

A New Black Hole Mass Estimate for Obscured AGNs

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More details can be found in
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ABSTRACT

- A major fraction of the neutral FeK α line core originates between the outer BLR and the inner dust torus.
- The neutral FeK α line core can be used as a potential indicator of the black hole mass for obscured AGNs.

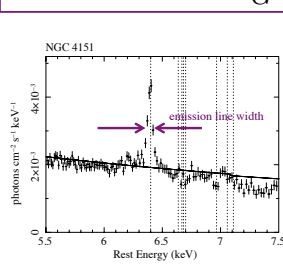
1. INTRODUCTION

- **Importance of estimating M_{BH} in obscured AGNs**
 - Obscured AGNs are important targets for studying the black hole – galaxy coevolution because their host galaxies can be investigated free from the strong central emission from the AGN itself.
 - Some types of obscured AGNs such as ULIRGs are of special importance because they have long been anticipated to be in the middle of the evolutionary sequence of AGNs (e.g., Sanders et al. 1988; Sanders & Mirabel 1996).

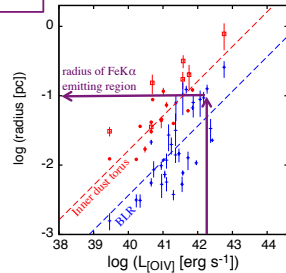
2. METHODS

- **A single-epoch black hole mass using narrow FeK α line width**

$$M_{\text{BH,FeK}\alpha} = f \frac{r_{\text{FeK}\alpha} \sigma_{\text{FeK}\alpha}^2}{G}$$



The X-ray spectrum in the FeK α energy band of NGC 4151 obtained by the Chandra HETG (Shu et al. 2010).



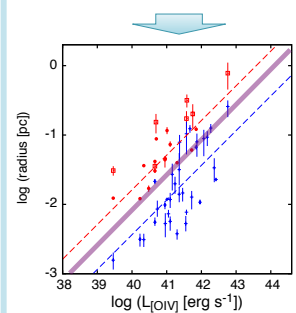
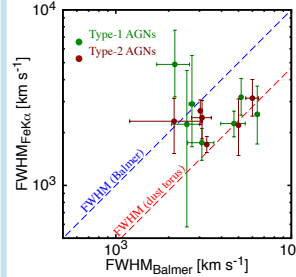
The radius-“isotropic” luminosity relations for the inner structures of AGNs (Koshida et al. 2014)

- The velocity of motion is obtained from the width of the neutral FeK α line core.
- The radius of the emitting region is obtained from the “isotropic” luminosity indicators via the radius – luminosity relation for the the neutral FeK α line core.
- **A preceding study for type-1 AGNs (Jiang, Wang, & Shu 2011)**
 - The width of the neutral FeK α line core for 10 AGNs were measured with Chandra HETG, which affords the best spectral resolution currently available in the FeK α energy band.
 - The emitting region radius of the neutral FeK line core was assumed to be equal to the dust reverberation radius and was estimated via the correlation between the radius and the optical luminosity (Suganuma et al. 2006).
 - The black hole mass using FeK α was compared with that estimated by the reverberation mapping observation of optical broad emission lines.
 - The correlation between the two black hole mass estimates was statistically insignificant, which could be attributed to large uncertainties in the measurements of the FeK α line widths and small sample size.

3. DATA

- **Targets including obscured AGNs**
 - 7 Type-1 AGNs whose black hole masses were estimated by the reverberation mapping observations of optical broad emission lines
 - 7 Type-2 AGNs with the polarized broad optical emission lines or the black hole masses estimated by the VLBI observations of the water maser
- **Data for estimating M_{BH}**
 - The data for FWHM(FeK α) are taken from Shu et al. 2010, 2011, which were measured with Chandra HETG.
 - The targets are further selected from the sample of Shu et al. 2010, for which the best FWHM constraint was obtained by the authors.
 - The luminosity of the [O IV] λ 25.89 μm emission line is used as an isotropic luminosity indicator.

4. RESULT – Neutral FeK α line emitting region



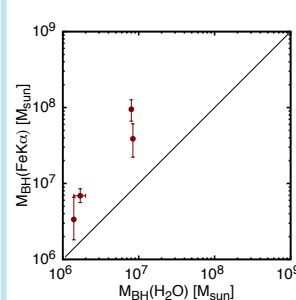
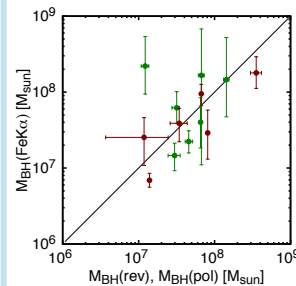
- **Location of the emitting region of the neutral FeK α line core**

- Assuming the virial relation, the velocity width of the neutral FeK α line core is compared with that of the broad Balmer emission lines and that corresponding to the dust reverberation radius to examine the location of its emitting region.
- FWHM(Balmer) > FWHM(FeK α) > FWHM(dust reverberation radius) for most of the target AGNs
- A major fraction of the neutral FeK α line core is supposed to originate between the outer BLR and the inner dust torus.
- However, there appears no clear correlation between FWHM(FeK α) and FWHM(Balmer) as has been reported by previous studies (Nandra 2006; Shu et al. 2010, 2011).

- **The radius-luminosity relation for the neutral FeK α line region**

$$\log r_{\text{FeK}\alpha} = -1.57 (\pm 0.19) + 0.5 \log L_{[\text{OIV}]} / 10^{41} \text{ erg s}^{-1}$$

5. RESULT – M_{BH} using neutral FeK α line core



- **M_{BH} (FeK α) compared with M_{BH} (optical broad line)**
 - The reverberation based $M_{\text{BH}}(\text{rev})$ is compared for 7 type-1 AGN.
 - The single-epoch $M_{\text{BH}}(\text{pol})$ based on the polarized broad Balmer emission line is compared for 6 Type-2 AGNs.
 - $M_{\text{BH}}(\text{FeK}\alpha)$ is consistent with $M_{\text{BH}}(\text{rev})$ and $M_{\text{BH}}(\text{pol})$ for most of the type-1 AGNs and all of the type-2 AGNs.
 - $M_{\text{BH}}(\text{FeK}\alpha)$ is correlated with $M_{\text{BH}}(\text{pol})$ for the type-2 AGNs.
- **M_{BH} (FeK α) compared with M_{BH} (H $_2$ O maser)**
 - The $M_{\text{BH}}(\text{H}_2\text{O})$ based on the VLBI observation of H $_2$ O maser emission is compared for 4 Type-2 AGNs.
 - $M_{\text{BH}}(\text{FeK}\alpha)$ is correlated with $M_{\text{BH}}(\text{H}_2\text{O})$.
 - $M_{\text{BH}}(\text{FeK}\alpha)$ is systematically larger than $M_{\text{BH}}(\text{H}_2\text{O})$ by a factor of 5.
 - $M_{\text{BH}}(\text{pol})$ is also measured for 3 targets; $M_{\text{BH}}(\text{pol})$ is also systematically larger than $M_{\text{BH}}(\text{H}_2\text{O})$ for them.

6. FUTURE PROSPECTS

- **Astro-H SXS**
 - Different origins such as the outer accretion disk, the BLR, the innermost dust torus, and/or their mixture for the neutral FeK α line core have been proposed (e.g., Yaqoob & Padmanabhan 2004; Nandra 2006; Bianchi et al. 2008; Liu et al. 2010; Ponti et al. 2013; Gandhi, Hönig & Kishimoto 2015). Those uncertainties will result in the possible error of this black hole mass estimate.
 - The Astro-H SXS is capable of unprecedented energy-resolution spectroscopy with superior sensitivity at the FeK α band.
 - It will enable us to study in more detail the origin of the neutral FeK α line core by examining the line profile of the neutral FeK α line and its time variation.
 - It will enable us to measure the black hole mass with improved accuracy for a large number of obscured AGNs.

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