Reflecting the Reflection: Impact of Returning Radiation in X-ray Binary Spectra

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Introduction & Motivation

X-ray reflection spectroscopy studies reflection spectra from X-ray binaries to probe the innermost accretion disk, test GR and measure the spin of black holes [1].

Returning radiation refers to photons emitted by the disk that are bent back onto it by the black hole's strong gravity.

During the soft spectral state, the corona is weak or even absent and disk *self-irradiation* is expected to dominate the reflection [2].

Currently, no XSPEC model self-consistently includes this effect.

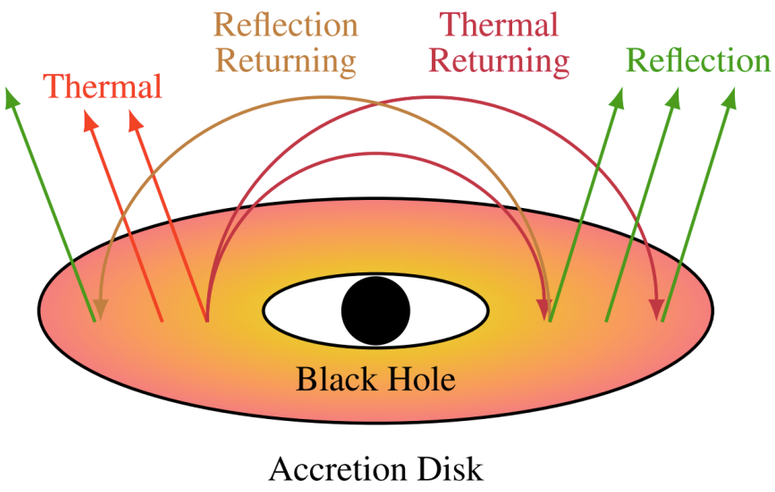

Figure 1. Black hole-disk model with reflection component from self-irradiation of the disk and iterative reflection.

Theoretical Model

Blackbody and reflection spectra are produced with the model `ziji` [3]. The accretion disk is described by the **Novikov-Thorne model** [4] in a **Kerr spacetime** [5].

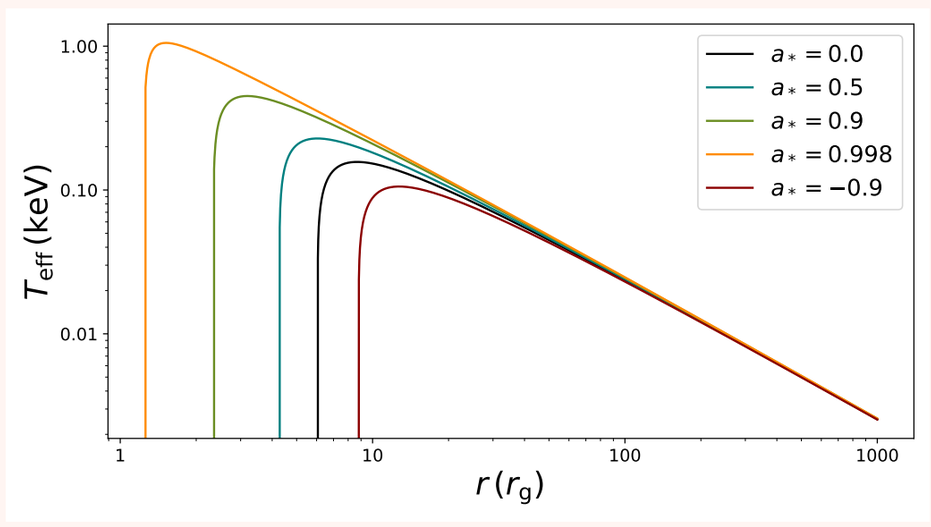

Figure 2. Effective temperature radial profile of a Novikov-Thorne disk around a $10\,\mathrm{M}_\odot$ Kerr Black hole with $\dot{M} = 10^{18}\,\mathrm{g/s}$, for different values of the spin parameter.

The *ionization* ξ at each radius r is given by:

$$\xi(r) = \frac{4\pi\Phi_{\rm X}(r)}{n_{\rm e}},$$

where $\Phi_{\rm X}(r)$ is the incident flux from returning radiation and $n_{\rm e}$ is the electron number density.

The radiation field incident on any point on the disk in our model includes only:

- **returning thermal radiation**; 0th iteration,
- **higher-order returning reflection**; up to 3 iterations.

We generate blackbody and reflection spectra over a grid of parameters, producing the first XSPEC table model that self-consistently includes returning radiation of both thermal and reflection components.

Results & Discussion

The effect of returning radiation becomes stronger at higher black hole spins, as the disk's inner edge, located at the ISCO radius, moves closer to the black hole, where gravity is stronger.

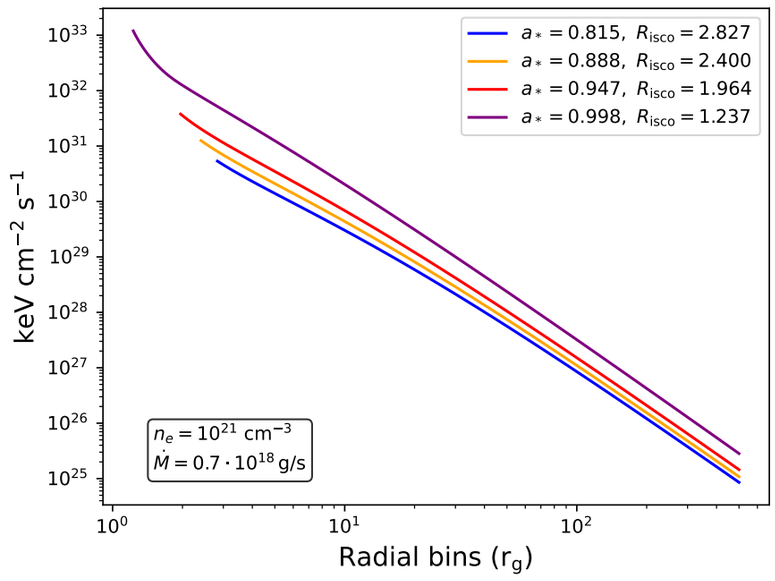

Figure 3. Returning radiation flux profile in the rest frame of the disk for a $10\,\mathrm{M}_\odot$ black hole and for different values of the spin parameter.

The reflection spectra show a spectral hardening at high energies:

- This is caused by iterative reflection.
- The effect appears only at high spins, where returning radiation is stronger.

This feature allows the production of spectra with extended high-energy tails without invoking a Comptonized component.

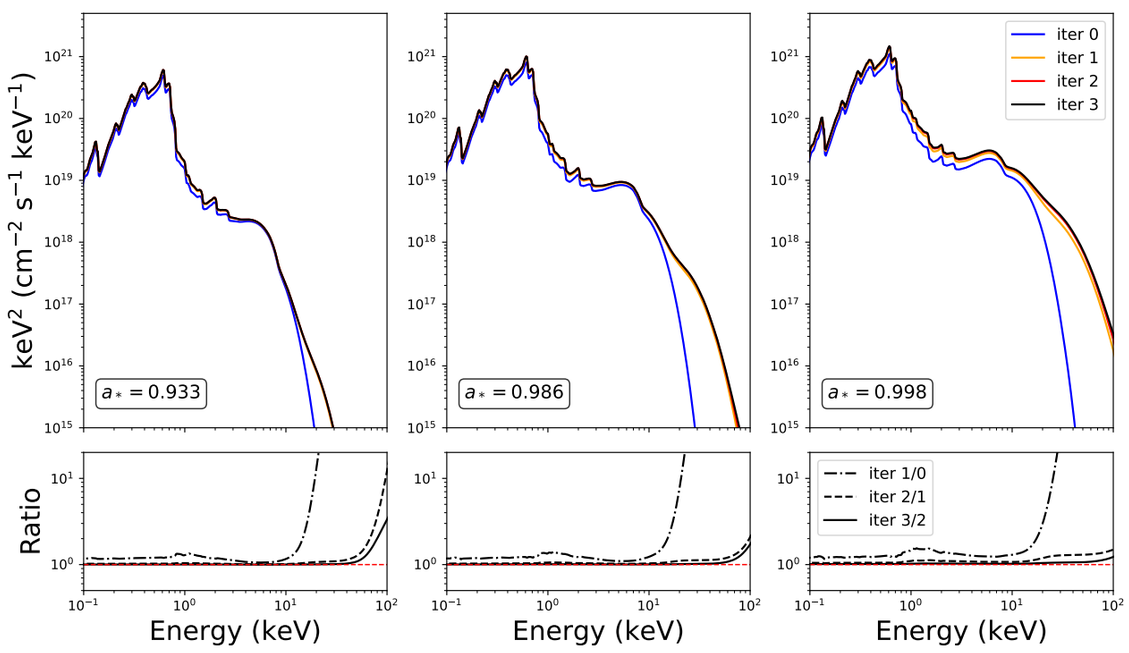

Figure 4. Relativistic reflection spectra for different numbers of iterative reflections (0–3) and spin values (upper panels). The bottom panels show the ratio between the flux of each successive iteration.

Future Work

- Validate the model with observational data.
- Include coronal emission.
- Change the metric – test the *Kerr hypothesis*.
- **Public release in XSPEC.**

References

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[4] *I. D. Novikov and K. S. Thorne, Black Holes, 1973.*

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