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E11: Neutral Iron K Lines in Type 1 Seyfert Galaxies observed with *Suzaku*

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Abstract

We report the systematical analysis of the iron line using the data of 35 type 1 Seyfert galaxies observed by *Suzaku* until October 2009. The iron line consists of two components, broad and narrow. A broad iron line appears broadened and skewed as a result of the Doppler effect and the gravitational redshift. A narrow iron line, which is peaking at ~ 6.4 keV, is most likely to be from the neutral iron. The origin of the narrow iron line is thought to be from the optical broad line region (BLR) or the molecular torus. It is not, however, clear.

We calculated the flux of emission line and examined the correlation of various physical quantities. We found the anti-correlation between the luminosity and the equivalent width of the narrow iron line (X-ray Baldwin Effect) and the correlation between the luminosity and the center energy of broad iron line.

In order to examine the origin of the narrow iron line, we referred the ionization parameter and the result of narrow iron line observed by the Chandra high-energy grating (HEG). We thought the BLR and the molecular torus are the most likely to be. It is required that the larger the luminosity gets, the smaller the solid angle emitting the narrow iron line becomes in order to explain the X-ray Baldwin Effect in either of them. The luminosity of the central BH has a large effect to the surrounding structure.

1.Introduction : What is the origin of the narrow iron line?

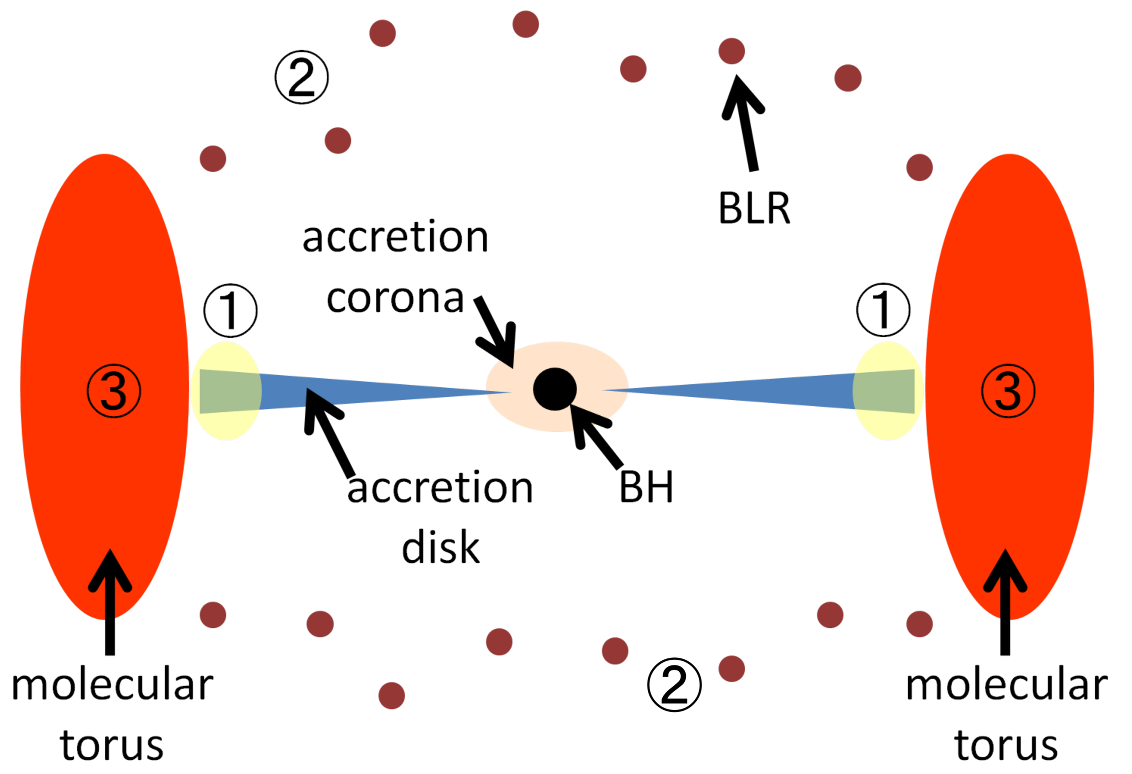


Fig.1 The central structure of AGN

①The outer part of accretion disk
•A rapidly variable narrow iron line in Mrk841[4].

②The optical broad line region (BLR)
•The narrow iron line is agreement with the value measured for the broad component of Hα in NGC7213[5].

③The molecular torus
•supersolar iron abundance
•anisotropic illumination of the line-emitting matter[3,6]

The systematical analysis of the iron line attending to the narrow iron line in particular

2.Approach

Overview : We examined the X-ray spectra in the 4.5-7.5 keV energy band of 35 type 1 Seyfert galaxies observed by *Suzaku*.

1. Fitting with only the power-law model (pow)
2. Adding the Gaussian model*1 (center energy : 6.4 keV, σ : 0.01 keV; fixed; gau1)
3. Adding the second Gaussian model*2 (center energy and σ are free; gau2) and the iron absorption edge (Fe_edge)
   - second Gaussian : 6 ≦ (center energy) ≦ 7 keV, 0 ≦ σ ≦ 1 keV
   - iron absorption edge : 7 ≦ (absorption energy) ≦7.5 keV; fixed

◆ 1 : Assuming the iron emission line which is far from the central BH
◆ 2 : Assuming the iron emission line which is except for "*1"

3.Results

top : wabs * pow   middle: wabs * (pow+gau1)   bottom : wabs * Fe_edge * (pow+gau1+gau2)

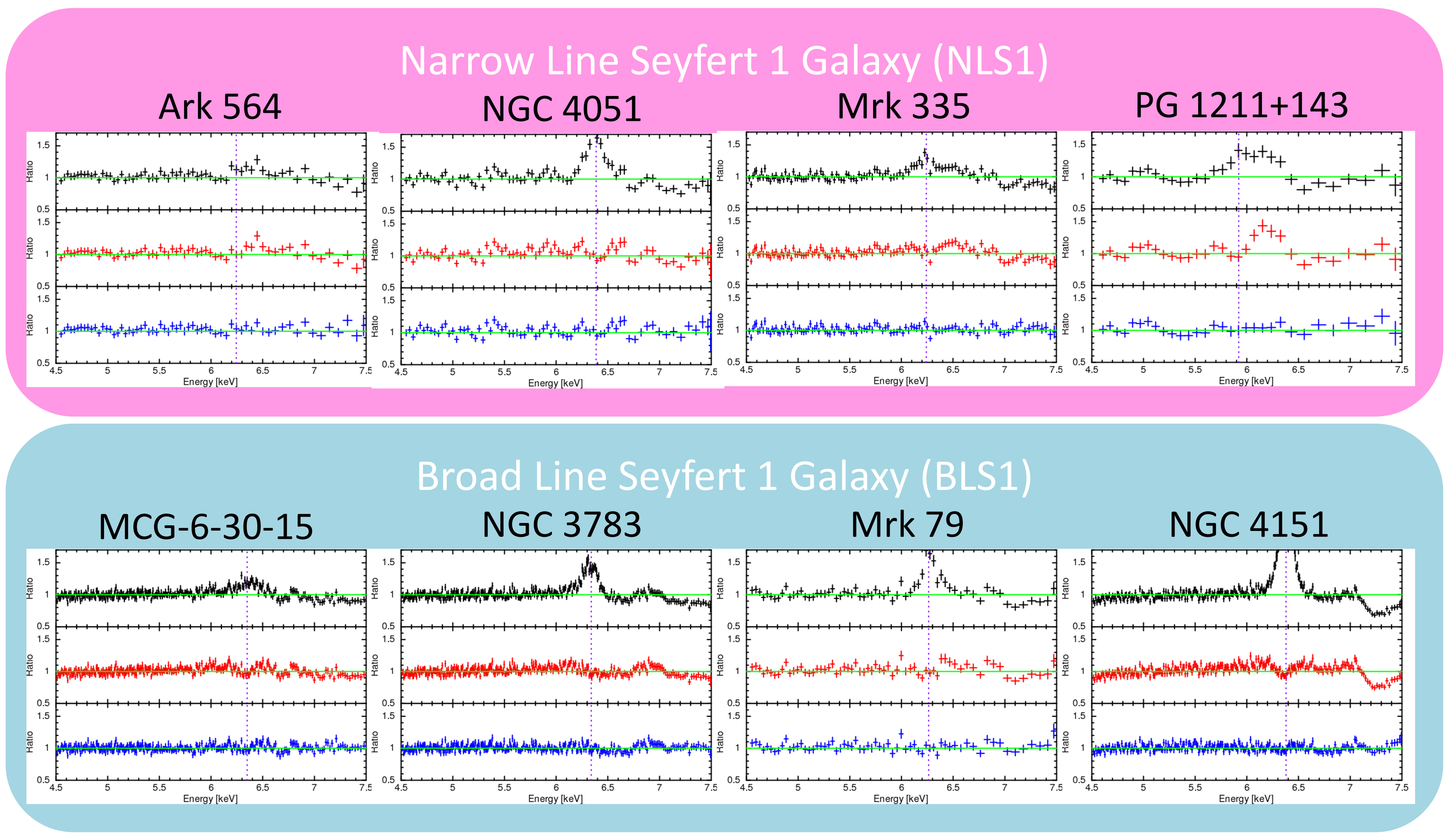
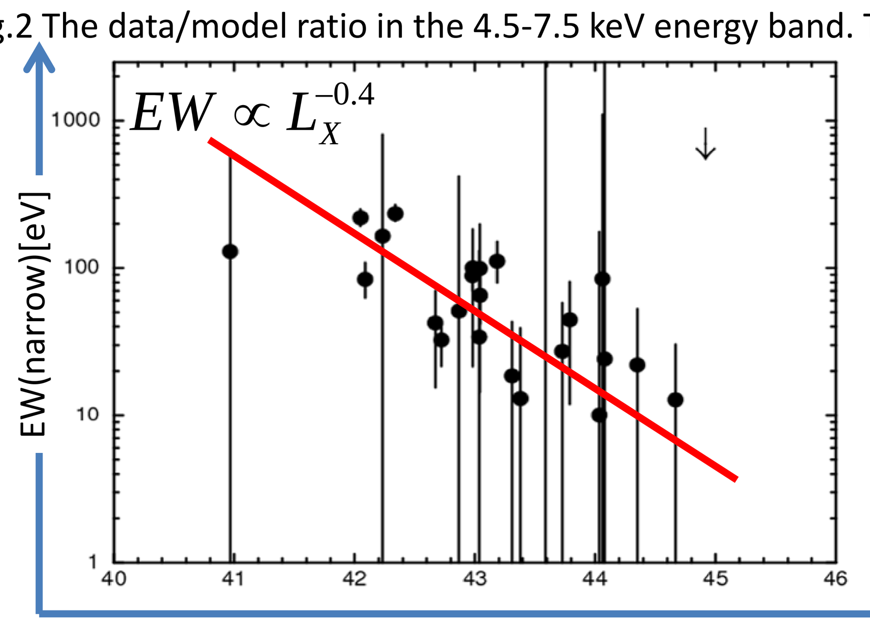


Fig.2 The data/model ratio in the 4.5-7.5 keV energy band. The energy for neutral iron is indicated in purple dotted line.



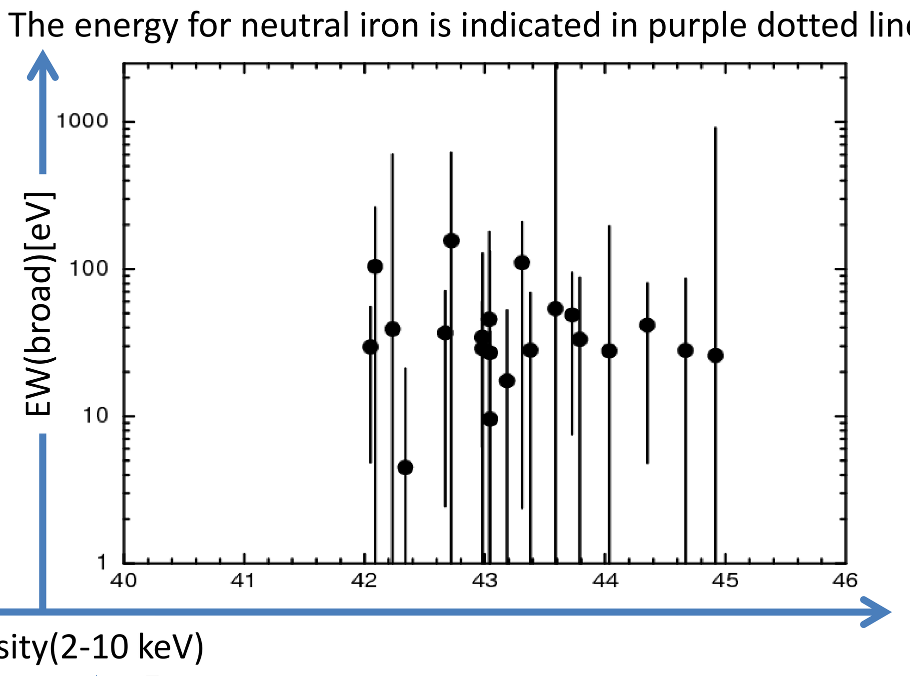
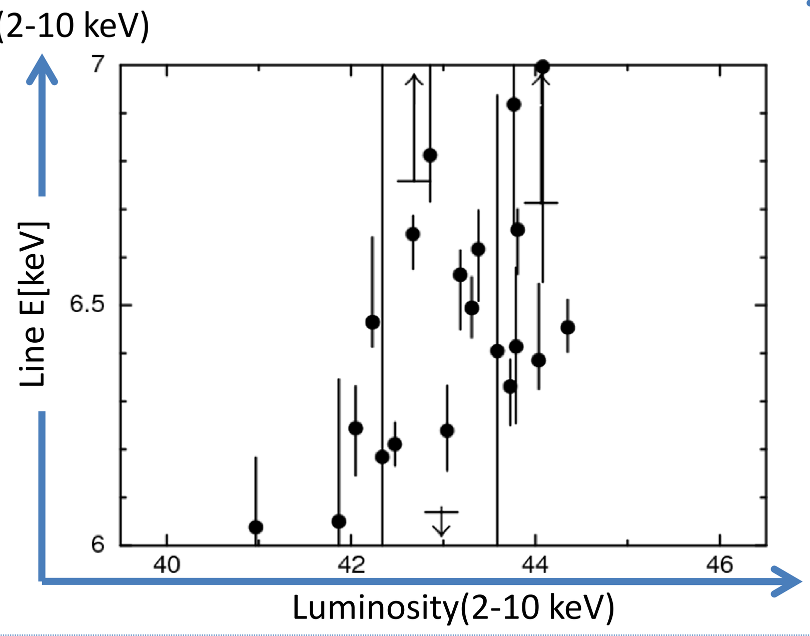


Fig.3 The correlations for various physical quantity
(top left) : L(2-10 keV) vs EW(narrow iron line)
(top right) : L(2-10 keV) vs EW(broad iron line)
(bottom right) : L(2-10 keV) vs line E(broad iron line)



The larger the luminosity gets, the smaller the flux for narrow iron line becomes.
= X-ray Baldwin Effect[2]

The larger the luminosity gets, the higher the broad iron line center energy becomes.
→The evidence of ionization proceeding

4.Discussion1 : The origin of the narrow iron line

Overview : We examined the origin of the narrow iron line by using the ionization parameter and the velocity dispersion.

$$\xi = \frac{L}{n \cdot r^2} = \begin{cases} L \cdots \text{ionizing luminosity } [\mathrm{erg\,s^{-1}}] \\ n \cdots \text{gas density } [\mathrm{cm^{-3}}] \\ r \cdots \text{distance of the material from the central BH } [\mathrm{cm}] \end{cases}$$

ξ≦100 : the narrow iron line ・・・ neutral [1]

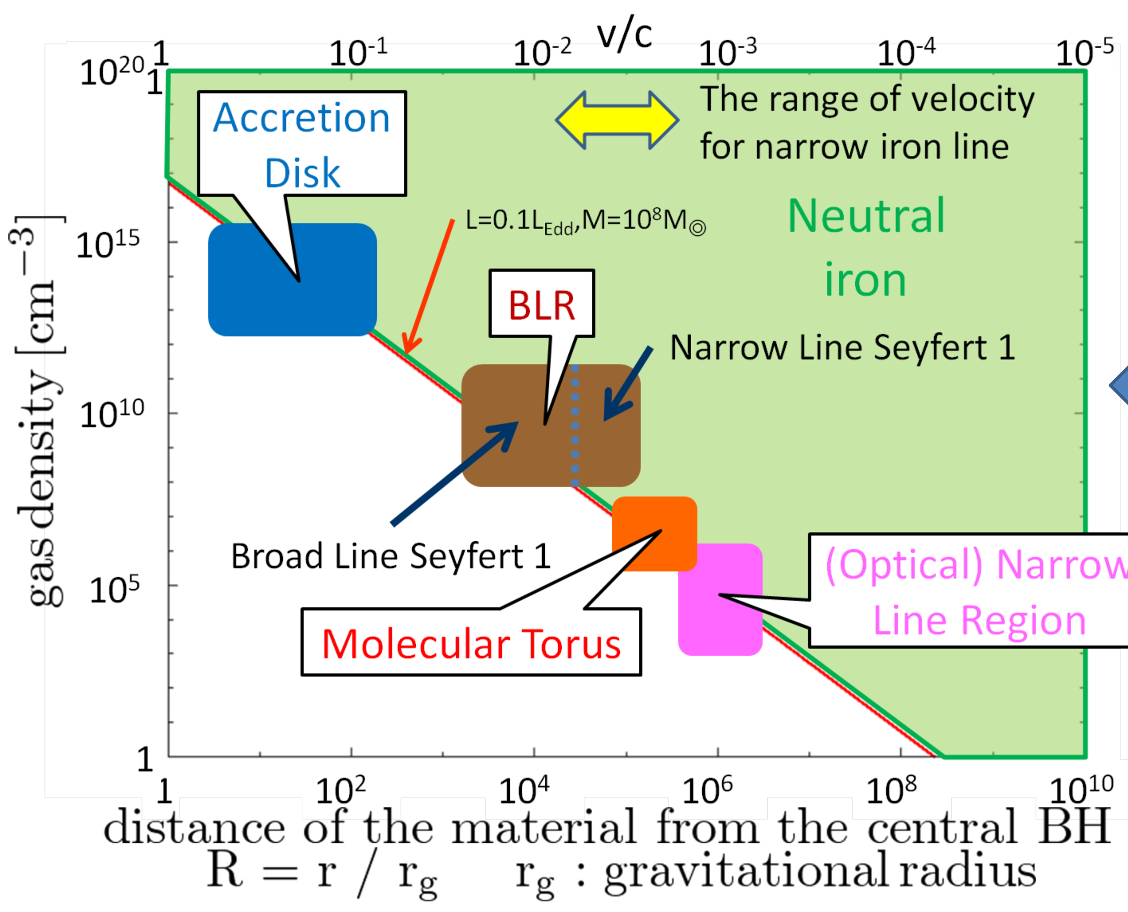


Fig.4 The range where each structure exists

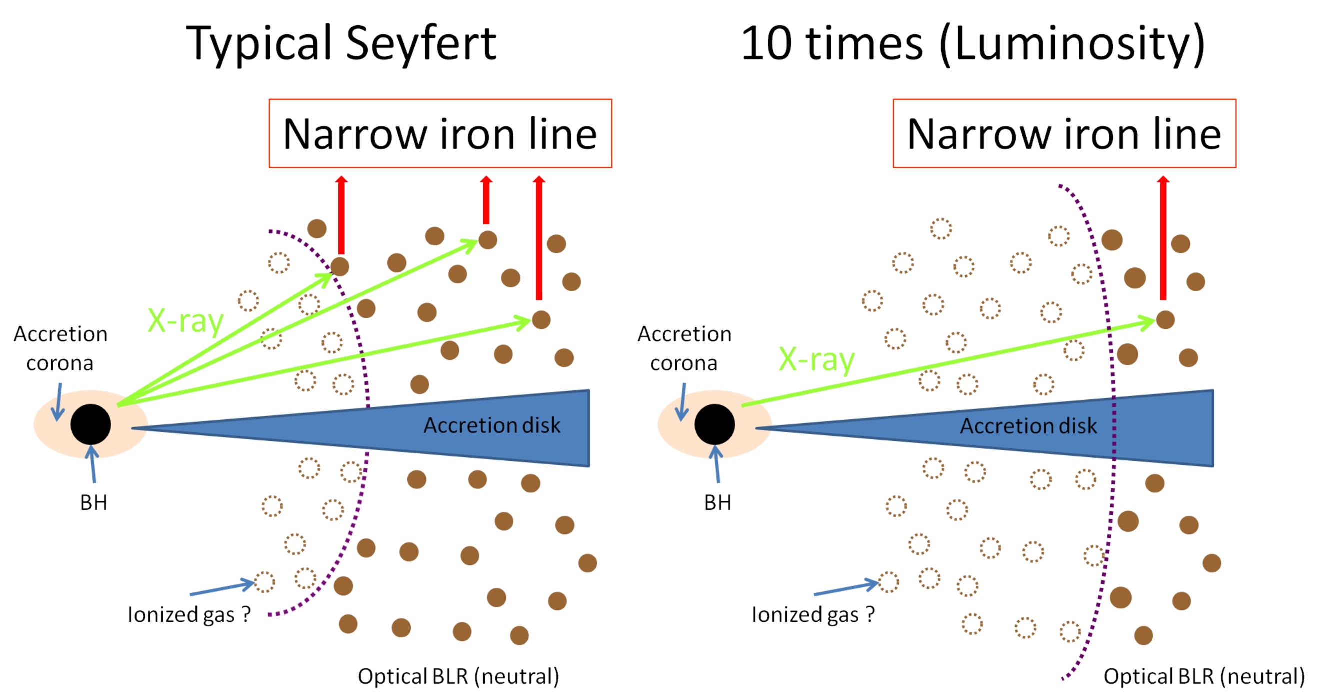
The velocity dispersion (FWHM) :
Refer to the result for the *Chandra*
FWHM = 2060 ± 230 [km s^{-1}][7]

Ionization is the important physical quantity

The BLR and the molecular torus is most likely to be possible

Consider the X-ray Baldwin Effect in each case

4.Discussion 2 : The origin of the X-ray Baldwin Effect



10 times Luminosity

Ionization for BLR proceeds near the central BH

The boundary between the ionized and neutral regions goes away

The solid angle of BLR viewed from the center becomes 1/3

EW for the narrow iron line also becomes 1/3

Fig.5a The explanation of the X-ray Baldwin Effect (case : the optical BLR)

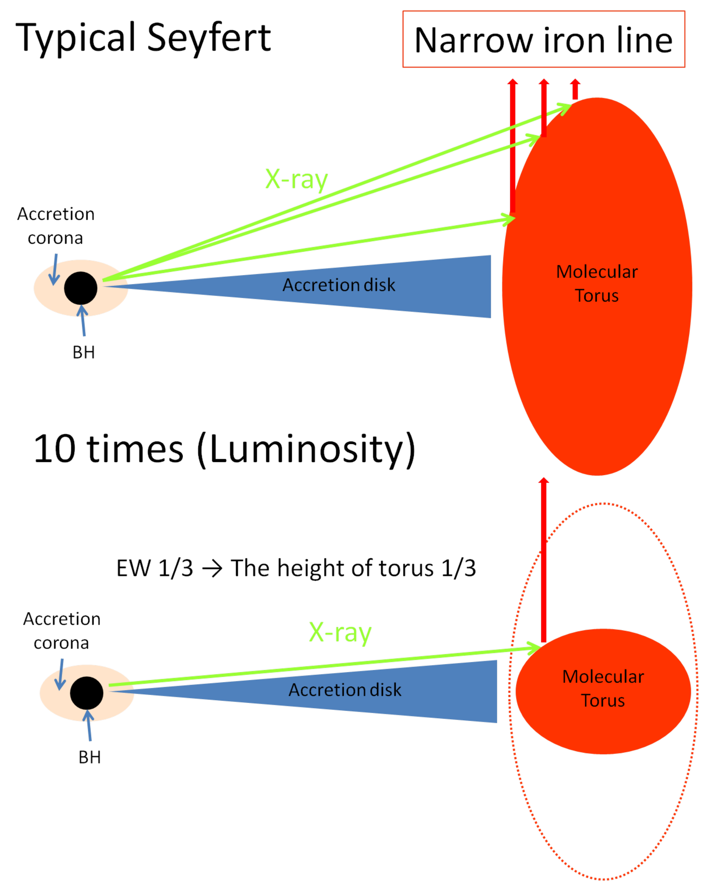


Fig.5b The explanation of the X-ray Baldwin Effect
(case : the molecular torus)

10 times Luminosity

The material in the surface of torus on BH side gets ionized

The height of torus shrinks to 1/3???

The solid angle of torus viewed from the center becomes 1/3

EW for the narrow iron line also becomes 1/3

The materials from torus flows

While the luminosity gets larger in the center, the scale of torus becomes smaller

EW for the narrow iron line also becomes 1/3

The narrow iron line is affected by the central luminosity ⇒ The central luminosity is must be taken into account for the unified schemes of type 1, 2 Seyfert galaxies

5.Summary

◆We systematically examined the iron line attending to the narrow component for the type 1 Seyfert galaxies observed by *Suzaku* until October 2009.

◆The anti-correlation between the luminosity and the flux for narrow iron line (X-ray Baldwin Effect) was found.

◆Although there was no correlation between the luminosity and the flux for broad iron line, we found that the larger the luminosity gets, the higher the line center energy for this line becomes.

◆The BLR and the molecular torus are most likely to be the origin of the narrow iron line. In the case of the BLR, the X-ray Baldwin Effect is explained by the solid angle of BLR becoming smaller when the luminosity gets large. In the case of the molecular torus, in order to explain the X-ray Baldwin Effect, it is required that the height of torus shrinks when the luminosity gets large. In either of them, there is a implication between the central luminosity and surrounding structures.

References

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