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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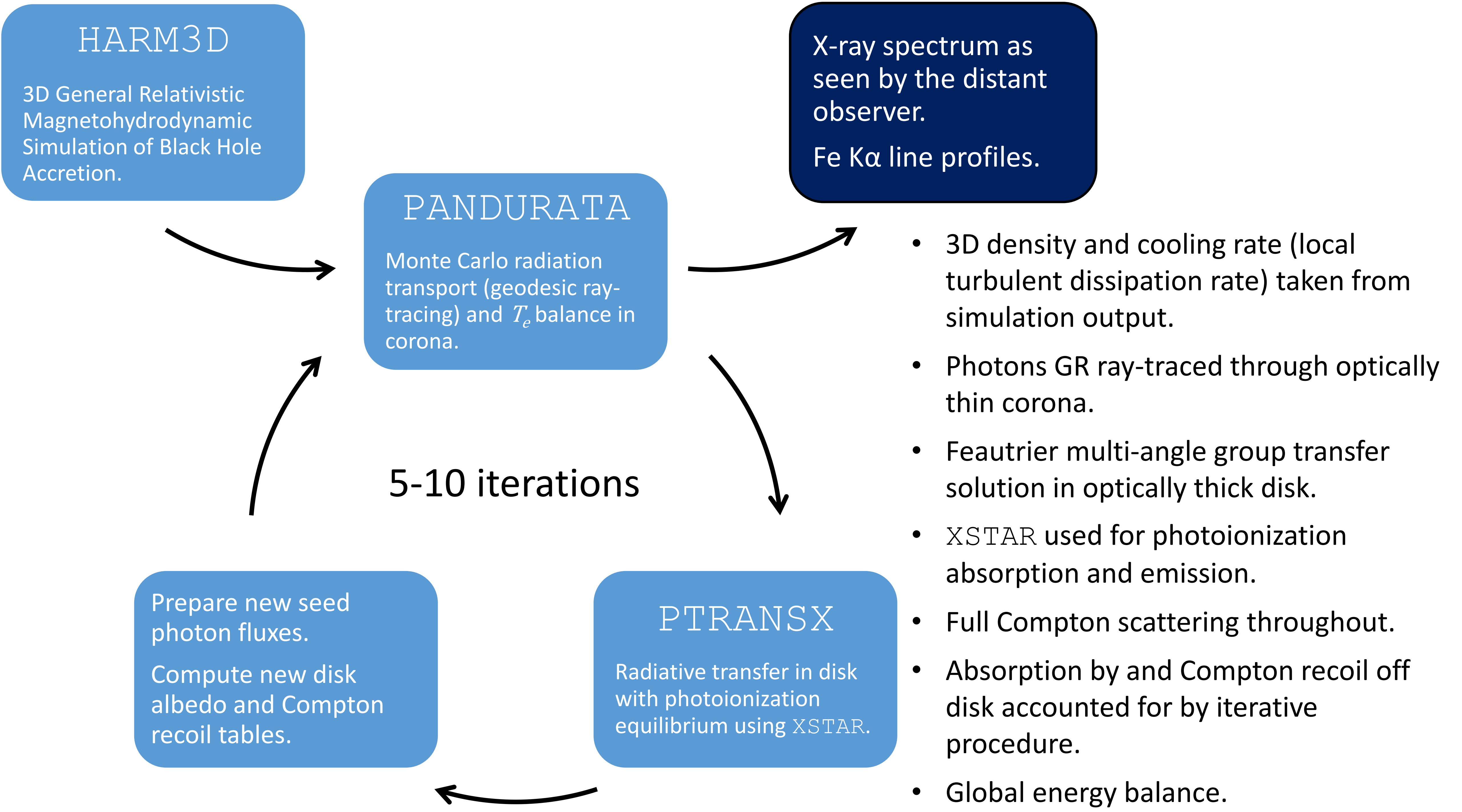
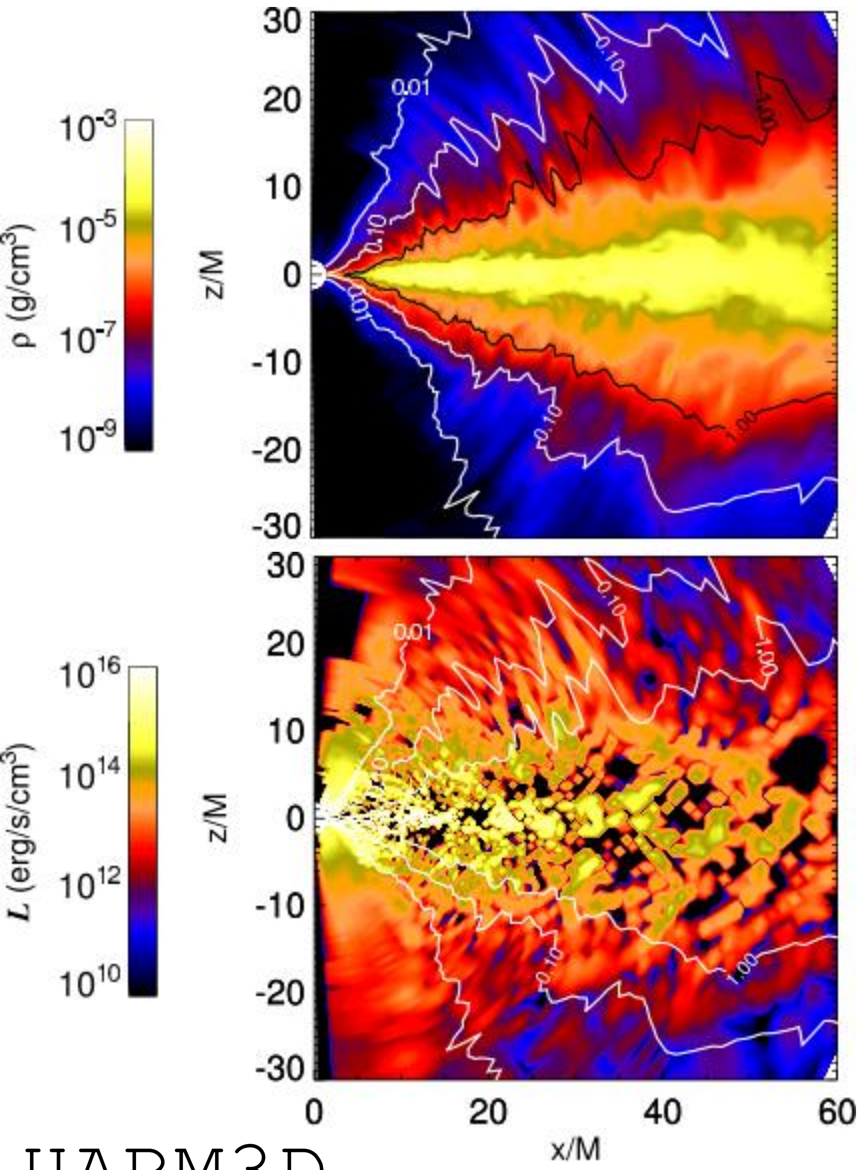
Outline:

- 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.
X-ray spectrum as seen by the distant observer.
Fe Kα line profiles.
5-10 iterations
PTRANSX
Radiative transfer in disk with photoionization equilibrium using XSTAR.
Prepare new seed photon fluxes.
Compute new disk albedo and Compton recoil tables.
• 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.



HARM3D

PANDURATA

+

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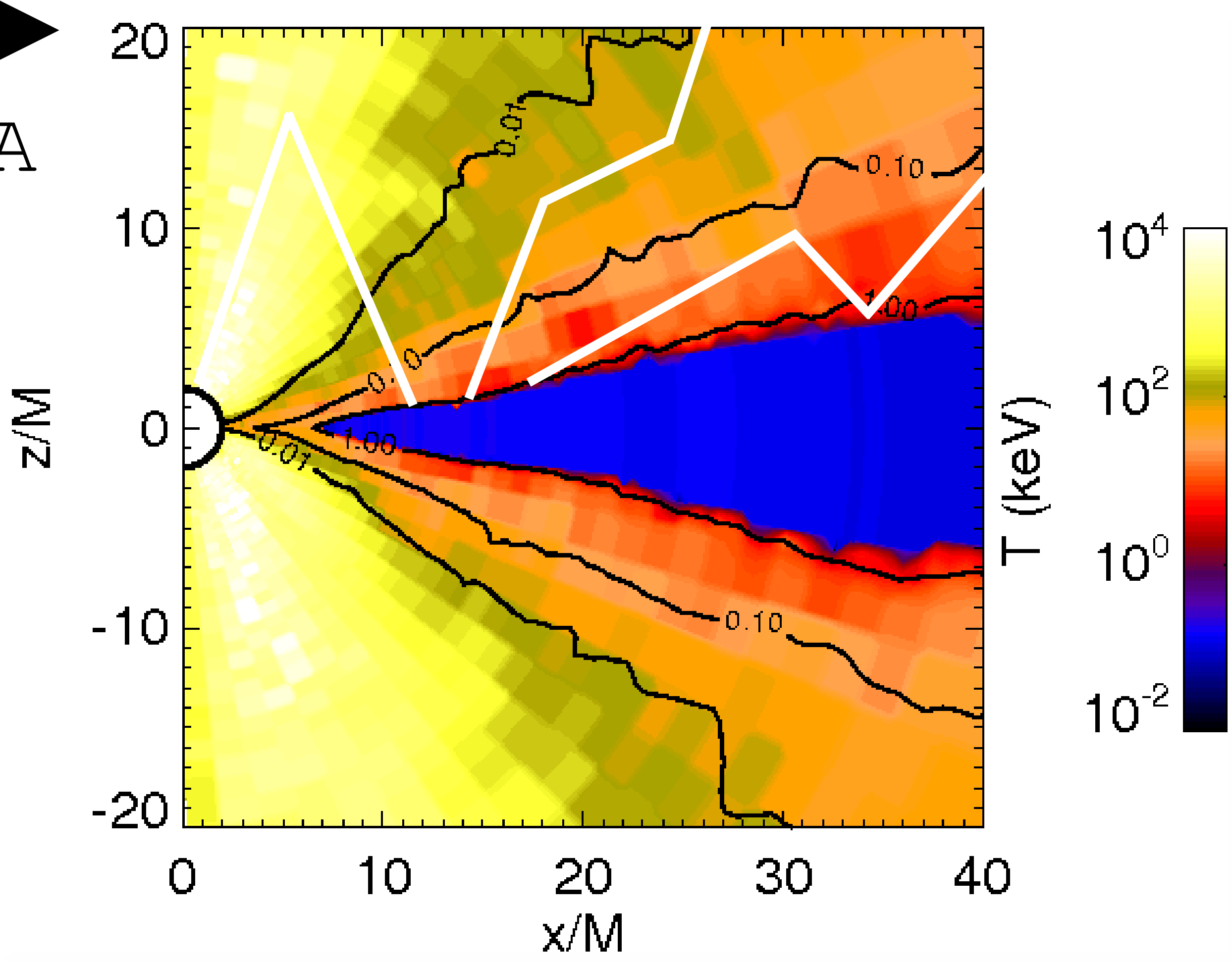
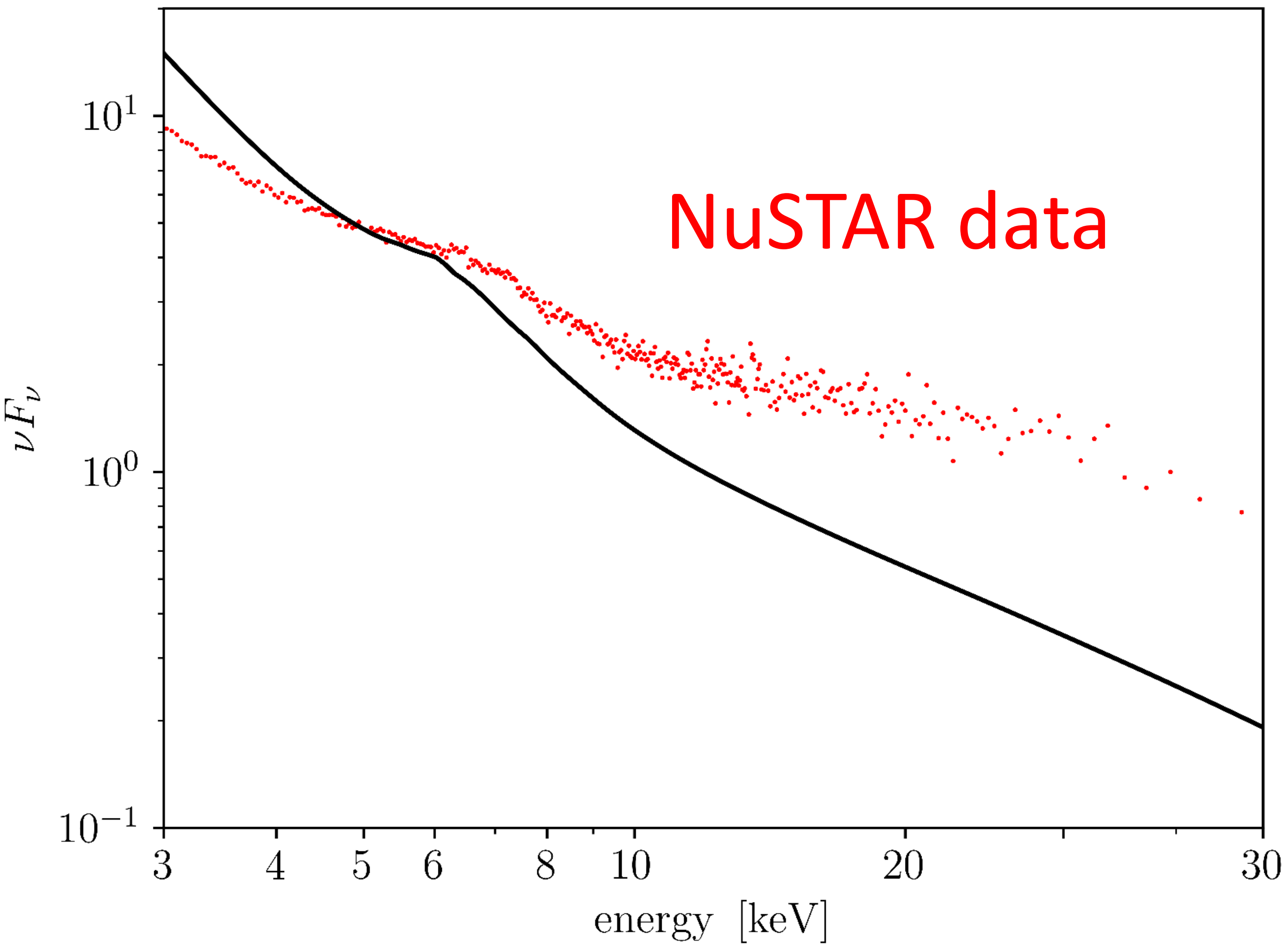


- Seed photons from disk upscatter in hot corona, illuminating the disk and escaping to the distant observer.
- T_e in the corona adjusted until IC power = simulation dissipation rate.
- Corona is extended and multi-temperature.

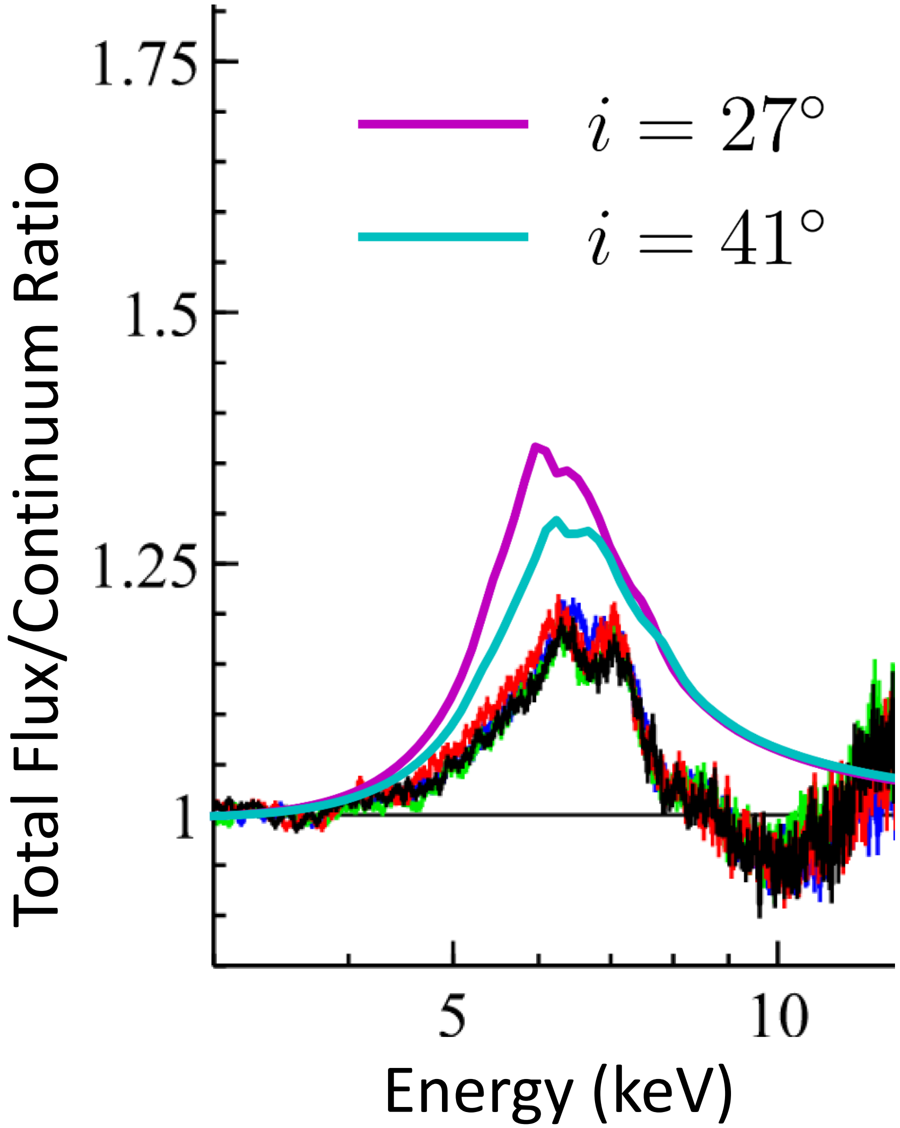
Comparison to Cyg X-1 soft state



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



Walton et al. 2016

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

More Results…

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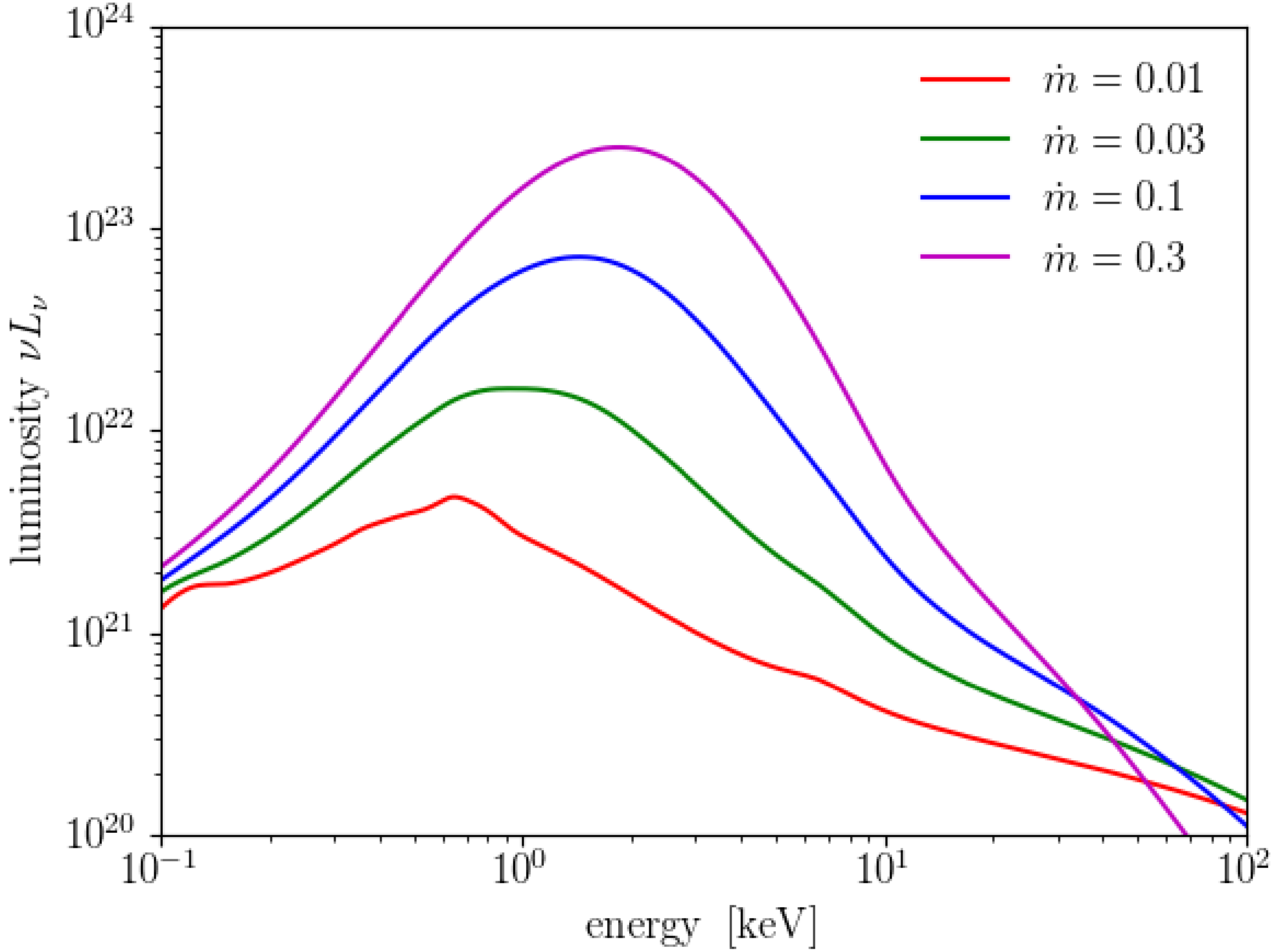

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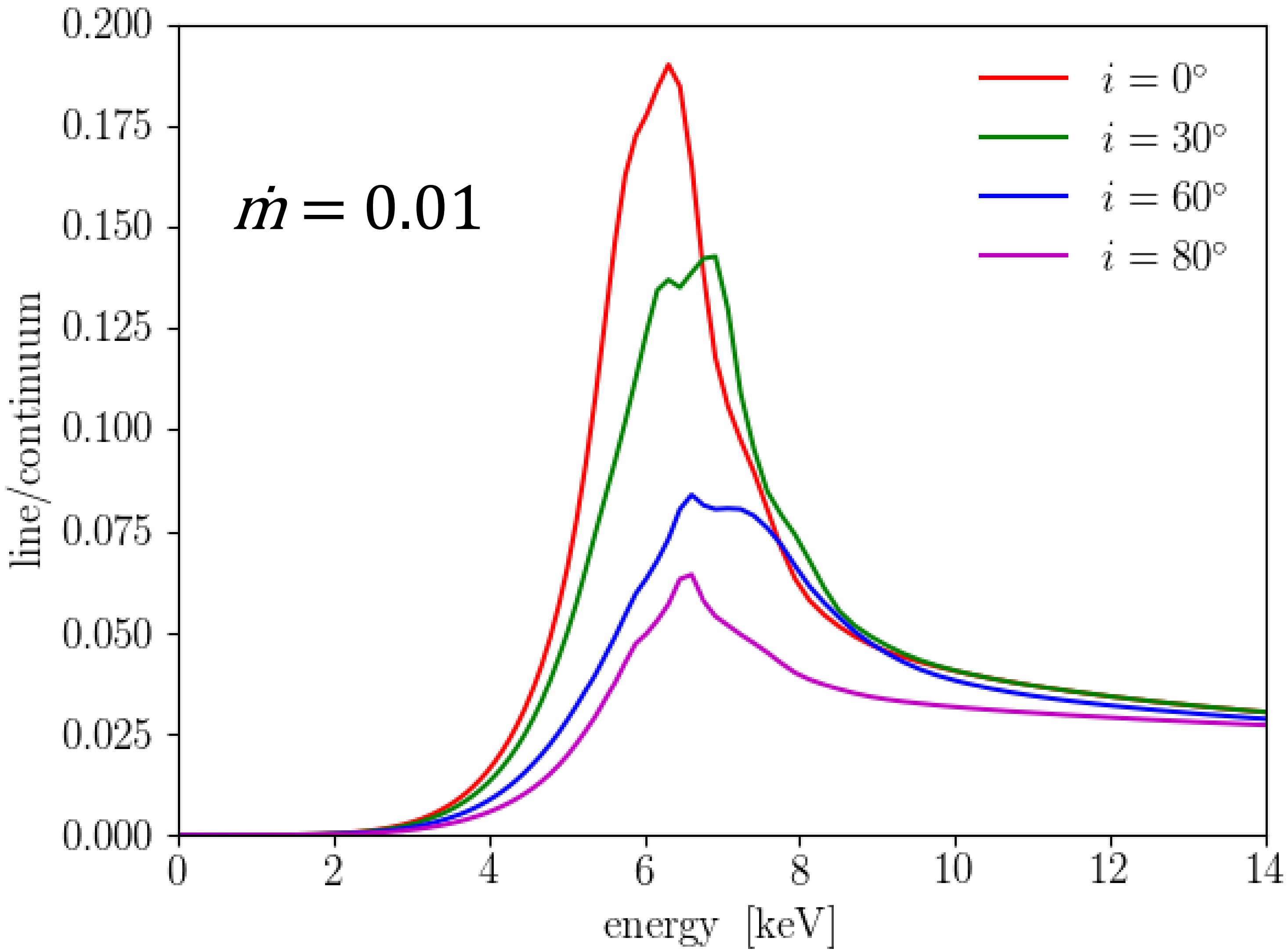

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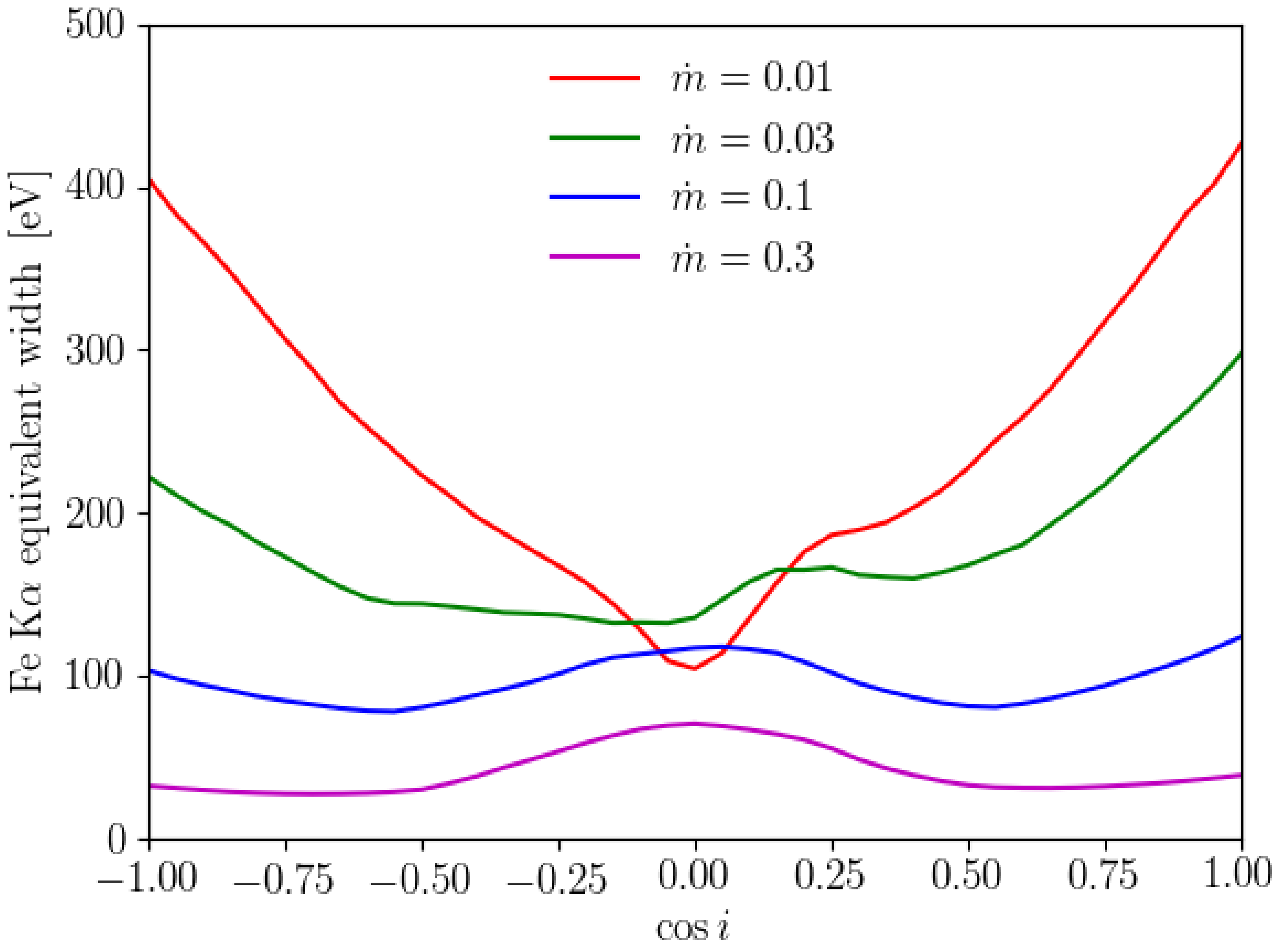

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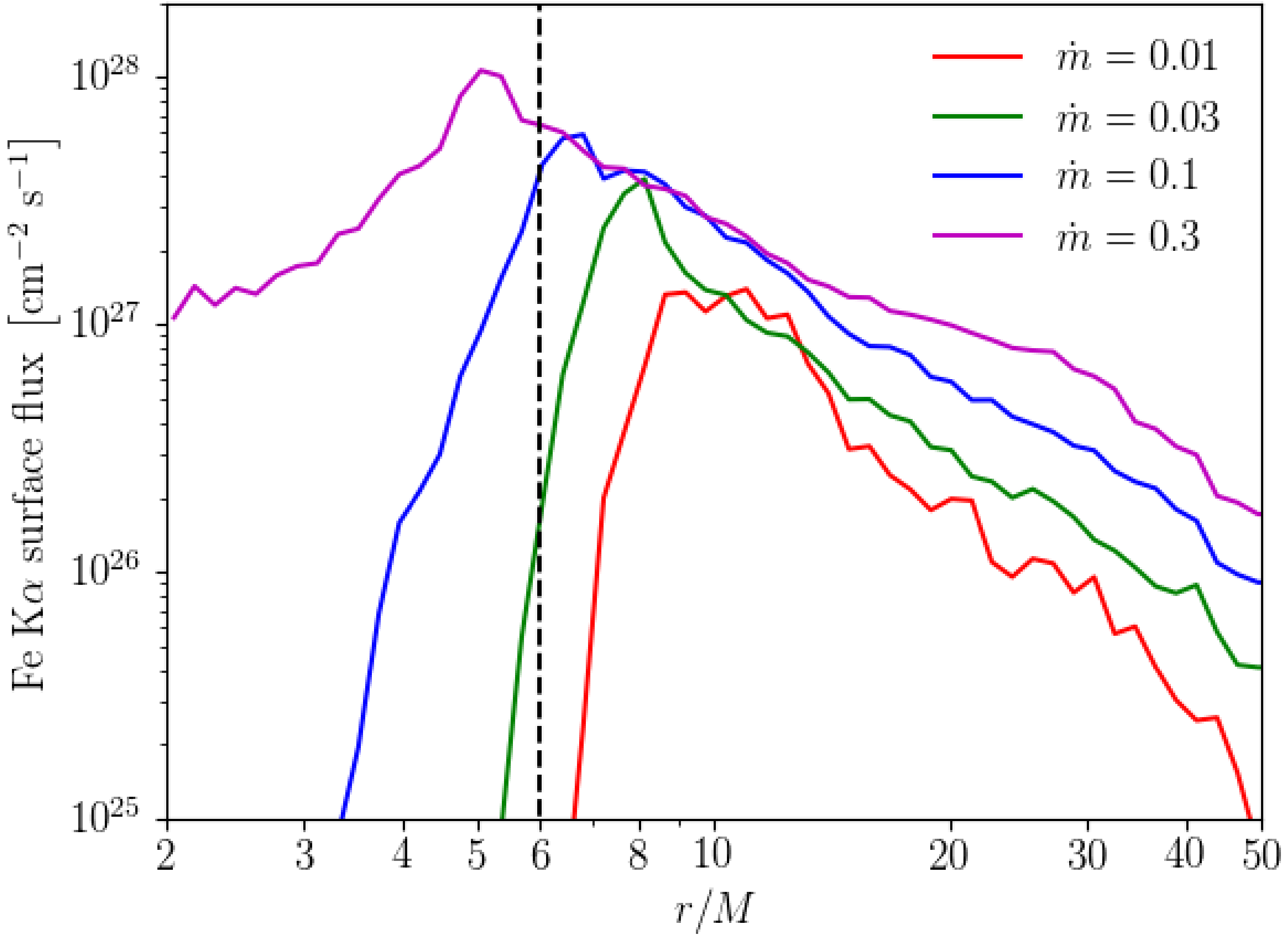

Conclusion:

- We are able to compute X-ray spectra reasonably comparable to observations from simulation output using a first principles, physics-based approach–with no 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.