Can magneto-centrifugal outflows from accretion discs explain wind signatures/features in black hole X-ray binaries?

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X-ray observations of black hole X-ray binaries (BHBs) suggest that disk winds occur in the softer (disk-dominated) states of the outburst and are less prominent or absent in the harder (power-law dominated) states, which are more characterized by radio-loud jets. We investigate the presence/absence and physical characteristics of disk winds in BHBs through the use of the magneto-hydrodynamic (MHD) solutions of Ferreira (1997). These models treat accretion and ejection self-consistently within a self-similar ansatz that allows to solve the full set of dynamical MHD equations without neglecting any term. As a consequence the ejection efficiency is no free parameter but depends on the global structure of the disk. By testing different sets of solutions with varying disk aspect ratio and ejection efficiency, we attempt to reproduce the observed state dependent prevalence of the winds. With no a priori theoretical assumption about the state of the black hole, we recover this observed bias of the winds for the softer states. In this talk I shall detail the methods employed by us, followed by the results.

Subject :	:	oral
Topics	:	Astrophysics

Magneto-centrifugal outflows from accretion discs in black hole X-ray binaries

by

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with

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OSUG, Université Joseph Fourier

for

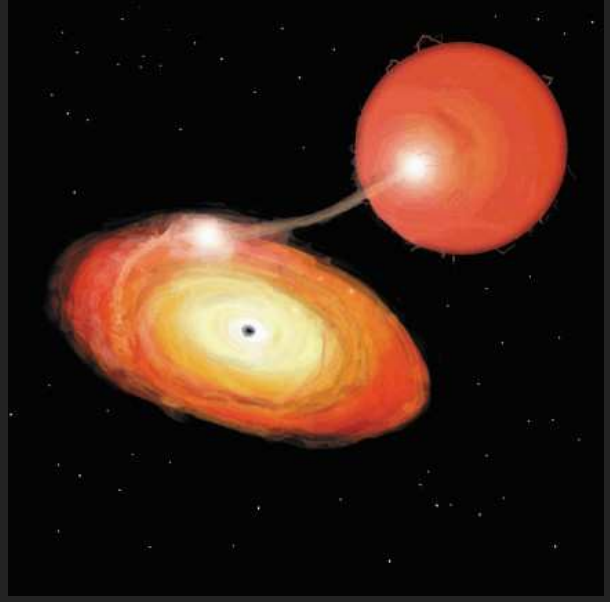
Accretion and Outflows throughout the scales

1 October, Lyon

Accreting black holes

Stellar mass black holes are found in binary systems.

These systems undergo semi-periodic out bursts and become bright in X-rays.



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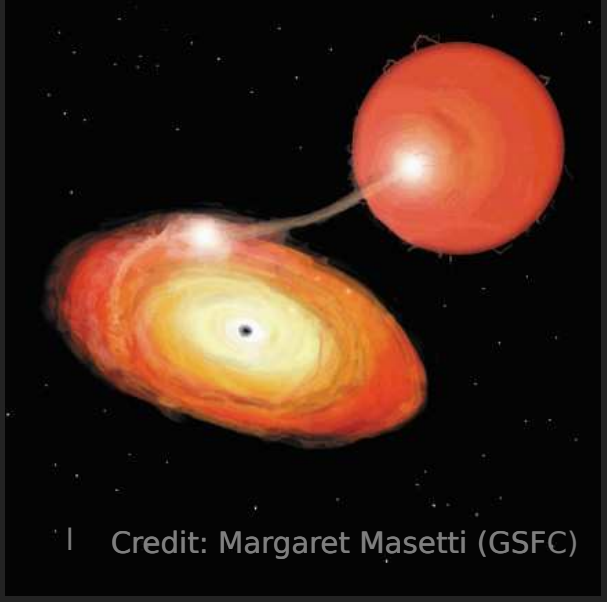
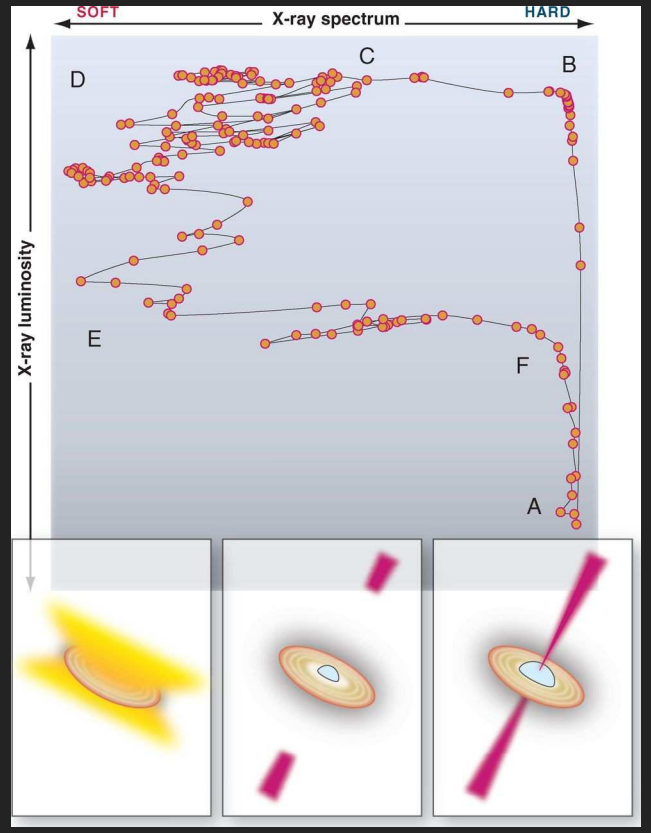


Credit: Margaret Masetti (GSFC)



During outburst the observed luminosity performs a “hysteresis” wrt spectral hardness.

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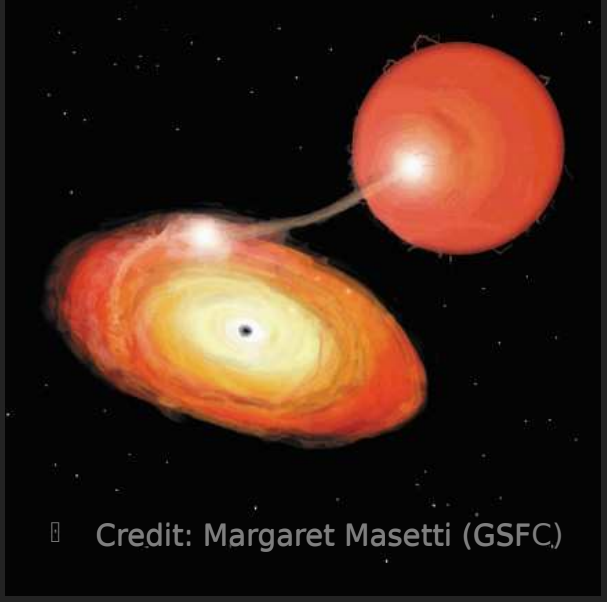

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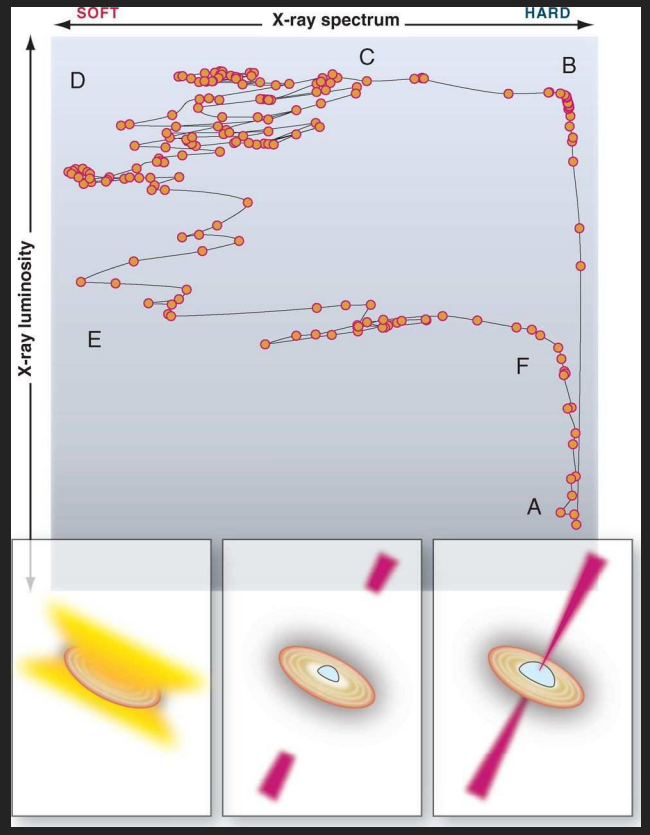

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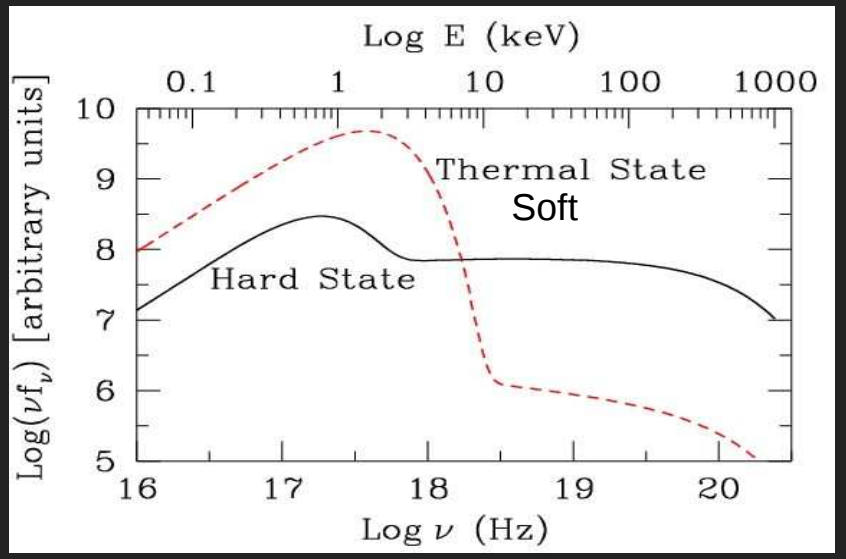


The binaries pass from Hard to Soft state and back.

The X-ray continuum for the two states are very different.

Thermal – optically thick disk; T ~ 1 keV
- optically thin corona
- h/r << 1 ~ 0.001

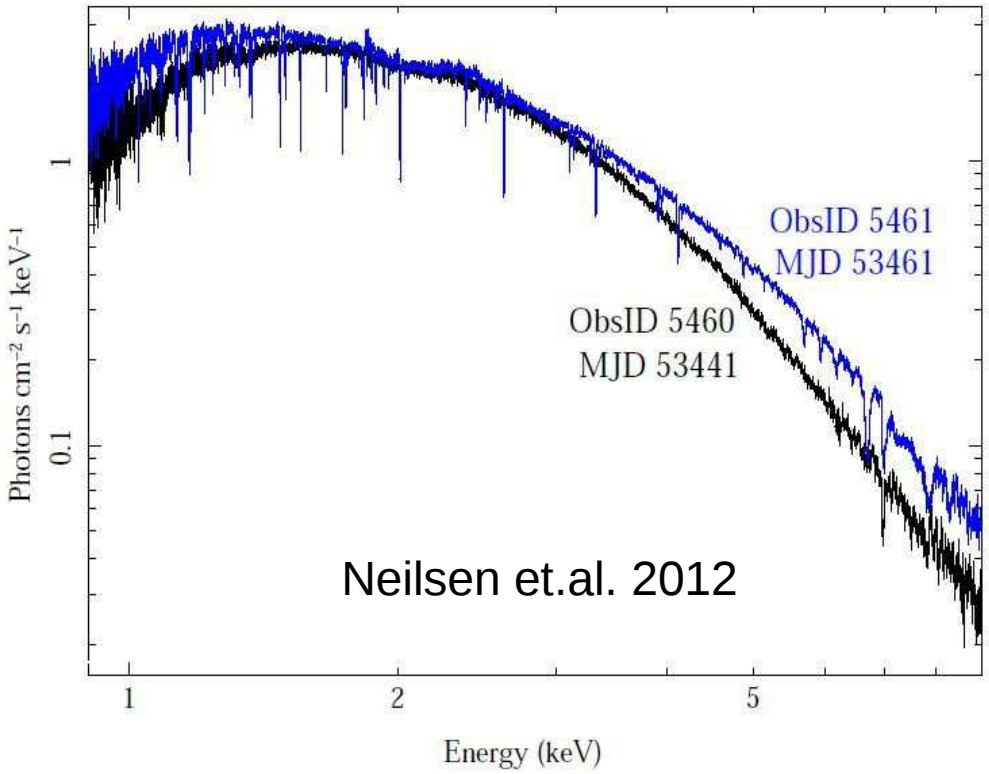
Hard – hot corona; T ~ 100 keV
- h/r ~ 0.1

Winds in black hole binaries

There are 20 confirmed black hole binaries

But ~5 show signature of outflows
most observations show absorption lines from ‘only’ FeXXV and FeXXVI
exception (?) GROJ1655, 2006 observation –
has absorption spectrum with numerous lines from OVIII to FeXXVI and beyond.

The presence of winds is a “state dependant” effect.



Neilsen et.al. 2012

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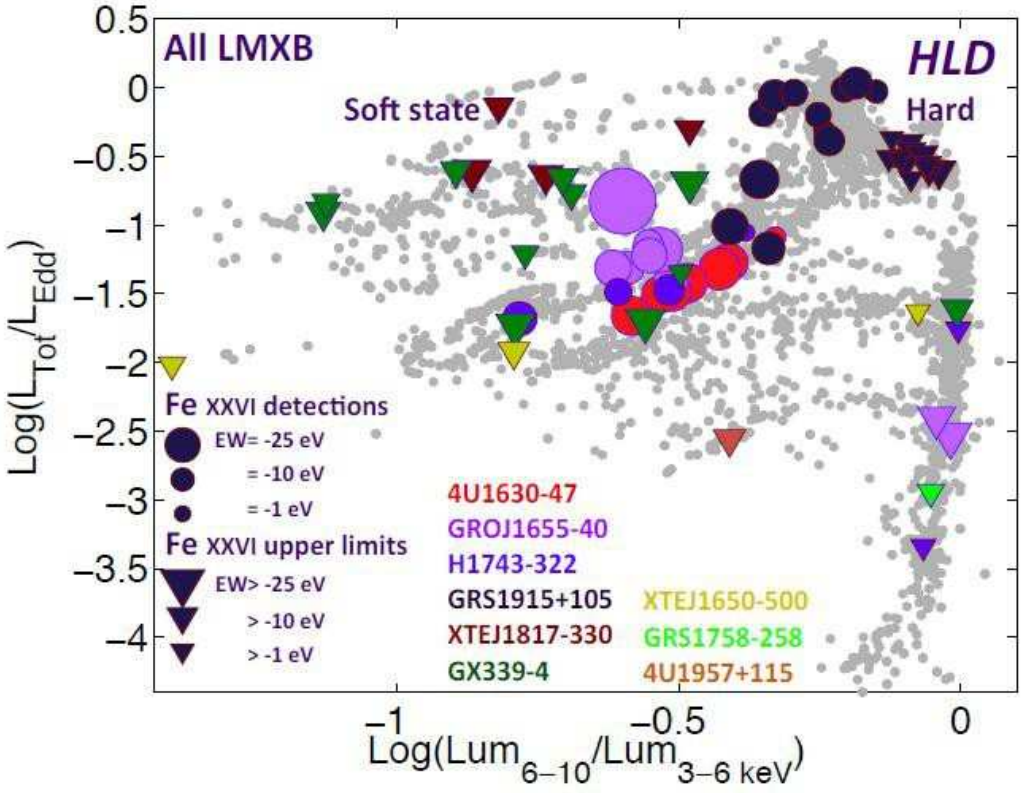

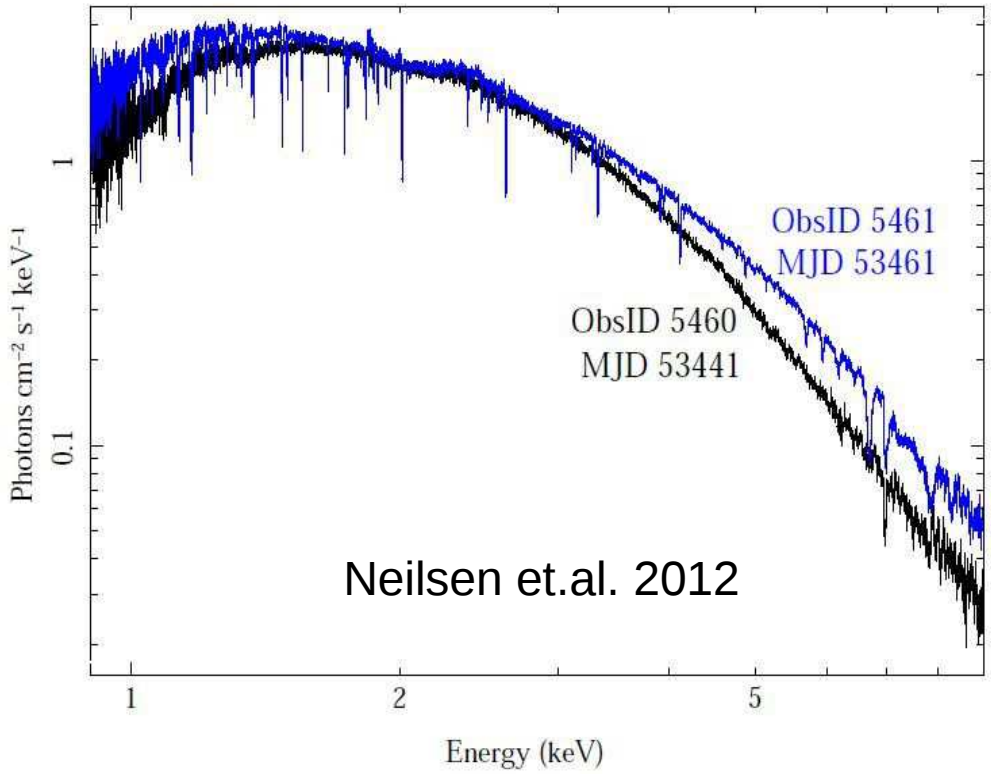

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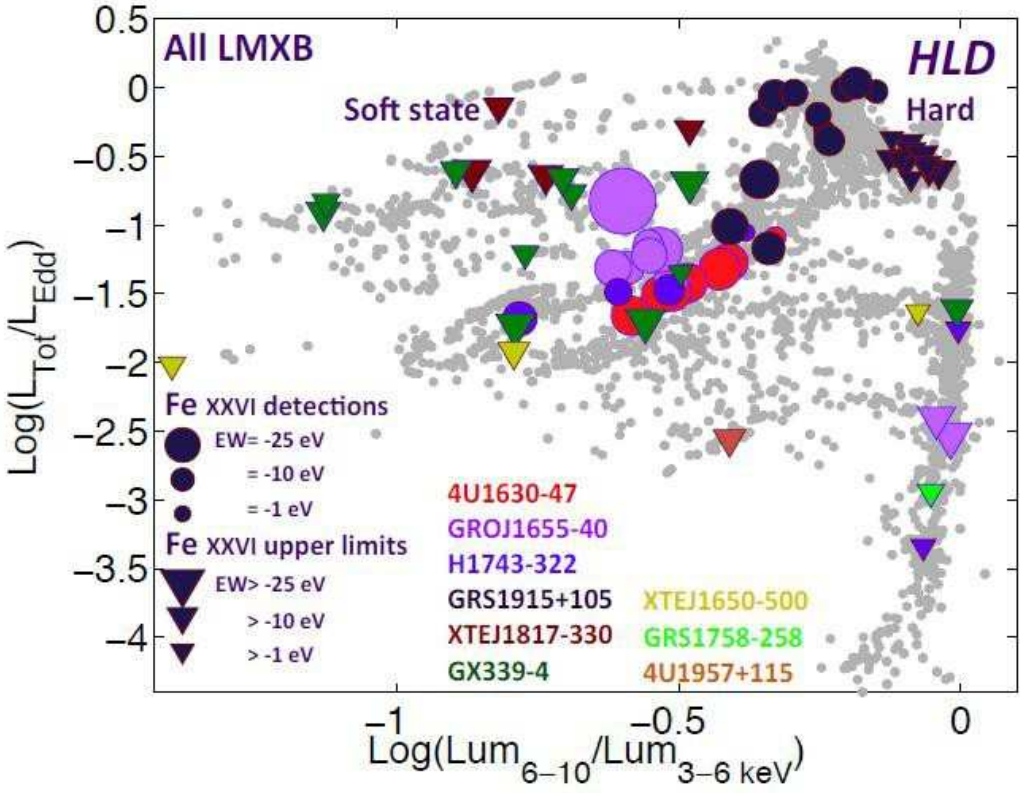


Winds are observed in the Soft state

Further, winds are observed in objects of high inclination (i.e. low equatorial angle)

Magnetohydrodynamic accretion disk wind solution

Ferreira 1997 MHD models are adopted for modeling the wind.

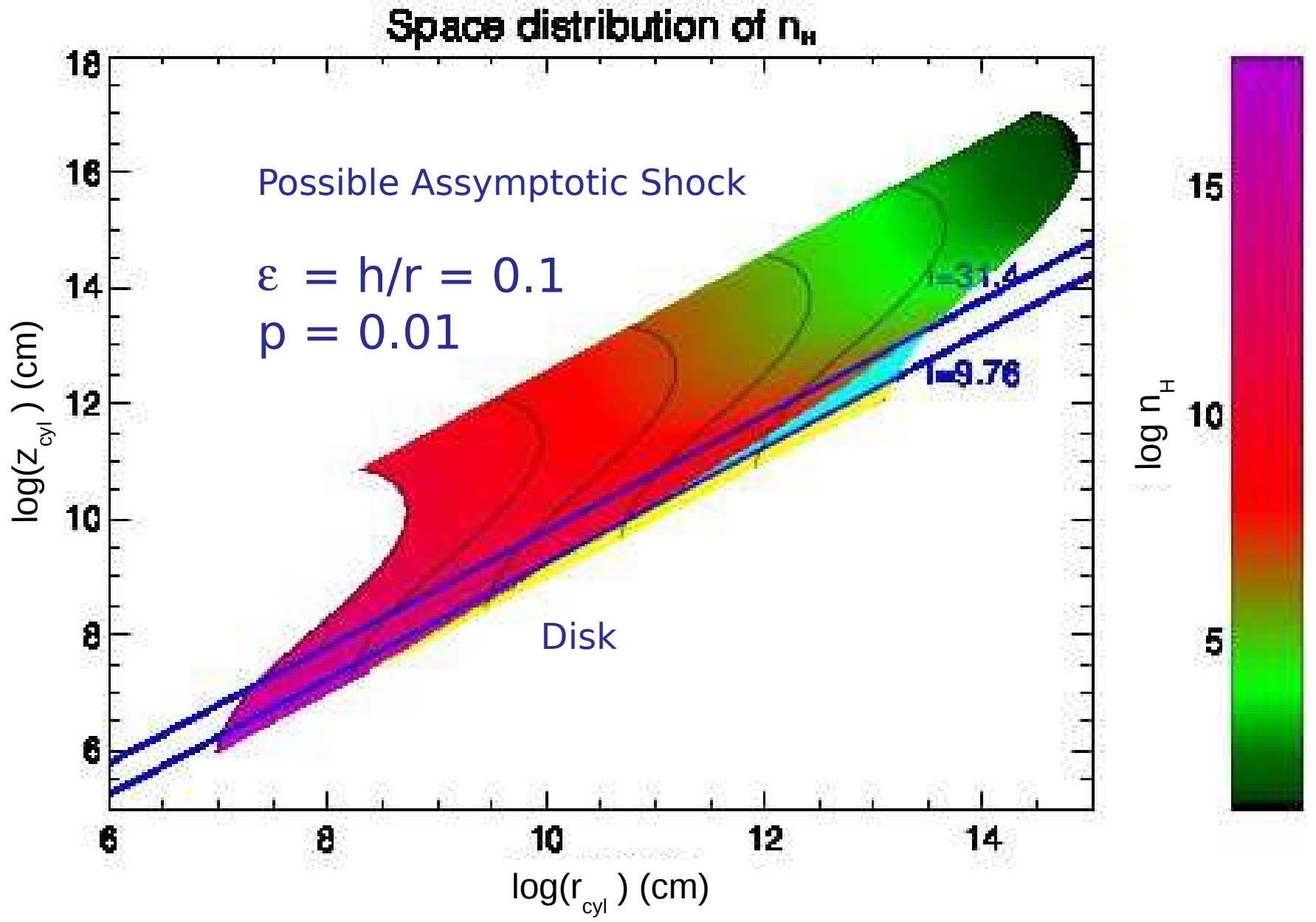
The ejection or outflow of material is related to the accretion mechanism.

Thus ejection efficiency is **not** a free parameter (unlike ADIOS scenarios)

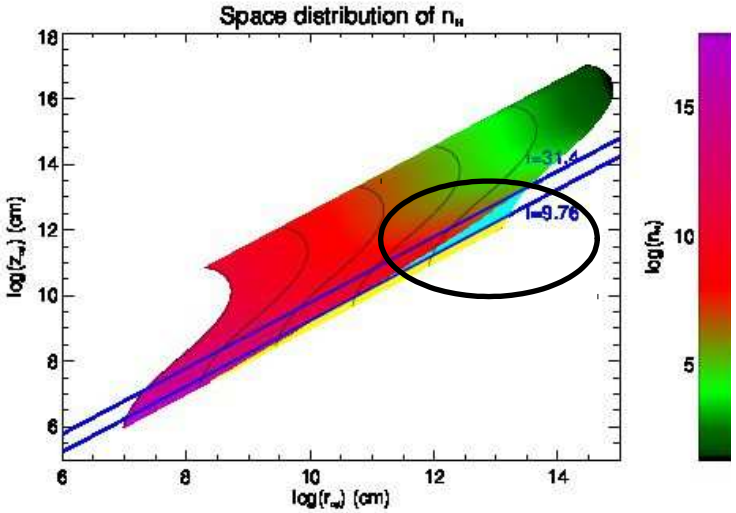
The solutions are self similar. Hence can spread out to large distances.

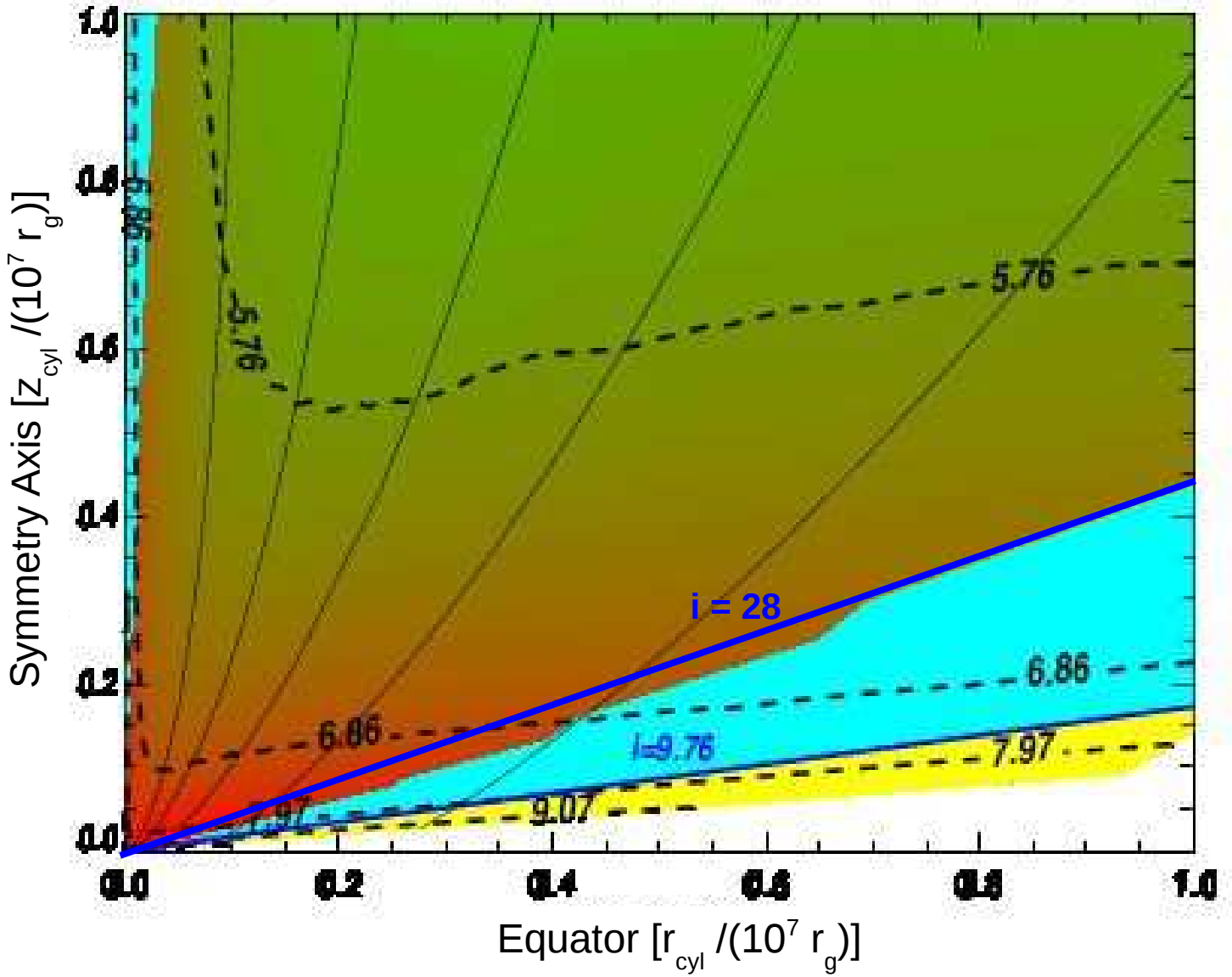
Described in terms of two main parameters:
Disk aspect ratio – $\varepsilon = h/r$
Accretion efficiency p – $\dot{M} = r^{p}$

Aim -
Can these solutions represent observable winds (in terms of ξ and N_H)?
Can we recover the state dependent observability?

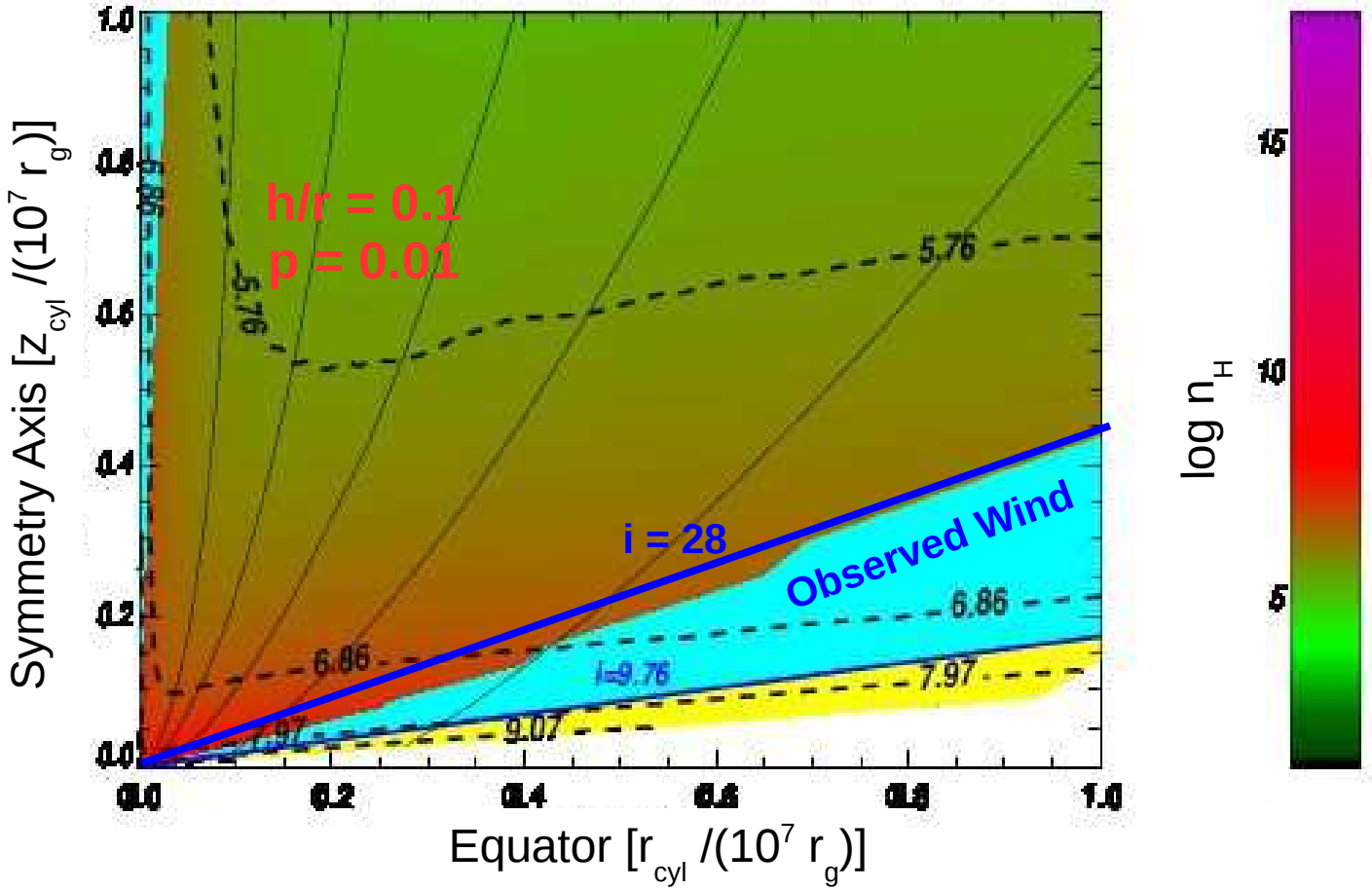

Space distribution of n_H
Possible Assymptotic Shock
ε = h/r = 0.1
p = 0.01
Disk
r=31.4
r=9.76
log(z_cyl) (cm)
log(r_cyl) (cm)
log n_H
18
16
14
12
10
8
6
6
8
10
12
14
15
10
5

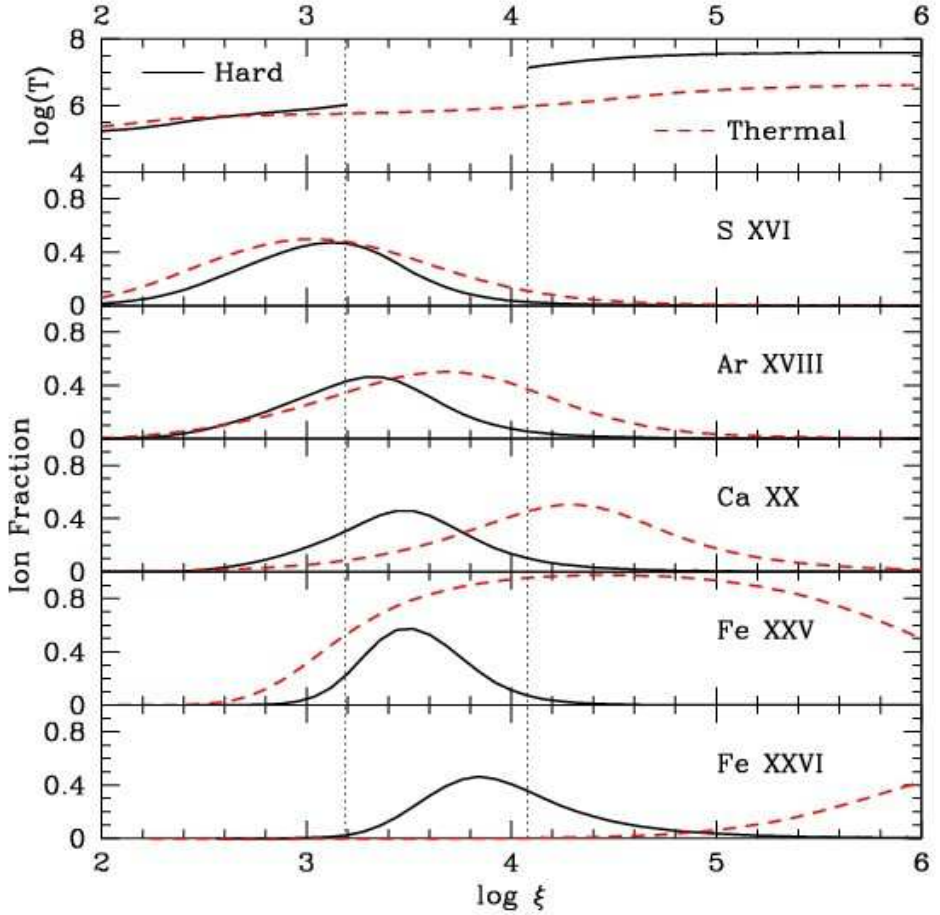
Constrain the “observed wind”





Constrain the “observed wind”





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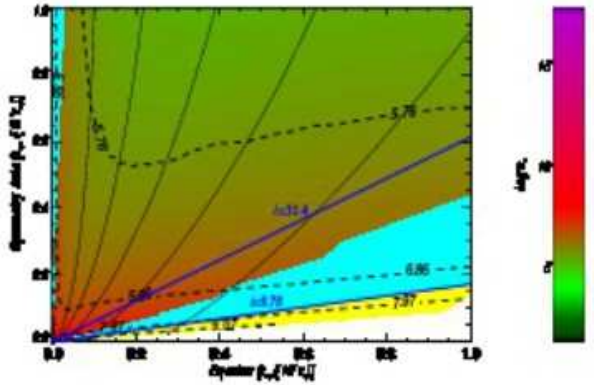
1. $\xi \leq 10^6$ – Ionization parameter $\xi = L/nR^2$

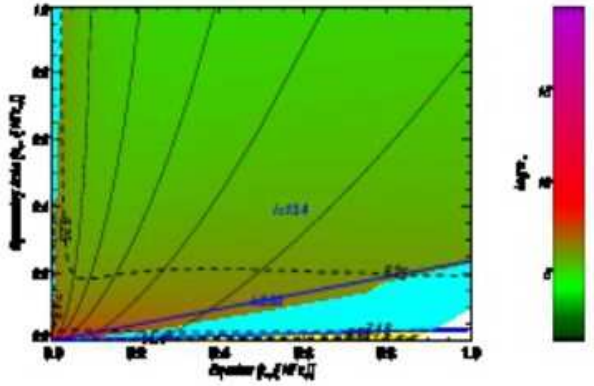
2. Column density $N_H \leq 10^{24}$ cm^{-2}

Theoretical phenomenology to find “most observable wind”

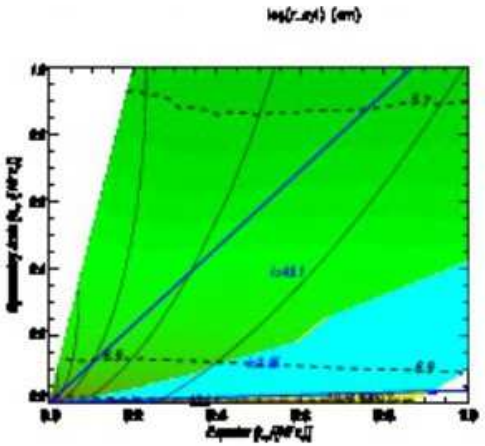
h/r = 0.1

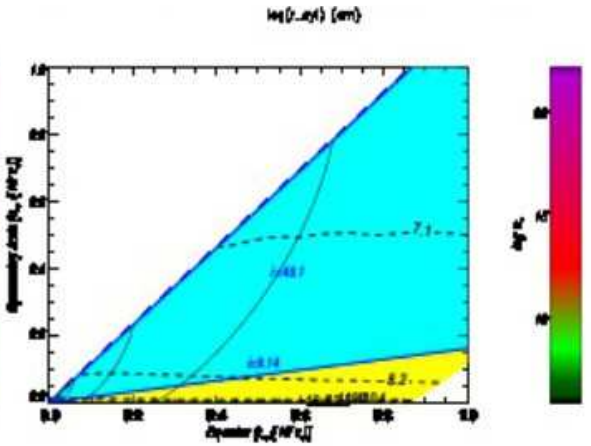


h/r = 0.01



h/r = 0.001



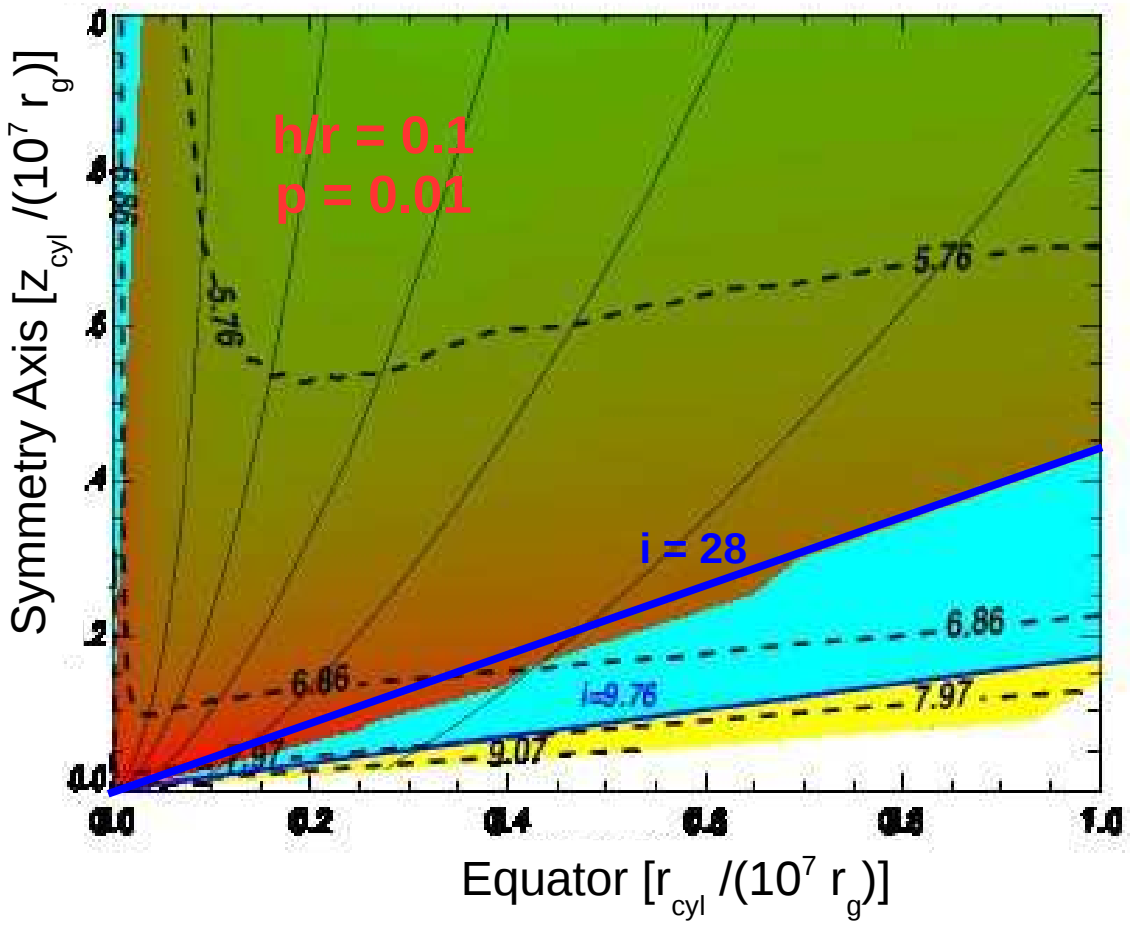


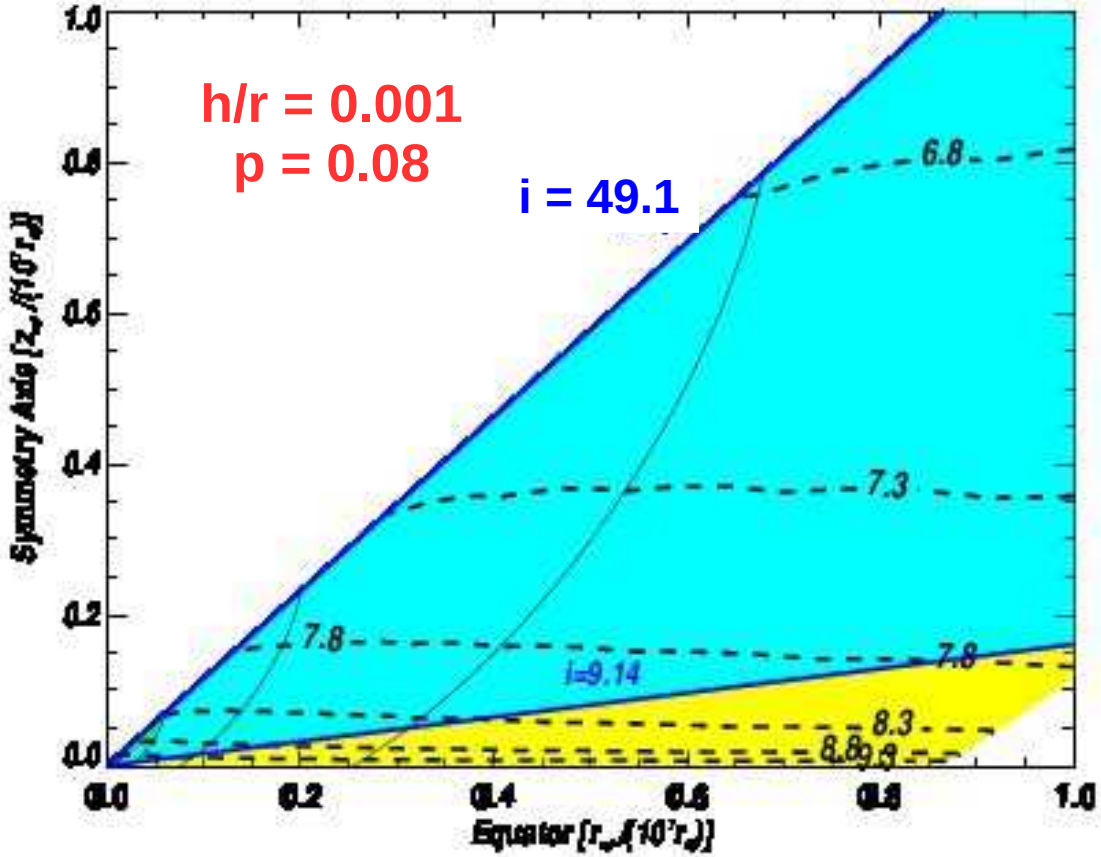
p = 0.01 p = 0.02 p = 0.08

p

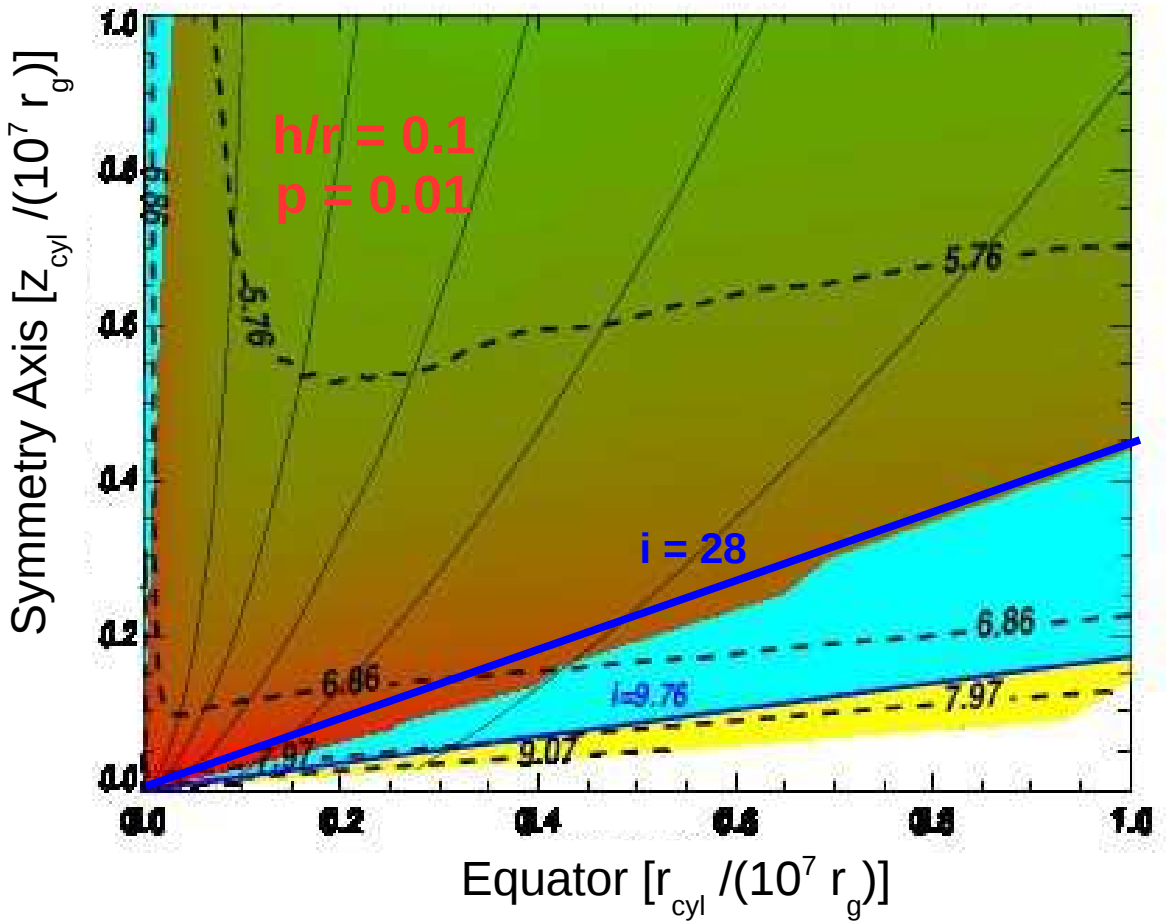
ε = h/r

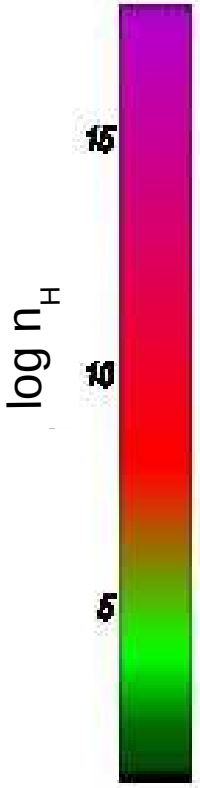
Low Hard vs Thermal Soft

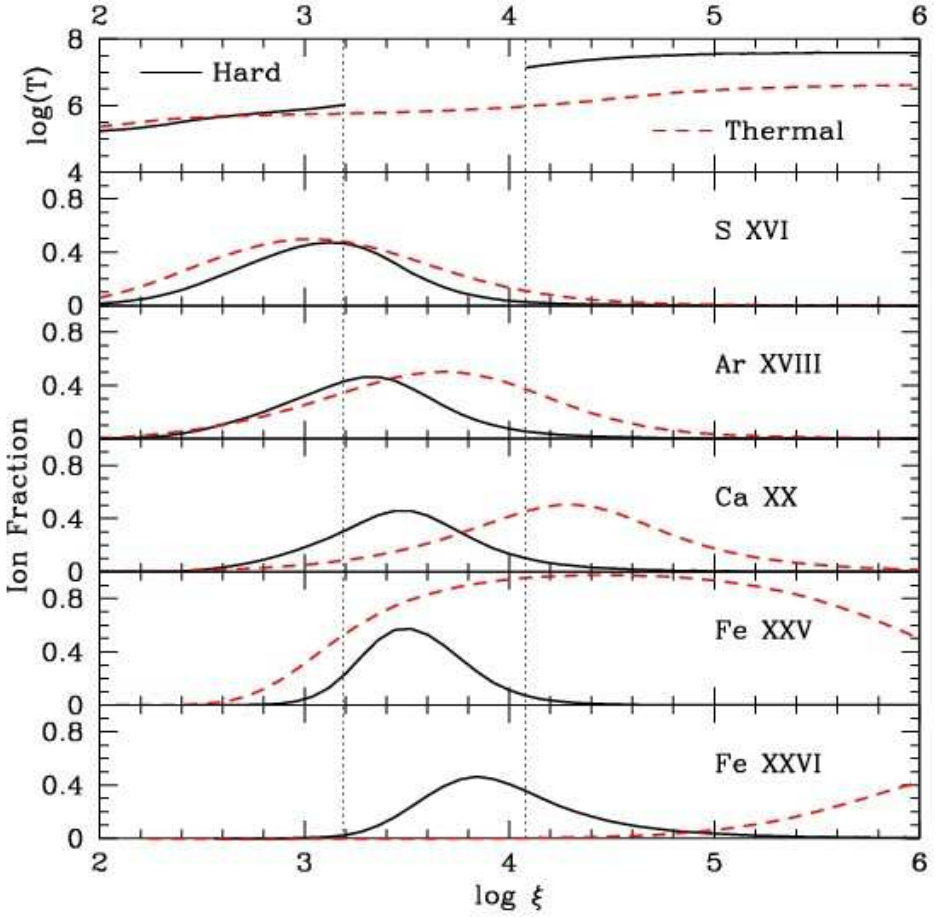




So, why don't we see wind in Hard state?







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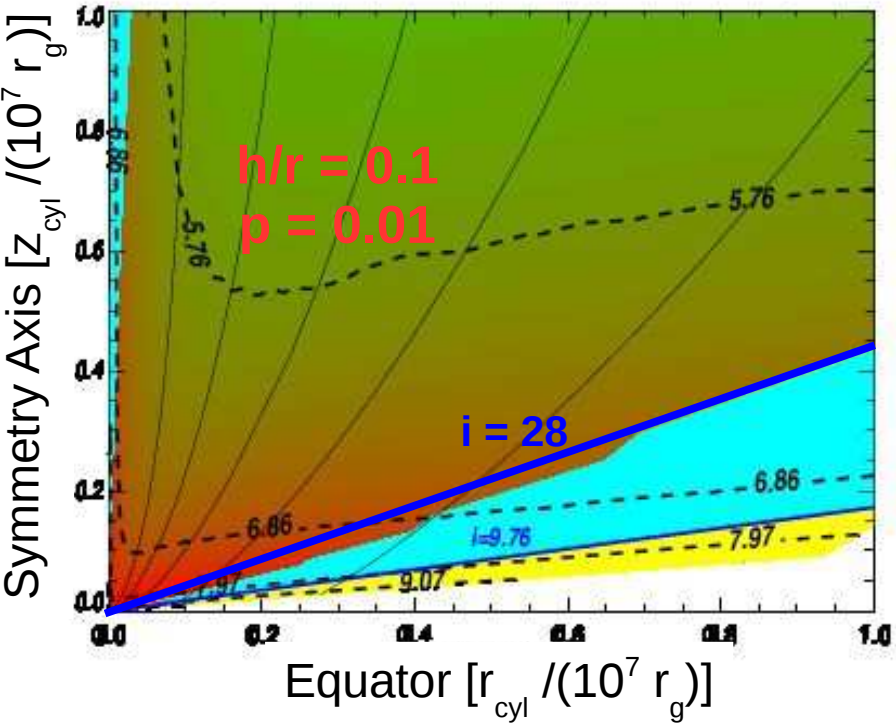

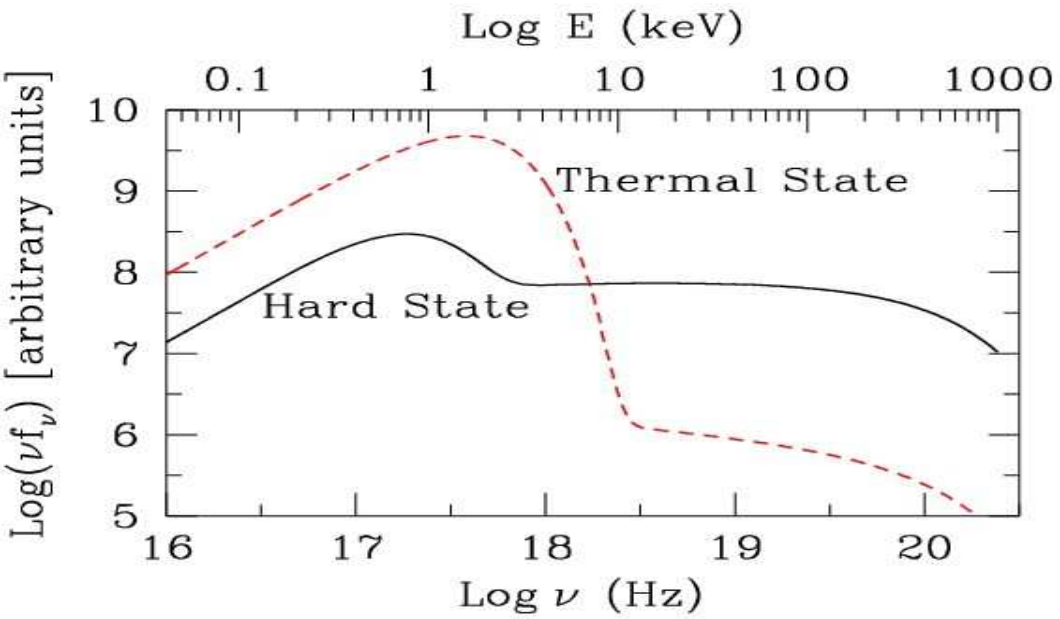

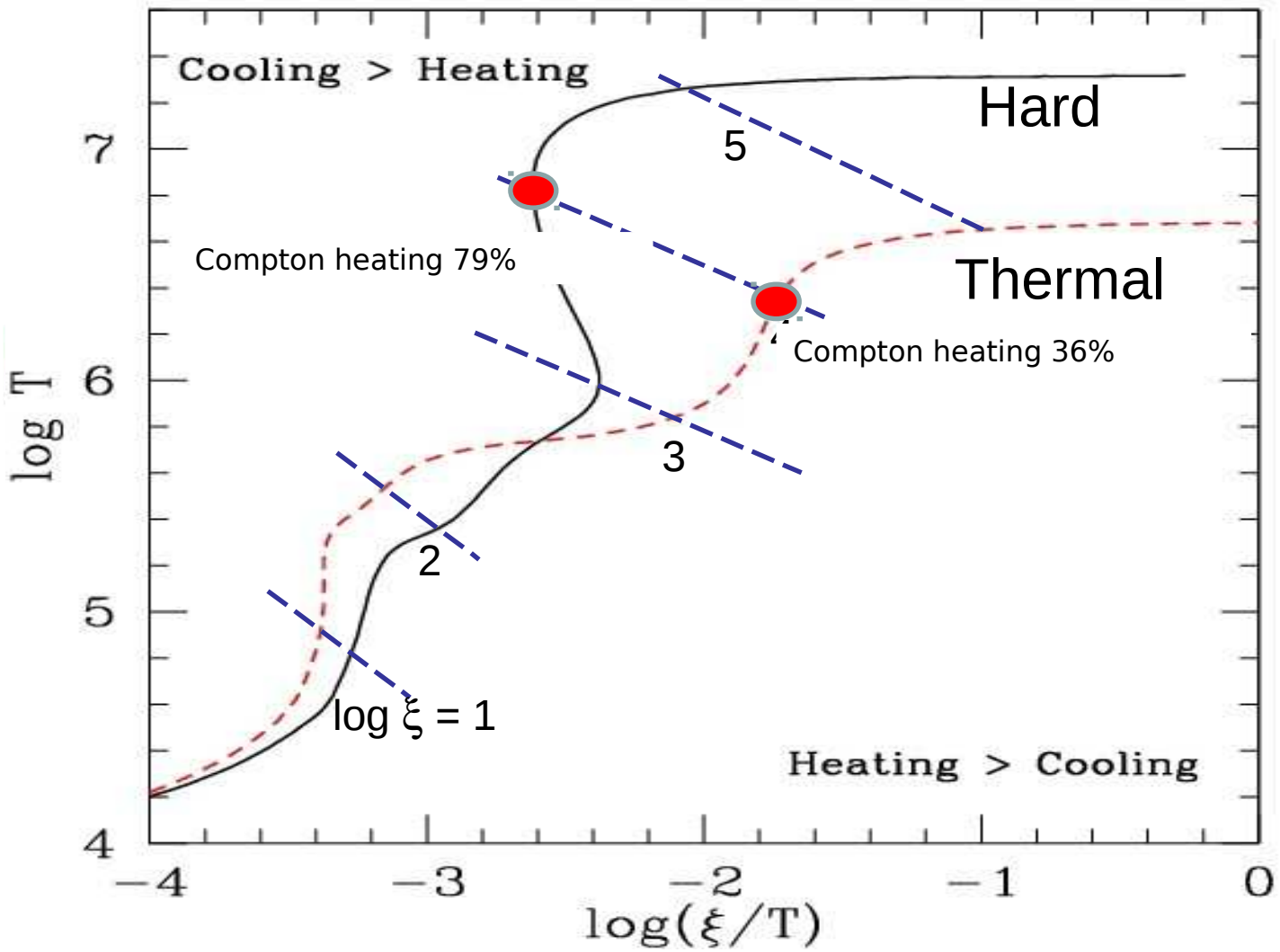

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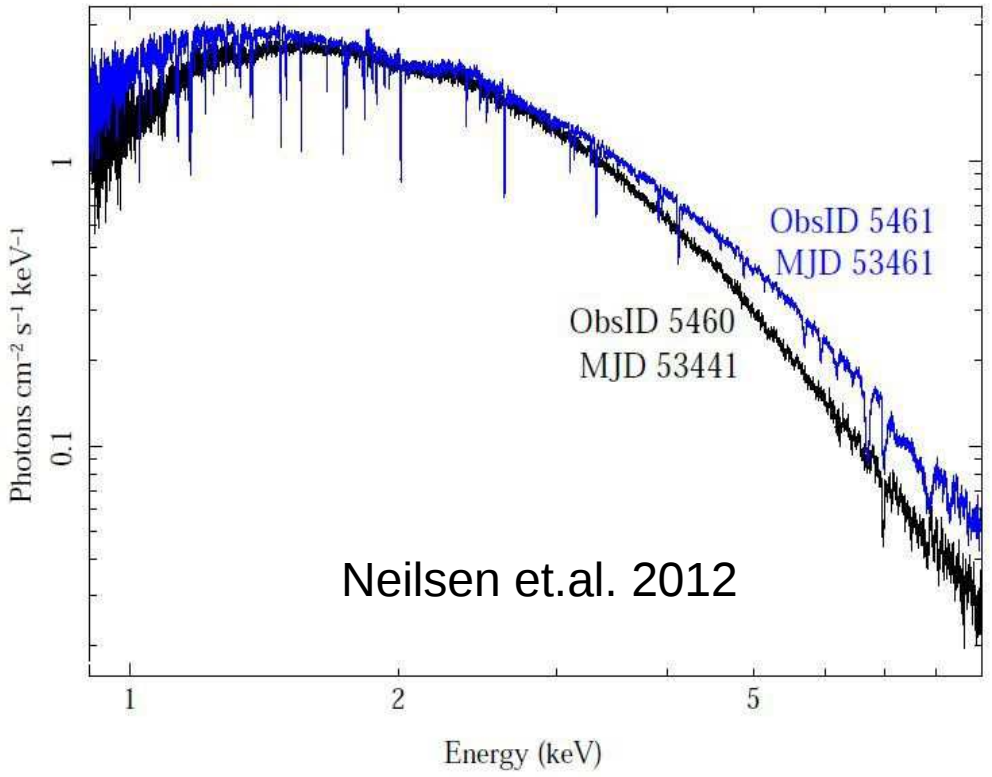
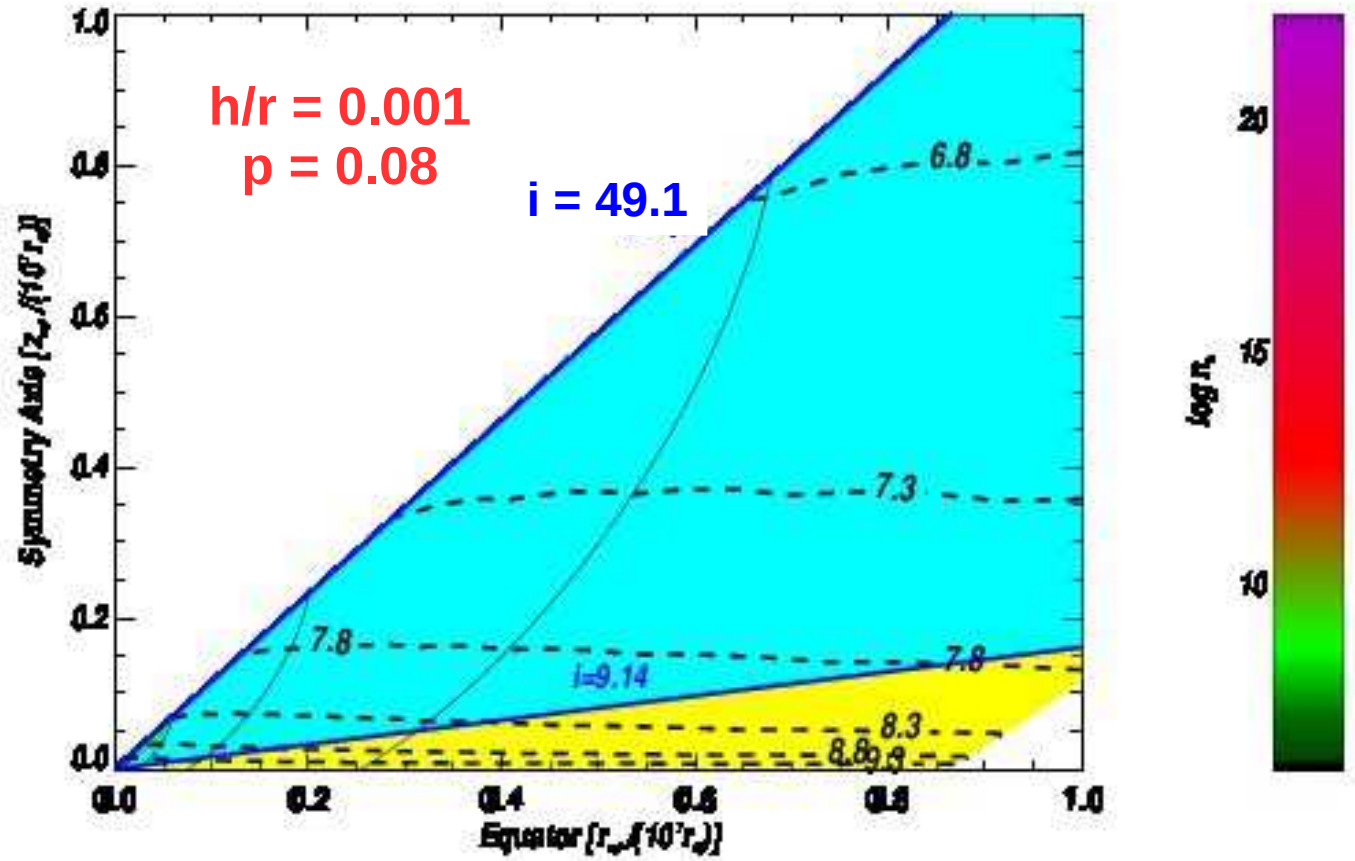
Disk surface heating can cause the low ionization winds



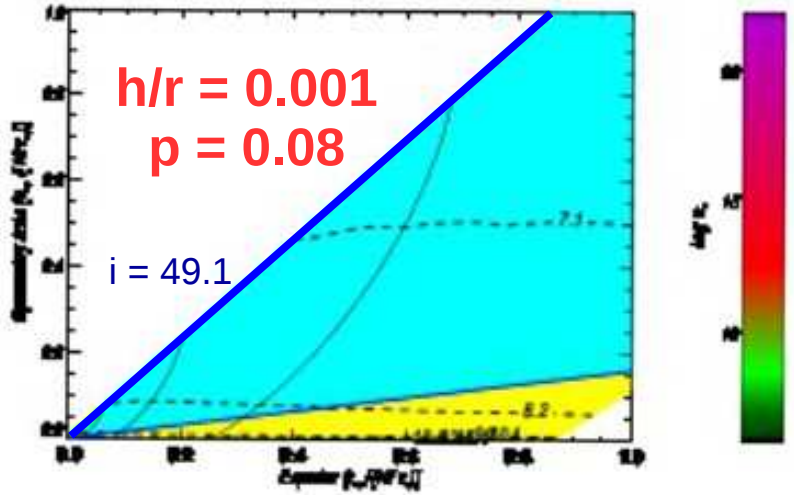


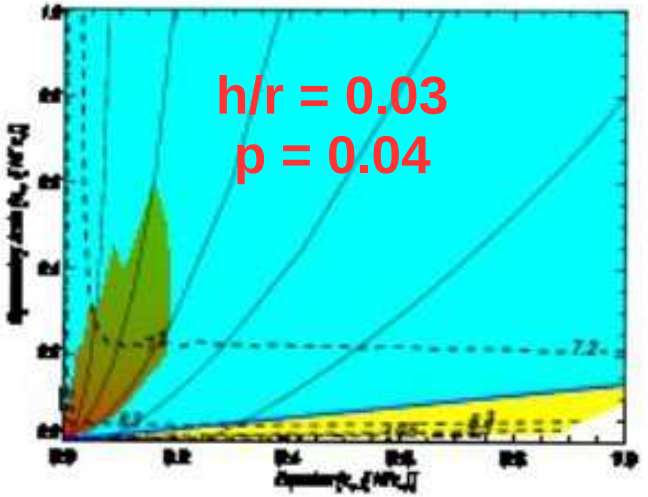
May not be enough to explain the low ionization (blue) wind in GROJ-1655.

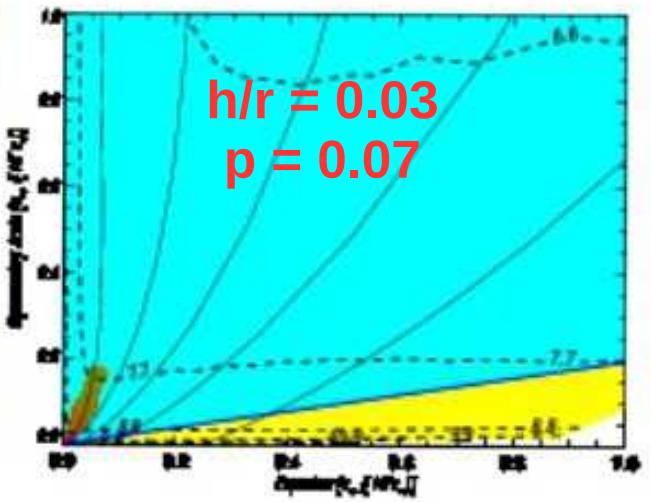
The MHD solutions by themselves , cannot be pushed to more extreme values,

We need some mechanism to aid the MHD.

Disk surface heating can cause the low ionization winds







Conclusions

The MHD models used here are more physical because the accretion and ejection are inter related

We find disk wind configurations consistent with observed winds

The favourable disk configurations are consistent with the soft state of the black hole

– this is a result derived without any imposed apriori conditions!

- thus the solutions seem to explain the state dependent prevalence of the winds as well
- the winds are ejected at low equatorial angles, in agreement with observations

For the special case of GROJ-1655, with low ionization wind

- we can explain such a outflow with “warm solutions”
- disk surface heating increases the amount of available material
- which is then accelerated by magnetic fields