The PdBI Arcsecond Whirlpool Survey (PAWS) I.
Molecular Gas, Dust and Star Formation.

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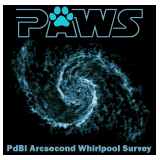


Abstract: While observations of nearby galaxies tell us that stars must form out of the cold neutral (molecular) gas, there is no satisfactory self-consistent physical model explaining the star formation process in galaxies. Detailed observations of molecular gas at the scales of Giant Molecular Clouds (GMCs) in a galactic disk such as obtained by the IRAM PdBI Arcsecond Whirlpool Survey (PAWS) can play an important role to help develop such a model. PAWS mapped the CO(1-0) line emission in the central 11 x 7 kpc of the nearby grand-design spiral galaxy M51a at the resolution of a typical GMC with a spatial resolution of 40pc and a 5σ mass sensitivity of $2x10^5$ M_{sun}. Comparison of the molecular gas line emission to other tracers of the interstellar medium probing either the cold ISM phase or regions impacted by ongoing massive star formation suggest that optical extinction, non-thermal radio continuum and PAH emission correlated very well with the cold dense gas distribution. However, atomic HI and [CII] line emission are better tracers of regions that are severely impacted by a strong radiation field leading to significant photo-dissociation of the molecules (i.e. PDRs). Finally, the distribution of young star formation (as seen in hot dust emission and Hα line emission) can be coincident with molecular gas, significantly offset or even absent on a scale of about 100pc. We interpret this as a dependance of galactic environment for molecular gas to collapse and form stars.

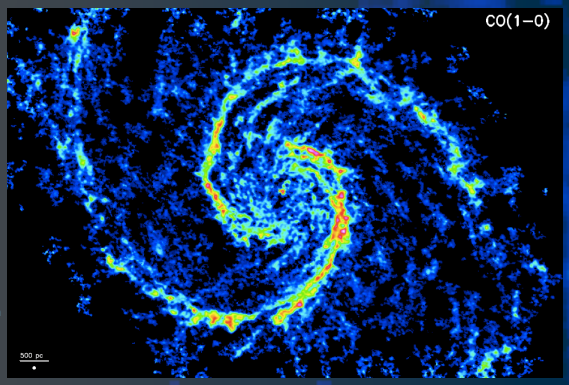
PAWS - PdBI Arcsecond Whirlpool Survey

IRAM Large Program (PI Schinnerer)

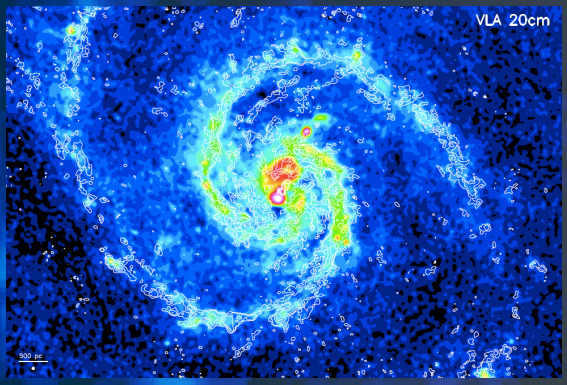
170 hr of PBDI
40 hr of 30m

1.16"x0.97"
~40pc
5σ: $2x10^5 M_{sun}$

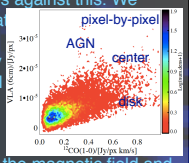
M51=NGC5194
D : 7.6 Mpc
1" : 37 pc
M_{star}:$4x10^{10} M_{sun}$
M_{mol}:$6x10^9$ M_{sun}
M_{gas}: $9x10^9$ M_{sun}



Molecular Gas vs. Cosmic Rays

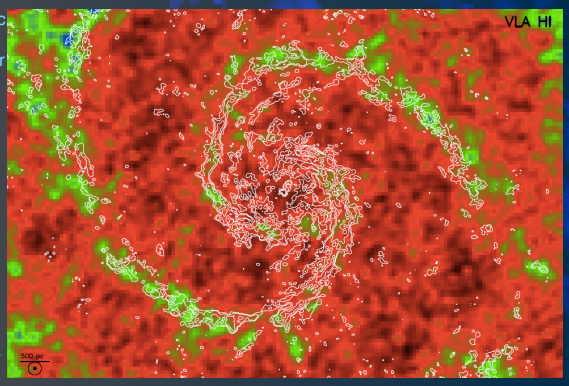


While the good correlation between radio continuum and CO line emission is well-known, the underlying cause is not. Supernova remnants have been suspected, but the presence of radio emission in the gas spiral arms where no star formation is seen argues against this. We suggest that the higher gas density in the spiral arms is the root cause via local coupling of the magnetic field and the gas density.

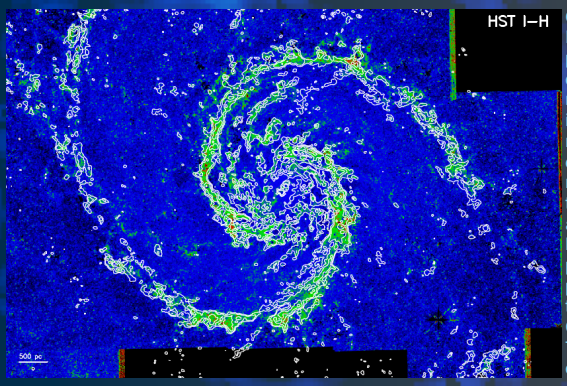


Neutral ISM: Molecular vs. Atomic (HI)

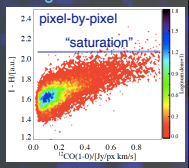
The central 9kpc are dominated by the molecular phase of the ISM. Enhanced HI line emission (from THINGS, Walter et al. 2008) is found downstream of the gas spiral arms likely due to photo-dissociation of H_2 in the massive star forming regions.



Molecular Gas vs. Dust: Cold (via A_V)

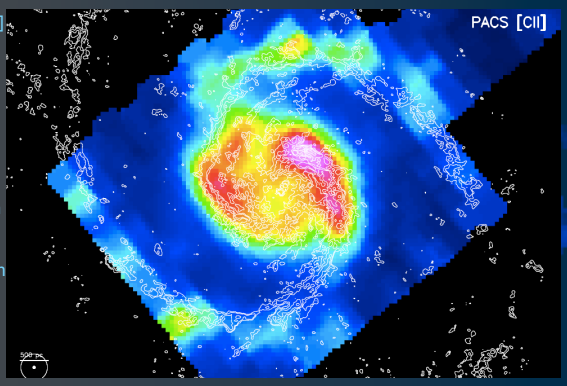


Optical extinction as traced by the HST i-H color is an excellent predictor of the underlying distribution of the cold dense, i.e. molecular, gas. However, a direct inference of the molecular gas mass from extinction as regularly done for Galactic clouds might not be straight-forward as the color appears to lose its predictive power for the largest CO fluxes. This is opposite to Galactic findings.

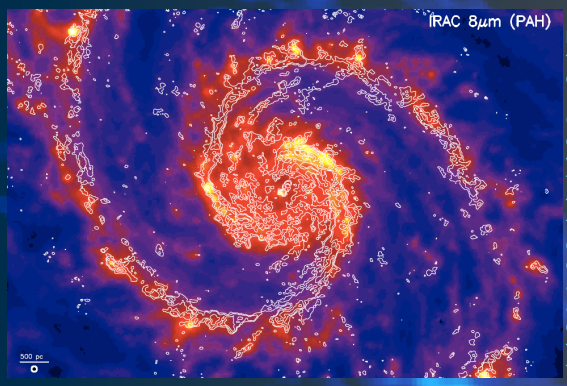


Neutral ISM: Molecular vs. Atomic ([CII])

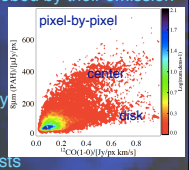
The 158μm [CII] cooling line (HSO; PI Wilson) is strongest in regions of massive star formation, and offset from the CO arms. Again photo-dissociations of CO molecules in massive star forming regions is a viable explanation.

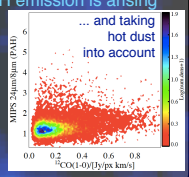


Molecular Gas vs. Dust: PAH



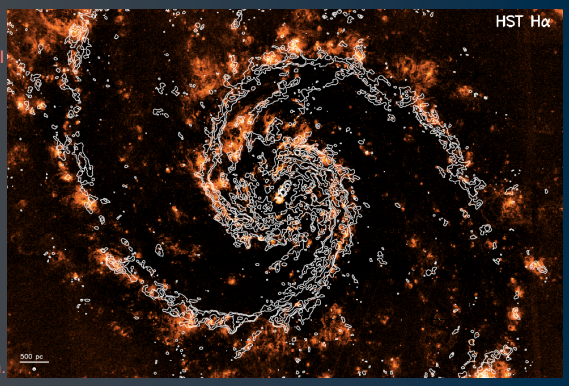
PAHs as probed by their emission bands in the 8μm channel of IRAC and CO intensity correlate very well. This suggests that the PAH emission is arising from the outer layer of GMCs and is thus a better dense gas than SFR tracer.



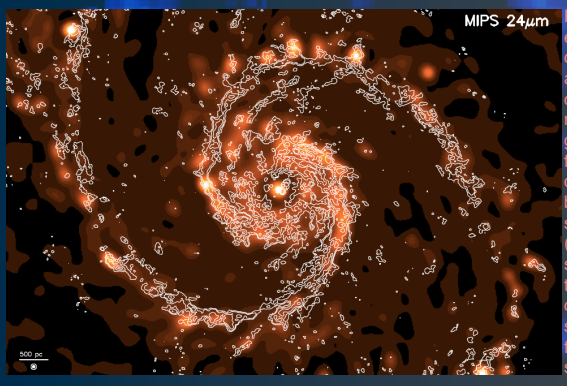


Star Formation: Molecular Gas vs. HII Regions

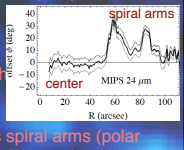
The HST Hα image reveals several giant HII regions along the spiral arms that are associated with gas spurs emanating from the arms. In a few spurs triggered star formation might have occured. Only few HII regions are found in the inter-arm region.

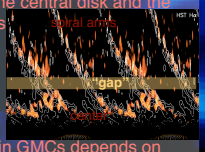


Star Formation: Molecular Gas vs. Hot Dust



Hot dust traced by 24μm mid-IR emission does not always correlate with molecular gas: offset from the gas spiral arms (polar cross correlation - top) and a gap between the central disk and the spiral arms (bottom) suggest that the onset of star formation in GMCs depends on several parameters.





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