Effects of geometry and mass accretion rate on thermal spectra of ULX sources

Michal Bursa

Astronomical Institute of the Czech Academy of Sciences

STRONGGRAVITY EU FP7-SPACE research project 312789 2013 - 2017

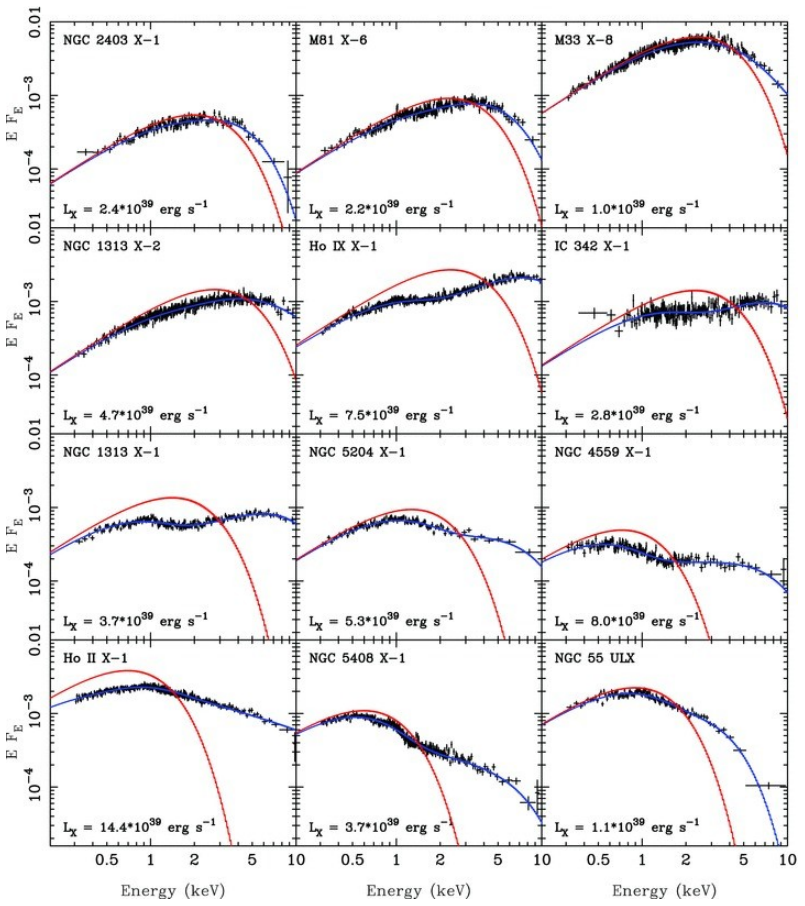
Arbatax, September 22, 2016

Motivation

Spectral modeling of ULXs:

- most often a model with disk+pl or disk+th_comp is used
- in place of a disk model we can see DISKBB, DISKPN, KERRBB, BHSPEC, GRAD, etc
- all of the listed disk models are based on thin disk model, which is inaccurate for L > 0.3 L_{Edd}
- BUT, such a modelling tends to give incorrect values for BH masses and for accretion rate (luminosity)
- how much wrong?

(Gladstone et al. 2009)

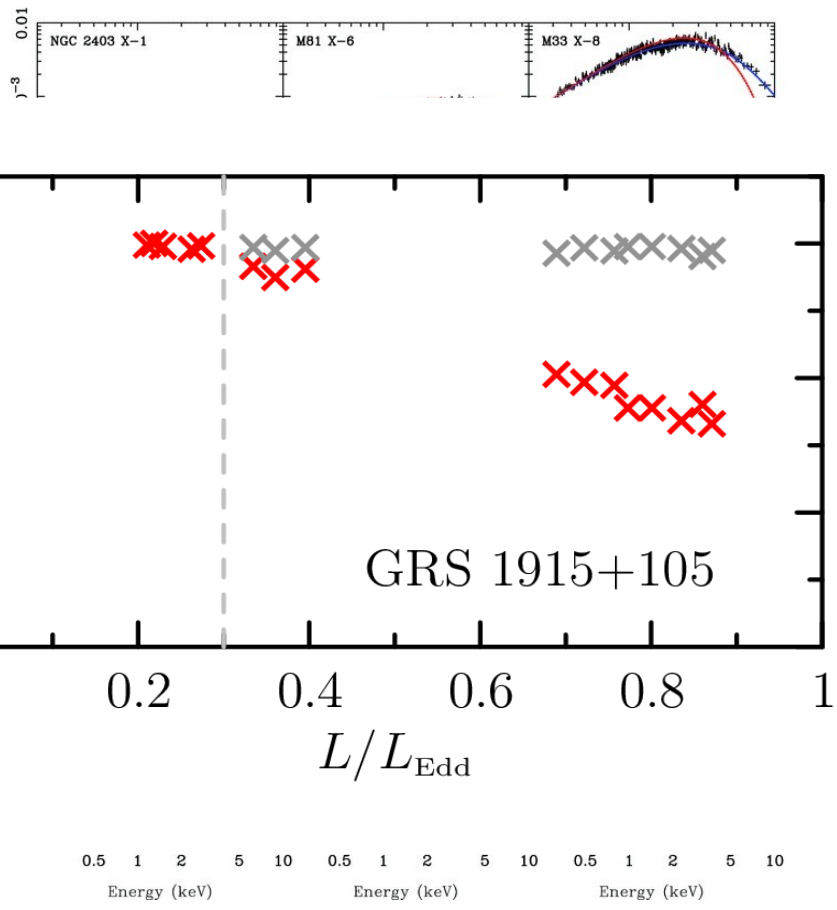


Motivation

Spectral modeling of ULXs:

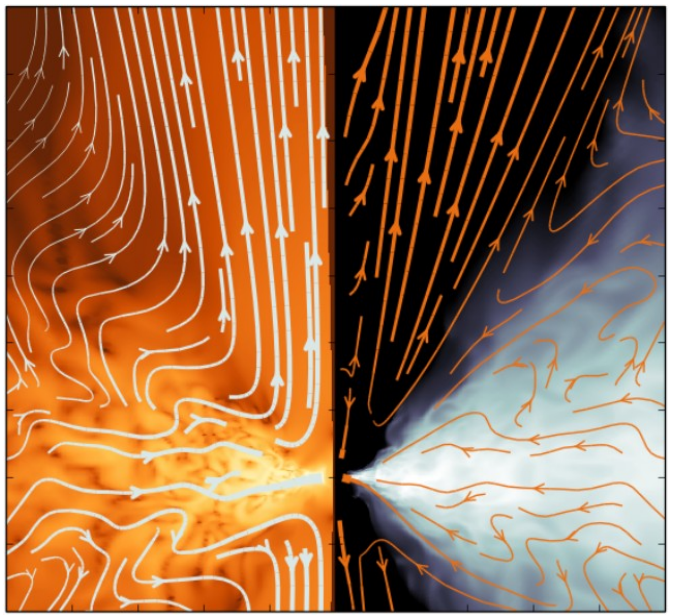
- most often a model with disk+pl or disk+th_comp is used
- in place of a disk model we can see DISKBB, DISKPN, KERRBB, BHSPEC, GRAD, etc
- all of the listed disk models are based on thin disk model, which is inaccurate for L > 0.3 L_{Edd}
- BUT, such a modelling tends to give incorrect values for BH masses and for accretion rate (luminosity)
- how much wrong?

(Gladstone et al. 2009)



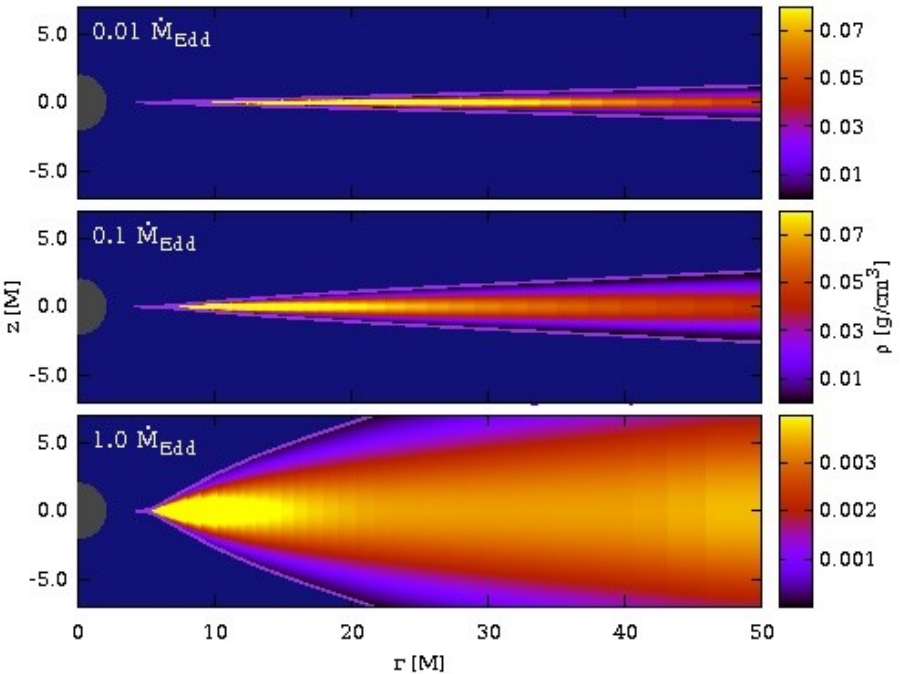
Spectral model based on slim disk model

Numerical simulations



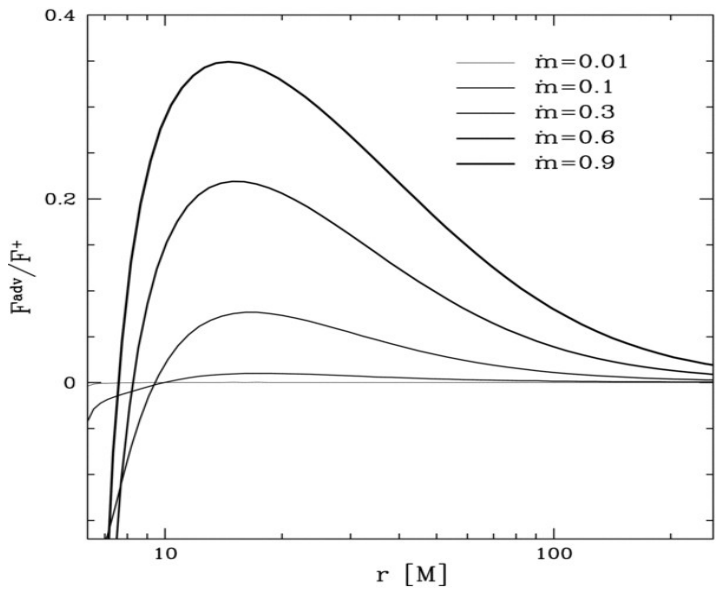
Credit: A. Sadowski

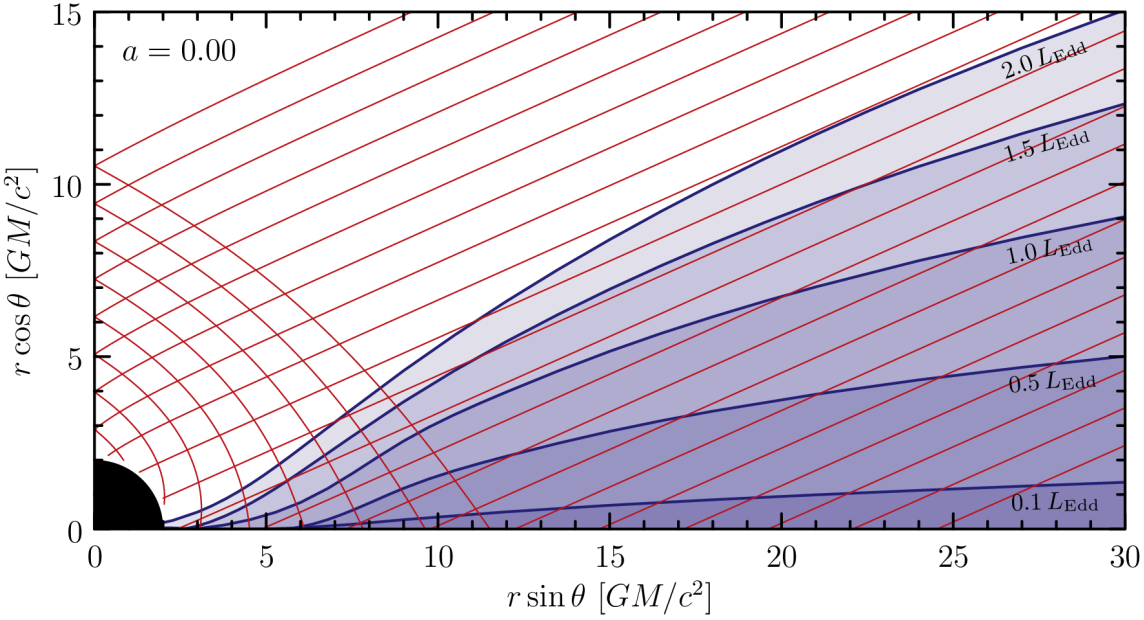
Analytical solutions



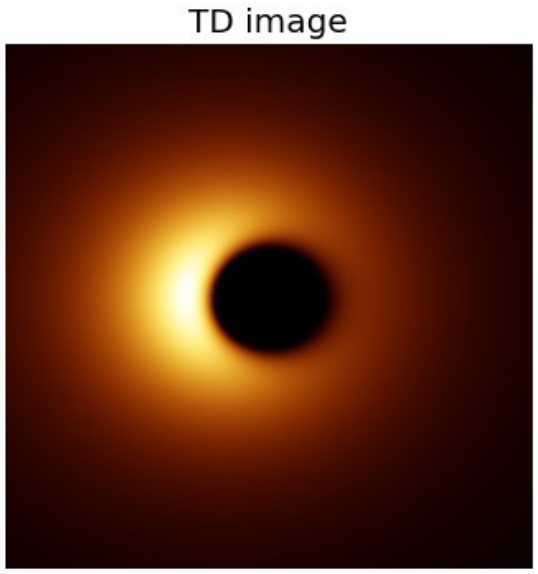
Sadowski+2009

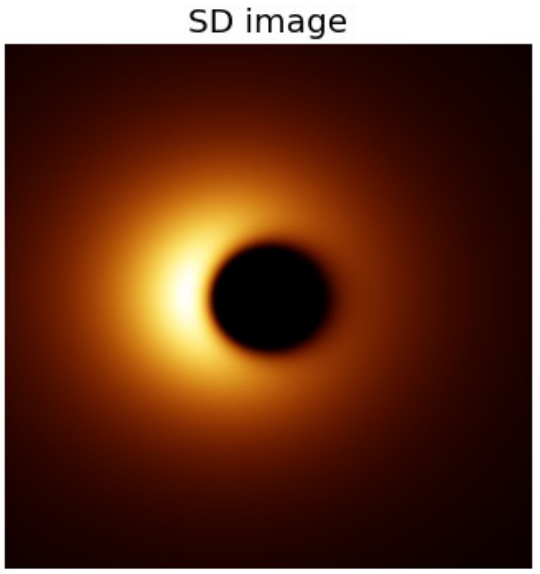
Spectral softening: advection & geometry

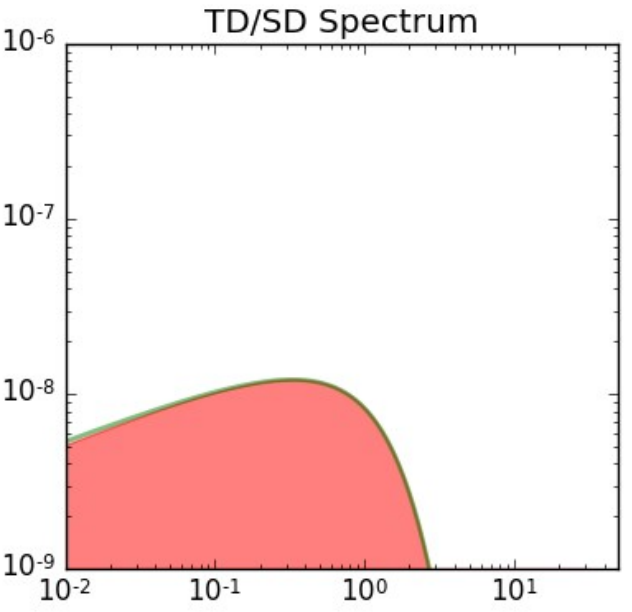


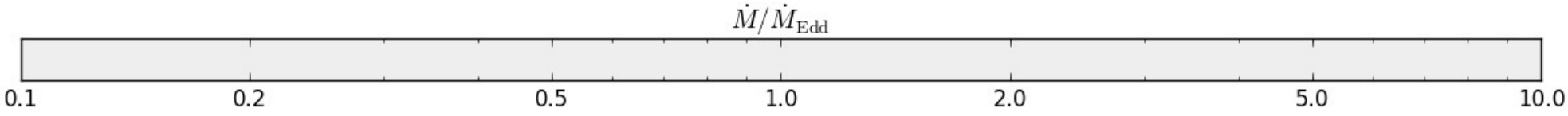


ULX spectra (a=0.00, i=30°)

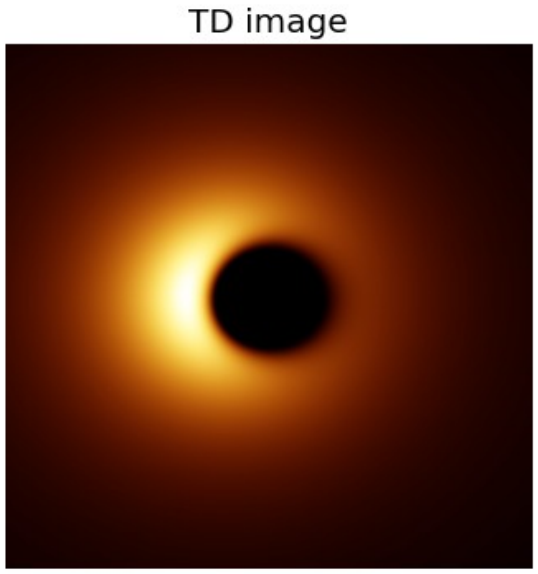


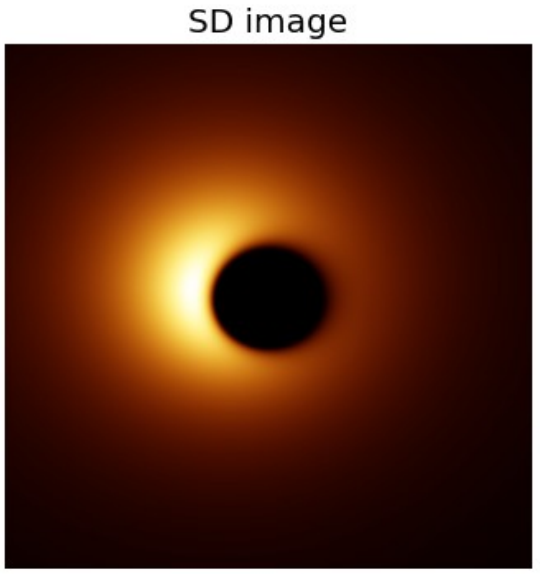


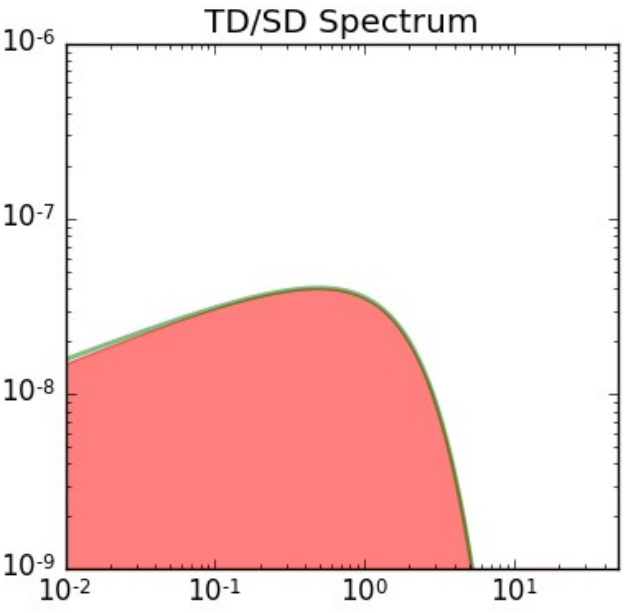


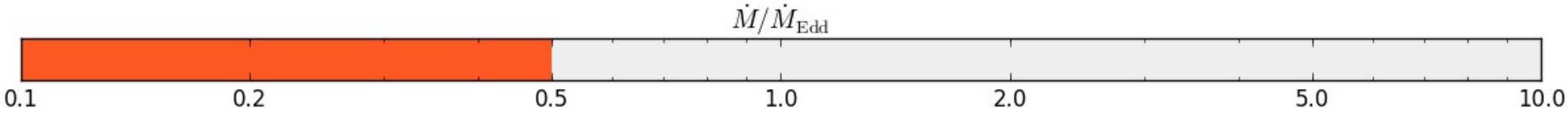


ULX spectra (a=0.00, i=30°)

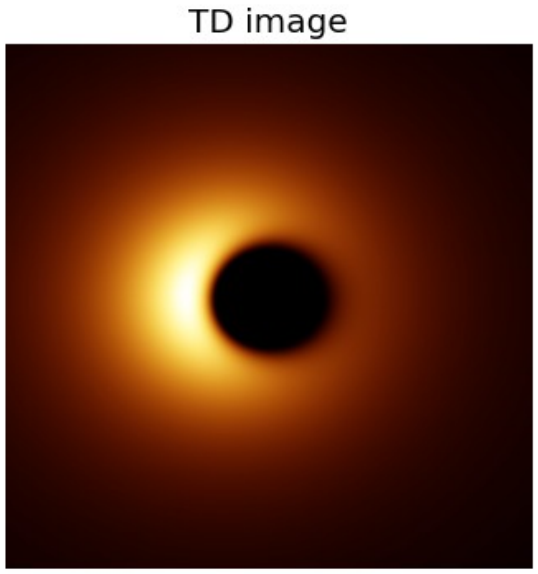


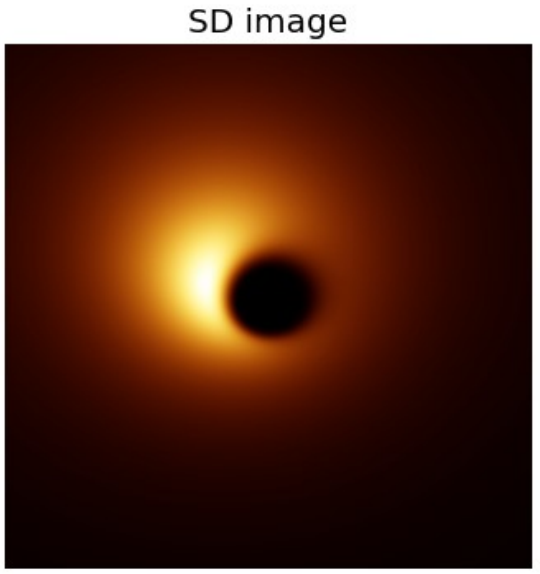


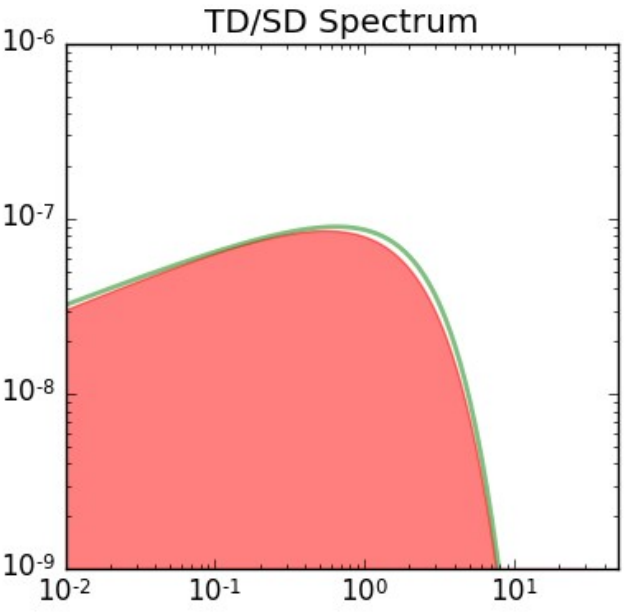


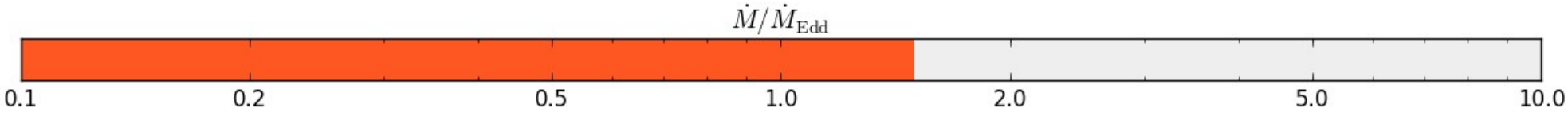


ULX spectra (a=0.00, i=30°)

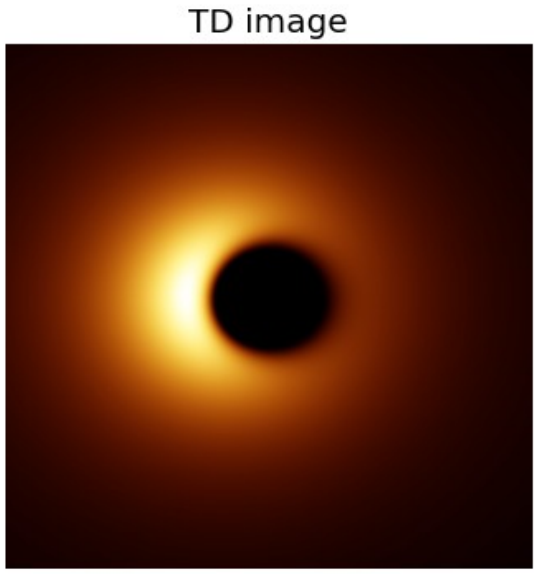


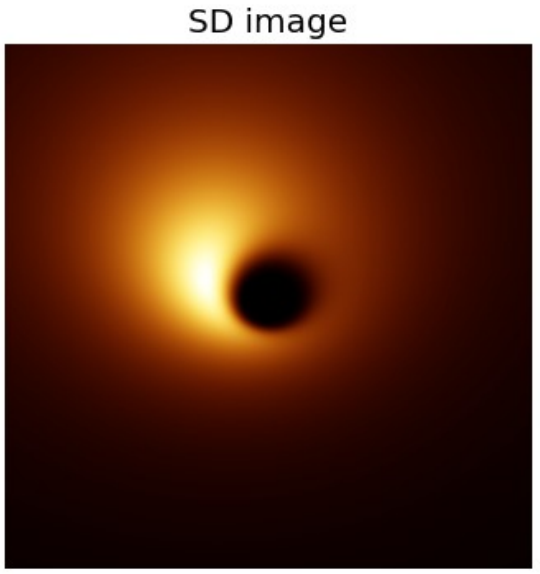


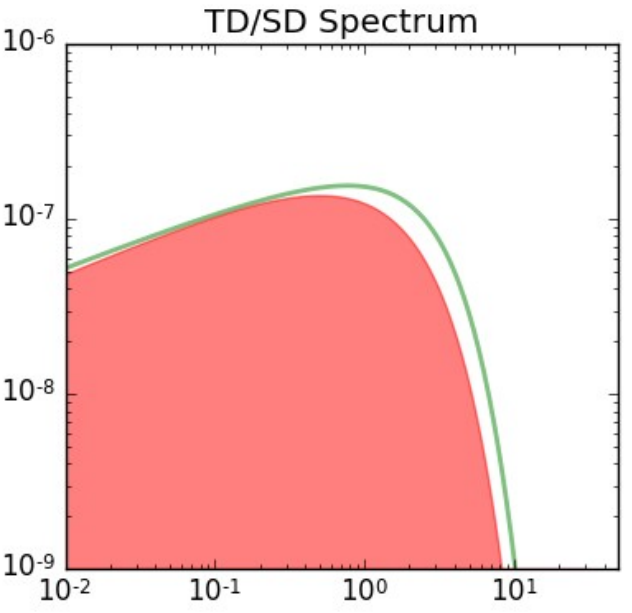


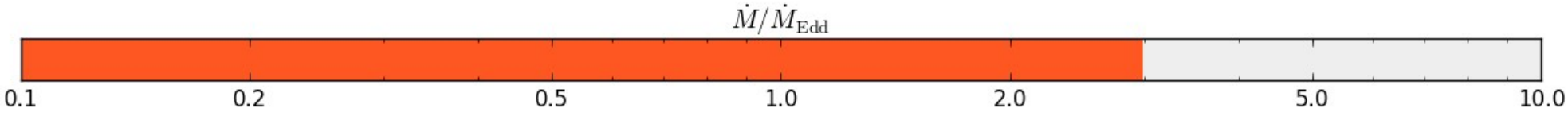


ULX spectra (a=0.00, i=30°)

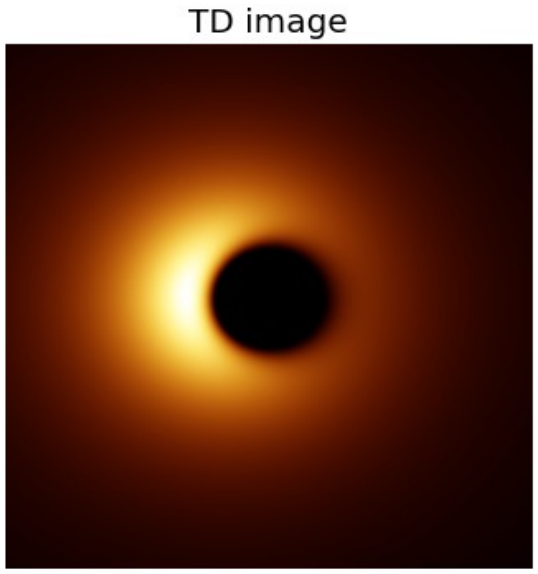


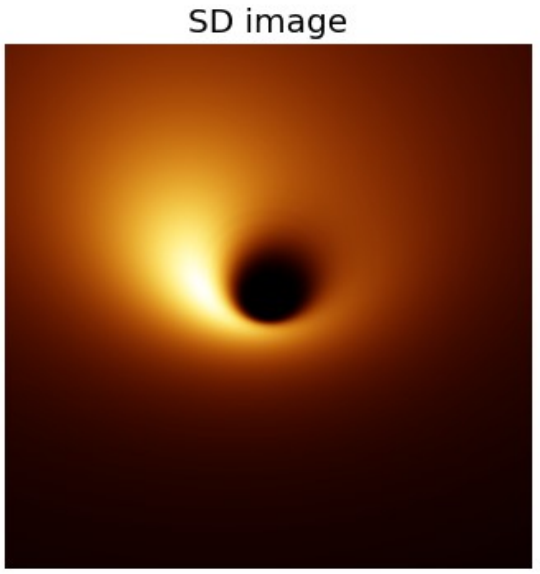


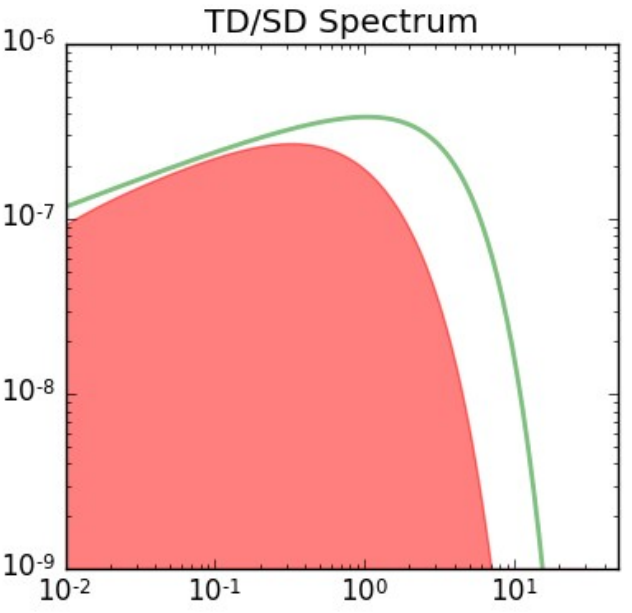


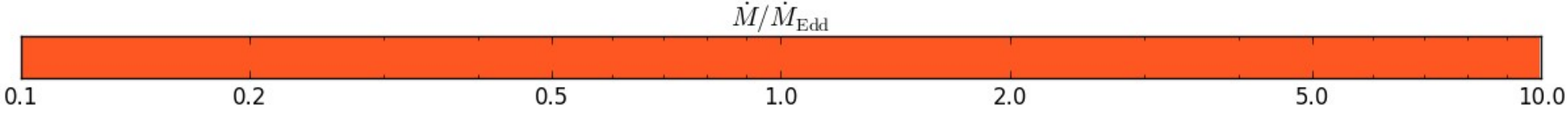


ULX spectra (a=0.00, i=30°)

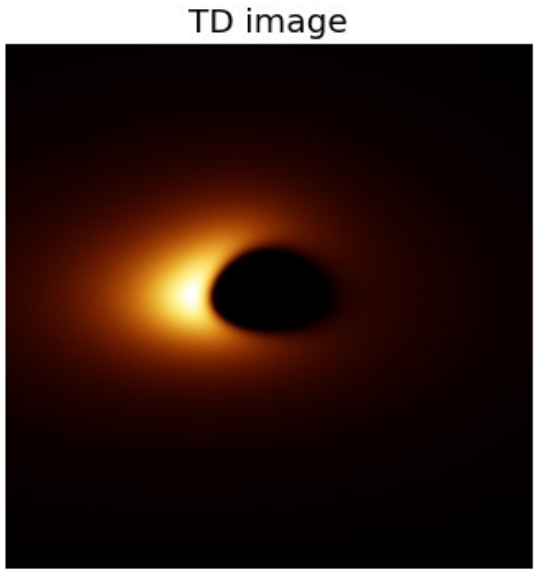


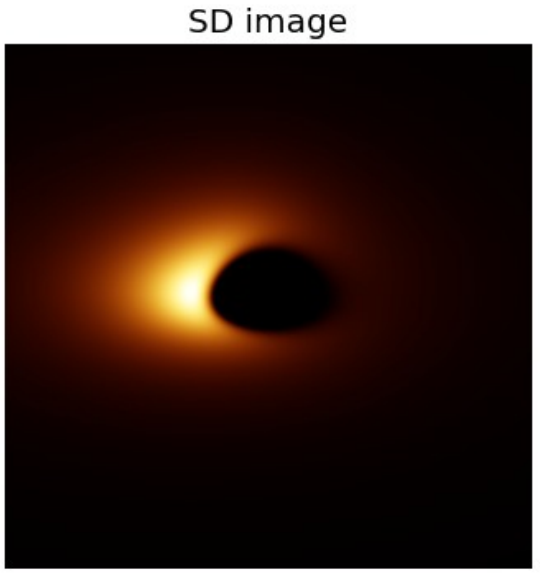


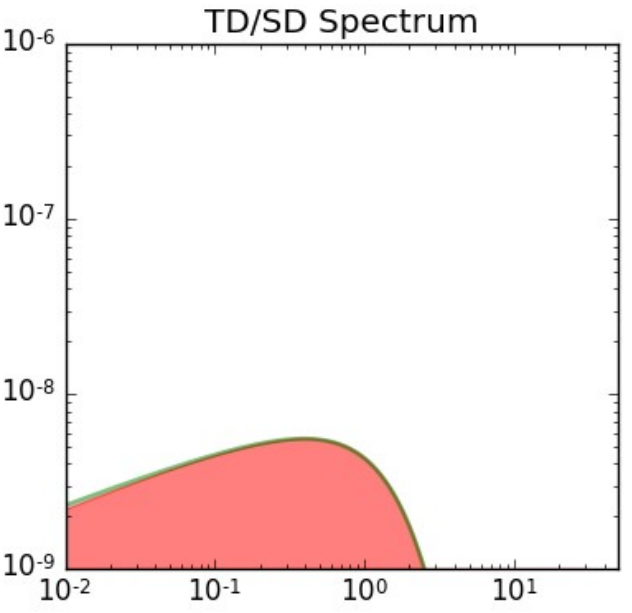


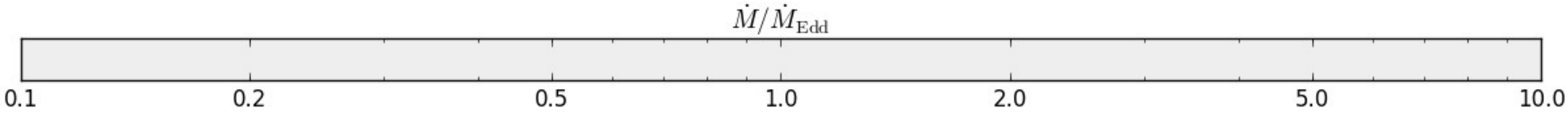


ULX spectra (a=0.00, i=60°)

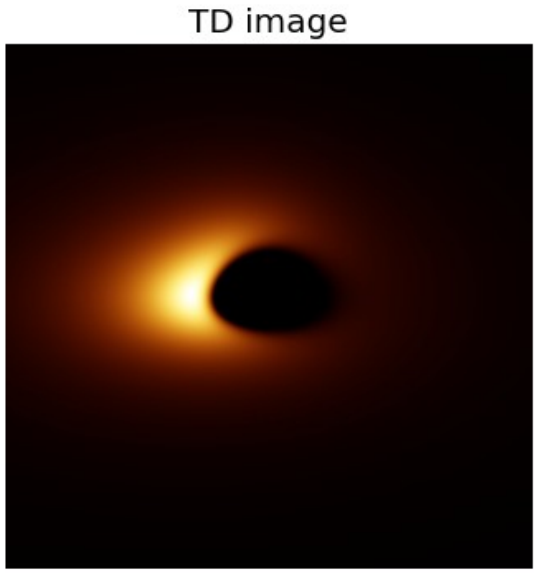


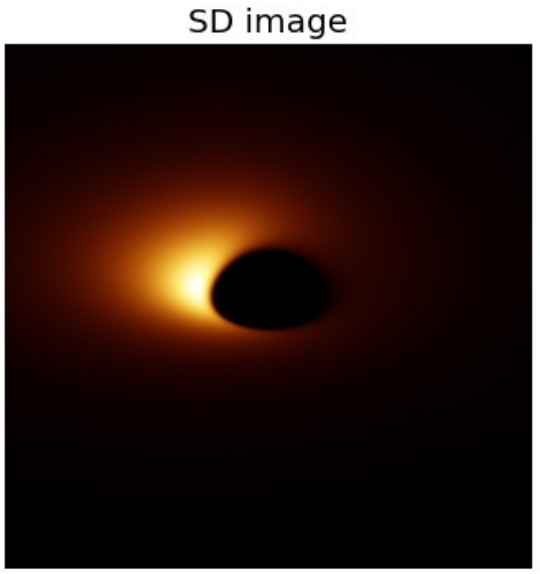


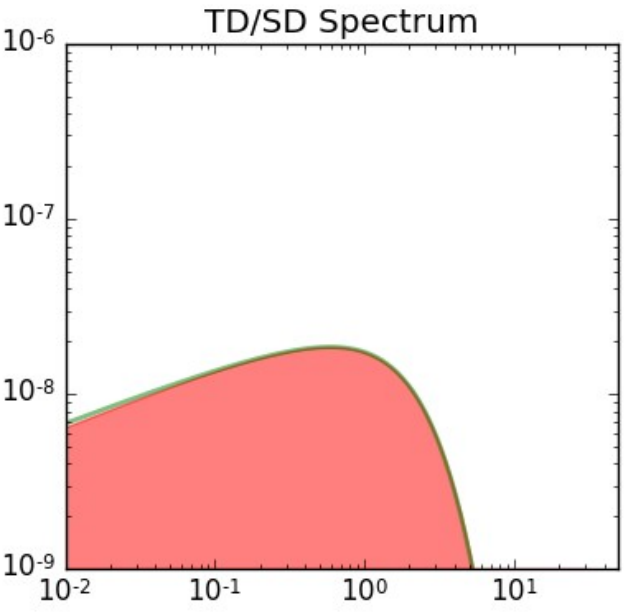


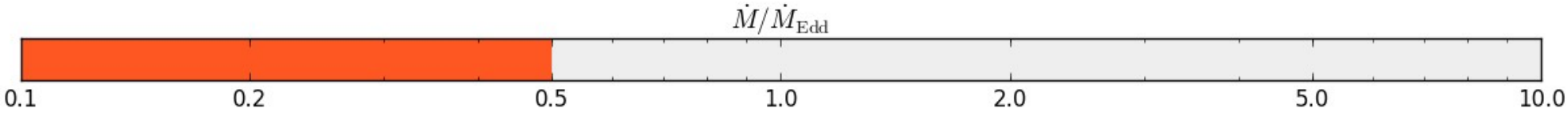


ULX spectra (a=0.00, i=60°)

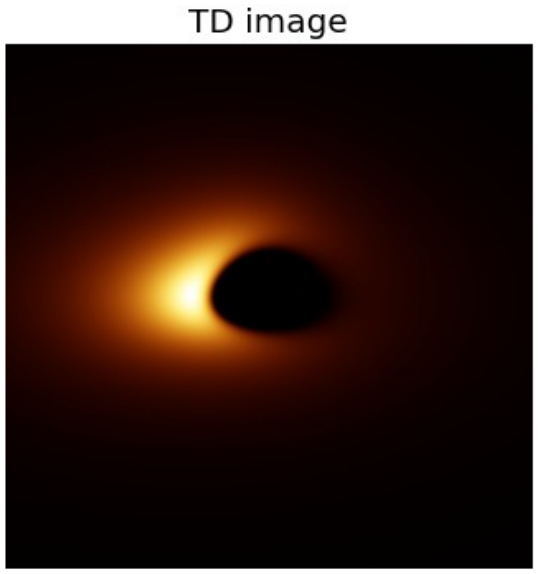


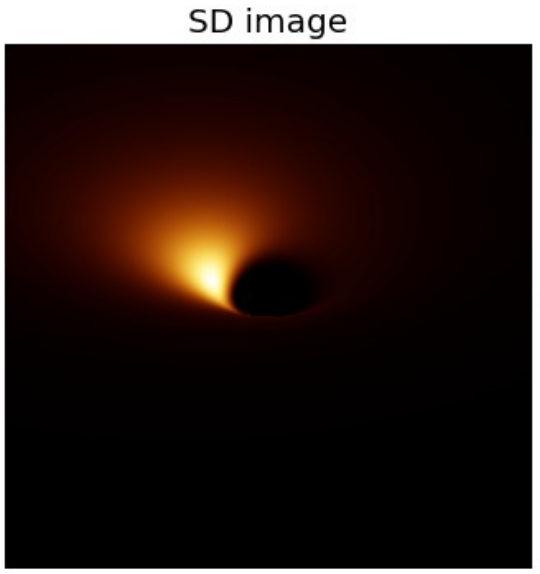


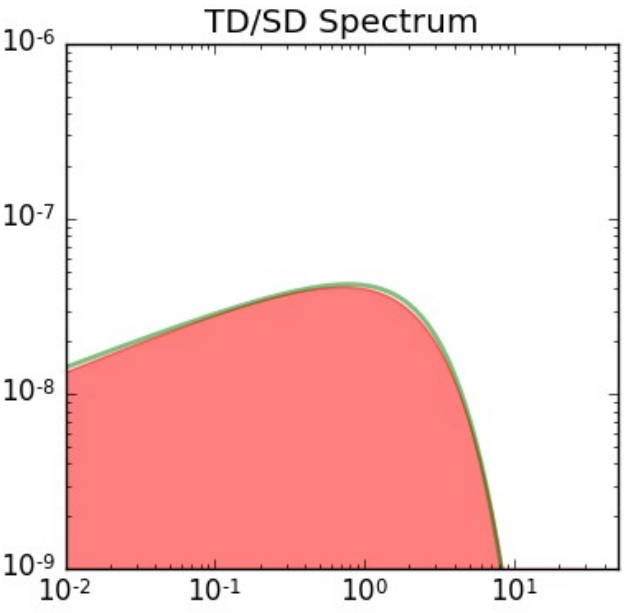


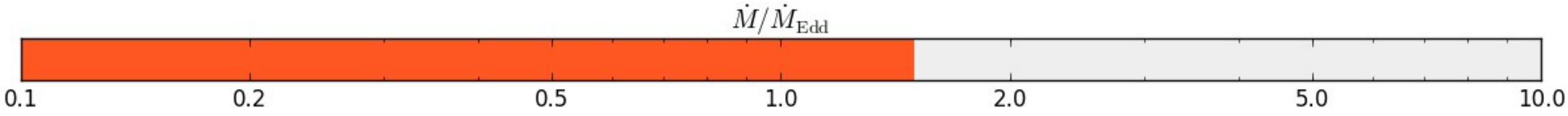


ULX spectra (a=0.00, i=60°)

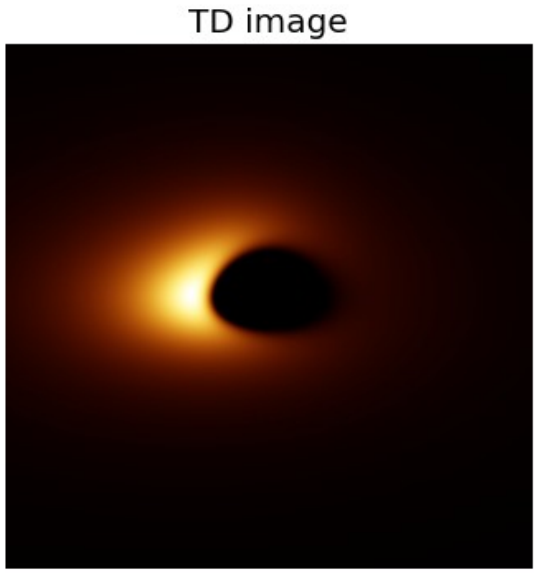


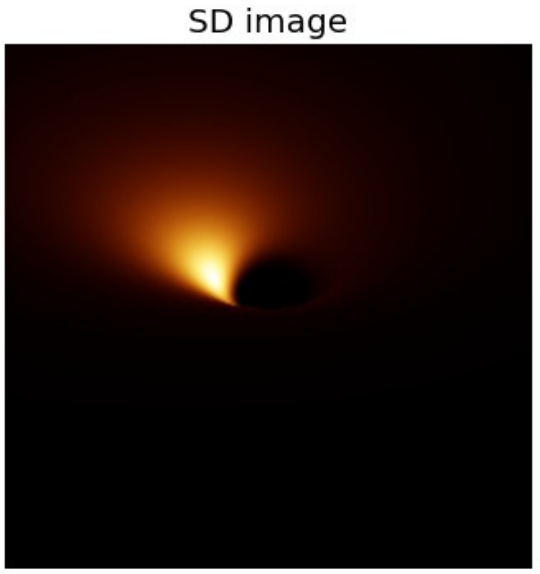


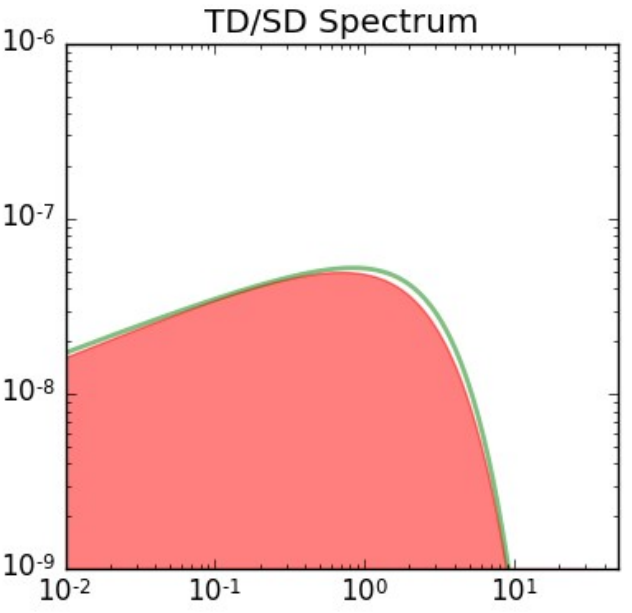


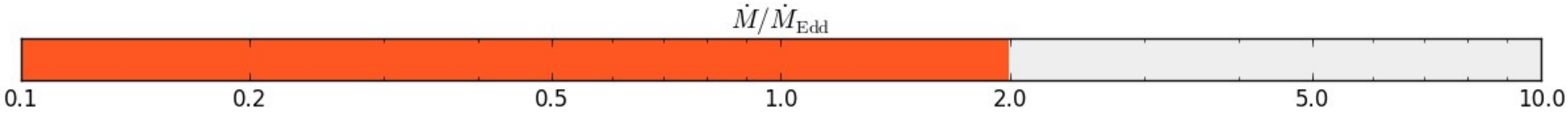


ULX spectra (a=0.00, i=60°)

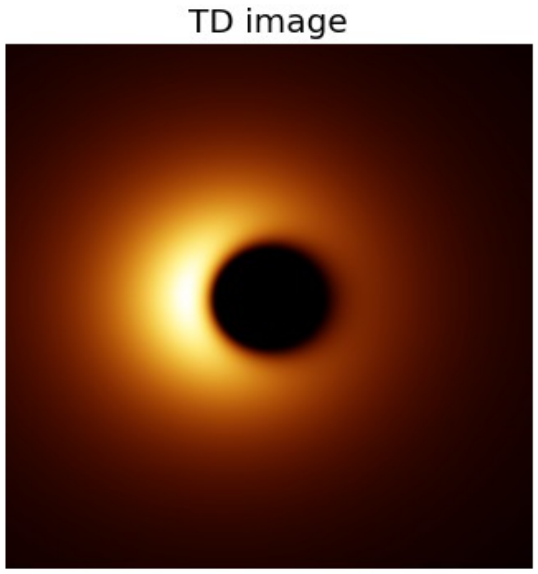


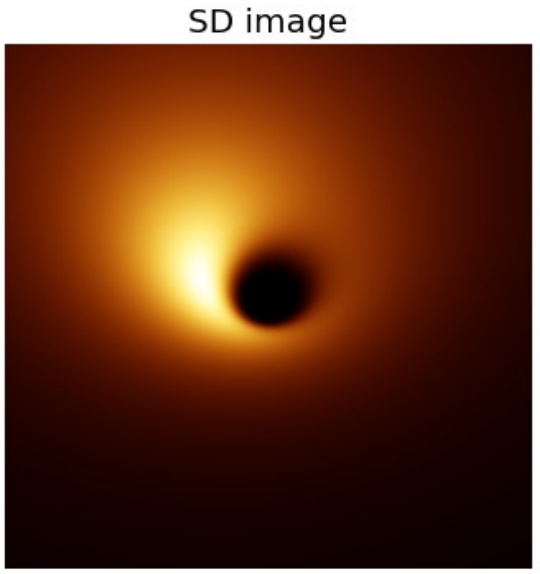


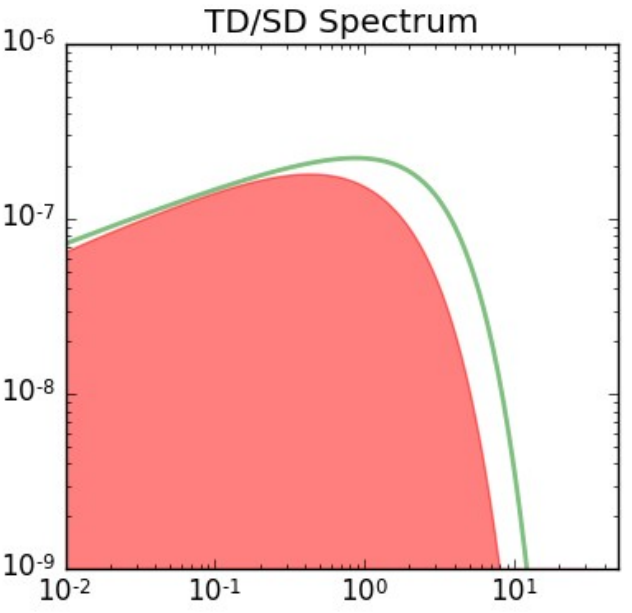


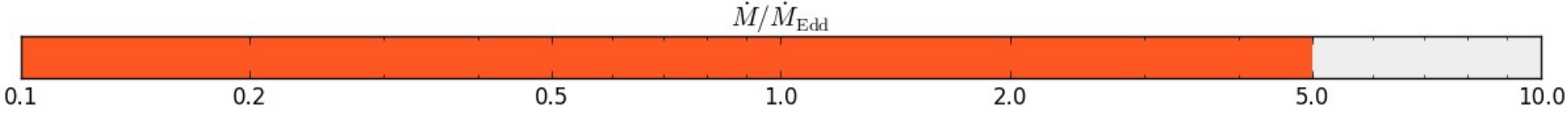


ULX spectra (a=0.00, i=60°)

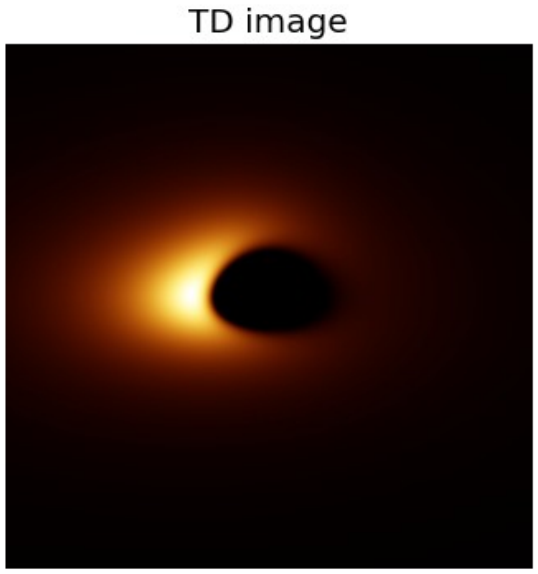


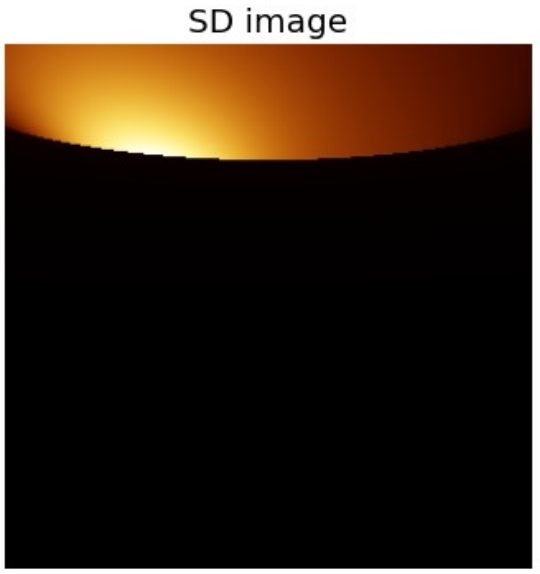


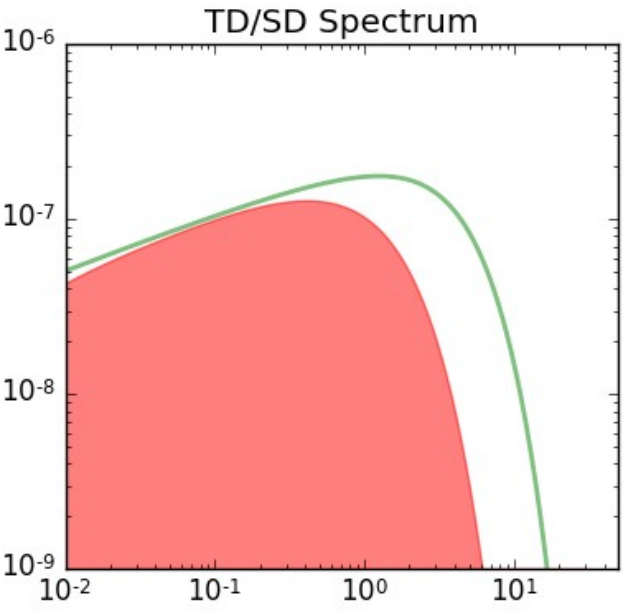


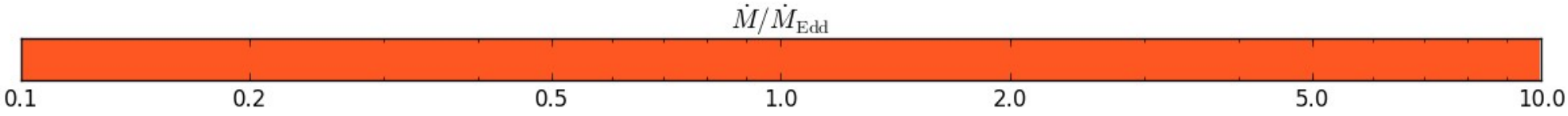


ULX spectra (a=0.00, i=60°)

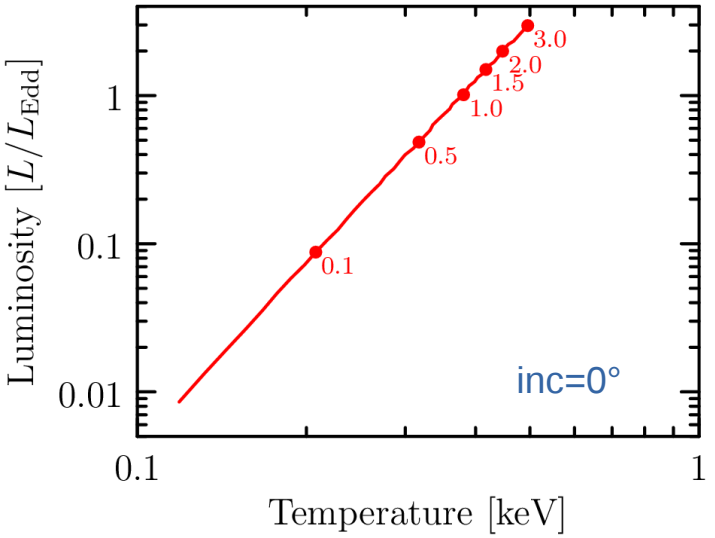








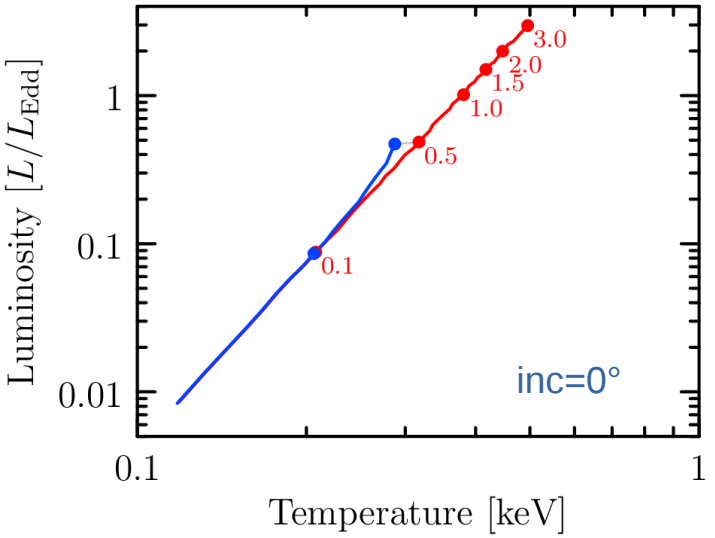
Luminosity vs. Temperature



L-T plot in super-eddington case:

- standard (thin) disks follow $L \sim T^4$ relation
- advection and obscuration effects cause significant deviations from that relation in super-Eddington regime
- the effect is strongly inclination dependent
- observed luminosity can stay arround eddington even if mass accretion rate is >>1
- that has implications for spectral modeling

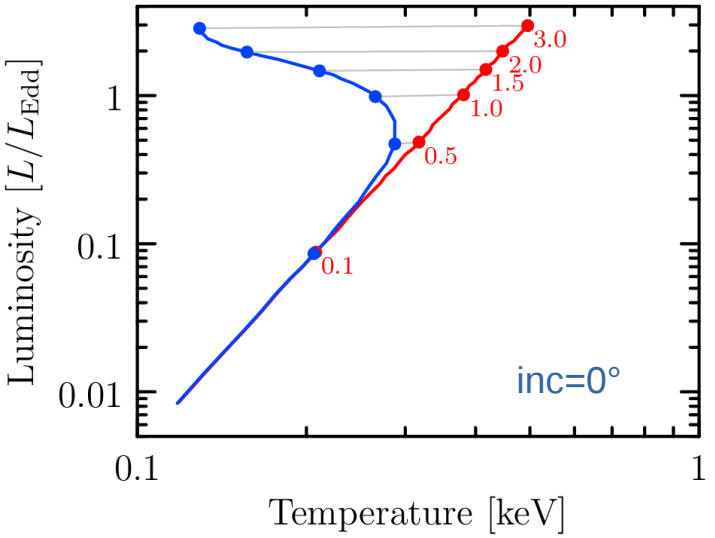
Luminosity vs. Temperature



L-T plot in super-eddington case:

- standard (thin) disks follow $L \sim T^4$ relation
- advection and obscuration effects cause significant deviations from that relation in super-Eddington regime
- the effect is strongly inclination dependent
- observed luminosity can stay arround eddington even if mass accretion rate is >>1
- that has implications for spectral modeling

Luminosity vs. Temperature



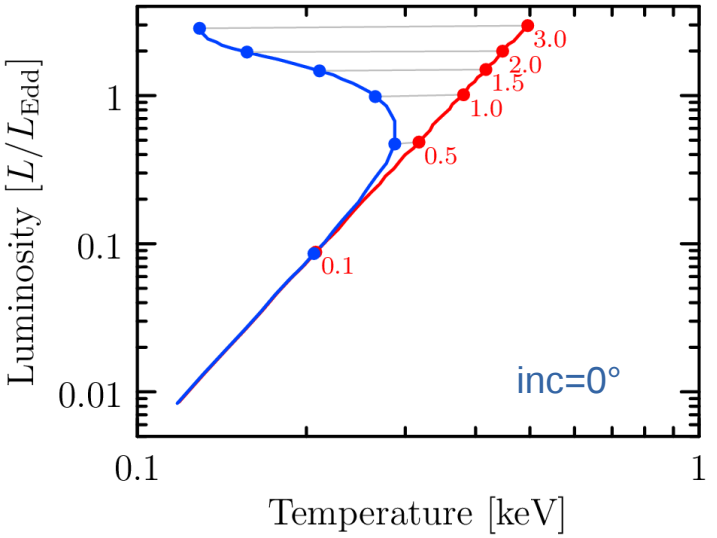
L-T plot in super-eddington case:

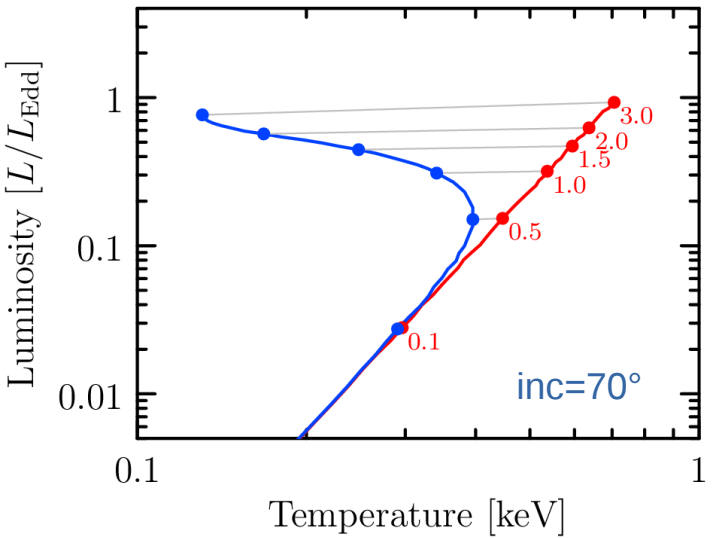
- standard (thin) disks follow $L \sim T^4$ relation
- advection and obscuration effects cause significant deviations from that relation in super-Eddington regime
- the effect is strongly inclination dependent
- observed luminosity can stay arround eddington even if mass accretion rate is >>1
- that has implications for spectral modeling

Luminosity vs. Temperature

L-T plot in super-eddington case:

- standard (thin) disks follow L~T^4 relation
- advection and obscuration effects cause significant deviations from that relation in super-Eddington regime
- the effect is strongly inclination dependent
- observed luminosity can stay arround eddington even if mass accretion rate is >>1
- that has implications for spectral modeling

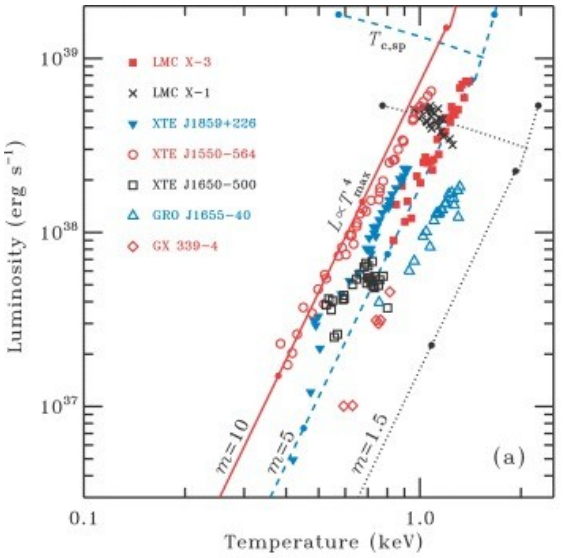


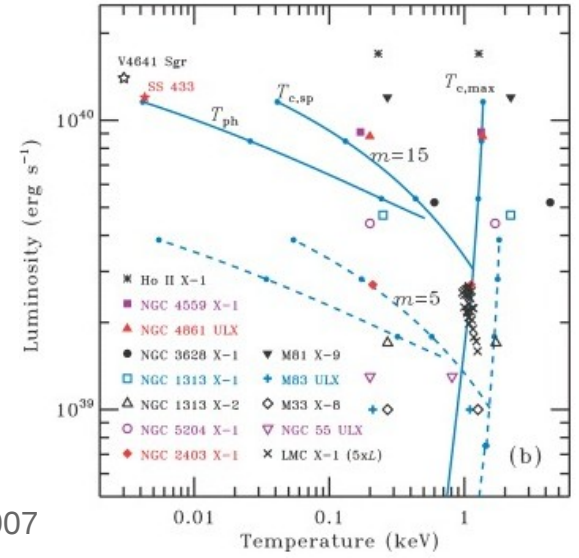


Luminosity vs. Temperature

L-T plot in super-eddington case:

- standard (thin) disks follow $L \sim T^4$ relation
- advection and obscuration effects cause significant deviations from that relation in super-Eddington regime
- the effect is strongly inclination dependent
- observed luminosity can stay arround eddington even if mass accretion rate is >>1
- that has implications for spectral modeling



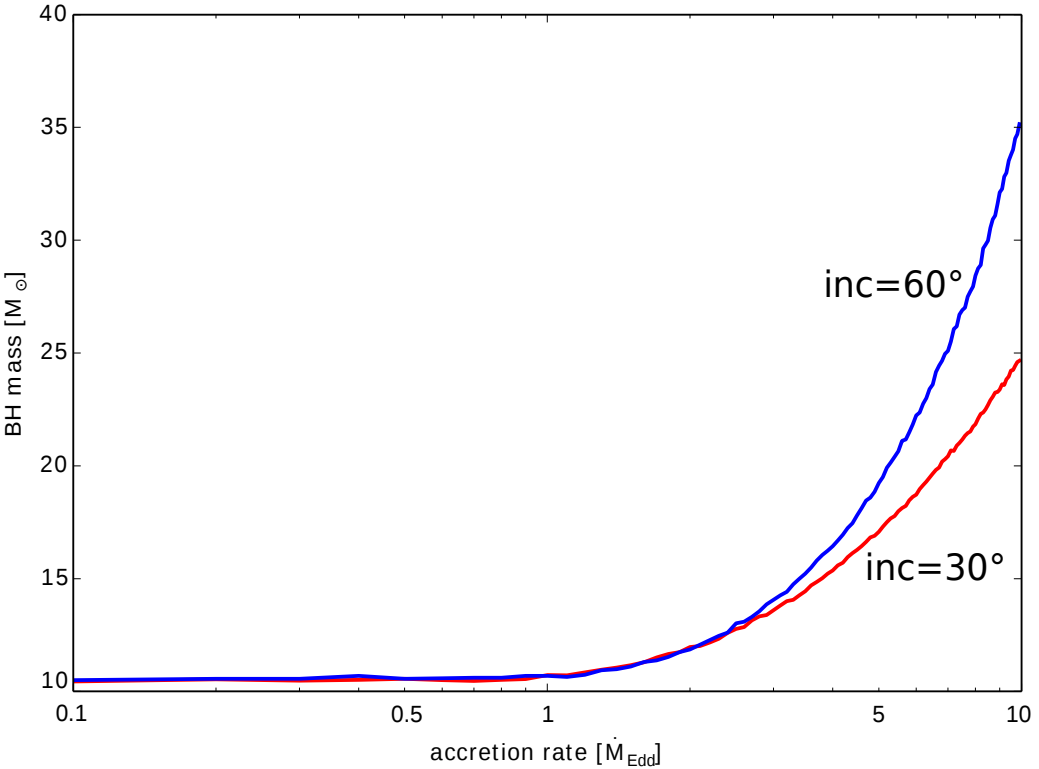


Poutanen+2007

Mass estimates from thermal spectra

SLIMULX spectra fitted with DISKBB

- simulated SLIMULX spectra are fitted with a thin disk model (DISKBB) and mass is obtained from the fit
- at low Mdot, the fit recovers the original mass, but at high Mdot, mass is much larger
- it appears to be quite tricky to estimate the ULX source parameters using thin disk models if the disk is strongly radiation pressure dominated
- **masses may be largely overestimated**



Limitations

Model limitations

- vertical equilibrium treatment ($Q \sim R^{-3}$ instead of $Q \sim [R^2+z^2]^{-3/2}$) limits H/R to ~1
- constant mass accretion rate, the solution misses transfer of gas to outflow
- reflection of radiation in the inner funnel; beaming
- feadback from radiation on the disk structure and shape
- hardening factor treatment

Fixes

- use insight from numerical simulations to apply scaling to the analytic model, possibly with accounting for comptonization in the outflowing wind

Summary

- slimulx model can be used fit BHB UXL spectra
- the model spectra reproduce a turnover in L-T track
- **compared to thin disk models, it gives lower BH masses**