X-ray Spectroscopy of Black Hole Accretion Disk Atmospheres
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ABSTRACT
The relativistic plasma near black holes will be probed spectroscopically with future X-ray observatories. To interpret these spectra, we will need to understand the structure and radiative transfer within the disk. The accretion disk produces emission lines which in principle can be used to measure the black hole parameters. The line profiles probe the disk dynamics and gravitational potential near the black hole event horizon, but they also probe the structure of the exterior layers of the disk, called an X-ray chromosphere or atmosphere. We model the structure and X-ray recombination spectra of the disk atmosphere and corona, assuming thermal and hydrostatic balance, and local photoionization equilibrium. We show that such models are able to explain the line-rich X-ray spectra observed with Chandra and XMM–Newton in accreting neutron star binaries, but in this case, the line emission occurs predominantly in the outer radii of the disk. Building upon this foundation, we compute the atmosphere and corona of the inner disk around a supermassive black hole, assuming illumination from disk flares covering the top of the corona, and including general relativistic tidal forces. Our ultimate objective is to Monte-Carlo the radiation transfer of both continuum and line photons in the 3-dimensional structure of the disk atmosphere, so that we can associate a spectrum with a given structure and black hole.

Structure of a Centrally Illuminated Accretion Disk Around a Neutron Star
Adjustable Parameters:
- Accretion Rate
- Neutron Star Mass
- Disk size
- Neutron Star Spectrum
- Inclination Angle

26 radial bins
Chandra and XMM–Newton are providing us with rich spectra which allow us to test our ideas about accretion disk atmospheres. Our black hole disk models are based on these well-tested neutron–star disk models.

Structure of a Flare–Illuminated Accretion Disk Around a Supermassive Black Hole
Adjustable Parameters:
- Accretion Rate
- Black Hole Mass
- Black Hole Spin
- Disk size
- Broadband X-ray Spectrum (=Flare)
- Flare Geometry
- Flare to Blackbody Flux Ratio
- Dissipation Parameter $\alpha$
- Inner Edge Torque

35 radial bins
Zoom into atmosphere

Comparison of synthetic spectra with those of accreting neutron stars
A) A dipper, type I burster: EXO 0748–676
B) An X-ray pulsar with a precessing disk: Her X-1

The line flux to continuum ratio, line profiles and plasma diagnostics match beautifully with the disk atmosphere model. The discrepancies indicate some improvements to the thermal stability and gas dynamics are needed.

Spectrum of Accretion Disk Model of Hercules X-1, Folded Through Calorimeter Response
A great number of new features in the Her X-1 spectrum will be revealed by Constellation-X. The line emission from photoionized plasmas has proven more difficult to detect than thermal line emission.

Preliminary Model Spectrum of A Black Hole Accretion Disk Atmosphere (2 innermost annuli, no continuum)

This spectrum illustrates the most prominent radiative recombination emission lines from the two innermost radii of our AGN model. The continuum opacity has been included in this model. Relativistic Doppler line broadening, and the propagation of photons in the Kerr metric are not included. The effects of Compton re-distribution and line transfer are not included in the plot, but we are calculating them with a Monte Carlo radiation transfer code (listen to C. Mauche’s talk, Monday at 2:30pm).

A preliminary result is the prominence of O VIII, and other H−like ions. The relative strength of these lines with respect to the 6.4 keV fluorescence line remains to be investigated. Note we have included the Fe XXV and Fe XXVI lines.

The line emission from photoionized plasmas has proven more difficult to detect than thermal line emission.

References: