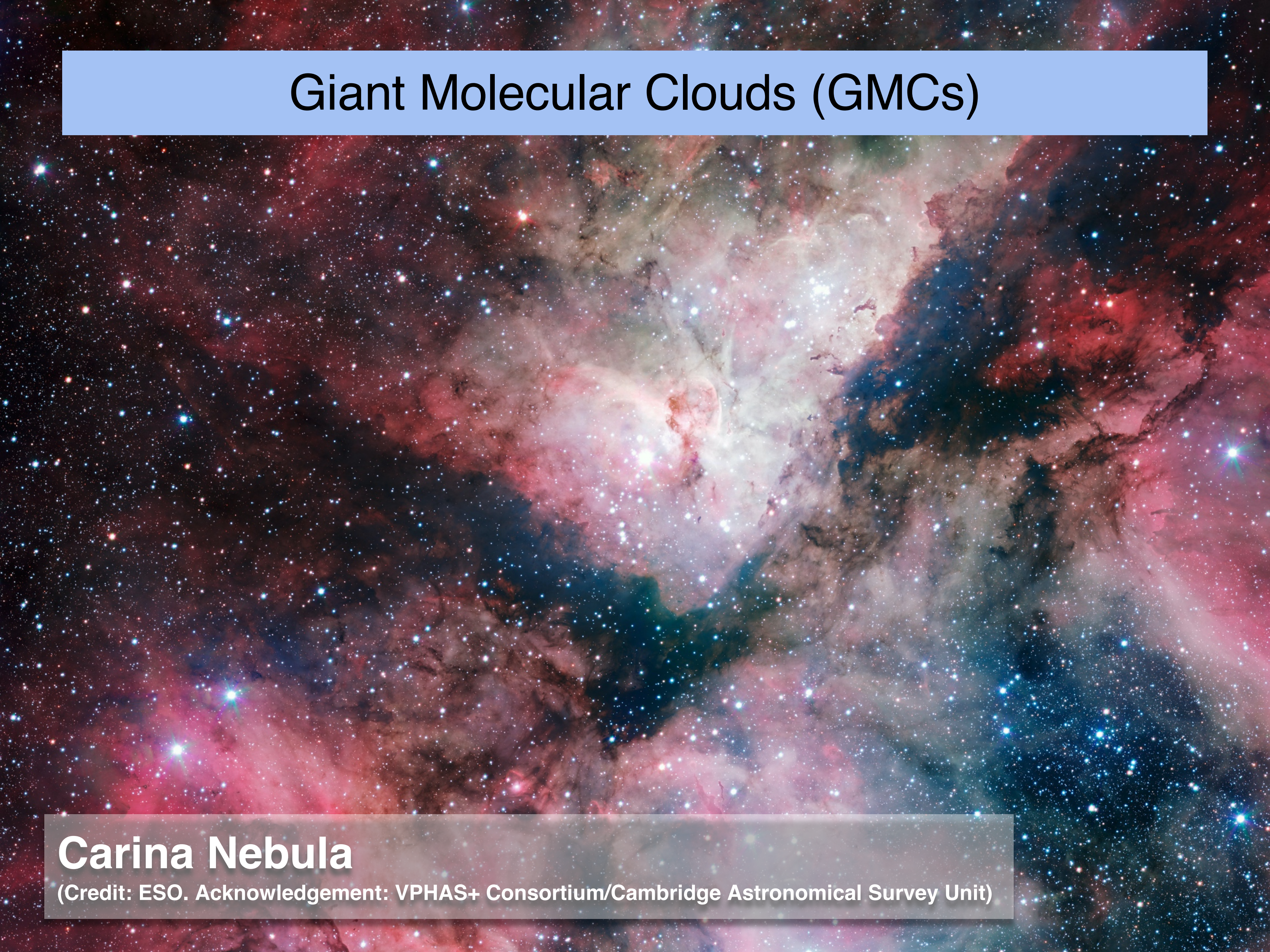
March 23, 2020 @ ALMA Workshop

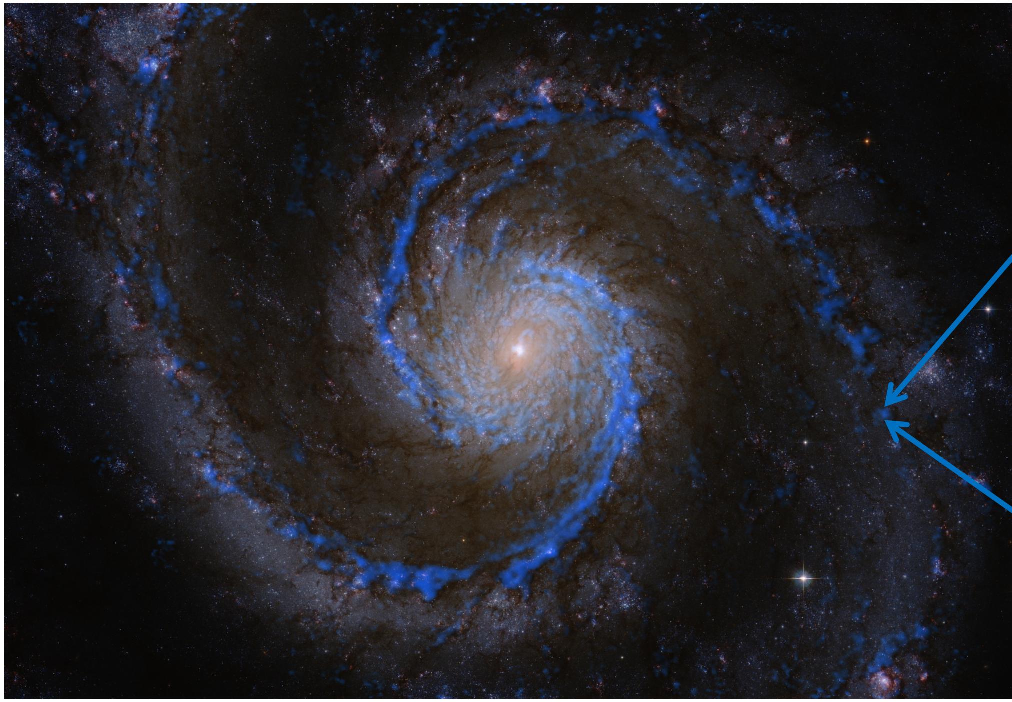
Giant Molecular Clouds (GMCs)



Carina Nebula

(Credit: ESO. Acknowledgement: VPHAS+ Consortium/Cambridge Astronomical Survey Unit)

Observing GMCs: Challenging Outside our Galaxy

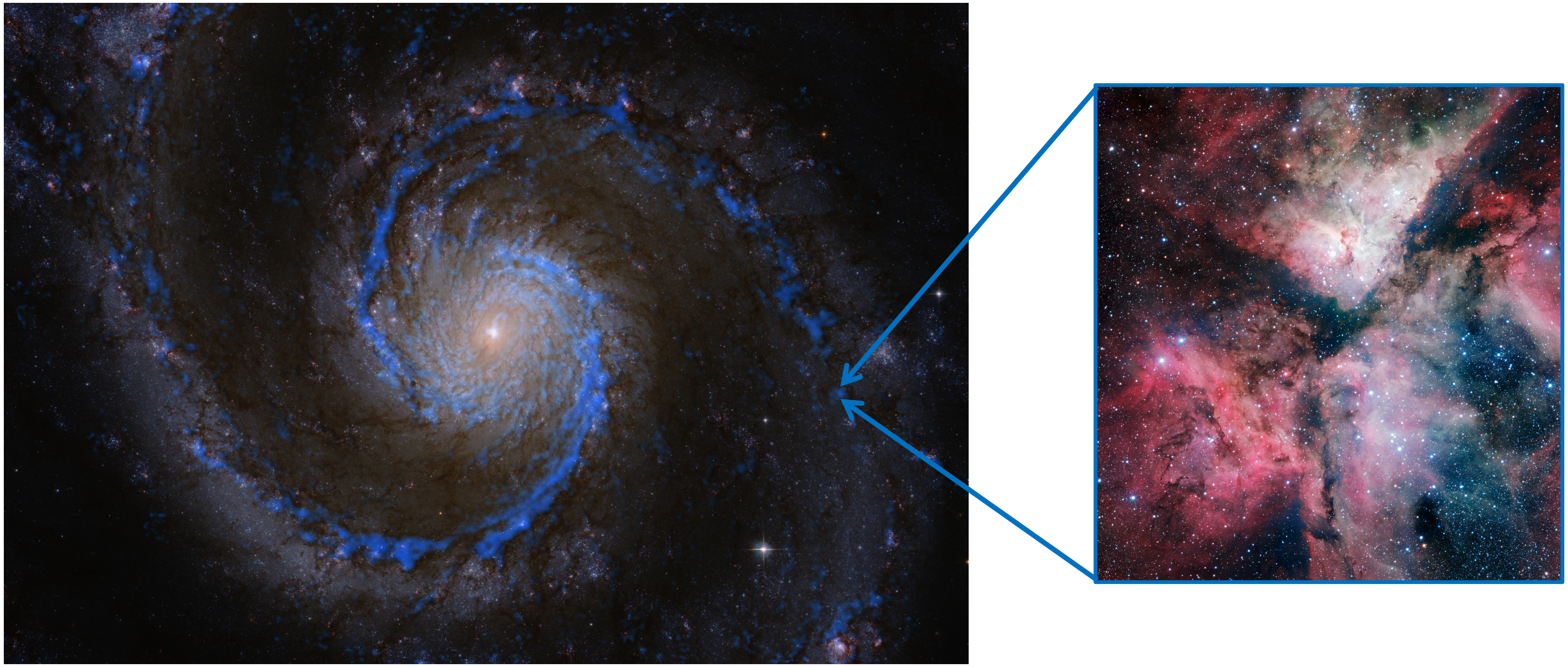


To detect the Carina Nebula (~50 pc in size, 10^5 Msun in mass) in CO(1-0) emission at the distance of M51 (~7 Mpc away) requires:

~1 arcsec angular resolution &
~1 mJy or ~0.1 K sensitivity at 115 GHz

Achievable with ALMA!

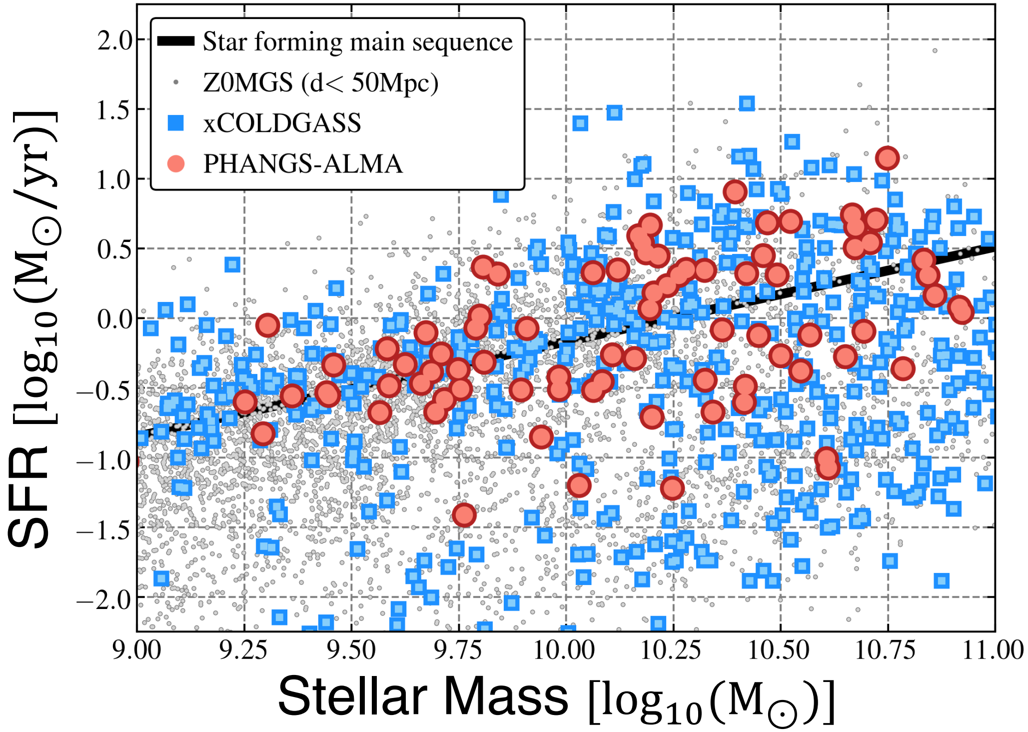
Observing GMCs: ~~Challenging~~ Outside our Galaxy



PHANGS-ALMA Survey

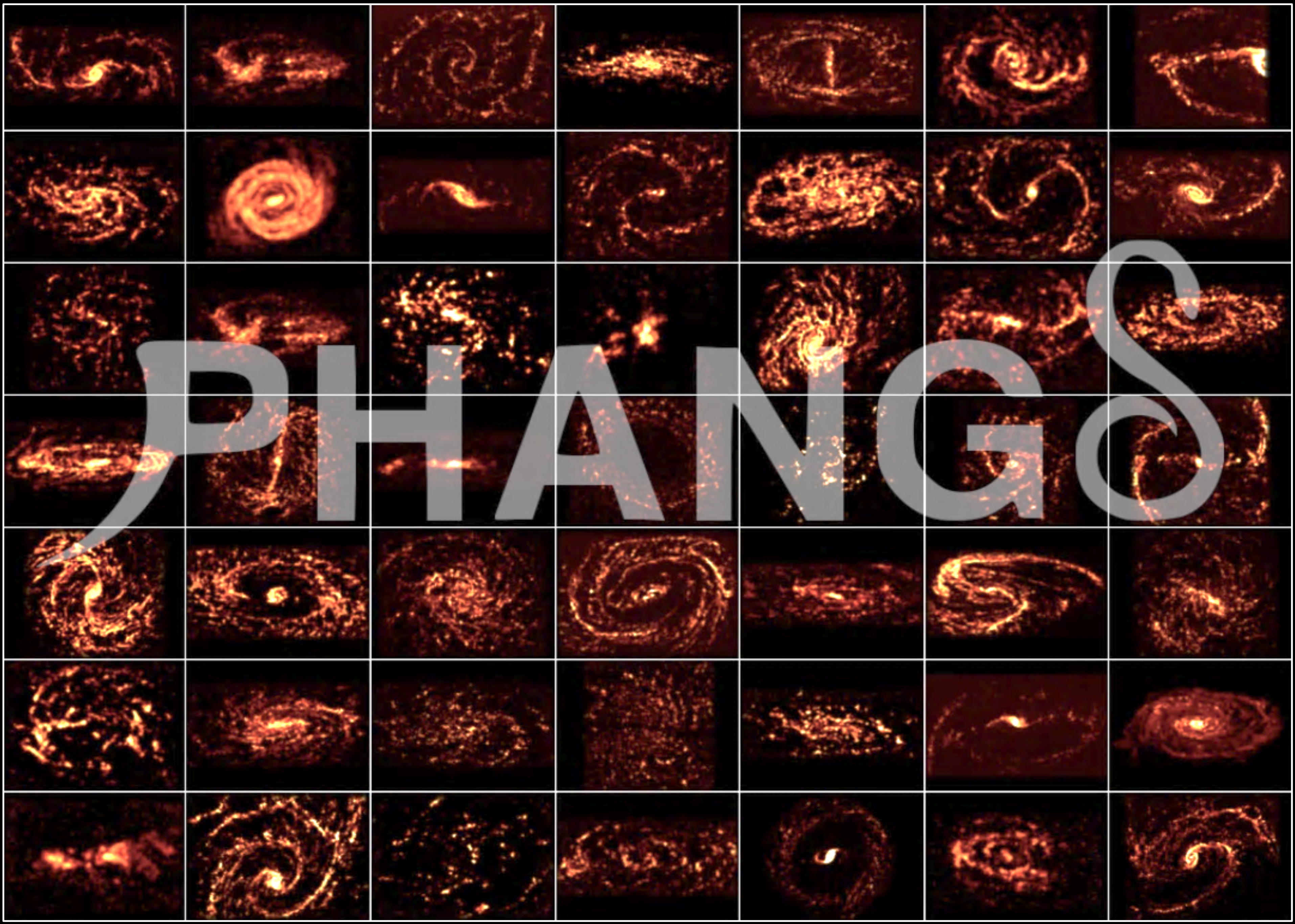
ALMA project (PI: Schinnerer) covering **almost 100** nearby galaxies in **CO(2-1)** at **1.0-1.5" resolution** (~50-150 pc at their distances).

This provides the most complete atlas ever of GMCs across the local star-forming galaxy population.



A. K. Leroy, E. Schinnerer et al. (2020, in prep.)

http://www.phangs.org



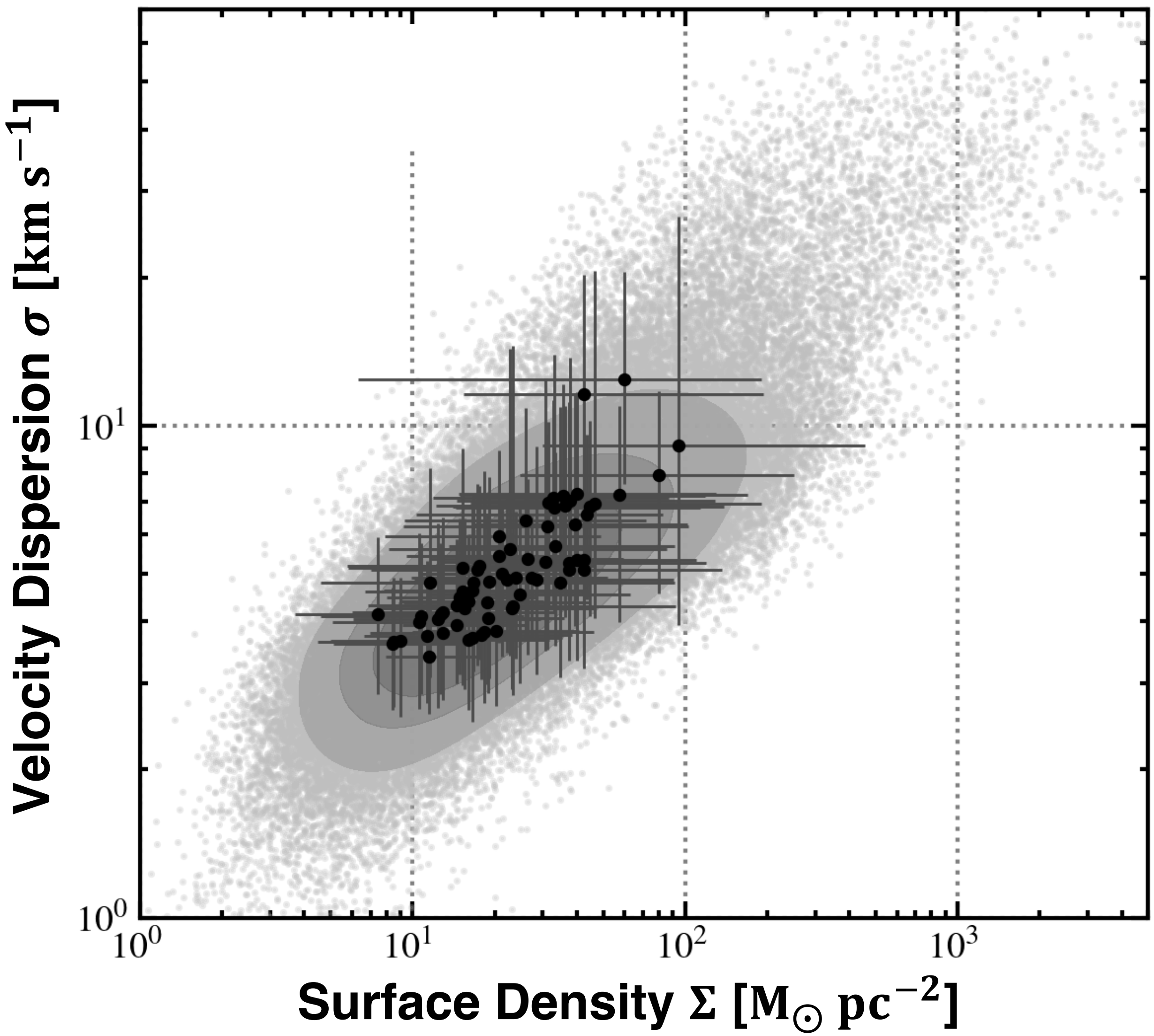
PI: E. Schinnerer (MPIA) *Image Credit: F. Santoro (MPIA), A. K. Leroy (OSU)*

What can we learn?

- **[Distribution]** For many key molecular cloud properties (e.g., surface density, velocity dispersion), what do their distribution look like across a representative sample of local star forming galaxies?

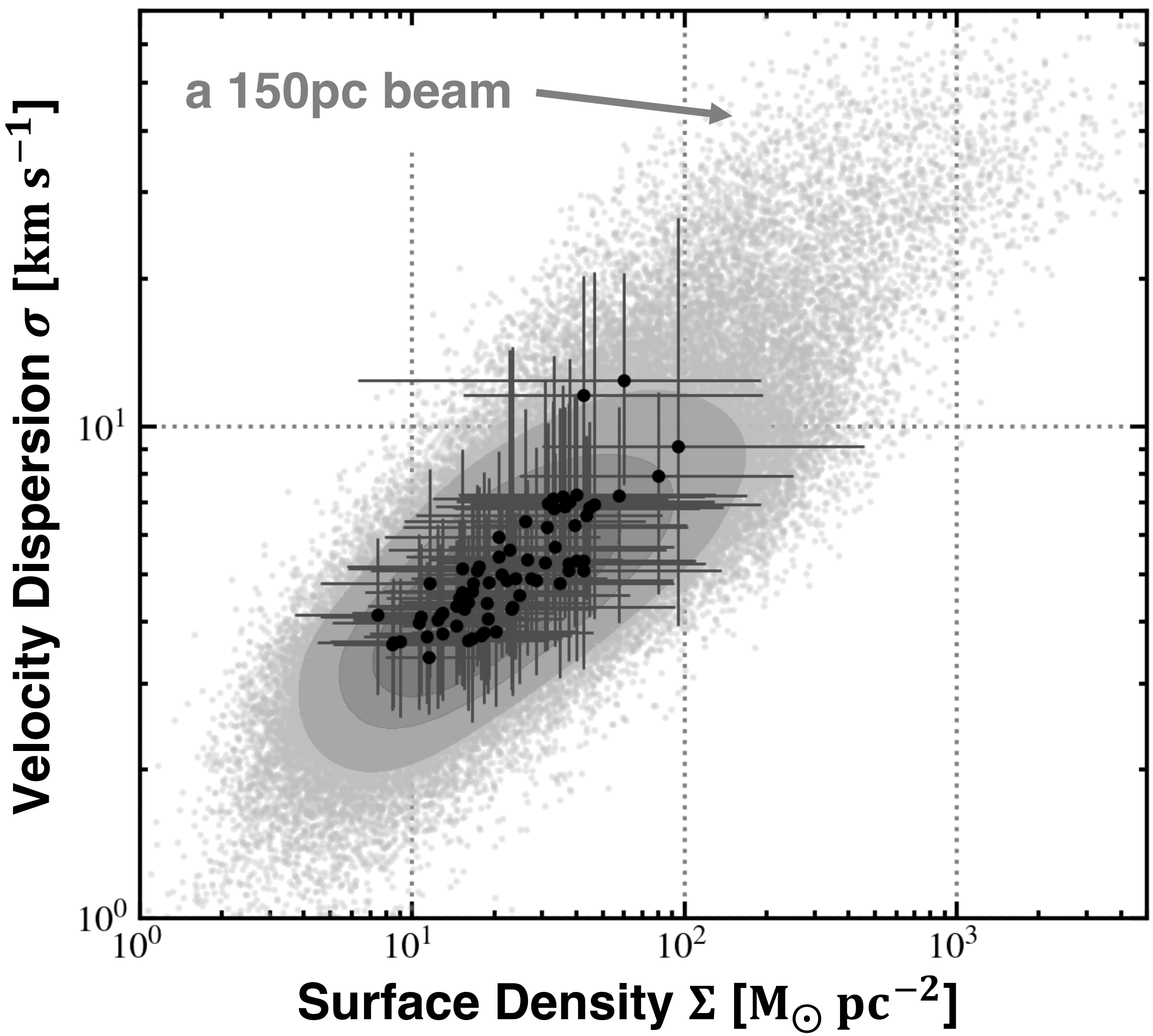
- **[Correlation]** How do properties of molecular clouds correlate with properties of their local (galactic) environment? What physics drives such correlation?

Surface Density – Velocity Dispersion Relation



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

Measurements on a Fixed 150pc Scale



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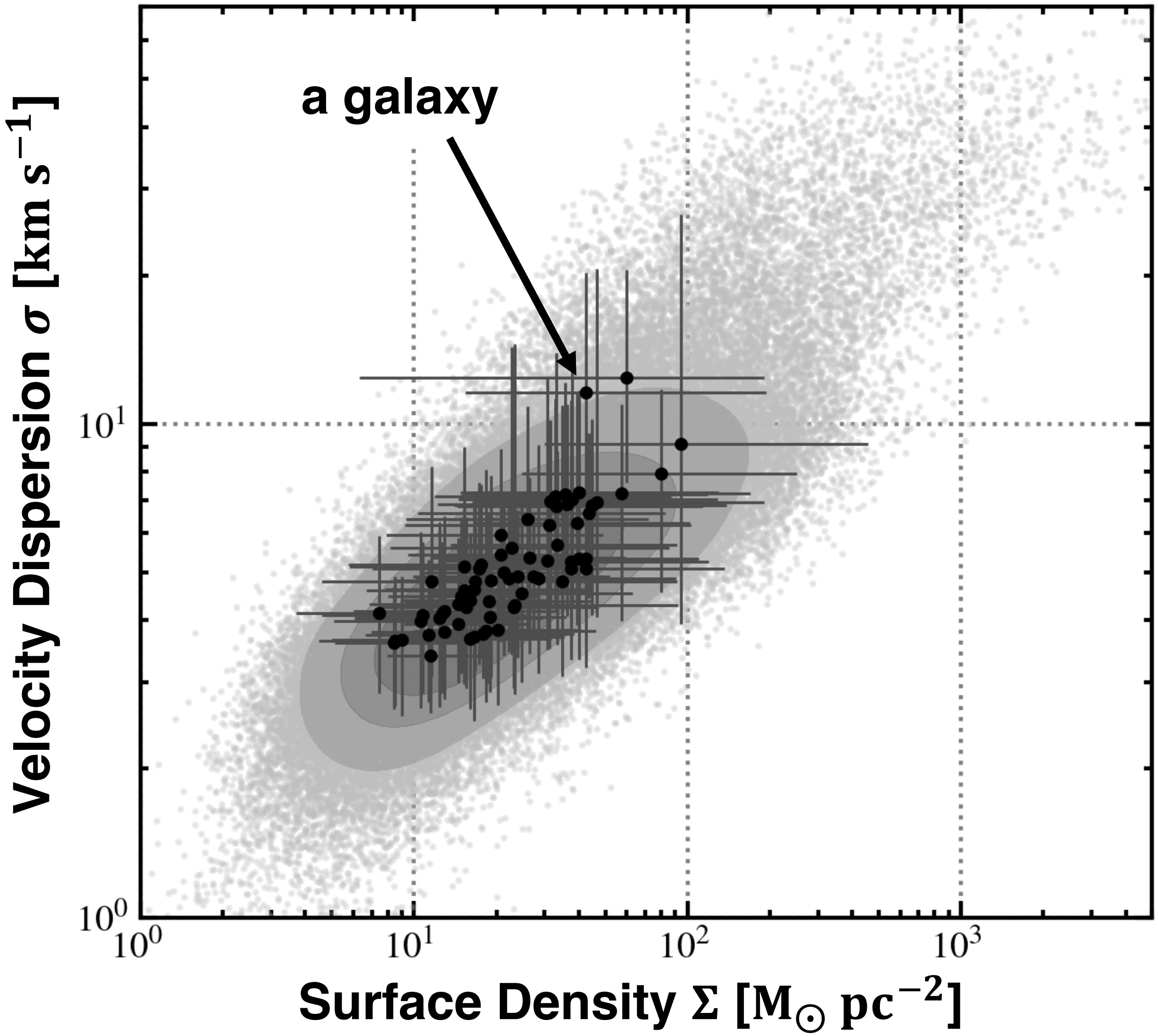
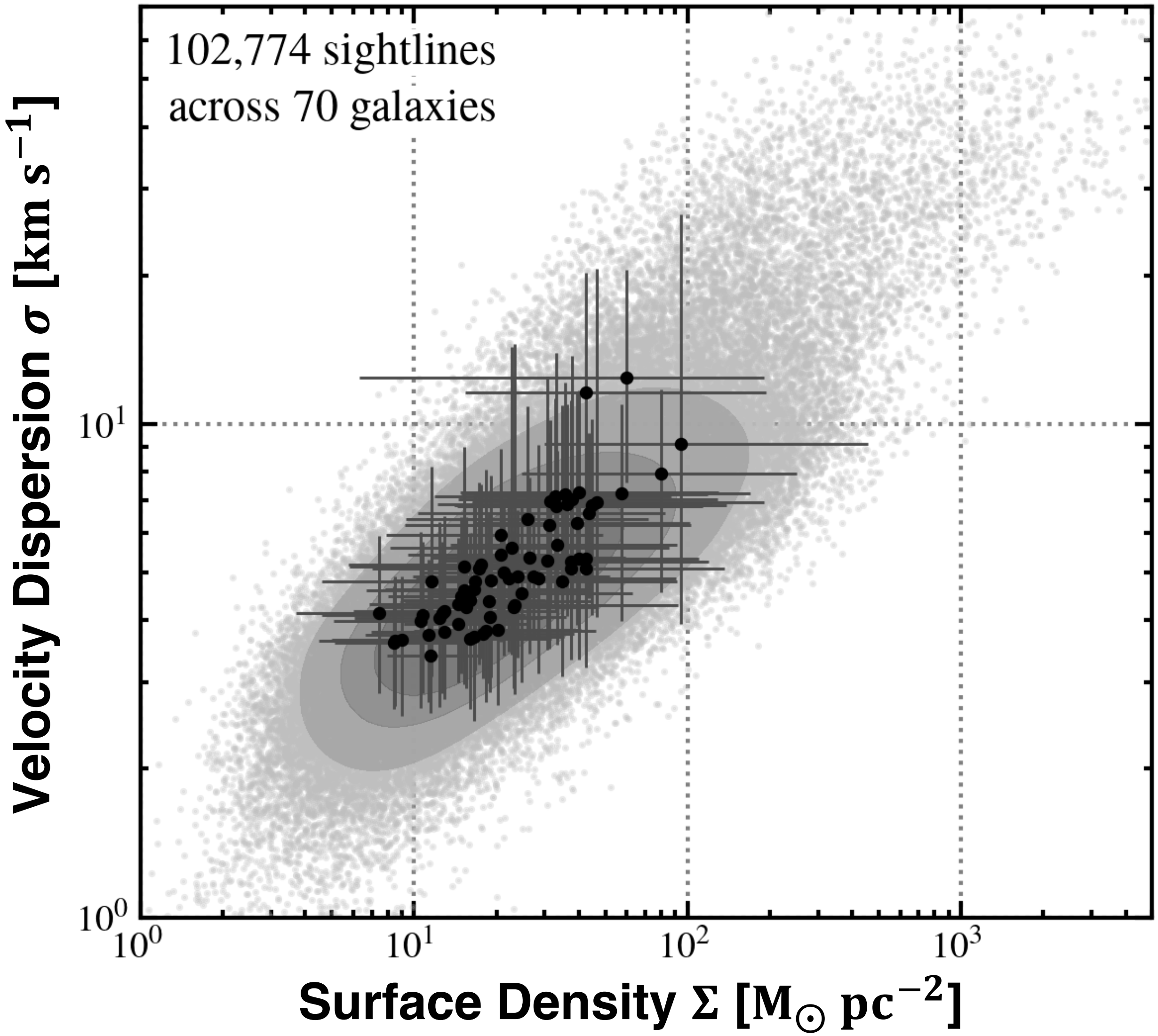
Measurements on a Fixed 150pc Scale



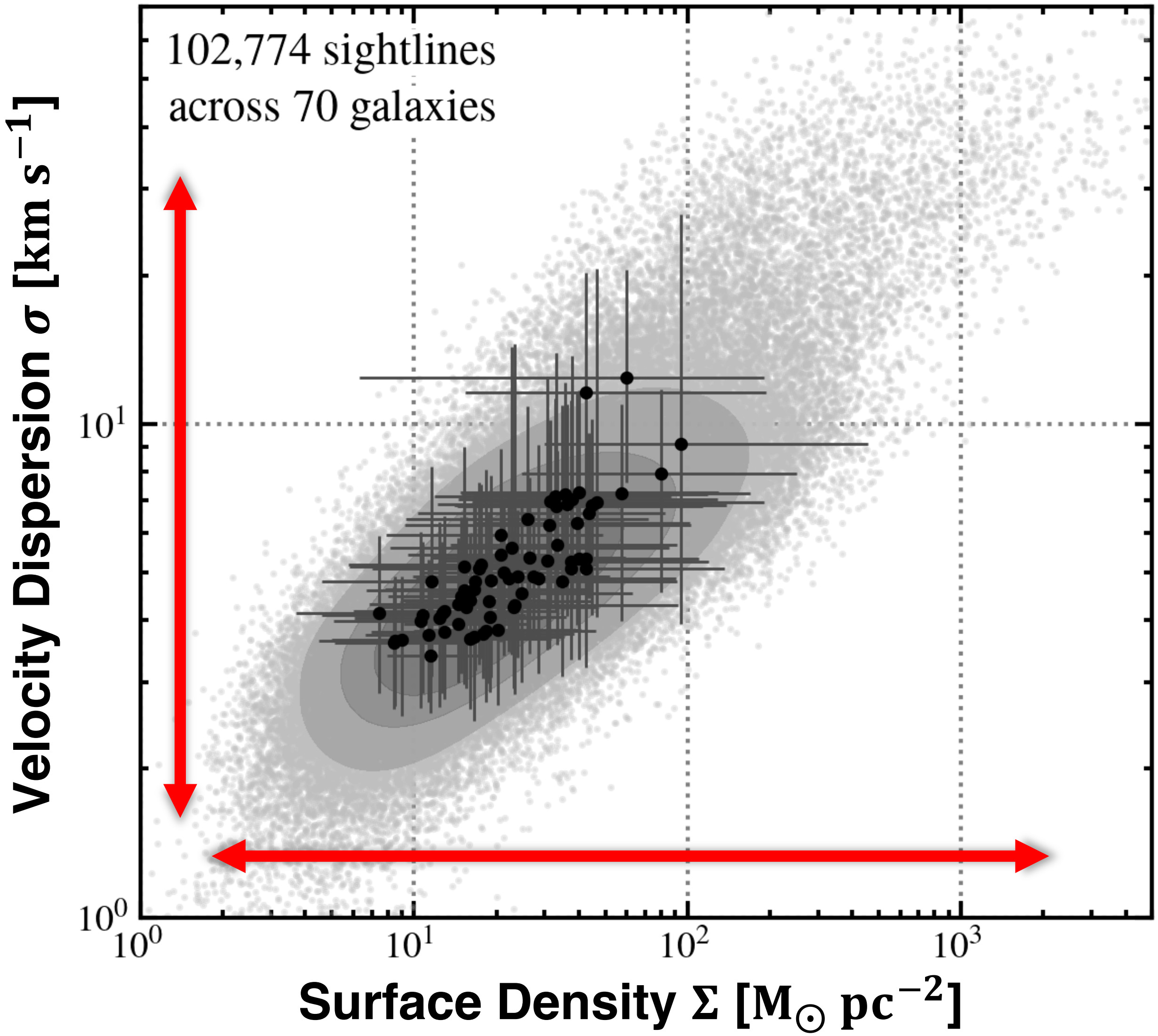
Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

Huge Sample & Homogeneous Data



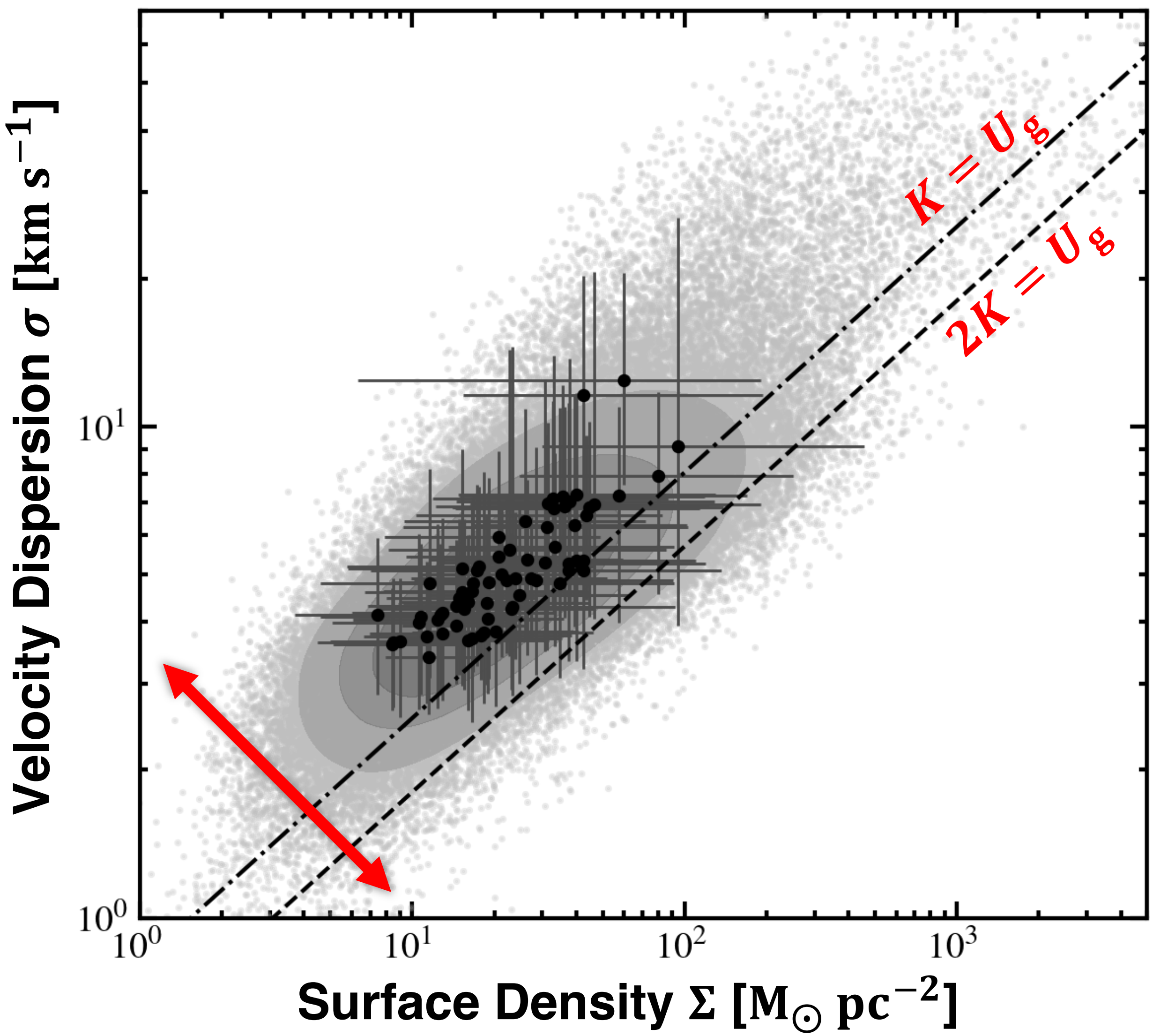
Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

GMC Properties Vary within & among Galaxies



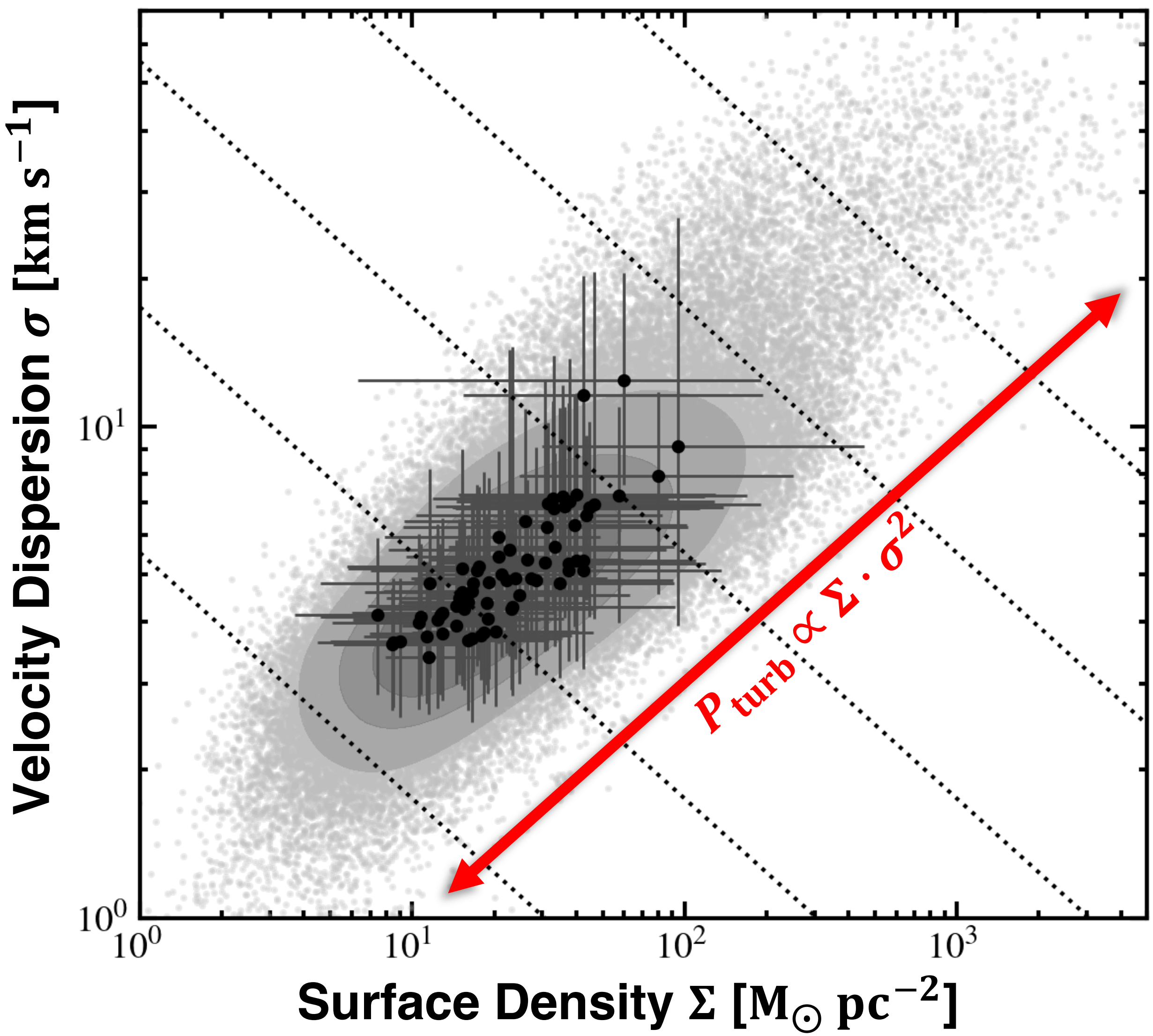
Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

Narrow Range of Dynamical State (Virial Parameter)



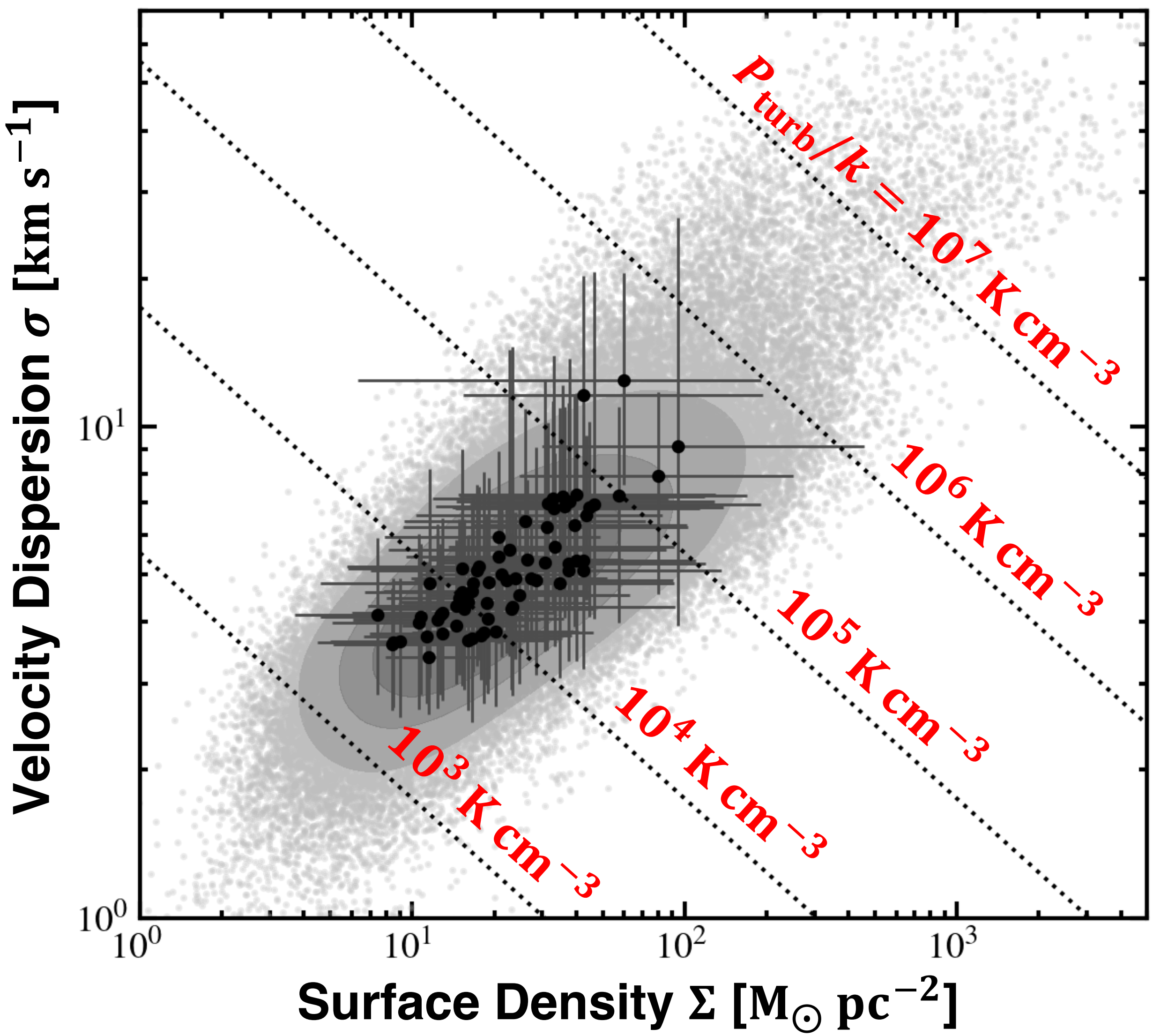
Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

Wide Range of Turbulent Pressure



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

Variation in Turbulent Pressure > 4 dex

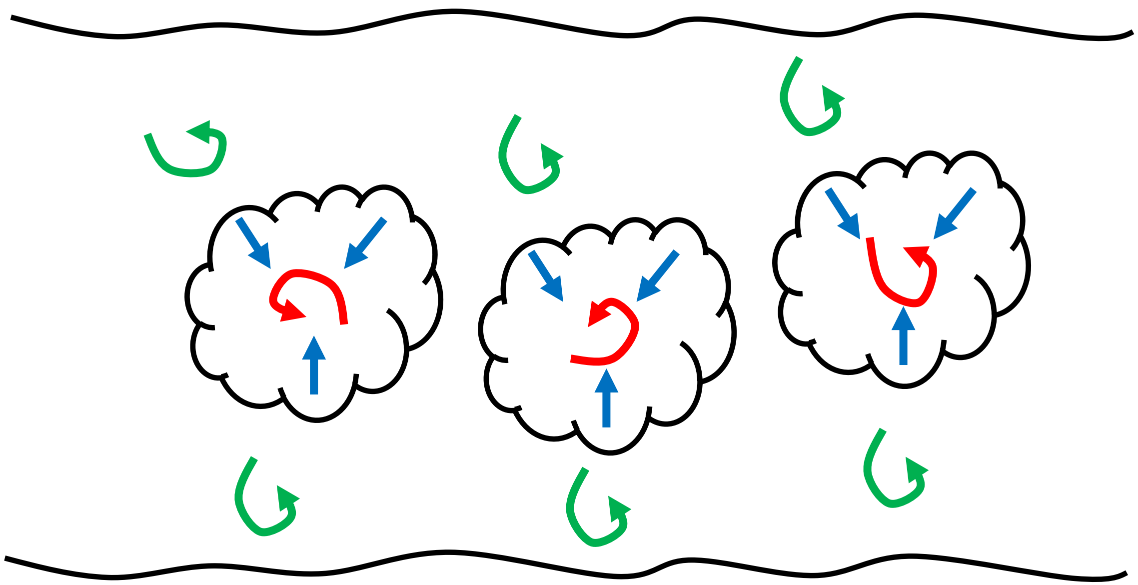


Sun et PHANGS (2018); Sun et PHANGS (2020, in prep.)

What Drives the Variation in Turbulent Pressure?

The dynamical equilibrium hypothesis:

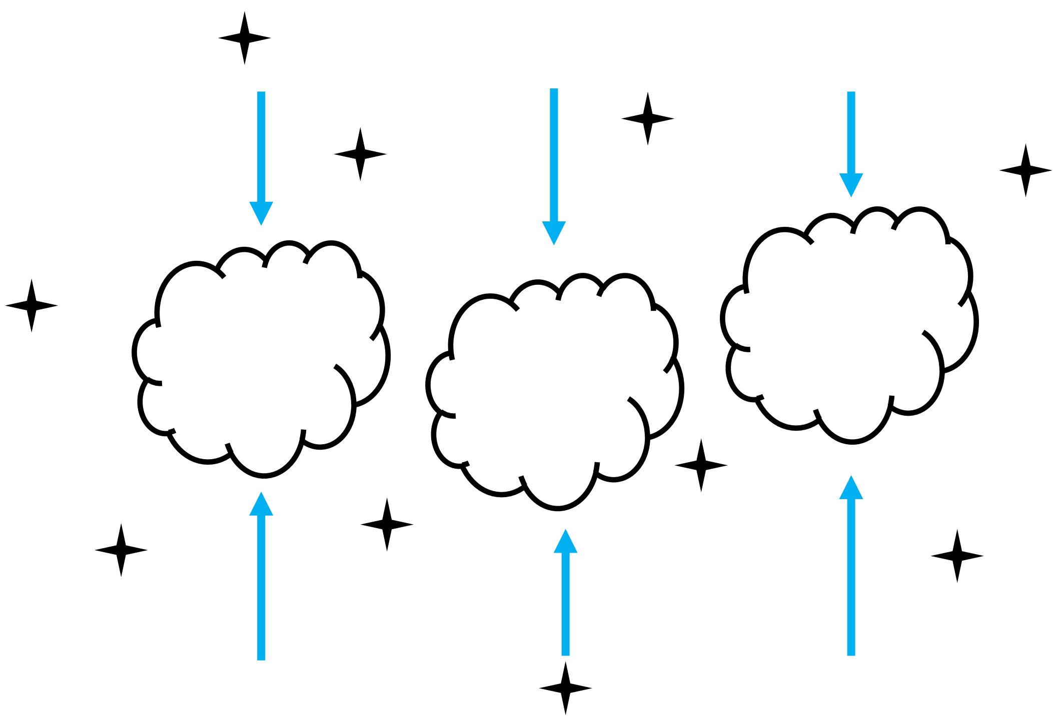
Turbulent pressure in the molecular gas
≈ its own weight due to self-gravity
\+ ambient pressure in the volume-filling atomic gas



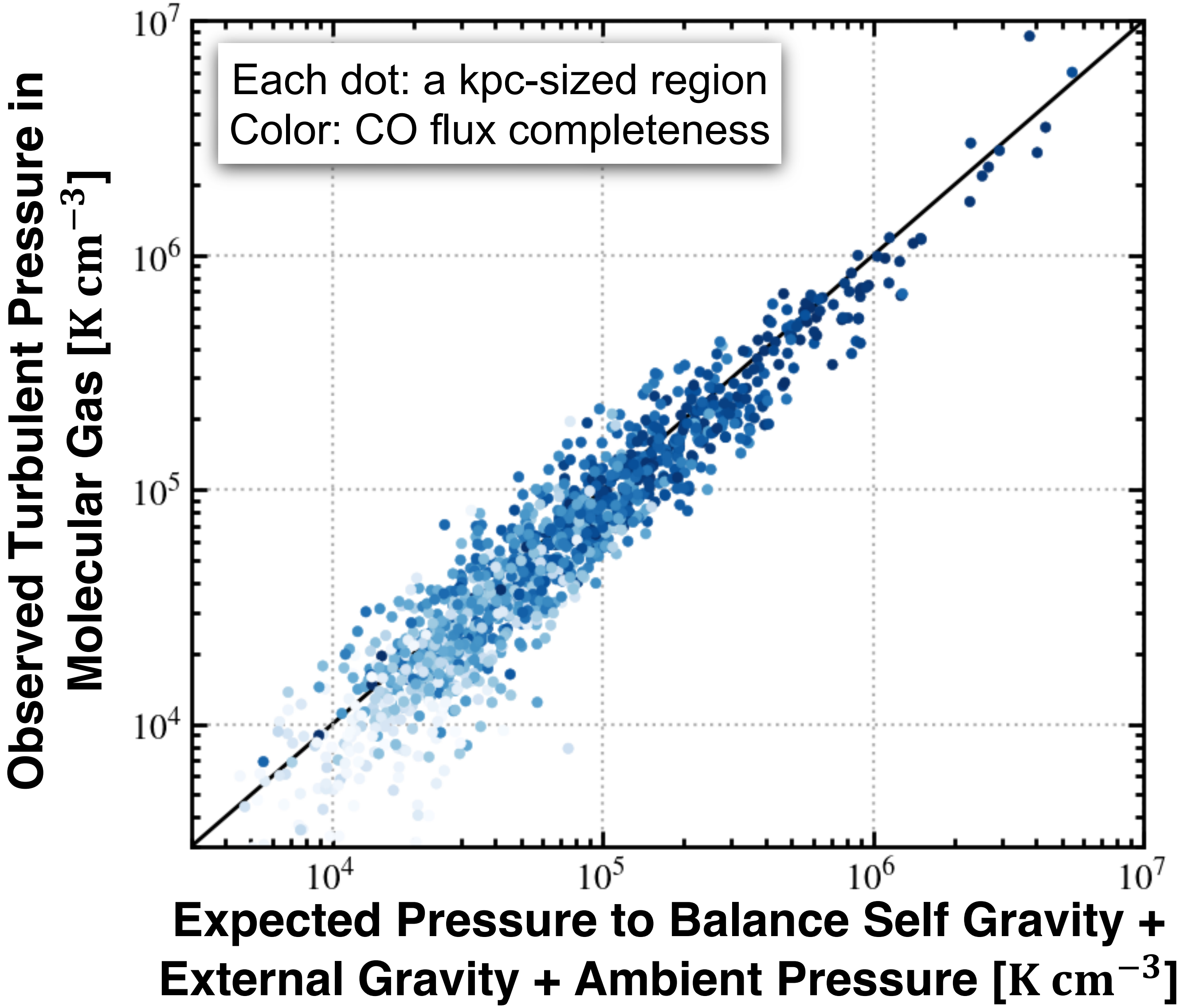
What Drives the Variation in Turbulent Pressure?

The dynamical equilibrium hypothesis:

Turbulent pressure in the molecular gas
≈ its own weight due to self-gravity
+ ambient pressure in the volume-filling atomic gas
+ its weight due to external gravity



Molecular Clouds near Dynamical Equilibrium



Sun et PHANGS (2020, ApJ in press); also see Schruba et al. (2019)

Summary

- PHANGS-ALMA surveys molecular clouds across ~90 nearby star-forming galaxies, thereby provides a representative picture of GMCs in the Local Universe.

- GMC properties vary systematically, both within a galaxy and across galaxies. Turbulent pressure appears to be the "principal axis" of the observed distribution.

- The observed turbulent pressure in molecular clouds is just adequate to balance self-gravity, external gravity, and ambient pressure. This means that the molecular cloud population in any given environment tends to adjust towards a dynamical equilibrium state.

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