X-Ray Spectra from 3D GRMHD Simulations of Accreting Black Holes:

Can MHD simulations of disks really predict the light we see?

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with

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Outline:

• A quick but thorough description of the machinery.

• A comparison to actual spectral data (Cyg X-1).

• The effect of varying the accretion rate and some interesting figures.

• Summary and where to go next.
HARM3D
3D General Relativistic Magnetohydrodynamic Simulation of Black Hole Accretion.

PANDURATA
Monte Carlo radiation transport (geodesic ray-tracing) and $T_e$ balance in corona.

PTRANSX
Radiative transfer in disk with photoionization equilibrium using XSTAR.

5-10 iterations

X-ray spectrum as seen by the distant observer. Fe Kα line profiles.

- 3D density and cooling rate (local turbulent dissipation rate) taken from simulation output.
- Photons GR ray-traced through optically thin corona.
- Feautrier multi-angle group transfer solution in optically thick disk.
- XSTAR used for photoionization absorption and emission.
- Full Compton scattering throughout.
- Absorption by and Compton recoil off disk accounted for by iterative procedure.
- Global energy balance.

Prepare new seed photon fluxes.
Compute new disk albedo and Compton recoil tables.
- Seed photons from disk upscatter in hot corona, illuminating the disk and escaping to the distant observer.
- $T_e$ in the corona adjusted until IC power = simulation dissipation rate.
- Corona is extended and multi-temperature.
Comparison to Cyg X-1 soft state

- We specify a handful of physical parameters:
  - $M = 14.8 \, M_{\odot}$
  - $\dot{m} = 0.022$
  - $a = 0$
  - abundances = solar
  - $i = 41^\circ$

- An entirely forward prediction: no feedback from observational data, and no parameter fitting.

- NuSTAR $\Gamma = 2.9$, our $\Gamma = 3.4$.

- Softer, but with a qualitative resemblance.

Walton et al. 2016
Comparison to Cyg X-1 soft state

- Our parameters:
  - $M = 14.8 \, M_\odot$
  - $\dot{m} = 0.022$
  - $a = 0$
  - abundances = solar
  - $i = 41^\circ$ and $27^\circ$

- Each curve is a total flux/continuum ratio.
- Observational data needs approximate (fit) continuum; we know what our underlying continuum is (tag the photons when ray-tracing).
- Slightly stronger, but similar in shape.
- We achieve sufficient EW with solar Fe abundance.

Walton et al. 2016
More Results...

$M = 14.8 \, M_\odot$

$a = 0$

abundances = solar
More Results...

$M = 14.8 \ M_\odot$

$a = 0$

abundances = solar

$\dot{m} = 0.01$
More Results...

\[ M = 14.8 \, M_\odot \]
\[ a = 0 \]
abundances = solar
$M = 14.8 \ M_\odot$

\(a = 0\)

abundances = solar
Conclusion:

• We are able to compute X-ray spectra reasonably comparable to observations from simulation output using a first principles, physics-based approach—without parameter fitting.

• These are *forward predictions*, specified by 4 physically meaningful parameters: mass, accretion rate, spin, and elemental abundances.

• We will soon explore AGN masses and nonzero spins.

• We plan to make an *XSPEC* package to provide observers with a few-parameters model with which to fit real X-ray data.