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The shape of the Fe Kα spectral line in the case of partly obscured accretion disk

Goals of this talk

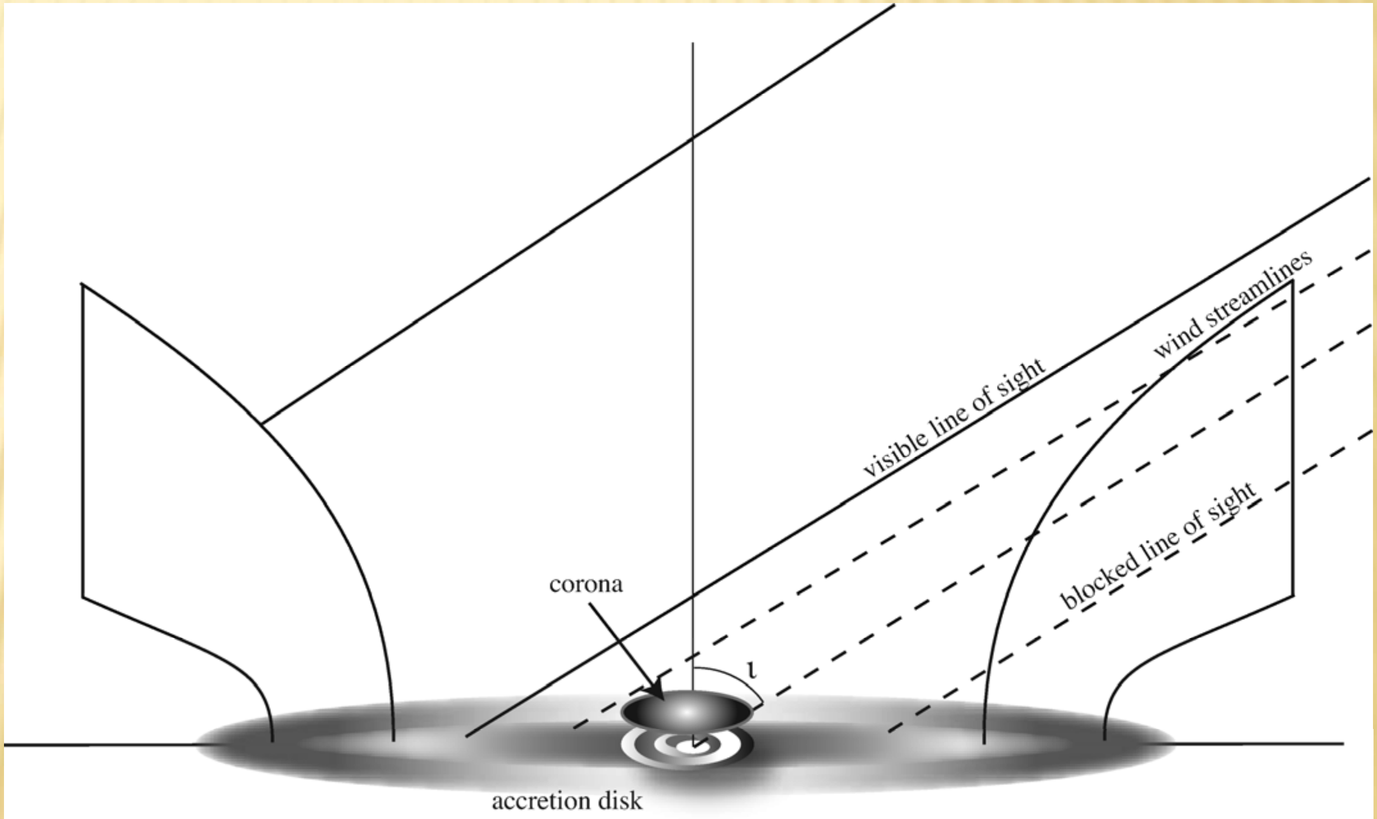
1. discussion about how much warm absorbers can change the Fe Kα spectral line profile emitted from a relativistic accretion disk of Active Galactic Nuclei (AGN)
2. modeling of the X-ray absorbing/obscuring region that can cause these changes and explain the P Cygni profile of the Fe Kα line observed in some narrow line Seyfert 1 galaxies

Absorption by an outflowing wind of X-ray emission from relativistic accretion disk of AGN

- significant in low ionization broad absorption line (LoBAL) quasars
- presence of X-ray absorbers confirmed in gravitationally lensed Cloverleaf quasar H 1413+117 (*z* = 2.56)

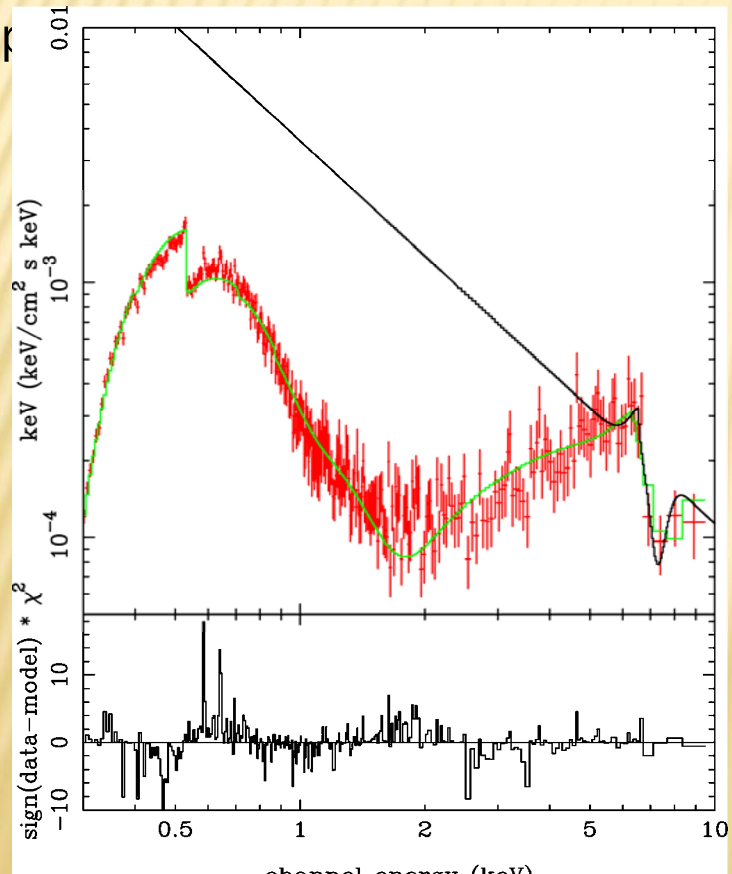
Chartas, G., Eracleous, M., Dai, X., Agol, E., Gallagher, S., 2007, *Astrophys J.*, 661, 678.

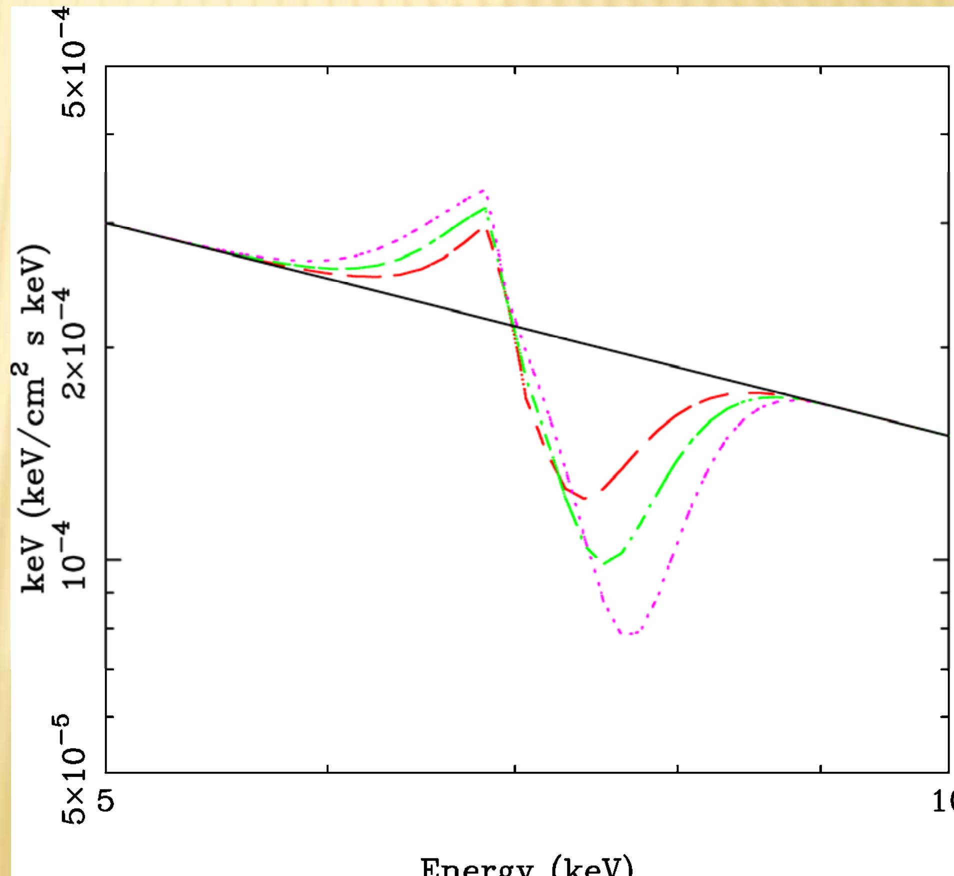
Chartas, G., Eracleous, M., Dai, X., Agol, E., Gallagher, S., 2006, *Astron. Nachr.* 327, 10, 1063



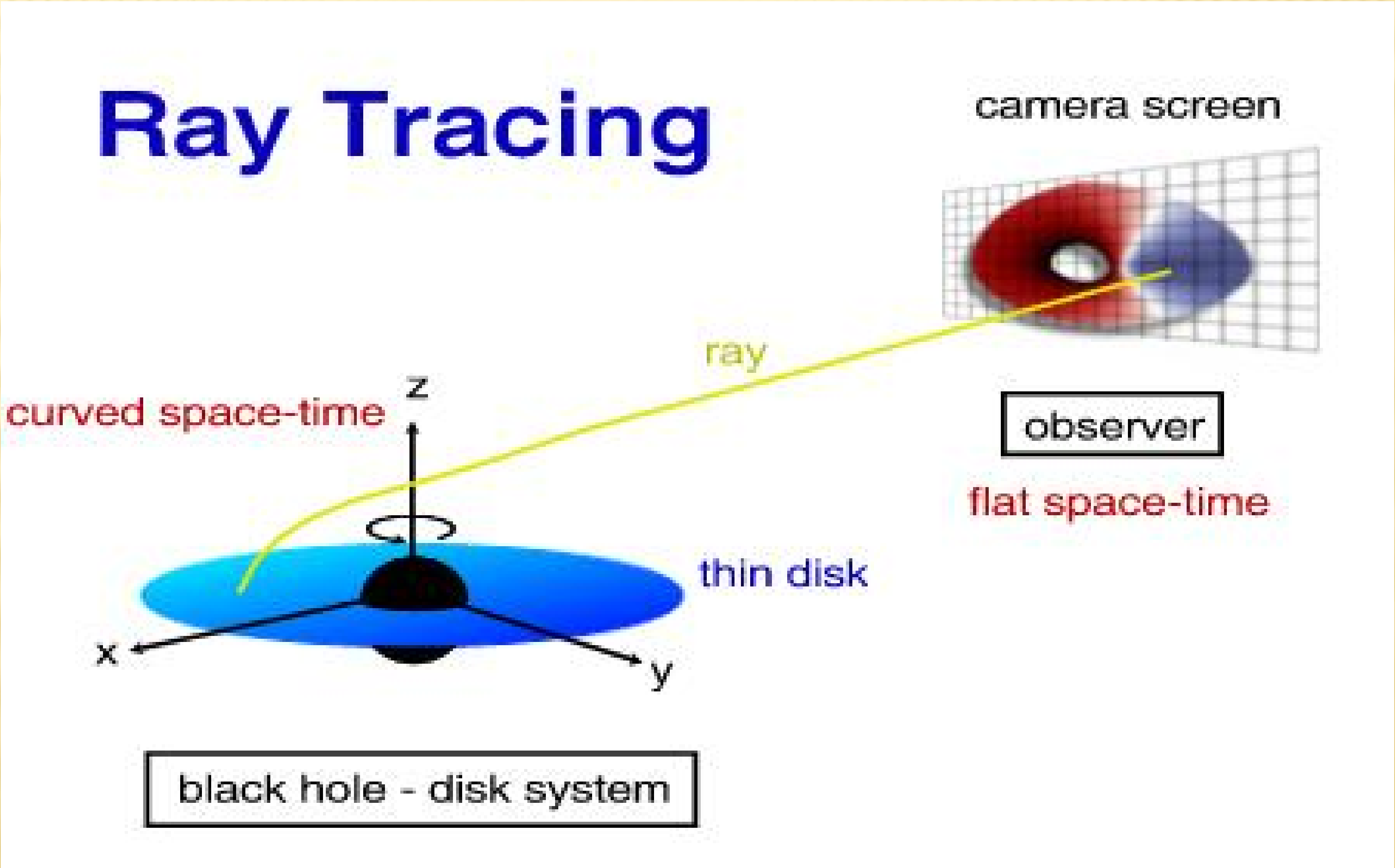
P Cygni profile of the Fe Kα line in narrow line Seyfert 1 galaxies

- complex X-ray spectra with a strong “soft excess” below 2 keV and emission line at ~5 keV which is followed by a strong absorption line at ~7 keV
- Done, C., Sobolewska, M. A., Gierlinski, M., Schurch, N. J., 2007, MNRAS, 374, L15:
- sharp feature at ~7 keV results from absorption/scattering/emission of iron Kα lines in the wind and in the case of 1H 0707-495 it can be fitted by P Cygni p





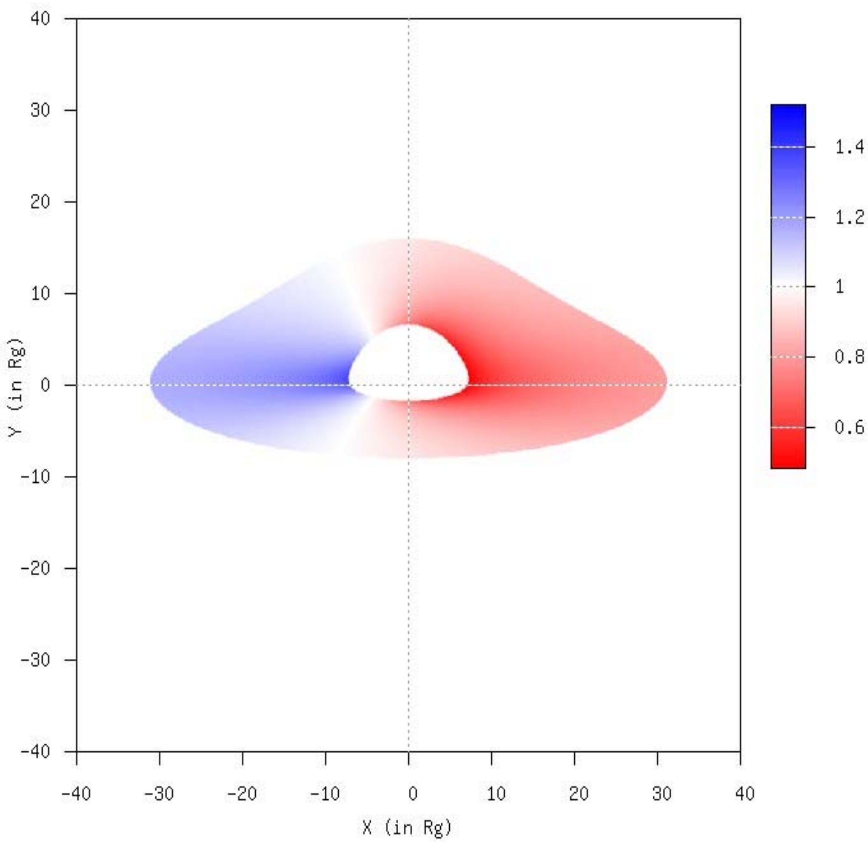
Numerical simulations of disk emission

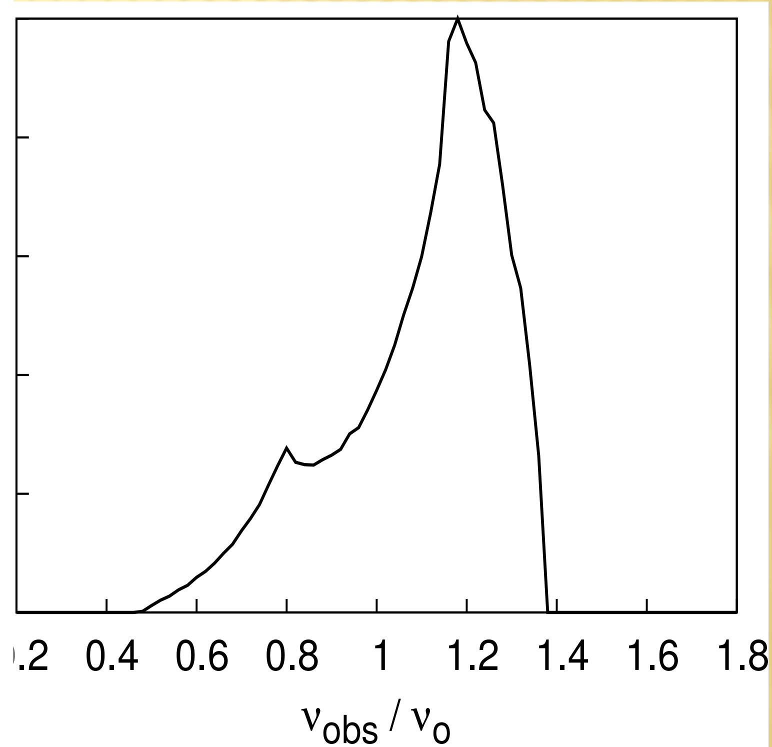


Fe Kα line

- broad emission line at 6.4 keV
- asymetric profile with narrow bright blue peak and wide faint red peak
- variability of both: line shape and intensity

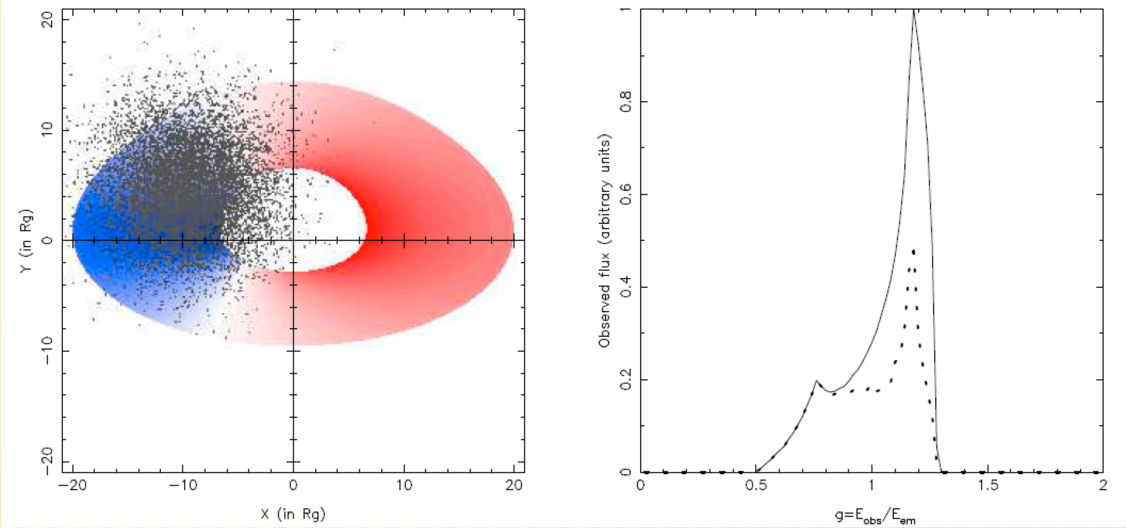
- line width corresponds to velocity:
  v ~ 80000 – 100000 km/s (MCG-6-30-15)
  v ~ 48000 km/s (MCG-5-23-16)
  v ~ 20000 – 30000 km/s (many other AGN)





A model of X-ray absorption region

- absorption region: composed of N_A individual spherical absorbing clouds with the same small radii r_A



coverage ratio of the disk:

$$\mathcal{N} = 100 \cdot \frac{N_{abs}}{N_{em}}$$

PDF of bivariate normal distribution:

$$f\left(X_i, Y_i\right) = \frac{1}{2\pi\sigma_X\sigma_Y\sqrt{1-\rho^2}} e^{-\frac{z}{2\left(1-\rho^2\right)}},$$

$$z = \frac{\left(X_i - \mu_X\right)^2}{\sigma_X^2} - 2\rho\frac{\left(X_i - \mu_X\right)\left(Y_i - \mu_Y\right)}{\sigma_X\sigma_Y} + \frac{\left(Y_i - \mu_Y\right)^2}{\sigma_Y^2}$$

absorption coefficient:

$$A(X,Y) = (1 - I_A(X,Y)) \cdot e^{-\left(\frac{g(X,Y)\ E_0 - E_A}{\sigma_E}\right)^2}$$

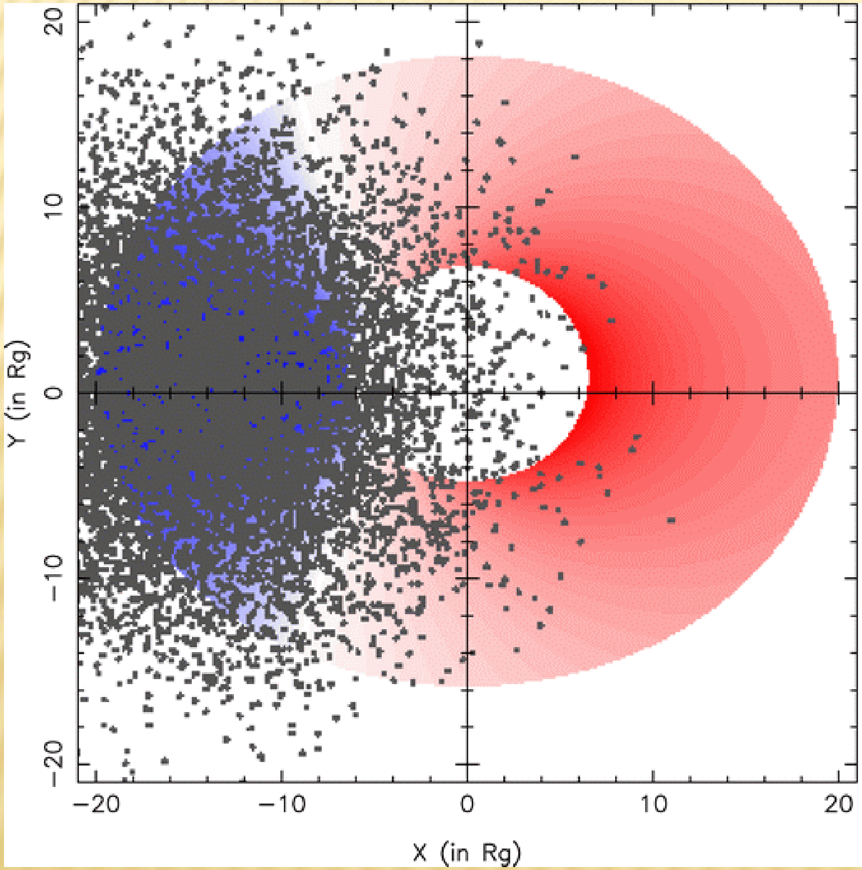
Parameters of accretion disk and absorption region

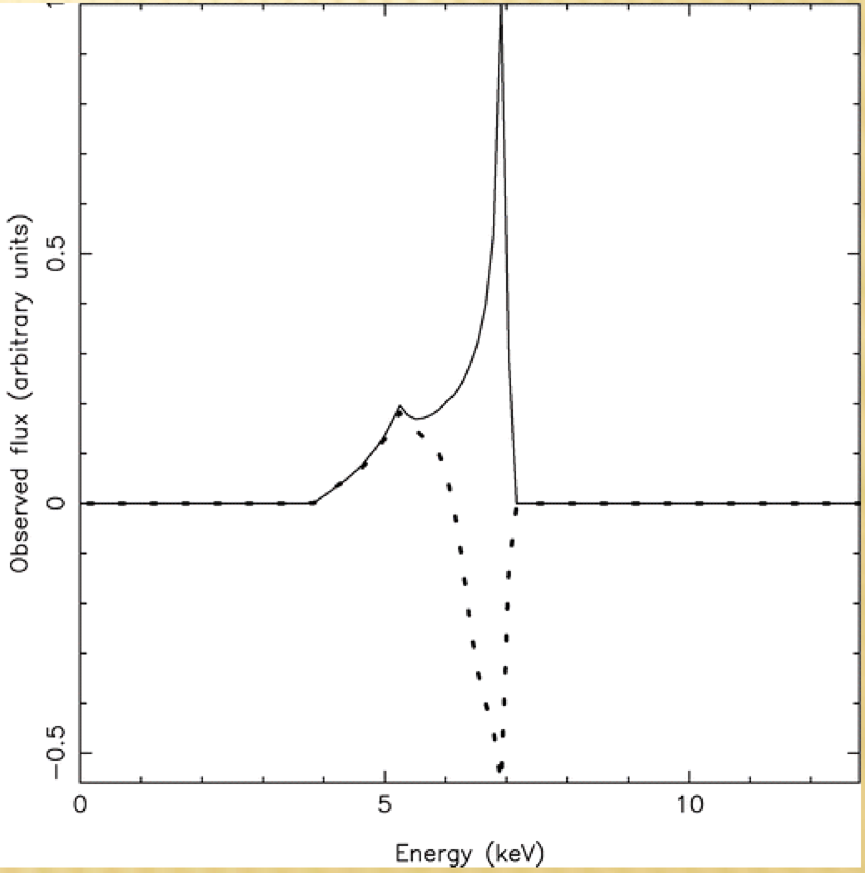
- Accretion disk parameters:
- disk inclination: $i = 35^o$
- power law emissivity index: $q = -2.5$
- inner radius of the disk: $R_{in} = R_{ms}$
- outer radius of the disk: $R_{out} = 20\ \mathrm{R}_g$

- Absorption region parameters:
- number of individual spherical absorbing clouds: $N_A = 10000$, 3000 and 1000
- radius of an individual spherical absorbing clouds: $r_A = 0.2\ R_g$
- radius of projection of entire absorption region: $R_A = 7\ R_g$
- absorption intensity coefficient: $I_A(X,Y) = const$
- central energy of absorption: $E_A = E_0 = 6.4\ keV$
- width of absorption band: $\sigma_E = 0.5\ keV$

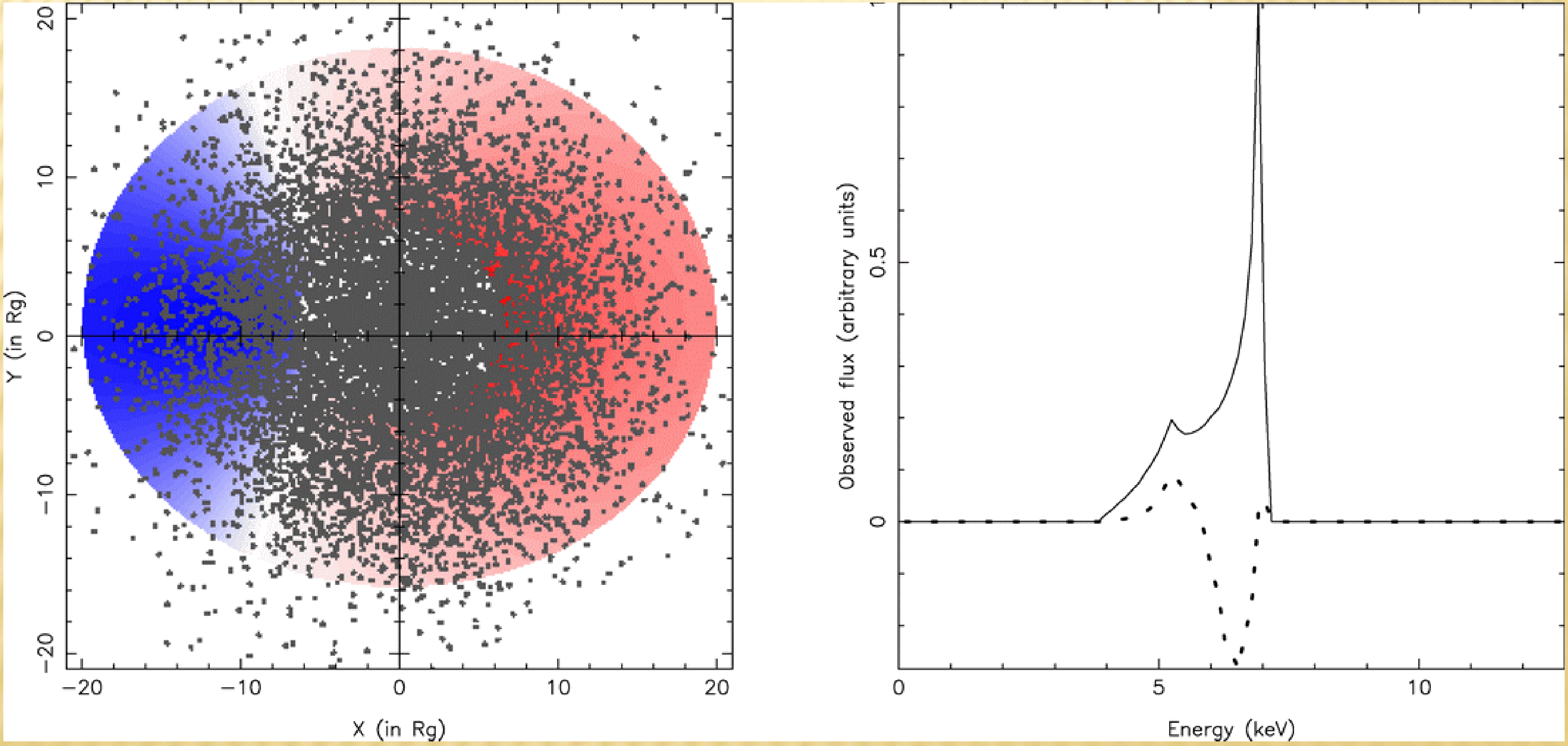
Results:

- Case I: $X_A = -15\ R_g$, $Y_A = 0\ R_g$

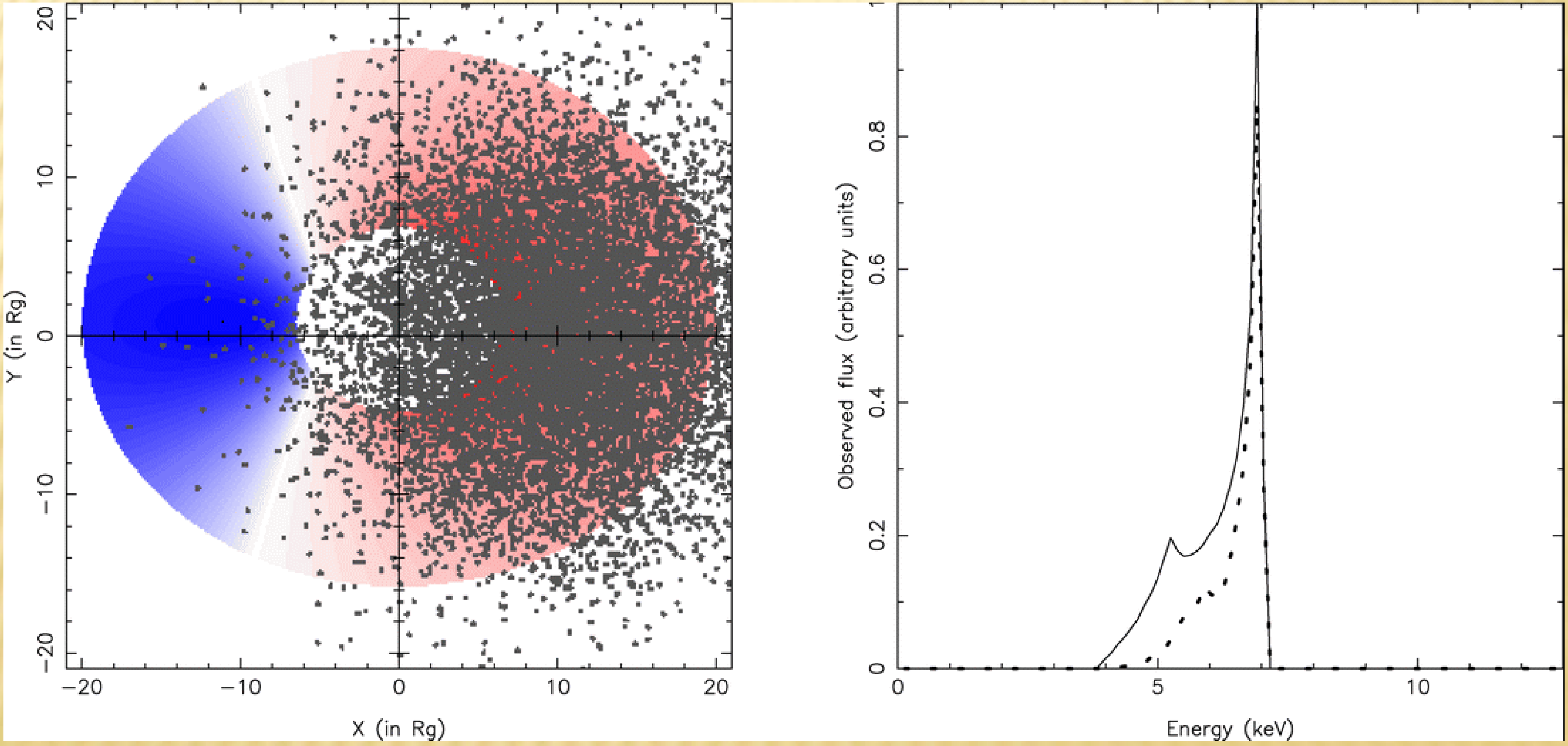




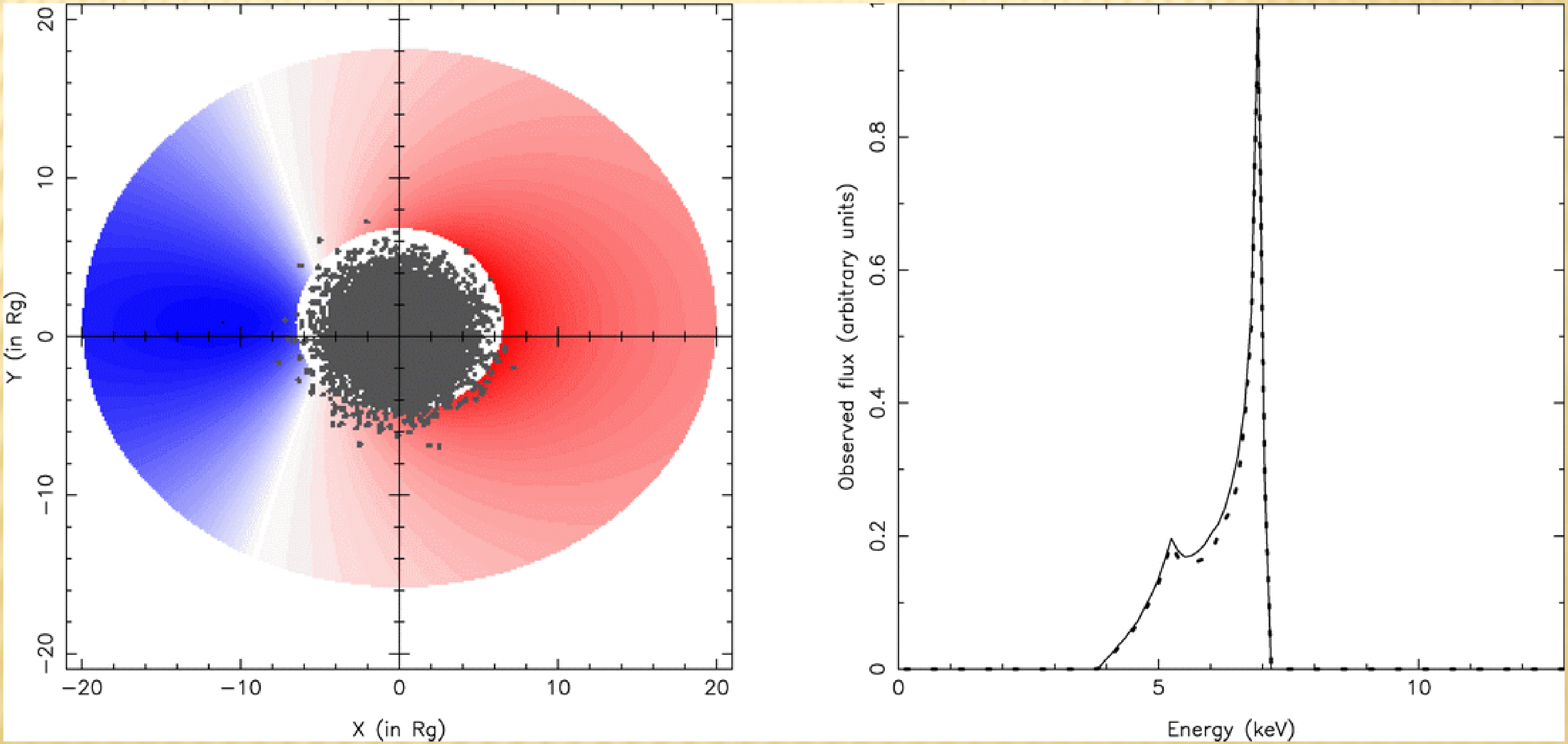
- Case II: $X_A = 0\ R_g$, $Y_A = 0\ R_g$



• Case III: $X_A = 10\ R_g$, $Y_A = 0\ R_g$



• Case IV: $X_A = 0\ R_g$, $Y_A = 0\ R_g$, $R_A = 2 - 40\ R_g$



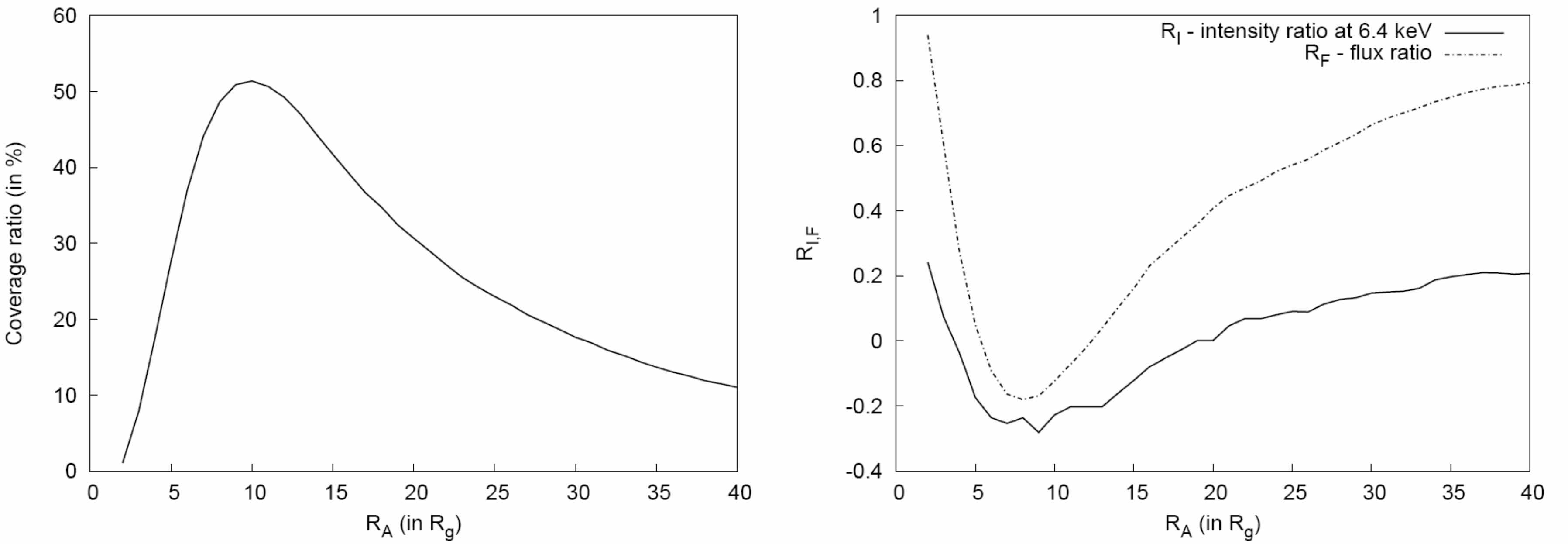


FIGURE 2. *Left:* coverage ratio $\mathcal{N}$ as a function of the radius of projection of entire absorption region R_A in the case ii) of §4. *Right:* ratio of absorbed line and unabsorbed line intensities at central energy of absorption $E_A = E_0 = 6.4$ keV (solid line) and ratio of their fluxes (dashed line) as functions of R_A in the case ii) of §4.

TABLE 1. Absorber coverage ratios $\mathcal{N}$, fluxes of absorbed line F_A and ratios F_A/F_L (F_L is flux of unabsorbed line) corresponding to the cases described in §4. Intensity of unabsorbed line is normalized to 1 and its flux is $F_L = 0.68069$. Fluxes are given in arbitrary units.

X_A, Y_A	N_A	$\mathcal{N}$ (%)	F_A	F_A/F_L
-15, 0	10000	32.19	-0.07910	-0.11621
	3000	16.68	0.28611	0.42032
	1000	6.86	0.51818	0.76126
0, 0	10000	44.14	-0.11142	-0.16368
	3000	19.10	0.30133	0.44268
	1000	7.07	0.52949	0.77788
10, 0	10000	38.95	0.40955	0.60167
	3000	19.22	0.56380	0.82828
	1000	7.74	0.63792	0.93717

Conclusions:

- we have developed a model of X-ray absorption region which can cause changes in the Fe Kα spectral line profile emitted from a relativistic accretion disk of AGN
- strong absorption of the iron line can occur when a significant part of approaching side of the accretion disk is covered by absorption region
- P Cygni profile of the Fe Kα line can be reproduced in the case when approaching side of the accretion disk is partially blocked from our view by the X-ray absorbing/obscuring material, while the rest of the disk is less absorbed/obscured and therefore is visible
- in such cases the emission Fe Kα line looks redshifted at *~5 keV* and is followed by a strong absorption line at *~7 keV*

Thank you for attention!