Investigating the ISM of local Seyfert galaxies by modelling their CO SLED

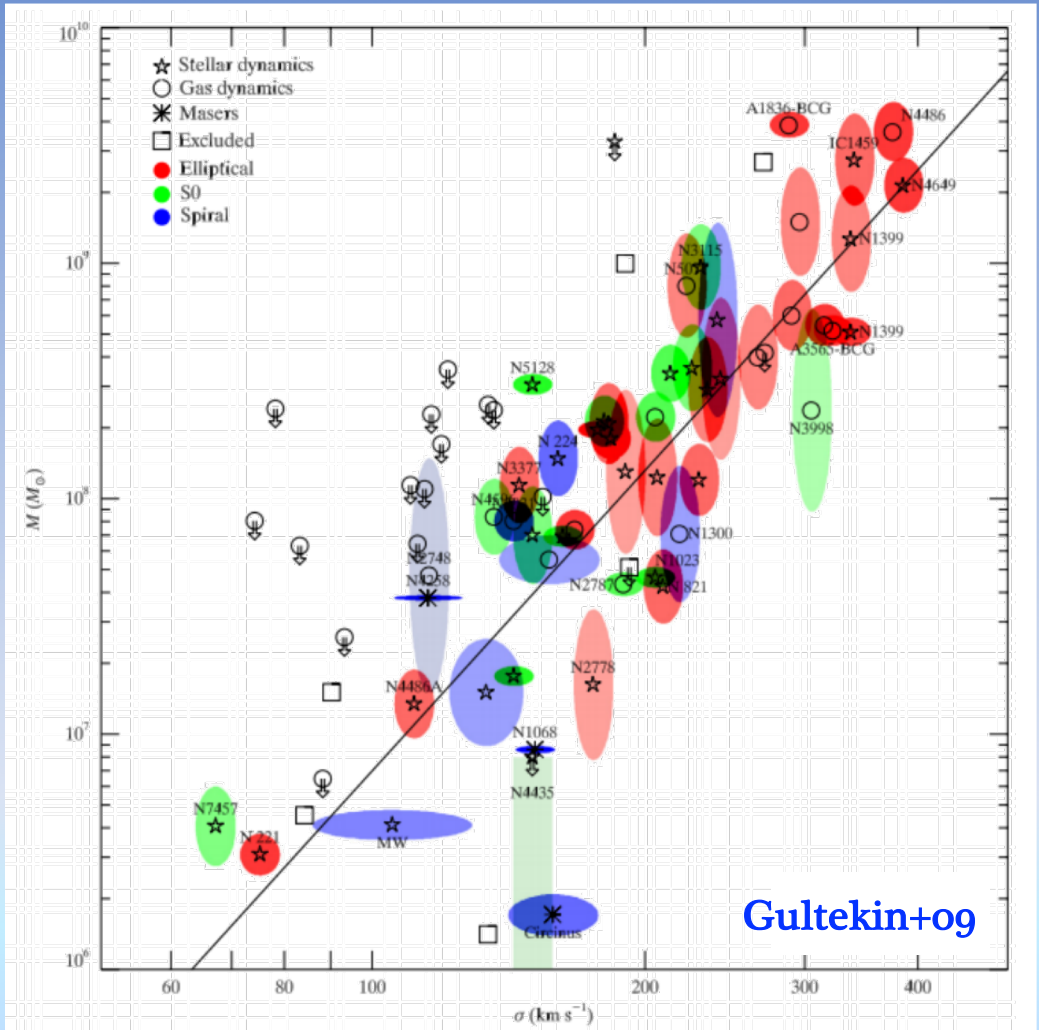
Matilde Mingozzi
University of Bologna - Arcetri Observatory

In collaboration with:
L. Vallini, F. Pozzi, C. Vignali, A. Mignano, C. Gruppioni,
M. Talia, A. Cimatti, G. Cresci, M. Massardi

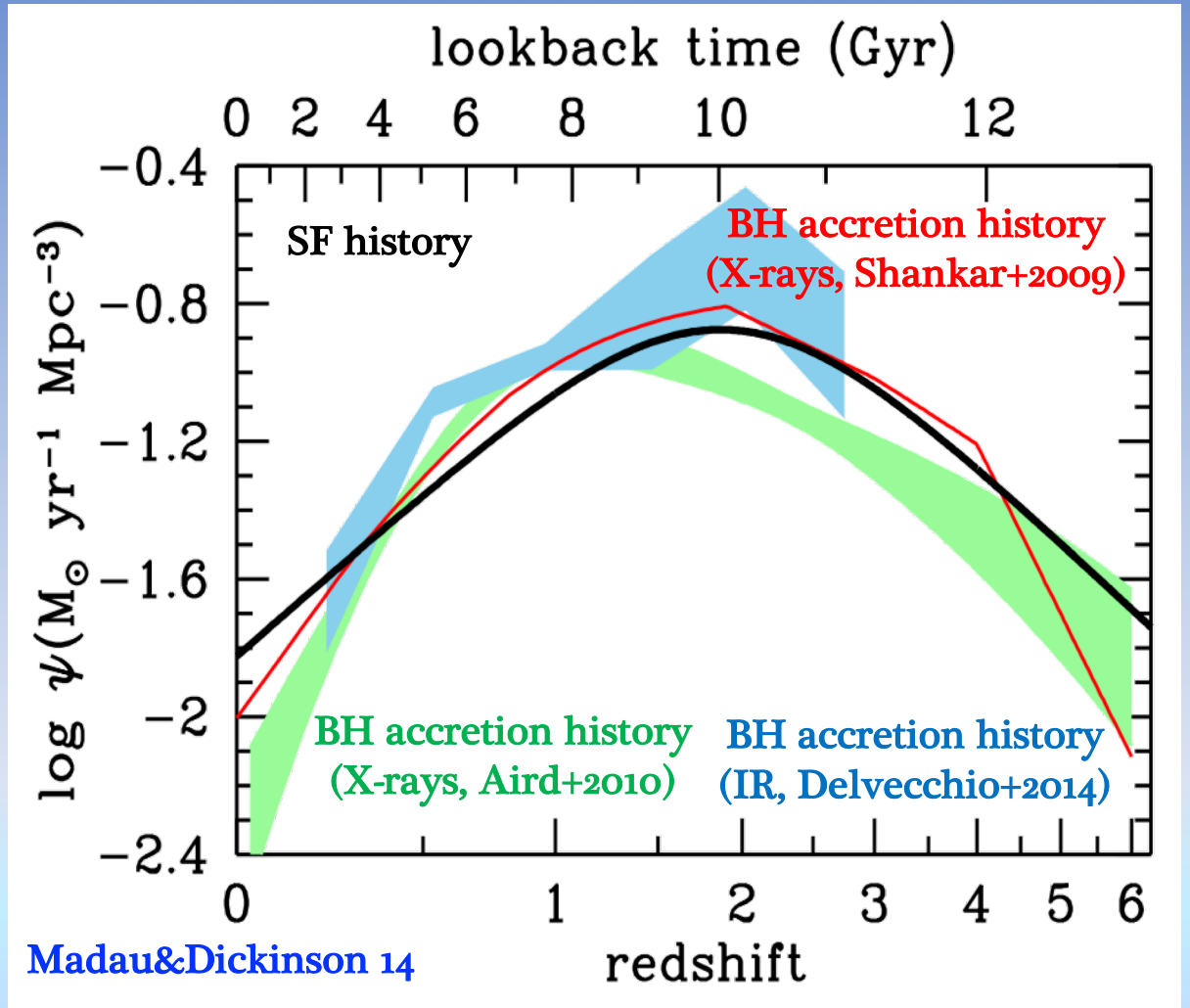
ALMA workshop 26/02/2019

AGN-galaxy co-evolution

M_{BH}-σ relation



BH accretion density and SFH of the Universe



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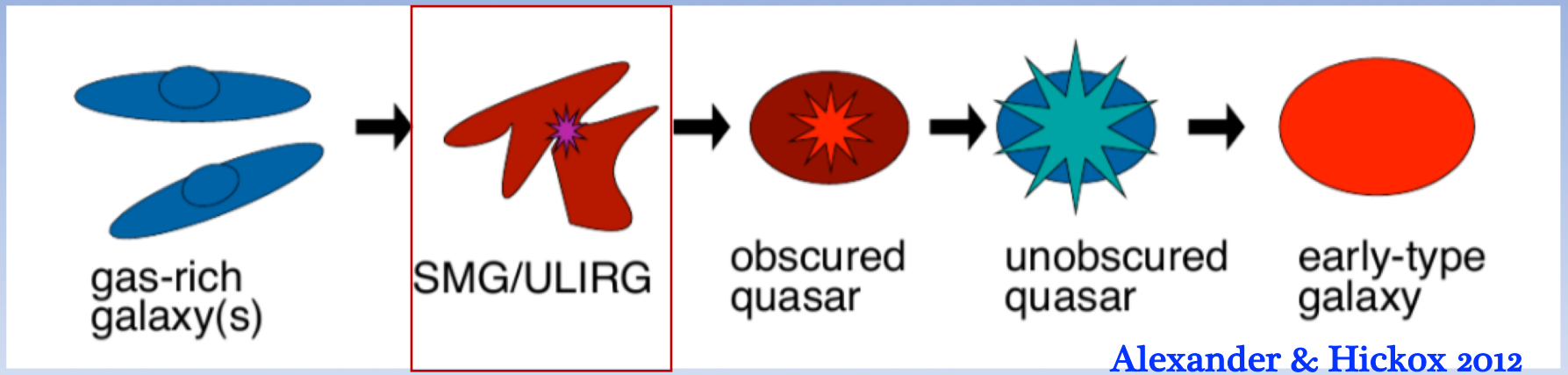
AGN-galaxy co-evolution

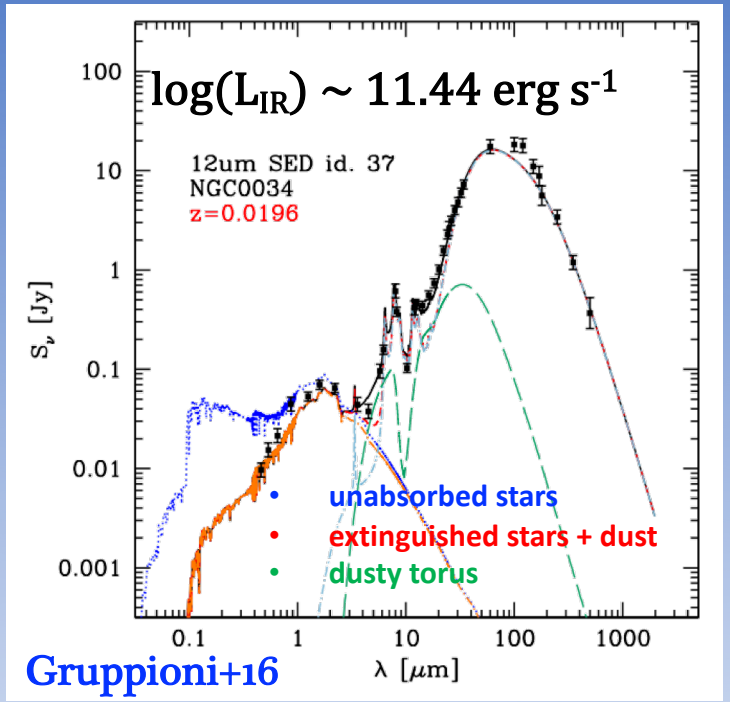
Key role of molecular gas to trigger **SF and AGN activity**



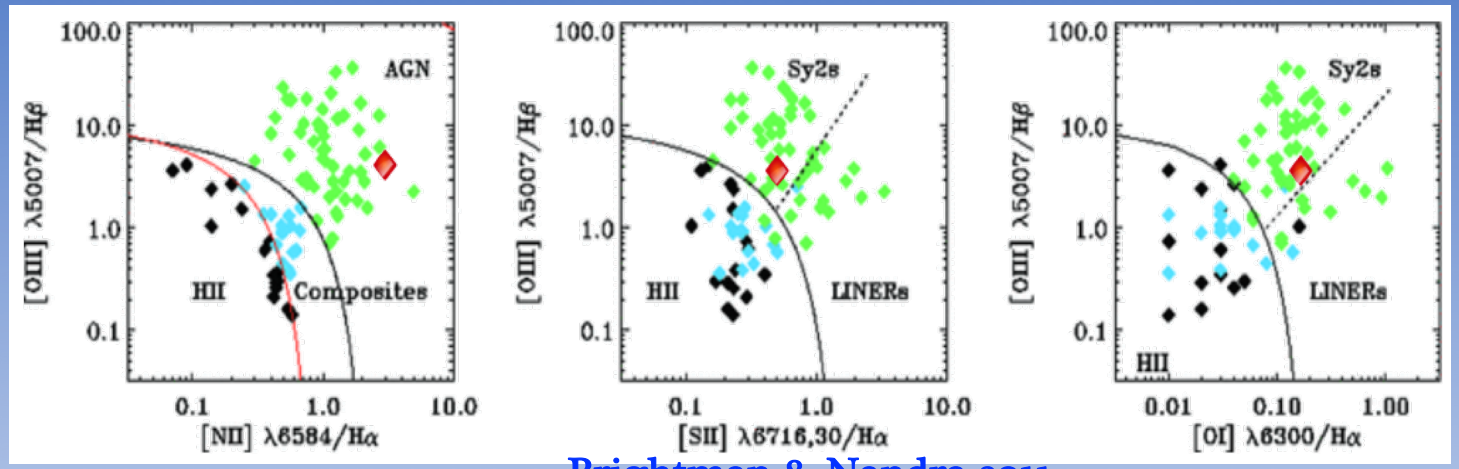
Alexander & Hickox 2012

luminous IR-active phase

The Seyfert galaxy NGC 34: an ambiguous object



Gruppioni+16

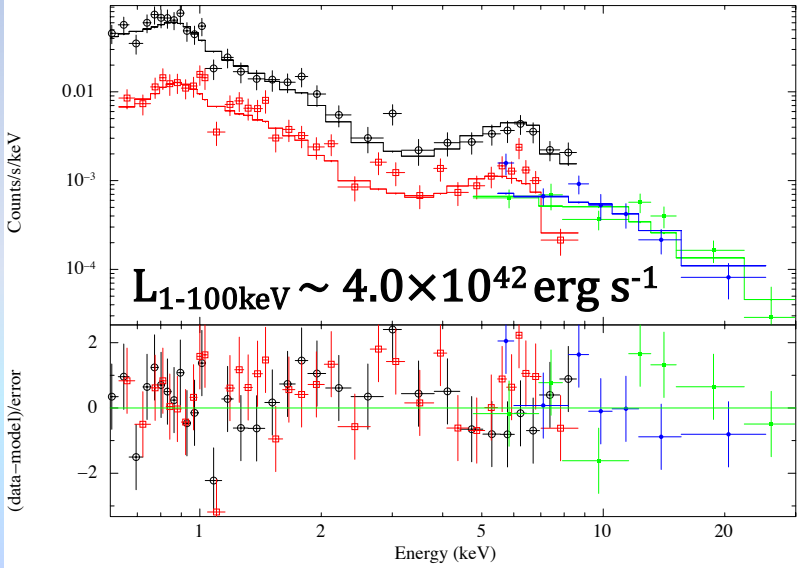


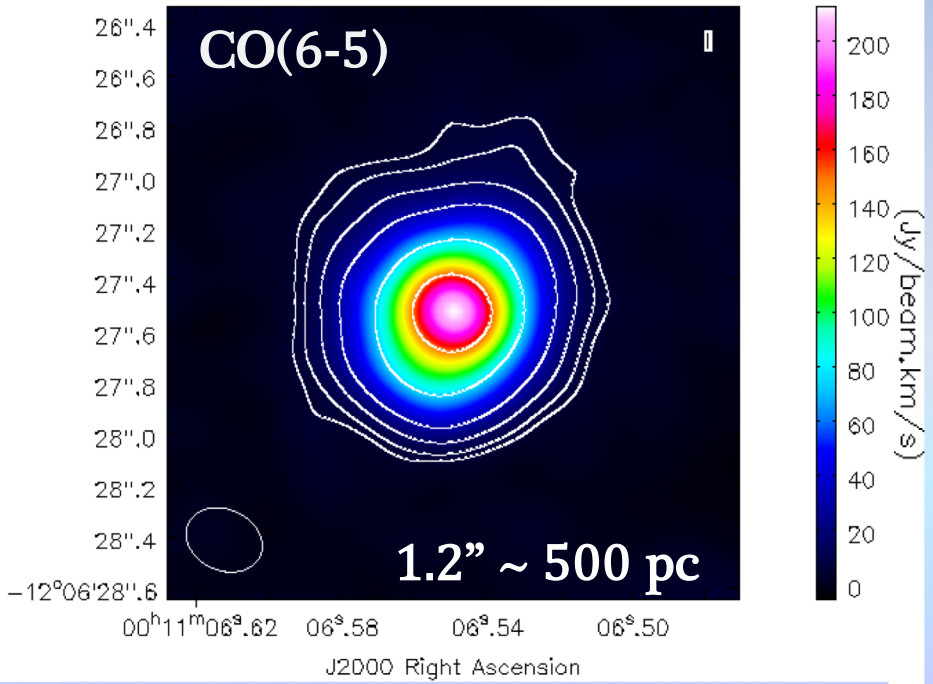
Brightman & Nandra 2011

The importance of ALMA

To spatially constrain the region where the AGN can actually dominate

XMM-Newton & NuSTAR





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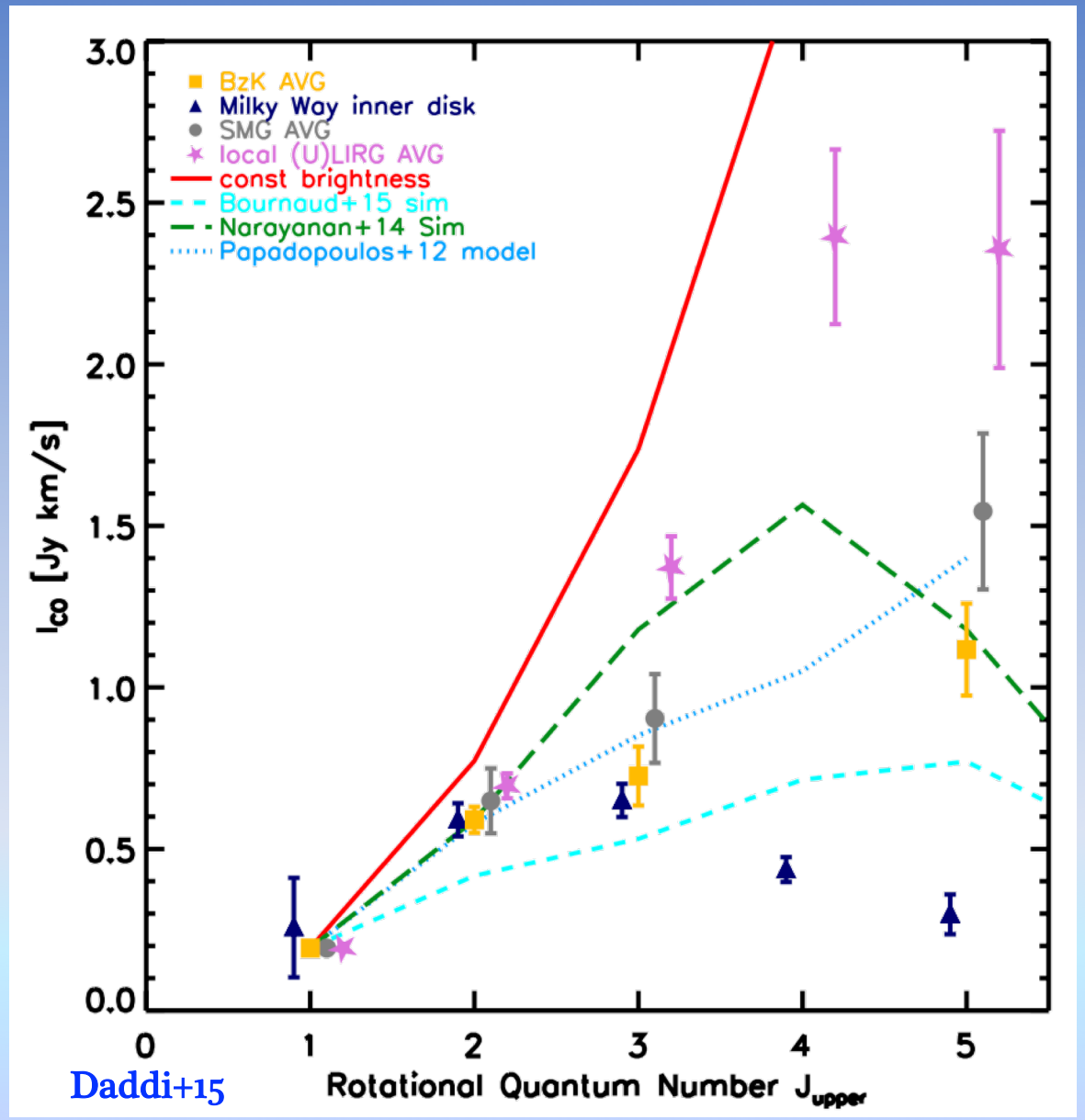
The CO spectral line energy distribution

Low-J

Sensitive to total gas reservoir

e.g.: CO(1-0)
n_{crit} ~10^3 cm^{-3}, T ~ 5.5 K

Source of excitation: FUV due to stars



Daddi+15

High-J

Incresingly luminous in the warm and dense gas

n_{crit} ~0.01-1.1 x 10^6 cm^{-3},
T ~ 17-7000 K

Source of excitation: FUV, X-ray, shocks

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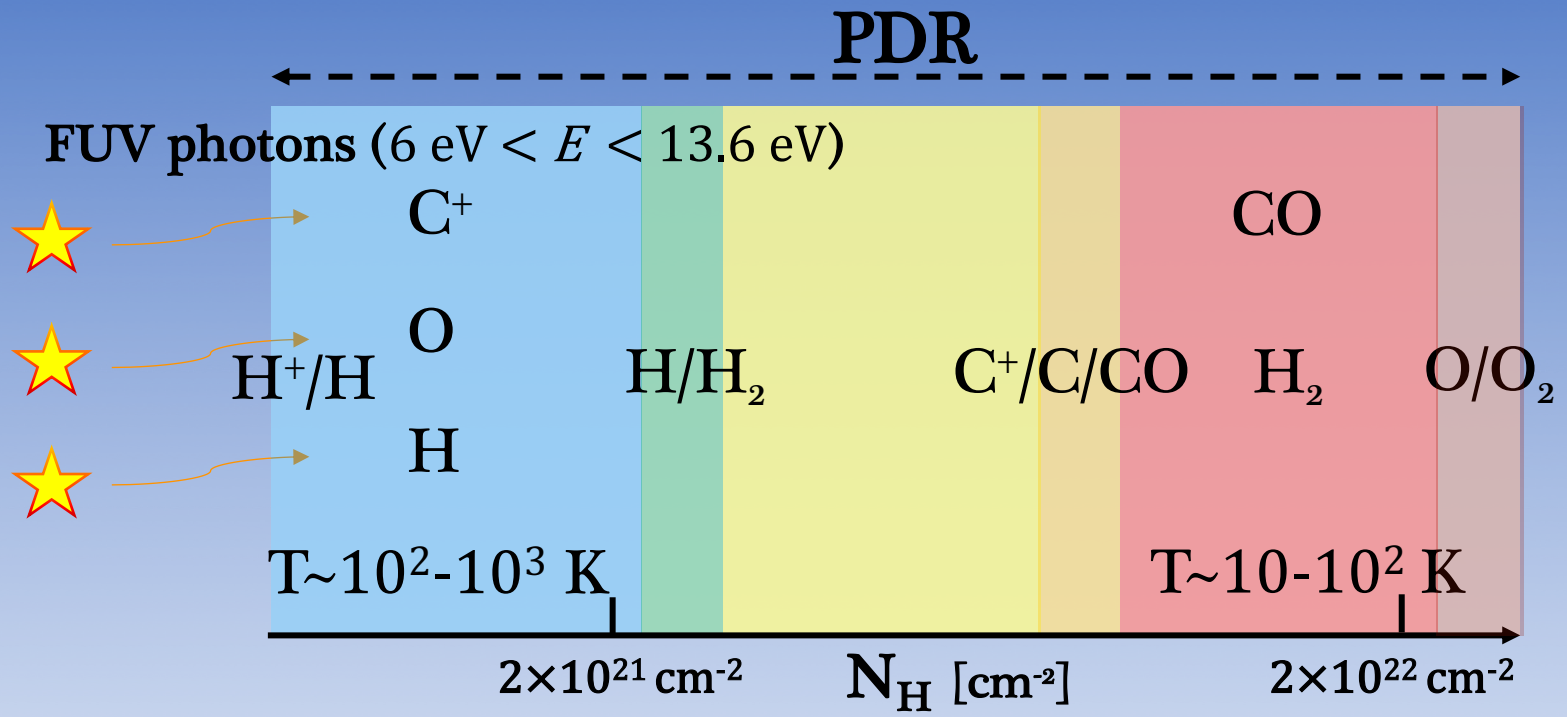
Photodissociation regions (PDRs) versus X-ray dominated regions (XDRs)



see Hollenbach&Tielens 1999

CO emission saturates at a typical column densities of $\log(N_{\rm H}/{\rm cm}^{-2}) \approx 22$

CO SLED drops and flattens at high-J

(van Dishoeck & Black 1988)

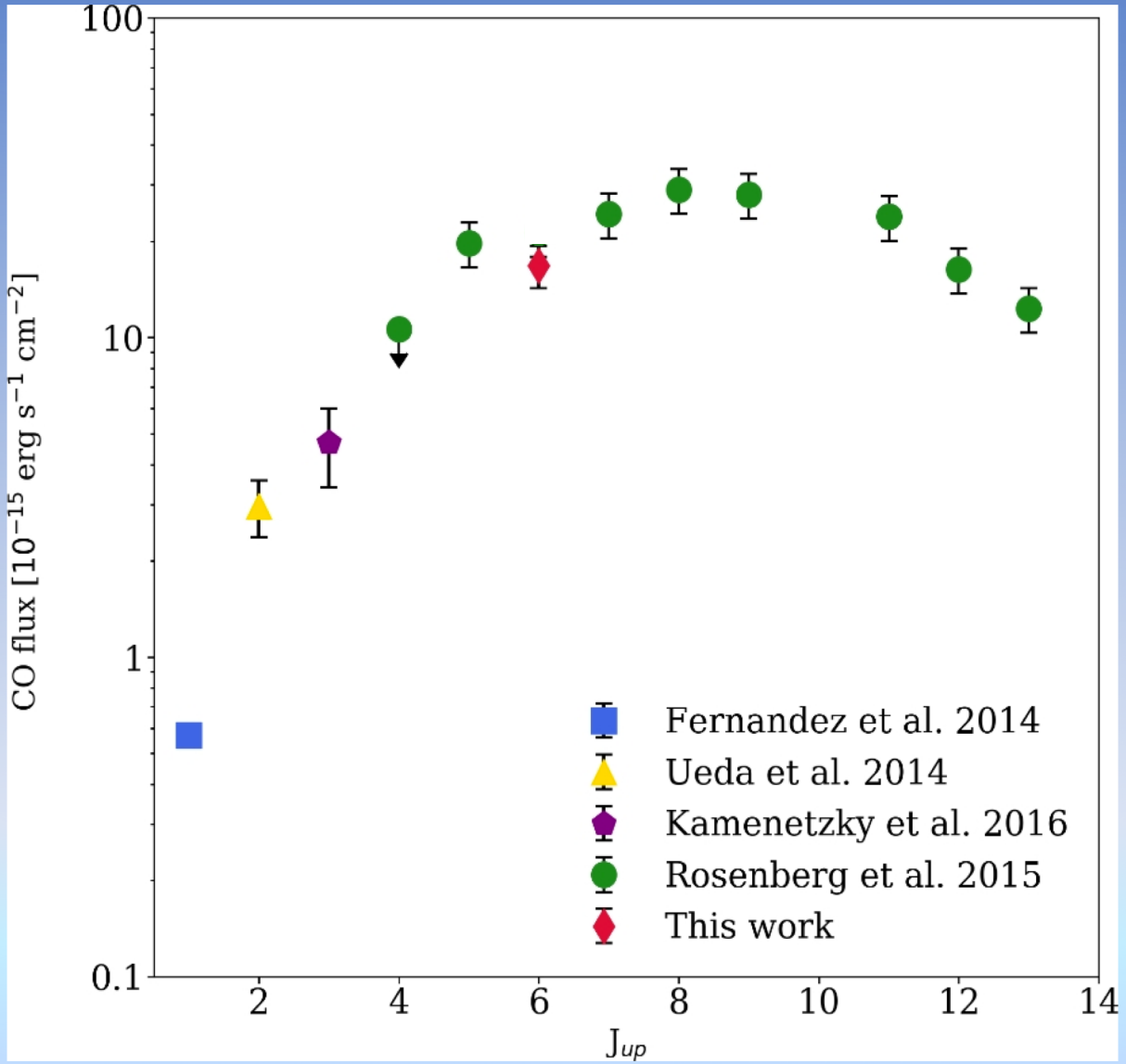
On the contrary in X-ray dominated regions (XDRs, 1 keV < E < 100 keV) X-rays penetrate deeper in the cloud, keeping the gas warmer: **CO SLED peaked at higher-J transitions**

(Maloney 1996)

Shocks can heat the gas above $T \approx 100$ K: **CO SLED peaked at higher-J transitions** simililarly to XDRs

(Hollenbach et al. 1989)

CO excitation in the Seyfert galaxy NGC 34: stars, shock or AGN driven?



CO SLED modelling

- Cloudy (Ferland 2013) PDR and XDR models
- Shock models (Flower & Pineau des Forêts 2013)

Contraints of the modelling

$SFR \approx 24\ \mathrm{M_\odot yr^{-1}}$

$L_X^{AGN} \approx 10^{42}\ \mathrm{erg\ s^{-1}}$

CO(6-5) diameter ≈ 500 pc

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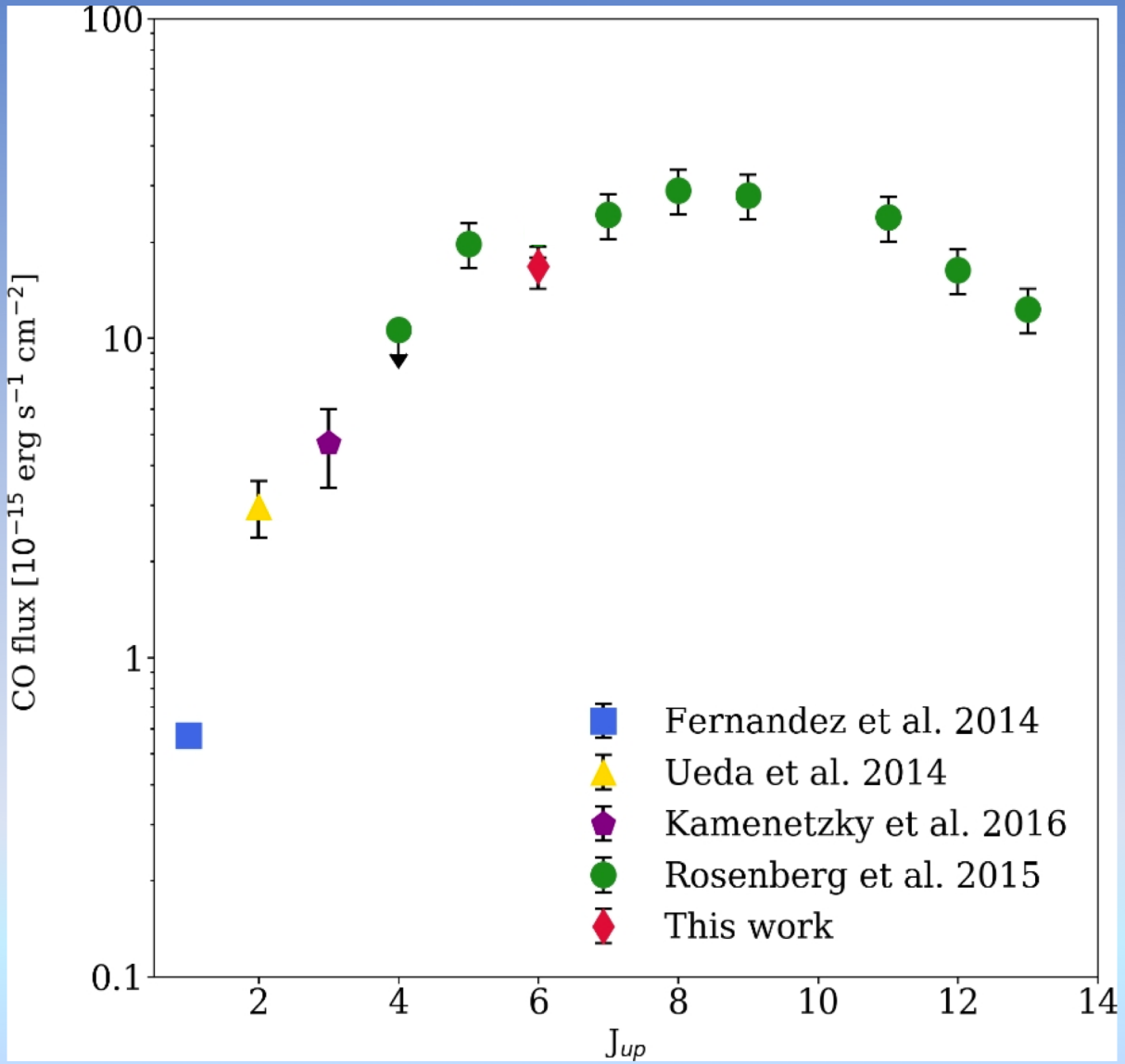
CO excitation in the Seyfert galaxy NGC 34: stars, shock or AGN driven?



⇝ **PDR1 + PDR2 :** *discarded*

$\tilde{\chi} = 3.3$

⇝ **PDR + shock :** *discarded*

Emitting shock area ≫ CO(6-5) area

~ (785 pc)^2 ≫ ~ (250 pc)^2

$L_{CO}/L_{IR} \sim 2.7 \times 10^{-5}$ ($L_{CO}/L_{IR} > 10^{-4}$ for shocks Meijerink+2013)

⇝ **PDR + XDR :** *fiducial model*

$\tilde{\chi} = 1.6$ + Supported by the X-ray analysis and the MIR SED fitting

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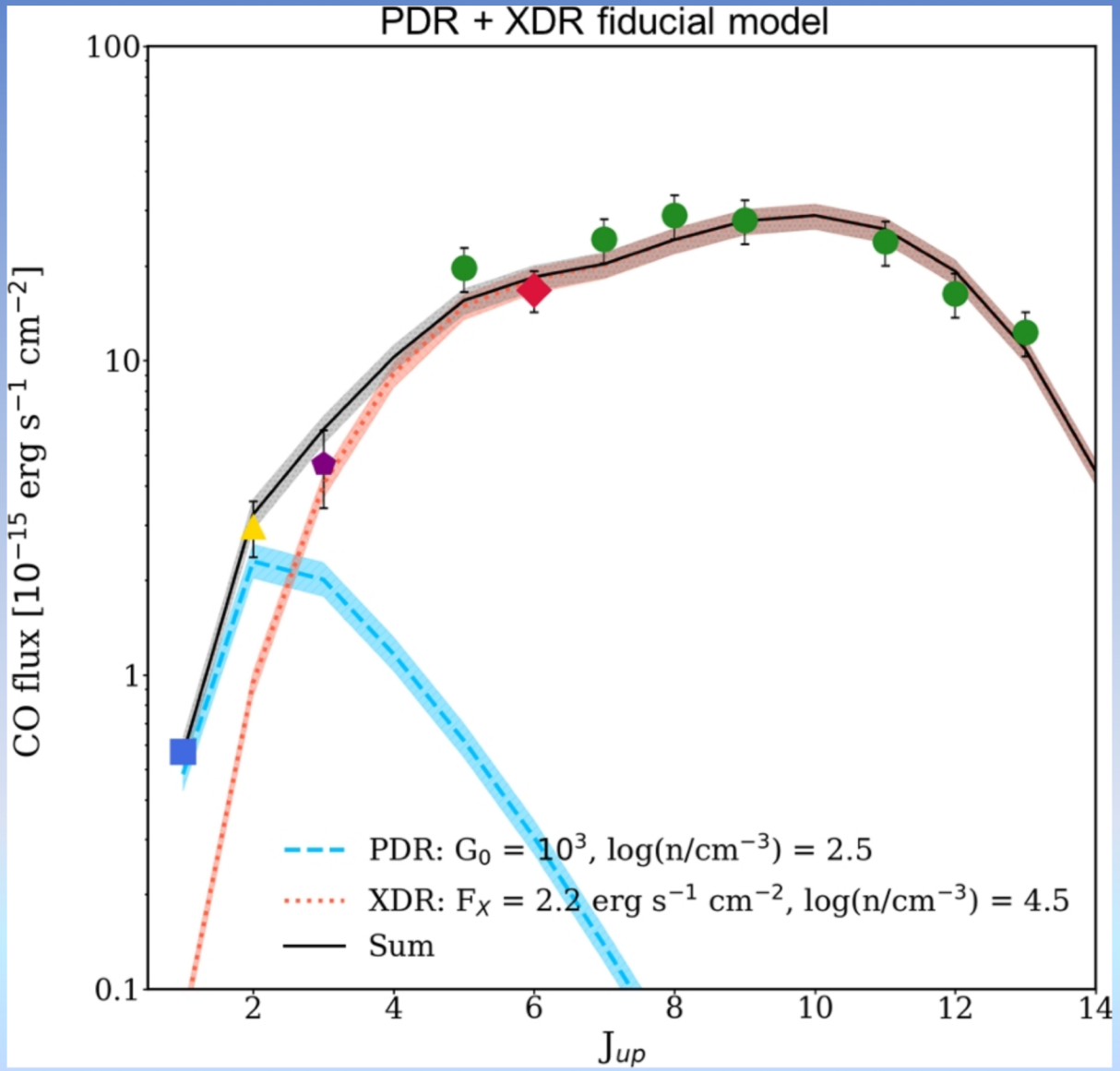
CO excitation in the Seyfert galaxy NGC 34: stars, shock or AGN driven?



⇝ **PDR + XDR :** ***fiducial model***

$\tilde{\chi} = 1.6$ + Supported by the X-ray analysis and the MIR SED fitting

Low density PDR

- log(n) = 2.5 cm^{-3}
- log(N_H) =21.8* cm^{-2}
- $G_0 = 10^3$
- N_clouds = 7 x 10^5

High density XDR

- log(n) = 4.5 cm^{-3}
- log(N_H) = 23.0* cm^{-2}
- F_X = 2.2 erg s^{-1} cm^{-2}
- N_clouds = 5 x 10^6

$M_{PDR} \sim 3 \times 10^9\ M_\odot \gg M_{XDR} \sim 2 \times 10^8\ M_\odot$

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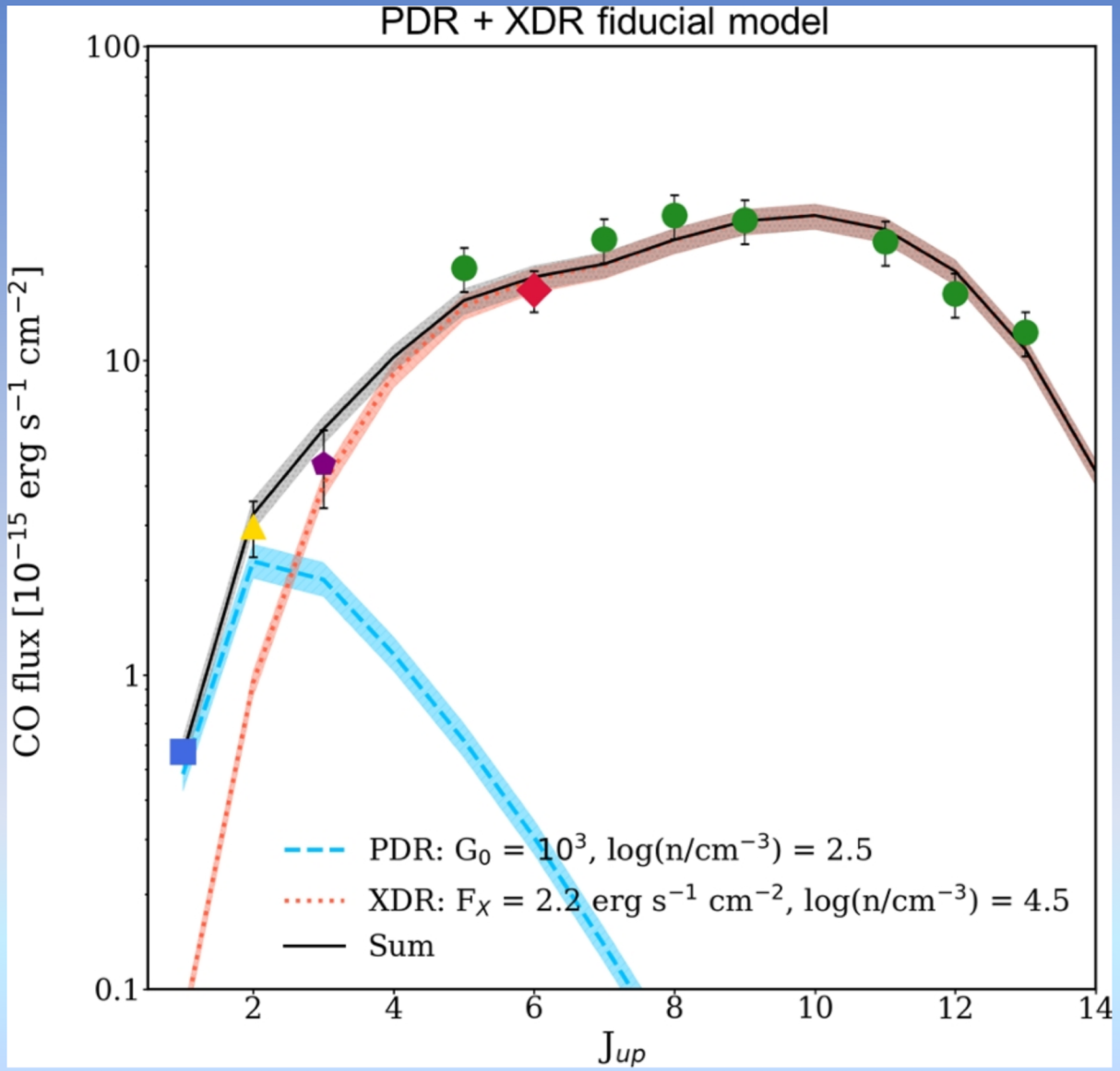
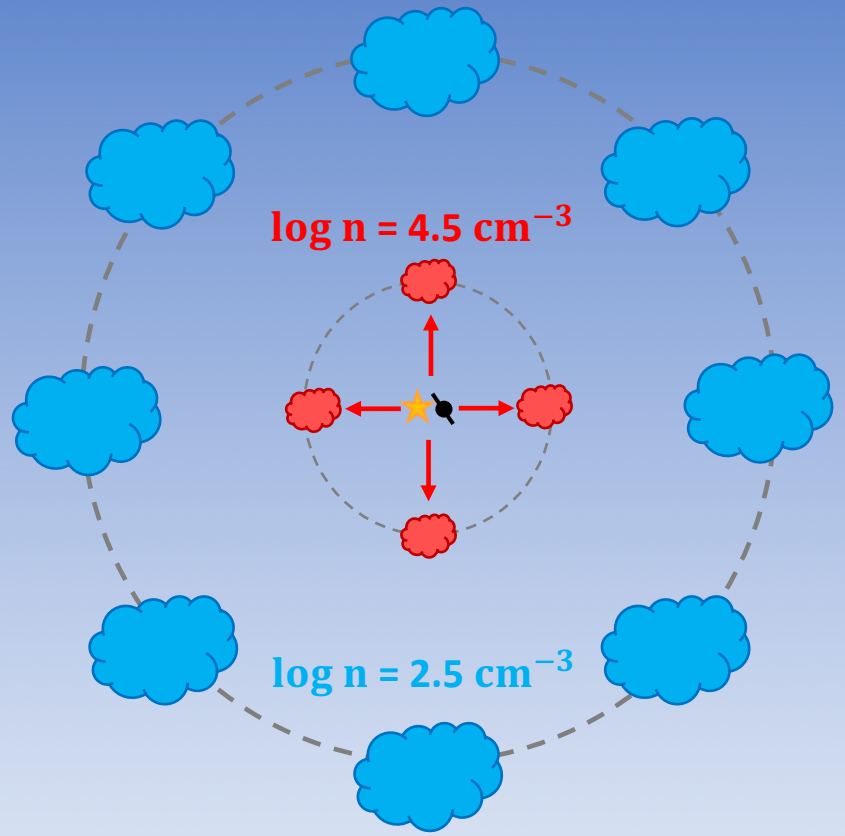
CO excitation in the Seyfert galaxy NGC 34: a simple model





$M_{PDR} \sim 3 \times 10^9\ M_\odot \gg M_{XDR} \sim 2 \times 10^8\ M_\odot$

From the CO(1-0) instead: $M_{gas} = (2.1 \pm 0.2) \times 10^9\ M_\odot$

Fernandez+2014

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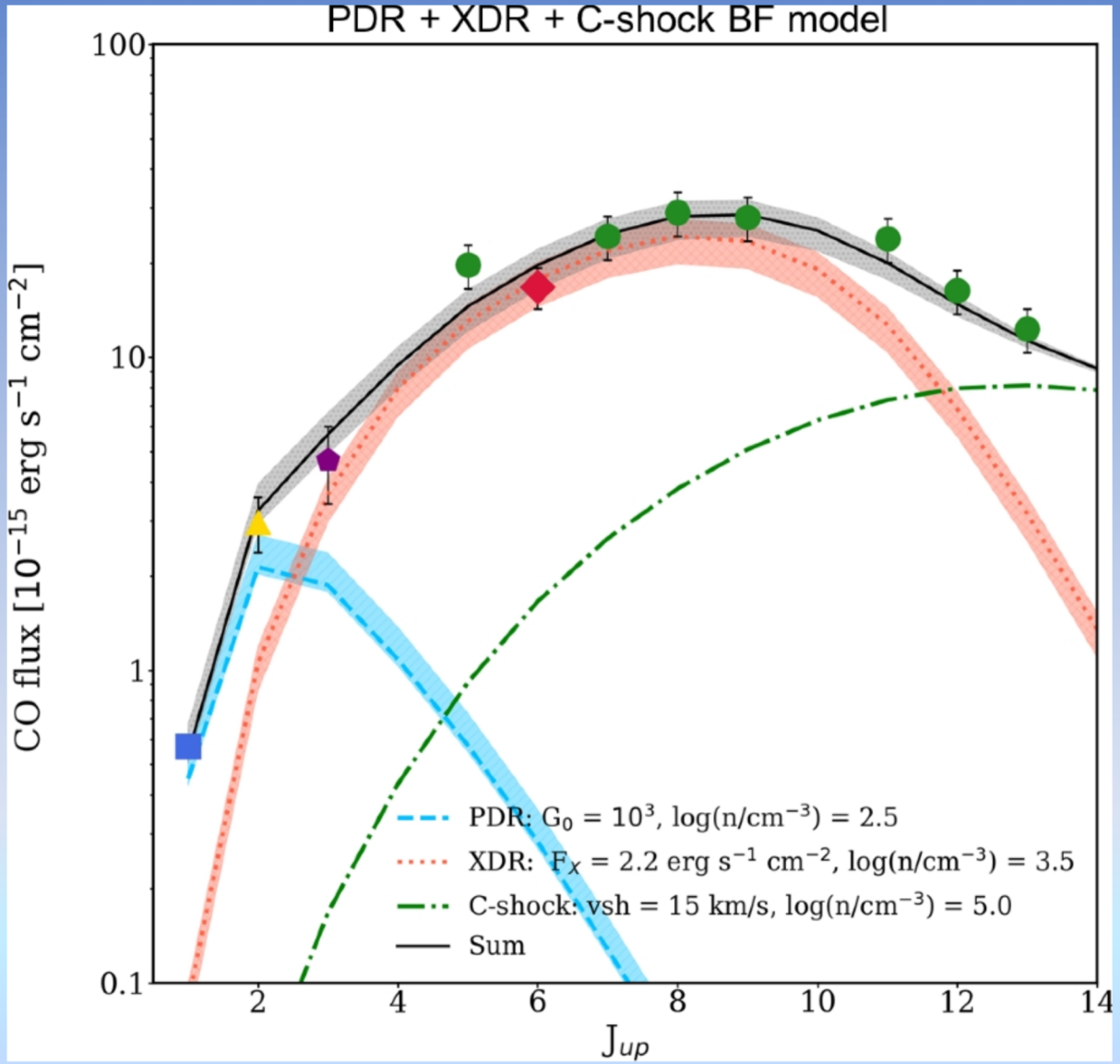
CO excitation in the Seyfert galaxy NGC 34: what about shocks?



PDR + XDR + SHOCK

fixing the shock area to the CO(6-5) emitting region
$A = (250\ pc)^2$

⇝ *Adding a third component not significant according to the F-test*

Shocks may not be completely absent but ***do not play a significant role*** in exciting the high-J CO transitions, more likely powered by the central AGN

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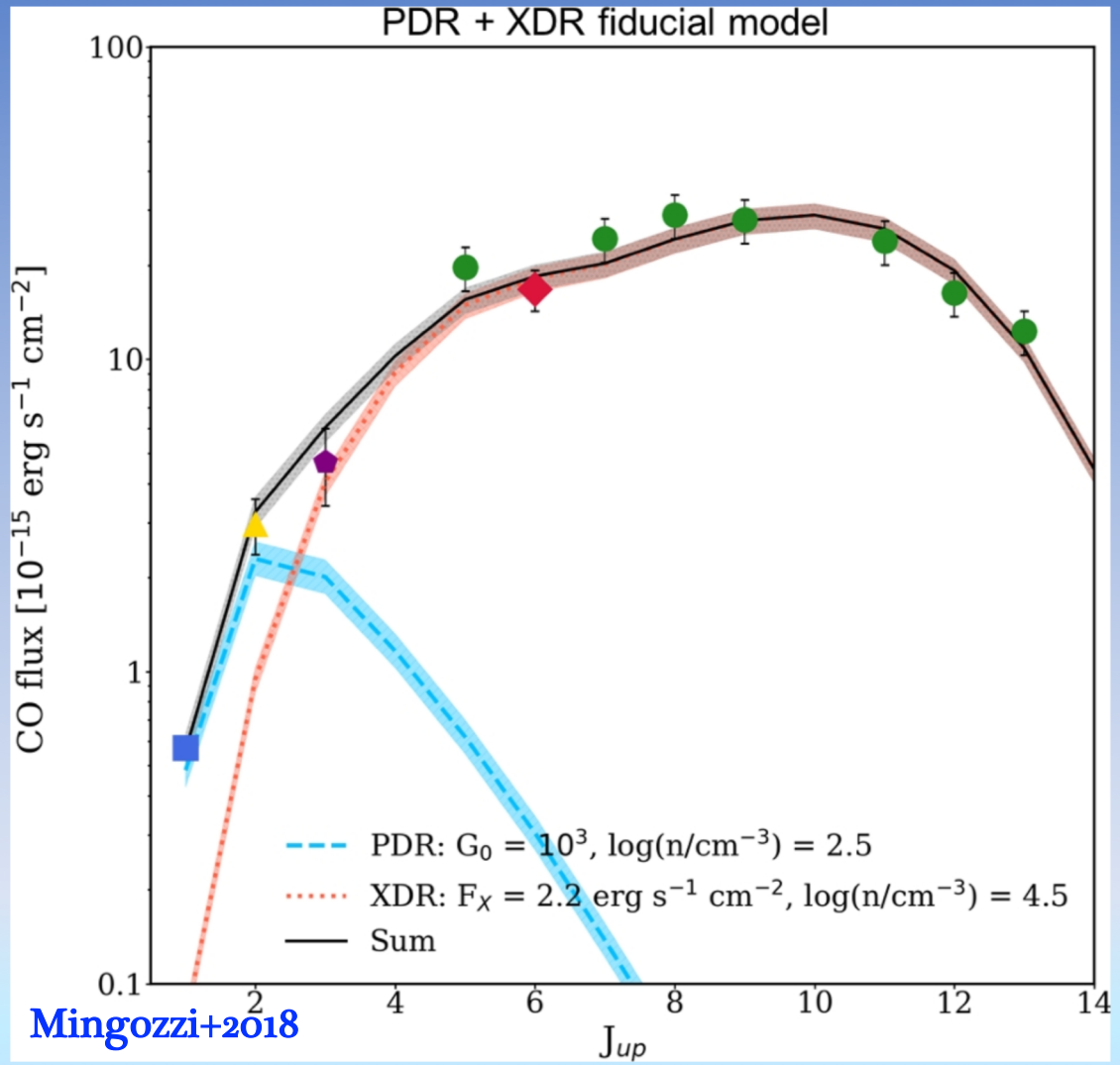
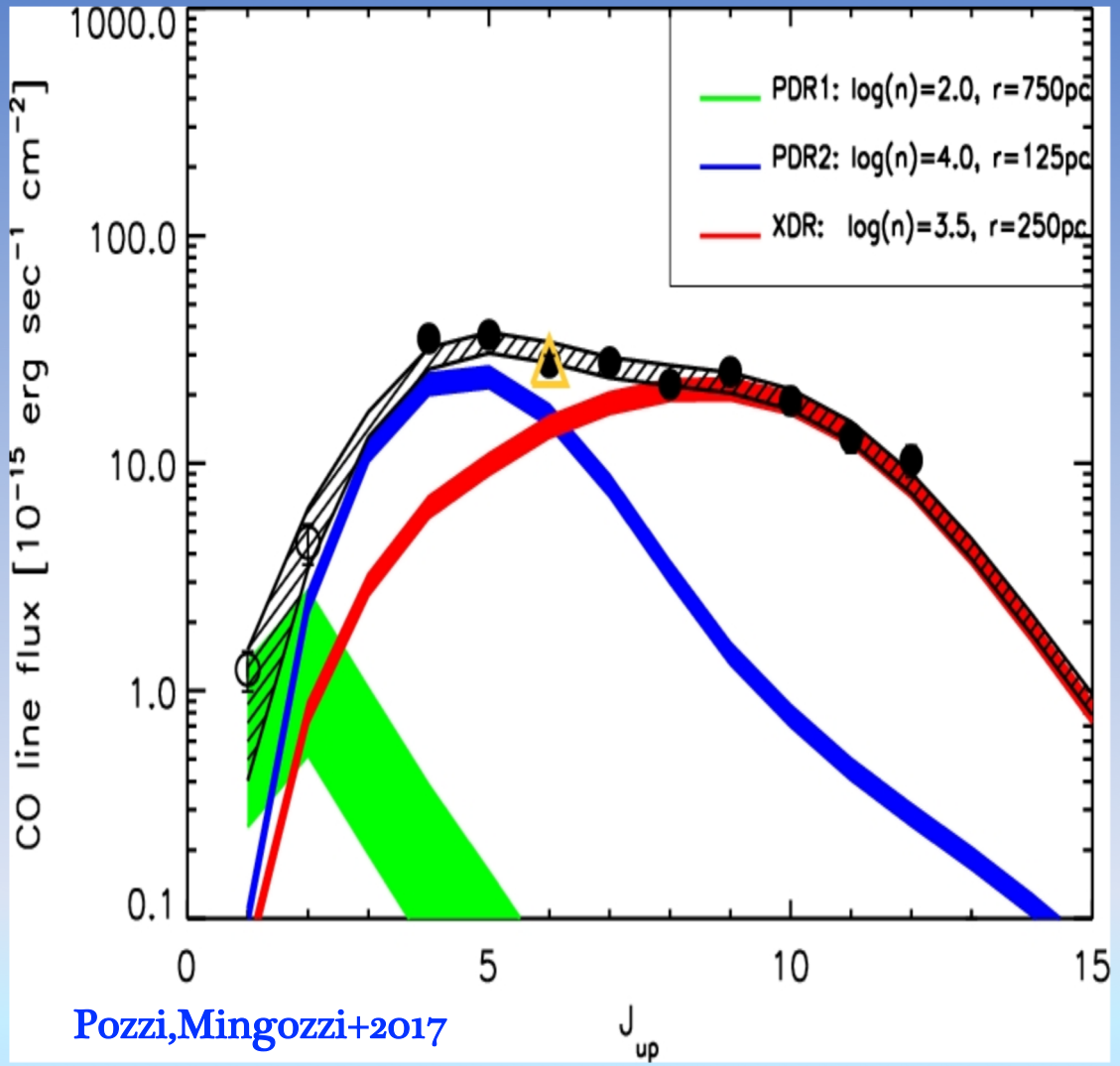
A pilot study: the two Seyfert/LIRG galaxies NGC 34 and NGC 7130



Mingozzi+2018



Pozzi,Mingozzi+2017

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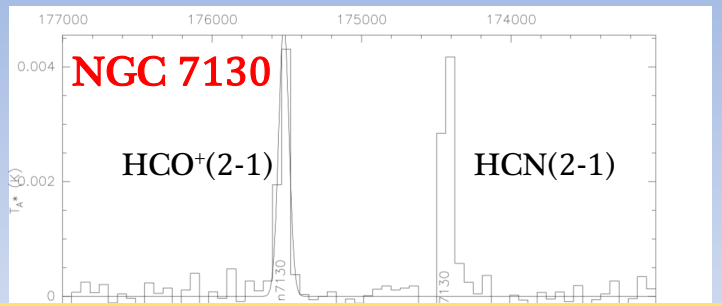
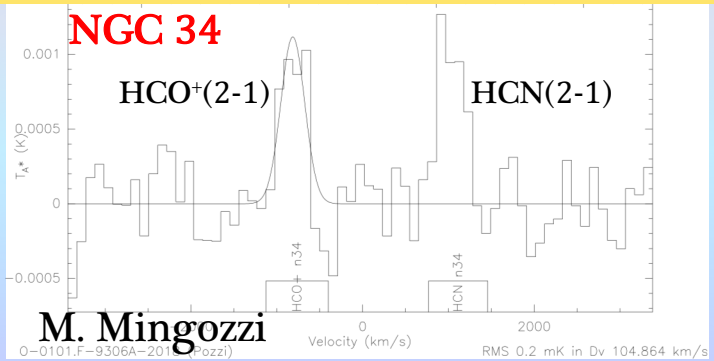
Conclusions and future perspectives

- ALMA fundamental to spatially constrain the region where the AGN can actually dominate
- CO SLED analysis: AGN contribution is significant in heating the molecular gas of NGC 34
- Shocks may not be completely absent but do not play a significant role in exciting the high-J CO (Mingozzi+18)
- Similar modelling with a PDR+XDR in the local Universe for the LIRG **NGC 7130** (Pozzi,Mingozzi+17)



To do: analysis of high critical densitiy molecules (APEX data)



PRELIMINARY

Vallini,Tielens 2019 in prep.