Neutral carbon emission in luminous infrared galaxies

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outline

- motivation and background
- sample
- result
- summary

CO molecular tracer

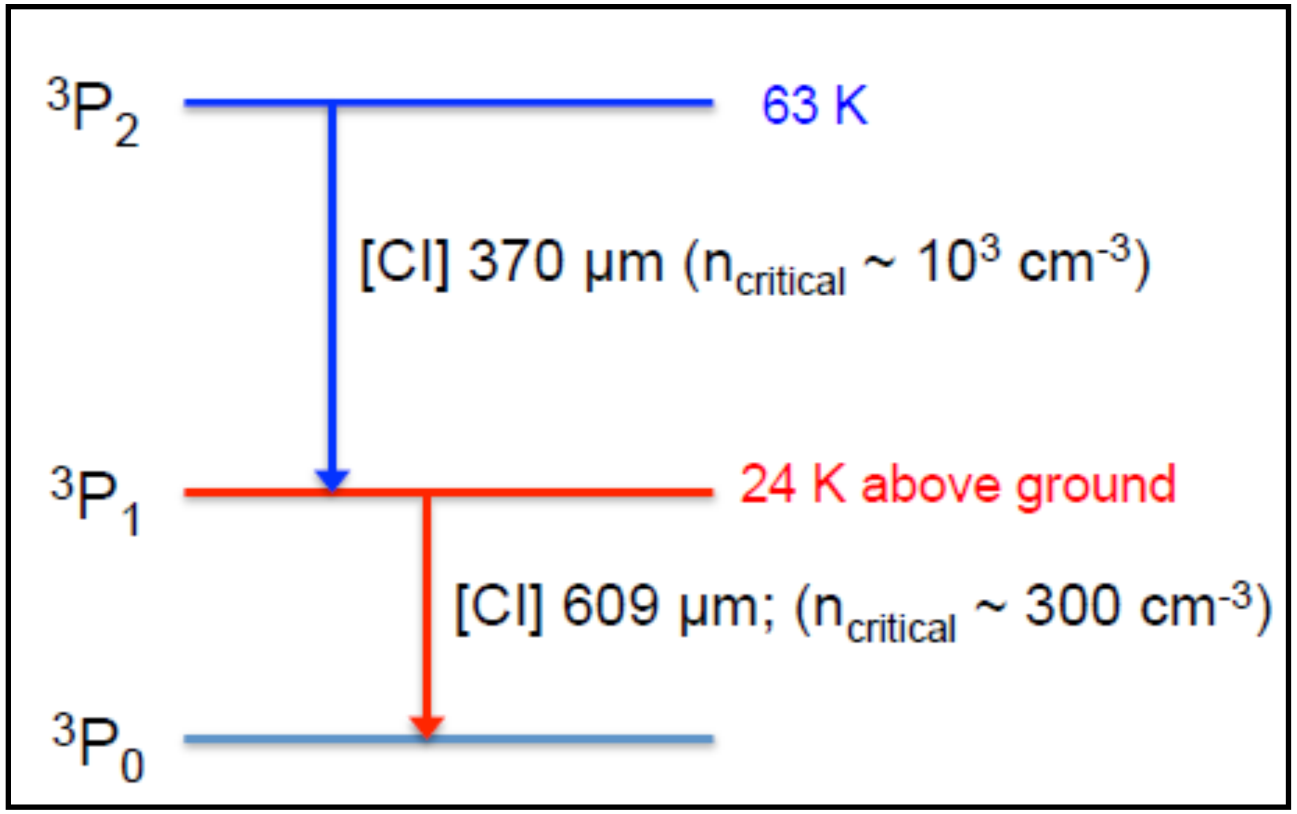
- CO is the most commonly used molecular tracer
- CO-to-H2 conversion factor (Xco) can trace the total gas mass
- **However**
- Xco vary by a factor of ~10 under different environments
- CO isotopes are difficult to observe

CI may be a powerful new molecular tracer

CI lines

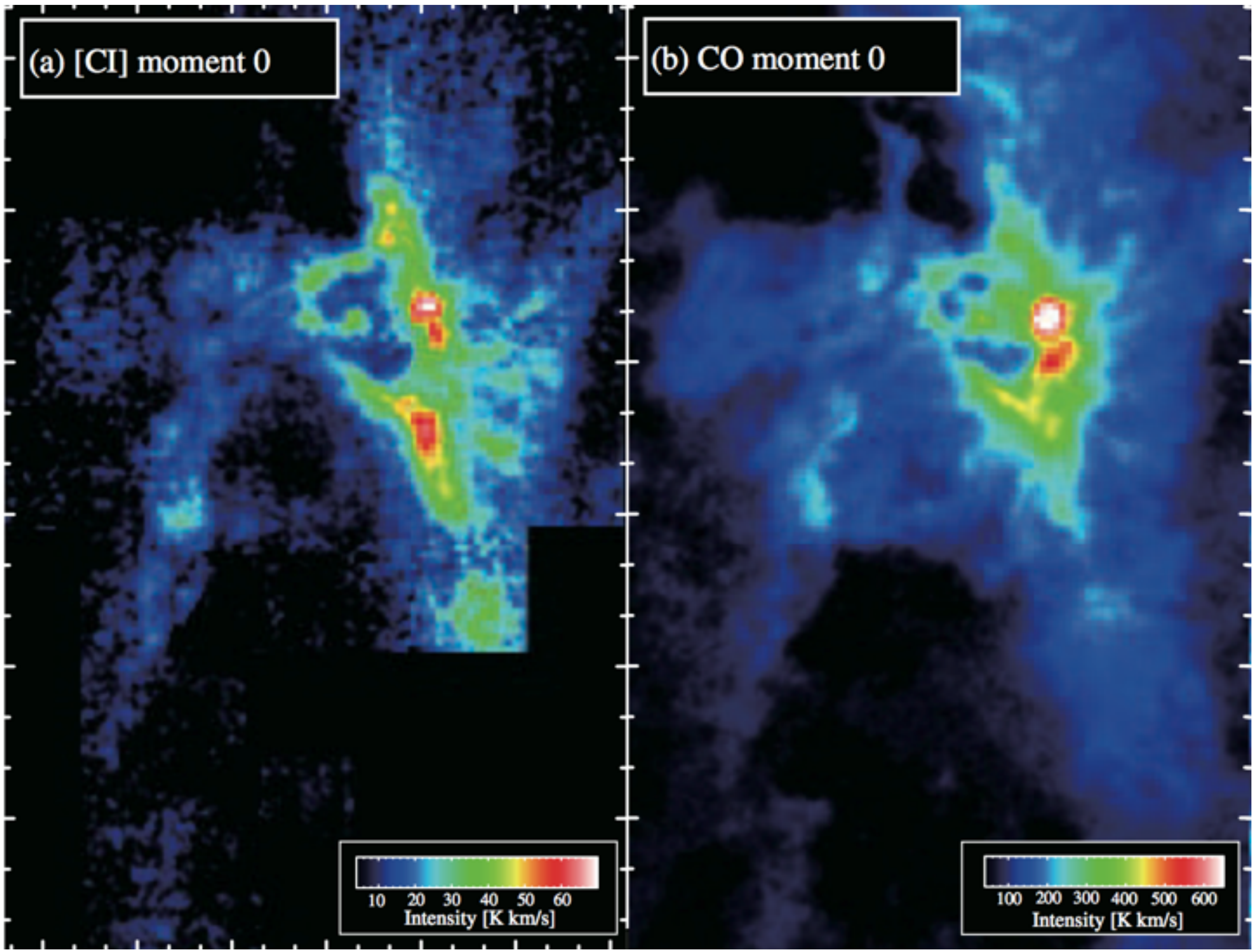
- the CI lines are difficult to observe because the atmosphere absorption

- traditional PDR theory: CI exist in narrow CII/CI/CO zone(Tielens & Hollenbach 1985)



Recent observations and models show that CI can coexist with CO

Orion-A GMC



Shimajiri et al. 2013

Modeling results (GMC)

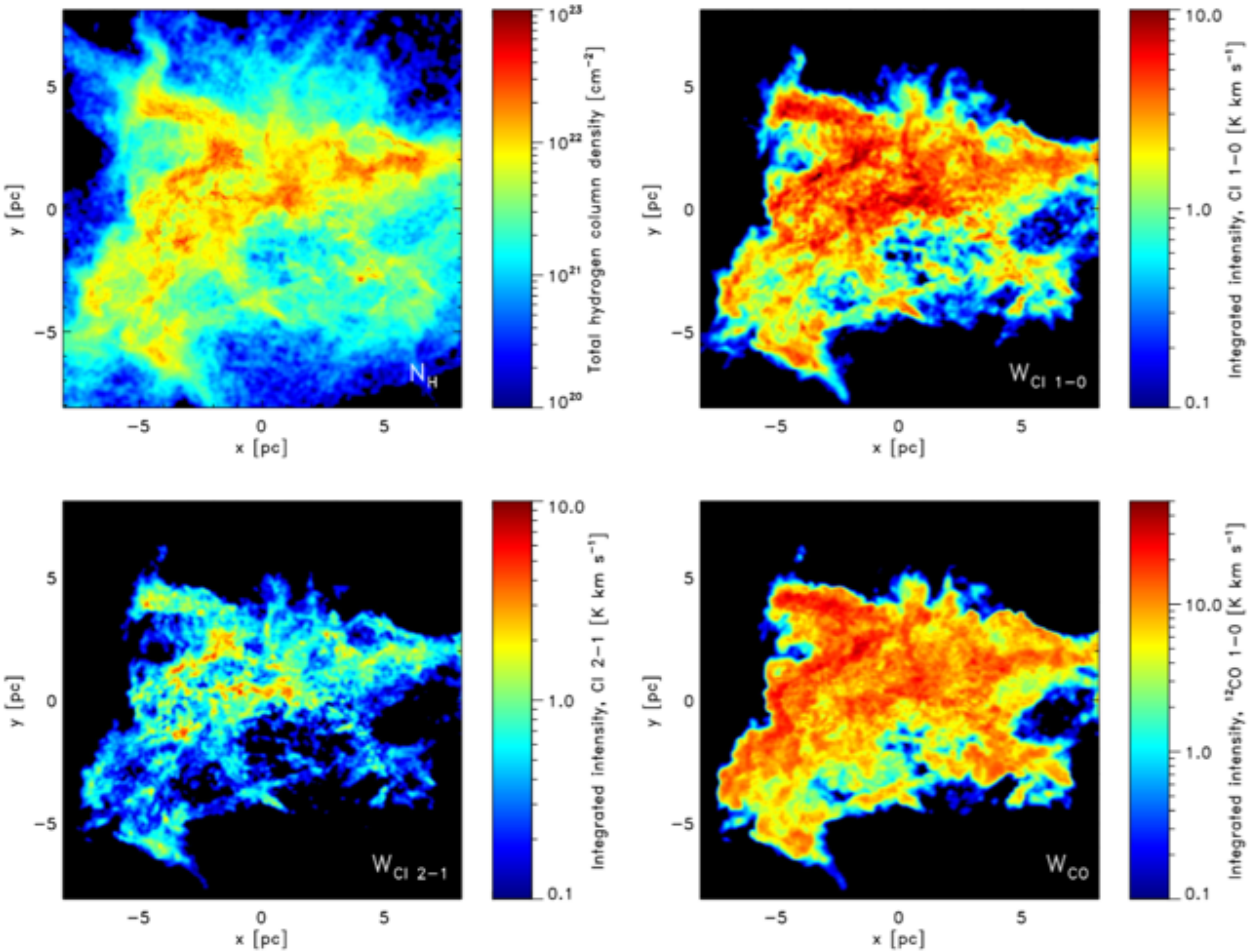
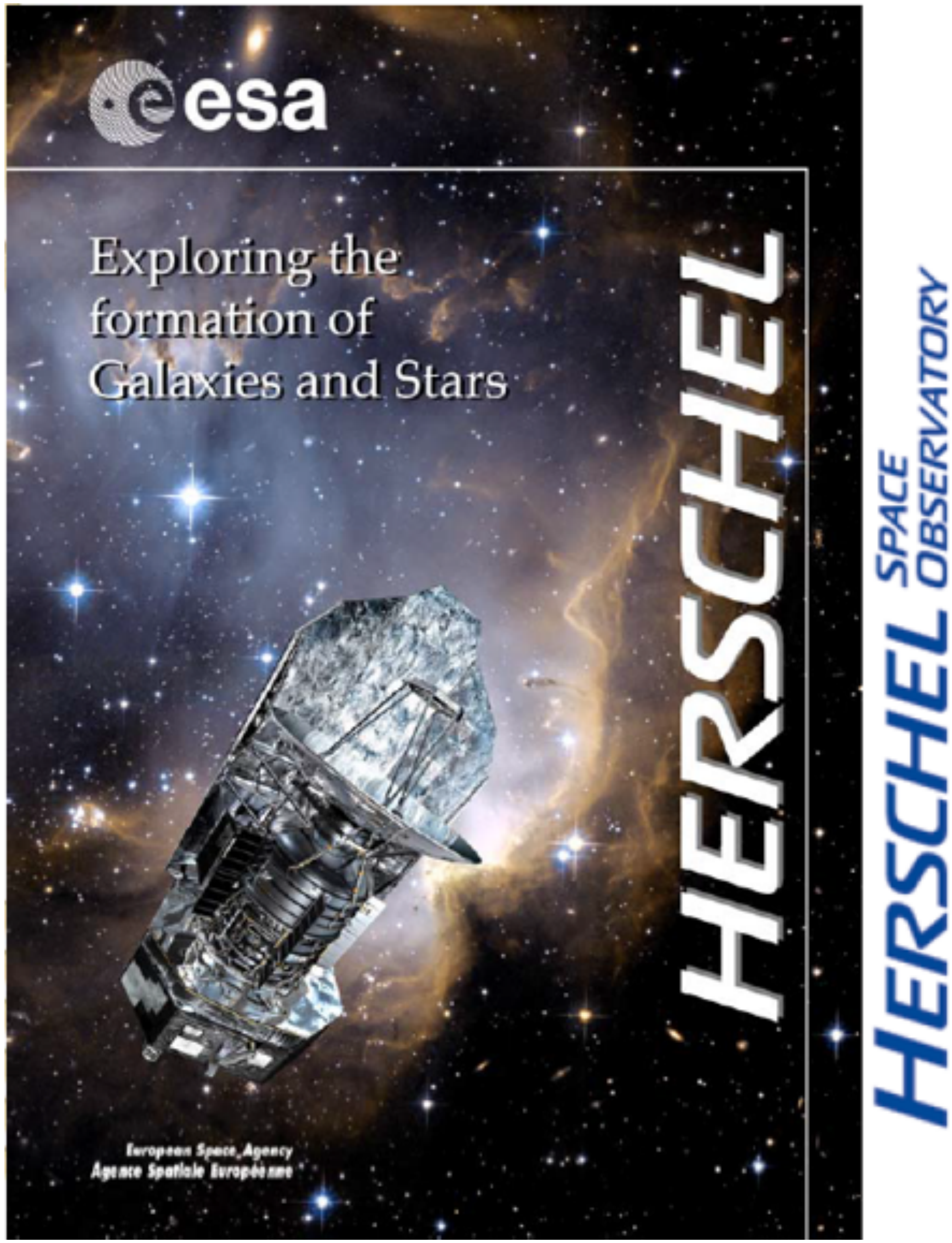
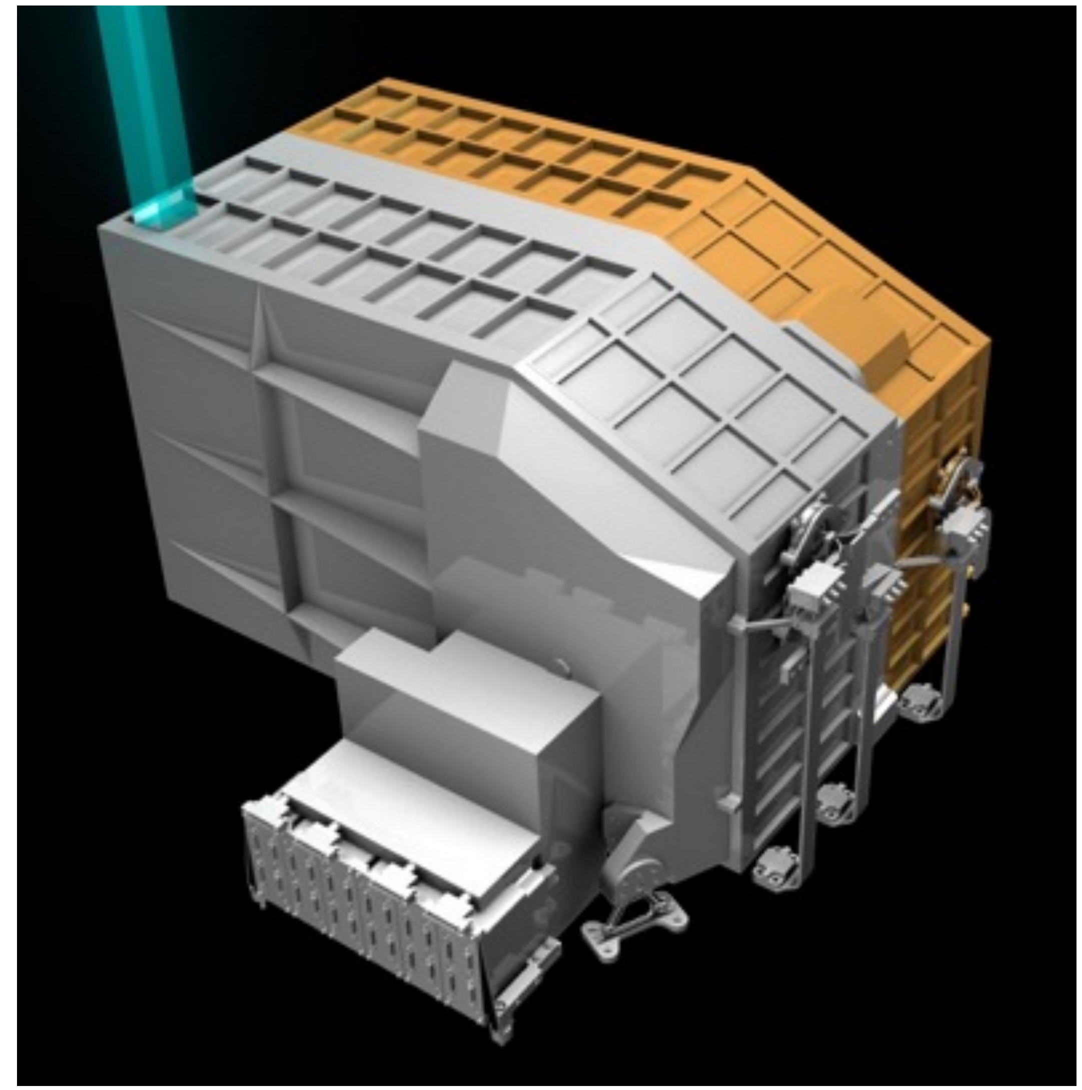


Figure 5. Top left: map of the total column density of hydrogen nuclei, N_{H}. The area shown is approximately 16 pc by 16 pc and contains most of the mass of the cloud. Top right: map of velocity-integrated intensity in the [C I] $1 \rightarrow 0$ transition, computed using RADMC-3D with the LVG approximation. Bottom left: the same as in the top-right panel, but for the [C I] $2 \rightarrow 1$ transition. Bottom right: the same as in the top-right panel, but for the $J = 1 \rightarrow 0$ transition of ^{12}CO.

Glover et al. 2015

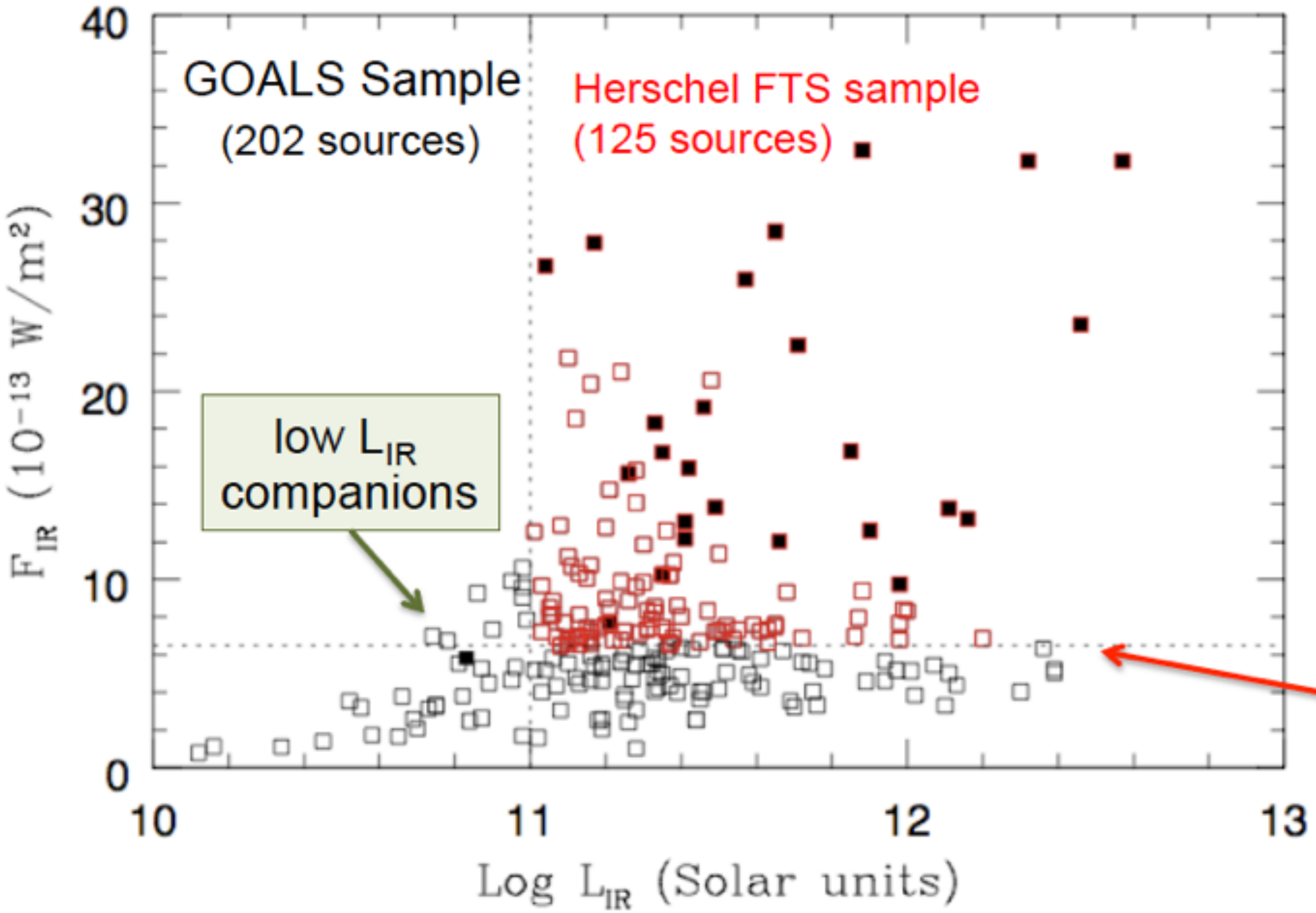
Sample





Herschel SPIRE FTS allow us to explore the CI emission

Sample



Open red squares:
Our targets (93)

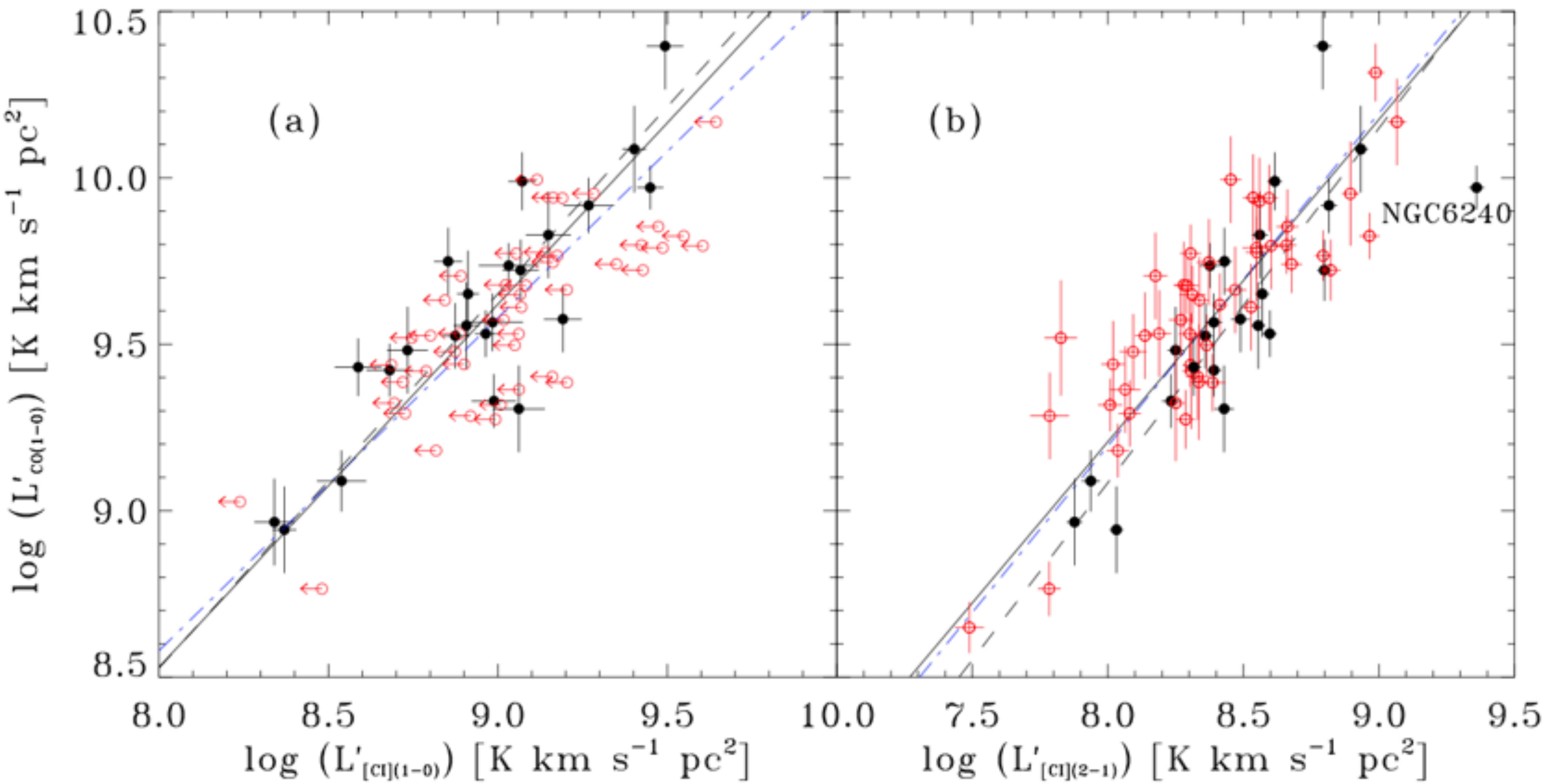
Solid squares:
Brighter ones (32) in prior Herschel programs.

$F_{IR} = 6.5 \times 10^{-13}$ W/m²

Sample

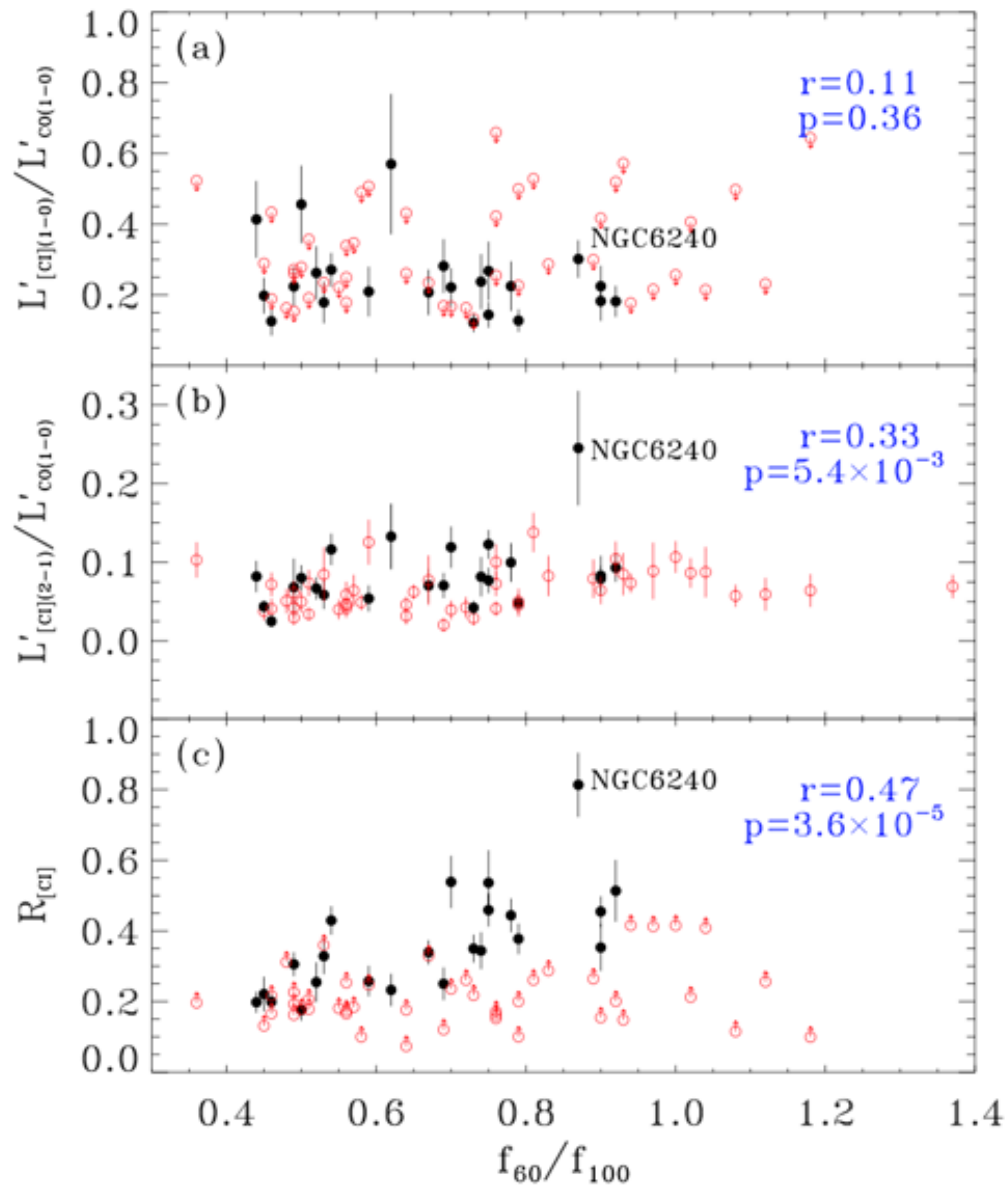
- point-like source with respect to the Herschel FTS beam (35”) (111 (U)LIRGs)
- CO(1-0) data (beam size not less than 35”) in previous sample (71 (U)LIRGs)
- ps: CI(1-0) 23 galaxies

L’ correlation



slope=1.12 (0.09) scatter: 0.18
slope=1.09 (0.15)

slope=1.07 (0.19) scatter: 0.21
slope=0.97 (0.08) scatter: 0.19



the luminosity of CI21 correlate well with IRAS 60/100 color

a_CI conversion factor

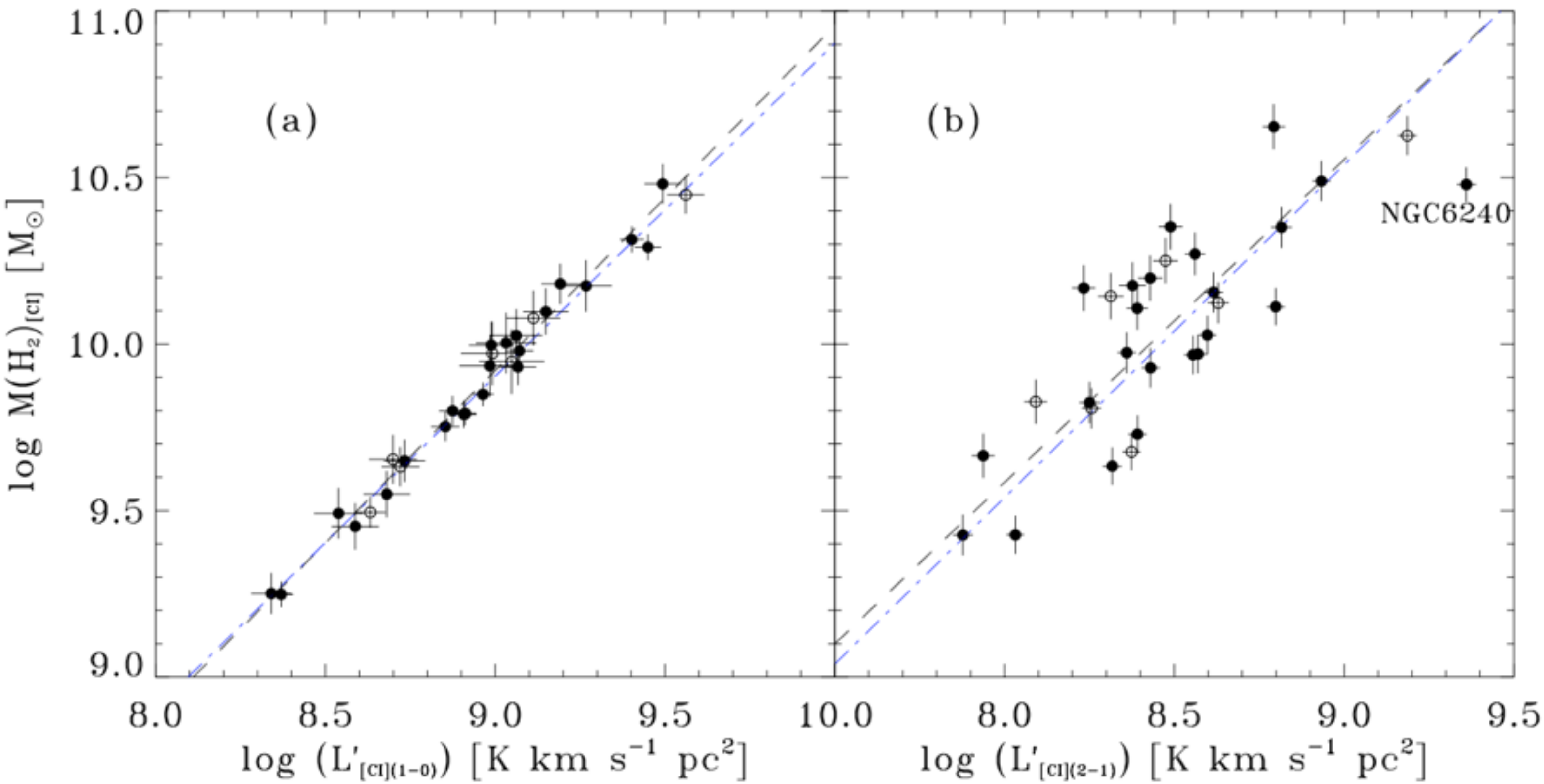
- Papadopoulos et al. (2004)

$$M_{CI}(H_2) = \frac{4\pi m_{H_2}}{hcA_{ul}X_{CI}}(\frac{D_L^2}{1+z})Q_{ul}^{-1}I_{CI}$$

- Papadopoulos et al. (2011)

$$L_x^{'} = 3.25\times 10^3[\frac{D_L^2(Mpc)}{1+z}](\frac{v_{x,rest}}{100(GHZ)})^{-2}[\frac{\int_{\Delta v} S_v dv}{Jy\cdot kms^{-1}}]$$

a_CI conversion factor



slope=1.04 (0.03) scatter: 0.06 **slope=0.98 (0.13) scatter: 0.25**

a_CI conversion factor

$$\log M_{\mathrm{CI(1-0)}}(\mathrm{H_2}) = (0.90 \pm 0.01) + \log L'_{\mathrm{CI(1-0)}}$$

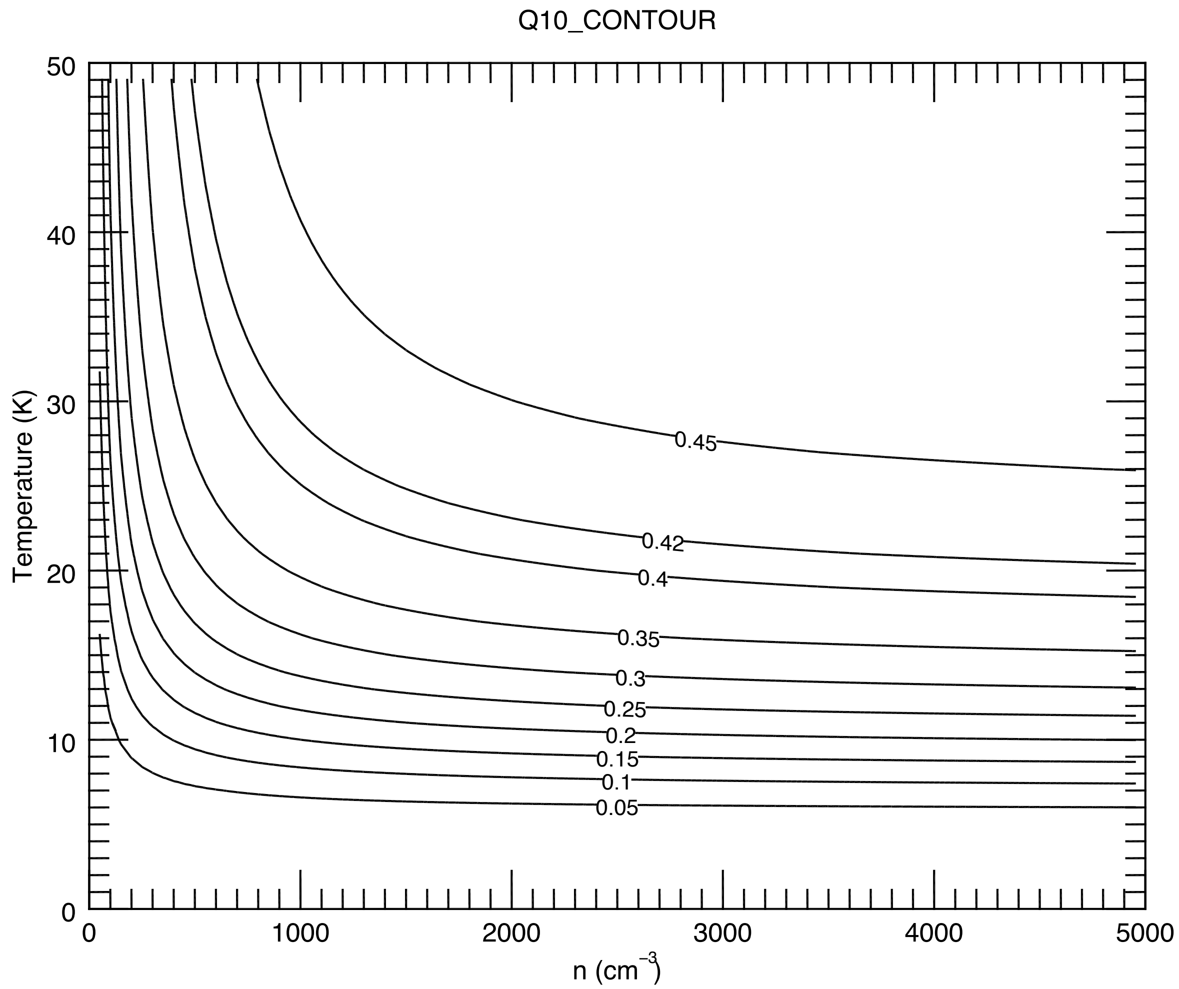
$$\log M_{\mathrm{CI(2-1)}}(\mathrm{H_2}) = (1.53 \pm 0.01) + \log L'_{\mathrm{CI(2-1)}}$$

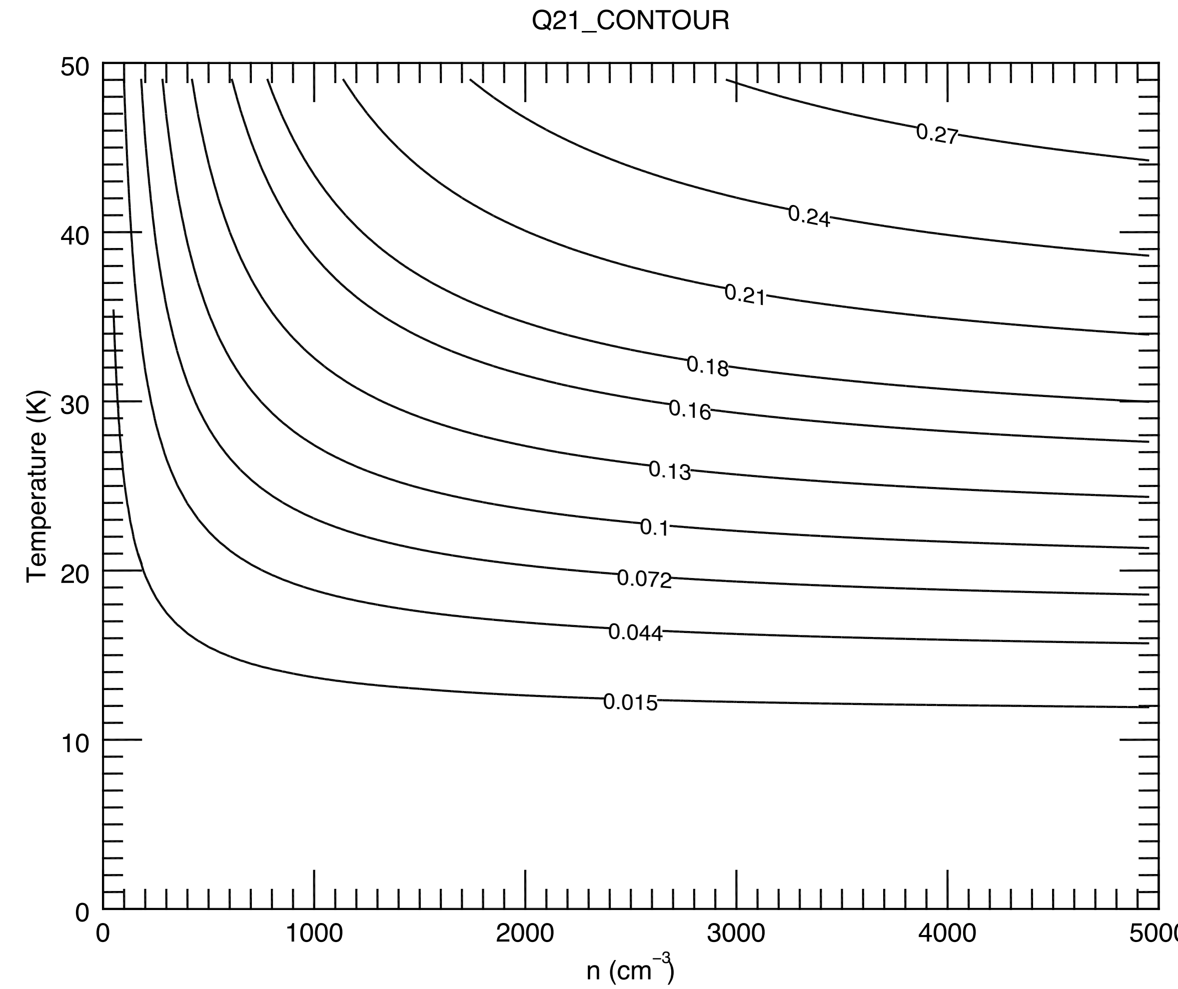
→

a_CI10=7.9

a_CI21=33.9

the conversion factor calculated by CI is 2-3 times larger than that calculated by CO





- excitation temperature is 20-30K for most (U)LIRGs
- excitation factor of CI10 is stable
- excitation factor of CI21 is sensitive with temperature

Future work

- other kind of galaxies
- CI distribution vs CO distribution

Summary

- The CI luminosities have a good correlation with CO luminosities
- The CI lines can be used as total molecular tracer at least in (U)LIRGs
- We give two CI conversation factors: a_CI10=7.9, a_CI21=33.9. The a_CI(1-0) is a better factor
- The intensity ratio R depend well on f60/f100 color, while the Lci(2-1)/Lco(1-0) depend weakly on color

Thank you !