Modeling Active Galactic Nuclei in the X-ray range:

Implications of Magnetic Flares

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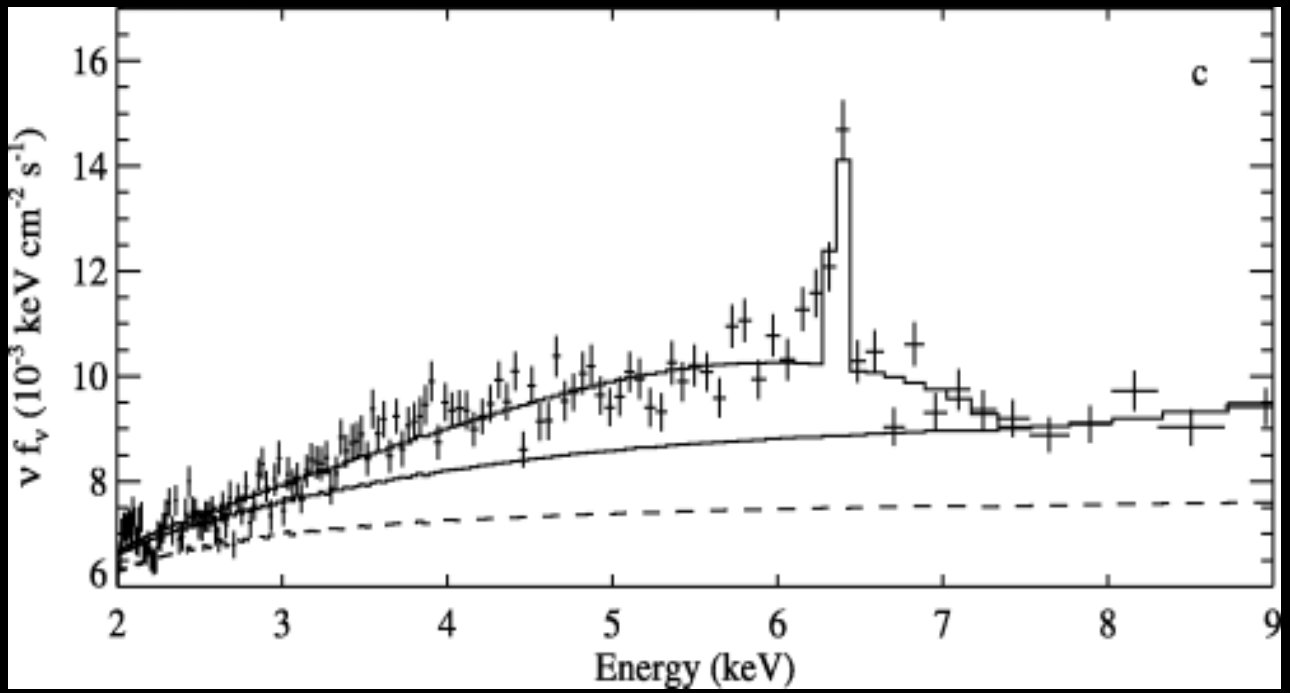
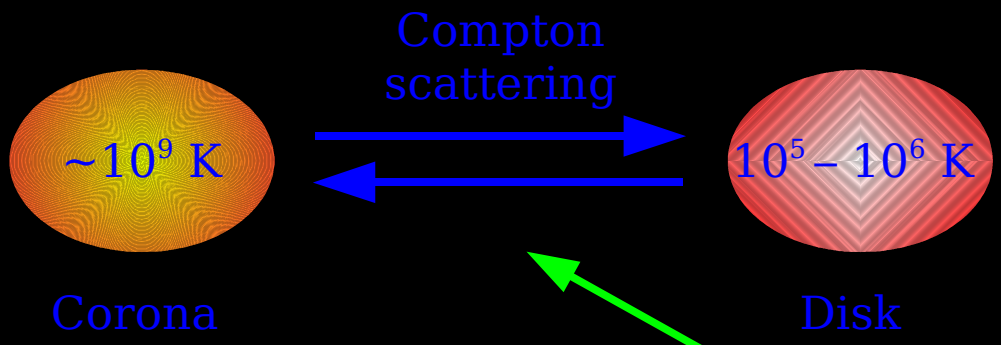
The iron Kα-line of MCG-6-30-15

The asymmetric profile can be fitted by a relativistic disk profile around a Kerr black hole



Spectrum of MCG -6-30-15, Wilms et al. (2001)

Origin of the X-rays in AGN

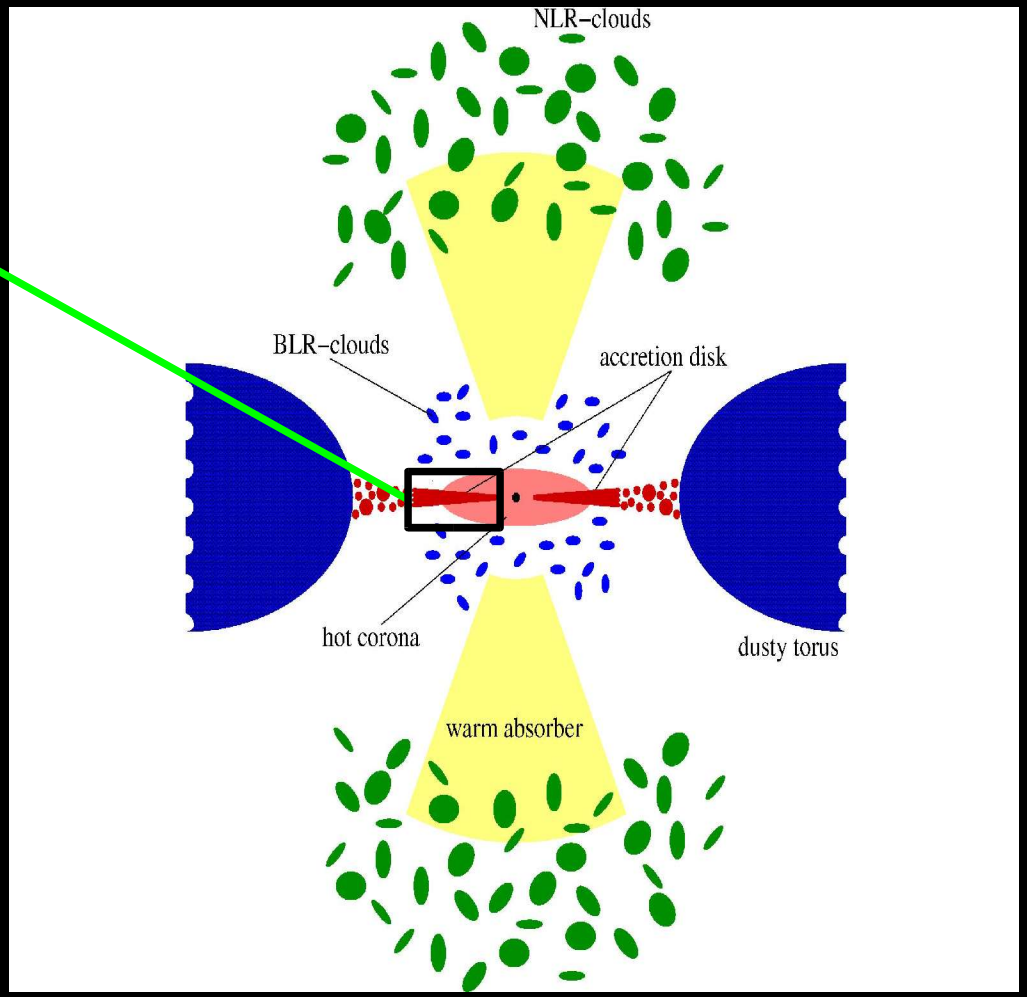


Production of the X-rays in the hot corona of the accretion disk, very close to the black hole

Two media, different in temperature, are coupled by radiative processes

Appearance of a reflected/reprocessed component coming from the disk

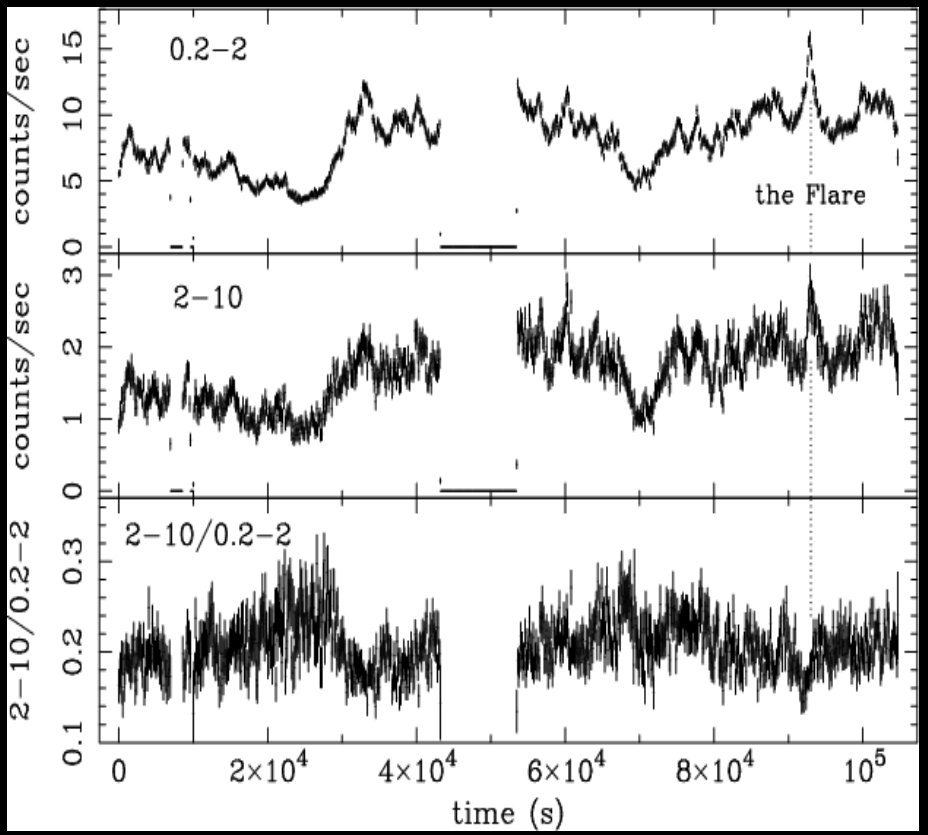
---> Kα–line, Compton hump



Rapid variability in MCG -6-15-30

Observation of X-ray variability on very small time scales (bin-to-bin variations of 300 s)

Toward the end of the observation a short flare event occurs



Short-term flare in MGC -6-30-15
Ponti et al., 2004

A flare event in MCG 6-15-30

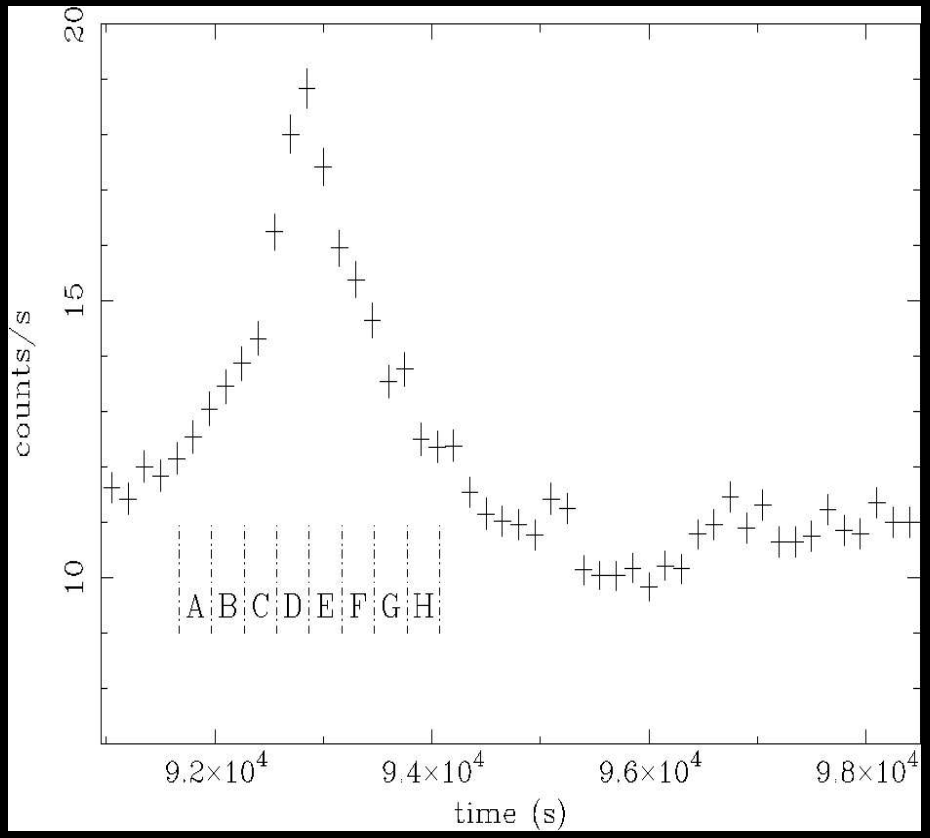
X-ray flare lasting ~ 2000 s with an increase of flux by a factor of 1.7

--> flare event dominates the spectrum of the AGN

Very short light travelling time

--> compact size of the emission region

--> flare event is local



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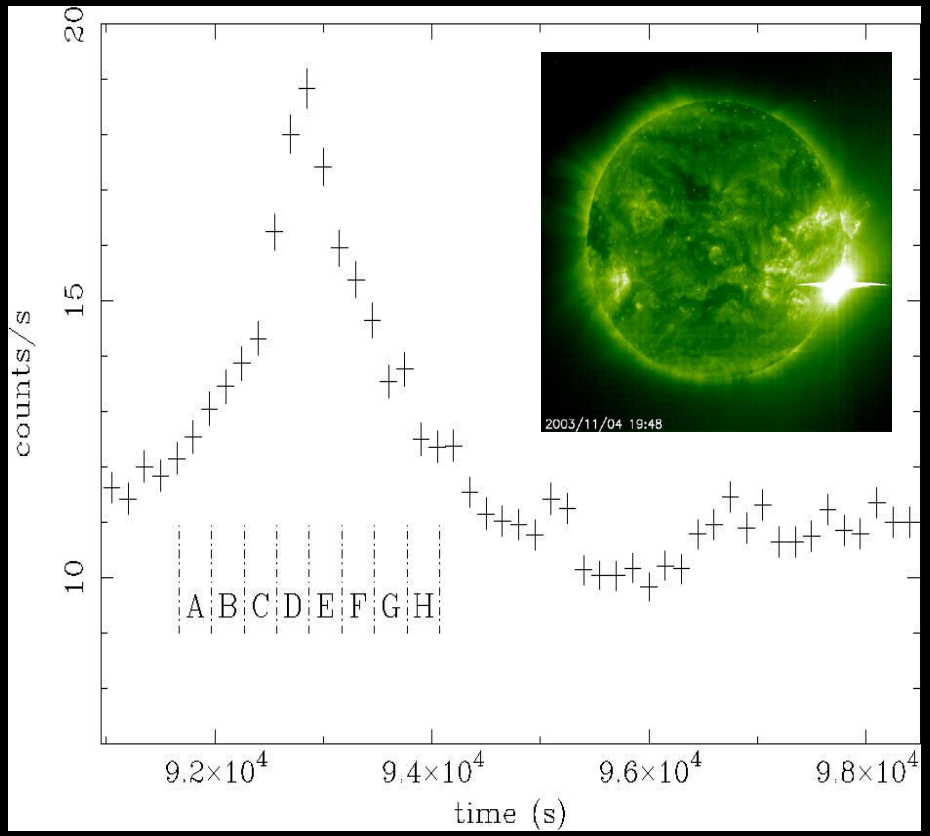


Short-term flare in MGC -6-30-15
Ponti et al., 2004

How to imagine a flare above the disk?

Magnetic flux tubes rise from the disk surface by buoyancy.

The tubes reconnect at a certain height above the disk and create a compact source of hard X-ray emission

Due to radiative cooling the emission ends after a certain time.

The radiation is partly reprocessed by the underlying disk.

Artistic impression (Vladimir Karas)

Multiple flares

Randomly distributed, hard X-ray sources located at low height above the disk

Nature of the flares could be similar to solar (magnetic) flares

Onset and fading of flares can model short-term X-ray variability

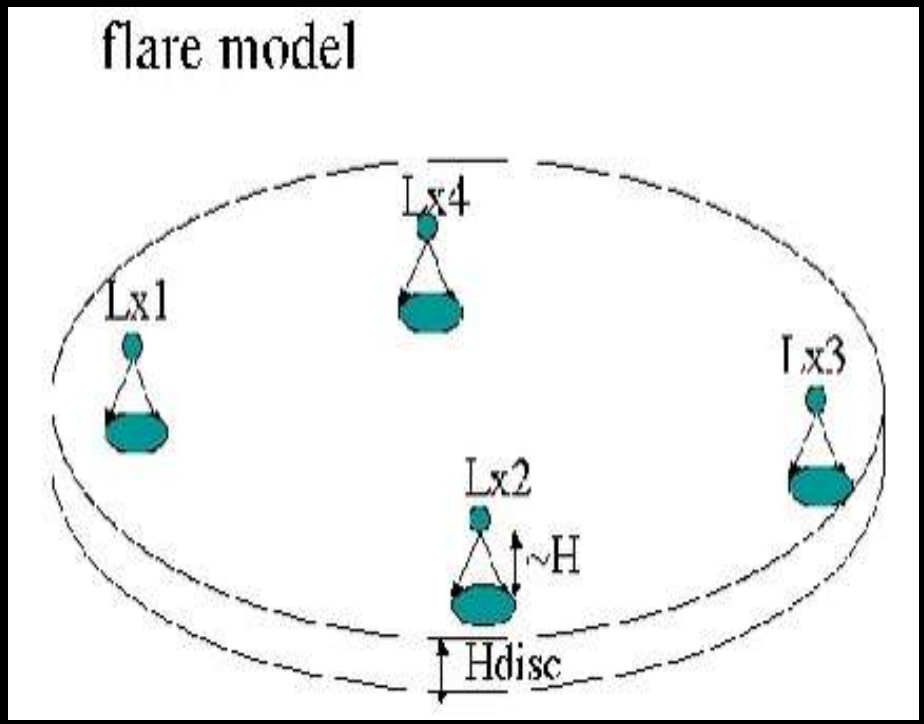


Illustration of several flares (Collin et al. 2003)

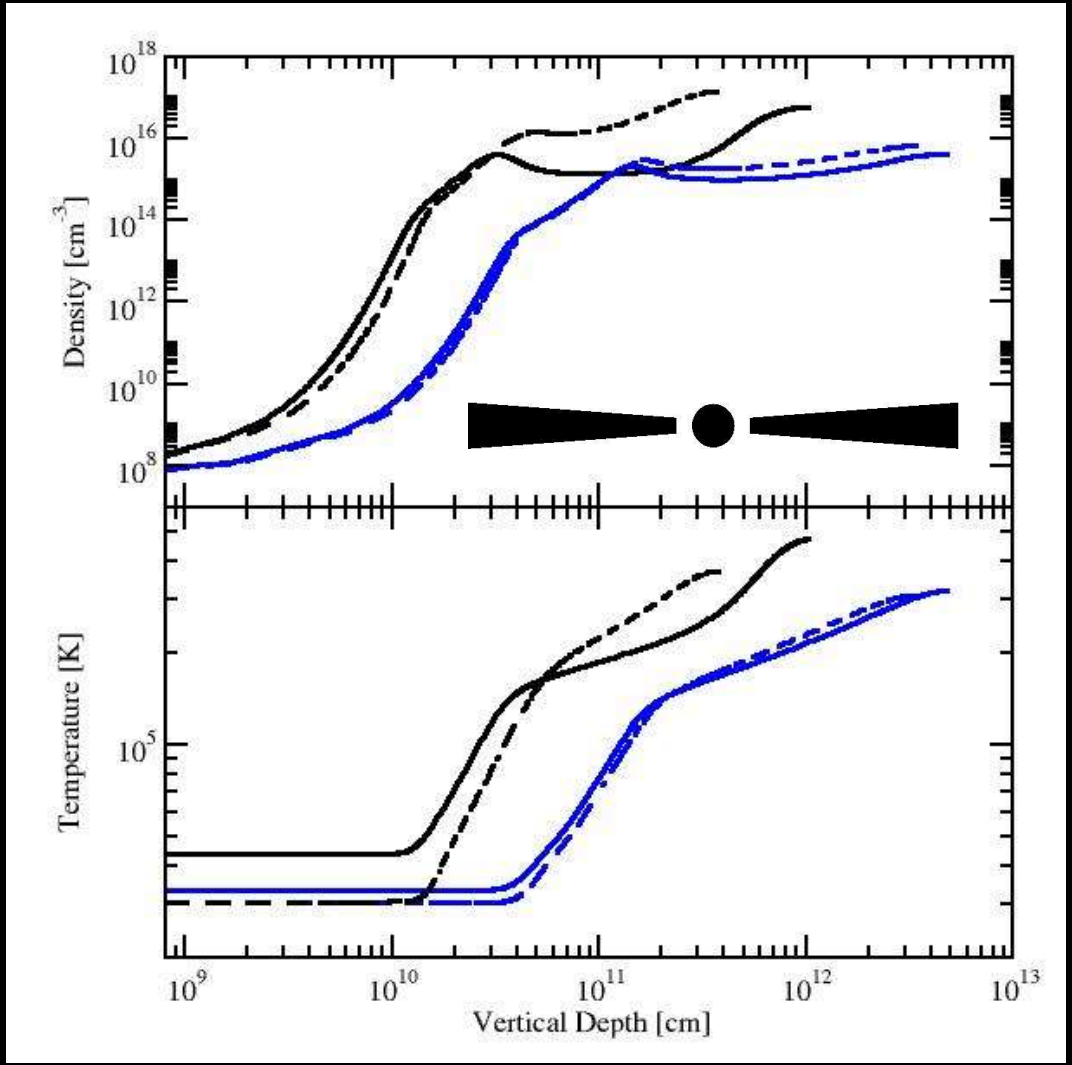
Hydrostatic equilibrium in the disk

Computing the vertical profile of the accretion disk

$M = 10^8\ M_{sun}$
dm/dt = 0.02 Edd. units
a / M = 0

— 7 R_g without rel. eff.
- - 7 R_g with rel. eff.

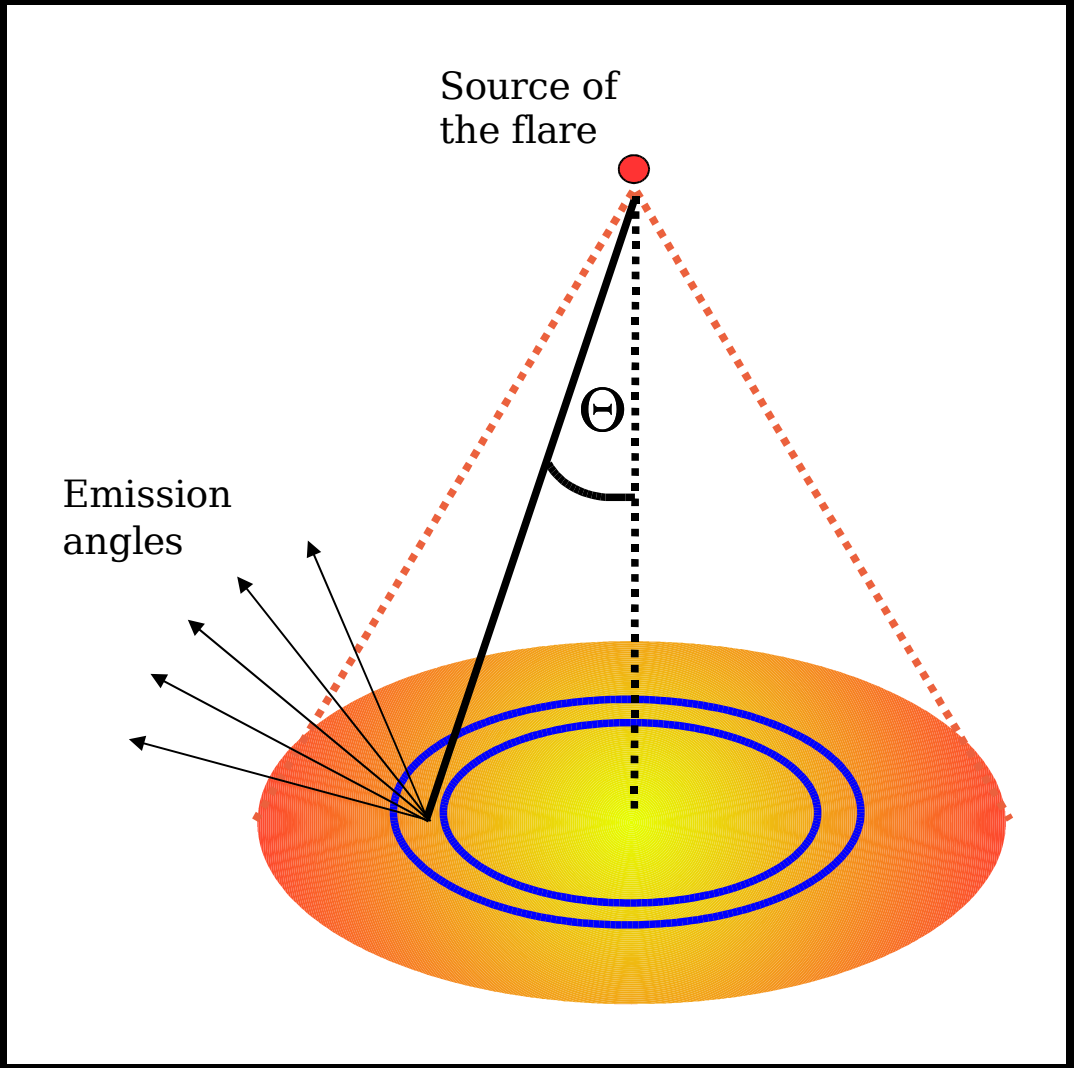
— 18 R_g without rel. eff.
- - 18 R_g with rel. eff.



Aspects of the flare modeling

The incident spectrum changes with the position inside the spot, and so does the reprocessed component.

The reprocessing depends on the viewing angle, hence, the inclination has to be considered as well.



The radiative transfer codes

TITAN
Transfer with ALI

Ionization and temperature profile

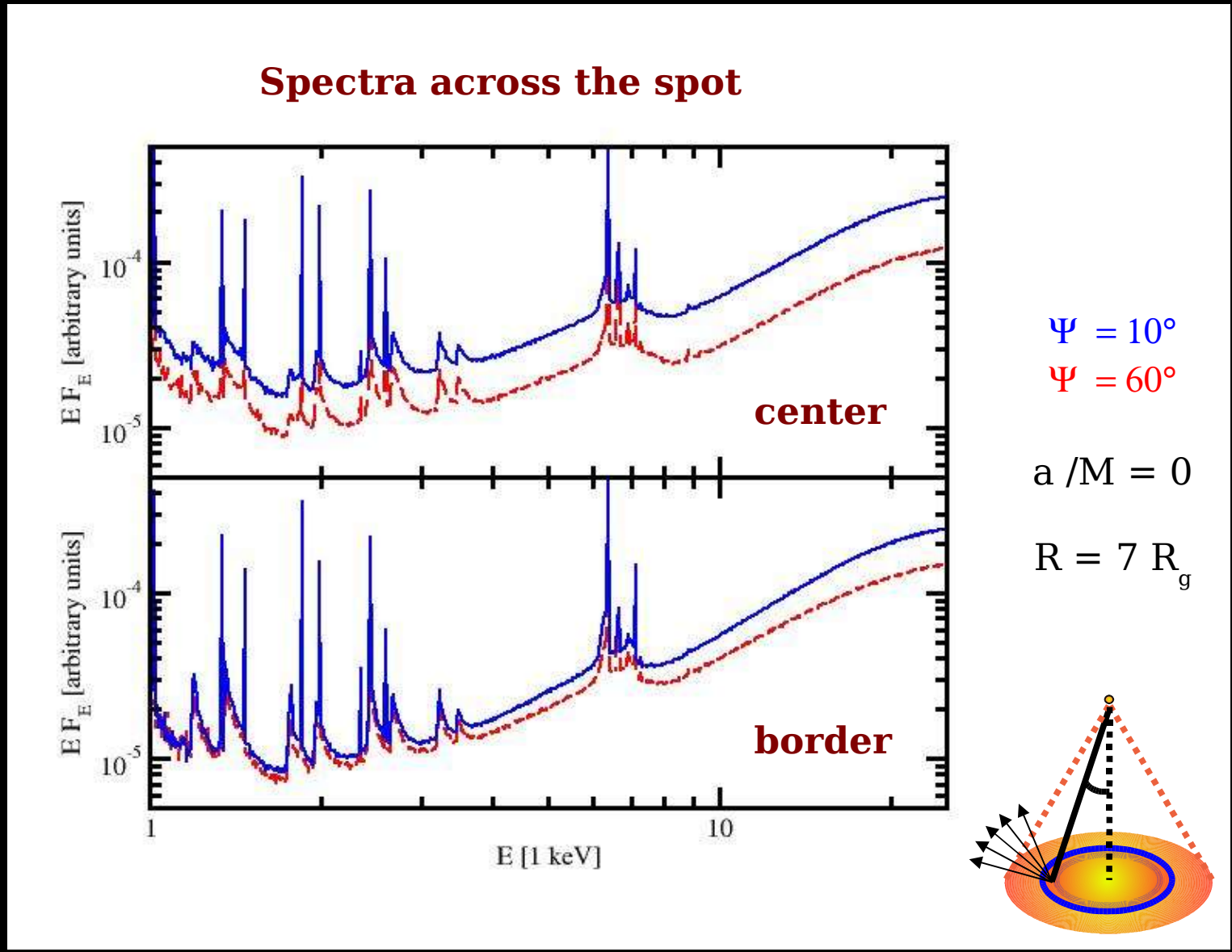
Profile of the Compton heating

NOAR
Transfer with Monte-Carlo method

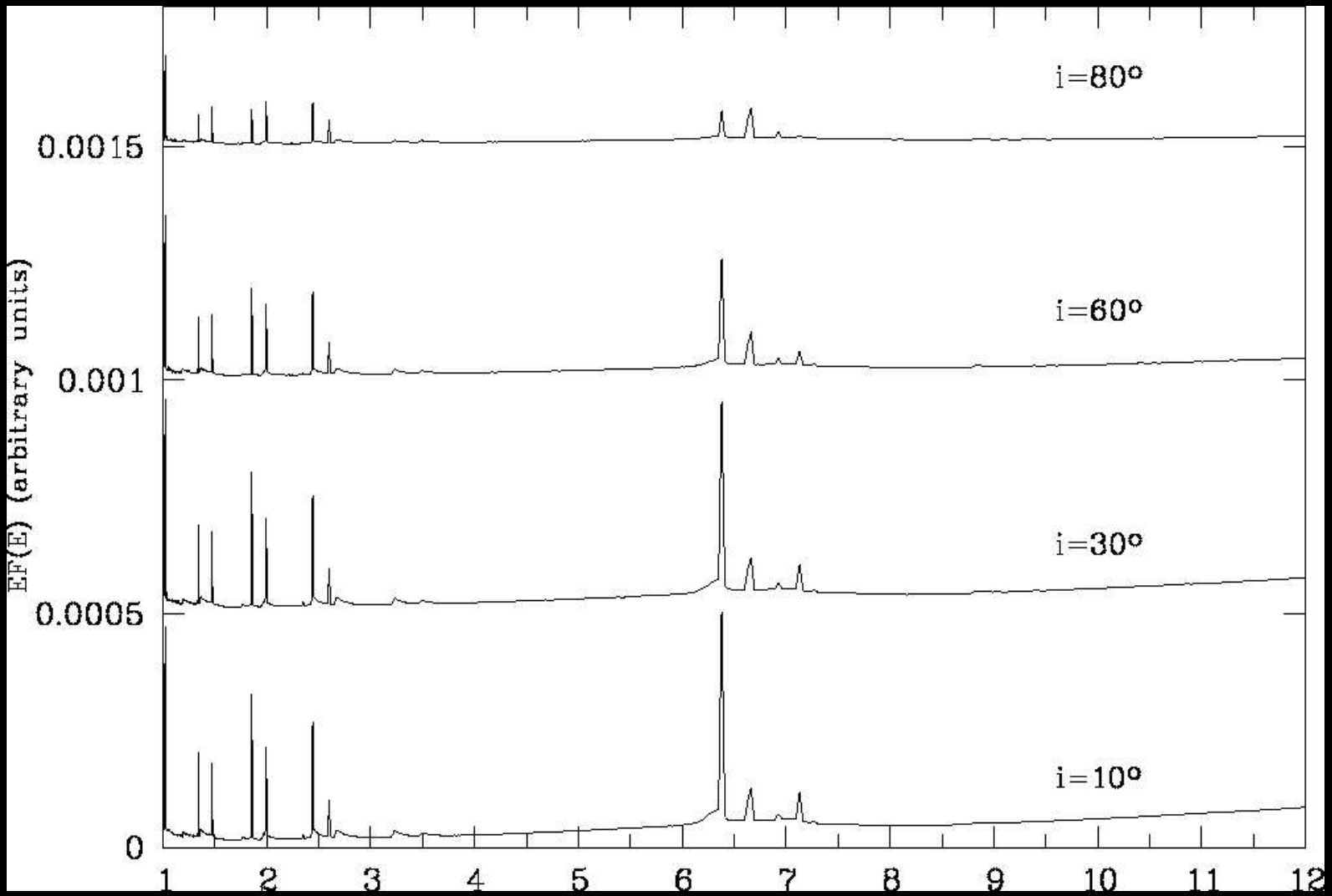
Convergence

Output of the reflected and transmitted spectra

Locally reprocessed spectra

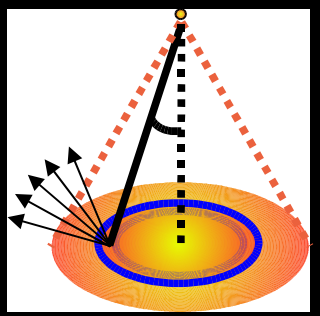


Dependencies of the iron K -line complex



spot center

$R = 7\ R_g$



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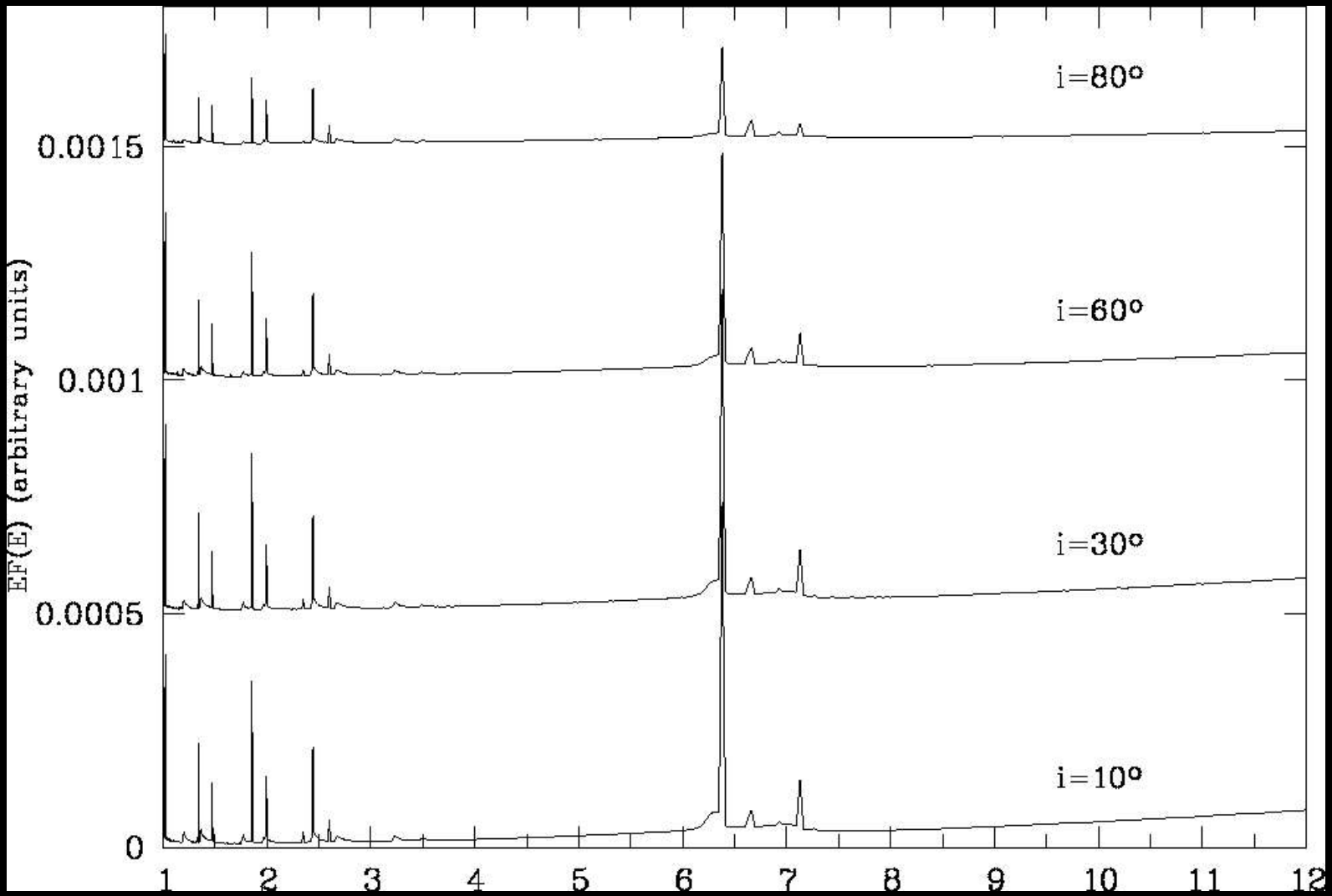
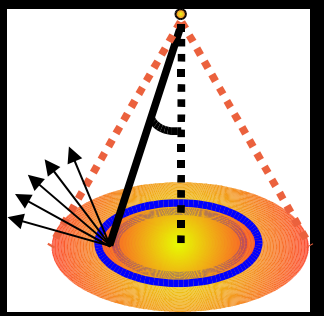
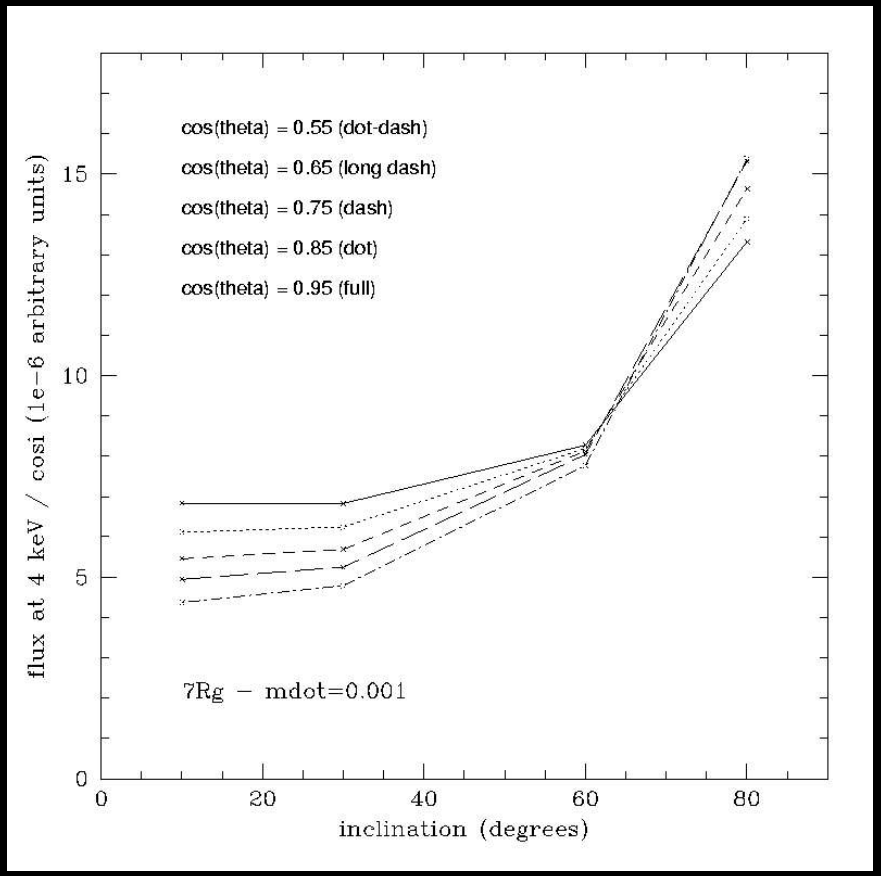


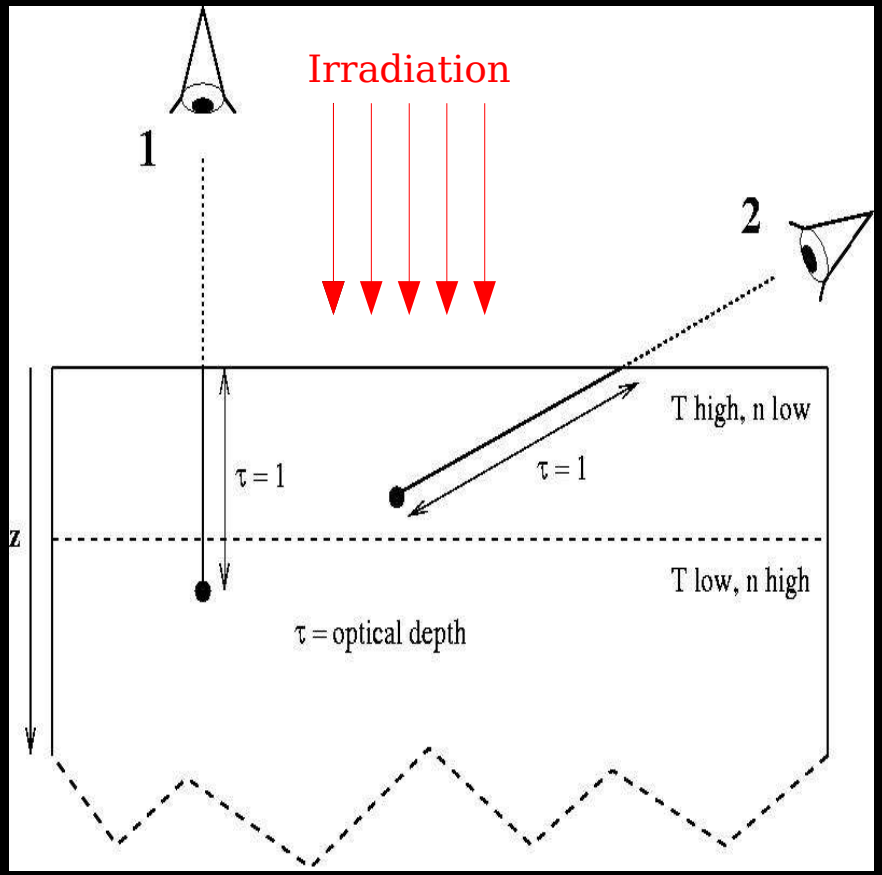
spot border

$R = 7\ R_g$

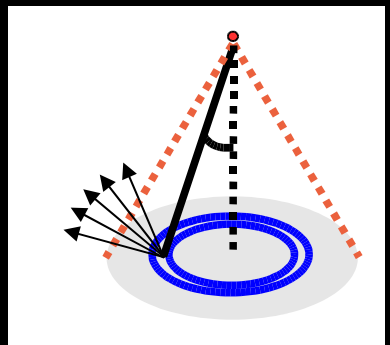


Local limb-brightening



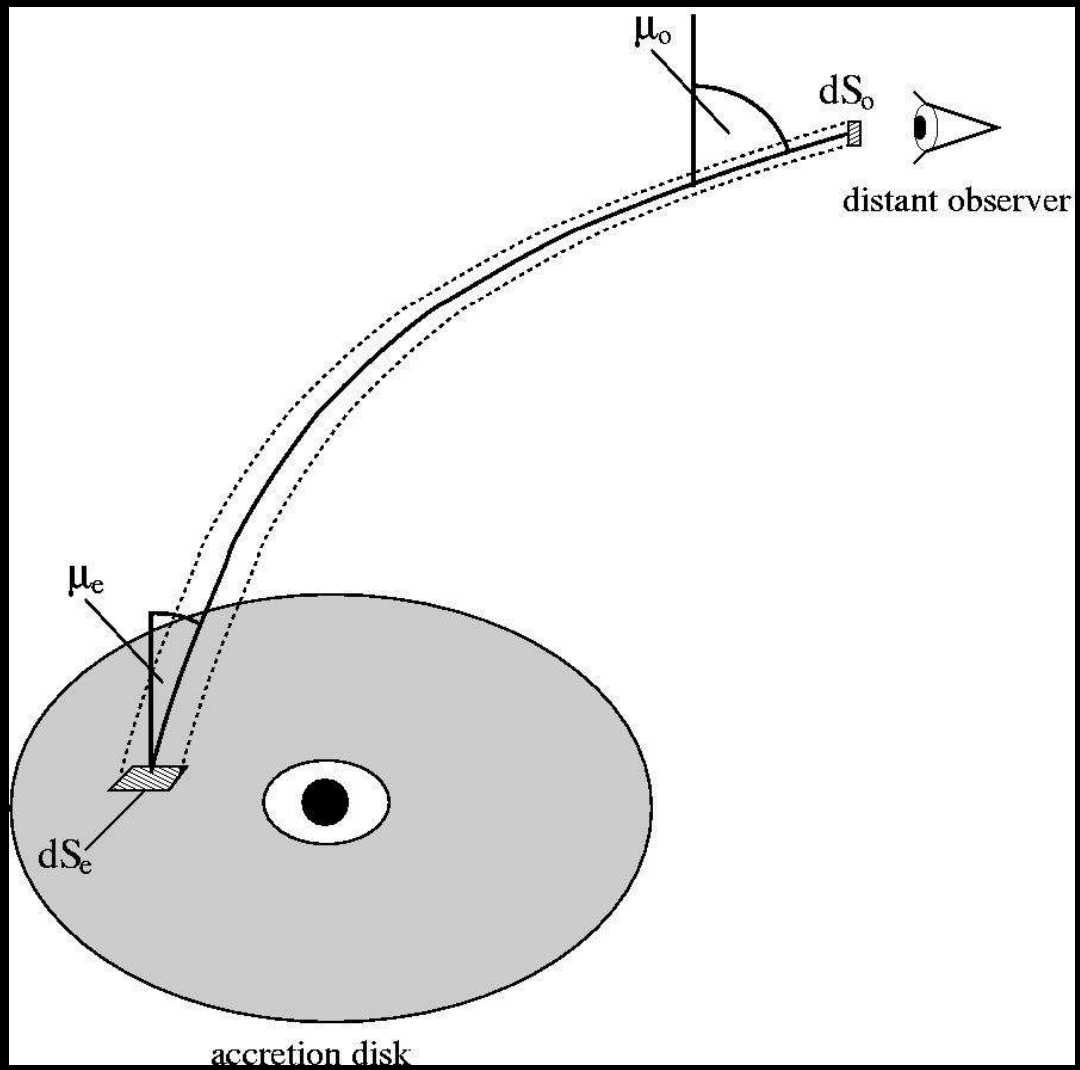


$R = 7\ R_g$, $E = 4$ keV



Including relativistic corrections

KY (Dovčiak et al. 2004, Dovčiak 2004) calculates the relativistic effects due to the curved space time (energy shift, lensing, time-delays, deflection)

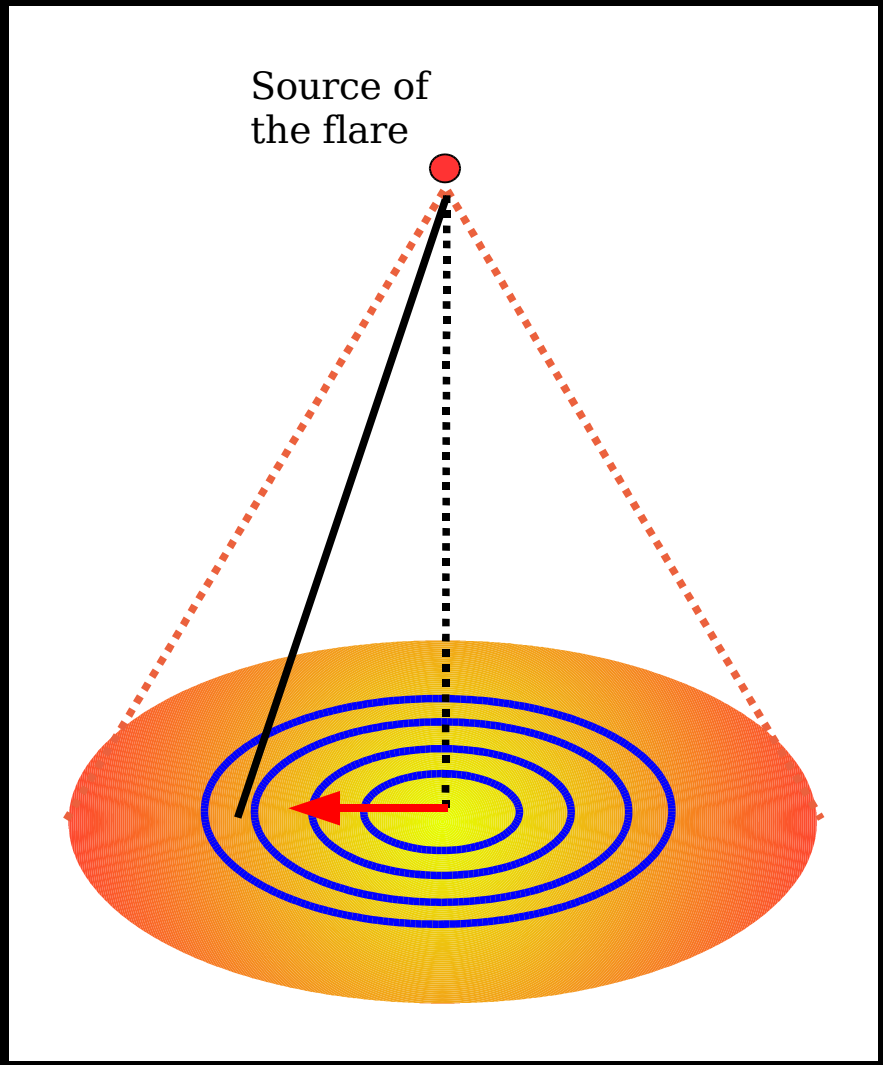


Modeling of short-term flares

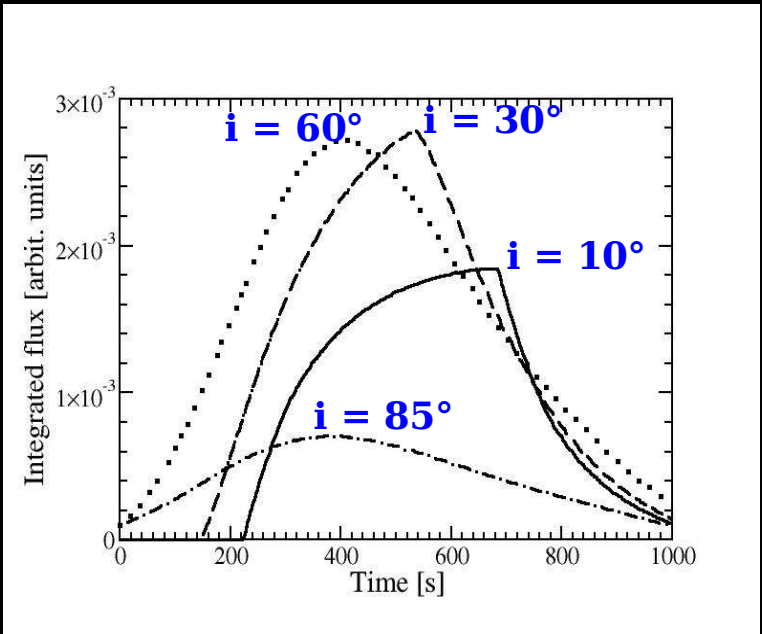
$M = 10^8\ M_{sun}$
dm/dt = 0.001
a = 0 (Schwarzschild)
$F_x = 144\ F_{disk}$
Primary: power-law, a = 0.9,
for 1 eV < E < 100 keV

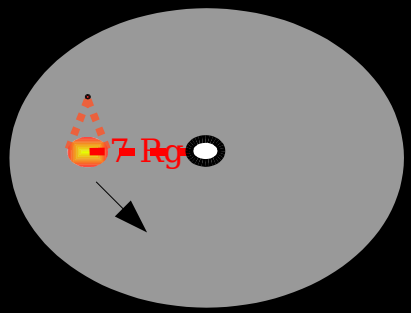
The flare duration is comparable to the light crossing time of the spot.

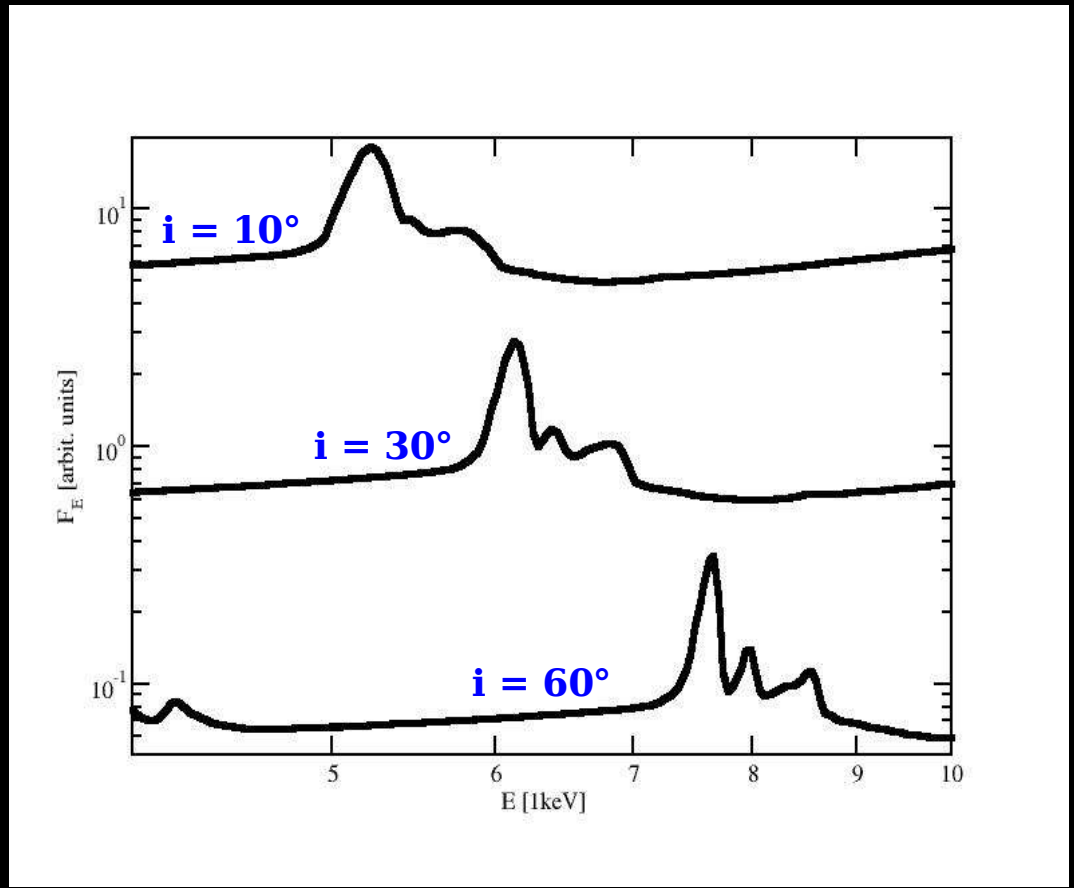
We investigate the time-evolution of the reprocessed / Compton reflection component.



Approaching short term flare







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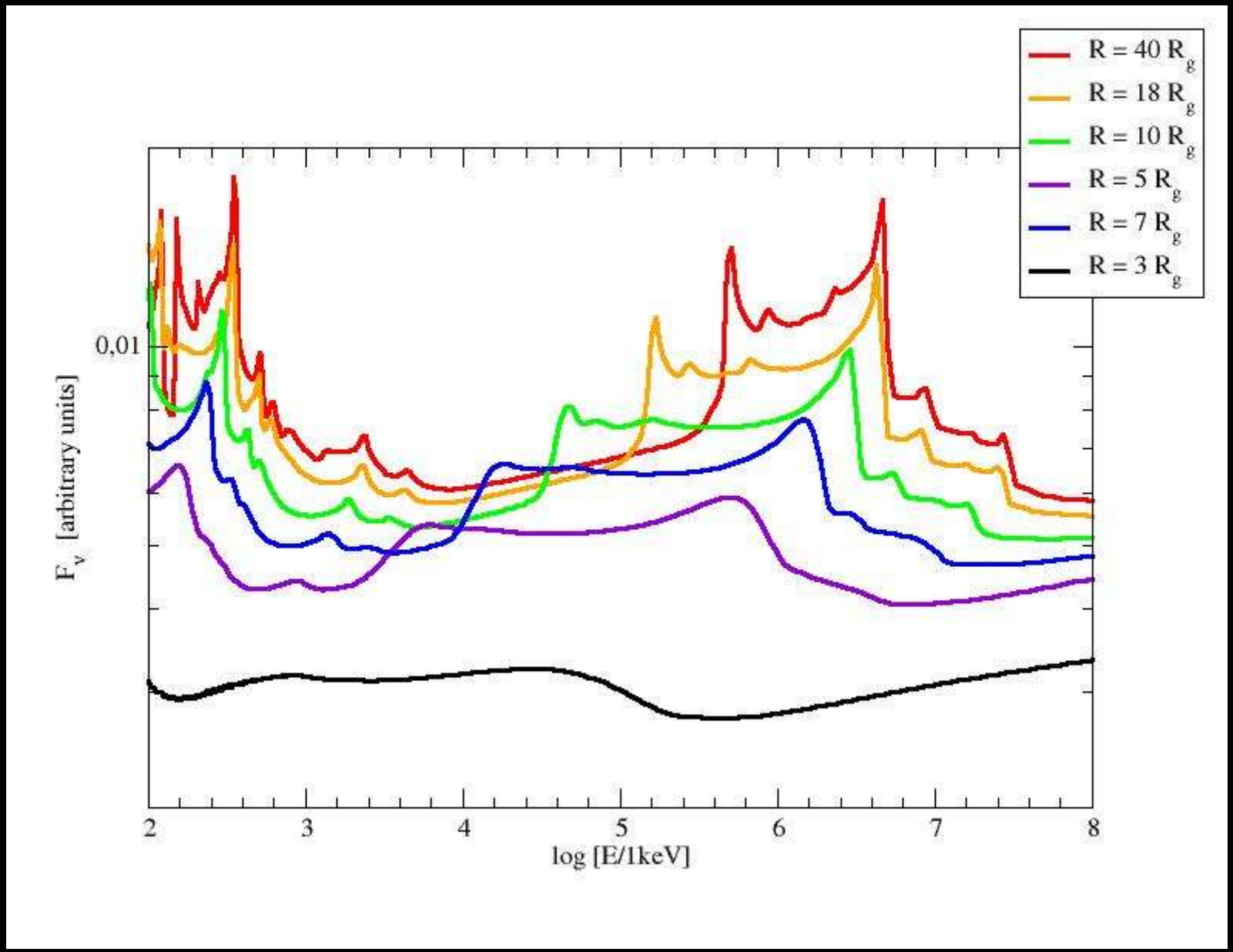


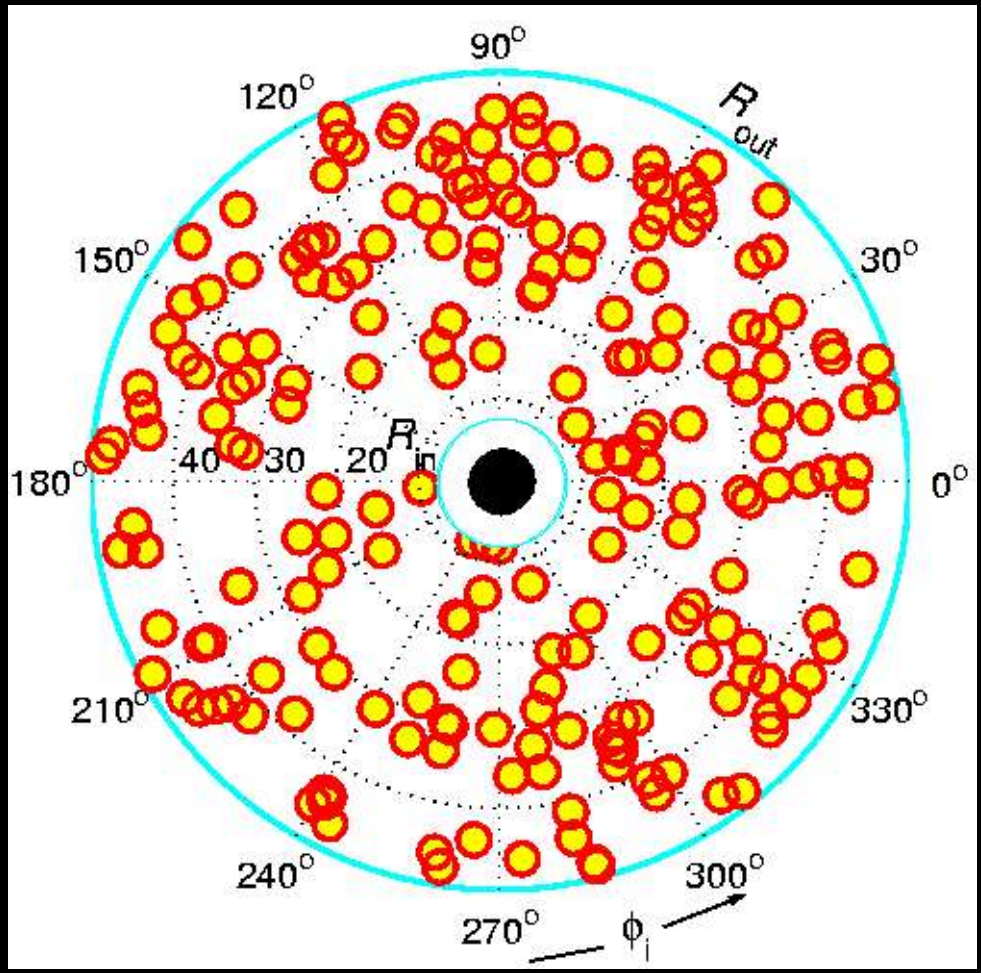
flares at various disk radii

Modeling many flares

Calculation of fractional variability spectra from Monte-Carlo simulations of flares distributed above the disk

Attempt to model the fractional variability spectrum of the Seyfert galaxy MCG -6-30-15

--> Goosmann et al. 2006
astro-ph/0604156



Randomly distributed flares above an accretion disk (Czerny et al. 2004)

Modeling many orbiting flares

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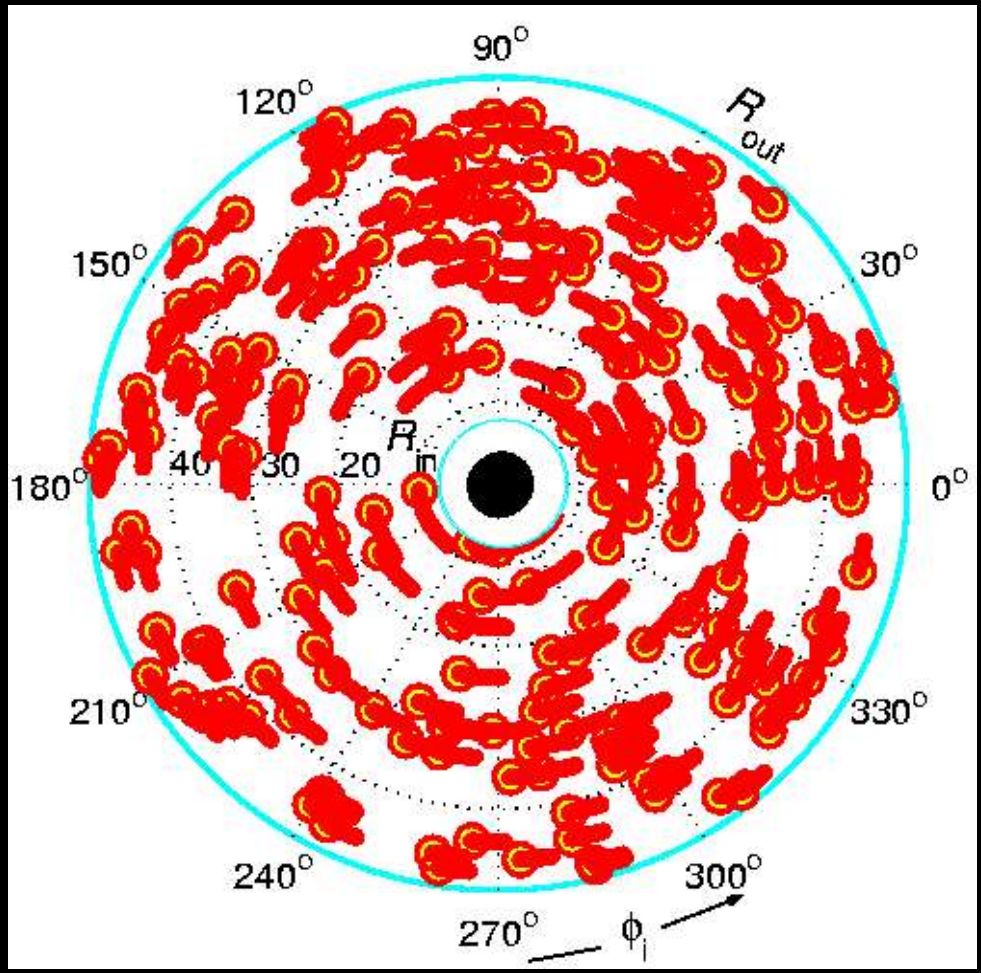


Randomly distributed flares above an accretion disk (Czerny et al. 2004)

Long-term modeling of MCG-6-30-15

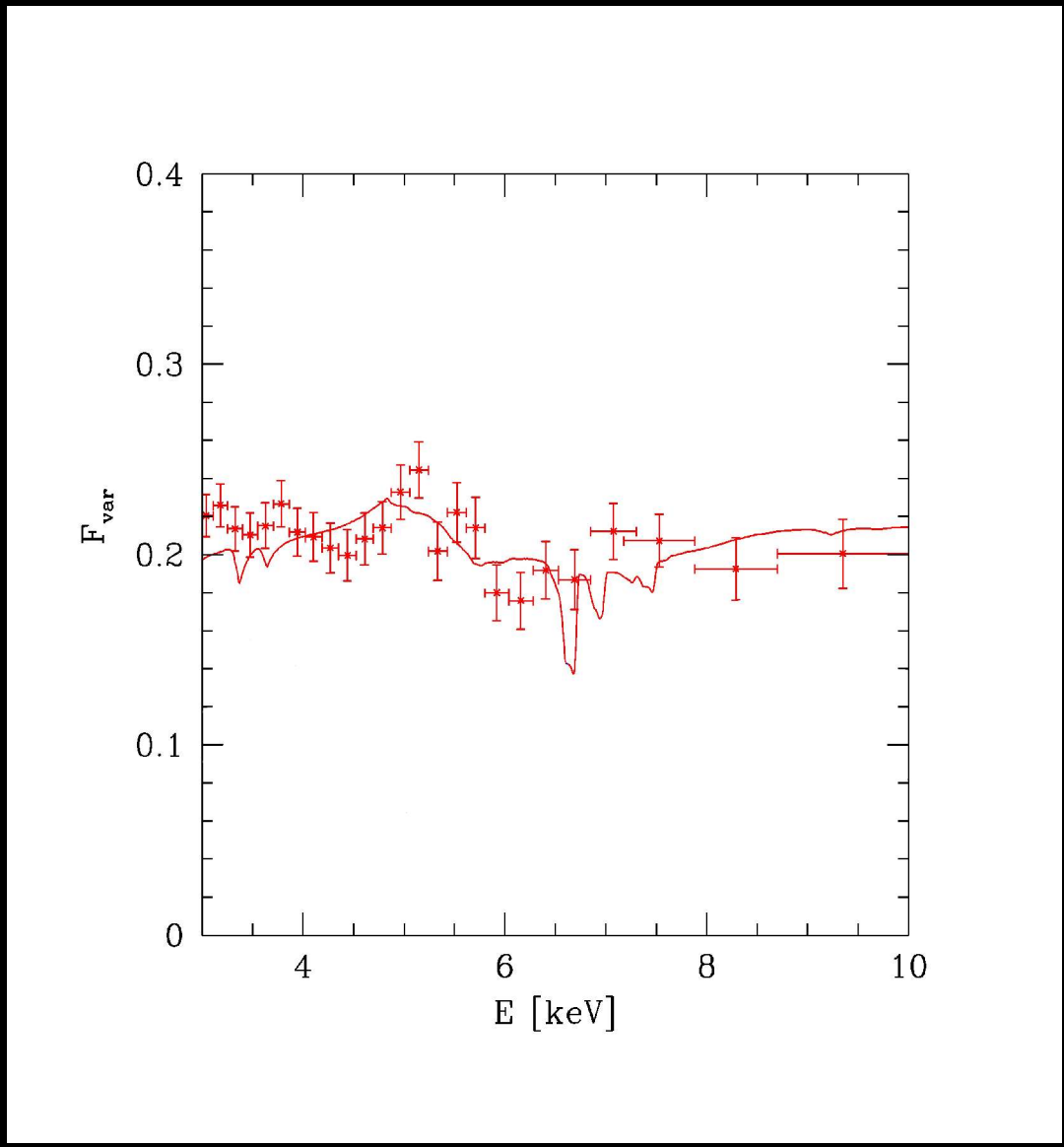
Satisfying representation of the observed rms-spectrum of MCG-6-30-15 for:

--> Black hole spin a = 0.95

--> Life-time of the flares scales with the Keplerian time-scale

--> Concentration of spot luminosity toward the disk center

--> Reflection dominated spectrum is needed



Conclusions

--> The irradiated spot underneath a magnetic flare is structured. The reprocessed spectrum depends on the location inside the spot and on the local emission angle.

--> Short-term flares should show characteristic lightcurves and Kα-line profiles depending on the inclination. However, such flares are still far from being observable with current technology.

--> Monte-Carlo simulations of flare distributions across an accretion disk correctly reproduce the observed fractional variability of the Seyfert galaxy MCG-6-30-15. This helps to constrain the black hole spin of the object, its radial luminosity profile, and the amount of disk reflection.