Black hole accretion preferentially occurs in gas rich galaxies

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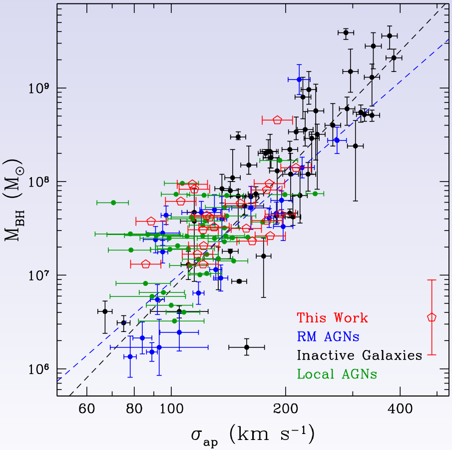
Outline

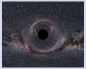
A connection between SMBH and galaxy properties

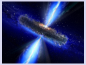


(Bennert et al. 2011)

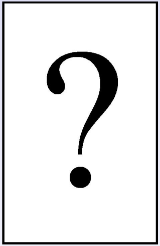
M_{BH} correlates with M_{bulge}, σ_v, L_{bulge}

e.g. Magorrian+98, Ferrarese & Merritt 00, Gebhardt+00, Tremaine+02, Marconi & Hunt 03, Häring & Rix 04, Kormendy+11, Kormendy & Ho 13, etc



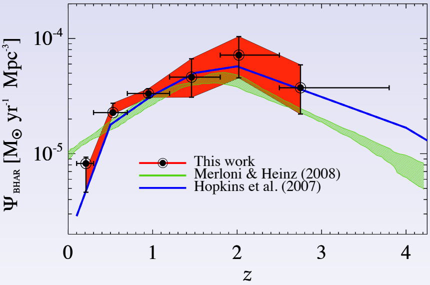


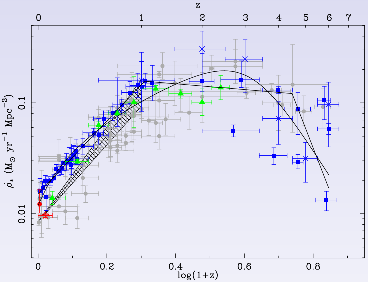
SMBH ⟶⟶⟶ grow through accretion ⟶⟶⟶ AGN



galaxies ⟶⟶ grow through star formation ⟶⟶⟶ SFR

SMBH accretion and SFR have similar redshift evolution





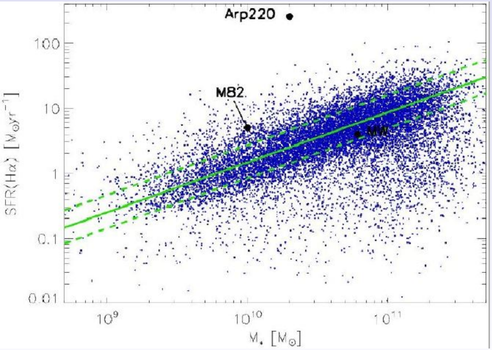
(Hopkins&Beacom06)

(Delvecchio+14; see also Boyle&Terlevich 98, Granato+01, Marconi+04, Hopkins&Beacom 06, Silverman+09, Aird+10)

AGN and galaxies share a COmmon EVOLUTION.

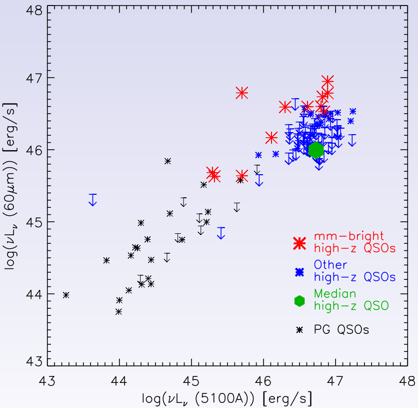
A more direct connection between AGN and the star formation?

Are AGN equally found in all types of galaxies (quiescent/star forming/starbursting galaxies)?



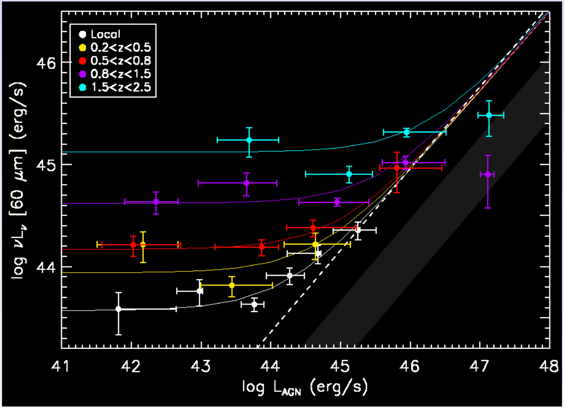
(Elbaz et al. 2007)

High-luminosity regime



(Lutz+08, see also Netzer+07)

$L_{60\mu m}$ (indicator of SFR) correlates with L_{opt} in Type I QSOs at $z \sim 2$



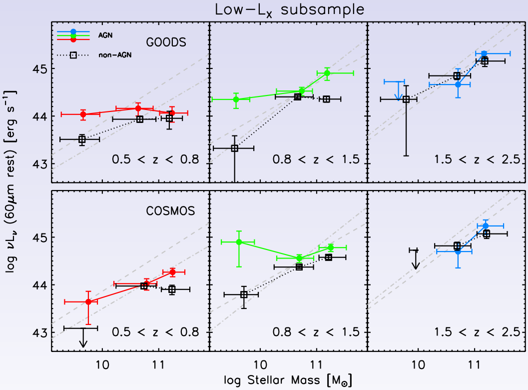
(Rosario+12, see also Shao+10)

$L_{60\mu m}$ used as an indicator of SFR

Two modes of AGN evolution? (see e.g. Lutz+08, Shao+10, Rosario+12,+13, Santini+12,+14)

- Wet merger driven at high L_{AGN} (AGN coupled with SF)
- Secular processes at low L_{AGN} (AGN not correlated with SF)

AGN reside preferentially in main sequence galaxies



(Santini+12)

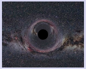
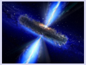
Slight enhancement at low-L, too.

It disappeares if only PACS detected objects are considered.

⇓

AGN prefer star forming galaxies

(see also Rosario+13, Silverman+09)

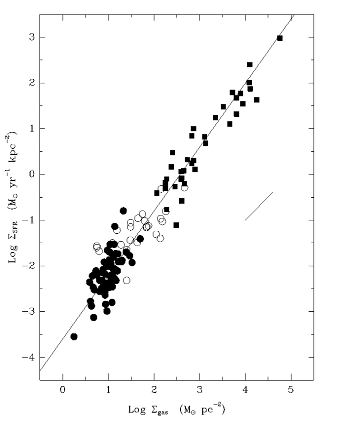
SMBH ⟶⟶⟶ grow through accretion ⟶⟶⟶ AGN


galaxies ⟶⟶ grow through star formation ⟶⟶⟶ SFR


A more fundamental property

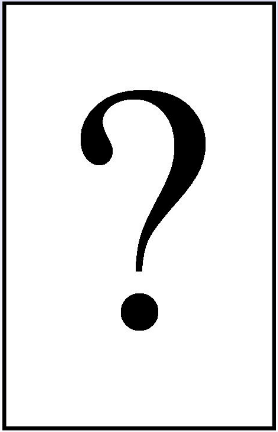
$\Sigma_{SFR} \propto \Sigma_{H2}^{1.5}$

(Schmidt 1959, Kennicutt 1998)

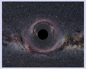


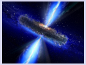
SFR vs GAS: ✓

$L_{AGN} \propto \dot{M}_{GAS}$



AGN vs GAS: ?





SMBH ⟶⟶⟶ grow through accretion ⟶⟶⟶ AGN

↑

GAS

↓

galaxies ⟶⟶ grow through star formation ⟶⟶⟶ SFR

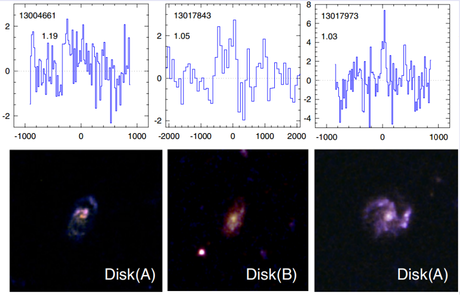
Measuring M_{gas}

CO-to-H_2 conversion factor

$$\alpha_{CO} = \frac{M_{H_2}}{L_{CO}} \qquad CO\ J = 1 \rightarrow 0$$

but..

- Very time consuming (hard to collect large samples)



(Tacconi+13)

- Conversion factor very uncertain and strongly dependent on metallicity and environment (see Bolatto+13 and references therein)

Measuring M_{gas}

Alternatively, dust-to-gas ratio

$M_{gas} = \frac{M_{dust}}{DGR}$ $\qquad$ $M_{gas} = M_{H_2} + M_{HI}$

see e.g. Eales+10, Leroy+11, Magdis+12, Scoville+12

How does it work?

- **$\mathbf{M_{dust}}$ from FIR/sub-mm SED fitting**
- M_* from UV-to-nearIR SED fitting
- Metallicity from FMR (Mannucci+10,+11)
- Assuming the local DGR-Z relation (Leroy+11 and references therein)

Caveats:

- **Uncertainties on $\mathbf{M_{dust}}$** (and M_*)
- Assuming local DGR-Z relation does not evolve (confirmed by e.g. Mannucci+10, Cresci+12, Nakajima+12, Henry+13, Belli+13)
- Indirect measurement of metallicity

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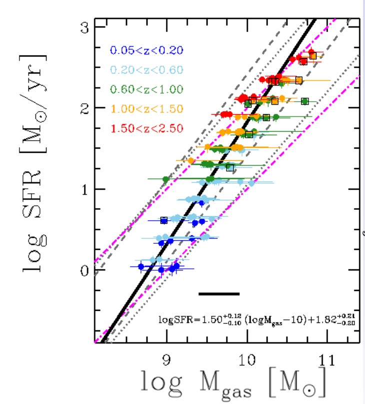
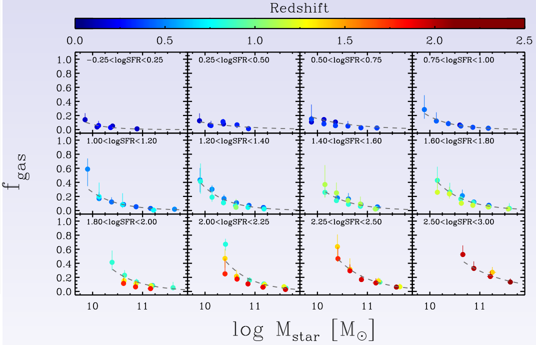
Gas content in galaxies (from dust)





(Santini+14)

(SFR vs M_{gas} $\longrightarrow$ "Integrated" SK relation, see also Daddi+10)

Goal of this work

Is the gas content in AGN-hosting galaxies different than in inactive galaxies?

Data set

- Data from COSMOS, GOODS-South and GOODS-North fields.
- Herschel FIR data from PEP (100 and 160 μm; Lutz+11, Berta+11) and HerMES (250, 350 and 500 μm; Oliver+12, Roseboom+10,+12) surveys.
- Multiwavelength coverage from X-rays to IR and redshifts (Alexander+03, Bauer+04, Grazian+06, Ilbert+09, Santini+09, Brusa+10, McCracken+10, Berta+11, Salvato+11, Xue+11, Civano+12)

AGN and galaxy samples selection

Parent sample selection:

1. $SNR \geq 10$ in the K band
2. $z \leq 1$

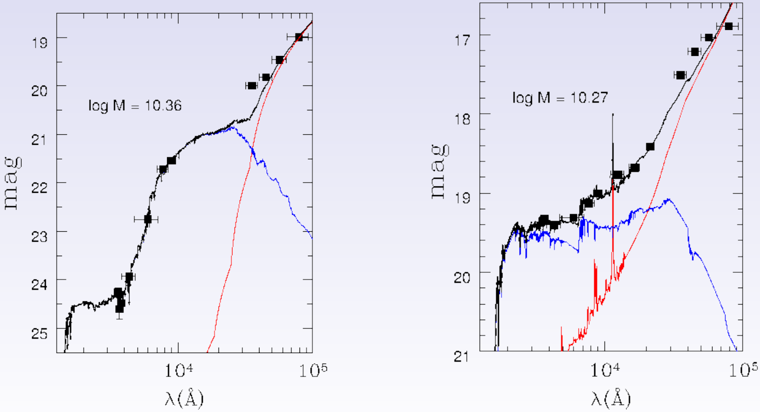
AGN classification:

- X-ray detected objects
  - Optical spectroscopy classification (Bauer+04, Brusa+10, Civano+12, Xue+11)
  - SED classification (Salvato+11)
  - X-ray classification (Bauer+04, Brusa+10, Civano+12, Xue+11)
- X-ray undetected objects
  - IRAC colours (Donley+12 criterion)

otherwise galaxy

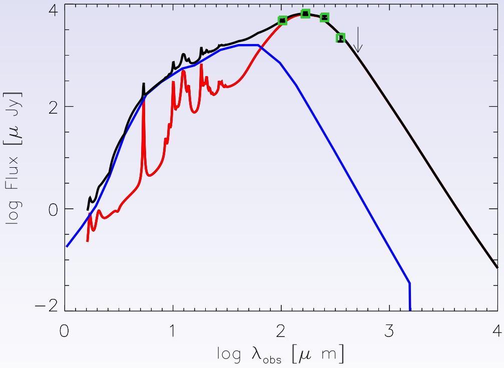
Parameters derivation: M_*

UV-to-nearIR photometry fitted with a combined library of synthetic stellar templates (Bruzual&Charlot 03) and AGN templates (Silva+04; only for AGN) as in Santini+12.



Parameters derivation: M_{dust}

Herschel FIR photometric points fitted with a combined library of dust emission (Draine&Li 07) and AGN templates (Silva+04; only for AGN).



Parameters derivation: M_{dust}

BUT...small fraction of sources (the most luminous in FIR) individually detected by Herschel

$\Downarrow$

Low statistics and luminosity/mass bias

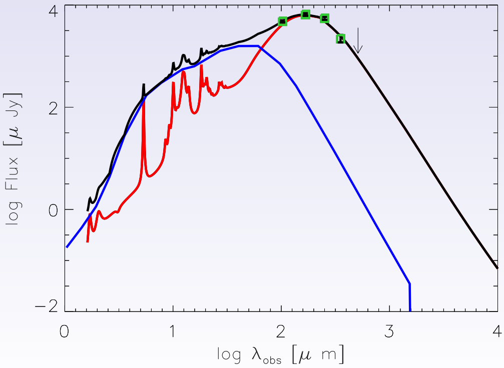
$\Downarrow$

Stacking Herschel fluxes (in bins of stellar mass and redshift) to increase statistics and luminosity completeness (see also Shao+10, Rosario+12, Santini+12,+13)

z	$\log(M_*/M_\odot)$					
	9-10	10-10.5	10.5-11	11-11.25	11.25-11.5	11.5-12
0.0-0.3						
0.3-0.6						
0.6-0.8						
0.8-1.0						

Parameters derivation: M_{dust}

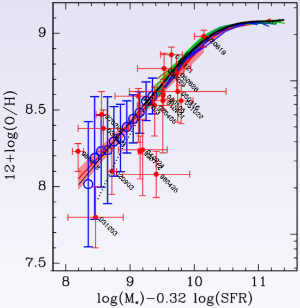
1. $\geq$ 10 objects in the bins
2. $\geq 3\sigma$ detection of the stacked flux for at least 3 Herschel bands
3. $\geq 3\sigma$ detection for at least 1 Herschel-SPIRE band (350 and/or 500μm)



$$\bar{S} = \frac{S_{stack} \times N_{stack} + \sum_{i=1}^{N_{det}} S_i}{N_{stack} + N_{det}}$$

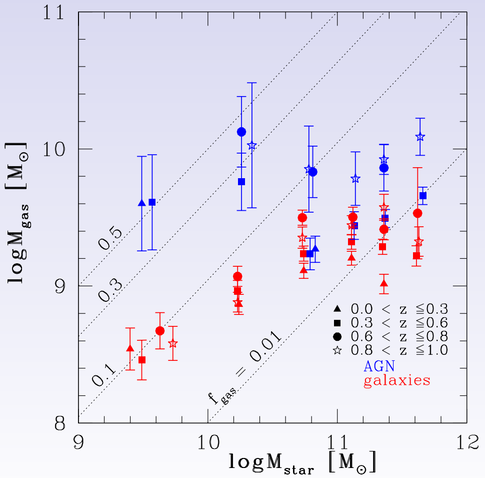
Parameters derivation: M_{gas}

1. $M_{gas} = M_{dust}/DGR$ (e.g. Eales+10, Leroy+11, Magdis+10,+12, Scoville+12)
2. $DGR = 0.01 \times 10^{Z-Z_\odot}$ from Draine+07, assuming local relation (many works suggest it does not evolve)
3. $Z = 12 + \log(O/H) = f(M_*, SFR)$ (Mannucci+10,+11)

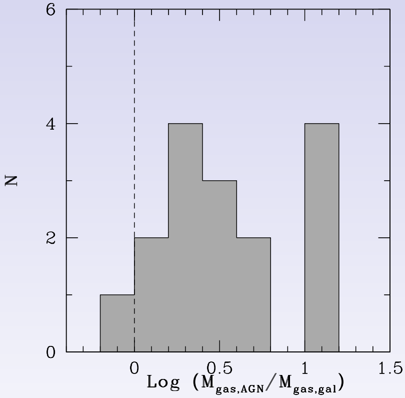


4. $SFR = 1.8 \times 10^{-10} L_{8-1000\,\mu m}$ (∼ Papovich+07, Bell+05. "Unobscured" SF not accounted for.)

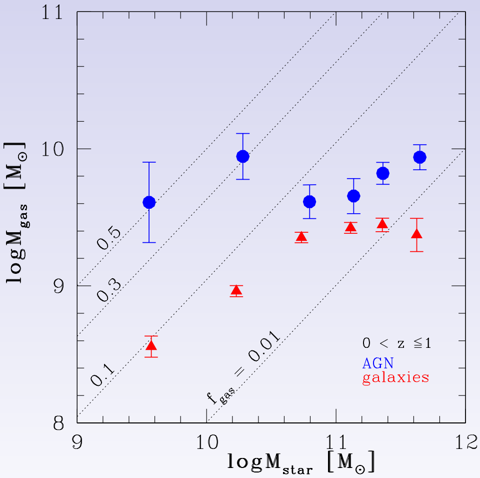
Main result



$f_{gas} = M_{gas} / (M_{gas} + M_*)$



In 15/16 $z - M_*$ bins $M_{gas,AGN} > M_{gas,gal}$ and $f_{gas,AGN} > f_{gas,gal}$
In almost 50% of the bins the difference is more than a factor of 3.



No clear trend with redshift ⟶ average over all redshift bins to gain statistics

Discussion and conclusions

Black hole accretion preferentially occurs in gas rich galaxies

as tentatively suggested by many authors (e.g. Silverman+09, Santini+12, Rosario+12,+13), but NOW WE SEE IT!

Not really surprising: more gas $\longrightarrow$ statistically easier that a gas cloud falls into the potential of the SMBH.

No need to invoke specific triggering mechanisms (but supporting triggering mechanisms due to disk instabilities, enhanced in gas-rich disks).

It also naturally explains why AGN preferentially reside in star forming galaxies.

However, AGN – SFR relation is less clear (additional spread introduced by SK relation, contribution of triggering mechanisms that affect the SF efficiency).

Future perspectives

ALMA observations (e.g. in COSMOS) can provide further constraints on the sub-mm/mm dust emission in galaxies and AGN, allowing us to relax the requirements on Herschel data and to explore a wider redshift range