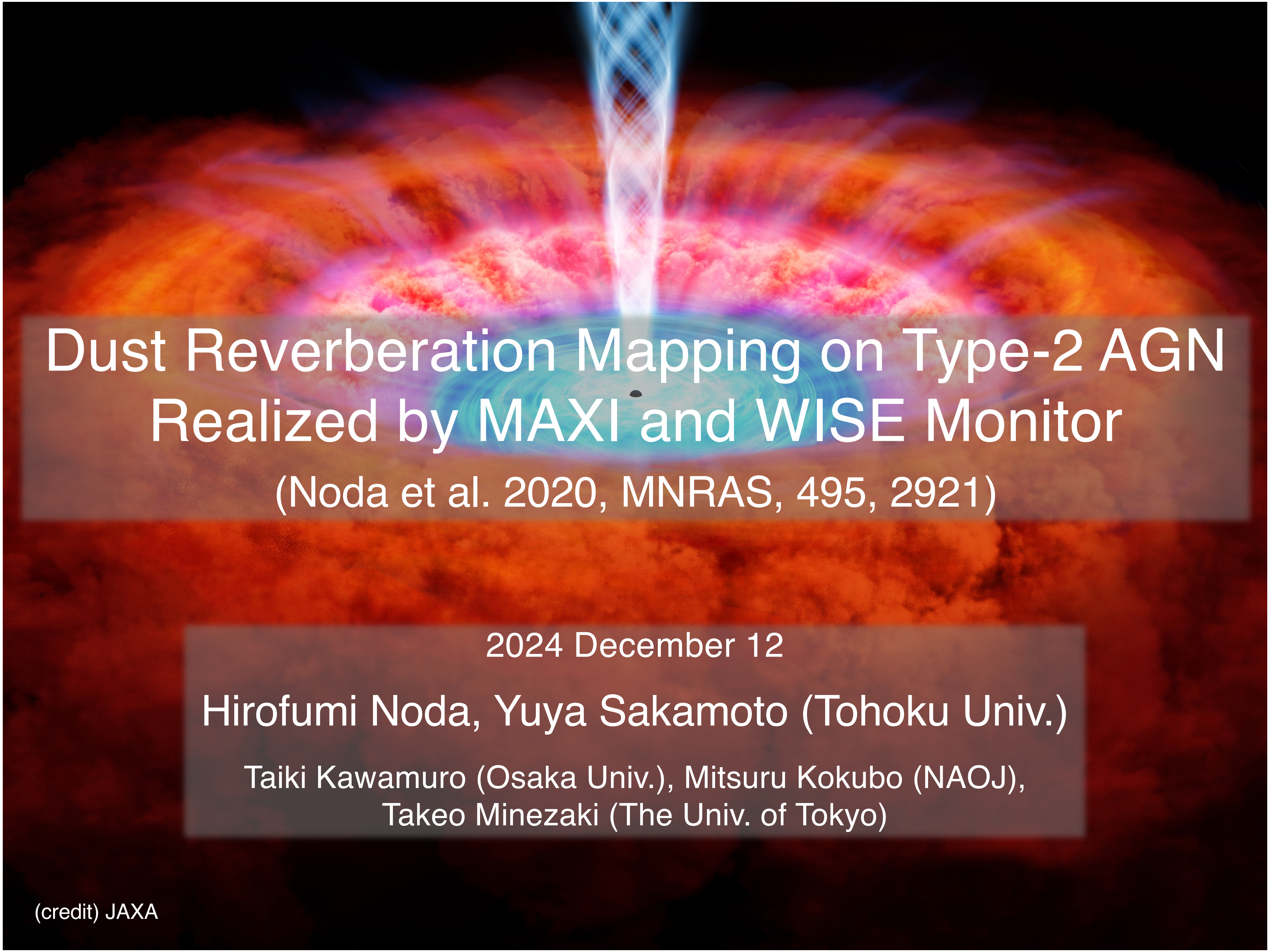


Dust Reverberation Mapping on Type-2 AGN Realized by MAXI and WISE Monitor

(Noda et al. 2020, MNRAS, 495, 2921)

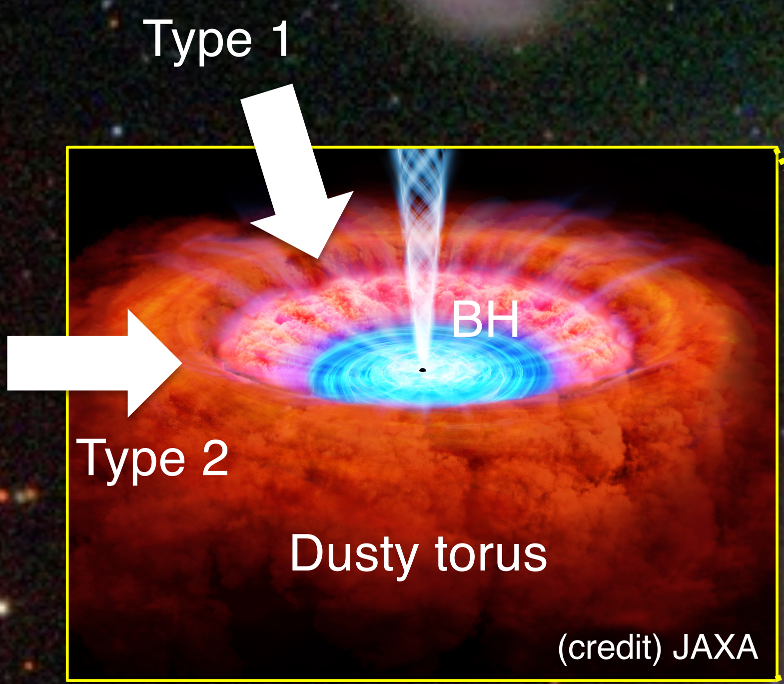
2024 December 12

Hirofumi Noda, Yuya Sakamoto (Tohoku Univ.)

Taiki Kawamuro (Osaka Univ.), Mitsuru Kokubo (NAOJ),
Takeo Minezaki (The Univ. of Tokyo)

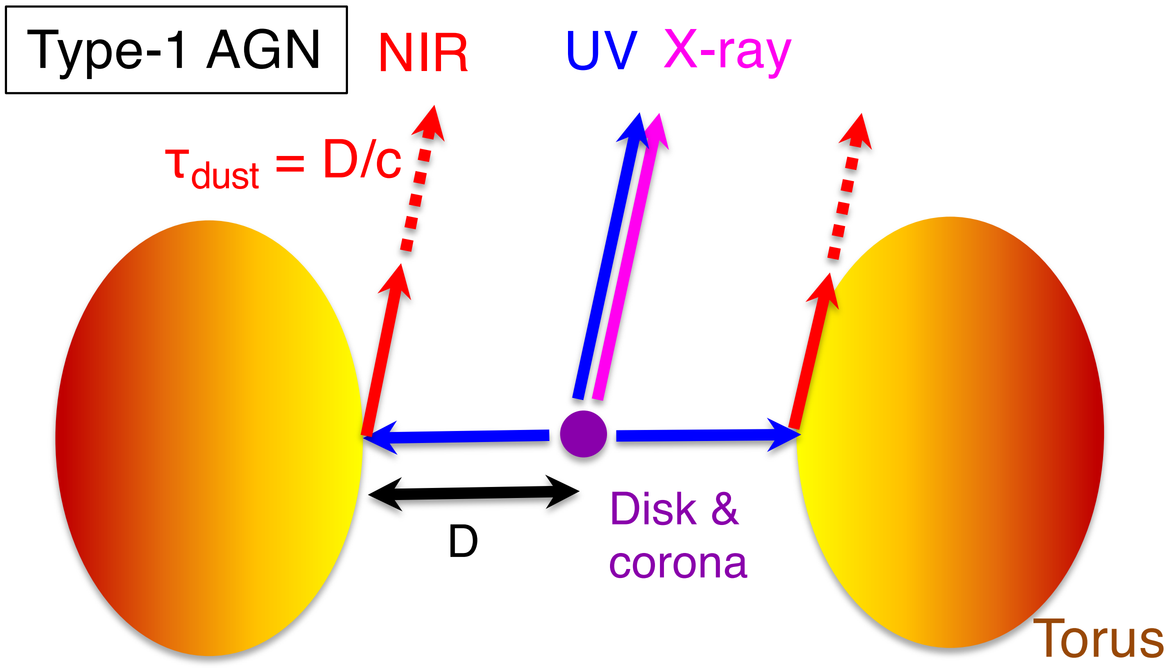
(credit) JAXA

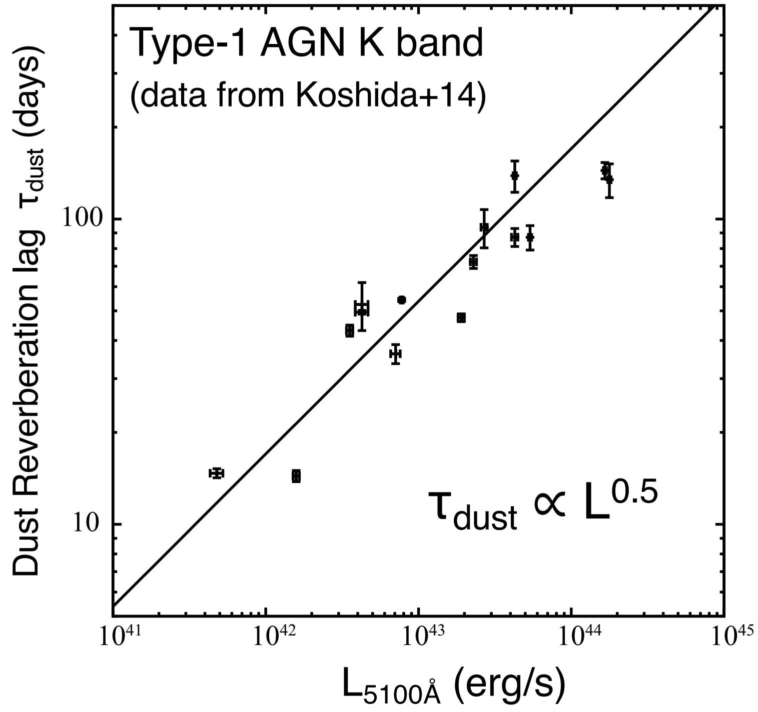
Importance of Studying AGN Dusty Tori



- The co-evolution of galaxies and black holes (BHs) is crucial for understanding the history of the universe
- The dusty torus is a key structure that serves as a reservoir of mass from the host galaxy and is also closely linked to AGN feedback
- The dusty torus can be investigated from various viewing angles by studying different types of AGNs

Dust Reverberation Mapping to Probe Dusty Torus





- Near IR (NIR) is due to dust heating by disk UV emission.
  Variability of NIR flux follows disk flux with τ_{dust} = D/c
- Tens of type-1 AGNs show the correlation b/w τ_{dust} and $L_{5100Å}$
  ➔ Torus inner radius ~ dust sublimation radius
- However, no clear results on type-2 AGNs were reported so far…
  ➔ We realize it on type-2 AGNs by X-ray & IR monitor

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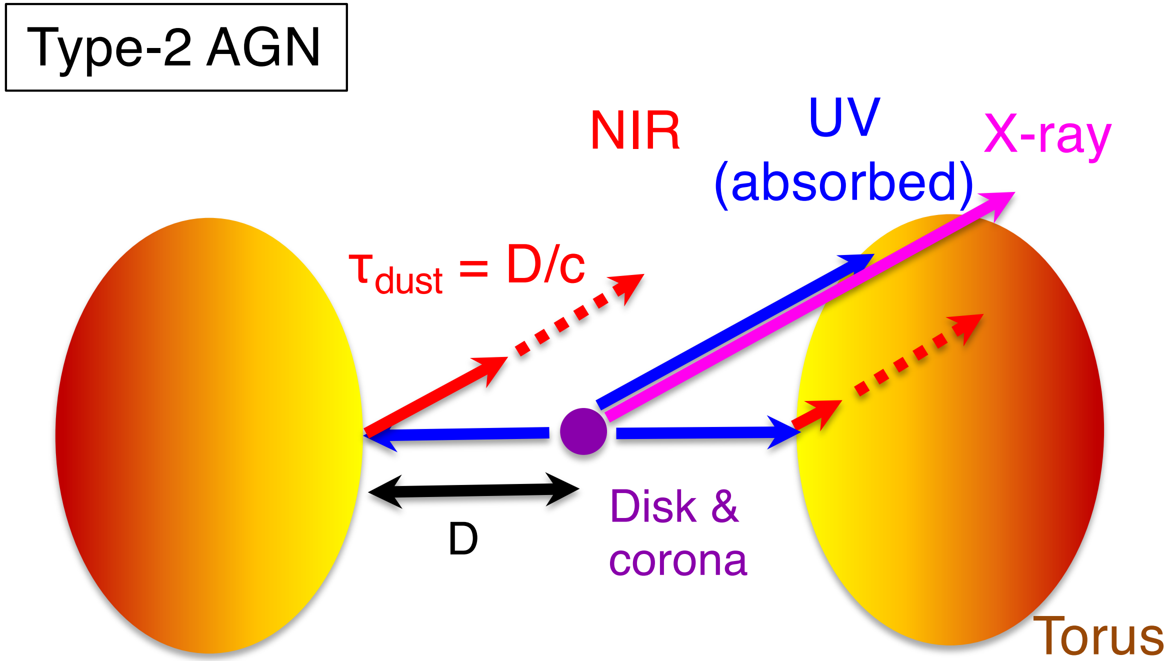

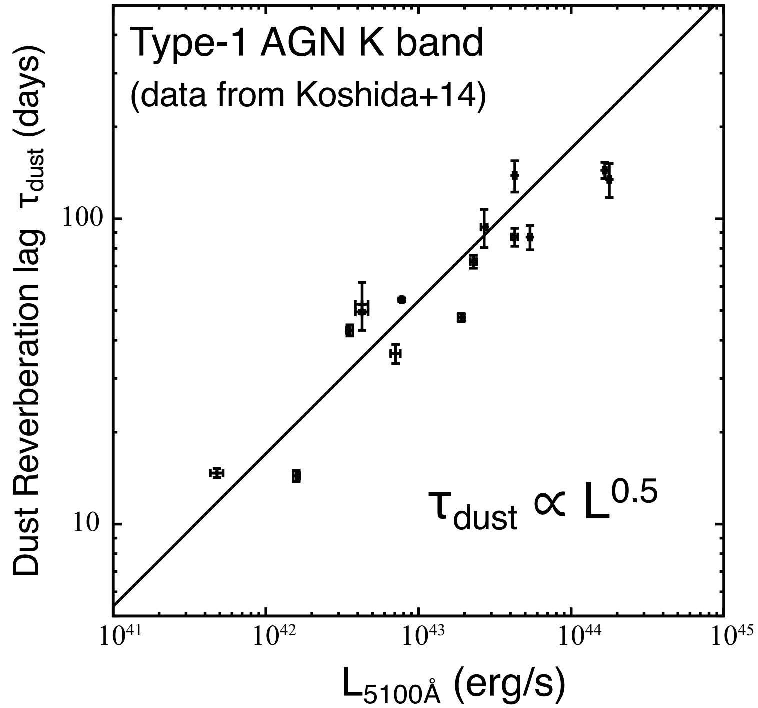

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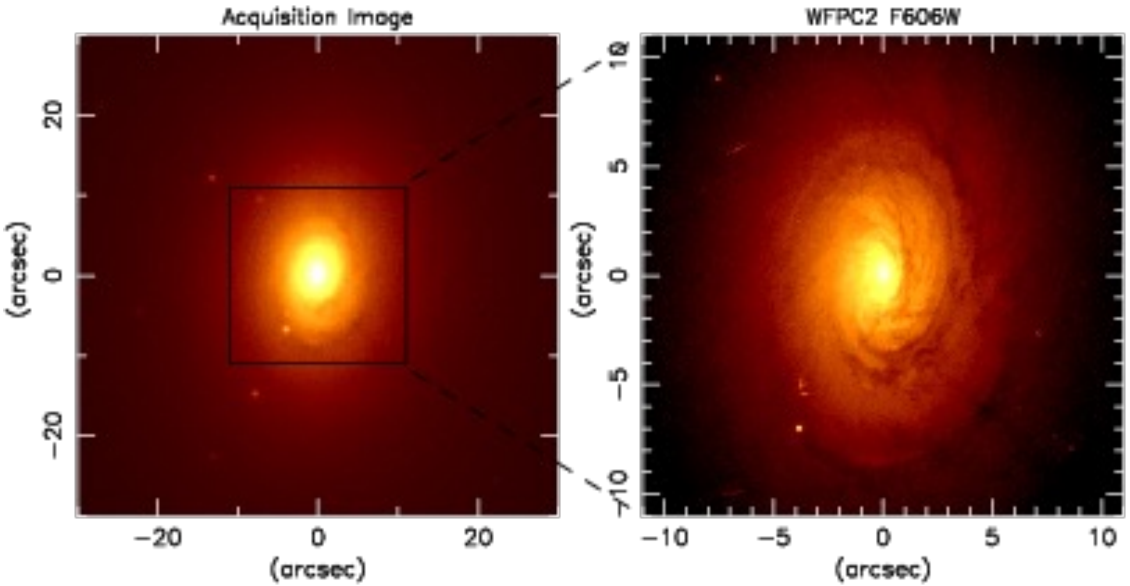
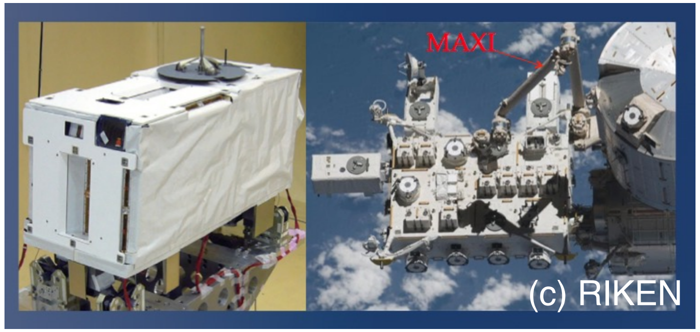
MAXI & WISE Monitor of Type-2 AGN NGC 2110



Schnorr-Muller+14

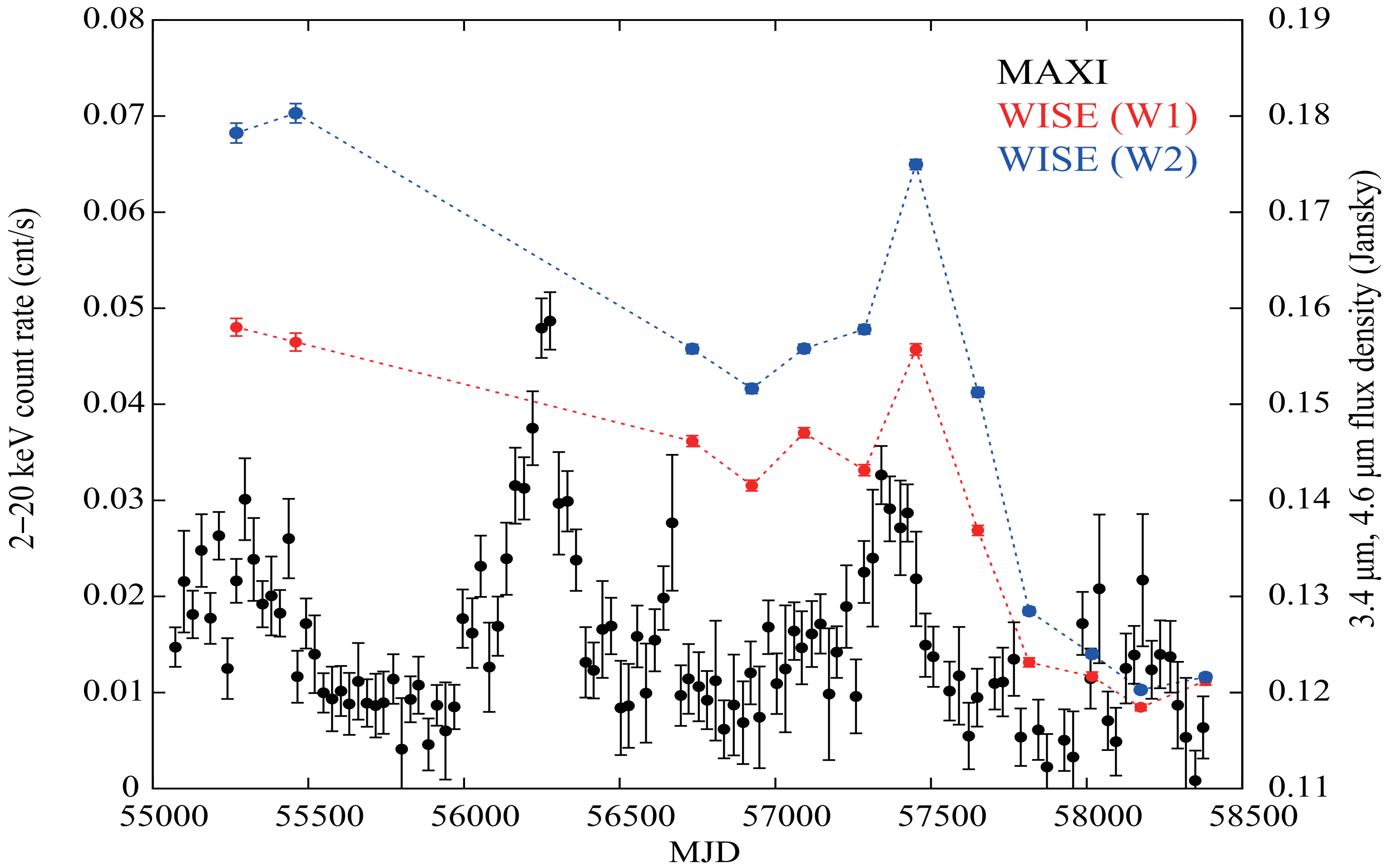


☆ X-ray-bright type-2 AGN NGC 2110

- BH mass : **2×10^8 $M_\odot$** (M–σ relation; Woo & Urry 02)
  2.5×10^7 $M_\odot$ (Fe-Kα; Minezaki & Matsushita 15)
- Viewing angle : ~53˚ (Storchi-Bergmann+99)

☆ MAXI : **2–20 keV** 15 year (2009–2024) data
WISE : **W1 (3.4 μm), W2 (4.6 μm),** W3 (12 μm), W4 (22 μm) bands
available from 2010 (only W1, W2 for NEOWISE)

Discovery of X-ray & IR Correlation (HN+20)

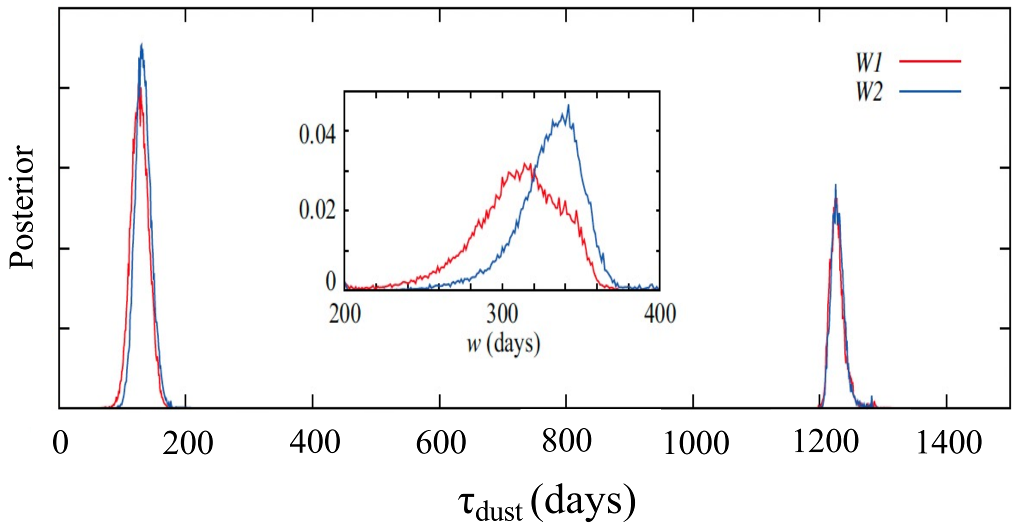


☆ 1-month binning MAXI light curves until 2019 showed mainly two flares

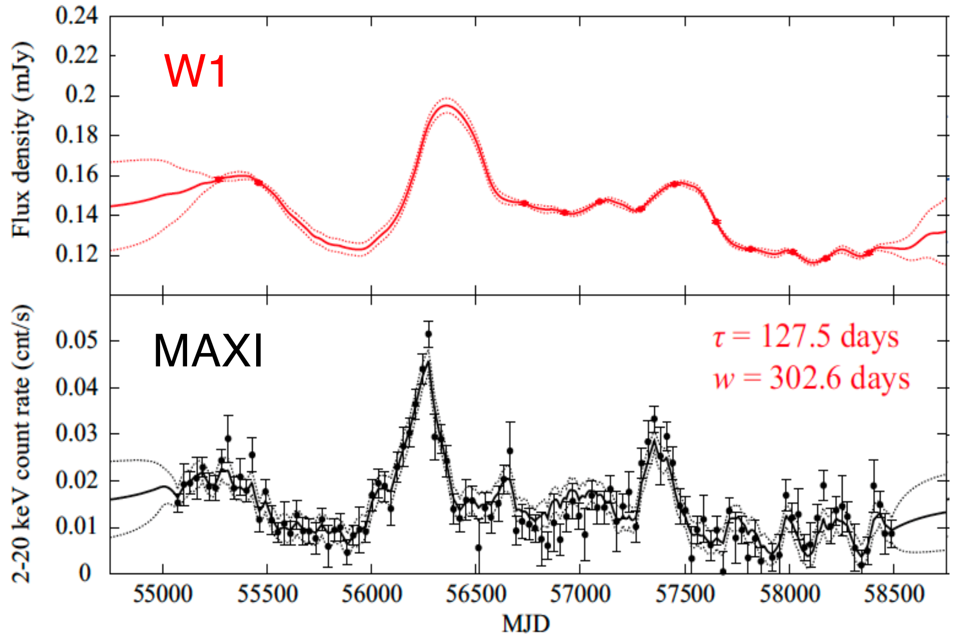
☆ The second X-ray flare was successfully covered by NEOWISE (W1 & W2)

Cross Correlation Analyses (HN+20)

Time Lag histogram



Modelled light curves with transfer function



☆ We performed two methods; ICCF (Peterson+98) & JAVELIN (Zu+11,13)

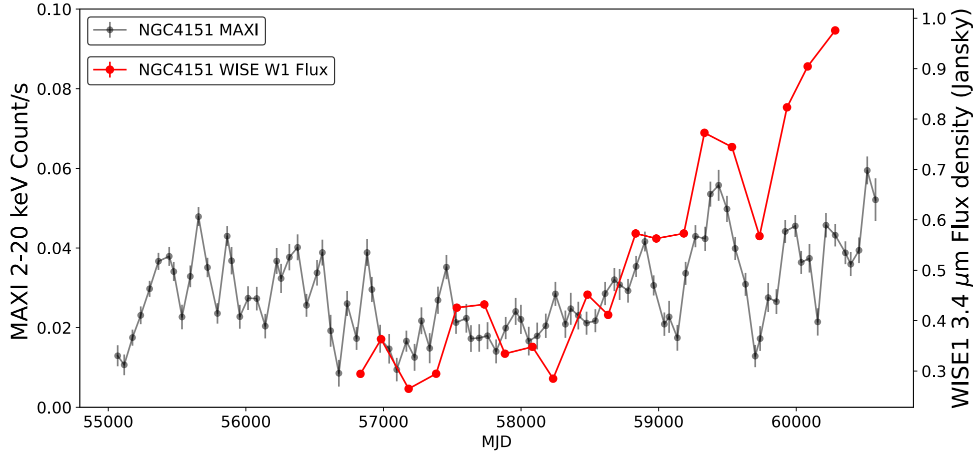
☆ Two τ_{dust} peaks were found at ~130 days and ~1250 days, corresponding to the 2nd and 1st X-ray flares, respectively

☆ We discussed that **τ_{dust} ~ 130 days is preferred**, based on the results of type-1 AGNs ➔ We apply it to data of multiple AGNs from 2009 to 2024

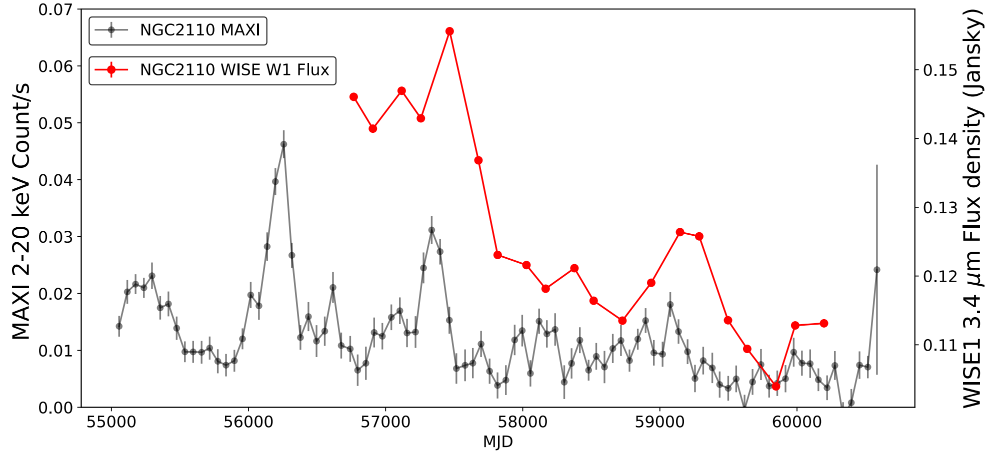
Systematic Dust Rev. Mapping by X-ray & IR Monitor (Preliminary)

Led by Yuya Sakamoto (Tohoku Univ.) Sakamoto, HN+ in prep

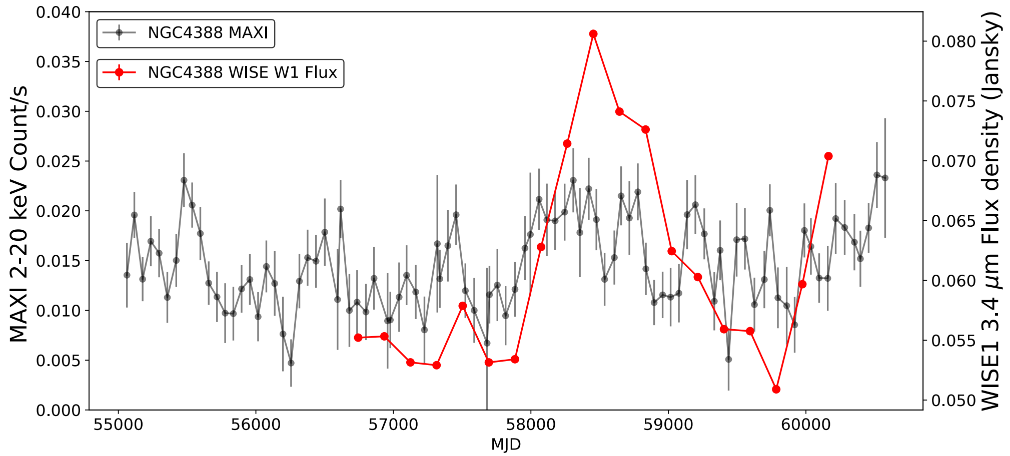
NGC 4151 (Type 1)



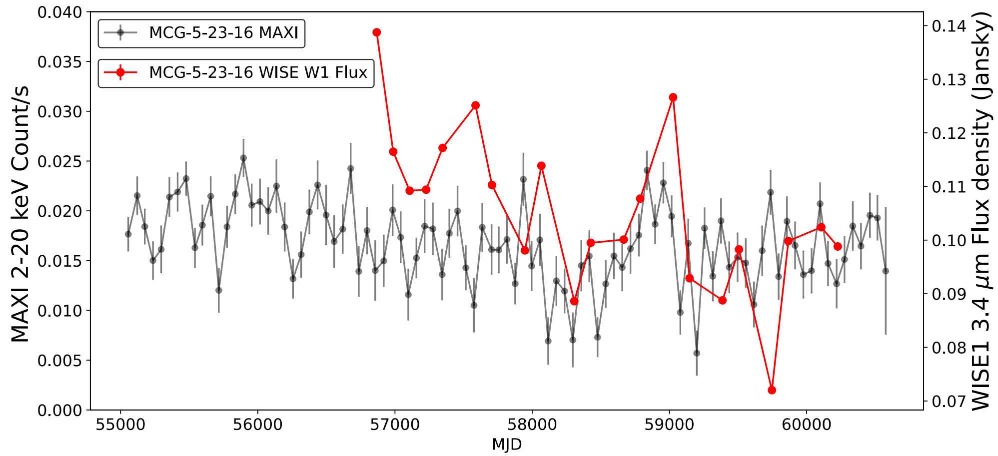
NGC 2110 (Type 2)



NGC 4388 (Type 2)



MCG-5-23-16 (Type 2)



☆ We selected AGNs with significant X-ray variability + not too high IR flux + weak jet

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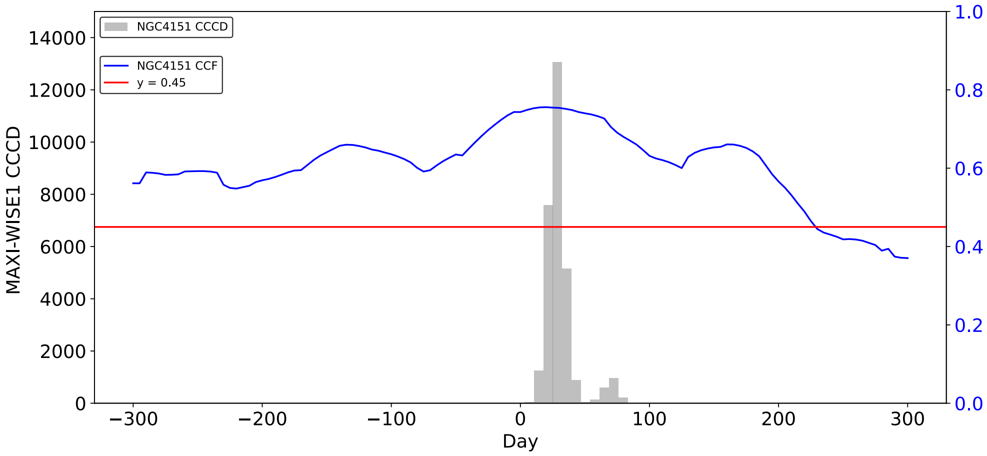
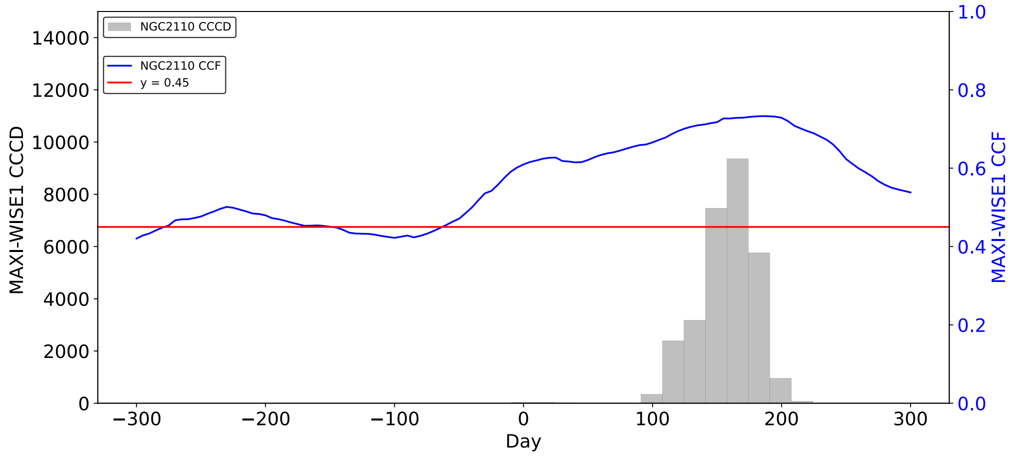


NGC 2110 (Type 2)



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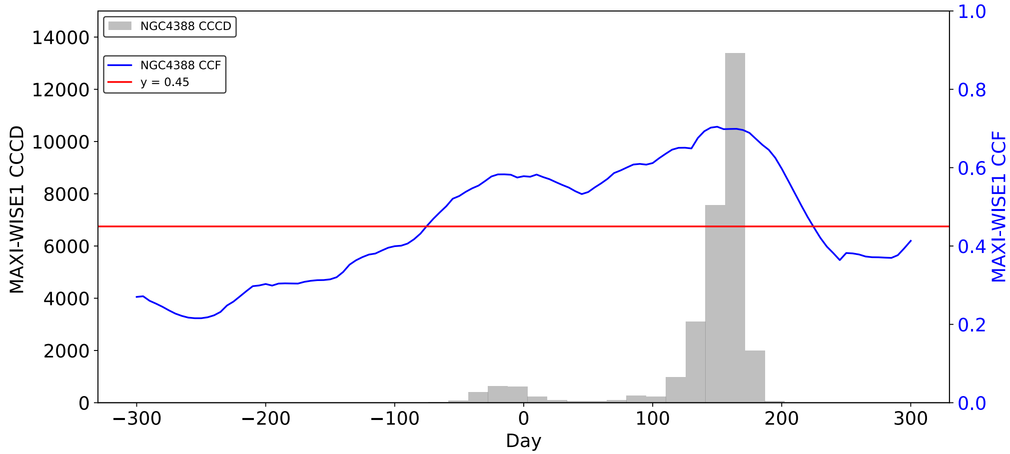

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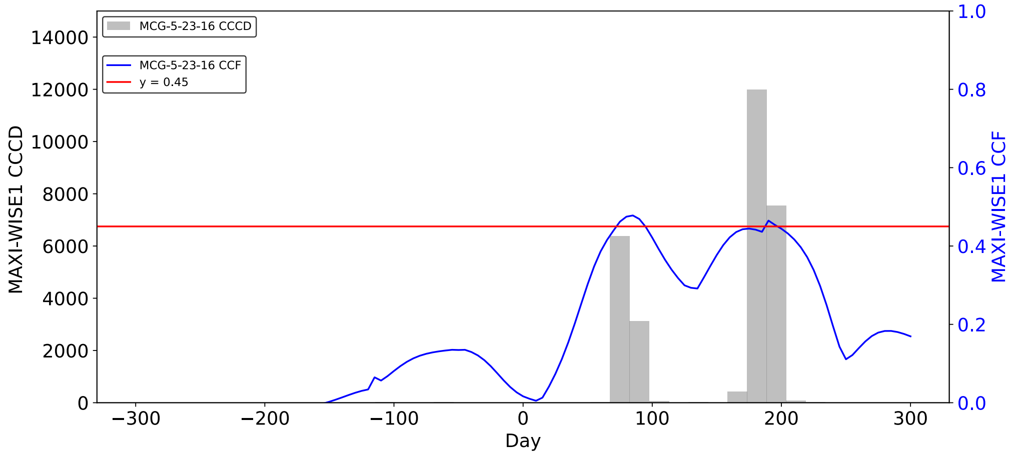
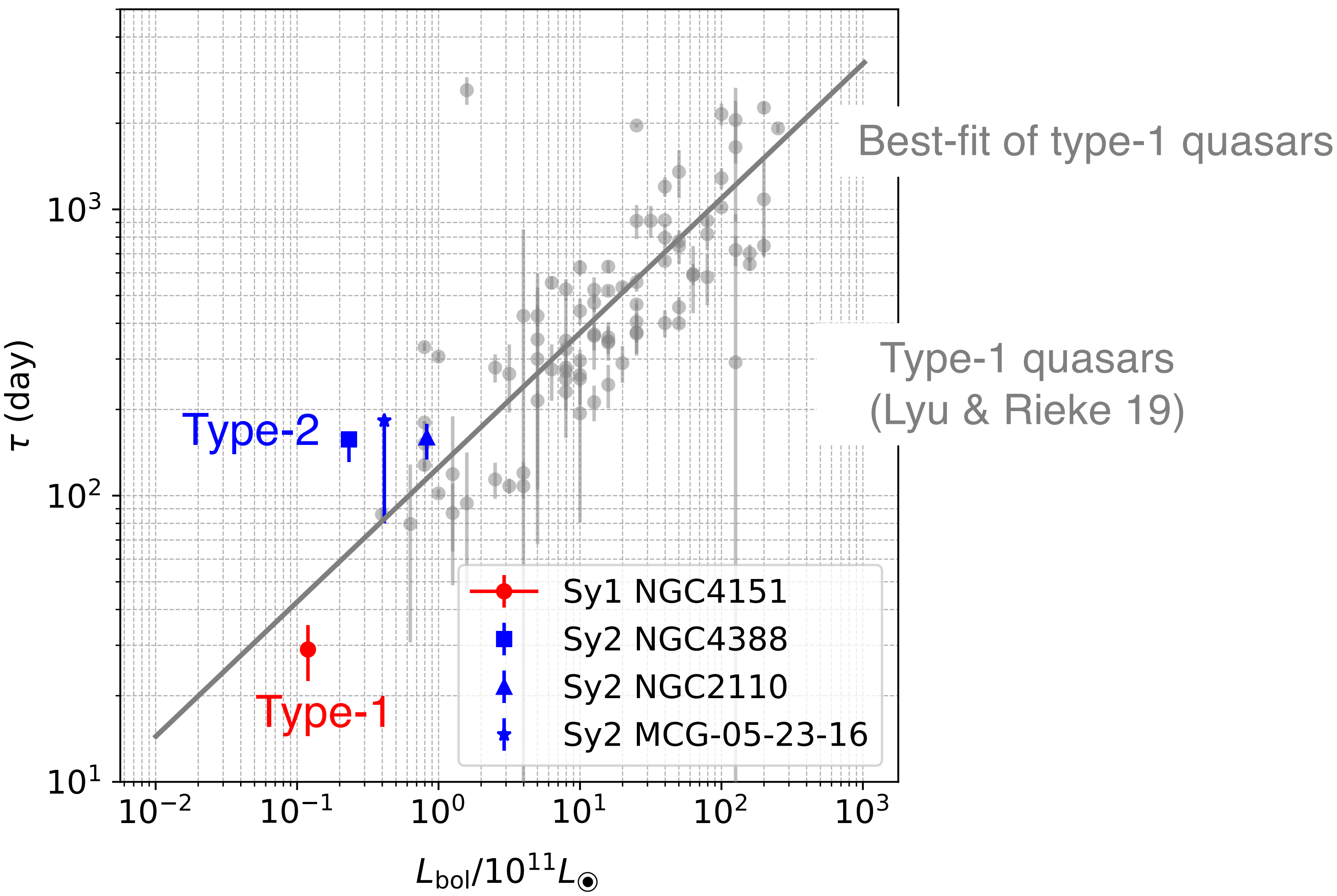


☆ We selected AGNs with significant X-ray variability + not too high IR flux + weak jet

☆ We determined τ_{dust} in both type 1 & type 2 AGNs (4 examples are shown)

First Comparison b/w Type-1 & -2 AGNs (Preliminary)

HN+20, Sakamoto, HN+ in prep



☆ We succeeded in comparing inner edge of tori of type-1 & -2 AGNs for the first time

☆ Do type-2 AGNs show larger τ_{dust}? ➔ More samples are required to confirm difference

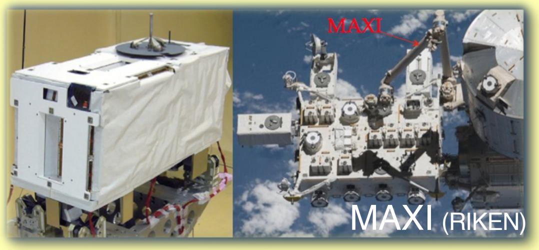
Future Prospect of X-ray & IR Reverberation Mapping

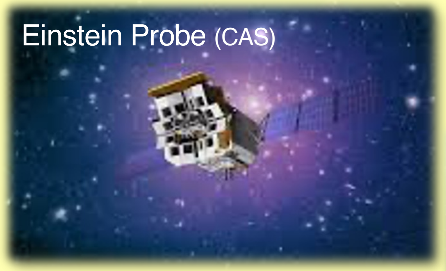
☆ Difference of the inner part of dusty tori b/w type-1 & -2 AGNs can be quantified, providing insights into the structure and origin of dusty tori

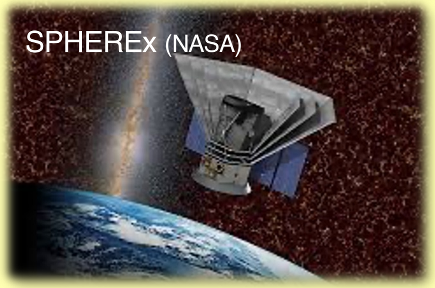
☆ Hidden disk activity of type-2 AGNs (including MM sources) can be potentially estimated by this new method

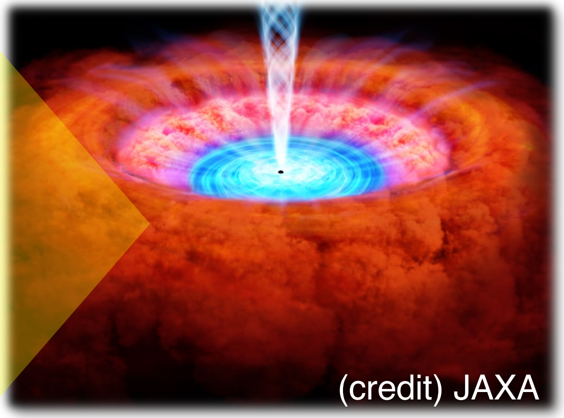
➔ High accuracy of the transfer function of X-ray to IR variability is required
Dense monitors by MAXI, BAT, EP, HZG & SPHEREx are highly effective

Combination of X-ray & IR all sky survey monitoring









Summary

☆ To extend dust reverberation mapping, previously conducted only for type-1 AGNs, to type-2 AGNs, we focus on the time variations in X-rays and NIR.

☆ We compared the ~10-year light curves of the MAXI 2–20 keV, WISE W1 (3.4 μm), and W2 (4.6 μm) bands, discovering a delay of approximately $\tau_{dust} \sim 130$ days (HN+20).

☆ We compared 15-year MAXI and WISE light curves on various AGNs, and found τ_{dust} on multiple type-1 and -2 AGNs (Sakamoto, HN+ in prep).

☆ For the first time, it has become possible to compare the inner edge structures of dusty tori in type-1 and -2 AGNs. Long-term monitoring by MAXI, BAT, EP, HZG, and SPHEREx are highly effective.