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

Quirino D'Amato

Alma Mater Studiorum – Università di Bologna

C.Vignali, R. Gilli, M. Massardi, C. Circosta

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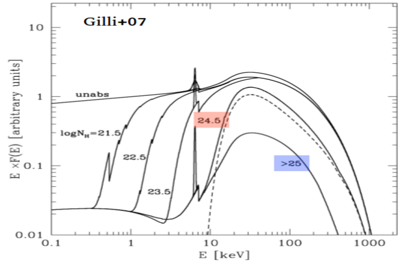
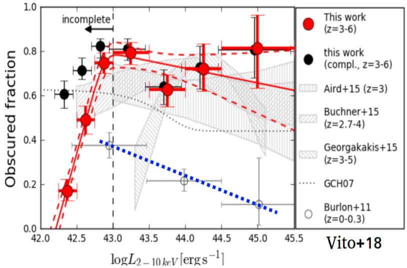
Obscured AGN

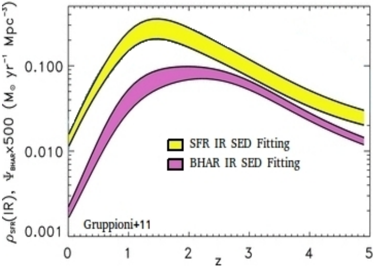


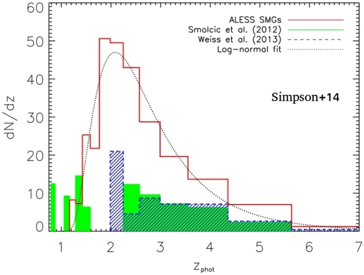


- **Unabsorbed**: $\log N_H < 21$
- **Compton thin**: $21 < \log N_H < 24$
- **Mildly Compton thick**: $\log N_H \sim 24 - 25$
- **Heavily Compton thick**: $\log N_H > 25$

AGN fraction increases at high redshift

Sub–Millimetre Galaxies





SFR density and BH accretion density peak at z ≈ 2

SMGs

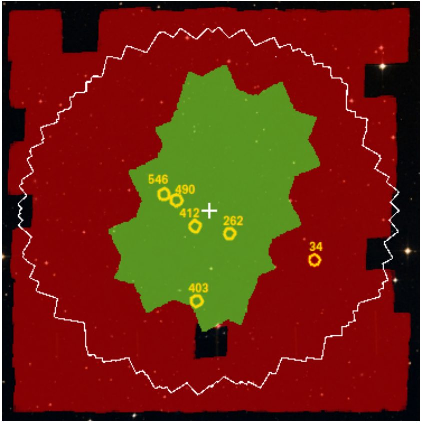
- Peak at z ≈ 2
- $M_* \sim 10^{10-11}\ M_\odot$
- $M_d \sim 10^8\ M_\odot$
- $M_{H_2} \sim 10^{10}\ M_\odot$
- SFR $\sim 10^{2-3}\ M_\odot/yr$
- $\tau_d \sim 10^8\ yr$
- AGN fraction:
  $\sim 0.5\ (L_{IR} < 10^{12}\ L_\odot)$
  $\sim 0.9\ (L_{IR} > 10^{12}\ L_\odot)$
- Size ∼ few kpc

Contribution of the host galaxy to the AGN obscuration?

Objectives and targets

- Measure masses and sizes of both dust and molecular gas components of a sample of SMGs at $z > 2.5$, observing continuum emission at $\sim$2.1 mm and one high–CO transition per source in ALMA band 4.
- Derive the column densities of the host ISM and compare them with those measured from the X–ray spectral fitting, assuming different geometries for the objects.
- Study the morphology and kinematics of the sources.

Objectives and targets



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

Parent samples

- 34 AGN at $z > 3$, selected in the 4–Ms CDF–S (Vito+13)
- 8 AGN at $z = 1.1$–3.7, selected in the 1–Ms CDF–S (Rigopoulou+09)

Selection criteria

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

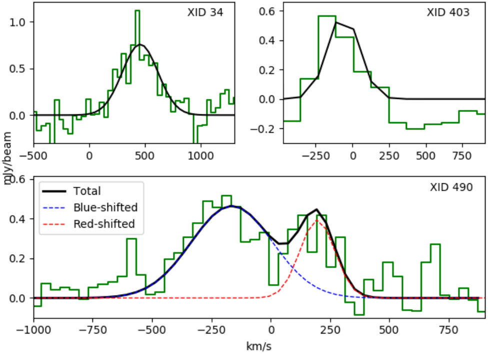
Derived sample: 6 sources

- $2.5 < z < 4.7$
- 260–2000 counts in the 7–Ms CDF–S, $(2 < L_{2-10keV} < 6) \times 10^{44}$ erg s^{-1}
- SFR $\sim 10^{2-3} M_\odot/yr$
- $M_* \sim 10^{11}\ M_\odot$

Spectral fitting

Three sources have been detected

Gaussian fitting of the lines



XID	v_0 (km/s)	FWHM (km/s)
34	498 ± 14	368 ± 32
403	-56 ± 33	308 ± 77
490(Blue c.)	-194 ± 26	474 ± 67
490(Red c.)	187 ± 12	162 ± 27

XID 34: the velocity peak is $\sim$ 500 km/s shifted wrt the rest–frame velocity at the spectroscopic redshift

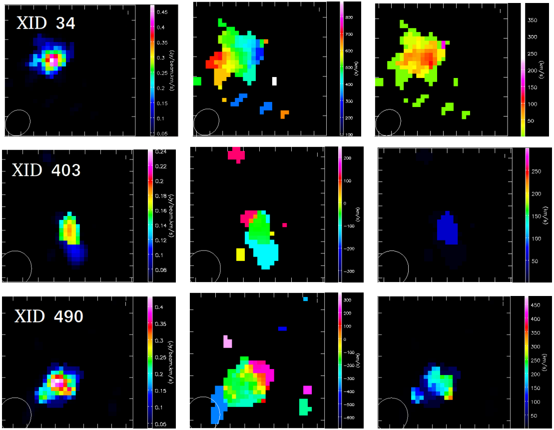
XID 490: double–peaked line, likely Doppler effect

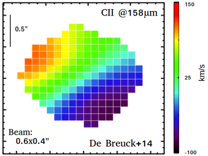
Moments of the line

Considered channels:
$v_0 \pm FWHM$

Image pixels $> 3\sigma$
Image sizes $\sim$ 2.7"

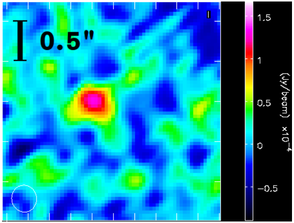
Flux | Velocity map | Velocity dispersion



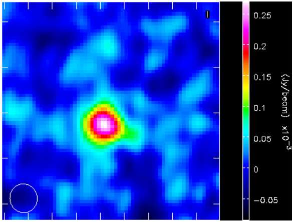


Continuum images

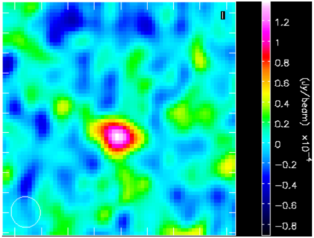
XID 34



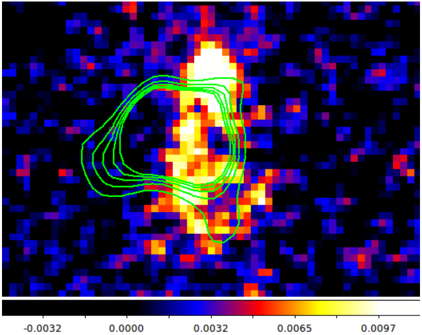
XID 403



XID 490



XID 34: Merger?



V–band ($\sim$ 600 nm) HST image

Green contours: ALMA continuum @3σ

Image size: 0.6 $\times$ 0.9 arcsec

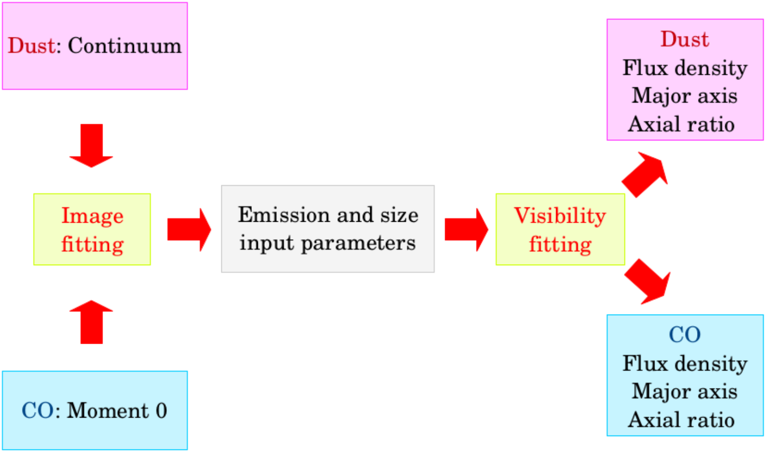
Displacement by $\sim$0.2" in the North direction between the center of the dust emission and the stellar bulk in UV band.

The shift of CO rest–frequency wrt optical spectrum rest–frequency can be explained as an intrinsic different motion velocity between the two regions.

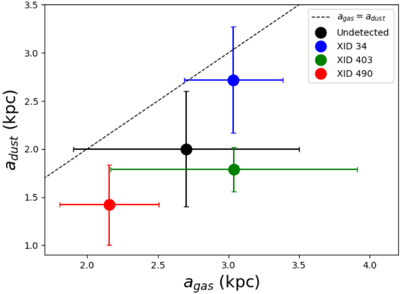
Astrometric problem?

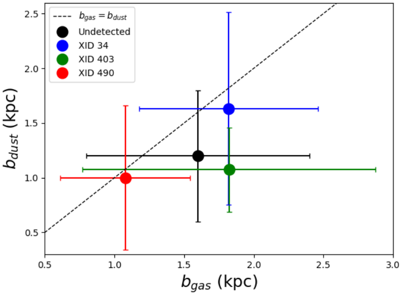
Data fitting – Procedure

Fitting model: 2–D Gaussian



Size of the sources



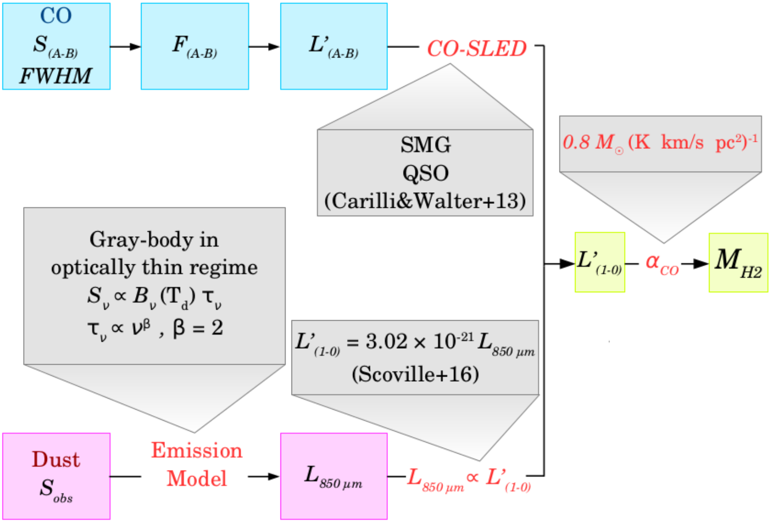


Assumptions

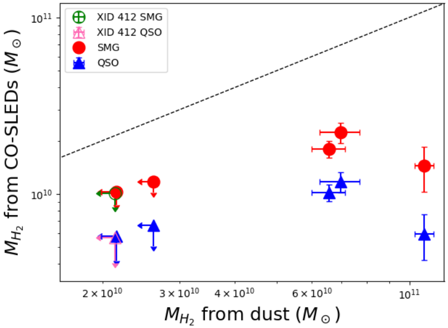
- **Undetected sources**: Size = mean of the detected sources, Error on $a = 30\%$, Error on $b = 50\%$
- **XID 490 dust** b: XID 490 dust b: Unconstrained by the fitting, assuming $R = 0.8$ (from the non–deconvolved image fitting), Error on $R = 50\%$

Size gas > Size dust

Gas mass - Different approaches



Gas mass



Undetected sources

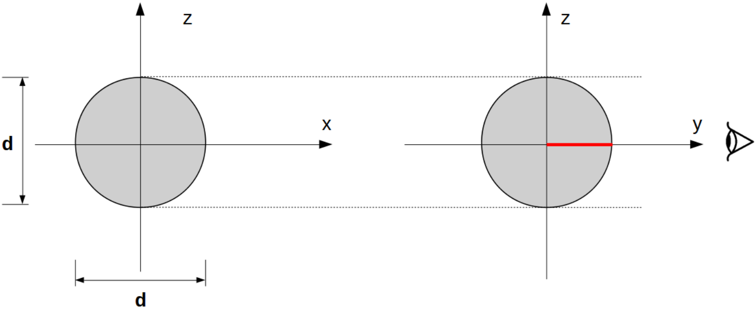
Upper limits at the 3σ level measured on the images for both the line and continuum emissions.

$$M_{H_2}^{DUST} > M_{H_2}^{CO-SLED}$$

$$M_{H_2}^{SMG} > M_{H_2}^{QSO}$$

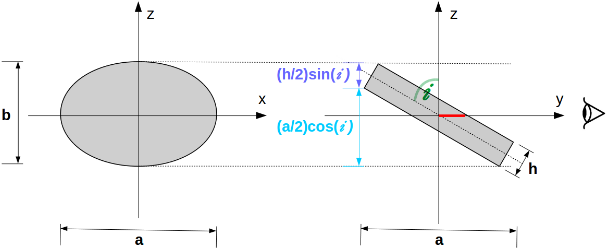
Geometrical models – Sphere

Goal: comparison with the rotating disk model



$$d = \frac{a_G + b_G}{2}$$

Geometrical models – Rotating disk



$$\begin{cases} b_D = a_D \cos(i) + h_D \sin(i) \\ b_G = a_G \cos(i) + h_G \sin(i) \end{cases} , \; h_G = h_D = h$$

POORLY

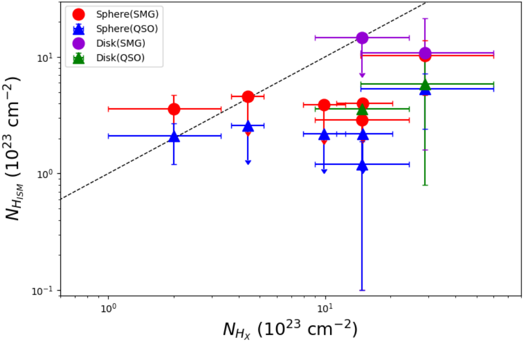
$$i_\pm = \pm \cos^{-1}\left(\frac{b_G - b_D}{a_G - a_D}\right) , \quad h_\pm = \frac{b_G - a_G \cos(i_\pm)}{\sin(i_\pm)}$$

CONSTRAINED

XID 403: $i = -41^{+84\,\circ}_{-60}$, $h < 1.68$ kpc , $h/a < 0.8$ @1σ

XID 490: $i = -81^{+52\,\circ}_{-53}$, $h = 0.8^{+0.6}_{-0.6}$ kpc , $h/a < 0.38^{+0.29}_{-0.28}$

Column density



Notes

- N_{H_X} from X–ray spectral fitting
- Upper limits at the 3σ level

N_{H_X} and $N_{H_{ISM}}$: same order of magnitude

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

Dust mass and temperature

XID	T (K)	M_d (10^8 $M_\odot$)
262	71	< 1.0
412	80	< 0.9
34	55	4.9 ± 0.7
403	65	4.8 ± 0.5
546	65	< 1.5
490	69	4.2 ± 0.5

Temperature

Single temperature (error $\approx \pm 5$ K), gray body IR–SED fitting:

$$S_\nu \propto B_\nu(T_d)\tau$$

$$\tau \propto \nu^\beta \ , \ \beta = 2$$

Mass

$$M_d = \frac{D_L^2 S_{obs}}{k_\nu B_\nu(T_d)(1+z)}$$

$$k_\nu \propto \nu^\beta \ , \ \beta = 2$$

Dynamical mass

$M_{dyn}\sin^2 i = 6.5 \cdot 10^4 \left(\frac{FWHM}{\mathrm{km\ s^{-1}}}\right)^2 \left(\frac{a}{\mathrm{kpc}}\right)\ M_\odot$ (Wang+13, Calura+14)
Assuming $v_{c,max} = 0.75 FWHM$

XID 403: $M_{dyn}\sin^2 i = 1.8^{+1.7}_{-0.9} \times 10^{10}\ M_\odot$ (Coppin+10 , De Breuk+14)

XID 490: $M_{dyn}\sin^2 i = 1.4^{+0.3}_{-0.3} \times 10^{10}\ M_\odot$

$M_{bar} = M_* + M_{H_2} + M_{HI} \approx 10^{11}\ M_\odot$, $\sim 10\ M_{dyn}\sin^2 i$
M_* from SED fitting , $M_{HI} \sim M_{H_2}/5$ (Calura+14)

For $M_{dyn} \approx M_{bar} \longrightarrow |i| \lesssim 10^\circ$, $h \gtrsim 6$ kpc UNREALISTIC

Possible causes

- Underestimate $M_{dyn}\sin^2 i$ conversion factor
- Different CANDELS/HST emitting region size wrt ALMA
- Uncertainty on position of $v_{c,max}$, underestimate a due to low sensitivity

Conclusions and future perspectives

- Sources have $M_{H_2} \sim 10^{10}\ M_\odot$ and $M_d \sim 10^8\ M_\odot$ confined in few kpc scale.
- The host galaxy ISM can significantly contribute to the obscuration of the central AGN for both spherical and disk model. $N_{H_{ISM}}^{SMG}$ is more consistent with N_{H_X} than $N_{H_{ISM}}^{QSO}$.
- Rotating systems and one possible merger.

- Future observations at better resolution ($< 0.1"$) and higher sensitivity ($\sim$6 h exposure to halve the current sensitivity) would drastically reduce the uncertainties on the physical quantities derived in this work.
- XID 403: CO–SLED coupling measured CO(7–6) with CO(2–1) by Coppin+2010 and CO(12–11) by Nagao+12 (upper limit).

San Giovanni in Monte complex

Registration (opening soon)

THANKS FOR YOUR ATTENTION