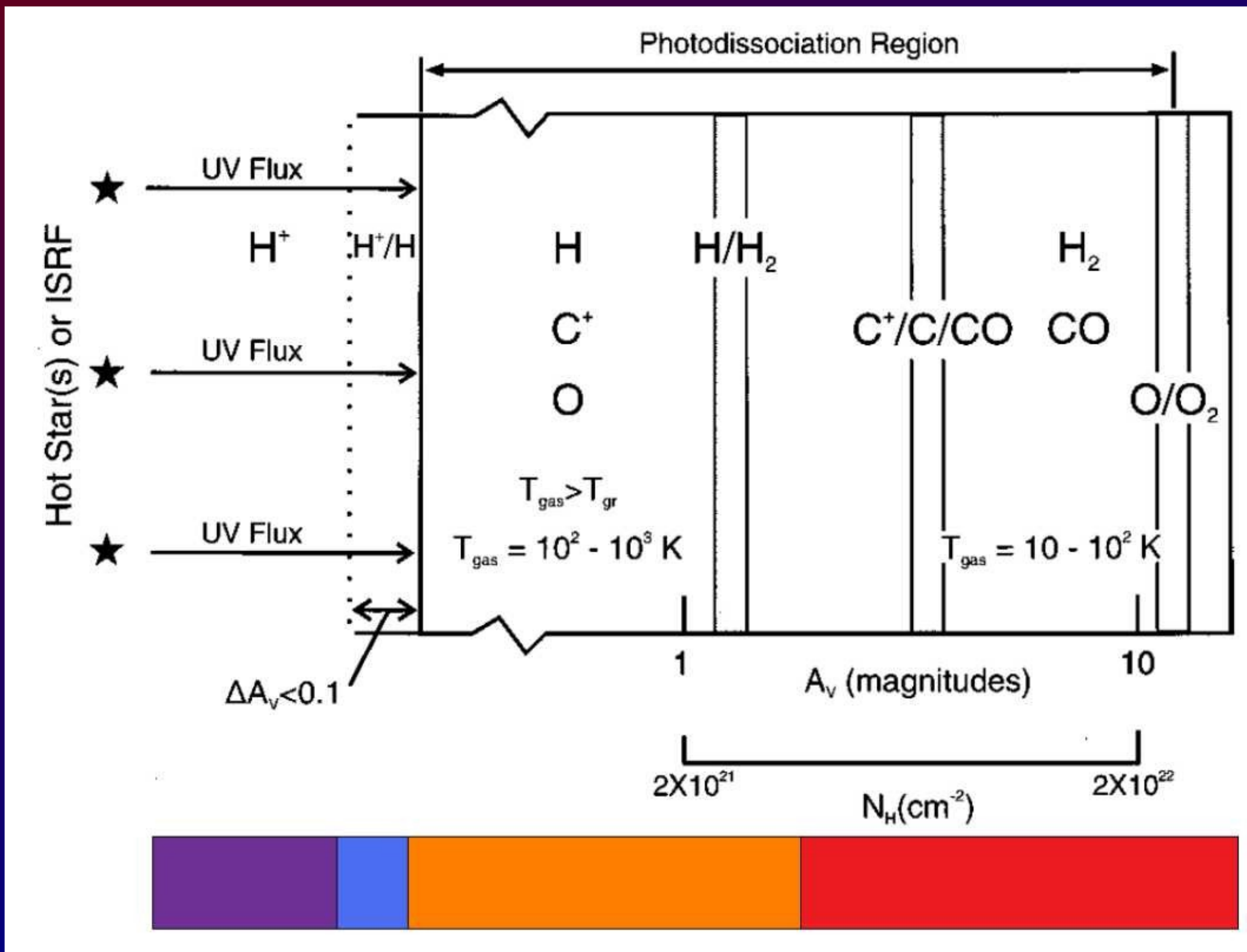
Spatially resolved physical conditions of molecular gas: a zoom-in from circumnuclear region of M83 to Carina nebula

Ronin WU
JSPS Postdoctoral Fellow, University of Tokyo

Outline

- Motivation
  - Star formation tracers in the ISM
  - Molecular gas and star formation
- Project I - Excitation of warm CO in the nucleus of M83
  (Wu et al. 2015 A&A 575 88)
  - Physical properties derived from CO spectral line energy distribution
  - Relationship between molecular CO and star formation rate
  - Comparison with dust properties
  - Molecular gas pressure
- Project II - Searching for the origin of the 22 micron feature near Trumpler 14 of the Carina Nebula
  (motivated by Chan and Onaka 2000 and Onaka 2008)
  - Variation of the 22 micron feature in the PDR near the Trumpler 14.
  - CO excitation in the PDR
- Concluding Remarks

Molecular gas and star formation



Hollenbach and Tielens 1999

~ a few pc

~ a few hundreds pc

HII region:

UV flux: young stars

Optical: Ha, nebular lines

Extinction from ISM

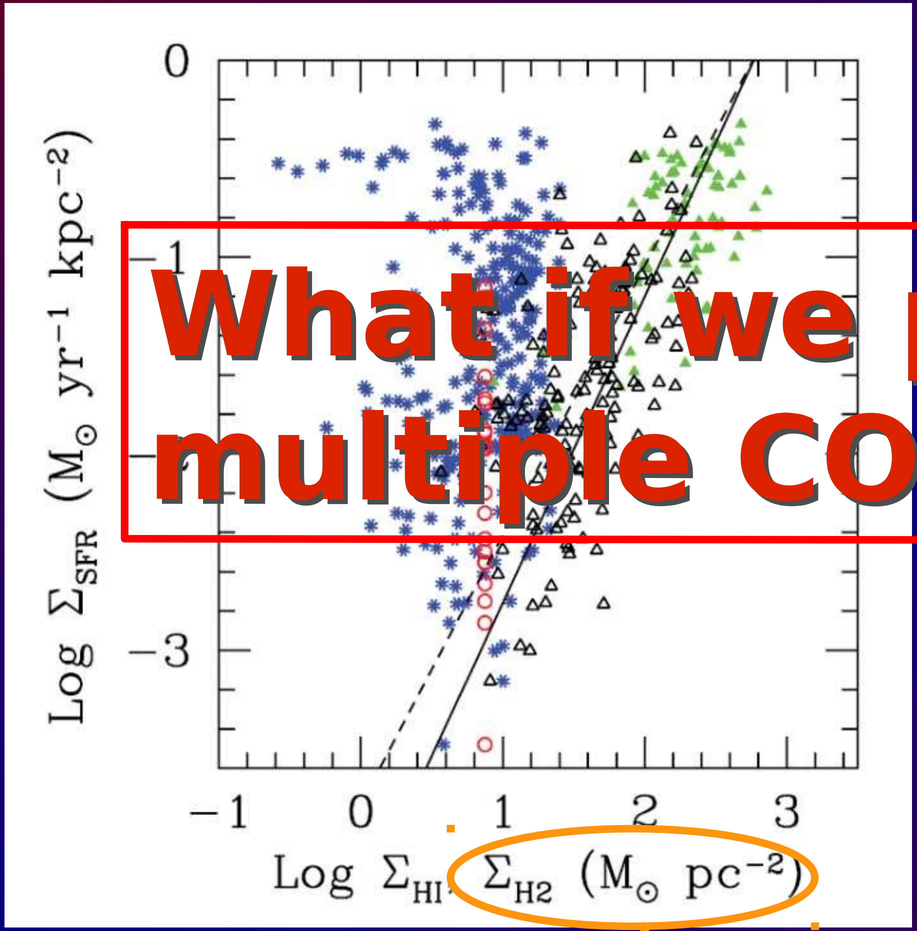
PDR:

mid-infrared: PAH, warm H2

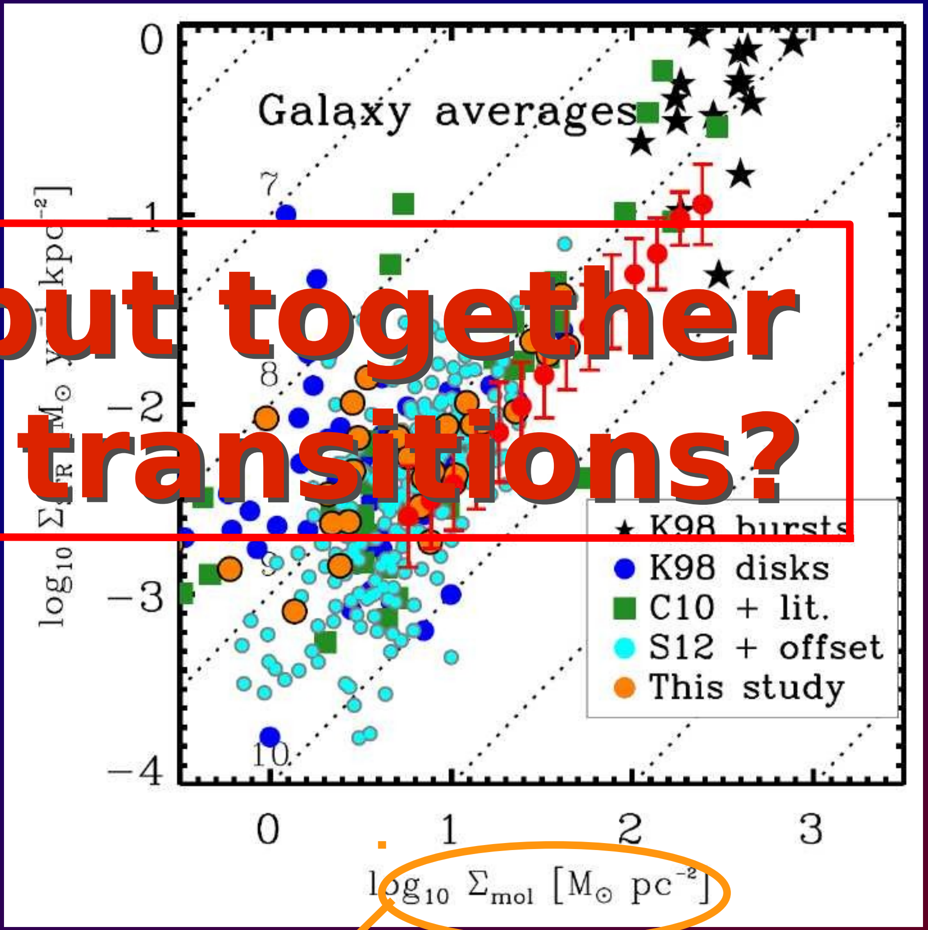
Far-infrared: CII, OI

Sub-millimeter: CO ladder

Tracing star formation with CO



Kennicutt et al. 2007



Leroy et al. 2013

What if we put together multiple CO transitions?

Converted from CO J=1–0 intensity

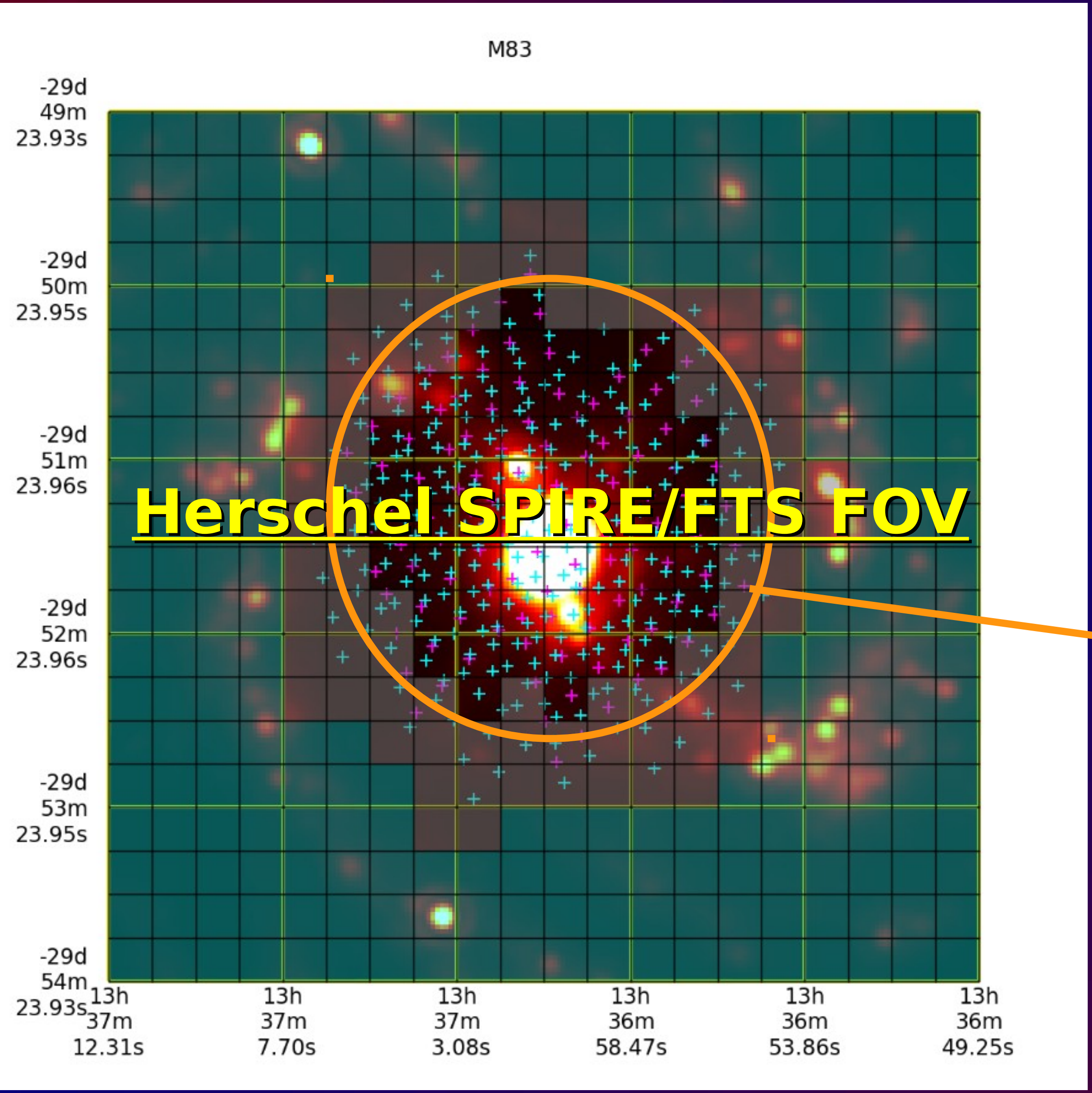
Project I

Excitation of warm CO gas in the nucleus of M83

Collaborators:

Suzanne Madden, Frédéric Galliano, Chris Wilson, Julia Kamenetzky, Min-Young Lee, Maximilien Schirm, Sacha Hony, Vianney Lebouteiller, Diane Cormier, Jason Glenn, Philip Maloney, Pasquale Panuzzo, Miguel Pereira-Santaella, Naseem Rangwala, Aurélie Rémy-Ruyer, Luigi Spinoglio, and Herschel SAG2 Consortium

Introducing M83



— 15″ ~ 300 pc

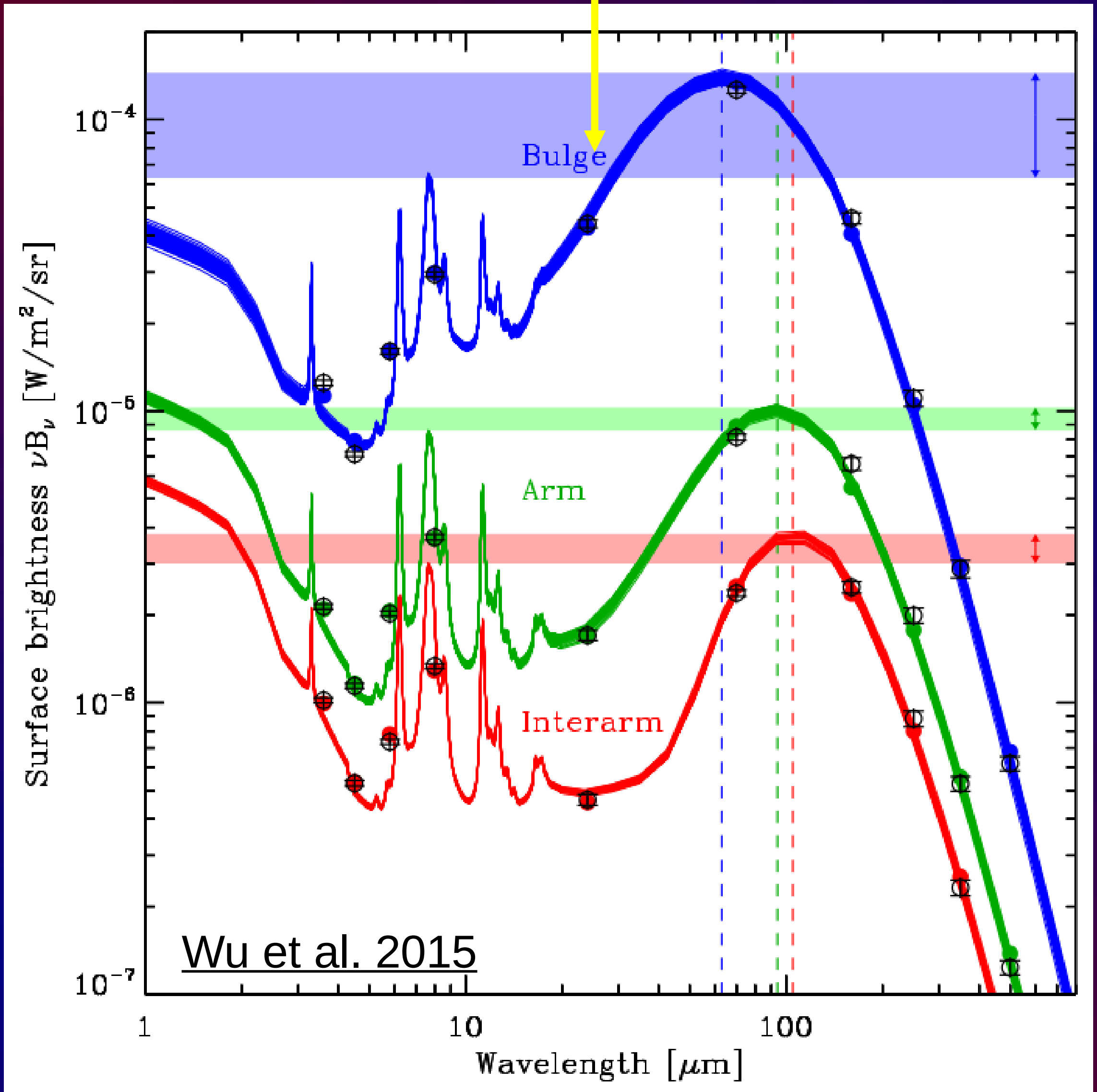
A.K.A NGC5236
Grand-design galaxy
4.5 Mpc away
Have many ancillary data

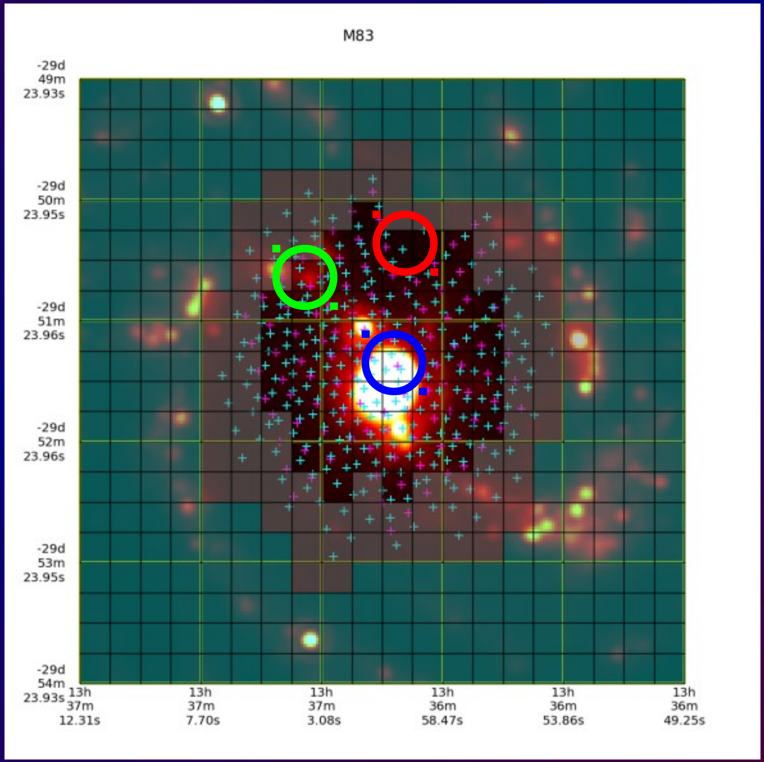
+ SSW (18″ ~ 400 pc)
(193 < λ < 320 μm)
CO J=9−8 to J=13−12
NII 205 μm

+ SLW (35″ ~ 800 pc)
(300 < λ < 685 μm)
CO J=4−3 to J=8−7
CI 370 and 609 μm

Dust properties from broad-band images

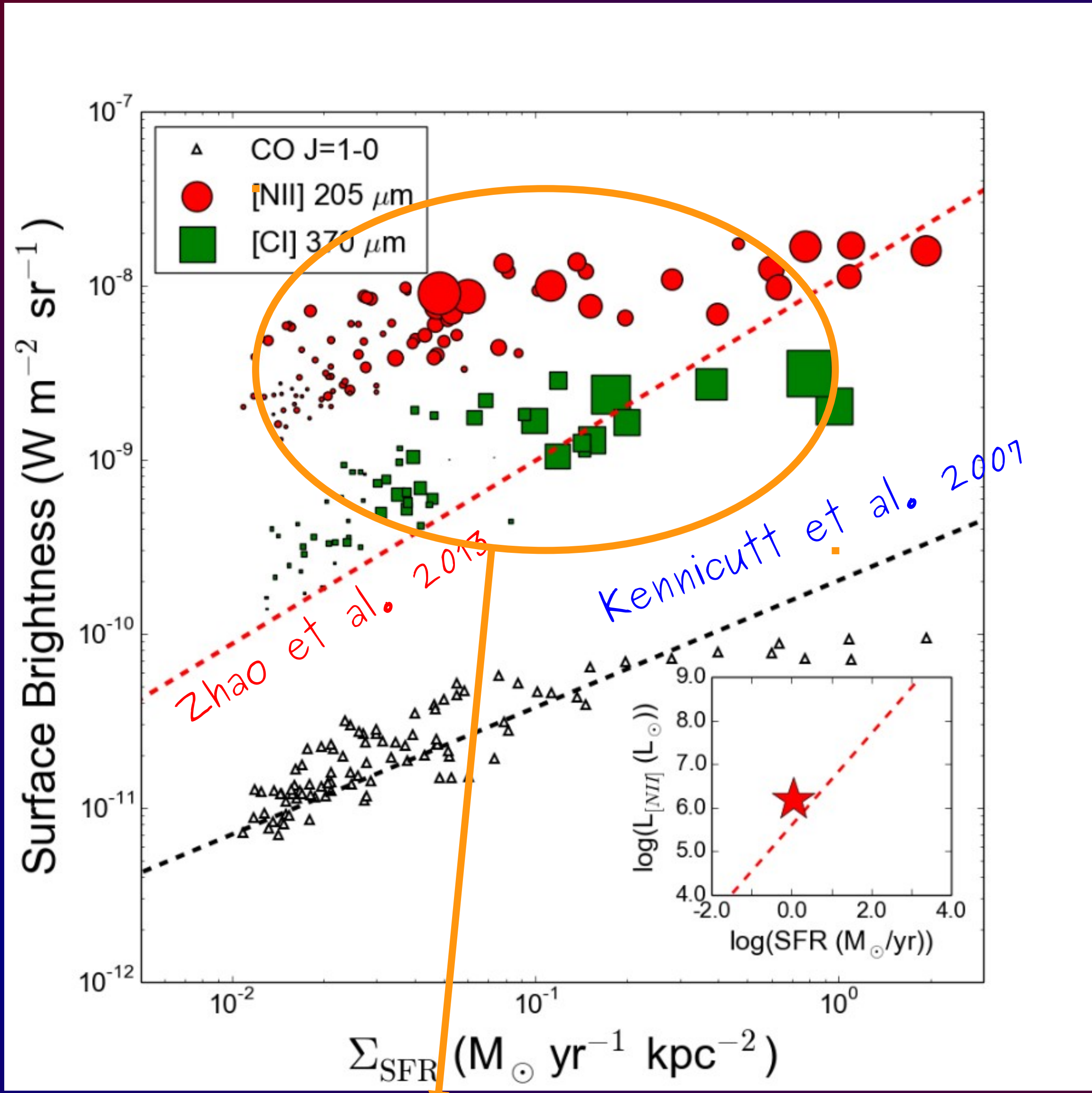
IRAC MIPS PACS+SPIRE

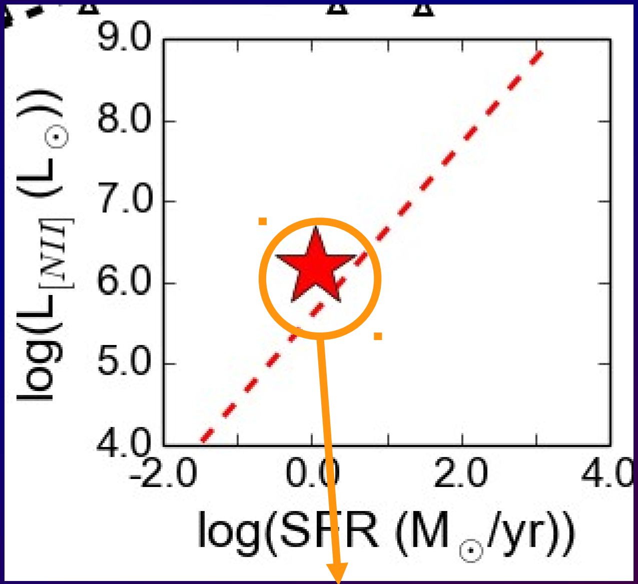




Main dust properties:
(Galliano et al. 2008)
Dust mass – M_{dust}
Starlight intensity – <U>

NII as a star formation rate tracer?



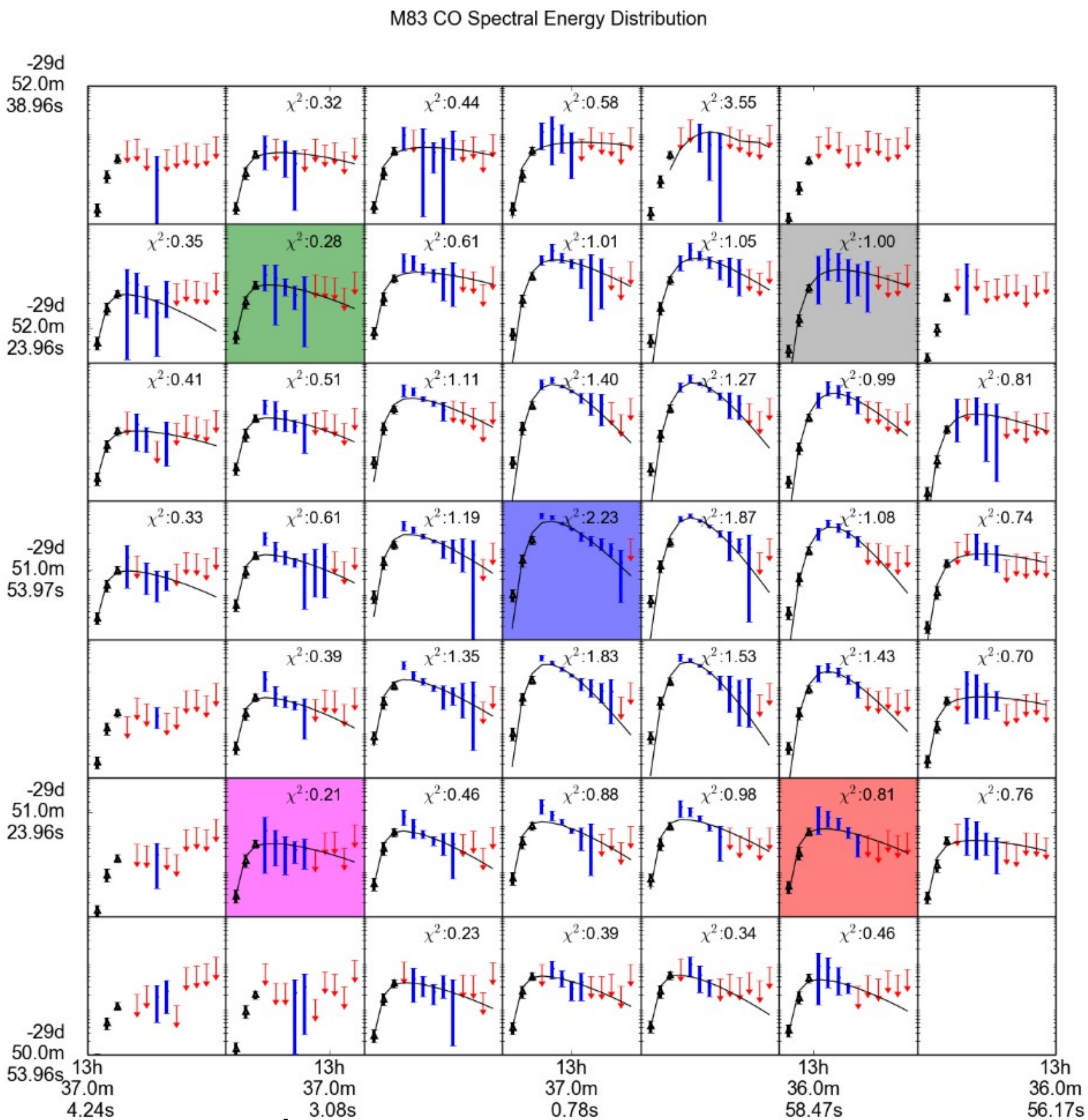


Integrated value from the entire galaxy

Wu et al. 2015

Due to the extensiveness of diffuse ionized gas?

CO Spectral line energy distribution



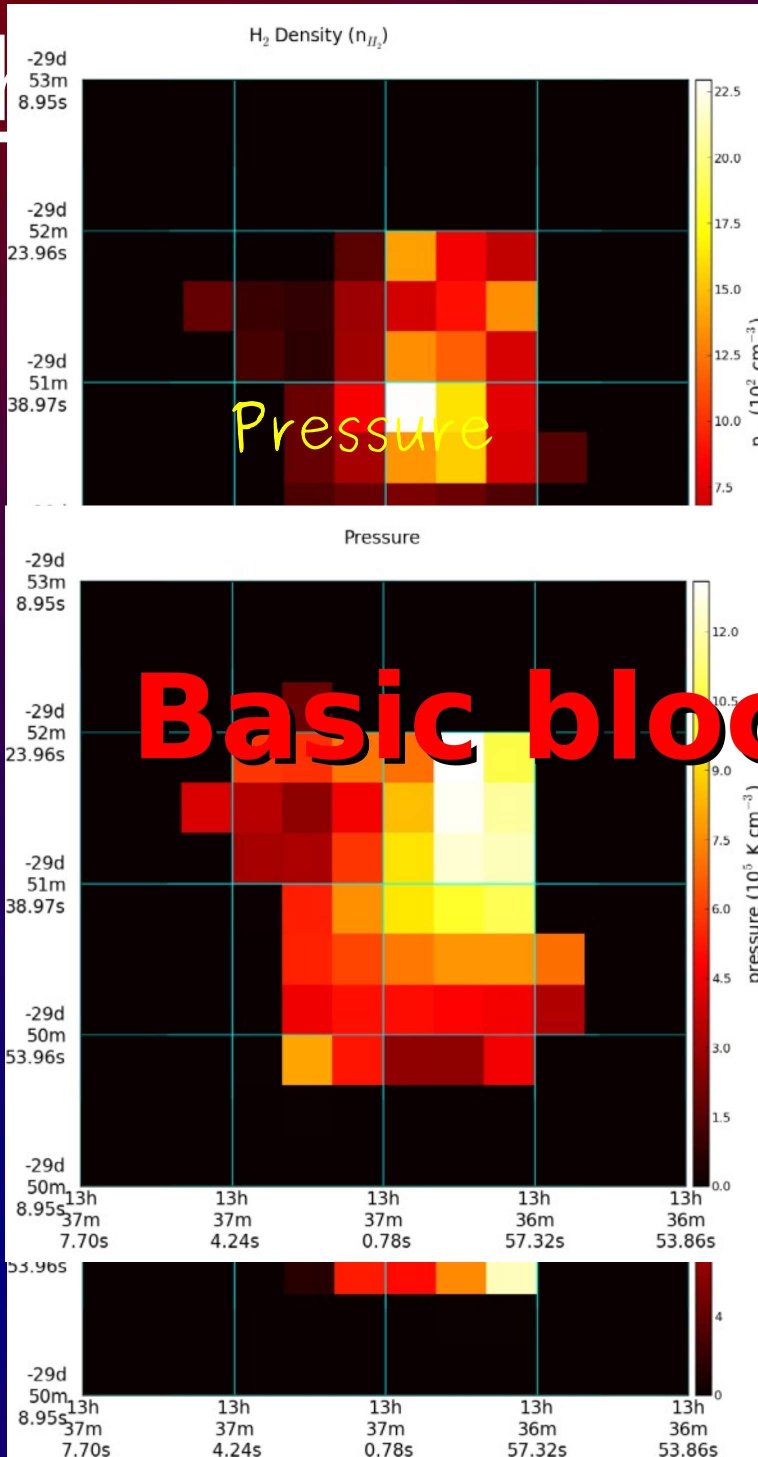
Wu et al. 2015

Thanks to Herschel SPIRE/FTS for enabling the CO SLED mapping!

Bruce Swinyard
(07/1962 – 05/2015)

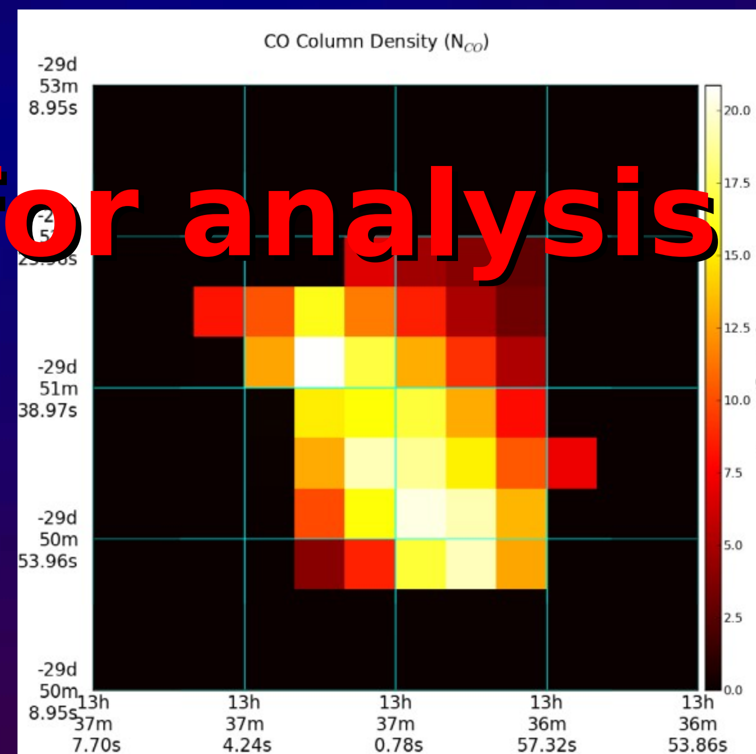
Best-fit parameters @ center
N(CO)=9.51e17 cm^-2
n(H2) = 2628 cm^-3
T_kin = 307 K

Ph… ters derived from SLED



Molecular hydrogen density

CO column density (N(CO))



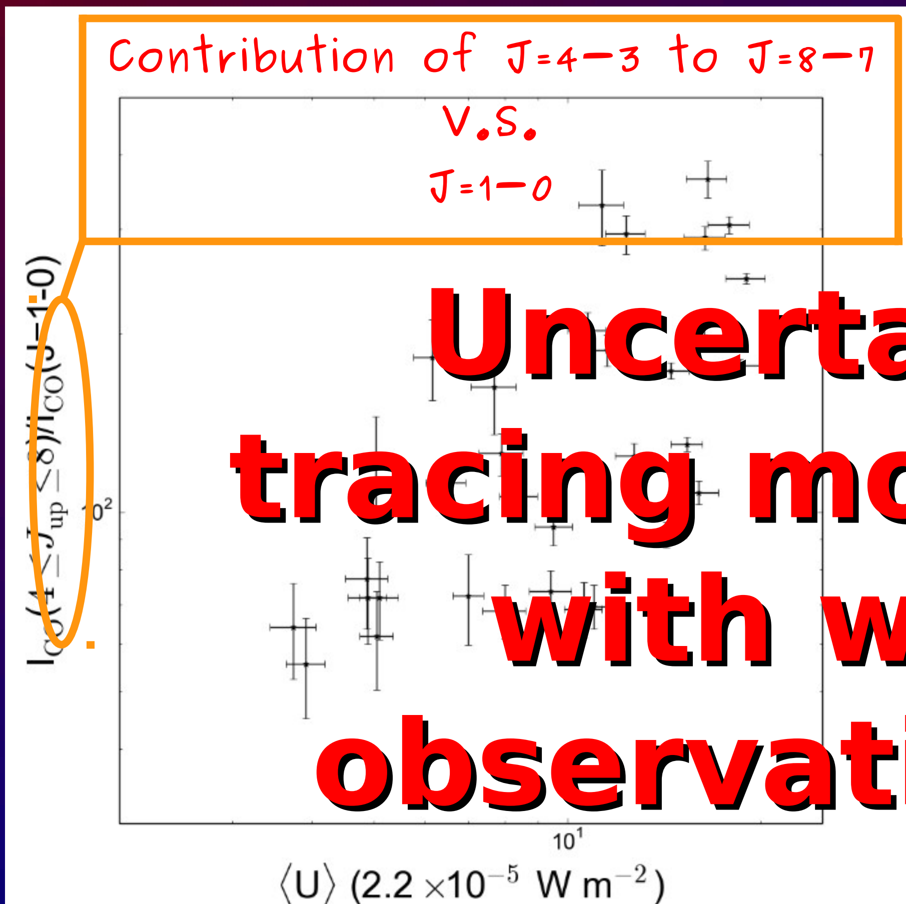
Basic blocks for analysis

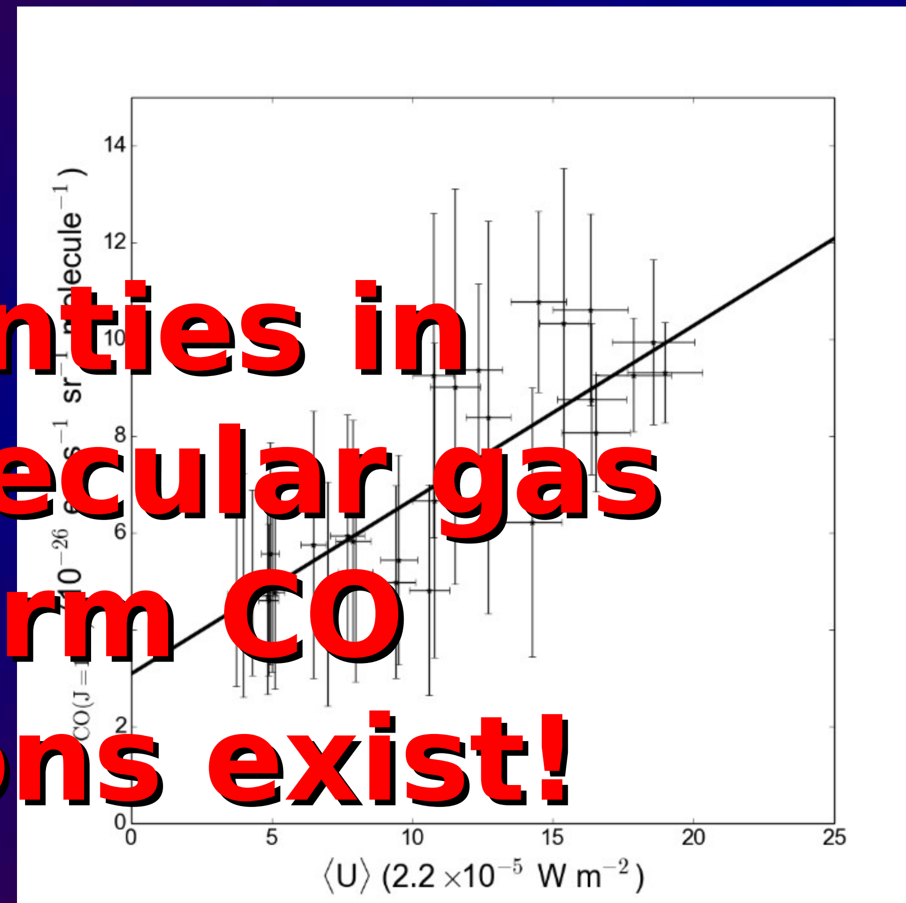
Kinetic Temperature

Wu et al. 2015

Emissivity of CO J=1-0

Wu et al. 2015





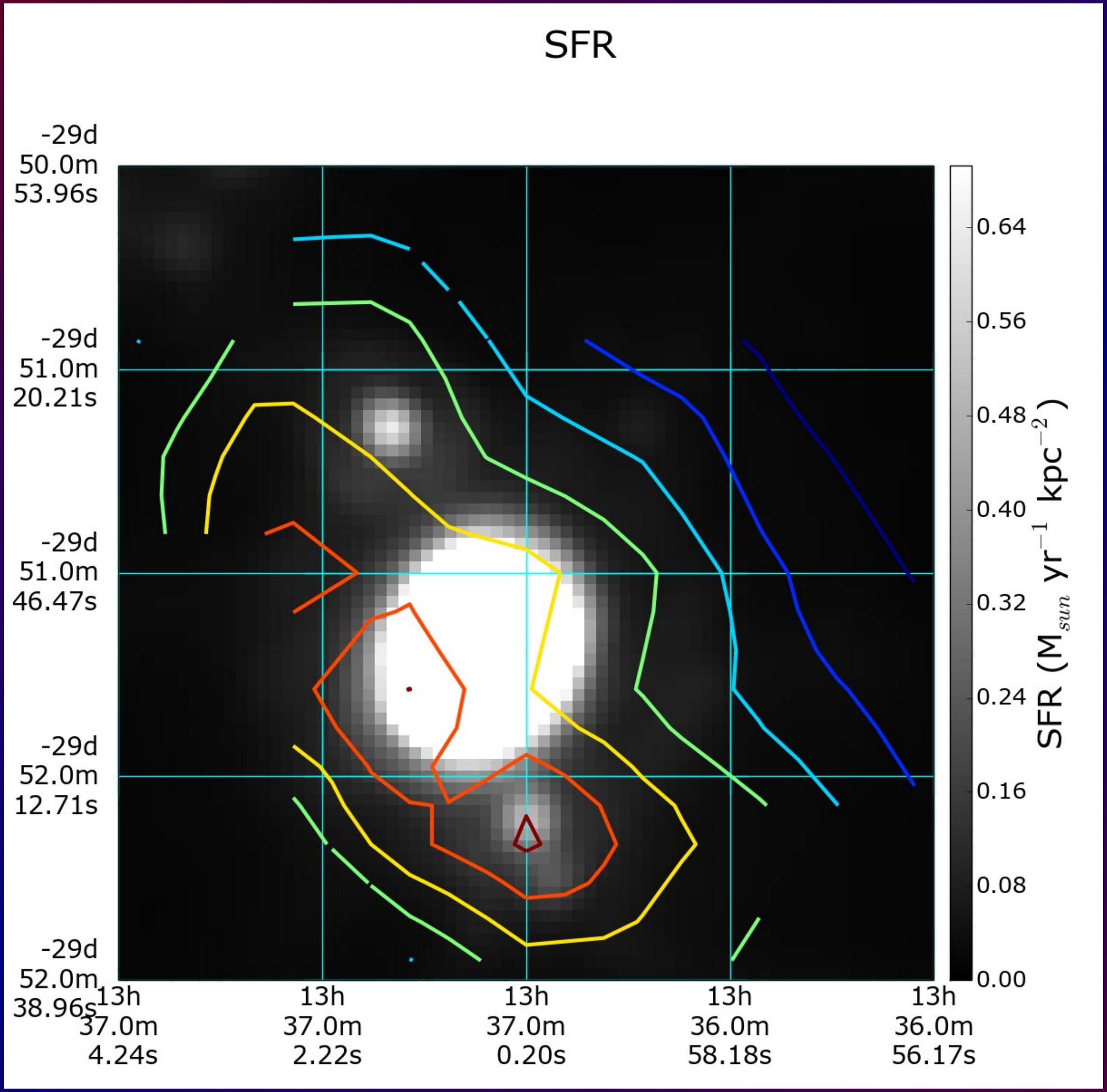
Uncertainties in tracing molecular gas with warm CO observations exist!

Higher-J transitions are enhanced by Higher starlight intensity

$$\epsilon_{CO(J=1-0)} = S_{CO(1-0)}/N(CO)$$
$$= X_{CO}^{-1}\ [CO/H_2]^{-1}$$

X_{CO} decreases as <U> increases ?

Cross-wavelength comparison: N(CO) v.s. SFR

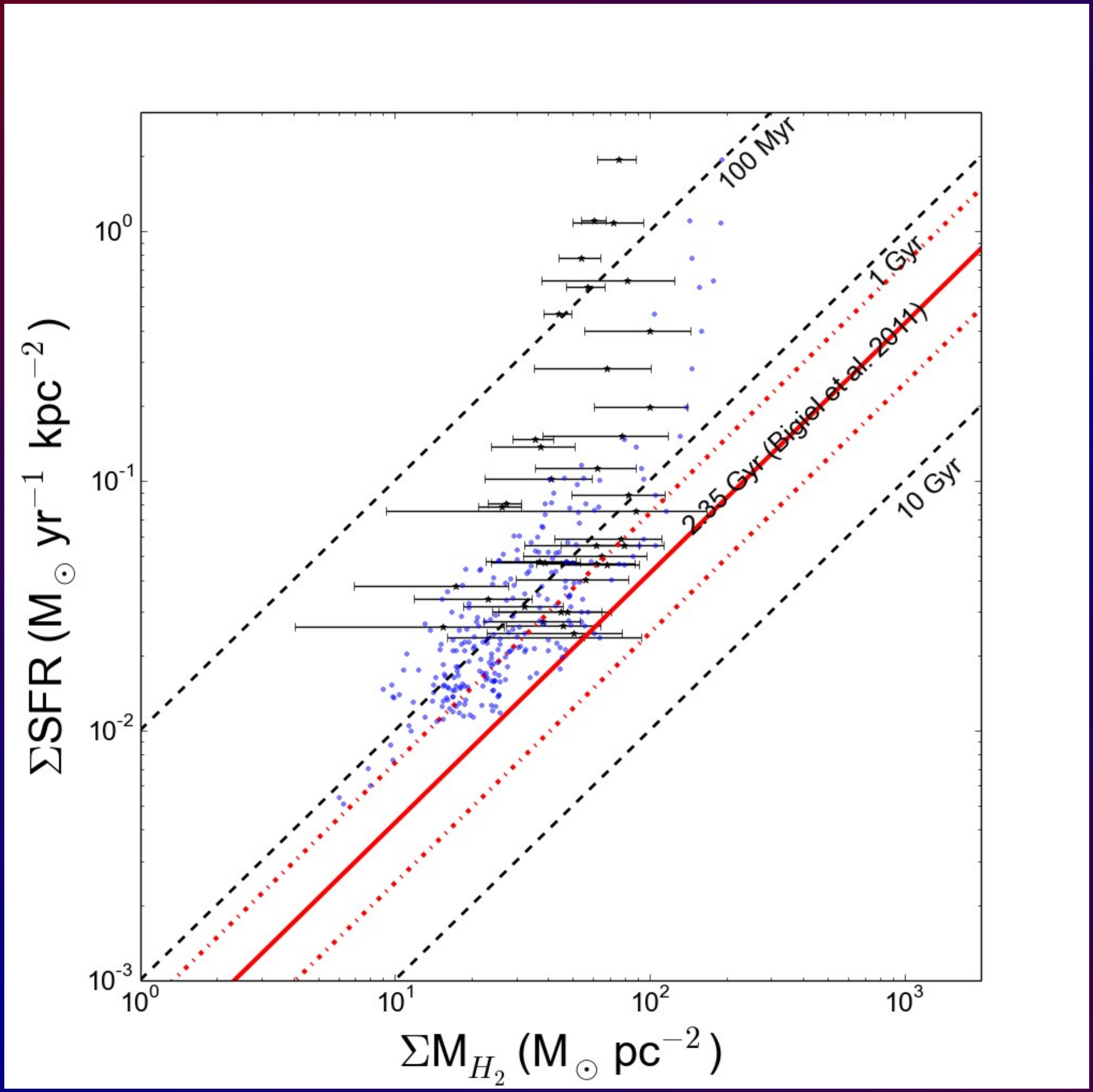


Wu et al. 2014

CO column density distribution resembles the distribution of SFR

SFR=FUV+24μm
(Hao et al. 2011)

Cross-wavelength comparison: N(CO) v.s. SFR



Wu et al. 2014

M83 shows a smaller gas-depetion rate

→

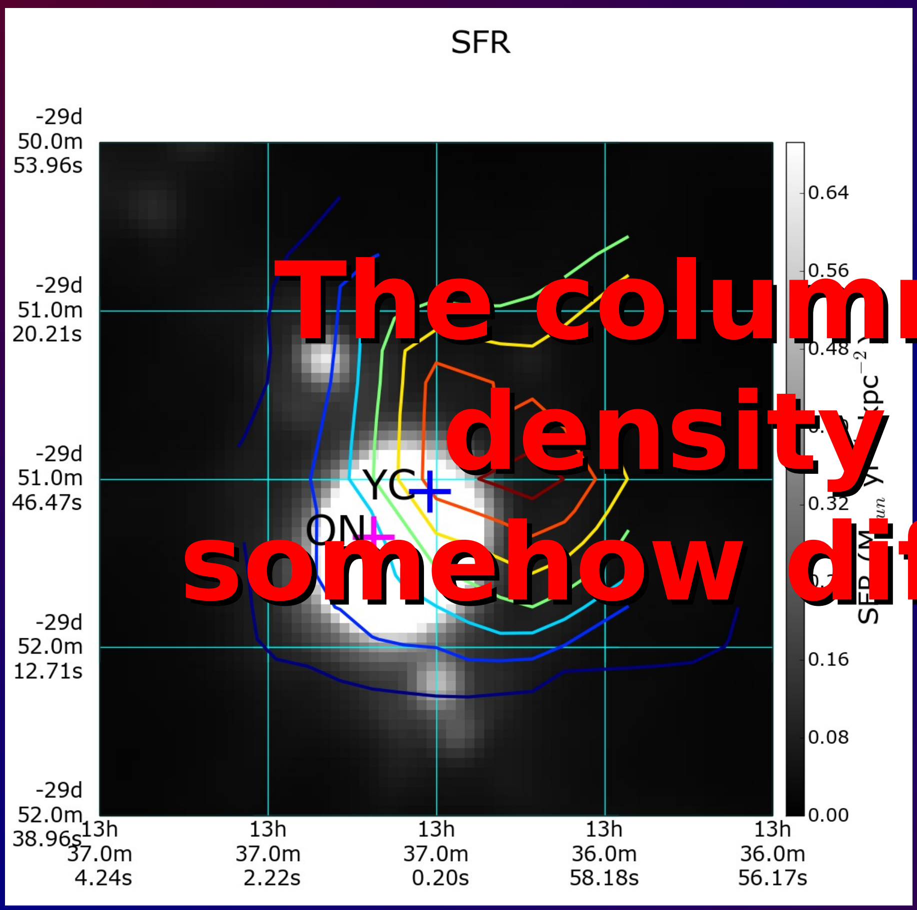
Because of its strong starburst nucleus?

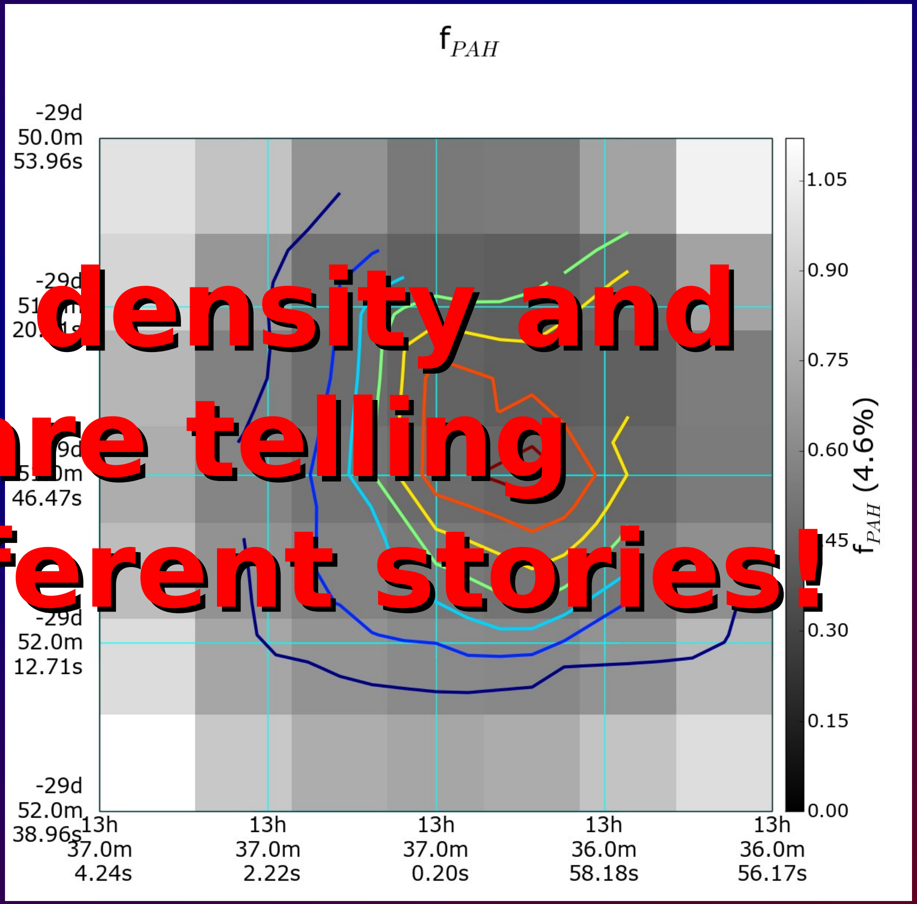
Conversion factors:

N(CO)/N(H2)=3e-4

N(H2)/I(CO)=2e20 (cm^-2(K km s^-1)^-1)

Cross-wavelength comparison: CO v.s. dust



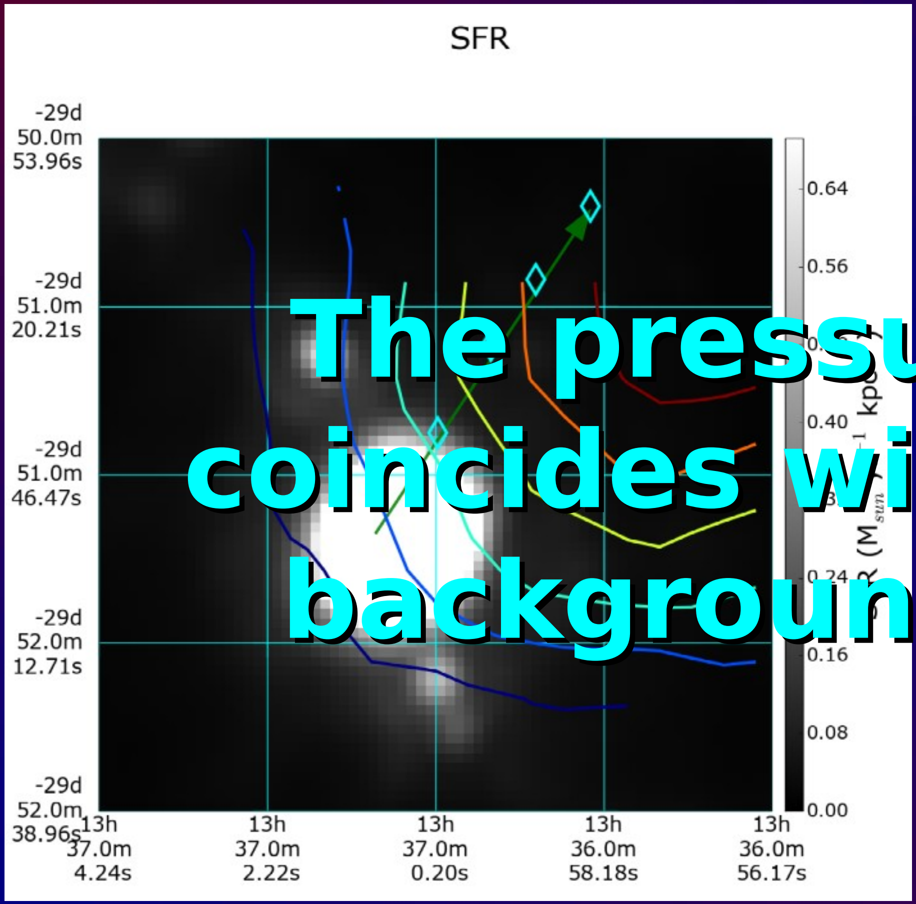


The column density and density are telling somehow different stories!

CO density offsets from the SFR center, but... sits right on top of the "PAH hole".

Wu et al. 2014

Comparison: pressure gradient v.s. Radio jet



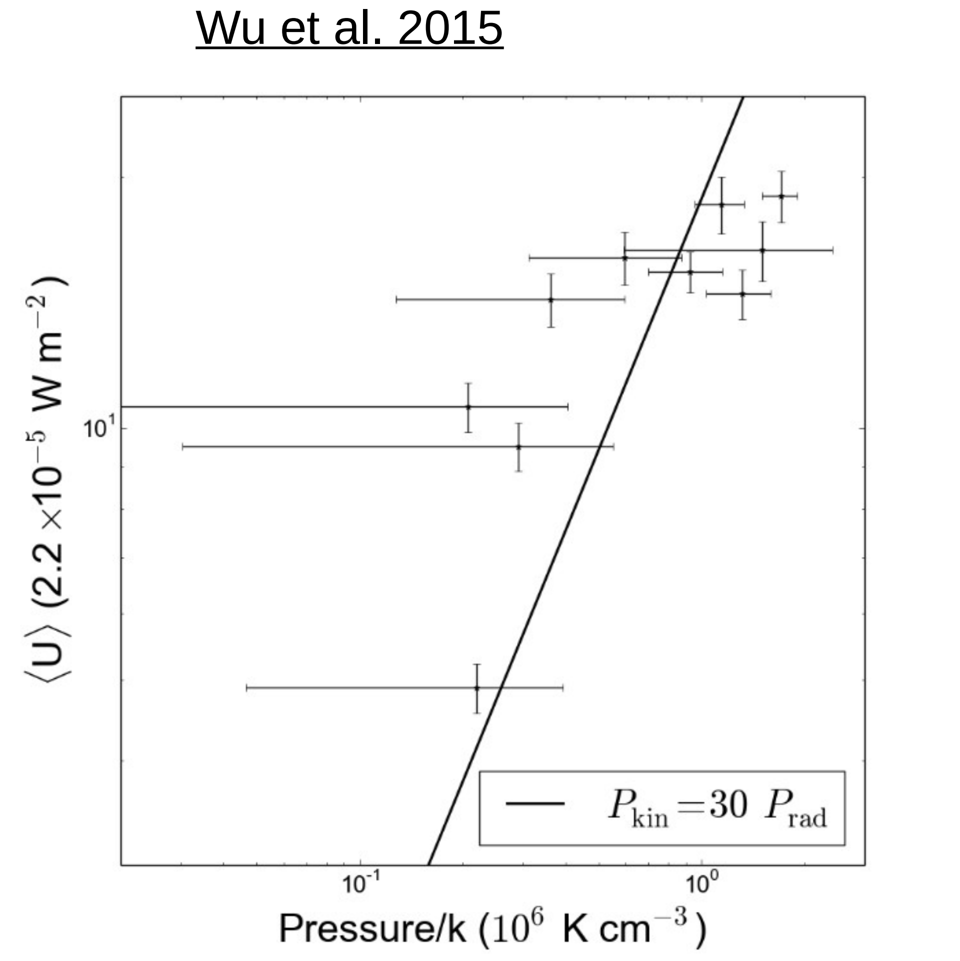
Wu et al. 2015

Dottori et al. 2010

X-ray / Hα / Radio

The pressure gradient coincides with a (possibly background) radio jet!

Molecular gas pressure



Radiation from interstellar radiation fields cannot sustain the observed pressure

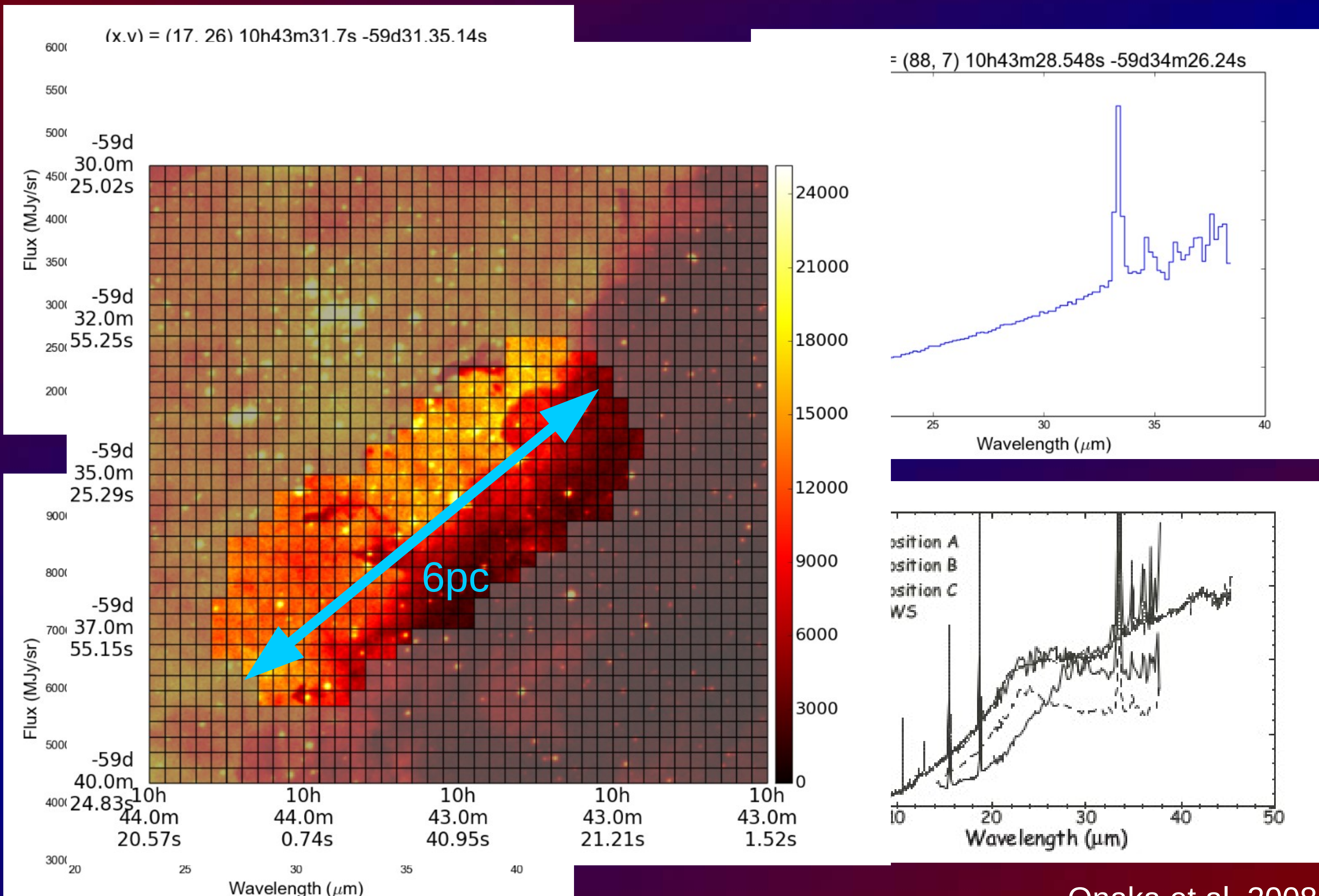
Spatially resolved pressure can be a good tool for studying stellar feedback

Project II

Tracing dust contents with warm CO in the Carina Nebula : Searching for the origin of the 22 micron feature

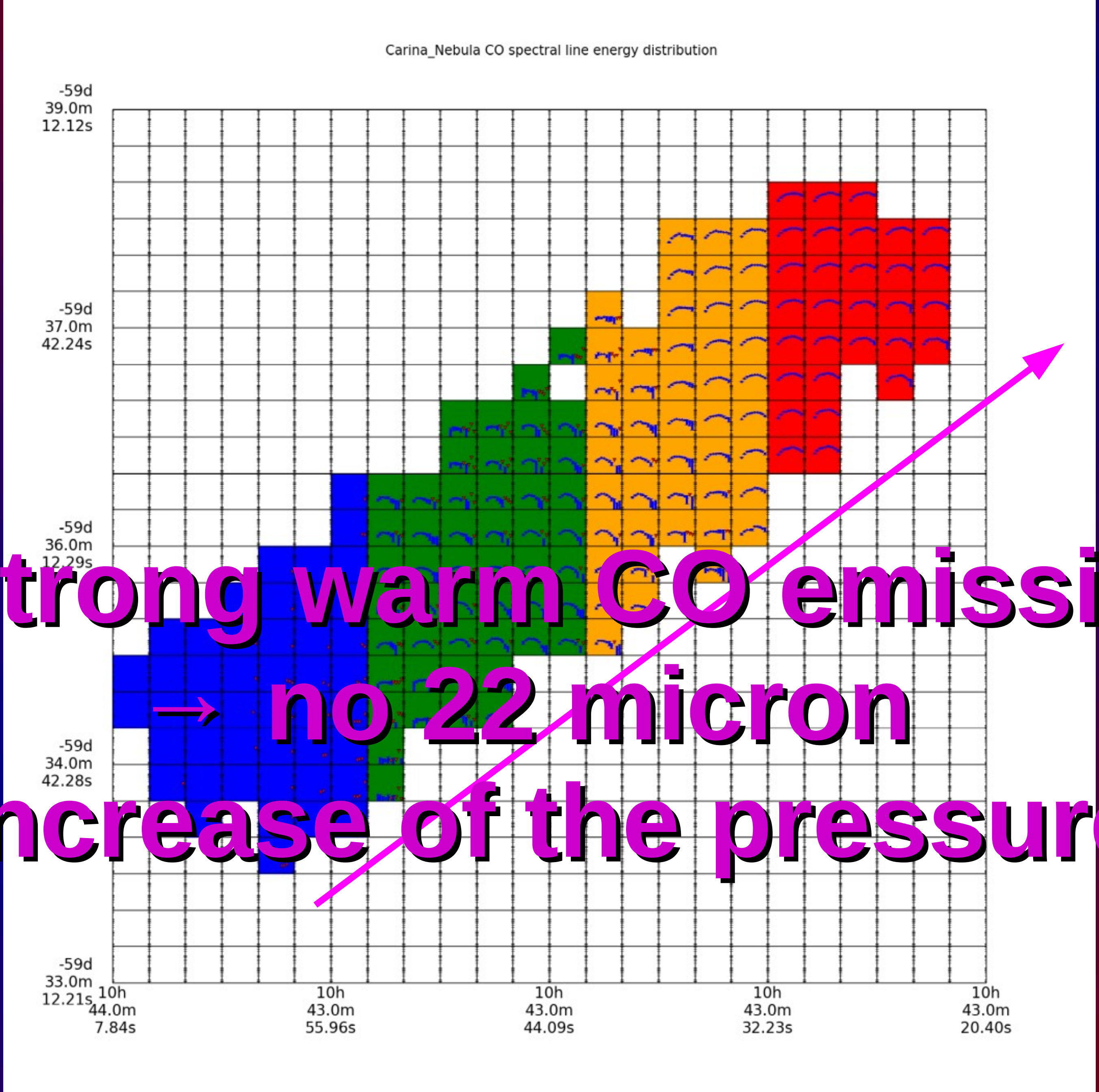
Collaborators:
Takashi Onaka, Tomihiko Nakamura, Fumihiko Usui, Tamami Mori, Frédéric Galliano, Itsuki Sakon, Vianney Lebouteiller, Diane Cormier, Suzanne Madden

The variation of 22 micron feature



Onaka et al. 2008

Excitation of CO



1. Strong warm CO emission

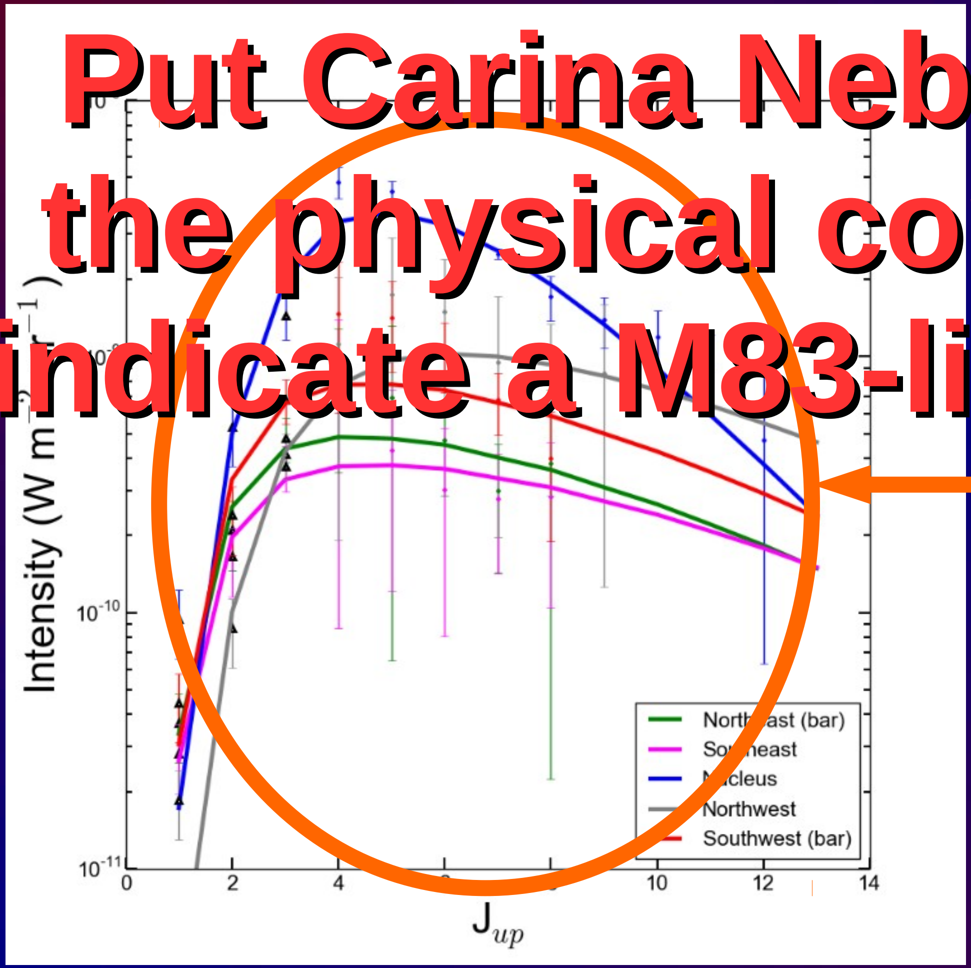
→ no 22 micron

2. Increase of the pressure?

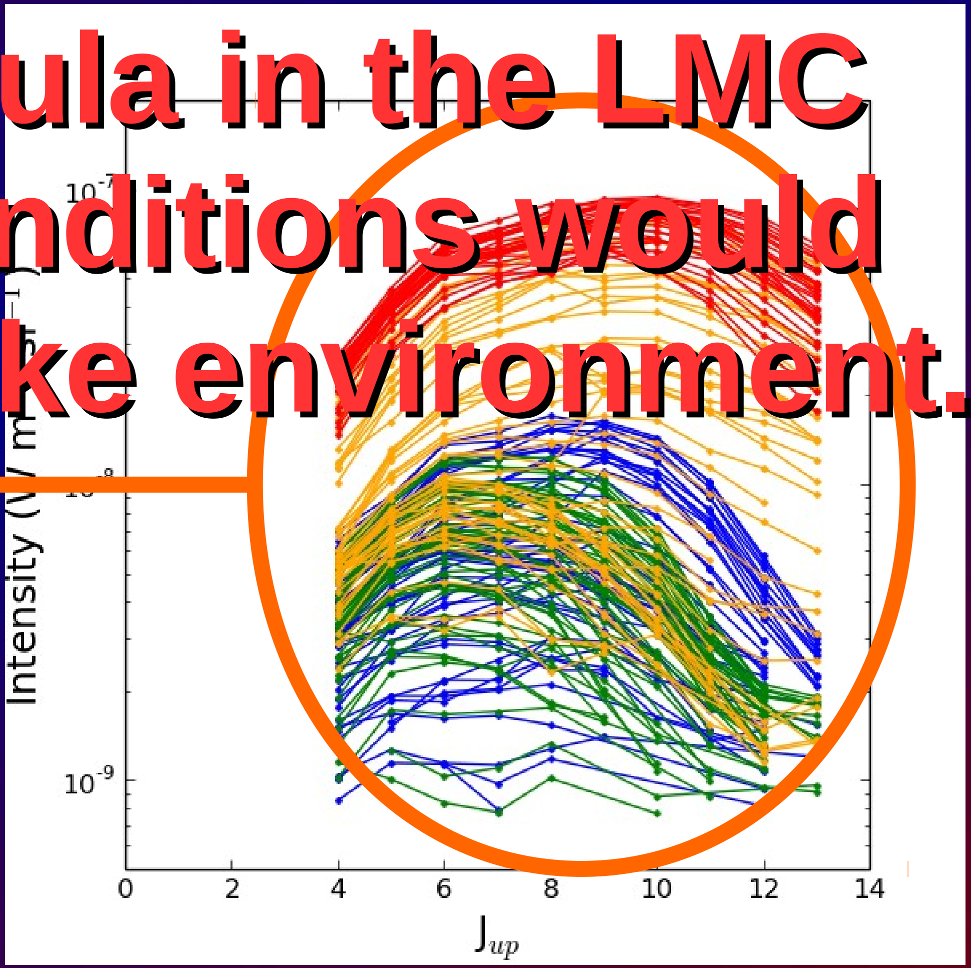
Wu et al. In prep.

SLEDs at 300 pc and 0.2 pc scales

M83



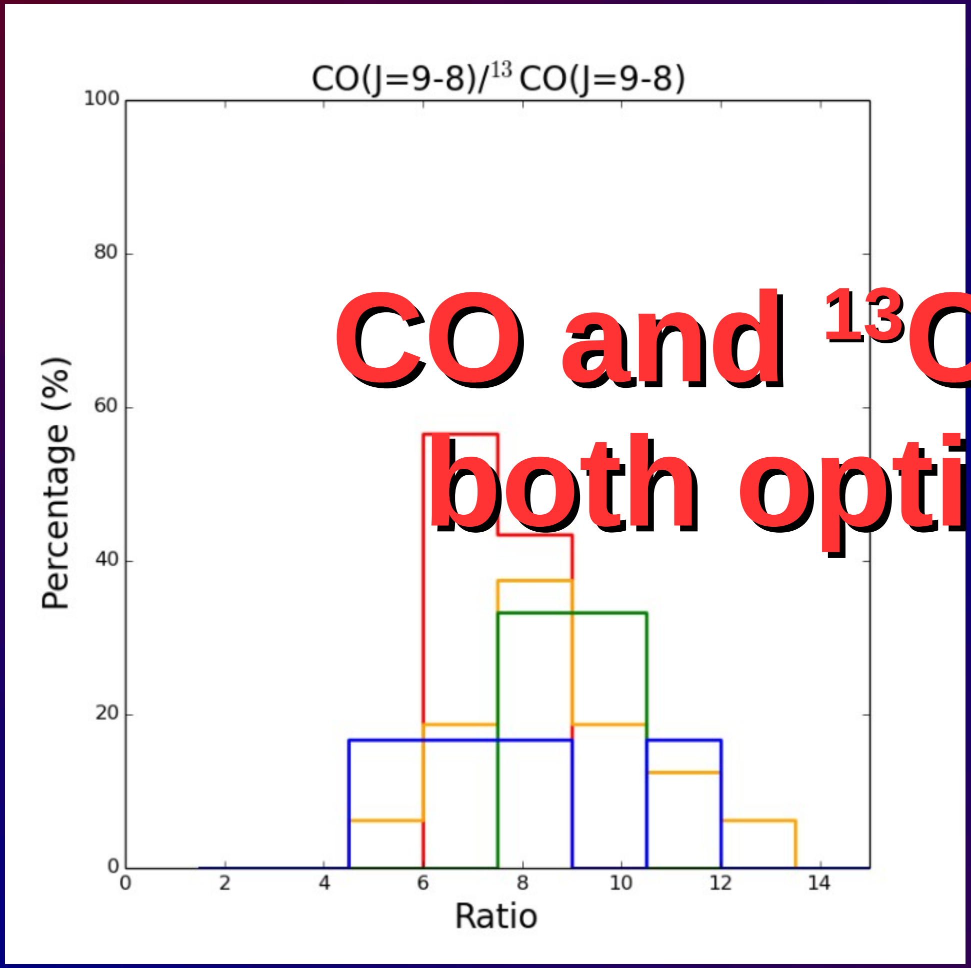
Carina Nebula

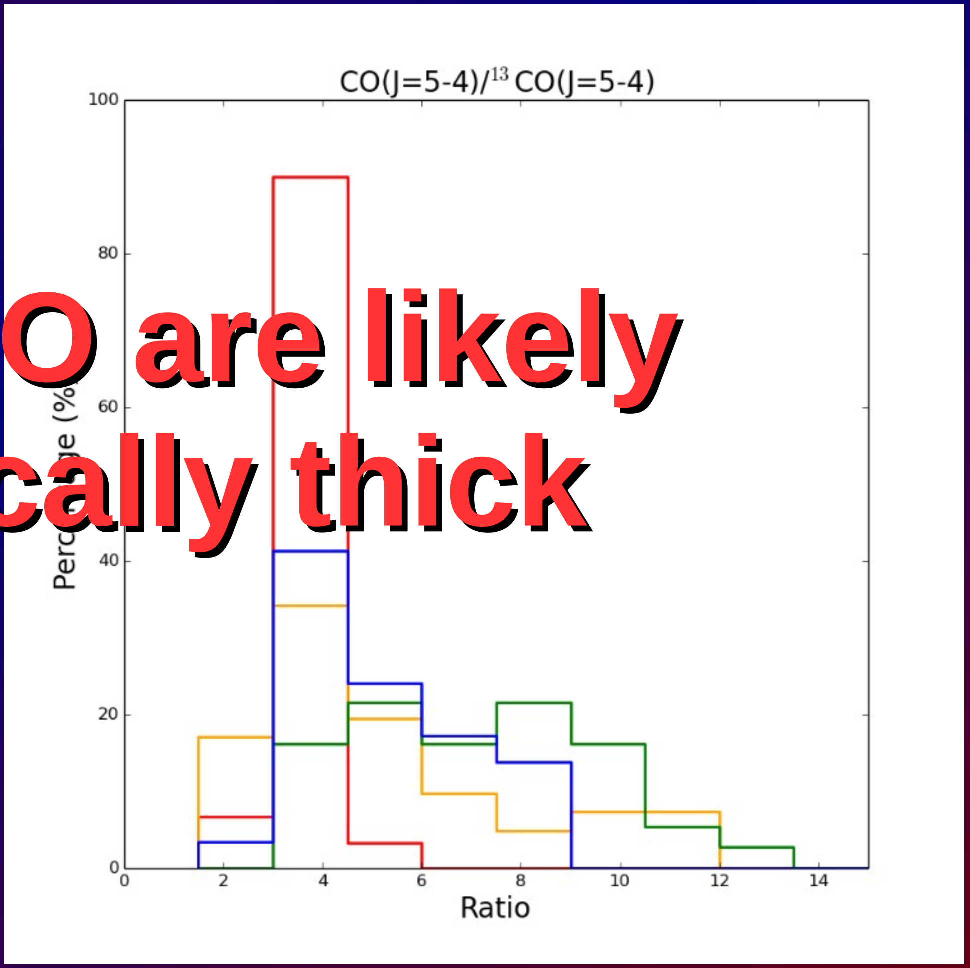


Put Carina Nebula in the LMC the physical conditions would indicate a M83-like environment.

Wu et al. 2015

Comparison of CO and ^{13}CO





CO and ^{13}CO are likely both optically thick

Wu et al. In prep.

Concluding Remarks

- It's only the beginning for our understanding of molecular gas.
- Project I - Physical parameters derived from CO SLED in the M83.
  (Wu et al. 2015 A&A 575 88)
  - Consistent with results derived independently from other wavelengths.
  - Physical scales have an impact on the [NII] as a SF tracer
  - Intriguing star-forming activities are happening in M83 nucleus, e.g. young star clusters (< 3 Myr), micro-quasar(?)
  - Pressure map can be a tool for studying stellar feedback.
- Project II - CO excitation in the Carina Nebula (c.f. Onaka 2008)
  - CO-bright regions show no significant 22 micron feature
  - Both CO and ^{13}CO appear optically thick
  - [Future prospective] What can we learn with the PDR modeling?