Molecular Gas & Star Formation in the Centers of Nearby Galaxies

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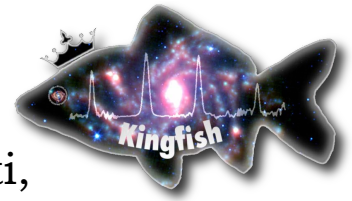
Collaborators



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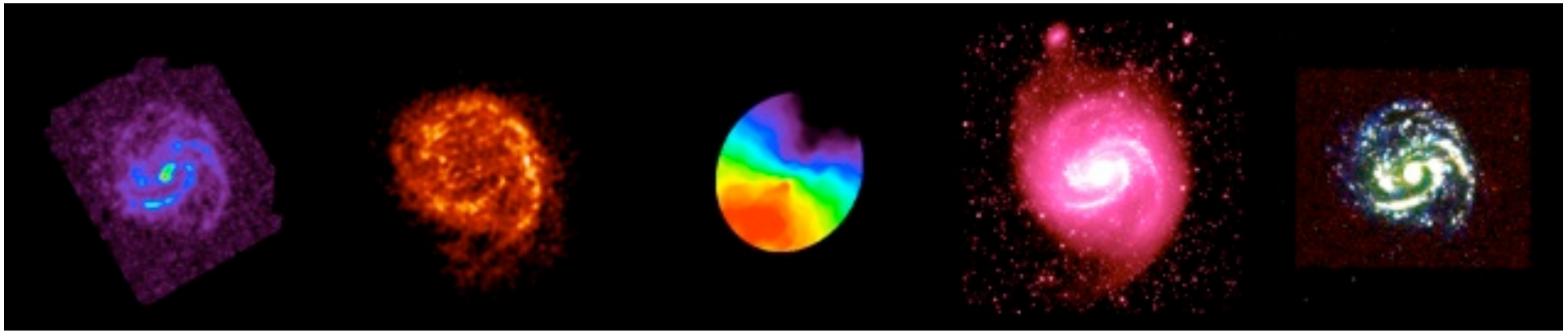
Galaxy centers host more extreme conditions compared to disks.

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

SF in centers has potential to alter galaxy morphology over time.

M51 Hubble ACS imaging
Credit: NASA/ESA/Hubble Heritage

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.

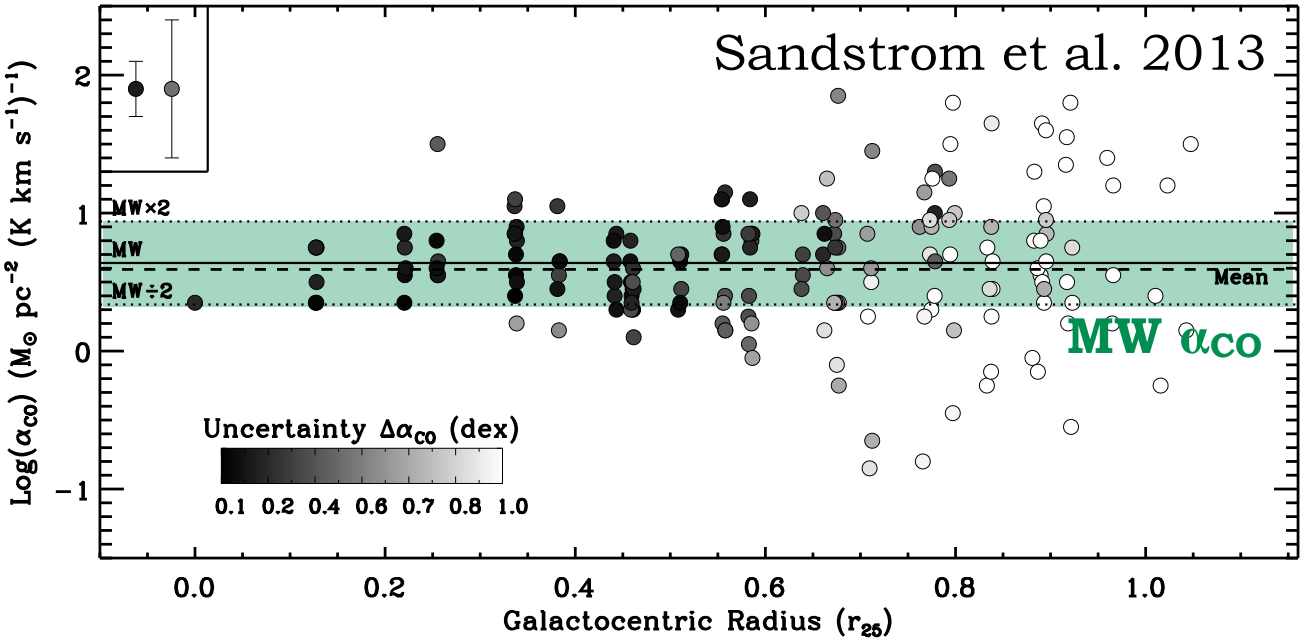
Questions:

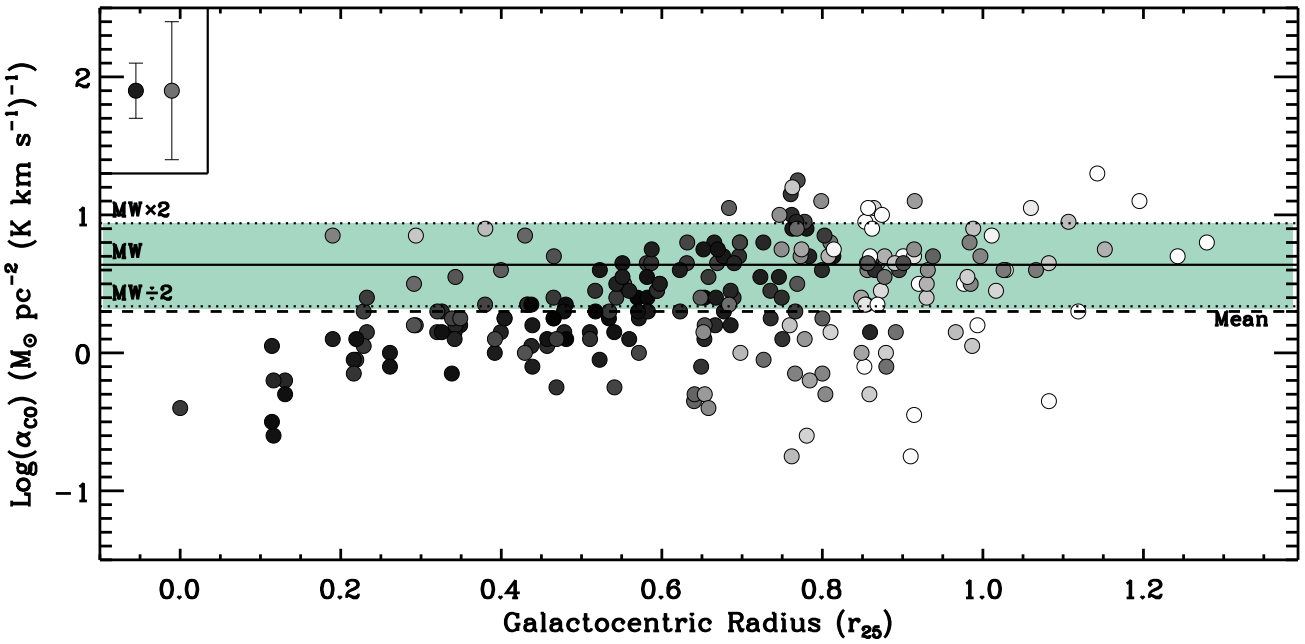
- How do we trace molecular gas in galaxy centers?
- What is the star formation efficiency like in these regions?
- What role does SF in galaxy centers play in galaxy evolution?

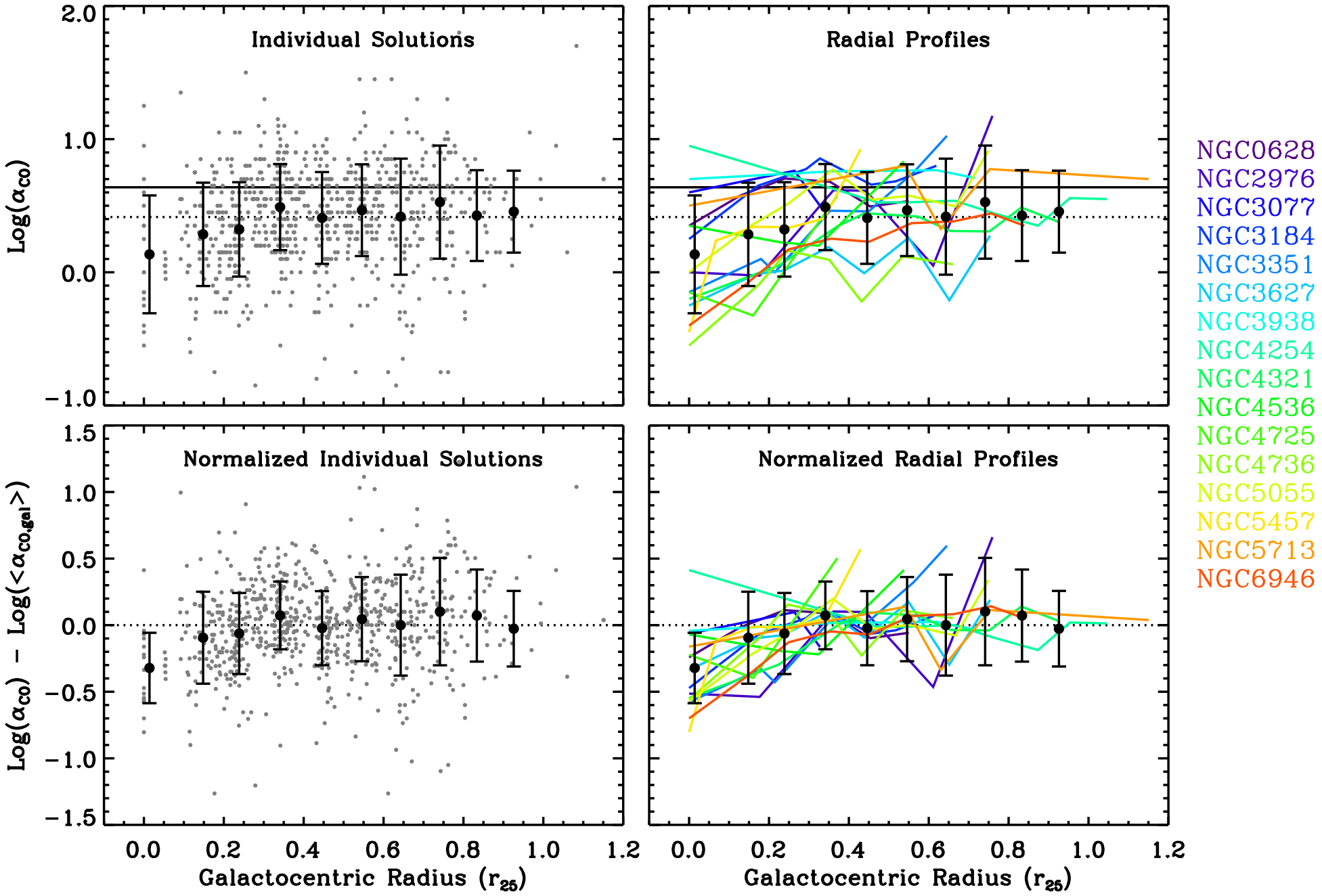
α_{CO} is *low* in some galaxy centers

NGC 0628

NGC 6946






Sandstrom et al. 2013
Individual Solutions
Radial Profiles
Normalized Individual Solutions
Normalized Radial Profiles
Log(αCO)
Log(αCO) − Log(<αCO,gal>)
Galactocentric Radius (r25)
Galactocentric Radius (r25)
NGC0628
NGC2976
NGC3077
NGC3184
NGC3351
NGC3627
NGC3938
NGC4254
NGC4321
NGC4536
NGC4725
NGC4736
NGC5055
NGC5457
NGC5713
NGC6946

Ackermann et al. 2012
Fermi-LAT γ-ray contstraints

α_{CO} consistently found to be low in central ~kpc.

Dahmen et al. 1998
$C^{18}O$ observations

MW disk α_{CO} overestimates mol. mass by factor ~10

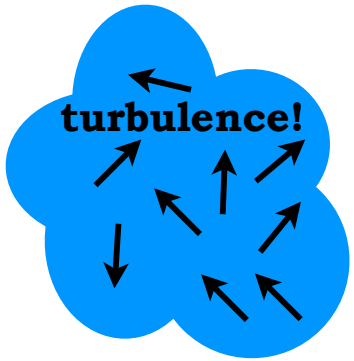
Sodroski et al. 1995
Σ_{dust} + DGR(Z)

MW disk α_{CO} overestimates mol. mass by factor ~3-10

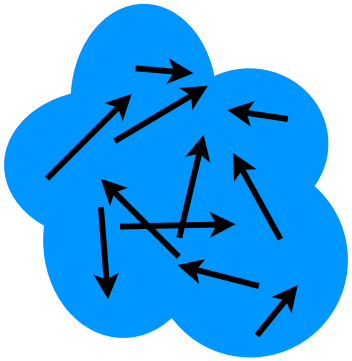
Milky Way CO-to-H_2 conversion factor is low in the center too...

Why is α_{CO} *lower* in the centers?

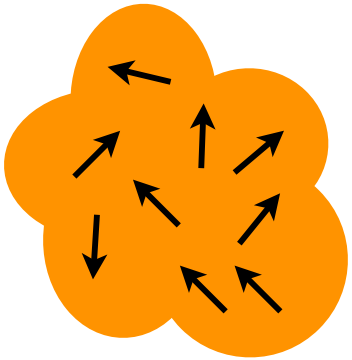
- If molecular gas in bound clouds (GMCs):
  - density, temperature, turbulence, can change α_{CO}



normal mol. cloud

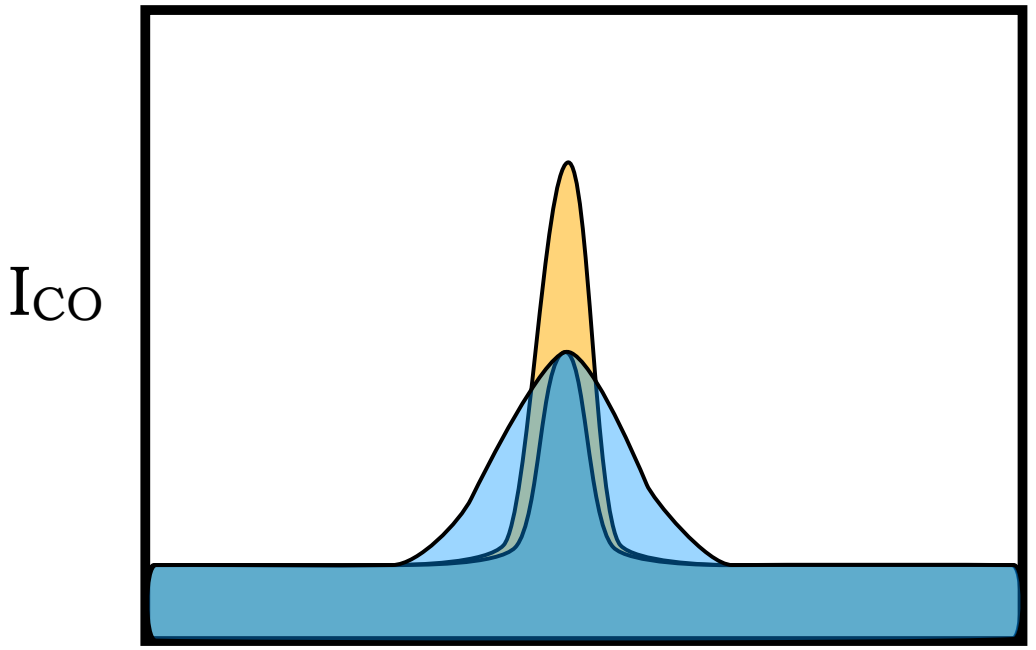


more turbulence



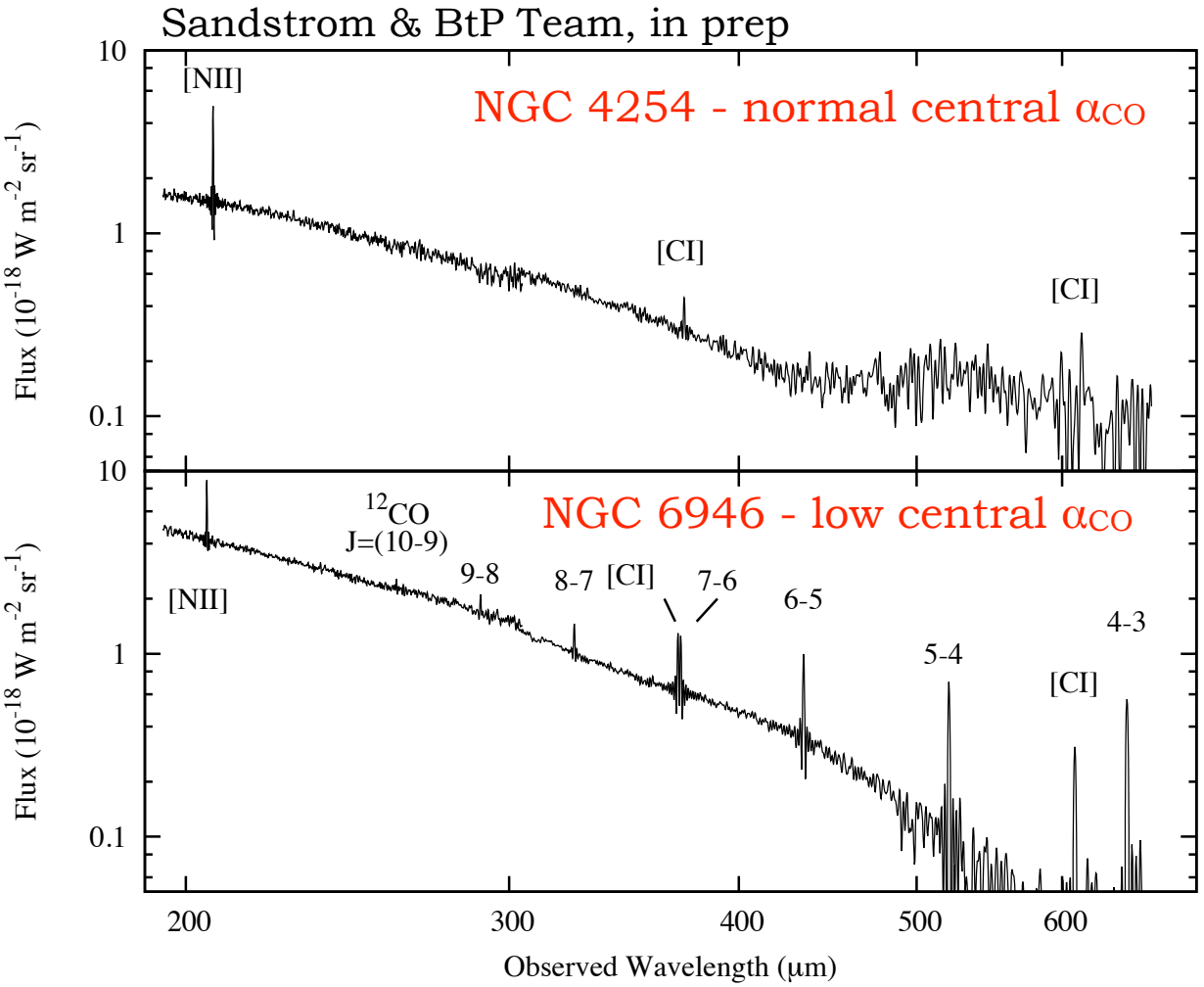
warmer gas

Effects of molecular cloud properties on α_{CO}.



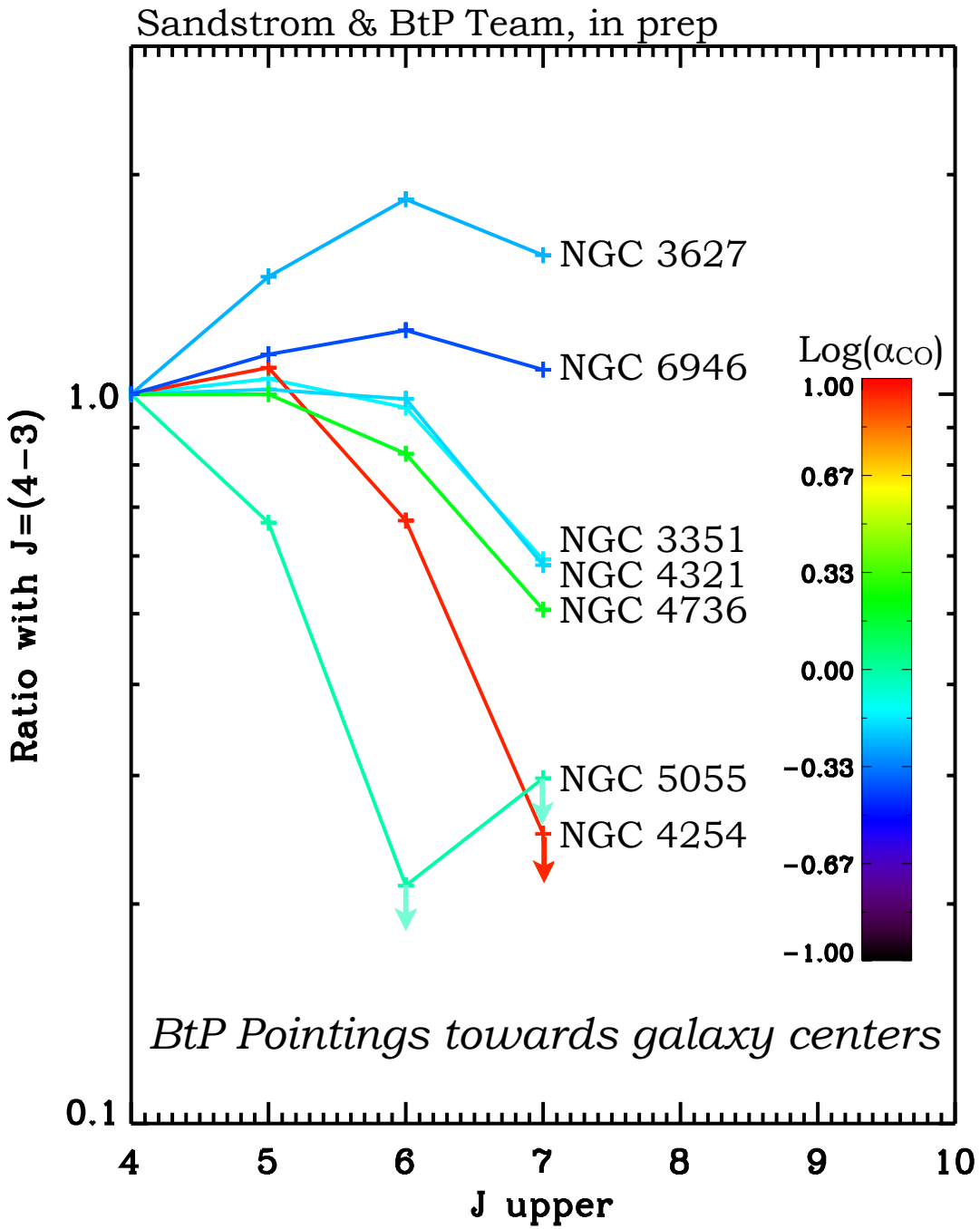
Why is α_{CO} *lower* in the centers?

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 α_{CO}.



Evidence for enhanced CO excitation in centers with low α_{CO} from BtP.

Why is α_{CO} *lower* in the centers?

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

Questions:

- How do we trace molecular gas in galaxy centers?
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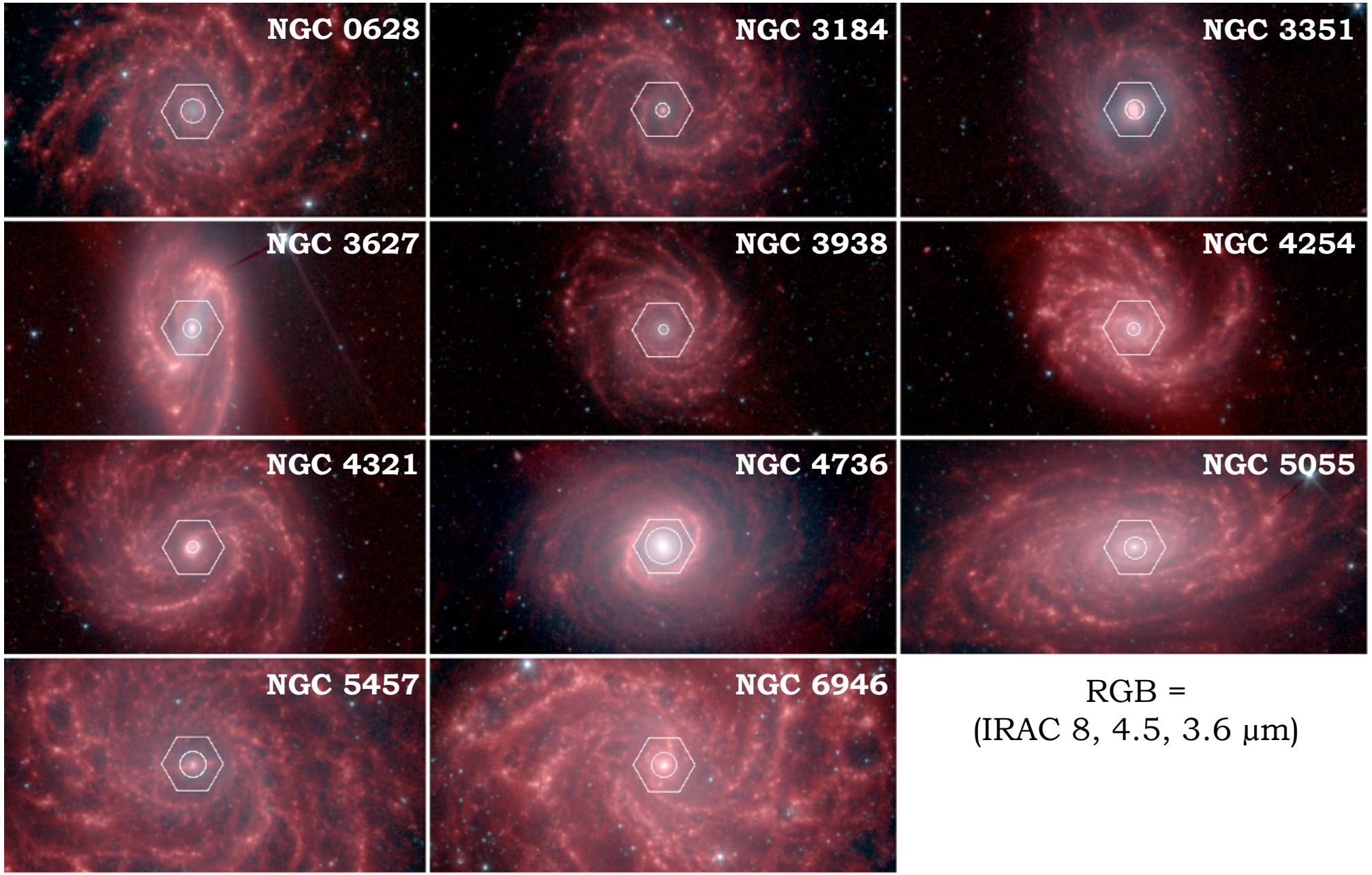
Gas Depletion Time

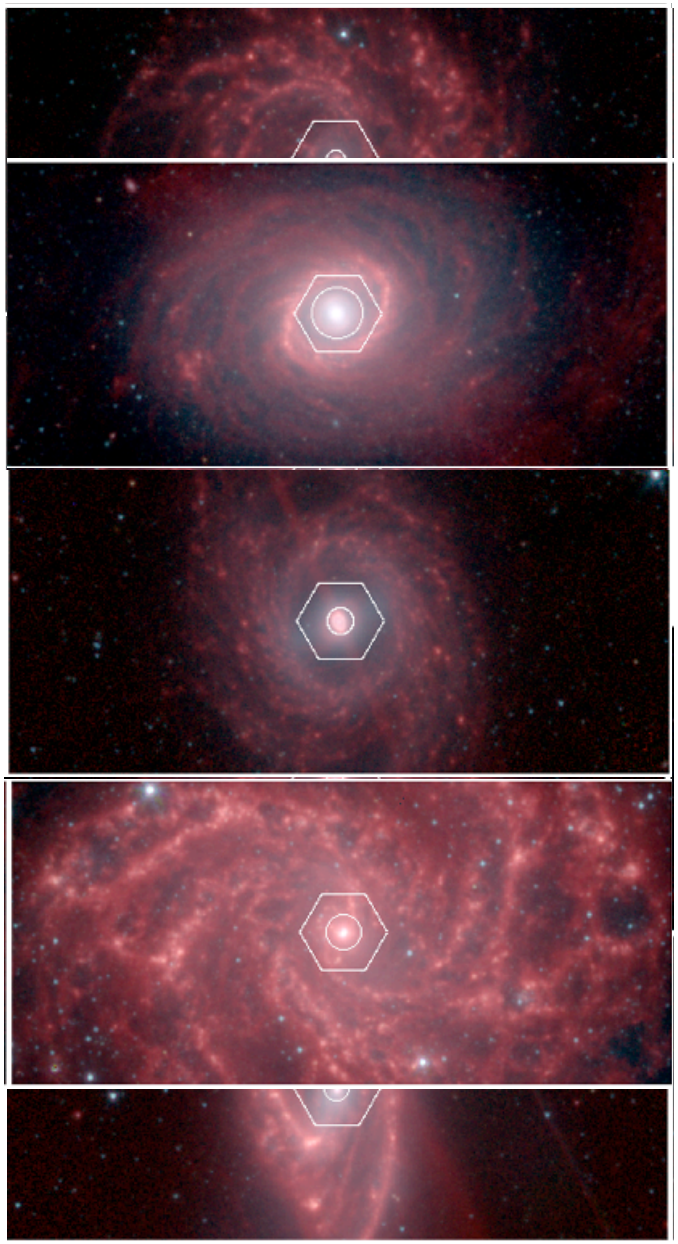
$$\tau_{dep} \equiv \Sigma_{H2}/\Sigma_{SFR}$$

Star Formation Efficiency

$$SFE \equiv \Sigma_{SFR}/\Sigma_{H2}$$



Subset with low incl and α_{CO} measured in Sandstrom et al (2013)



SFE increasing

SAcd *un-barred*

SABcd *weakly barred*

SAab *oval*

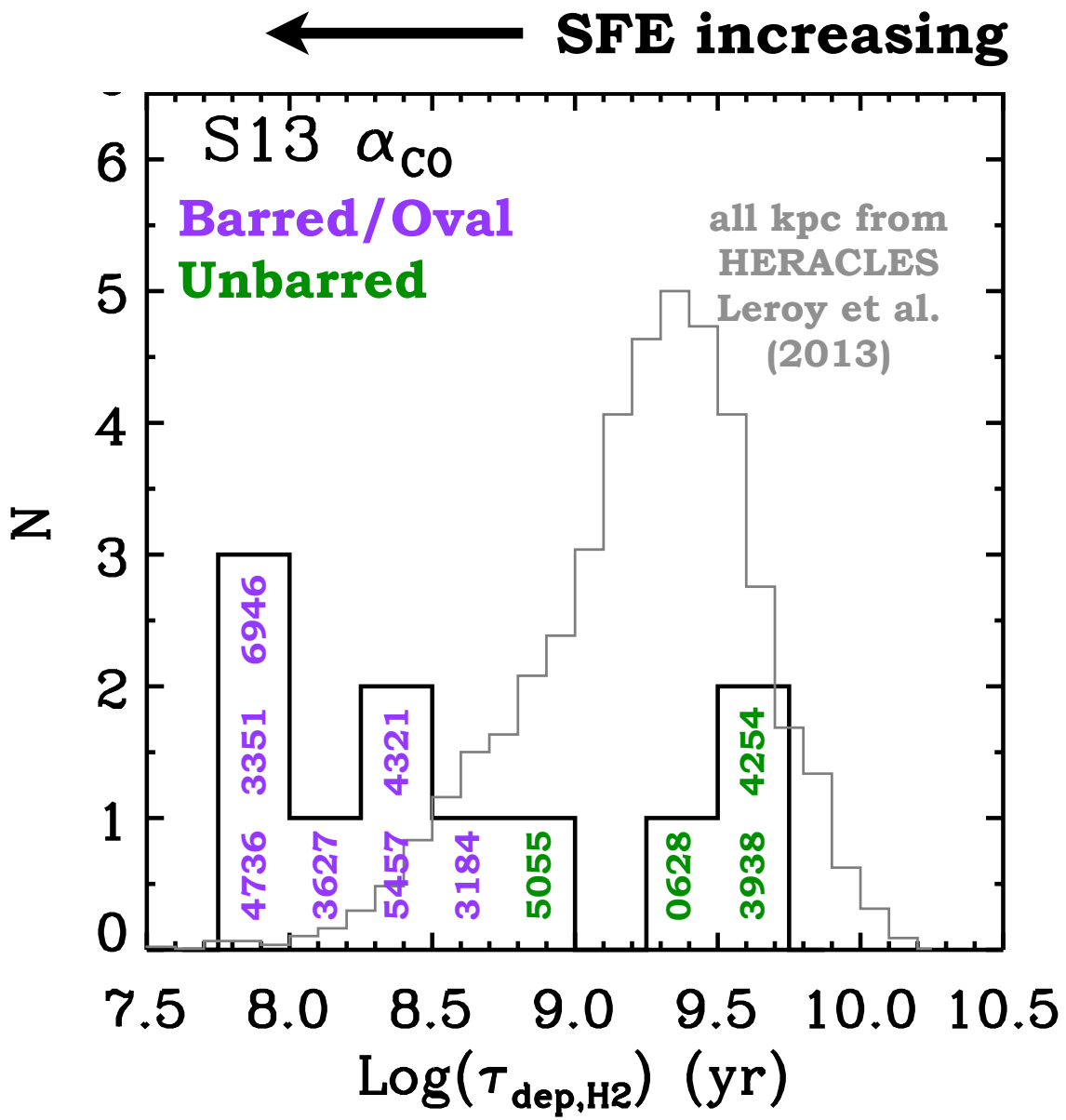
SABcd *un-barred*

SBb *barred*

SABbc *un-barred*

SABcd *oval*

SABb *un-barred*



What causes higher SFE in the barred/oval galaxy centers?

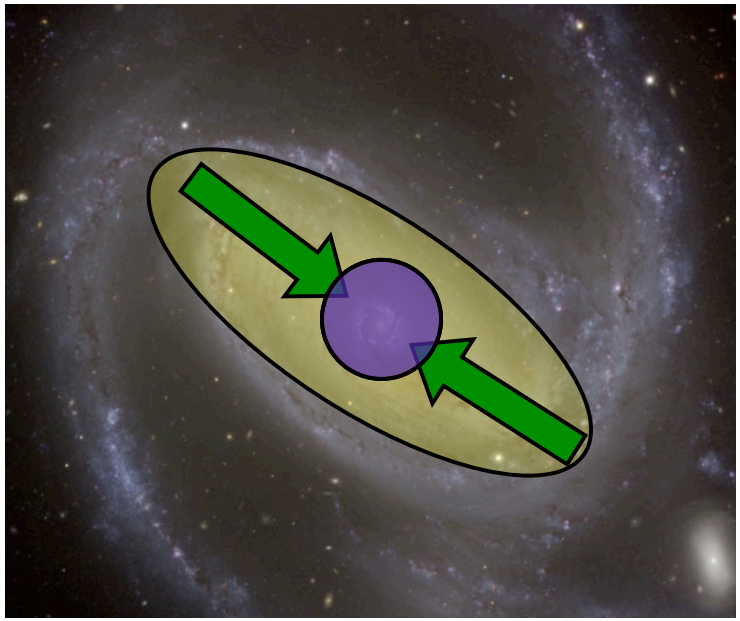
Questions:

- 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?

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

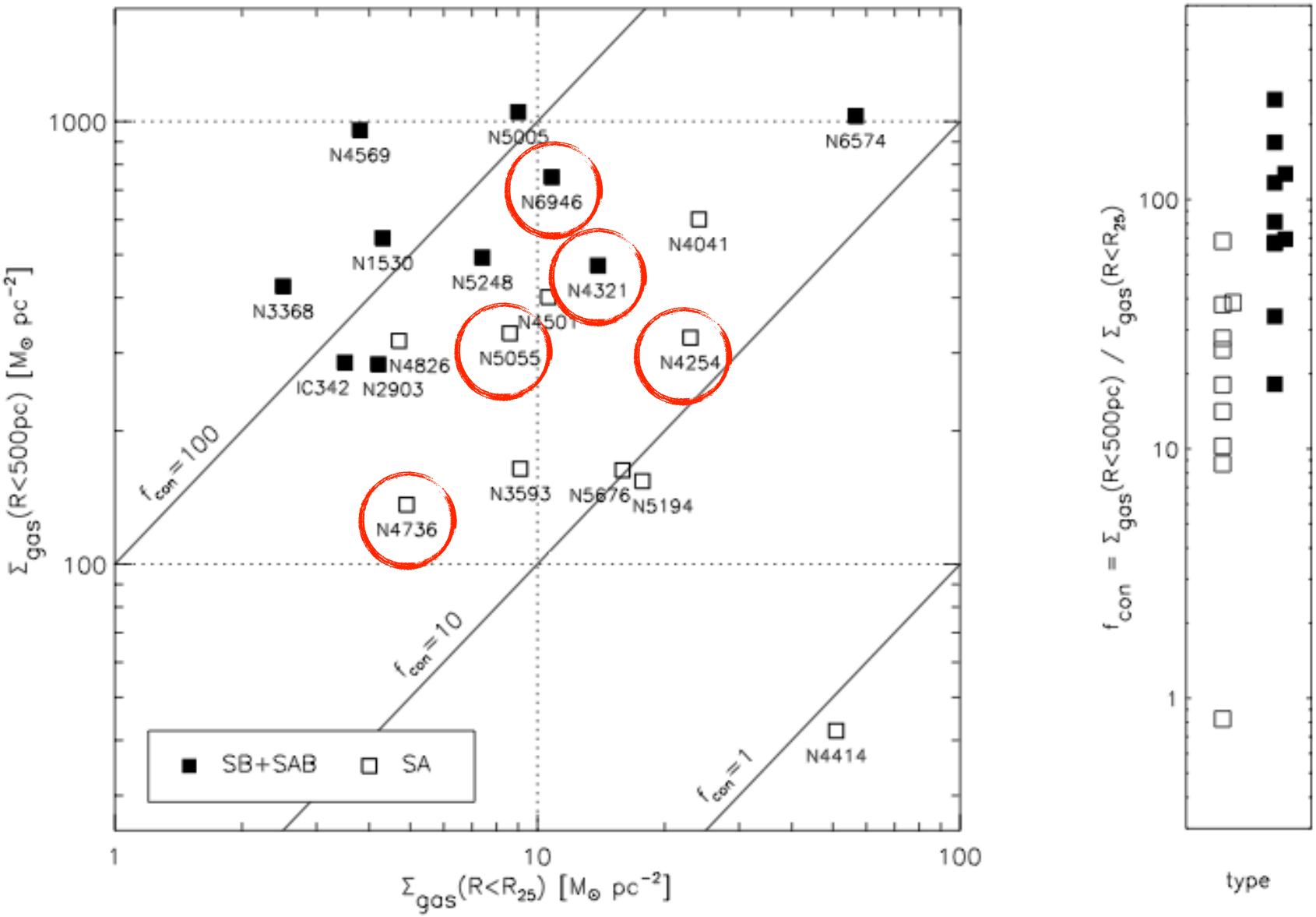


Stellar Bar/Oval

Drives gas inflow

Gas concentration builds in center

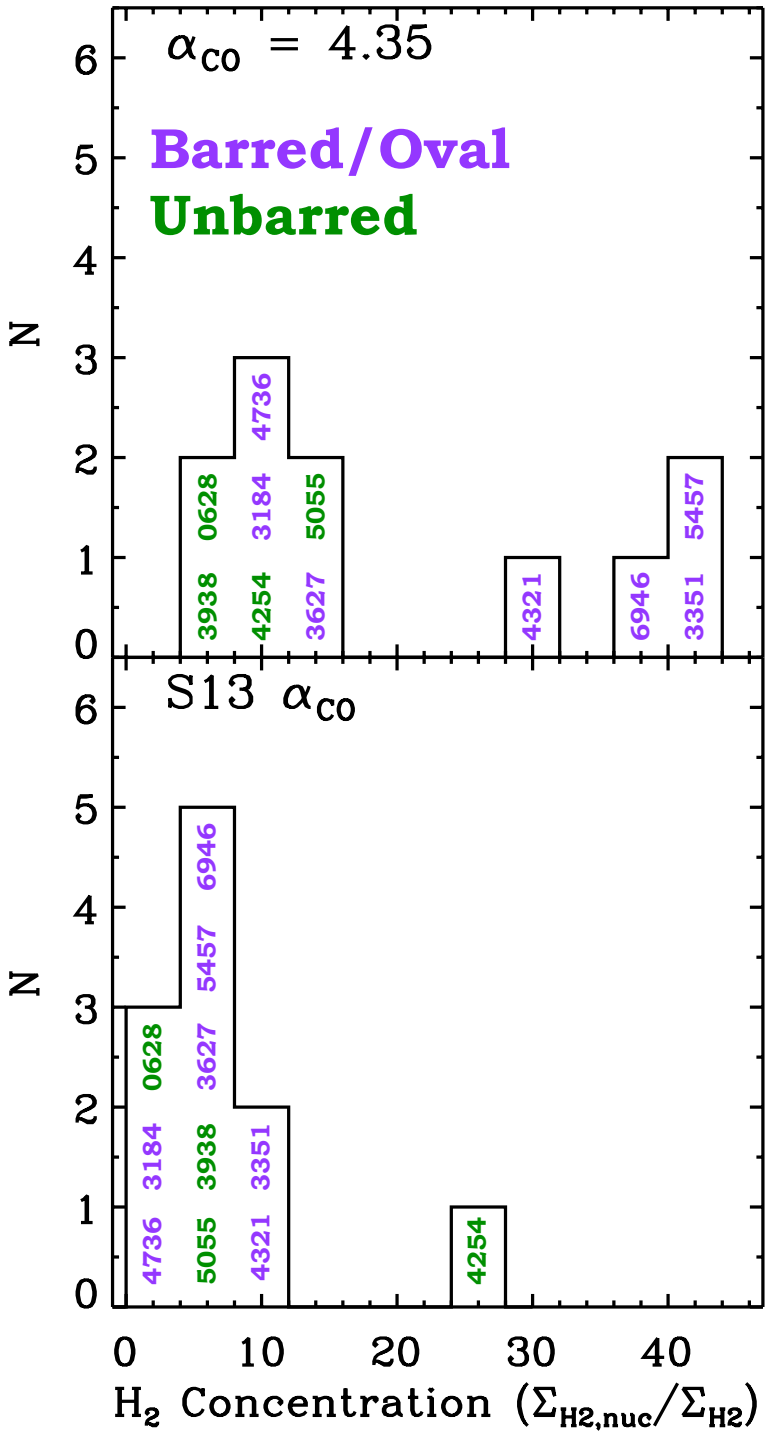
Star formation & pseudobulge growth



Sakamoto et al. 1999

Barred galaxies have higher central concentrations of gas.

...but this assumes MW α_{CO}*!*



Concentration = $\Sigma_{H2(<500pc)}/\Sigma_{H2(<r25)}$

After applying our α_{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-H_2 conversion factor is different in some galaxy centers.
- Tracing 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.