THE MOST OBSCURED PHASE OF ACCRETING BLACK HOLES:
FIRST ACCRETING BLACK HOLE CANDIDATES

Hyewon SuH
Subaru Telescope
Tracing the growth of Black Holes and Galaxies

Highest-z quasar $z=7.54$

Highest-z galaxy $z=11.1$

Cosmic Dawn

Modern galaxies form

Reionisation Era

First stars?

Cosmic “Dark Ages”

Big Bang
Tracing the growth of Black Holes and Galaxies

(CO-)EVOLUTION OF BLACK HOLES AND GALAXIES

Highest-z quasar
$z=7.54$

Highest-z galaxy
$z=11.1$

Cosmic Growth History

SFRD

Redshift

Present day

Modern galaxies form

Cosmic Noon

Cosmic Dawn

Reionisation Era

$z = 8.68$

$z = 11.1$

Cosmic “Dark Ages”

First stars?

Big Bang

Redshift
Tracing the growth of Black Holes and Galaxies

Local Scaling Relation

Cosmic Growth History

Highest-z quasar $z=7.54$

Highest-z galaxy $z=11.1$

Modern galaxies form

Cosmic Noon

Cosmic Dawn

Reionisation Era

Cosmic “Dark Ages”

First stars?

Big Bang
X-RAY SELECTED AGN SAMPLE

Chandra-COSMOS Legacy Survey

One of the largest samples of X-ray AGNs with ready-high quality multi-wavelength data

+ **Wide enough** to span 2.2 deg$^2$ to have a large sample of AGNs
+ **Deep enough** to reach z>3 AGN in significant numbers
+ **Bright enough** that ~99% of sources can be identified
+ **Multi-wavelength data** is already available for 96.6% of the sources
+ **Optical/NIR Spectroscopy** with Keck/DEIMOS and Subaru/FMOS

4016 sources

Civano et al.(2016); Marchesi et al.(2016)

Hasinger, Suh et al. (2018); Suh et al. (2015)
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4016 sources

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X-RAY SELECTED AGN SAMPLE

X-RAY SELECTED AGN at $z=4.66$

CID-781

Chandra X-ray
Most Representative AGN sample at z>1

SDSS (i<21mag)  
Subaru/HSC (i<27mag)  
Keck/DEIMOS (i<25mag)
No significant evolution of BH—stellar mass relation up to z~3
SMBH Formation and Growth

There are a number of open issues in our current understanding of SMBH formation and growth:

- The existence of SMBHs with masses $>10^9$ at $z>7$ (Morlock+2011, Bañados+2018)
- Direct Collapse Black Hole (DCBH) (Haehnelt and Rees 1993, Volonteri+2008, Yue+2013)
- Cosmic X-ray and Infrared Background
HEAVILY OBSCURED AGN POPULATION

Cosmic X-ray Background

\[ E^2 \frac{dJ}{dE} [\text{keV}^2 \text{cm}^{-2} \text{s}^{-1} \text{keV}^{-1} \text{sr}^{-1}] \]

Energy [keV]

\[ \text{erg cm}^{-2} \text{s}^{-1} \text{sr}^{-1} \]

Compton-thick AGN

4X more

Gilli+07

Kashilinsky et al. 2019
Cross-correlation signal CIB X CXB

- Heavily obscured AGNs at z~2 (Gilli et al. 2007, Salvaterra et al. 2017) or even higher z (Kashlinsky et al. 2018, 2019)

- Rapidly accreting black holes at z>6 (Cappellutti et al. 2017, Kashlinsky et al. 2019)

- First accreting black holes at z>9 (DCBH, Yue et al. 2013)

- Primordial black holes contributing to the dark matter (Ali-Haimoud et al. 2019)
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**FIRST ACCRETING BH CANDIDATES**

Hasinger, Suh et al. (2018); Suh et al. (2015)

Civano et al.(2016); Marchesi et al.(2016)
FIRST ACCRETING BH CANDIDATES

X-RAY SELECTED AGN: Chandra-COSMOS Legacy Survey

One of the largest samples of X-ray AGNs with ready-high quality multi-wavelength data

+ **Wide enough** to span 2.2 deg$^2$
to have a large sample of AGNs
+ **Deep enough** to reach $z>3$ AGN
+ **Bright enough** that ~99% of sources can be identified
+ **Multi-wavelength data** is already available for 96.6% of the sources
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Hasinger, Suh et al. (2018); Suh et al. (2015)

1% of unidentified sources!

Civano et al. (2016); Marchesi et al. (2016)

4016 sources
FIRST ACCRETING BH CANDIDATES

Unidentified X-ray sources
FIRST ACCRETING BH CANDIDATES

Unidentified X-ray sources: 62 Truly empty!

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- >28.4mag
- >28.0mag
- >27.7mag
- >27.1mag
- >26.6mag
- >25.7mag
- >25.4mag
- >25.1mag
- >24.9mag
FIRST ACCRETING BH CANDIDATES

The most obscured phase of Accreting BHs?

Obscured AGN+Starburst/ULIRG (Polletta et al. 2017)
Direct Collapse Black Hole (DCBH)

- DCBHs will predominantly emit only in the IR-submm (1-1000um) and X-ray with a very steep in the IR

- $f_x/f_{\text{optical}} \gg 1$, $f_x/f_{1\mu m} \ll 1$

Pacucci et al. 2015, 2019
FIRST ACCRETING BH CANDIDATES

Direct Collapse Black Hole (DCBH) at $z>9$?

Pacucci et al. 2015, 2019
Newly Discovered Heavily obscured population

- 62 X-ray sources without any optical/NIR counterparts
- Most promising First population of accreting BHs at $z>7$ and/or Heavily obscured population at $z>4-5$
- ALMA Cycle 7 (PI:Suh) are scheduled!
- Follow-up observations with JWST