# Monte-Carlo Simulation of SS-433 Spectrum

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# SS433

- It is almost certain that there is a black hole in SS433 system.

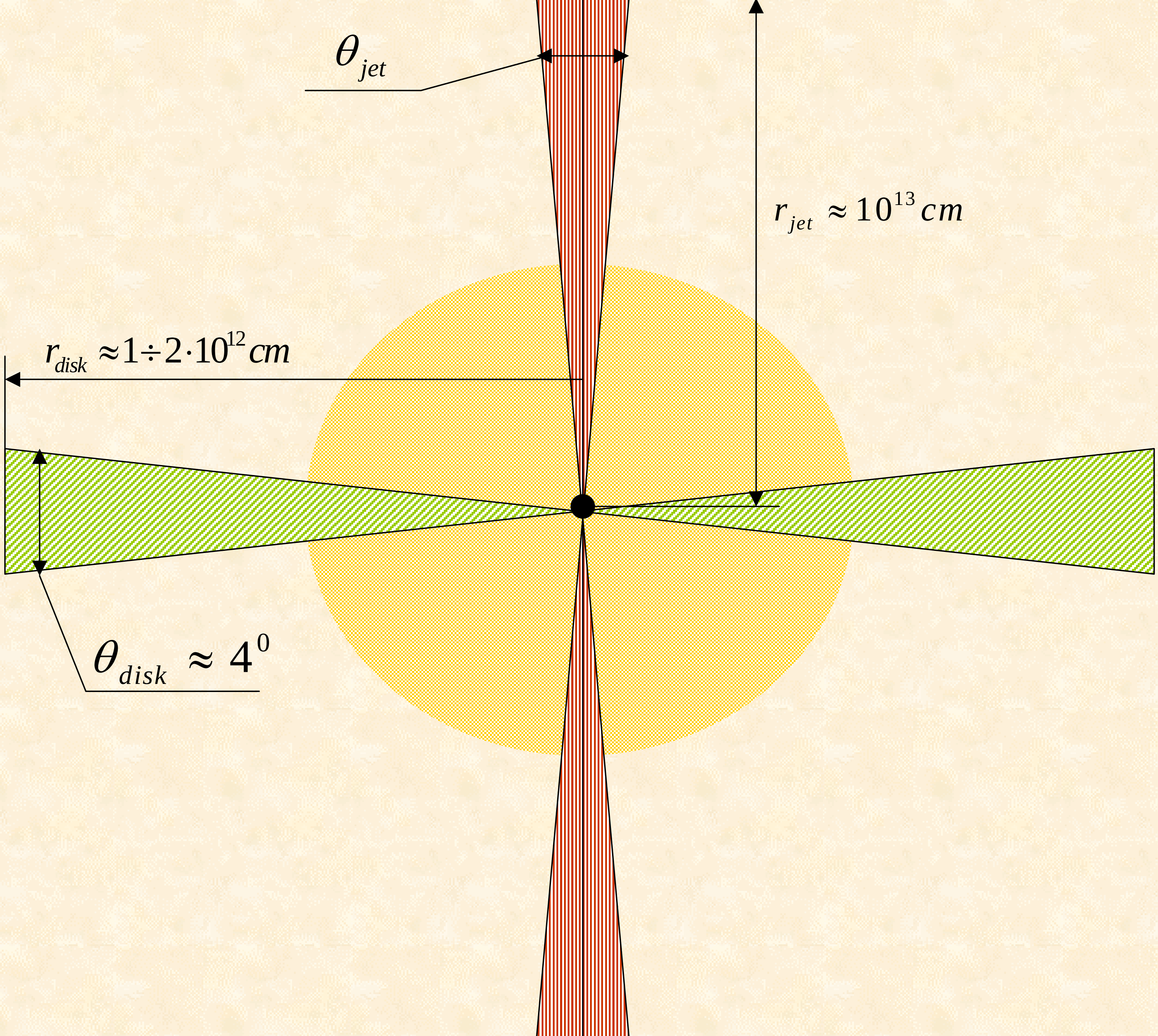
- This binary system consists of an optical star and a relativistic object (neutron star or black hole), surrounded by an accretion disk with a couple of jets. Mass ratio of SS433 components is $q = M_X / M_V = 0.2 \div 0.3$ .

- One of SS433 pecularities is supercritical regime of accretion onto relativistic object

( $\dot{M} \sim 10^{-4} M_{sun} / yr$ , $\dot{M}_{cr} \sim 10^{-7} M_{sun} / yr (M_X = 10 M_{sun})$ )

- Powerful jets of conical shape have kinetic luminosity about ( $L_k \sim 10^{39-40} erg / s$ ), the velocity of matter in jets is almost one third of light speed (0.26c)

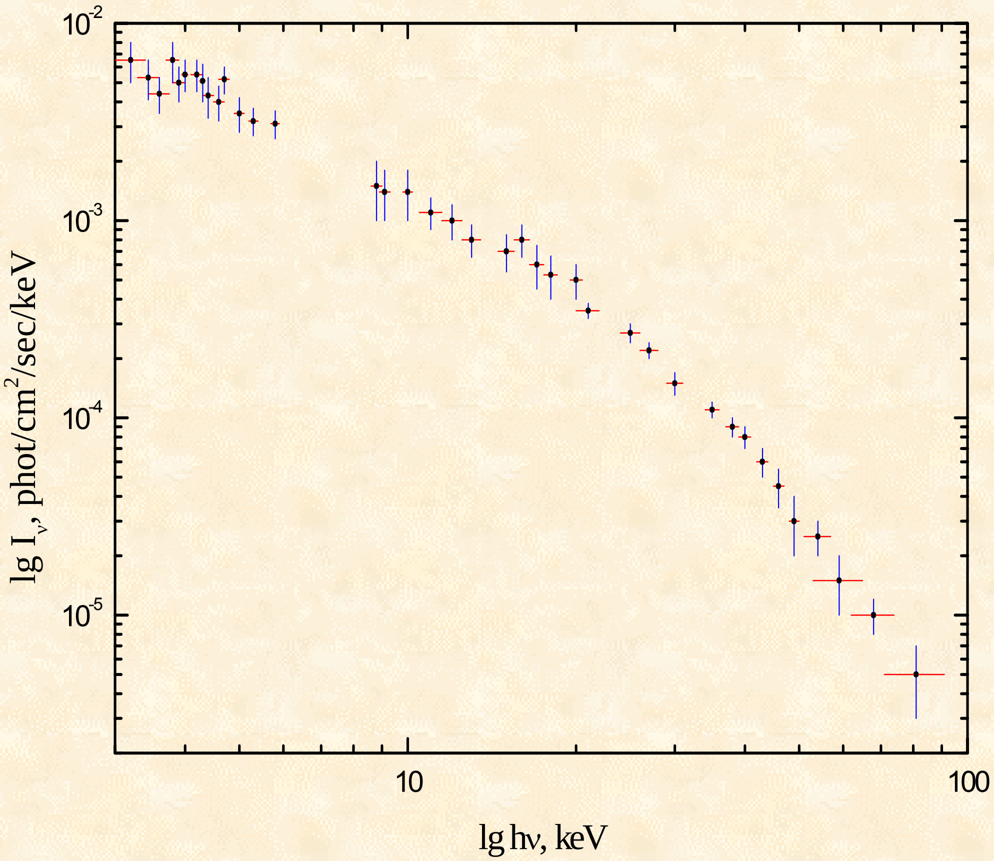
Fabrika S.//ApSS Reviews, vol.12, p.1 (2004)



$\theta_{jet}$
$r_{jet} \approx 10^{13} cm$
$r_{disk} \approx 1 \div 2 \cdot 10^{12} cm$
$\theta_{disk} \approx 4^0$

# Observational data

In this figure the SS433 spectrum in the range from 3 to 90 keV is presented. It was obtained from INTEGRAL data (JEM-X points from 3 to 20 keV and IBIS (ISGRI) points from 20 to 90 keV). The spectum corresponds to precessional moment T3, i.e. when the angle between jet axis and the line of sight is equal 60 degrees.





Cherepashchuk A.M.,Sunyaev R.A., Fabrika S.N., Postnov K.A. et al.//A&A, 437, 561 (2005)

Cherepashchuk A.M.,Sunyaev R.A. et al.// Proceeding of 6th INTEGRAL Workshop, Moscow, Russia (2006)

# Model's physical parameters

Concentration in jet and corona:

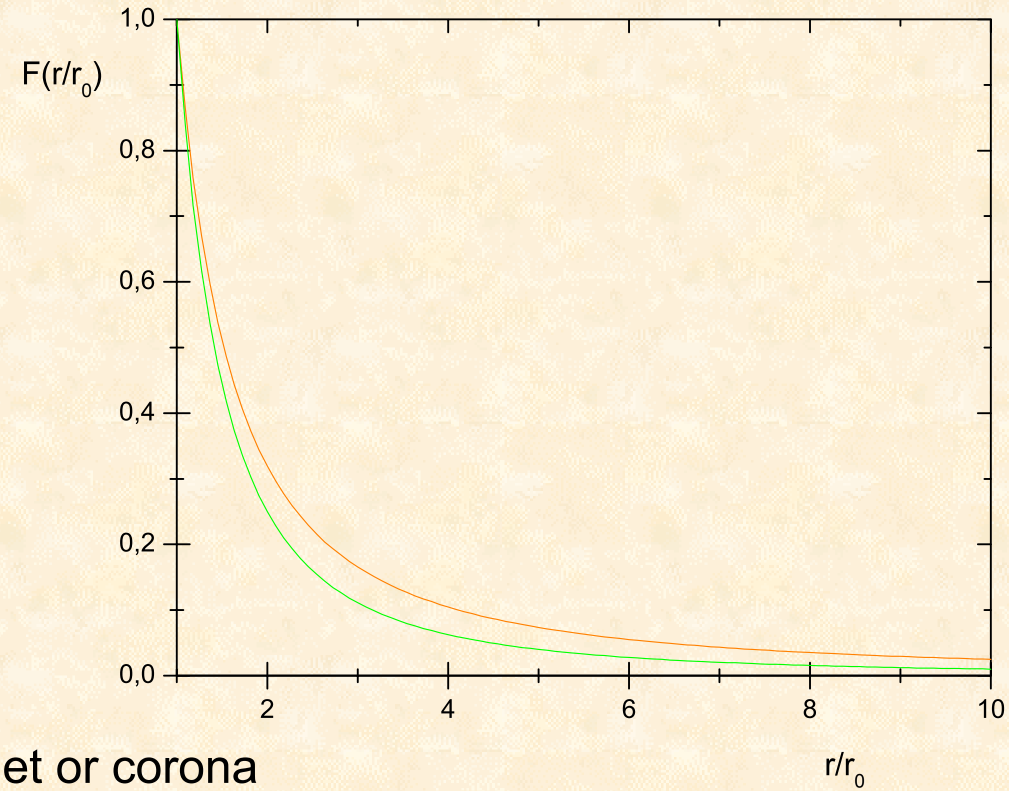
$$n = n_0 \left( \frac{r_0}{r} \right)^2 \qquad n_0 = \frac{\dot{M}}{m_p v_0 r_0^2 \Omega}$$

Green line in the figure

Jet's temperature:

$$T_{jet} = T_{cor} \left( \frac{r_0}{r} \right)^{\frac{4}{3}}$$

Orange line in the figure

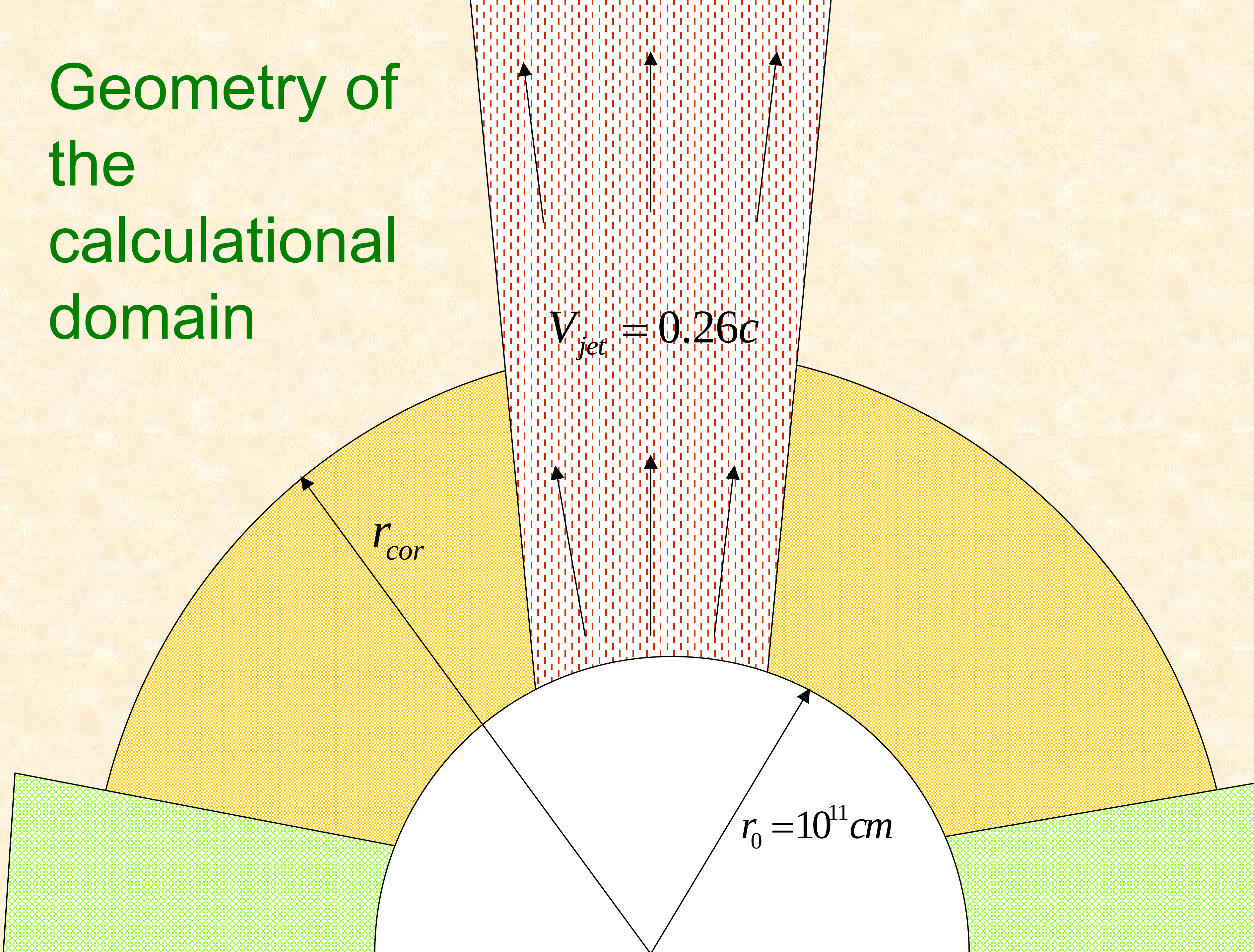



$\Omega$ is the solid angle, occupied by jet or corona

$$\tau_{cor} = \sigma_T \int_{r_0}^{r_{cor}} n(r) dr = \sigma_T n_0 r_0 \left( 1 - \frac{r_0}{r_{cor}} \right)$$

- optical depth of corona with respect to Thomson scattering

# Geometry of the calculational domain



## The Monte-Carlo method in brief

Indivisible photon packets method is used (Lucy L.B.,A&A,345,211-220 (1999)).

*Its main points are:*

• individual photons are grouped in packets of constant energy $\varepsilon_0 = nh\nu$

• luminosity is computed and thus we can obtain the value $\frac{\varepsilon_0}{\triangle t} = \frac{L}{N}$

• after Monte-Carlo experiment we obtain $\triangle t$ , and calculate $\varepsilon_0$

• interacting with matter photon packet behaves as a whole (that's why the are called indivisible)

## The algorithm for initial data can be described as following:

- Firstly, we set the number of model photons (photon packets), their greater number means greater precision of the result.

- Secondly, we divide the spectrum into frequency bins, their number should be big enough to provide smooth spectral curve, but small enough so the number of photons per bin is much greater than the number of bins.

- Thirdly, we determine how many photons will represent each emission component.

- Fouthly, we determine initial coordinates of photons.

- Fifthly, we determine initial direction of photon’s motion.

We simulate photon's trajectory as in propagates through the media (corona or jet). Escaped photons make their contribution to the source's spectrum. Algorithm for simulating photon's trajectory:

1. Determination of optical depth according to formula $\tau = -\ln \xi$

2. Determination of coordinates of the interaction point

3. Choosing event (Compton scattering or free-free absorbtion), according to criteria: $z \le \dfrac{\sigma_C}{\sigma_C + n_e k_\nu}$

4. Determinaion of photon's new frequency and direction of motion

These steps should be repeated consequently until photon gets absorbed or escapes.

# The free-free emission model

It is assumed that source's spectrum origin is free-free emission of two kinds:

1) free-free emission of isothermal corona with 20 keV temperature
2) free-free jet emission, jet's basis temperature is equal to corona's

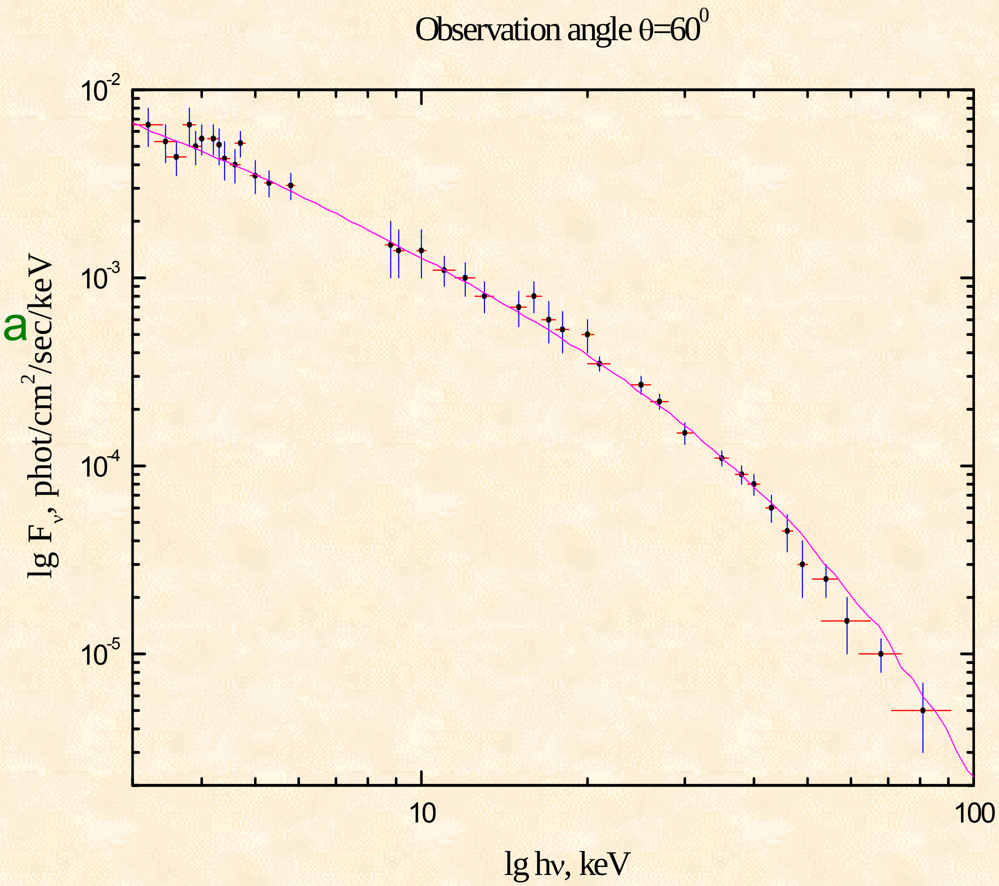
Parameters of model:

$$\theta_{jet} = 1.2^0$$

$$\tau_{cor} = 1.5$$

$$T_{cor} = 20 keV$$

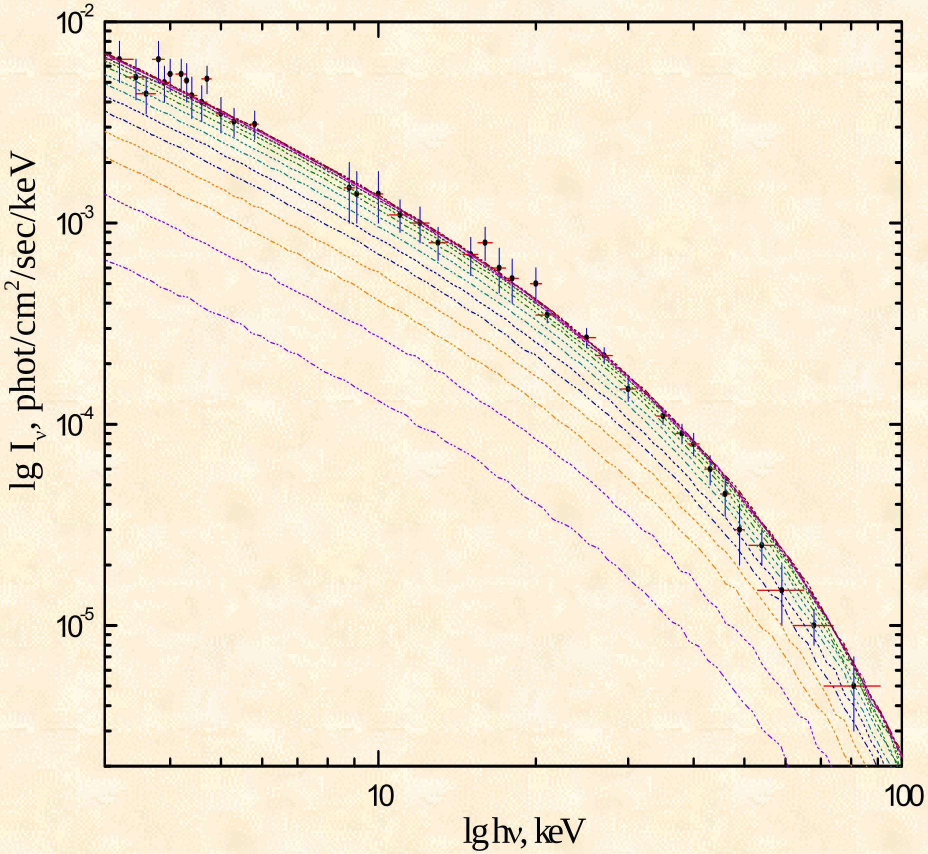
$$\dot{M}_{jet} = 2 \cdot 10^{20} g/s$$




$$L_k = 6 \cdot 10^{39} erg/s$$

# Angle dependence of SS433 spectrum

In the figure the angle dependence for SS433 spectrum is shown. The lowest curve corresponds to 5 deg angle, the next – 10 deg etc. For angles equal 55 deg and greater spectra do not vary significantly. It is so because of isotropization of emission propagating through considerably optically thick corona.



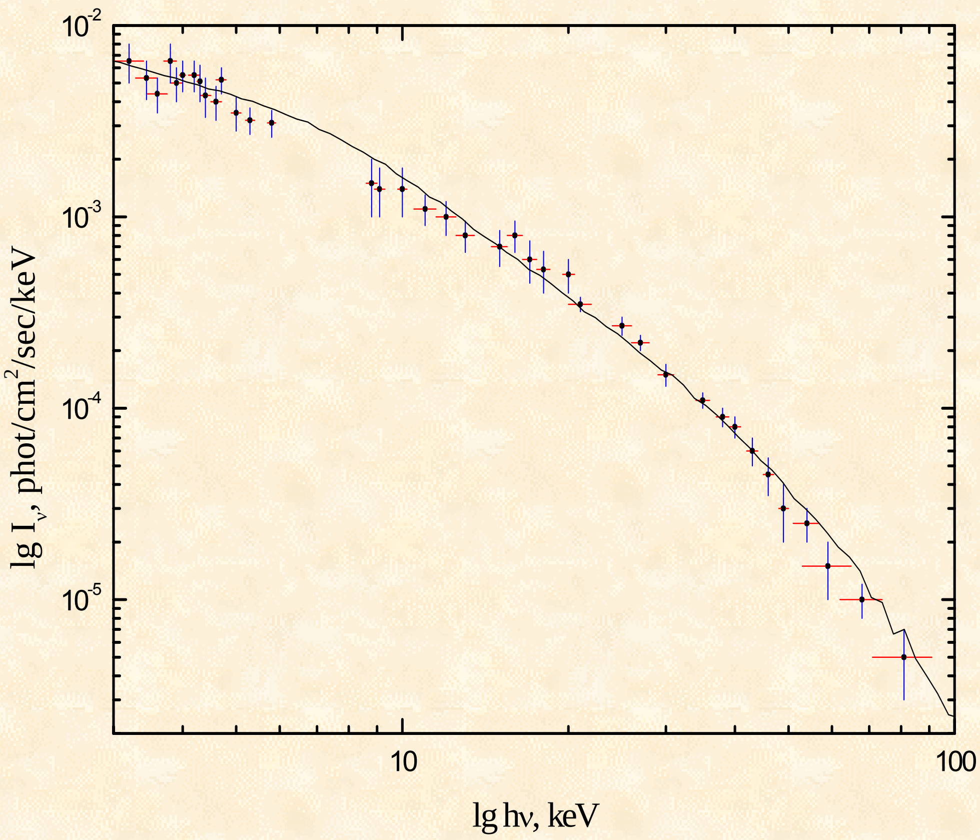
# Three components emission model

To reduce jet's kinetic luminosity it was proposed to include emission from inner layers of accretion disk with certain spectrum. The point was that the third component would give emission in soft X-ray thus reducing jet's luminosity in this region and therefore its mass loss rate.

$$F_\nu = \frac{4}{7} \cdot \frac{L_{disk}}{S \cdot \nu_c} \cdot \left(\frac{\nu}{\nu_c}\right)^{\frac{1}{3}}, \nu < \nu_c$$

$$F_\nu = \frac{4}{7} \cdot \frac{L_{disk}}{S \cdot \nu_c} \cdot e^{1-\frac{\nu}{\nu_c}}, \nu > \nu_c$$

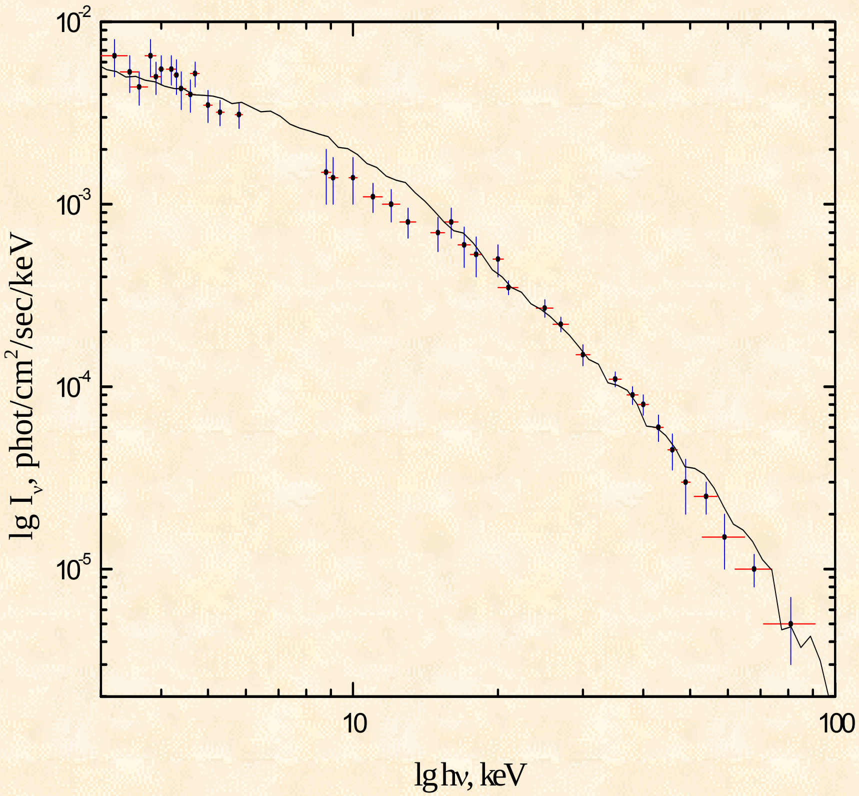
$$\nu_c = \frac{hT_{ef}}{k}, T_{ef} = 5 \cdot 10^6 K$$

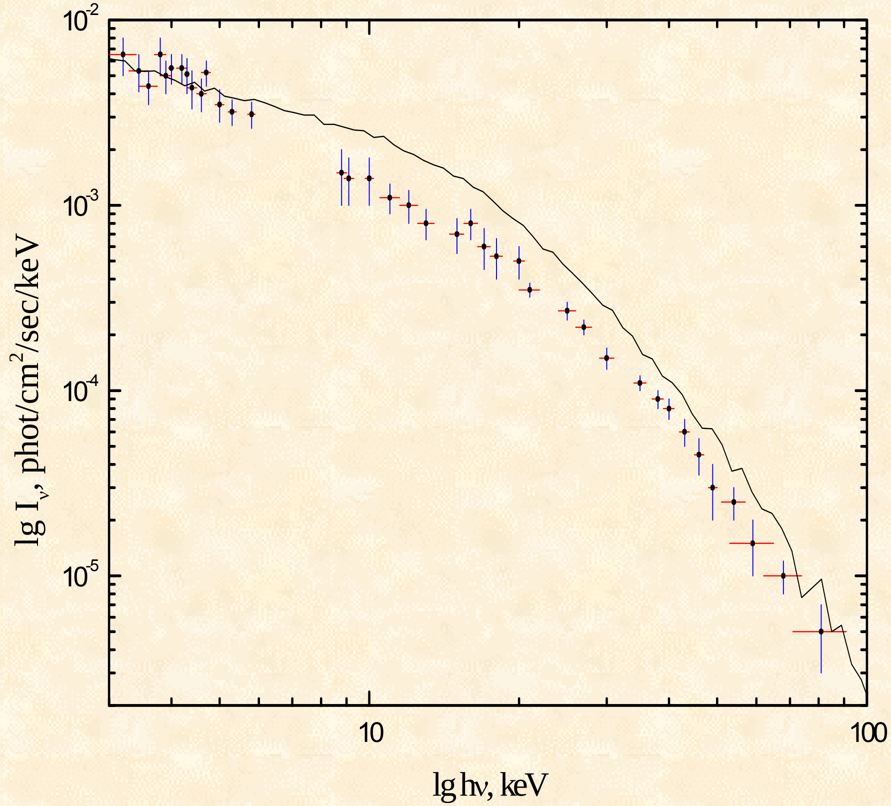



$$\frac{L_{jet}}{L_{disk}} = 3$$

$$\dot{M}_{jet} = 10^{20} g/s$$

# Three components emission model




$$\frac{L_{jet}}{L_{disk}} = 1 \qquad \dot{M}_{jet} = 6.5 \cdot 10^{19} g/s$$

$$\frac{L_{jet}}{L_{disk}} = 0.3 \qquad \dot{M}_{jet} = 3.5 \cdot 10^{19} g/s$$

# Conclusion

Summing up the results of simulation one can draw the following:

- SS433 spectrum in the region form 3 to 90 keV origins from free-free emission of corona and jet (with the exception of small region near 7 keV, where line formation is important)

- emission from accretion disk can make its contribution to the final spectrum, but the best fit occurs in its absence