What are the inner truncation radii of accretion discs?

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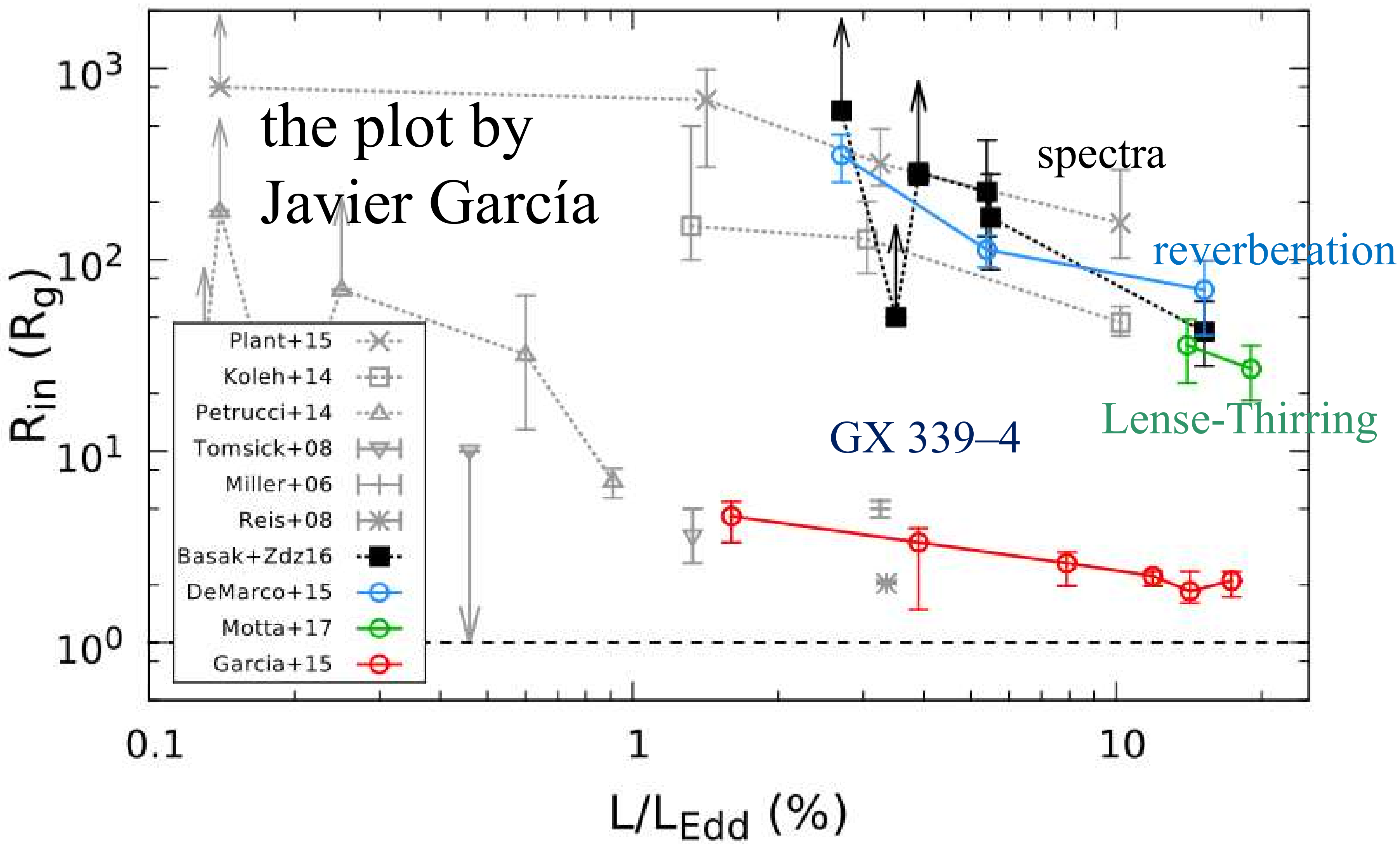
An example controversy: the hard state of GX 339–4



New improved codes for relativistic reflection

- reflkerr, reflkerr_lp, hreflect etc.
- Niedźwiecki, Szanecki & AAZ 2018, arXiv:1805.06065, also Niedźwiecki & AAZ, 2018, MNRAS, 477, 4269, Niedźwiecki, AAZ & Szanecki 2016, ApJ, 821, L1.
- Can be downloaded from users.camk.edu.pl/mitsza/reflkerr

The incident spectra: thermal Comptonization

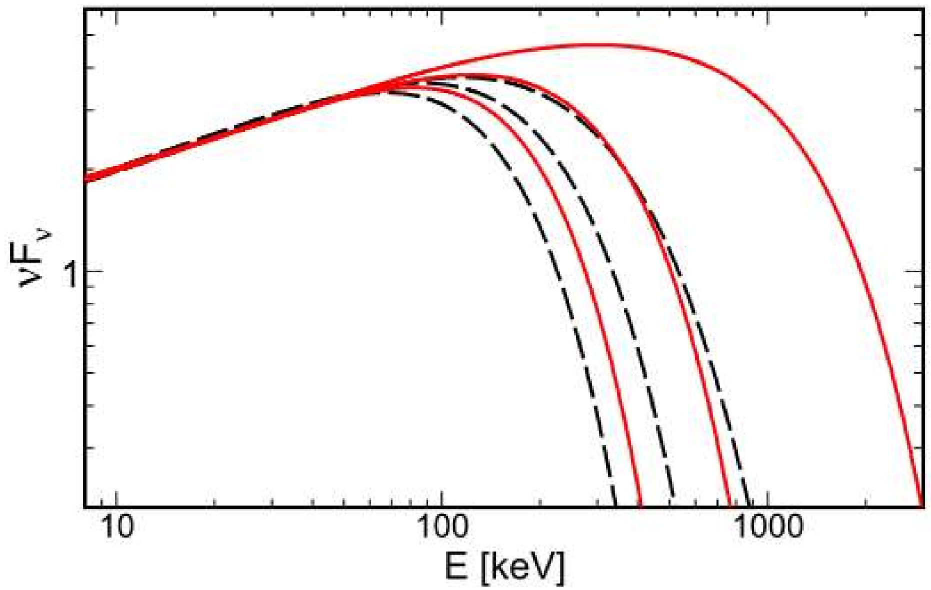


Figure 1. Rest-frame thermal Comptonization spectra for $kT_{\rm bb} = 1$ eV, $\Gamma = 1.7$ and $kT_{\rm e} = 50$, 100 and 400 keV (from left to right) computed with `compps` in spherical geometry (red solid curves) and with `nthcomp` (black dashed curves). We see that `nthcomp` significantly underestimates the positions of the high-energy cutoff.

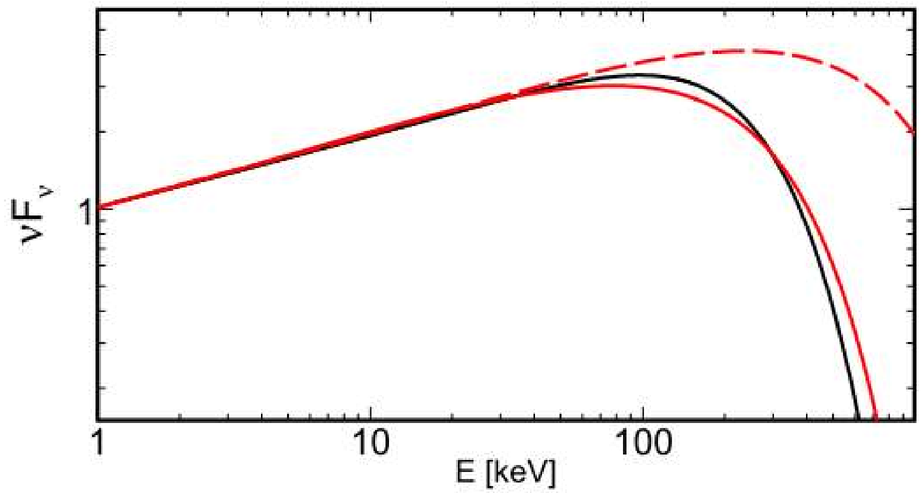
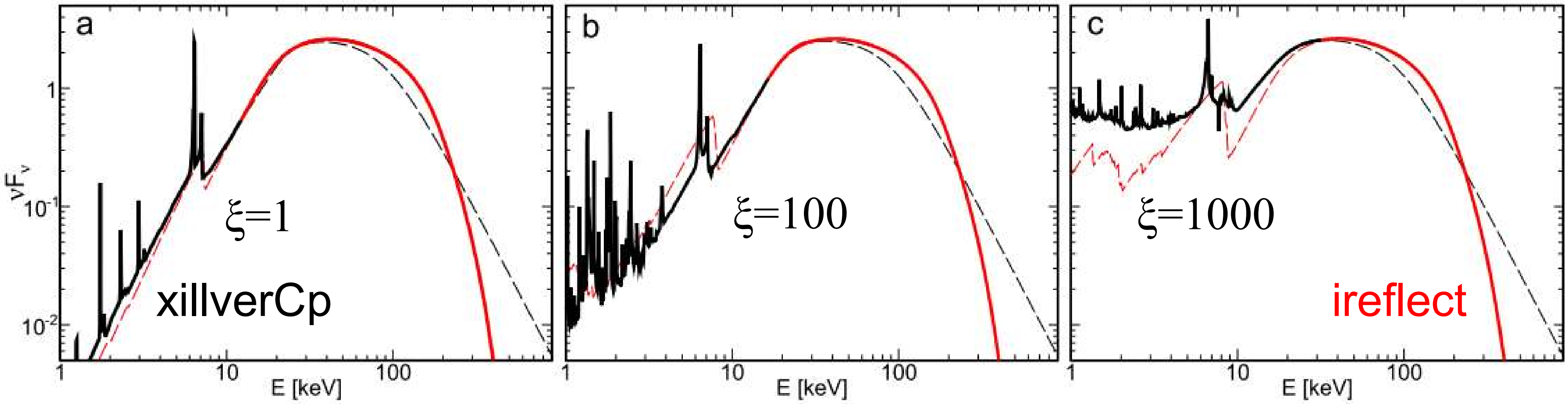


Figure 6. The effect of the gravitational redshift on thermal Comptonization spectra. The solid black and dashed red curves show the rest-frame spectra of our model, $E^2 N_{\rm PS}$, for $kT_{\rm e} = 100$ and 300 keV, respectively, $\Gamma = 1.7$ and $kT_{\rm bb} = 1$ eV. The solid red curve shows the spectrum for $kT_{\rm e} = 300$ keV redshifted by $g_{\rm so} = 1/3$. We see it significantly differs from the spectrum calculated for $g_{\rm so} kT_{\rm e}$.

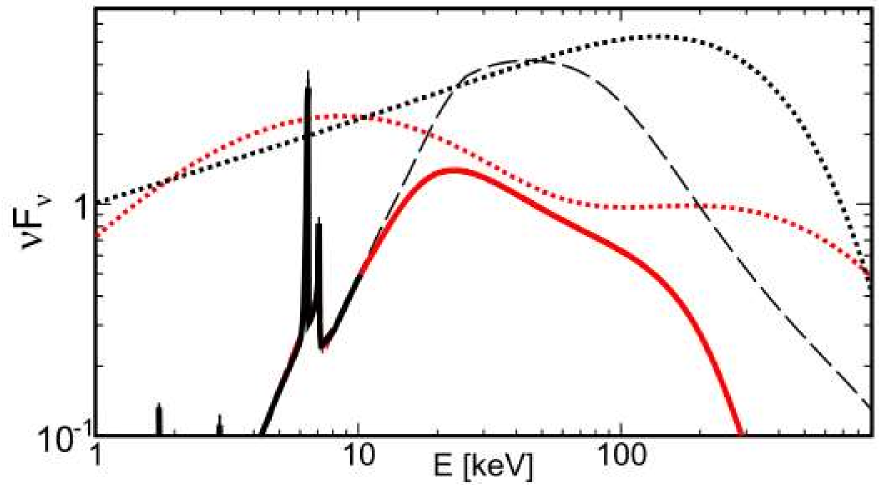
We use accurate thermal Comptonization spectra (compps).
We take into account the redshift of the direct emission (unlike relxill).
Note that a spectrum redshifted by $(1+z)$ is different from that for $kT_{\rm e}/(1+z)$.

Rest-frame reflection

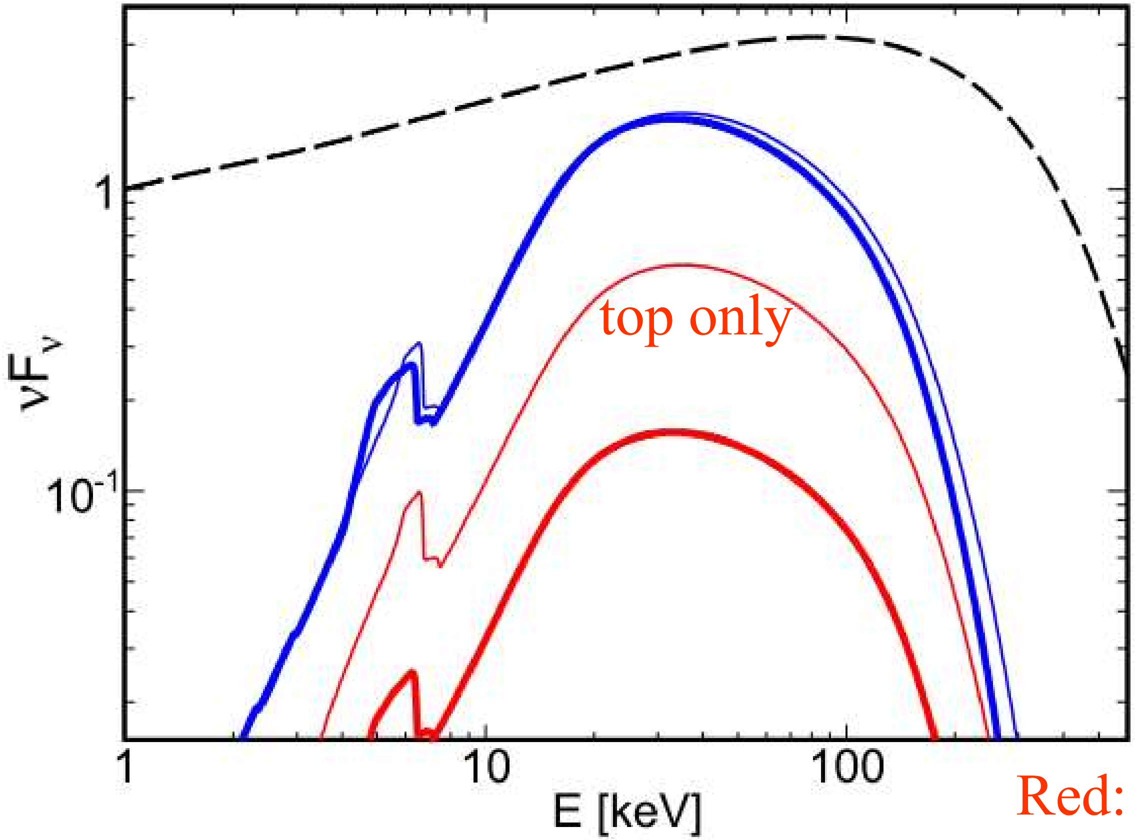


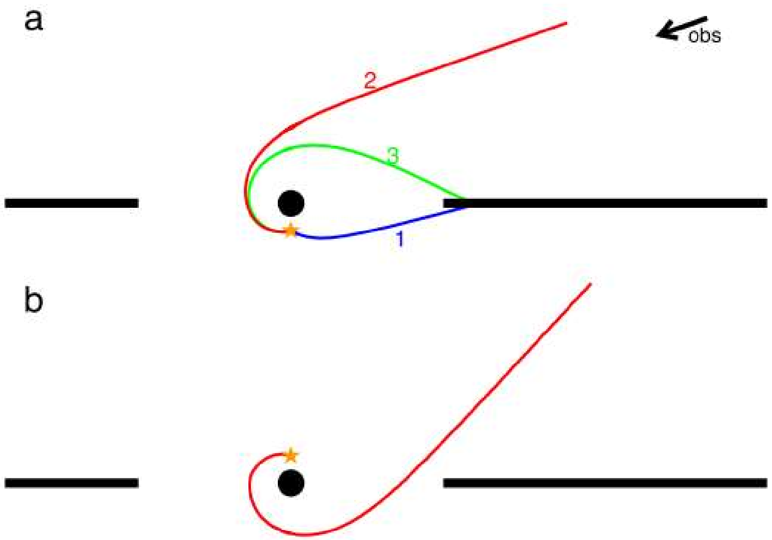
Merging xillverCp at at low energies with ireflect(compps) at high energies (similar to a model of Chris).

A high temperature case: 500 keV (e.g., for fitted spectra for lampposts close to the horizon). The true Comptonization spectrum is bumpy, and xillver gives incorrect results.



The effect of the bottom source in the lamppost model



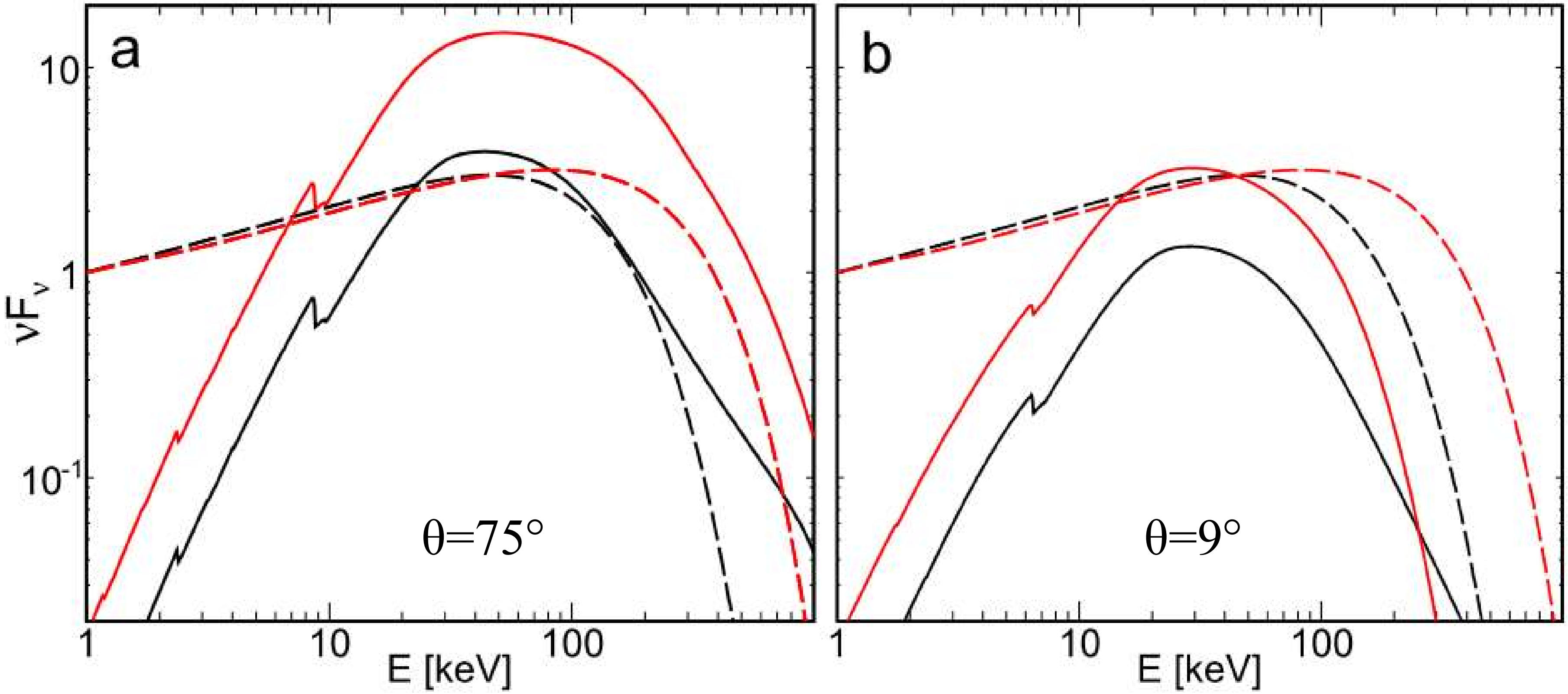


Red: θ=9°, blue: θ=30°. h=2, r_{in}=4.9 [R_g]

The BH is a gravitaional lense, enhancing the direct emission of the bottom source. Here, we normalize the spectra to the incident one. Thus, that enhancement is seen as a reduction in the reflection amplitude.

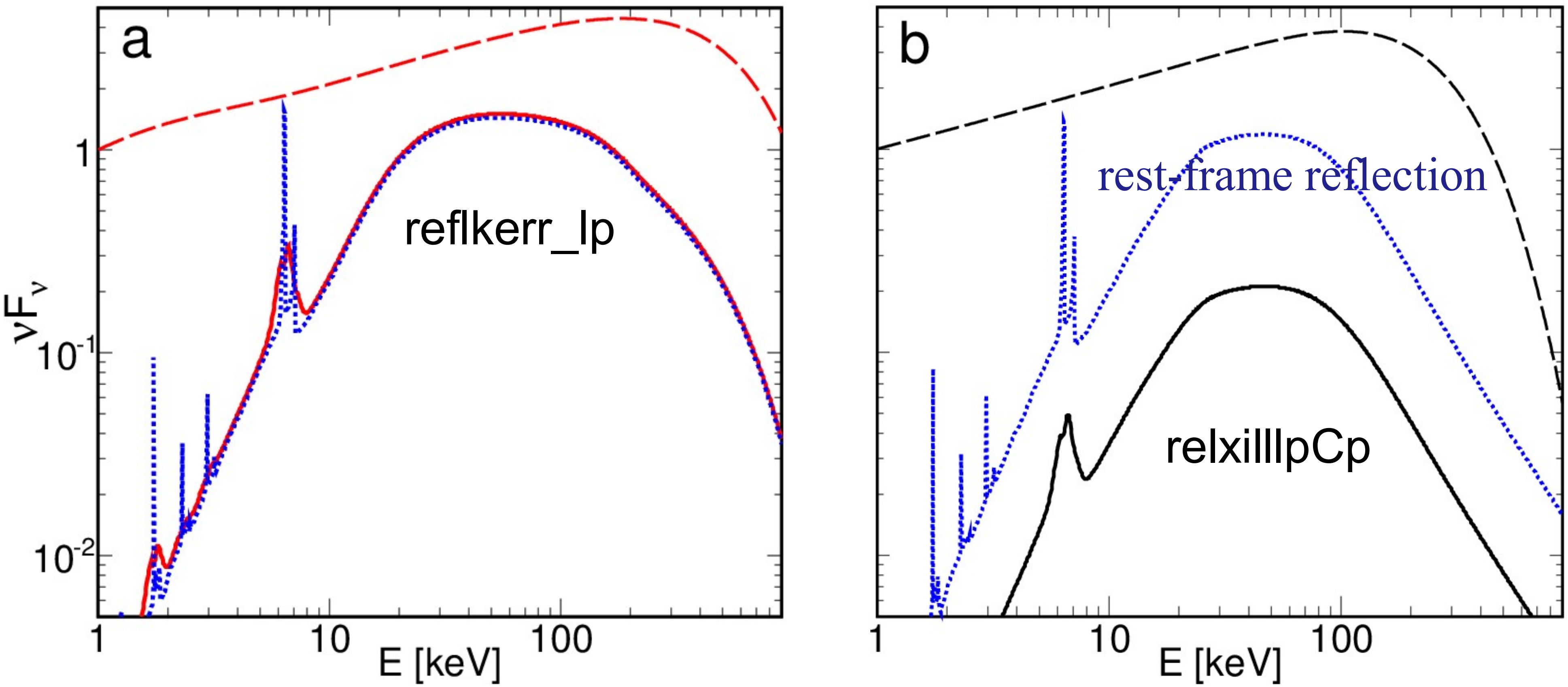
A comparison of relxilllpCp (black) with reflkerr_lp (red)

h=2, r_{in}=r_{ISCO}=1.24 [R_g], a=0.998, Γ=1.7, kT_e = 200 keV, ξ=1



relxilllpCp gives incorrect high-energy cutoff and incorrect reflection amplitude.

A test: a high lamppost height. The GR effects negligible, the reflection should be approximately the same as in the rest frame.

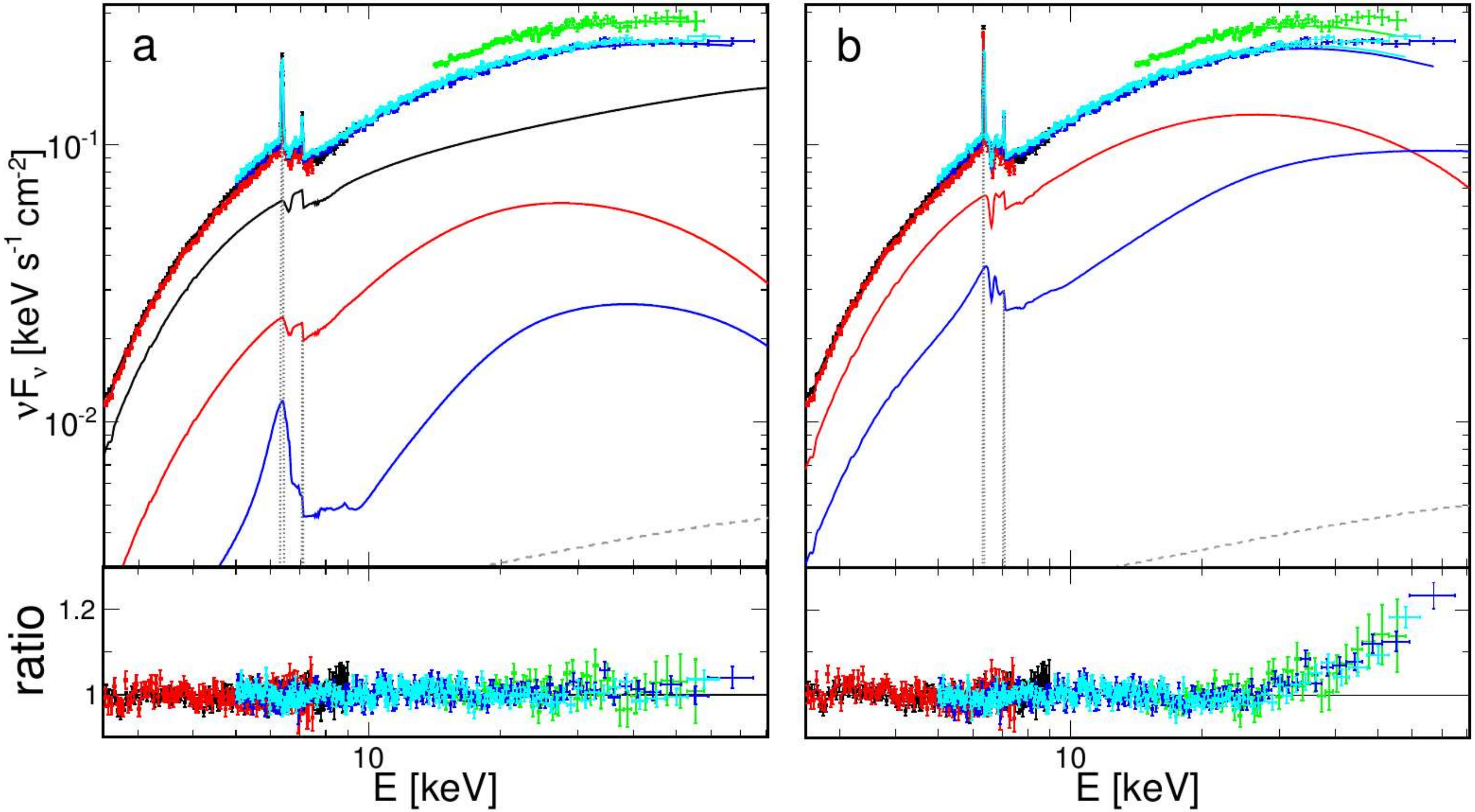


h=100, r_{in}=r_{ISCO}, θ=75°

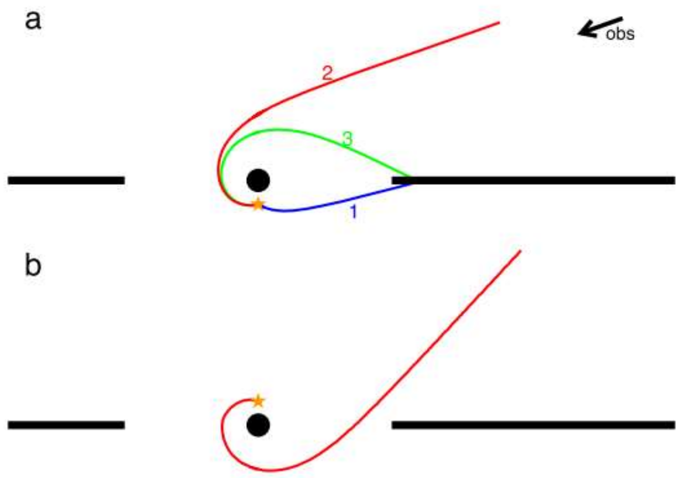
NGC 4151 spectra from *Suzaku* and *NuSTAR* fitted by Beuchert+2017

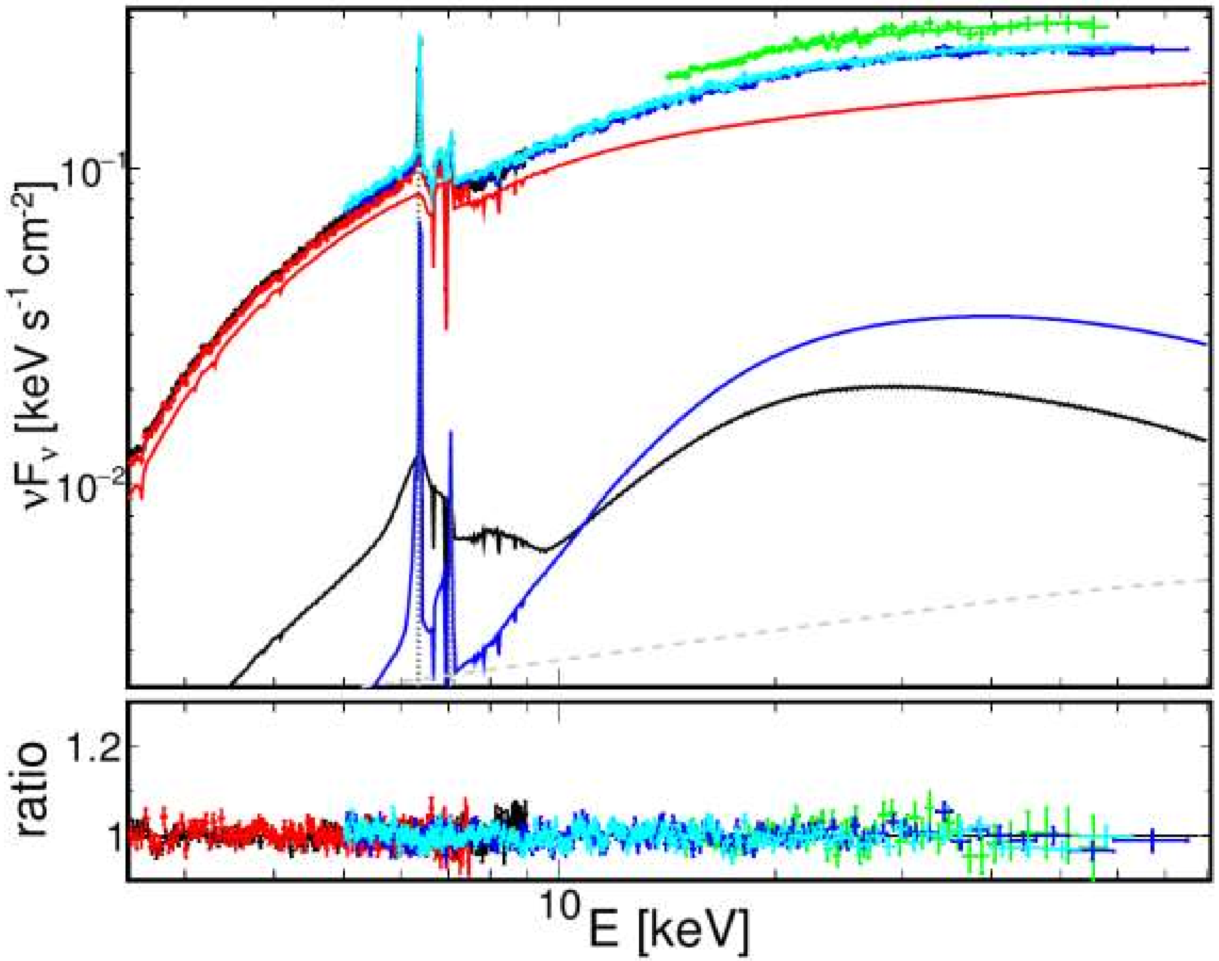
They found the best fit with relxilllpCp as two lampposts at h=1.17, 15, a=0.998, $r_{in} \approx r_{ISCO}$=1.24, but with (unphysical) free reflection normalization.

We find no good fit with reflkerr for the physical normalization.



NGC 4151 spectra from *Suzaku* and *NuSTAR* fitted with our symmetric-lamppost model



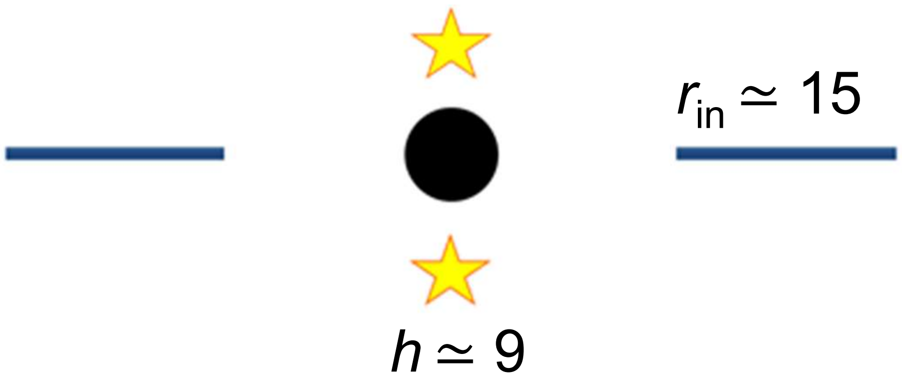


A truncated disc, h=12, r_{in}=19 (a=0.998) at the physical reflection normalization; $\Delta\chi^2\approx-350$ w/r to the original model of Beuchert+.

Cyg X-1, hard state

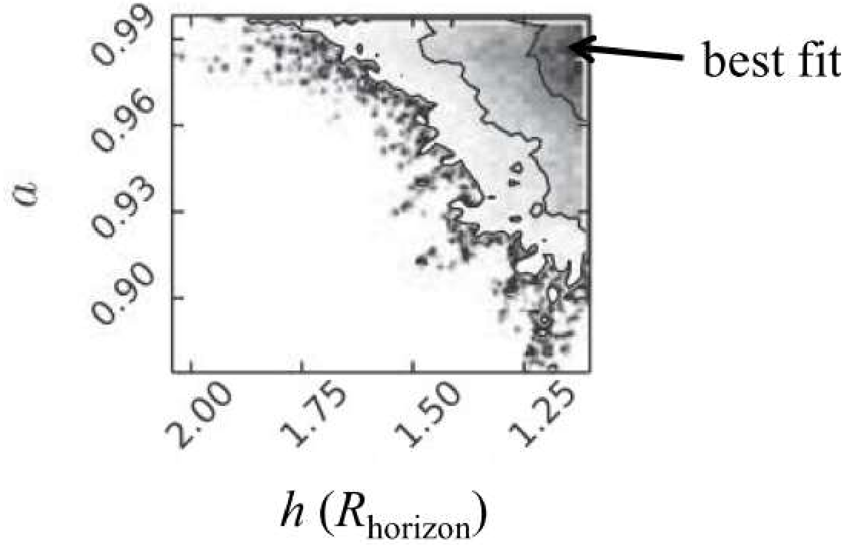
simultaneous *Suzaku*/*NuSTAR* observation of in 2014.

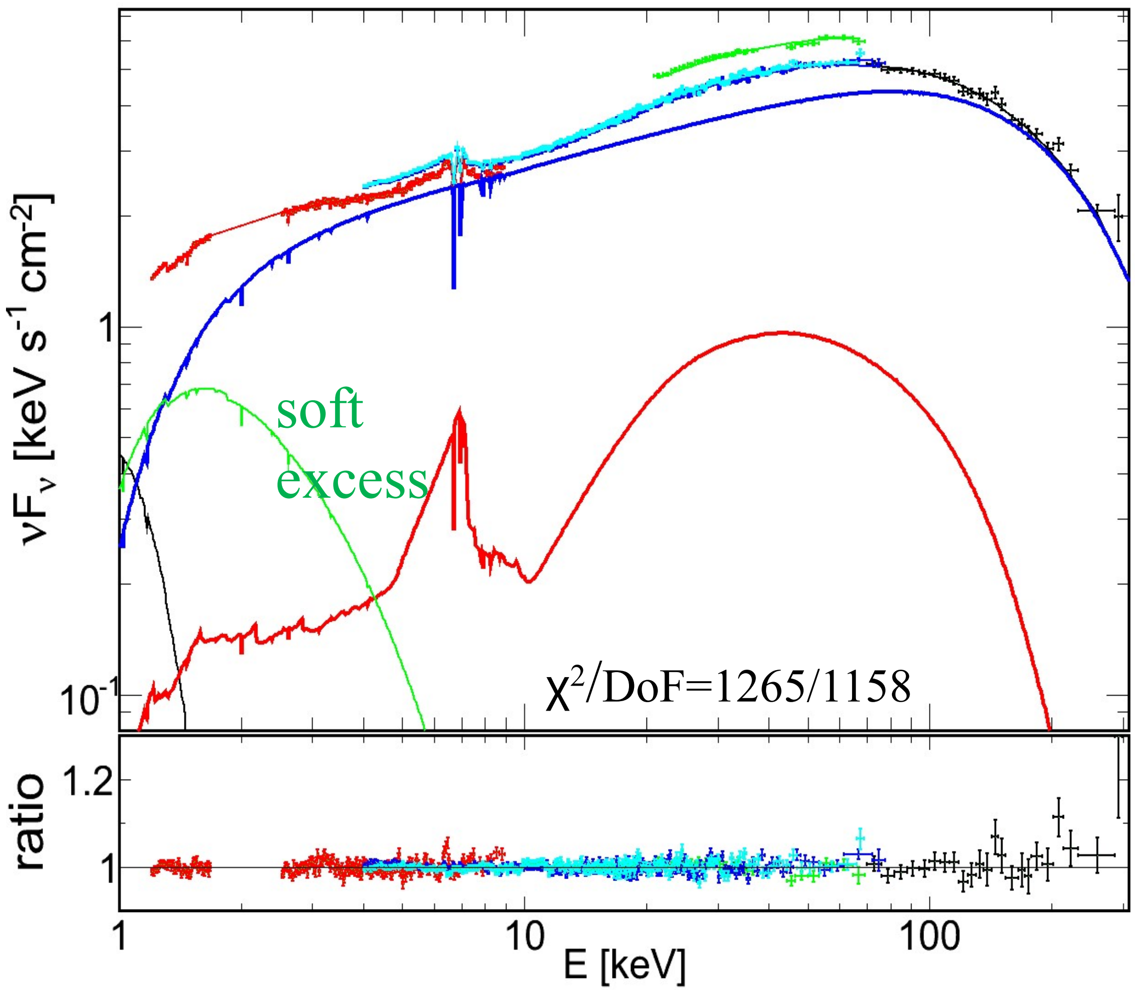
A good, physically-consistent, fit with a truncated disc, parameters similar to those of the model fitted to NGC 4151.



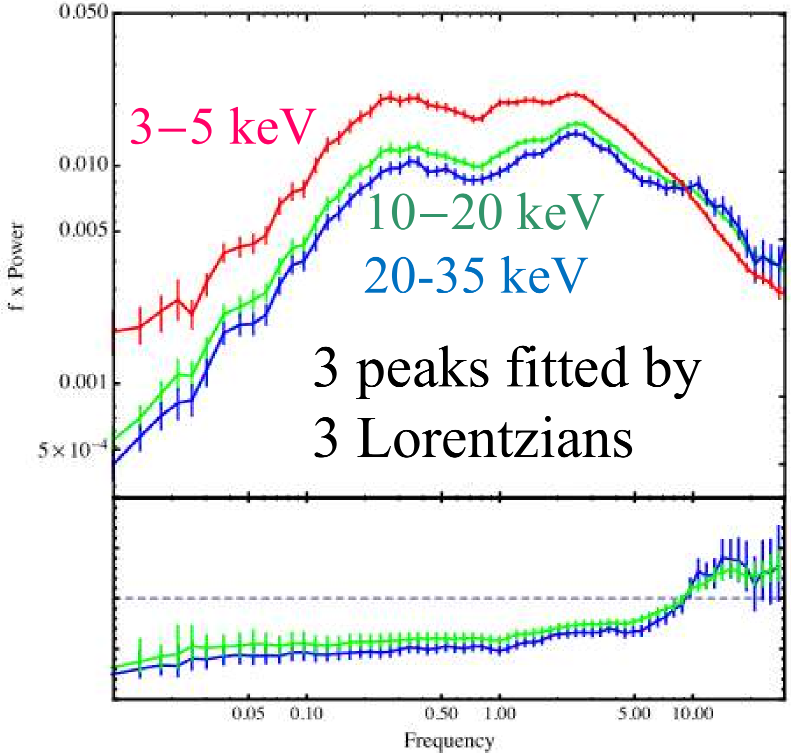
$i \simeq 39°$, $kT_e \simeq 74$ keV, $\Gamma \simeq 1.74$

Parker+2015 found $r_{in} \approx r_{ISCO}$ and

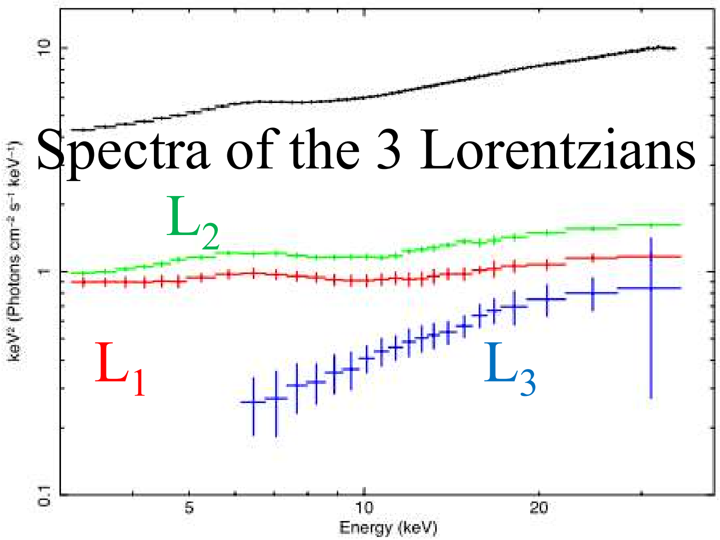


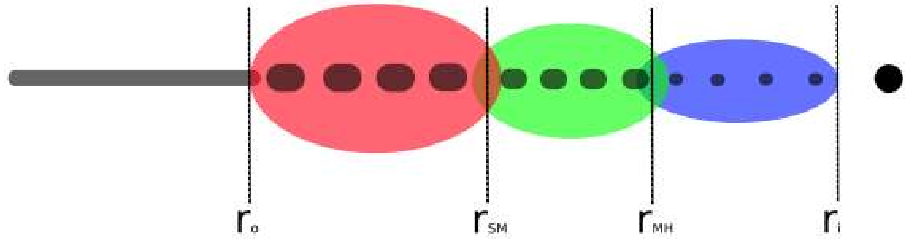


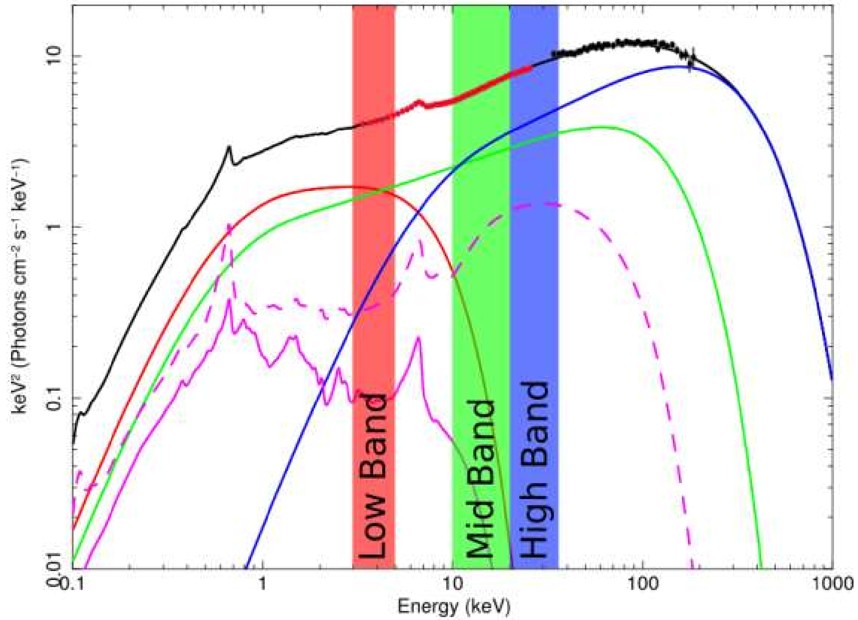
The underlying spectrum is not a power law: Fourier-resolved spectroscopy and a model of Cyg X-1 (Axelsson & Done 2018; Mahmoud & Done 2018)



Power spectra in 3 energy ranges







Summary

- Improved models for relativistic reflection (Niedźwiecki, Szanecki & Zdziarski, 2018): **`reflkerr`** for a broken power-law radial emissivity profile, approximating a disc corona, and **`reflkerr_lp`** for the lamppost geometry.
- **`compps`** (Poutanen & Svensson 1996) for primary rest-frame emission (an e-folded power law also possible).
- Accurate rest-frame reflection.
- Photon transfer in the Kerr metric for both the observed and reflected photon flux.
- For lamppost, the sources on both sides of the accretion disc are taken into account, important for disc truncation.
- Can be downloaded from users.camk.edu.pl/mitsza/reflkerr
- Truncated discs fit NGC 4151 and Cyg X-1.