Accretion disk geometry in the low/hard state of black-hole binaries

A spectral analysis of the black-hole candidate Swift J1753.5-0127

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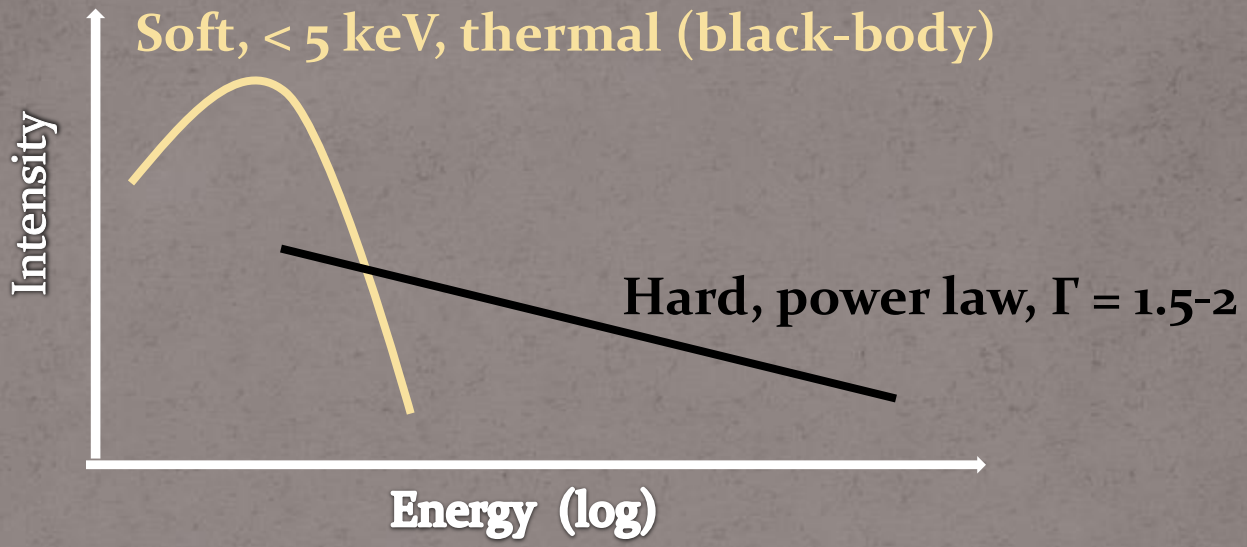
Spectral states of black-holes

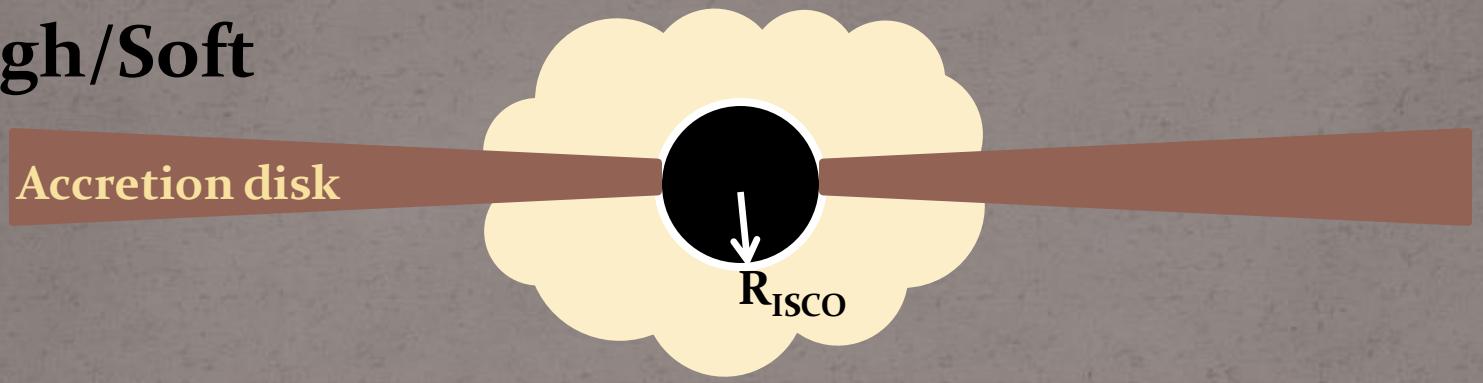


Soft emission originates from standard accretion disk

Hard emission produced by inverse Comptonizing corona

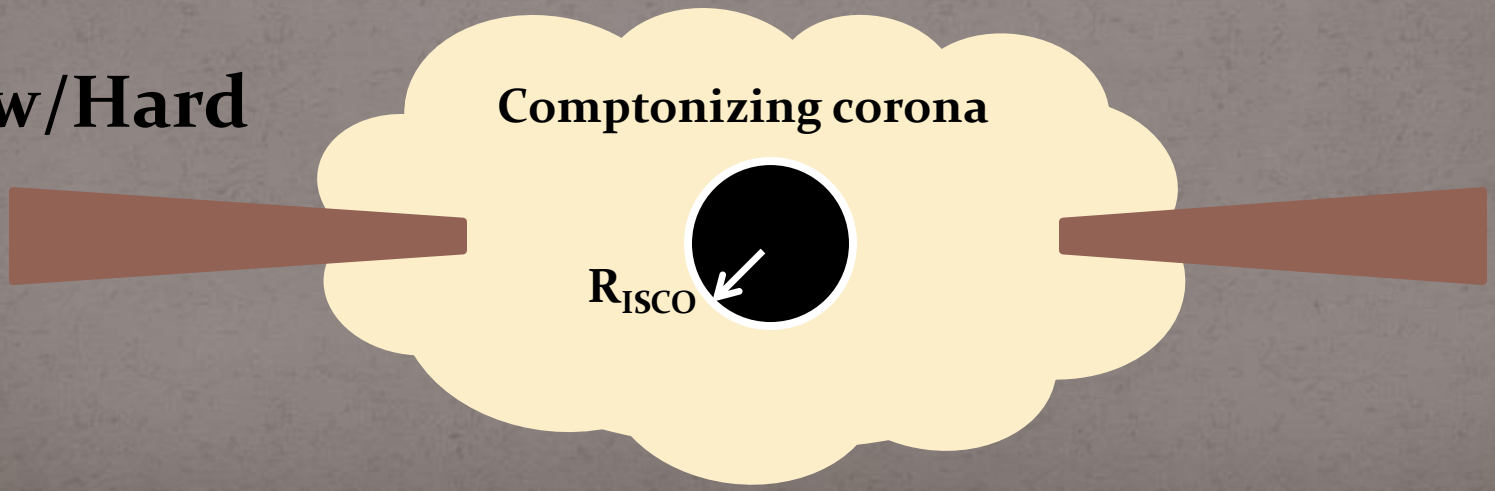
Accretion disk geometry

High/Soft



STANDARD SCENARIO

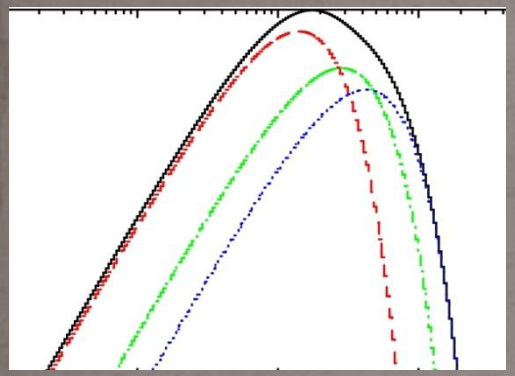
Low/Hard



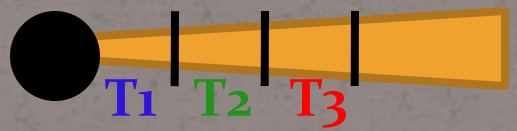
How do they come to this?

- Multi-color black-body disk model

(Shakura & Sunyaev 1973; Mitsuda et al. 1984)



$$T(R) \propto R^{-3/4}$$



H/S state: R_{in} constant ➔ ISCO (Tanaka 1992)

L/H state: sources at low absorption cool disk truncated at large radii (McClintock et al. 2001)

How do they come to this?

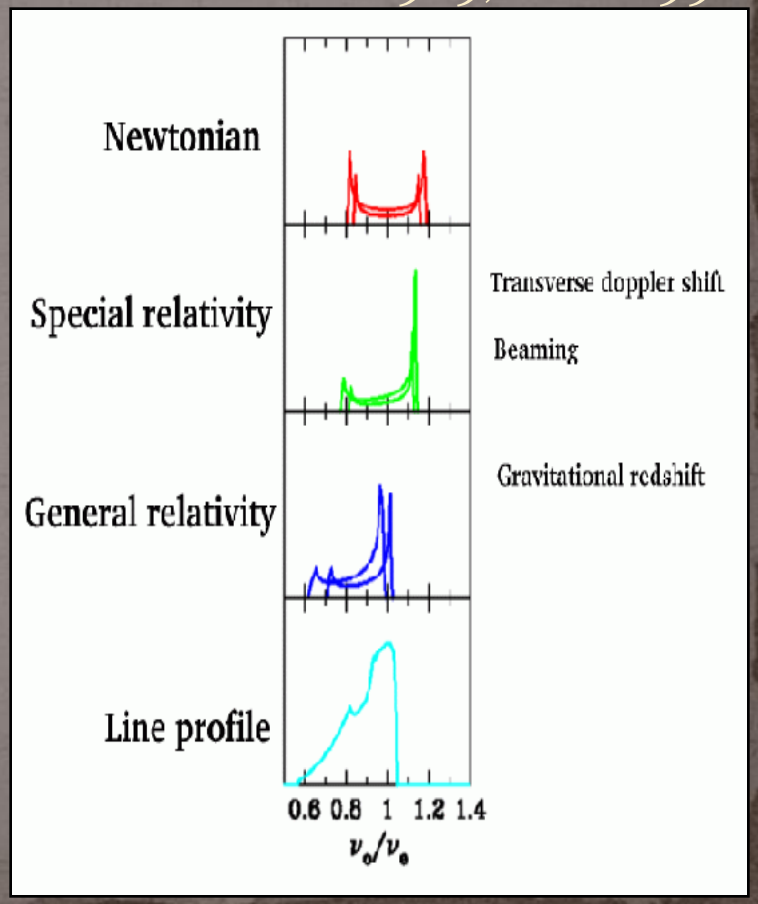
Iron emission line:

- Produced by Comptonized photons reflected off the disk
- Profile due to disk rotation and relativistic effects

Line profile is used to deduce the inner disk radius

- Broad lines in HSS
- No/narrow in LHS

Fabian et al. 1989; Laor 1991



Is the disk truncated in the LHS?

Iron line in low/hard state:

- GX 339-4 (Miller et al. 2006b)

Soft excess in low/hard state:

- Swift J1753-0127 (Miller et al 2006a)
- GX 339-4 (Miller et al. 2006b)
- XTE J1817-300 (Rykoff et al. 2007)

  $T \approx 0.2\text{-}0.3$ keV ➔ $R_{in} \sim 2\text{-}6\ R_g$

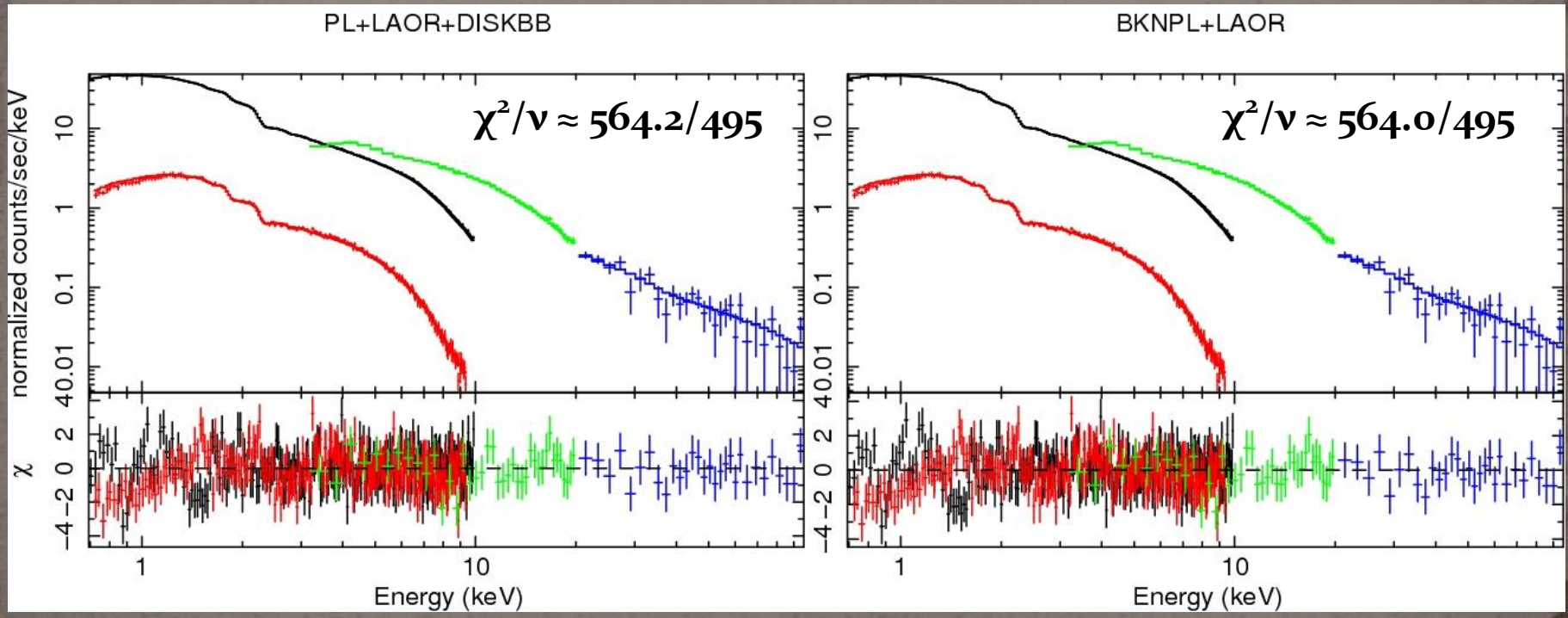
What we did?

- (Re)-analysis of XMM-Newton/RXTE data of Swift J1753-0127 in the Low/Hard state
  - same data as Miller et al. 2006a: soft excess, non-truncated disk

- Fitted several continuum and line models **(XSPEC)**
  - with and without disk component, to test whether soft emission is required

Results

No disk component required, but data also consistent with models including a thermal component: we find 2-3 less flux than Miller et al. (2006a)

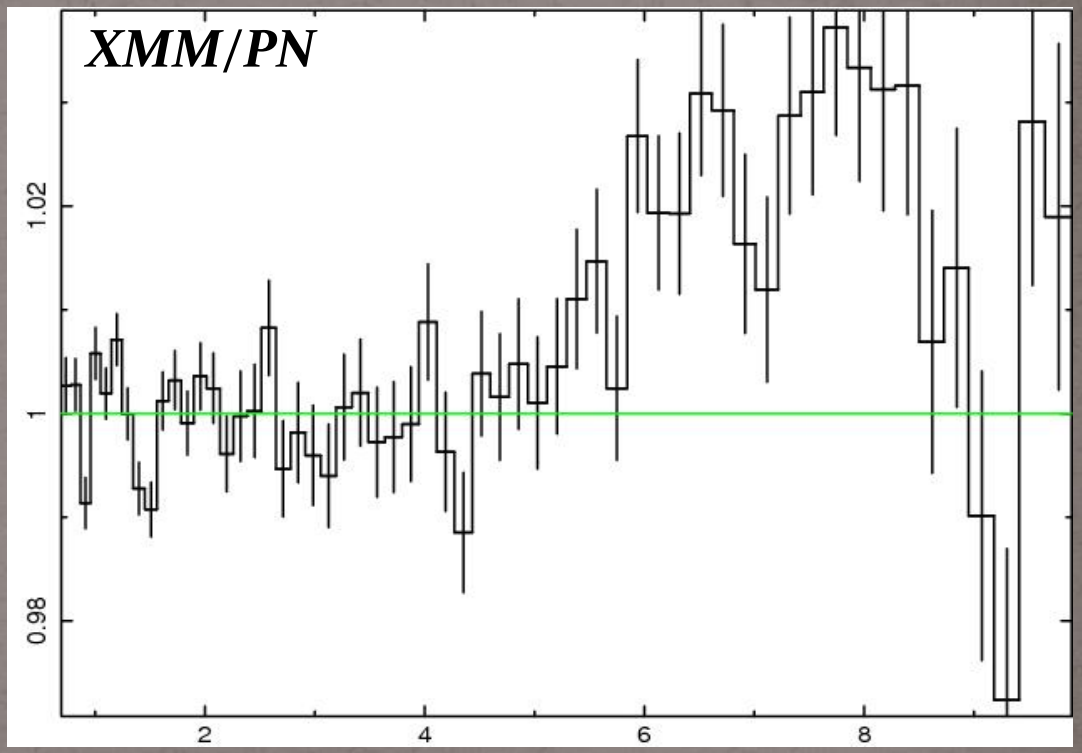


Results

Significant broad Fe line around ~7 keV present

Line properties

- Broad: ~5-9 keV
- EW: 60-187 eV, depending on model
- R_{in}: ~2-16 R_g, depending on profile



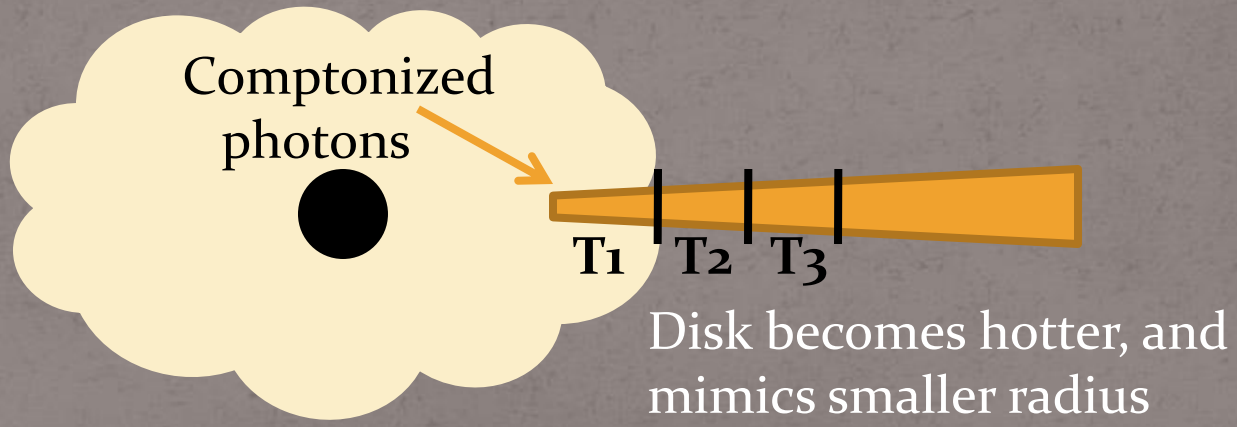
Cannot exclude if disk is truncated or not...

Alternative models

Soft excess:

Irradiation of disk by Comptonized photons, inner disk radius is underestimated with a factor of 2-3

(Gierlinski et al. 2008)



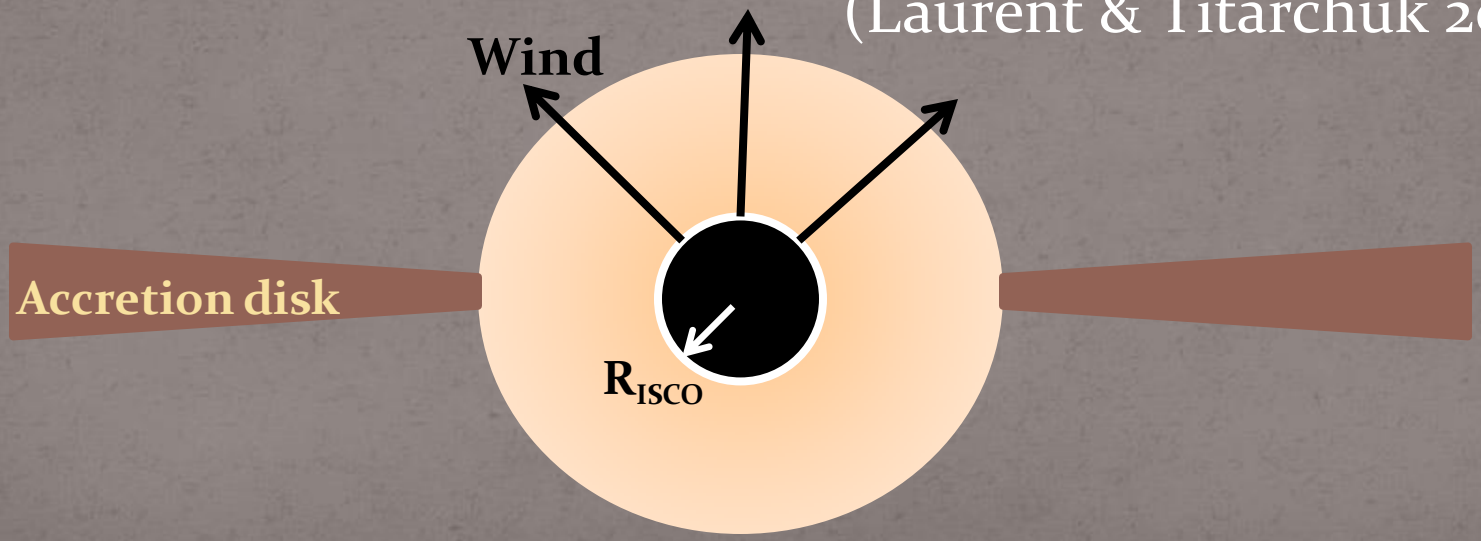
Note: we did not include this irradiation in our analysis

Alternative models

Line broadening mechanism:

Properties of iron line can be explained in terms of down-scattering of hard photons in a Comptonizing outflow, with an optical depth >1

(Laurent & Titarchuk 2007)



Summary

- Disk geometry in the low/hard state of black holes is still a point of debate.
- Spectral analysis of Swift J1753-0127 does not provide any definite answer.

Things to keep in mind:

- Alternative models for soft emission and line broadening mechanisms. More interpretations are possible (future work)
- Line profile depends on underlying continuum

More information…

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Discovery of a broad iron line in the black-hole candidate Swift J1753.5−0127, and the disk emission in the low/hard state revisited.

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ABSTRACT
We analyzed simultaneous archival *XMM-Newton* and *RXTE* observations of the X-ray binary and black hole candidate Swift J1753.5−0127. In a previous analysis of the same data a soft thermal component was found in the X-ray spectrum, and the presence of an accretion disk extending close to the innermost stable circular orbit was proposed. This is in contrast with the standard picture in which the accretion disk is truncated at large radii in the low/hard state. We tested a number of spectral models and we found that several of them fit the observed spectra without the need of a soft disk-like component. This result implies that the classical paradigm of a truncated accretion disk in the low/hard state can not be ruled out by these data. We further discovered a broad iron emission line between 6 and 7 keV in these data. From fits to the line profile we found an inner disk radius that ranges between ∼6–16 gravitational radii, which can be in fact much larger, up to ∼250 gravitational radii, depending on the model used to fit the continuum and the line. We discuss the implications of these results in the context of a fully or partially truncated accretion disk.

Key words: accretion disks, disk states – stars: individual (Swift J1753.5−0127) – X-rays: binaries