AGN demography and SED: from the X-ray to the optical

Vincenzo Mainieri
• What are the links between black-hole growth and their host galaxies and large-scale environments?
• What is the detailed nature of AGN feedback and its effects on black-hole fuelling and star formation?

AGN11: Where Black Holes and Galaxies meet, Trieste Sep 25, 2014
Context

GOAL : Link the physical properties of the central SMBH with those of its host galaxy

In order to achieve this goal there are some “preliminary” steps that we have to do:

- Detect “all” AGNs: the AGN population traces the cosmic SMBH growth history
- Disentangle AGN and galaxy emission … characterize the properties of their host galaxies (e.g. SFR, $M_{\text{star}}$)
- Characterize their evolution … and compare it to that of their host galaxies
Tool: X-ray surveys

- X-ray is the cleanest way to select AGNs
- [0.5-10 keV] biased against C-thick sources
The AGN Luminosity Function as the main demographic quantity
(e.g. Maccacaro+91; Boyle+93; Miyaji+00; Wolf+03; Ueda+03; Hasinger+05; La Franca+05; Richards+06;
Bongiorno+07; Della Ceca+08; Silverman+08; Aird+10; Assef+11; Fiore+12; Ueda+14)
Co-moving space number density of C-thin AGN

AGN “downsizing”

The most luminous AGNs at the peak of their activity at higher redshift

Marchesini+09

M$_{\text{star}}$ “downsizing”

The most massive galaxies assemble their mass at higher redshift.

Ueda+14

F. Shankar & M. Hirschmann talks

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Space density of high-z AGNs

Chandra Cosmos Legacy Survey
4031 sources
$z>3$ : 55 z-spec, 129 z-phot+z-spec

Civano et al.; Marchesi et al. in prep

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Cosmic evolution in BHM and $\lambda$

SDSS +VVDS+zCOSMOS

BHM “downsizing”:
Stronger decrease of the space density at the high MBH mass end compared to lower BH masses

ERDF: at $z\approx 2$ flattening for $\lambda<0.1$ compared to $z=0 \rightarrow$ higher average $\lambda$
The obscured fraction of AGN

- Demographic studies: $N_{\text{type2}}/(N_{\text{type1}}+N_{\text{type2}})$

  e.g. Lawrence & Elvis 1982; Ueda+03; Steffen+03; Simpson 2005; Hasinger 2008; Bongiorno+10; Brusa+10; Burlon+11; Assef+13; Merloni+13

- SED-based studies:

  $$f_{\text{obsc}} \sim \frac{R}{1 + R(1 - p)}$$

  $R = L_{\text{IR}}/L_{\text{bol}}$

  $L_{\text{IR}} =$ re-processed AGN emission

  $L_{\text{bol}} =$ AGN emission (opt-UV+X-ray)

  $p = 1$ (optically thin) ; $p << 1$ (optically thick)

  e.g. Maiolino+07; Treister, Krolik & Dullemond 2008; Sazonov+12; Lusso+13; Roseboom+13

- EW Fek$\alpha$ (“Iwasawa-Taniguchi effect”)

  e.g. Iwasawa & Taniguchi 1993; Bianchi+07

  See Bianchi+12 for a review
$f_{\text{obsc}}$ vs $L_x$ : demography

- 1300 AGNs in XMM-COSMOS
- Type-1 / Type-2 classification based on : optical spectra + SED or X-ray spectra
- Rest-frame absorption corrected $L[2-10 \text{ keV}]$, trying to limit the bias of flux limited X-ray samples.

The fraction of optically obscured AGN decreases with luminosity
Obscured fraction vs $L_{\text{bol}}$: SED studies

- Correct $L_{\text{bol}}$ for host galaxy/reddening contamination
- Estimate $f_{\text{obsc}}$ without assuming any bolometric correction

\[
f_{\text{obsc}} \simeq \frac{R}{1 + R(1 - p)}
\]

$p = 1$ (optically thin)
$p \ll 1$ (optically thick)

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Obscured fraction vs Lbol

SED-based studies also confirm a decrease of $f_{\text{obsc}}$ with luminosity

Maiolino (2007)
SED-based vs L5100Å
$f_{\text{obsc}} \sim L_{6.7\mu m}/L_{5100Å}$

Simpson (2005)
Demographics vs L[OIII]

Lusso (2013)
Filled circles: thin regime
Empty circle: thick regime

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Obscured fraction vs L[2-10 keV]

Lusso+13

Merloni+14

X-ray (HRz) classification

0.3<z<0.8

0.8<z<1.1

1.1<z<1.5

1.5<z<2.1

2.1<z<3.5

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AGN classification

- X-ray & optical type 1
- X-ray & optical type 2
- X-ray type-1, no BL
- X-ray obscured, BLAGN

“True” Type-2 (e.g. Panessa & Bassani 2002, Nicastro+00, Nenkova+08, Elitzur & Ho +09), C-thick, BL diluted by galaxy light
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Merloni+14

Risaliti+07

NGC1365

X-ray absorber within or inside the BLR

Perola+04, Fiore+12, Lanzuisi+13

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Obscured fraction vs z

Yes: La Franca+05; Treister & Urry+06; Hasinger+08; Trump+09; Iwasawa+12; Ueda+14  
No: Ueda03; Dwelly & Page+06; Gilli+07  
Maybe: e.g. Merloni+14 (at high Lx)

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C-thick AGNs: $X/[\text{NeV}]$

- $X/[\text{NeV}]$ as a tool to select C-thick objects: [NeV] as a proxy of the intrinsic emission
- 9/72 (13\%) are good C-thick candidates ($X/[\text{NeV}]<15$)
- X-ray stacking + Monte-Carlo simulations indicate that the overall fraction of Compton-thick AGN is $\approx43\%$

Gilli+10, Mignoli+13

Gandhi+09

MIR $>>$ expected $L_x$

SED decomposition

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C-thick AGNs: \( \frac{X}{[NeV]} \) and MIR excess

\[
\begin{align*}
\text{Observed Energy (keV)} & \\
\text{Counts/s/keV} & \\
\end{align*}
\]

\[
\begin{align*}
VimosID=813250 & \text{ CID 1019 } z=0.7302 \\
X/[NeV]=40 & \\
\end{align*}
\]

\[
\begin{align*}
VimosID 812432 & \text{ VIMOS-ID 812432 } z=0.661 \\
X/[NeV]<10 & \\
\end{align*}
\]

\[
\begin{align*}
VimosID 826908 & \text{ VIMOS-ID 826908 } z=1.025 \\
X/[NeV]<90 & \\
\end{align*}
\]

Vignali et al. in prep

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30% of all AGN that have MID-IR SEDs purely explainable by AGN activity are Compton-thick AGN candidates.
C-thick AGNs: host galaxies properties.

The properties of the obscuring medium do not correlate with the host galaxy total SFR.

Manuela Magliocchetti’s talk
X-ray stacking

Obscured AGN at z>1.7: rest-frame 9-20 keV excess sources

Iwasawa+12
NuSTAR+Chandra/XMM: 
\[ N_H \approx 6 \times 10^{23} \text{ cm}^{-2} \]
~2–3 times higher than that 
previously found using Chandra or 
XMM data alone

Luca Zappacosta’s talk
SED decomposition: AGN fraction

- \( \sim 1500 \) X-ray selected AGNs
- 54% spec-z, 46% photo-z
- \( \sim 600 \) unobscured, 900 obscured
- Wide and deep multi-wl coverage

"Specific accretion rate" (Aird+12)

- AGN fraction is independent of \( M_{\text{star}} \)
- Its normalization evolve as \((1+z)^4\) (~ sSFR)
SED decomposition: $k_{\text{bol}}$

380 Type-1+ 550 Type-2 from XMM-COSMOS

Higher $k_{\text{bol}}$ at higher $\lambda_{\text{Edd}}$: the emission from the X-ray corona becomes weaker relative to the disc as the accretion rate increases.
Summary

- Demographic tools (LF, BHMF, ERDF) support the downsizing evolution of SMBHs.
- AGN obscuring medium (pc and sub-pc) does not correlate with the host galaxy total SFR.
- SED decomposition studies are fundamental to characterize the properties of the host galaxies ($M_{\text{star}}$, SFR) and those of the central SMBH (e.g. $L_{\text{bol}}$).
- The obscured AGN fraction decreases as a function of luminosity $\rightarrow$ receding torus model?
- The obscured AGN fraction vs z: increasing at high-Lx (merger driven) but not at low-Lx (secular processes)?
- C-thick: combine deep X-ray observations with indirect evidence (e.g. IR, [OIII], [NeV]).
- $Z>3$ space density: improvement from new medium square degree surveys (e.g. COSMOS Legacy Survey).
- Future X-ray surveys: NuSTAR (present), eROSITA, ATHENA $\rightarrow$ M. Brusa and M. Cappi talks.
Thanks!