ALMA view of a massive spheroid progenitor: a compact rotating core of molecular gas in an AGN host at z=2.226

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SUMMARY

We present ALMA observations at 107.291 GHz (band 3) and 214.532 GHz (band 6) of GMASS 0953, a star-forming galaxy at z=2.226 hosting an obscured AGN that has been proposed as a **progenitor of compact quiescent galaxies** (QG). We measure for the first time the size of the dust and molecular gas emission of GMASS 0953 that we find to be extremely compact (~1kpc). This result, coupled with a very high ISM density ($n \sim 10^{5.5}$ cm^{-3}), a low gas mass fraction (~0.2) and a short gas depletion timescale (~150 Myr) imply that GMASS 0953 is experiencing an episode of intense star-formation in its central region that will rapidly exhaust its gas reservoirs, likely aided by AGN-induced feedback, confirming its fate as a compact QG. Kinematic analysis of the CO(6-5) line shows evidence of rapidly-rotating gas (Vrot~320 km/s), as observed also in a handful of similar sources at the same redshift. On-going quenching mechanisms could either destroy the rotation or leave it intact leading the galaxy to evolve into a rotating QG.

1. ID card

GMASS 0953

MS galaxy
$M_* = 1.15 \times 10^{11}\ M_\odot$
SFR = 214 $M_\odot$/yr

LIRG
$L_{IR} = 2.14 \times 10^{12}\ L_\odot$

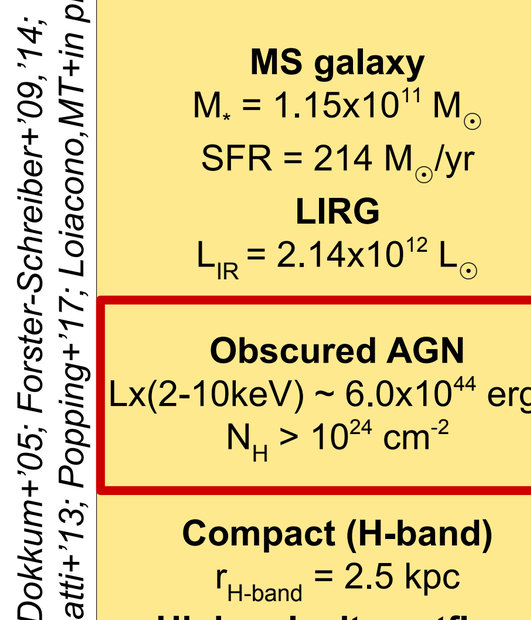
Obscured AGN
Lx(2-10keV) ~ 6.0×10^{44} erg/s
$N_H > 10^{24}$ cm^{-2}

Compact (H-band)
$r_{H\text{-band}}$ = 2.5 kpc

High-velocity outflow (neutral/ionized gas)
Δv ~ -800 km/s

vanDokkum+'05; Forster-Schreiber+'09,'14; Cimatti+'13; Popping+'17; Loiacono,MT+in prep.

2. Compactness

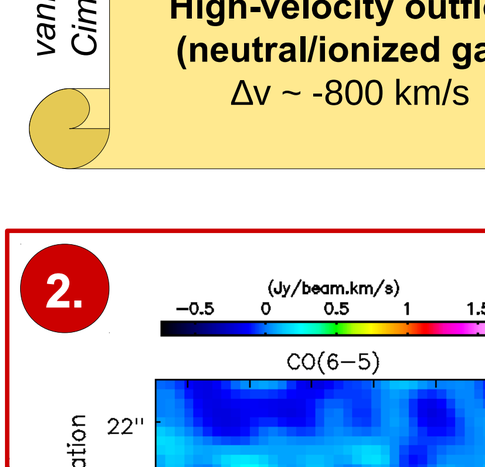


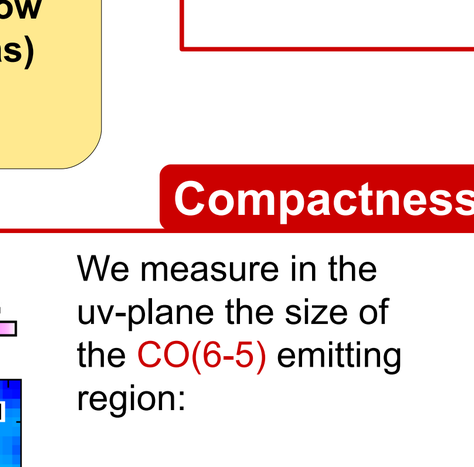
We measure in the uv-plane the size of the CO(6-5) emitting region:

$r_{CO} = 0.75 \pm 0.25$ kpc

that is very compact and comparable to dust continuum (SFR):

$r_{dust} = 1.24 \pm 0.40$ kpc



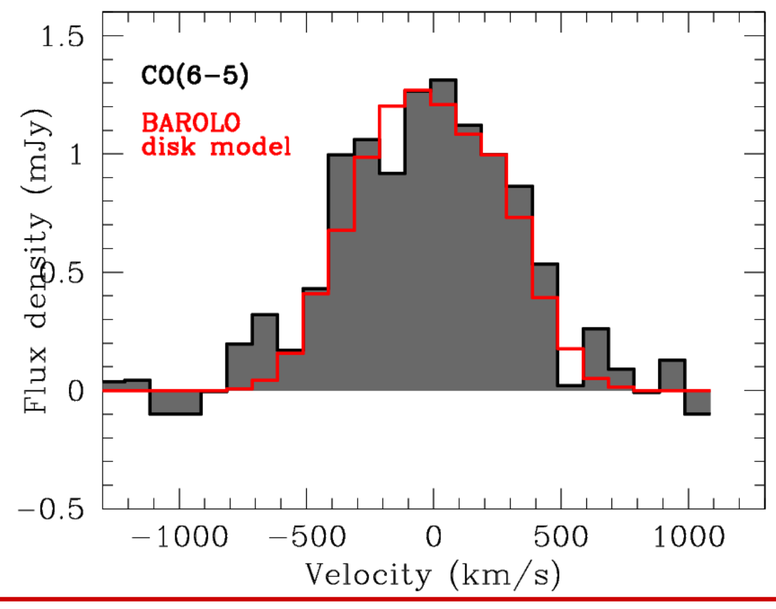


ALMA data	Band 3	Band 6
On-source time	32 mins	1.3 hrs
CO line	**CO(3-2)**	**CO(6-5)**
Central freq.	107.3 GHz	214.5 GHz
Ang. Res.	**0.6"**	**0.6"**
Bandwidth	1.875 GHz	1.875 GHz

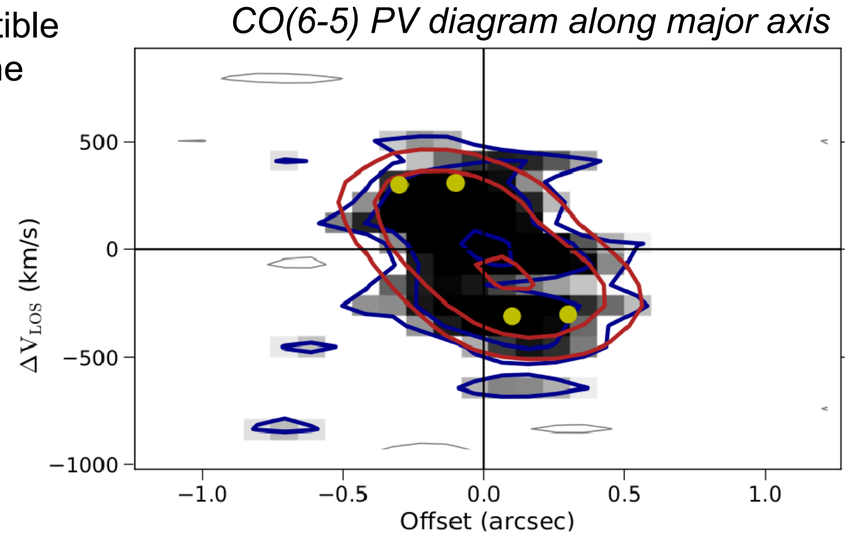
See also: Barro'+13,'15,'16,'17; Tadaki+'17a,b; Brusa+'18

3. Rapidly-rotating gas disk

The CO(6-5) line shows a velocity gradient compatible with disk-like rotation. We fit tilted-ring models to the datacube with **^{3D}Barolo** code *(Di Teodoro+'15)*



CO(6-5) PV diagram along major axis



Disk parameters:

$V_{rot} = 320 \pm 70$ km s^{-1} $\quad 60° < i < 90°$

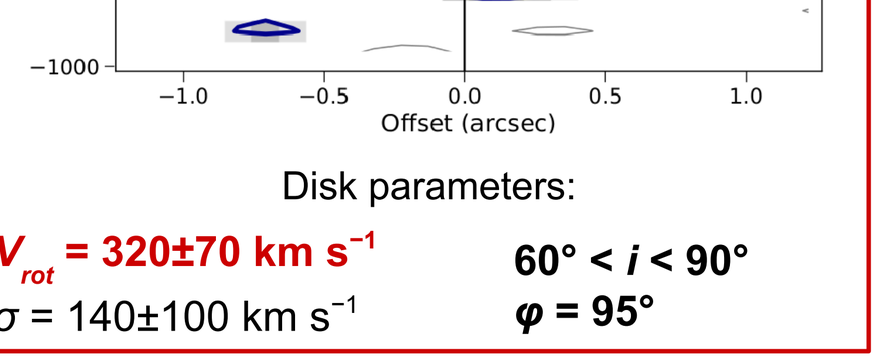
$\sigma = 140 \pm 100$ km s^{-1} $\quad \varphi = 95°$

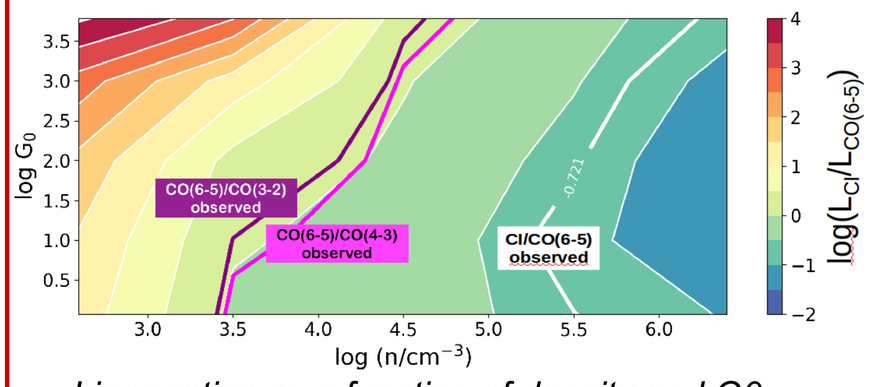
Extreme ISM properties and short depletion time-scale

4. We compare observed lines ratios with CLOUDY models (*Ferland+'17*) predictions. We find that at least two gas components are needed to reproduce the observations:

- diffuse, extended PDR (low-J)
- compact, high-density PDR or XDR, with an estimated density typical of starbursts:

$\log(n_{2nd}) = 5.5$ cm^{-3}





Lines ratios as a function of density and G0

From different tracers (CO-SLED, dust) we estimate the total gas mass:

$M_{gas} = 3.24 \times 10^{10}\ M_\odot$

and the depletion time-scale:

$\tau = M_{gas}/SFR = 150$ Myr

which is much shorter than in MS galaxies at the same redshift

Will GMASS 0953 evolve into a compact quiescent galaxy?

5.

Gas cooling/infall
→ Dust-obscured SF & BH growth

YES!

→ **Powerful AGN activity**
"Quasar" mode: luminous obscured phase
– feedback (outflow; gas ejection)
– fast gas consumption (short τ)

Compact core

Rapid gas rotation

→ Quenching of SF
Puffing-up; dry mergers
→ Compact quenched galaxy ("red nugget")

Lapi+'18