On the dust and gas content of high-redshift galaxies hosting obscured AGN in the CDF-S

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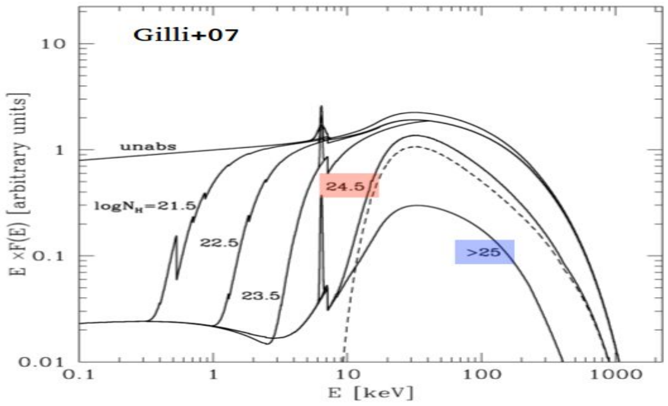
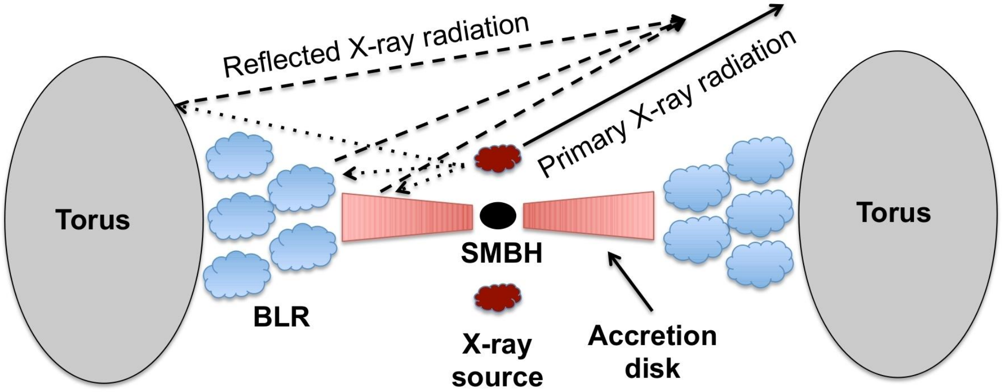
Obscured AGN



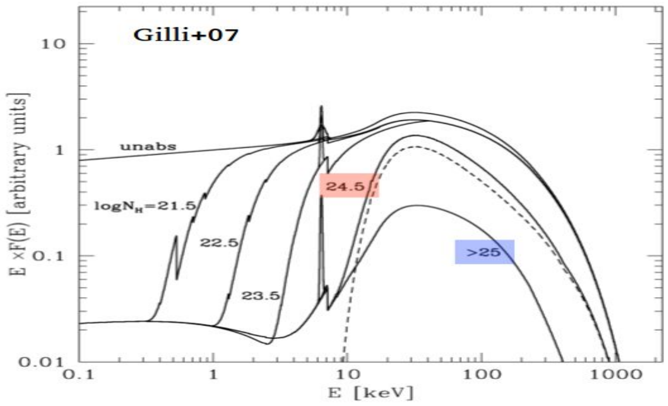
- Unabsorbed: log N_H > 21
- Compton thin: 21 < log N_H < 24
- Mildy Compton thick: log N_H ≈ 24 -25
- Heavily Compton thick: log N_H > 25

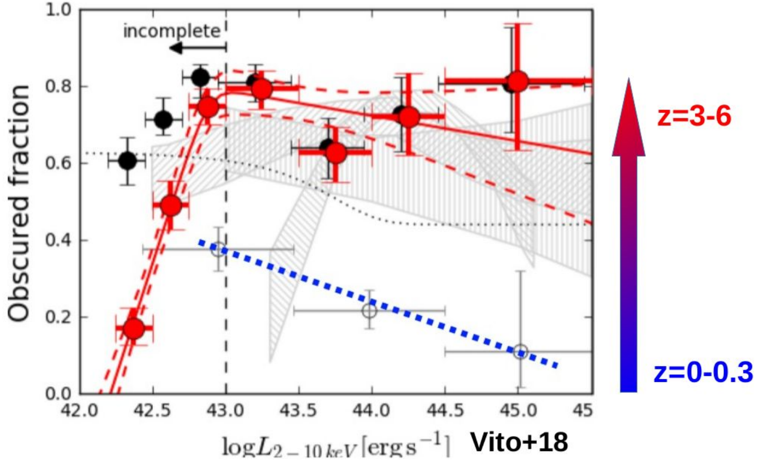


Unified Model…

What at high-z?

Obscured AGN





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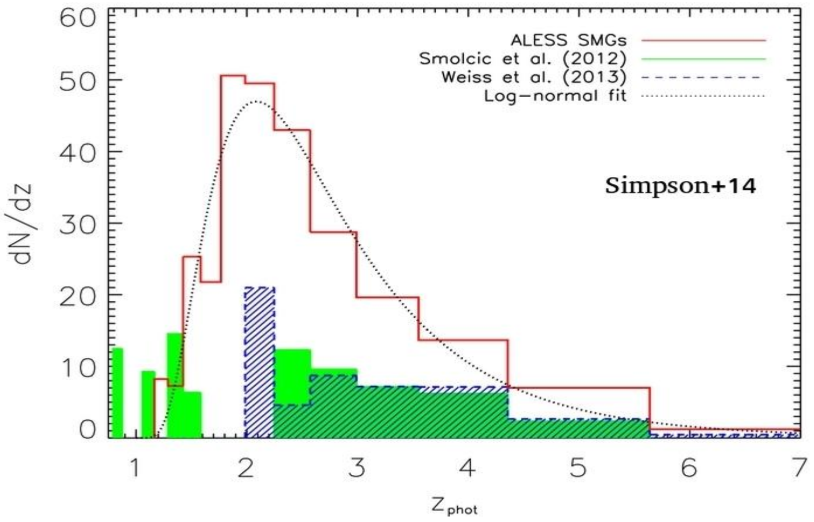
Obscured AGN fraction increases at high redshift

Sub-Millimetre Galaxies (SMGs)

Very luminous galaxies (rest-frame $L_{IR} \gtrsim 10^{12}\ L_\odot$) whose distribution peaks at the same redshift ($z \approx 2$) of SFR and BH accretion rate.

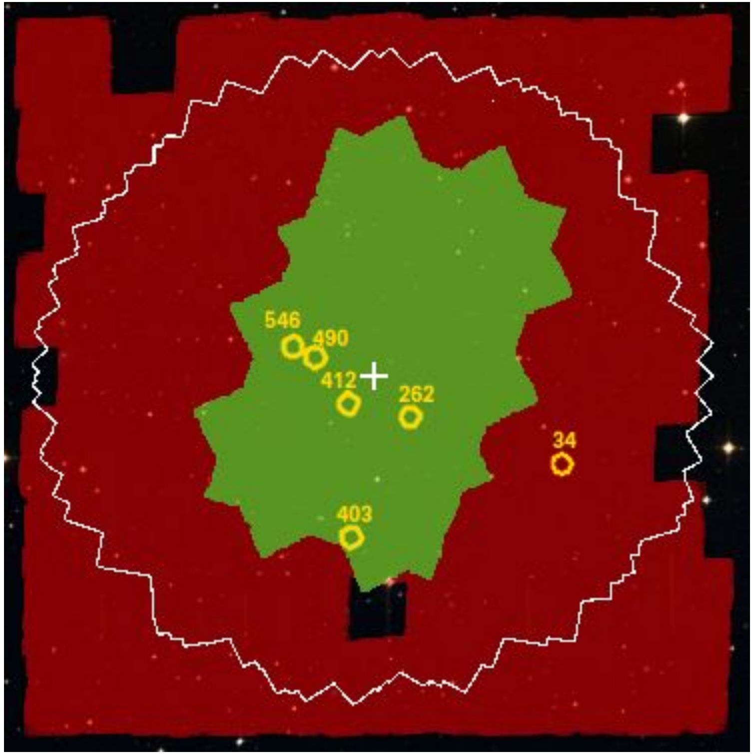


Extremely dense objects

- $M_{H2} \sim 10^{10}\ M_\odot$
- size ~ kpc
- AGN fraction 50%-90%

Contribution of the host galaxy to the AGN obscuration?

Target selection



28' × 28'
White contour: **CDF–S**
Red area: **GEMS**
Green area: **CANDELS**

Parent sample: 42 AGN

- 34 AGN in 4-Ms at z > 3 (Vito+13)
- 8 AGN in 1-Ms at z=1.1-3.7 (Rigopoulou+09)

Selection criteria:

- Secure spectroscopic z > 2.5
- Column density log N_H > 23
- Detection at $\lambda_{obs} \geq 100$ µm

Derived sample: 6 AGN

- 2.5 < z < 4.7
- Good X-ray and IR coverage
- $M_* \sim 10^{11} M_\odot$, SFR ~ $10^{2\text{-}3} M_\odot$/yr

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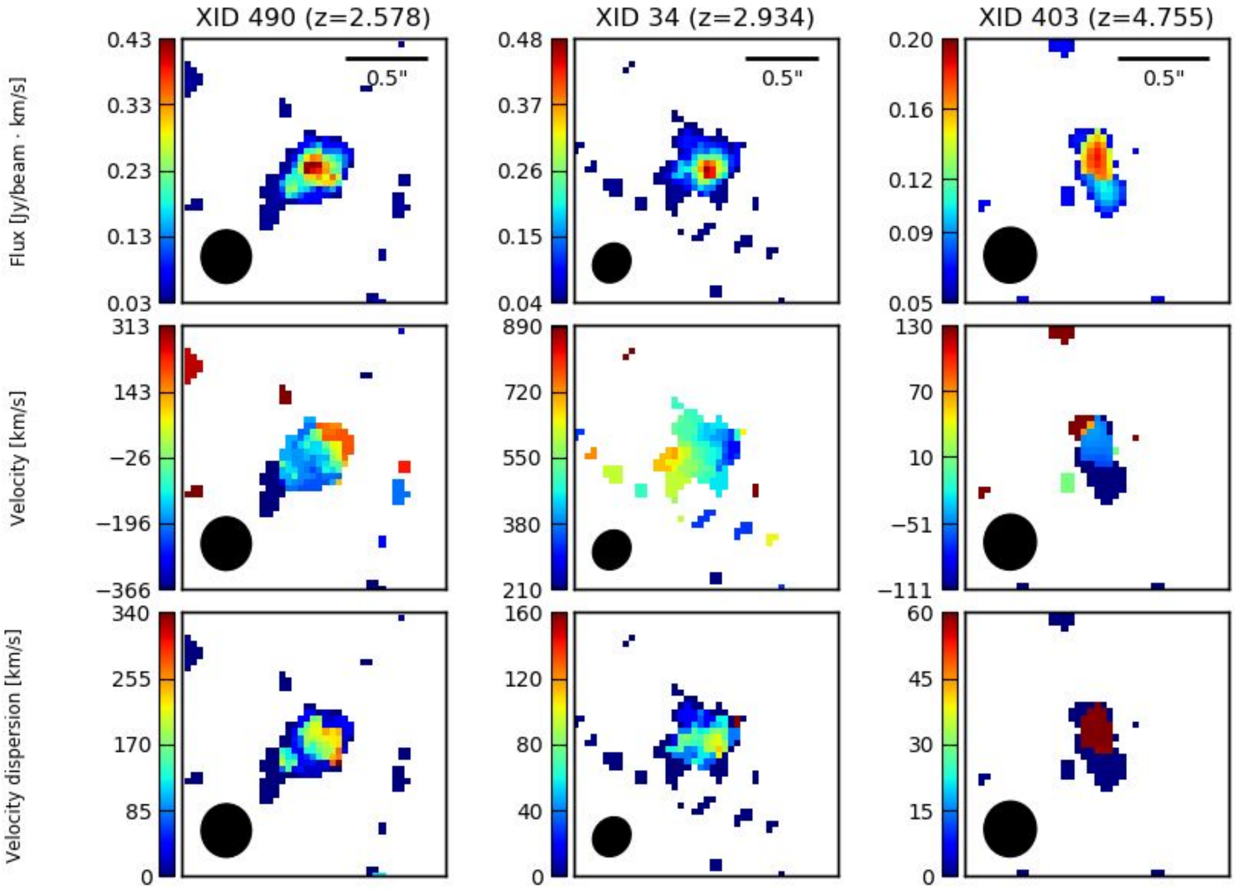
New **ALMA** band 4 (~ 2.1 mm) observations of both one CO high-J transition and continuum for each source

- Good X-ray and IR coverage
- $M_* \sim 10^{11}\ M_\odot$, SFR $\sim 10^{2\text{-}3}\ M_\odot$/yr

ALMA observations: CO lines



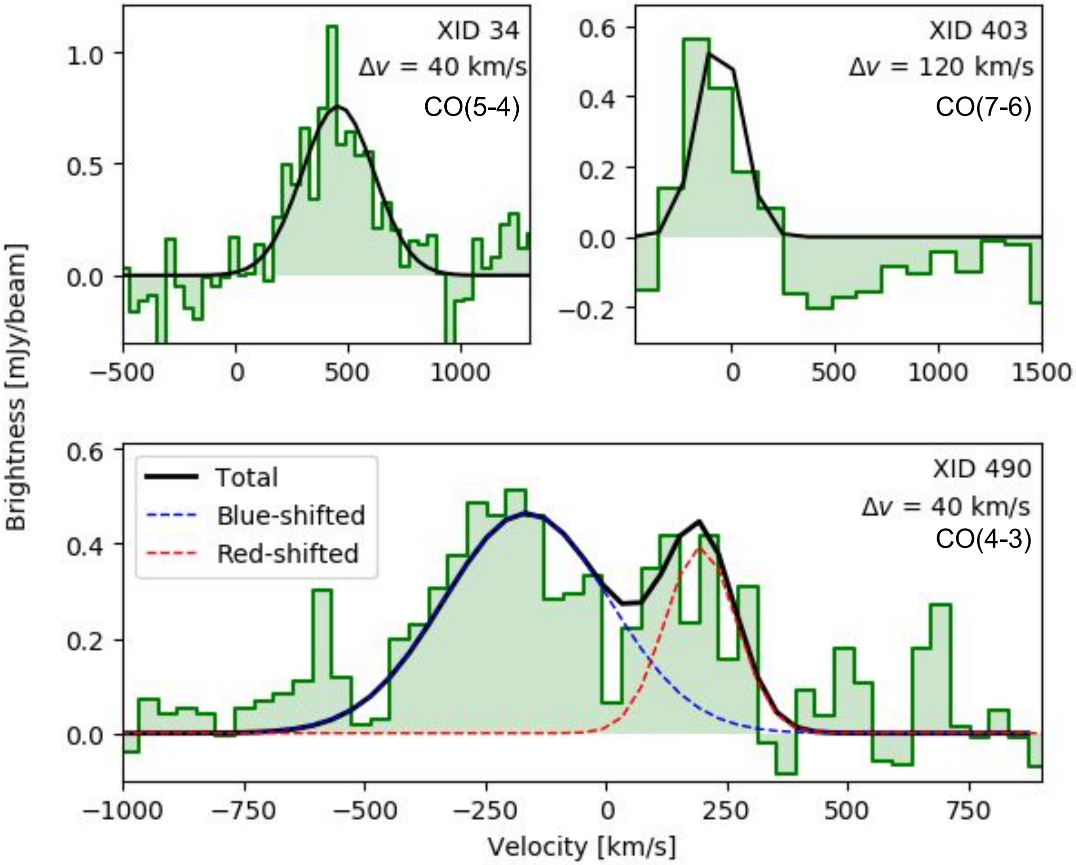
Three detected sources out of six

- XID 490: Rotating (merger?)
- XID 34: Chaotic structure…
- XID 403: Rotating ?

Poor resolution....

Pixels > 3σ
Channels v_0± FWHM

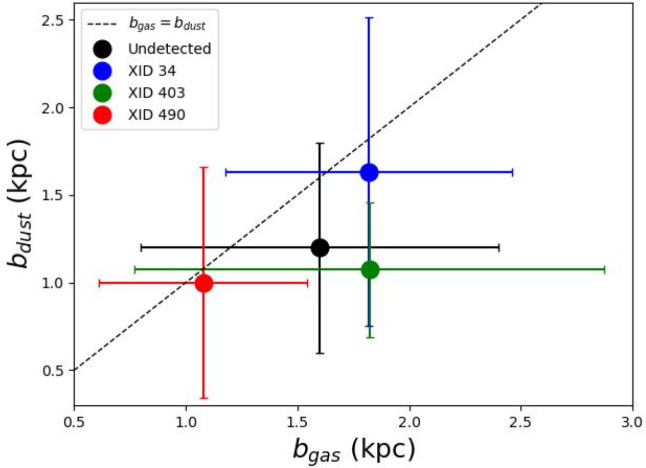
Spectral fitting

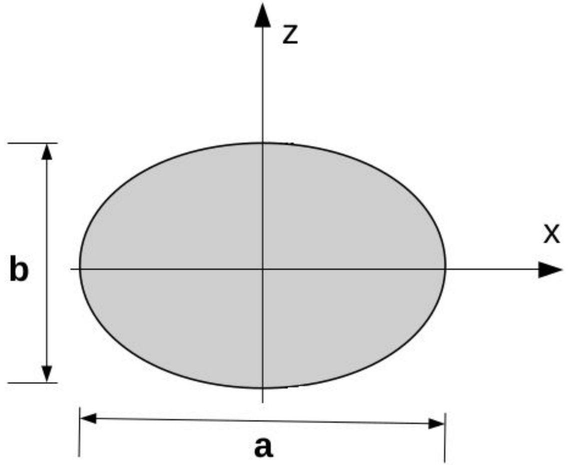


FWHM ~ few 10^2 km/s

Double peak:
rotating disk or two non-resolved systems?

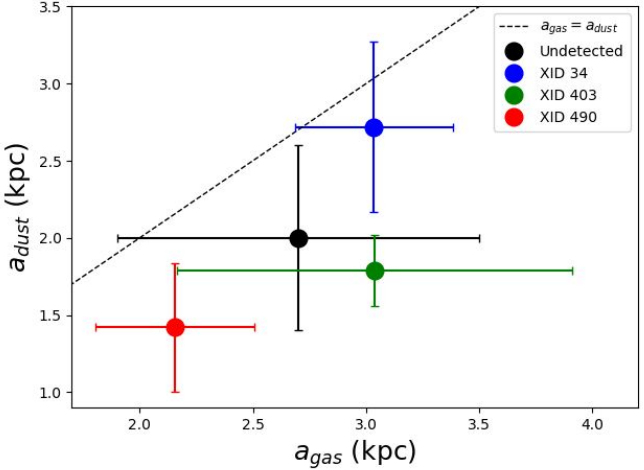
Spatial fitting: 2D Gaussian





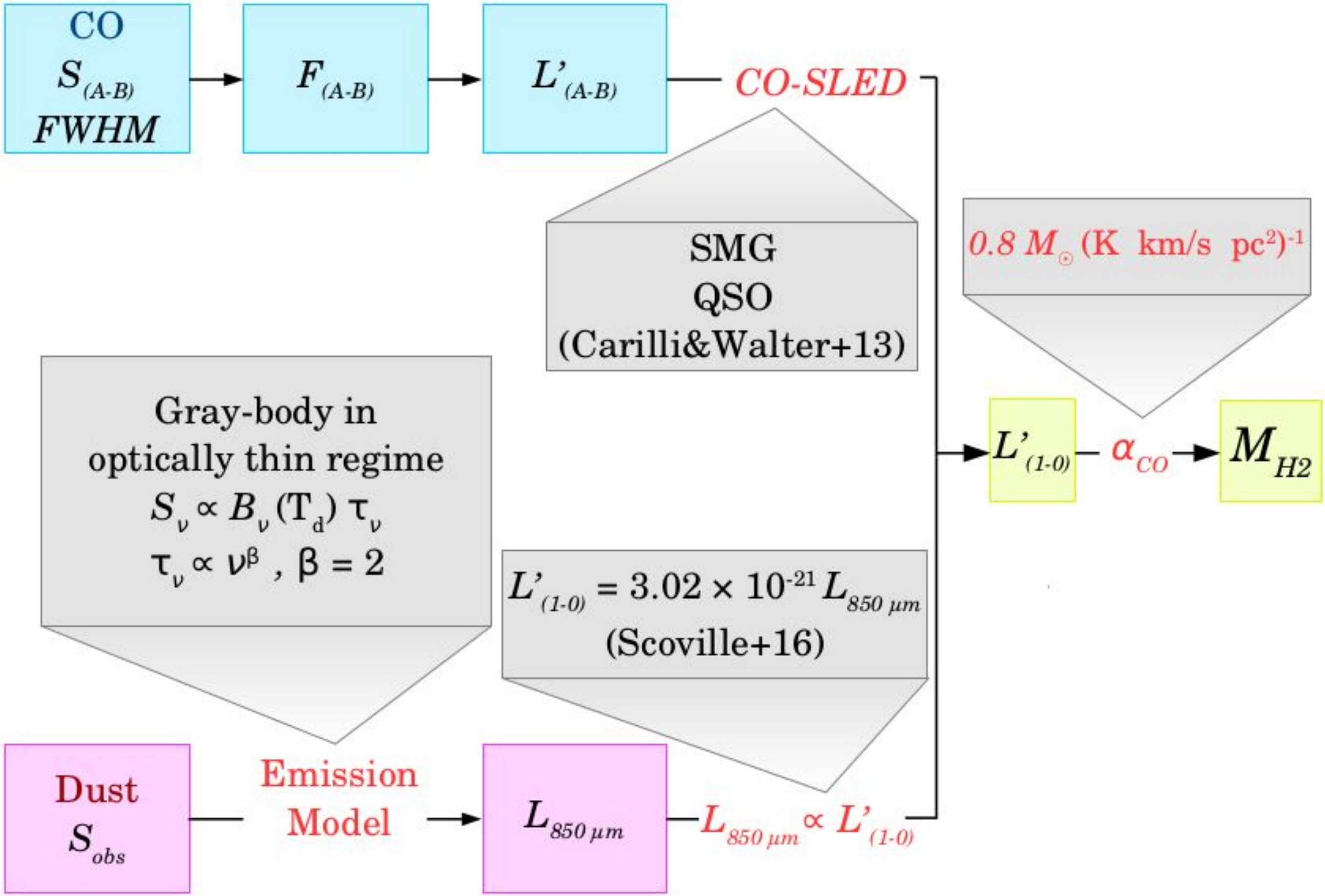
Gas size > dust size

- Physical?
- Observation bias?
- Radial decrease of the dust temperature and gas column density (Calistro Rivera+18)

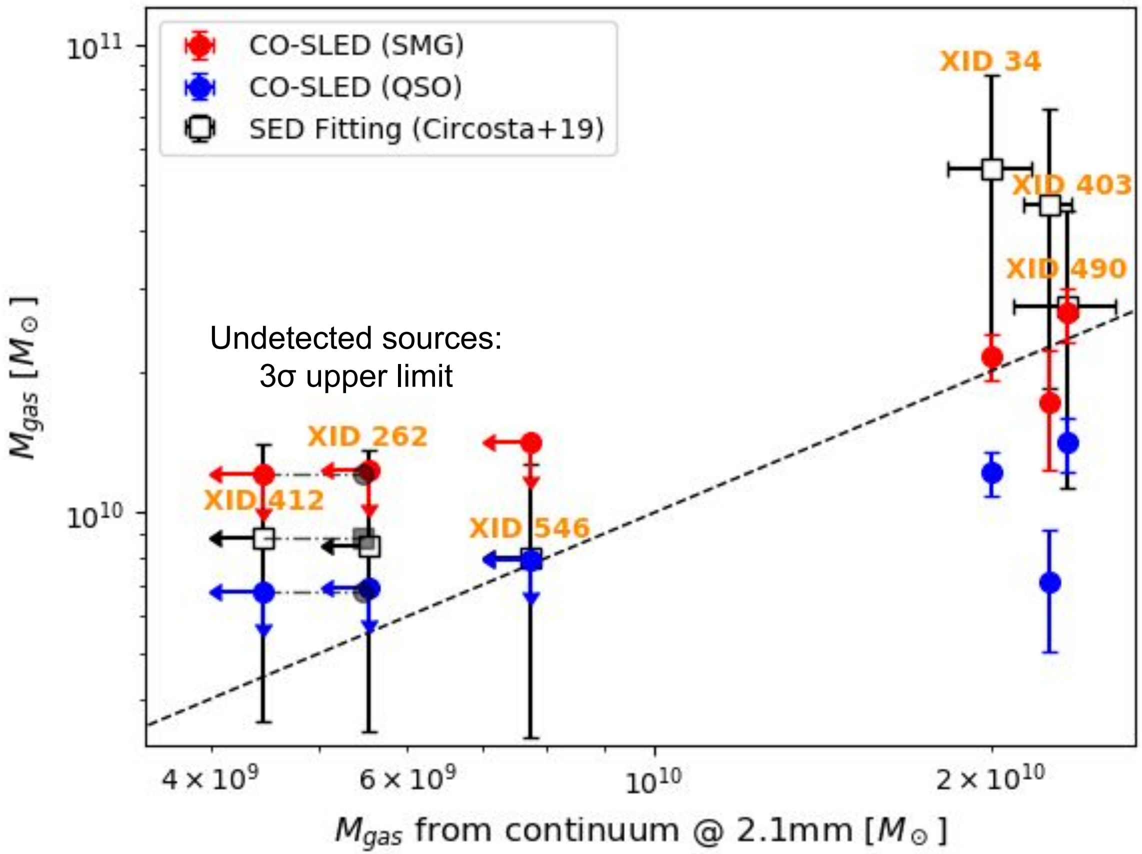


Assumption:
Undetected sources size equal to the mean of the detected sources

Gas mass: different approaches

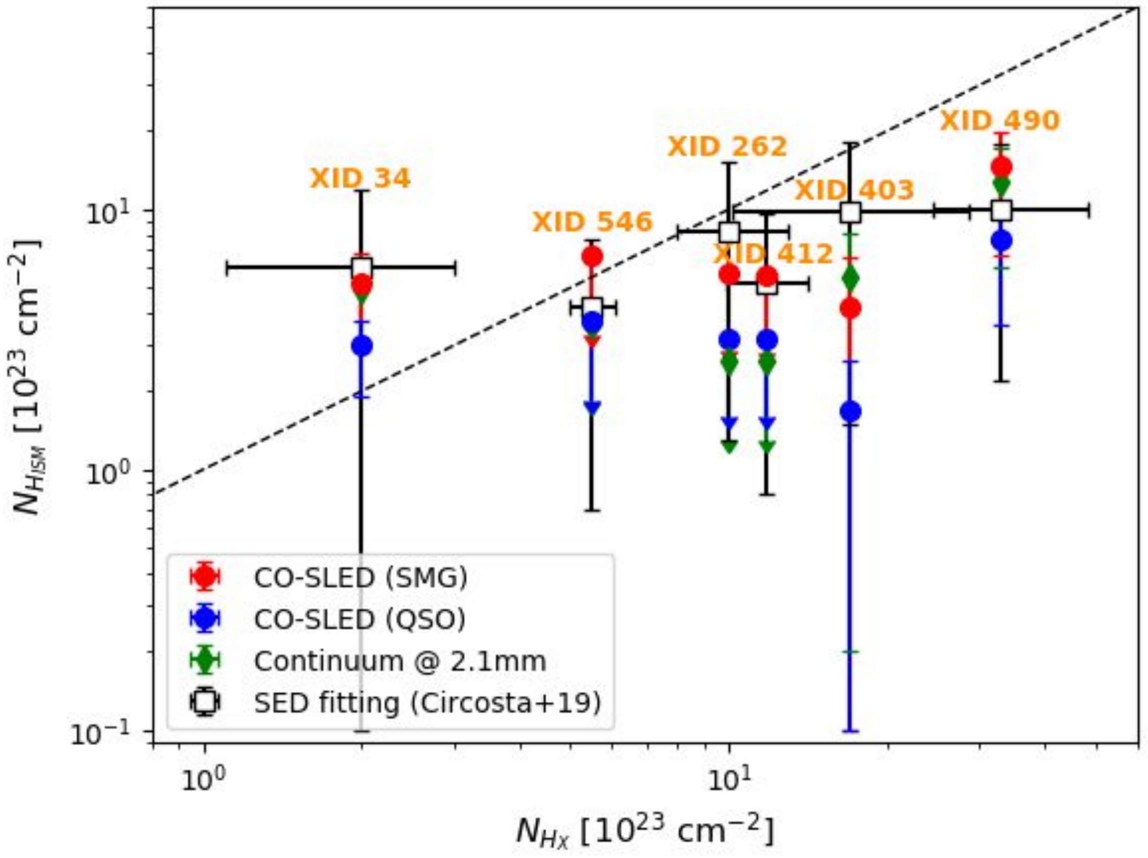


Gas mass: results



Good agreement between three independent measurements

Column density - Uniforme Sphere

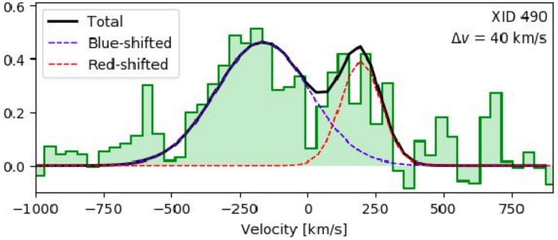


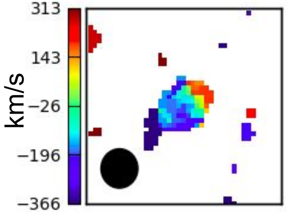
$N_{H,X}$ and $N_{H,ISM}$: same order of magnitude

Host ISM can significantly contribute to the obscuration of the central AGN

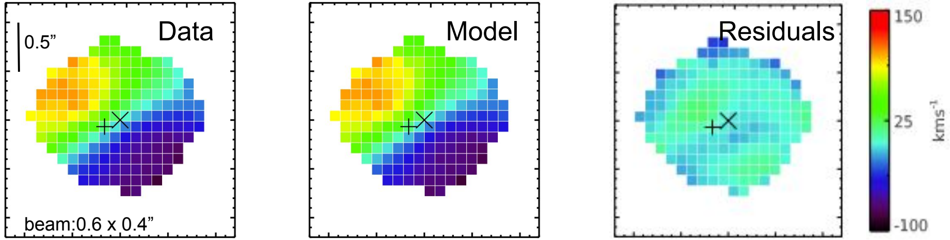
Column density - rotating disk (?)

XID 490 (z=2.578)

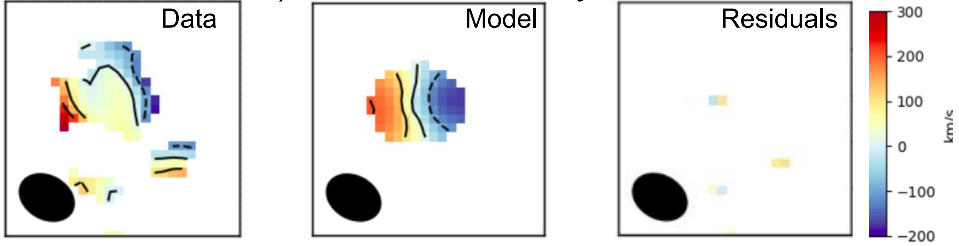




XID 403 (z=4.755) C[II] emission (De Breuk+14)



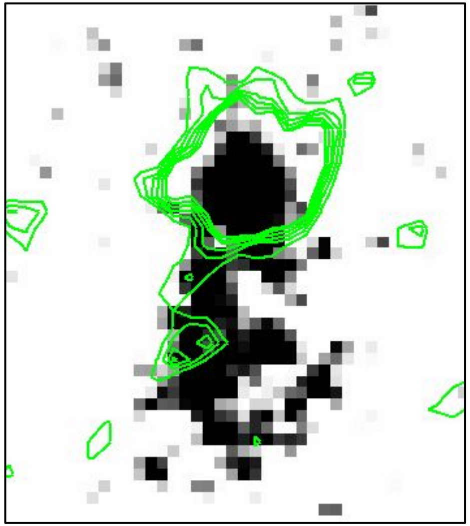
XID 34 (z=2.974) C[II] emission (Rybak+19)



However... →

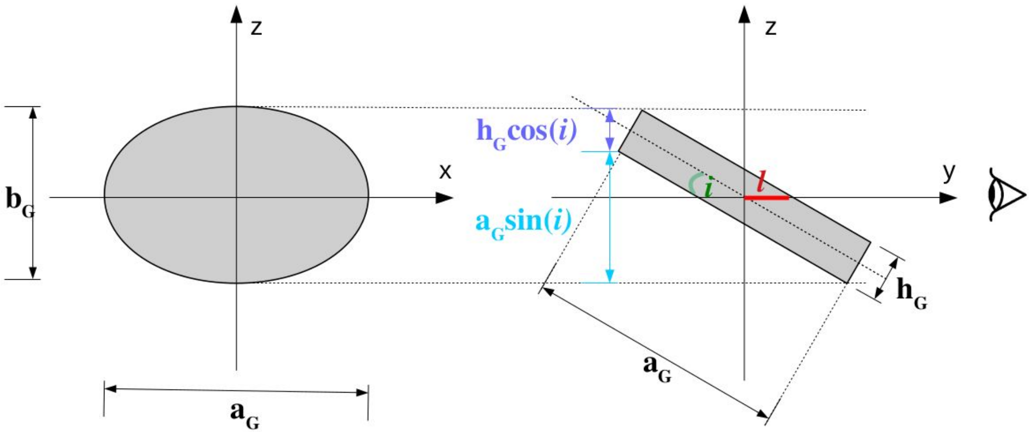
XID 34 V–band (~600 nm) HST image:

irregular shape



Green contours: CO moment 0

Column density - rotating “coin” disk



$N_{ISM,\ disk} \approx$ up to 5 $N_{ISM,\ sphere}$

$$\begin{cases} b_G = a_G\sin(i) + h_G\cos(i) \\ h_G = 0.15 \cdot a_G \end{cases}$$ Elmegreen & Elmegreen(‘06)

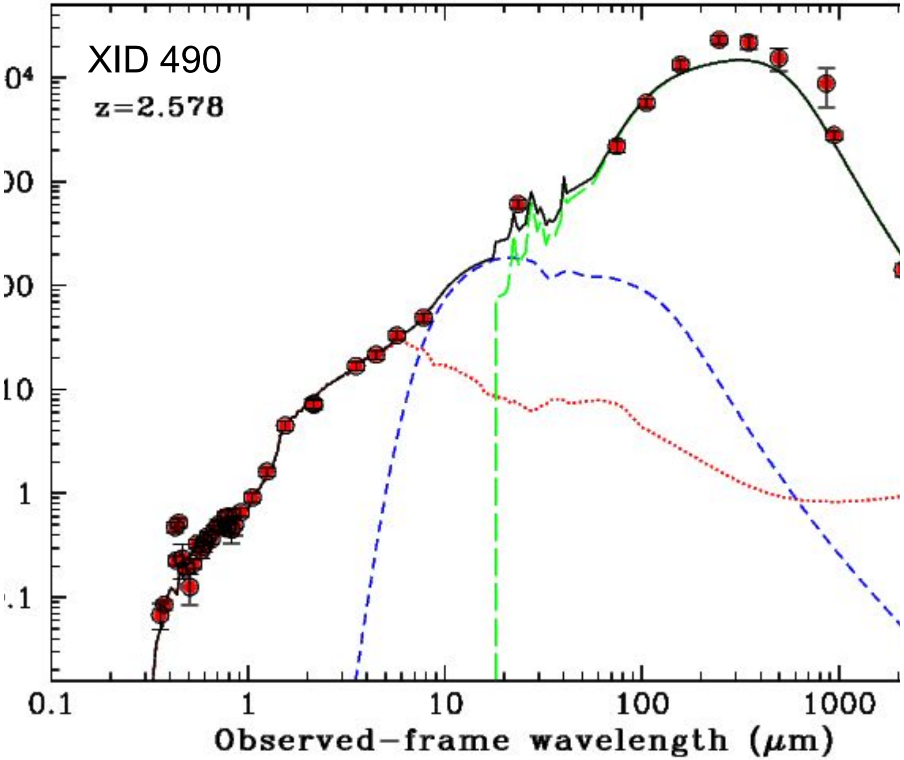
ISM column density can contribute to the obscuration even in heavily Compton thick AGN

i = 32°, 37°, 27° for XID 34, XID 403, XID 490, respectively

$$l = (a_G/2)\sin(i) + (h_G/2)\cos(i)$$

But POORLY CONSTRAINED, due to poor resolution

Dust temperature and mass



Temperatures:

Single temperature (error ≈ ±5 K), gray body IR–SED fitting:

$$\begin{cases} S_\nu \propto B_\nu (T_d)\, \tau \\ \tau \propto \nu^\beta ,\ \beta = 2 \end{cases} \Longrightarrow T_d \approx 65\text{-}80\ \mathrm{K}$$

Mass:

$$\begin{cases} M_d = \dfrac{D_L^2 S_{obs}}{k_\nu B_\nu(T_d)(1+z)} \\ k_\nu \propto \nu_\beta ,\ \beta = 2 \end{cases} \Longrightarrow M_d \approx 10^8\, M_\odot$$

Dynamical mass

$$M_{dyn}\cos^2 i = 6.5\cdot 10^4 \left(\frac{\Delta \mathrm{v}}{\mathrm{km\ s^{-1}}}\right)^2 \left(\frac{a_G}{\mathrm{kpc}}\right) M_\odot$$

For XID 34, XID 403 ($v_{c,proj}$ = *0.75 FWHM*, Wang+13)

$$M_{dyn}\cos^2 i = 1.16\cdot 10^5 \left(\frac{v_{c,proj}}{\mathrm{km\ s^{-1}}}\right)^2 \left(\frac{a_G}{\mathrm{kpc}}\right) M_\odot$$

For XID 490, for which we assumed $v_{c,proj}$ = peaks separation

We found **M_{dyn}≈ 10^{10} $M_\odot$**, < M_* ≈ few 10^{11} $M_\odot$ (30% error) Circosta+19

De Breuck+14 and Coppin+10 found same discrepancy for XID 403

Possible causes:

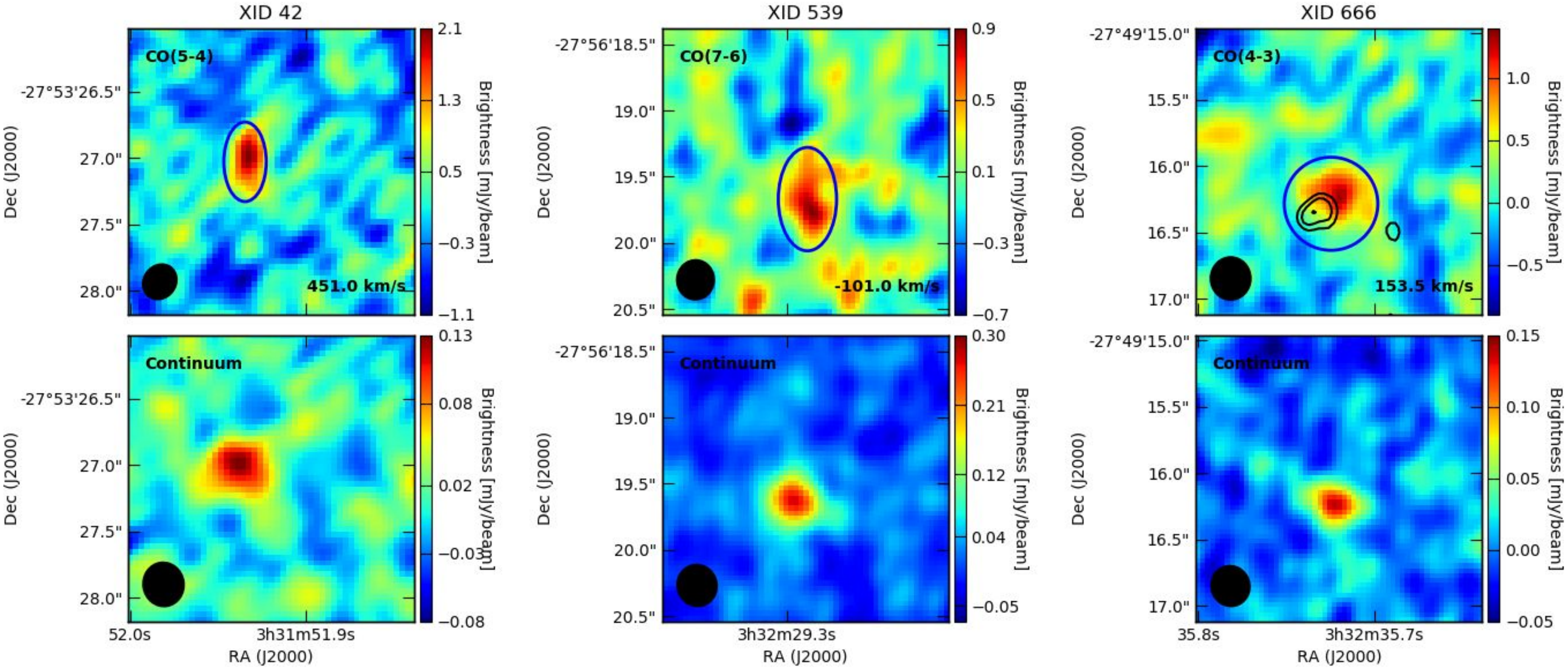
- Different CANDELS/HST emitting region size wrt ALMA
- Underestimate of the stella mass error (different IMF…)
- Underestimate of a_G and Δv due to low sensitivity

Conclusions

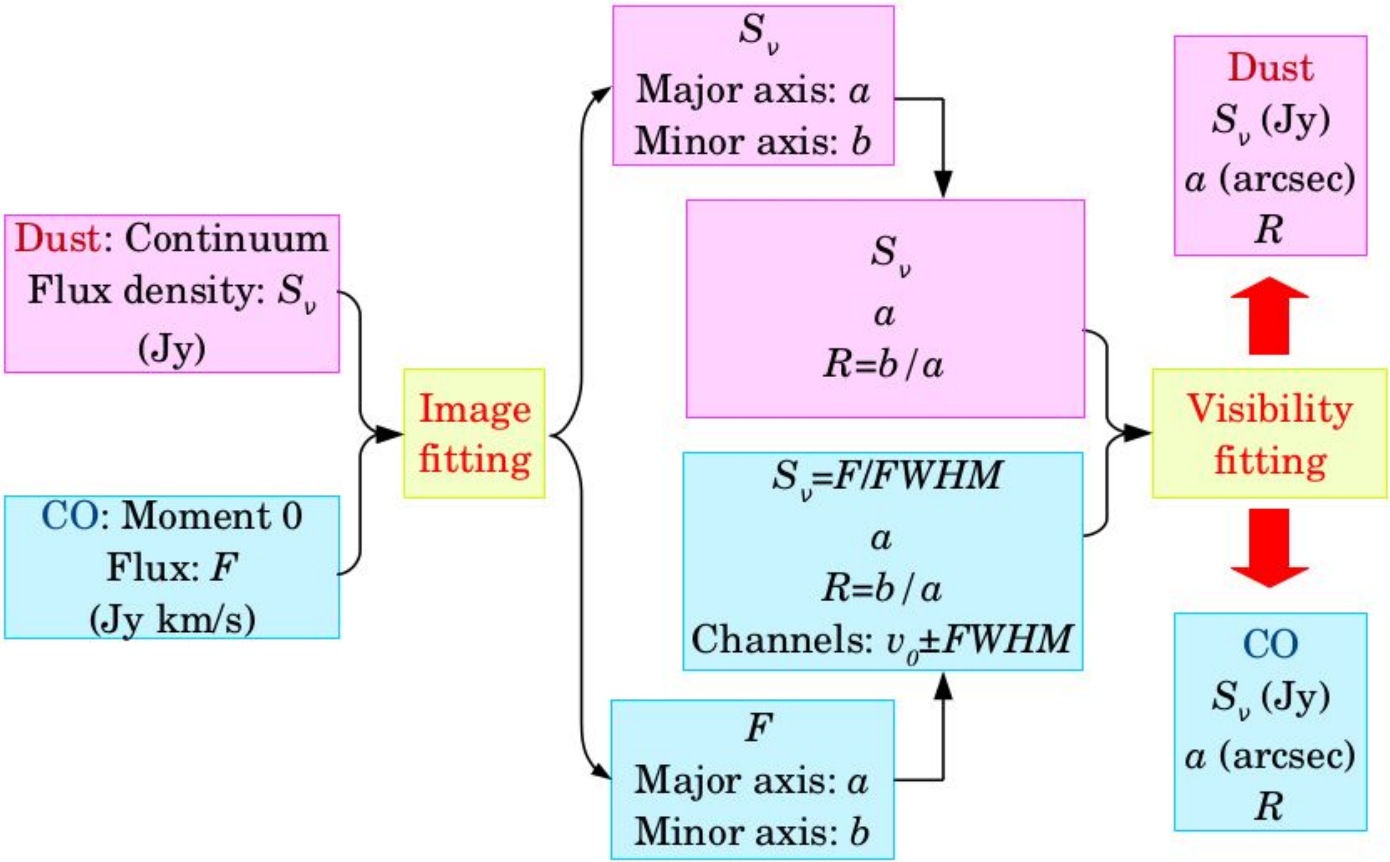
- Molecular masses derived from three different and totally independent measurements (i.e, CO transitions, continuum emission and SED fitting) are in agreement.
- Sources have M_{H2} ~ 10^{10} $M_{\odot}$ and M_{dust} ~ 10^{8} $M_{\odot}$ confined in few kpc.
- The host galaxy ISM can significantly contribute to the obscuration of the central AGN up to few 10^{24} cm^{-2} for the spherical model and up to tens 10^{24} cm^{-2} for the disk model.
- We found indication for both rotating system and more chaotical (possibly ascribed to a merger) structures.
- We found $M_{dyn} \approx 10^{10}$ $M_{\odot}$, $< M_{*} \approx$ few 10^{11} $M_{\odot}$.

Results in D'Amato et al (Submitted)

Peak channels and continuum



Fitting model: 2–D Gaussian



Fitting model: 2–D Gaussian

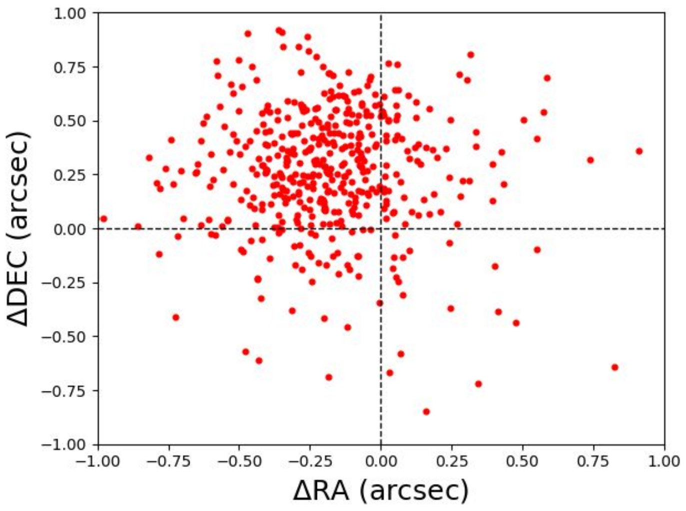
CO line

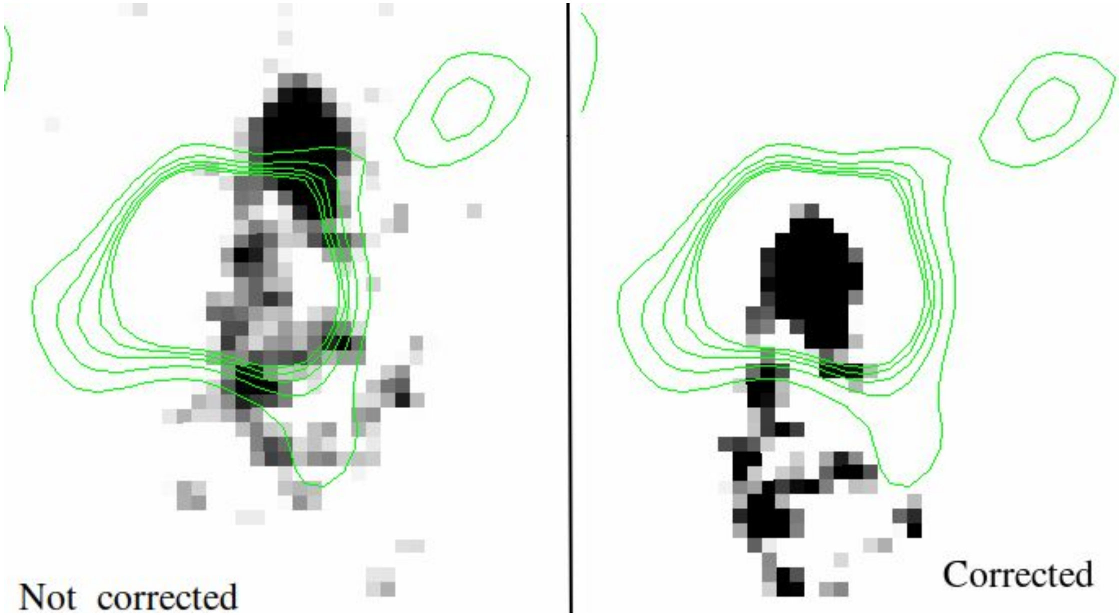
XID	Flux density (mJy)	Major axis (arcsec)	Axial ratio
34	1.5 ± 0.1	0.38 ± 0.04	0.6 ± 0.2
403	0.7 ± 0.1	0.46 ± 0.13	0.6 ± 0.3
490	1.01 ± 0.07	0.26 ± 0.04	0.5 ± 0.2

Dust Continuum

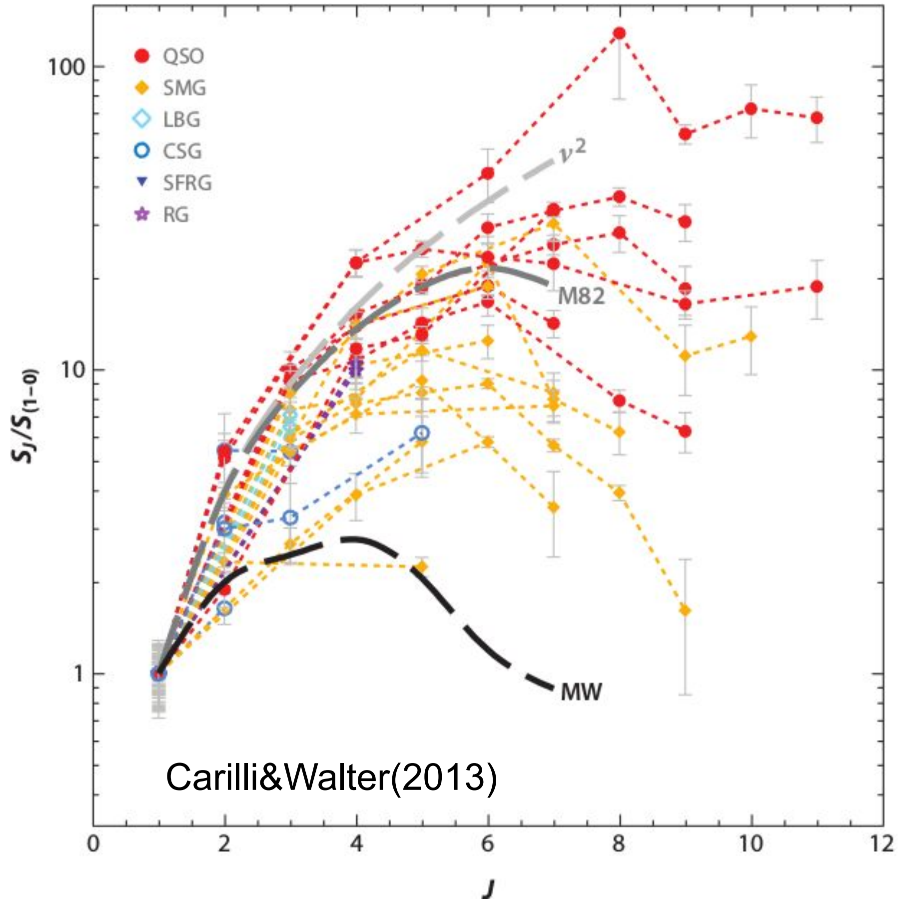
XID	Flux density (mJy)	Major axis (arcsec)	axial ratio
34	0.23 ± 0.02	0.34 ± 0.07	0.6 ± 0.3
403	0.41 ± 0.02	0.27 ± 0.03	0.6 ± 0.2
490	0.19 ± 0.02	0.17 ± 0.05	–

XID 34 displacement

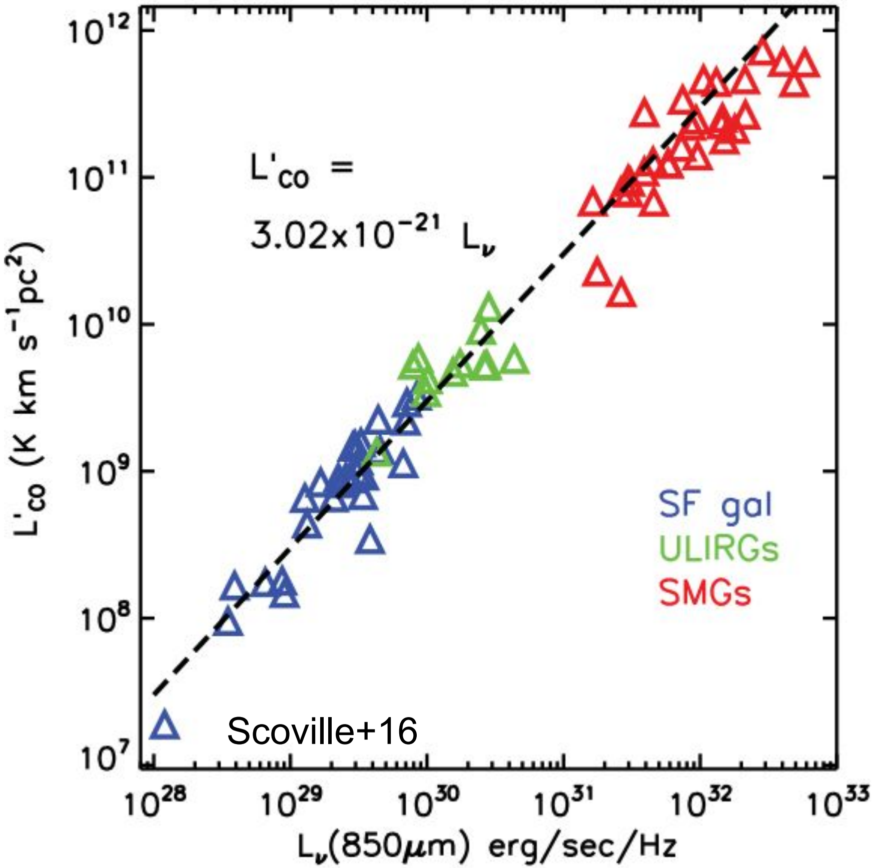




CO-SLEDs and Scoville relation



Carilli&Walter(2013)



Scoville+16