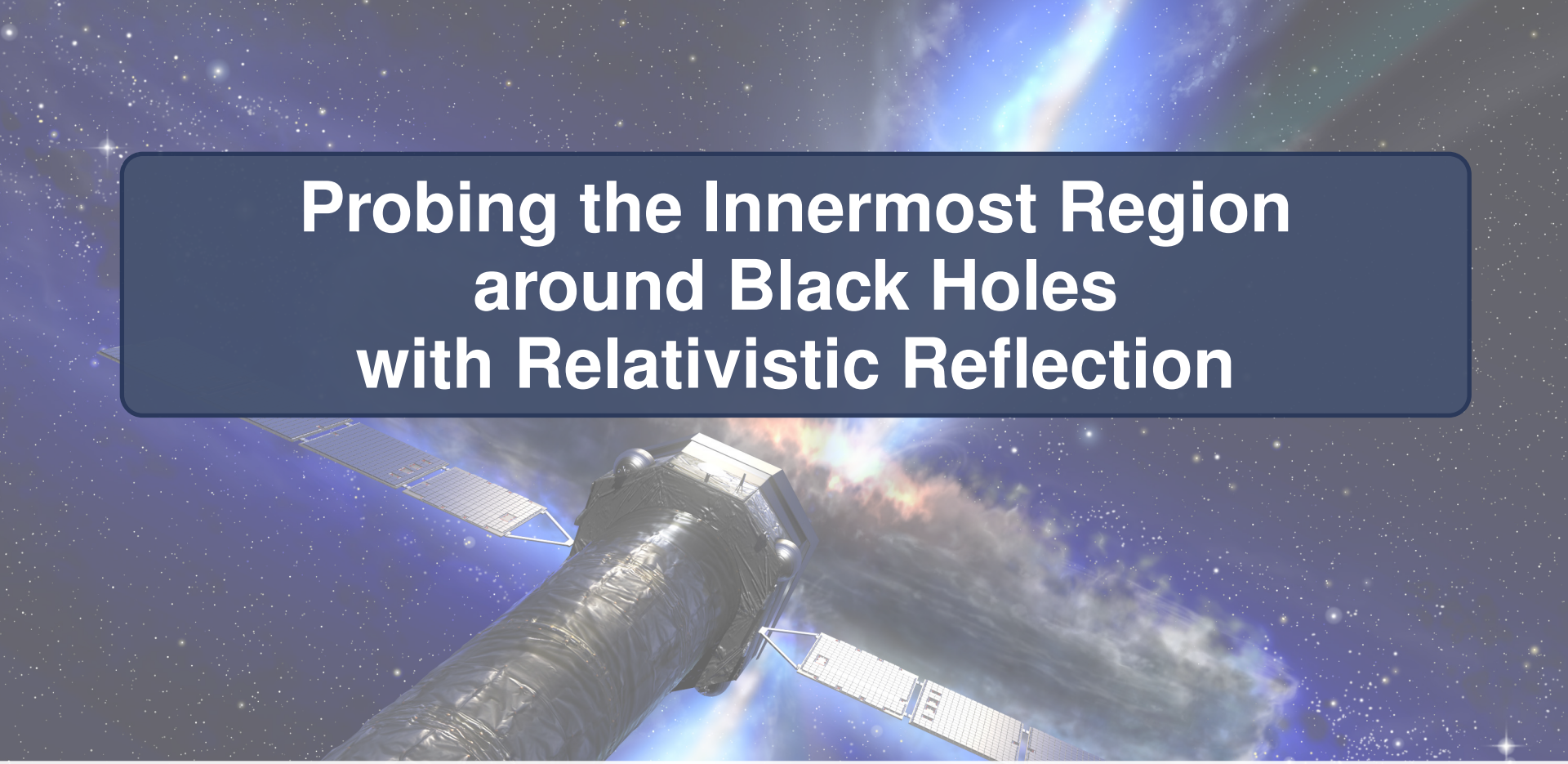
Probing the Innermost Region around Black Holes with Relativistic Reflection



Thomas Dauser – Remeis Observatory Bamberg & ECAP

in collaboration with P. Weber (Remeis), A. Jocye (Remeis), O. König (ECAP), J. Wilms (Remeis), J. García (Caltech), R. Connors (Caltech), C.S. Reynolds (IoA), and many more

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

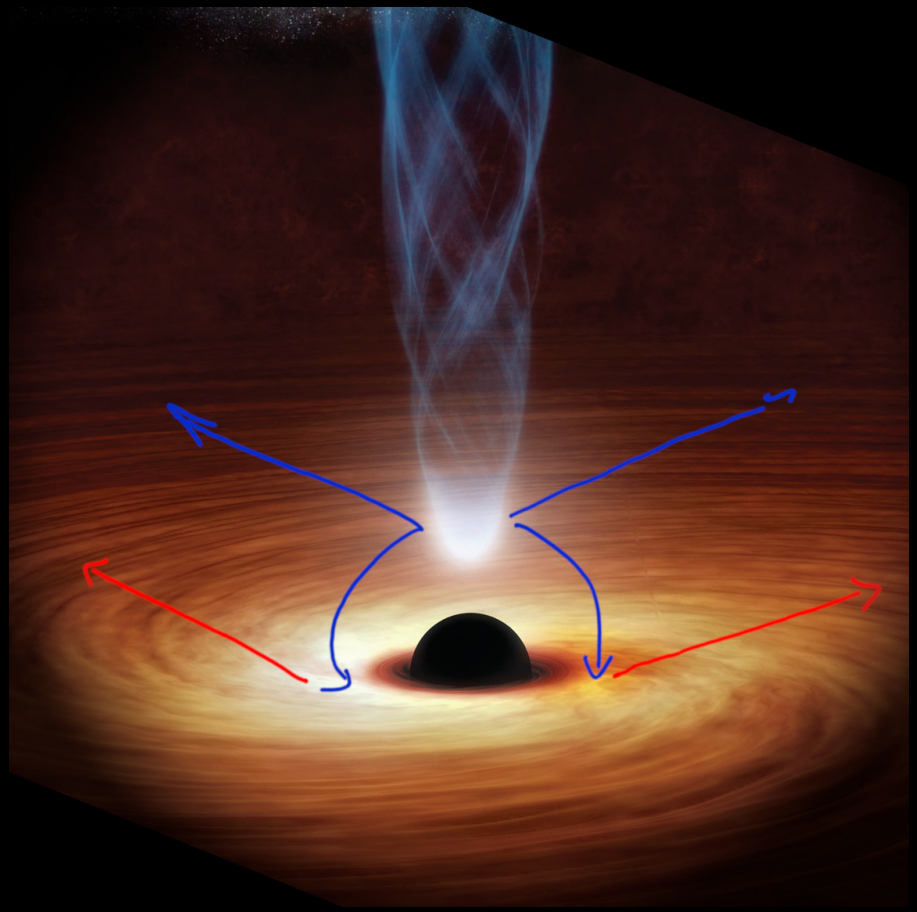
ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

ATHENA

The Innermost Region

NASA/Caltech-JPL

The Innermost Region: Reflection



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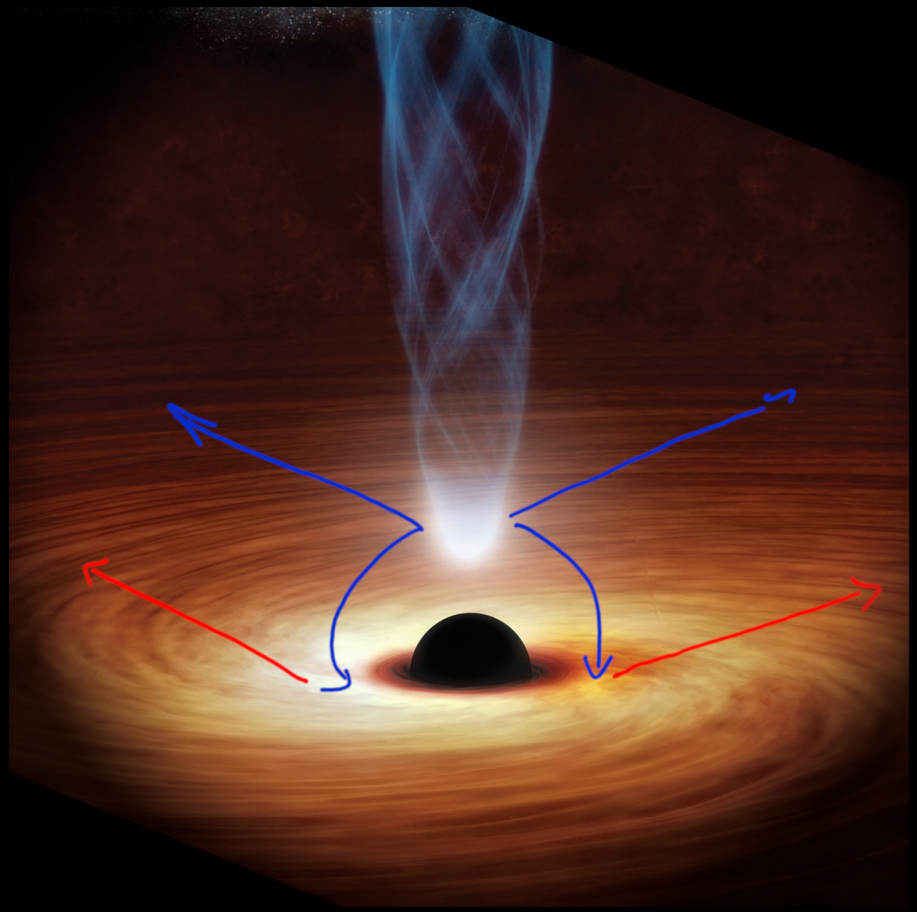
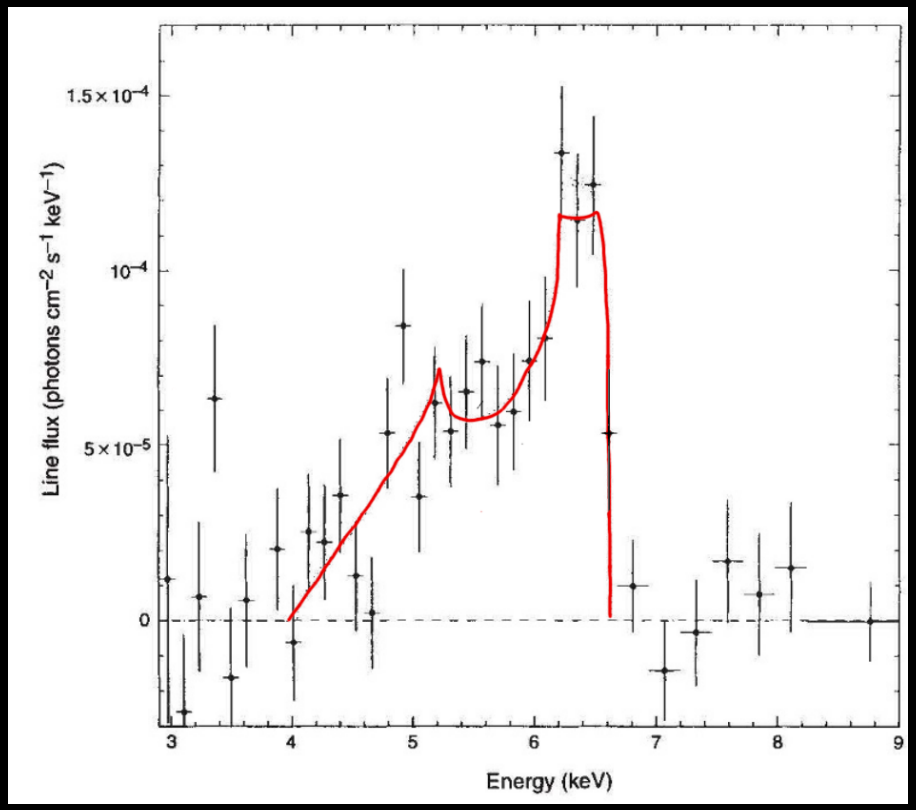
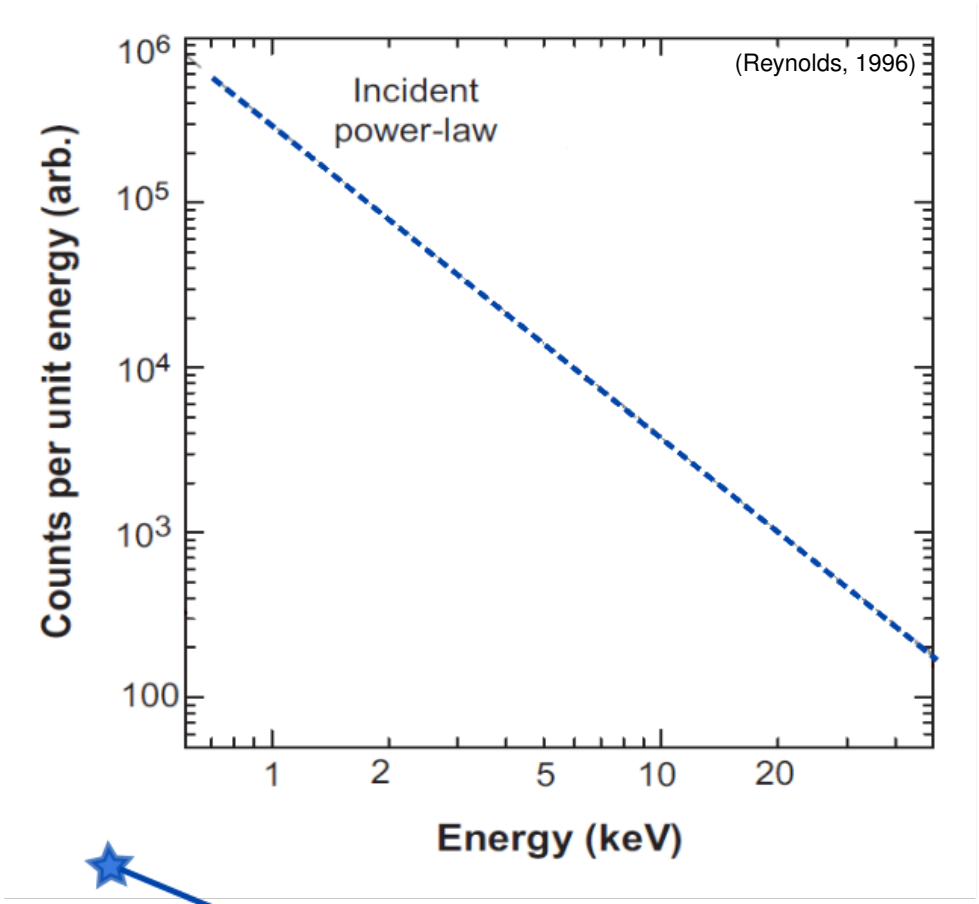


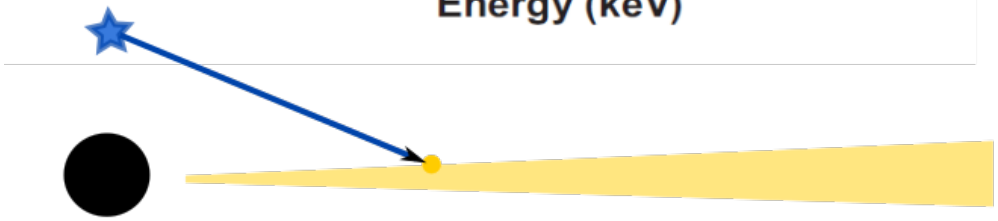


First detection: **ASCA observations of the AGN MCG−6-30-15**

Tanaka et al. (1995): "*The most plausible mechanisms which can produce this extensive red wing are* ***Doppler and gravitational shifts*** ***close to the central black hole****.* "

Reflection at the Accretion Disk





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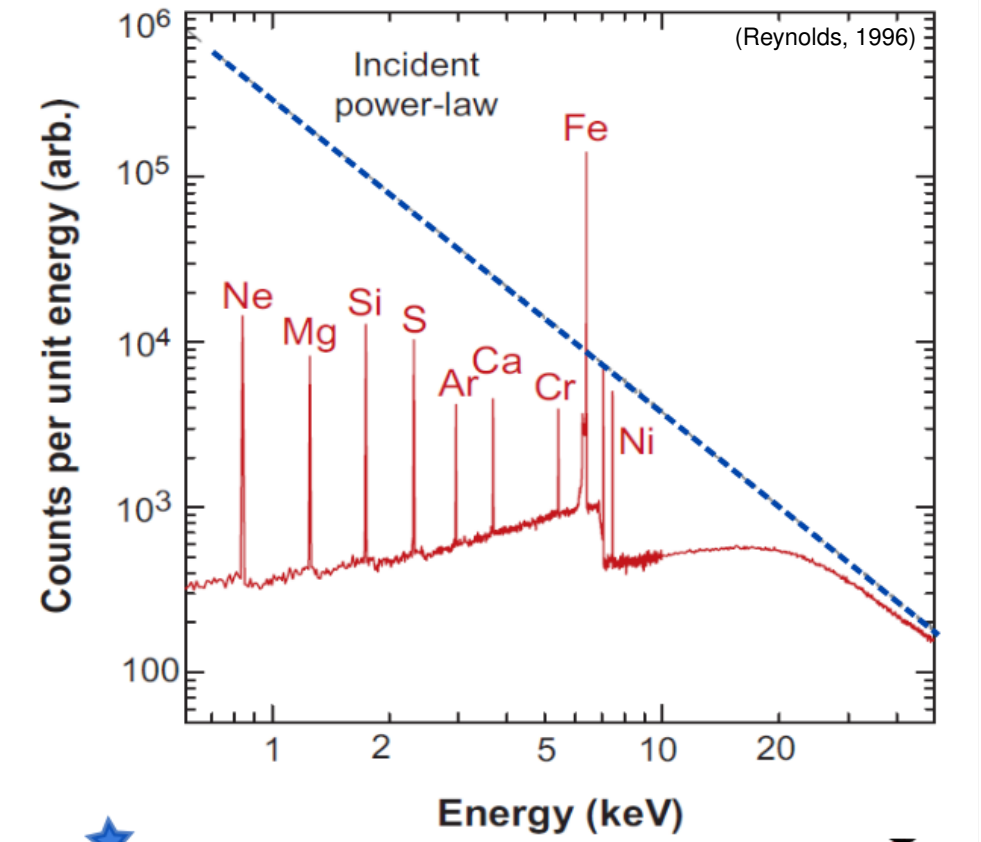
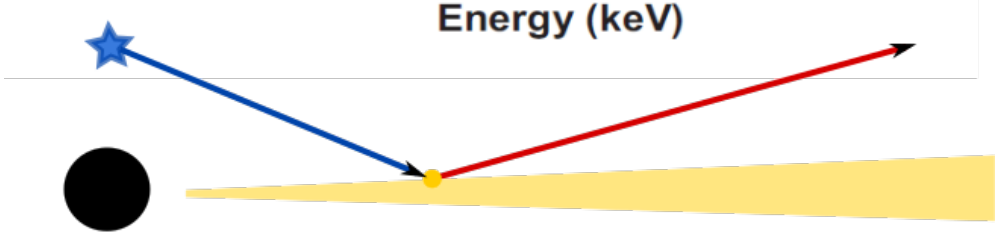
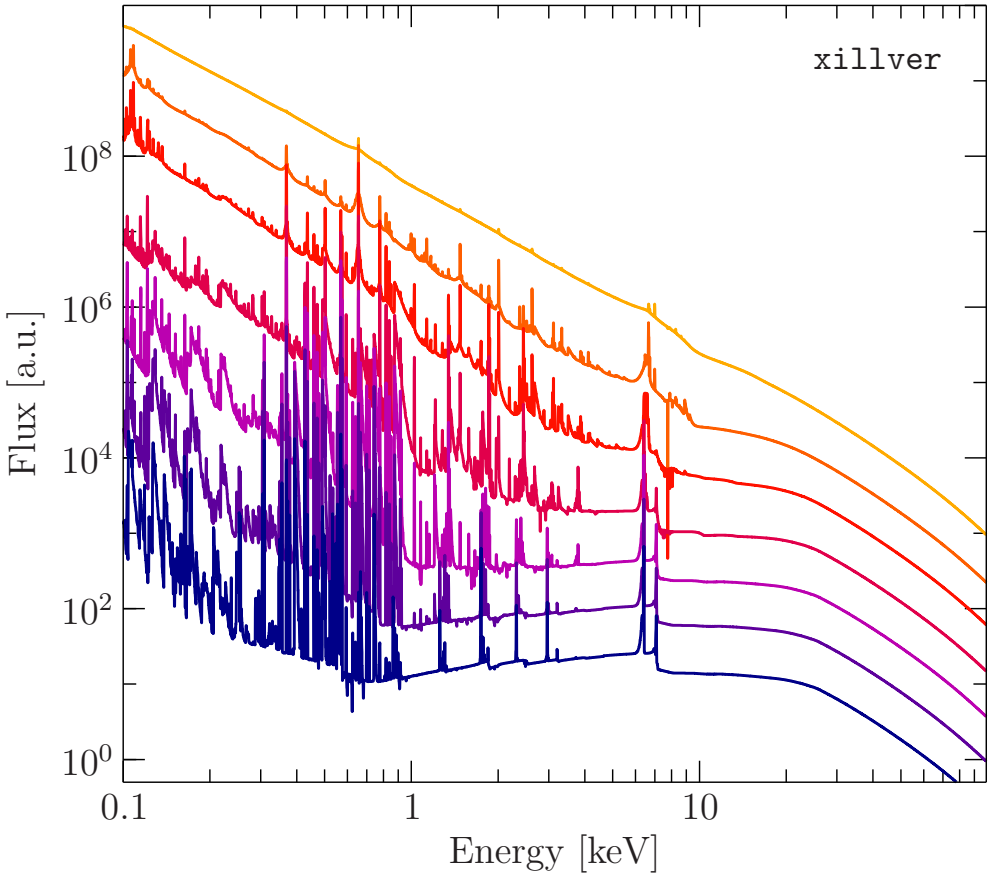




Reflection on cold accretion disk produces **fluorescent line emission** and **Compton scattering**
(Matt et al., 1991; Reynolds, 1996, ...)

Reflection at the Accretion Disk

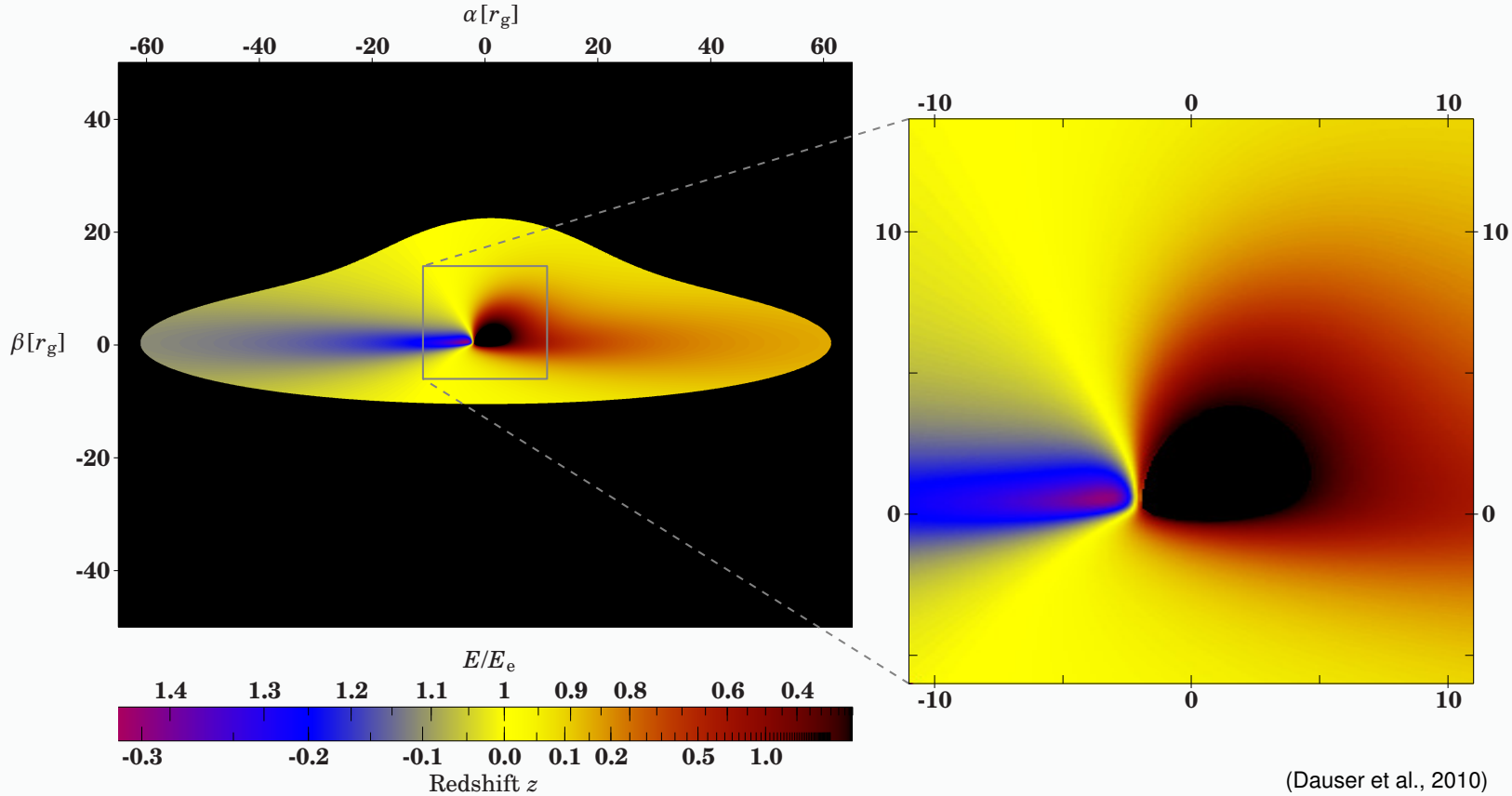


Reflection on cold accretion disk produces **fluorescent line emission** and **Compton scattering**
(Matt et al., 1991; Reynolds, 1996, ...)

irradiation ionizes the disk, strongly affecting the reflection
(Ross & Fabian, 1993; Rozanska & Czerny, 1996; Nayakshin & Kallman, 2001; Dumont et al., 2002; Ross & Fabian, 2005; Garćia et al., 2011, ...)

$\Rightarrow$ **complex spectrum containing a wealth of information**

Relativistic Broadening: Effects Close to the Black Hole



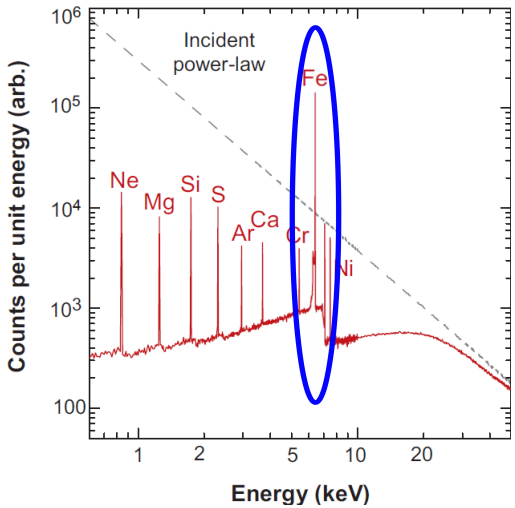
(Dauser et al., 2010)

Rotating black hole: Metric depends on **M** (mass) and *a* (spin)

$\rightarrow$ special relativistic beaming, light bending, and gravitational redshift

(Kerr, 1963; Cunningham, 1975; Fabian et al., 1989; Laor, 1991; Dovčiak et al., 2004; Dauser et al., 2010)

Relativistic Effects Close to the Black Hole



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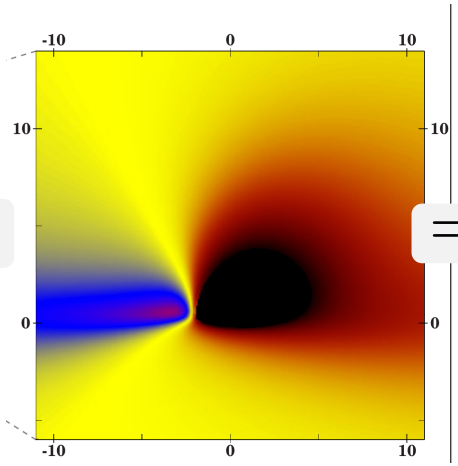
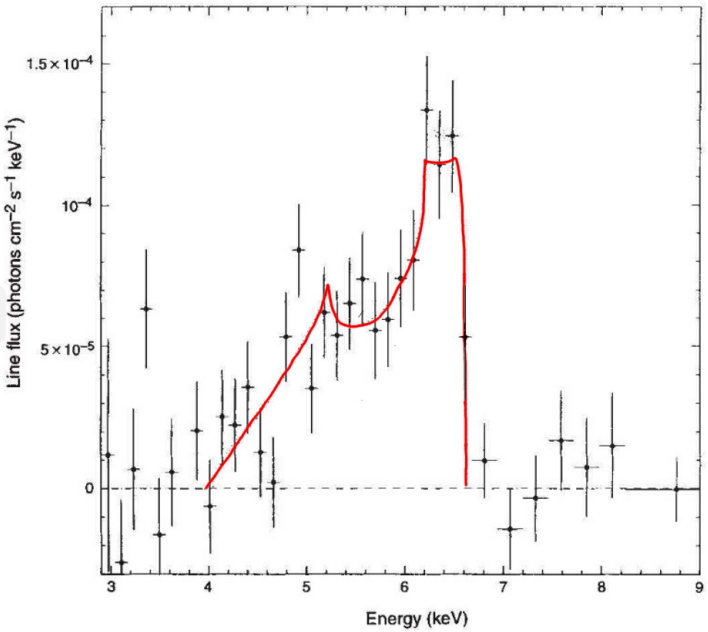
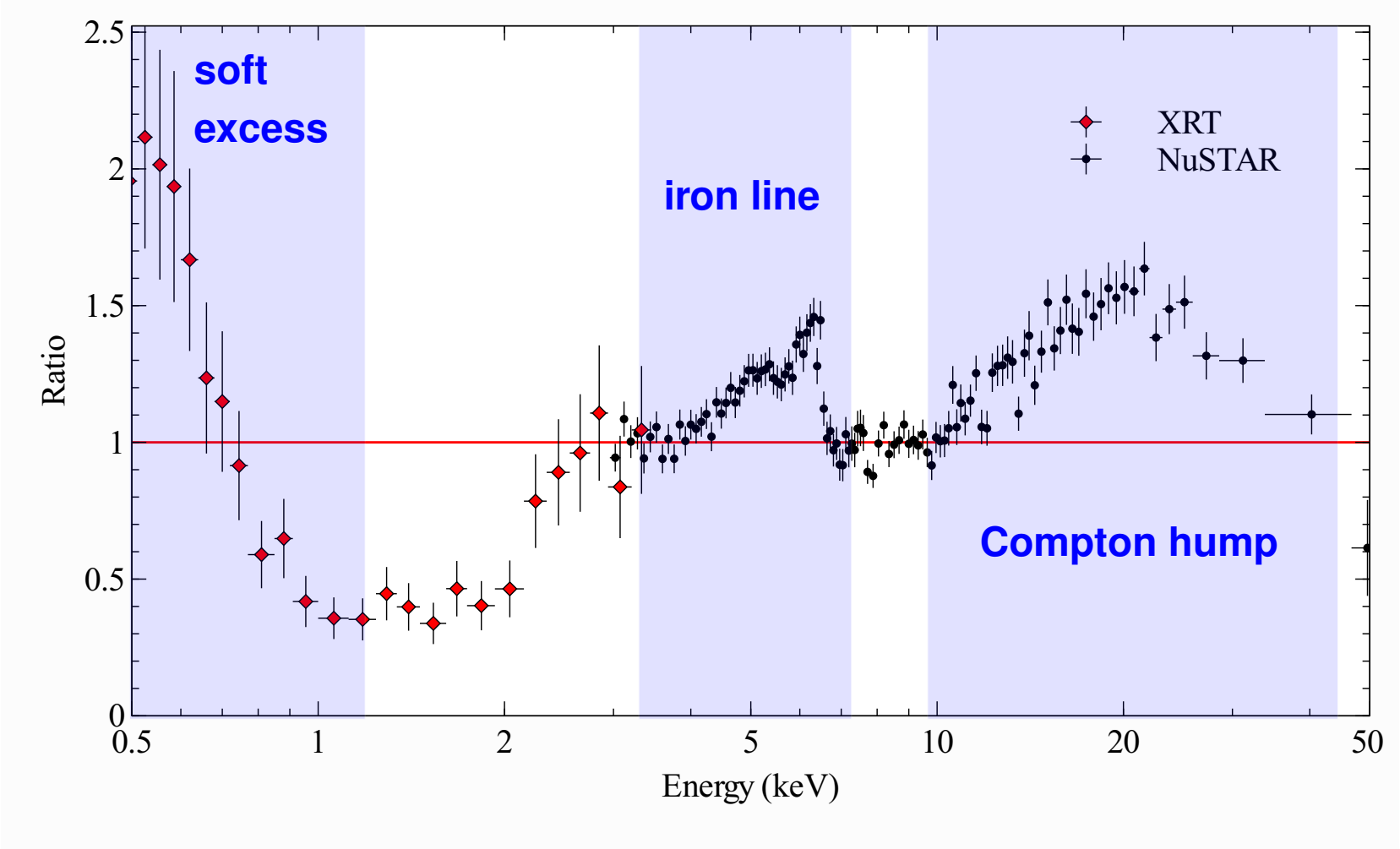


⇒



Relativistic Reflection from the Innermost Region

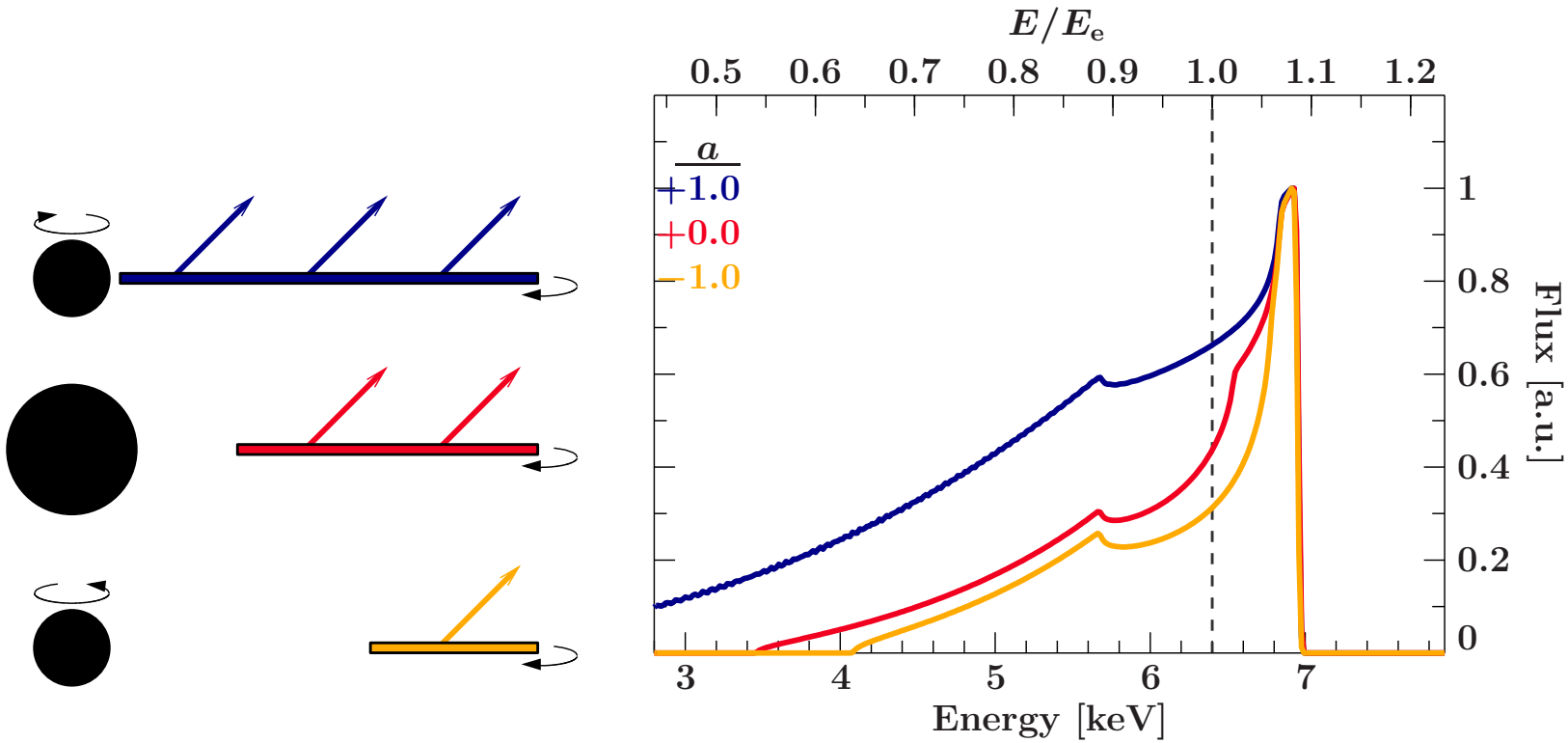
Mrk 335 observed with NuSTAR and Swift (Parker et al., 2014)



Strong broadening of **multiple reflection features**

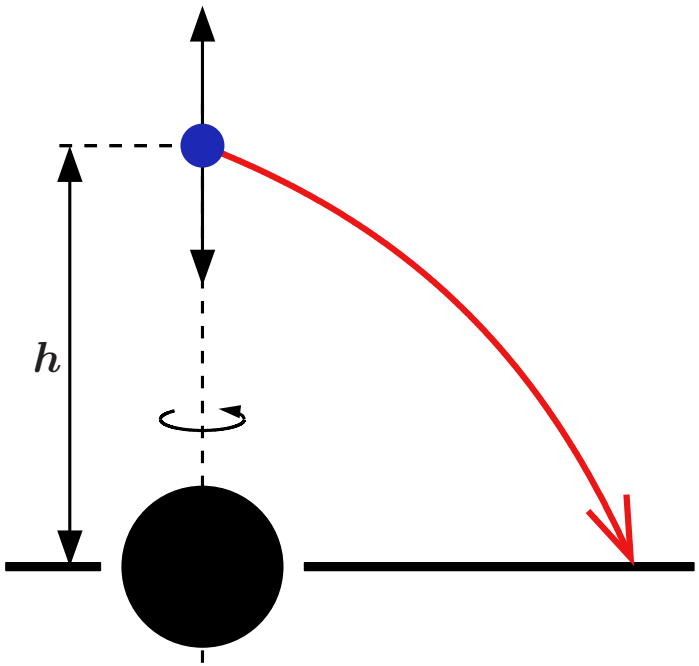
$\Rightarrow$ emission from just outside the event horizon

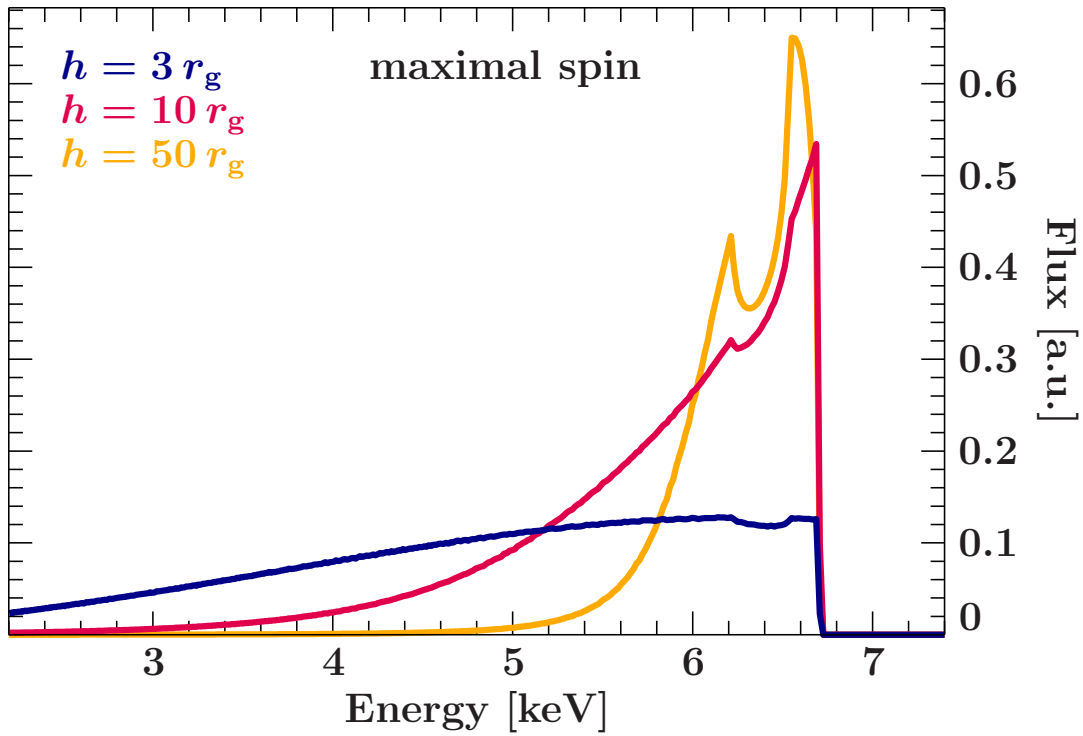
Relativistic Effects: Black Hole Spin



high spin ⟶ smaller inner radius ⟶ **broad line**

Relativistic Effects: Probing the Primary X-ray source





low height $\Rightarrow$ **enhanced irradiation** of the **inner parts**

Relativistic Reflection: a Tool to understand Black Holes

(1) powerful method for measuring the spin of a black hole

→ link between black hole spin and the creation of jets (Blandford & Znajek, 1977)?

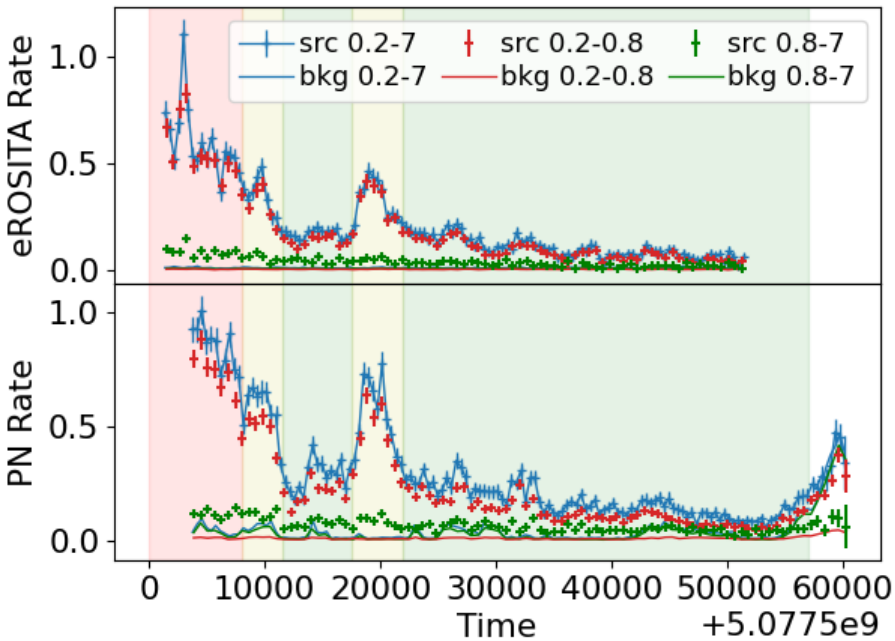
→ galaxy evolution models predict different spin distributions

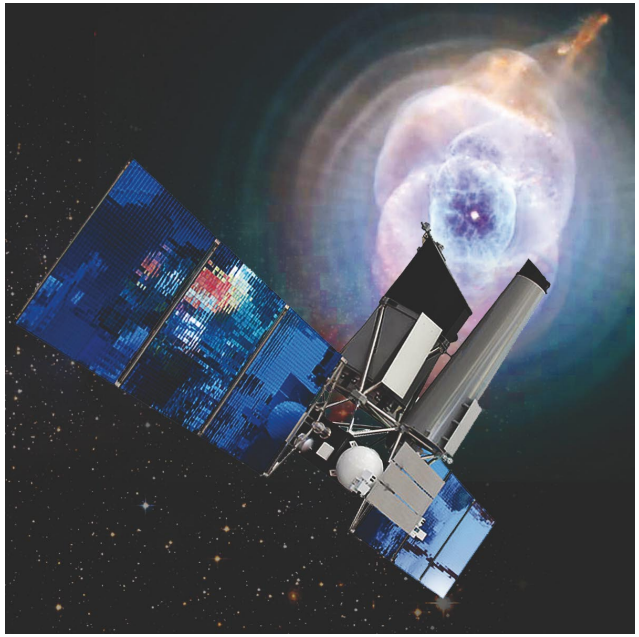
(2) study the closest environment around black holes

→ what is the nature and location of the primary source of X-rays?

eROSITA/XMM-Newton observation of 1H0707−495

Boller et al. (2021)





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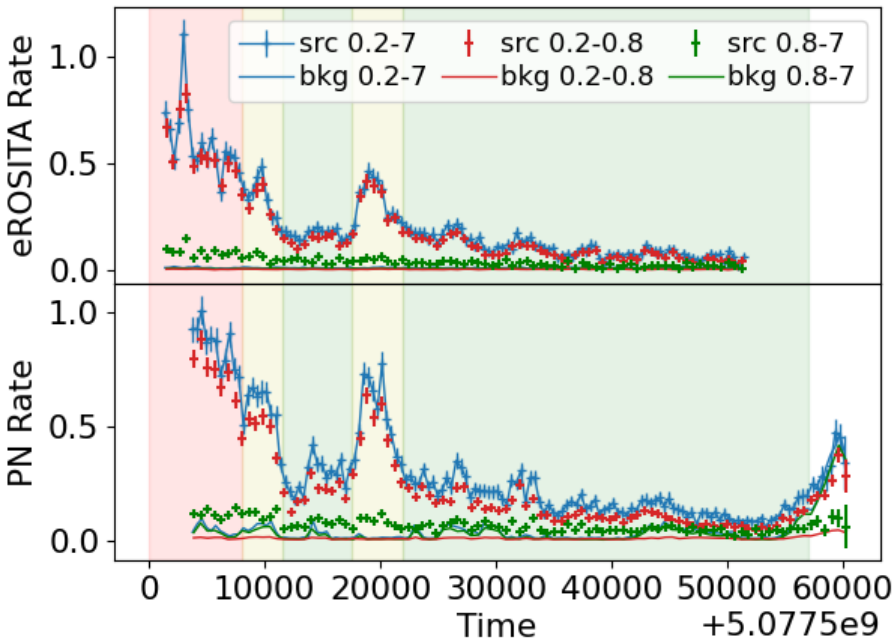
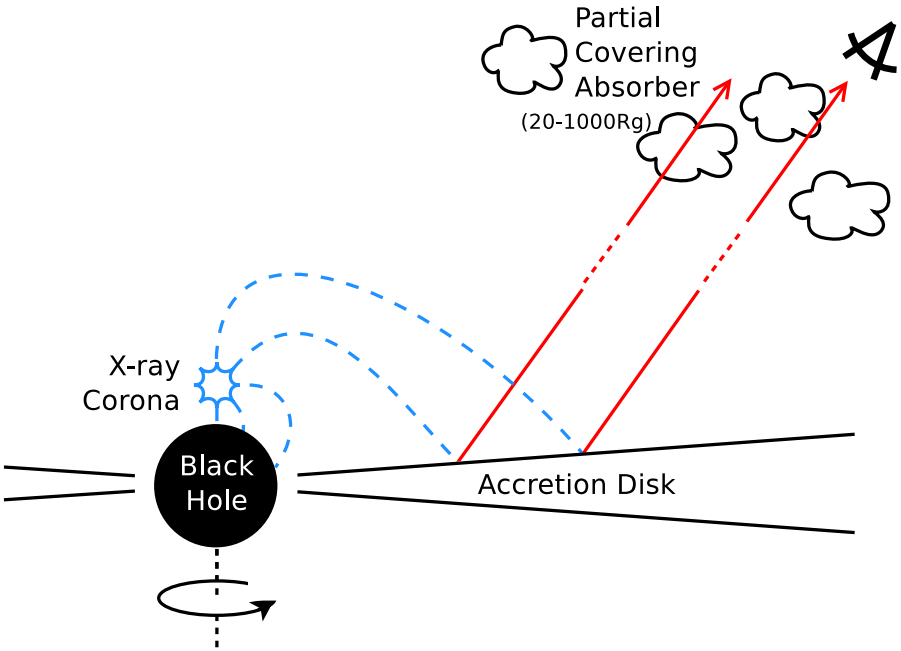
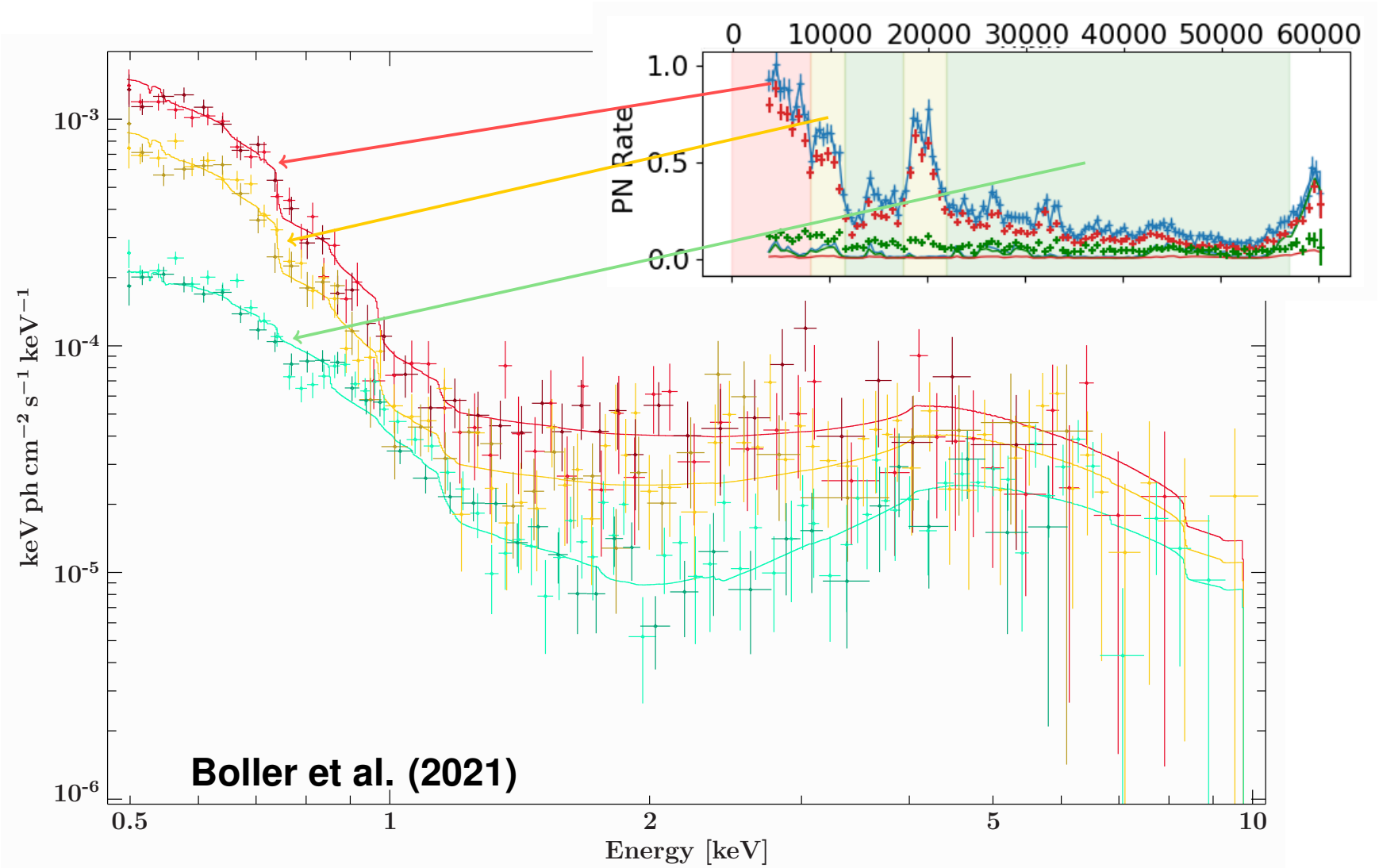




soft flux variability and strong relativistic reflection: explained by a **variable partial covering absorber** and **constant corona**

eROSITA/XMM observation of 1H0707−495



⇒ high spin ($a = 0.996 \pm 0.003$) and compact corona ($h = 1.4 \pm 0.1\ R_{\rm g}$)

⇒ not possible to constrain the ionization of the absorbing clouds

Athena X-IFU Simulation of 1H0707−495 observation

next generation X-ray observatory (to be lanuched in the 2030s)

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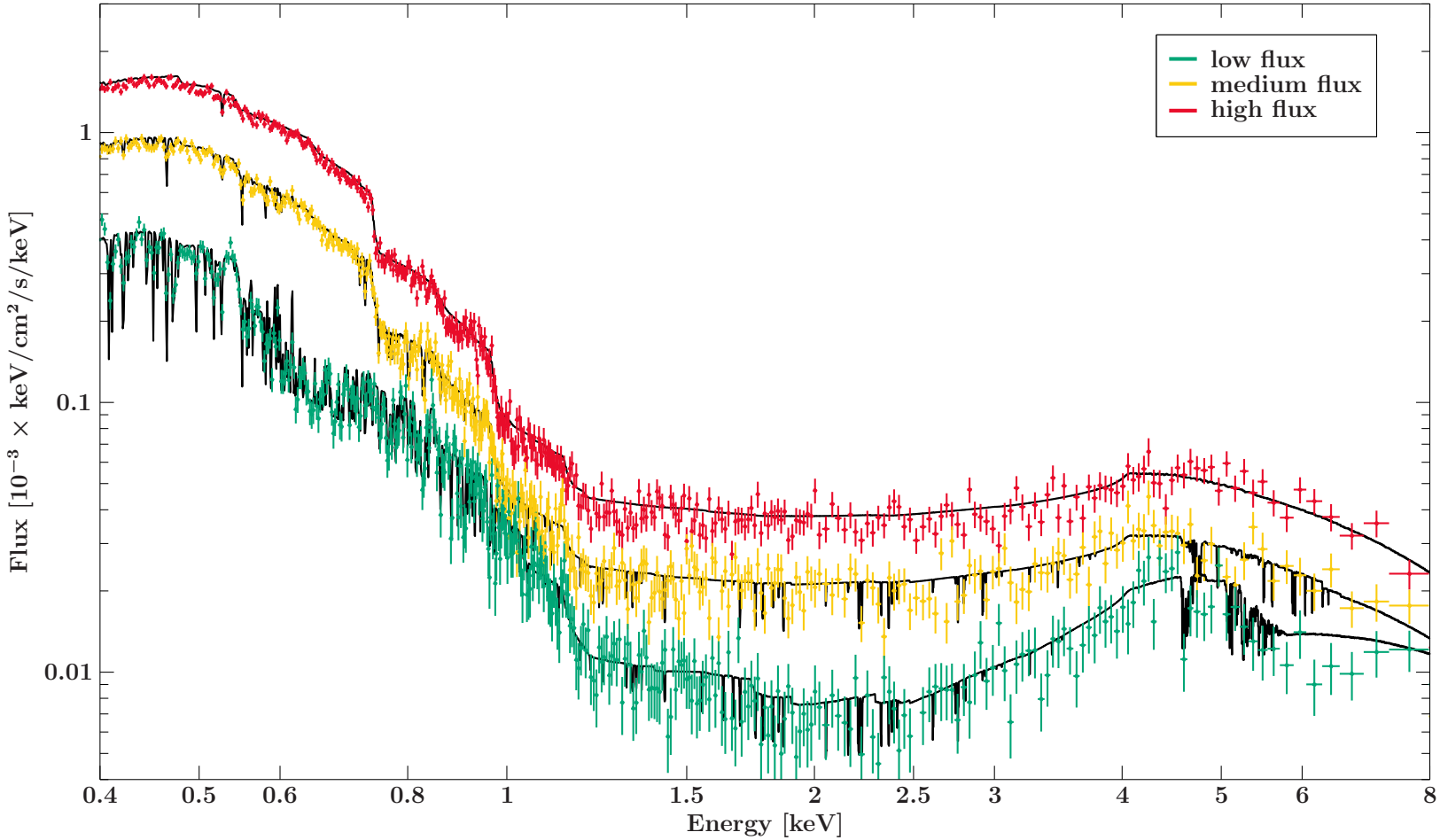

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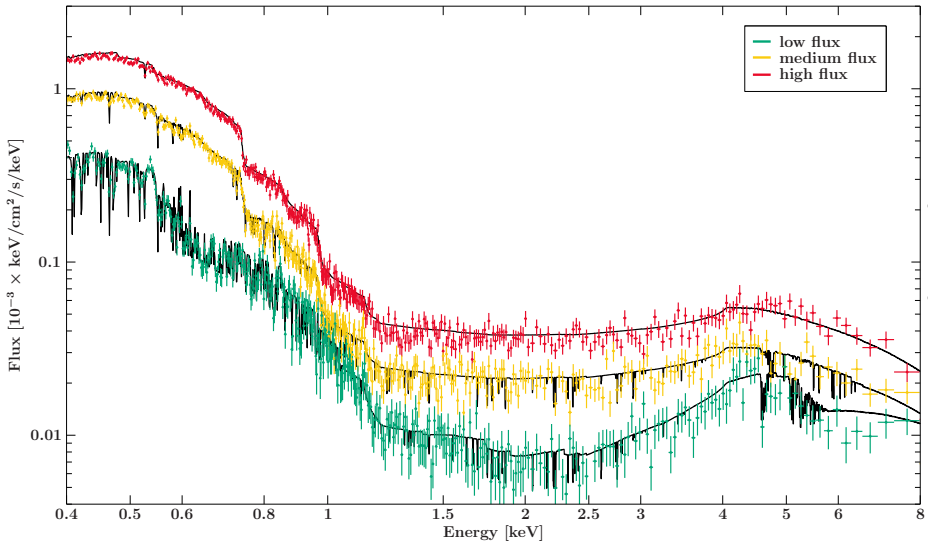

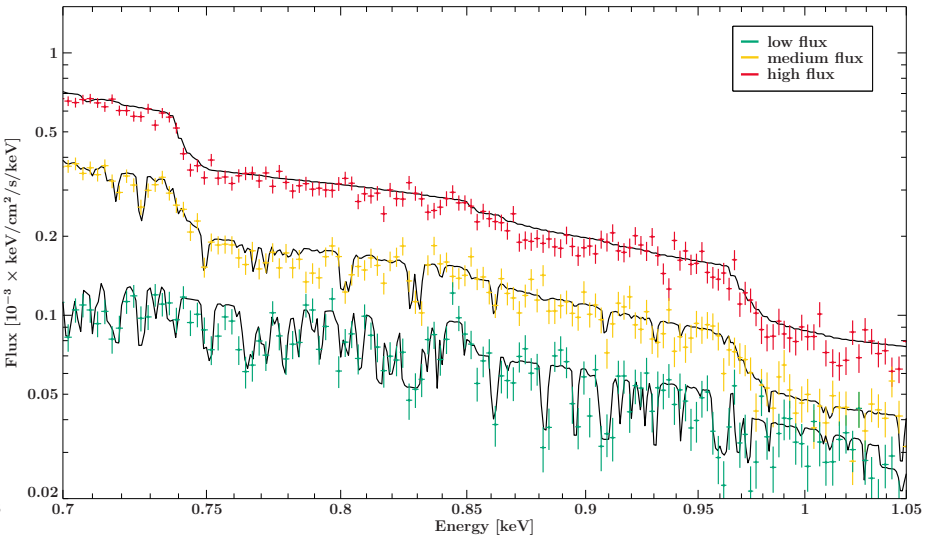

measure on typical timescales of such obscuration events (∼hours):

- **absorber properties** (ionization, column density)
- **relativistic parameters** (spin, height of the corona)

Summary

(1) Relativistic reflection is complex, but uniquely probes the vicinity of BHs: spin, primary X-ray source, accretion disk ionization, . . .

(2) Strong relativistic reflection observed in several sources: produced by a compact X-ray source above the black hole

(3) Observations: Complex Absorption and Instrinsic Variability: doable, large improvement by next generation X-ray telescopes

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