A NEW MODEL FOR MOLECULAR CLOUDS AND CO EXCITATION IN AGN-HOST GALAXIES

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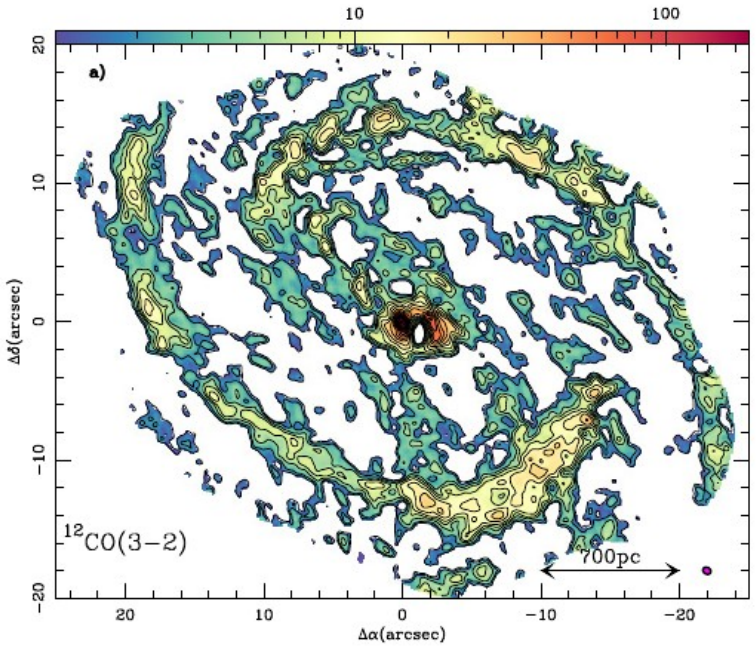
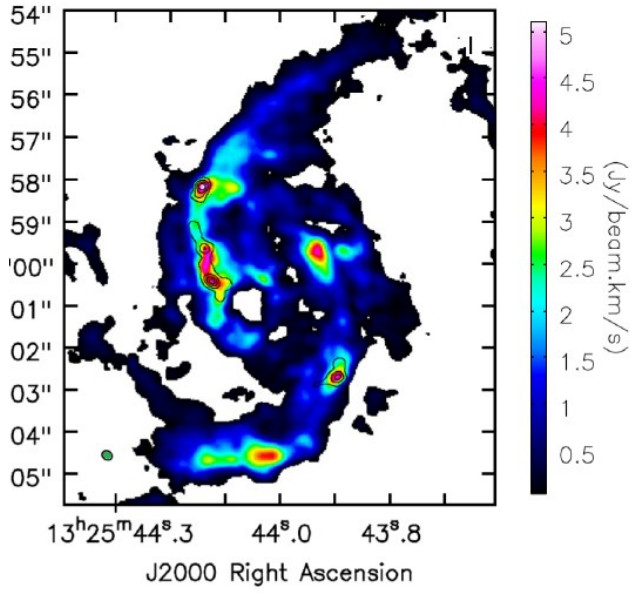
LOW-J CO LINES IMAGED BY ALMA IN LOCAL AGN

CO(3-2) in NGC 1068



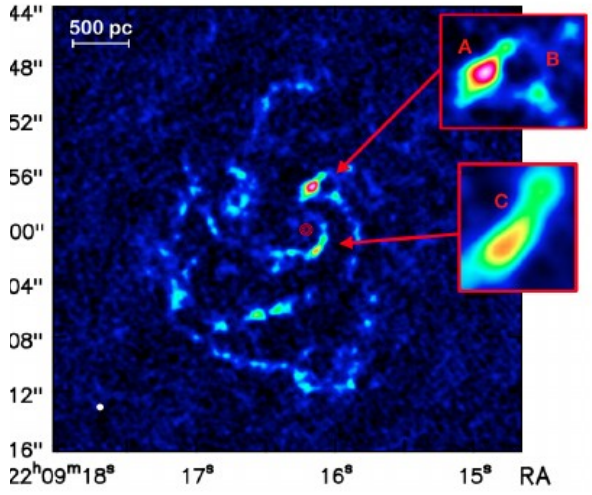
Garcia-Burillo+2014

CO(2-1) in NGC 5135



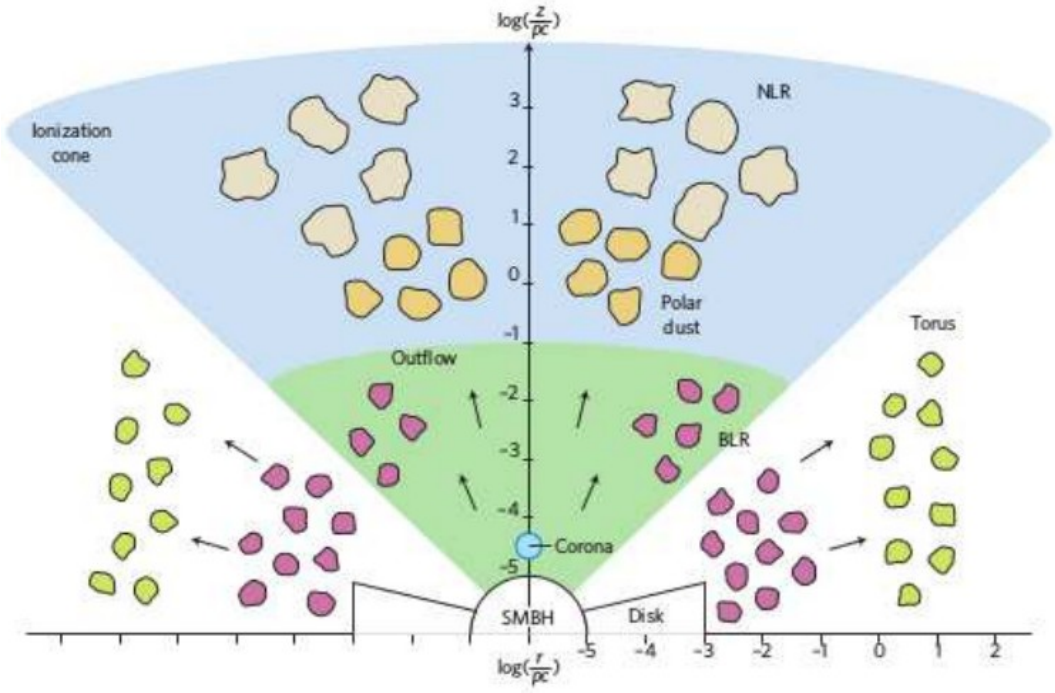
Sabatini+2018

CO(2-1) in NGC 7213



Salvestrini+2020

AGN STRUCTURE AND (SOME) OBSERVABLES



Ramos-Almeida & Ricci 2017

RADIATION

- AGN are powered by accretion on the supermassive black hole (**SMBH**)
- the **accretion disk** emits optical/UV photons, and most of them are
  - up-scattered by electrons in the hot coronal gas → **X-ray emission**
  - absorbed and re-emitted by dust (polar/torus) → **IR/sub-mm emission**

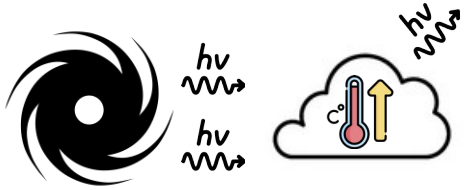
OUTFLOWS

- thermal/radiation/CR/jets-ram **pressures** produce winds and outflows
- gas can be then mechanically **dragged**

AGN FEEDBACK ON MOLECULAR GAS

study gas **excitation**

radiative feedback: X-ray dominated regions (XDR)
(e.g. Van der Werf et al. 2010, Pozzi et al. 2017)



AGN FEEDBACK ON MOLECULAR GAS

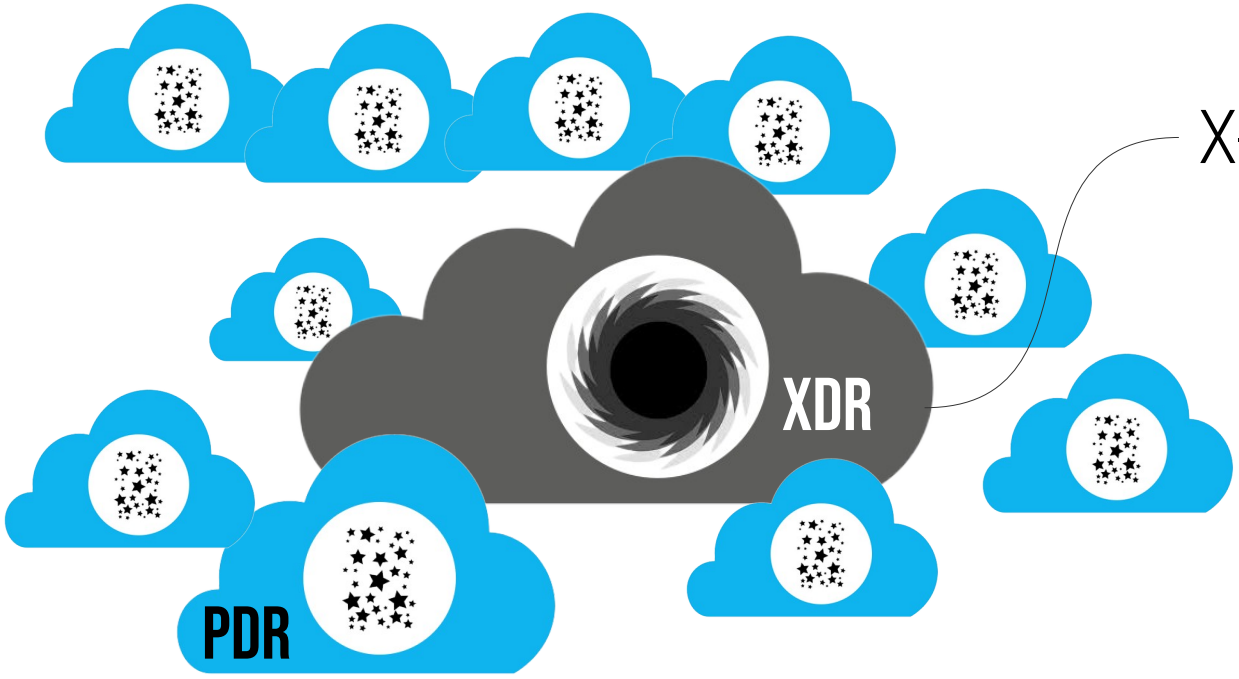
study gas **excitation**

radiative feedback: X-ray dominated regions (XDR)
(e.g. Van der Werf et al. 2010, Pozzi et al. 2017)

mechanical feedback: outflows / shocks / jets
(e.g. Mingozzi et al. 2018, García-Bernete et al. 2021)

study gas **kinematics**

AGN VS. STELLAR FEEDBACK



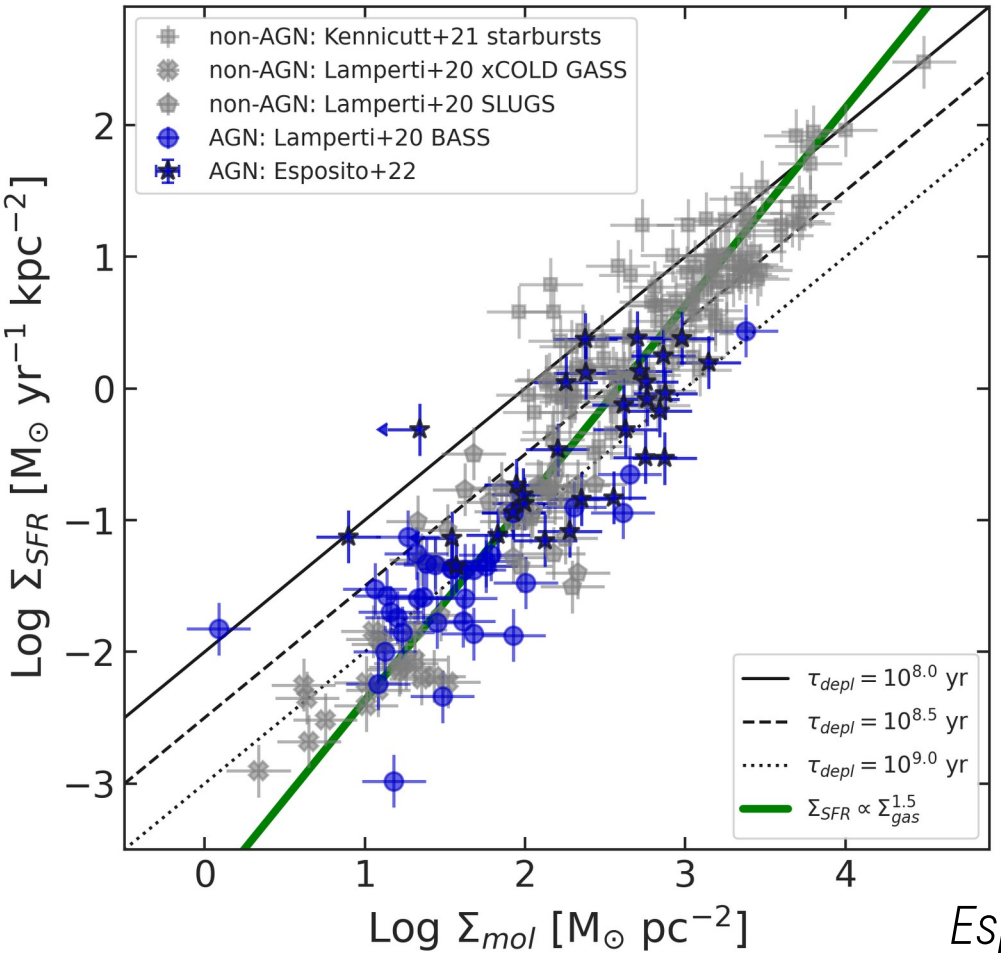
X-ray (1-100 keV) photons : F_X

AGN Feedback

Stellar Feedback

FUV (6-13.6 eV) photons : G_0

AGN EFFECT ON KPC-SCALE: NOT EVIDENT

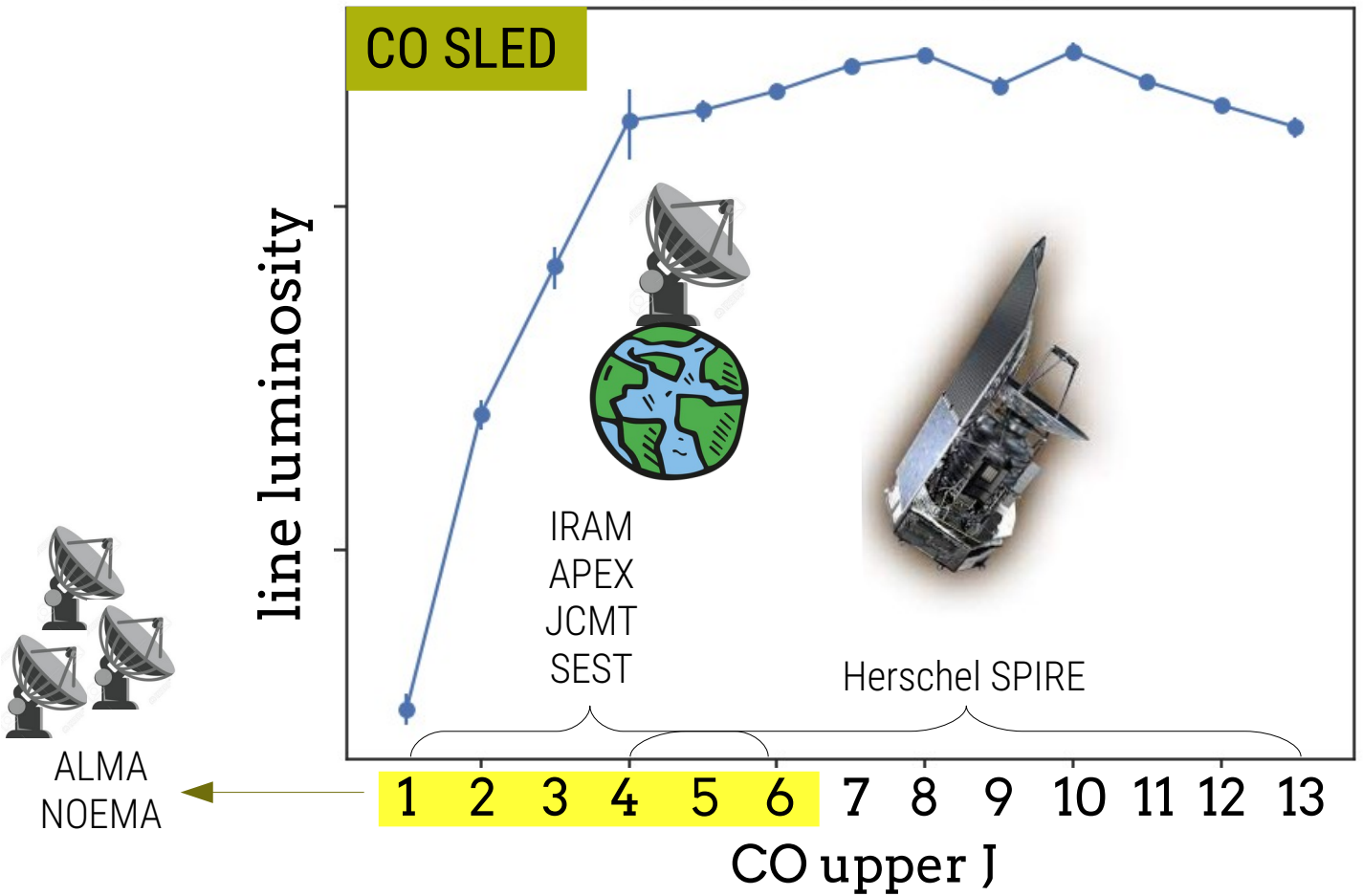


comparing non-AGN with
a sample of local AGN
on the Schmidt-Kennicutt plane
(**molecular mass** vs. **SFR**)

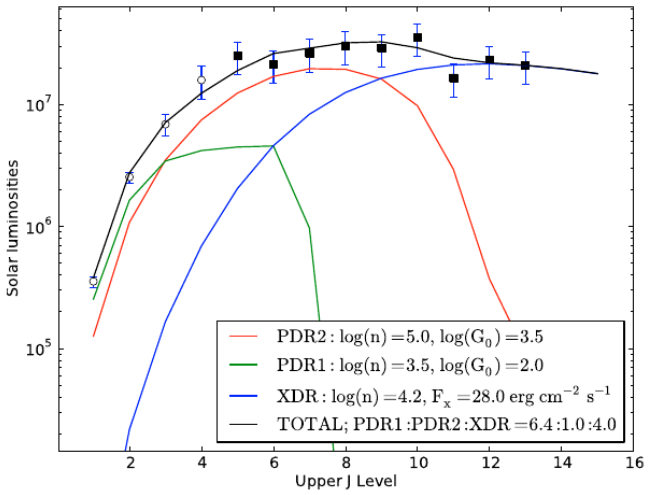
CO(1-0)

Esposito et al. 2022, MNRAS 512, 686–711

MOLECULAR GAS OBSERVATIONS



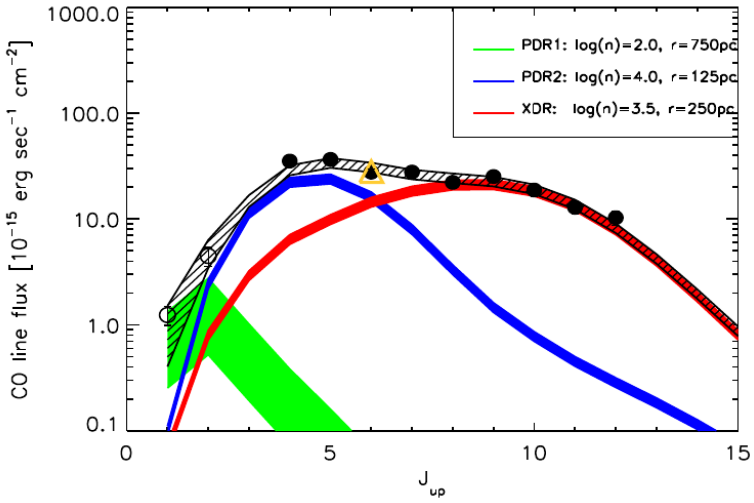
PDR AND XDR CO SLEDS: LITERATURE RESULTS



Van der Werf et al. 2010

used Meijerink+2006 model

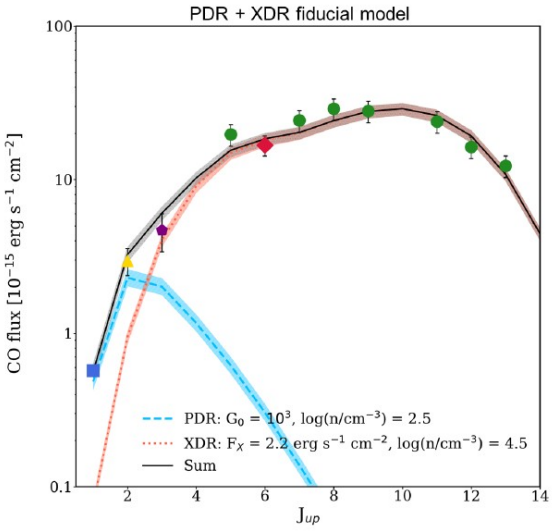
to fit the Mrk 231 CO SLED



Pozzi et al. 2017

used the CLOUDY code

to fit the NGC 7130 CO SLED

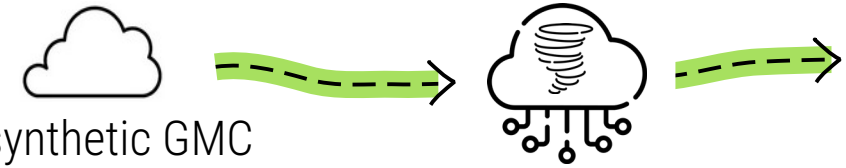


Mingozzi et al. 2018

used CLOUDY and shocks

to fit the NGC 34 CO SLED

A NEW MODEL FOR MOLECULAR EMISSION



a synthetic GMC
(M, R, n_0, Mach)

clumps extraction

$$p_s ds = \frac{1}{\sqrt{(2\pi\sigma_s^2)}} \exp\left[-\frac{1}{2}\left(\frac{s - s_0}{\sigma_s}\right)^2\right]$$

GMC internal structure: turbulence-driven lognormal PDF
(Vazquez-Semadeni 1994, Federrath & Klessen 2013)

model inspired by Vallini et al. 2017, 2018, 2019

Esposito et al. 2023, almost *submitted*

A NEW MODEL FOR MOLECULAR EMISSION

a synthetic GMC
(M, R, n_0, Mach)

clumps extraction

CO SLED
generation

Cloudy

clumps CO SLEDs
(∀ incident flux)

GMC is ready!

$$p_s\,ds = \frac{1}{\sqrt{(2\pi\sigma_s^2)}} \exp\left[-\frac{1}{2}\left(\frac{s-s_0}{\sigma_s}\right)^2\right]$$

GMC internal structure: turbulence-driven lognormal PDF
(Vazquez-Semadeni 1994, Federrath & Klessen 2013)

radiative transfer (PDR and XDR models)

model inspired by Vallini et al. 2017, 2018, 2019

Esposito et al. 2023, almost *submitted*

ADDING A GMC MASS DISTRIBUTION

a synthetic GMC
(M, R, n_0, Mach)

clumps extraction

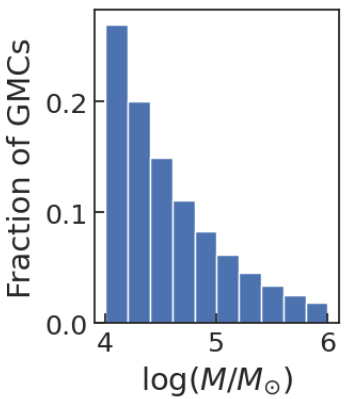
CO SLED
generation

clumps CO SLEDs
(∀ incident flux)

GMC is ready!

different GMCs

mass distribution
of the GMCs



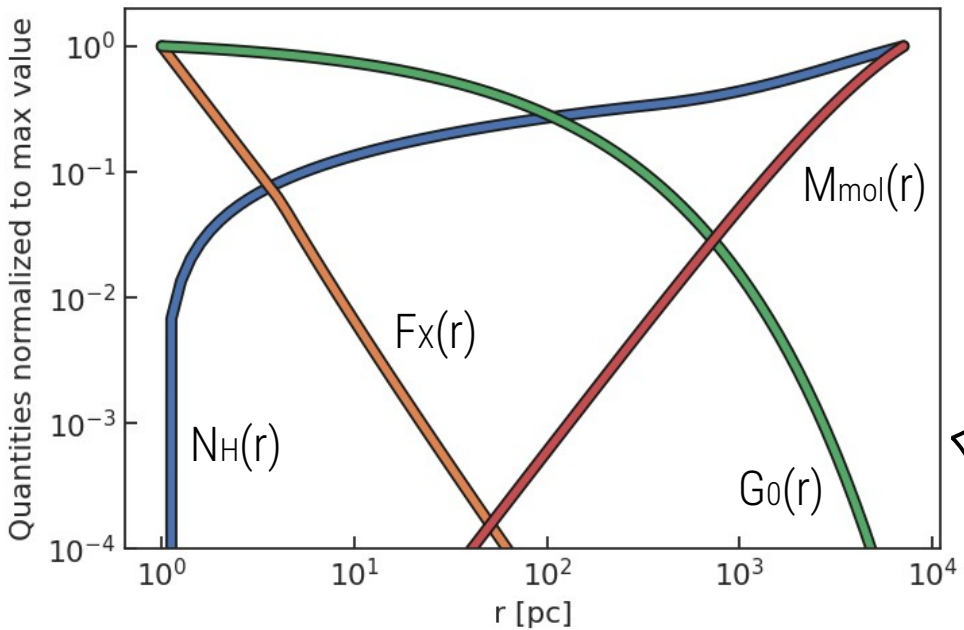
$$\frac{dN}{dM} \propto M^{-1.64}$$

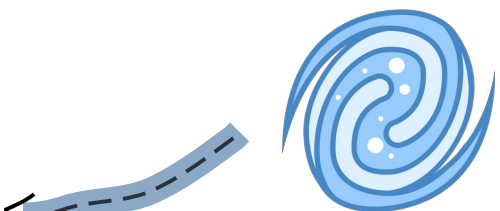
following Roman-Duval et al. 2010,
Dutkowska & Kristensen 2022

Esposito et al. 2023, almost *submitted*

A NEW MODEL FOR MOLECULAR EMISSION

edge-on galaxy view





galaxy observed
$M_{mol}(r)$, $F_X(r)$, $G_0(r)$

from Esposito et al. 2022

Esposito et al. 2023, almost *submitted*

CO SLED GENERATION: THE WORKFLOW

a synthetic GMC
(M, R, n_0, Mach)

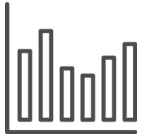
clumps extraction

CO SLED
generation

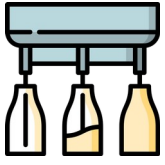
clumps CO SLEDs
(∀ incident flux)

GMC is ready!

different GMCs



mass distribution
of the GMCs



filling the radial bins
with GMC distribution

galaxy observed
$M_{mol}(r)$, $F_X(r)$, $G_0(r)$

CO SLED GENERATION: THE WORKFLOW

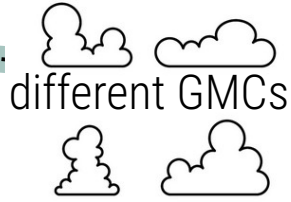
a synthetic GMC
(M, R, n_0, Mach)

clumps extraction

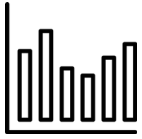
CO SLED
generation

clumps CO SLEDs
(∀ incident flux)

GMC is ready!

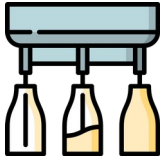


different GMCs



mass distribution
of the GMCs

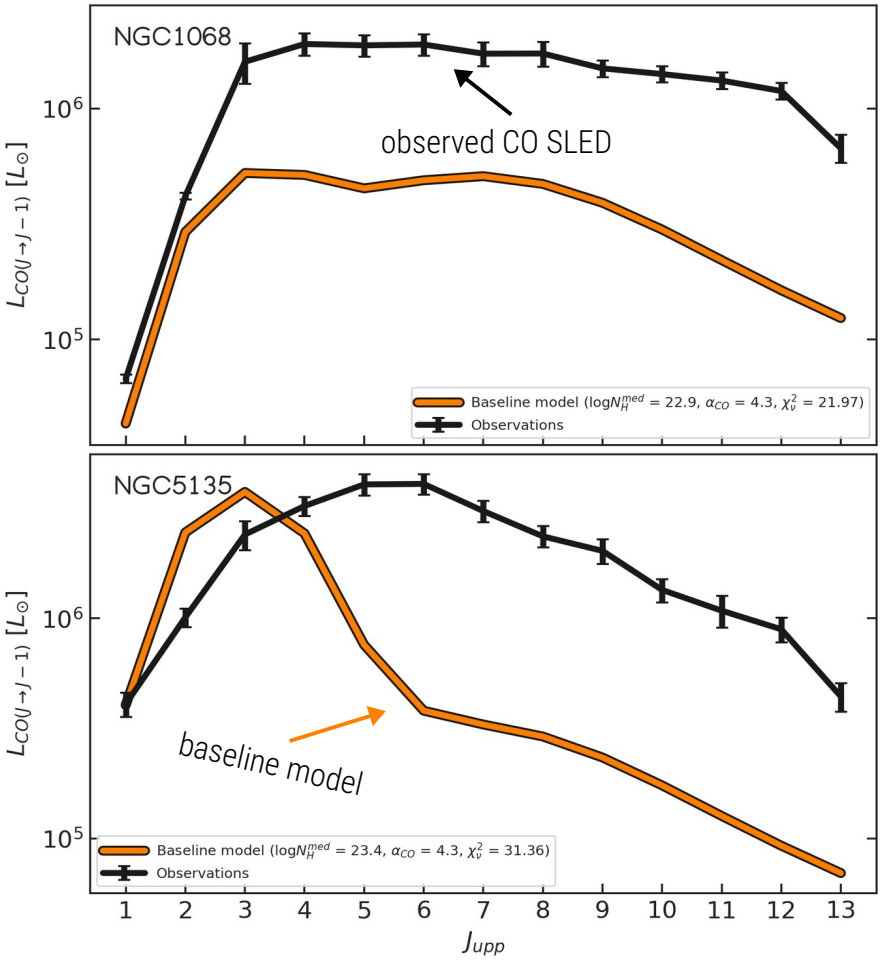
match GMC position
and incident fluxes

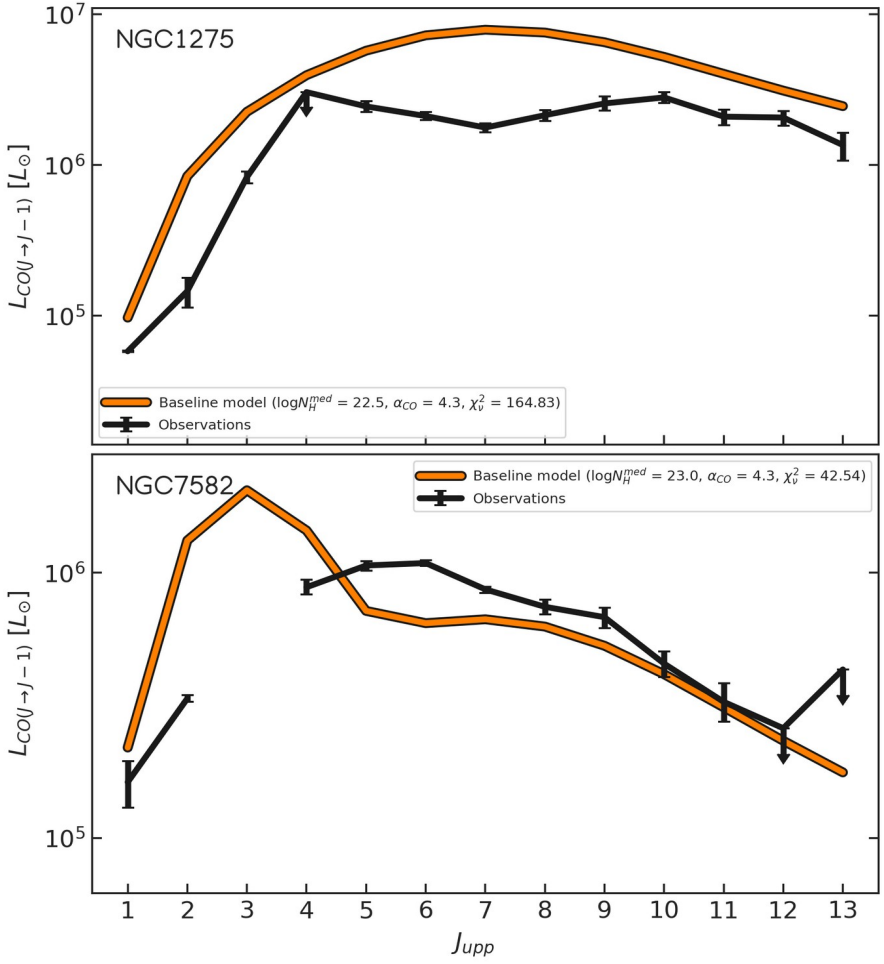


filling the radial bins
with GMC distribution

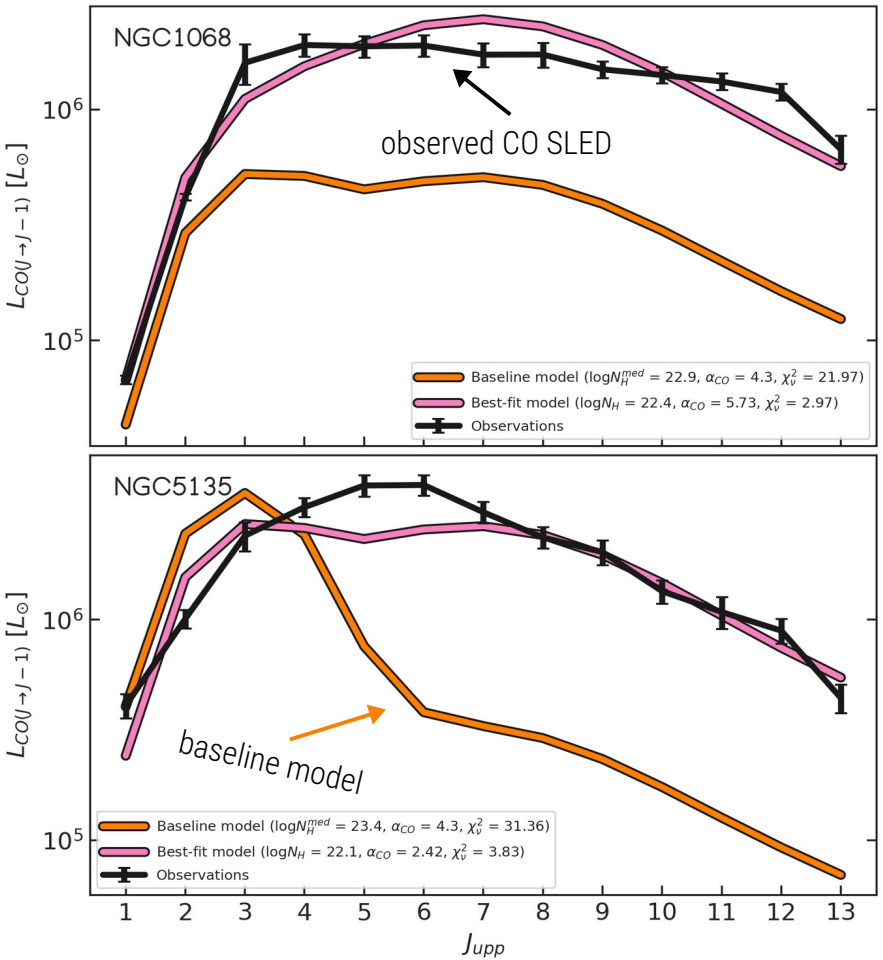
galaxy observed
$M_{mol}(r)$, $F_X(r)$, $G_0(r)$

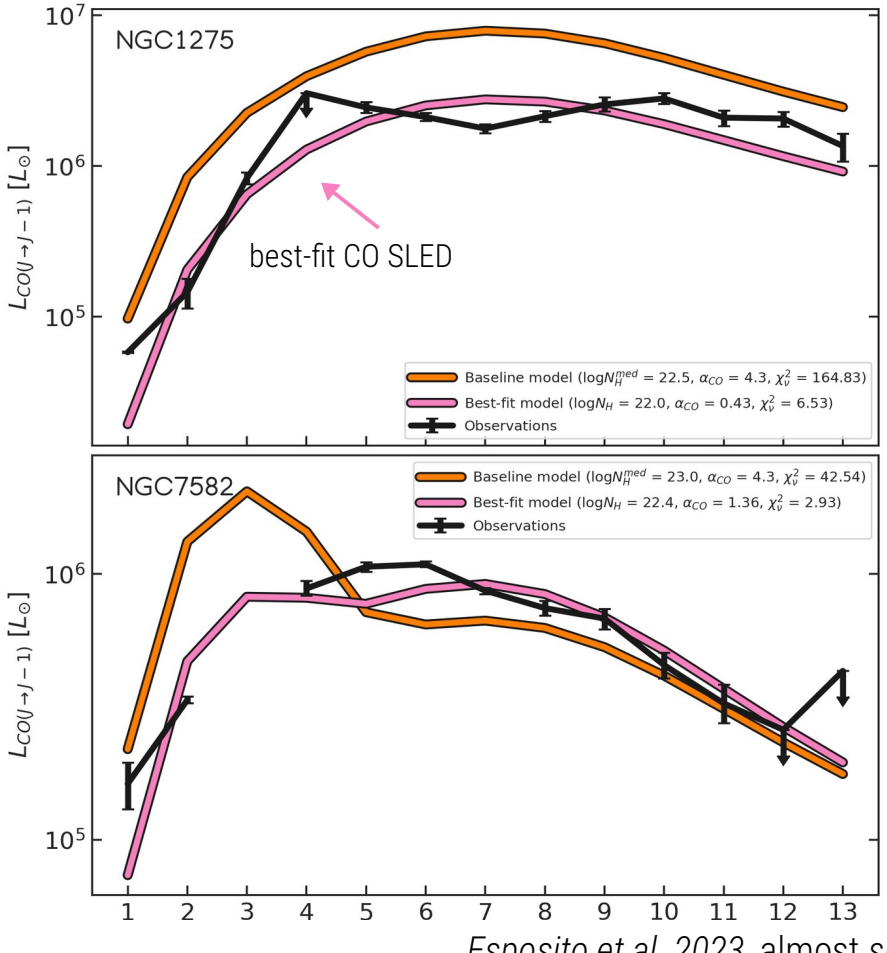
CO SLEDS OF GALAXIES: BASELINE MODEL





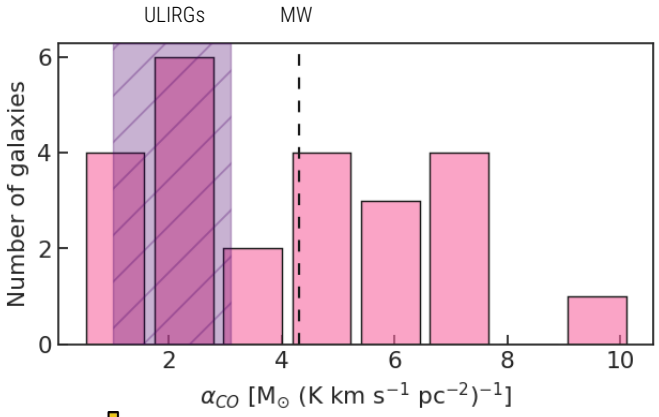
CO SLEDS OF GALAXIES: BEST FIT (ALPHA-CO, NH)





Esposito et al. 2023, almost *submitted*

NEW MODEL: RESULTS

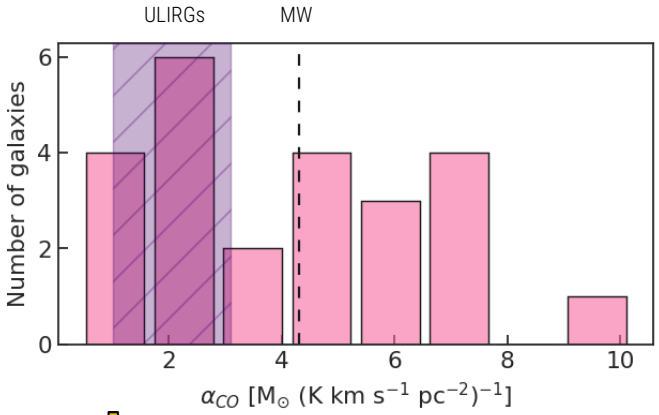


$$\alpha_{CO} = 3.8^{+3.9}_{-2.1}$$

Modelling molecular clouds and CO excitation in AGN-host galaxies

Esposito et al. 2023, almost *submitted*

NEW MODEL: RESULTS



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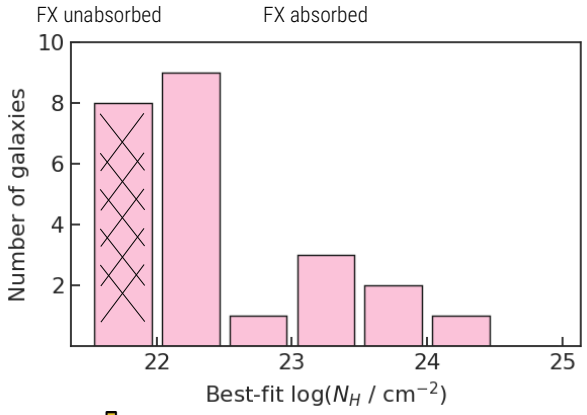
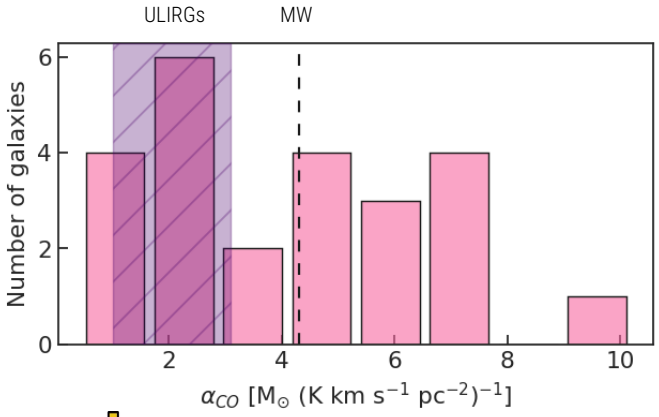


$\log N_H = 22.4^{+1.4}_{-0.2}$

Modelling molecular clouds and CO excitation in AGN-host galaxies

Esposito et al. 2023, almost *submitted*

NEW MODEL: RESULTS



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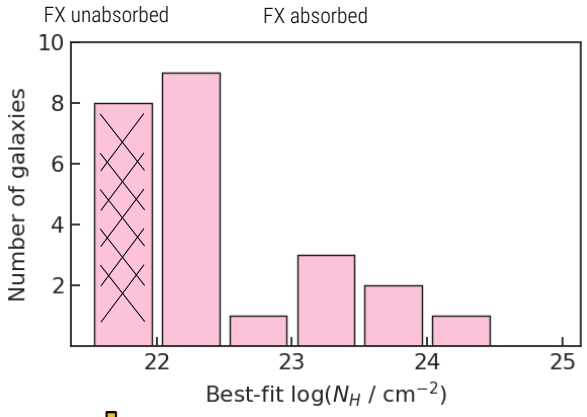

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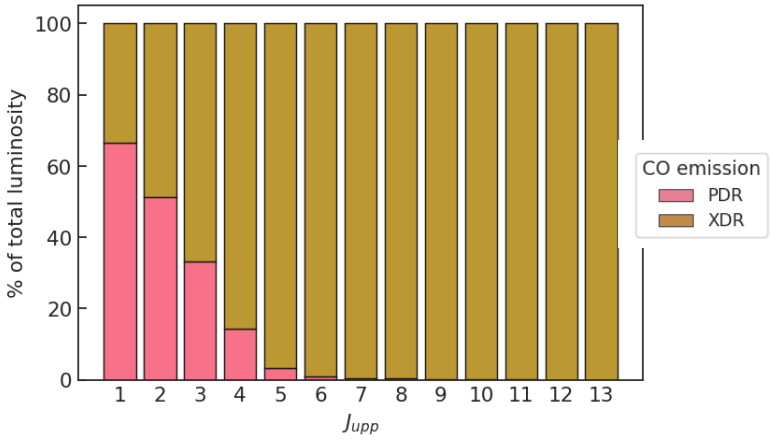
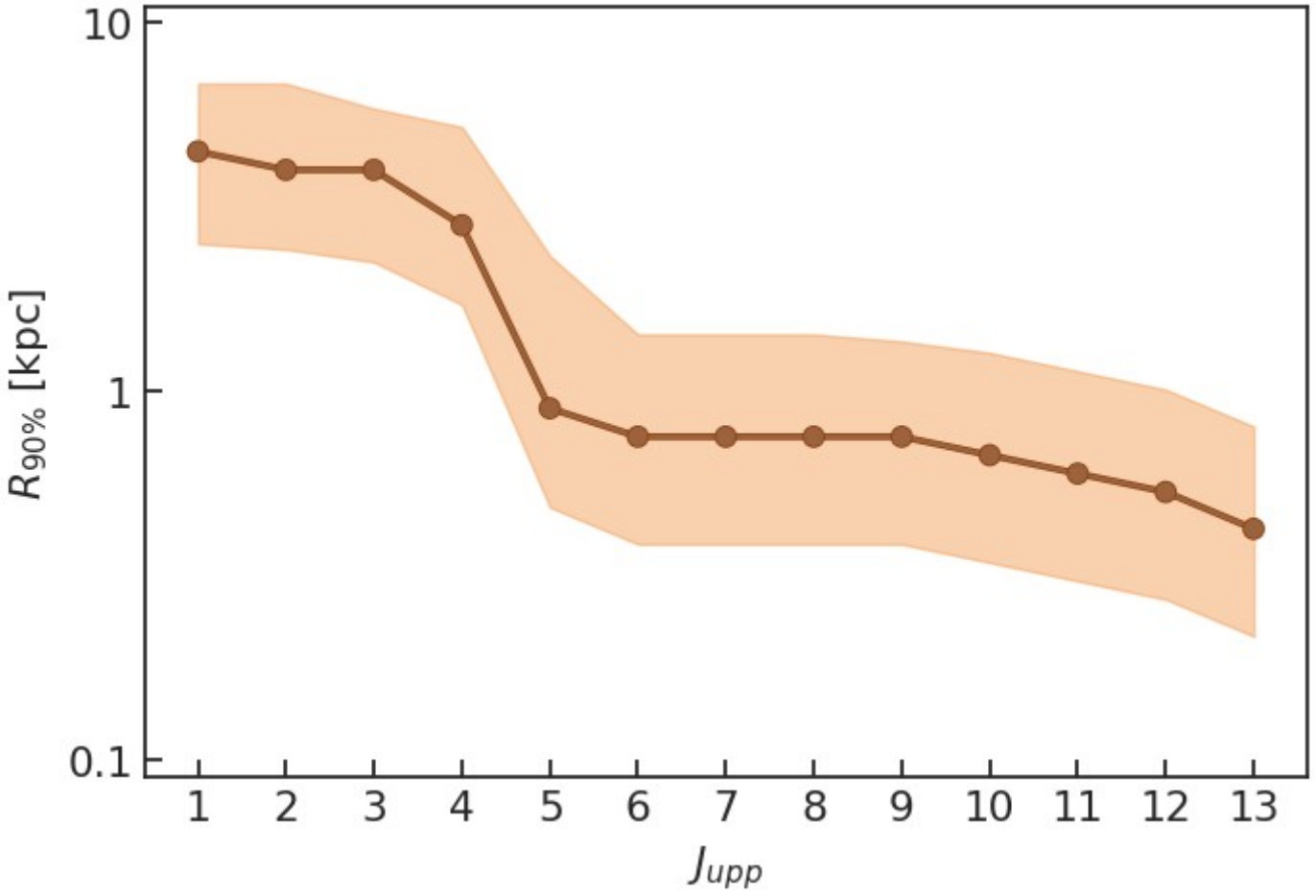


XDRs are fundamental to reproduce CO SLEDs from AGNs (for J_{upp} > 4)

Modelling molecular clouds and CO excitation in AGN-host galaxies

Esposito et al. 2023, almost *submitted*

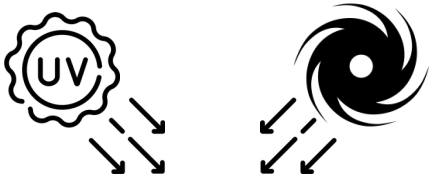
NEW MODEL: CO SLED RADIAL BUILD-UP



high Fx

MODEL IN A NUTSHELL

GMC internal structure
(turbulent clumps)



radiative transfer
(PDR and XDR)

GMC mass distribution
in observed $M_{mol}(r)$

CONCLUSIONS

- The model can **reproduce** observed CO SLED and **infer** galaxies properties (α_{CO}, N_H)
- **AGN feedback** (as opposed to stellar feedback) is the **dominant** mechanism for $J_{upp} > 4$
- Given observed galaxies properties (M_{mol}, L_X, G_0) it can predict **intensity** and **physical size** of CO lines