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Evidence for feedback in action from the molecular gas content of an obscured QSO at z~1.5

Marcella Brusa

DIFA-Dipartimento di Fisica e Astronomia / Università di Bologna
 INAF / Osservatorio Astronomico di Bologna

C. Feruglio G. Cresci, V. Mainieri, M. Sargent, M. Perna et al.

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Active Galactic Nuclei in a cosmological framework

1) AGN trace SMBH

MAIN FACTS:

2) (non active) SMBH are ubiquitous in nearby galaxies Chandra, HST, VLA/VLBI surveys of Palomar sample, AMUSE-VIRGO (Elvís § Keel '84; Ho, Fílíppenko, Nagar, Wílson, Gallo etc. 1997-2007)

→ AGN transient phase

Phase in an evolutionary sequence

Hopkins et al. 2008 (see also Gilli talk)



Silk & Rees 1998, Granato+2004, Di Matte+2005, Croton +2006, Fontanot+2006, De Lucia+2006, Sijacki+2007, Menci+2008, Marulli+2009, Lapi+2014, Toft+2014

Major mergers can trigger SF and BH activity

strong correlation between M_{BH} and bulge properties (e.g. Ferrarese & Merritt 2000, Gebhardt et al. 2000, Marconi & Hunt 2003, Haring & Rix 2004, Gultekin et al. 2009, Kormendy & Ho 2013)

QSO-ULIRGS connection (e.g. Sanders et al. 1988,)

see also Hickox+2009, Allevato+2011,Wang+2014 from cross-correlation studies see also Draper & Ballantyne 2012 from XRB modeling

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!!! only one of the possible paths... mergers vs. secular vs. regulation/hot halo!!!
Cen 2012, Di Matteo et al. 2011, Bournaud et al. 2011, Ciotti&Ostriker 2007

MAIN IMPLICATIONS:

"Feedback" in the form of "ejecting" wind

e.g. Sanders+1988, Di Matteo+2005, Hopkins+2008, Debuhr+2012



Compton Thick BH Growth INFRARED

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OPTICAL

MERGERS MODEL PREDICTIONS/IMPLICATIONS:

- 1) **blow-out/feedback** phase very short (**<< 100 Myr) RARE !**
- 2) BH growth and SF almost "simultaneous"
- 3) blow-out/feedback phase X-ray active and obscured
- 4) blow-out/feedback phase IR bright



Finding the "sweet spot" for feedback

-Law Source Subrent Flux

0.6

Time (Gyr)

0.8

Peak SFR * Peak BH Accretion .

1.0

3

e.g. Sanders+1988, Di Matteo+2005, Hopkins+2008, Debuhr+2012



AGN in FEEDBACK/OUTFLOWS:

X-ray luminous, obscured and "dusty" at z=1-3, on large area X-ray surveys •

XMM-COSMOS obscured QSOs

Brusa+2015, MNRAS



Selection based on X-ray-to-optical (X/O) or MIR to optical (MIR/O) and NIR to optical (R-K, R-3.6) colors

Efficient to pick-up **luminous** (X/O correlates with Lx, e.g. Fiore,MB+2003) and **obscured** (X/O and MIR/O correlates with NH, e.g. Mignoli+2005, Fiore+2008, Lanzuisi+2009) at **z=1-3** (R-K>4.5 indicate z=1-3, galaxy-AGN coevolution peak)

Based on **observed properties** rather than physical properties, i.e. "fast and cheap" selection wrt to other selections (e.g. N_H vs. L/L_{Edd} Fabian+2008, Raimundo+2010, Ballo+2014) and also more unbiased (e.g. wrt BAL QSOs)

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XMM-COSMOS obscured QSOs

Brusa+2015, MNRAS

2

0

-1 _0

log(X/0)

all XM

phot

IO targets X-ray (Lx>44) and K-band (K<19) brightest objects at z~1.25-1.72 from XMM-COSMOS AGN sample observed in the NIR with VLT/X-shooter

including XID2028

Selection based on X-Efficient to pick-up **Iui** NH, e.g. Mignoli+2005, Fiore

Based on **observed** selections (e.g. N_H vs

9. A PROTOTYPICAL OBSCURED QSO AT z = 1.59

Almost by definition, most of the high-z obscured AGN candidates isolated Section 7 are expected to be undergoing this peculiar phase of their evolution. The most extreme object in the spectroscopically identified sample which satisfies the selection criteria described in Section 7 is XID 2028 (z = 1.592), marked

(from Brusa+2010)



X-shooter broad-band VIS to NIR spectra

4 with spec-z available (DEIMOS, VIMOS), 6 with photo-z. 5/6 new spec-z assigned (very high success rate)

wrt 50% in e.g., Banerji+2012,15 see also Bongiorno+2014



X-shooter broad-band VIS to NIR spectra

4 with spec-z available (DEIMOS, VIMOS), 6 with photo-z. 5/6 new spec-z assigned (very high success rate)

simultaneous multi-component fit systemic+BLR+outflow

"Narrow" Systemic: measure redshift

BLR (Broad Hα): (FWHM>2000 km/s) measure BH mass

detected in 5/8SMBHs with $M_{BH}=10^8-10^{10} M_{\odot}$ (massive!) (Bongiorno, Maiolino, MB et al. 2014)

"Broad/shifted" ([OIII], [NII]): (FWHM=900-1600 km/s) ascribed to **outflows**

detected in 6/8 (75%) common feature!







Foerster-Schreiber+14, Genzel+14

Zakamska&Greene14, Harrison+14

XID2028: Revealing the outflow (1) X-shooter slit-resolved spectroscopy

Perna, MB+2015, A&A



XID2028: Revealing the outflow (2) SINFONI J-band data (PI: V. Mainieri)



XID2028: Revealing the outflow (2) SINFONI J-band data (PI: V. Mainieri)



XID2028: Feedback in action SINFONI H-band data and ACS

Residual map of **narrow H** α **component** (tracing star formation) from H+K SINFONI data

HST rest-frame UV countours

same pattern! SF is patchy with 2 blobs

Outflow contours and velocity width

outflow lies at the center of a cavity in SF regions!



the outflow is removing gas from the host galaxy **(negative feedback)** and is triggering SF by outflow induced pressure at the edges **(positive feedback)** - see also Carniani+2015 (see Alessandro Marconi talk)

Cresci, Mainieri, MB+2015, ApJ



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Plateau de Bure Interferometer observations



Brusa, Feruglio et al. 2015, A&A

Plateau de Bure Interferometer observations



Gas content

Brusa, Feruglio et al. 2015, A&A

From observed to physical properties --> which excitation ratio? which αCO?



consistent with **non-detection in CO(2-1)** SFE~110 (in between ULIRGs/QSO and MS galaxies) **Gas content**

Brusa, Feruglio et al. 2015, A&A

From observed to physical properties --> which excitation ratio? which αCO ?



consistent with **non-detection in CO(2-1)** SFE~110 (in between ULIRGs/QSO and MS galaxies) RED: "ULIRG" assumption (compact system) BLUE: "MS" assumption (extended SF disk) GREEN: dust fitting (Vito+2014)

(b)

1000

Gas content

Brusa, Feruglio et al. 2015, A&A

From observed to physical properties --> which excitation ratio? which αCO ?







XID2028 is among the objects with the lowest gas fraction for its sSFR detected so far in the high-z Universe and associated to normal MS galaxies (especially when compared to similar masses) and a clear outlier in the tdepl-sSFR plane





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Summary

(I) Feedback phase is luminous, X-ray bright and dusty

---> "cheap" selection based on optical to NIR to MIR colors applied to X-ray sources

(2) Selection does work!

large scale (>10 kpc) outflow present in X-ray luminous, obscured XMM-COSMOS QSOs

- ---> inferred for 6 sources from [OIII] widths & shifts in integrated X-shooter spectra Brusa et al. 2015a, MNRAS
- ---> confirmed by X-shooter slit-resolved spectroscopy (XID5321, XID2028) Perna et al. 2015, A&A
- ---> directly detected in SINFONI/IFU data (XID2028) Cresci et al. 2015, ApJ

(3) Outflow has effect on host galaxy (XID2028)

---> "negative" and "positive" feedback revealed Cresci et al. 2015

--> less gas than expected! Feedback already removed the gas Brusa et al. 2015b, A&A

FOLLOW-UP planned to sample high-J transitions (excitation) and imaging with more resolution (morphology) and sensitivity (molecular outflow, broad wing; see Gallerani talk)





of normal "MS" galaxies --> different physical processes --> less gas because it is depleted!









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