On the approximations and assumptions when describing Comptonization in accreting sources
– a spectroscopical/timing view with MoCA –

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MoCA in a nutshell

MoCA: a Monte Carlo code for Comptonization in Astrophysics

- single-photon source-to-observer class (Fortran2003) [~*Schnittman&Krolik*, ~*Krawczynski&Beheshtipour*]

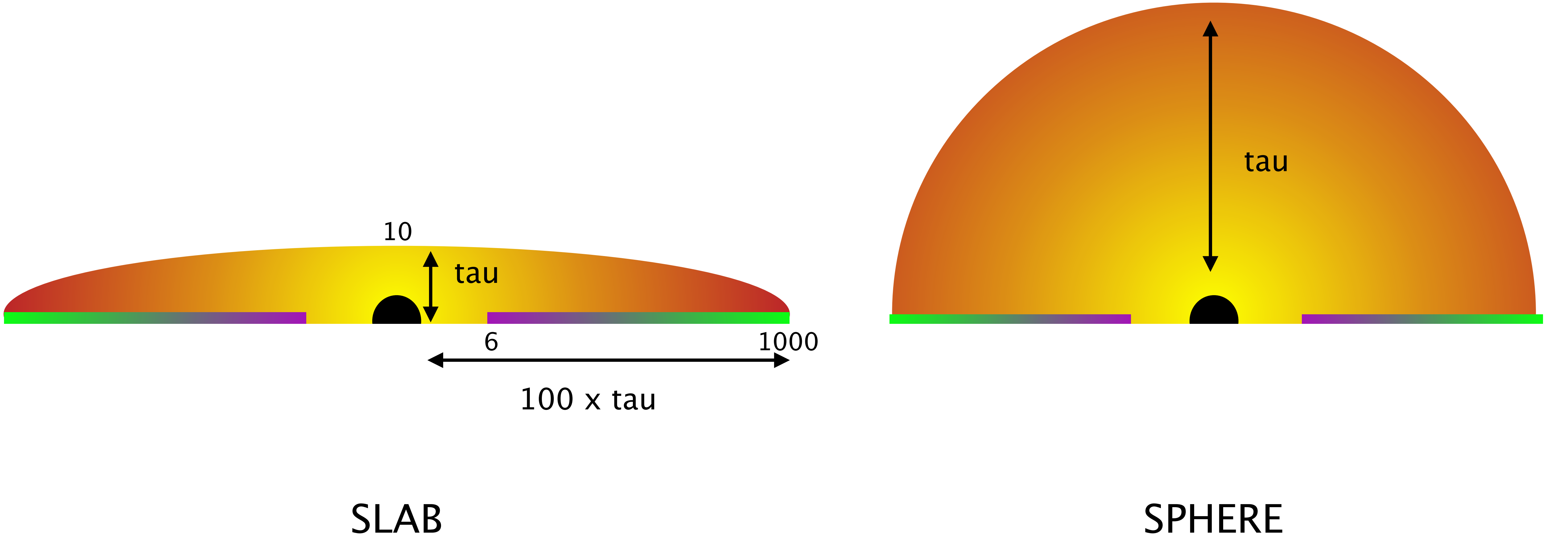
- complete special relativistic and quantum treatment of Comptonization (Maxwell-Juttner distribution, KN cross-section & scattering angle distribution)

- complete GR description of the process (N-T disk, ray-tracing, parallel transport of P vector)

- parallelisation & interoperability with C

- modular and easily customisable

Extended geometries for the corona



Beloborodov formula

$$\Gamma \sim \frac{9}{4} y^{-\frac{2}{9}} \sim \frac{9}{4} \frac{1}{y^{0.22}}$$

$$y = 4(\Theta + 4\Theta^2)\, \tau(\tau + 1)$$

	kT = 20	kT = 100	kT = 200
tau = 0.5	G = 3.49	G = 2.27	G = 1.76
tau = 1	G = 2.81	G = 1.79	G = 1.42
tau = 2	G = 2.21	G = 1.41	G = 1.12
tau = 3	G = 1.89	G = 1.23	G = 0.96
tau = 4	G = 1.69	G = 1.08	G = 0.86
tau = 100		G = 0.27	

Beloborodov 99 used Coppi 92 code which is based on Sunyaev-Titarchuk work.

Comptonization comes from a source inside a sphere (not clear to me if it is in the center or diffused with some radial dependance but it should be negligible in the regime E_source << kT_sphere)

Point-source inside a sphere

MoCA noGR
En =0.01 keV
sphere radius 100
Thomson regime

tau = 0.5 kT=20
G = 5.30 (VS 3.49), 0.02-0.09 keV

tau = 0.5 kT=100
G = 2.30 (VS 2.27), 0.1-10 keV

tau = 0.5 kT=200
G = 1.77 (VS 1.76), 0.1-100 keV

tau = 1 kT=20
G = 4.47 (VS 2.81) 0.02-0.2 keV

tau = 1 kT=100
G = 1.92 (VS 1.79) 0.1-100 keV
KN G=1.90

tau = 1 kT=200
G = 1.53 (VS 1.42), 0.1-100 keV

tau = 2 kT=20
G = 3.42 (VS 2.21), 0.02-0.4 keV

tau = 2 kT=100
G = 1.53 (VS 1.41), 0.1-10 keV
G = 1.60, 10-100 keV

tau = 2 kT=200
G = 1.26 (VS 1.12), 0.1-100 keV

tau = 4 kT=20
G = 2.61 (VS 1.69), 0.1-3 keV
KN G=2.57

tau = 4 kT=100
G = 1.18 (VS 1.08), 0.1-10 keV
G = 1.30, 10-100 keV

tau = 4 kT=200
G = 1.02 (VS 0.86), 0.1-100 keV
KN G=1.01

Agreement with Beloborodov formula is far from being consistent and it may deviates by a large DeltaG in some regimes.
KN changes mainly the cut-off. In the power-law dominated part of the spectrum Gamma is ~ the same

SMBH with spherical corona NOGR comparison VS point-source

SMBH = 10^8 / mdot = 0.1 / a=0
disc: 6-1000 isotropic
spherical corona radius 1000
Thomson regime

tau = 0.5 kT=100
G = 2.28 (point 2.30) (B 2.27),
0.5-8 keV

tau = 0.5 kT=200
G = 1.72 (point 1.77) (B 1.76),
0.5-100 keV

tau = 1 kT=100
G = 2.00 (point 1.92) (B 1.79)
0.5-100 keV

tau = 2 kT=20
G = 3.50 (point 3.42) (B 2.21)
0.1-1.0 keV

tau = 2 kT=200
G = 1.25 (point 1.26) (B 1.12),
0.5-100 keV

For extended spherical corona the power-law slope is almost identical to the point-source test case

SMBH with spherical corona
GR VS NOGR

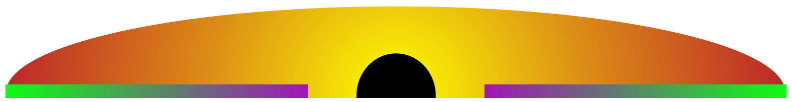
SMBH = 10^8 / mdot = 0.1 / a=0
disc: 6–1000 isotropic
spherical corona radius 1000
Thomson regime

tau = 1 kT=100
G = 1.97 (NOGR 2.00)
0.5–100 keV

tau = 2 kT=200
G = 1.25 (NOGR 1.25)
0.5–100 keV

For extended spherical corona GR effects play any role

BHB with slab corona
GR VS NOGR



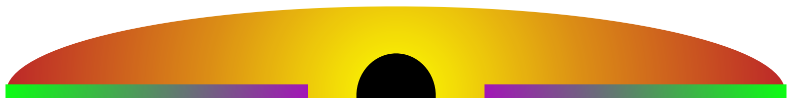
BHB = 10 / mdot = 0.1 / a=0
disc: 6–1000 isotropic
slab corona 10x1000
K–N regime

tau = 1 kT=100
G = 1.63 (NOGR 1.58)
10–100 keV

tau = 2 kT=200
G = 0.95 (NOGR 0.93)
10–100 keV

The rotation

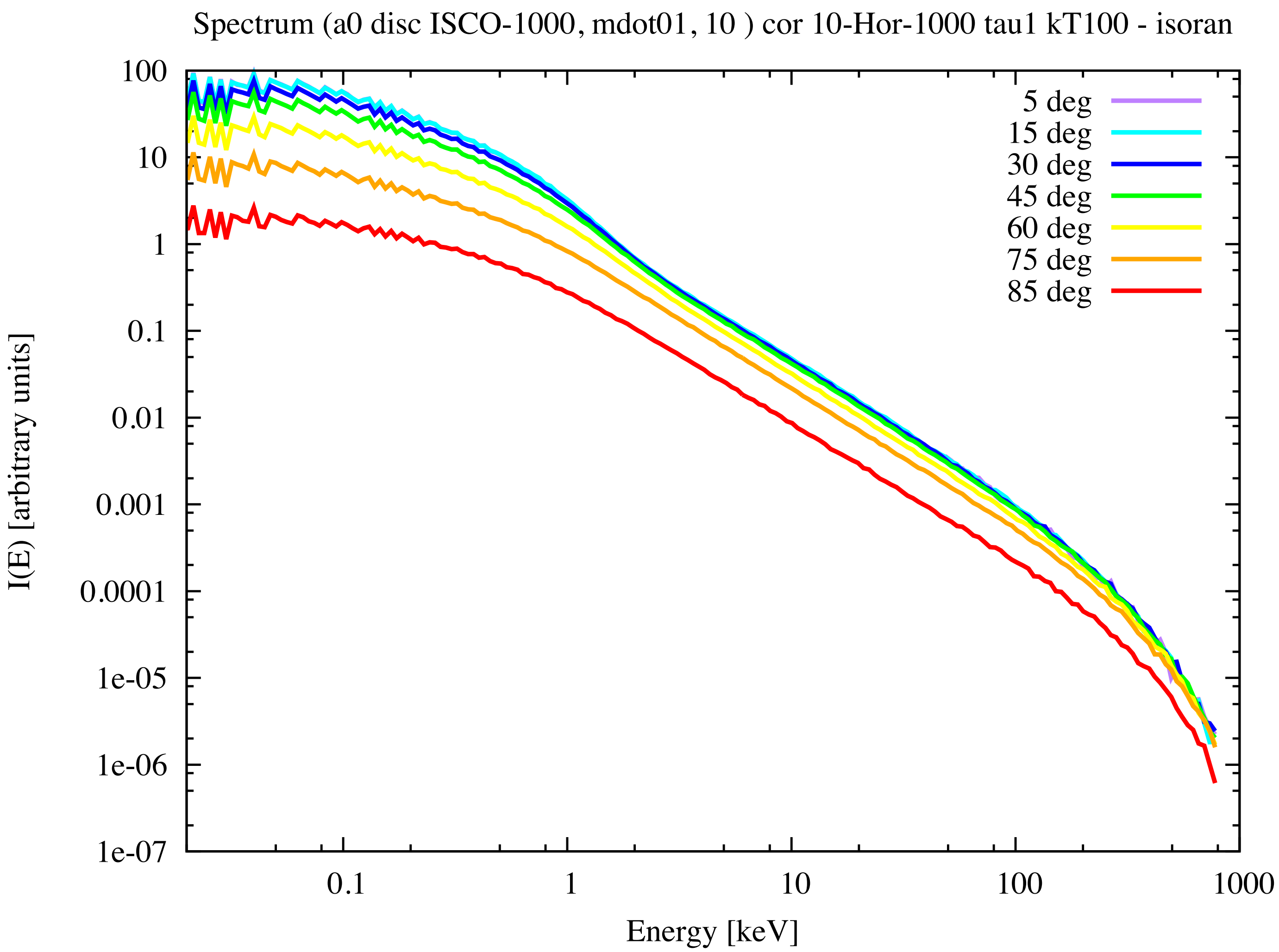
BHB with slab corona



BHB = 10 / mdot = 0.1 / a=0
disc: 6–1000 isotropic
slab corona 10x1000
GR / K-N regime

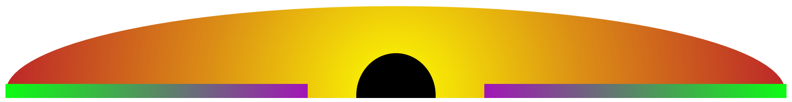
tau = 1 kT=100

with or without rotation
5 deg G = 1.66
85 deg G = 1.58
(integrated 1.63)
10–100 keV



The spin

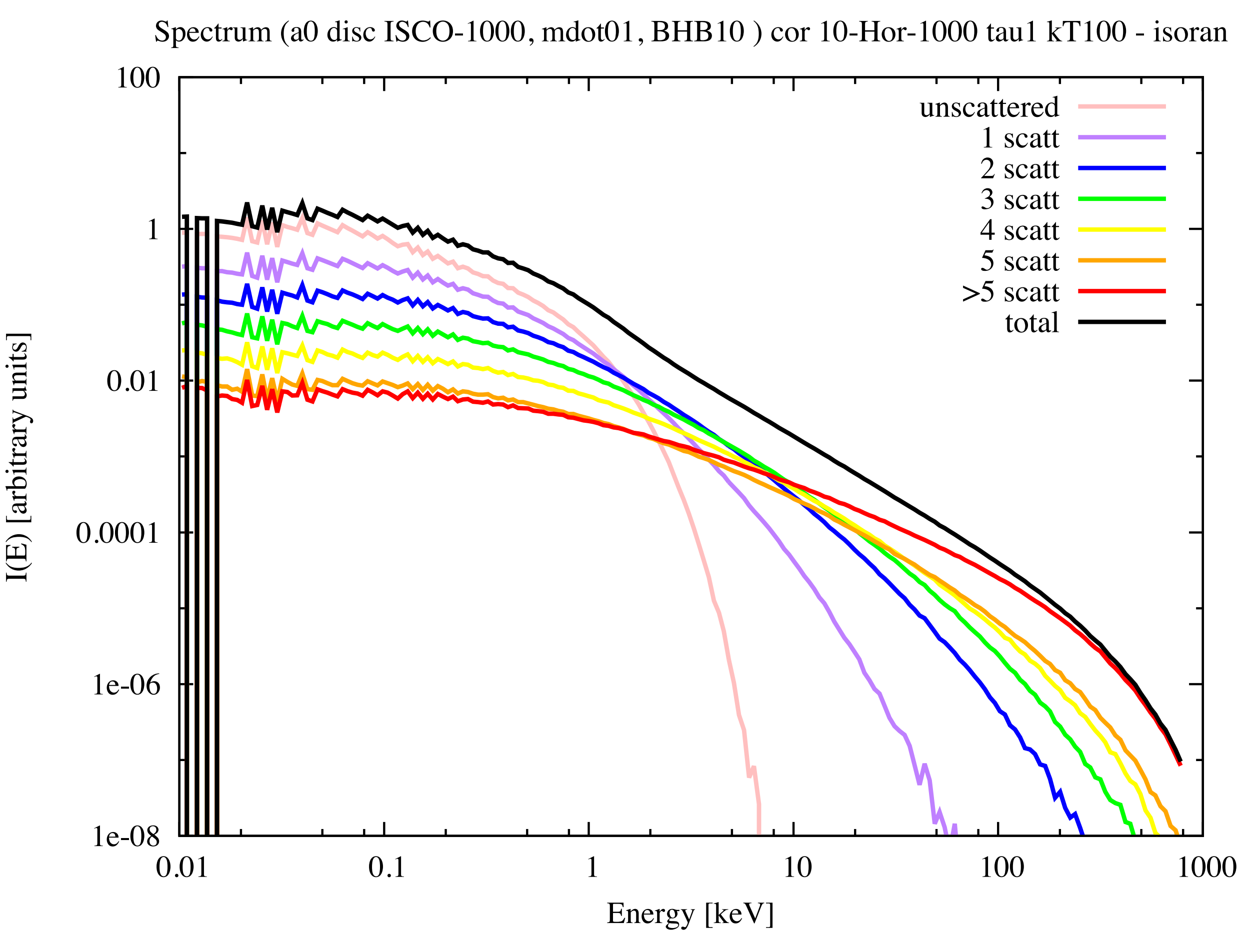
BHB with slab corona
Kerr VS Schwarzschild

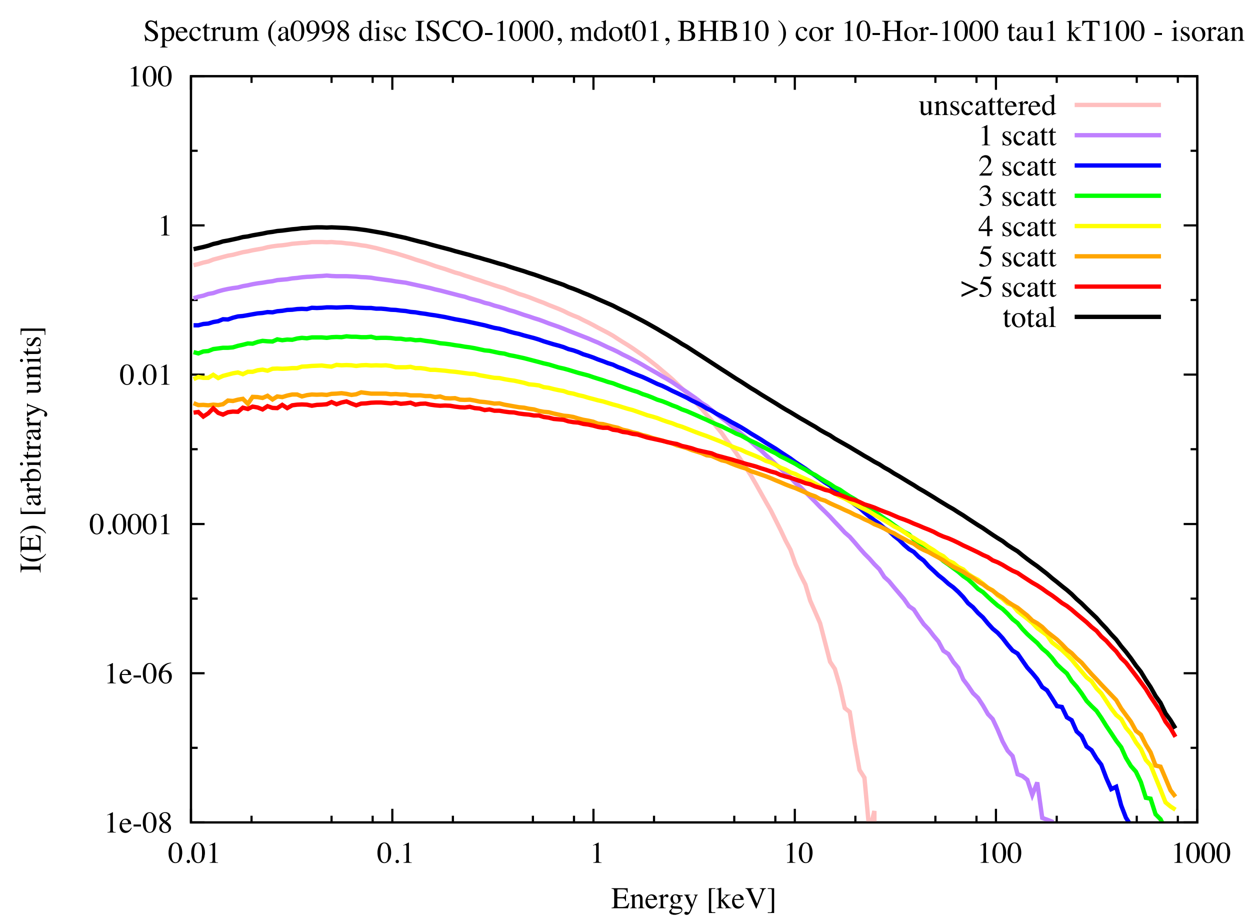


BHB = 10 / mdot = 0.1
disc: 6-1000 isotropic
slab corona 10x1000
K-N regime

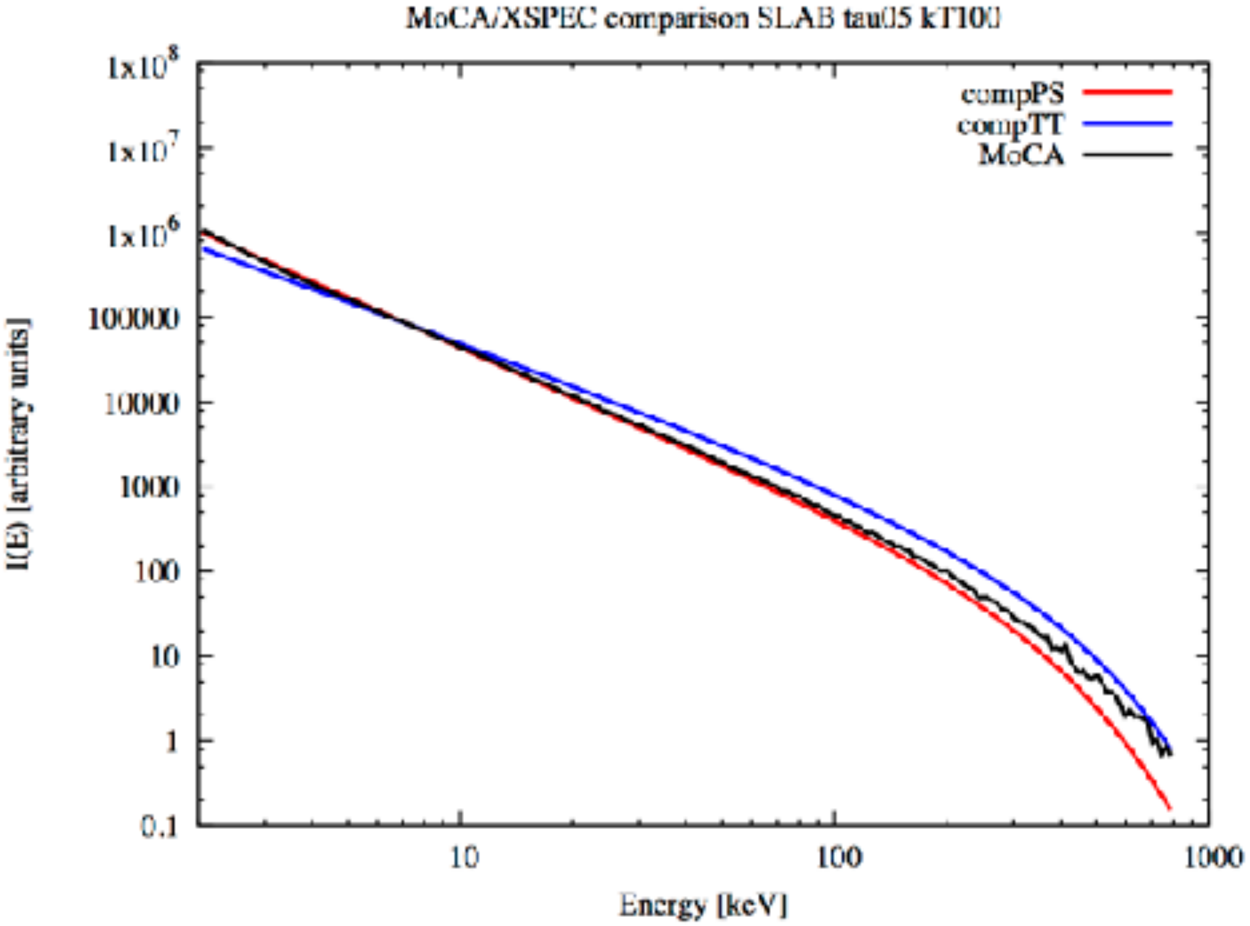
tau = 1 kT=100
G Kerr = 1.59 (Schw 1.63)
10-100 keV

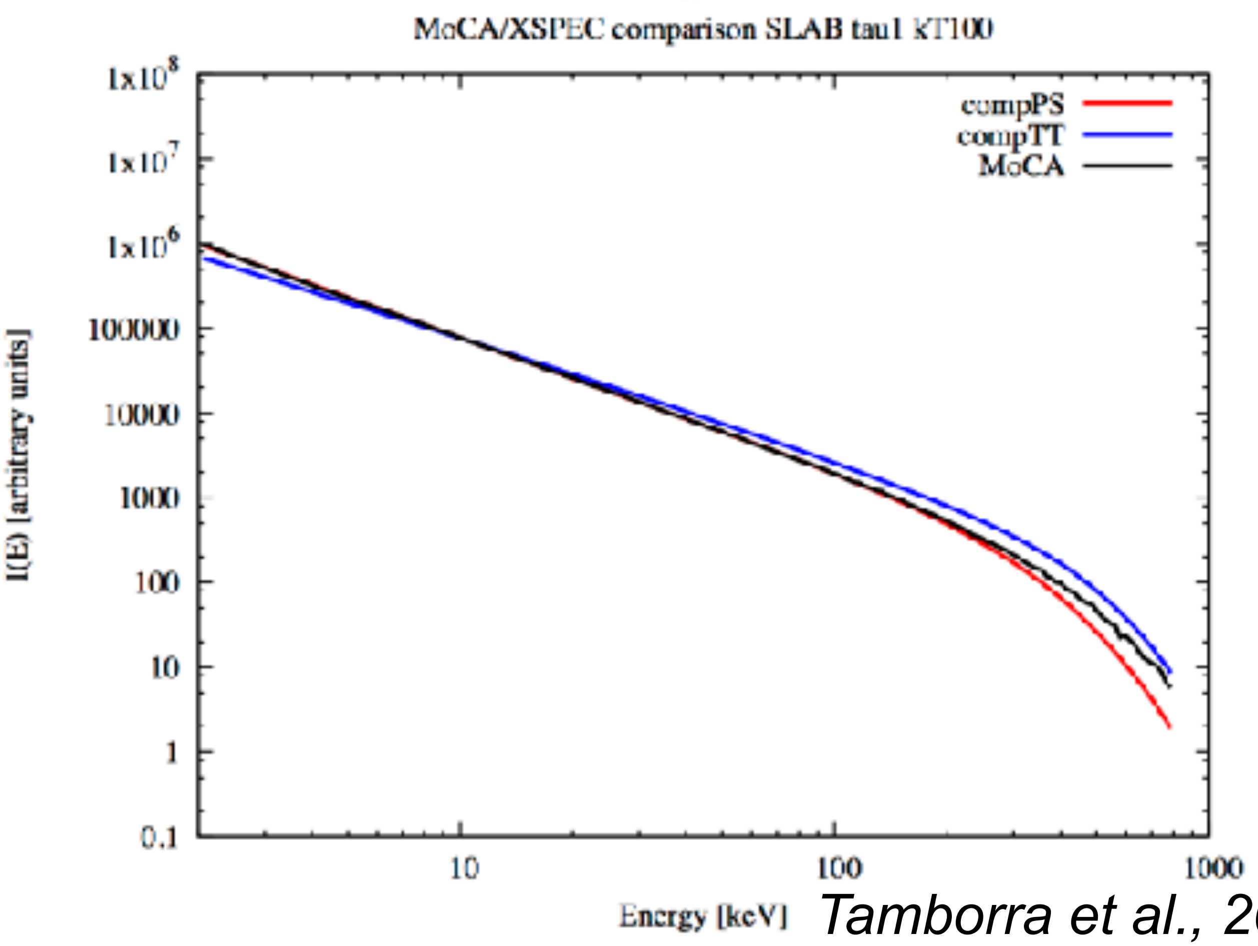
and, again, rotation is irrelevant at any inclination





The comparison with XSPEC models





Tamborra et al., 2018 - forthcoming on A&A

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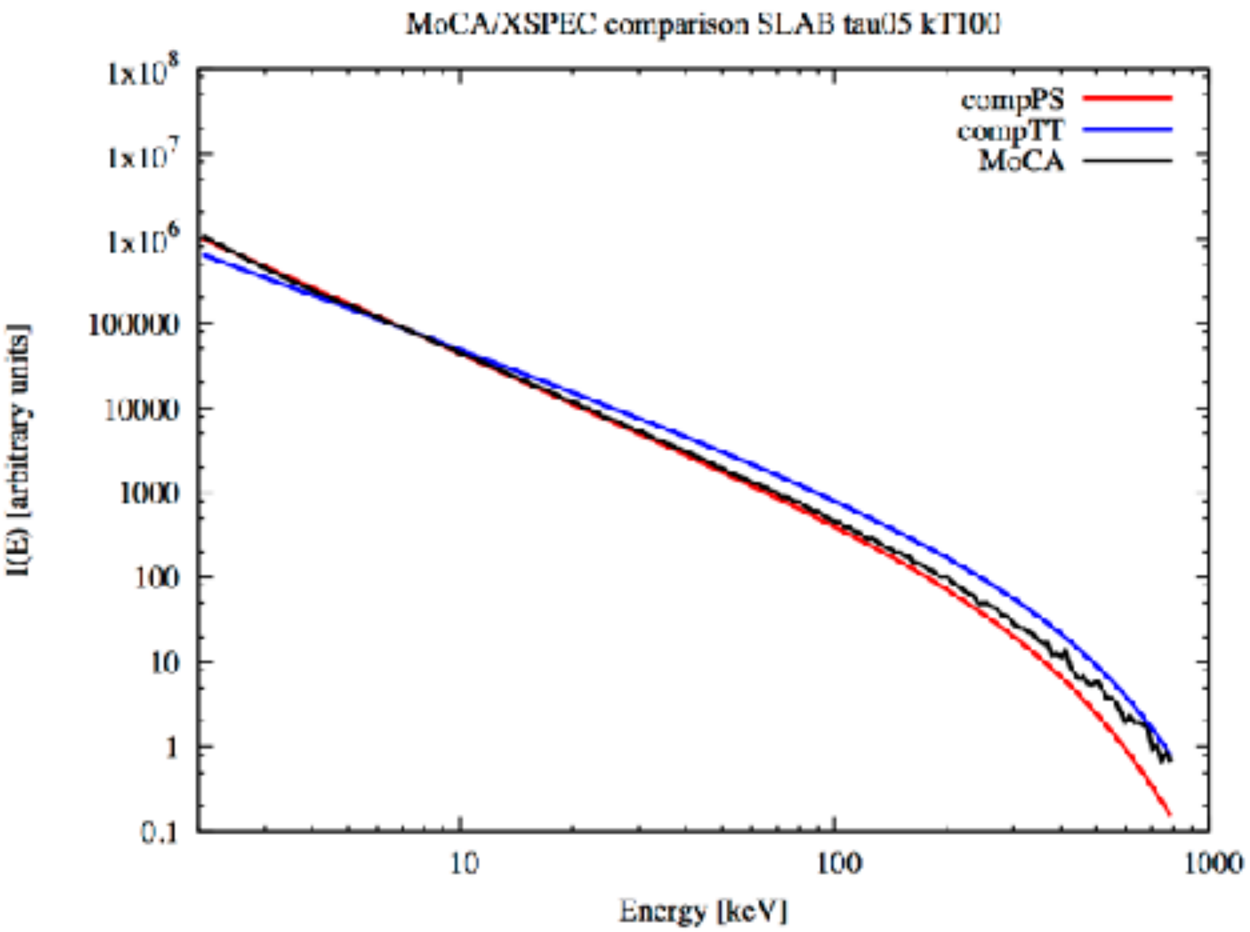

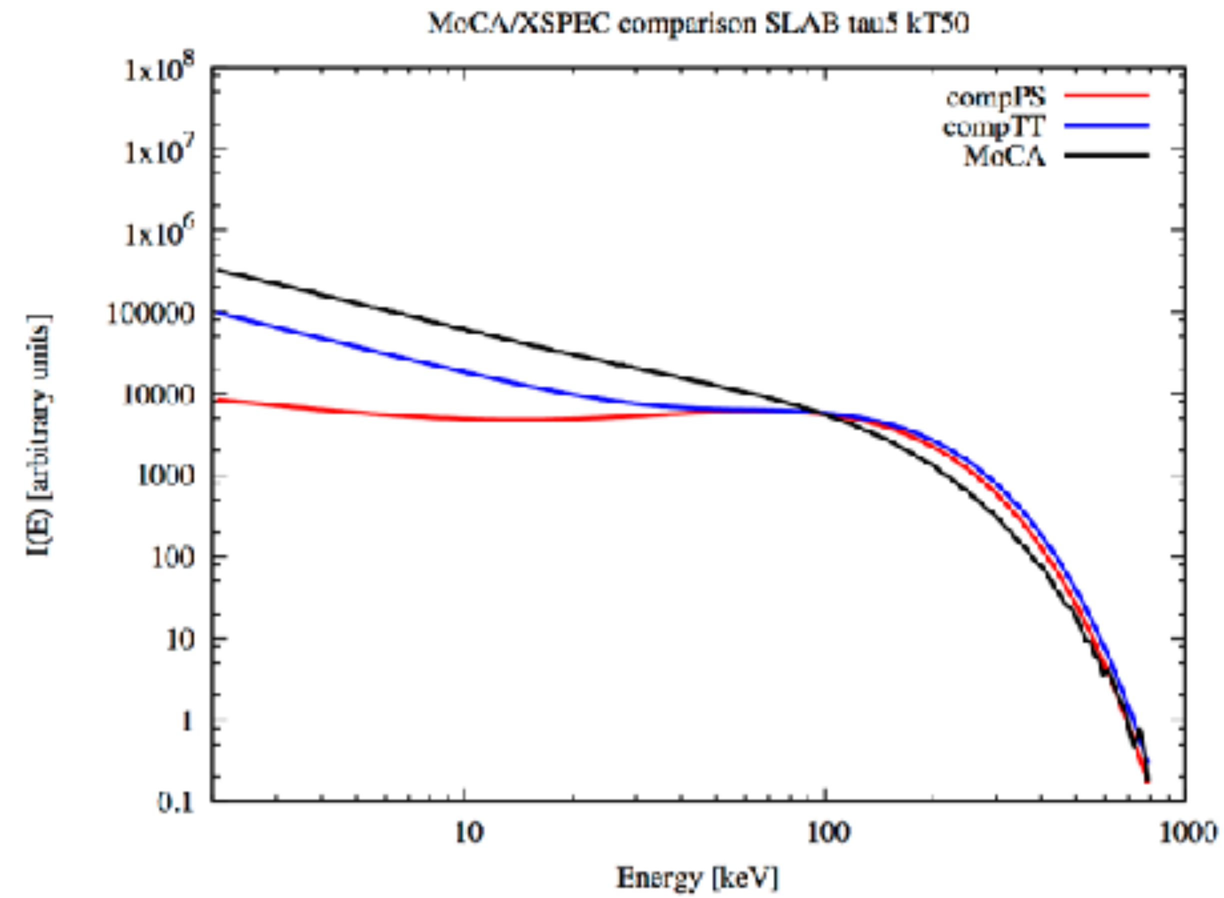

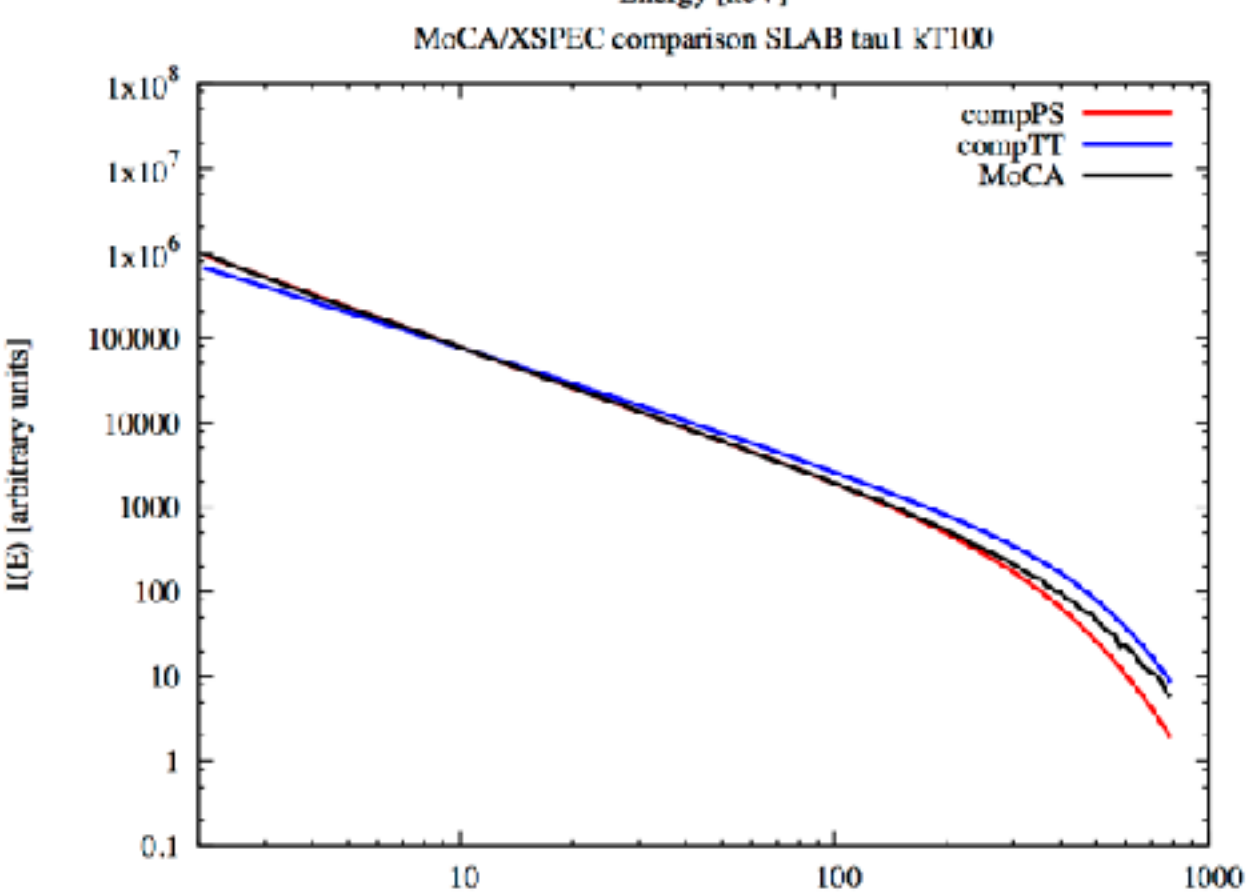

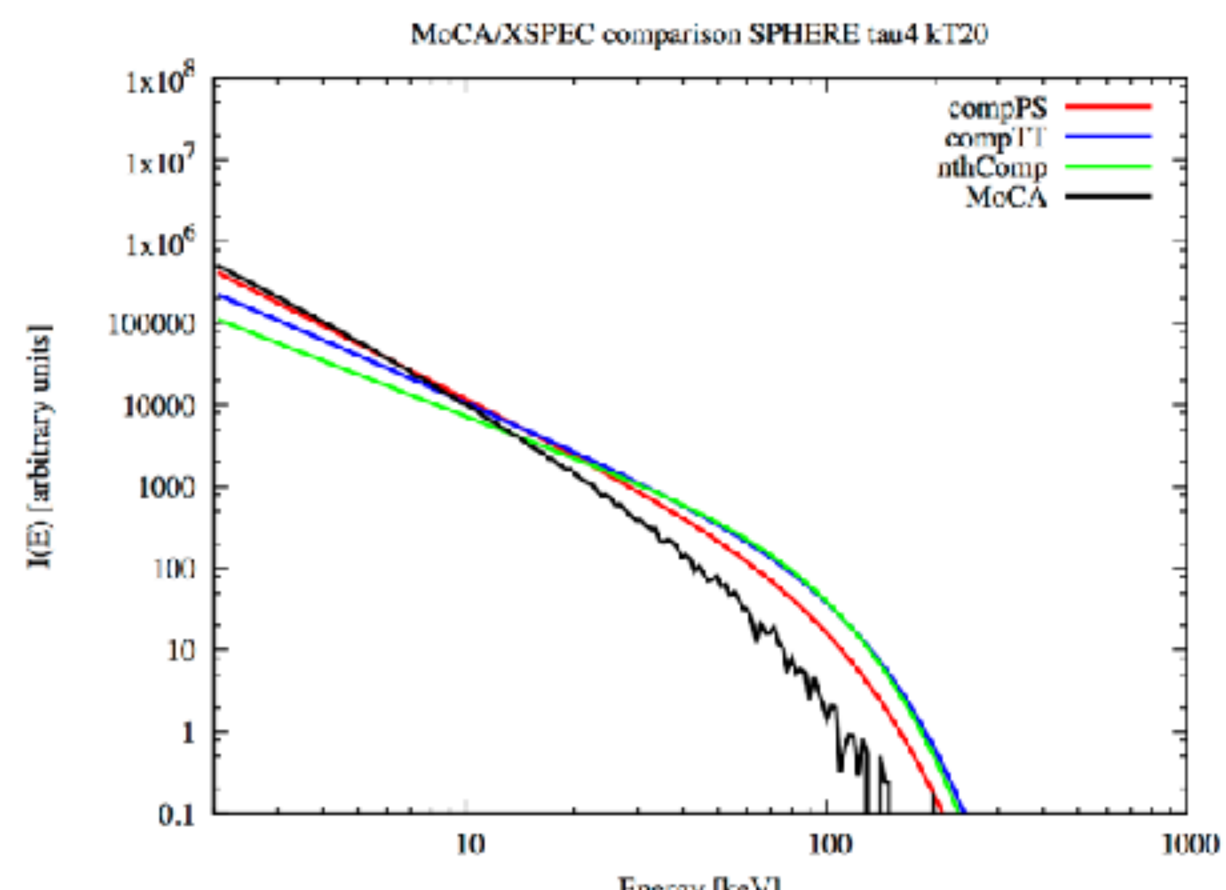

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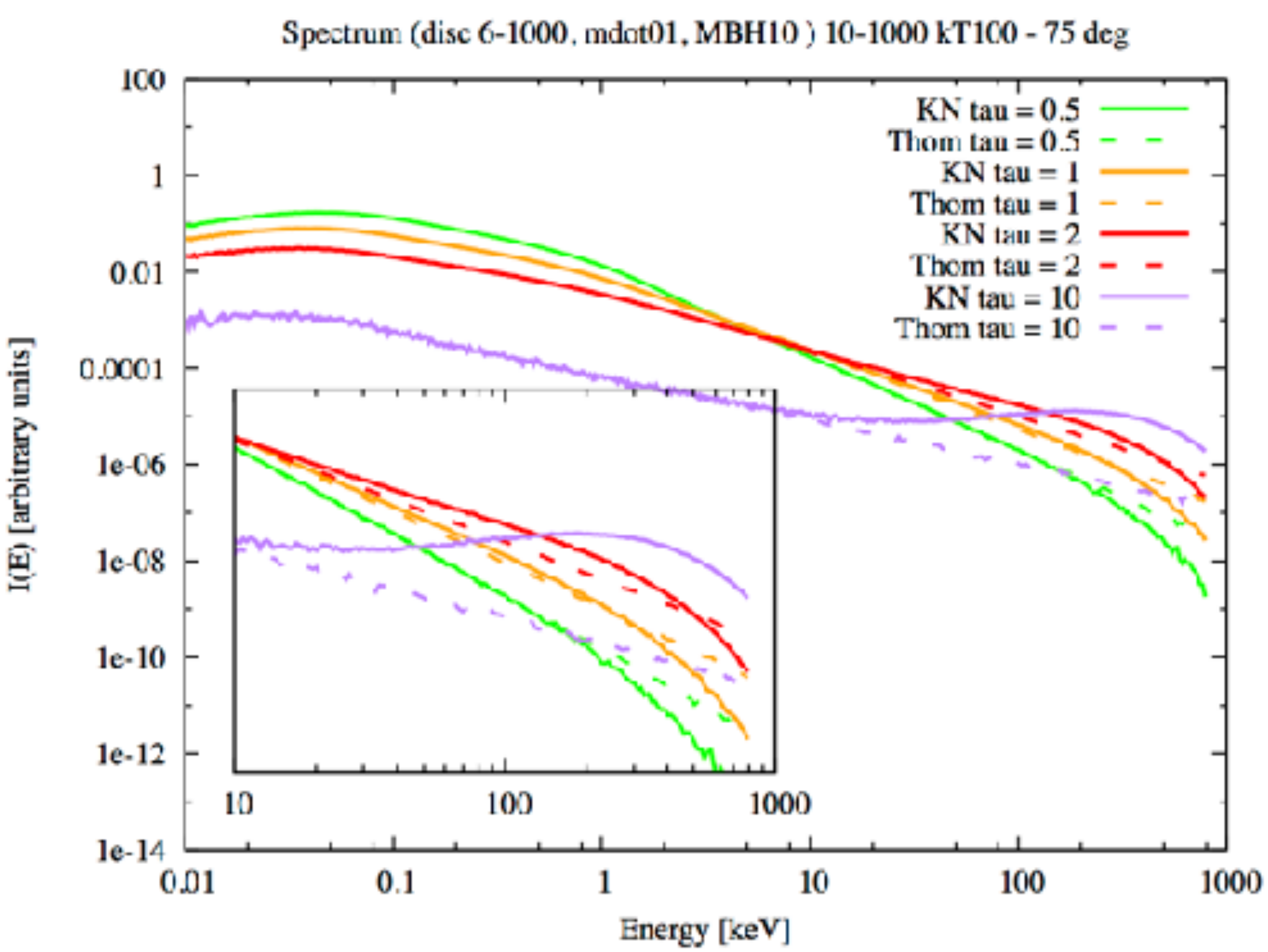
Conclusions

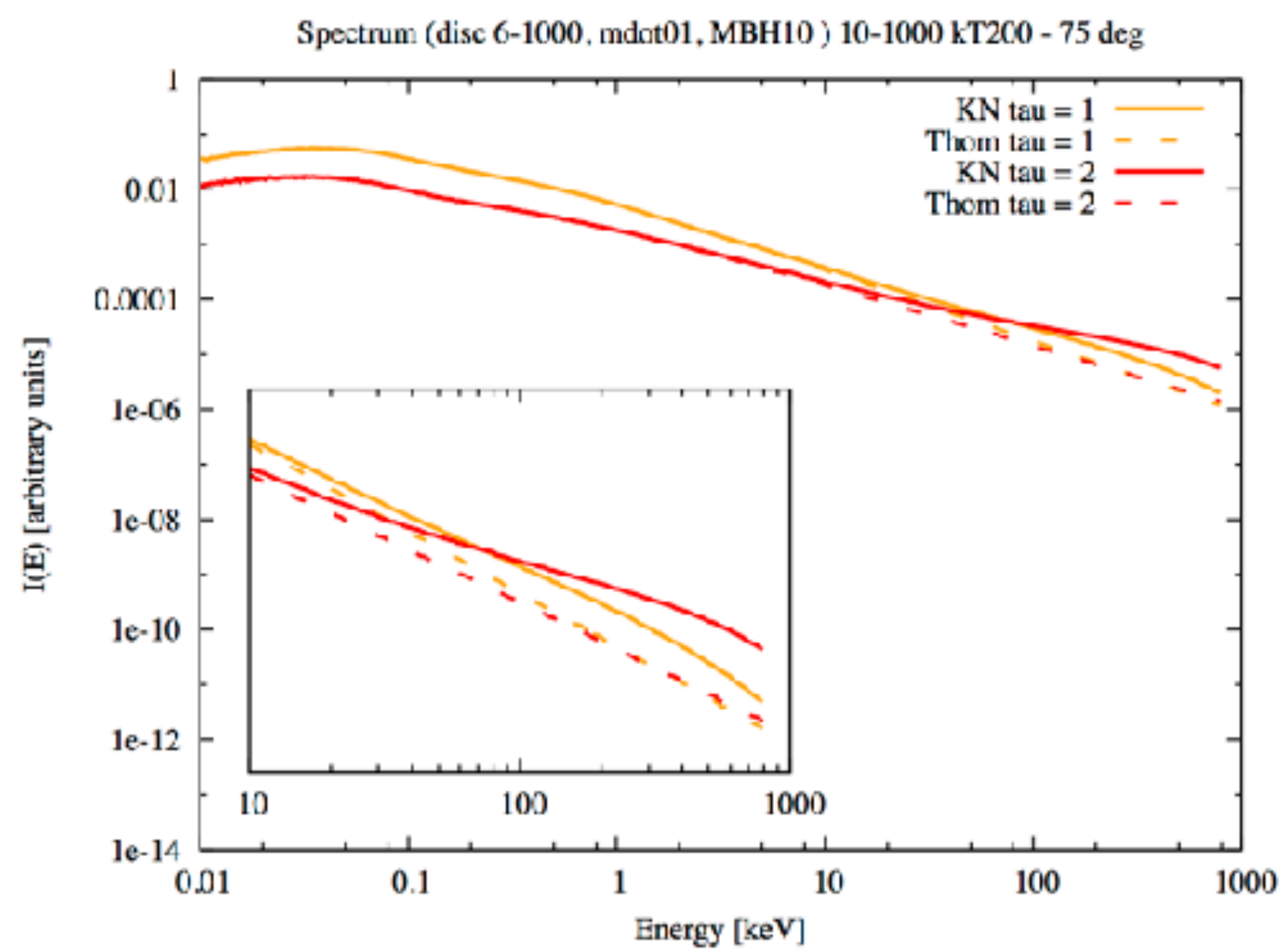
For extended coronae, nothing really matters…

…except Klein-Nishina for the high-energy cut-off and the slope in some cases.

tau=2 kT=200 (75 deg)

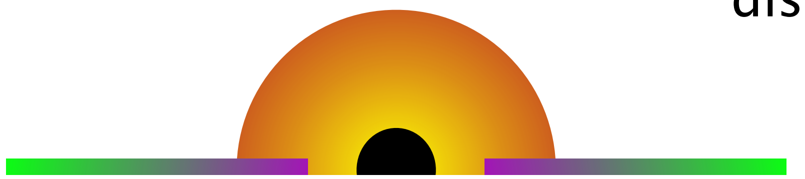
G-KN = 0.84
G-Thom = 1.09
10-100 keV

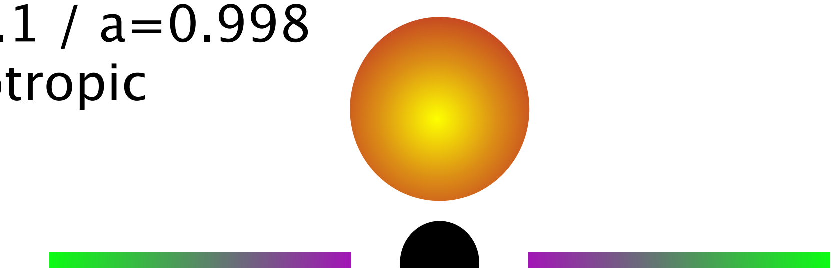




The continuum variability induced by Comptonization

SBHB = 10^6 / mdot = 0.1 / a=0.998
disc: ISCO−100 isotropic
K−N regime

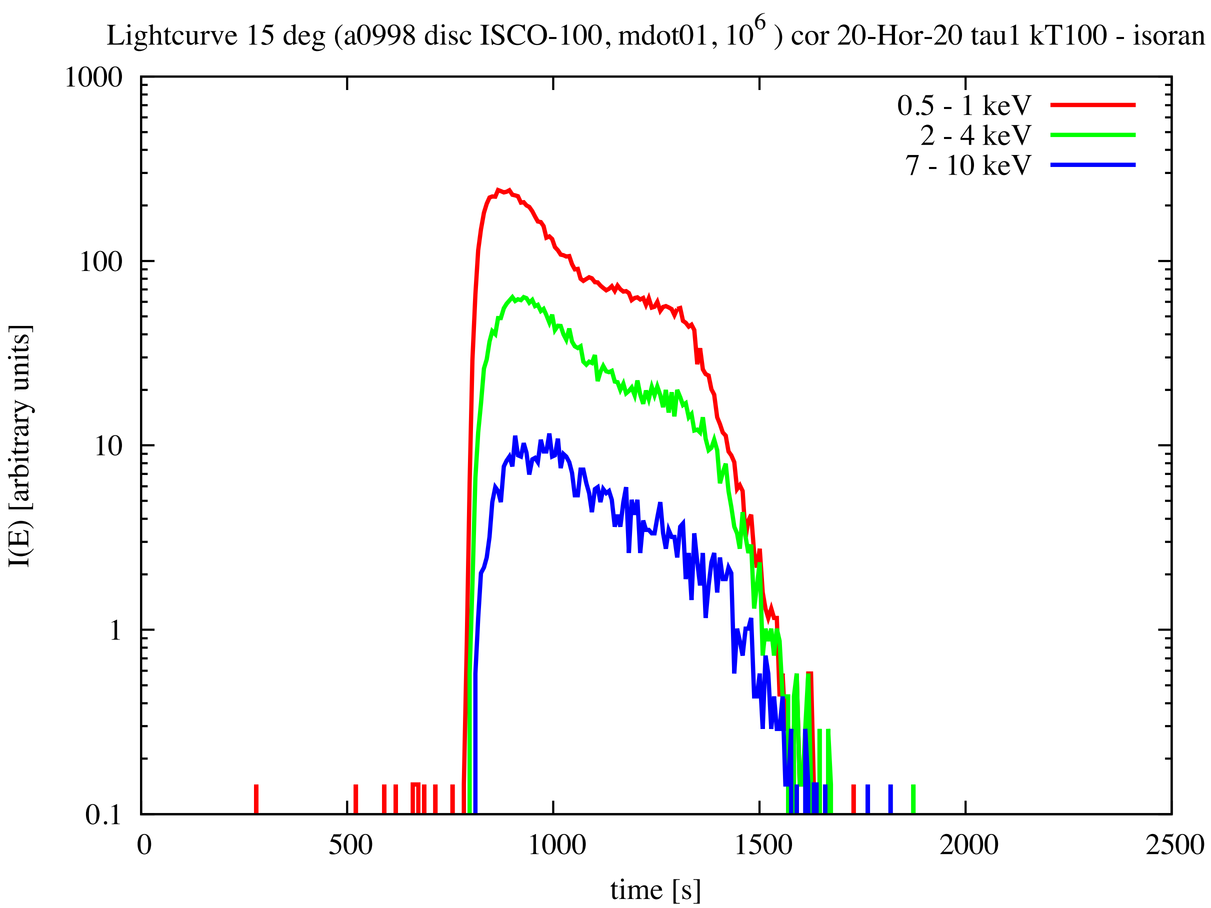


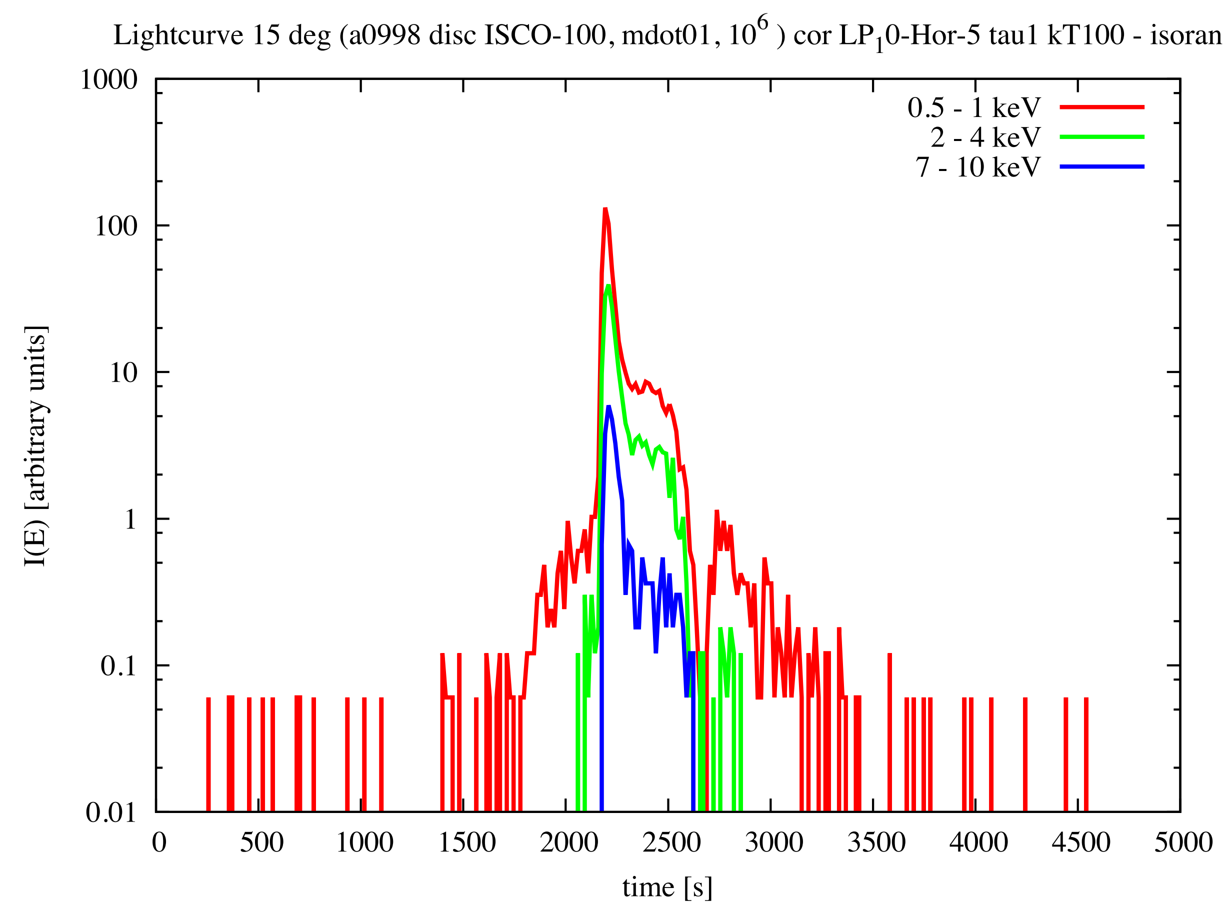


Radius = 20

H = 10 / R = 5

15 deg





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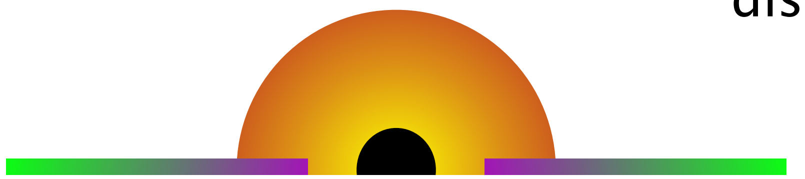
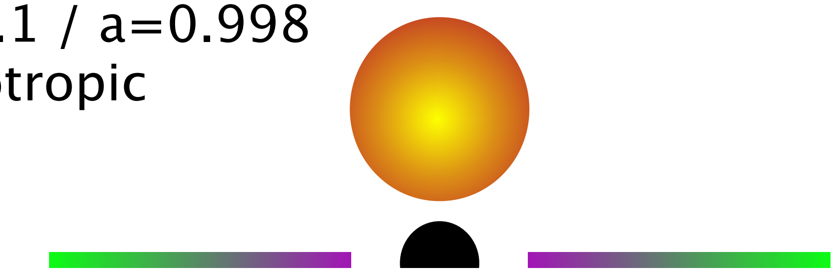
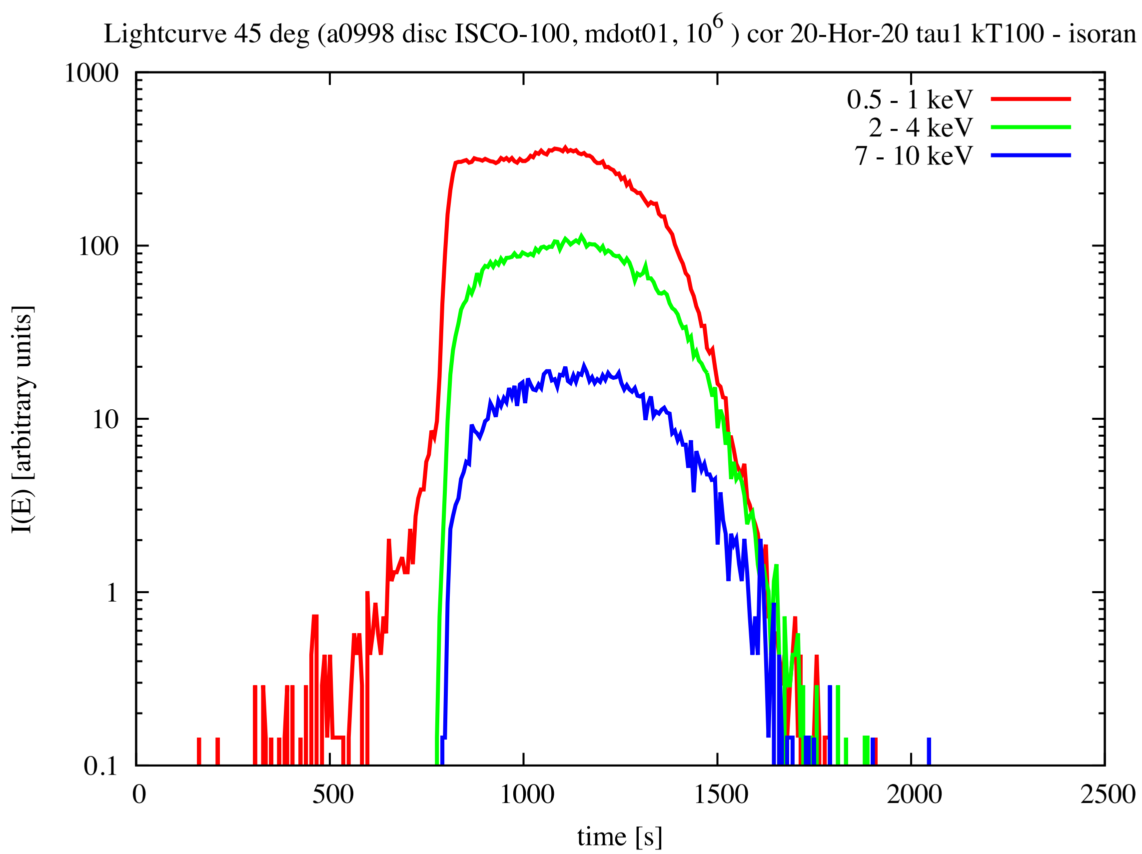


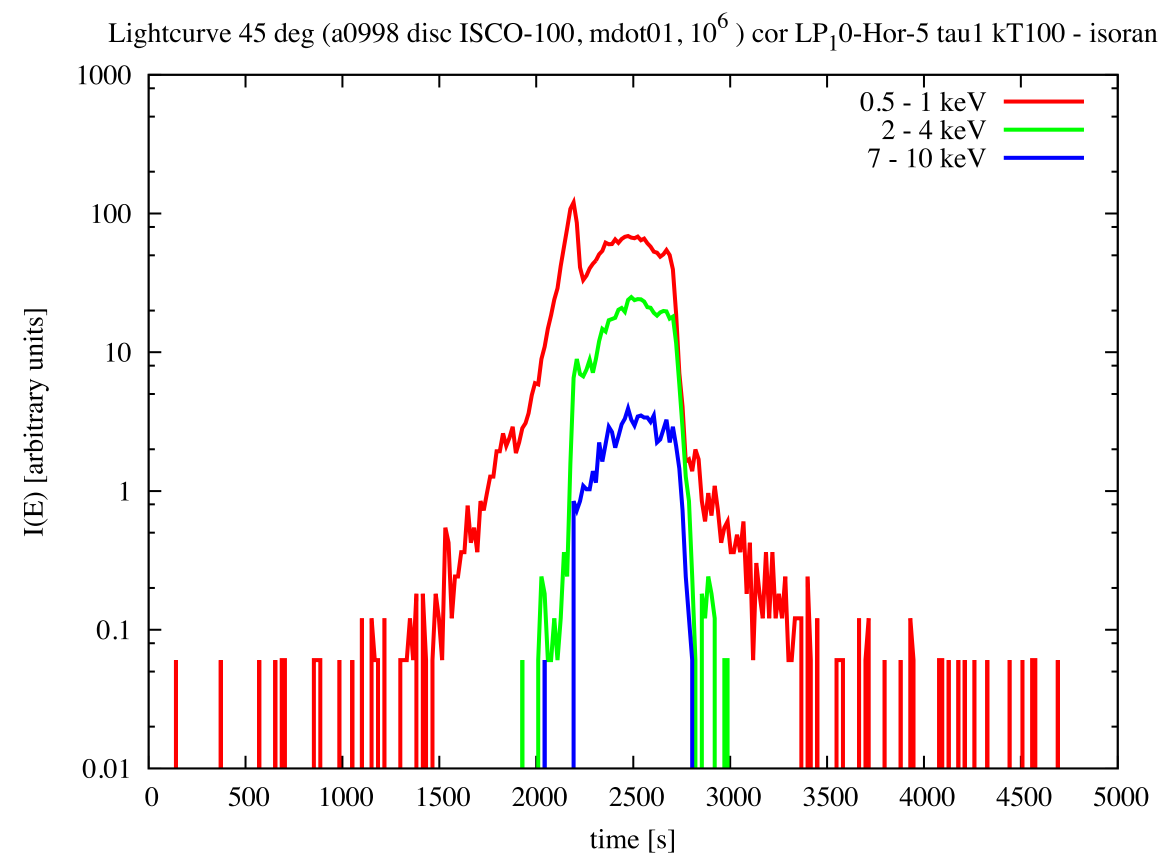


Radius = 20

H = 10 / R = 5

45 deg





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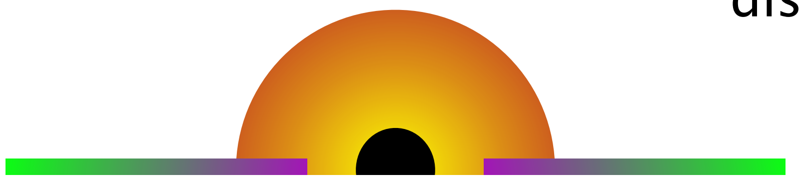
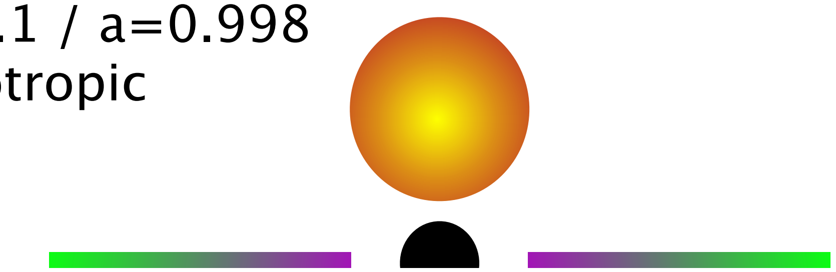
disc: ISCO-100 isotropic
K-N regime

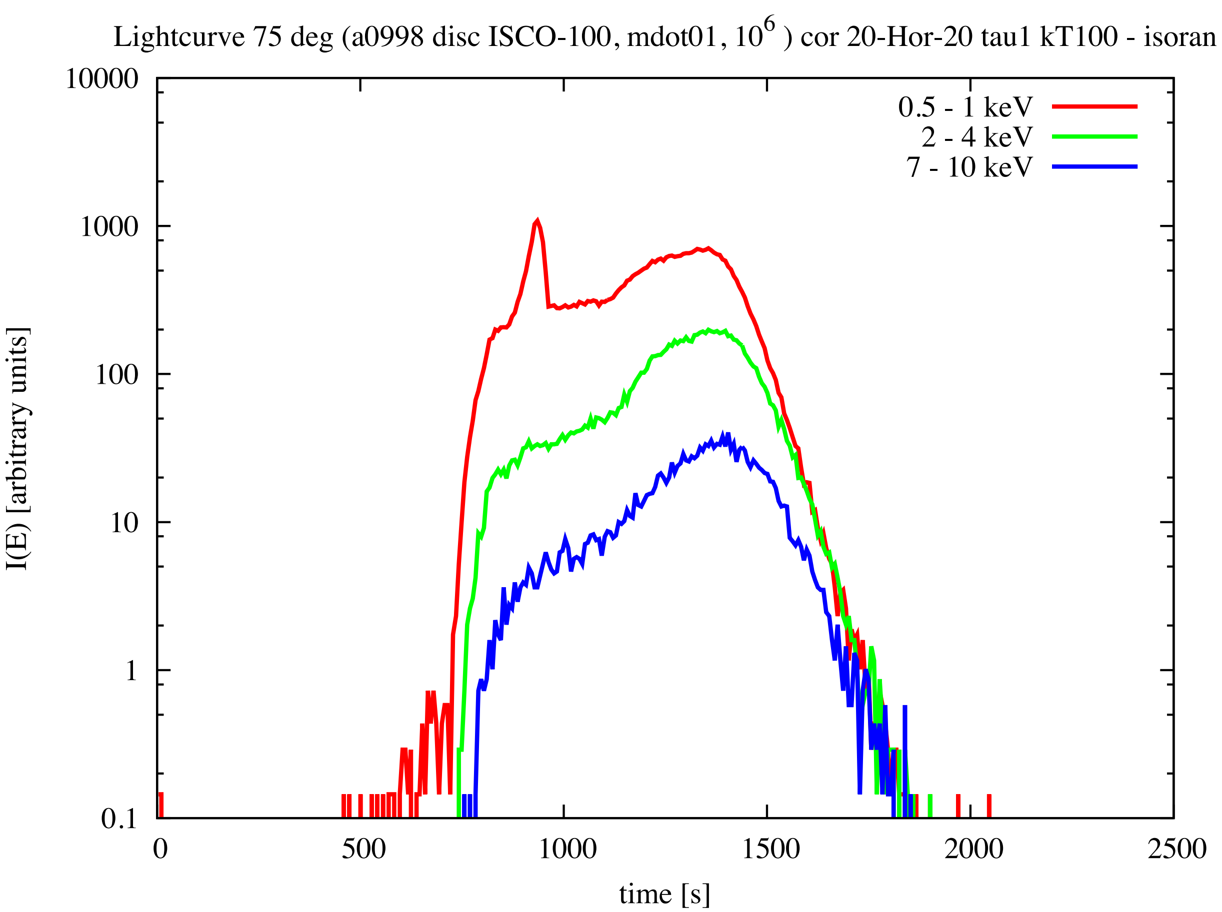


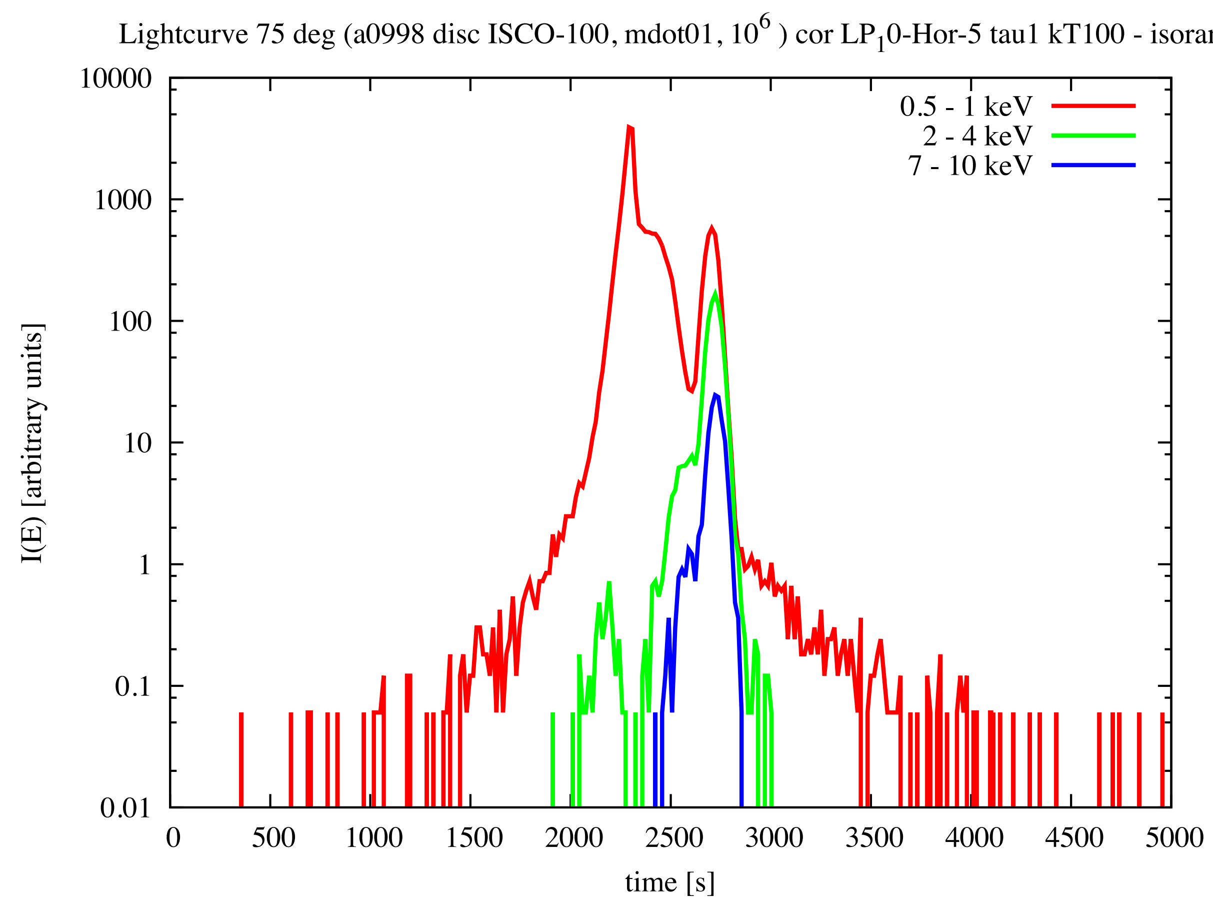


Radius = 20

H = 10 / R = 5

75 deg





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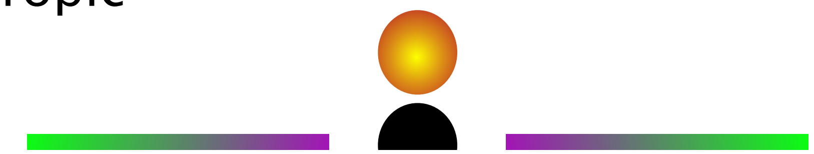
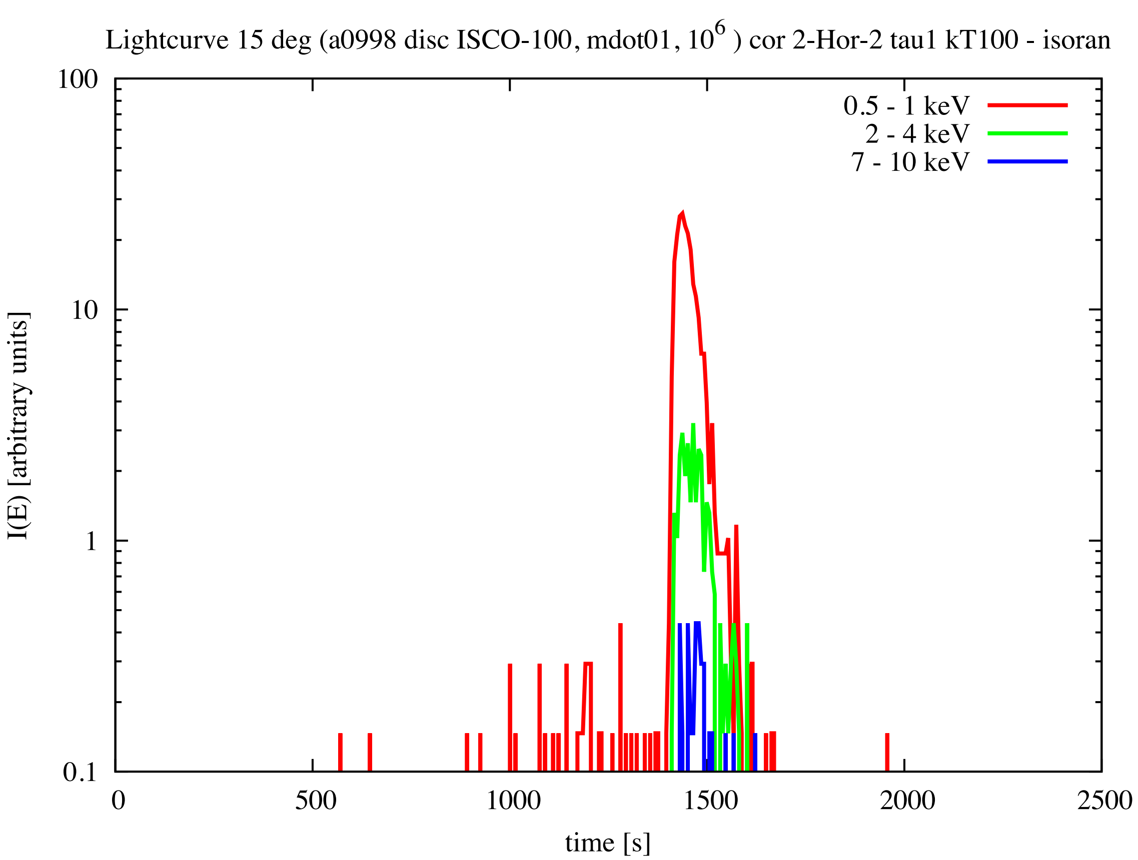
disc: ISCO–100 isotropic
K–N regime

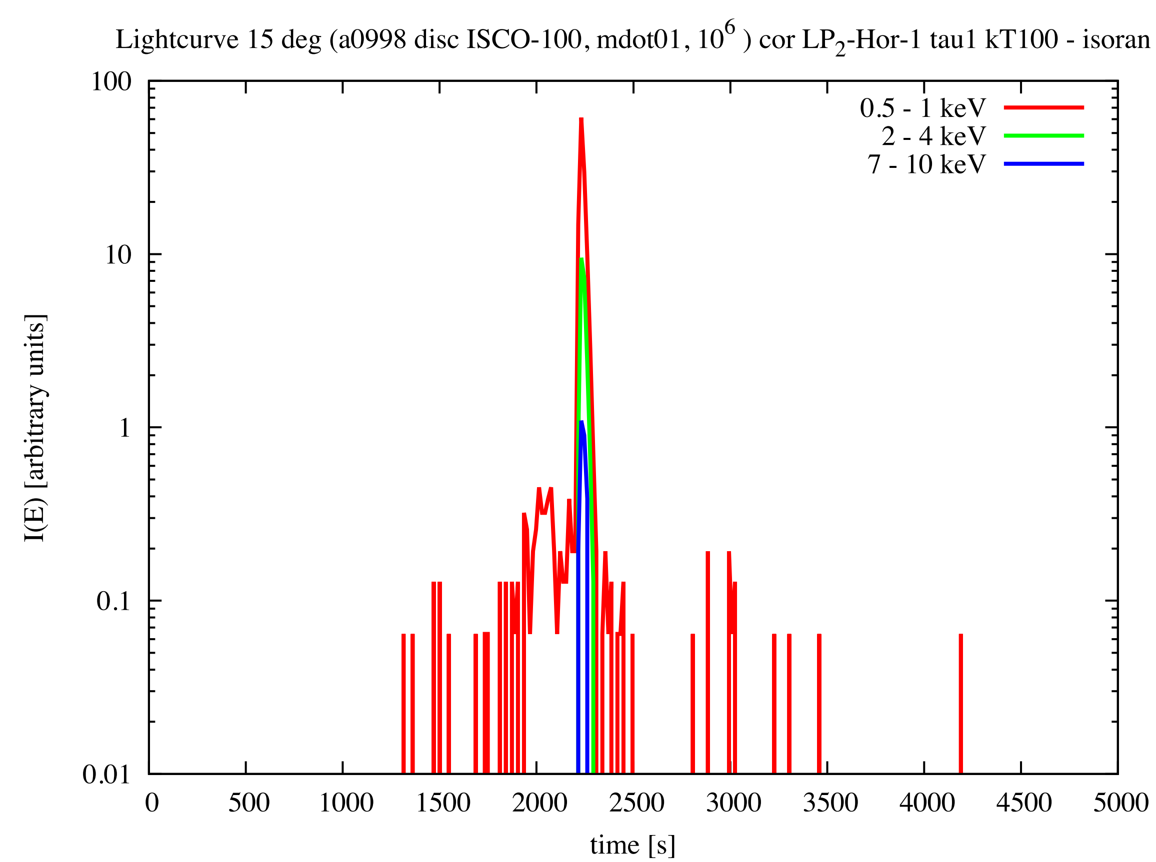


Radius = 2

H = 2 / R = 1

15 deg





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K–N regime

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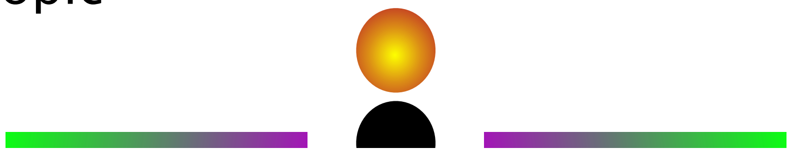
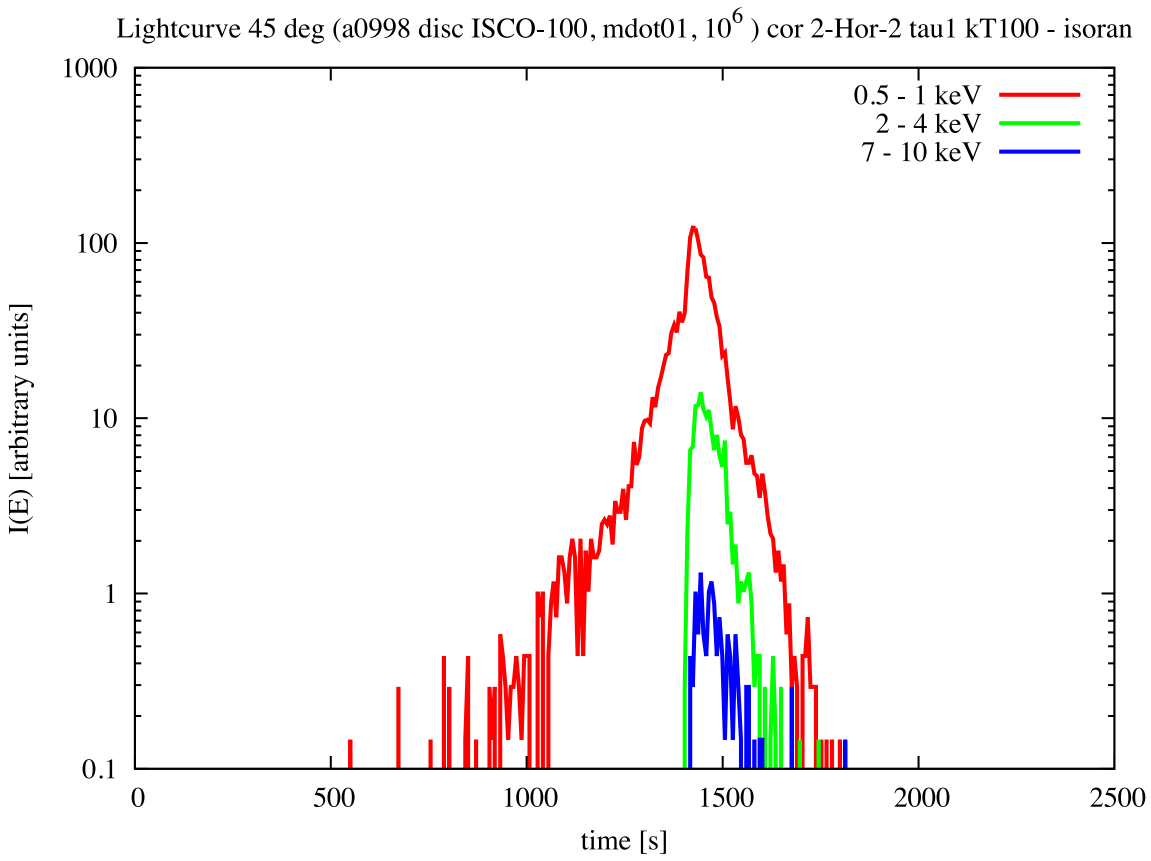
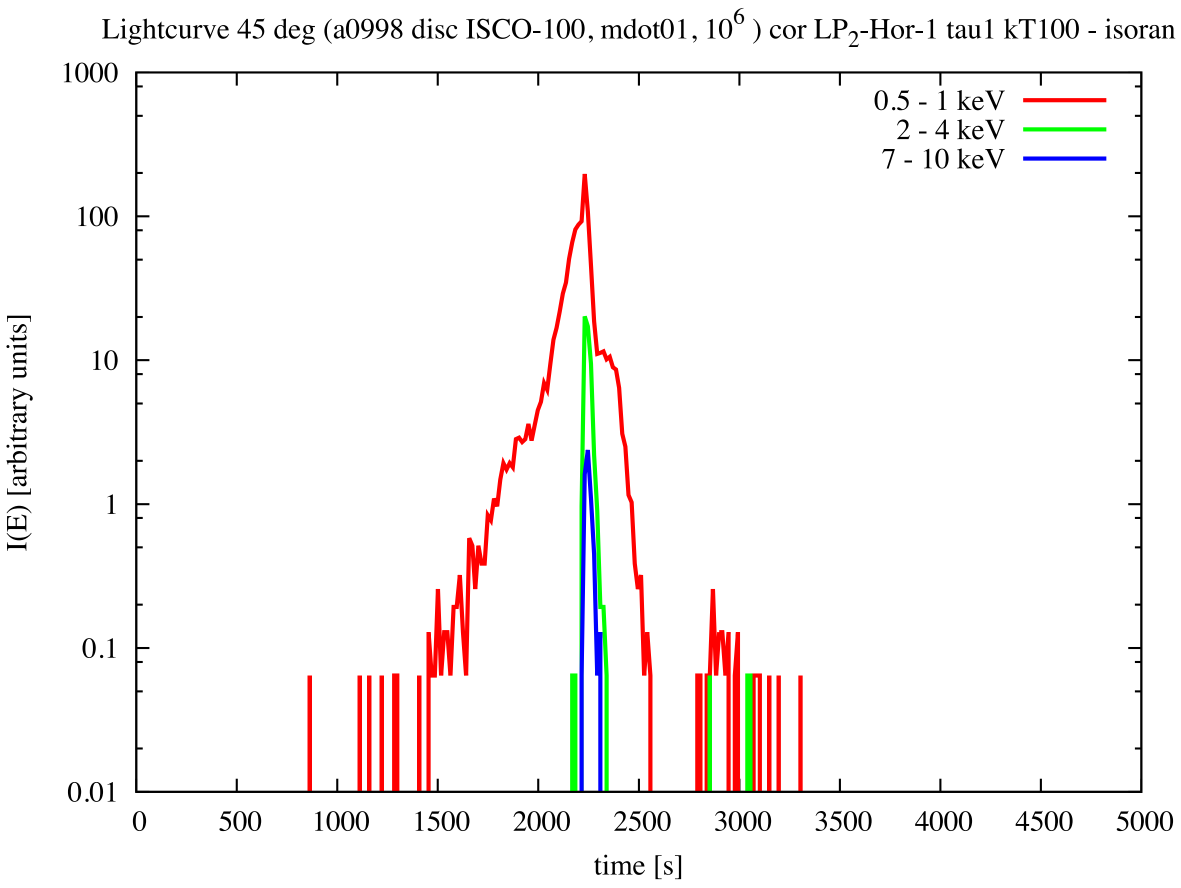


H = 2 / R = 1

45 deg





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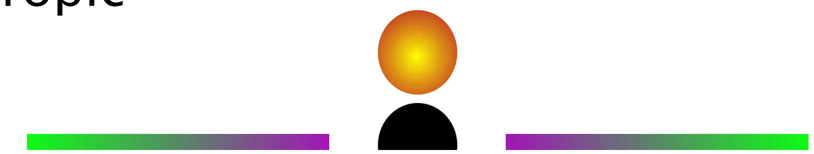
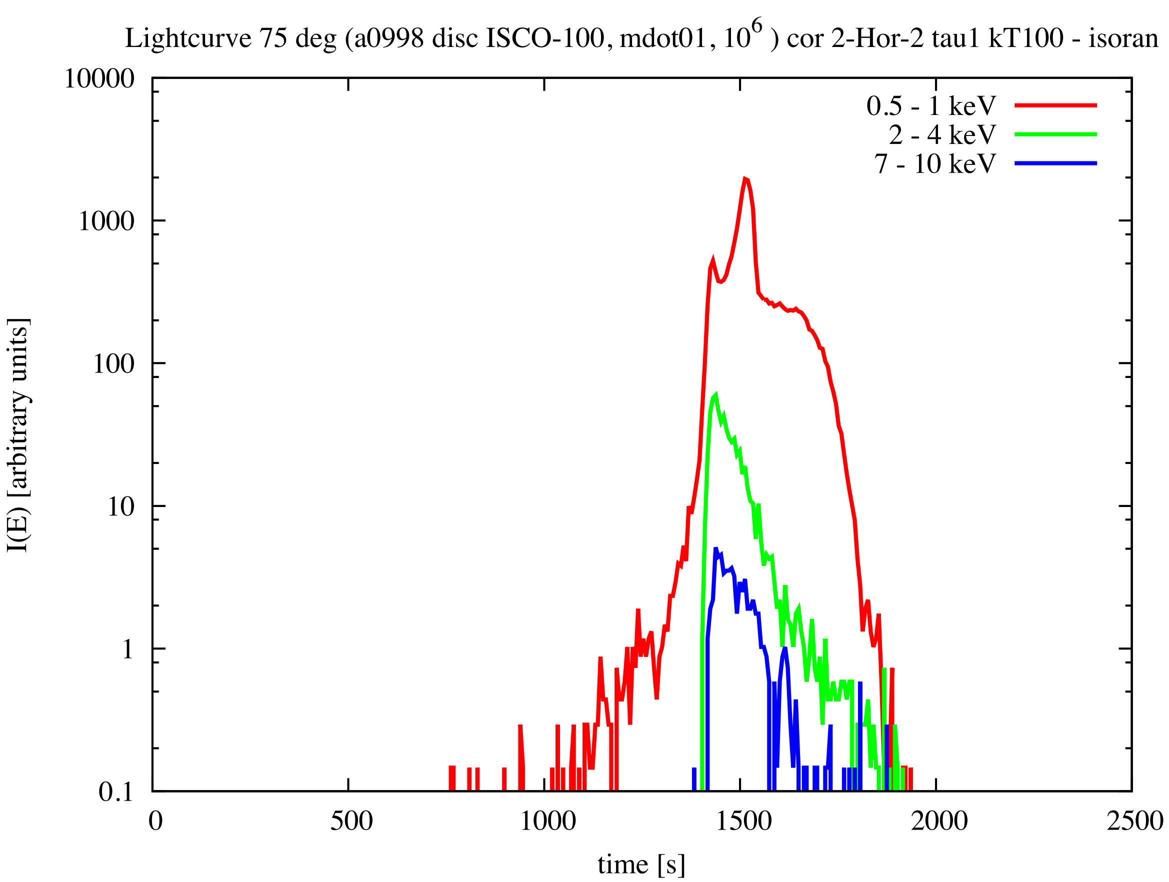
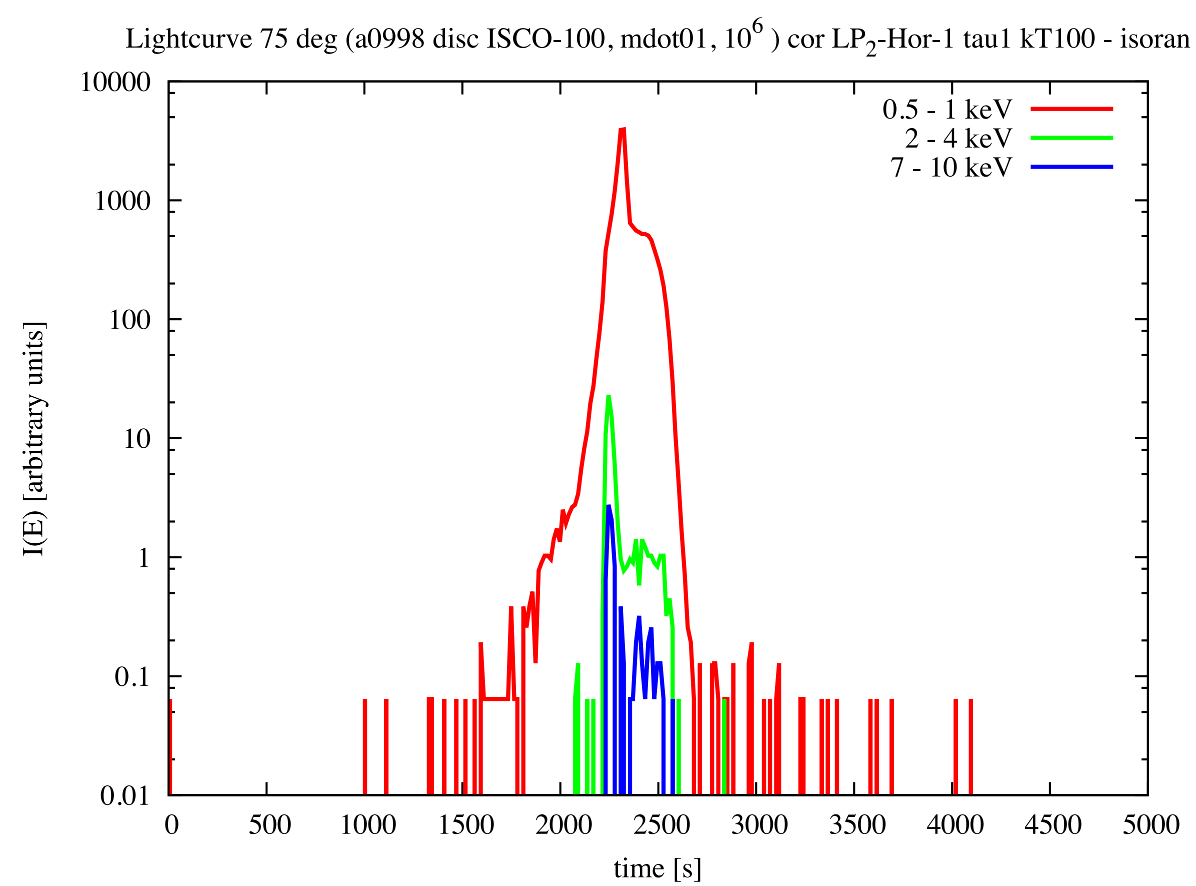


Radius = 2

75 deg

H = 2 / R = 1





Thanks for your attention !