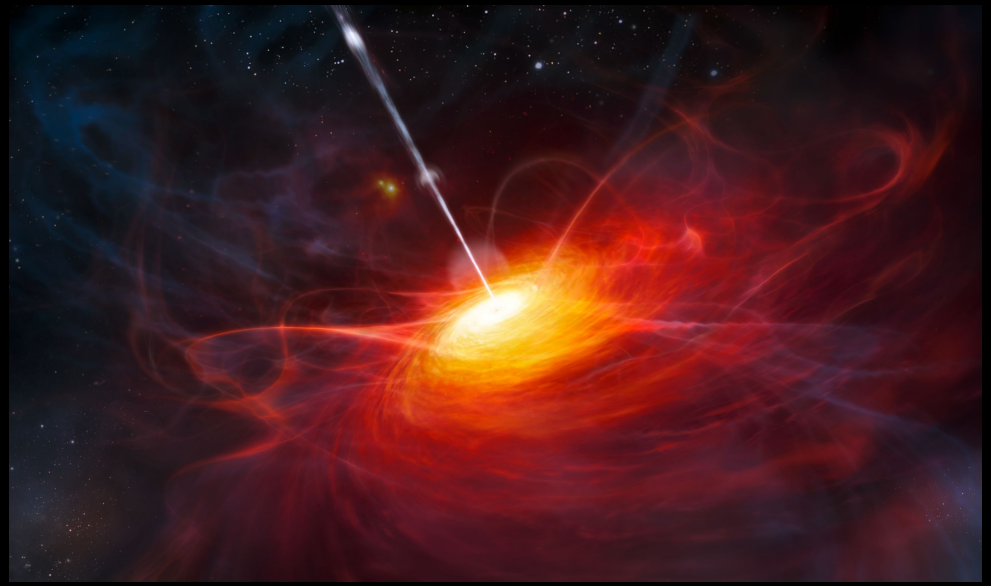
Digging Out Buried Black Holes with NASA'S Chandra

hundreds of hidden black holes found

Dong-Woo Kim

Center for Astrophysics
Harvard & Smithsonian
kim@cfa.Harvard.edu
617-413-7457

Main Collaborators
Amanda Malnati (Smith College)
Alyssa Cassity (Univ. British Columbia)



(ESO Science Release 2011)

X-ray Bright Optically Normal Galaxies (XBONG)

Mysterious objects known for 40 years

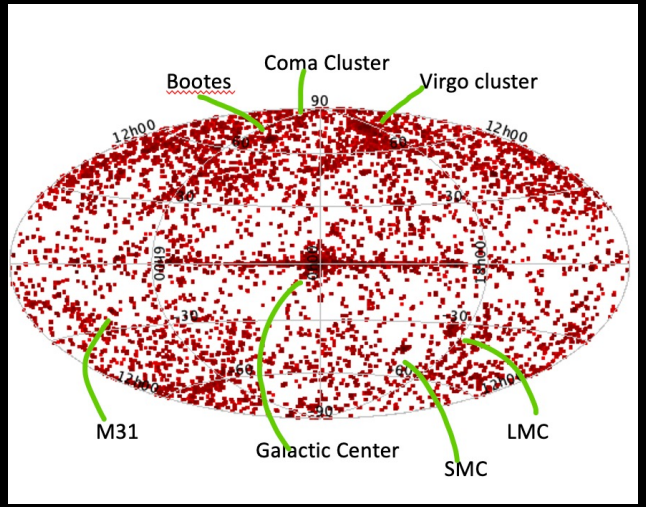
Galaxy
X-ray faint (X-ray binaries+ hot gas)
Optical lines (Star formation)

Quasar
X-ray bright (AGN*)
Optical lines (AGN*)

*AGN (Active Galactic Nuclei): a rapidly growing supermassive black hole

Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

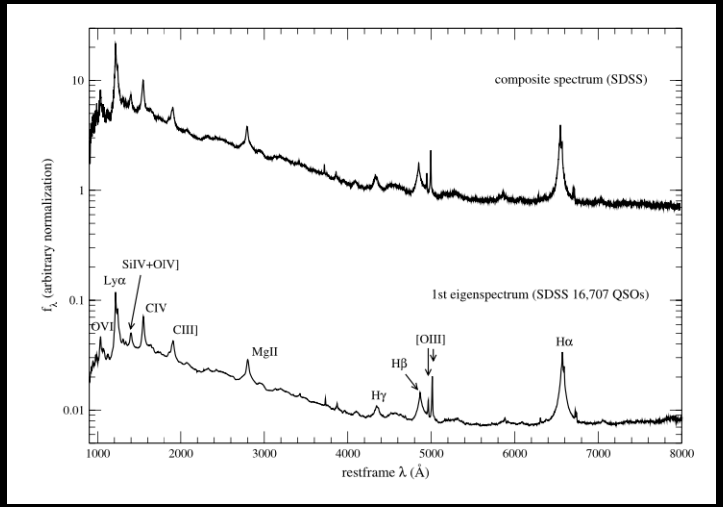
Chandra Source Catalog



15 years of Chandra observations (1999-2014)

320,000 unique X-ray sources
with accurate positions and high-quality data

SDSS Optical Spectra



(Yip et al. 2004)

16 years of optical observations

5 million objects with optical spectra
can classify stars, galaxies, and quasars

Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

Identified 820 XBONGs

select X-ray bright, SDSS spec-classified galaxy (no AGN signature)
the largest sample
10% of quasars; similar number of normal galaxies

Hypothesis 1. Obscured AGNs

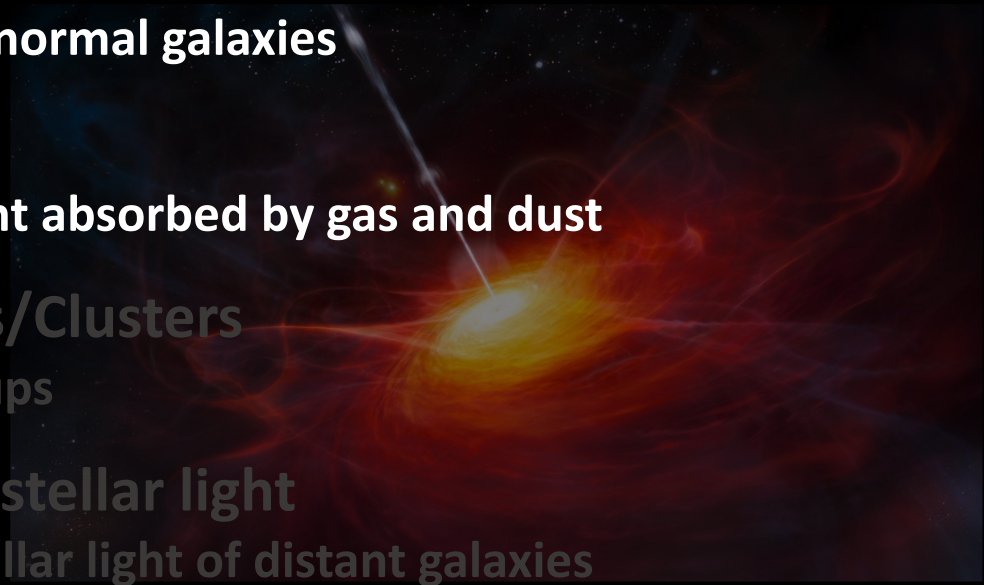
X-ray can penetrate, but optical light absorbed by gas and dust

Hypothesis 2. Hot gas in Groups/Clusters

Poor groups/clusters and fossil groups

Hypothesis 3. Diluted AGNs by stellar light

The aperture includes the entire stellar light of distant galaxies



Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

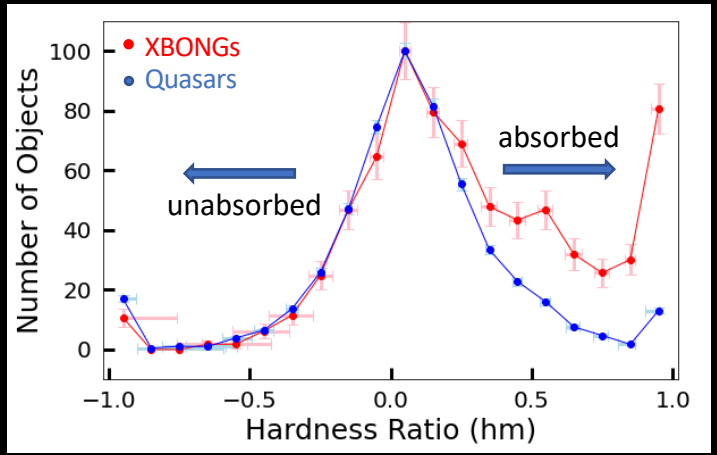
Hypothesis: Obscured AGNs

To measure the amount of absorption, use the X-ray spectral info
absorption ➔ reduce lower energy X-rays ➔ harder X-ray spectra
(energy-dependent absorption ➔ optically redder)

Hardness Ratio (like optical color)

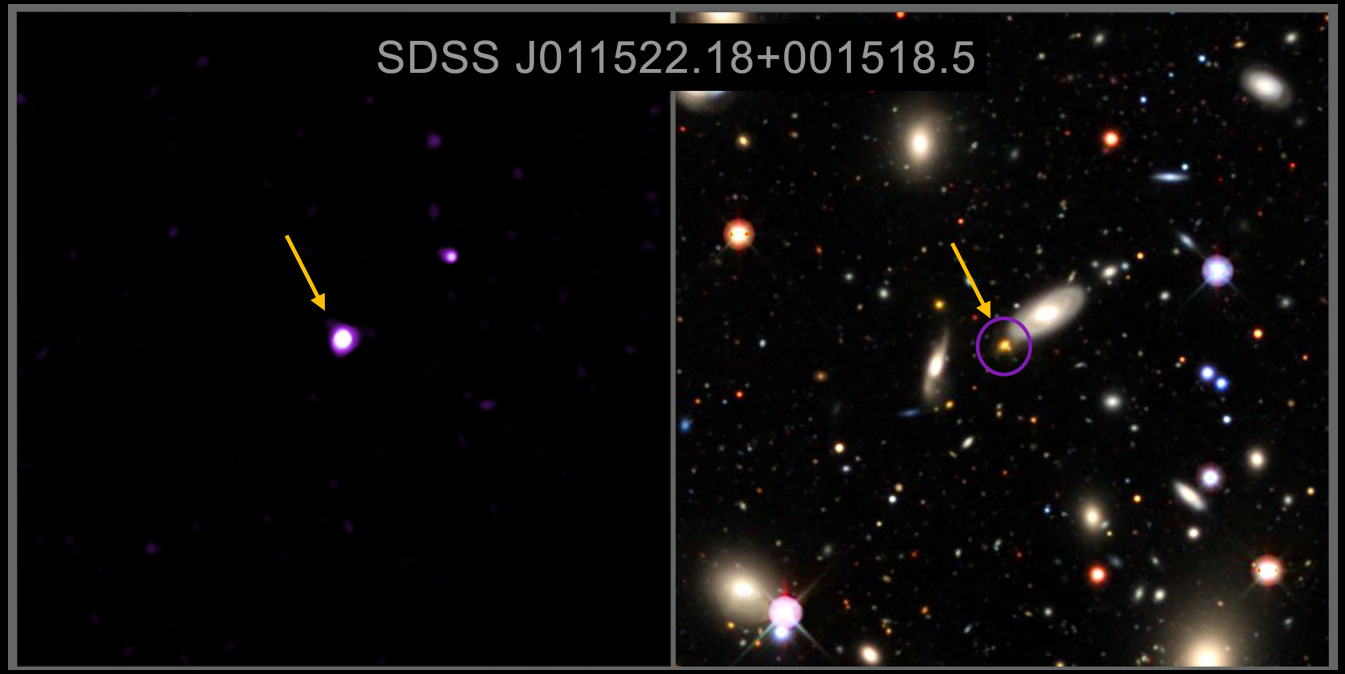
Fraction of obscured population is higher in XBONGs than in quasars

Considering all corrections,
about 50% of XBONGs are obscured AGNs



Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

Obscured XBONGs



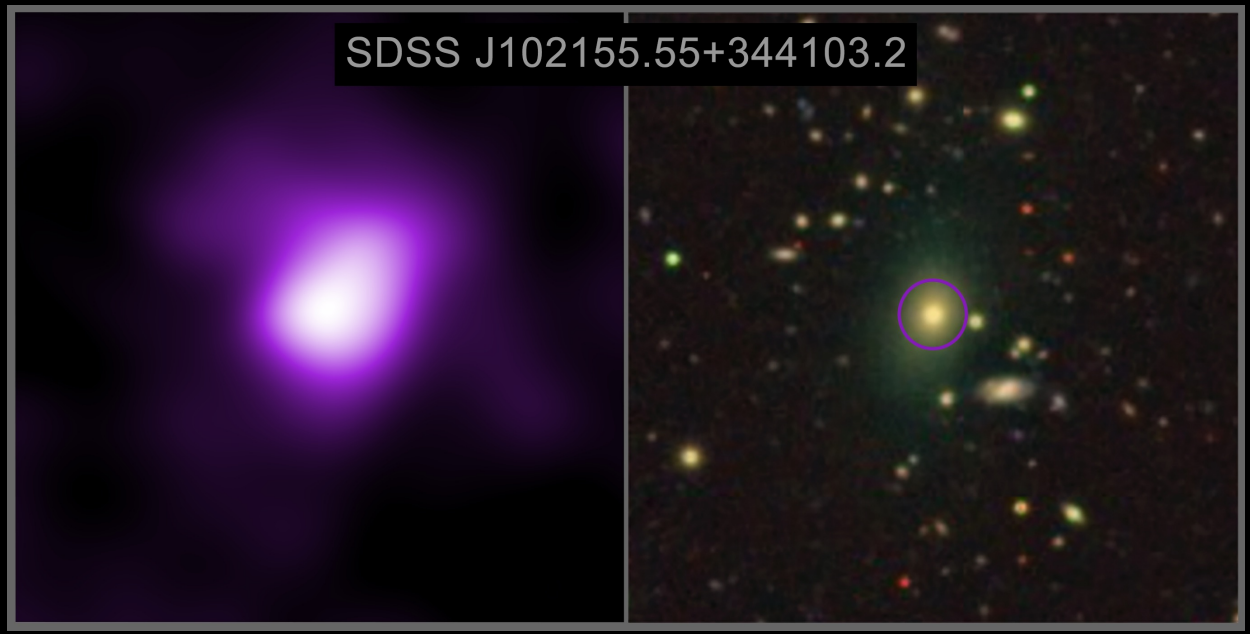
Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

2. Hot gas in Groups/Clusters

(groups/clusters or fossil groups)

~100 extended sources

< 20% of XBONGs



Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

3. Diluted AGNs

AGN signatures diluted by stellar light of host galaxies

Approximate estimate of the fraction of XBONGs by the dilution:

(1) distant ($z>0.3$) such that the aperture used in observations includes a large portion of a host galaxy
(2) optically bright for the expected AGN luminosity for a given L_X
(3) unobscured.

==> 30% of XBONGs

Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457

Summary

- **Using the Chandra Source Catalog and SDSS optical spectra,**
  820 XBONGs, the largest ever known.
- **50% of XBONGs – obscured AGNs (by X-ray hardness ratio)**
- **<20% of XBONGs – extended hot gas in groups/clusters**
- **30% of XBONGs – diluted AGNs by stellar light**

==> *hundreds of buried BHs recovered*

Future works:

will increases the sample with

recent Chandra observations (after 2015) +30%

SDSS-V (targeting Chandra sources) +100%

(iPoster 408.3 Thursday morning)

Dong-Woo Kim kim@cfa.Harvard.edu 617-413-7457