X-ray reflection from ionised accretion discs – a new XSPEC model

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European Space Astronomy Centre, Villafranca del Castillo

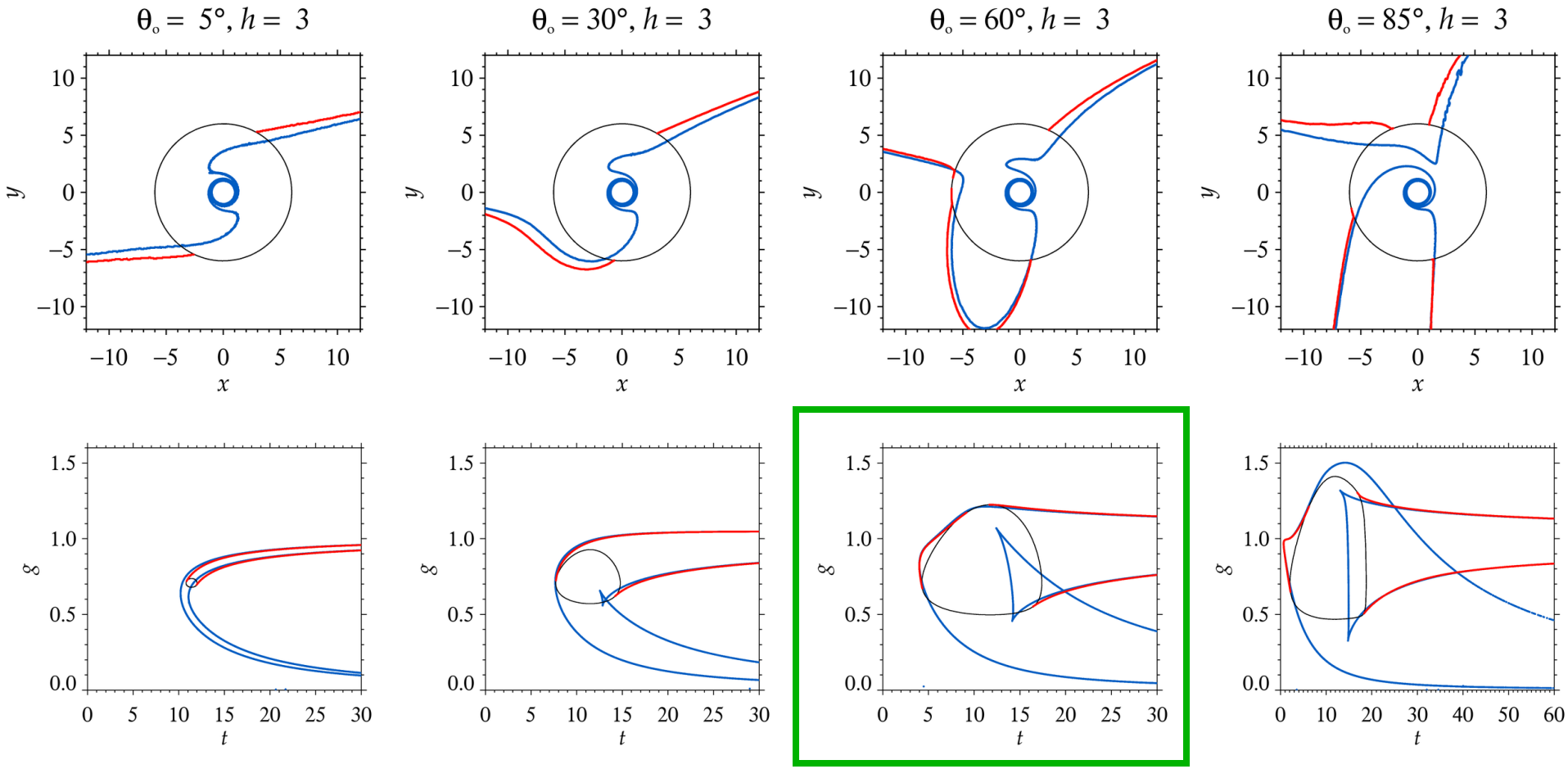
From the Dolomites to the event horizon:
Sledging down the Black Hole potential well

Sesto Val Pusteria, 15th – 19th July 2013

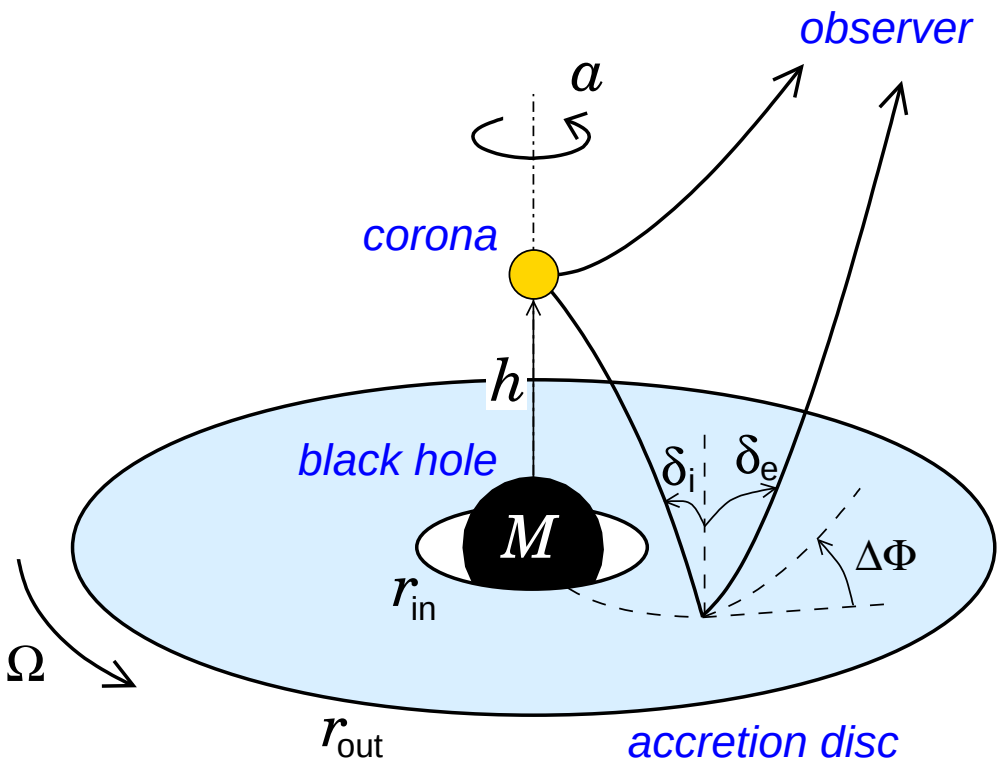
SEVENTH FRAMEWORK PROGRAMME

STRONGGRAVITY
EU FP7-SPACE research project 312789 2013 - 2017

StrongGravity logo explanation

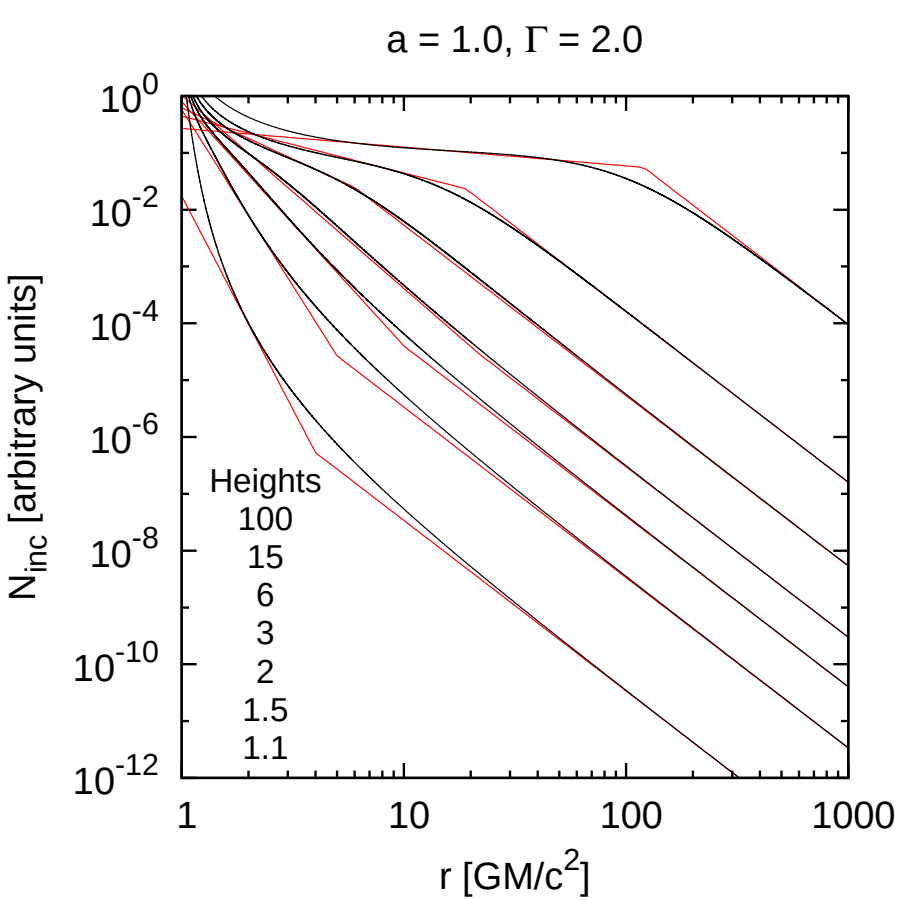


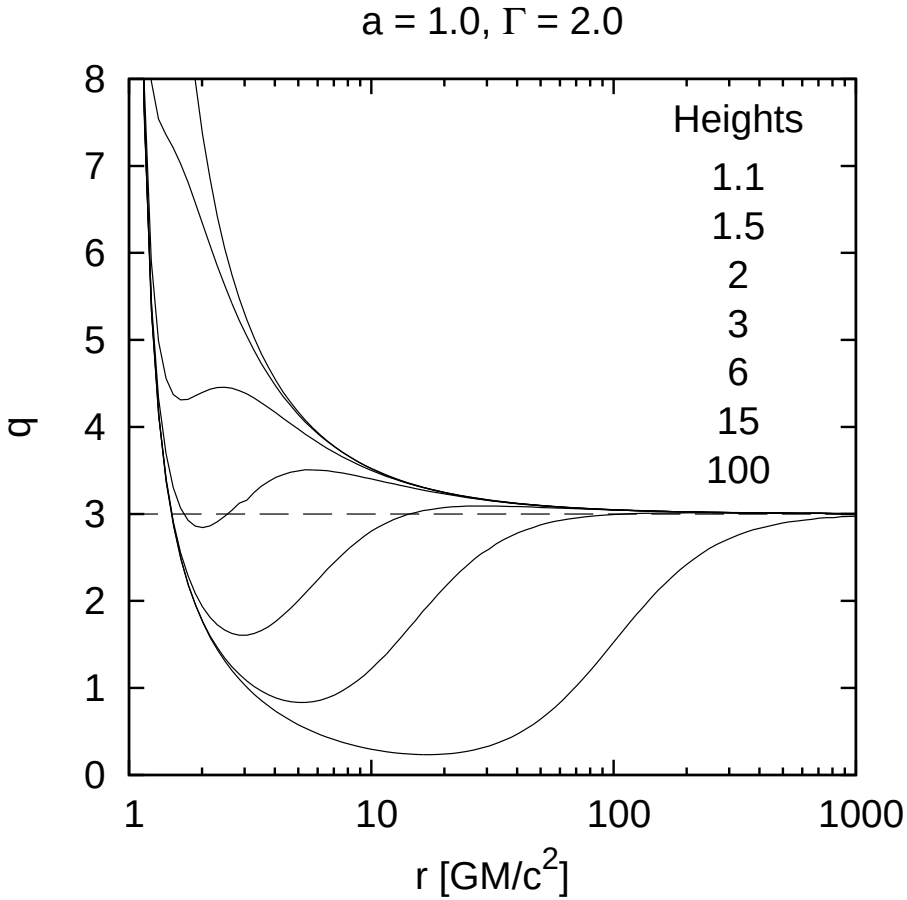
Scheme of the lamp-post geometry



- spin a
- inclination $\theta_{\rm o}$
- height h
- photon index Γ
- luminosity $L/L_{\rm edd}$
- mass M/M_8 ($M_8 = 10^8\,M_\odot$)
- density $n_{\rm H}$

Illumination geometry



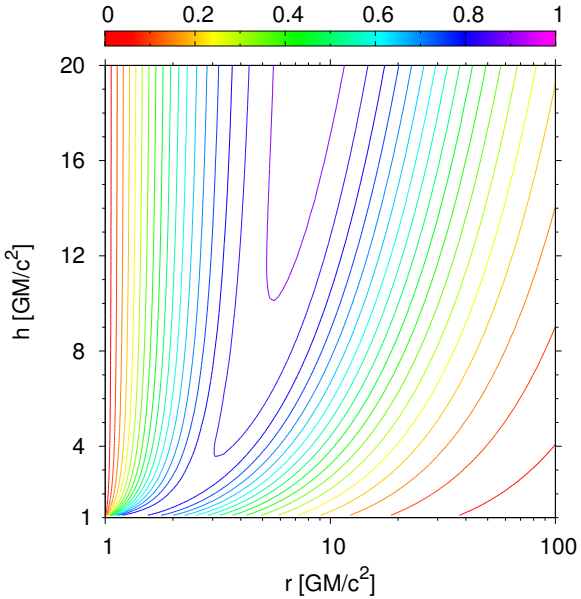


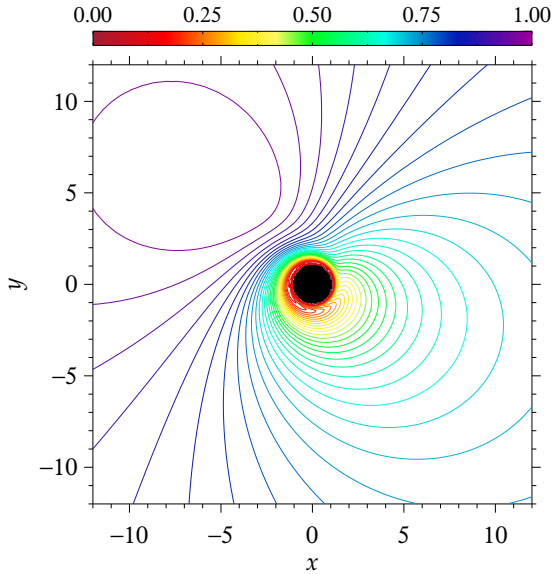
- Wilkins DR & Fabian AC (2011) **MNRAS**, 414, 1269
- Svoboda J, Dovčiak M, Goosmann RW, Jethwa P, Karas V, Miniutti G & Guainazzi M (2012) **A&A**, 545, A106
- Wilkins DR & Fabian AC (2012) **MNRAS**, 424, 1284

Emission directionality

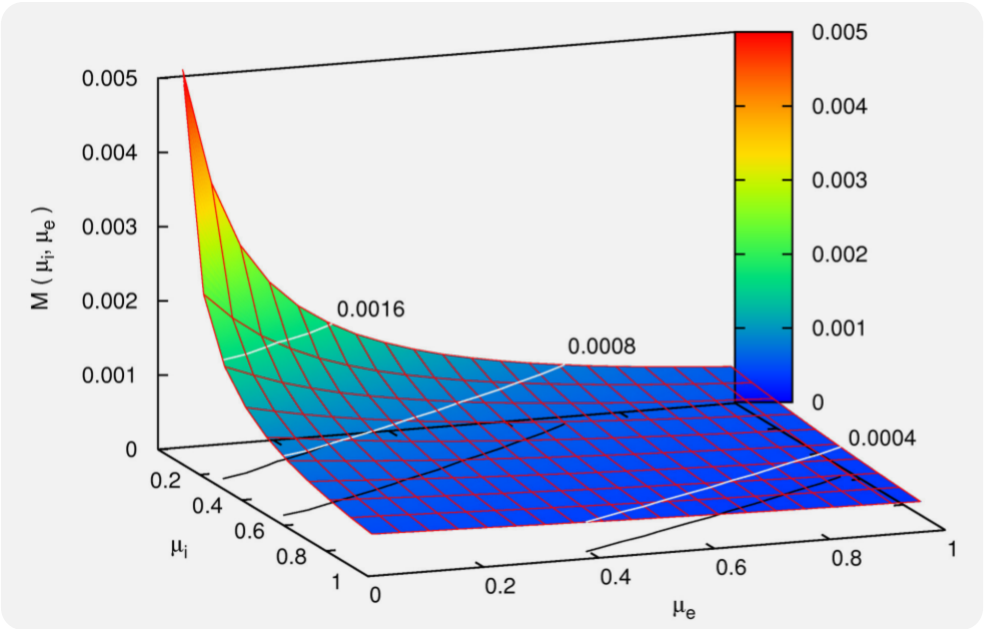
$a = 1,\ \theta = 30°,\ \Gamma = 2$

incident angle μ_i





emission angle μ_e



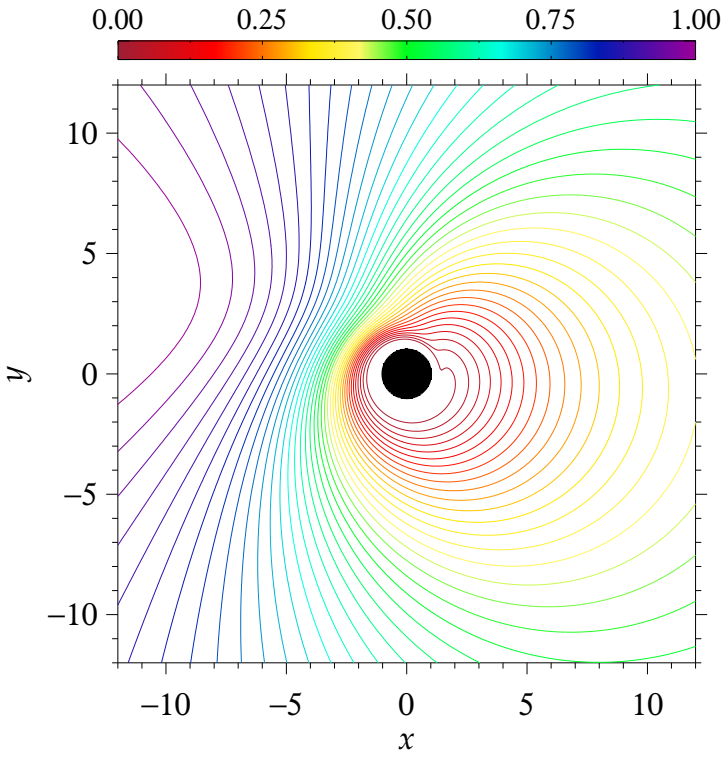
emission directionality $\mathscr{M}(\mu_\mathrm{i}, \mu_\mathrm{e})$

- Svoboda J, Dovčiak M, Goosmann RW & Karas V (2009) **A&A**, 507, 1

Emission directionality

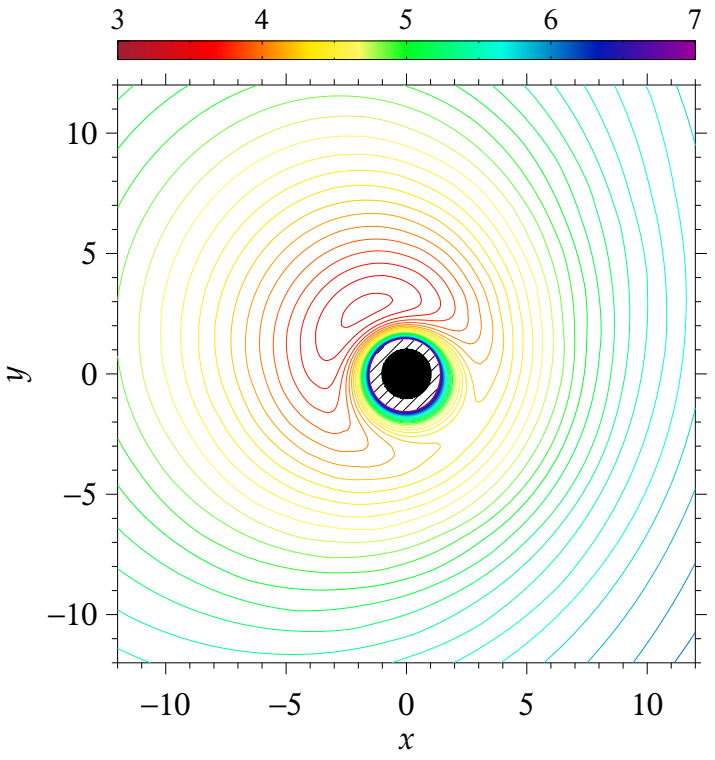
$$a = 1,\ \theta_o = 30^\circ,\ h = 3,\ \Gamma = 2$$

G — transfer function



relativistic effects

$\mathscr{M}$ — angular directionality

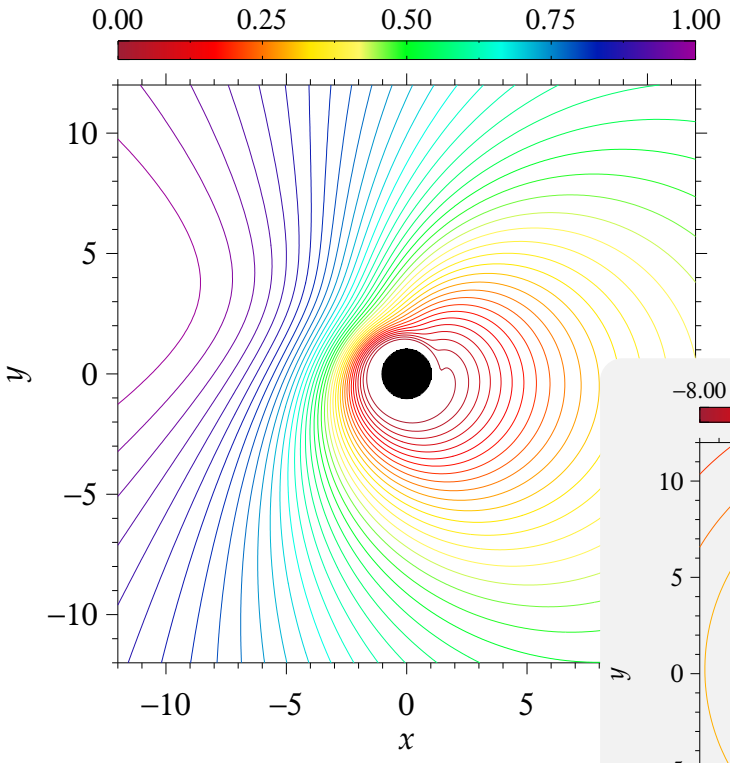


local re-processing

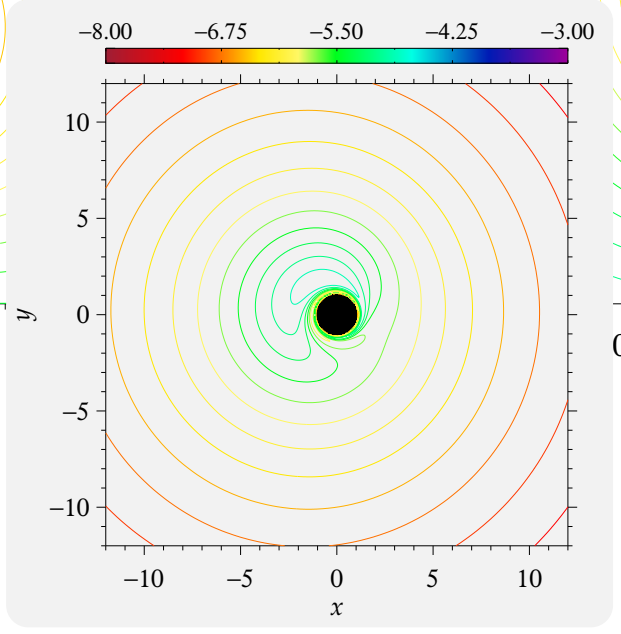
Emission directionality

$$a = 1,\ \theta_o = 30^\circ,\ h = 3,\ \Gamma = 2$$

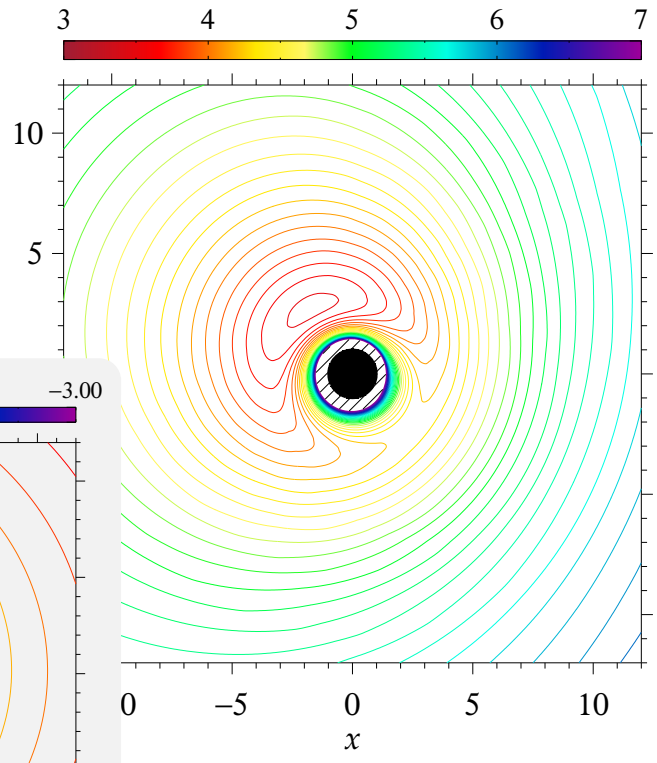
G — transfer function



relativistic effects



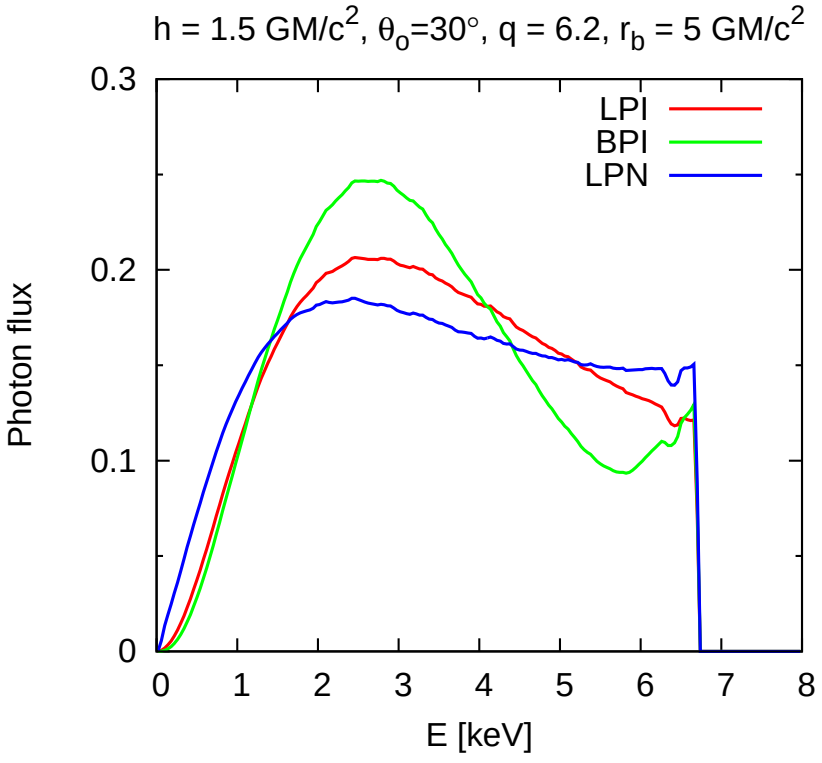
$\mathscr{M}$ — angular directionality

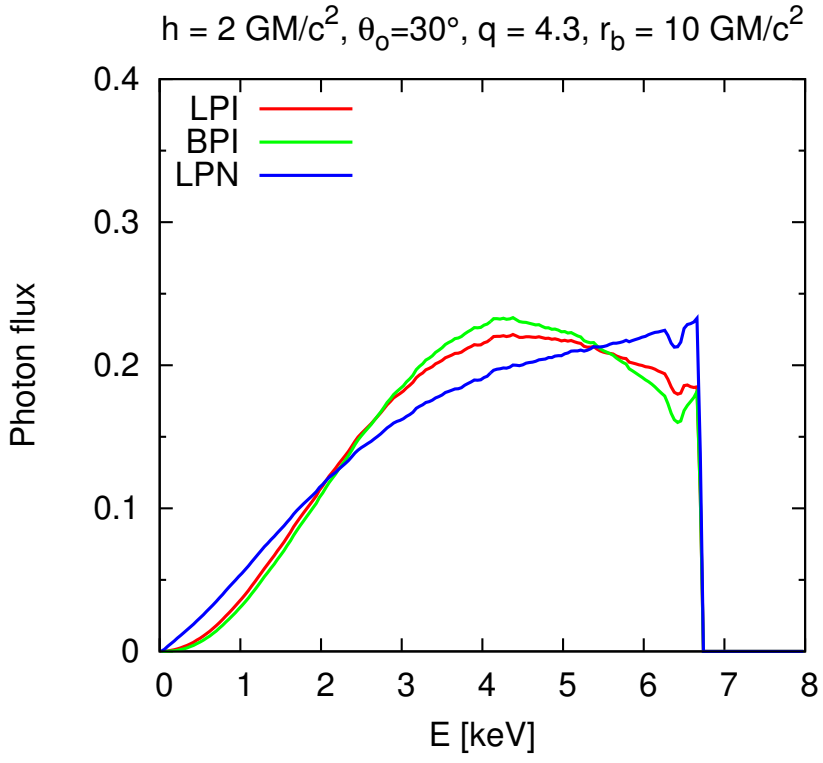


local re-processing

$G \times \mathscr{R} \times \mathscr{M}$

Lamp-post geometry versus broken power law

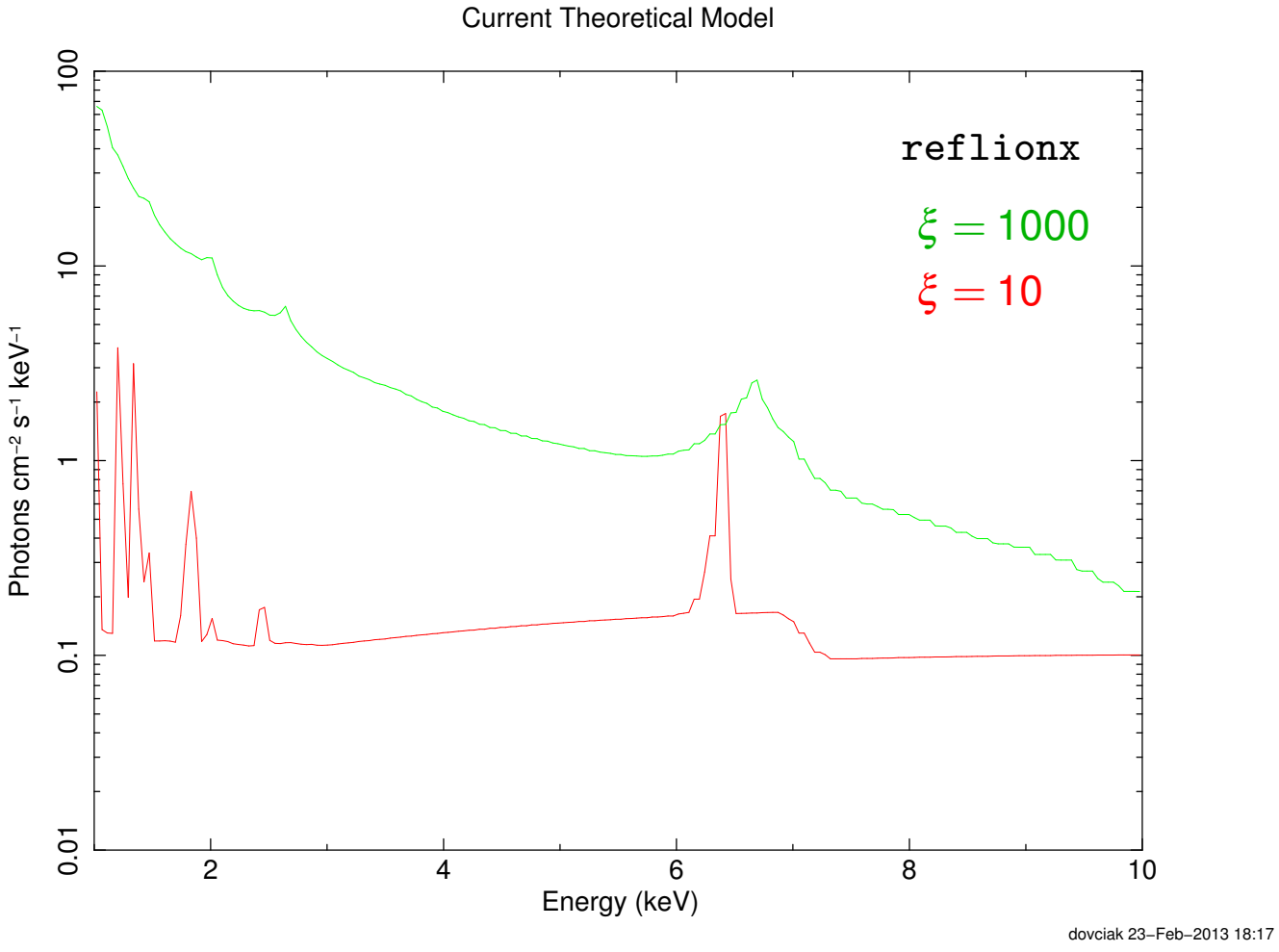




For low heights:

- → broken power-law is not a good approximation of lamp-post geometry
- → line shape is greatly influenced by the emission directionality
  - → this is mainly due to its dependence on the incident angle

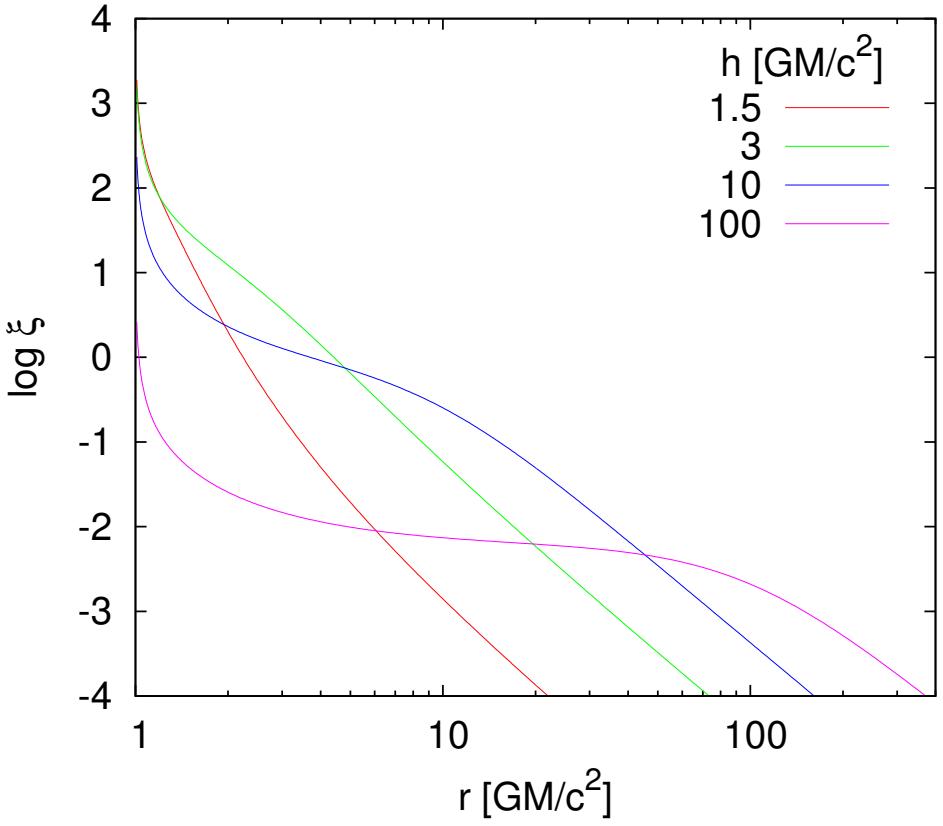
Disc ionization



- Ross RR & Fabian AC (2005), **MNRAS**, 358, 211
- Svoboda J, Dovčiak M, Goosmann RW, Jethwa P, Karas V, Miniutti G & Guainazzi M (2012) **A&A**, 545, A106

Disc ionization

Dependence on height:



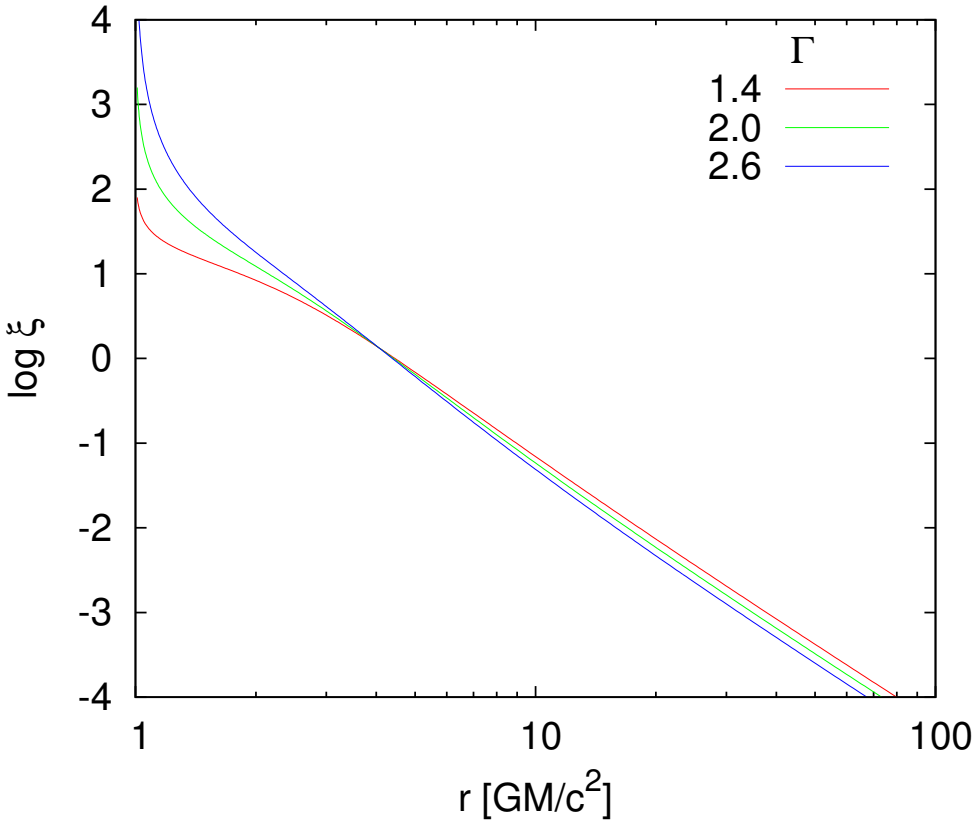
$$\xi \sim \frac{L/L_{\rm edd}}{M\, n_{\rm H}}$$

$$\begin{aligned} L &= 0.001\, L_{\rm edd} \\ M &= 10^8 M_\odot \\ n_{\rm H} &= 10^{15} cm^{-3} \end{aligned}$$

$$a = 1, \Gamma = 2.0$$

Disc ionization

Dependence on photon index:



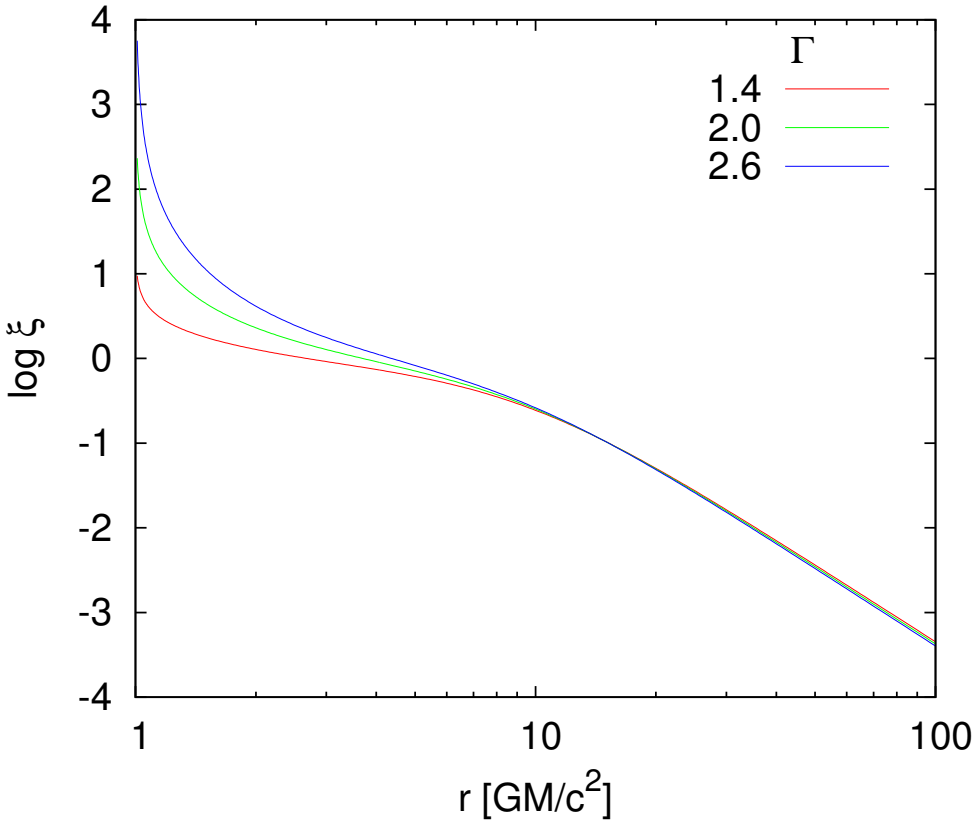
$$\xi \sim \frac{L/L_{\rm edd}}{M\, n_{\rm H}}$$

$$\begin{aligned} L &= 0.001\, L_{\rm edd} \\ M &= 10^8 M_\odot \\ n_{\rm H} &= 10^{15} cm^{-3} \end{aligned}$$

$a = 1,\ h = 3$

Disc ionization

Dependence on photon index:



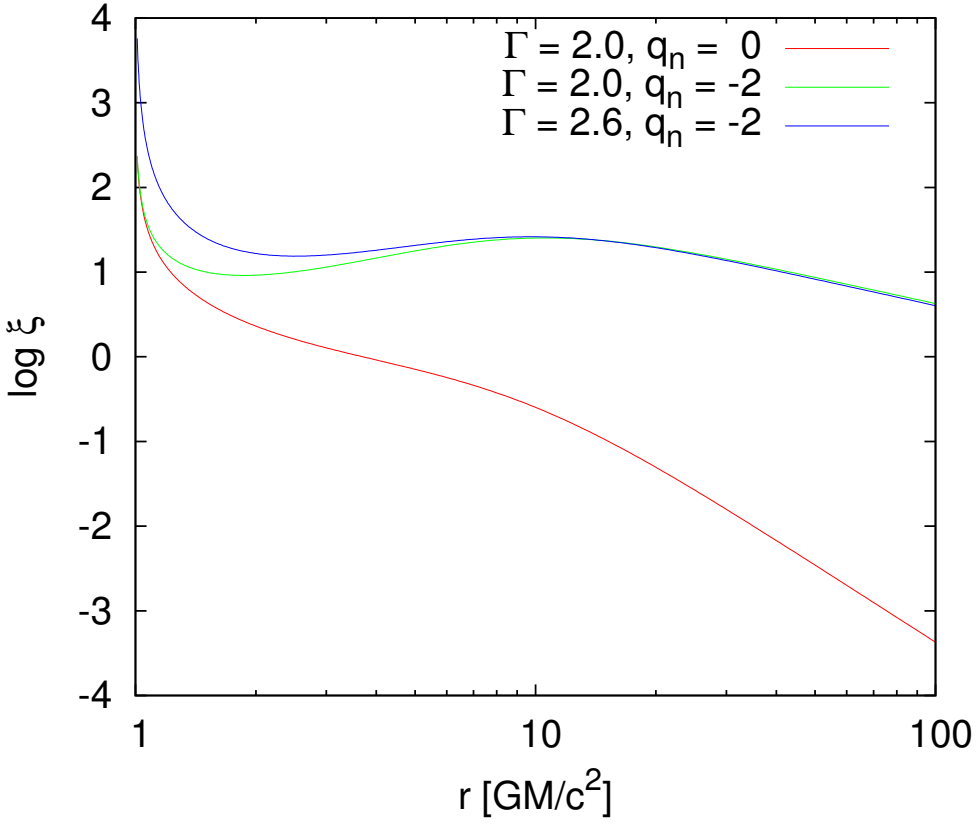
$$\xi \sim \frac{L/L_{\rm edd}}{M\, n_{\rm H}}$$

$$\begin{aligned} L &= 0.001\, L_{\rm edd} \\ M &= 10^8 M_\odot \\ n_{\rm H} &= 10^{15} cm^{-3} \end{aligned}$$

$$a = 1,\ h = 10$$

Disc ionization

Dependence on density profile:



$$\xi \sim \frac{L/L_{\rm edd}}{M\, n_{\rm H}}$$

$$\begin{aligned} L &= 0.001\, L_{\rm edd} \\ M &= 10^8 M_\odot \\ n_{\rm H} &= 10^{15} cm^{-3} \end{aligned}$$

$$a = 1,\ h = 10$$

$$n_{\rm H} \sim r^{q_n}$$

KYREFLIONX parameters

a/M	GM/c	0.9982	0.	1.
theta_o	deg	30.	0.	89.
rin	GM/c^2	1.	1.	1000.
ms		1.	0.	1.
rout	GM/c^2	400.	1.	1000.
M/M8		1.	1e-8	1e+3
height	GM/c^2	3.	1.1	100.
PhoIndex		2.	1.4	3.3
L/Ledd		0.001	1e-10	1e+10
Np:Nr		0.	0.	10.
density		1.	1e-8	1e+8
den_prof		0.	-5.	0.
abun		1.	0.1	20.
zshift		0.	-0.999	10.
limb		0.	0.	2.
tab		2.	1.	2.
sw		2.	1.	2.

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- scales the primary flux (given in $L_{\rm edd}$)
- scales the incident flux (as D^{-1})
- scales the ionization
- scales the reflected flux

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- affects the primary flux (light bending model)
- affects the incident flux (radial structure)
- affects the ionization
- affects the reflected flux

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- scales the primary flux
- scales the incident flux
- scales the ionization
- scales the reflected flux

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may be used to estimate discrepancy between the primary and reflected flux (e.g. due to the anisotropy or obscuration of the primary radiation)

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- affect the ionization

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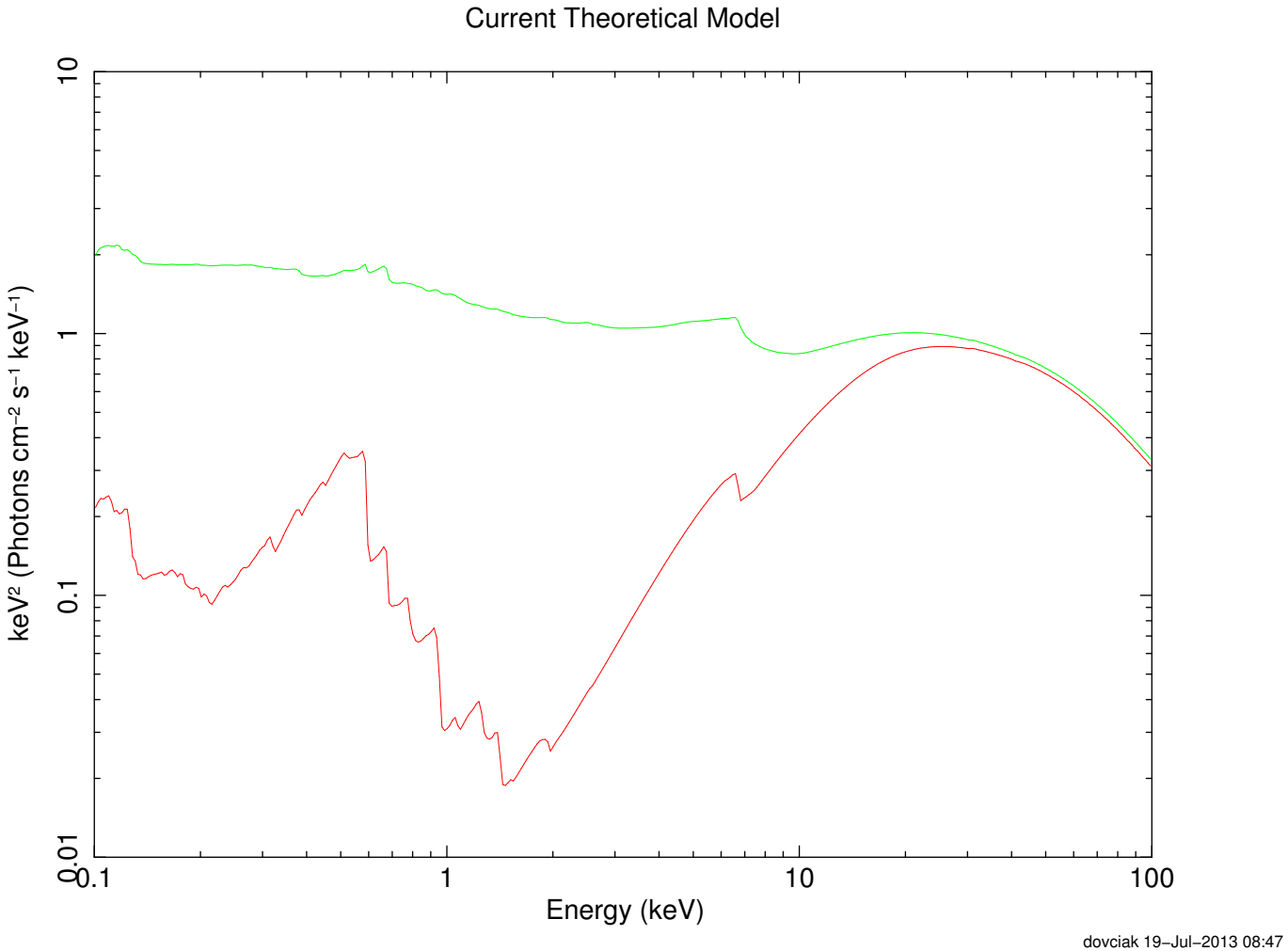
KYREFLIONX example



Dynamic spectrum – ionized reflection

$$E \times F_E$$