

Gas & Dust in Spiral Galaxies with PHANGS

Inês Froes Heitor, Margarida Pólvora Fonseca
02/04/2026

PHANGS: Physics at High Angular resolution in Nearby Galaxies



- Multiwavelength (e.g. HST, ALMA, JWST, VLT)
- High resolution
- Large sample of nearby galaxies
- Interplay between gas and star formation, galactic structure and galaxy evolution.

**Molecular Gas Properties on Cloud Scales
across the Local Star-forming Galaxy
Population, Sun et al. 2020**

&

**PHANGS–JWST First Results: ISM structure on
the turbulent Jeans scale in four disk galaxies
observed by JWST and ALMA, Meidt et al. 2022**

Molecular Gas Properties on Cloud Scales across the Local Star-forming Galaxy Population, Sun et al. 2020

Objective

- Characterize molecular gas properties on cloud scales and the cloud-environment connection

Data

- 70 PHANGS-ALMA galaxies
- PHANGS-ALMA CO(2-1) data with spatial resolution of 50-150pc

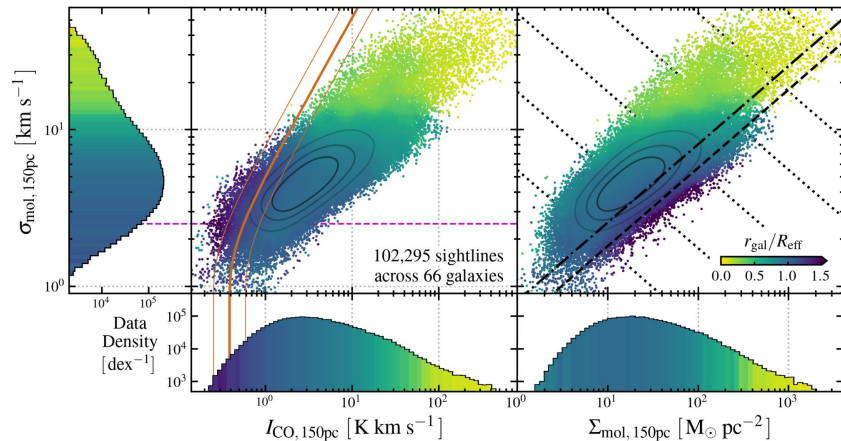
Methods

- Measurements of Σ_{mol} , σ_{mol} and estimates of P_{turb} and α_{vir} at 150pc resolution in 70 galaxies and 90pc resolution in 35 galaxies.

Molecular Gas Properties on Cloud Scales across the Local Star-forming Galaxy Population, Sun et al. 2020

Results

- Correlation with radius: Σ_{mol} and σ_{mol} increase towards the center of the galaxies (gradient colors)
- For fixed Σ_{mol} , excess of σ_{mol} at smaller $r_{\text{gal}}/R_{\text{eff}}$ suggests gas more clumpy in the inner parts of the galaxy



Lecture 2

What about the Gas Distribution?

Obviously, spiral galaxies have gas (neutral hydrogen, molecular hydrogen, ionized hydrogen). Most of the gas resides in the disk. Some gas disks are warped in the outer parts.

Typical gas masses are around $3\text{--}6 \times 10^9$ solar masses. In galaxies like our own, the amount of neutral gas and molecular gas are similar.

The molecular gas is concentrated mostly towards the center of the gas.

Neutral gas content in a strongly warped galaxy:

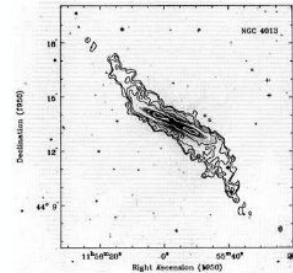
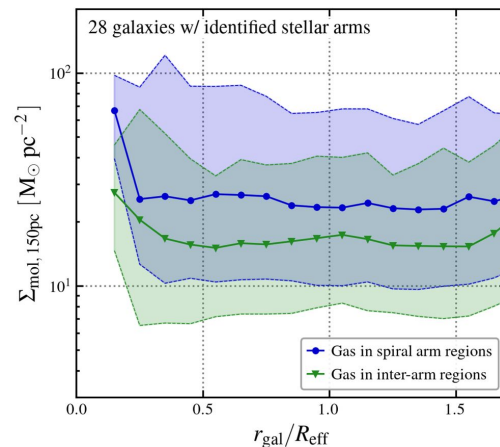
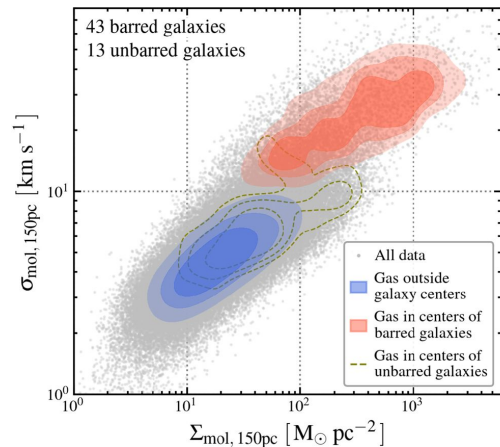


Fig. 1. Total H I map of NGC 4013 superposed on the optical image. Colours are at levels of 1.02×10^{21} , 2.03×10^{21} , 4.06×10^{21} , 8.13×10^{21} , 20.32×10^{21} , and 46.82×10^{21} H-atoms cm^{-2} . The resolution is indicated by the beam in the lower right corner.

Molecular Gas Properties on Cloud Scales across the Local Star-forming Galaxy Population, Sun et al. 2020

Results

- Barred galaxies have higher Σ_{mol} and σ_{mol} than non-barred galaxies, which is linked to star formation.
 - Stellar bars drive large scale gas inflows
 - Stellar and AGN feedback enhance local turbulence
- Spiral arms have molecular clouds with higher surface density, turbulence and more bound gas, when compared to inter-arm regions.



Molecular Gas Properties on Cloud Scales across the Local Star-forming Galaxy Population, Sun et al. 2020

Results

- In more massive and higher star forming galaxies (darker color code) the molecular gas is:
 - More dense (Σ_{mol})
 - More turbulent (σ_{mol} , P_{turb})
 - More self-gravitating (α_{vir})

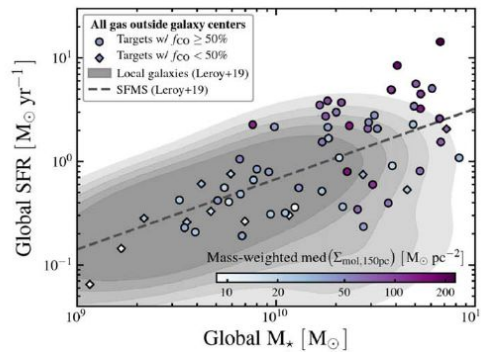
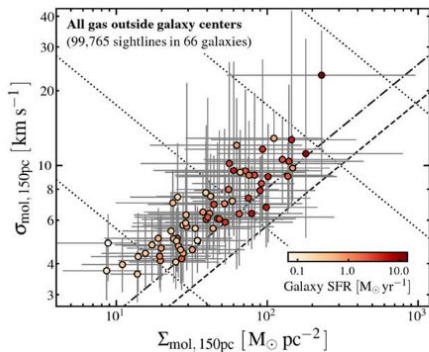
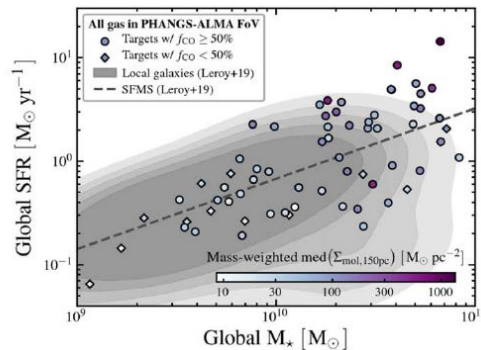
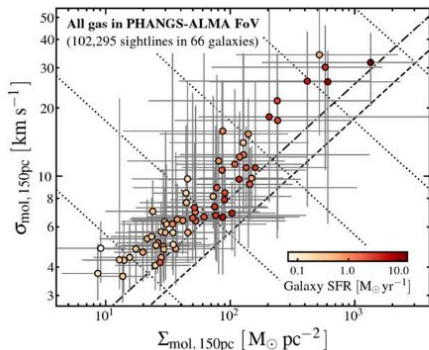
Global galaxy properties



Local galaxy properties



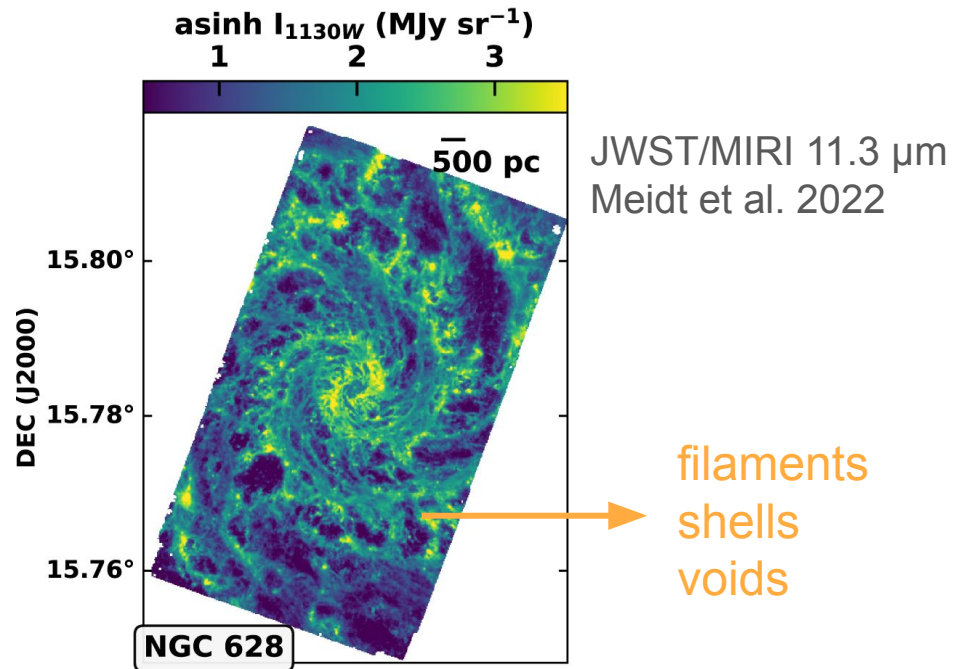
Molecular gas properties



PHANGS–JWST First Results: ISM structure on the turbulent Jeans scale in four disk galaxies observed by JWST and ALMA, Meidt et al. 2022

Objective

Examine whether the multiscale network of gas structure is consistent with the fragmentation of the gas disk through gravitational instability, namely the Jeans and the Toomre instabilities



PHANGS–JWST First Results: ISM structure on the turbulent Jeans scale in four disk galaxies observed by JWST and ALMA, Meidt et al. 2022

Connection to the lecture slides (lecture 3)

Jeans Instability

In summary, for $dF_p > dF_g \implies$ fluid pressure resists gravitational collapse

However, for $dF_p < dF_g \implies$ system undergoes gravitational collapse

$dF_p = dF_g$ represents a specific physical scale.

$$dF_p = \alpha v_s^2 / r = \alpha GM / r^2 = dF_g$$

Using $M = \rho \frac{4}{3} \pi r^3$,

$$v_s^2 / r = G \rho \frac{4}{3} \pi r$$

We find:

$$r_J \sim (3 v_s^2 / (4\pi G \rho))^{1/2}$$

Perturbations on a larger scale than the Jeans scale r_J will result in a gravitational collapse.

Toomre Instability Criterion

In spiral/disk galaxies, the stability criterion is more complex, due to the shearing type motion

Similarly for a disk galaxies, there is also a stability criterion. Any perturbations with wavelength larger than λ_{crit} are unstable.

$$\lambda_{crit} = 2\pi / k_{crit} = 4\pi^2 G \Sigma / \kappa^2$$

Random motions by stars tend to stabilize disks. Disks with stellar motions are unstable if

$$Q = \frac{\sigma_R \kappa}{3.36 G \Sigma} < 1$$

This is the Toomre criterion. It assume that the disk is thin and unstable modes are much smaller than the size of the sky. Again, significant dispersion in the velocities of stars will stabilize the disk.

PHANGS–JWST First Results: ISM structure on the turbulent Jeans scale in four disk galaxies observed by JWST and ALMA, Meidt et al. 2022

Data

Four disk galaxies:

- IC 5332: flocculent dwarf spiral
- NGC 628: moderate-mass, grand design spiral
- NGC 1365: massive, strongly barred spiral
- NGC 7496: moderate-mass, barred spiral

Methods

- Used FilFinder algorithm to detect filamentary features and determine characteristic radial and azimuthal spacings
- Compared these to estimates of the most Toomre-unstable length, the turbulent Jeans length, and the disk scale height obtained through observations of molecular gas

PHANGS–JWST First Results: ISM structure on the turbulent Jeans scale in four disk galaxies observed by JWST and ALMA, Meidt et al. 2022

Results

- Filament spacing matches the Jeans scale
- Poor agreement with other characteristic scales



Best explained by the 3D turbulent Jeans scale, not by classical 2D instability scales

Gravity dominates over rotation on these scales

