The ISM scaling relations using inner HI and an application of estimating dust mass

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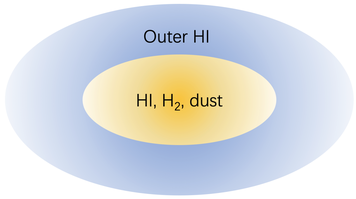
Motivation



- **Part I:** The trend of gas-to-dust ratio with metallicity is an important scaling relation to constrain dust evolution models and to link the H I, H_2, and dust. However, the gas-to-dust ratio tends to be overestimated due to the different radial extensions of multi-phase ISM, especially H I gas.
  We use the method based on Wang2020 to obtain the inner H I mass and calibrate a new dust–inner gas mass relation, which shows a stronger and tighter correlation than the dust–integral gas mass relation.
- **Part II:** W3 12 μm luminosity can indicate SFRs because PAHs and small warm dust grains can be heated in the PDRs (Cluver2017). We demonstrate a simple application of the scaling relations derived above, by predicting dust mass based on the inner gas mass from a larger and relatively representative sample of disk galaxies, to take a new look into the influence of galactic internal environments, including the metallicity, ionization parameter, and stellar mass surface density of old stars, on the W3 12 μm luminosity as an SFR indicator.

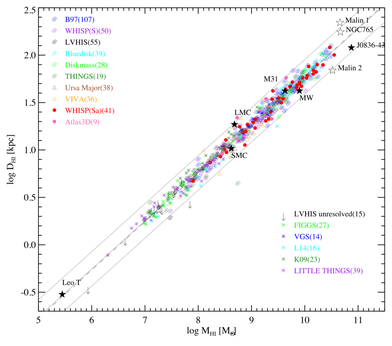
Data

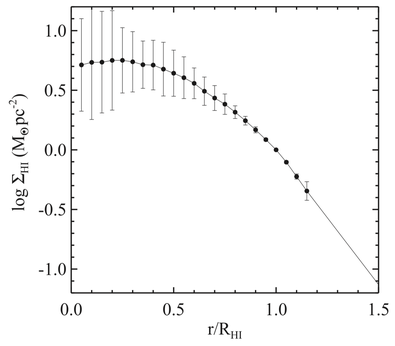
- **Part I:** We selected a disk-like galaxy sample with observations of the H I, H_2 and dust from HRS to study the relationship between gas-to-dust ratio and metallicity in the inner region of galaxies.
- **Part II:** We selected a disk-like galaxy sample with observations of the H I and H_2 from xCOLD GASS to predict dust mass and validate our calibration. We further combined it with the JINGLE sample to study the metallicity dependence of the WISE W3 band at a given dust mass and SFR.

Method

We follow the method in Wang2020, which estimates the H I mass within the optical radius r_{90} from the integral H I mass $M_{\rm HI}$.

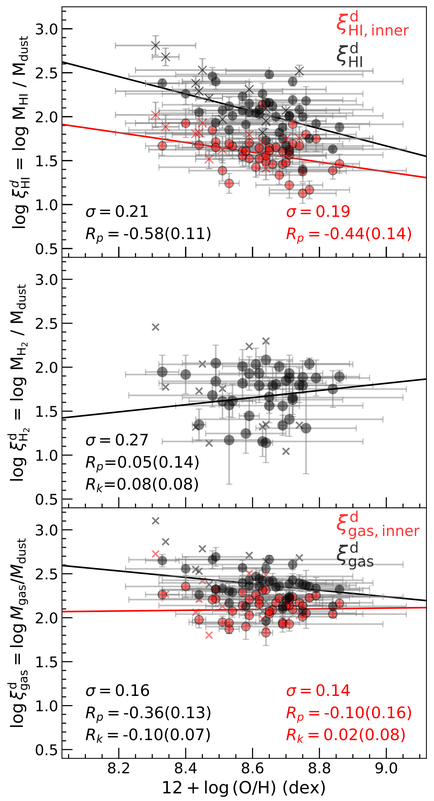
- First of all, for the given $M_{\rm HI}$ of a galaxy, we estimate the characteristic radius $R_{\rm HI}$ based on the relation between $D_{\rm HI}$ and $M_{\rm HI}$.
- Then, we estimate the H I mass beyond the optical r_{90} ($M_{\rm HI,out}$) based on the H I surface density $\Sigma_{\rm H\,I}$ profiles of disk-like galaxies from Wang2020. After subtracting $M_{\rm HI,out}$ from $M_{\rm HI}$, we obtain the H I mass within r_{90}, .



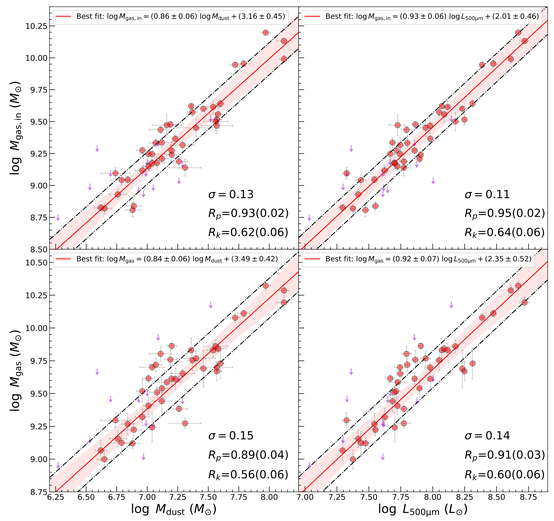


Gas-to-dust ratio for inner H I and inner gas

- The trend of $\xi_{\rm HI,in}$ with metallicity is weaker compared to that of $\xi_{\rm HI}$ and shows a slightly smaller scatter.
- The $\xi_{\rm gas}$ show an anti-correlation with $12+\log({\rm O/H})$, but $\xi_{\rm gas,in}$ do not significantly depend on $12+\log({\rm O/H})$.
- The $\xi_{\rm gas,in}$ also shows the smallest scatter at a given metallicity within all of these relations.
- These results indicate that at least part of the relation between $\xi_{\rm gas}$ and metallicity is due to the inclusion of metal-poor and outlying H I gas.
- It supports that dust is more closely associated with co-spatial cold gas than the overall cold gas.
- The inner gas mass has a unique but overlooked role in studying galactic star formation and galaxy evolution.

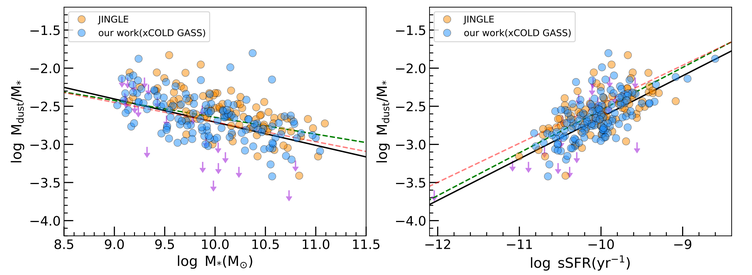


Predicting $M_{\rm gas,in}$ with $M_{\rm dust}$ and infrared luminosity



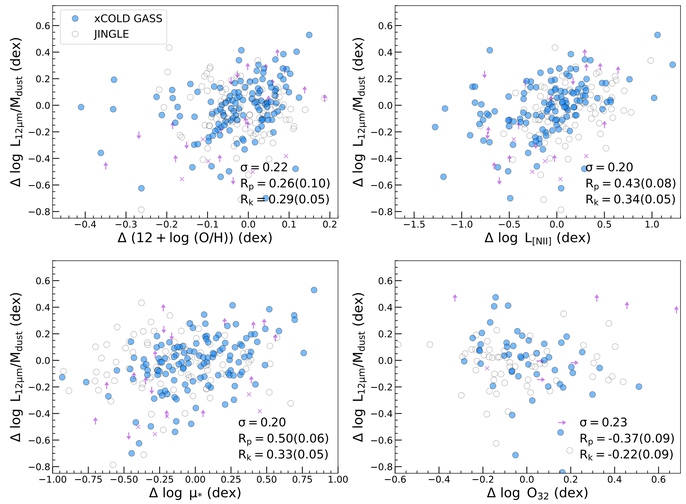
- The inner gas mass shows a stronger and tighter correlation with the dust mass than that of the integral gas mass.
- These strong connections enable us to better predict the inner gas mass based on IR/dust measurements, or the other way round.
- Based on that, we calibrate scaling relations between the $M_{\rm gas,in}$, $M_{\rm dust}$, and $L_{500\mu m}$.

Predicting dust masses for xCOLD GASS disk sample



- We apply the inner gas–dust mass relation to estimate dust masses for the xCOLD GASS disk sample, which supports that the $M_{\rm gas,in}$–$M_{\rm dust}$ relation could provide a reasonable prediction of dust mass.
- These relations are consistent with the fiducial relations in the literature.

WISE W3 band as an SFR indicator



- First of all, we calculate for each galactic property the residual from its scaling relations with SFR, and study the metallicity dependence of WISE 12 μm luminosity at given $M_{\rm dust}$.
- The galactic WISE W3 luminosities show median dependence on the metallicity, ionization parameter, and the stellar mass surface density.
- Such dependence highlights the caveat of using the W3 luminosity as an integral SFR indicator.

Key References

[1] M. E. Cluver, T. H. Jarrett, D. A. Dale, J.-D. T. Smith, Tamlyn August, and M. J. I. Brown. Calibrating star formation iniWISE/iusing total infrared luminosity. *The Astrophysical Journal*, 850(1):68, November 2017.

[2] Jing Wang, Barbara Catinella, Amélie Saintonge, Zhizheng Pan, Paolo Serra, and Li Shao. xGASS: H i fueling of star formation in disk-dominated galaxies. 890(1):63, February 2020.