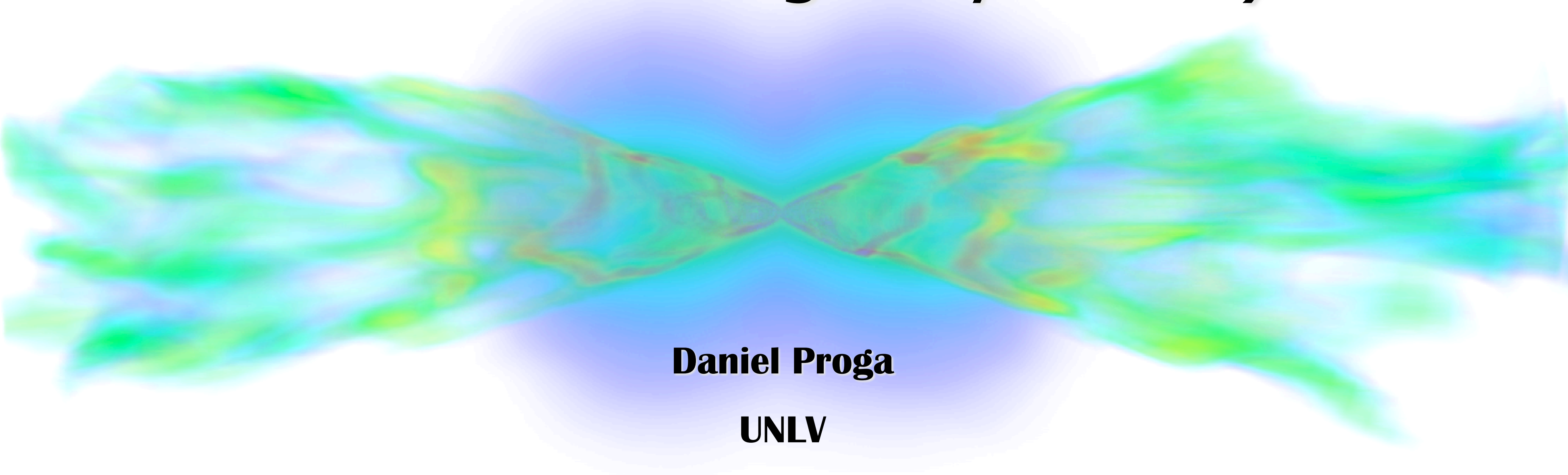
Radiative properties of AGN (lessons from numerical simulations of gas dynamics)



Daniel Proga

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OUTLINE

1. Introduction (accretion power).
2. Three examples of computing spectra of AGN:
   - radiation inefficient accretion flows,
   - radiation dominated accretion disks, and
   - QSOs and their winds.
3. Conclusions

Q: What Powers AGN?

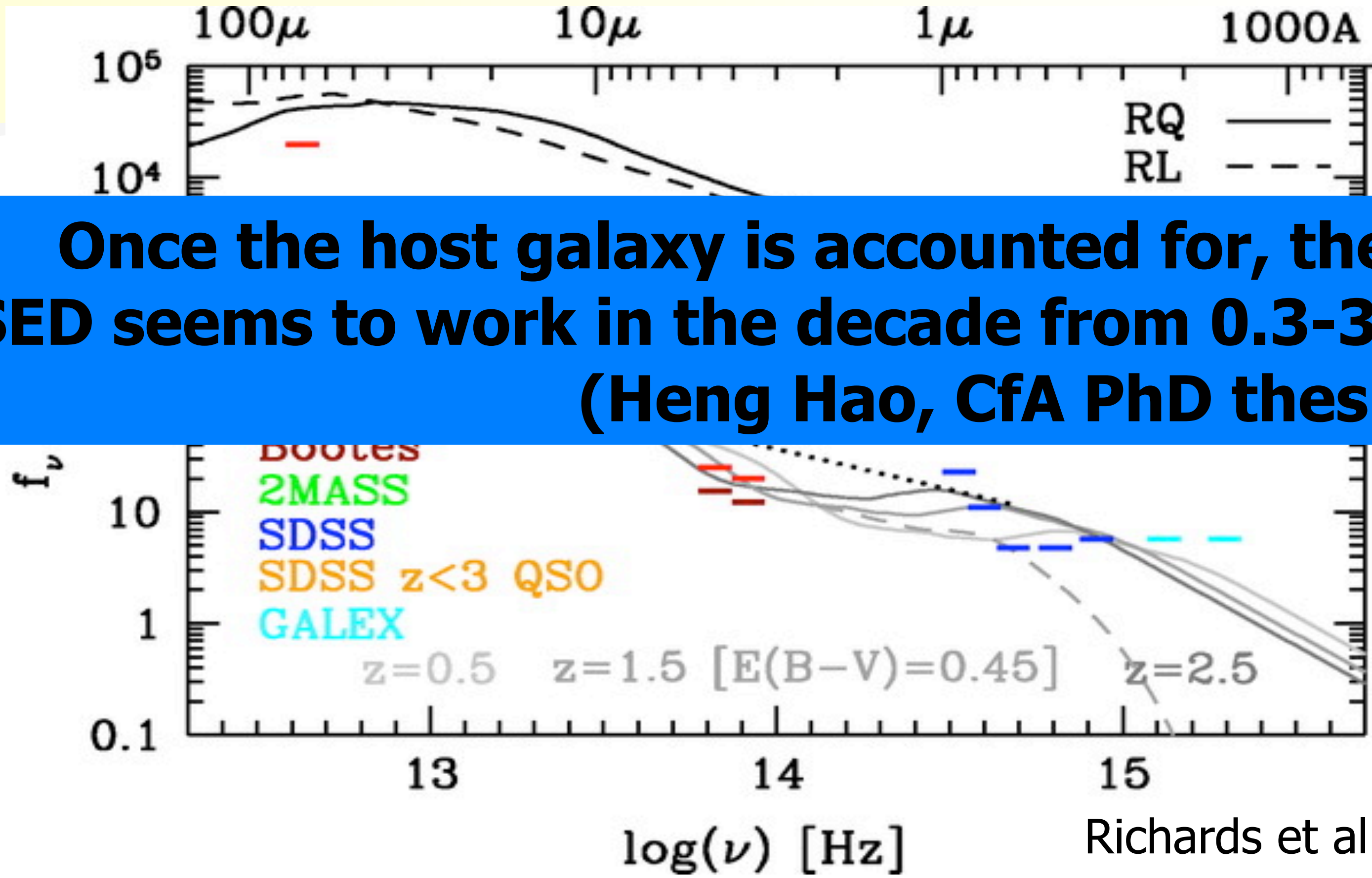
A: Accretion on Black Holes!

$$L = \eta c^2 \dot{M}_a$$

Q: But how much radiation is produced at a give energy band?

A: Could you repeat the question?

The observed SED

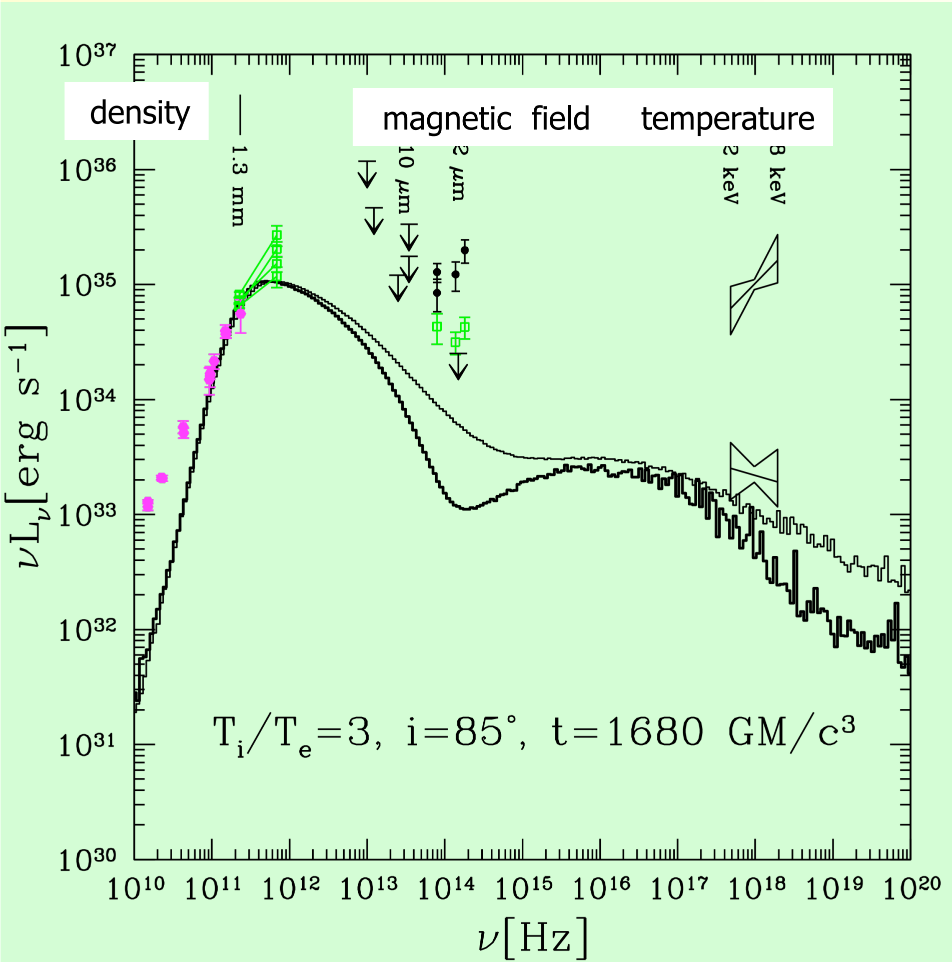


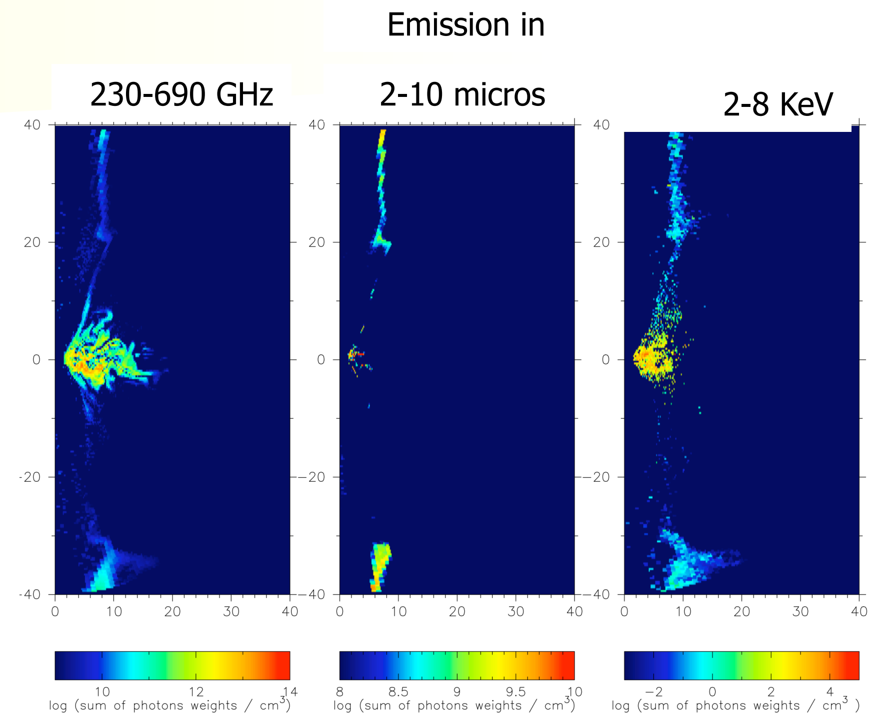
Once the host galaxy is accounted for, the old E94 SED seems to work in the decade from 0.3-3 microns (Heng Hao, CfA PhD thesis 2010).

Richards et al. (2006)

But we now have more and much better quality data thanks to XMM-Newton, Chandra, Suzaku, HST, Spitzer, SDSS, Fermi etc.

Sgr A* and LL AGN

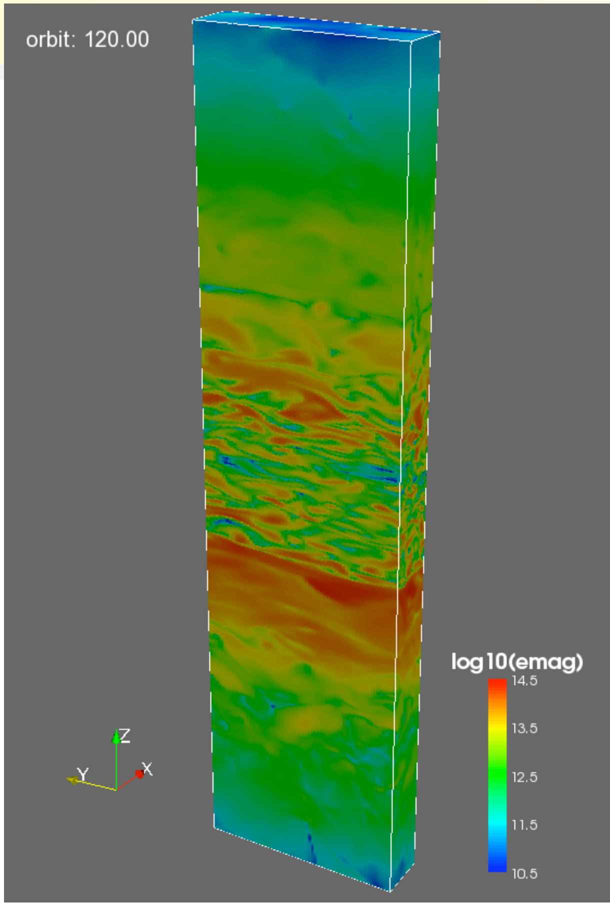


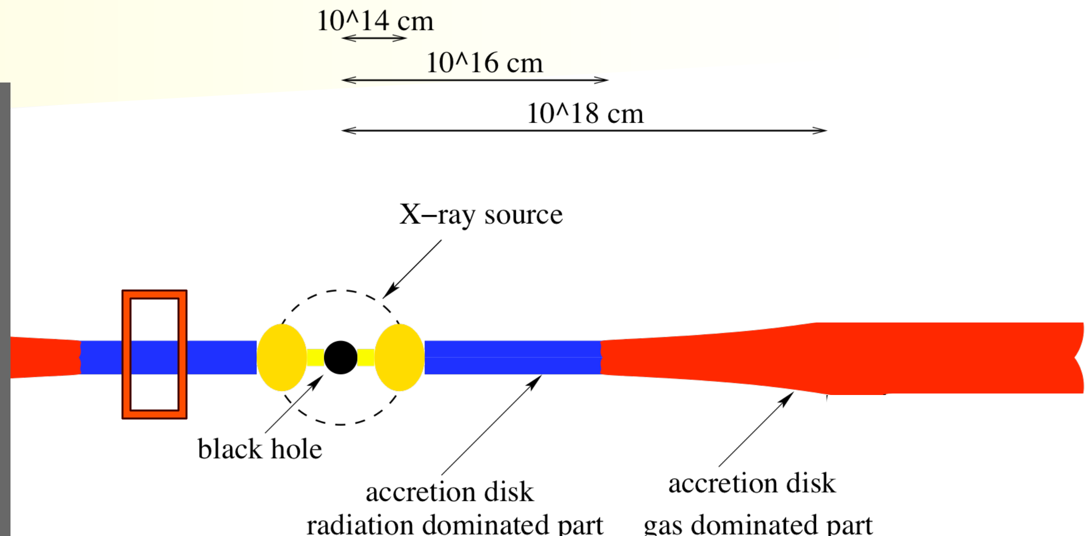


MC calculations including synchrotron radiation and Compton scattering

Moscibrodzka, Gammie + (2009), see also Moscibrodzka, Proga +2007 for a similar approach to compute spectra using MHD simulations and MC methods)

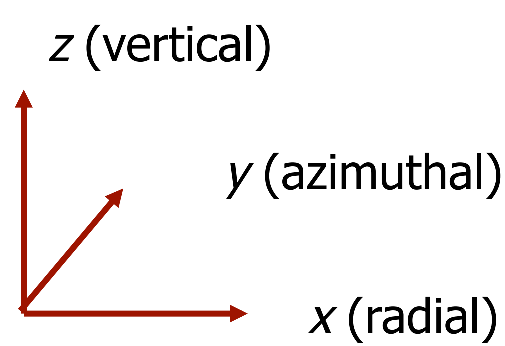
How about luminous AGN?





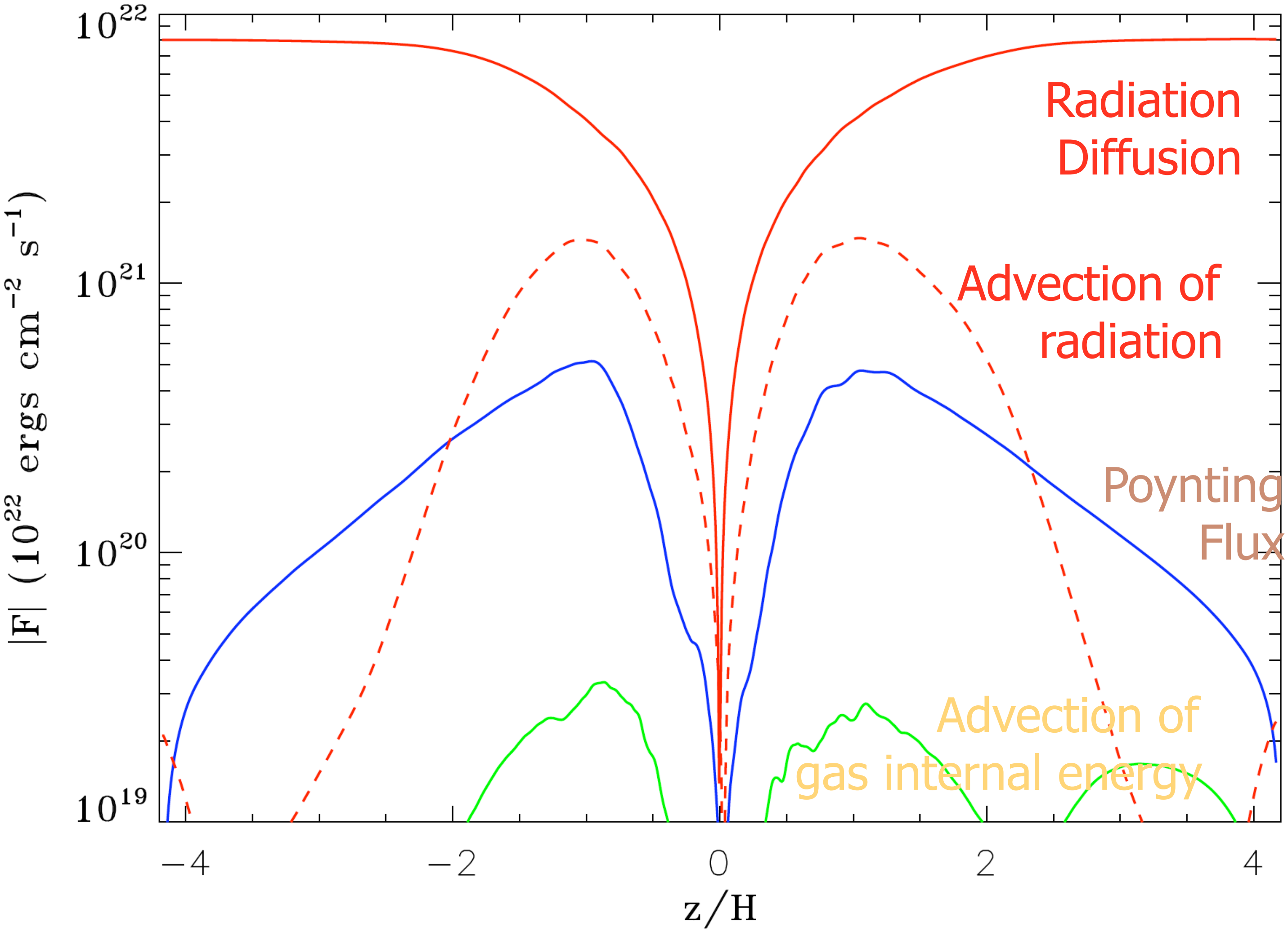
Local instead global calculations (e.g., of the stratified shearing box)

Cartesian box corotating with fluid at center of box.



Blaes,Hirose, Krolik, & Stone collaboration

Time Averaged Vertical Energy Transport



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Overall Vertical Structure for all P_{rad}/P_{gas} Regimes

Photospheres

$P_{mag} > P_{rad}$, P_{gas}

Parker Unstable Regions

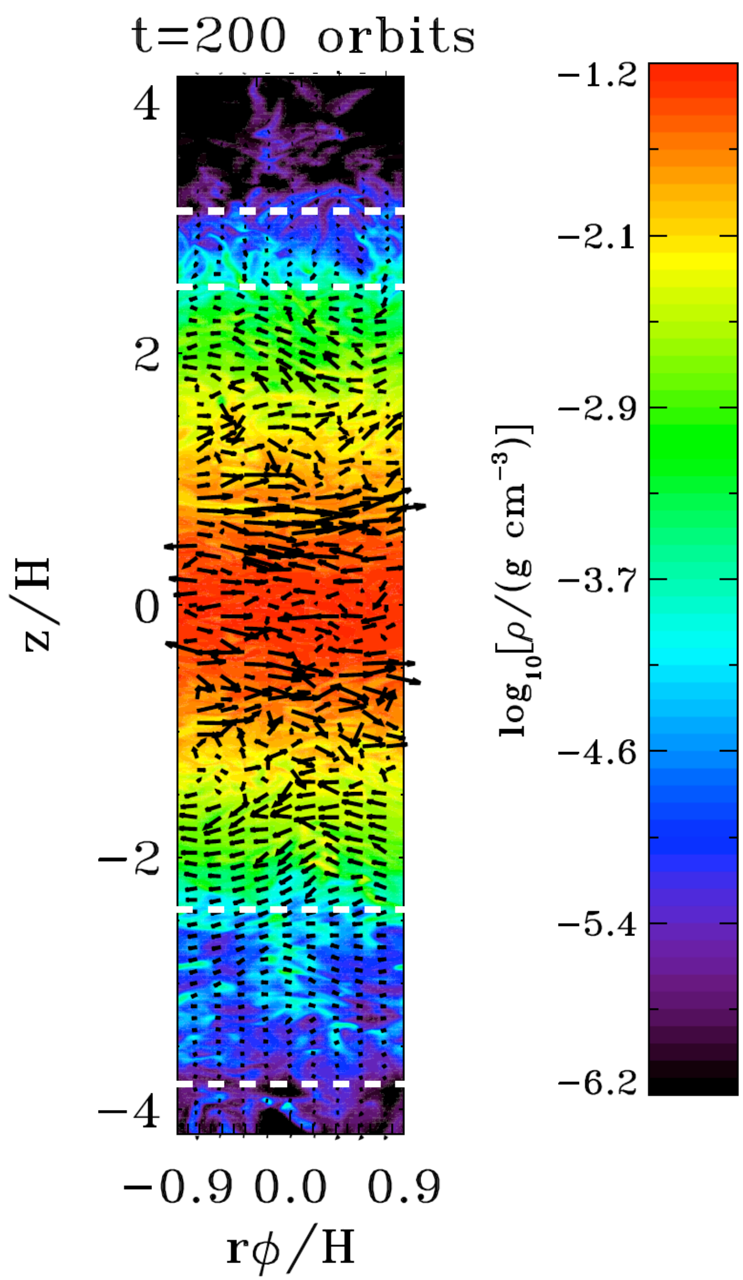
P_{rad}, $P_{gas} > P_{mag}$

MRI - the source of accretion power

Parker Unstable Regions

$P_{mag} > P_{rad}$, P_{gas}

Photospheres



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Summary about the Vertical Structure of Disks

- Hydrostatic balance: Disks are supported by thermal pressure near the midplane, but by magnetic forces in the outer (but still subphotospheric) layers.
- Thermal balance: Dissipation (numerical) occurs at great depth, and accretion power is transported outward largely by radiative diffusion. There is no locally generated corona.
- Stability: There is no radiation pressure driven thermal instability

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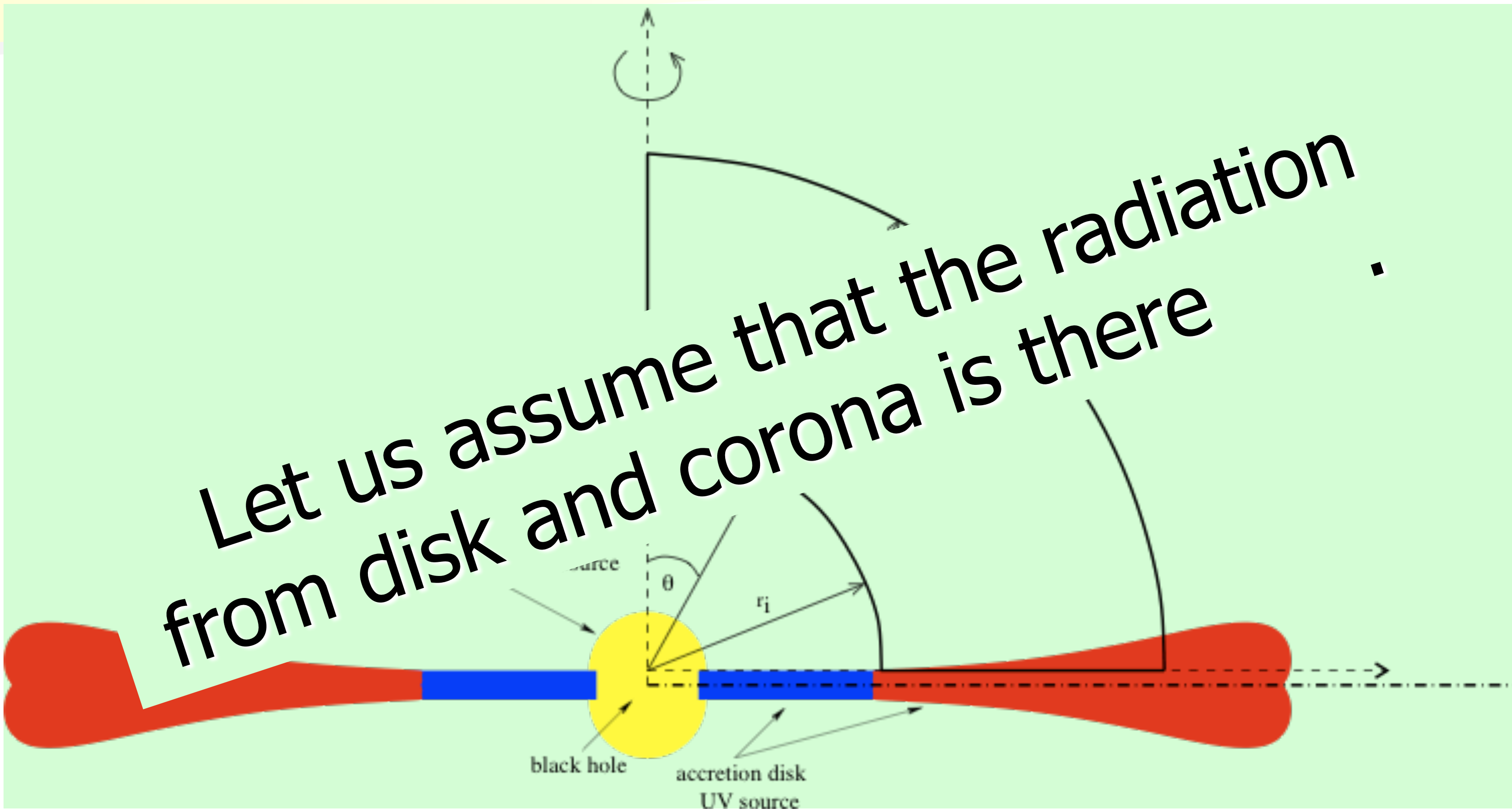
Implications of Simulation Data on Spectra

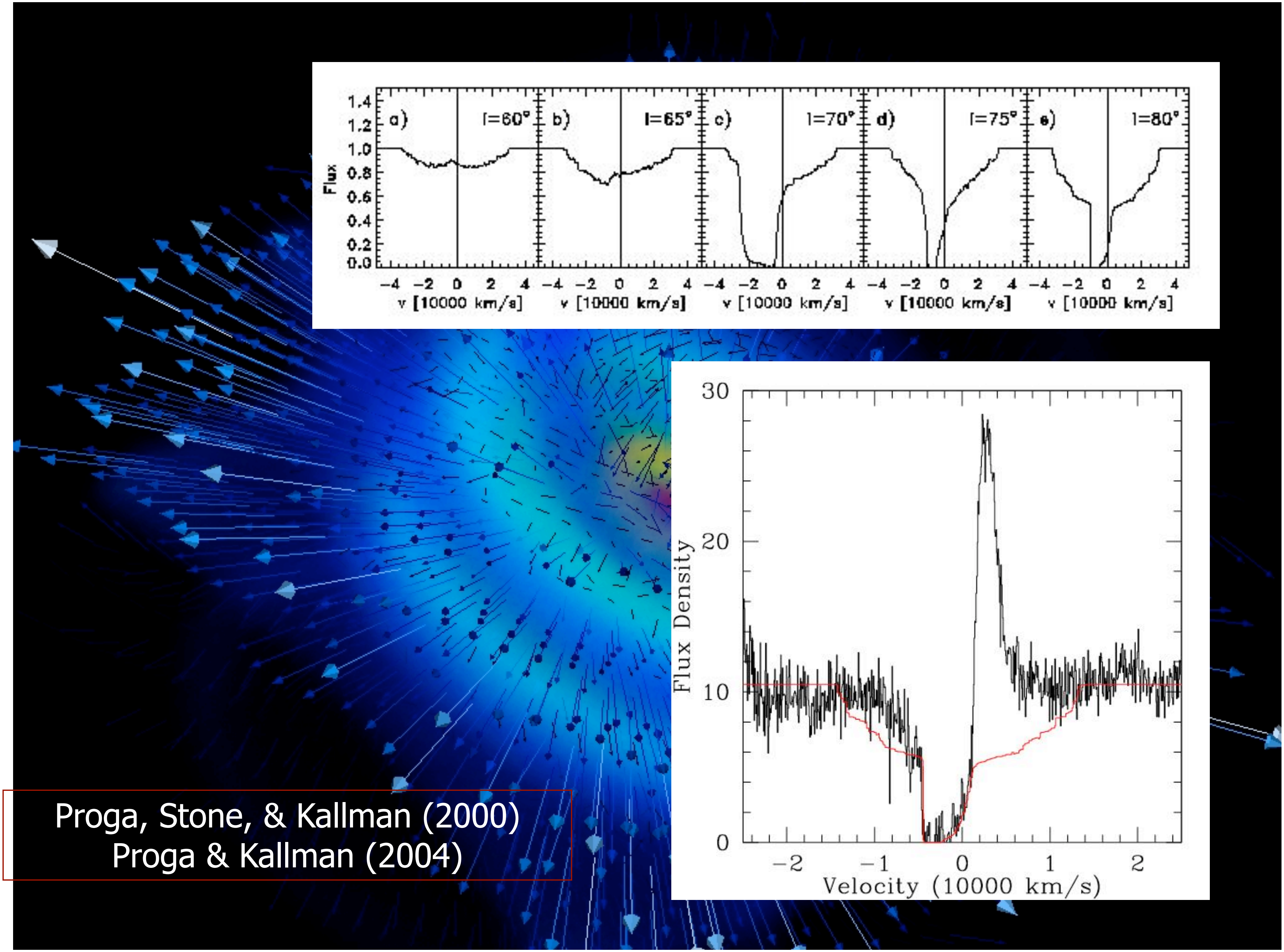
- Actual stress ("alpha") and vertical dissipation profiles are irrelevant, provided disk remains effectively thick.
- Magnetically supported upper layers *decrease* density at effective photosphere, producing a (~20%) *hardening* of the spectrum.
- Strong density inhomogeneities at photosphere produce a (~10%) *softening* of the spectrum.

Blaes,Hirose, Krolik, & Stone collaboration

Numerical simulations

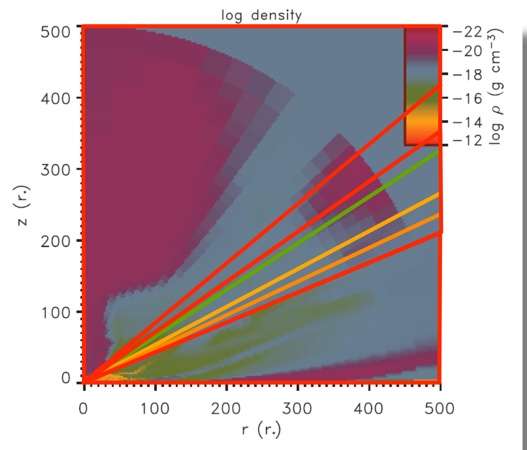


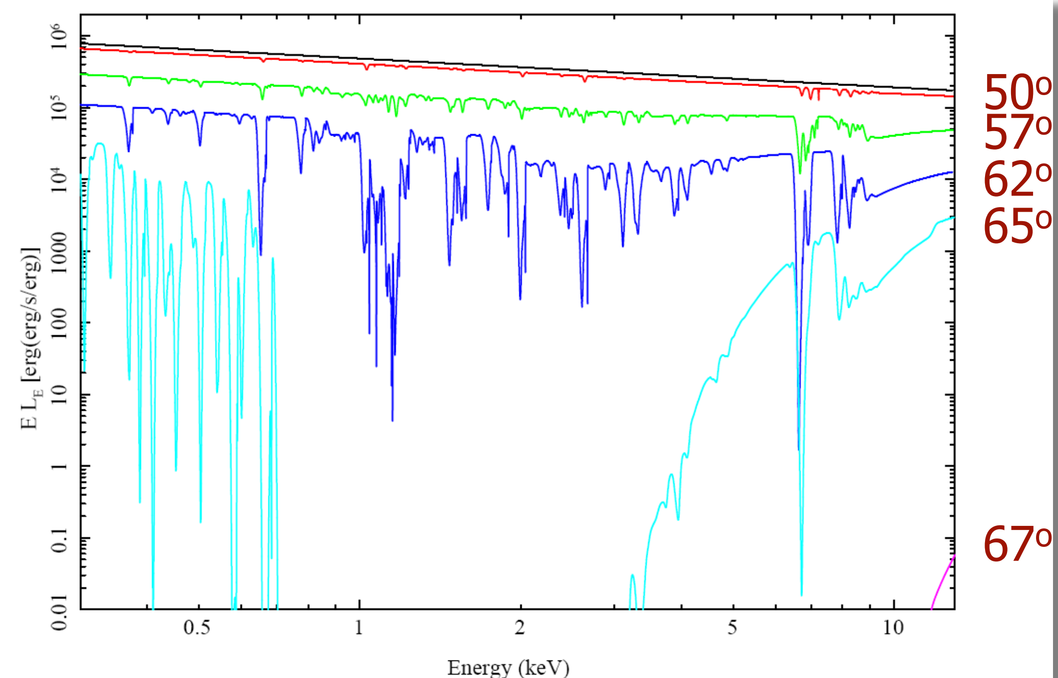
Let us assume that the radiation from disk and corona is there .



Proga, Stone, & Kallman (2000)
Proga & Kallman (2004)

Broad band spectra for various l.o.s.



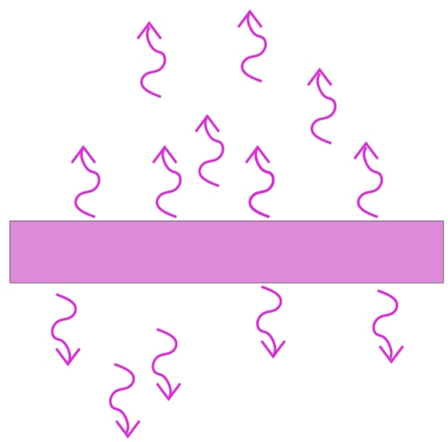


Schurch, Done, & Proga (2009)

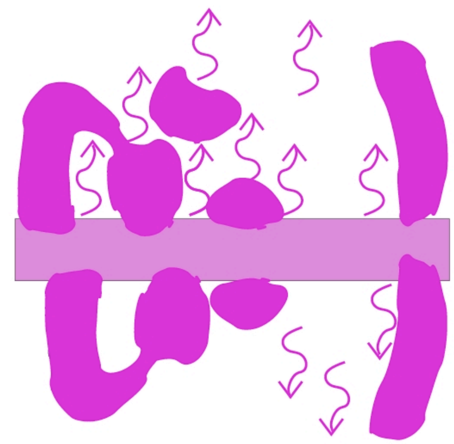
See a talk by G. Miniutti for implications for soft X-ray excess in AGN

Quenching Disk Corona

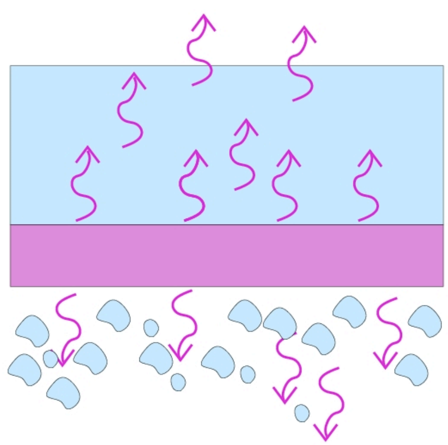
Disk



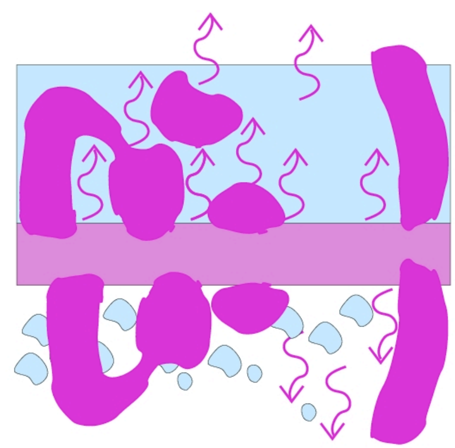
Disk and inflow/outflow



Disk and corona

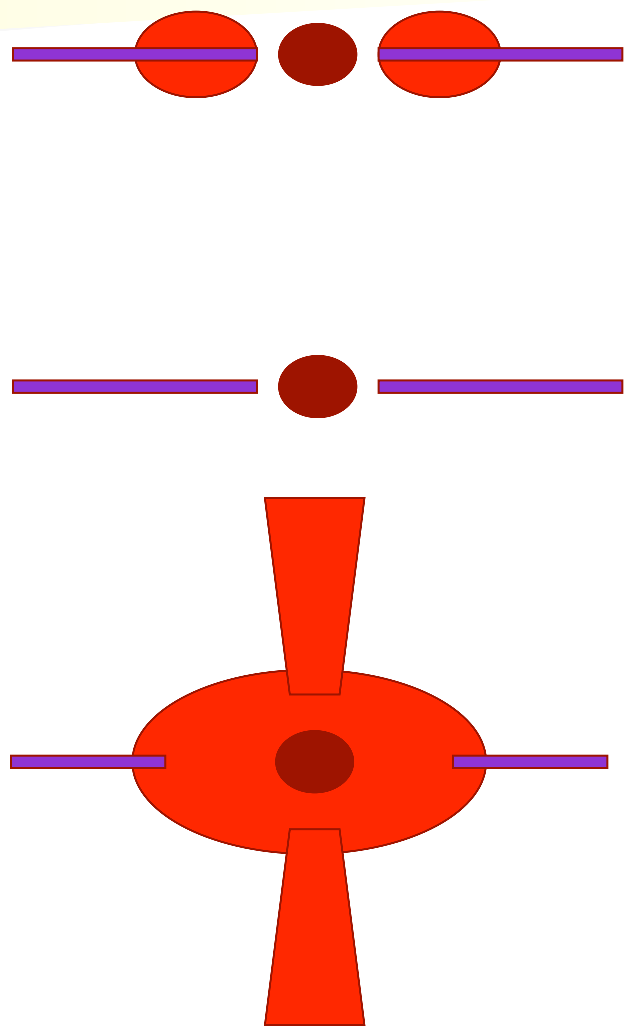


Disk and ???



Proga (2005)

Quenching Disk Corona



Conclusions

- Simulations of accretion flows provide insights into the dynamics and geometry of the material that produces radiation (we can use the simulations to assess the effects of radiation on the flow properties).
- The simulations can be and are used to compute synthetic spectra for direct comparison with the observations. As such, the simulations are useful in explaining specific spectral features as well as overall shape of the SED (not just pretty movies with complex physics behind).
- In general, we have moved beyond spectra modeling: we can predict spectra based on a physical model, many properties of which can be determined from first principles.