Radio-excess: a signature of AGN in distant star-forming galaxies

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In collaboration with:

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Why looking for missing AGN?

**BH-spheroid growth connection**

**Missing AGN population**

- Worsley et al. (2005)

X-ray background is not fully resolved at >6 keV

**Major-merger evolution scenarios**

- gas-rich galaxy(s) → SMG/ULIRG → obscured quasar → unobscured quasar → early-type galaxy

Alexander & Hickox (2012), review
Deep X-ray surveys are great to detect distant AGN…
… but still not complete

Brandt & Hasinger (2005) for a review
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Go multiwavelengths!

3C 273
I Zwicky 1
NGC5548
NGC3783
NGC6240
NGC4051
NGC1068
5 ks NDWFS Bootes
2 Ms CDF-N detection limit
Track for N1068
Track for N210

log (observe-frame 0.5-8.0 keV luminosity) erg s$^{-1}$

Redshift

38
40
42
44
46

0.1
1
10

Unidentified AGNs (majority)

GOODS-Herschel
PI: D. Elbaz

Herschel
Spitzer
VLA
Competing processes heating the dust

SMBH accretion

Star formation

Dust

Reprocessed emission in the infrared/sub-mm bands
AGN-galaxy SED decomposition

5 host galaxy templates (Mullaney+2011)

Extended to:
- 3 um using average SB SED (Dale+2001)
- radio band ($f_{\nu} = \nu^{-0.7}$), FIR/radio ratio ~2.2 (Helou+1985)

Empirically defined AGN template (Mullaney+2011)
+ Extinction

Chi squared $f$-test
Identifying the AGN dominating the cosmic BH growth

- Large population of X-ray undetected AGN are identified in IR at z<2

- Stacking of X-ray undetected IR AGN at z<1 consistent with reflection dominated spectrum

Del Moro et al., in prep

Alexander et al. (2011)
Radio-excess sources

- Tight FIR/radio correlation for star-forming galaxies $q \approx 2.2$ (Helou et al. 1985)

- Population of 51 radio-excess sources $q < 1.68$ out to $z = 3$

- 47% are undetected in X-rays
Excess radio emission from AGN

- Compact radio core detected by VLBI for 8 sources
- Radio core flux predicted within a factor ~2 by SED analysis

Chi et al. (2009)
Identified 3 types of SEDs:
- IR SFG
- IR AGN
- Passive systems

Limited in identifying AGN component when not dominating the SED

Discrepancy between X-ray and 6 um luminosities

▶ heavily obscured AGN
Star-formation in radio-excess AGN

- Star-formation rate per unit mass lower than typical X-ray selected AGN
- Different stages of evolution?
Summary

- IR SED analysis very effective in identifying AGN out to $z \approx 2$
- Stacked X-ray data of X-ray undetected IR AGN at $z < 1$ consistent with reflection dominated spectrum $\Rightarrow$ heavily obscured/CT AGN
- Radio-excess emission can reveal the presence of AGN activity when other methods cannot
- Heterogeneous SEDs of radio-excess sources: IR SFG, IR AGN, passive systems $\Rightarrow$ snapshots of different stages of evolution?
- Specific SFR lower than typical X-ray selected sources $\Rightarrow$ radio-excess or dimmed star-formation?
Stacked X-ray data of the X-ray undetected IR AGNs: consistent with reflection dominated: heavily obscured/Compton thick

Properties consistent with producing the unresolved X-ray background at 30 keV:

z~1, intrinsic $L_X \sim 10^{43}$ erg/s
And heavily obscured