活动星系核的X射线冕区辐射

王俊贤

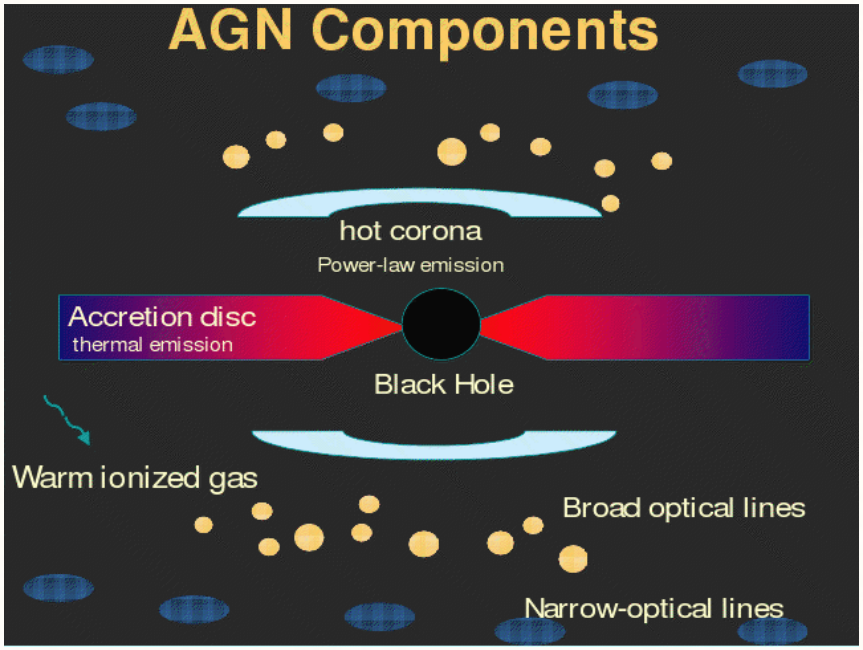
University of Science and Technology of China

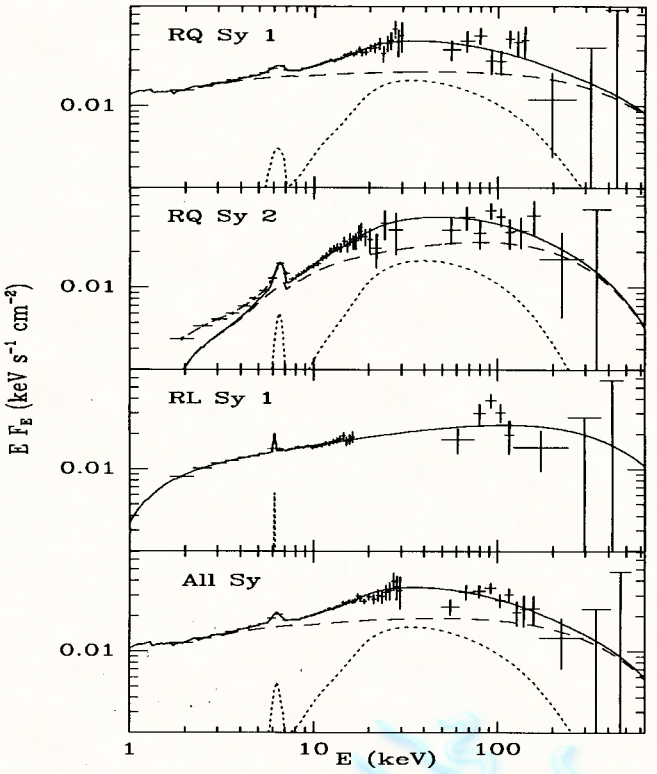
X-ray emission in AGNs

AGN's primary X-ray emission powerlaw with high energy cutoff

$$A(E) = KE^{-\alpha} \exp\left(-E/\beta\right)$$

Hot corona model is favored





Zdziarski et al. 1995

Disk-corona model (Haardt & Marashi 1991)

Analogy between AGN and solar corona?

Hot accretion flow (ADAF) for low accretion AGNs

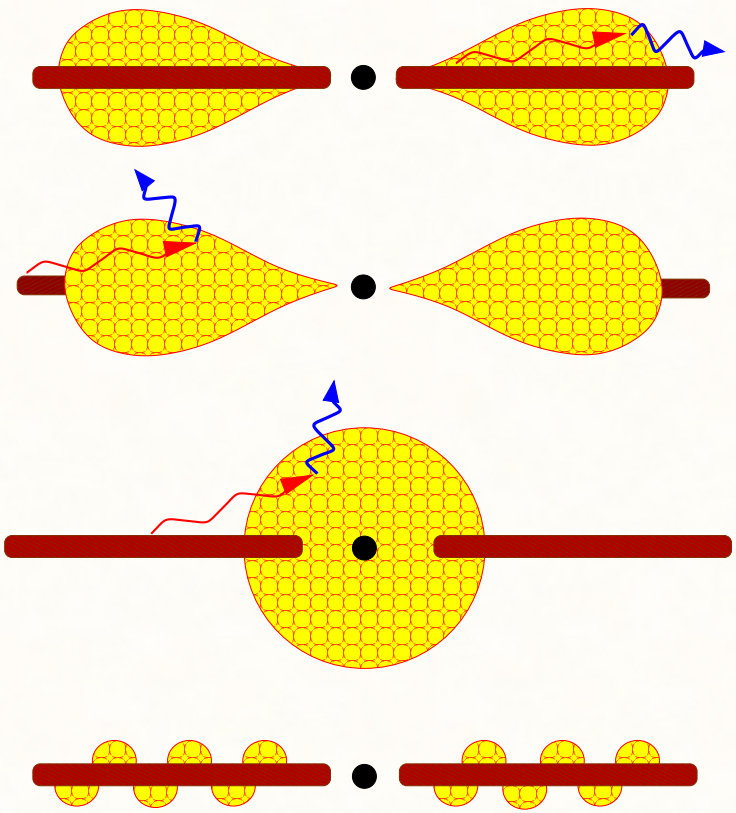


Fig. 6. Suggested geometries for an accretion disk and Comptonizing corona for predominantly spectrally hard states. The top figure is referred to as a "slab" or "sandwich" geometry; however, it tends to predict spectra softer than observed. The remaining three show "photon starved geometries" wherein the corona is less effectively cooled by soft photons from the disk. The middle two geometries are often referred to as "sphere+disk geometries", while the bottom geometry is often referred to as a "patchy corona" or "pill box" model [140].

Flares like solar X-ray corona

Galeev et al. 1979

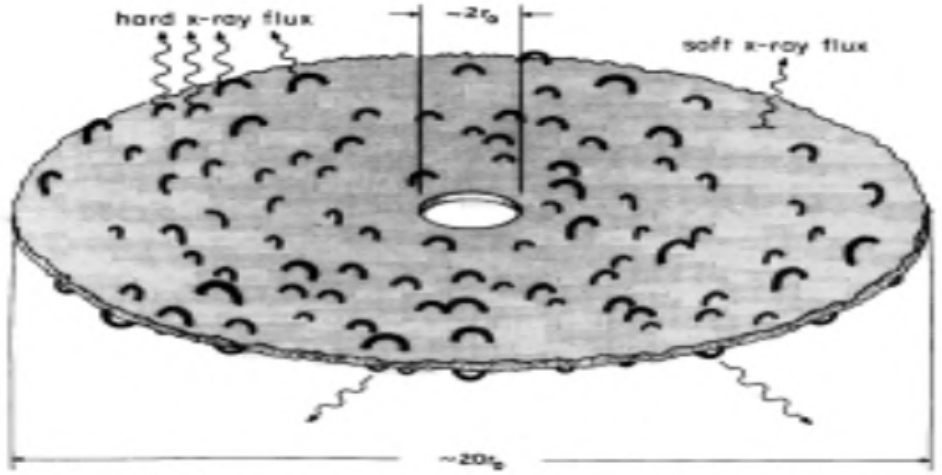


FIG. 3.—Schematic drawing of the inner accretion disk coronal geometry, with $r_0 = 6GM/c^2 \sim 10^7$ cm in the case of Cyg X-1; only the inner portion of the disk is shown. The soft X-ray component derives from the relatively cool disk (including the outer portion not shown here) while the hard X-ray component is emitted by the ensemble of hot ($T_e \gtrsim 5 \times 10^8$ K) plasma loop structures which have emerged from the inner disk. The length of typical loop structures is of the order of 10^8 cm, but can be expected to vary considerably as the loops

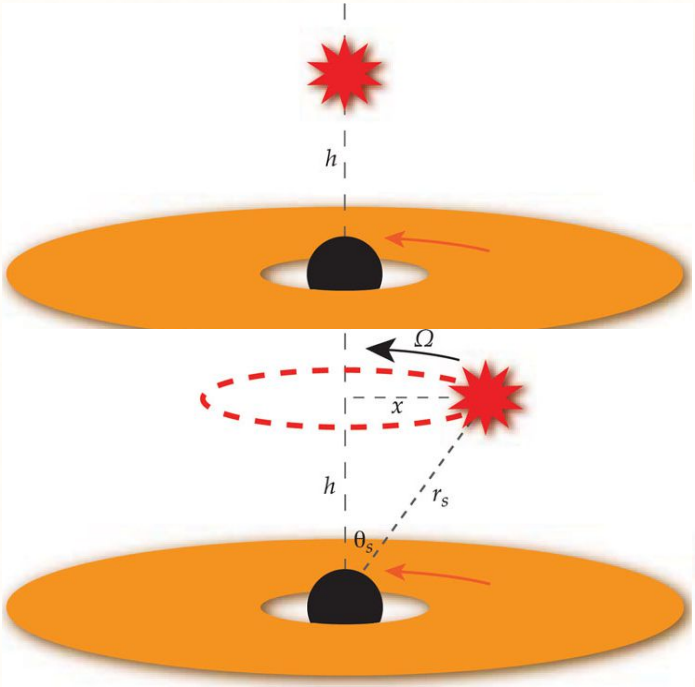
We still know very poor about the corona

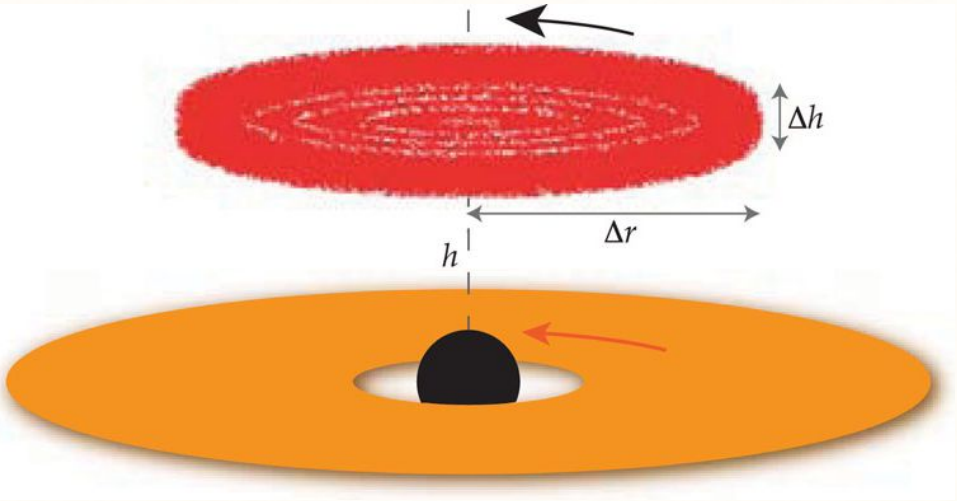
some geometric models

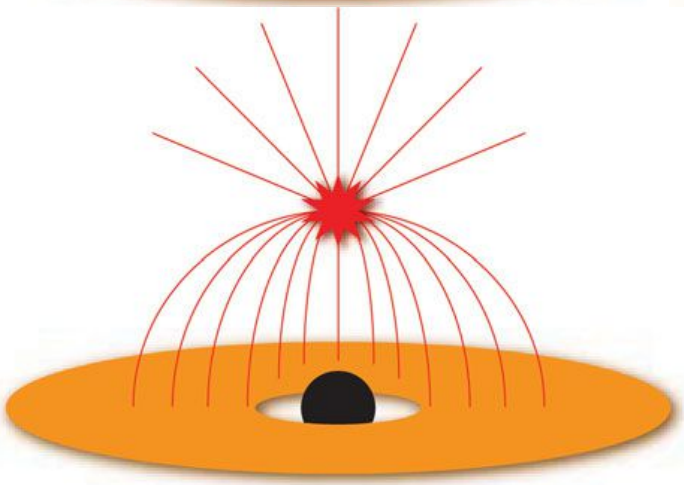
Figure from Renolds & Nowak 2003

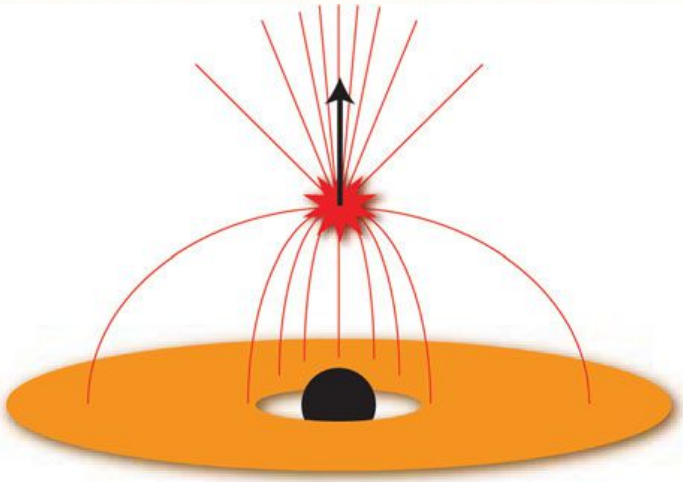
We still know poor about the corona

More toy models Wilkins & Fabian 2012

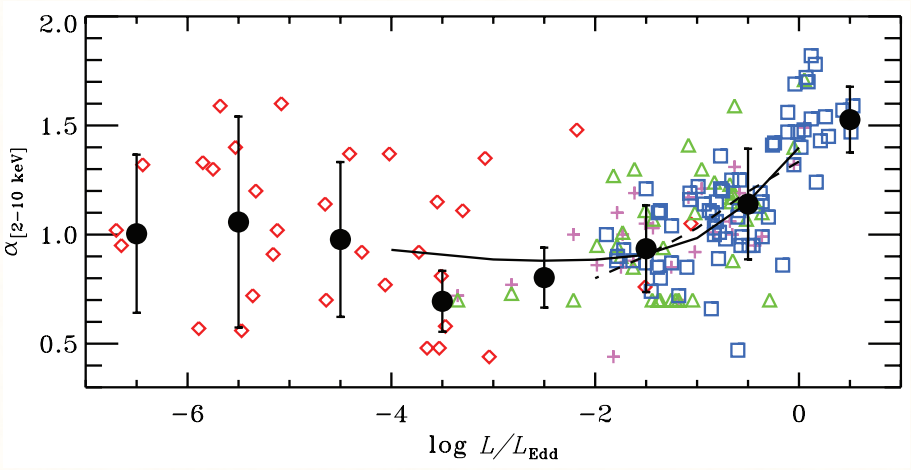




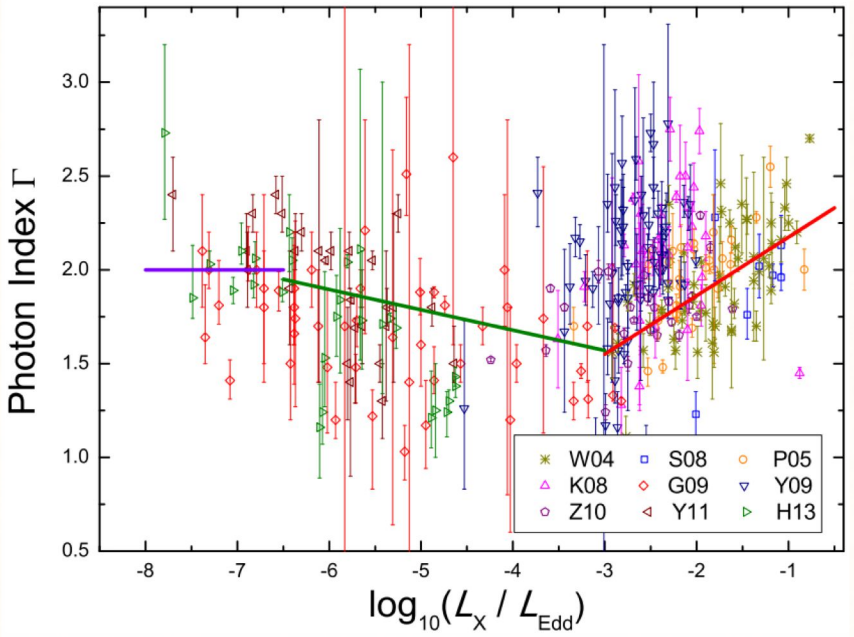




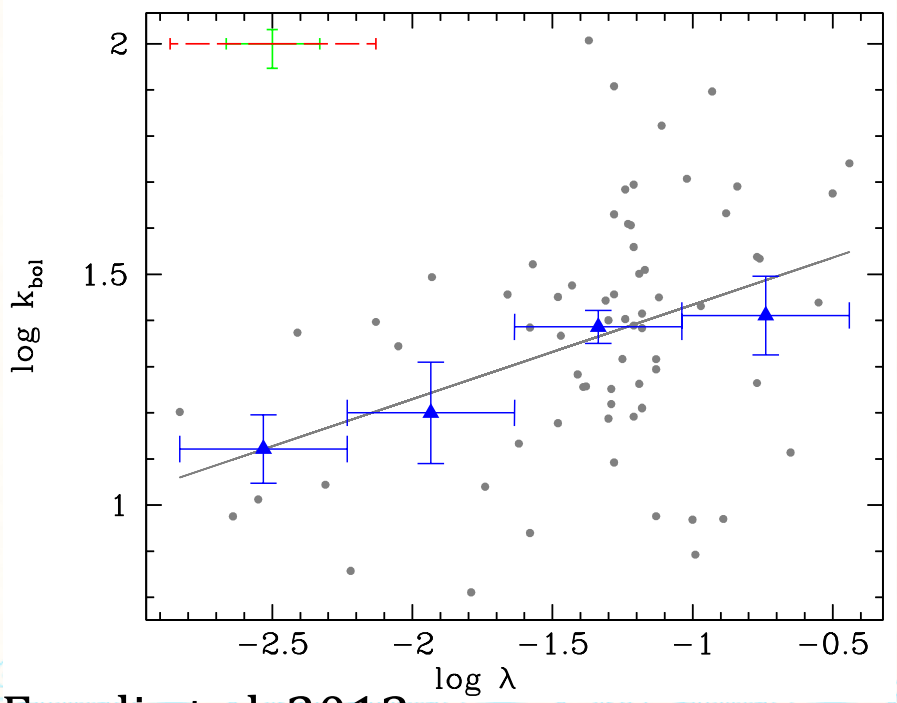
Spectra slope evolves with Eddington ratio



Alexander+11



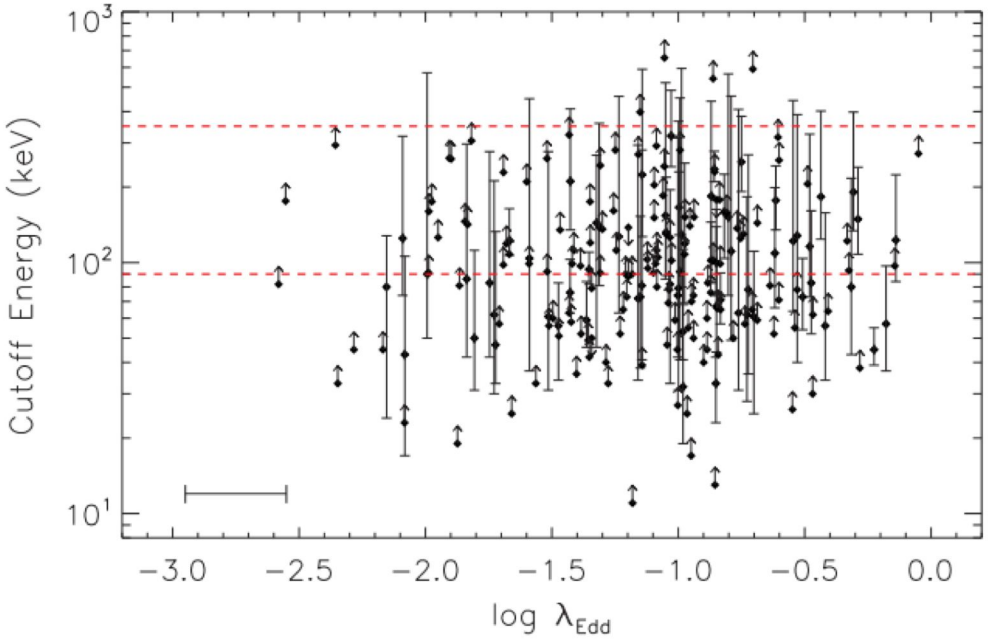
Yang+16

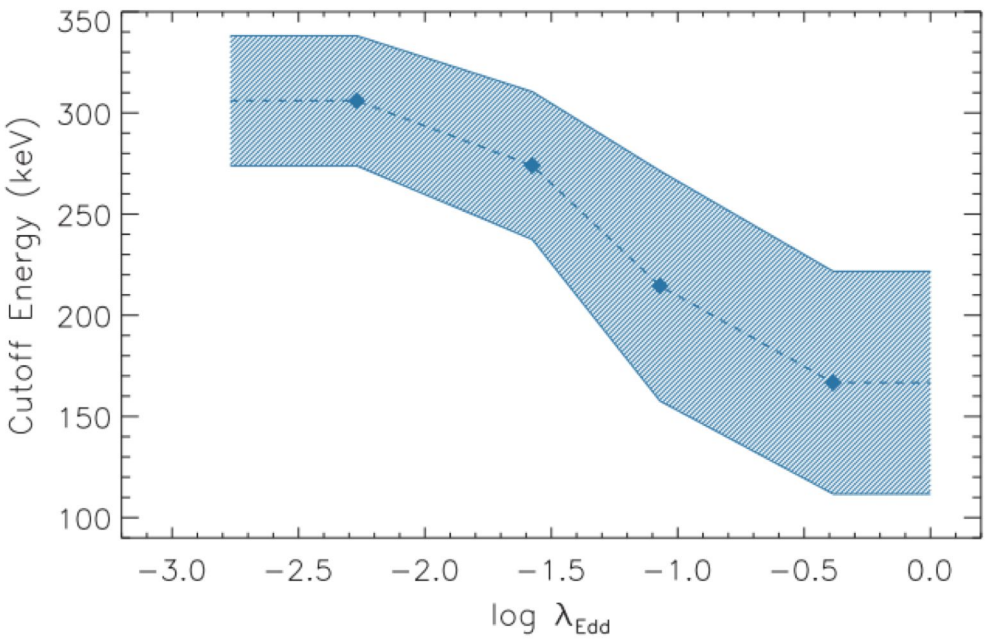


Fanali et al. 2013

At high Eddington ratio, cooling by seed photons is more efficient, thus the corona is cooler thus could lead to softer spectrum?

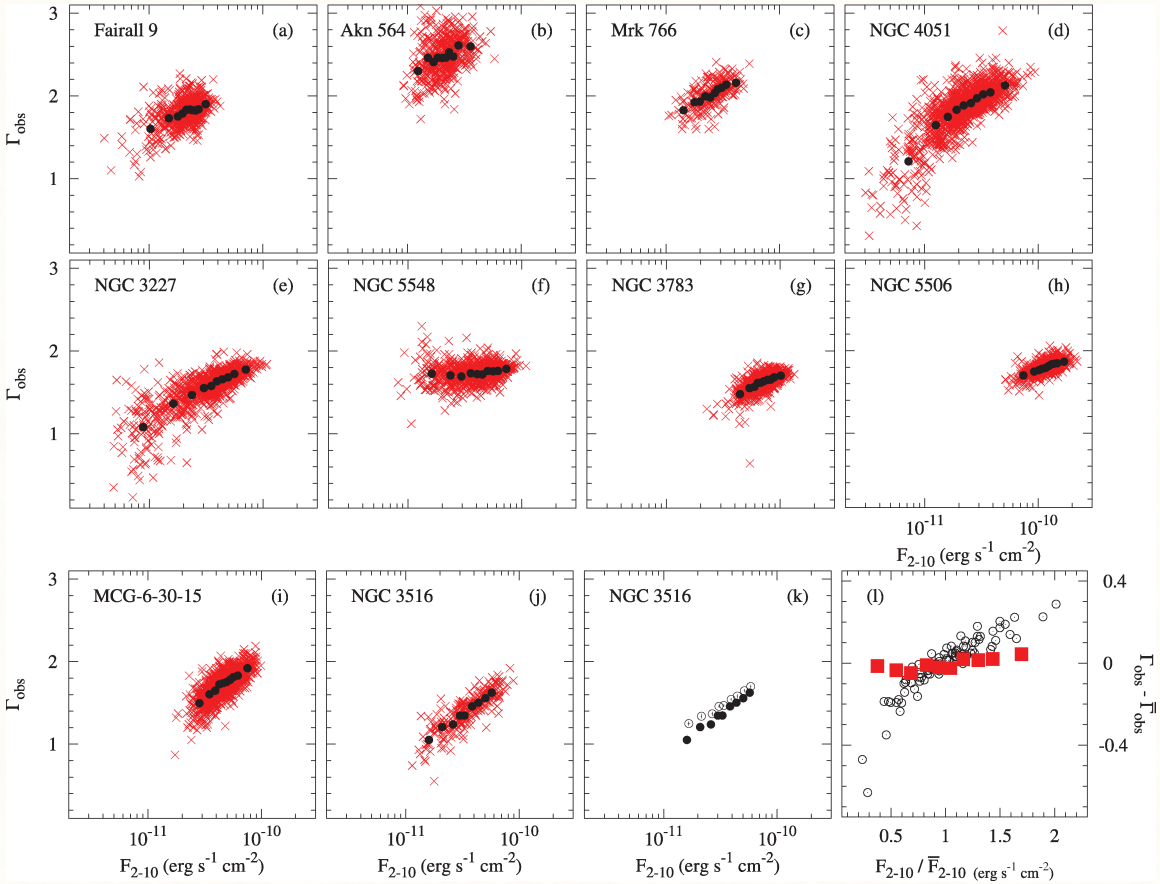
Cooler corona at higher λ_{Edd}?





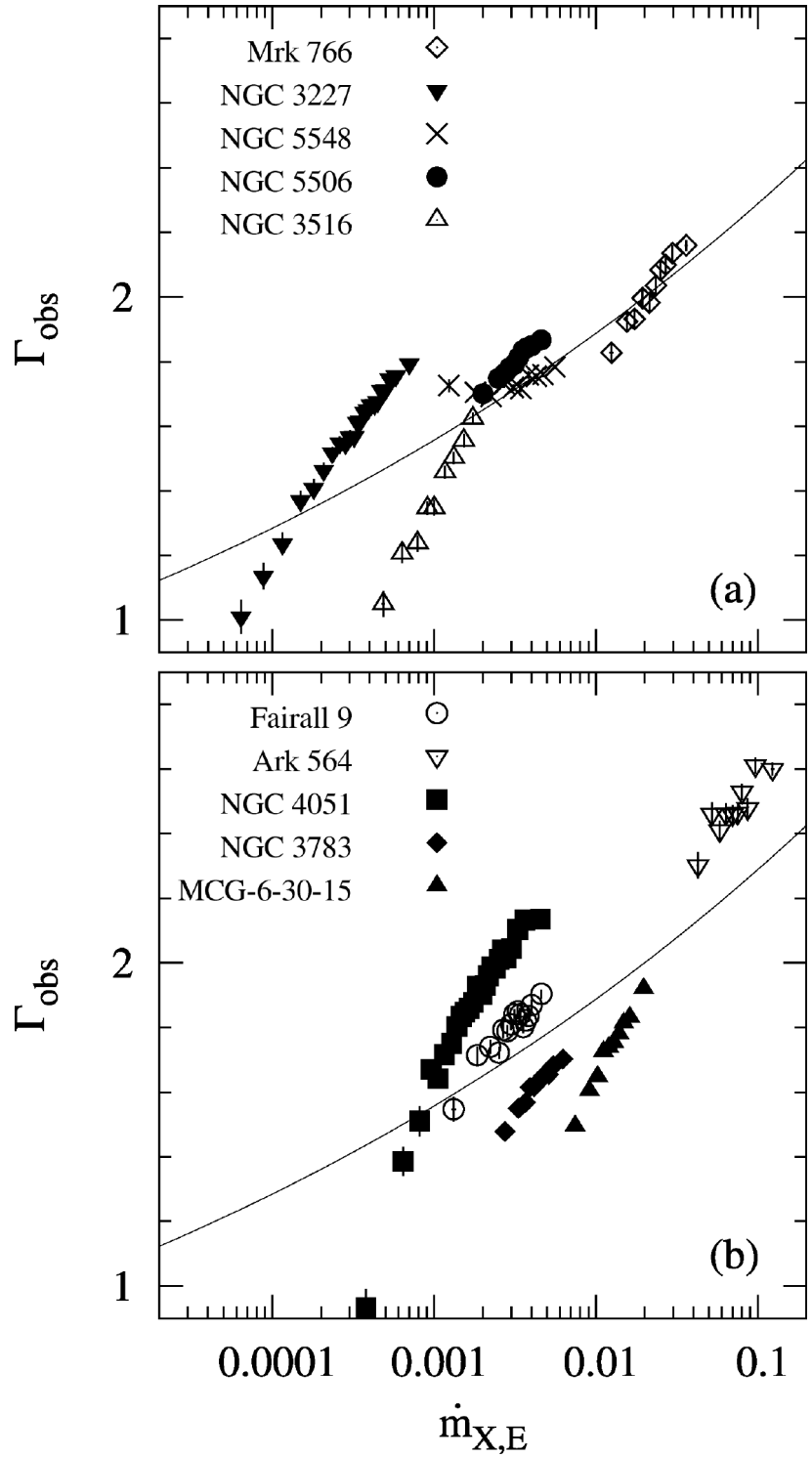
Ricci+18 SWIFT/BAT spectra

X-ray spectral variation in individual AGNs: Softer-when-brighter



A common Softer-when-brighter pattern in individual sources

Sobolewska & Papadakis 2009



Variations in individual AGNs vs between different AGNs

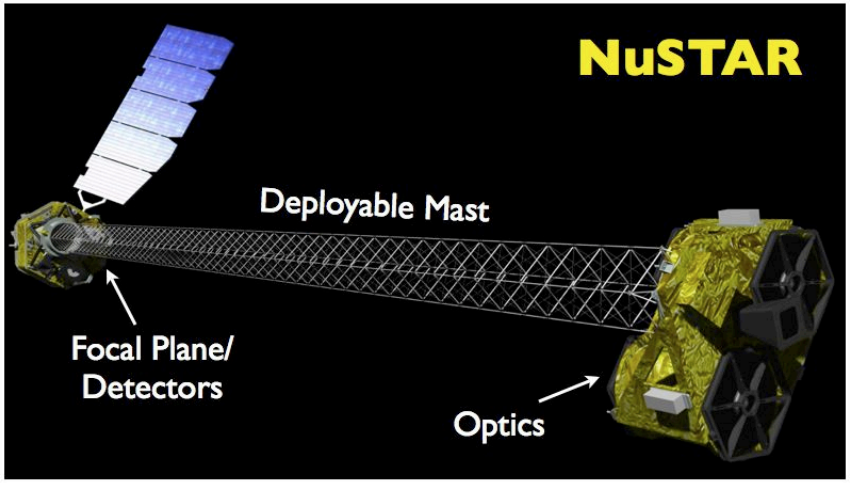
Softer-when-brighter due to accretion rate variability?

Cooler corona at higher X-ray flux?

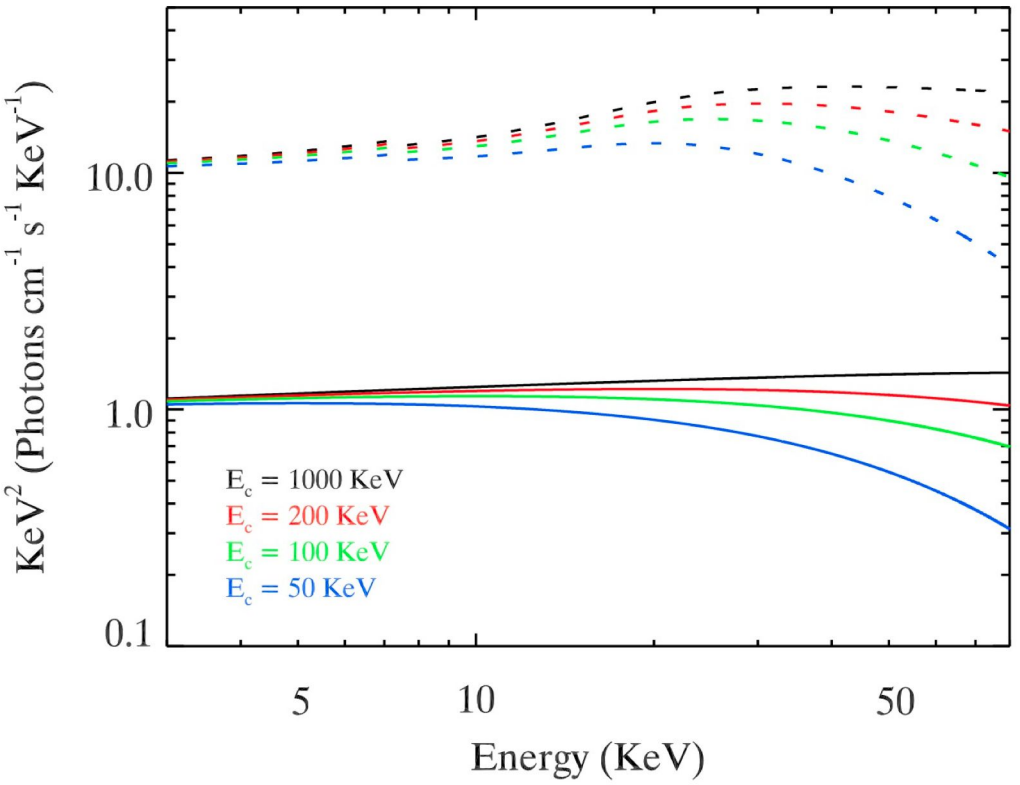
Variation of cutoff energy in individual sources?

Sobolewska & Papadakis 2009

Measuring high energy cutoff (E_c) with NuSTAR

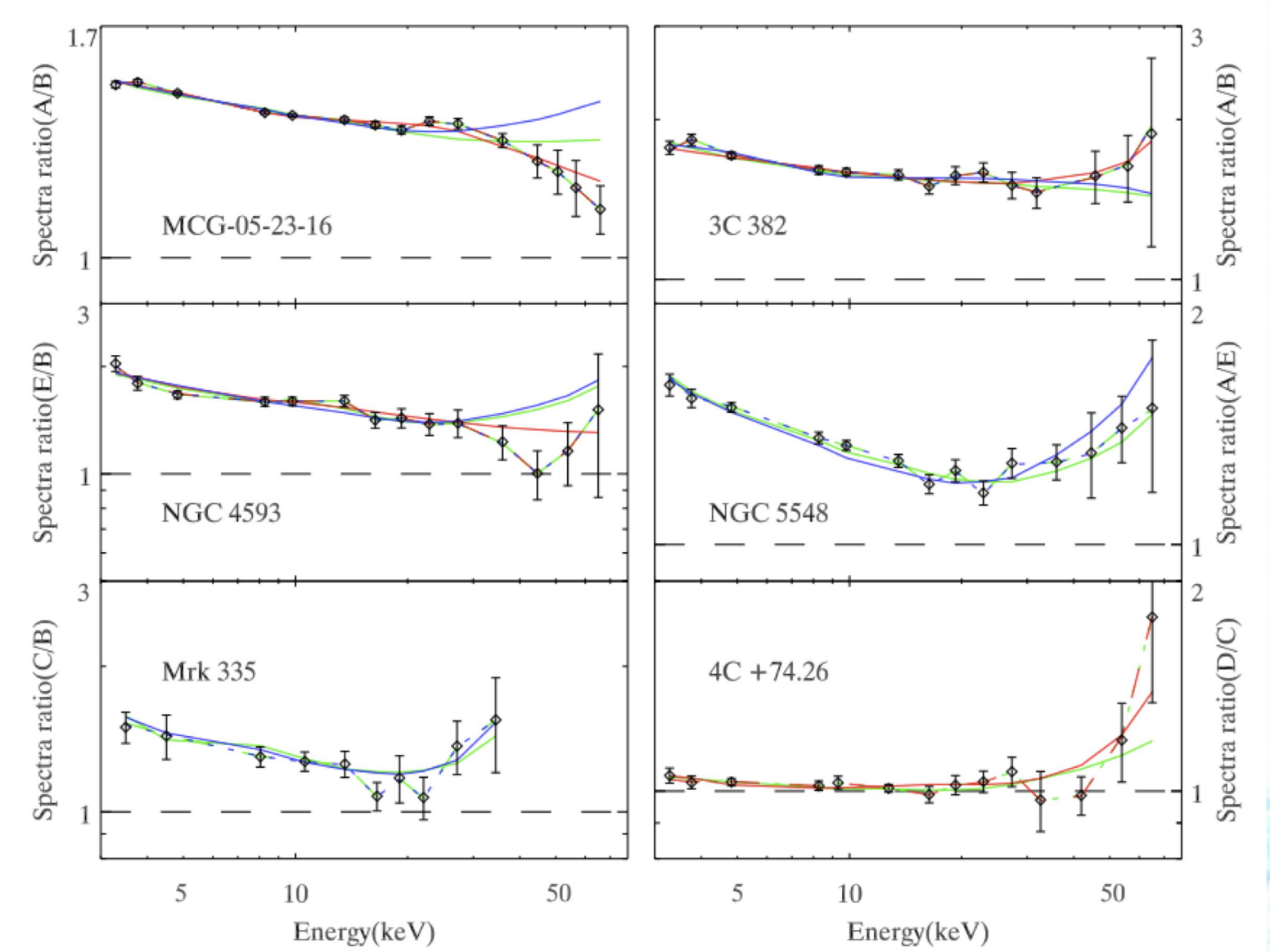


$$A(E) = KE^{-\alpha} \exp\left(-E/\beta\right)$$



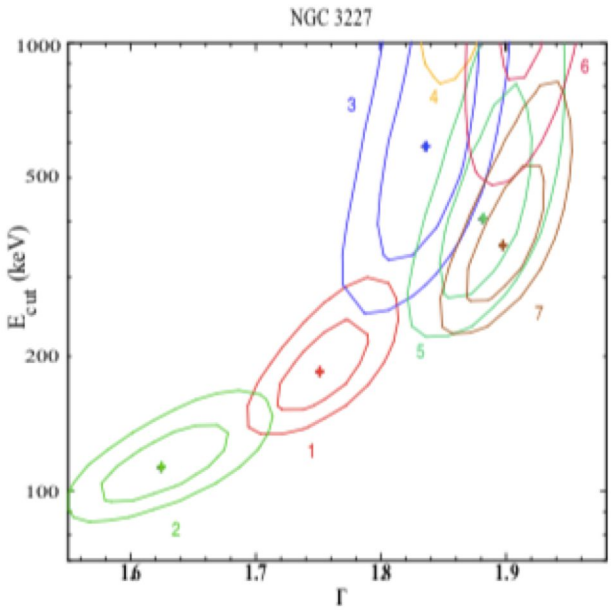
Credit: Zhang Jixian

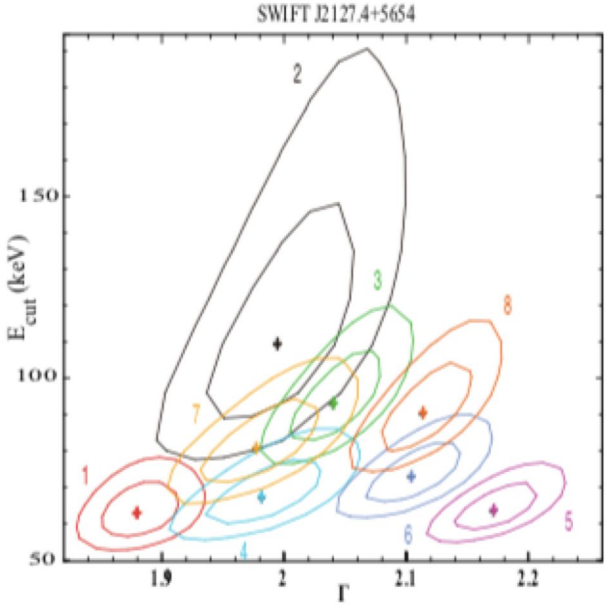
Hotter -- when -- softer & brighter is common

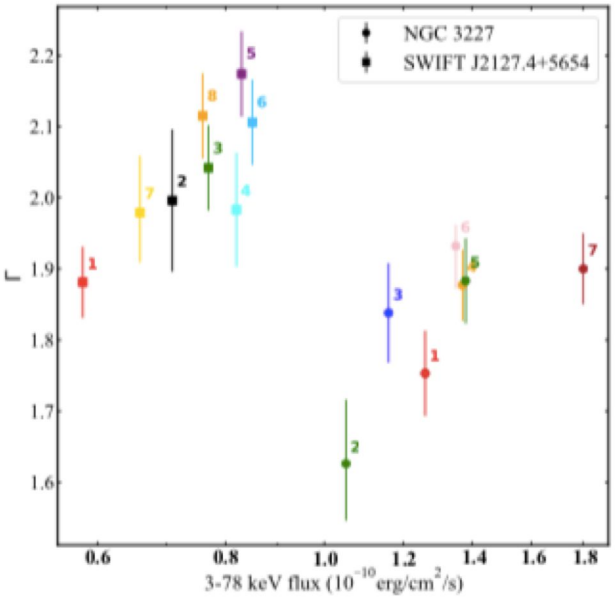


Zhang+18 ApJ

Distinct Ecut variation patterns in two Seyferts



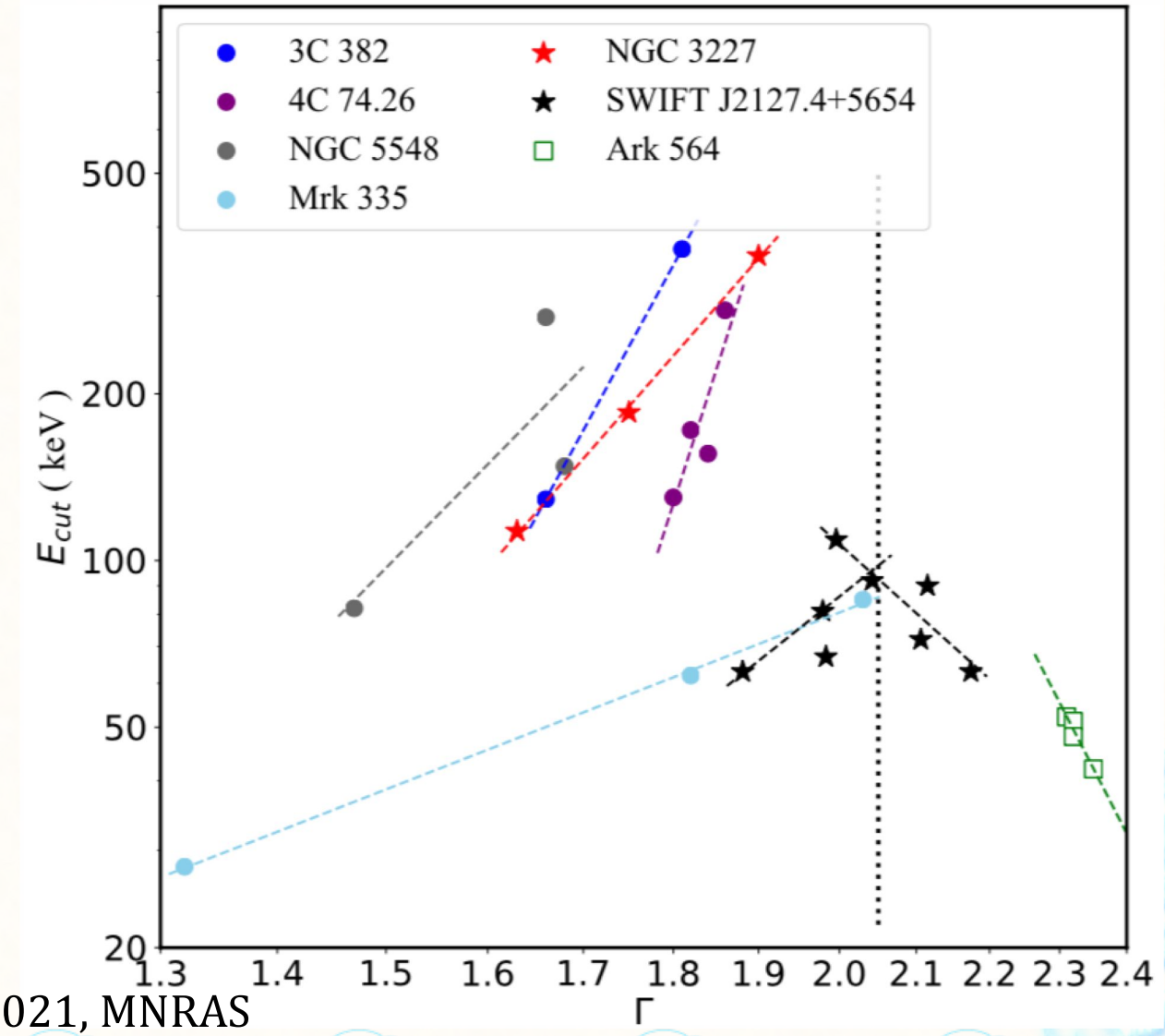




Kang+, 2021, MNRAS

A **Λ** pattern?

A Λ pattern?



Kang+, 2021, MNRAS

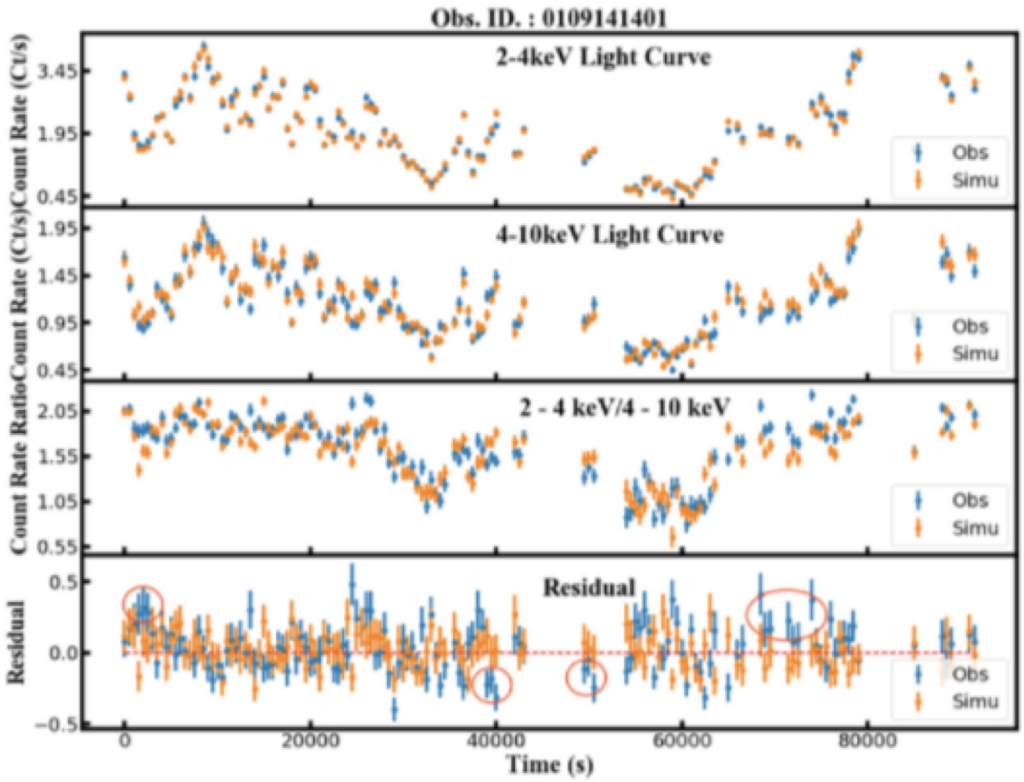
A Λ pattern

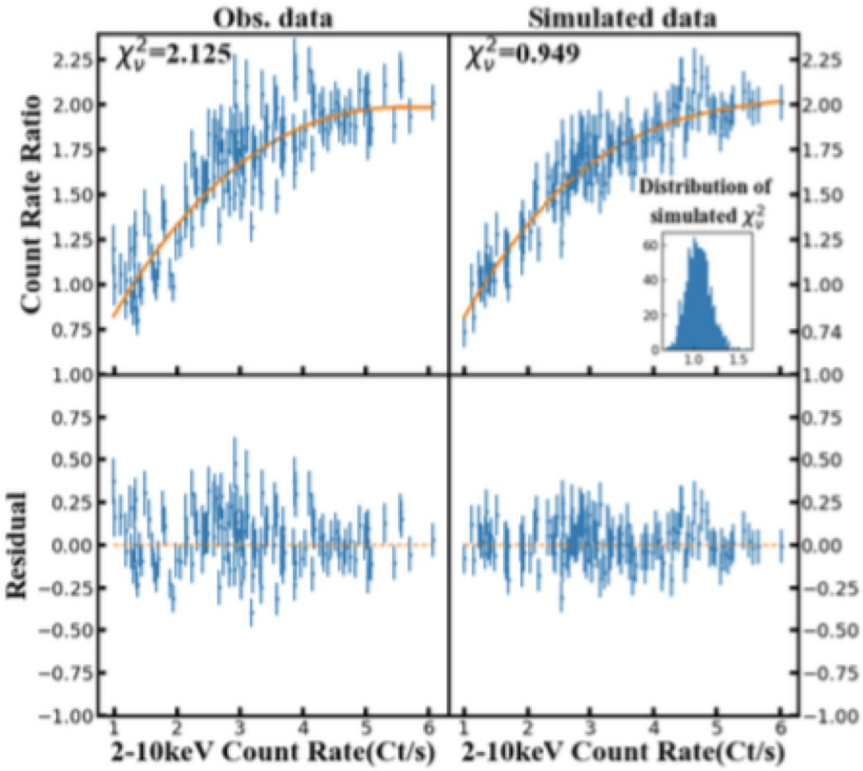
- More energy injected into the corona
- →Te & flux increase
- →corona expand (likely vertical)
- →smaller opacity
- →steeper spectrum
- hotter-softer-brighter

- When corona further expands:
- →intercept more seed photons
- →cooling more efficient?

Kang+, 2021

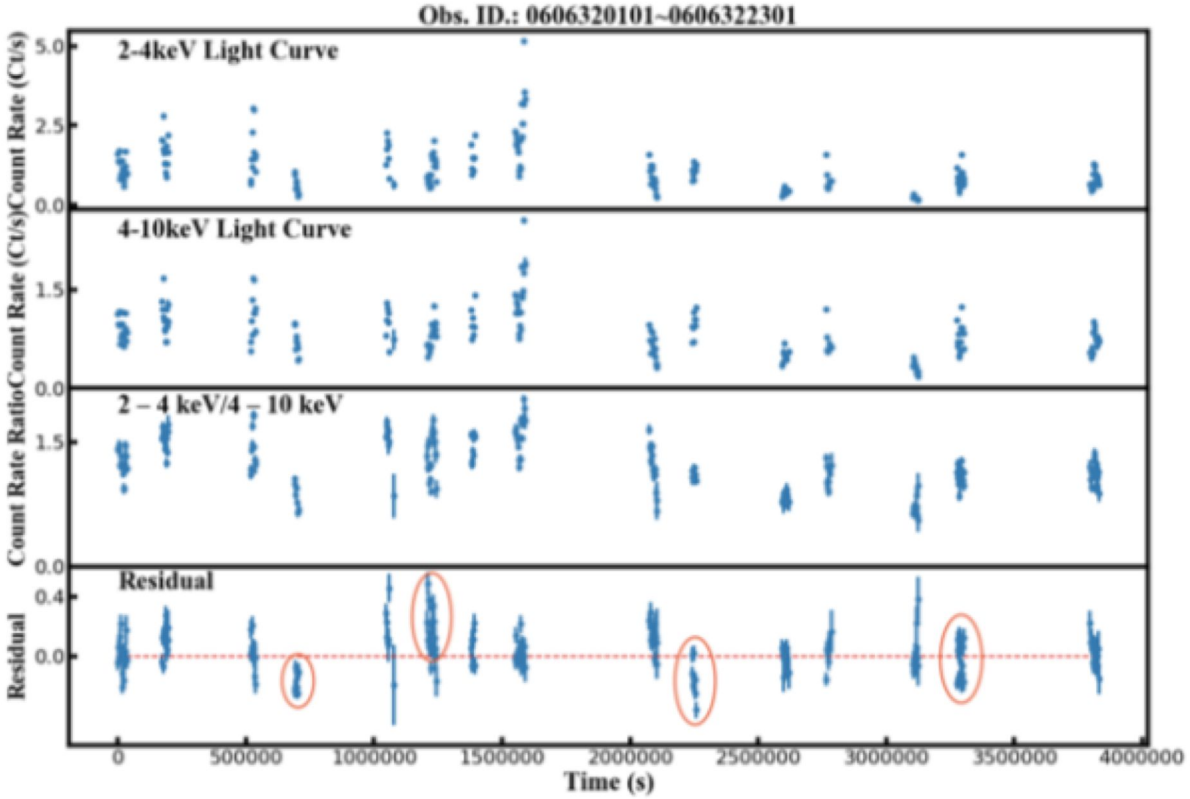
Scrutinize the softer-when-brighter pattern

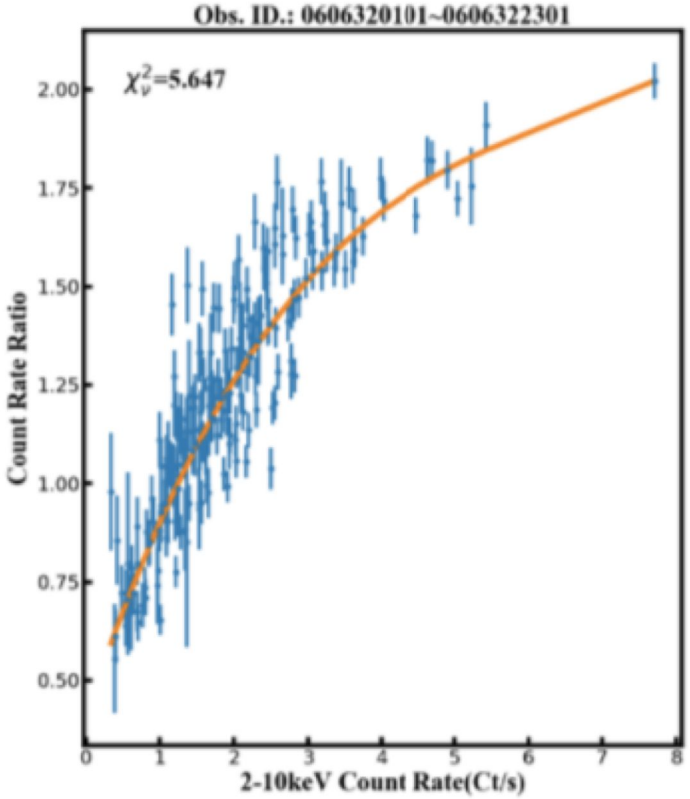




Rapid deviation from the empirical softer-when-brighter trend. Nano flares???

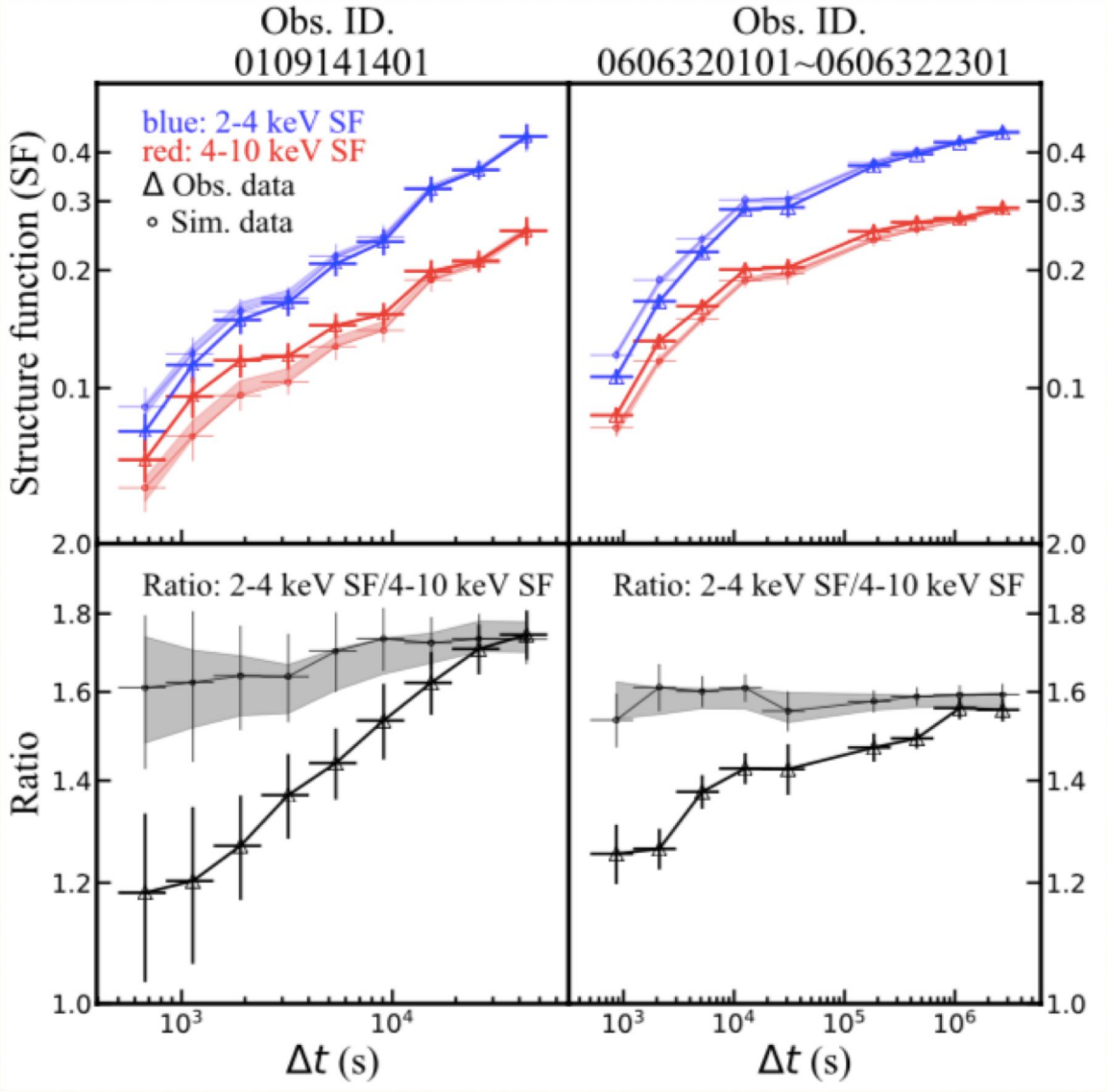
XMM observation of NGC 4051
Wu YJ+, 2020

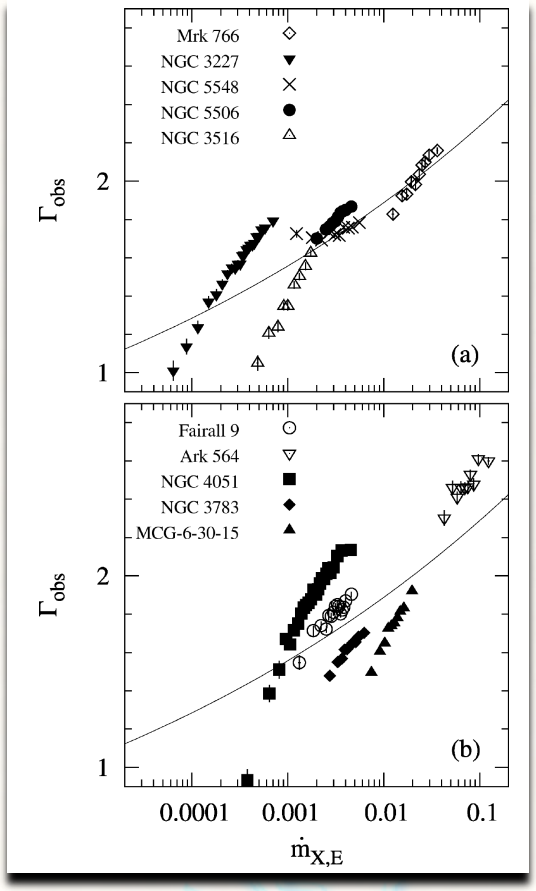




Deviations on long timescales.

Weaker softer-when-brighter at shorter timescale

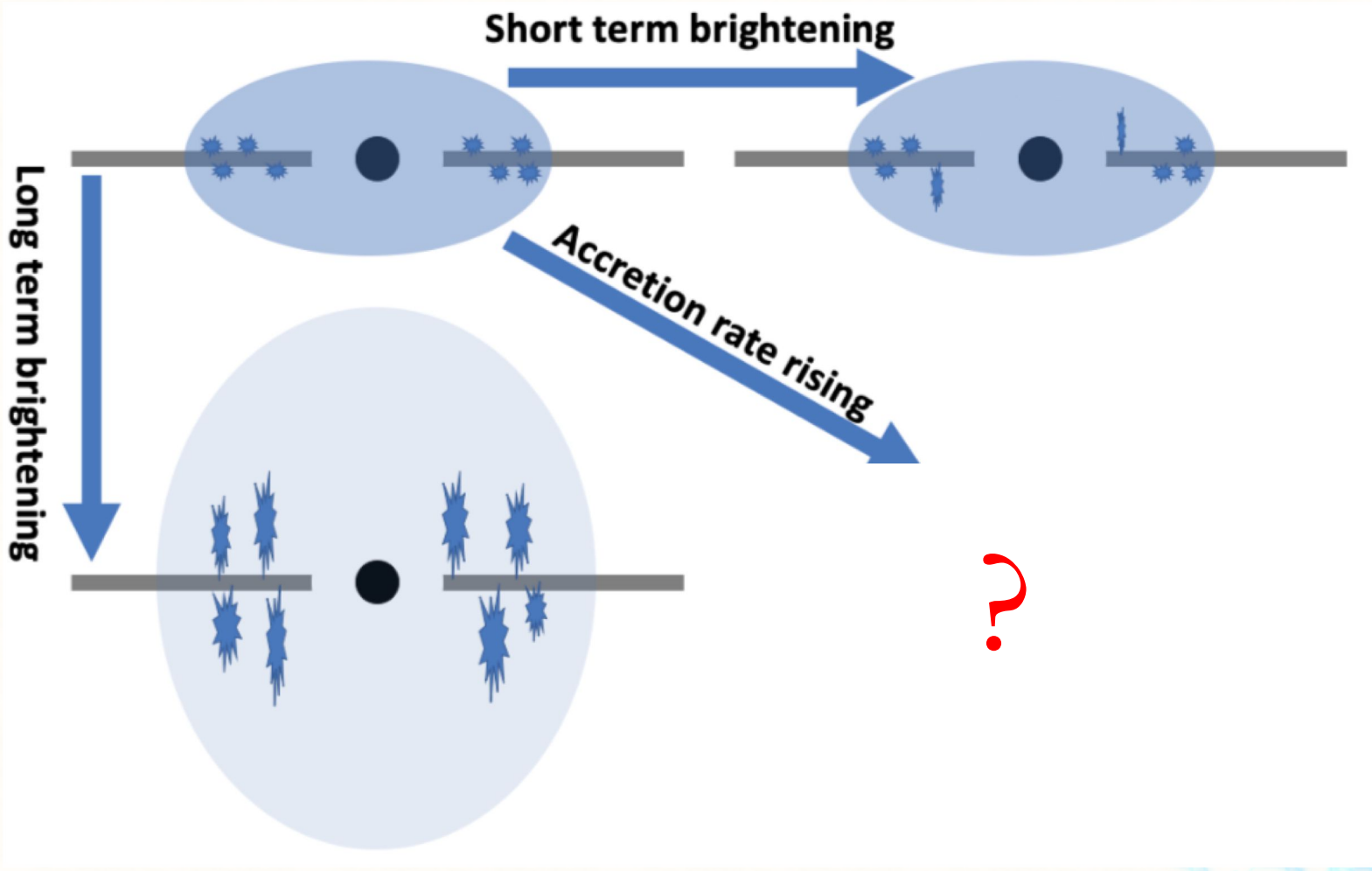




The timescale dependence of the softer-when-brighter trend.

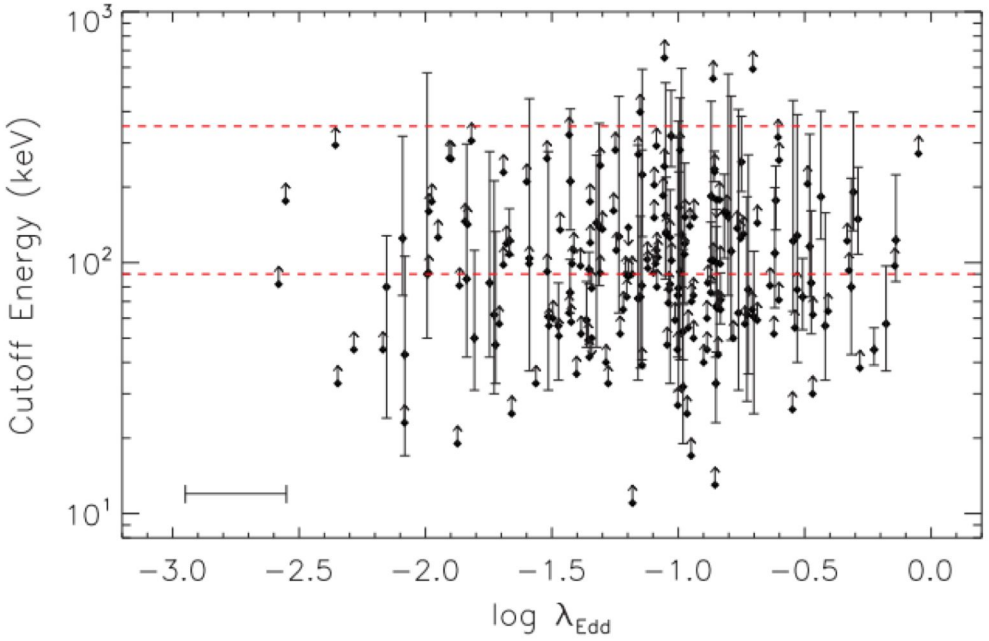
What is the underlying physics?

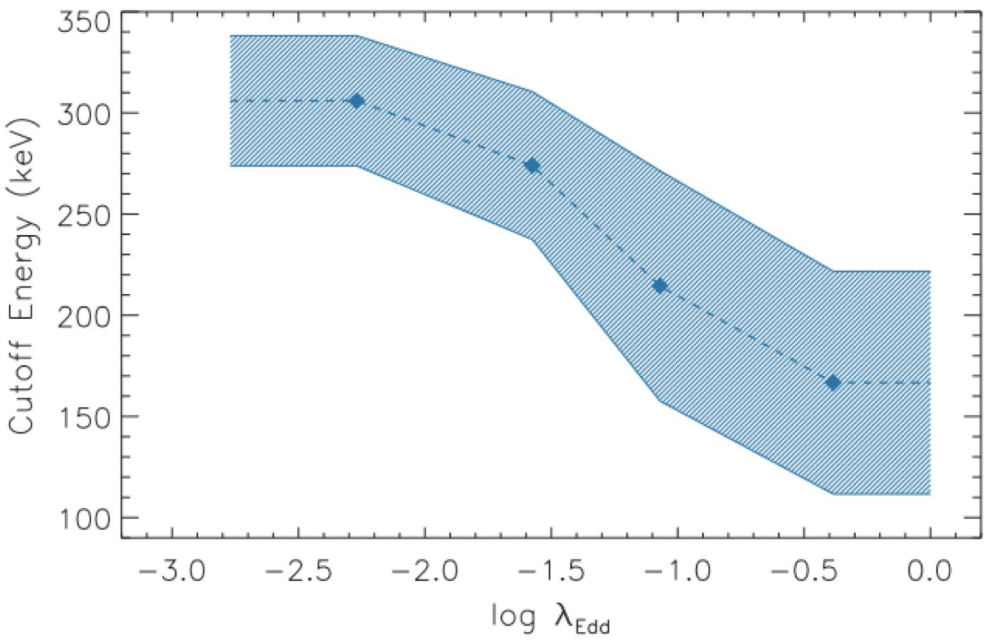
Two-tier geometry (in analogy to solar corona)?



Flares/Nano-flares + extended corona Wu+2020

Cooler corona at higher λ_{Edd}?





Ricci+18 SWIFT/BAT spectra

The X-Ray Coronae in NuSTAR Bright Active Galactic Nuclei

Jia-Lai Kang[1,2] and Jun-Xian Wang[1,2]

[1] CAS Key Laboratory for Research in Galaxies and Cosmology, Department of Astronomy, University of Science and Technology of China, Hefei, Anhui 230026 People's Republic of China; ericofk@mail.ustc.edu.cn, jxw@ustc.edu.cn

[2] School of Astronomy and Space Science, University of Science and Technology of China, Hefei 230026, People's Republic of China

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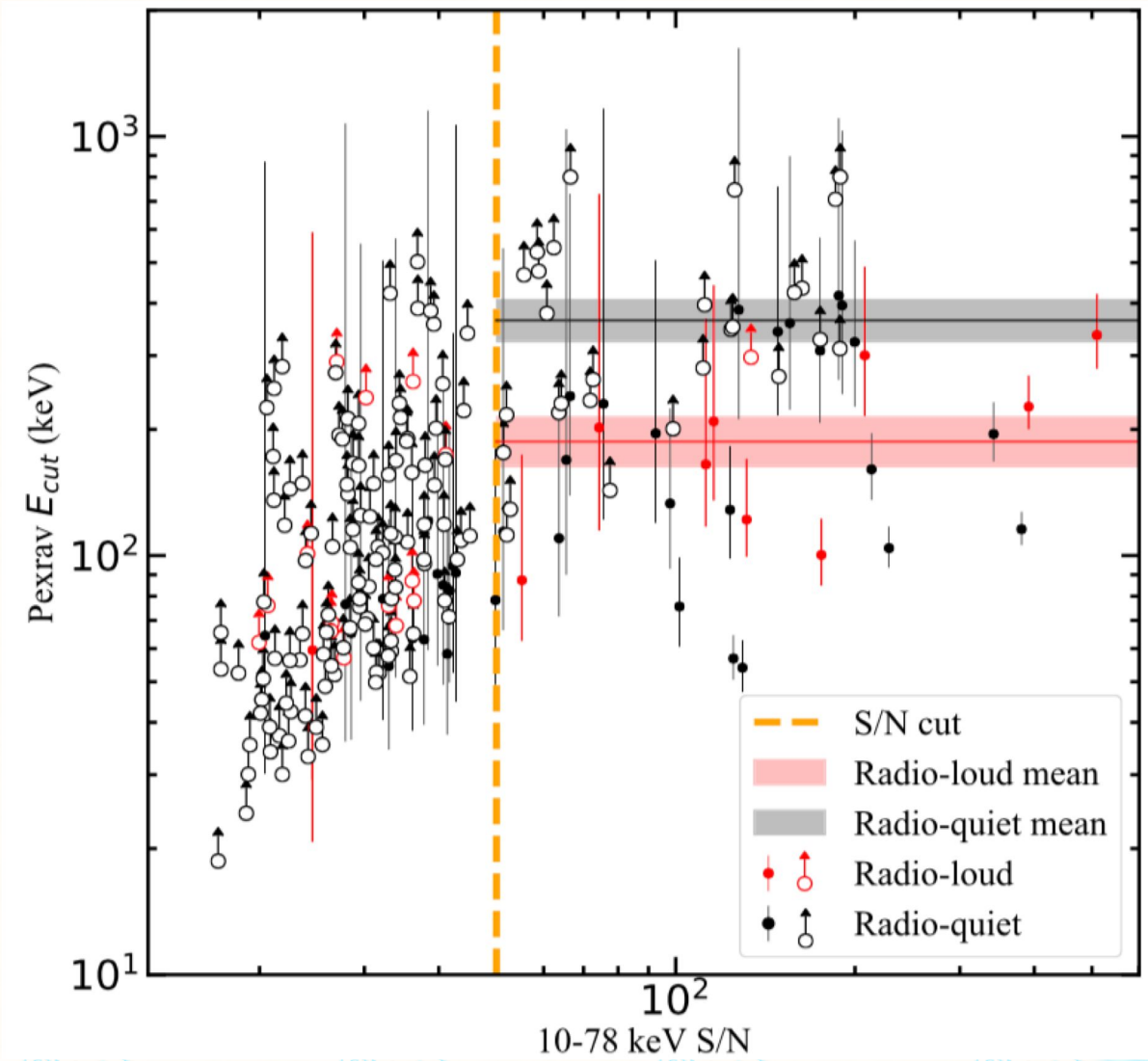
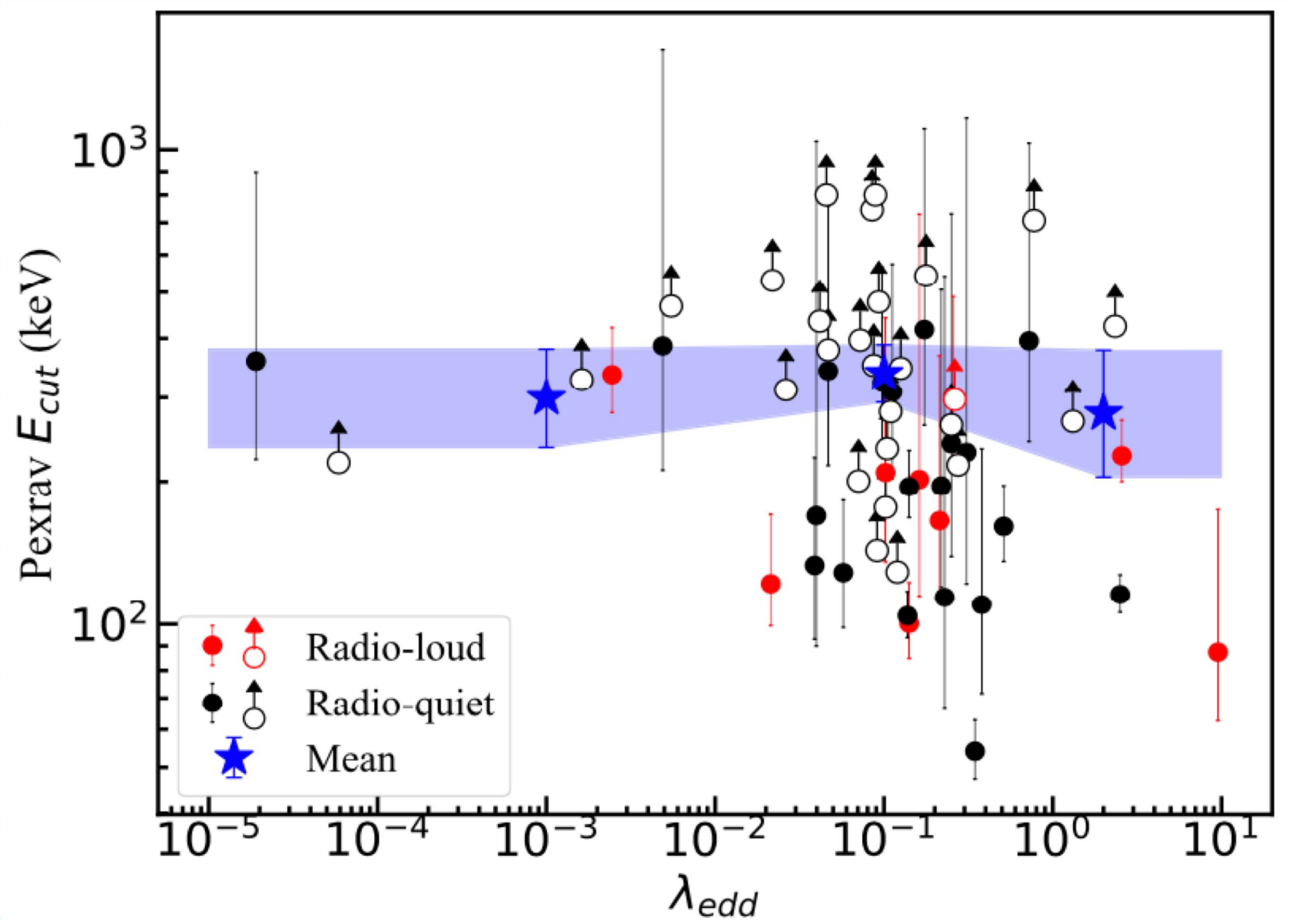
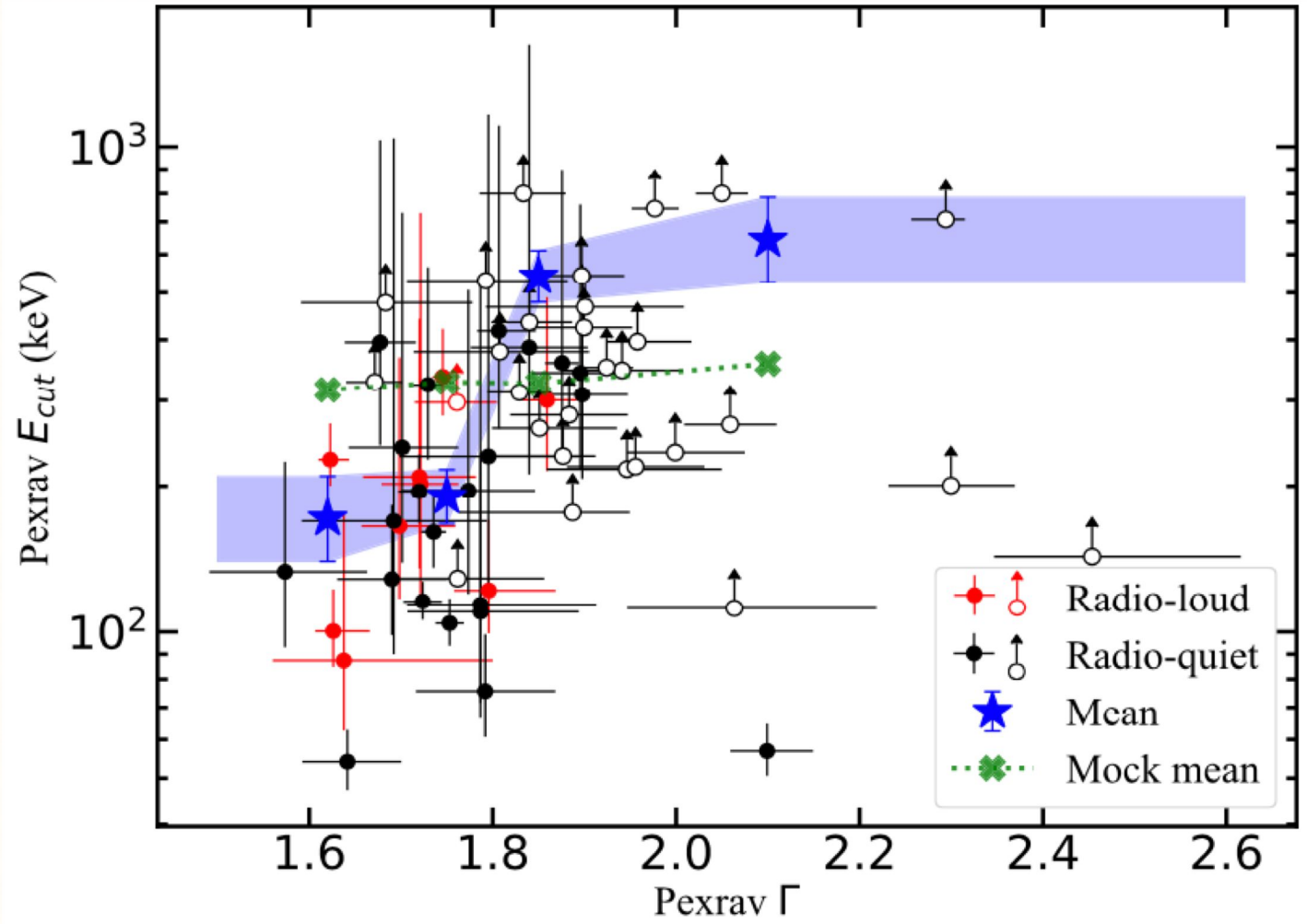


No dependence on Eddington ratio

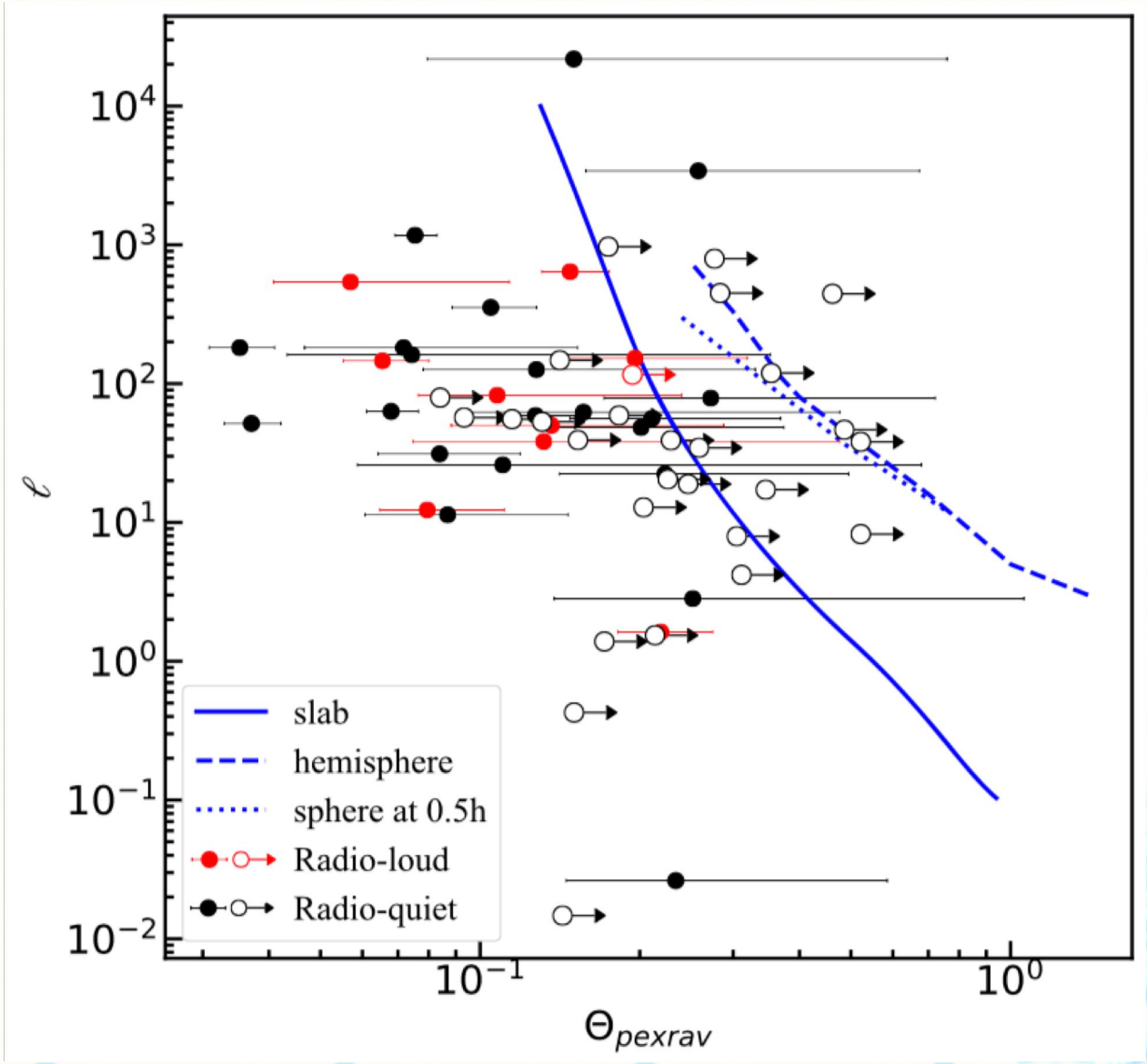


Increase with Gamma



Higher temperature, but smaller coronal opacity in high accretion rate AGNs? Underlying physics unclear.

Some beyond forbidden regions



So

- 个源变亮时，通常冕温度上升，冕膨胀

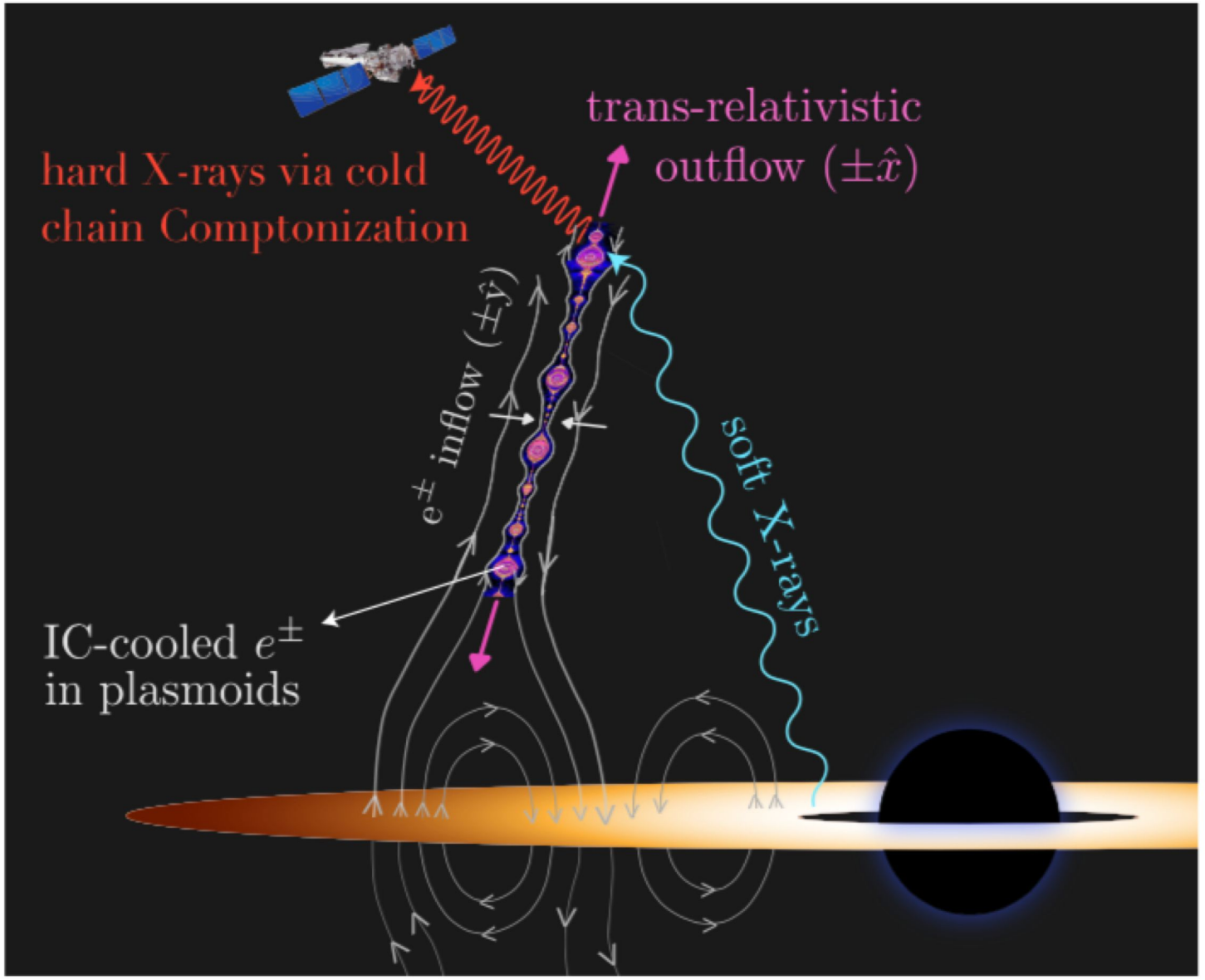
  VS 吸积率上升，冕温度上升?

- 个源冕温度变化可能存在Λ模式
- 变亮变软行为存在时标依赖
- 双层冕模型（纳耀斑+延展冕?）
- 射线冕区存在动态变化（外流、膨胀收缩等）

  VS 静态唯像模型?

- 需要更物理的动态模型

Comptonization by reconnection plasmoids ?



Sridhar+21

Thank you