A Theoretical Study on the Geometry of Accretion Flow in AGN

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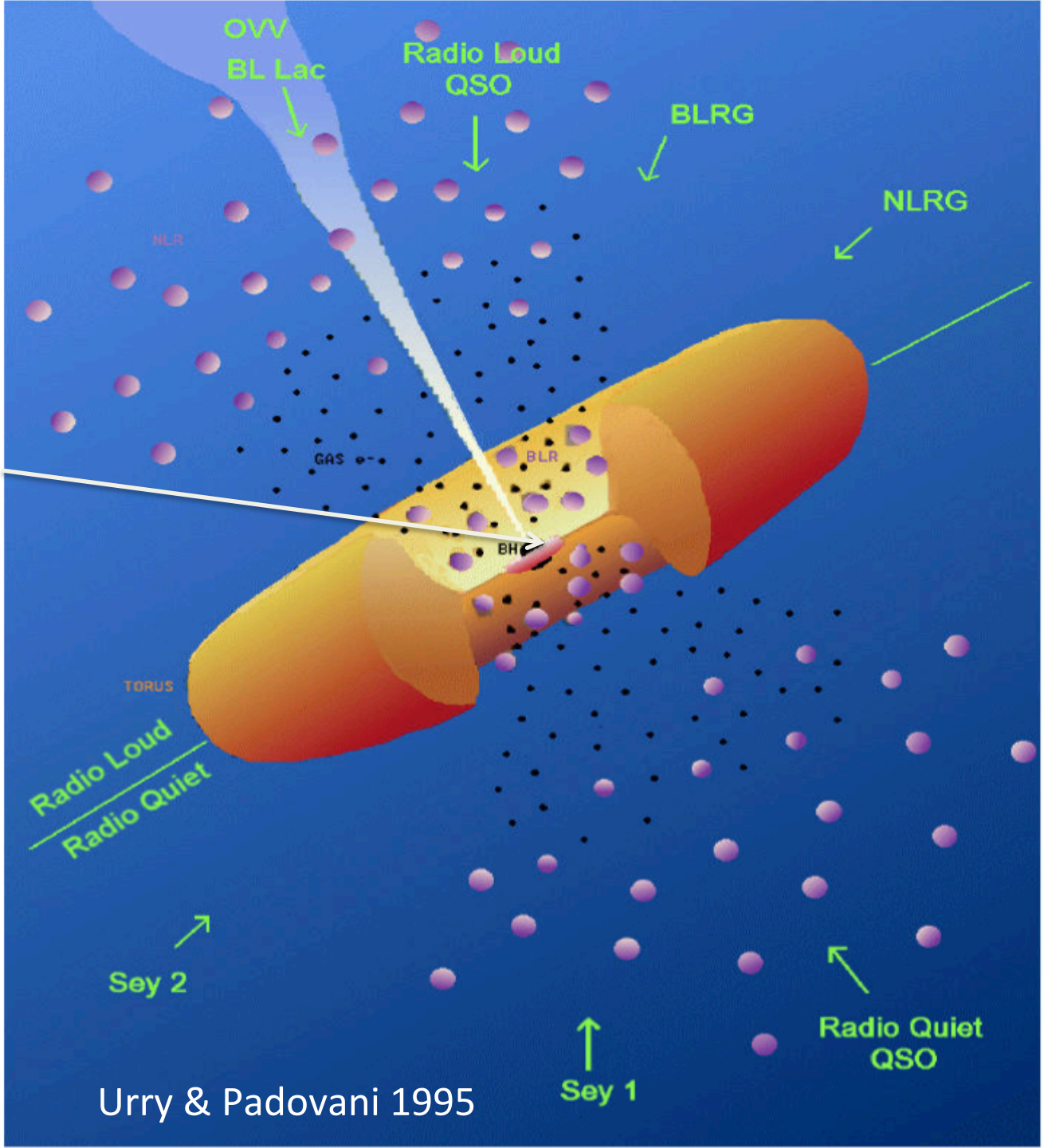
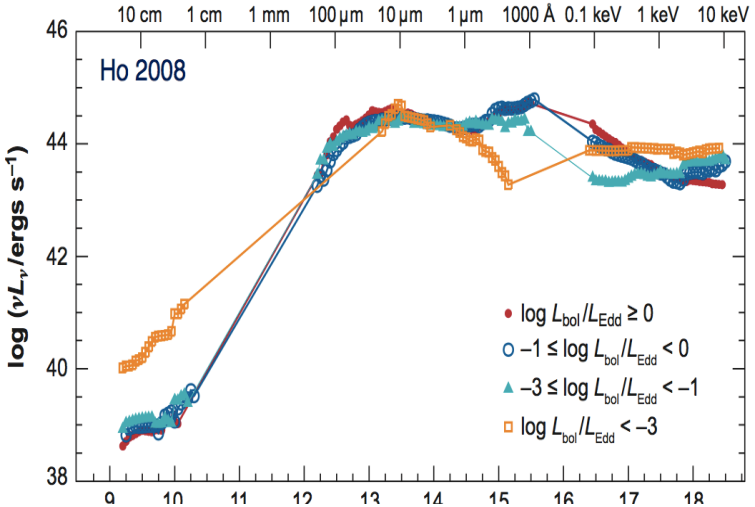
In the center:
Geometry?
Physics?

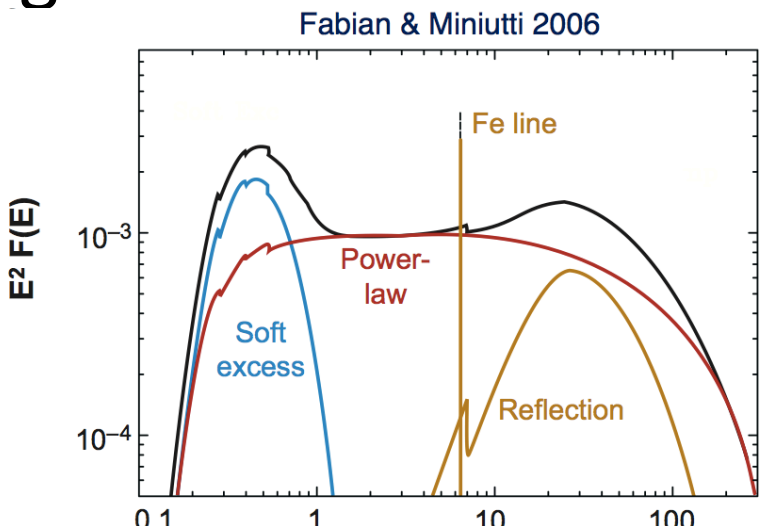


Urry & Padovani 1995

Coexistence of disk and corona in bright AGN

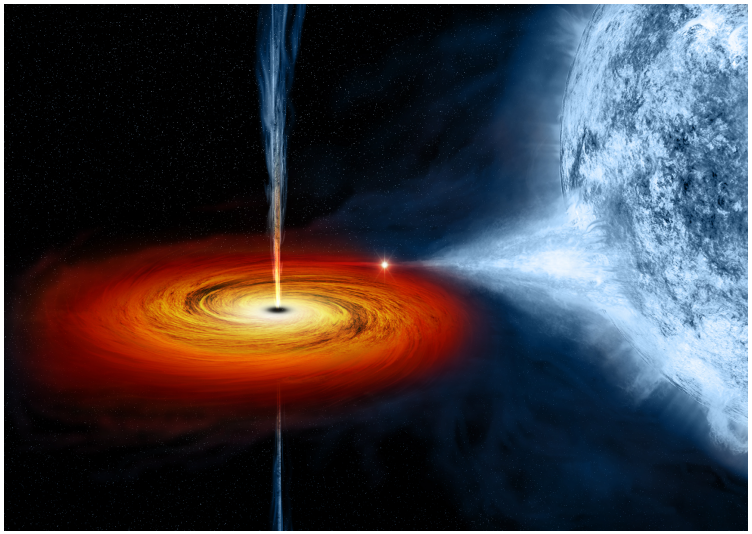
- Overall spectrum: inverse Compton scattering+ high-energy cut off
- Detection of Compton reflection hump in many sources
- Reverberation time lag



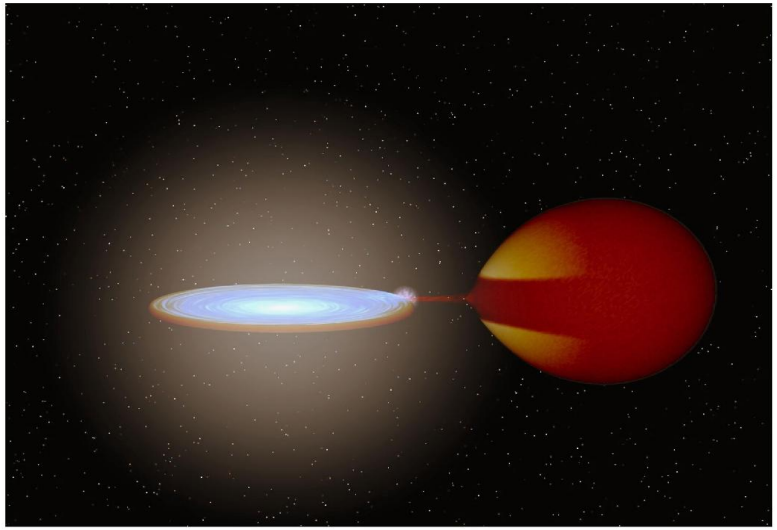


Is the accretion flow the same as that in BHXRBs?

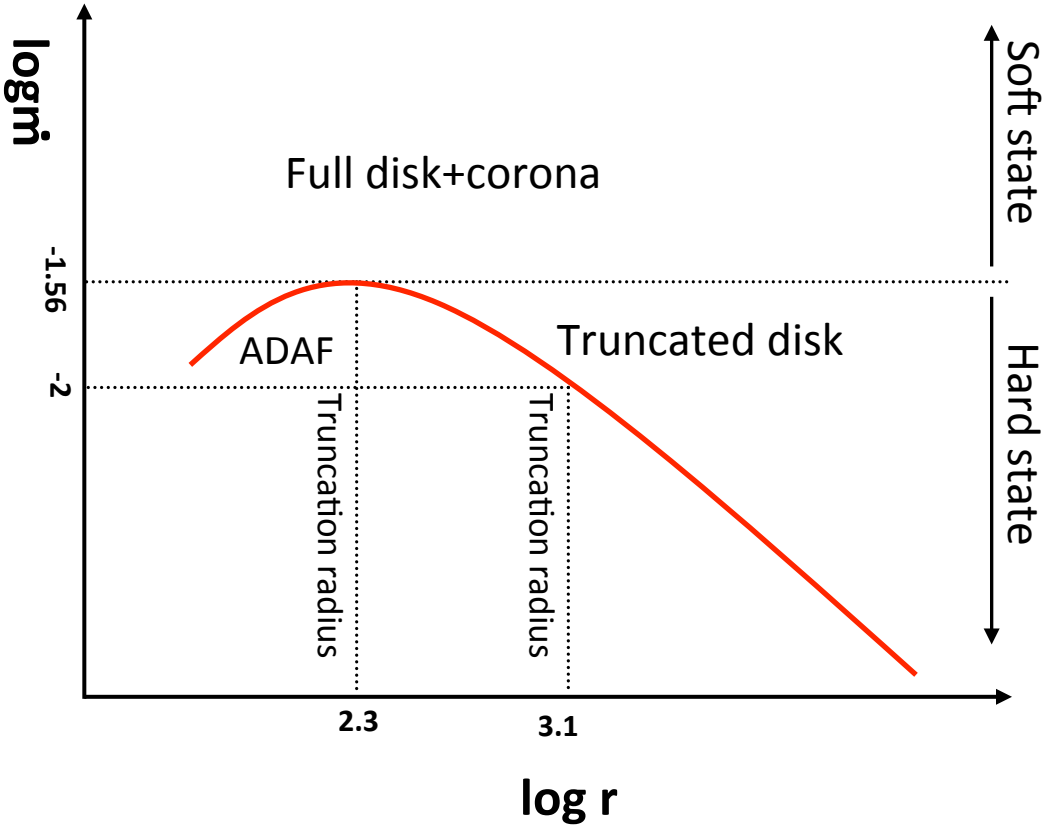
Accretion flows in BHXRBs



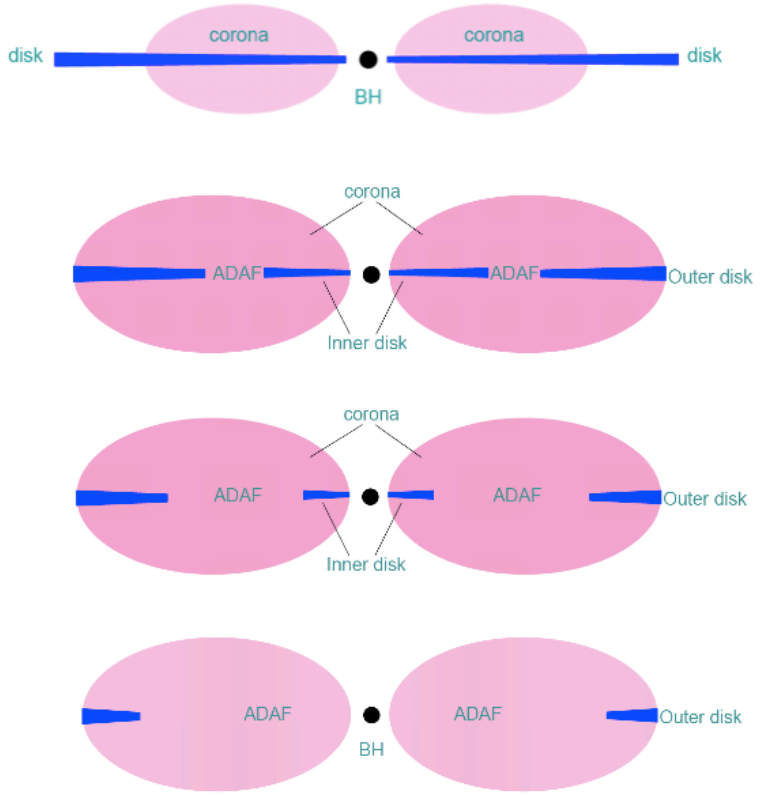
Corona forms through thermal instability on the disk surface or in the same way as solar corona



Spectral state transition in BHXRBs



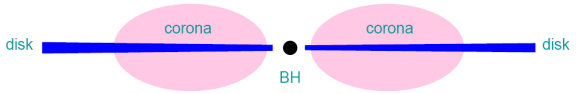
Meyer, Liu, Meyer-Hofmesiater 2000



Liu et al. 2012

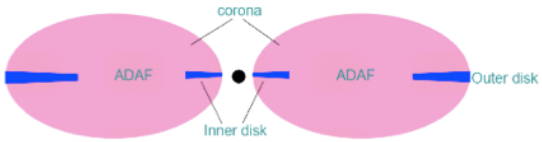
Similar accretion flow in AGN?

RQ QSO, Sys



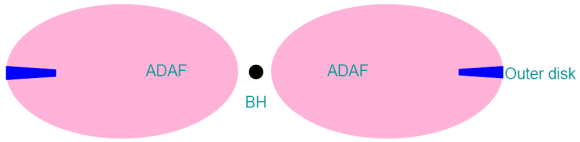
High/soft state

Low-Luminosity Sys



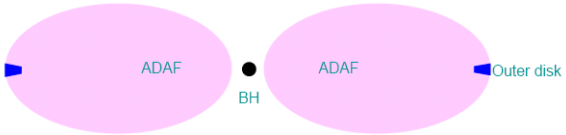
Immediate state

LINERS



Low/hard state

Neaby AGNs



Quiescent state

The corona fed by disk evaporation too weak compared to the energetic X-rays in bright AGN!

Two possibilities to support a strong X-ray emitting corona

- Accretion energy is transported from the disk to the corona (Haardt & Maraschi 1991;1993)

  e.g. magnectic reconnection heating (Liu et al. 2002;2003;2016), open questions remain

- strong hot (advection) accretion flow supply
  - natural in AGN environment: accretion of wind/ interstellar medium, unlike RLO in BHXRBs
  - necessary

Why hot gas supply necessary?

In the strong gravitation field, gas either accretes/falls to BH or lost in wind/outflows.

For $M=10^8 M_\odot$, $R=10R_s$

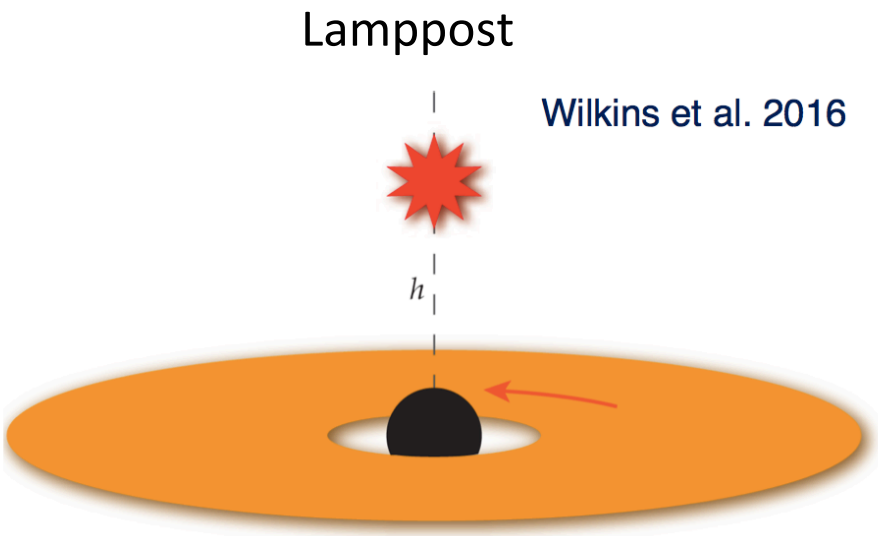
- Timescale for hot gas to accrete to the BH

  $t_{acc} \sim (1/\alpha\Omega)(R/H)^2 \sim (1/\alpha\Omega) \sim 5$days

- Timescale for hot gas to fall free to the BH

  $t_{fall} \sim (1/\Omega) \sim 12$hrs

Hot gas cannot exist long near the black hole, while X-ray emission in AGN lasts much longer



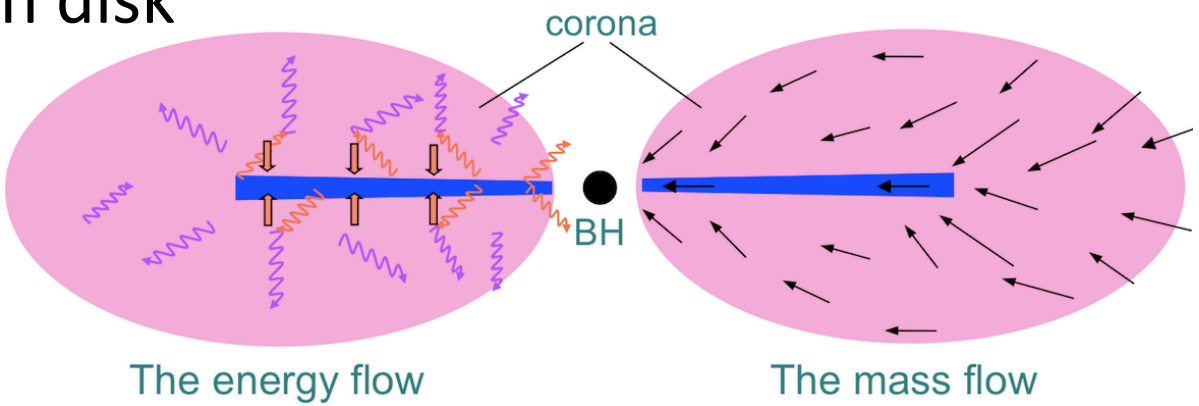
Only hot gas is not enough!

Continuous hot gas "fill in" is necessary

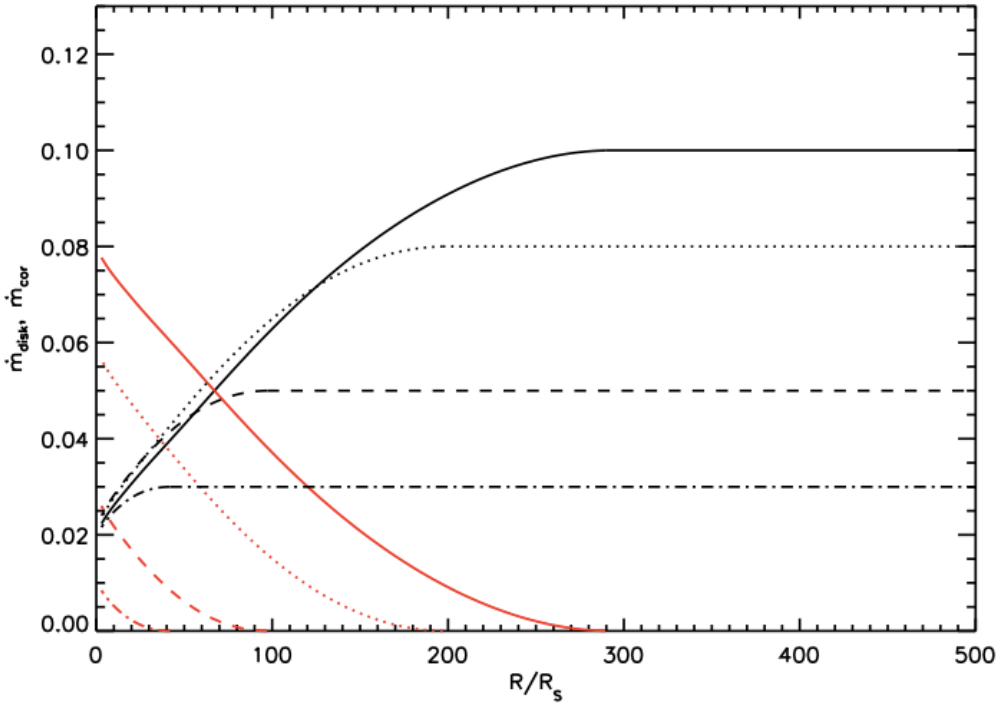
Coupled disk and corona in AGN

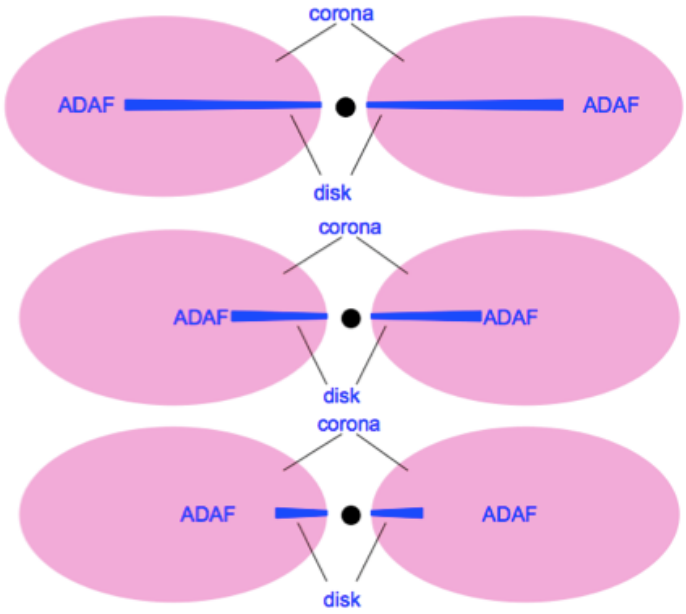
Liu et al. ApJ 806:223,2015

- Mass supply for the accretion in AGN is stellar wind or interstellar medium
- Diverse distributed gas ➔not necessary to form a thin disk, but easy to form a hot flow in outer region
- Disk and corona are coupled through radiation and gas
- Coronal gas condenses to the inner disk, supporting a thin accretion disk



Accretion rate distribution in corona and disk





Re-distribution of the accretion rate in the disk and corona: higher gas supply rate, larger disk, higher accretion rate in the disk

Is this extended corona consistent with reverberation analyses?

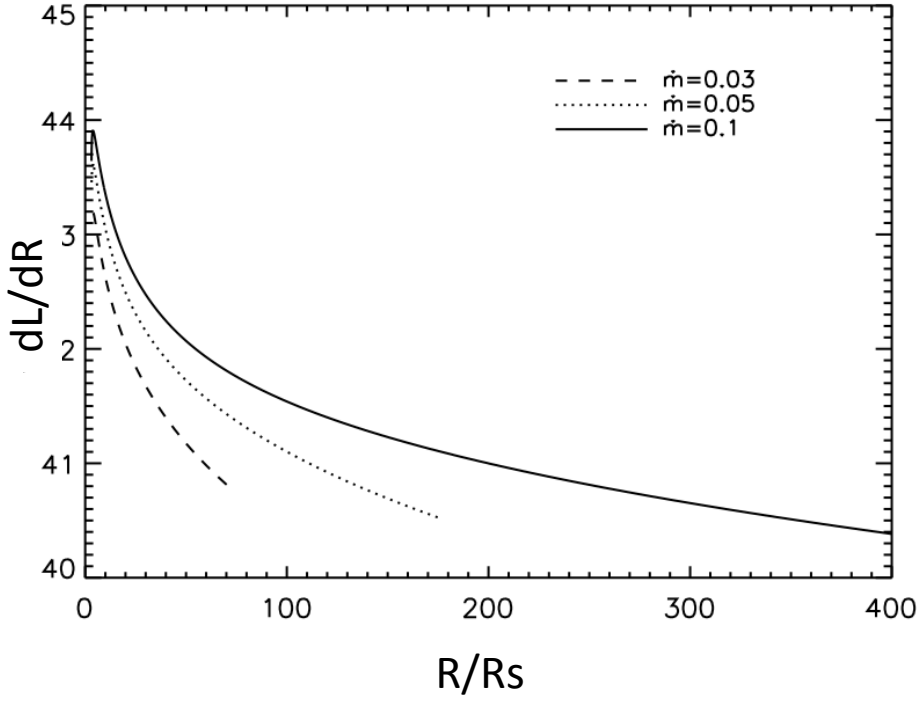
Contradictory to reverberation lag?

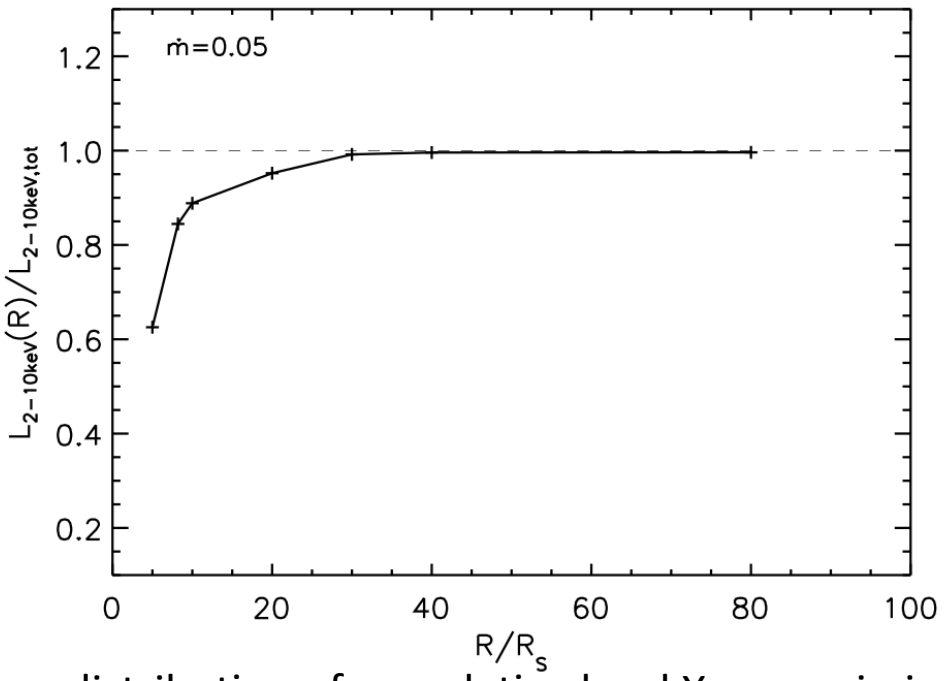
- Reverberation time lags demand that hard X-ray emission in black hole systems be centrally concentrated, with height H ≤10 Rg (e.g. Fabian 2009)
- Micro-lensing measurements show half-light radius ≤20 Rg (e.g. Chartas et al. 2009)

Dominant X-ray emission region:

Bulk hard X-ray emission is concentrated within R<10Rs

➔consistent with reverberation time lag and micro-lensing measurement

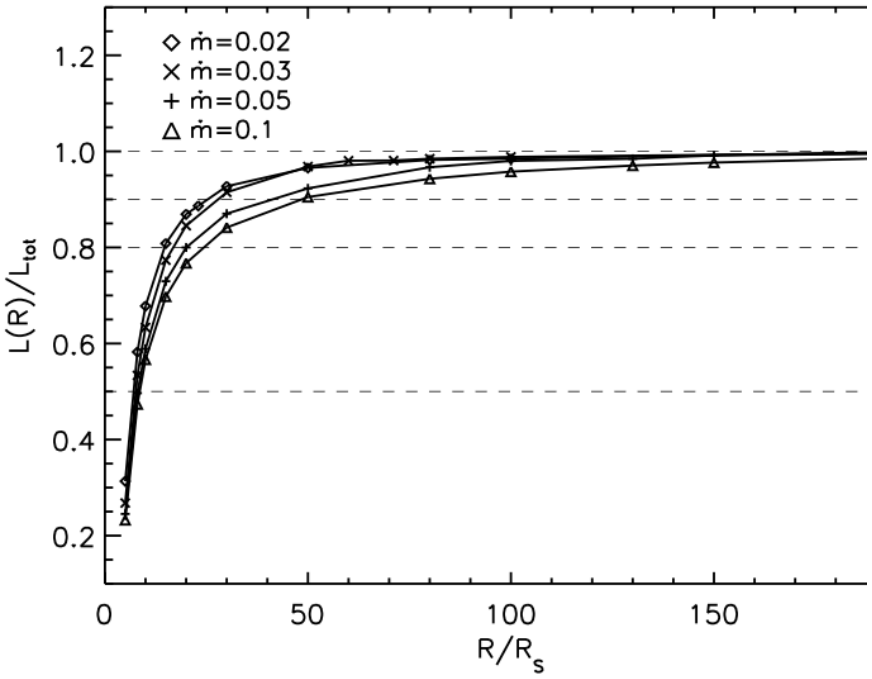


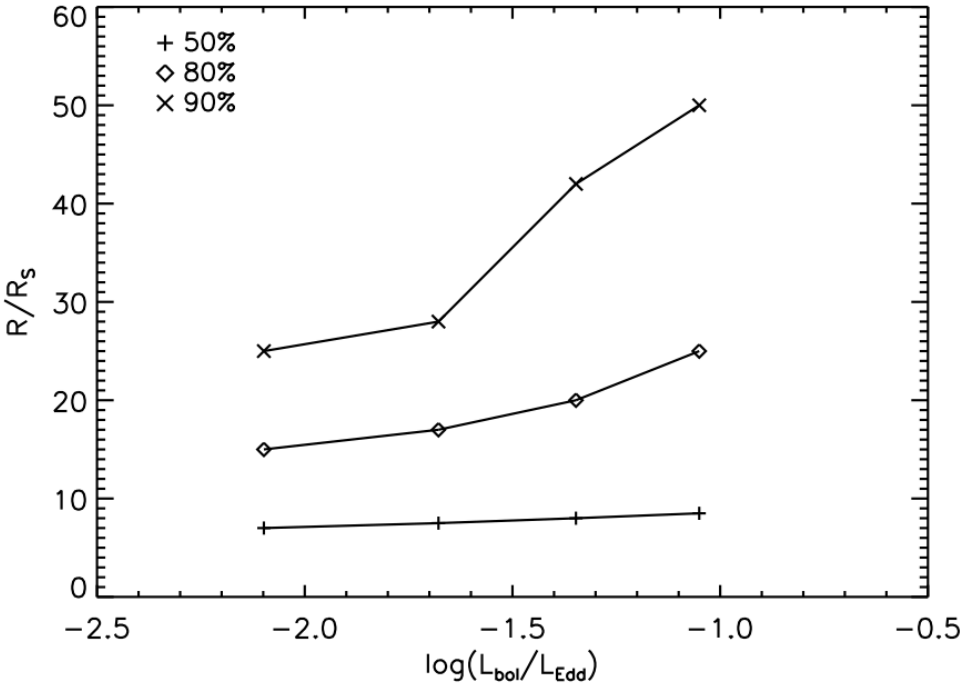


distribution of cumulative hard X-ray emission

The higher Eddington ratio, the larger the bulk emission region

➔consistent with large sample results (e.g. Kara et al)



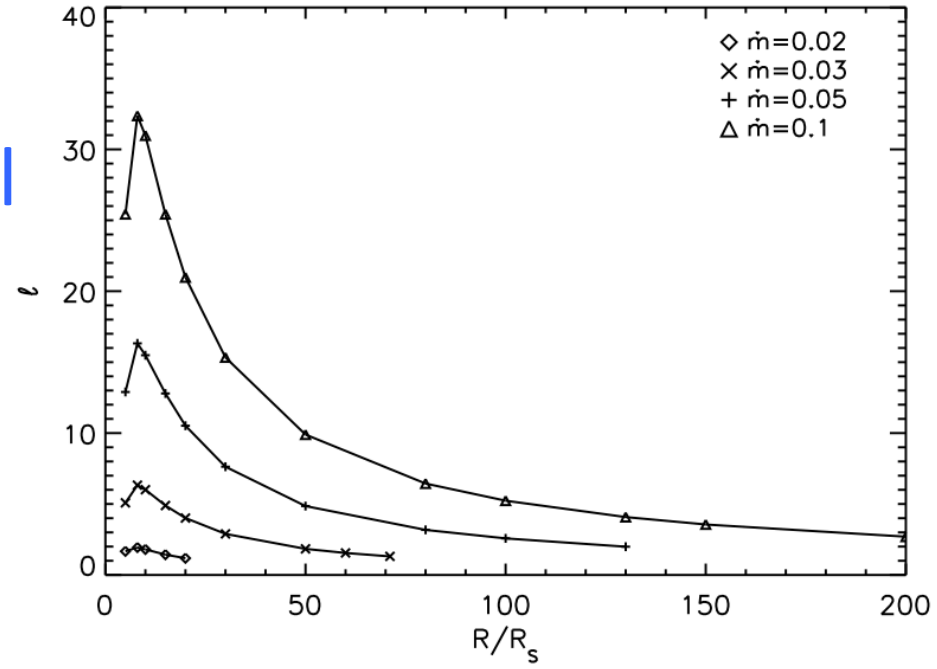


The compactness parameter $l = \frac{L}{R}\frac{\sigma_{\rm T}}{m_{\rm e}c^3}$

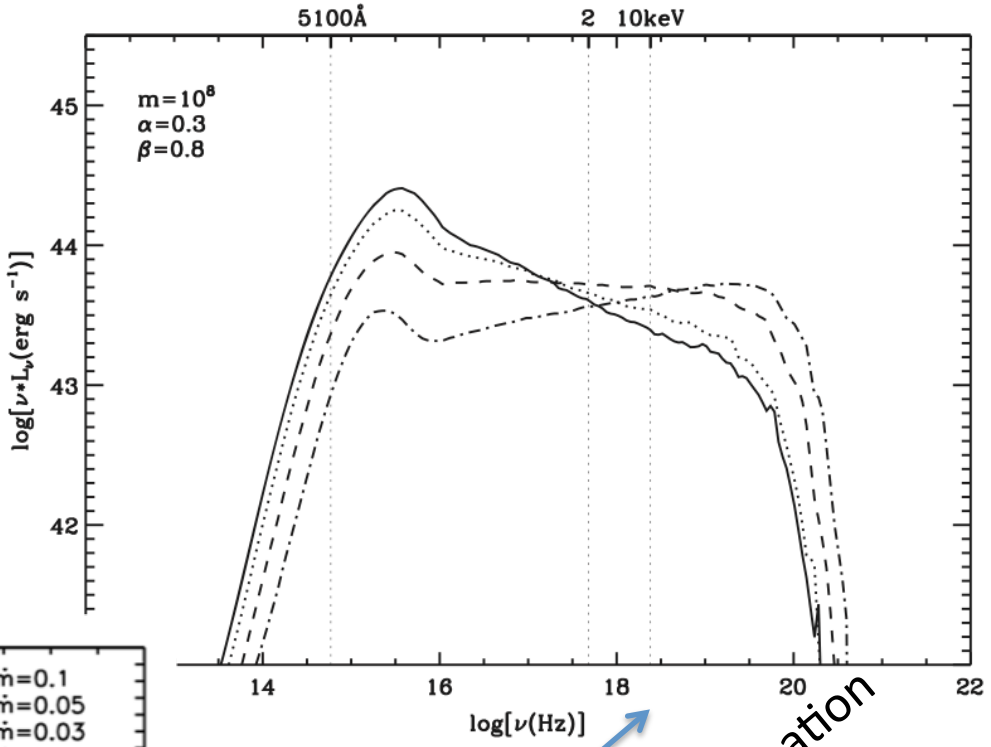
marginally below the critical value for pair production, indicating pair production is not the dominant process

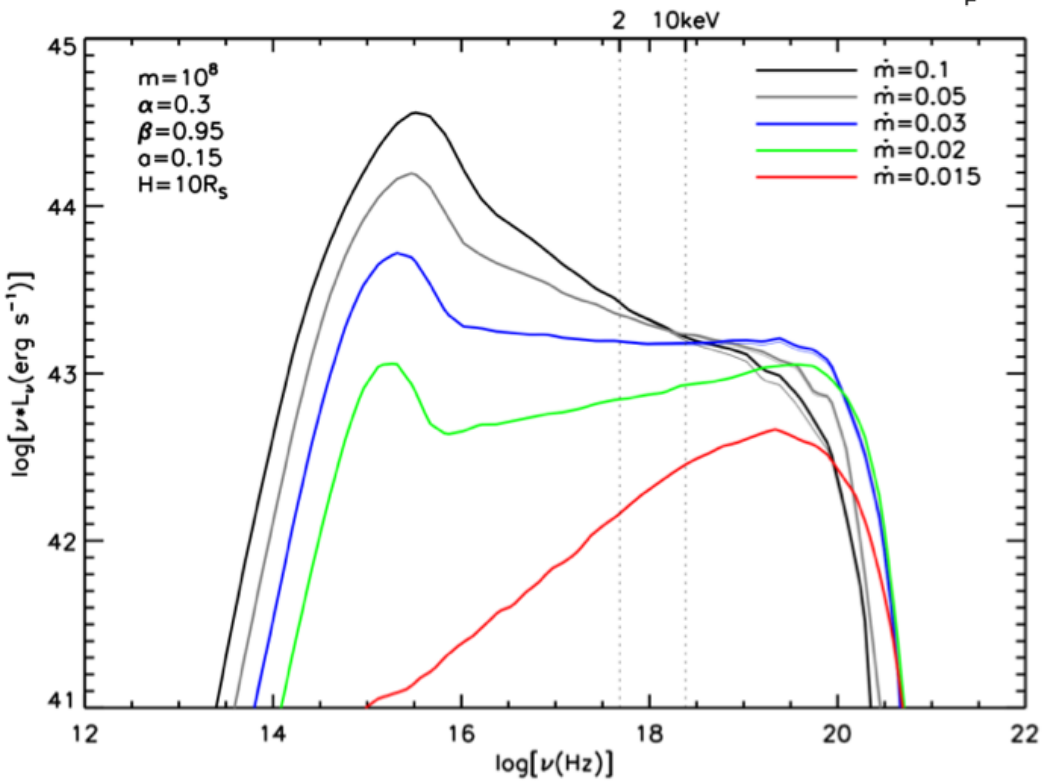
➔IC spectrum is not affected by pair production

➔Self-consistent model



Spectra from the accretion disk and corona (Liu et al. 2015; Qiao &Liu 2017)

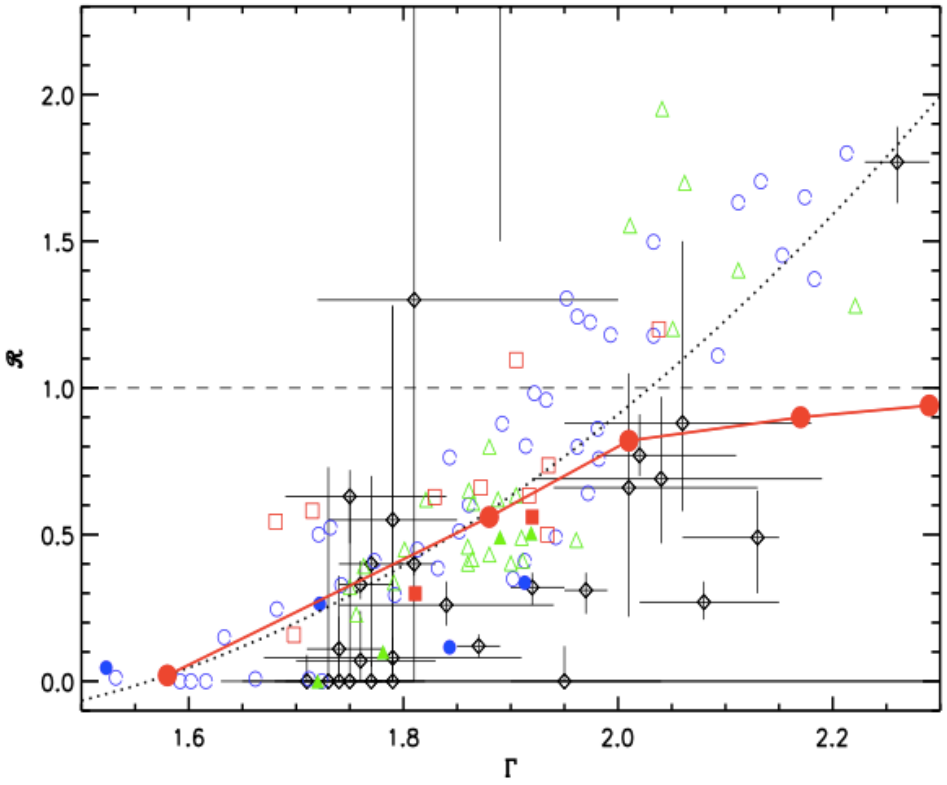




different magnetic filed and illumination

Correlation between the hard X-ray photon index and reflection scaling factor (Qiao &Liu 2017)

$\Re$



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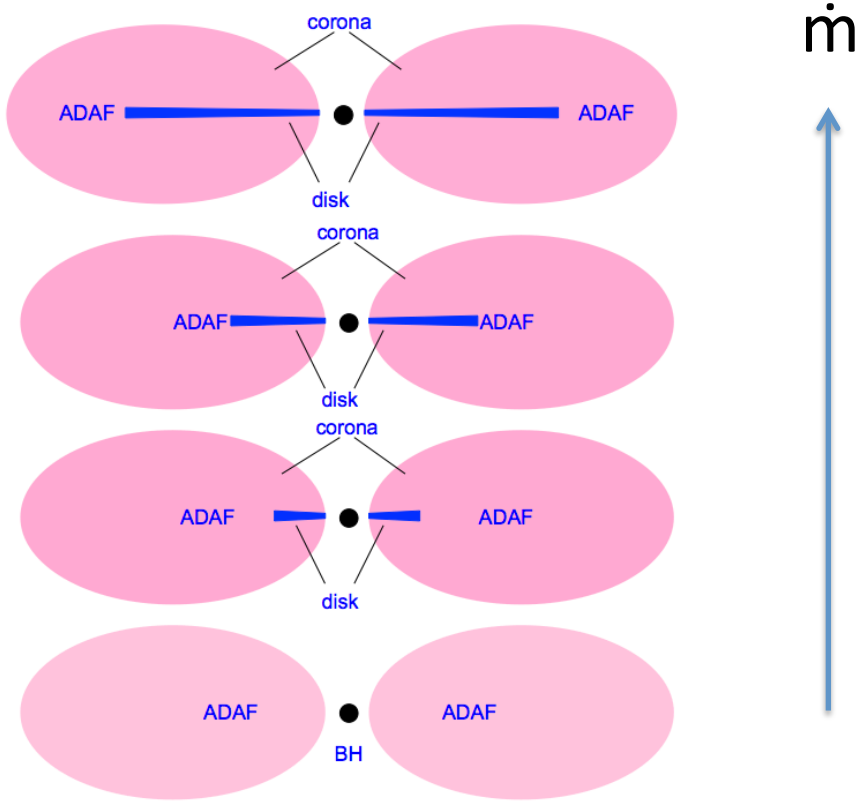
The spectral state transition in AGN



Summary

- The accretion flow in AGN differs from that in BHXRBs due to different environment (gas supply to accretion)
- A well-coupled thin accretion disk + hot accretion corona can interpret both of the spectra and reverberation lag for most bright AGN

Discussion: Alternative scenario?

Vertically collimated corona/ejecta/outflows

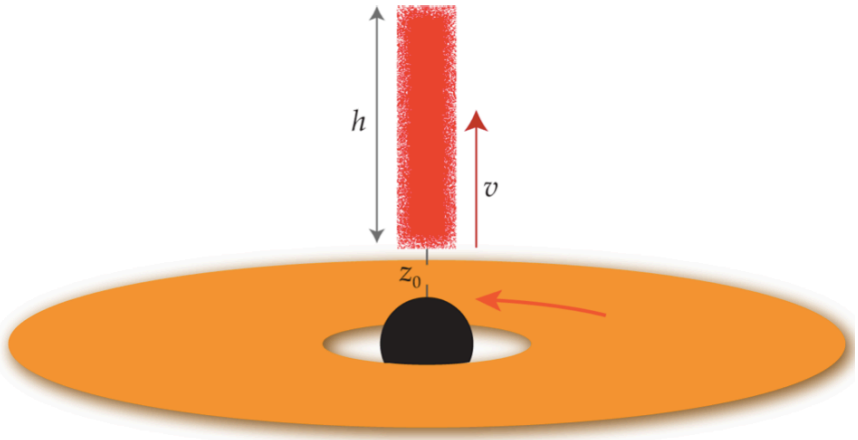
– no/weak reflection, if vertically extended

Not the observational case

– pair production dominates, if compact (e.g. jet base)

unclear, non-IC spectrum

large background γ-rays



Wilkins et al. 2016