Variability Search for Faint AGN using the HSC SSP-Survey Data: Properties of the low-luminosity AGN in the COSMOS field

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- The paper draft is under circulation among the HSC-SSP colleagues.
Kimura et al. (2019) to be submitted
1. Introduction

- **Low-mass BH in galaxies at intermediate/high redshift**
  - Early evolution of massive BH
  - BH in bulges of disk galaxies (MW BH \( \sim 4 \times 10^6 M_{\odot} \))

- **Studying low-luminosity AGN with optical variability**
  - The deepest X-ray data \( L(0.5-2\text{keV}) \sim 10^{43}\text{erg/s} @ z \sim 1 \)
  - \( M_{\text{BH}} \sim 10^7 (BC/10)(\lambda_{\text{Edd}}/0.1)^{-1} M_{\odot} \)
  - Host contamination makes it difficult to identify AGN by, line (BPT) or MIR (hot dust) diagnostics
2. Variability study with HSC Ultradeep Data

HSC-SSP Ultradeep Data in COSMOS Field
taken from 2014 March to 2017 April.
8, 10, 13, 15 epochs in g, r, i, and z-band, respectively

Images by N. Yasuda

R-band depth in each epoch 25.3-26.0

e.g.,
PanSTARS1 survey (Simm et al. 2015) $r \sim 21.9$ (COSMOS)
VST survey (De Cicco et al. 2019) $r \sim 23.5$ (COSMOS)
SDSS Stripe 82 (Baldassare et al. 2019) $r \sim 20.5$
3. Detection of the Variable Objects

- Fixed aperture photometry
- Different depth in different intervals ➔ Ensemble probability
- Correlation of light curves in multi band
- Visual check

In this talk, we show the results with the threshold for the most robust sample.
Very robust sample of variable objects

- 491 AGN
- 440 X-ray detected
  - 51 undetected
- Spec-z for 337 objects
  - photo-z: AGN+gal SED

Recover 99% of PS1, 80% of VST results
Supernova

AGN
X-ray Detected

AGN
X-ray Undetected
AGN Covering Factor (type2 fraction)

- Fraction of variable objects among the “X-ray-selected” sample

- Covering factor from variability and X-ray absorption (Ricci et al. 2017, Ichikawa et al. 2019) are similar

Similar distribution along line of sight for the absorbing neutral gas and dust
X-ray stacking analysis for the X-undet variable objects (CSTACK Miyaji et al. 2008)

- Significant X-ray detection by the stacking
- They are low-luminosity AGN, still too luminous for other X-ray components in galaxies.
Very hard X-ray spectra: puzzling results

HR \sim 0.6 \ (if \ low \ host \ stellar \ mass, \ HR>0.8)

\begin{align*}
N_H &= 10^{22.5} \text{cm}^{-2} \\
N_H &= 10^{23} \text{cm}^{-2} \\
N_H &= 10^{23.5} \text{cm}^{-2} \\
\Gamma &= 1.8
\end{align*}
Very hard X-ray spectra: puzzling results
HR ~ 0.6 (if low host stellar mass, HR>0.8)

What are they?
- Optically variable objects -- we see BLR
- X-ray absorption -- dense gas in l.o.s.
- Low-mass host (<$10^{10}$M$_{\text{sun}}$)
- Specific BH accretion rate is high (suggesting high Eddington ratio)

➔ Outflowing Gas ?
➔ Shielding by geometrically thick slim disk?
NLS1-like objects?  

Luo et al. (2015)
Weak-line QSO
Stellar Mass of host galaxies

Stacking of X-undet objects

$z < 0.7$

0.7 < $z$ < 2.0

Low mass

High mass

A

B

C

D

$\log(M_*/[M_\odot])$

redshift
Very robust sample of variable objects

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AGN ‘Ensemble’ Structure Function analysis

- Structure Function after empirical correction for wavelength and luminosity dependence due to the host galaxies

- SDSS Strip82 results slope $=0.51$ (Kozlowski et al. 2016)

- DRW model (Kelly et al. 2009) with $\tau = 500$ days

- Slope: $0.487 \pm 0.007$
AGN Structure Function analysis and effects of host galaxies (SF from aperture photometry)
AGN Structure Function analysis and effects of host galaxies (SF from aperture photometry)

- We model the SF with galaxy SED templates

- “starburst” or “Sdm”-like host SED consistently explain the SF behavior

- AGN with $L_x=10^{42.5-44}$ erg/s ($L_{bol}=10^{43.5-45}$ erg/s) are typically hosted in star-forming galaxies

- Median redshift $\sim 1$
AGN Structure Function analysis and effects of host galaxies (SF from aperture photometry)

Modeling the host galaxy light contamination and subtraction
Summary

1. We conducted deep multi-color variability survey using HSC-SSP COSMOS Ultradeep data taken in 2014-2017

2. The most robust sample of variable AGN: 491 sources 441 are detected in one of the deepest X-ray image but the other 50 are not.

3. AGN Covering factor (type-2 fraction) similarly behaves as that obtained by X-ray absorption, which suggests that the absorption by neutral gas and dust along los occur at the similar place.

4. Significant X-ray emission from the variable objects individually not detected is detected by the stacking analysis. They are also AGN but with very hard X-ray spectra.

5. Structure function analysis shows that the current sample of variable objects are hosted in star-forming galaxies.