Molecular Gas & Star Formation in the Centers of Nearby Galaxies

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Galaxy centers host more extreme conditions compared to disks.

Galaxy centers are where starbursts, AGN, outflows, etc exist.

SF in centers has potential to alter galaxy morphology over time.
Multi-Wavelength View of Nearby Galaxies:

- HI - THINGS (Walter et al. 2008)
- CO - HERACLES (Leroy et al. 2009, 2013)
- Dust - SINGS & KINGFISH (Kennicutt et al. 2003, 2011)
- Star Formation - GALEX NGS, SINGS & other optical narrow-band or IFU surveys
- metallicity, stellar mass, dynamics, etc.
Questions:

• How do we trace molecular gas in galaxy centers?

• What is the star formation efficiency like in these regions?

• What role does SF in galaxy centers play in galaxy evolution?
\( \alpha_{\text{CO}} \) is low in some galaxy centers

Sandstrom et al. 2013
Ackermann et al. 2012
Fermi-LAT γ-ray constraints

\( \alpha_{\text{CO}} \) consistently found to be low in central \( \sim kpc \).

Dahmen et al. 1998
\( \text{C}^{18}\text{O} \) observations

MW disk \( \alpha_{\text{CO}} \) overestimates mol. mass by factor \( \sim 10 \)

Sodroski et al. 1995
\( \Sigma_{\text{dust}} + \text{DGR(Z)} \)

MW disk \( \alpha_{\text{CO}} \) overestimates mol. mass by factor \( \sim 3-10 \)

Milky Way CO-to-H\(_2\) conversion factor is low in the center too...
Why is $\alpha_{\text{CO}}$ lower in the centers?

- If molecular gas in bound clouds (GMCs):
  - density, temperature, turbulence, can change $\alpha_{\text{CO}}$

- If there aren't "clouds" but instead molecular gas is in a more extended/diffuse phase:
  - chemistry/radiative transfer/excitation can change (e.g. Liszt & Pety (2010))
  - velocity dispersion enhanced due to grav. potential and dynamics in the center (e.g. ULIRGS)
Effects of molecular cloud properties on $\alpha_{\text{CO}}$.

- normal mol. cloud
- more turbulence
- warmer gas
Why is $\alpha_{CO}$ lower in the centers?

*molecular gas temperature plays a role...*

Survey of 22 galaxies with *Herschel* SPIRE-FTS
(200-600 µm spectroscopy)
PI J.D. Smith

Trend for higher CO excitation in centers with low $\alpha_{CO}$. 

**Sandstrom & BtP Team, in prep**

![Beyond the Peak](image.png)
Evidence for enhanced CO excitation in centers with low $\alpha_{\text{CO}}$ from BtP.
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Gas Depletion Time
\[ \tau_{\text{dep}} \equiv \frac{\Sigma_{\text{H}_2}}{\Sigma_{\text{SFR}}} \]

Star Formation Efficiency
\[ \text{SFE} \equiv \frac{\Sigma_{\text{SFR}}}{\Sigma_{\text{H}_2}} \]
Subset with low incl and $\alpha_{\text{CO}}$ measured in Sandstrom et al (2013)

RGB = (IRAC 8, 4.5, 3.6 $\mu$m)
SFE increasing

- SABcd: weakly barred
- SAab: oval
- SABcd: un-barred
- SBb: barred
- SABbc: un-barred
- SABcd: oval
- SAAAbb: un-barred
What causes higher SFE in the barred/oval galaxy centers?
Questions:

• How do we trace molecular gas in galaxy centers?

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Implications for Secular Evolution

“...the slow rearrangement of energy and mass that results from interactions involving collective phenomena such as bars, oval disks, spiral structure, and triaxial dark halos.”

- Kormendy & Kennicutt 2004 ARA&A

**Stellar Bar/Oval**

**Drives gas inflow**

**Gas concentration builds in center**

**Star formation & pseudobulge growth**
Sakamoto et al. 1999
Barred galaxies have higher central concentrations of gas.

...but this assumes MW $\alpha_{CO}$!
After applying our $\alpha_{\text{CO}}$, barred & non-barred galaxies have similar concentrations.

If star-formation is much more efficient, do we expect gas concentrations to build?
Summary

• The CO-to-$\text{H}_2$ conversion factor is different in some galaxy centers.

• Tracing $\text{H}_2$ properly reveals SFE enhancements in barred/oval galaxy centers.

• SFE enhancements may play a role in secular evolution.

• ALMA observations can show what is different about molecular gas in these regions.