National Radio Astronomy Observatory

ALMA Band-2 (Extragalactic Science)

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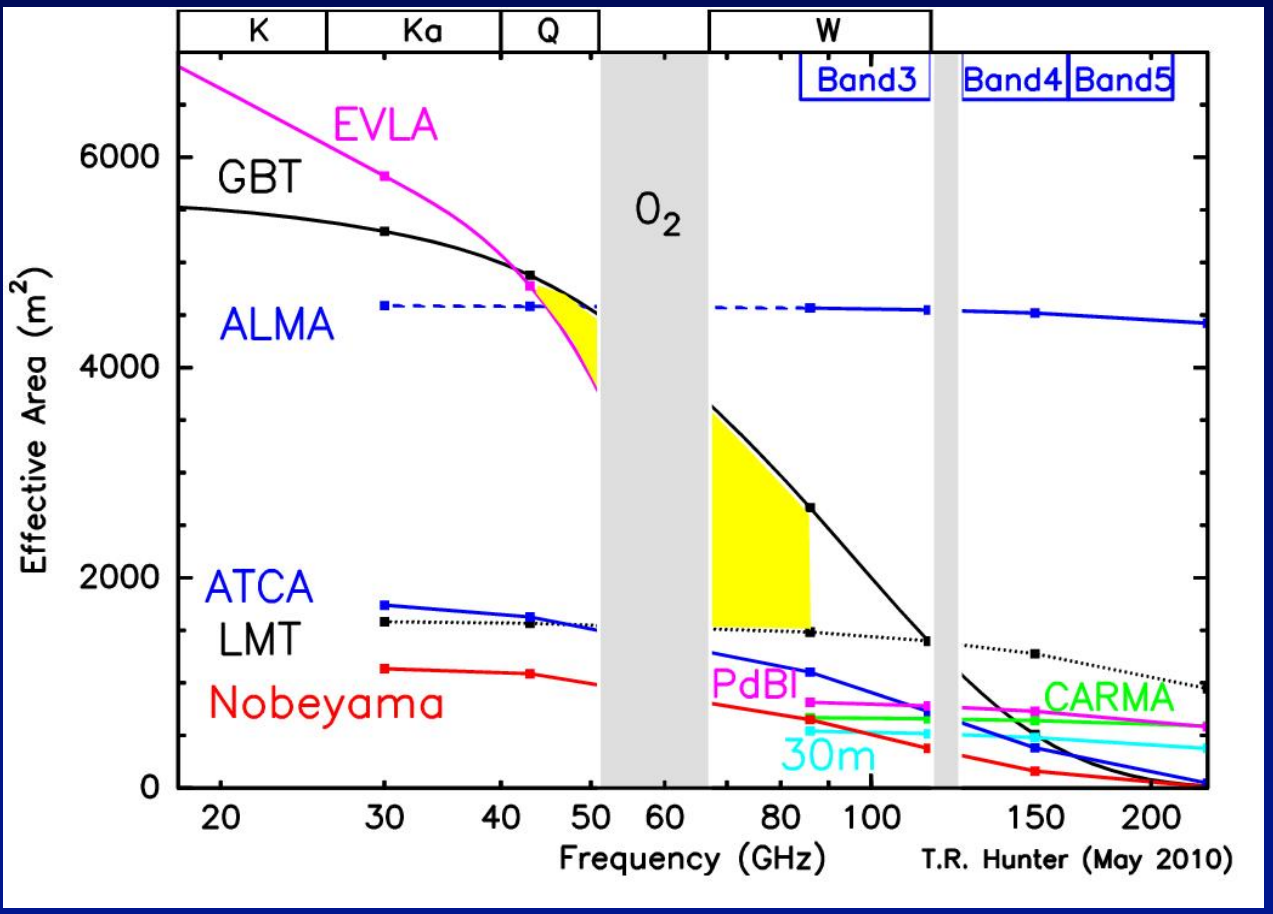
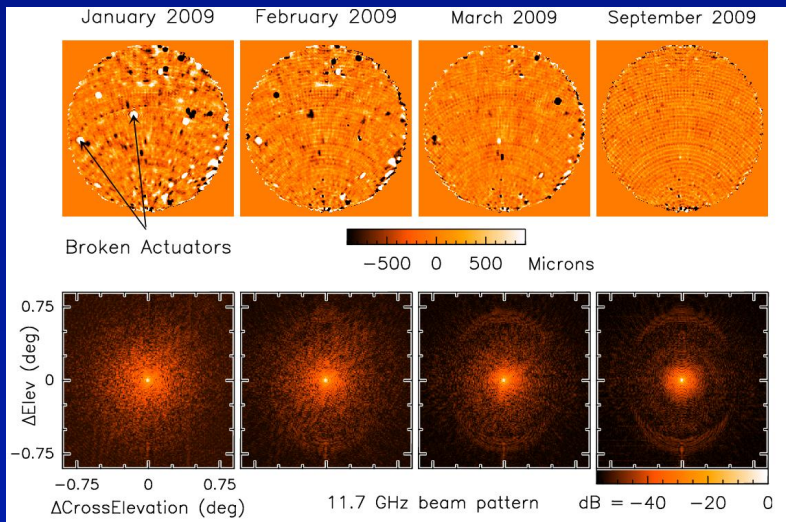
ALMA Band-2 (68-90 GHz) is a crucial missing band for astronomy. Very little sensitive coverage below 80 GHz with current telescopes ➔ A primary motivation for the GBT 4mm Rx (68-92 GHz) currently under construction (http://www.gb.nrao.edu/4mm/).



Robert C. Byrd Green Bank Telescope

Given recent surface improvements, the GBT has the largest effective collecting area at Q and 4mm (ALMA band2). Note that there 1000+ hr per year with good weather conditions for 90 GHz at Green Bank.



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(ALMA Band-2) 4mm Rx "Key Science"

- **Fundamental Physics –** With VLBI, probe the physics near the base of black hole jets in nearby galaxies {and measure the size of the galaxy via parallax of SagA*}.
- **The Context of Star Formation –** Deuterium species and dense gas tracers key for studies of cold cloud cores from which stars form.
- **Origin of Life –** Complex organic molecules and pre-biotic molecules in the ISM and comets which are key for studying the conditions from which life eventually forms (unexplored frequencies --- lots of discovery potential in astro/bio-chemistry).
- **Galaxies Across Cosmic Time –** CO(1-0) at intermediate redshifts where the evolution of galaxies is proceeding rapidly and dense gas tracers, such as HCN and HCO+, in local star-forming galaxies.

From the GBT 4mm Science Case

Bright Extragalactic Lines

FCRAO RSR:
NGC253+M82

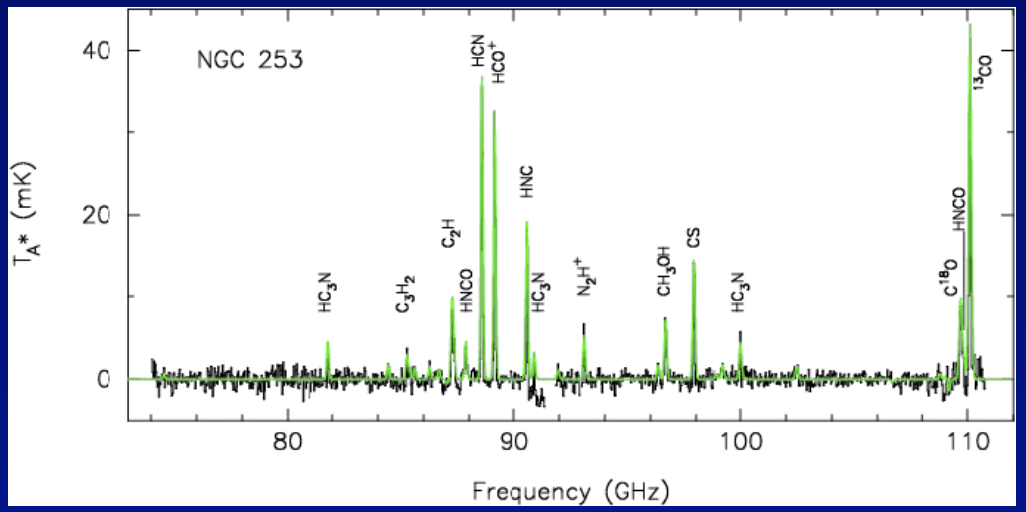
12CO: 0.25<z<0.7

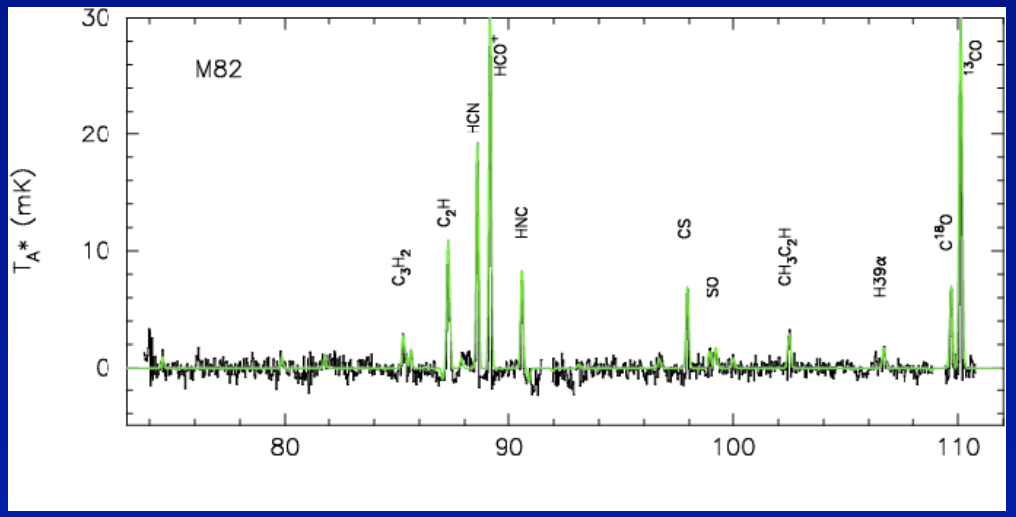
13CO: 0.2<z<0.64

HCN: 0<z<0.29

HCO+: 0<z<0.33

Intermediate redshifts and (1-0) transitions key.

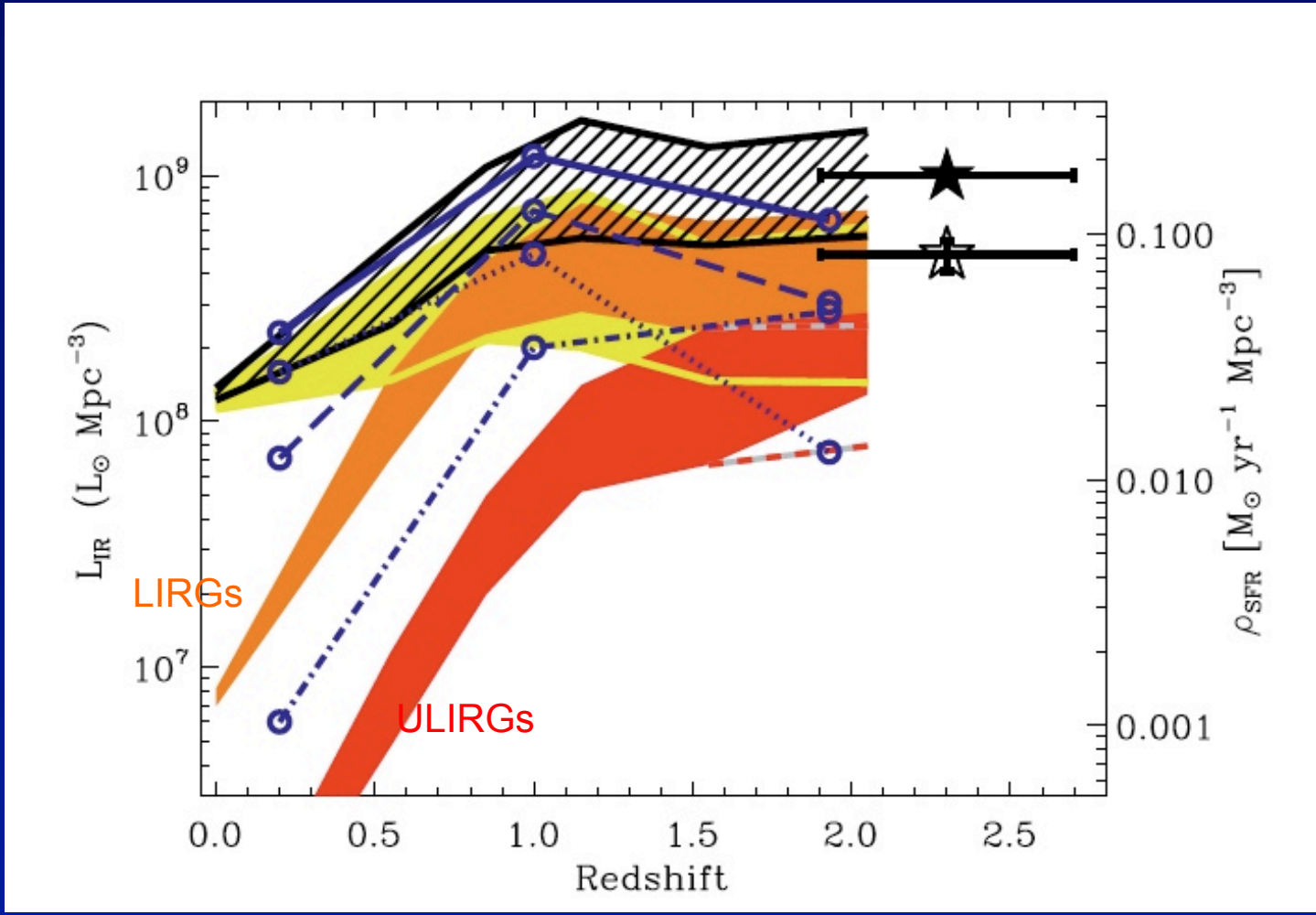




Star-Formation History from the Infrared

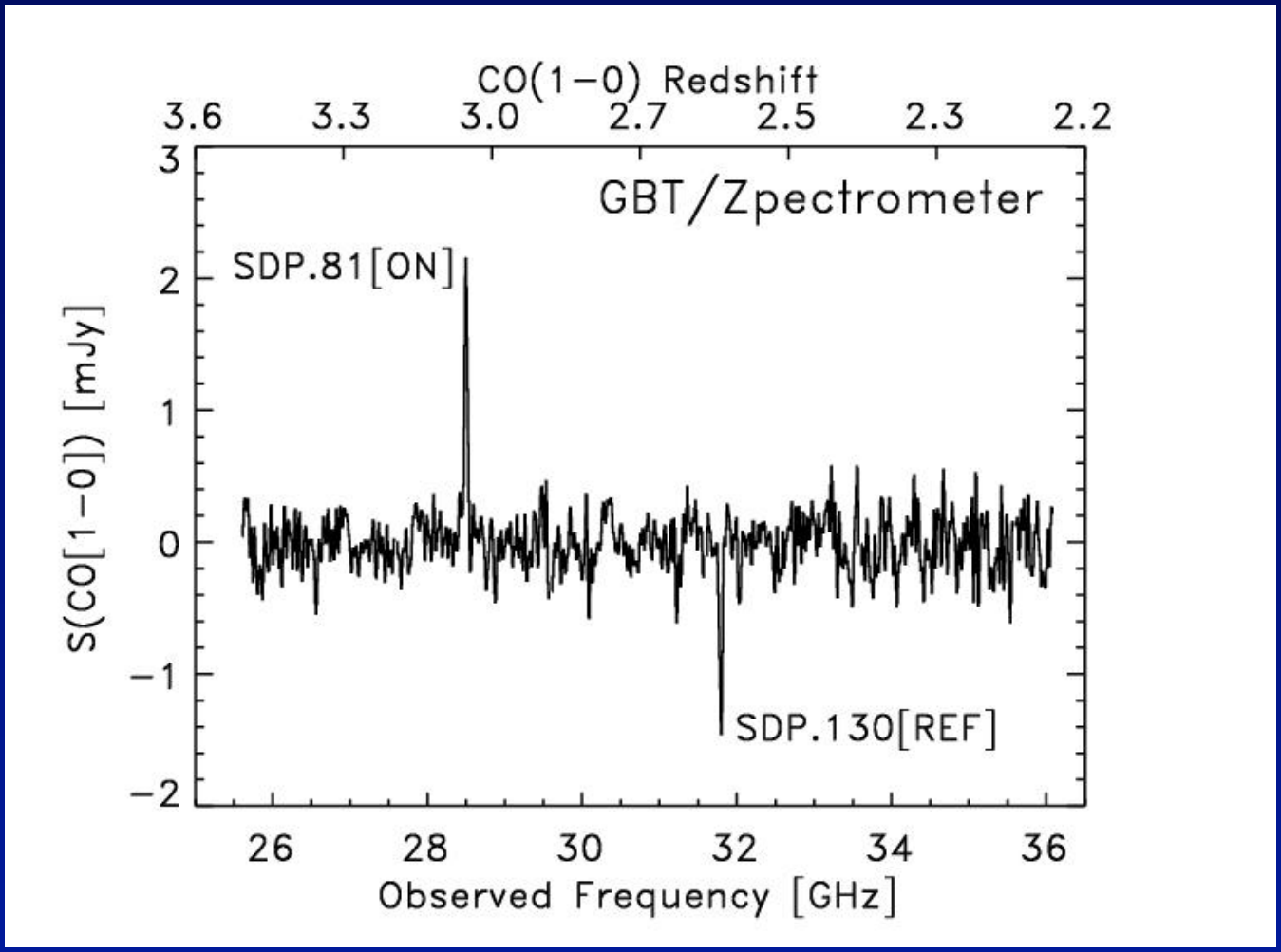
Bulk of the infrared CIB at z~1, and rapid evolution from now to z~1 in luminous infrared star-forming galaxies. ➔ CO intermediate redshifts key.

Lots of z~0.3-1 LIRGS found by Herschel and Spitzer Surveys.



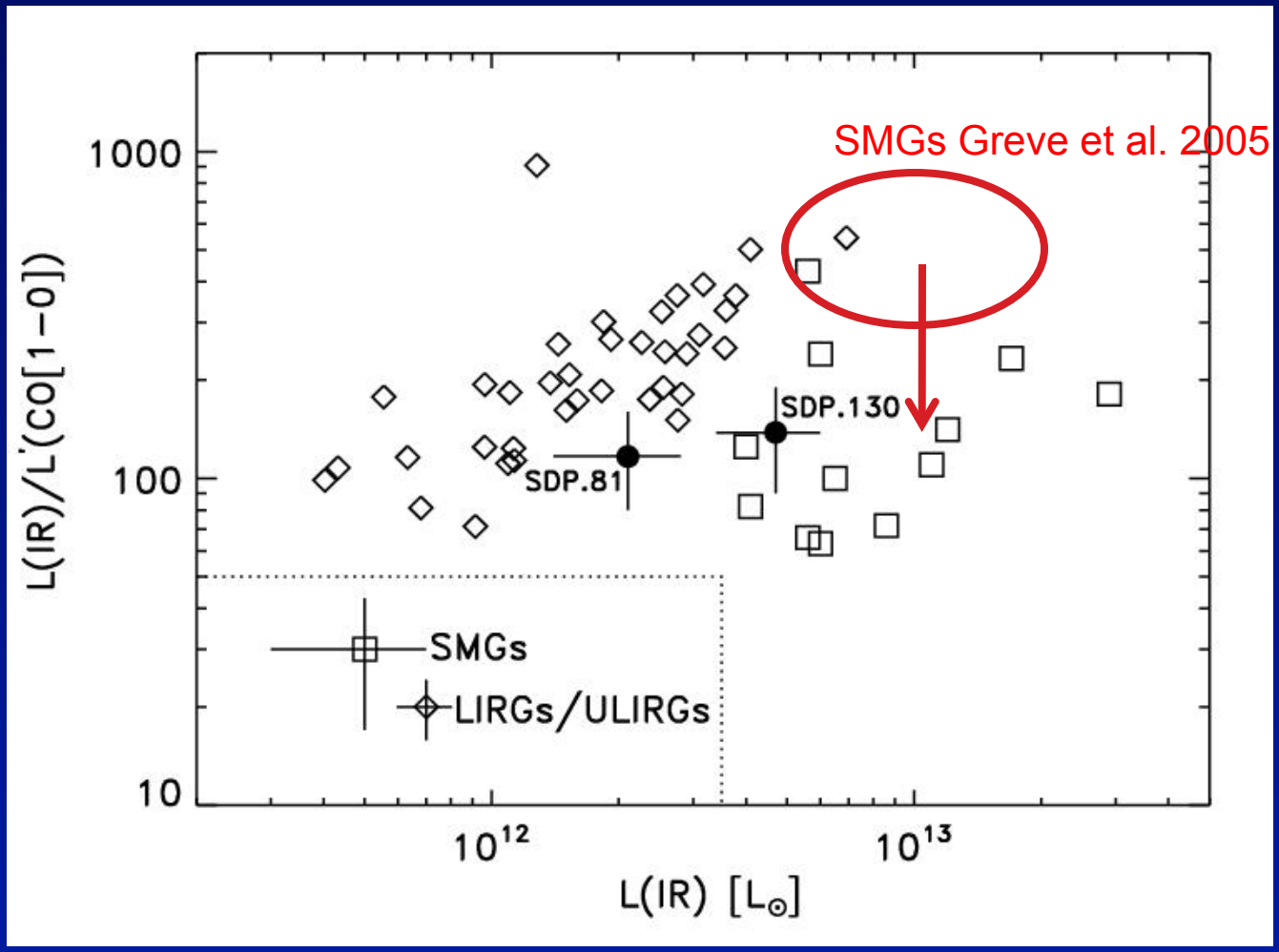
Magnelli, et al. 2009 (Spitzer FIDEL-70um result)

GBT/Zpectrometer CO(1-0) (Frayer et al. 2010)



SDP.81(ON)+SDP.130 (REF, negative): CO(1-0) redshifts measured. Confirms sources are background lensed galaxies [only 1.15hr integration time per source]. Both sources confirmed with PdBI CO(3-2) data.

CO(1-0) Key for Mass Measurements



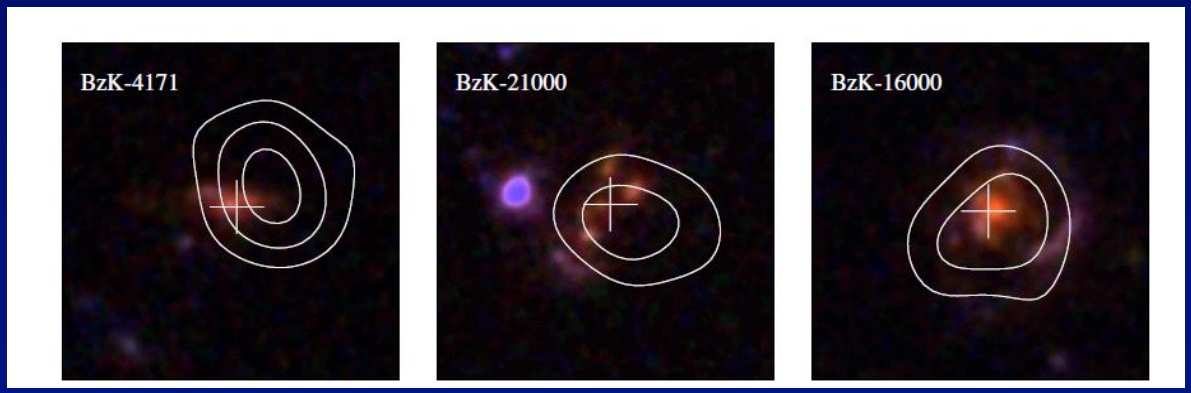
Frayer et al. 2010

Previous SMG results assumed warmer dust (40K) which overestimated Lir by ~2x for the measured SMG Td~35K and the adopted L'CO(3-2)/ L'CO(1-0) = 1, underestimated L'CO(1-0) by 1.7

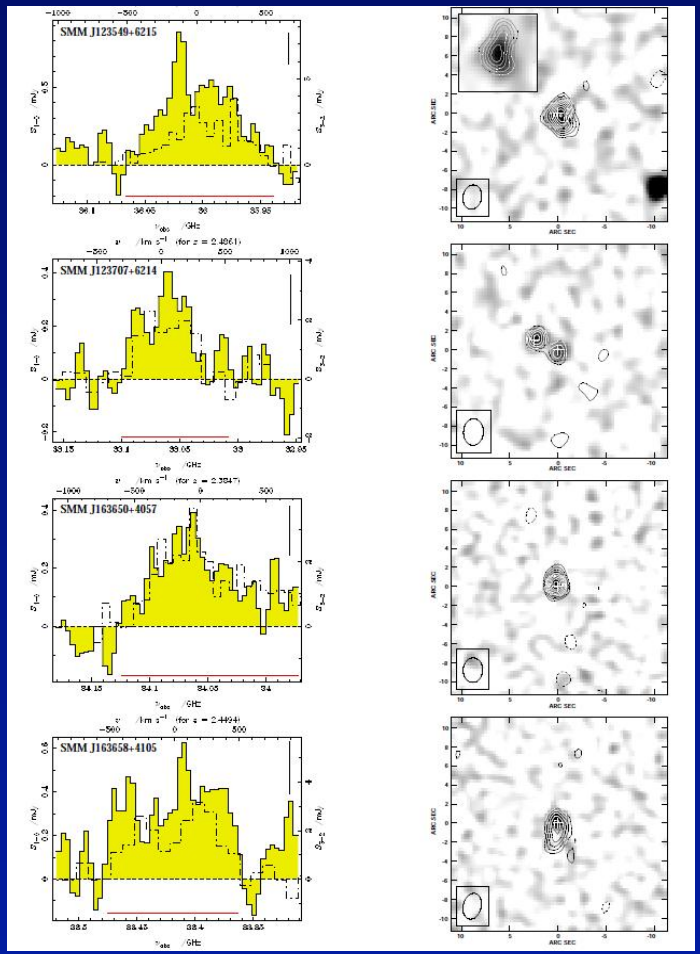
Need good FIR measurements with CO(1-0)

VLA/eVLA CO(1-0) Imaging

BzKs (Aravena et al. 2010):

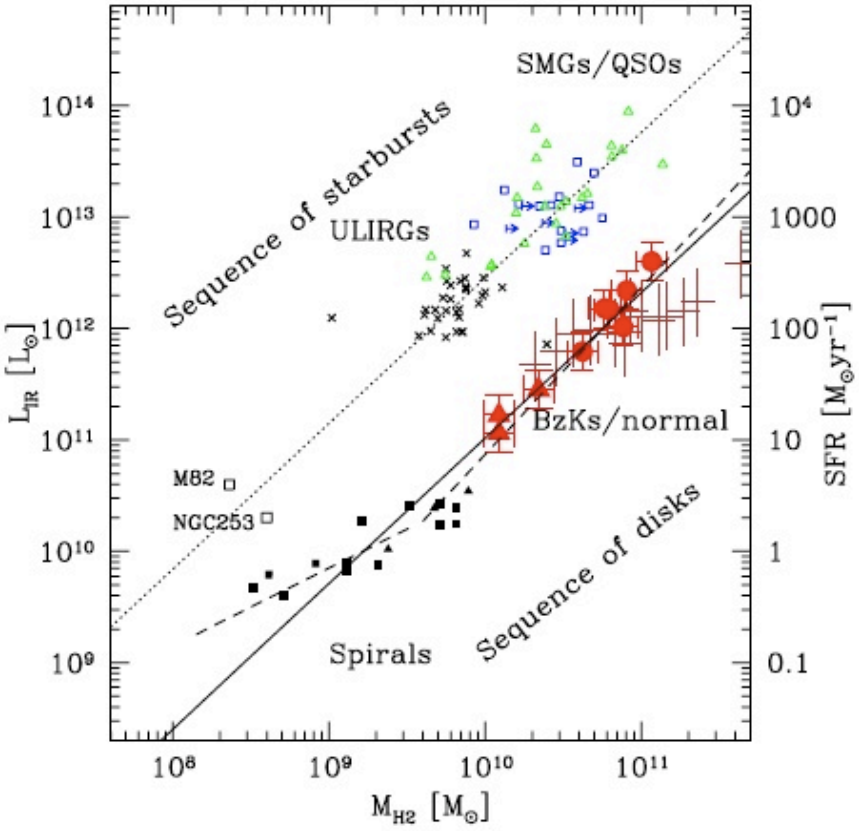


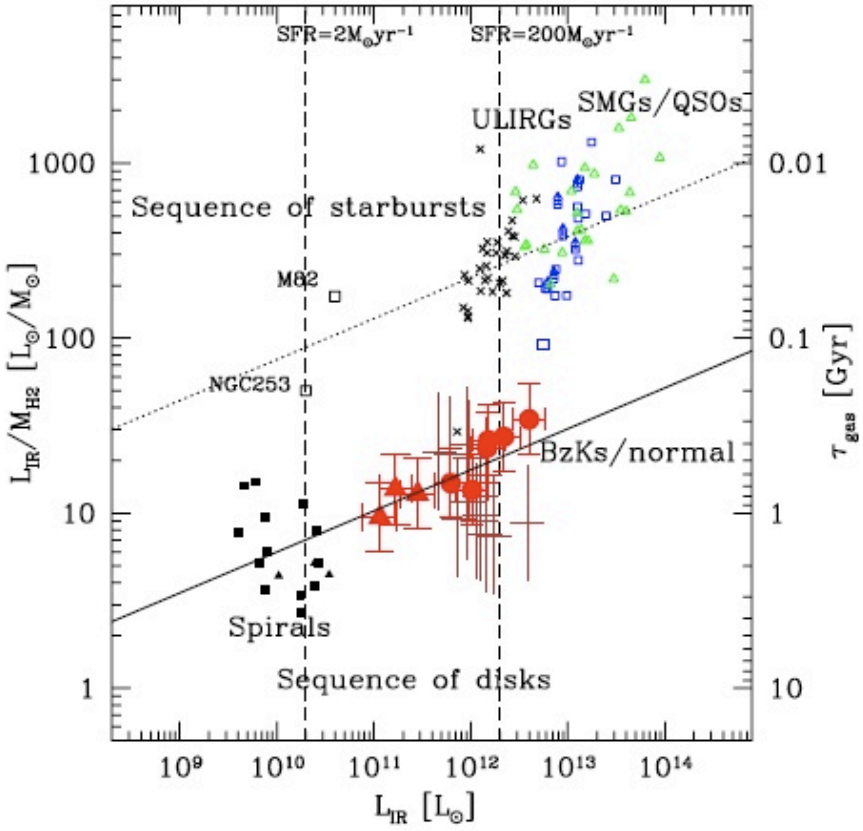
SMGs (Ivison et al. 2010):



Observations suggest low-CO excitation for both the BzK's and SMG samples➔ extended cold CO(1-0)!? Very extended or just separated clumps ➔ ALMA

Evolution Disks vs “Merger” Starbursts

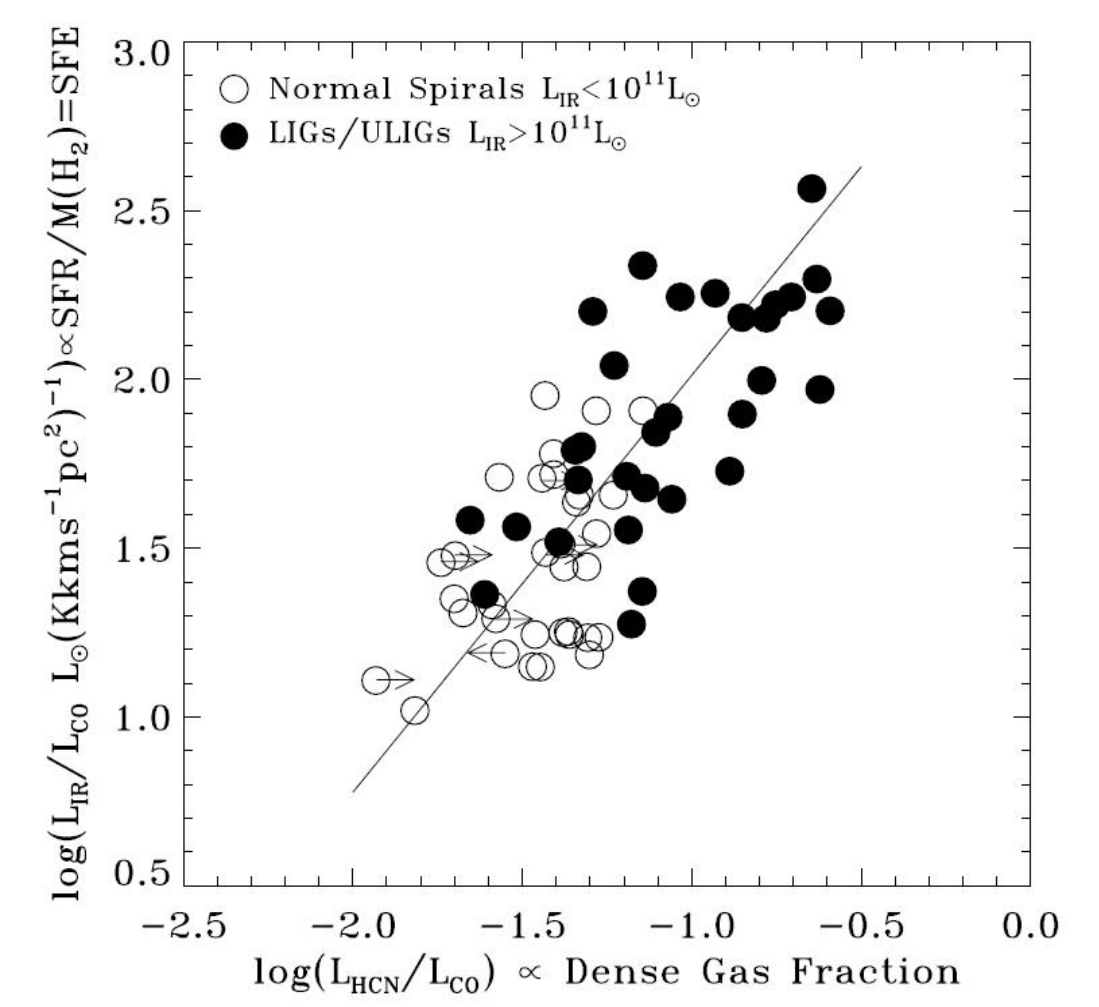




Daddi et al. 2010b BzK’s and Tacconi et al. 2010 disk selected sample compared with the SMGs ➔ Need CO(1-0) for CO to H_2 conversion factor.

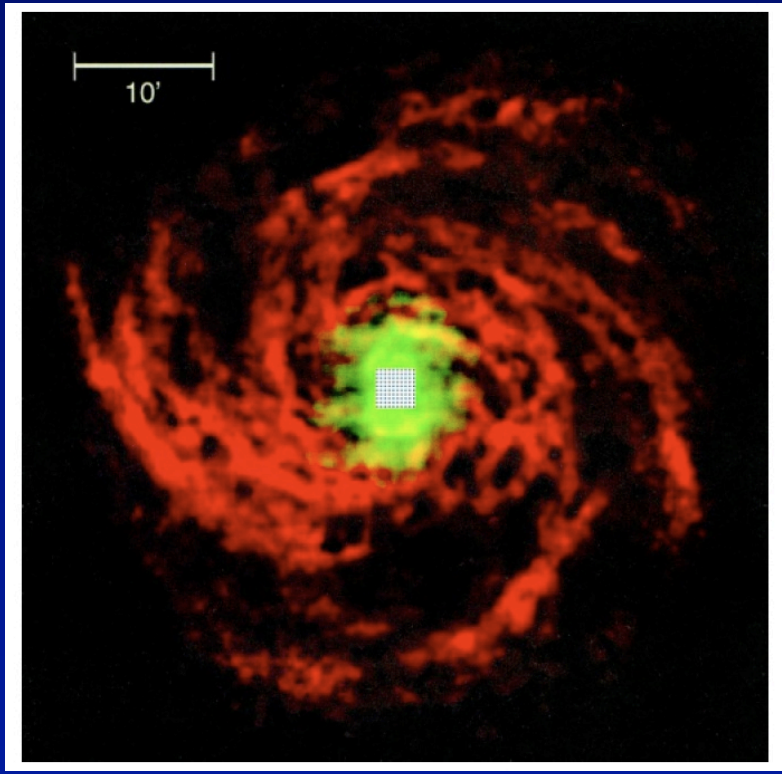
Dense Gas in Local Galaxies

Gao & Solomon 2004: Dense gas traced by HCN better correlated with Lir than CO. SFE correlated with dense gas fraction. ➔ HCN & HCO+

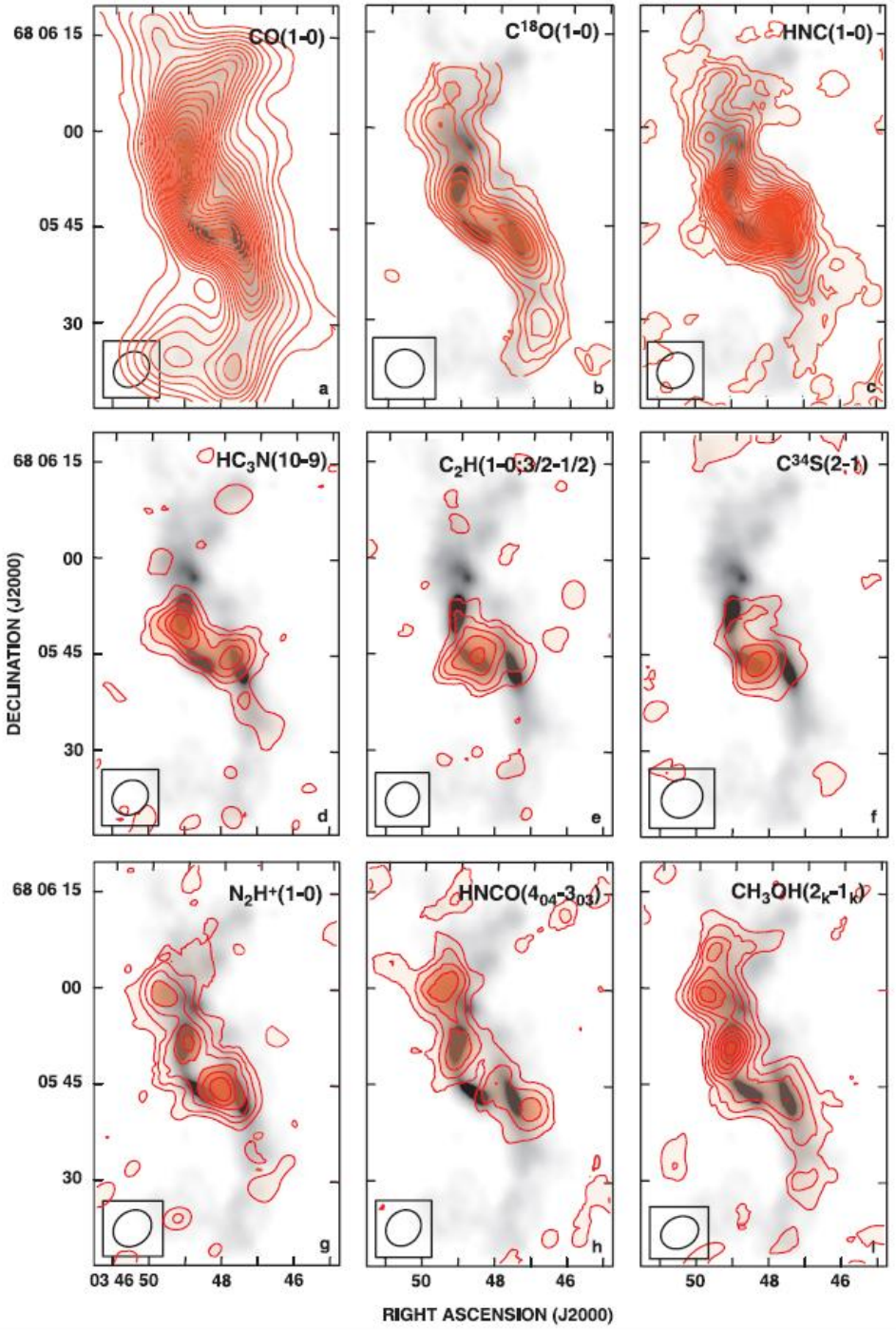


Variations of Molecular Lines in Nearby Galaxies, e.g.

IC342 Meier & Turner 2005



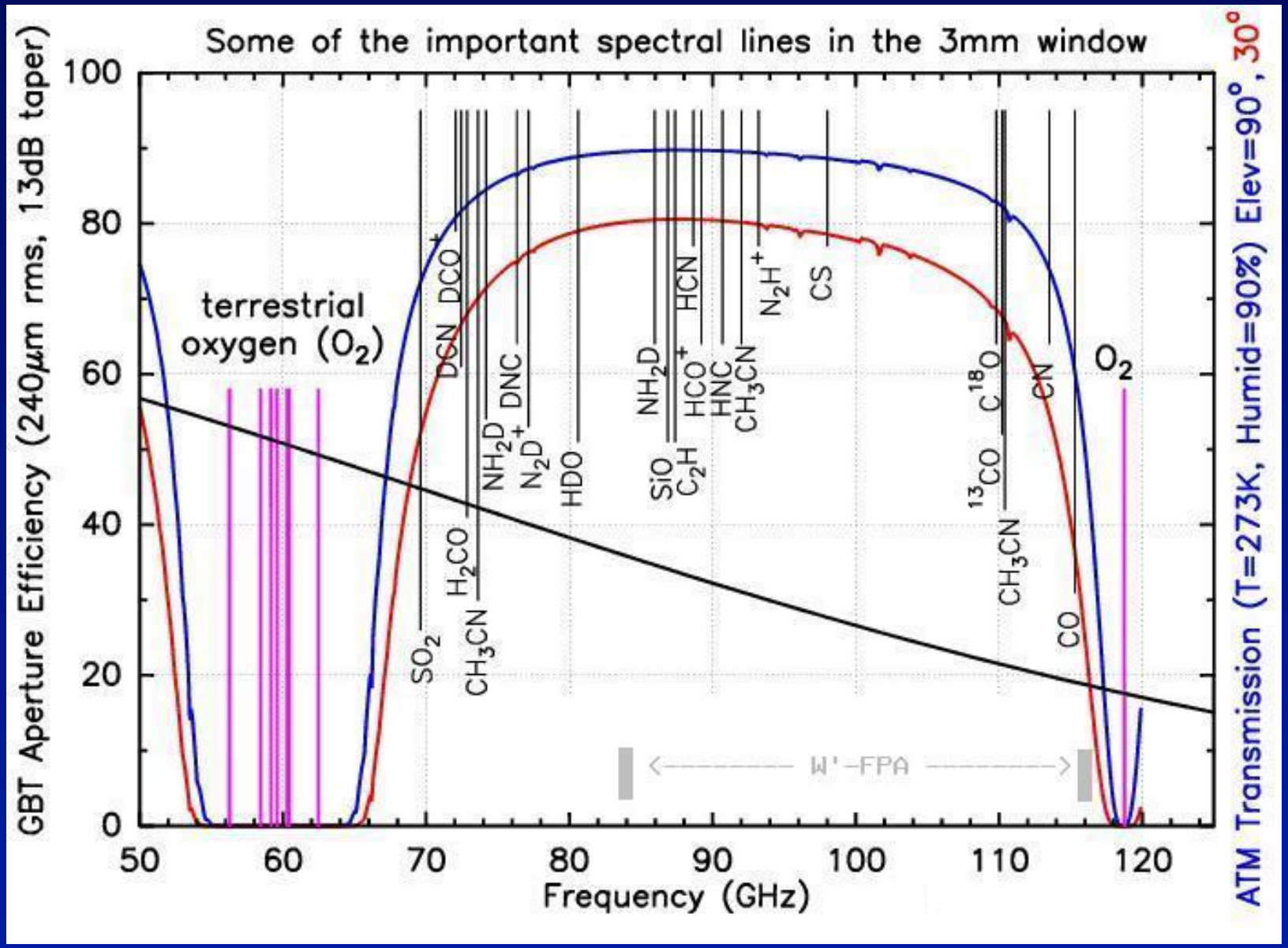
IC342: CO=green, HI=red

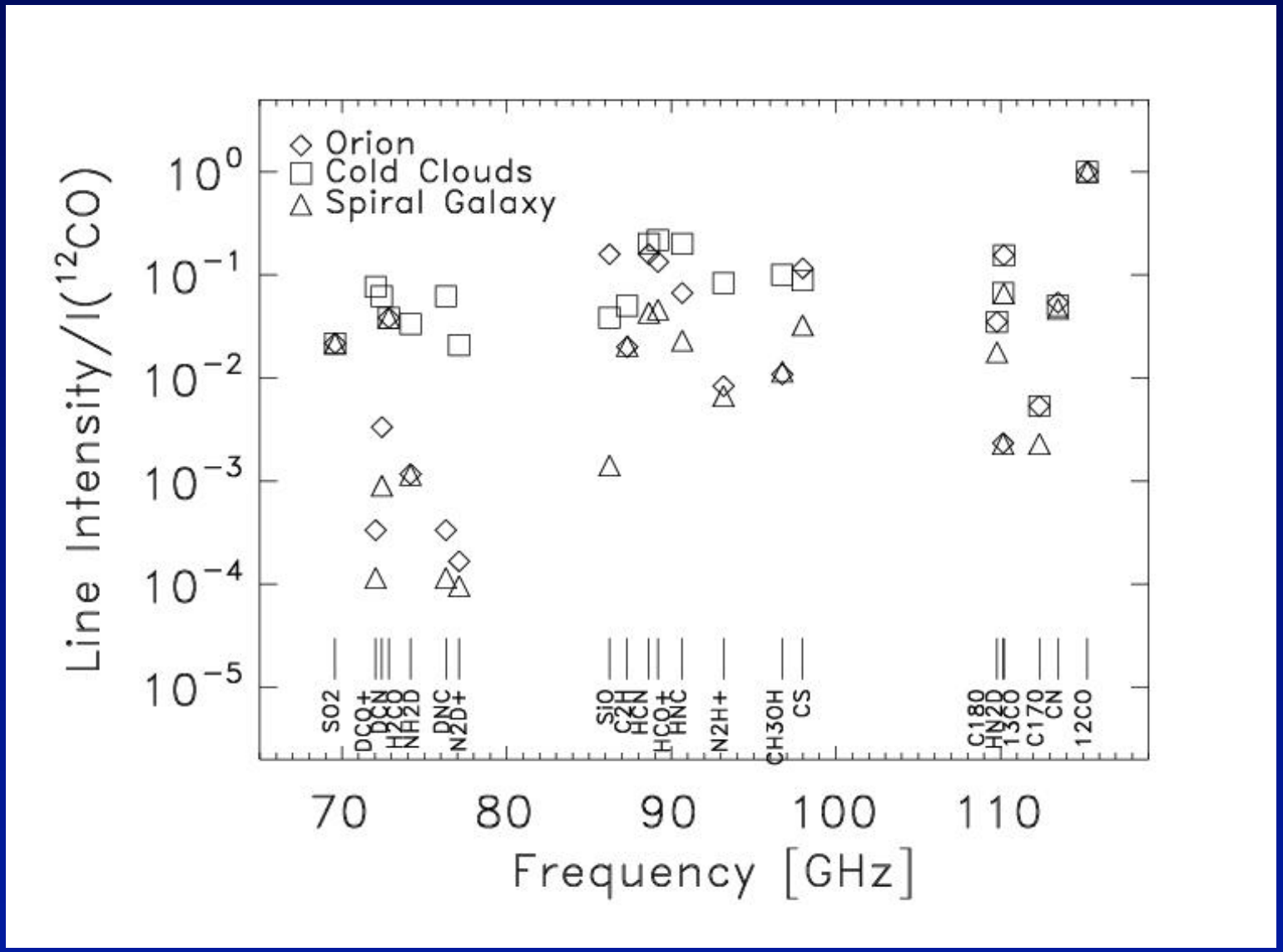


Concluding Remarks (Band-2/4mm)

- Galaxy evolution via CO(1-0) at intermediate redshifts.
- Dense gas (HCN & HCO+) and molecular variations in nearby starbursts
- Technical synergies of 67—116 GHz (ALMA Band-2+3 and GBT W’ FPA)

Backup slides


Some of the important spectral lines in the 3mm window
GBT Aperture Efficiency (240μm rms, 13dB taper)
ATM Transmission (T=273K, Humid=90%) Elev=90°, 30°
Frequency (GHz)
terrestrial oxygen (O_2)
SO_2
DCN
DCO^+
H_2CO
CH_3CN
NH_2D
N_2D^+
DNC
HDO
SiO
C_2H
NH_2D
HCO^+
HCN
HNC
CH_3CN
N_2H^+
CS
^{13}CO
$C^{18}O$
CH_3CN
CN
CO
O_2
W'-FPA


Orion
Cold Clouds
Spiral Galaxy
Line Intensity/I(12CO)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
SO2
DCO+
DCN
H13CO+
NH2D
DNC
N2D+
SiO
C2H
HCN
H13CO+
HNC
N2H+
CH3OH
CS
C18O
HN13C
N2D+
C17O
CN
12CO
70
80
90
100
110
Frequency [GHz]

New GBT Molecules