Summary of Graduation Thesis

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Title	X-Ray Study of the Seyfert 1.9 Galaxy MCG-5-23-16 and the Implication of Radiation Mechanism Through Variability Study						

[Motivation]

Active galactic nuclei (AGNs) have been studied extensively in the soft (<10 keV) X-ray band, but not in the hard (>10 keV) X-ray band. The launch of *NuSTAR* in 2012 has provided high quality data in the hard energy band, but information about the geometry and properties of AGNs, often pronounced in the hard band, have not been explored in detail yet. Among the different classes of AGN, Seyfert galaxies are excellent subjects, as various emission components are degenerated in the soft band. MCG–5–23–16 is one of the brightest Seyfert galaxies in the 2–10 keV band with a typical flux of (7–10)×10^{-11} erg cm^{-2} s^{-1}, making it an ideal target for exploration. This paper studies the timing properties of MCG–5–23–16 in the 0.5–79 keV energy band using the X-ray satellites *Suzaku* and *NuSTAR*. The broad energy band study attempts to determine the geometry and emission mechanism using only the timing information, and subsequently confirm the results from the conventional spectral fitting method.

[Data Analysis]

Three *Suzaku* and five *NuSTAR* observation data were studied. First, the energy dependence of variability and lag were evaluated. Second, the emission spectrum from *Suzaku* and *NuSTAR* were fitted independently with models with properties as suggested from the variability and lag analyses. Lastly, the simultaneous *Suzaku* and *NuSTAR* observation spectrum was fitted with the spectral model to confirm its validity in the broad energy band.

[Results and Discussion]

Analysis of the X-ray observation data indicates three major results.

First, we succeeded in discriminating the various emission components using temporal variability. AGNs are known to have a varying primary emission described by a power law. A low variability hence implies the existence of a stationary component in addition to the primary emission. The observed emission could be separated into 4 components (Fig. 1): the primary variable emission (orange), the steady soft emission (<1 keV, green), the Fe fluorescent emission (6–7 keV, blue) and the relatively steady hard emission (>6 keV, blue).

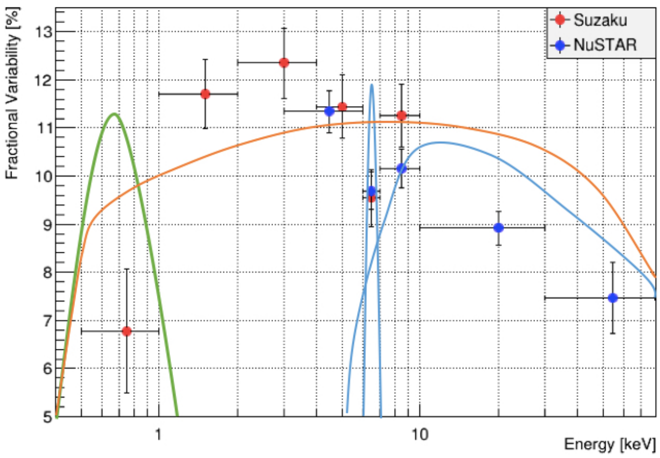

Fig 1. Fractional variability overlaid with the schematic of the distinguished emission components

Second, the lag analysis disclosed the geometry and properties of the emission components. Although the soft stable component (~ –2300 s) seems to precede the primary emission, this is considered an artifact since their variabilities are not well correlated and hence uncertainty is large. The soft stable component is hence expected to be independent from the other components. This feature, common in many Type 2 Seyfert galaxies, is thought to be the emission from distant photoionized gas. The hard components lag ~300 s and ~1400 s in the <30 keV and >30 keV bands respectively. These lags support the widely accepted perspective that the hard emission is a reflection of the primary component. The existence of a narrow Fe emission in the spectrum indicates that the reflection emission is mainly due to the Compton scattering of distant matter (most likely the molecular torus) by the primary emission photons (which is known to be due to bremsstrahlung from near the central black hole).

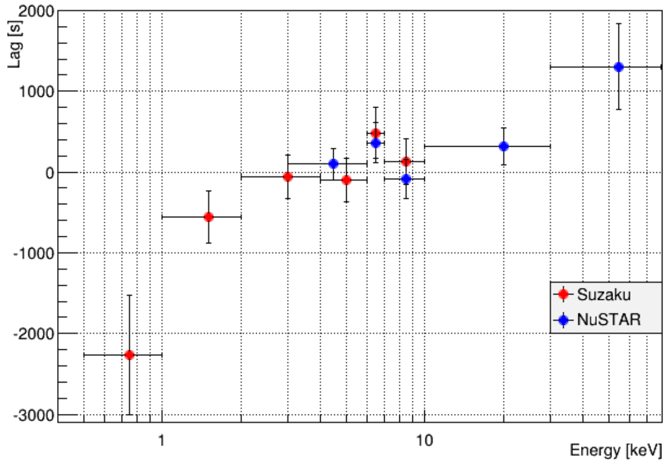

Fig. 2. Lag relative to the primary emission

Third, the broad 0.5–79 keV emission spectrum of MCG–5–23–16 was well reproduced with models describing the emission components found in previous analyses. The spectrum fitted well with a reflected power law absorbed by two layers of gases: the absorbing layer at MCG–5–23–16, and the galactic absorption column. The soft component fitted well with a steep power law absorbed only by the galactic column.

[Conclusion]

This paper succeeded in reproducing the energy spectrum of MCG–5–23–16 with models based on properties found through timing analysis. Analyzing the energy dependence of variability and lag indicated the existence of 4 components: the primary variable emission, the soft (<1 keV) steady component due to distant photoionized gas, the Fe fluorescent emission (6–7 keV) and the hard (>6 keV) reflection of primary emission by Compton scattering at the molecular torus. These components reproduced the observed spectrum well in the broad 0.5–79 keV, strongly suggesting the validity of the derived results. This result obtained only through timing analysis is also in good agreement with results obtained with the conventional spectral fitting method.