AGN EVOLUTION:
OUTSTANDING ISSUES AND PROSPECTS FOR IXO

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Thanks to: James Aird, Mitesh Patel, Xavier Barcons, Andrea Comastri, George Chartas, Yuichi Terashima… and the IXO team
OUTSTANDING QUESTIONS

How do AGN evolve?
OUTSTANDING QUESTIONS

• Are AGN important in the early universe (z>6) and do they affect galaxy formation?
• How do they affect the subsequent evolution of galaxies (co-evolution)?
• Do we have a complete census (e.g. is there a significant population of CT AGN?)
• Why did the accretion power in the universe decline since z~1?
• What triggers AGN activity?
OUTSTANDING QUESTIONS

• Are AGN important in the early universe (z>6) and do they affect galaxy formation?
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AGN “Downsizing” Typical BH mass or accretion rate reduces with $z$? Galaxy “downsizing”: most massive galaxies formed their stars early

La Franca et al. 2005

Hasinger et al. (2005)

Also Ueda et al. 2003
AGN-GALAXY CO-EVOLUTION


AGN number density: Silverman et al. (2005)

Similar evolution: Boyle & Terlevich 1998
NEW HARD X-RAY LF

Methodology:
• X-ray completeness and bias correction*
• Spectro completeness
• Photo-z errors
• Colour selection vs photz
• Bayesian model comp

RESULTS
• L* evolves +ve to $z \sim 1$
• $\Phi^*$ mildly -ve above
• LDDE NOT preferred

Aird et al. (2009)

*Georgakakis et al. 2008
BLACK HOLE GROWTH HISTORY

Luminosity density

\[ z_{\text{peak}} = 1.25 \]

Black Hole Growth

Aird et al. (2009)
ACCRETION VS STAR FORMATION

AGN Luminosity density
Aird et al. (2009)

SFR density
Hopkins (2004)

Wilkins et al. (2008)

XLF only known to here so far!
FORMATION OF THE FIRST SMBH

Li et al. 2007
Z=6 QUASARS: SDSS+UKIDSS

Mortlock et al. (2009)
\[ z = 6.127 \]

Warren et al. (2009)
\[ z = 6.04 \]

Venemans et al. (2007)
\[ z=5.86 \]

Credit: Mitesh Patel, Daniel Mortlock, Steve Warren

THE NEED FOR X-RAYS

BOLOMETRIC LUMINOSITY FUNCTIONS

QSOs sample ~30% of accretion power: obscuration and host galaxy dilution

Warning: Proposal
WHAT CAN IXO DO?

- X-ray redshift at z=5 (XMS)
- Ultra obscured Compton thick AGN at z=3.7
- Temperature and abundances of z=1.25 galaxy group
- AGN spin at z=1 via broad Fe line

IXO/WFI 1Ms

HJDIF

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WHAT CAN IXO DO?

CDF-S 2Ms

CDF-N 2Ms

AEGIS-X 3.4Ms

IXO 1Ms

Simulations: James Aird
IXO: SENSITIVITY
WHAT CAN IXO DO?

CDF-S 2Ms
CDF-N 2Ms
AEGIS-X 3.4Ms
IXO 100ks

IXO meeting, Otaru, 2009

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WHAT CAN IXO DO?

CDF-S, 2Ms

IXO delivers a factor $>20$ improvement for deep surveys
IXO: HIGH Z PREDICTIONS

Best observational estimate of high z numbers
IXO: HIGH Z PREDICTIONS

Best estimate

[Graph showing best estimate with various data points and lines indicating optimistic and pessimistic scenarios.]
IXO: PREDICTED XLF

Chandra $z=6$ (Fictional)

IXO $z=6$

IXO $z=8$

IXO $z=10$
IDENTIFICATIONS

IXO astrometry is comparable to Chandra

Redshifts can be determined by JWST or ELTs
MULTIWAVELENGTH FOLLOWUP

JWST, ELTs, ALMA will give host galaxy stellar ages, masses, populations etc. to constrain models of early SMBH formation.
TESTING MODELS

- Do SMBH form by monolithic collapse?
  - No star formation
  - No stellar population

- Or hierarchical merging?
  - Strong star formation
  - Significant stellar pop
  - Molecular gas
  - Dense environments

- Early Structure formation
  - Hard radiation affects cooling and physical state of IGM
  - Extended reionization

(e.g. Bromm & Leob 2003; Begelman et al. 2006)
(e.g. Li et al. 2007)
CONCLUSIONS

• IXO will Trace SMBH growth at z>6 (to z=8-10)
  • Total accretion power in early universe
  • Contribution to ionizing radiation
  • SMBH feedback in formation of first galaxies
Worsley et al. (2005)

$\nu_{\nu}$ (keV cm$^{-2}$ s$^{-1}$ sr$^{-1}$ keV$^{-1}$)

Energy (keV)

$N_H = 4.0 \times 10^{23}$ cm$^{-2}$

$R_{\text{intrinsic}} = 2$

$R = 1$

SOME OF THE X-RAY BACKGROUND IS MISSING
30 keV PEAK PROBABLY “COMPTON THICK” AGN
MERGER-DRIVEN FEEDBACK

- Gas rich major merger
- Inflows trigger BH accretion & starbursts
- Dust/gas clouds obscure AGN
- AGN wind sweeps away gas, quenching SF and BH accretion.

Hernquist (1989)
Springel et al. (2005)
Hopkins et al. (2006)
AEGIS: AGN HOST MORPHOLOGIES

Disks/spirals

Bulges

Peculiar/interacting

Georgakakis et al., MNRAS, in press

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ACCRETION HISTORY: INTEGRAL LIMITS

Integral HXLF:
\[ \rho_{BH} = 2.2 \pm 0.3 \times 10^5 M_{\text{sun}} \text{ Mpc}^{-1} \]

(Aird et al. 2009)

Local BH mass function
\[ \rho_{BH} = 2.5 \pm 0.4 \times 10^5 M_{\text{sun}} \text{ Mpc}^{-1} \]

Yu & Tremaine (2002)

\[ \rho_{BH} = 4.6^{+1.9}_{-1.4} M_{\text{sun}} \text{ Mpc}^{-1} \]

Marconi et al. (2004)

There may be a contribution from Compton thick AGN
(e.g. Worsley et al. 2005; Gilli et al. 2007; Daddi et al. 2007)
COMPTON THICK AGN POPULATION?

also Fiore et al. (2008); Georgantopoulos et al. (2008)
BUT see Donley et al. 2008; Georgakakis et al. 2008, 2009
Feedback in Action?

Buried AGN revealed

G. Chartas
CONCLUSIONS

• Trace SMBH growth at $z>6$ (to $z=8-10$)
  • Total accretion power in early universe
  • Contribution to ionizing radiation
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• Provide complete census at $z<3$
  • Major epoch of galaxy growth
  • Compton thick objects
  • SMBH regulation of star formation
  • AGN/Galaxy Co-evolution