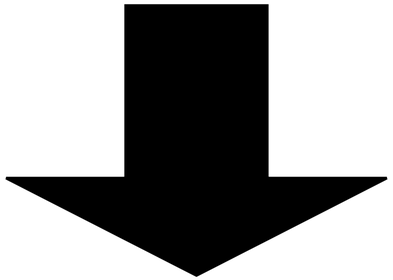
TeVPA 2021

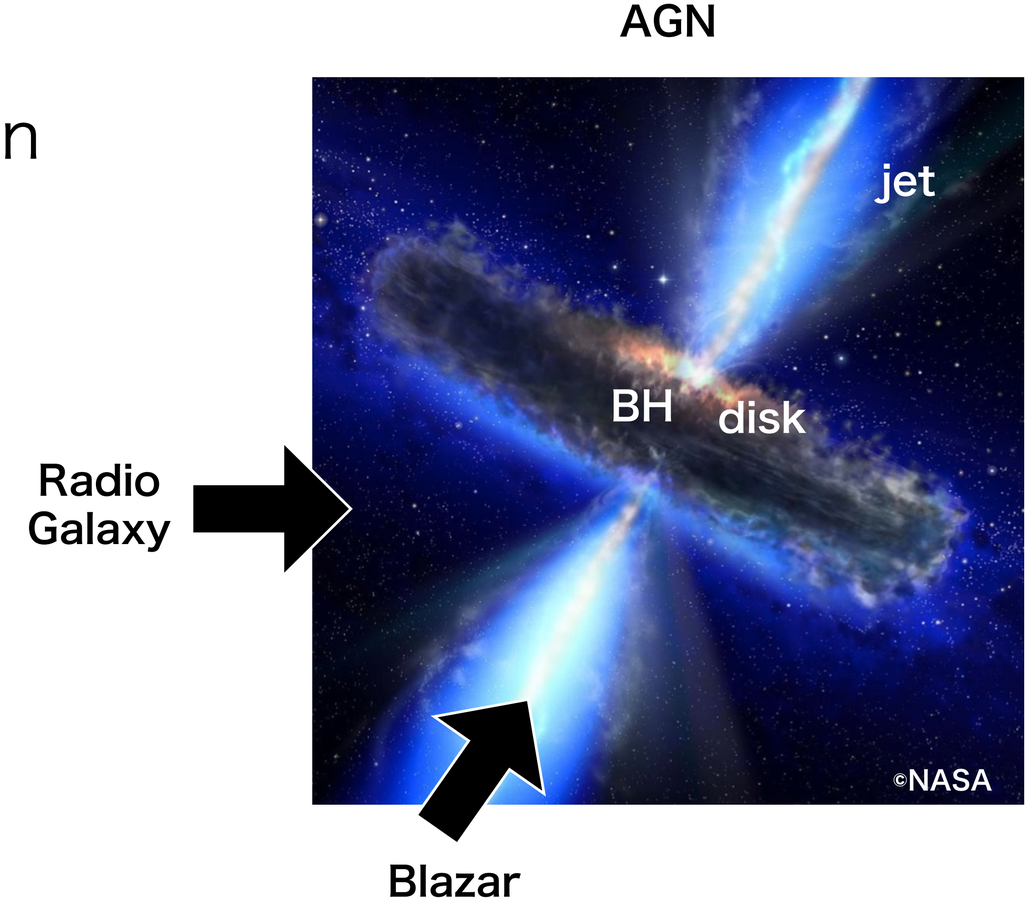
Relationship between gamma-ray loudness and X-ray spectra of radio galaxies

Taishu Kayanoki, Yasushi Fukazawa
(Hiroshima University, Japan)

1 Radio Galaxies(RGs)

- Strong radio emission has been observed in about 10% of AGN(Active Galactic Nuclei)
  →Blazar, Radio Galaxy(RG)
- RGs : jet is viewed with a large angle.





In this study, we investigated the difference in their X-rays properties between GeV-loud and GeV-quiet RGs

1 Radio Galaxies(RGs)

Classiification of RGs (FR-I, FR- II)

FR- I ：

・Radio Luminosity (178MHz) < $10^{26}\mathrm{WHz}^{-1}$

・Radio flux is high near the core and fades toward the outer region

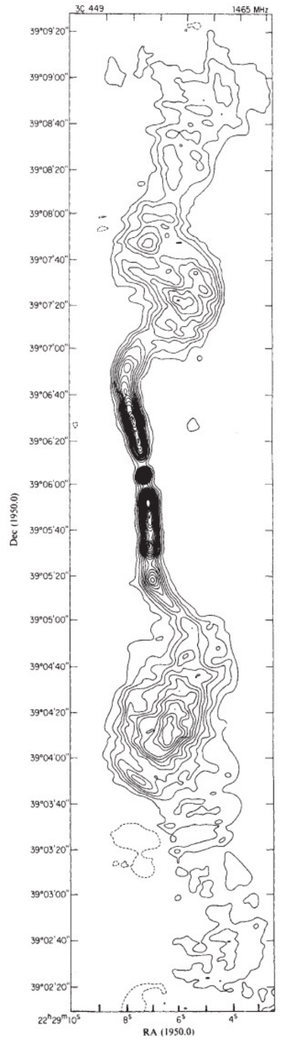
・accretion rate → Low

FR- II ：

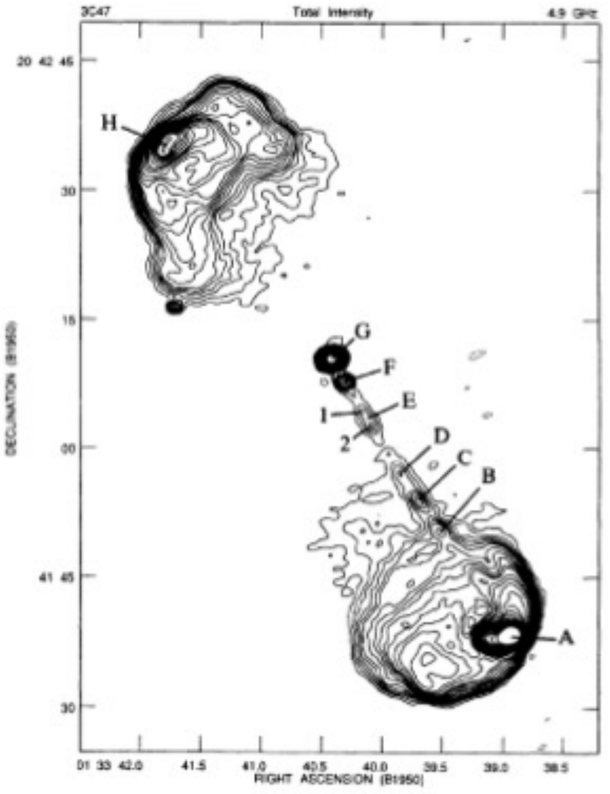
・Radio Luminosity (178MHz) > $10^{26}\mathrm{WHz}^{-1}$

・ Radio flux is low near the core and becomes bright toward the lobe edge region with bright hot spots

・accretion rate → High



FR- I [1]



FR- II [2]

[1] R. A. Perley, A. G. Willis and J.S.Scott, 1979, Nature volume 281, p.437 UTF2013442(1979)
[2]Bridle, A. H., Hough, D. H., Lonsdale, C. J., Burns, J. O., and Laing, R. A., 1994, The Astronomical Journal, vol. 108, no. 3, p.766-820

2 Purpose and Sample of RGs

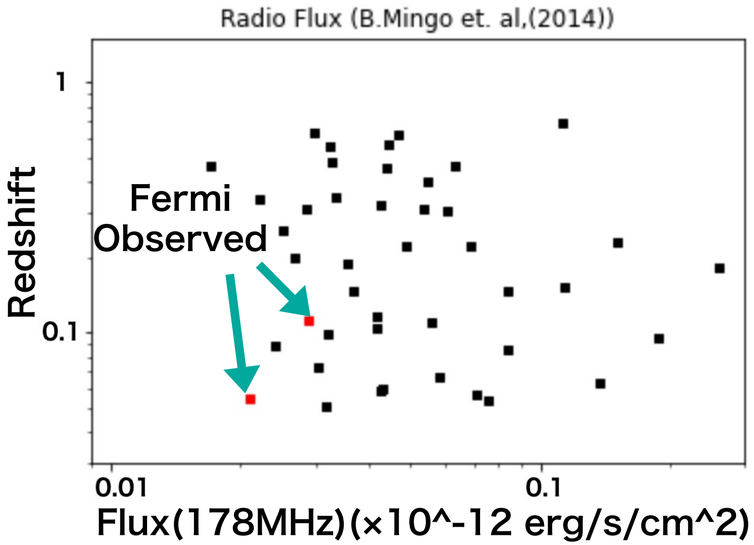
purpose : We investigated the difference in their X-rays properties between GeV-loud and GeV-quiet RGs.

GeV-quiet RGs(radio flux limited sample) :
B.Mingo et al. (2014) & F.Massaro et al. (2015) → 25 objects

GeV-loud RGs : 38 objects

total : 63 objects

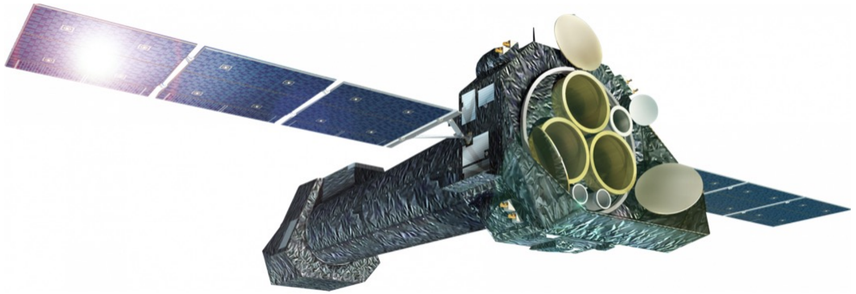
RGs radio flux and redshift
(B.Mingo et al. (2014))



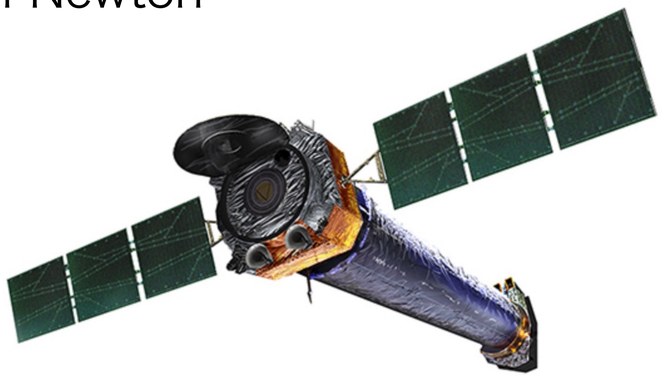
GeV-loud RGs are no bias in radio flux

Analyzed 63 RGs
- FR-I : 30 objects (19 objects are GeV-loud)
- FR-II : 25 objects (12 objects are GeV-loud)
- other (CSS, SSRQ) : 8 objects
  (7 objects are GeV-loud)

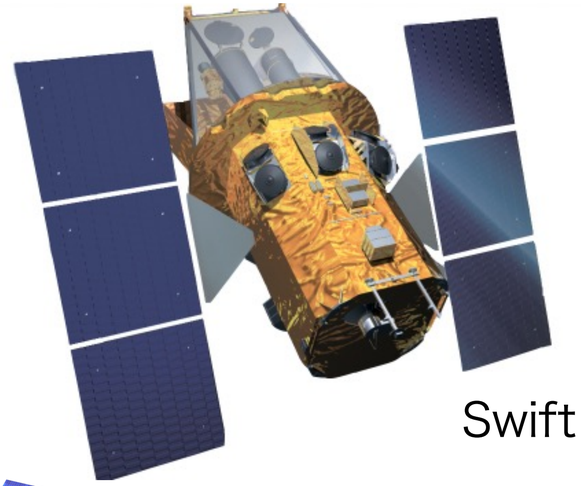
3 X-ray data



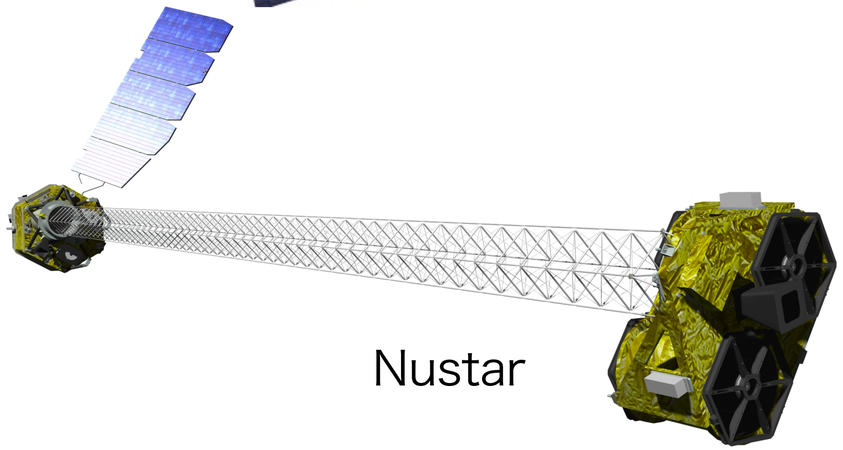
XMM-Newton



Chandra



Swift



Nustar

Priority of selection：XMM-Newton > Chandra > Swift, Nustar

4 X-ray emission of AGN

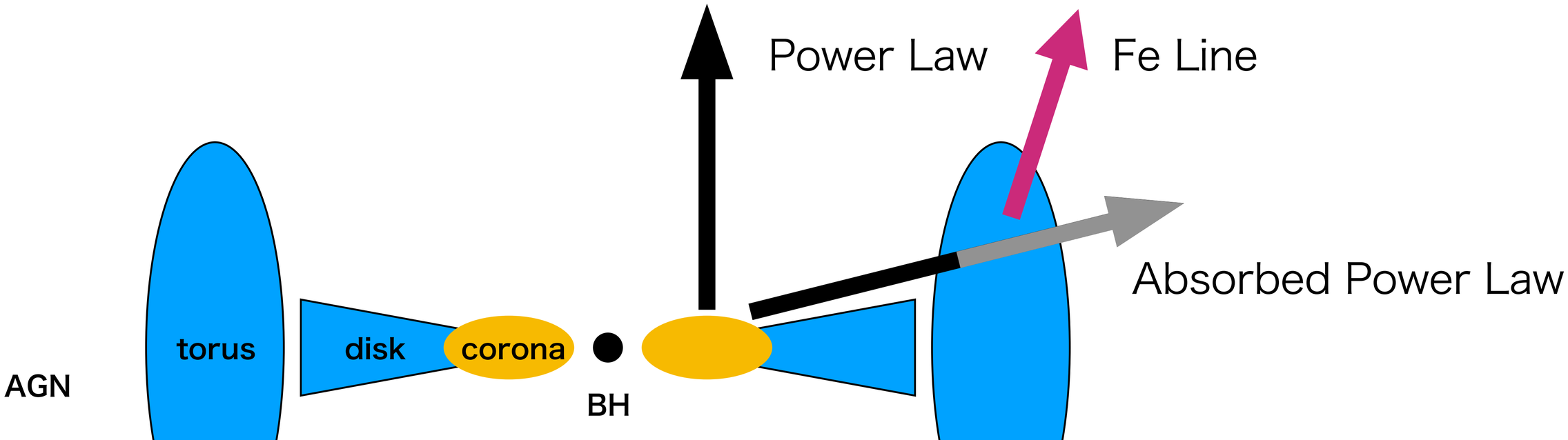
Features seen in the X-ray spectrum of AGN :

・Power laws commonly found in AGN ($\propto E^{-\Gamma}$)

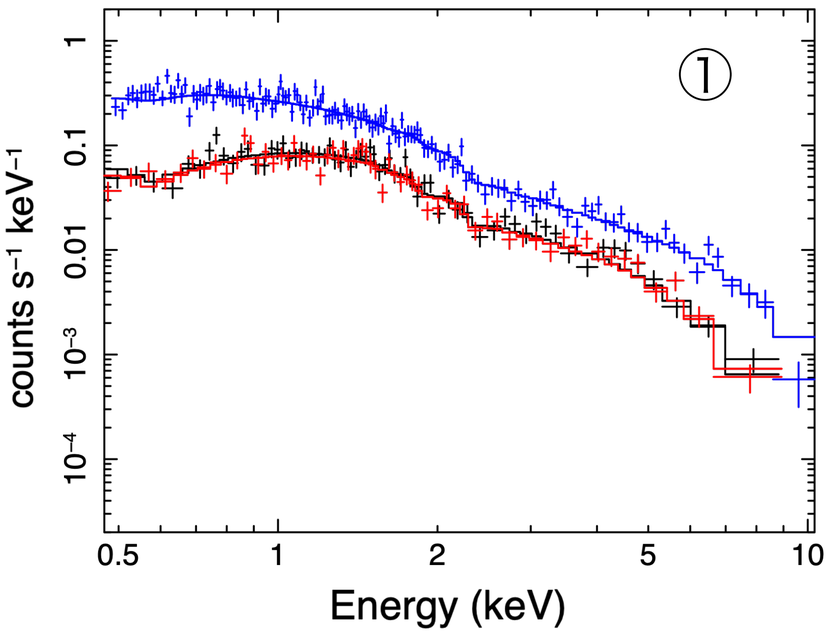
・Fe line produced when emission is scattered by a torus (6.4keV)

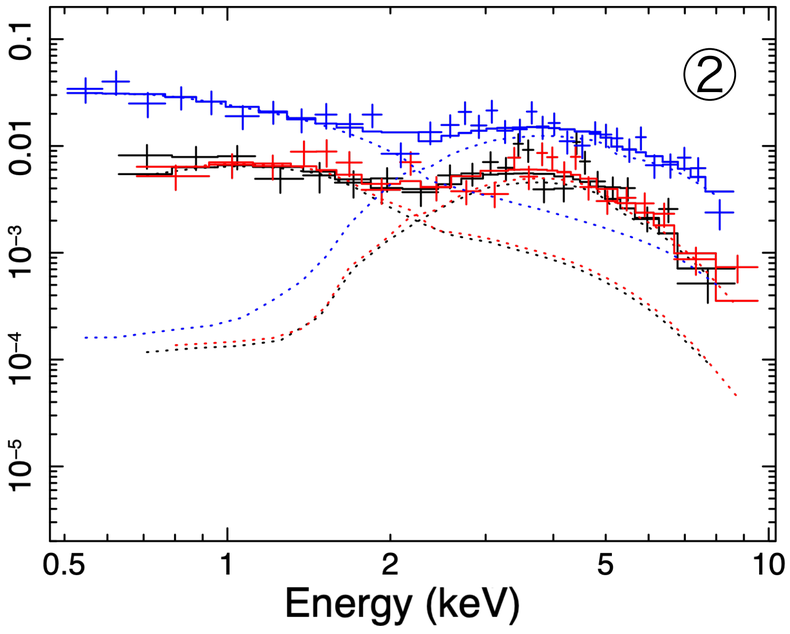
・Emission blocked by the torus becomes Absorbed Power Law

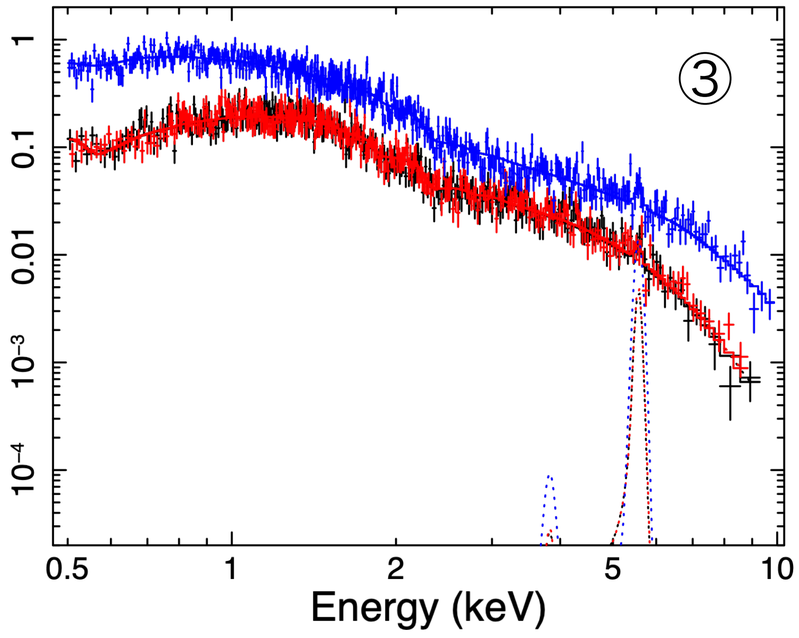
＊If there is a high-temperature plasma around the AGN, a high-temperature plasma emission (apec) component is generated.

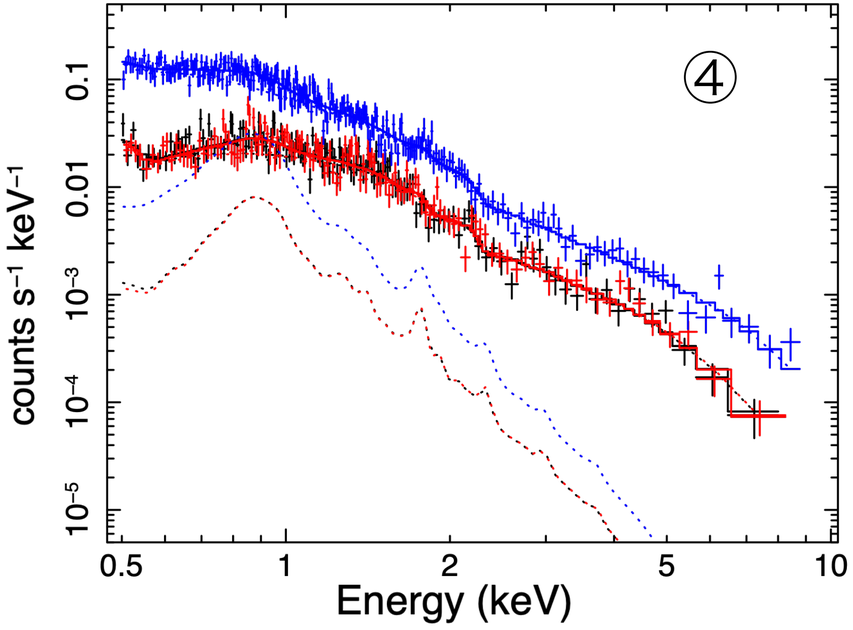


5 X-ray spectral analysis









① One Power Law

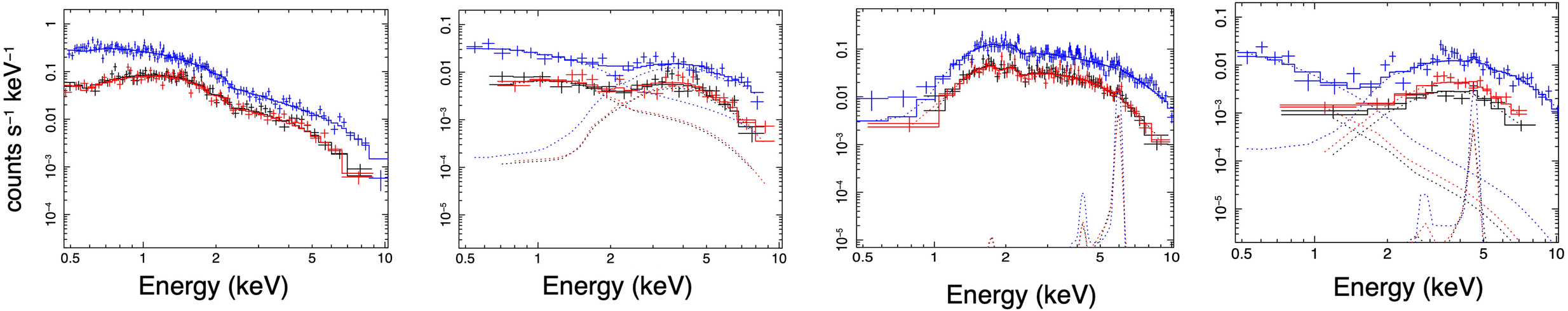
② One Power Law & Absorbed Power Law

③ One Power Law & Gaussian function

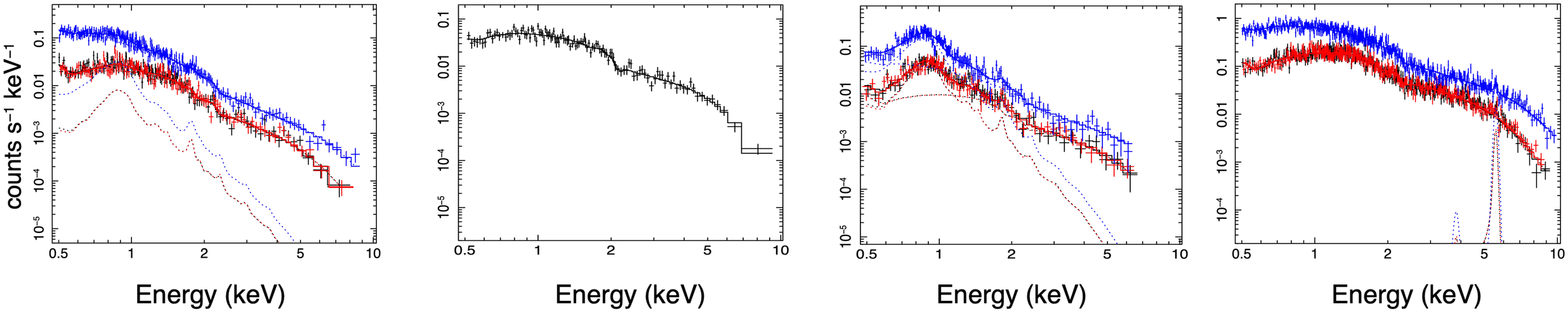
④ One Power Law & apec component

6 Example of spectra

GeV-quiet RGs

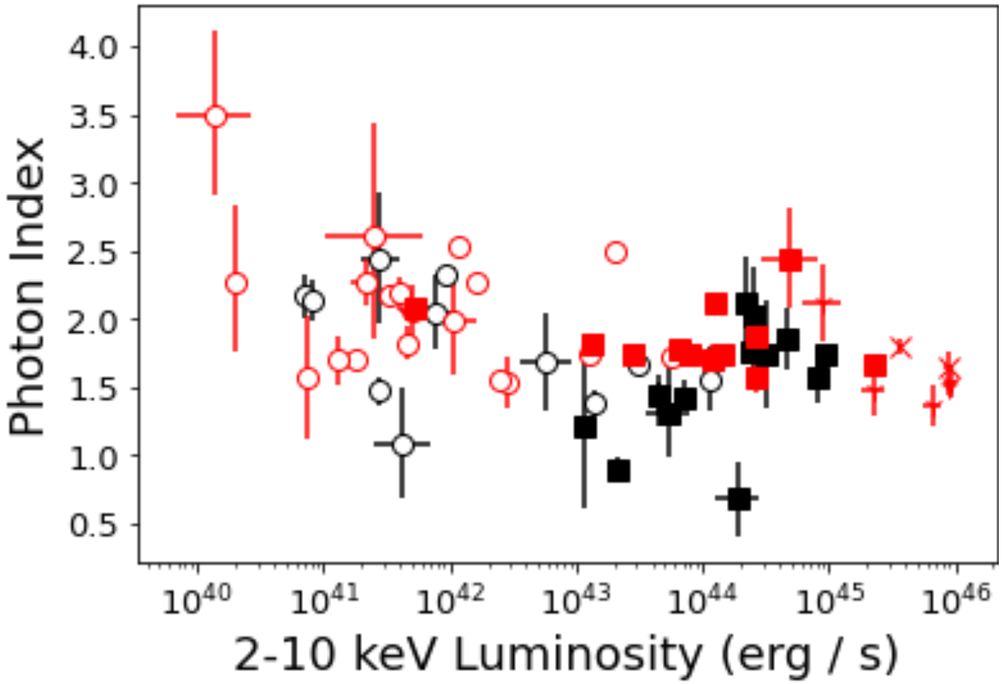


GeV-loud RGs

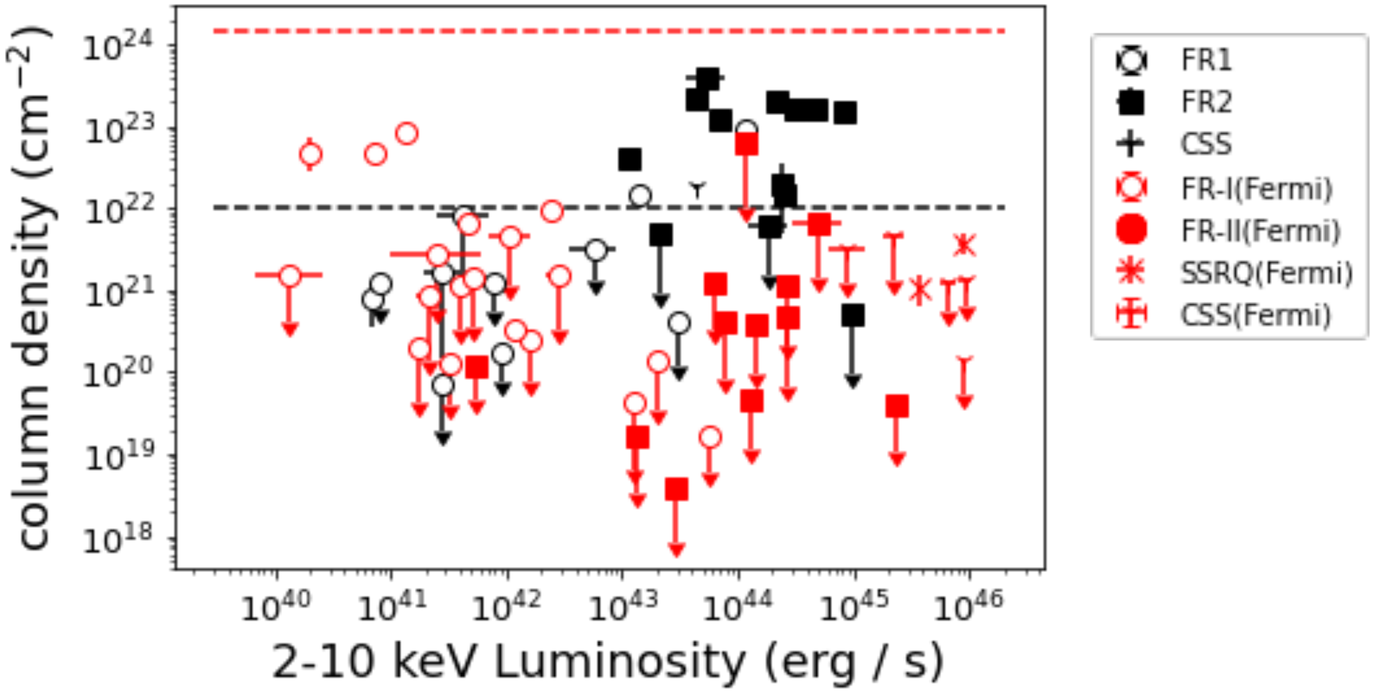


7 Results (scatter plot)

2—10 keV luminosity $L_{2-10}\mathrm{erg/s}$ vs Photon Index



2—10 keV luminosity $L_{2-10}\mathrm{erg/s}$ vs Absorption $N_{\mathrm{H}}\mathrm{cm}^{-2}$



- There is no obvious difference between GeV-loud and GeV-quiet RGs in both Photon Index and Luminosity.
- Few GeV-loud RGs are undergoing significant absorption.

8 Discussion (On the absorption N_{H})

Table : Fraction of absorbed RGs ($N_{\mathrm{H}} > 10^{22}$)

	FR-I	FR-II	CSS	SSRQ	total
GeV-quiet	0.18	0.77	1	-	0.52
GeV-loud	0.16	0	0	0	0.08
total	0.17	0.4	0.17	0	0.25

・Nearly half of GeV-quiet RGs undergo absorption

→ GeV-quiet FR-II is mostly absorbed RGs

8 Discussion Few GeV-loud RGs are undergoing significant absorption.

GeV-loud RGs

By beaming, jets are brightened in the gamma-ray

→ looking at jet from a smaller angle

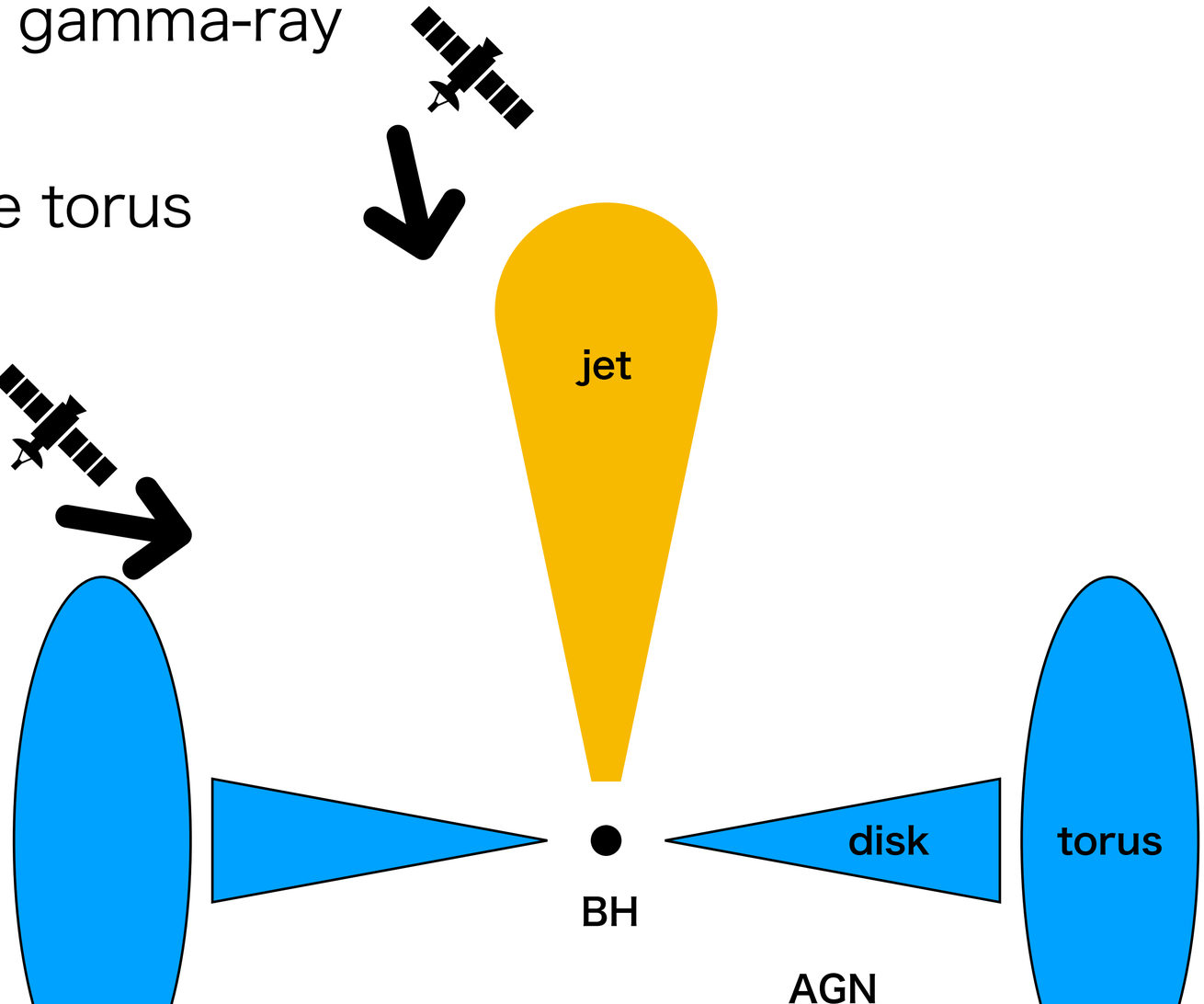
→ X-ray emission is not blocked by the torus

GeV-quiet RGs

Due to the weak beaming of the jet, the gamma-rays emission is weak and hard to observe

→ looking at the jet from a large angle

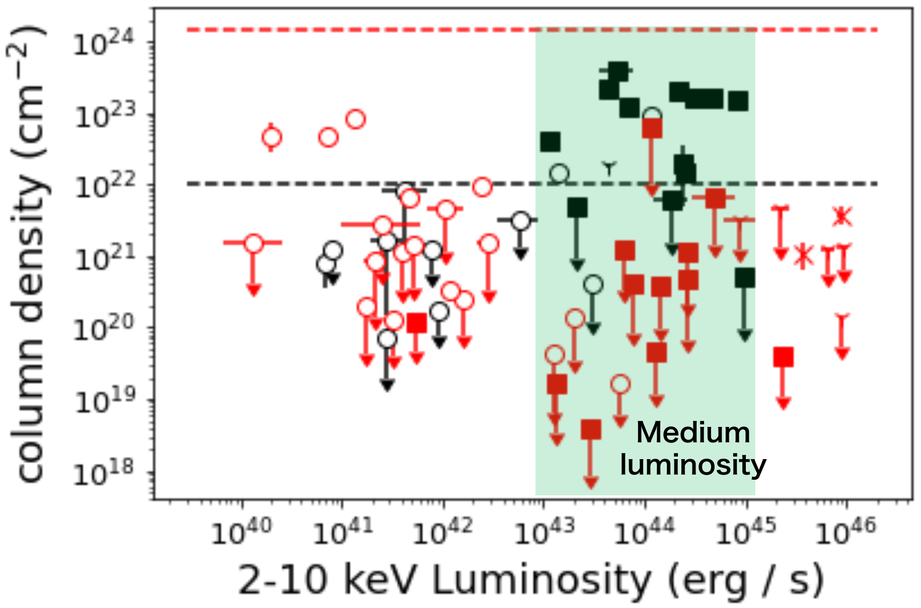
→ X-ray emission is easily blocked by the torus



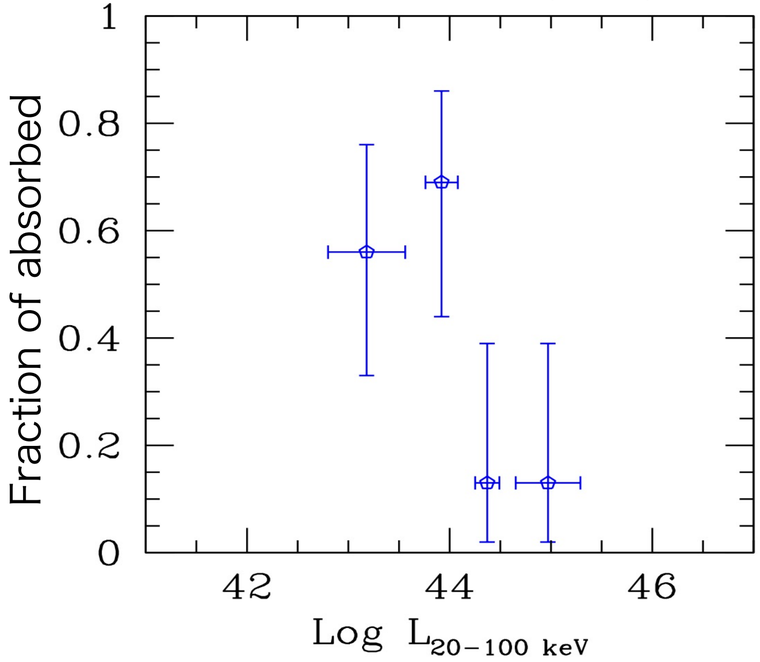
8 Discussion (luminosity)

The relationship between X-ray luminosity and absorption of RGs, including low-luminosity RGs, was investigated statistically.

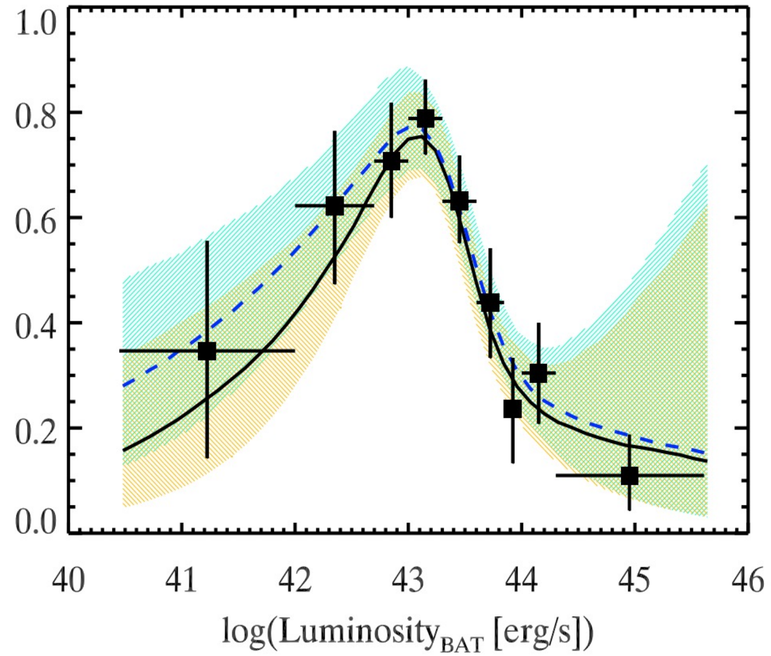
2–10 keV luminosity $L_{2-10}\mathrm{erg/s}$ vs Absorption N_{H} cm^{-2}



Relationship of **Radio galaxies**
F. Panessa et al. (2016)



Relationship of **Seyfert galaxies**
D. Burlon et al. (2011)



Few high and low-luminosity RGs undergo absorption, while about half of medium-luminosity RGs undergo absorption

9 conclusion

- We analyzed the X-ray spectra of 63 RGs.
- Few GeV-loud RGs are undergoing significant absorption

→ GeV-loud RGs are looking at the jet from a smaller angle, while GeV-quiet RGs are looking at the jet from a larger angle

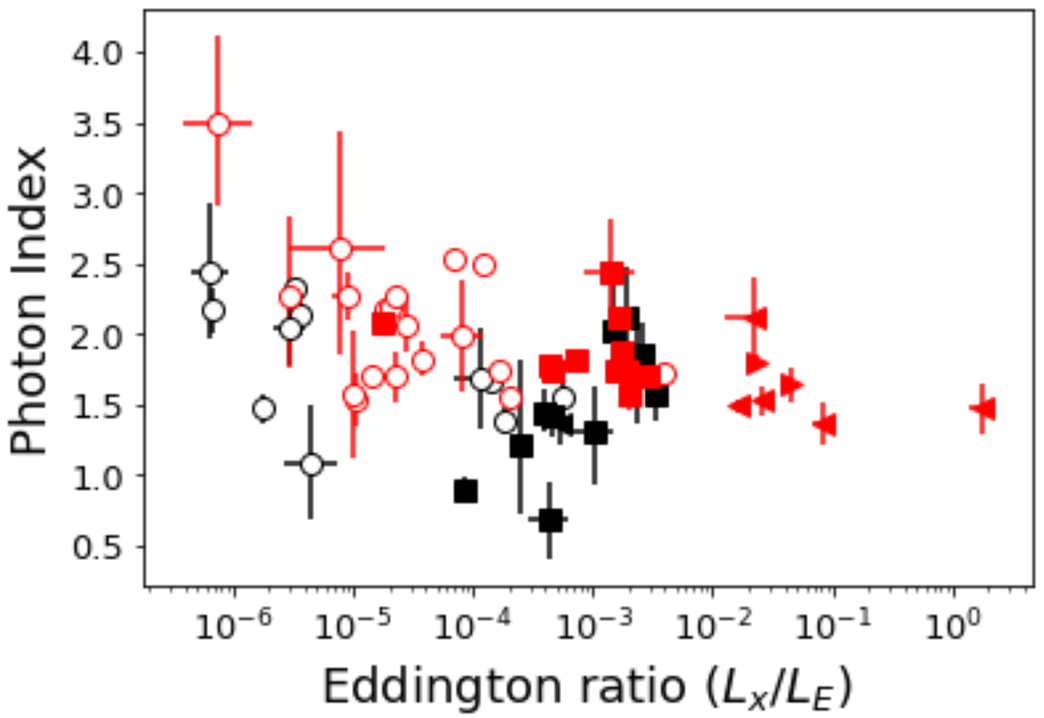
- The relationship between X-ray luminosity and absorption of RGs, including low-luminosity RGs, was investigated statistically for the first time

→ Few high and low-luminosity RGs were found to be absorbed, while about half of the medium-luminosity RGs were found to be absorbed

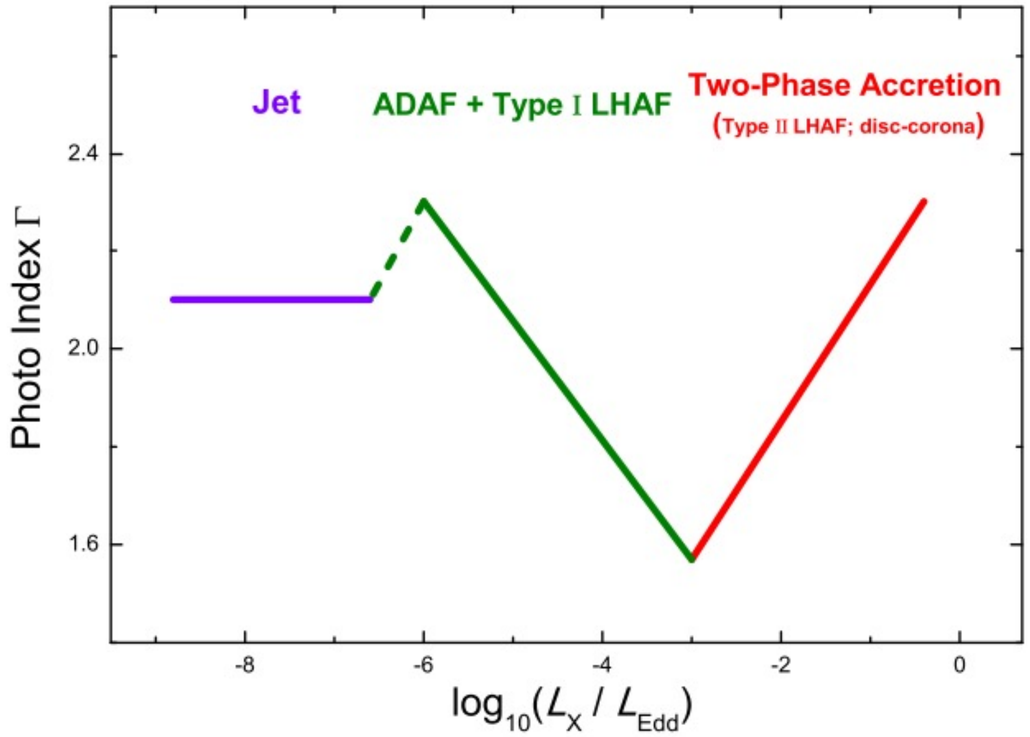
8 Discussion (Eddington ratio)

We examined the relationship between the Eddington ratio and the Photon Index.

Eddington Ratio vs Photon Index

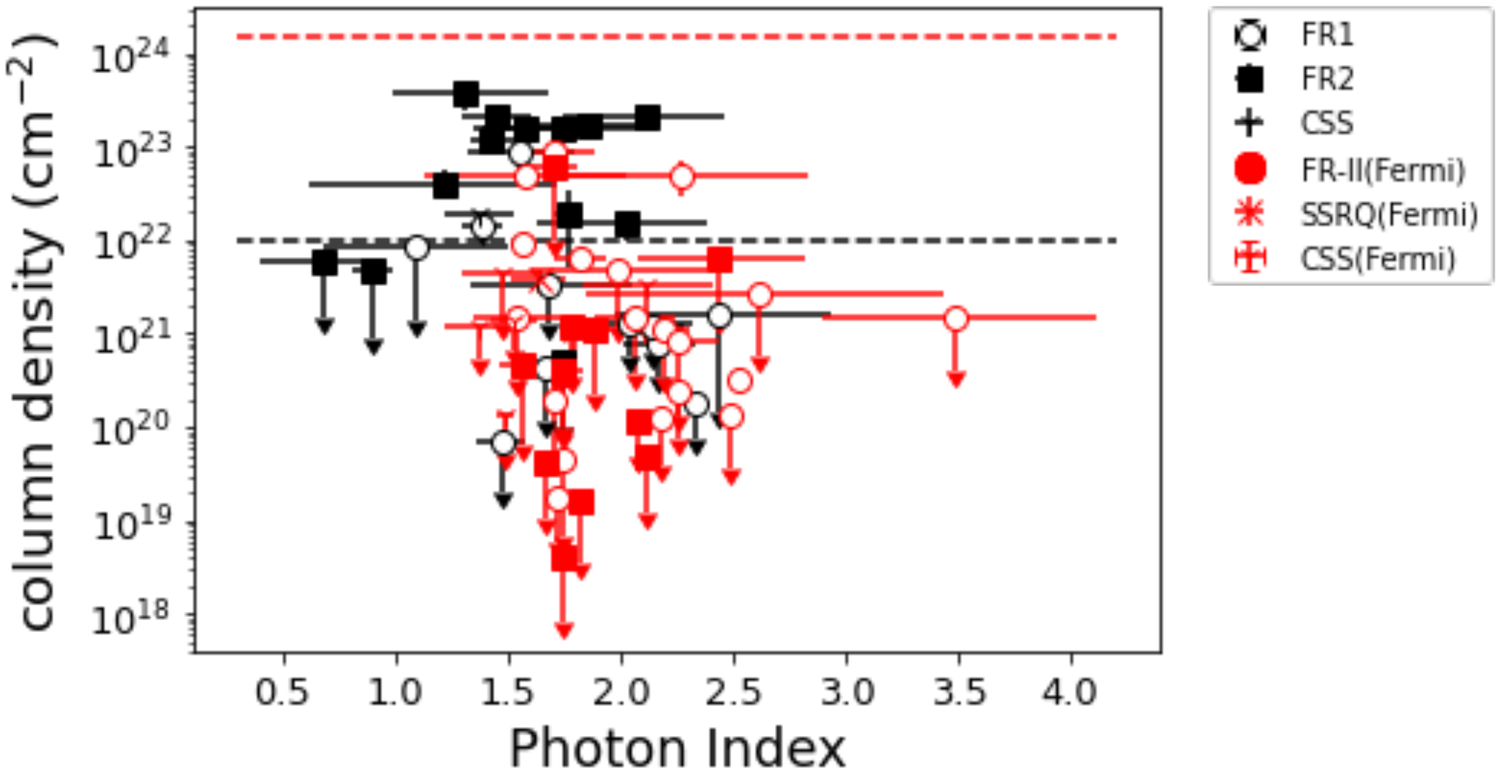


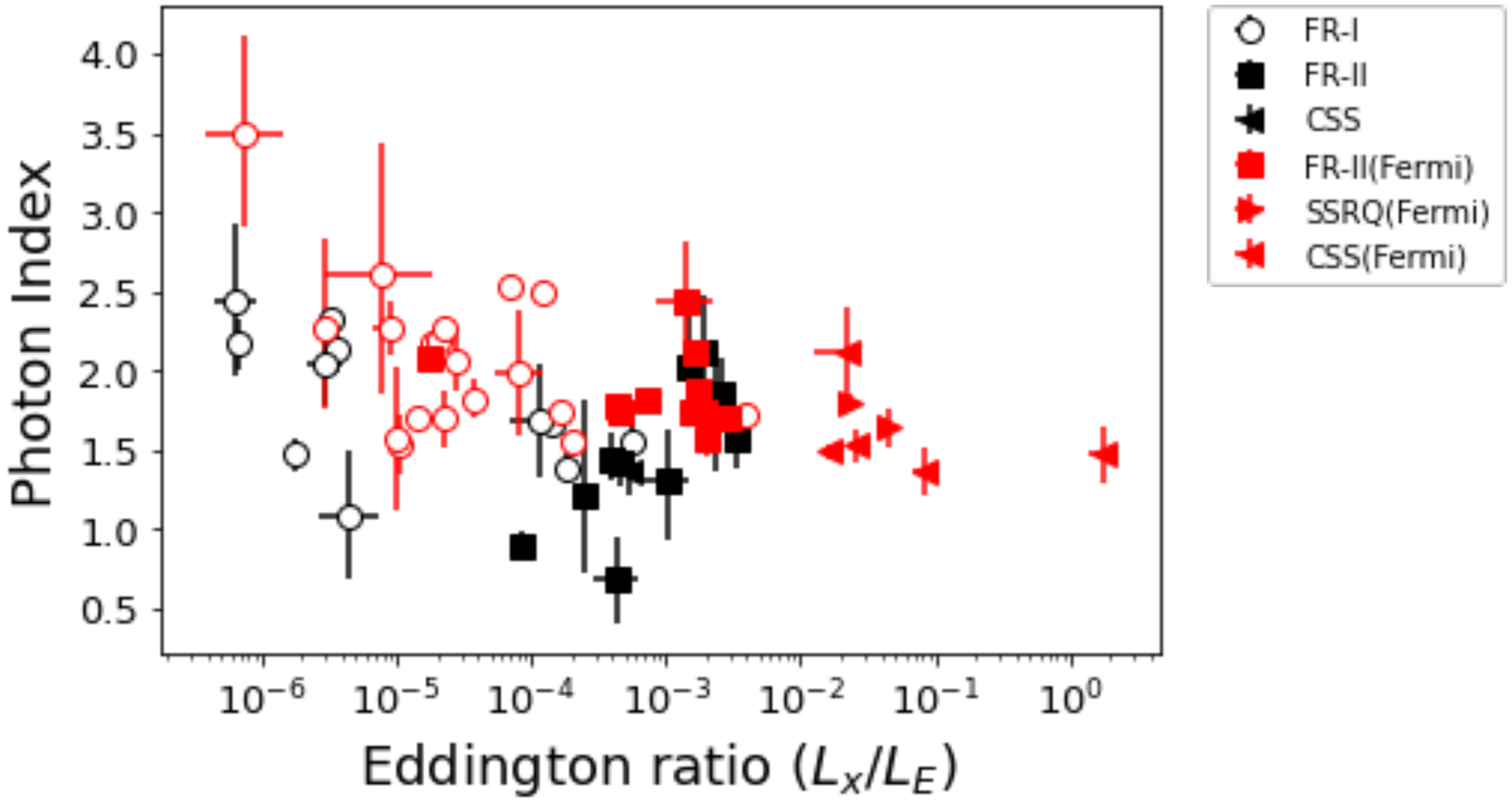
Relationship between Eddington Ratio and Photon Index
Q.Yang et al. (2014)



Falling right for $\lesssim 10^{-4}$ and rising right for $\gtrsim 10^{-4}$

→ Consistent? with AGN's relationship between Eddington Ratio and Photon Index


column density (cm^{-2})
10^{24}
10^{23}
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Photon Index
FR1
FR2
CSS
FR-II(Fermi)
SSRQ(Fermi)
CSS(Fermi)


Photon Index
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
Eddington ratio (L_x/L_E)
FR-I
FR-II
CSS
FR-II(Fermi)
SSRQ(Fermi)
CSS(Fermi)