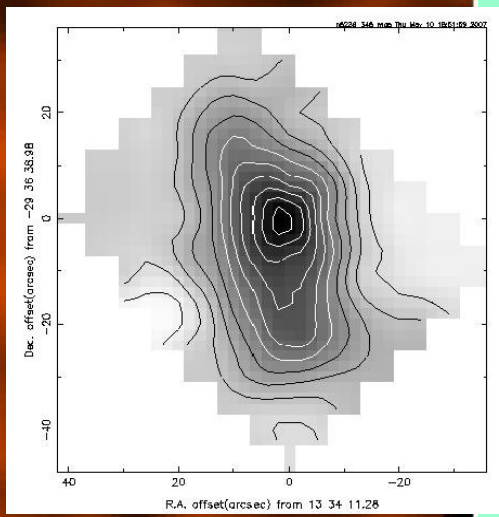
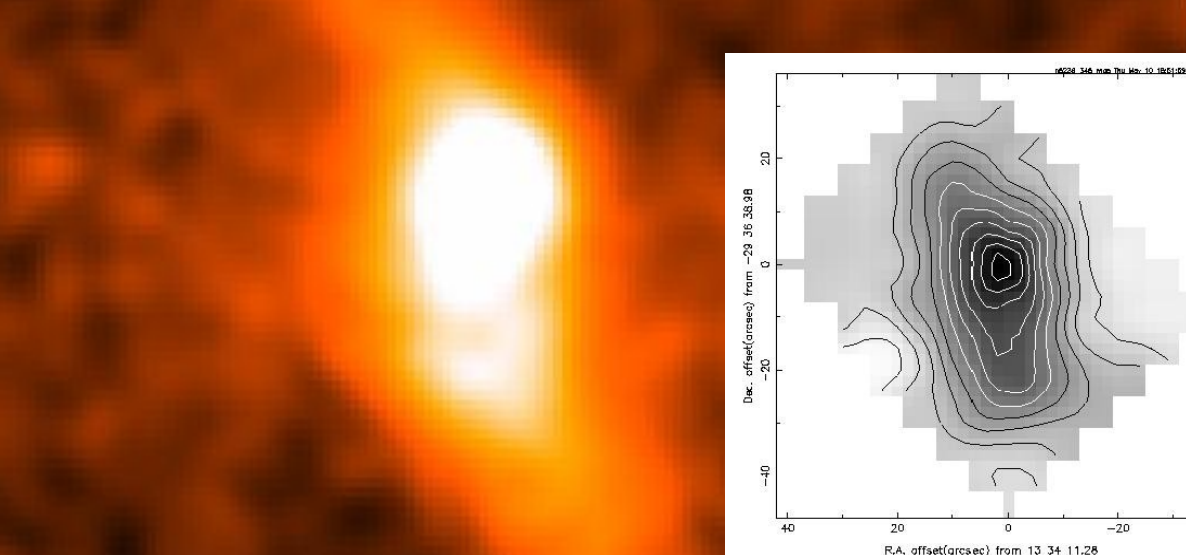


MOLECULAR GAS IN SPIRAL GALAXY CENTERS

F.P. Israel, Sterrewacht Leiden

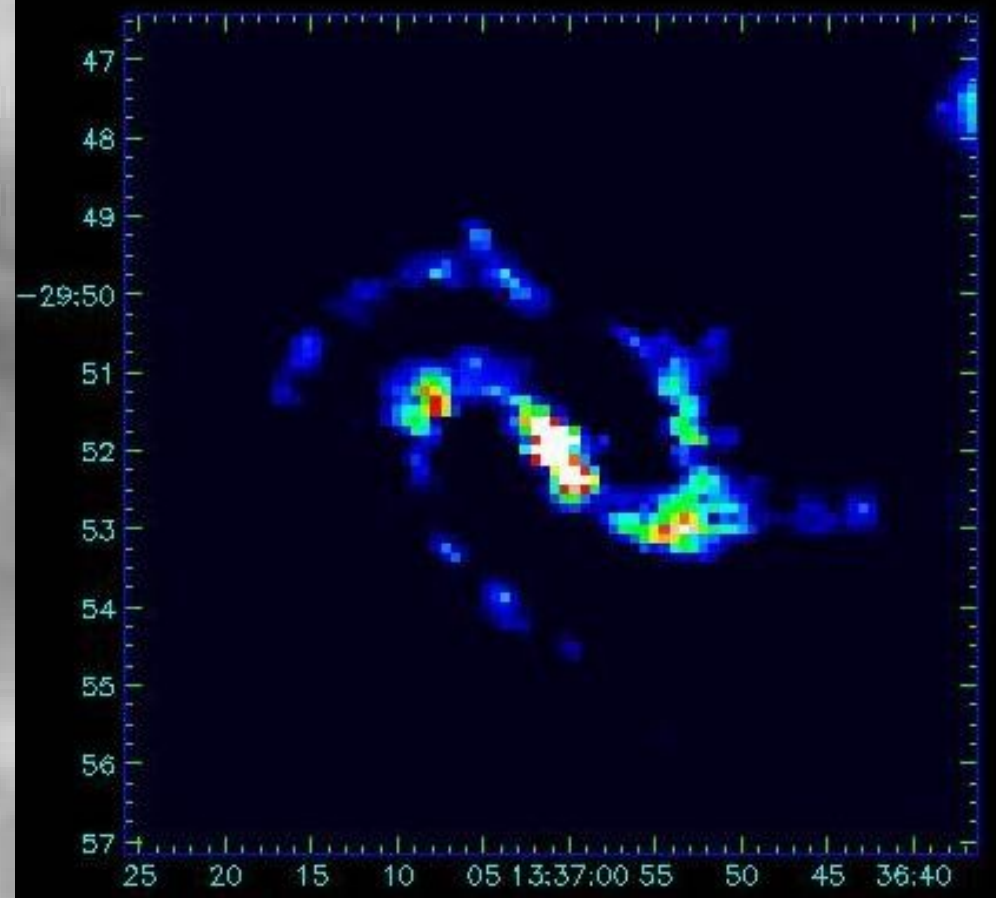


M83

- Dust:** JCMT/SCUBA
- CO:** JCMT/RecB
- HI:** VLA
- CO:** JCMT/HARP



m83_remb12_msk_totco_fillbad



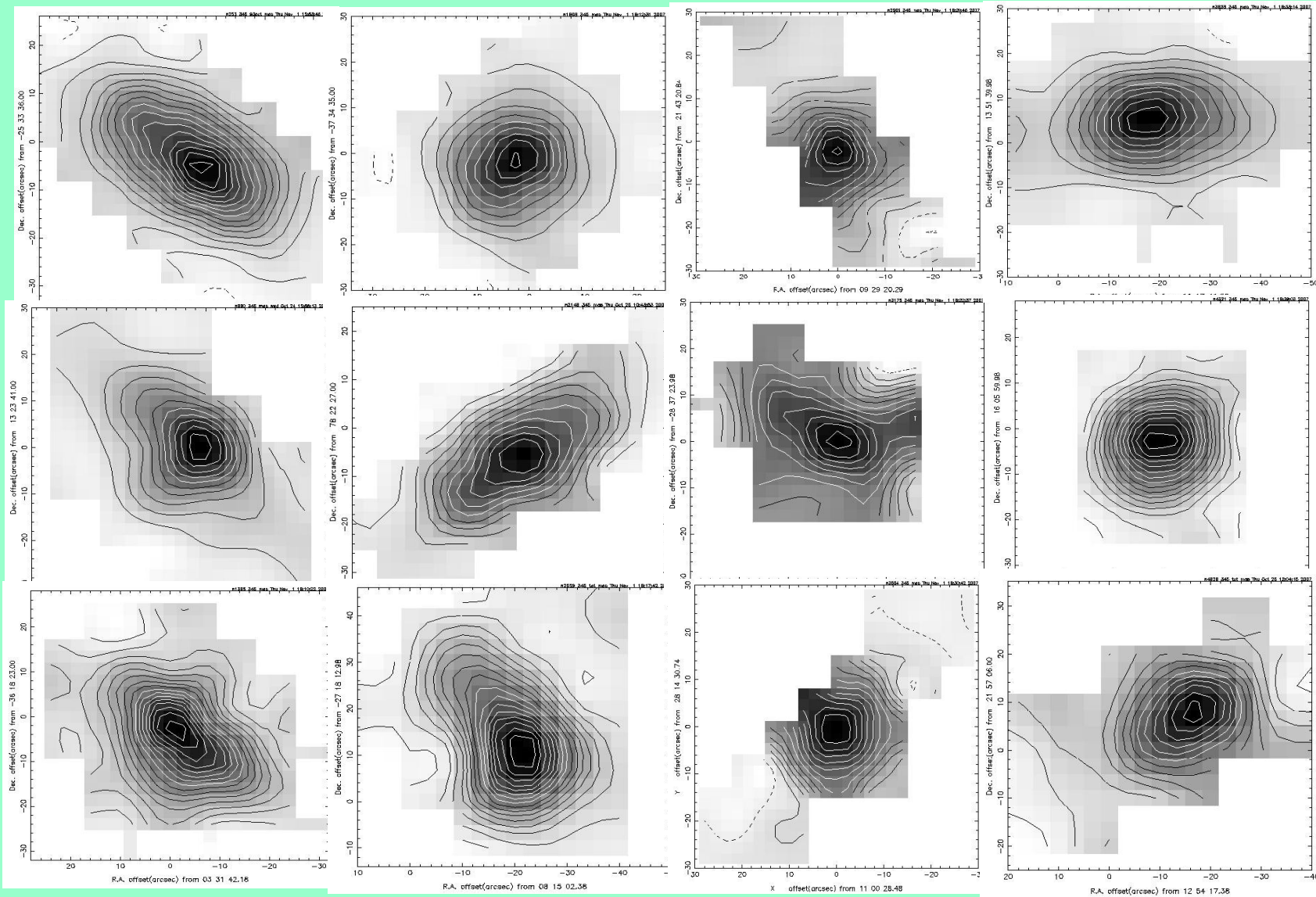
ISM in Spiral Galaxies: Where?

- Atomic gas *avoids* galaxy centers
- Molecular gas *seeks* galaxy centers
- Dust traces total gas

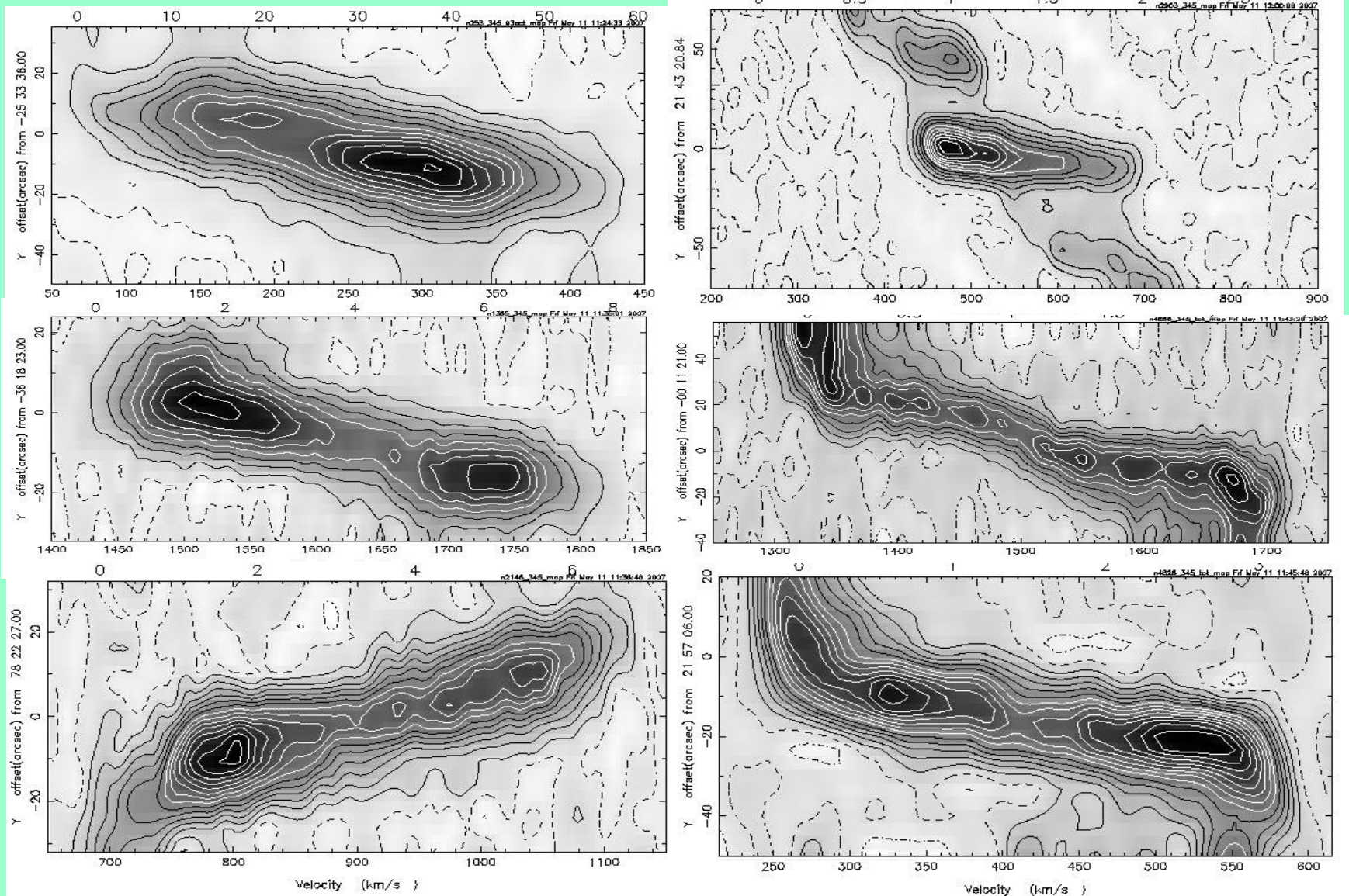
- Metallicity & excitation gradients
 - Center: almost exclusively molecular
 - Inner disk: molecules dominant
 - Outer disk: atoms dominant

Nuclear CO Concentrations

JCMT 12CO(3-2) 1' x 1' maps



Nuclear CO Concentrations: Disk, Torus or Arms?



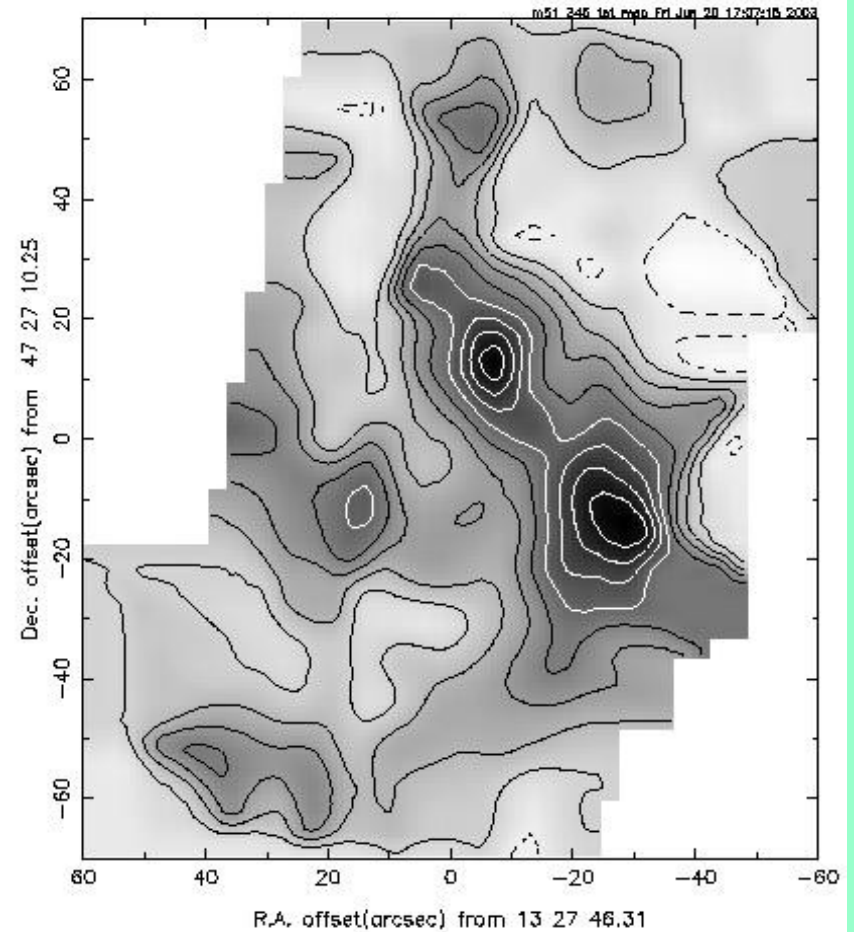
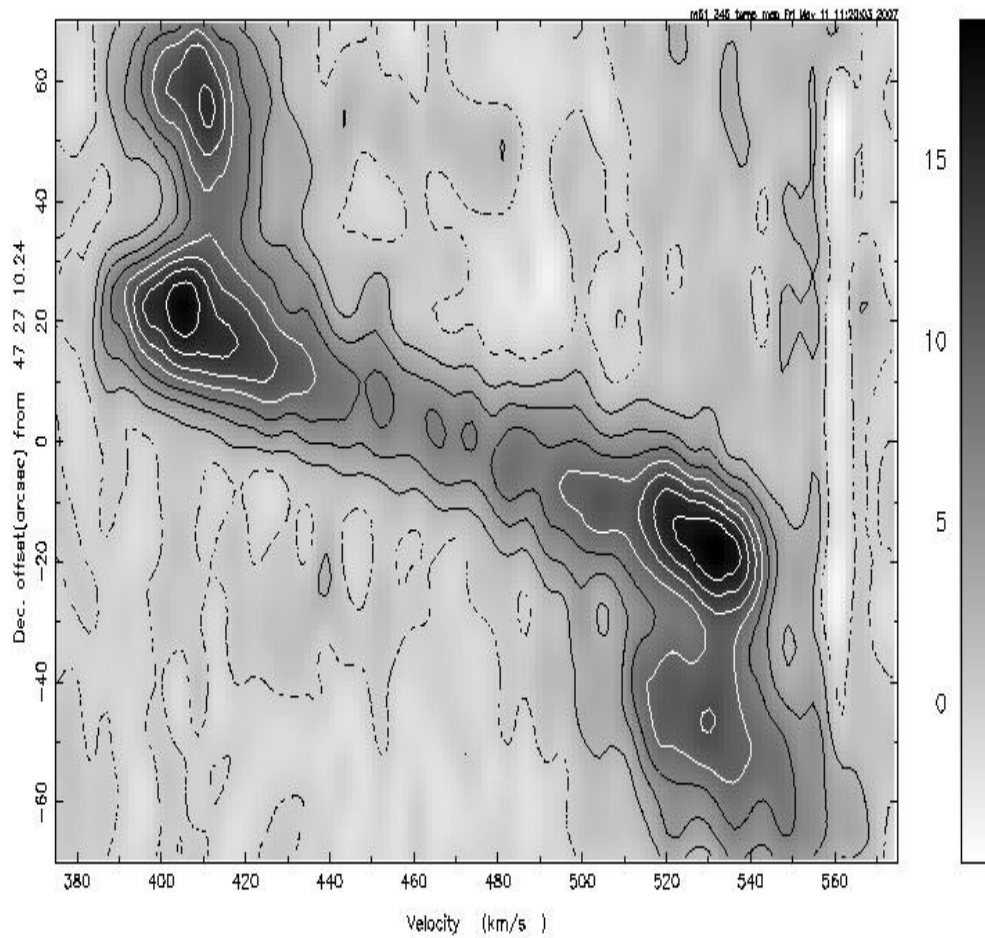
Molecular Concentrations in Galaxy Centers: How Big?

- Highly concentrated in central kiloparsec
- High contrast with disk CO
- CO minimum within $R < 50$ pc
- Compact source at nucleus $R < 10$ pc

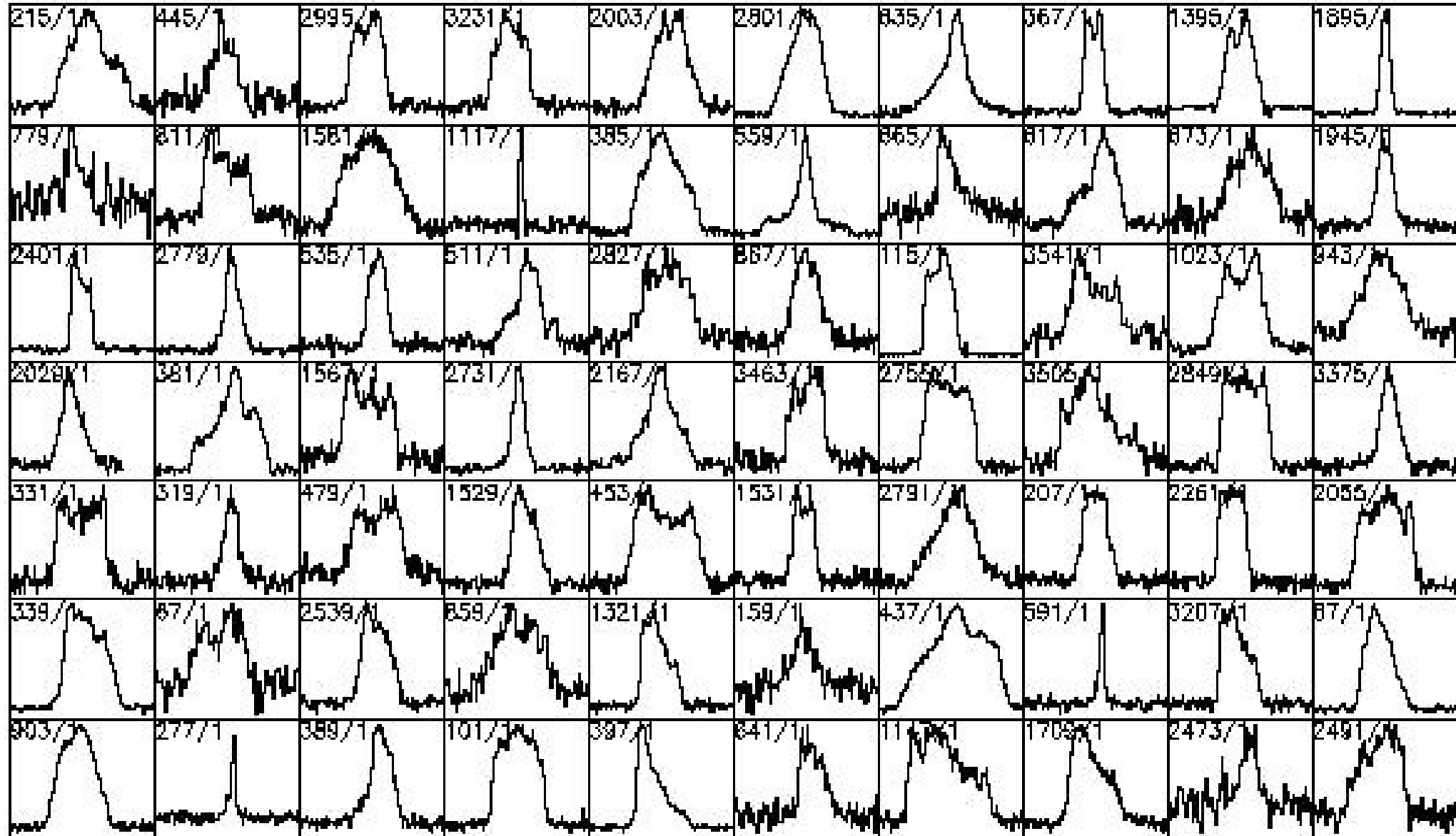
- CO enhanced in inner spiral arms!
- No evidence for disk or torus!

M51 12CO(3-2)

not all gas-rich galaxies have strong central molecular concentrations ...



Galaxy $^{12}\text{CO}(1-0)$ Central Profiles IRAM 30m

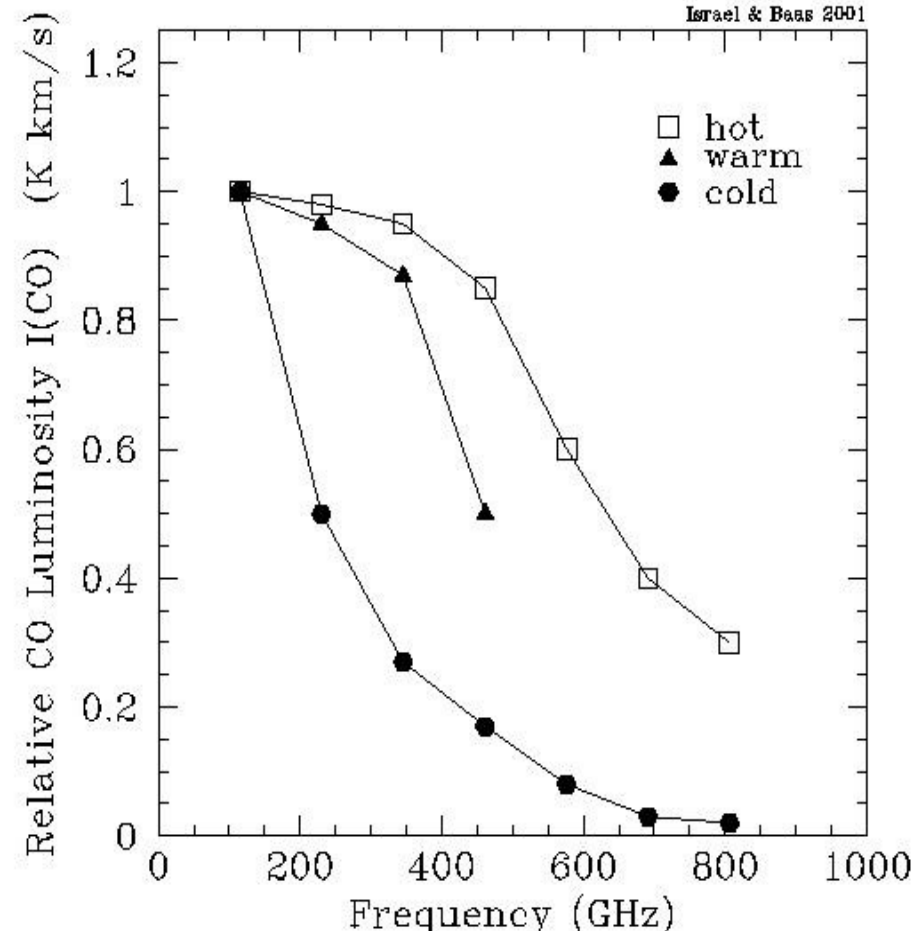


12CO yields physical information, but not enough!

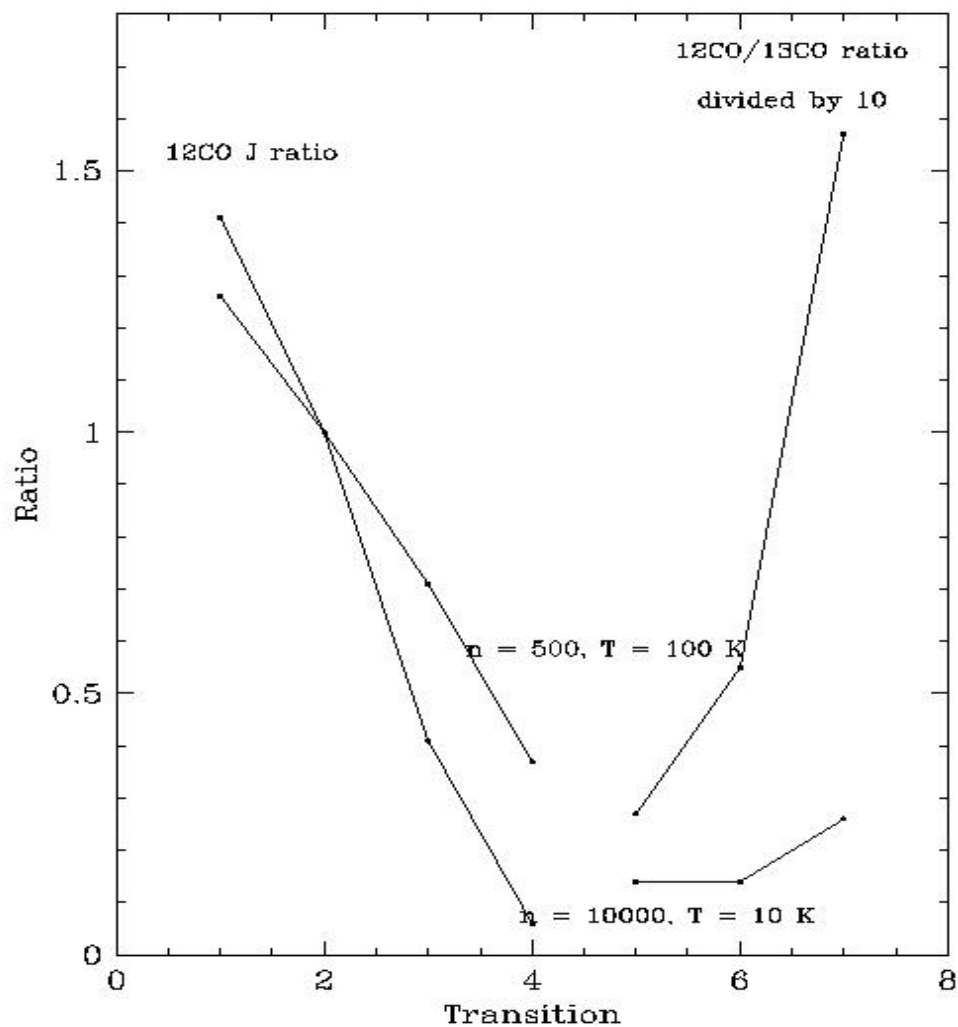
Degeneracy must be resolved by 13CO

Galaxy Centers

Israel & Baas 2001

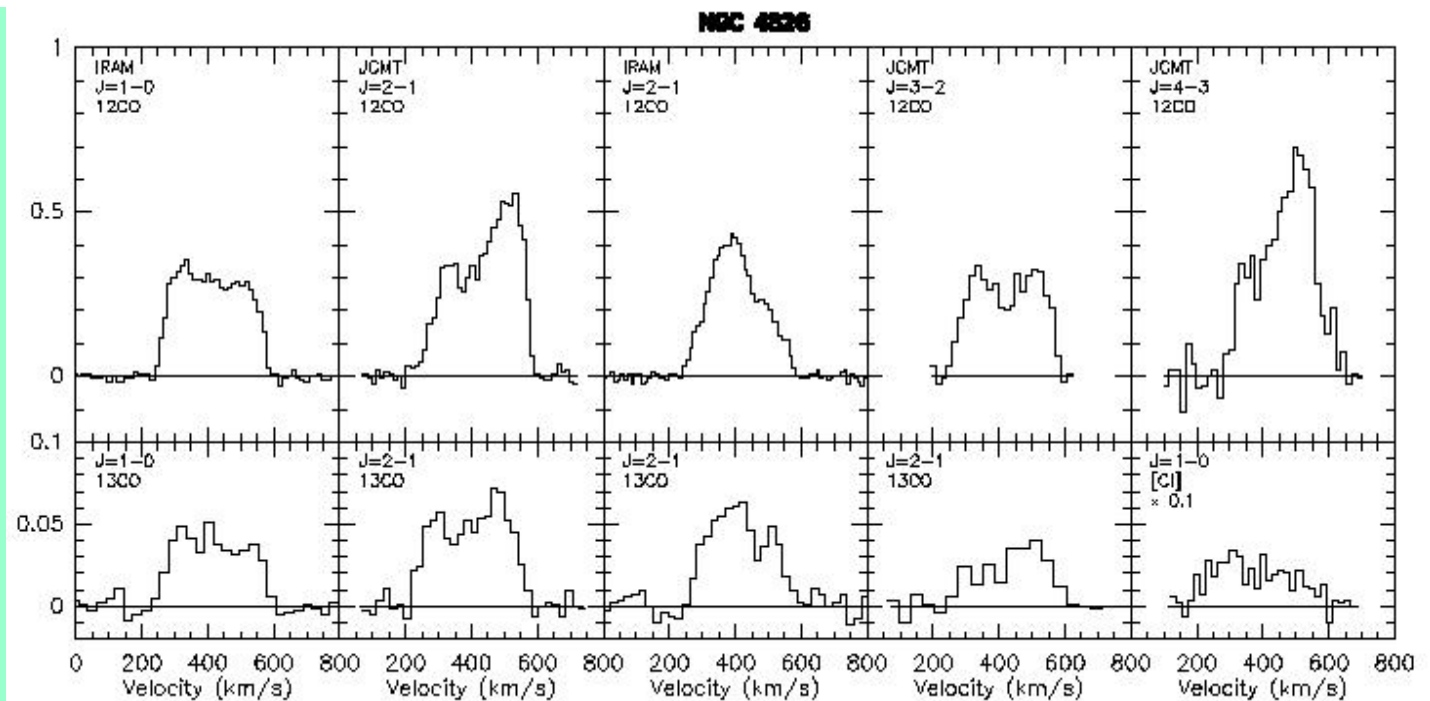
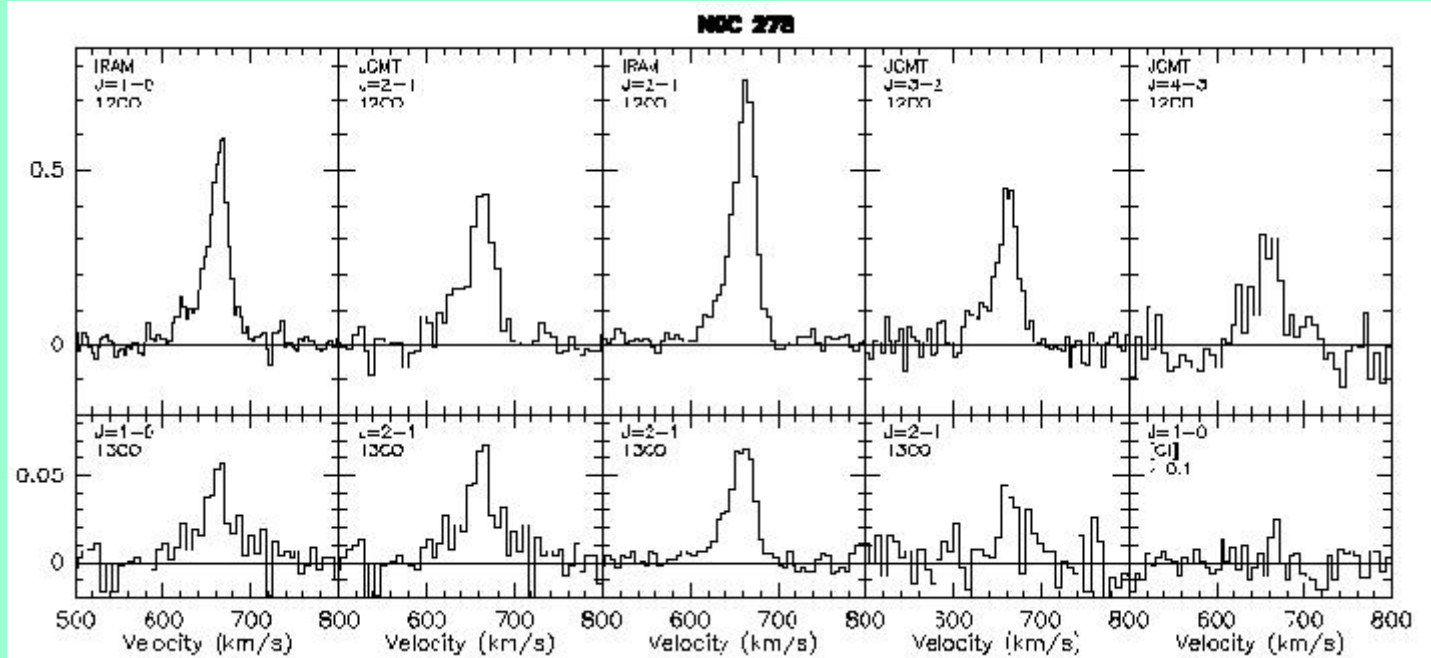


Degeneracy Hot&Tenuous, Cold&Dense CO

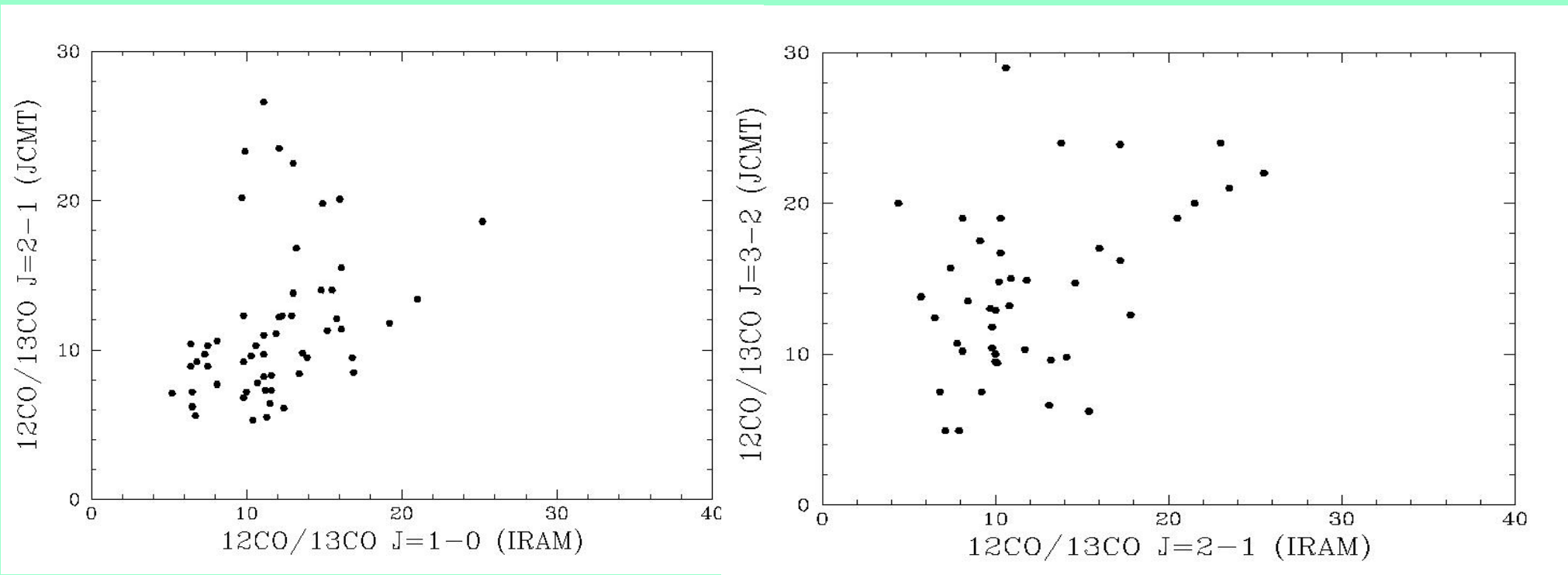


Galaxy Center CO Transitions

IRAM 30m
JCMT 15m

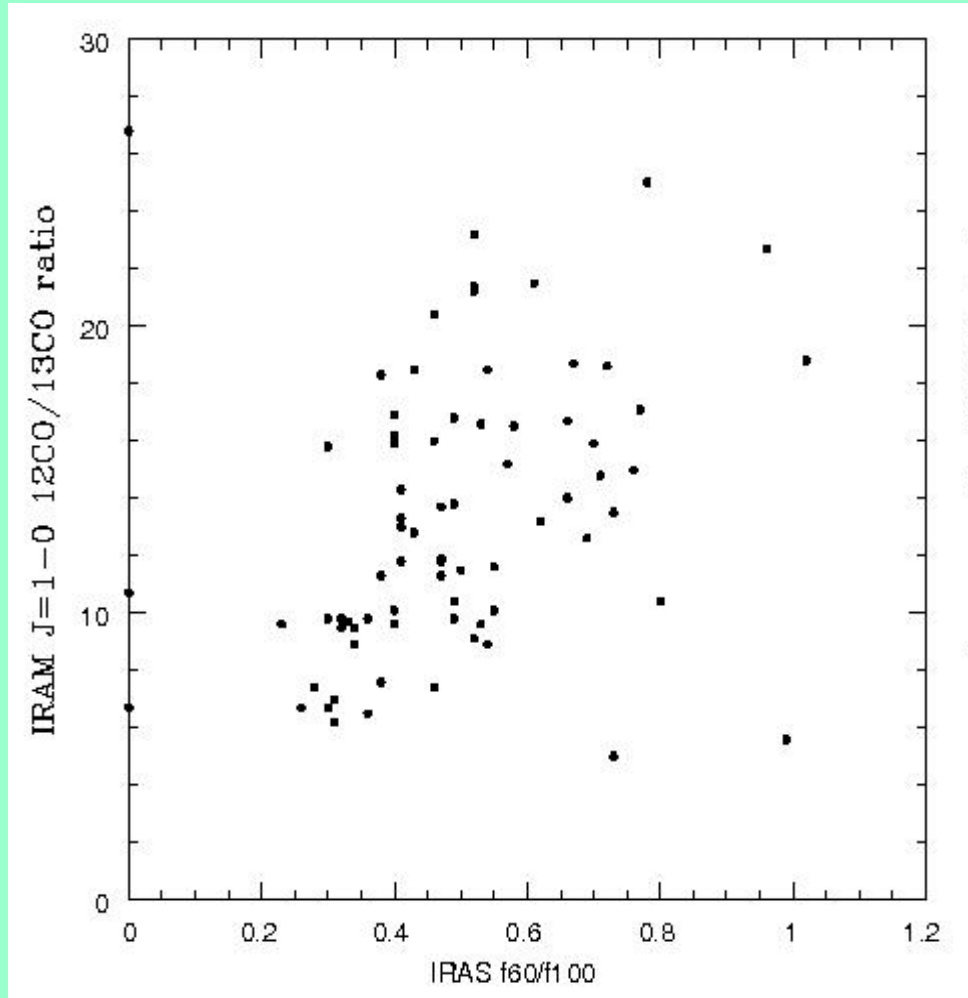


Diagnostic $^{12}\text{CO}/^{13}\text{CO}$ ratios

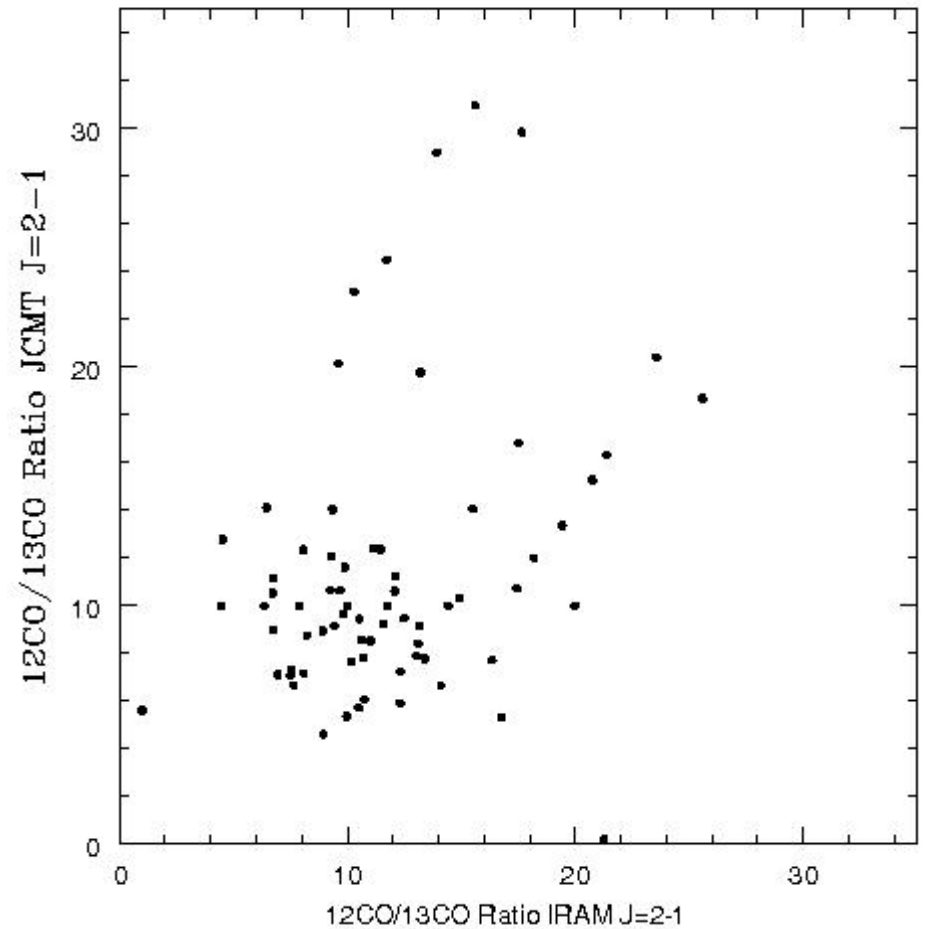


**ratios in identical beams
spread is intrinsic!**

Hot Gas in Galaxy Centers



hot dust, hot gas



hot gas less compact

Molecules in Galaxy Centers

How Dense, How Warm?

- Physics *only* from multiline analysis!
- At least two components:

→ **Lukewarm and dense**

$$T_k = 30\text{-}50 \text{ K}, \quad n(\text{H}_2) = 10^3\text{-}10^5 \text{ cm}^{-3}$$

→ **Hot and tenuous**

$$T_k = 100\text{-}150 \text{ K}, \quad n(\text{H}_2) = 10^2\text{-}10^3 \text{ cm}^{-3}$$

- Hot and tenuous gas: *often more than half* of the total mass!

Molecular gas in galaxy centers I

- Molecular gas concentrations within central kiloparsec
- Enhanced spiral arms, no disk/torus
- Most central molecular gas is hot and relatively tenuous
- Hot gas is more spread out than cold gas

Molecular gas in galaxy centers II

- $X = N(\text{H}_2)/I(\text{CO}) = 0.05 - 0.25 X_{\text{MW}}$

Much less H_2 than expected from observed
CO intensity

- Molecular gas still is $>90\%$ of the total gas mass
- Molecular gas is only $0.3-3.0\%$ of the dynamical mass



Picture by Lauri Haikala

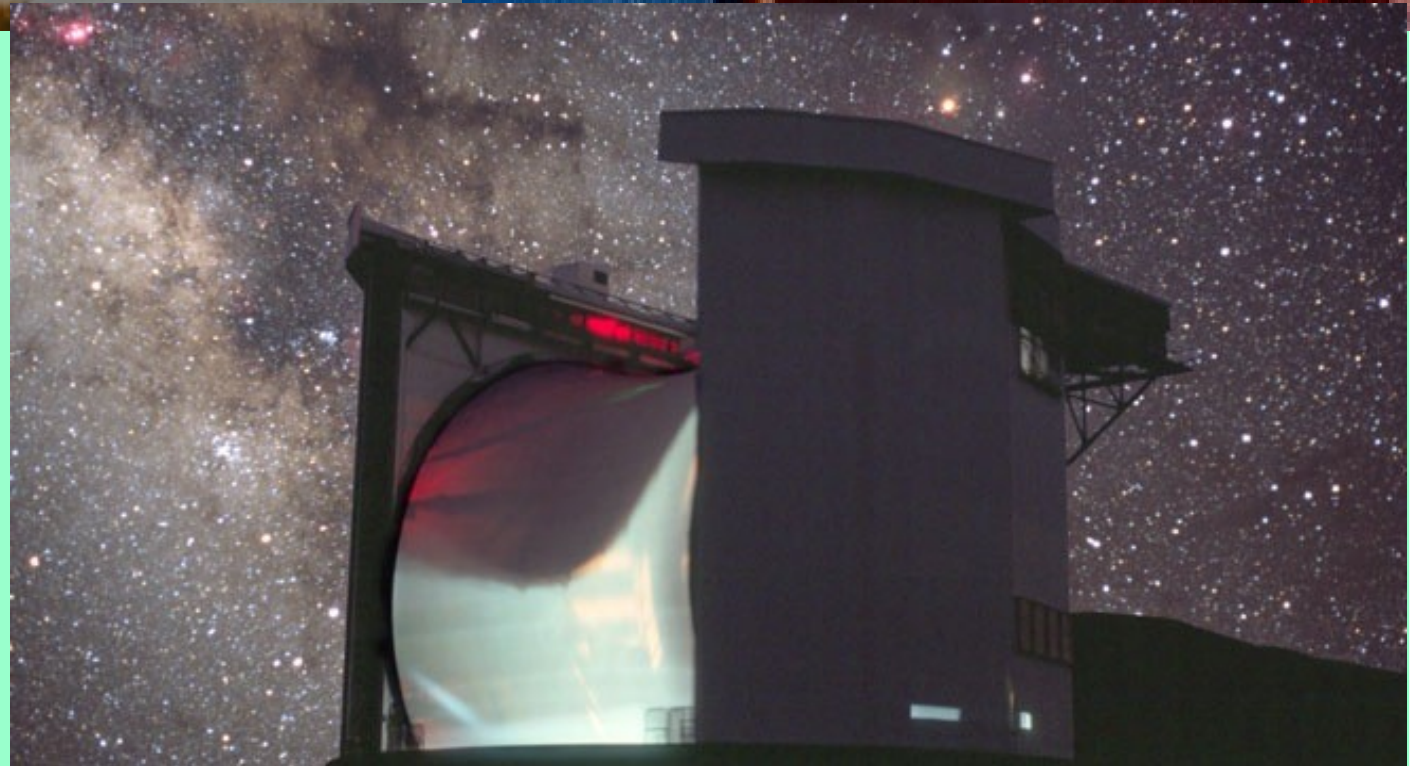


**Over 100
galaxy nuclei
measured**

SEST 15m

JCMT 15m

**and
IRAM 30m**



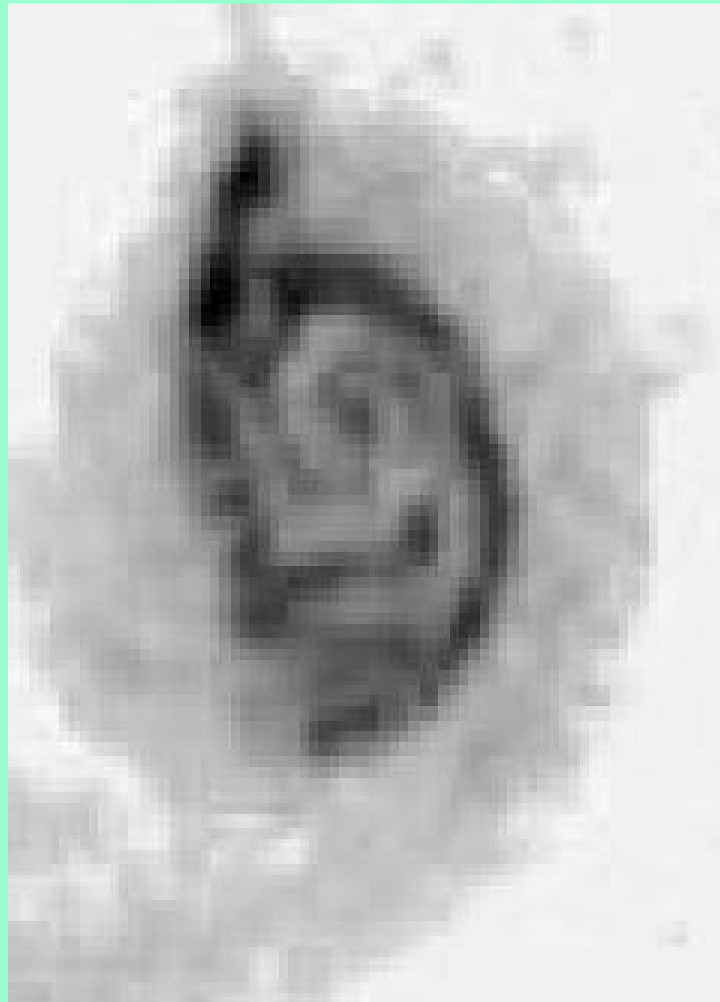
Bonus: HST Face-on View of the Whirlpool

no disk, no torus, only spiral arms

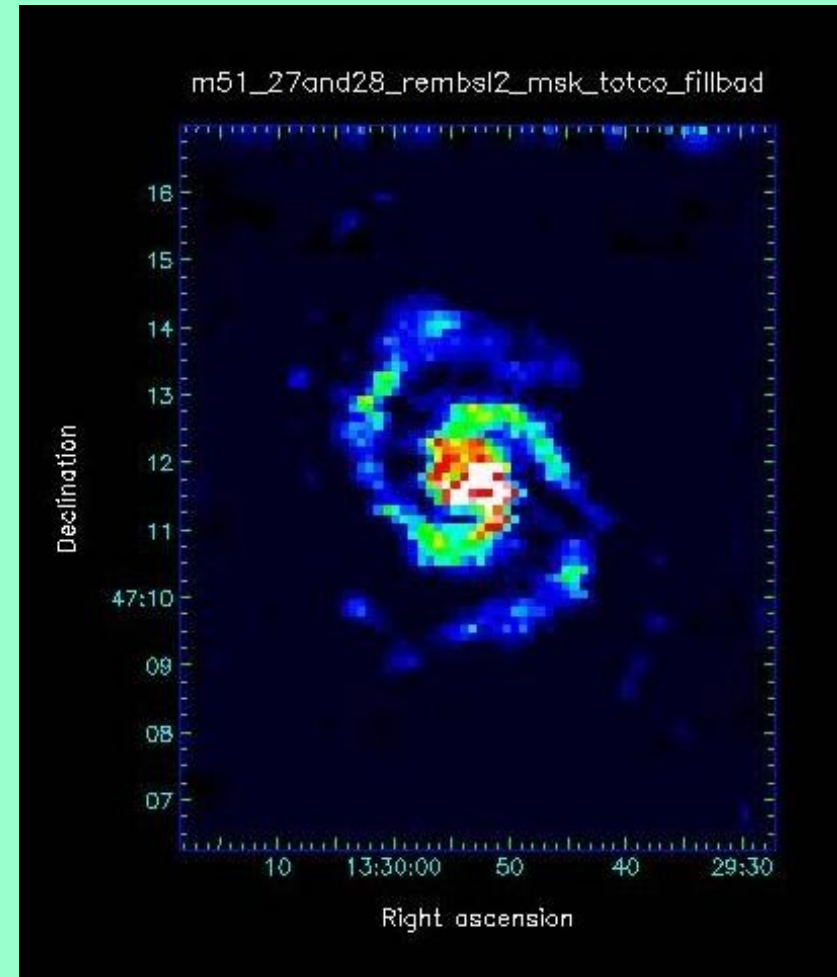


ATOMS MOLECULES IN M51

VLA HI

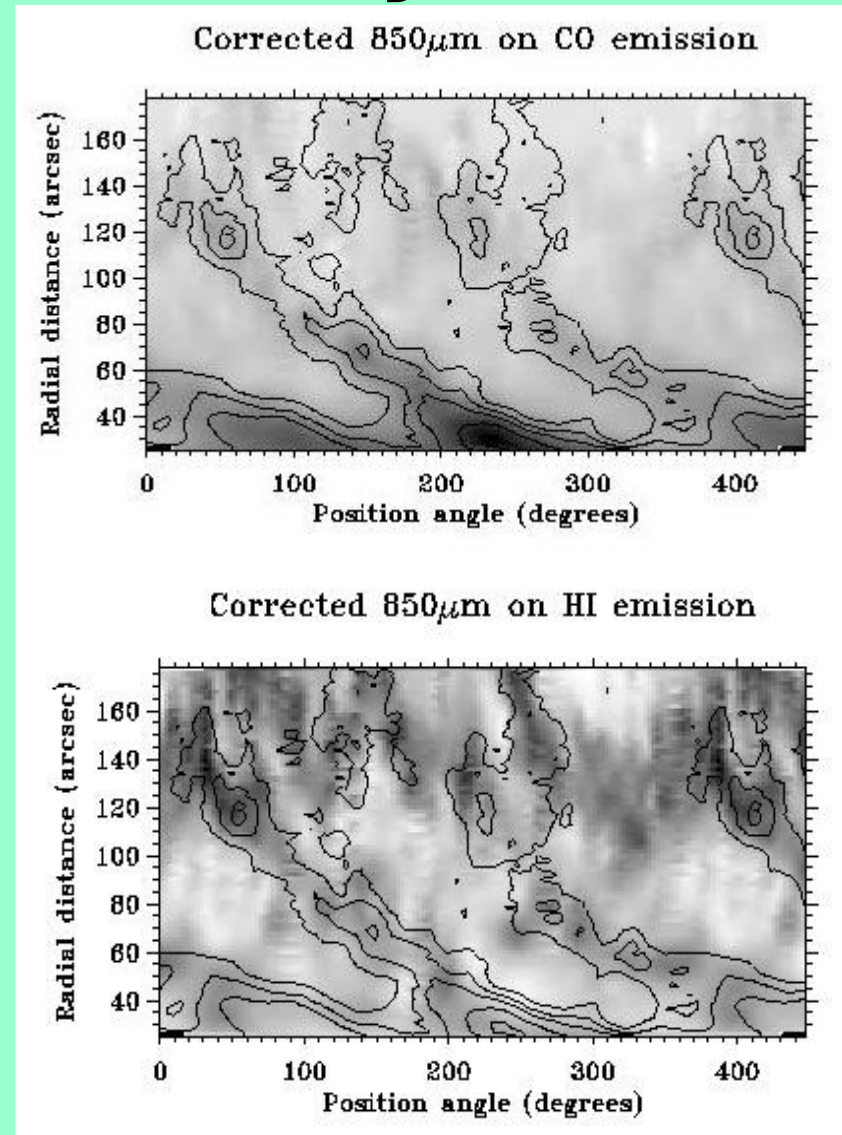
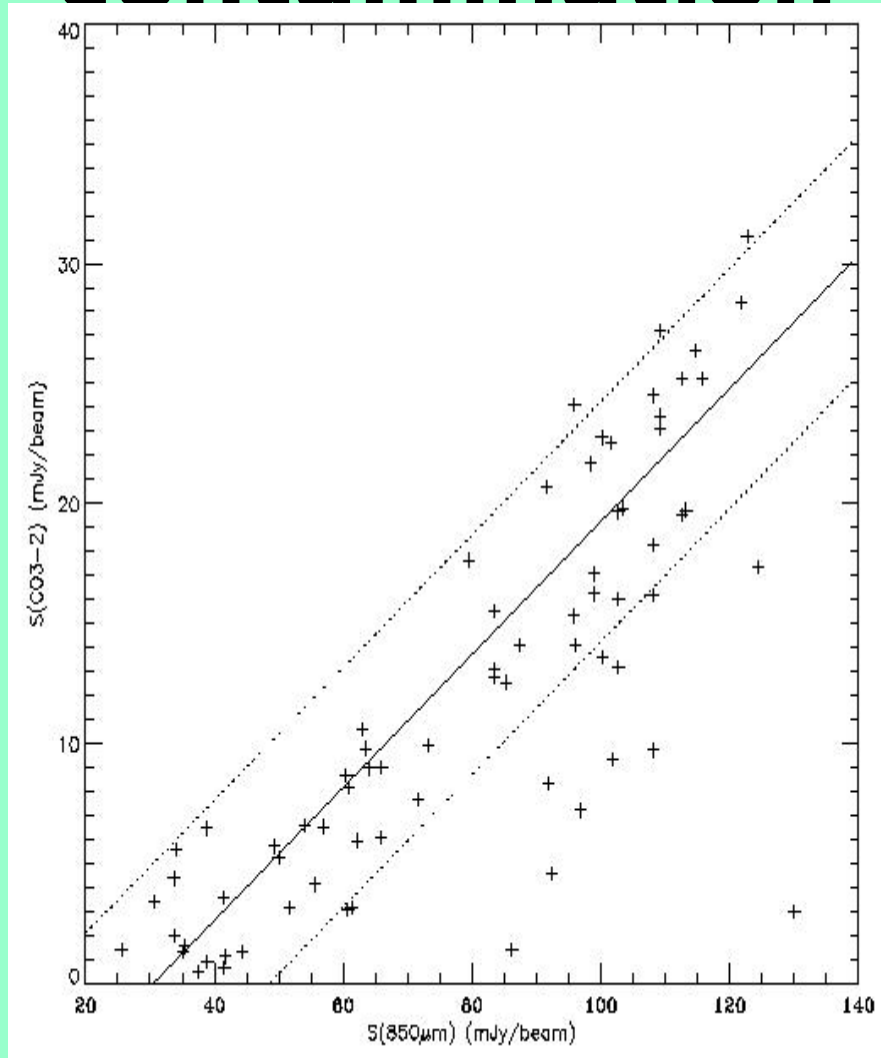


HARP 12CO(3-2)



M51 Lines and Continuum

complementarity
contamination



X-factor as function of metallicity

Filled symbols:
large beam

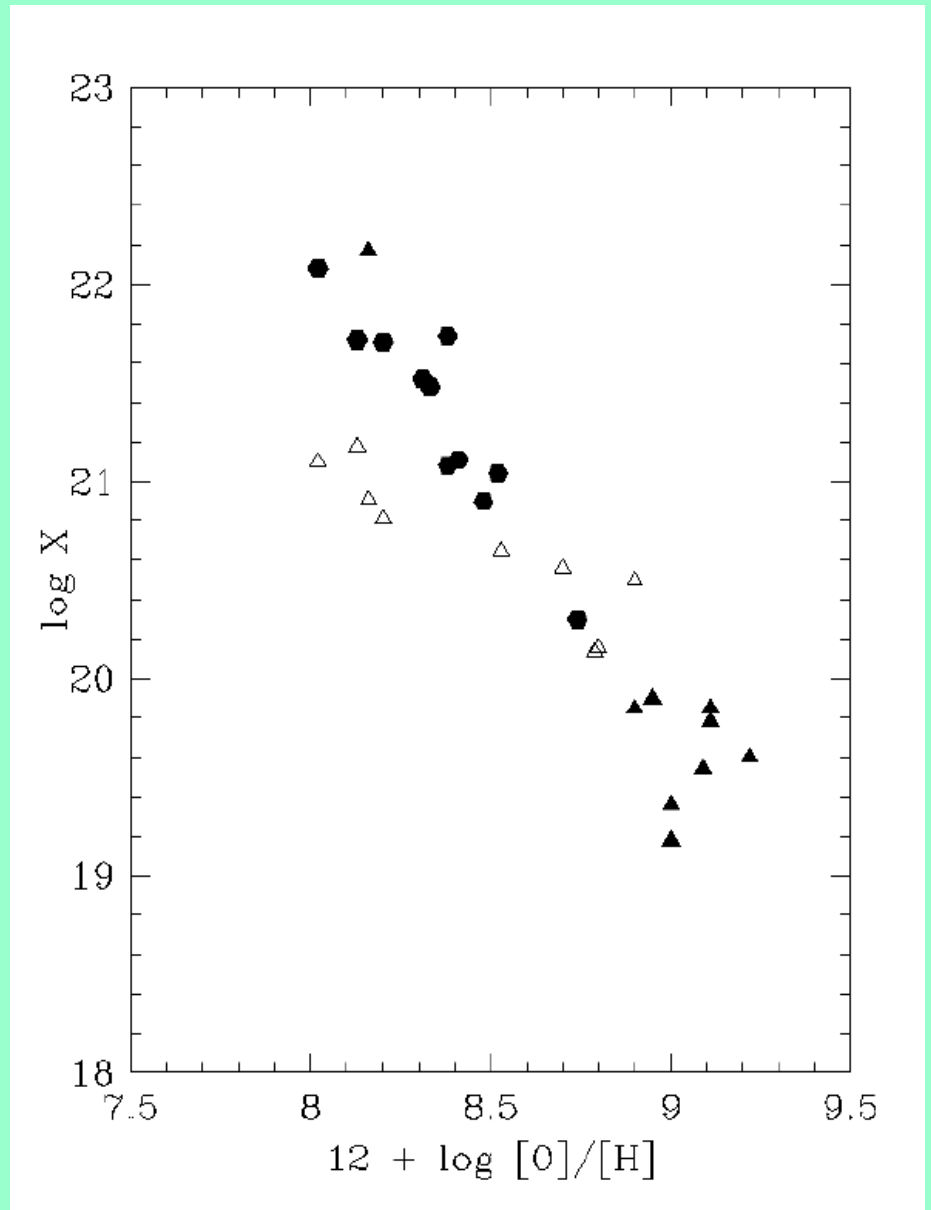
Open symbols:
resolved clouds

$$\log X =$$

$$-\alpha \log [O]/[H] + c$$

$$\alpha = 2.3 (+/-0.3)$$

Israel 1997, 2000



What next?

JCMT Legacy Survey HARP-B and
SCUBA2

IRAM 30m & Array: NUGA

APEX FLASH & CHAMP

ISO/SPITZER/HERSCHEL

but above all:

Full and self-consistent physical
modelling

ADVERTISEMENT

We have a vacancy for a paid PhD student position to work on models of the ISM in the inner kiloparsec of galaxies

For more information,
contact Frank Israel at:

israel@strw.leidenuniv.nl