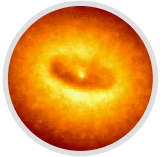


Hard X-ray and Millimeter Broadband Study of AGN Corona

Xiurui Zhao

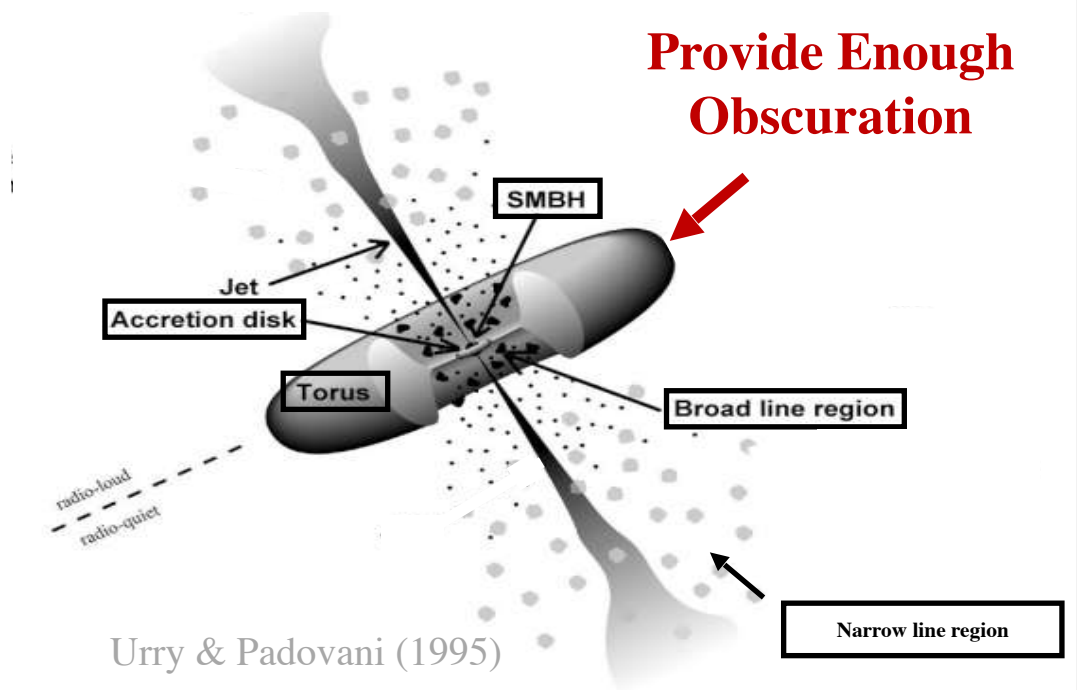
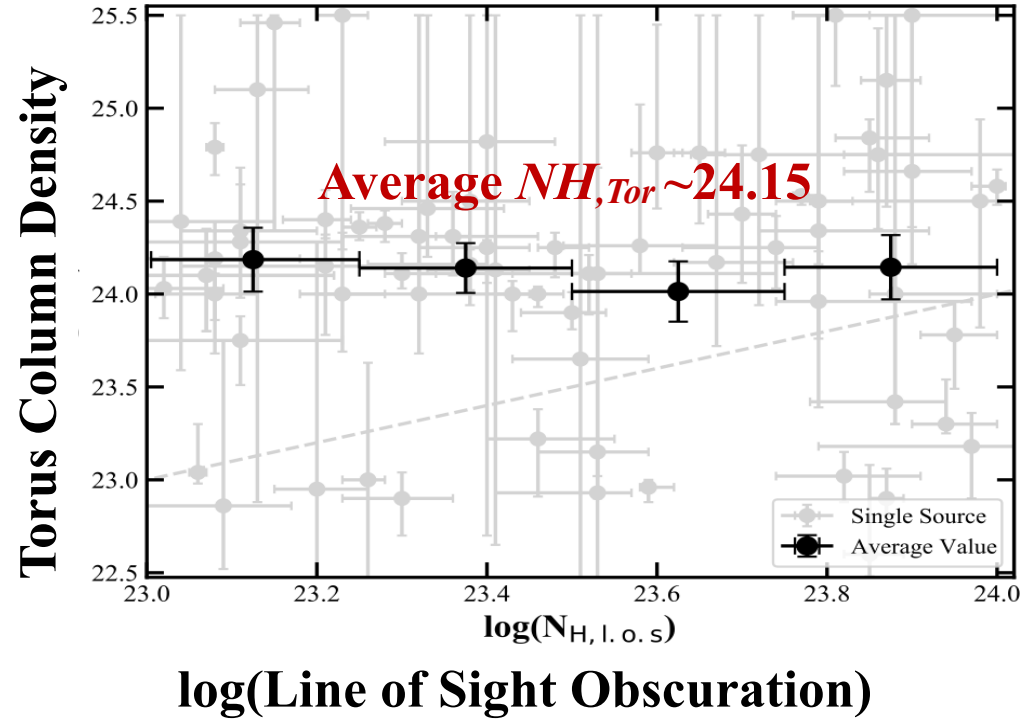
California Institute of Technology

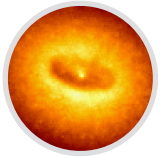
Illuminating the Active Universe, ESO, 2026 Sep 15th



Torus

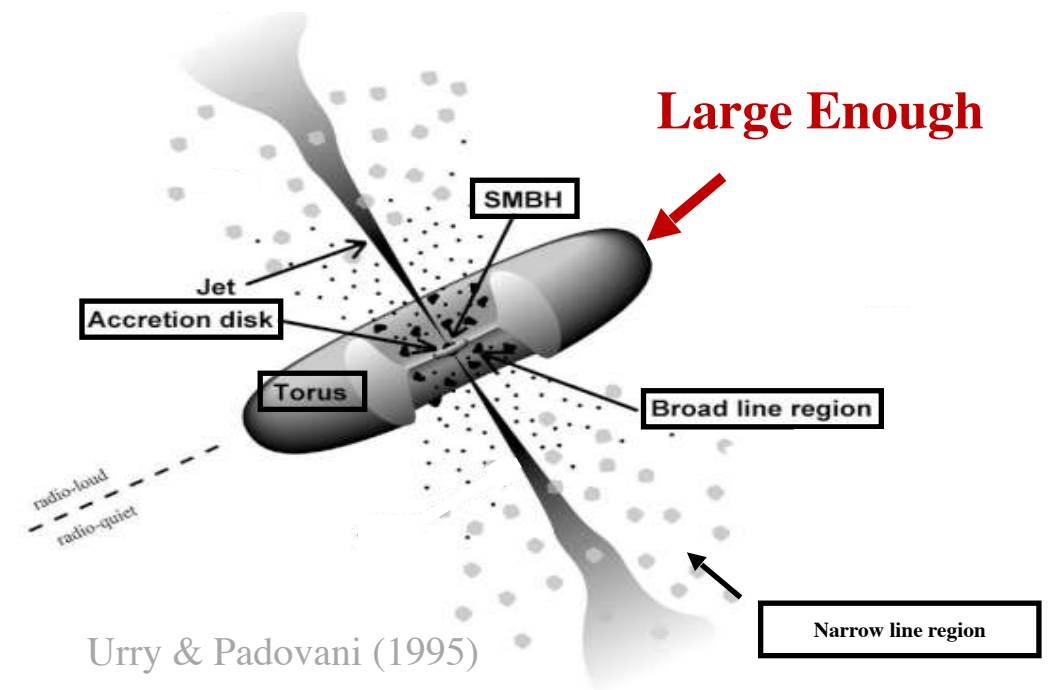
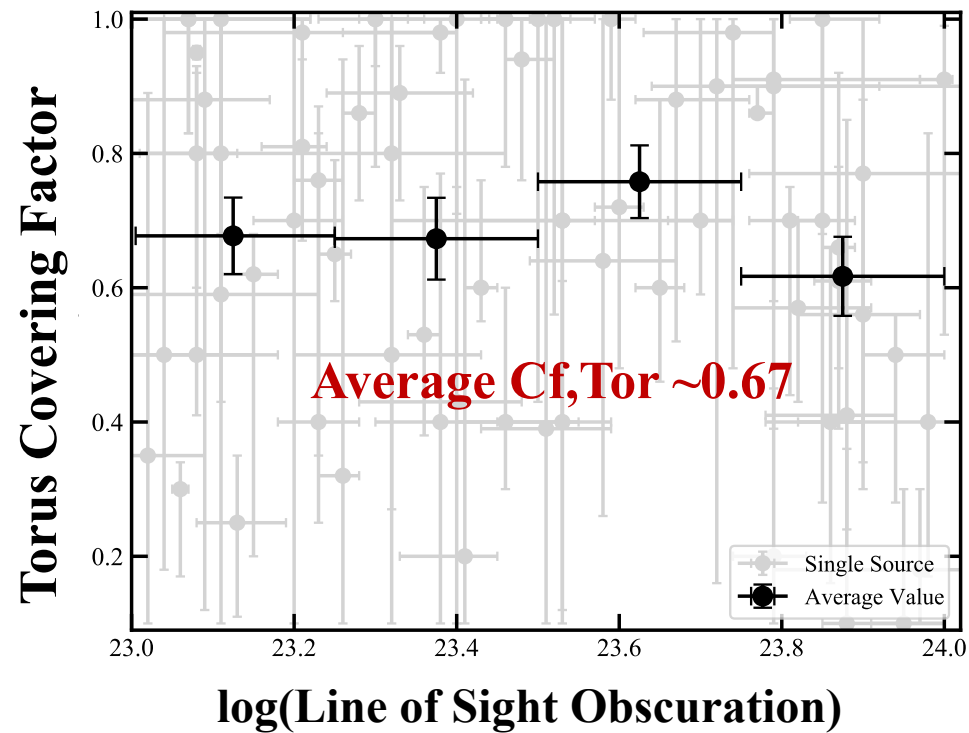
- Torus column density is on average $\log(N_{\text{H,Tor}}) \sim 24.15$, i.e., optically thick. Provide enough obscuration.
- N_{H} in the direction of Galactic center is $\log(n_{\text{H}}) \sim 23.15$ with $A_{\text{V}} \gg 10$ (Schlegel+1998) or 100 A4 papers.

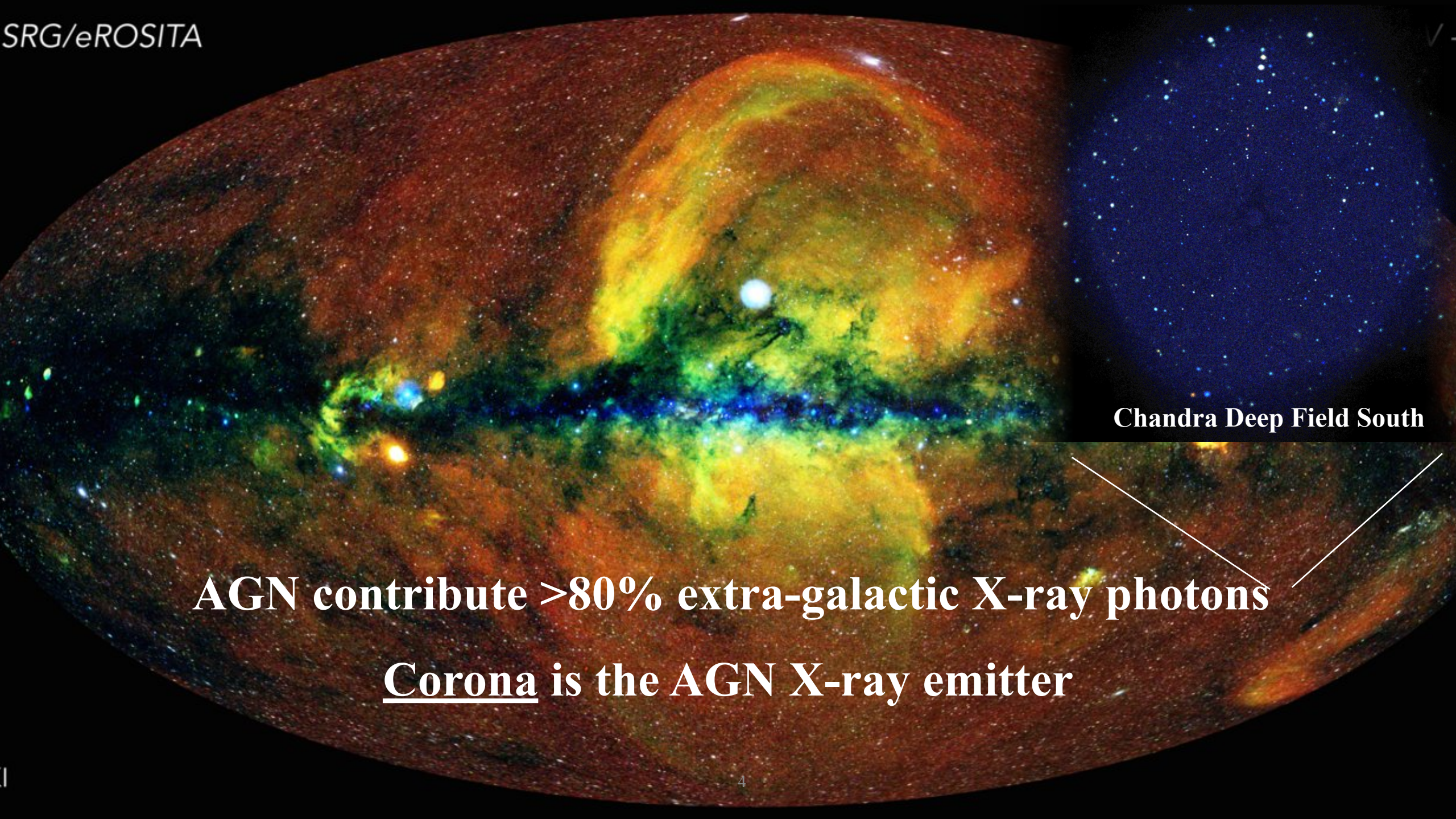




Torus

- Torus covering factor is ~ 0.67 . Large enough to obscure the BLR.

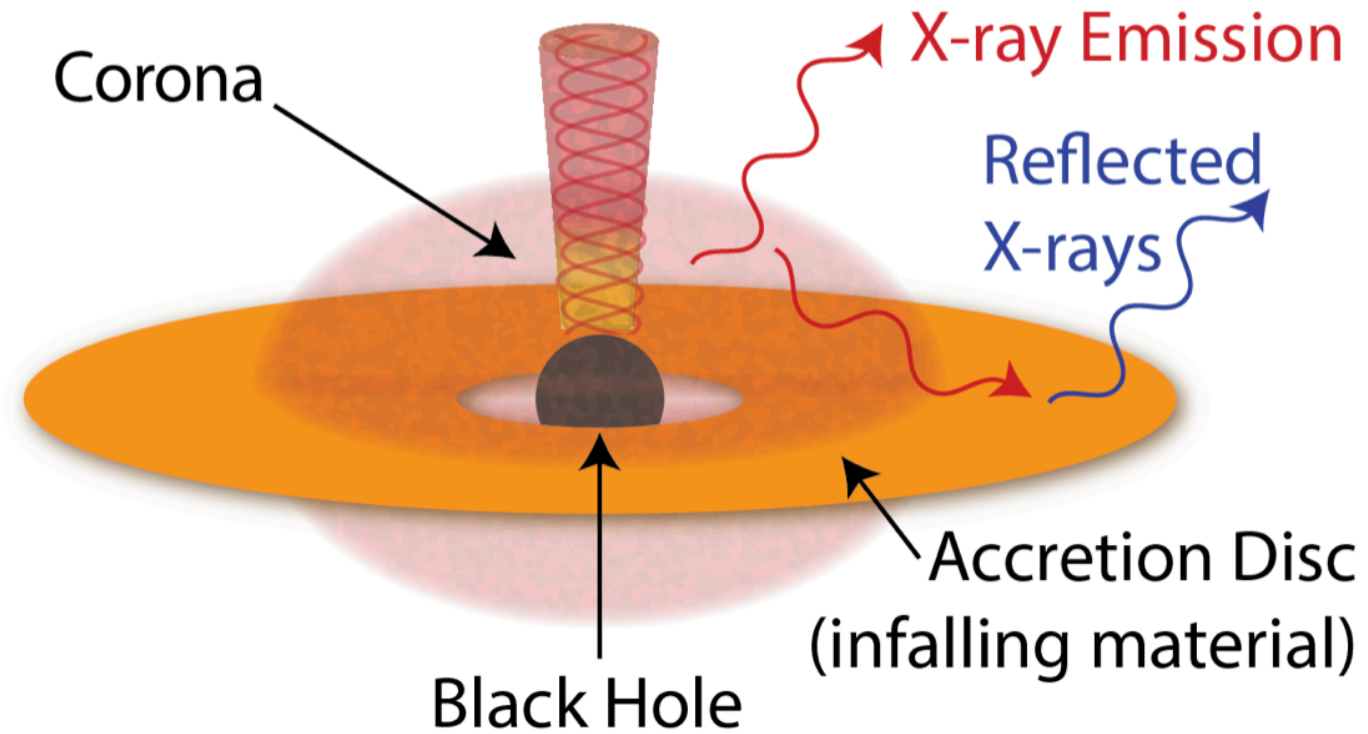




Chandra Deep Field South

AGN contribute >80% extra-galactic X-ray photons

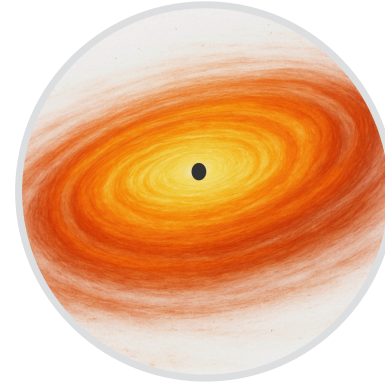
Corona is the AGN X-ray emitter



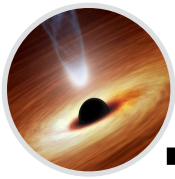
Credit: D. Wilkins



Corona Cooling Mechanism

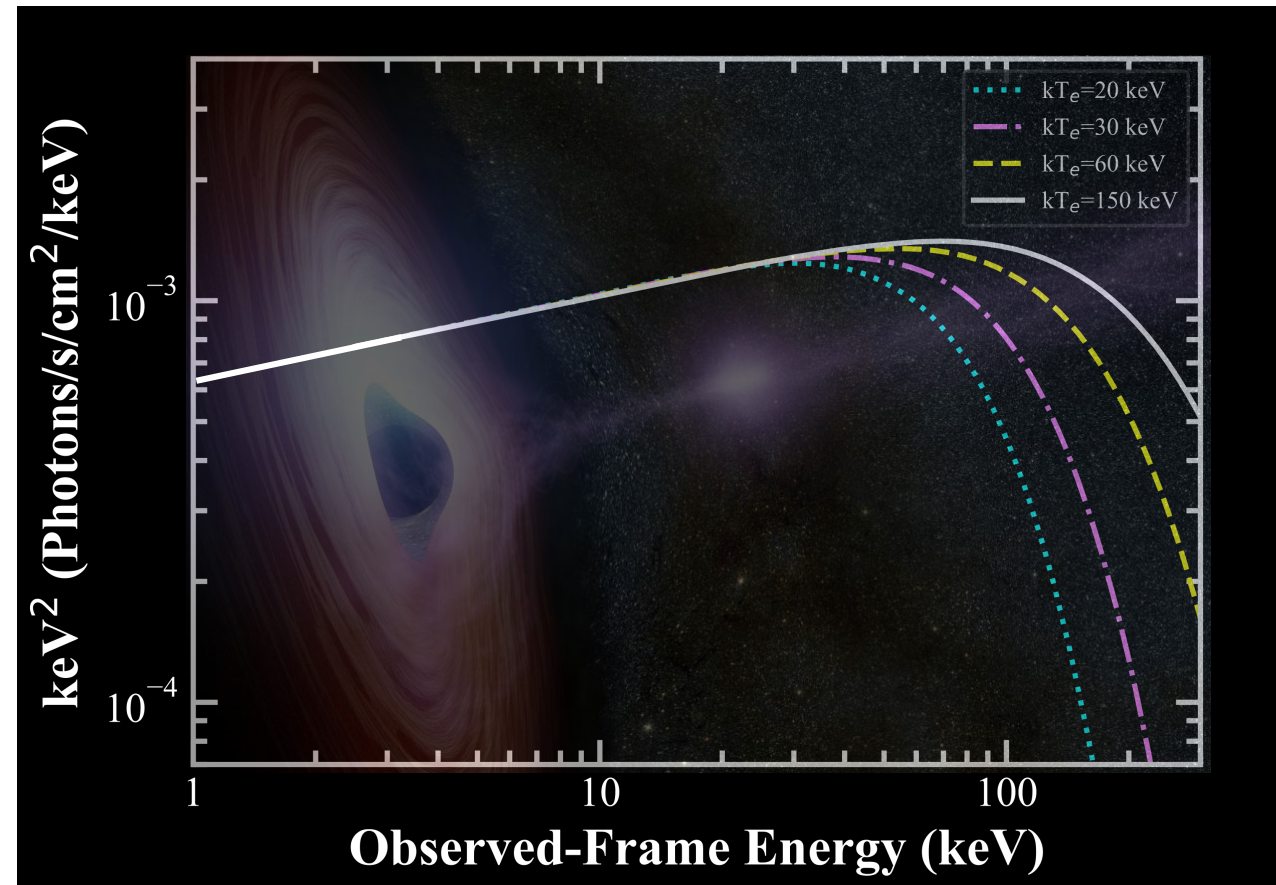


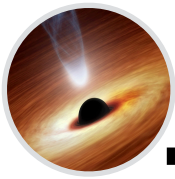
Coronal Variability



Corona

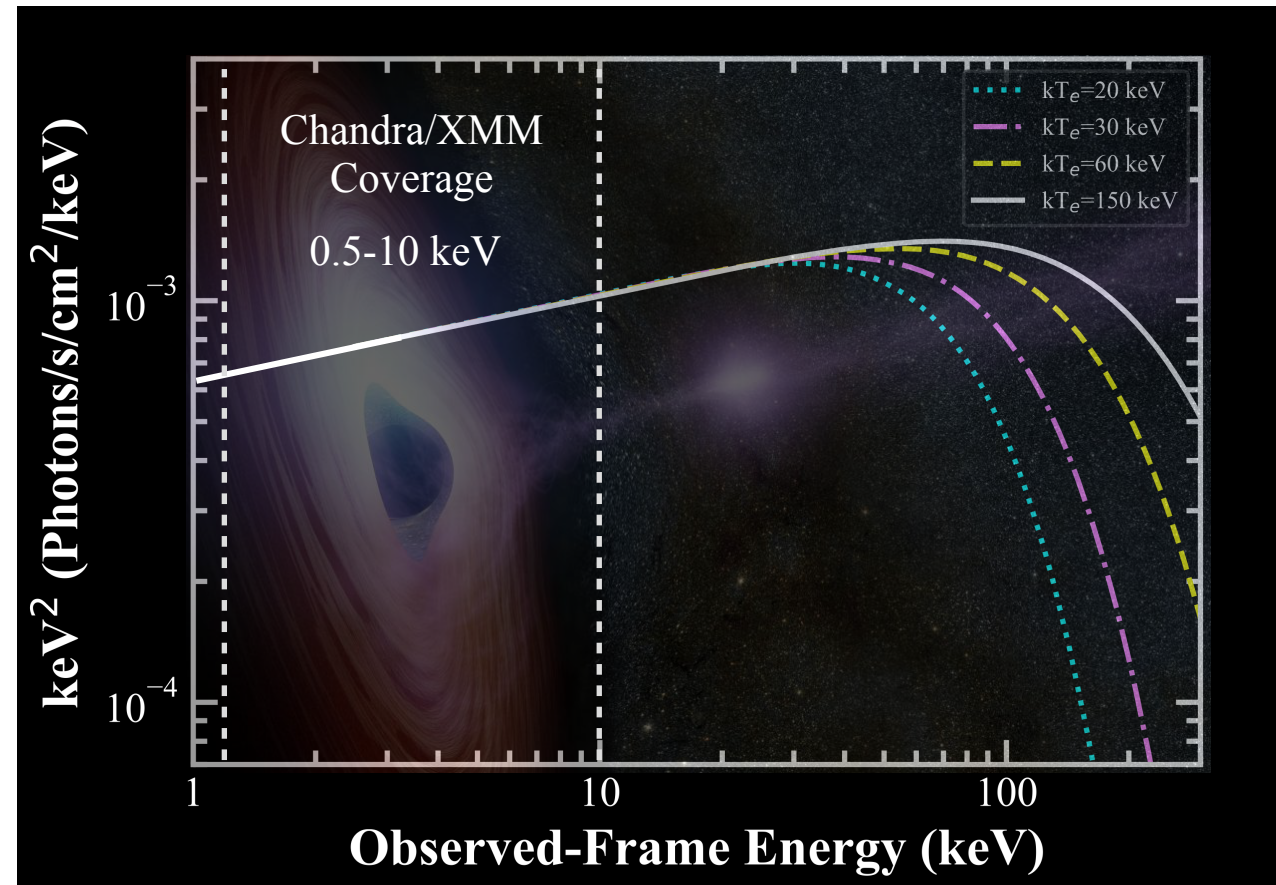
- A Comptonization model
- Coronal temperature is a fundamental property of coronae.

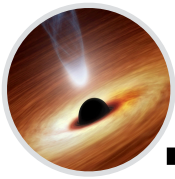




Corona

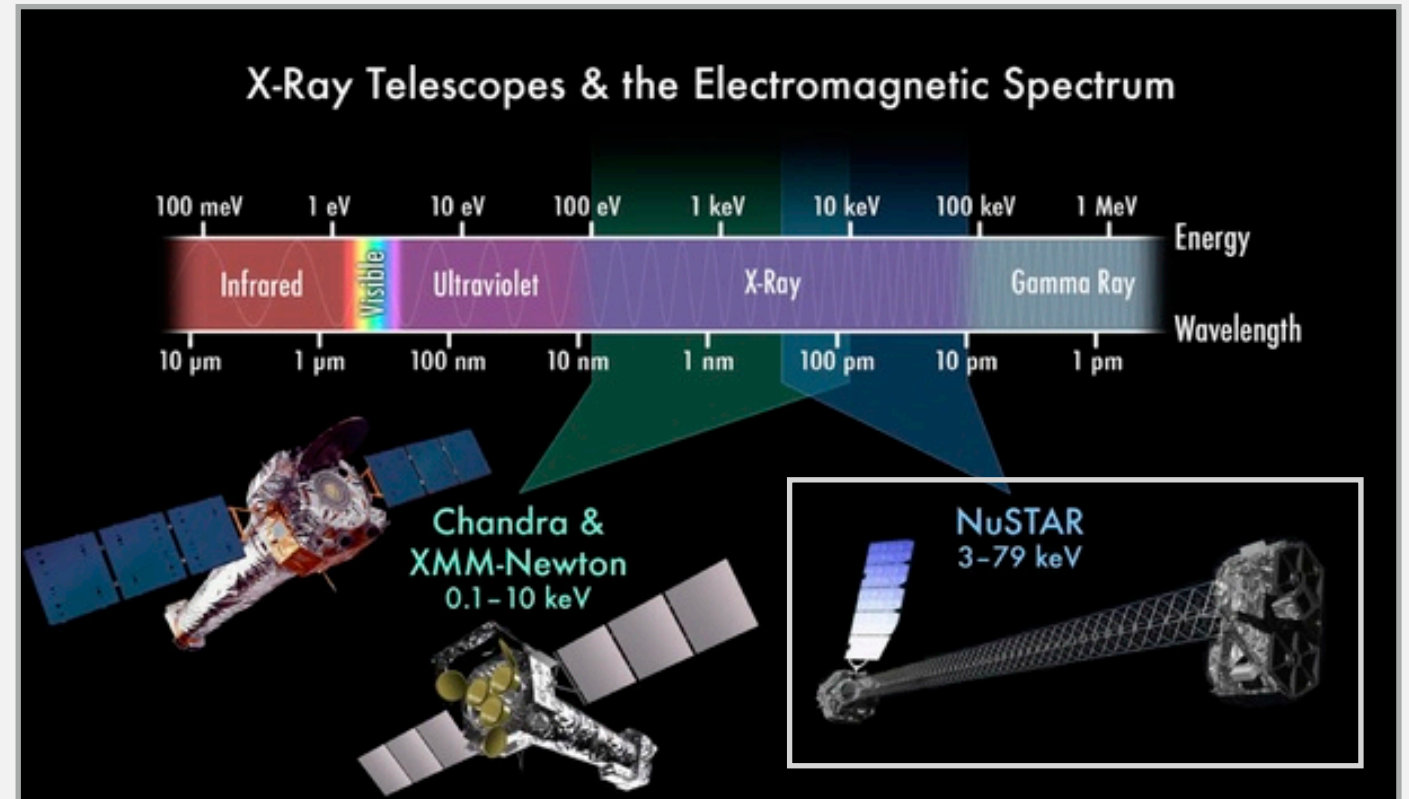
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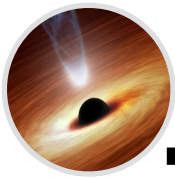


NuSTAR

- Energy bandpass: (3-79 keV)
- Launched in 2012 (PI: F. Harrison)

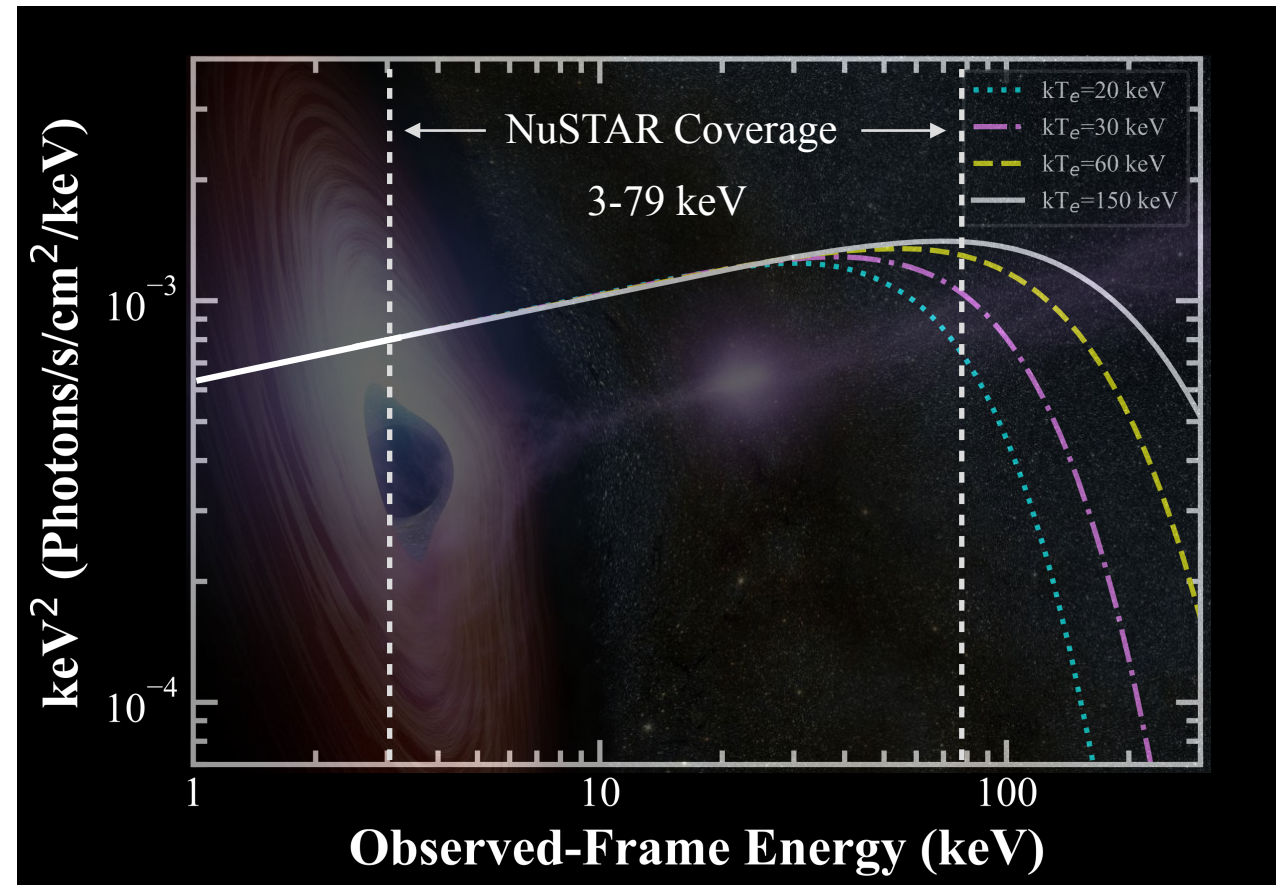


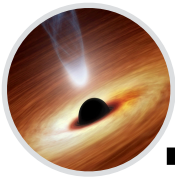
Courtesy: NASA/JPL-Caltech



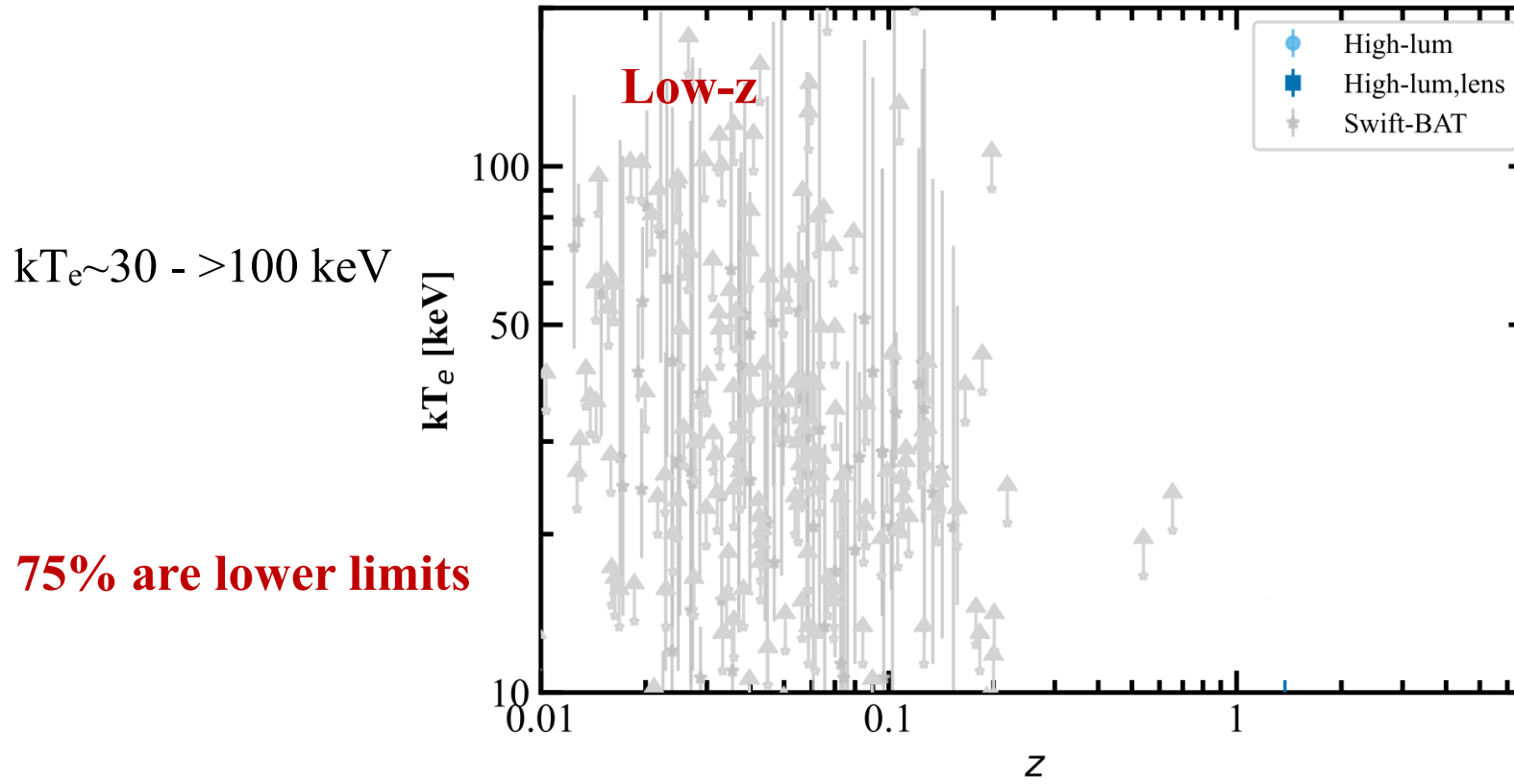
Corona

- * Measure coronal temperature with NuSTAR
- * Previous works: larger sample size, but mostly unconstrained due to the limited bandpass.

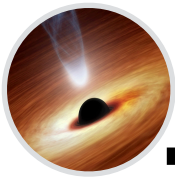




Corona

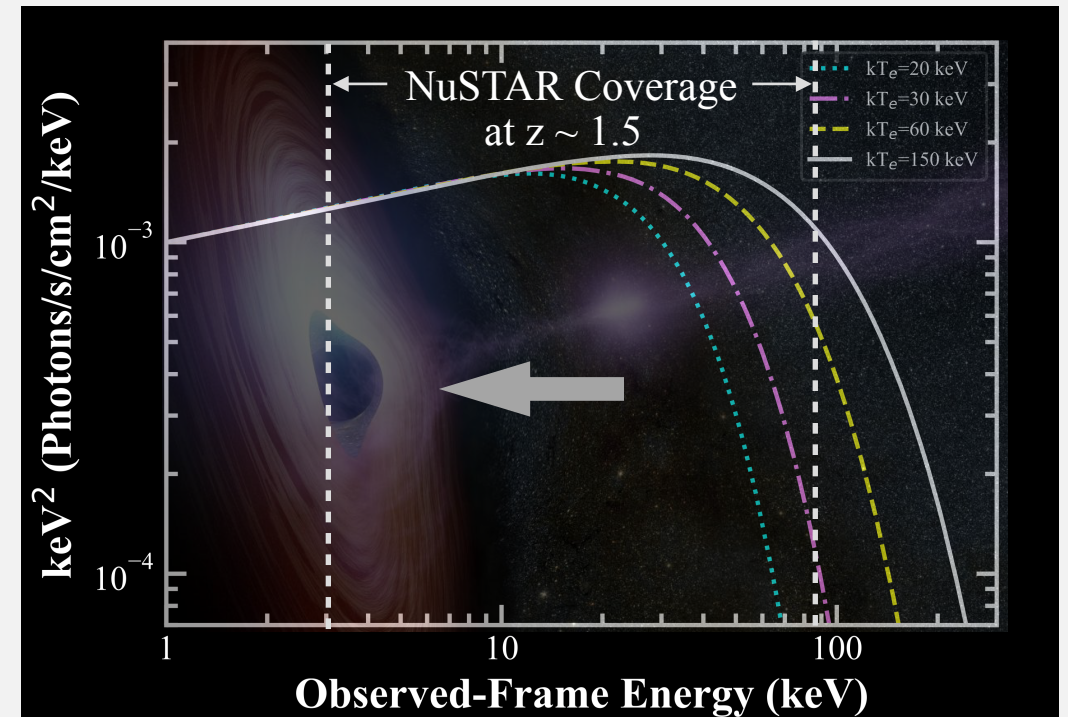
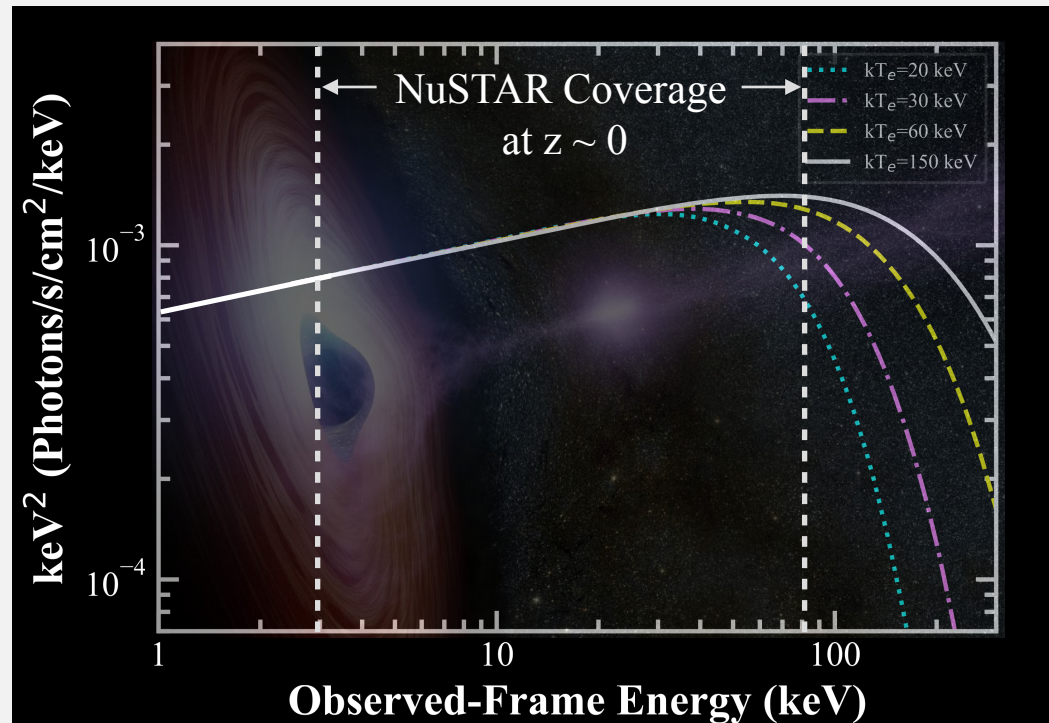


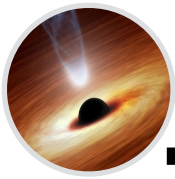
Akylas+2021



Corona

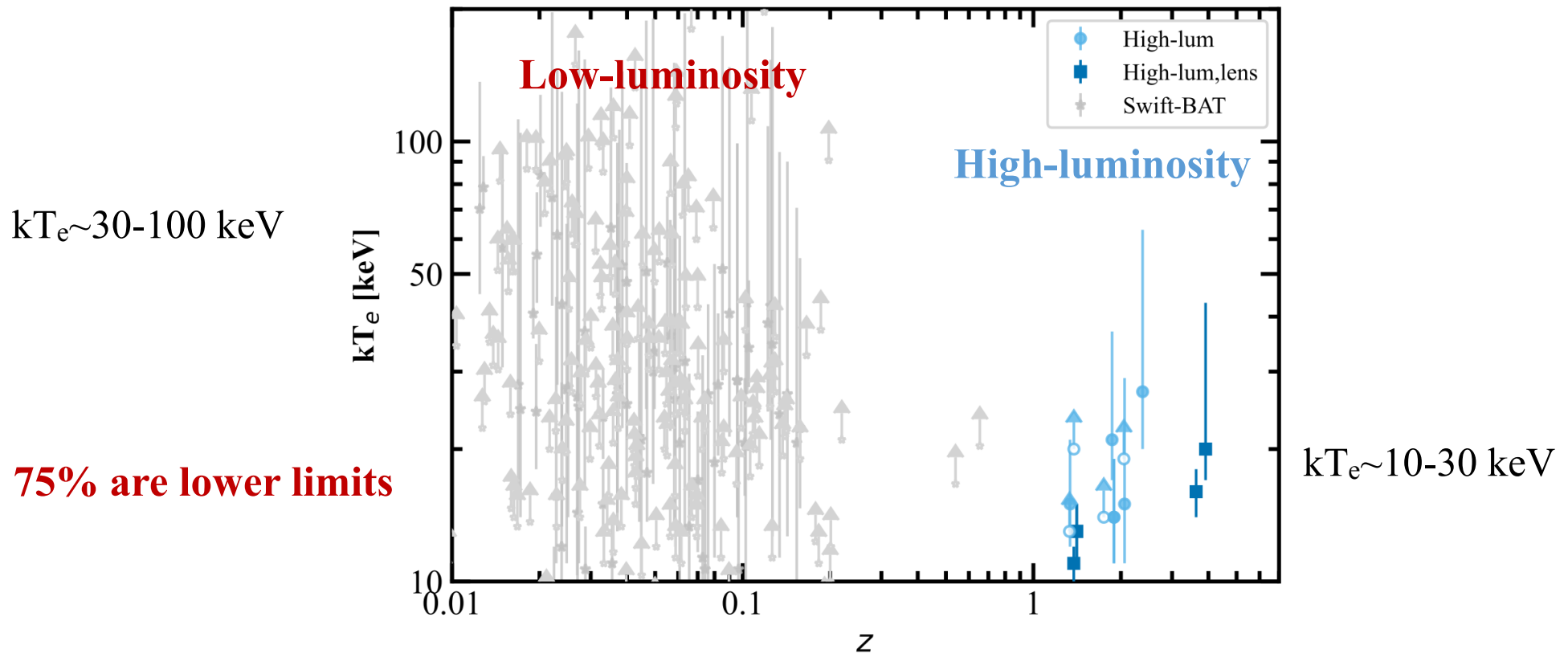
High- z AGN provides a great sample to systematically constrain AGN coronae.

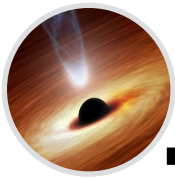




Corona

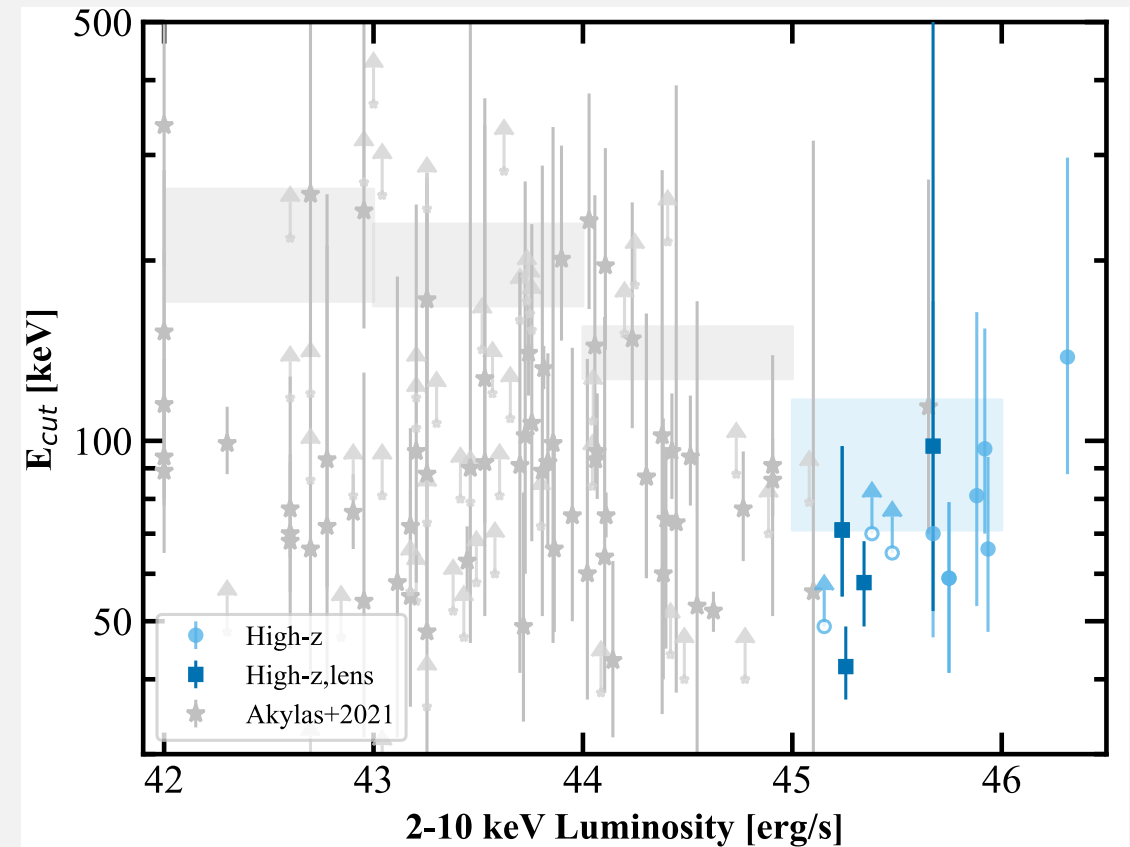
Eight $z > 1$ radio-quiet AGN with **400 hrs** *NuSTAR* and **150 hrs** XMM observations (PI: Zhao)

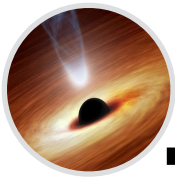




Corona

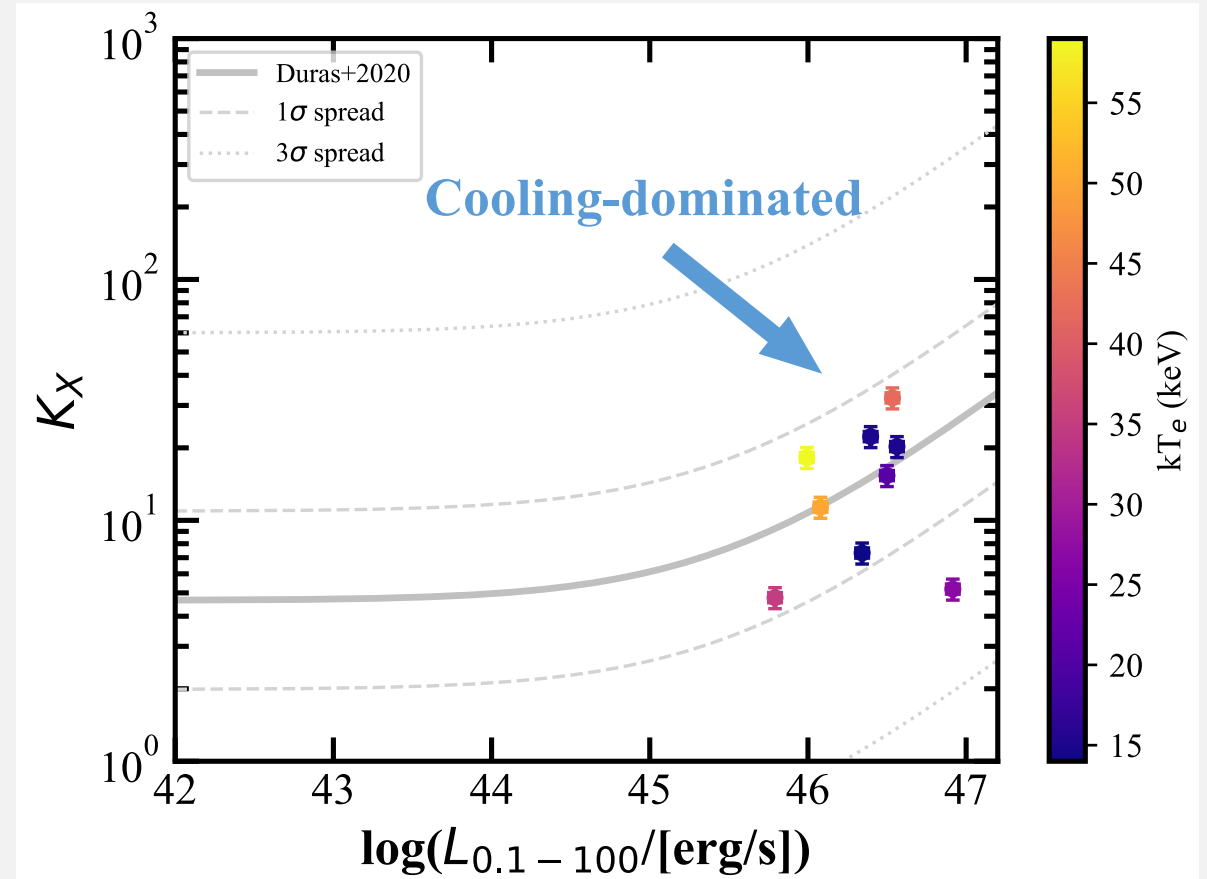
- ❖ Evidence for anti-correlation between cutoff energy (coronal temperature) and luminosity.
- ❖ More Compton Cooling compared with heating at higher luminosity.





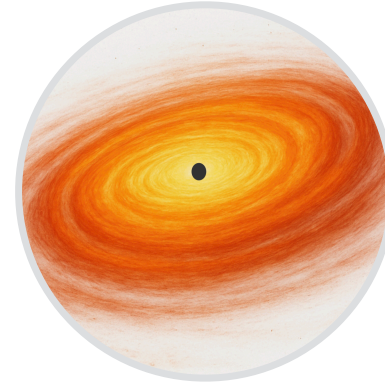
Corona

- ❖ More Compton Cooling compared with heating at higher luminosity.
- ❖ Lower X-ray luminosity to bolometric luminosity ratio suggests high-L coronae are dominated by cooling.
- ❖ Heating/accreting power does not scale as cooling at higher-luminosity?

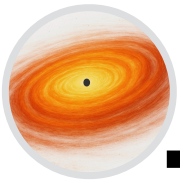




Corona Cooling Mechanism

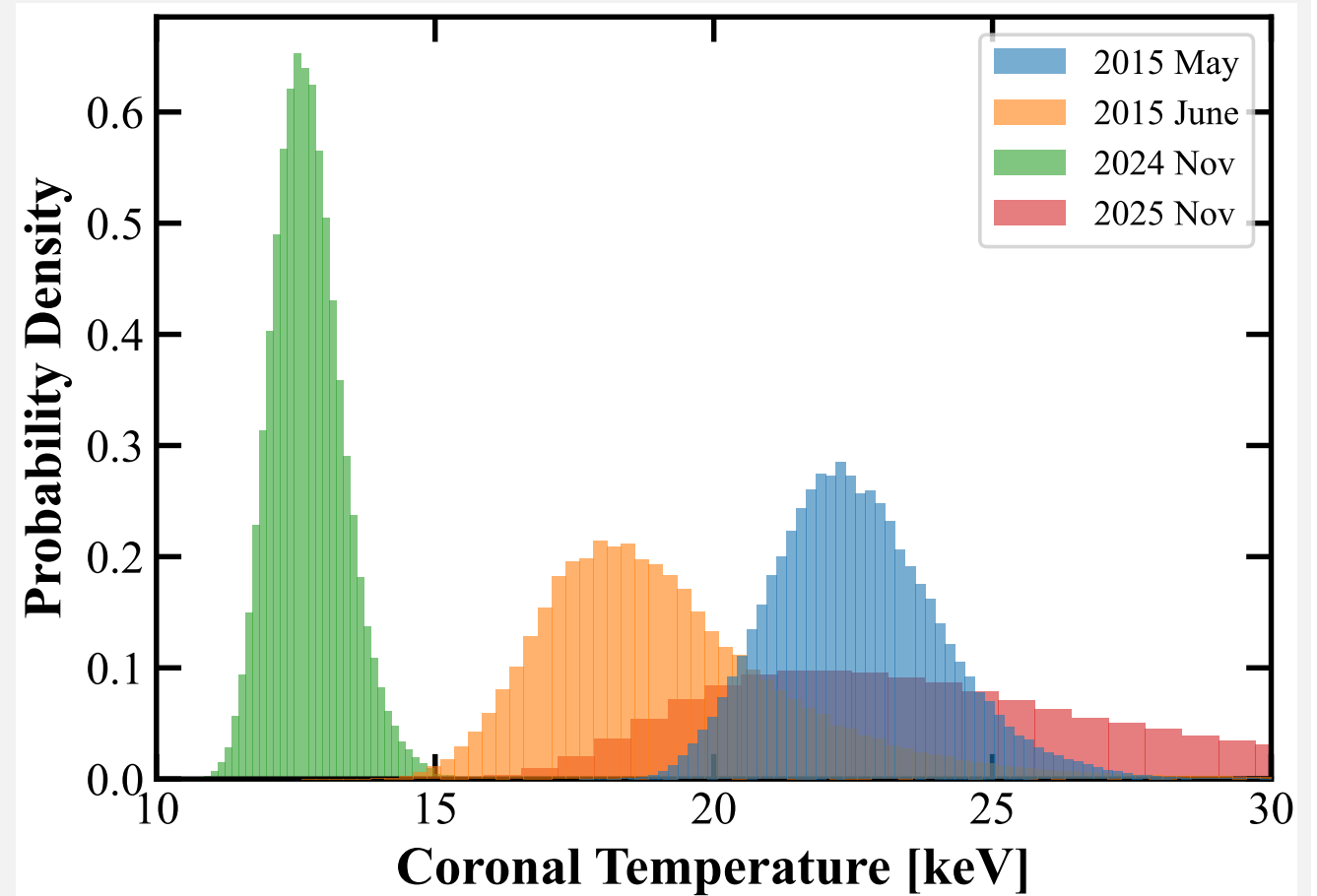


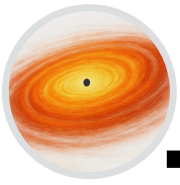
Coronal Variability



Mrk 509

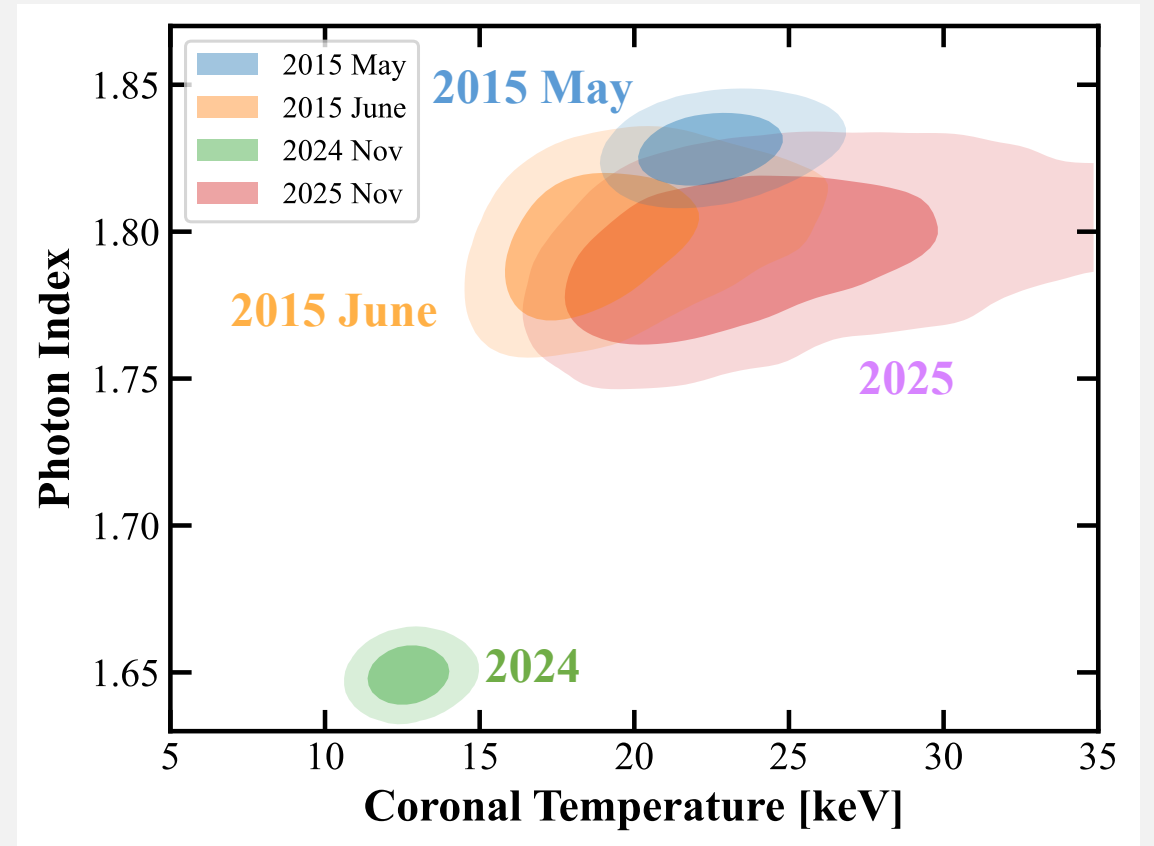
- * Local, bright, type 1 AGN
- * $kT_{\text{e}} \sim 10\text{-}30$ keV
- * Four epochs observations
- * NuSTAR ToO (cycle 11+12, PI: Zhao)

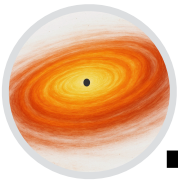




Mrk 509

Significant photon index and
temperature variations in 2024

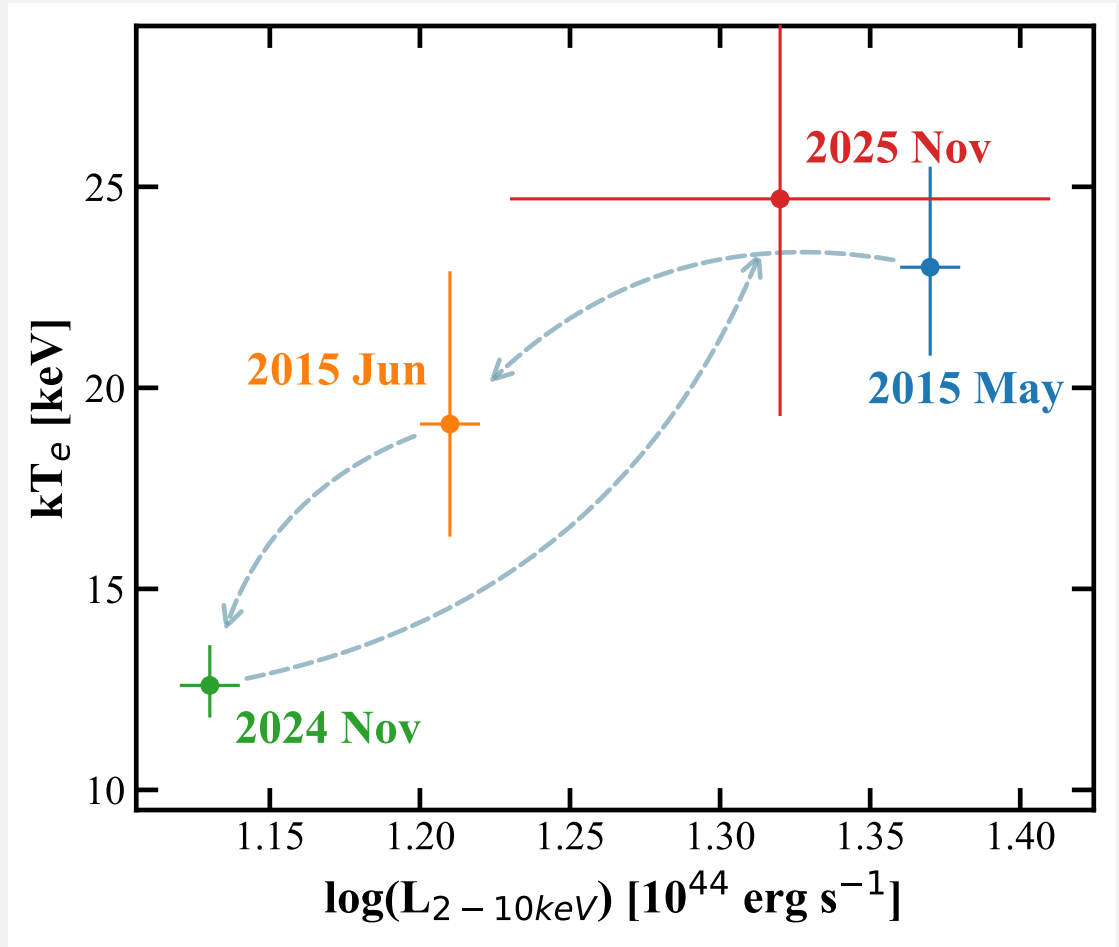
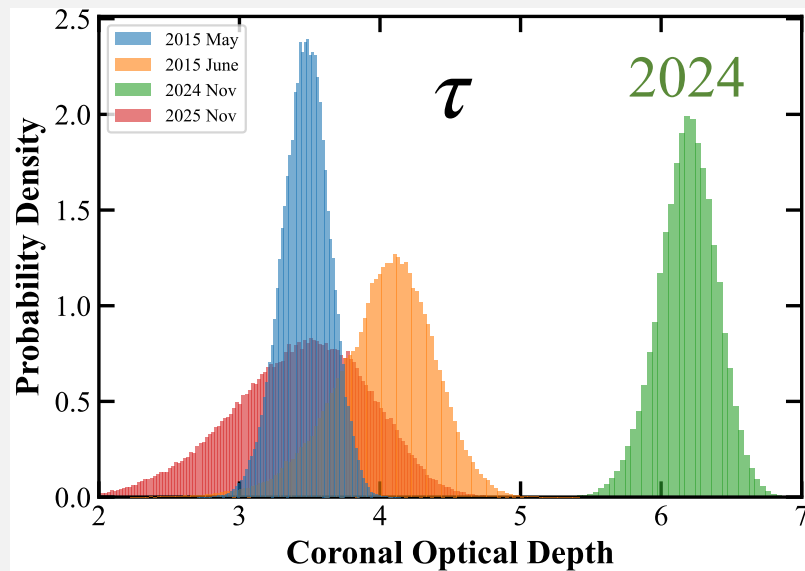


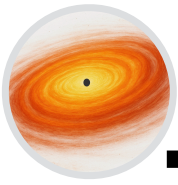


Mrk 509

❖ What drive the coronal cooling and heating?

Lum ↓ τ ↑↑ kT_e ↓↓

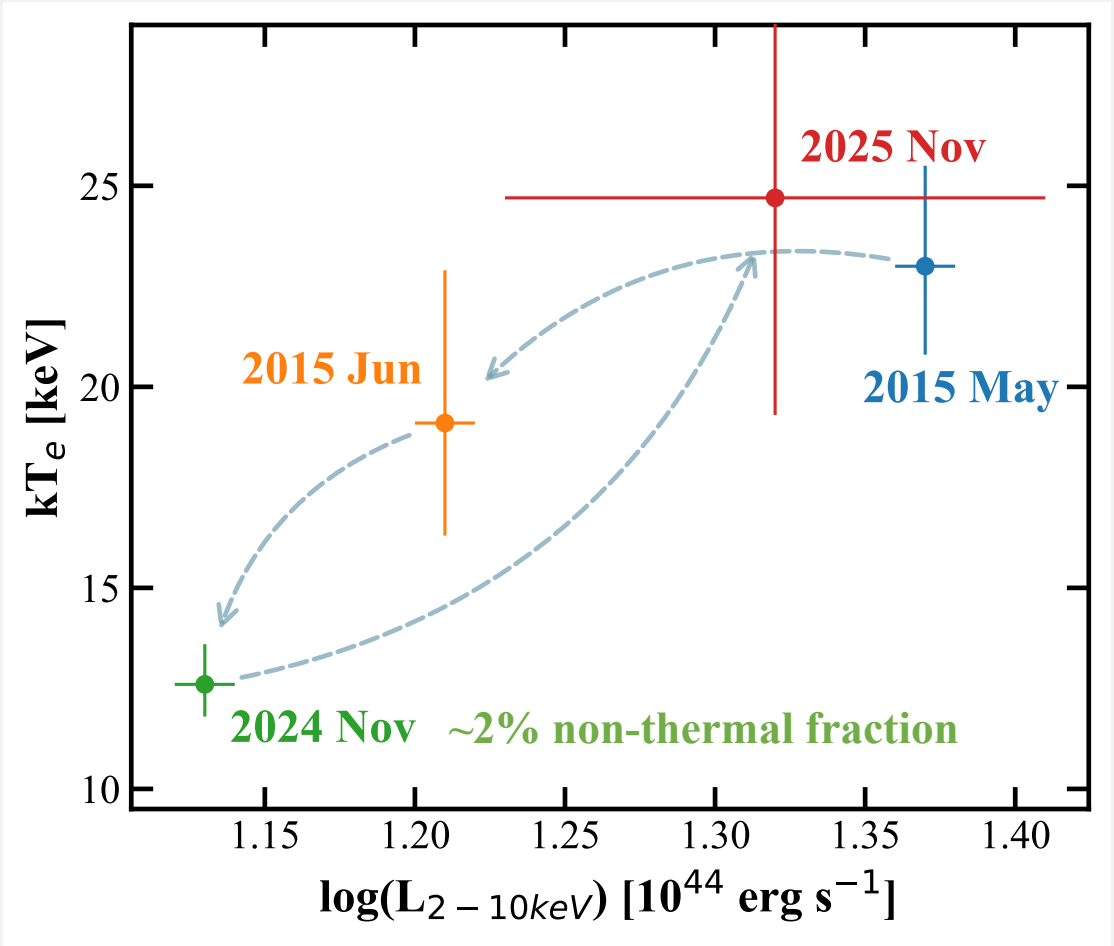
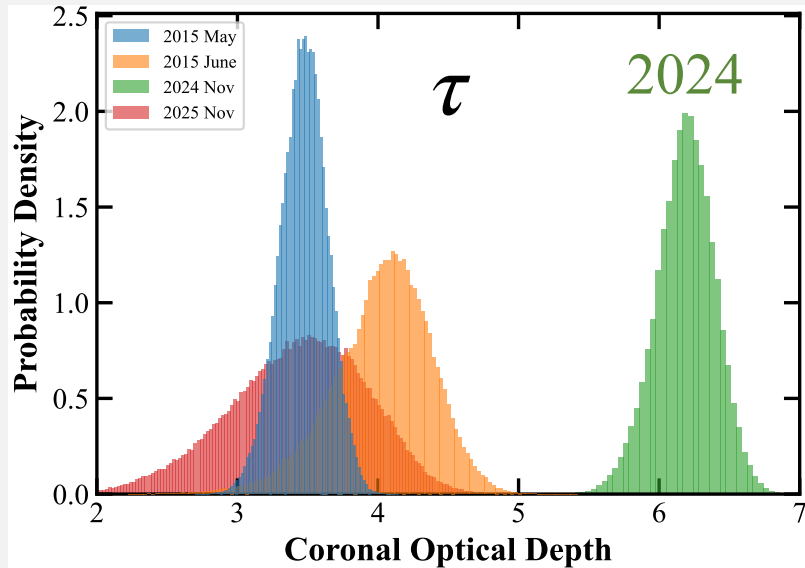


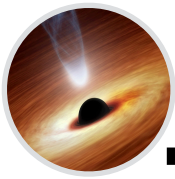


Mrk 509

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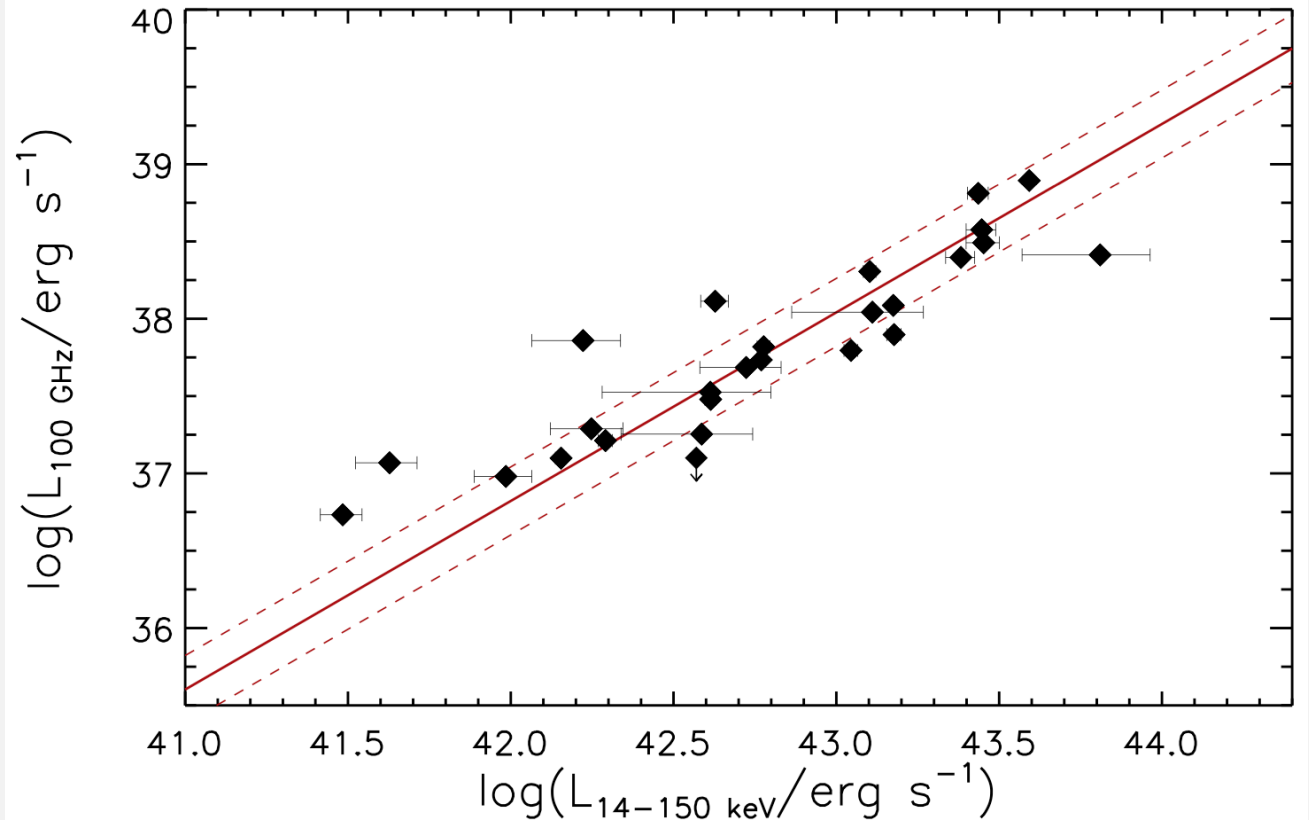


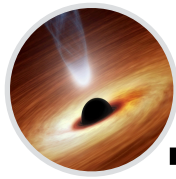


Corona

A multi-wavelength view of AGN corona

- ❖ X-ray and sub-mm luminosity significantly correlated.
- ❖ Constrain coronal properties complementary.

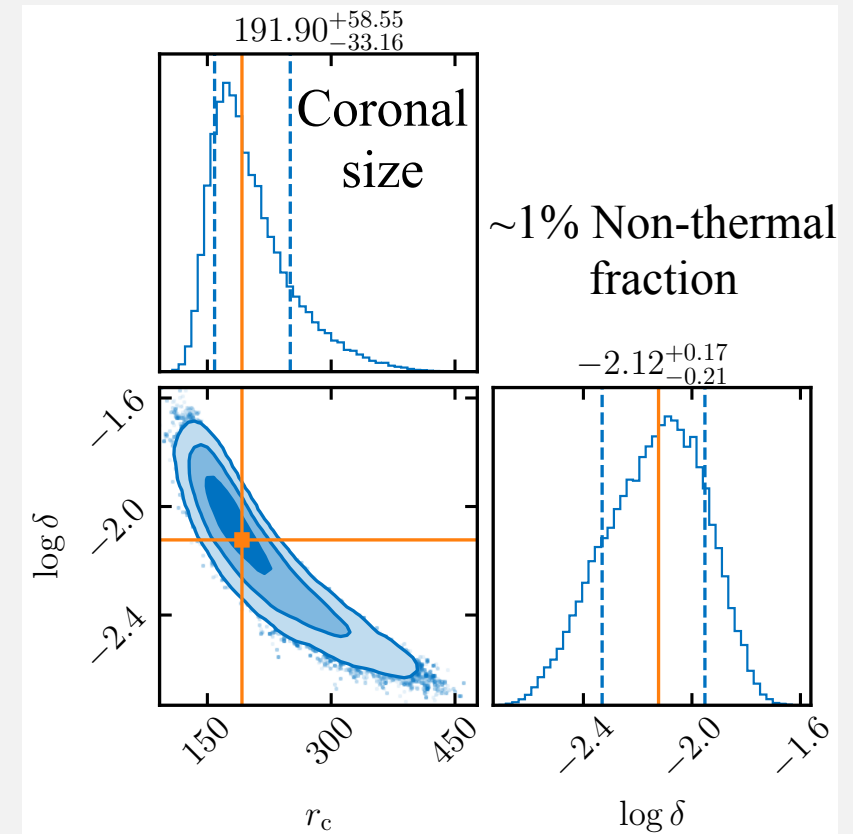
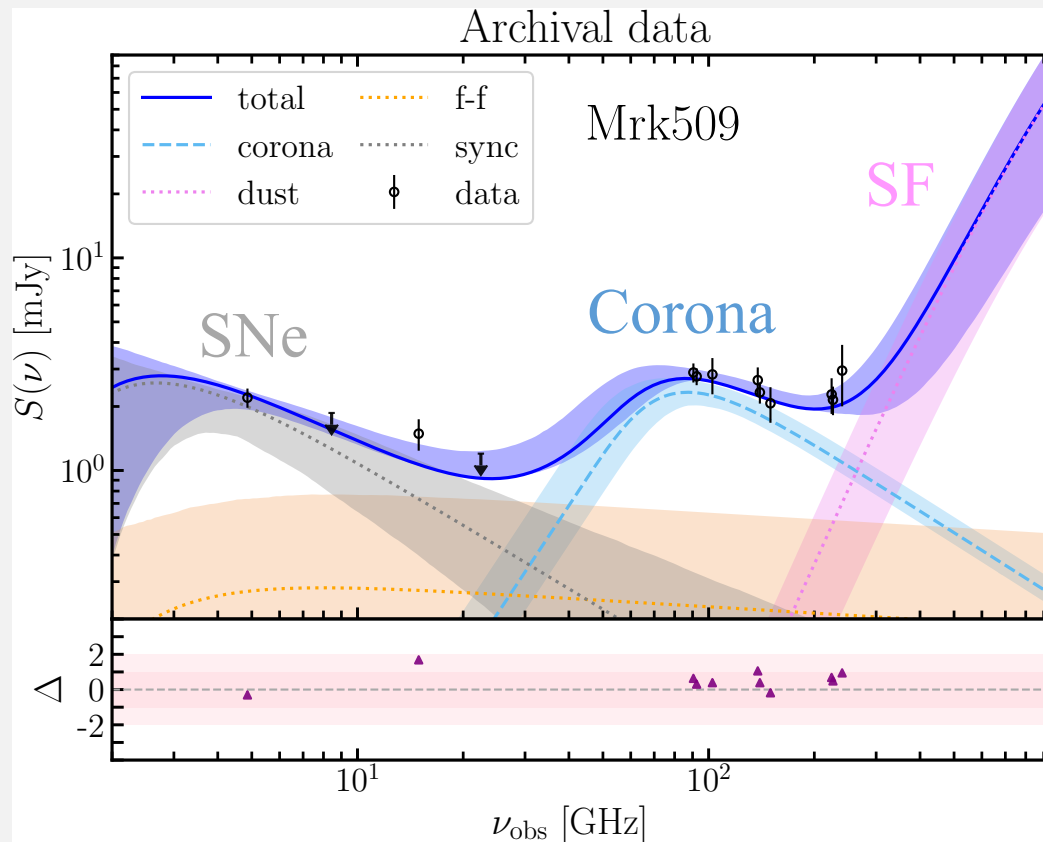




Corona

A multi-wavelength view of AGN corona

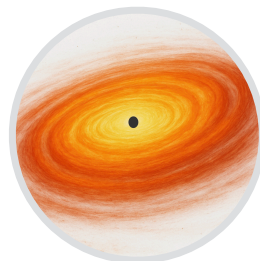
ALMA high-angular resolution observation of AGN corona.



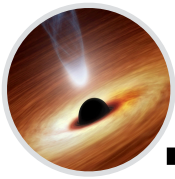
Take Home



The systematically lower coronal temperatures in high-luminosity AGN suggests a heating-inefficient corona at higher-luminosity.



Coronae can significantly vary at similar luminosity level. A small fraction of non-thermal electrons might exist in corona.



Corona

- ❖ No clear evidence for correlation between cutoff energy (coronal temperature) and Eddington ratio.

