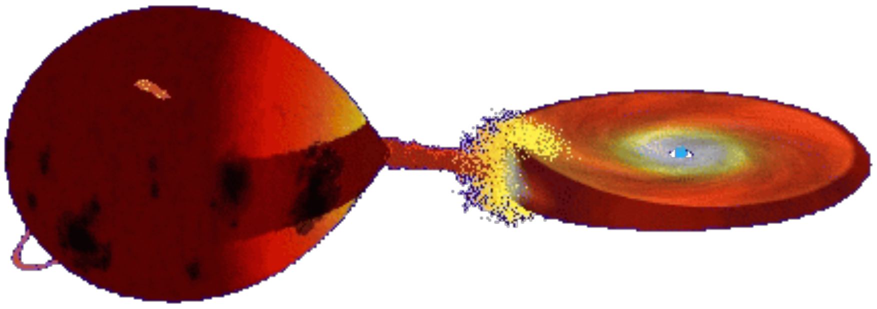
Winds in (disc accreting) binaries



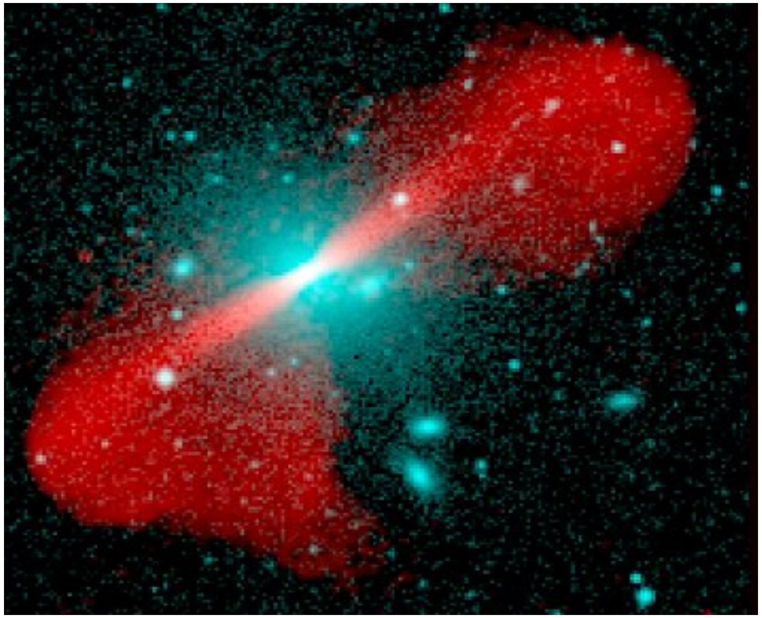
Chris Done, University of Durham
Ryota Tomaru, Megumi Shidatsu, Tad Takahashi
Misaki Mizumoto

AGN feedback via wind and jet

- Winds: 0.0001<v<0.4c
- Thermal pressure driven
- Radiative driving ?

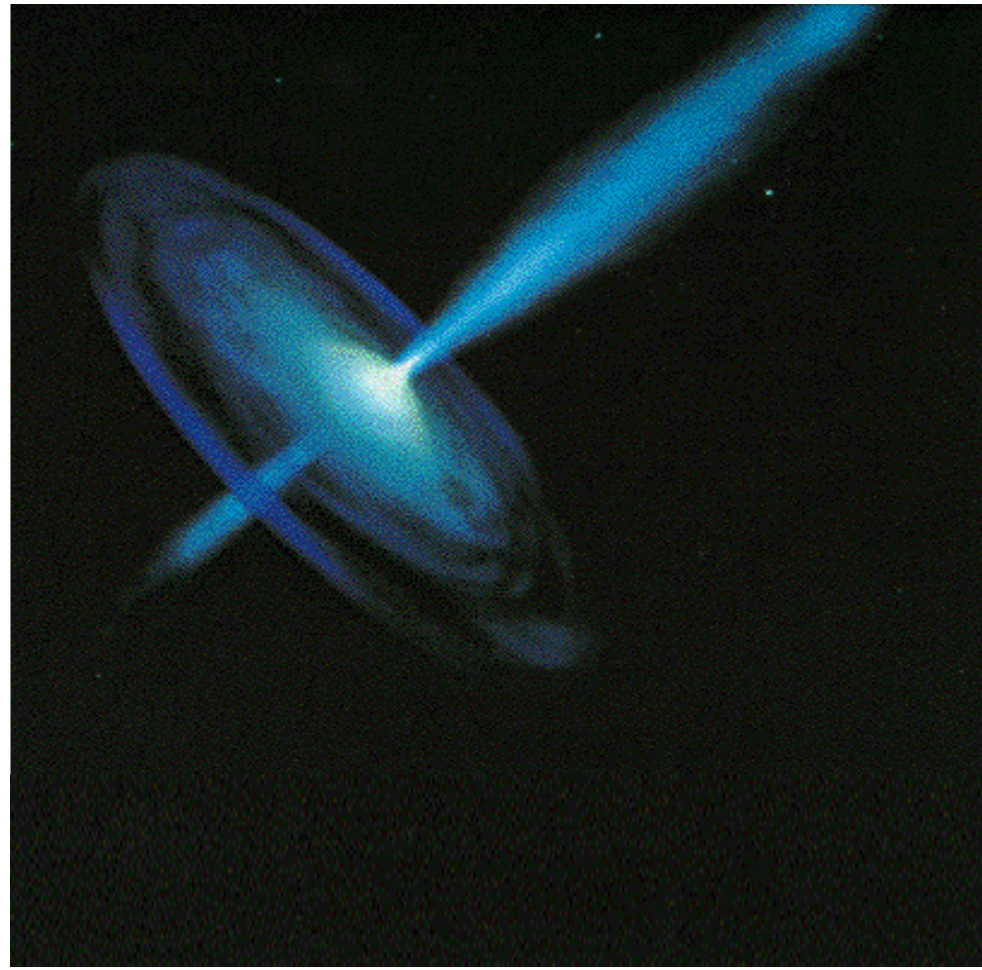
  L> σ_T/σ LEdd
  - UV line driven
  - superEddington
- Magnetic ? Transports L as well as M/KE/p

- Jets: Γ~10
- Magnetic !!



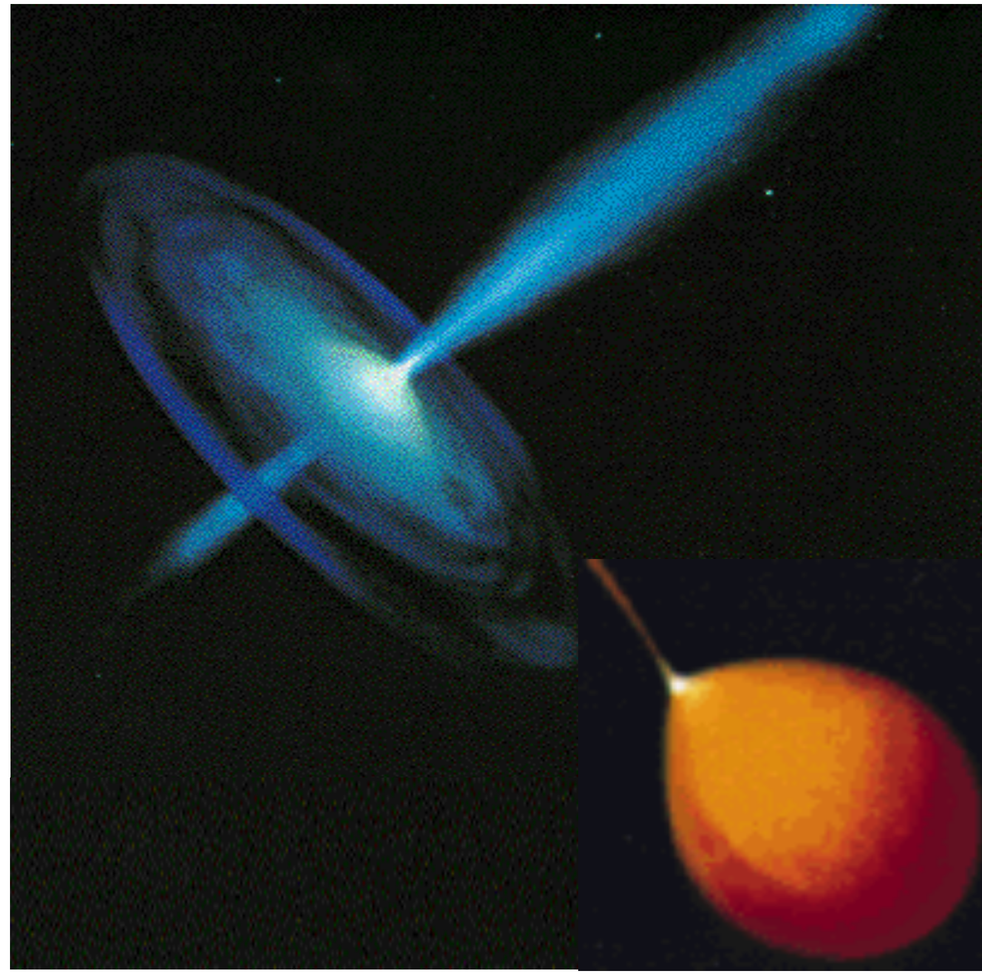
AGN feedback

- How do the wind and jet link to the accretion flow?



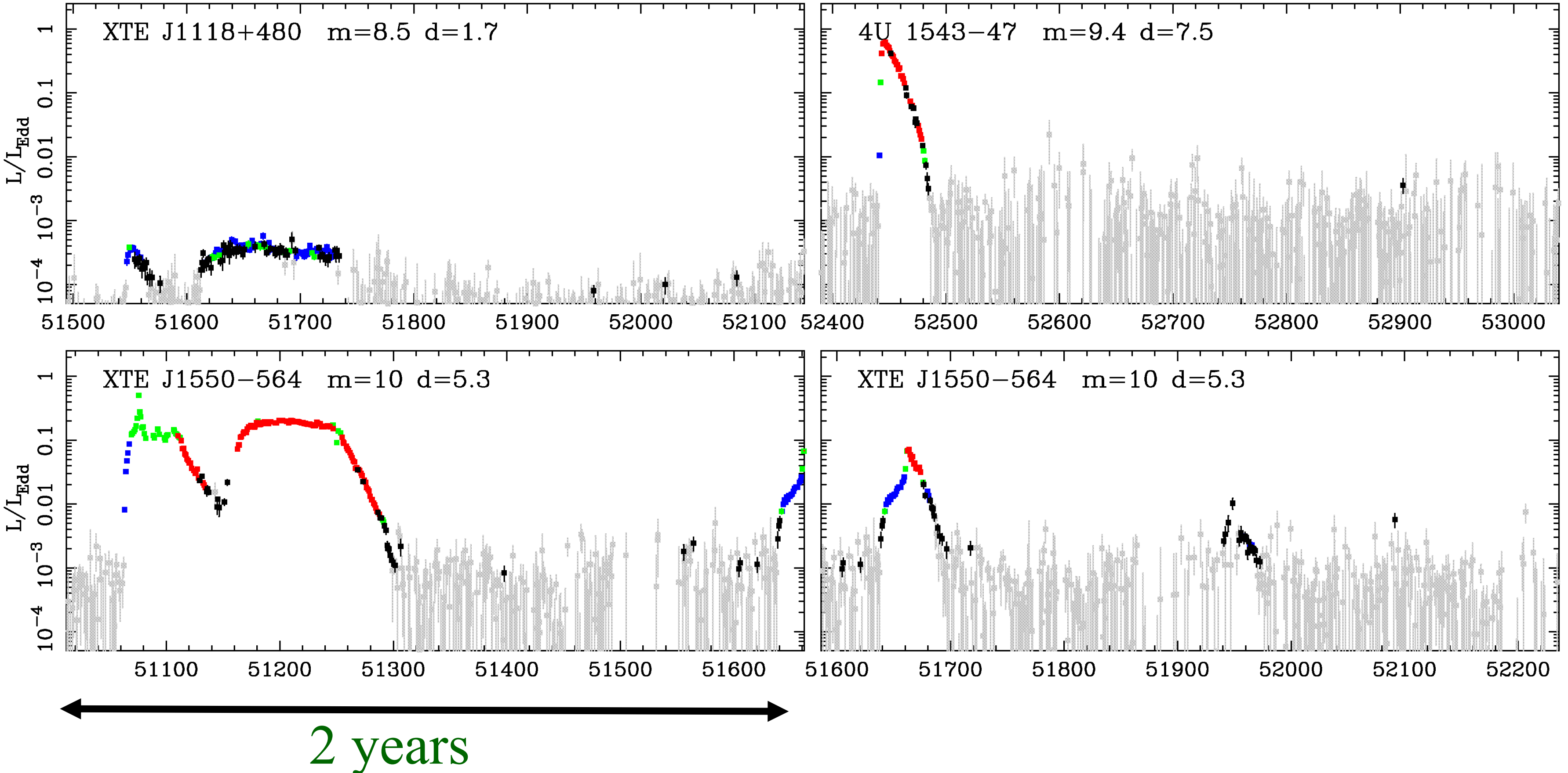
Winds from discs in strong gravity

- How do the wind and jet link to the accretion flow?
- Study more easily in galactic binaries as watch them change together!
- Should be comparable (scaleable) if everything B fields (plasma)
- Jet surely is B field !
- Wind maybe!



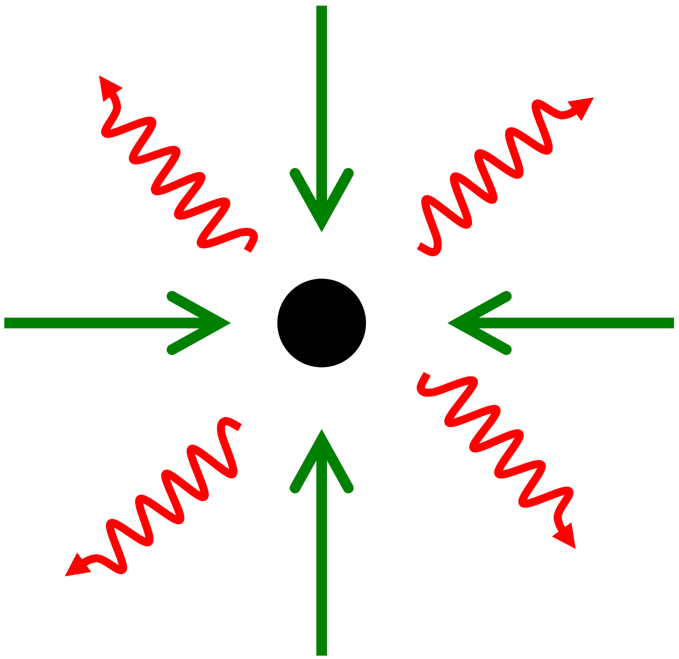
Stellar mass BH/NS disc varies!

- Mass accretion rate through the disc varies on timescales of days/weeks/months – especially dramatic in BHB!
- Not often L>Ledd - but a few do!



SuperEddington winds

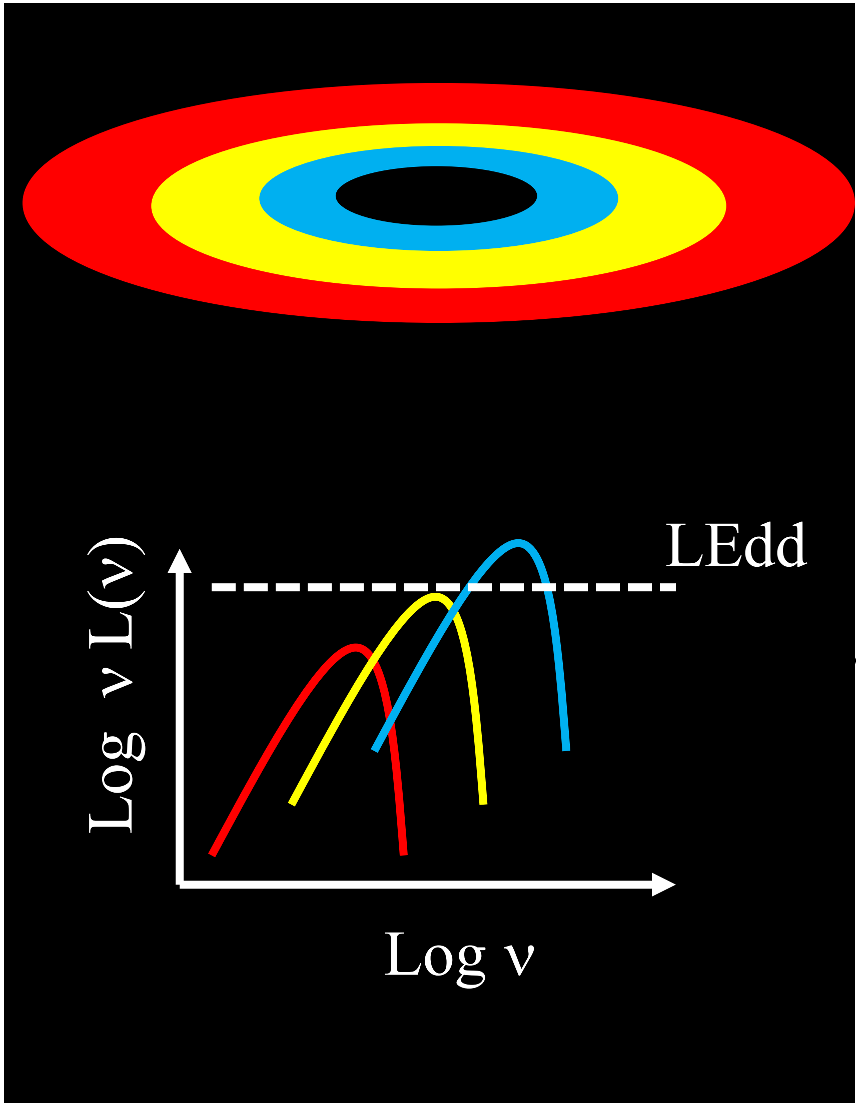
- Eddington limit
- inward gravity balanced by outward radiation pressure on electrons
- $F_{grav} = (1 - L/L_{Edd})\ GM/R^2$
- superEddington flows:
- $L > L_{Edd}$
- But disc geometry?



SuperEddington winds

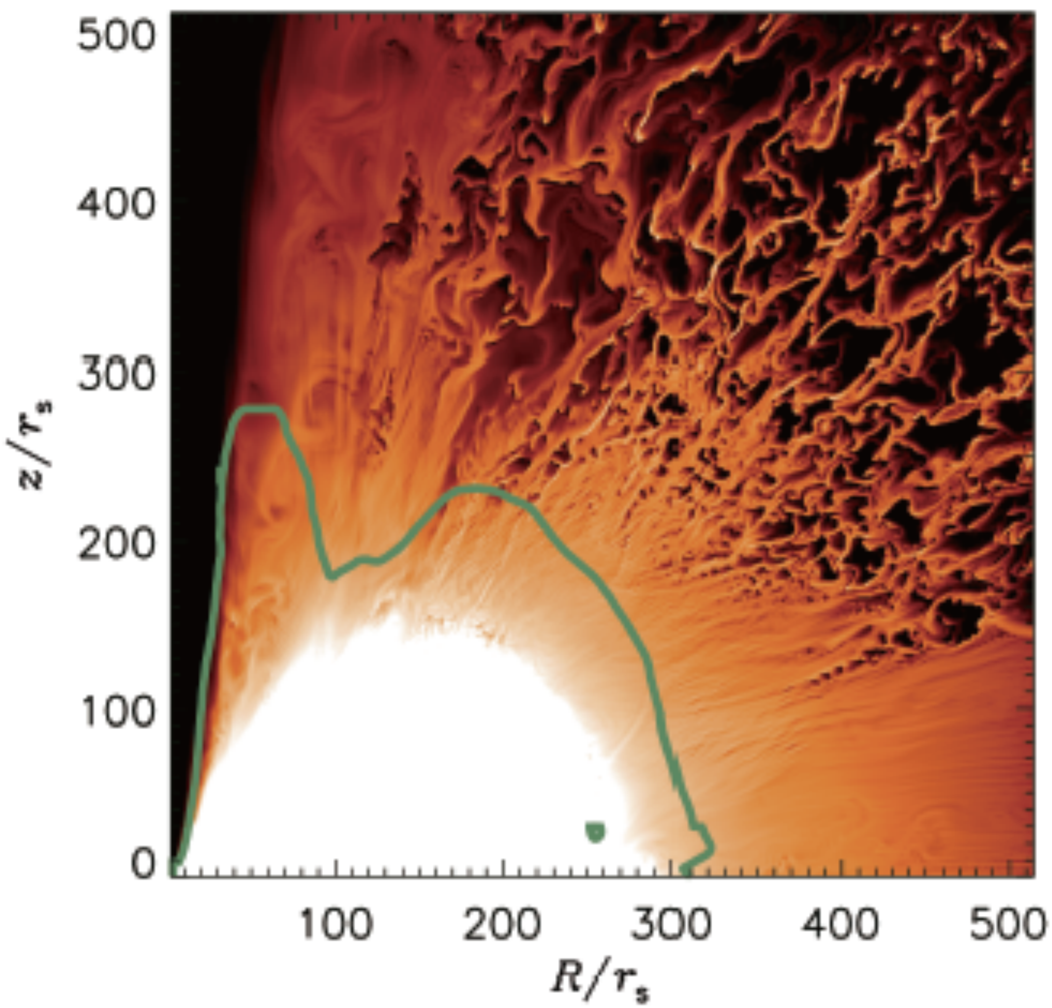
- Ldisc>Ledd
- Launch wind from inner disc - fast, v~0.3c for launch radius ~20Rg for L~2-10 LEdd (Shakura & Sunyaev 1973; Kubota & Done 2019)

- BHB: V404 Cyg, GRS1915, GROJ1655(?)
- NS: ULX-P, Z sources
- AGN: extreme NLS1



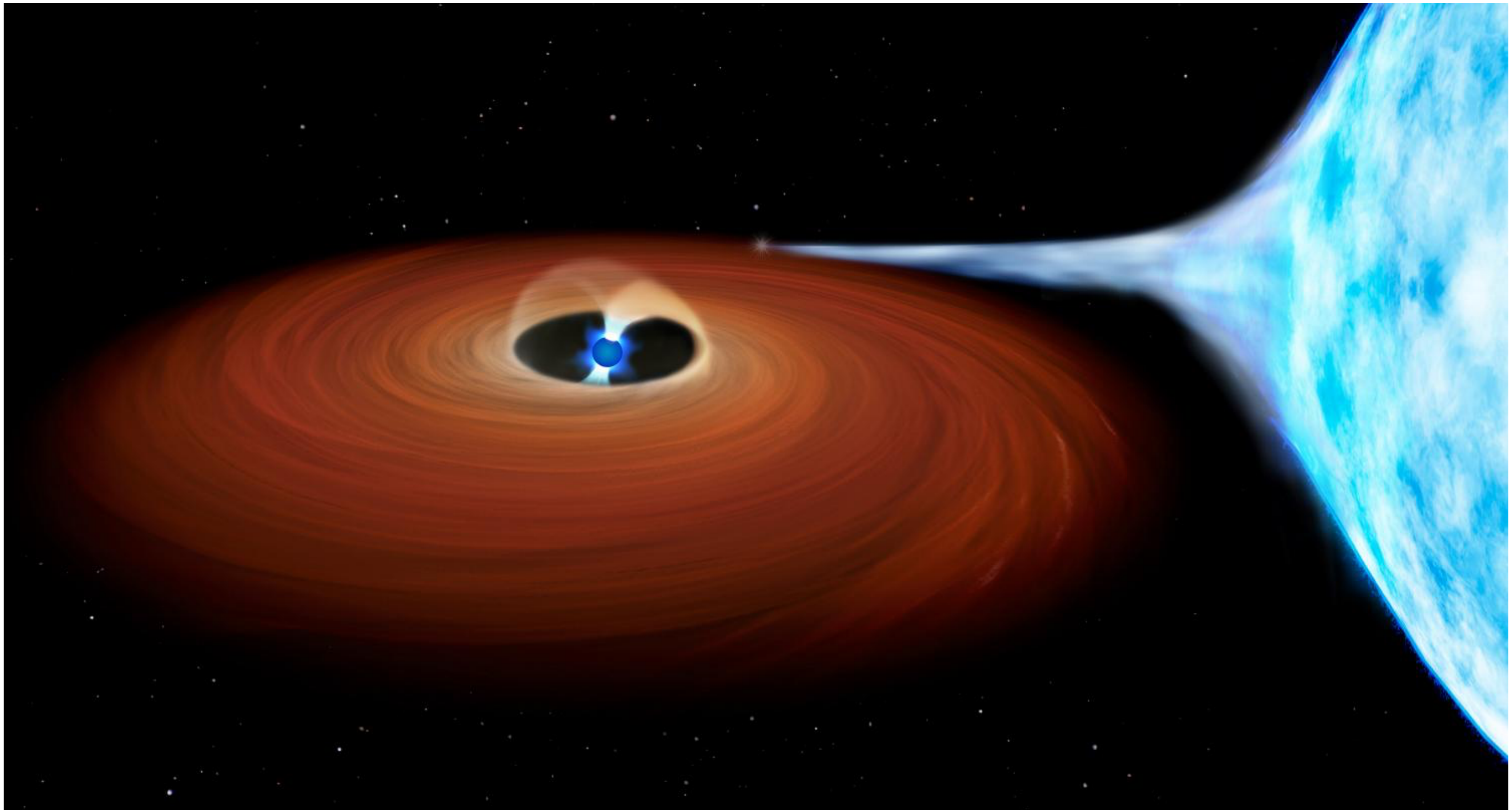
SuperEddington winds

- Can advect inwards or power wind outwards
- Or both!
- Lacc~10 Ledd
- W|inds L_{KE}~L_{rad}
- Clumpy, complex
- Takeuchi, Ohsuga, Mineshige (2013)



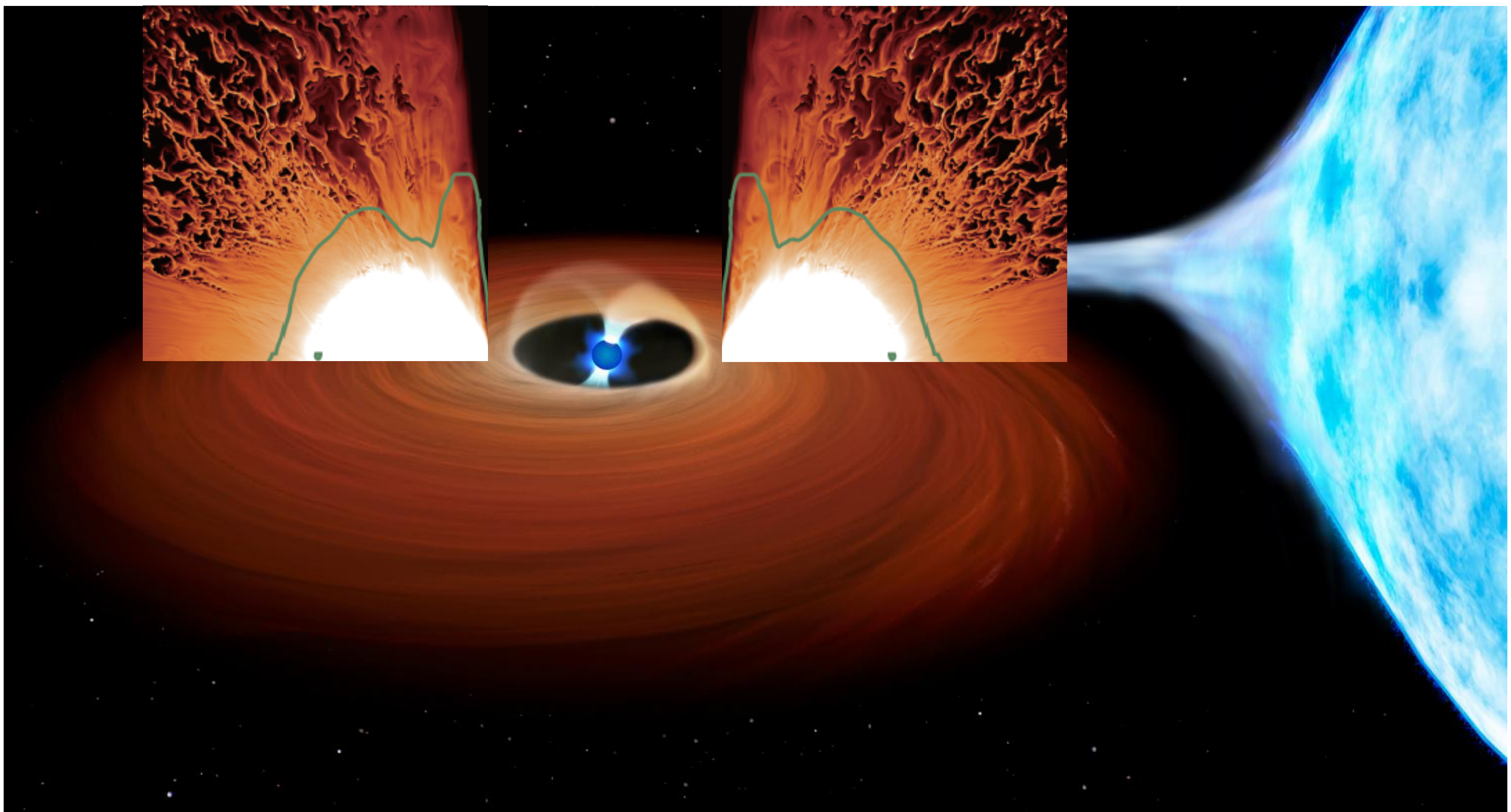
SuperEddington winds

- ULX-P: L~100LEdd to get to 10^{40} ergs/s from NS
- Wind from R>100Rg: non conservative mass transfer – GW progenitors



SuperEddington winds

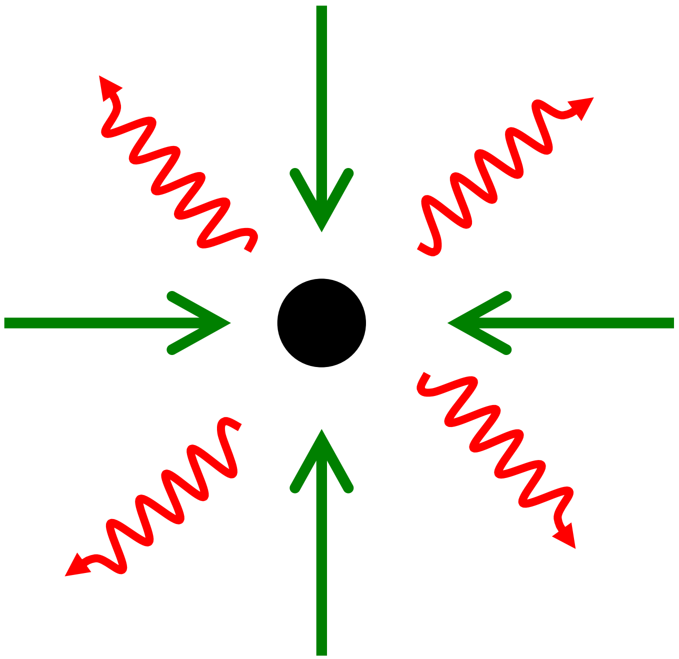
- ULX-P: L~100LEdd to get to 10^{40} ergs/s from NS
- Wind from R>100Rg: non conservative mass transfer – GW progenitors. BUT FAINT IN XRISM!!



Effectively superEddington winds: σ>σT

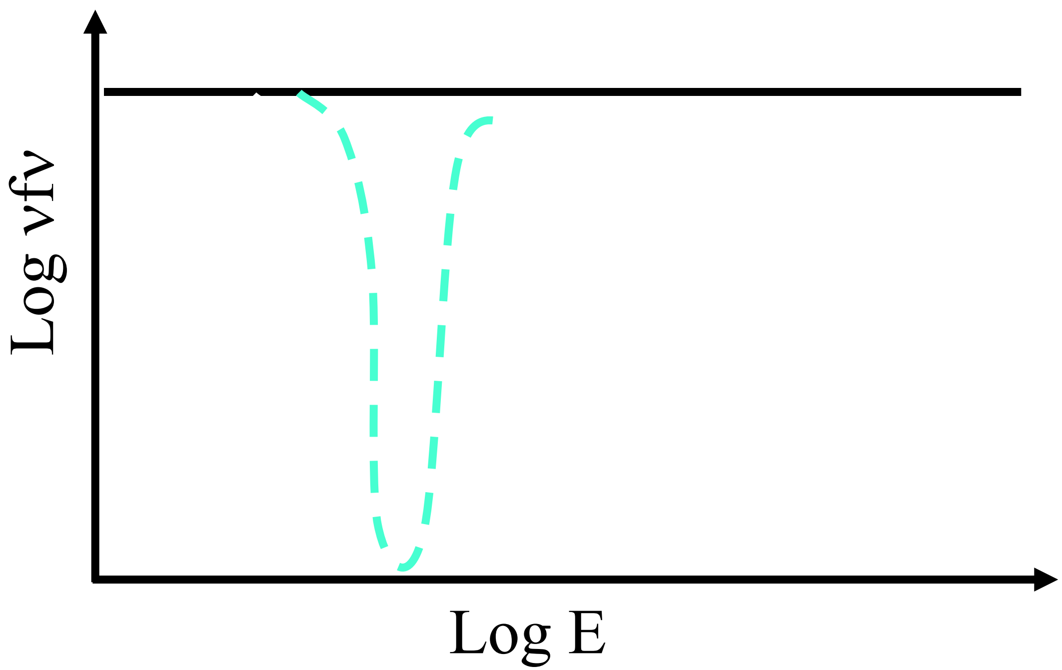
- Eddington defined for electron scattering σT
- Wind if additional coupling σ>σT.
- *M*=σ/σT force multiplier
- Wind if L > Ledd / *M*

- M~1000 'classic' UV line driving low ionisation



UV line driven Winds

- Momentum absorbed in line accelerates wind so more momentum absorbed in line
- UV line cross-section much bigger than electron scattering, so wind at $L_{UV} \sim \sigma_{es}/\sigma_{UV}\, L_{edd} << L_{Edd}$



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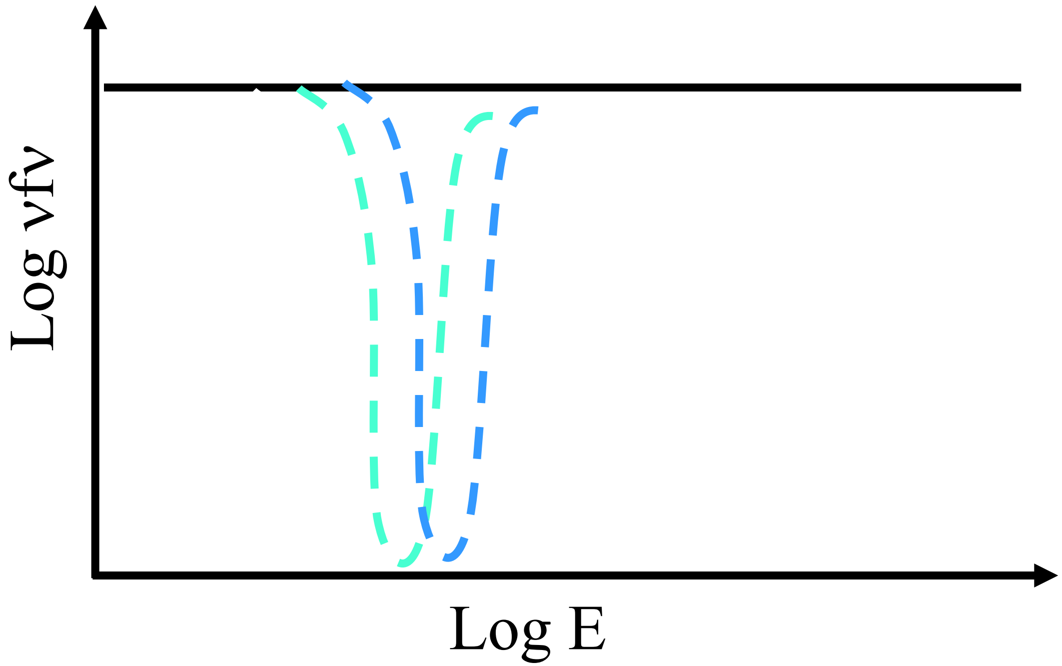

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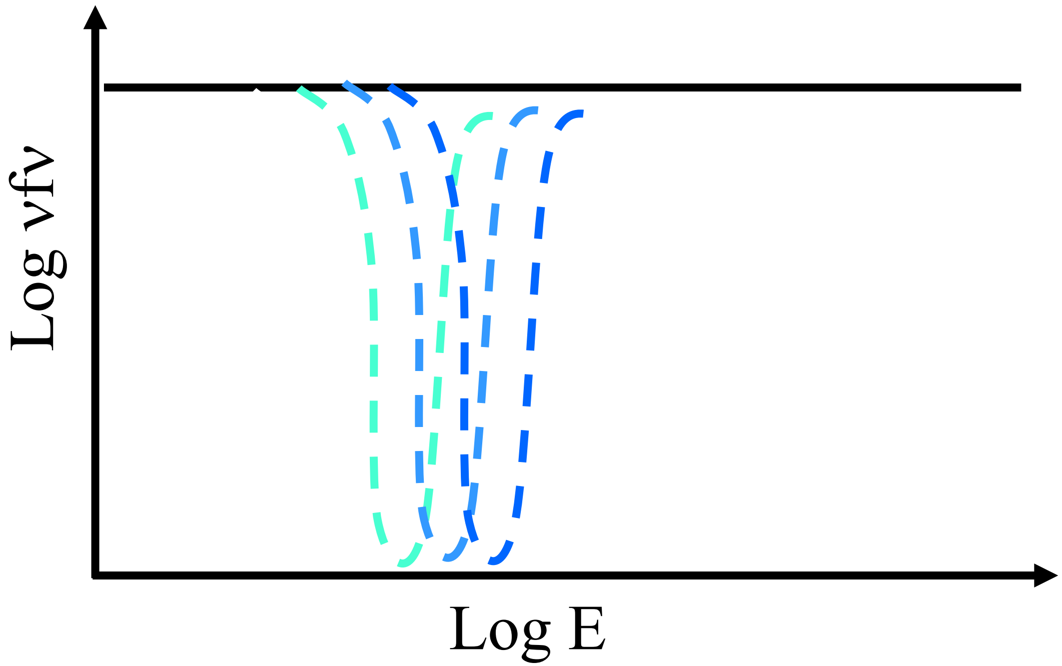

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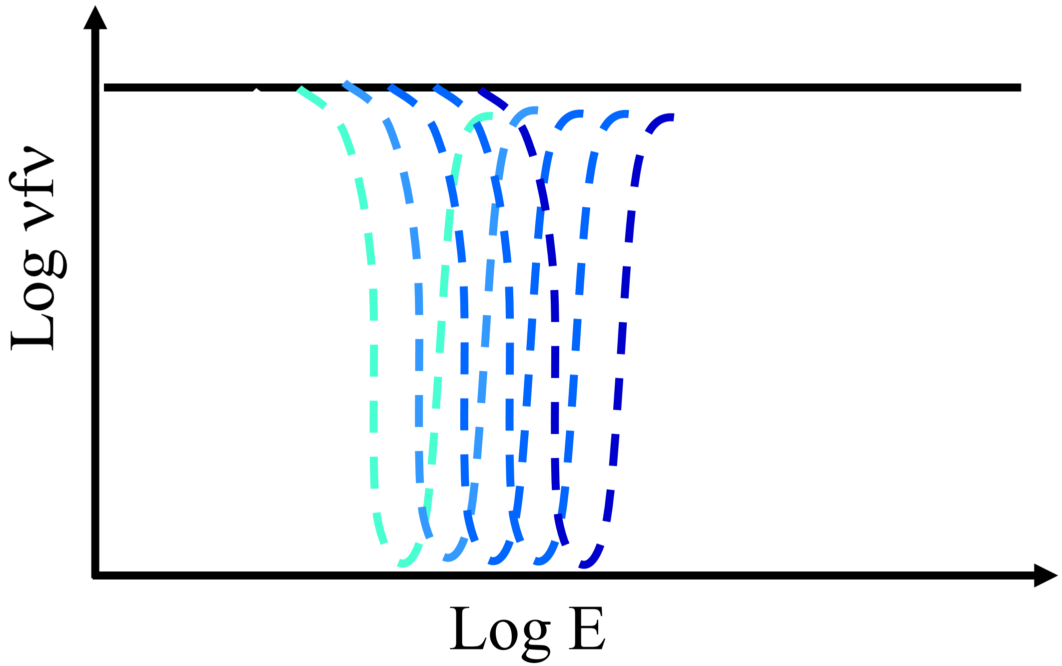
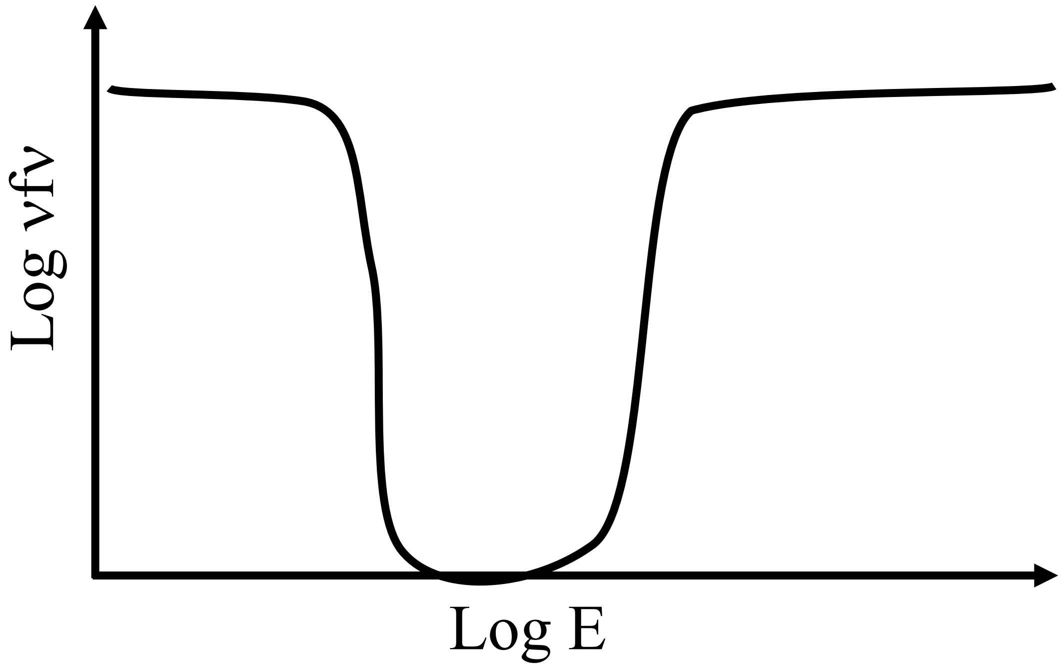


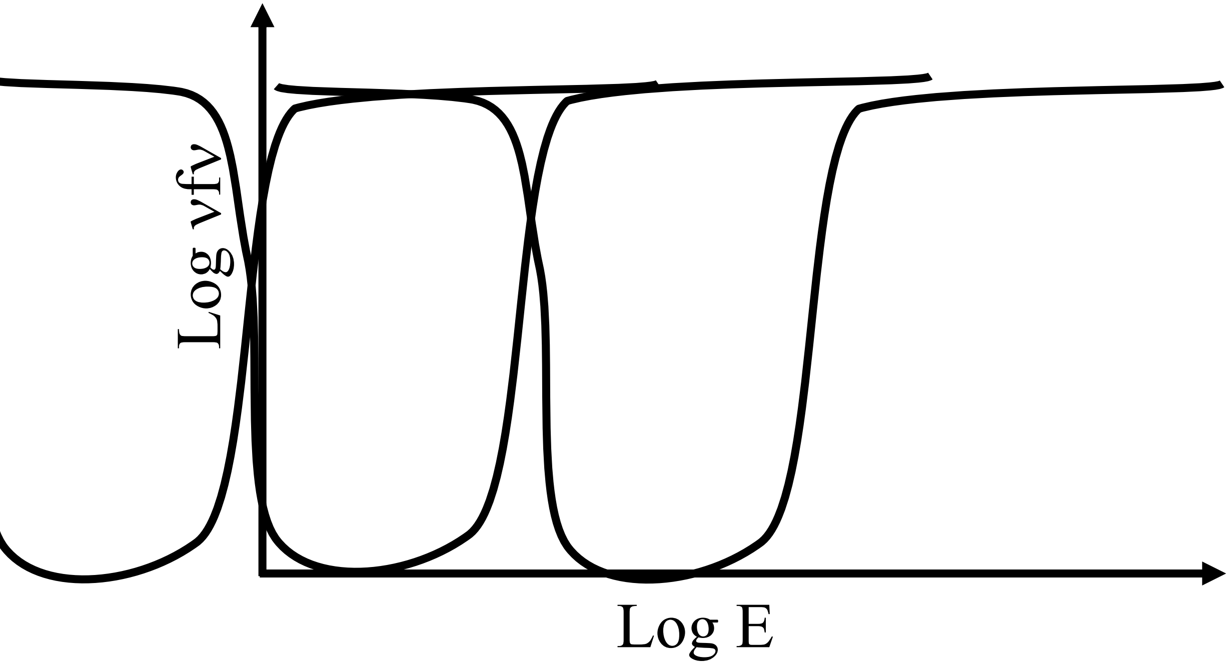
UV line driven Winds ?

- UV radiation
- Low ionisation state in disc photosphere so abundant ions with UV line transitions – weak FUV/X-ray irradiation!



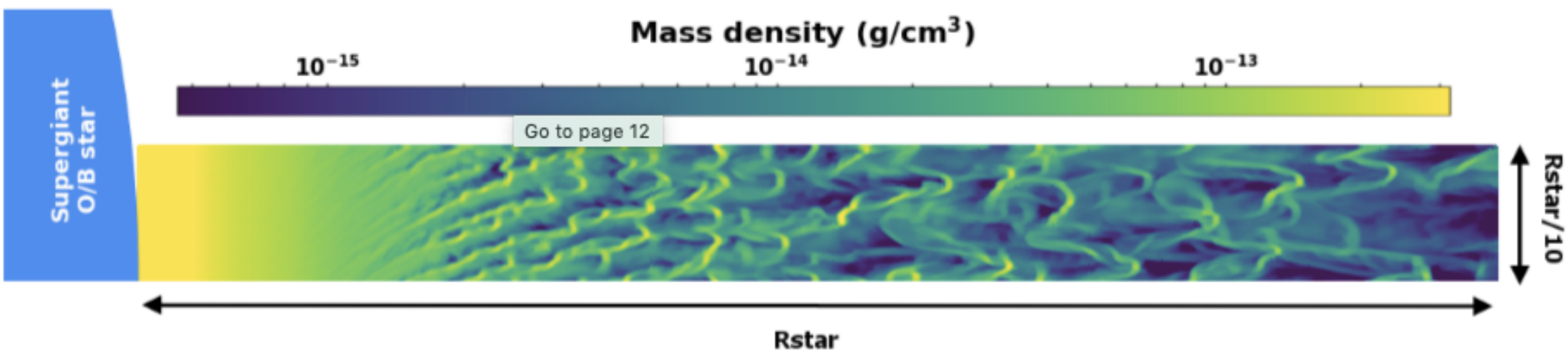
UV line driven Winds ?

- UV radiation
- Low ionisation state in disc photosphere so abundant ions with UV line transitions – weak FUV/X-ray irradiation!
- Multiple UV transitions!!



O stars!

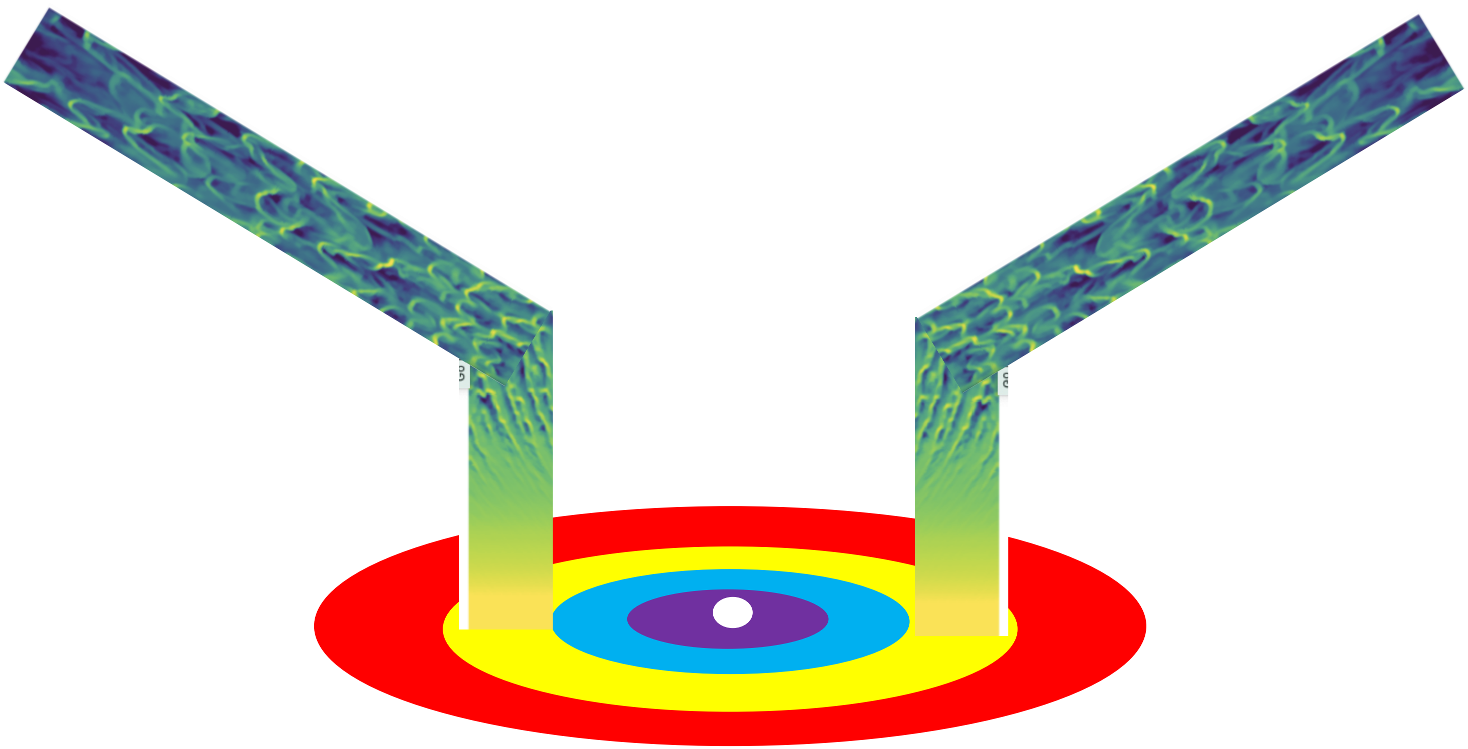
- UV radiation: Castor Abott Klein (CAK)
- Low ionisation state: abundant ions with UV line transitions – weak FUV/X-ray from shocks in the wind M~1000
- Complex structure (radiation driving always unstable – shadows!)



El Mellah et al 2017

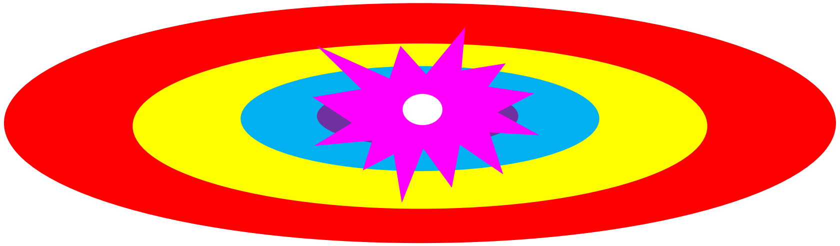
UV section of disc

- Disk wind geometry – rise up to H~R, have too much L for radius so pushed outwards
- Wind from UV section of disc $v^2 \sim Rg/R$



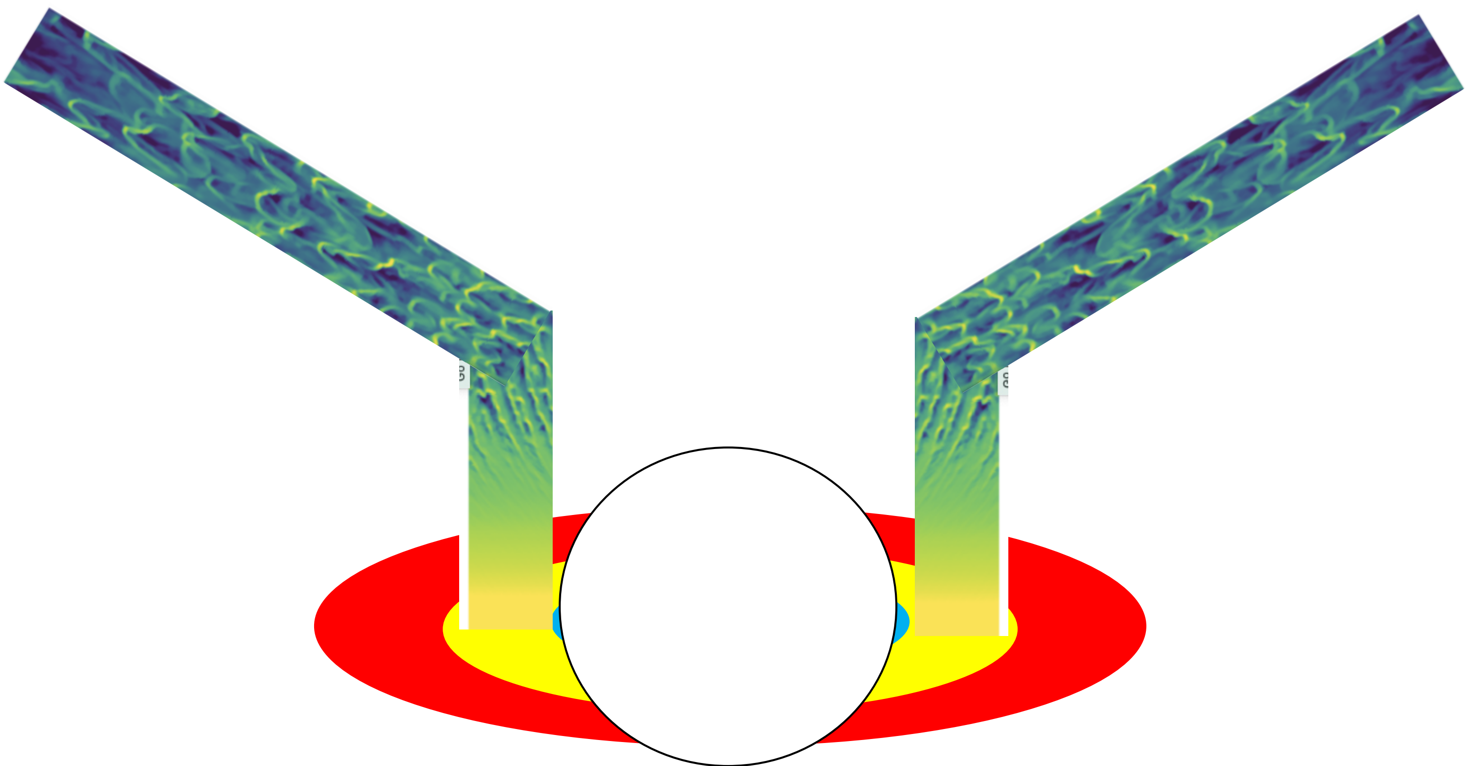
UV section of disc: NS/BHB

- NS/BHB at ~Ledd: UV at large R so low L_{UV}
- X-rays from small R ionise so M~few not 1000 Proga & Kallman 2002



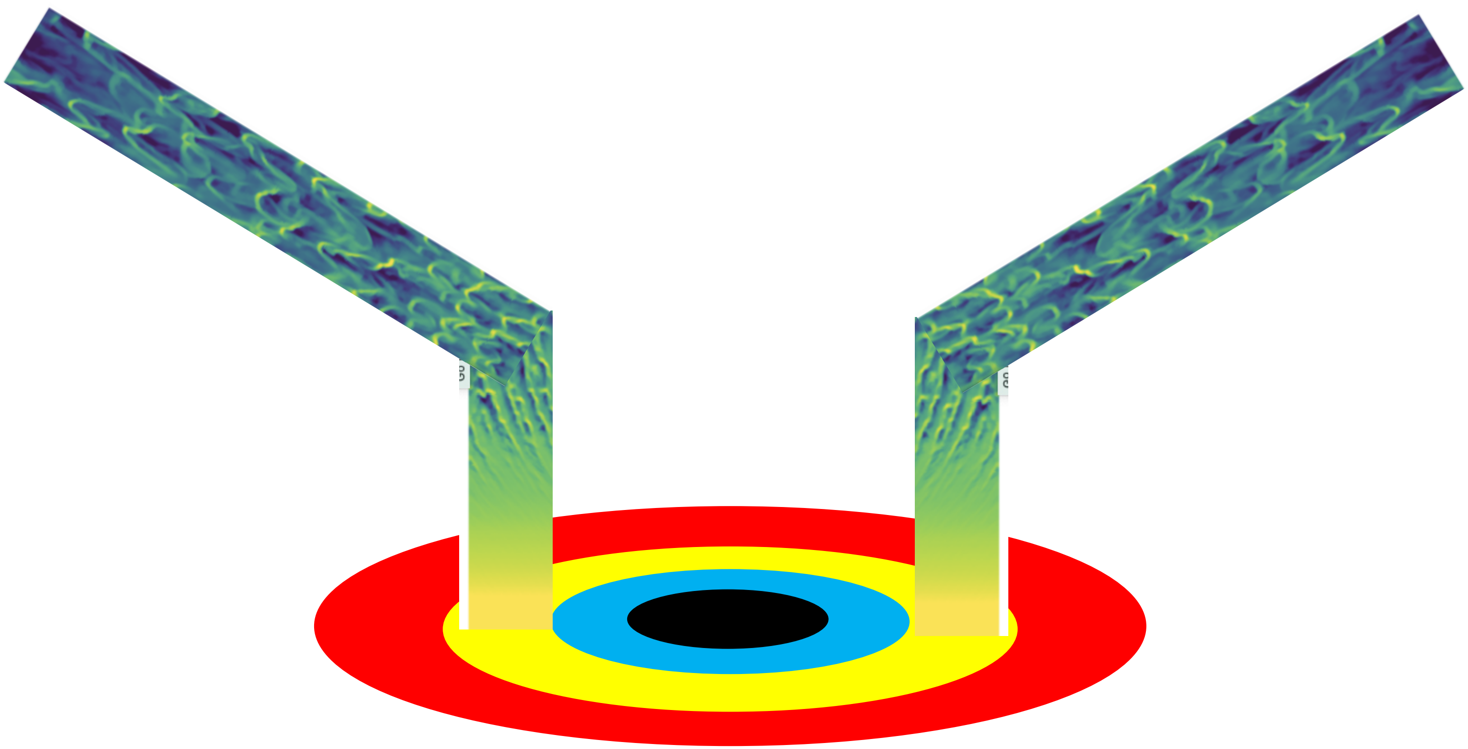
UV section of disc: WD

- WD: R~1000x larger than NS so L~1000x smaller
- NS at 0.5Ledd=10^{38} means WD at 10^{35} ergs/s
- But M=1000 so effectively Ledd for UV wind!



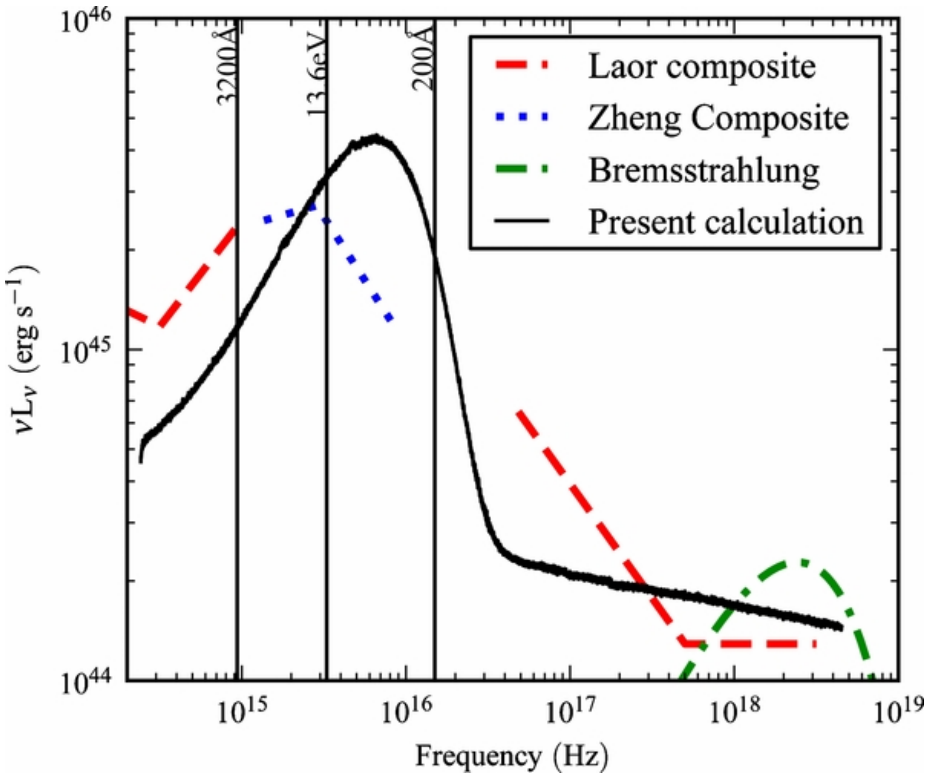
UV section of disc: AGN

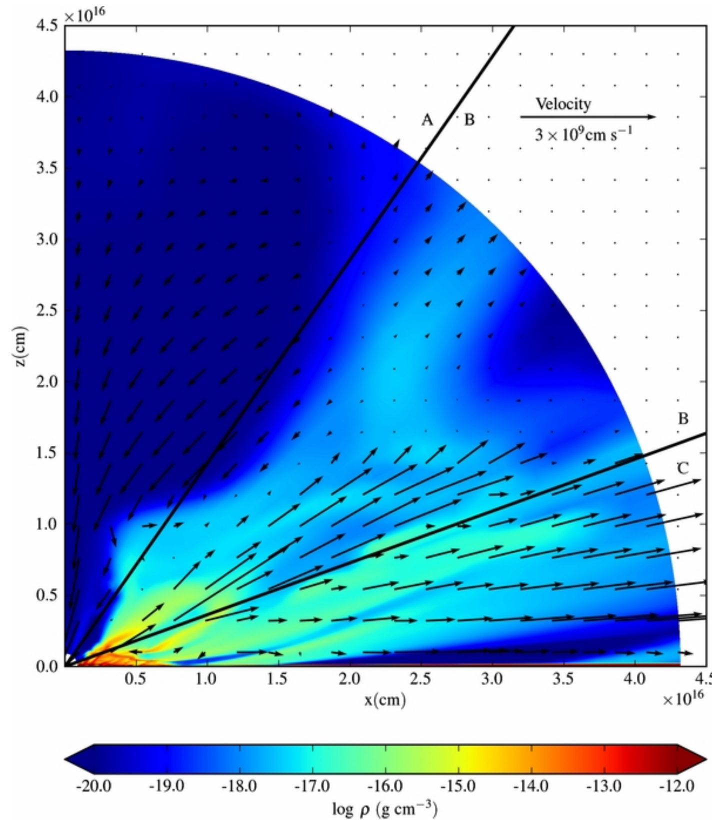
- BH at 0.5Ledd for 10^8 M gives UV zone at small R
- High velocity wind – 0.2c BALs/UFOs
- M=1000 if no X-rays
- M~10 even if quite strong X-rays so effectively superEdd



UV line driven Winds ?

- Clumpy, complex
- 10^8 Msun, L/Ledd = 0.5 Proga et al 2004, Elvis & Risaliti 2010, Nomura et al 2019. Mizumoto talk





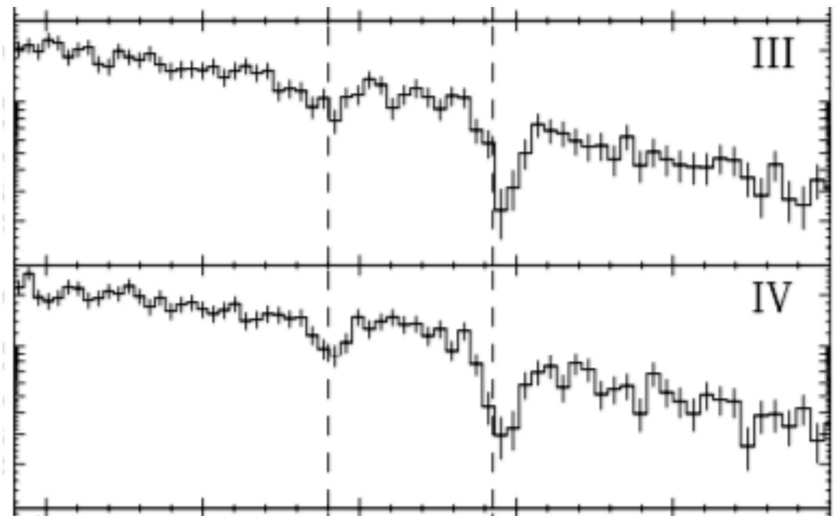
Higginbottom et al 2014

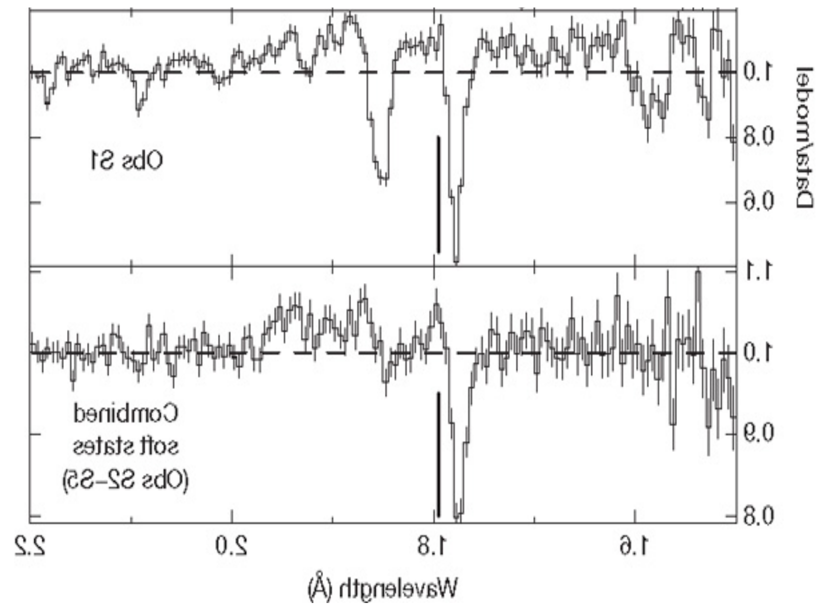
Radiation driven winds

- L>Ledd: anything! ULX, BHB, NS
- L<LEdd: UV line driving
  - AGN: UV zone at small R/Rg – fast wind. BALs & UFO (Mizumoto talk!)
  - WD: UV zone at larger R/Rg – slowish wind.

- BUT WE ALSO SEE WINDS IN L<LEdd BHB/NS!!!

Winds in NS & winds in BHB





GX13+1 0.5 LEdd

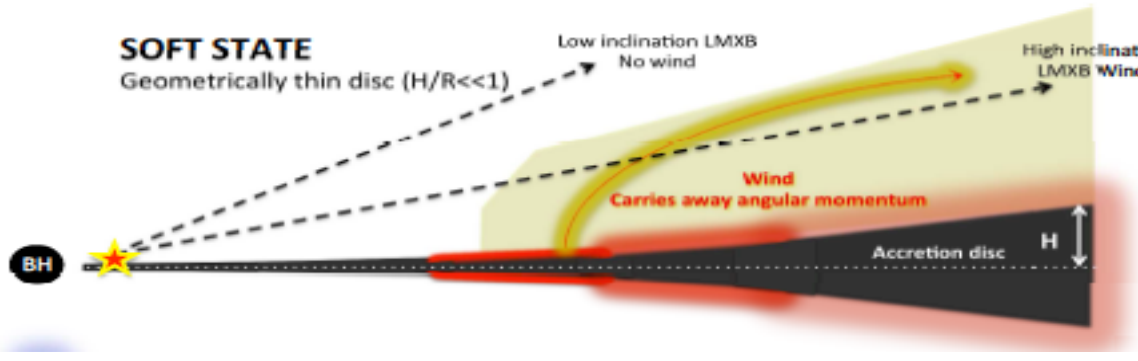
Ueda et al 2004, Allen et al 2018

GRS1915+105 0.3-3LEdd

Neilsen & Lee 2009

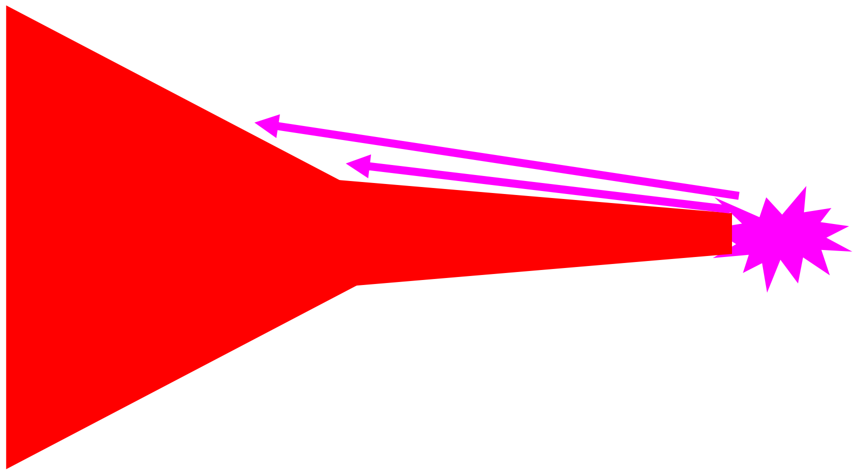
Winds in NS & winds in BHB

- Slow!! v<~1000km/s, Narrow vbroad<~vout:
- Most material is highly ionised – FeXXVI & XXV
- SPECTACULAR IN XRISM: resolution at 6-10 keV
- Not seen in all systems! High inclination (Ponti et al 2012), large discs/long Porb (Diaz Trigo 2016)
- GRS1915, 4U1630, H1743, GRO J1655
- GX13+1, Cir X-1, T5X2



Thermally driven Winds

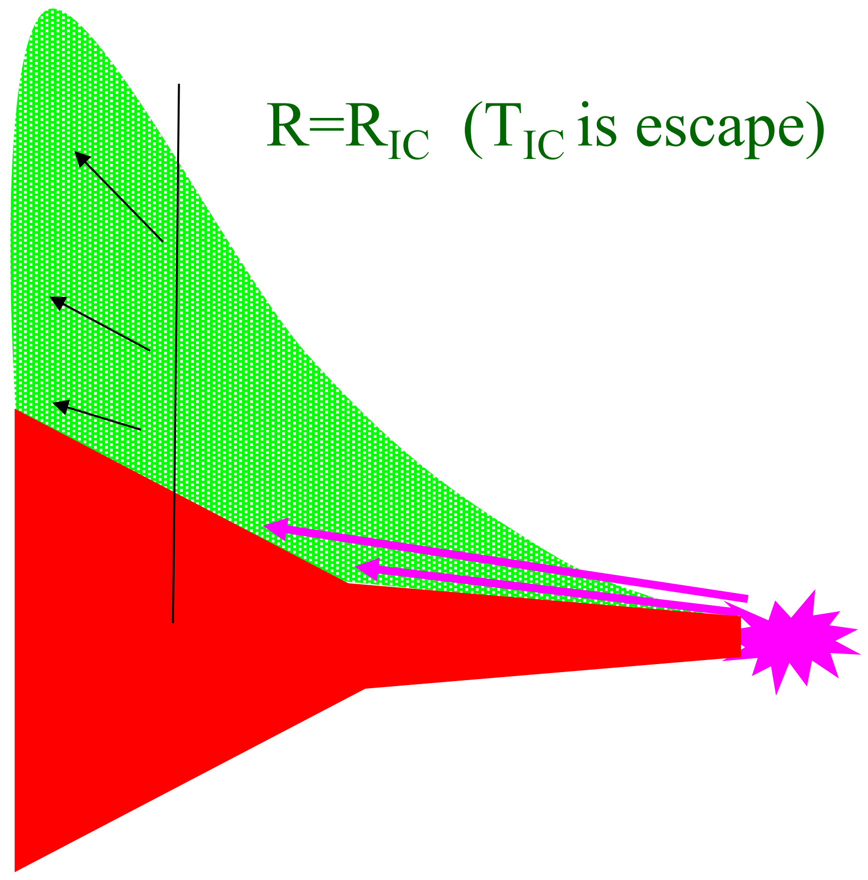
- X-ray source irradiates top of disc, heating it to Compton temperature
- T_{IC} depends only on spectrum



Begelman McKee Shields 1983

Thermally driven Winds

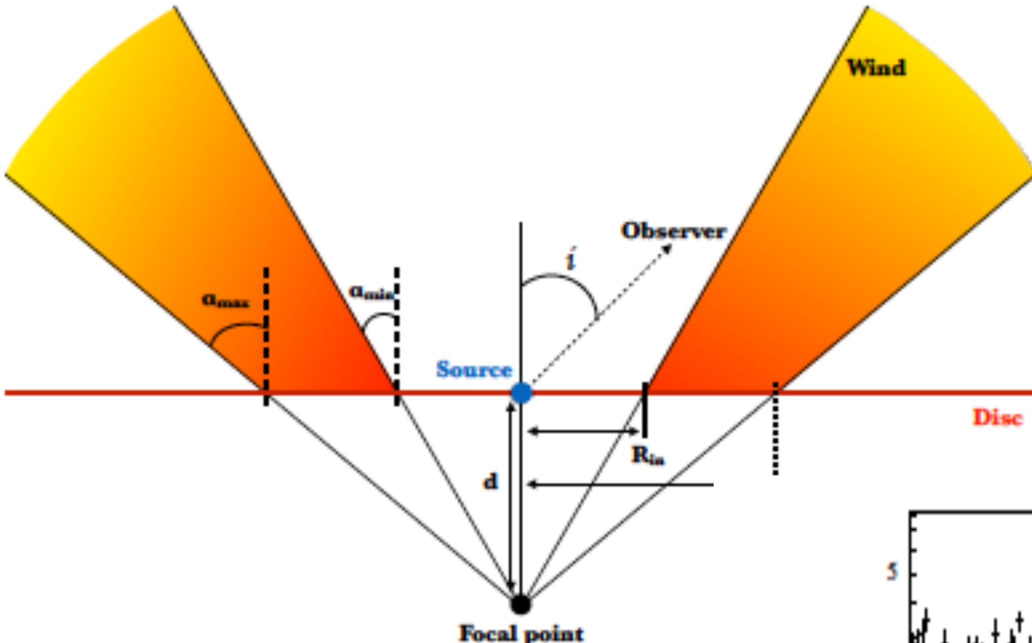
- Hot so expands
- Radius where thermal velocity is escape: RIC
- Wind for R > R_{IC} driven by pressure gradient so $v_\infty = v_{esc}$
- Bigger disc, bigger wind!!
- Can't have thermal wind if launched at R<< 0.1 R_{IC} by $L << L_{edd}$



Begelman McKee Shields 1983

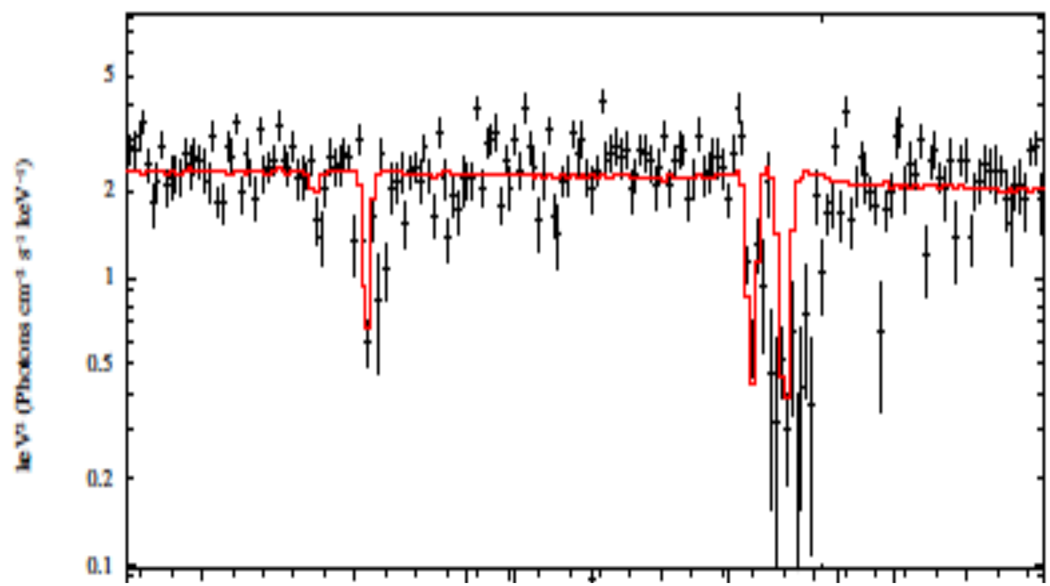
- Mdot(wind)~Mdot(acc) x log Rout/RIC!! $L_{KE} << Lrad$

Can it work ? GX13+1 NS 0.5LEdd



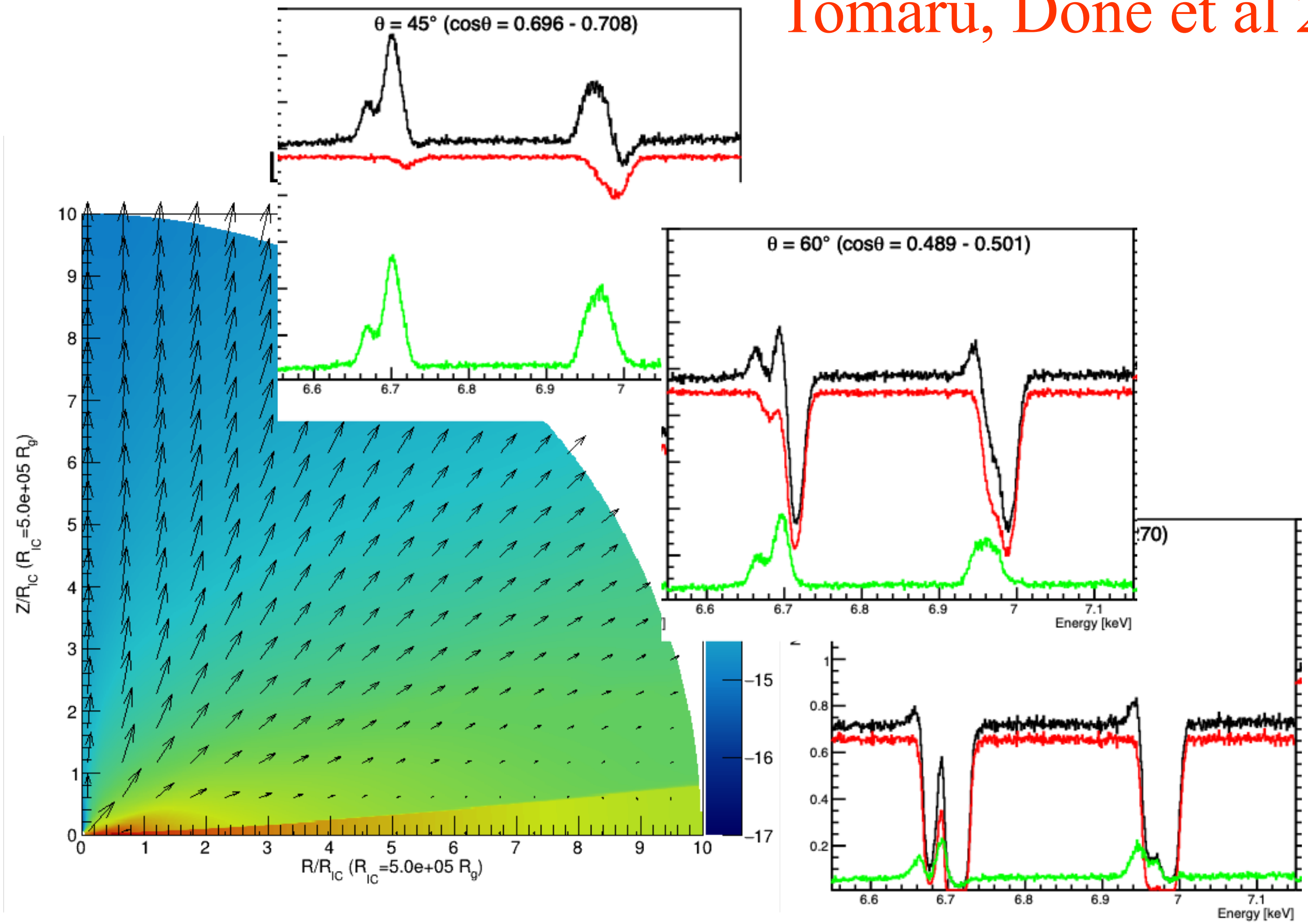
- Bipolar wind based on analytic thermal-radiative models
- Misses the fastest parts of the wind

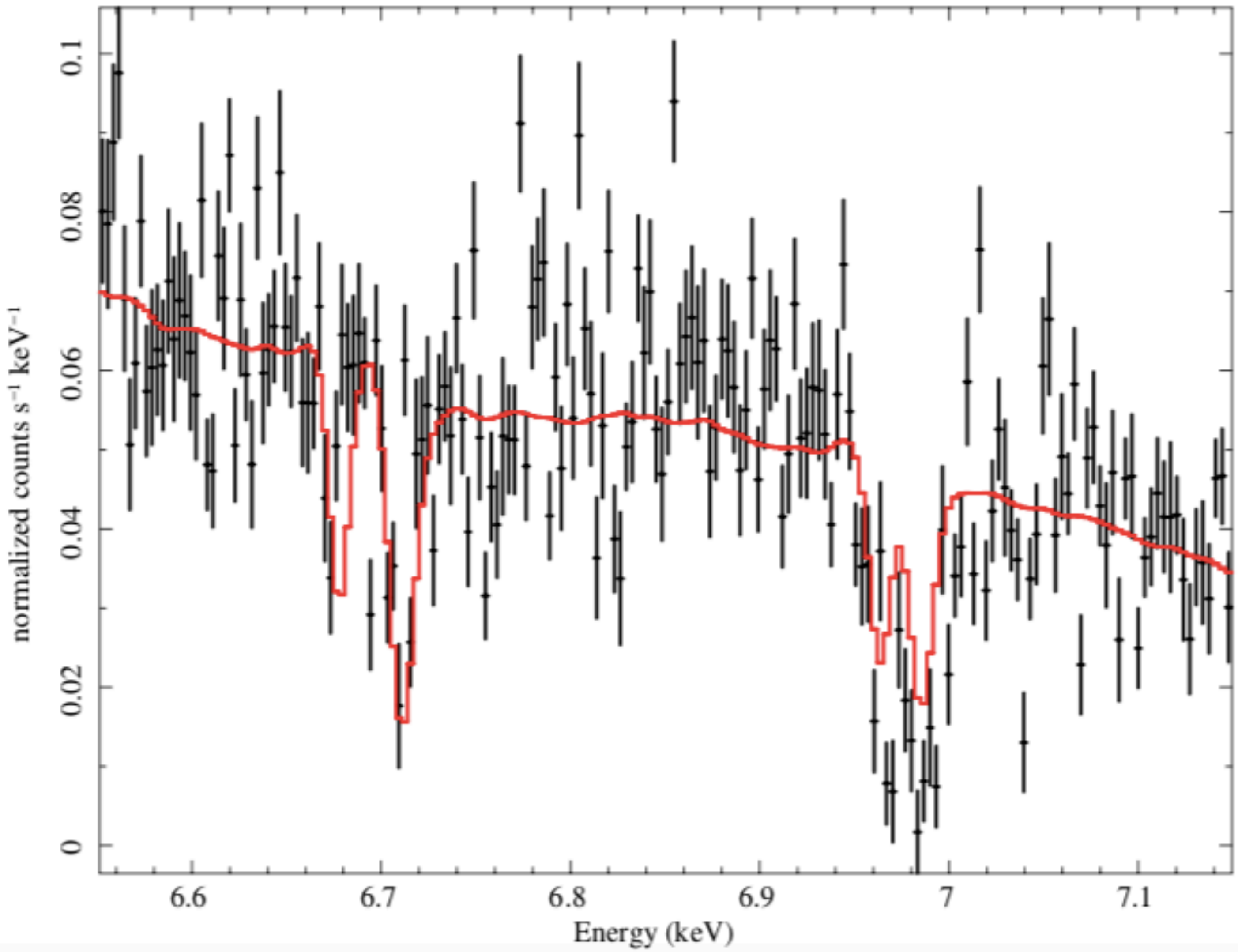
Tomaru, Done et al 2018



Do proper models - Radiation hydro

Tomaru, Done et al 2019a, b





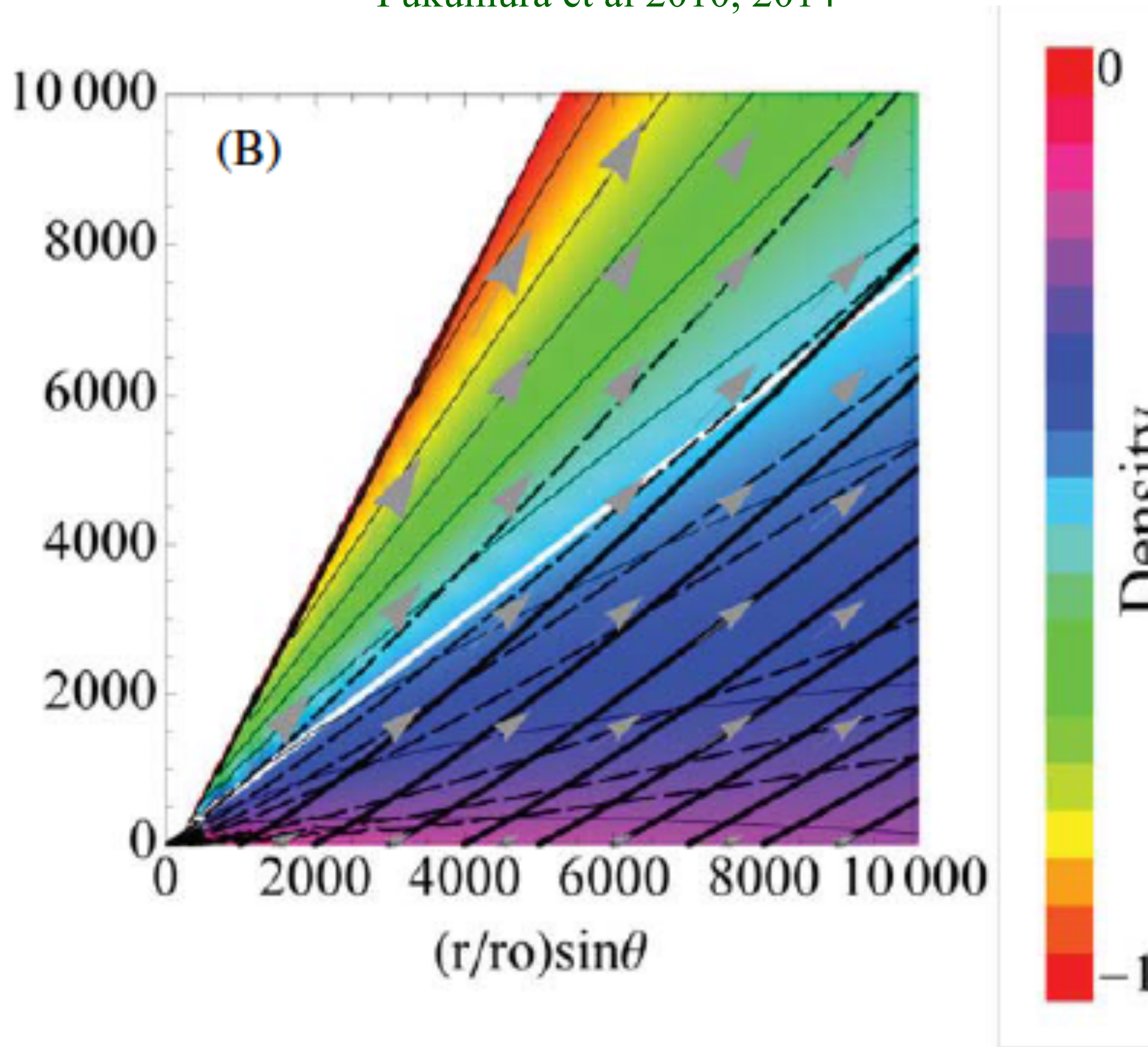
Tomaru, Done et al 2019a, b

And even 3rd order HEG!!

What about magnetically driven winds??

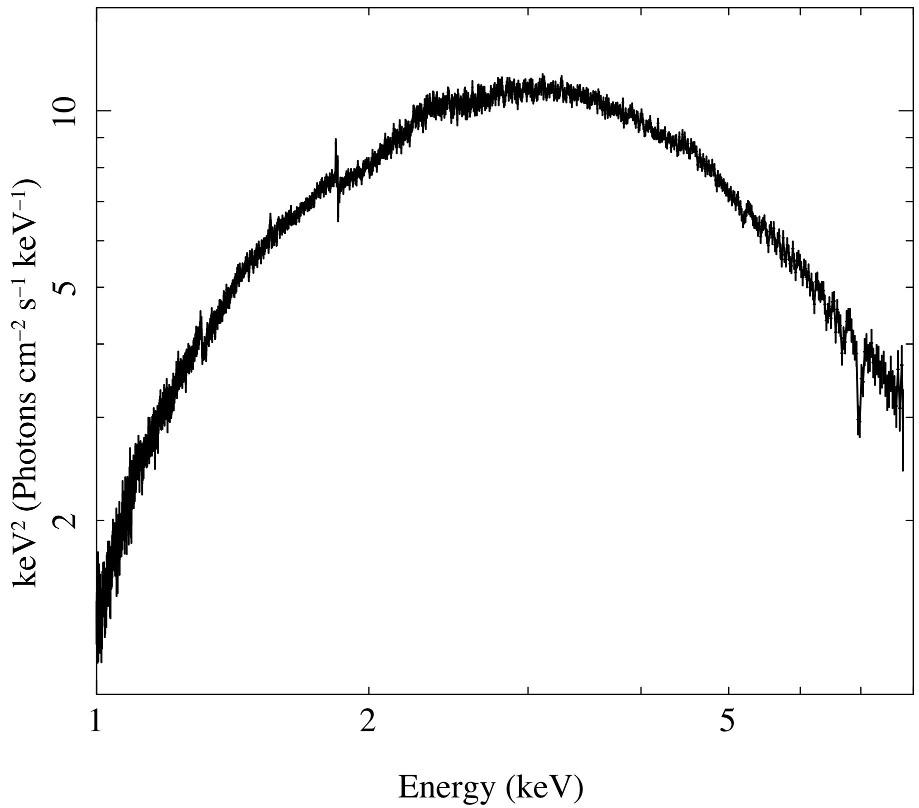
- Unknown!!
- Need specific B field geometry but then can get powerful wind from inner disc
- TRANSPORTS L as well as mass/energy
- Intrinsic part of accretion process!

Fukumura et al 2010, 2014



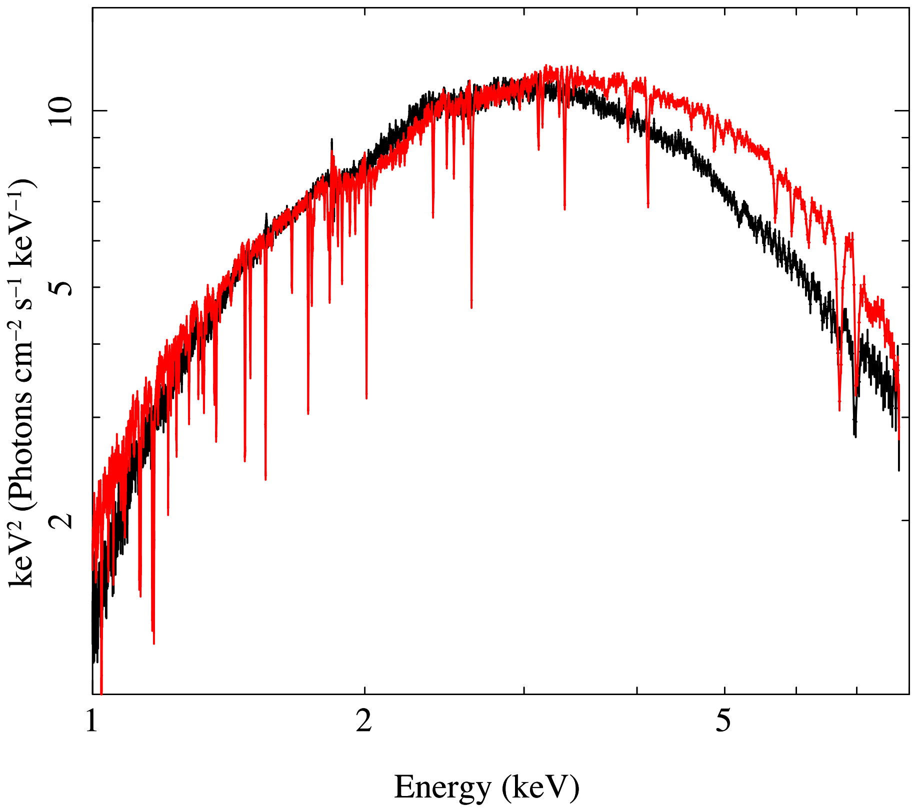
B winds? GRO J1655

- March 12 standard wind! L~0.05-0.1LEdd



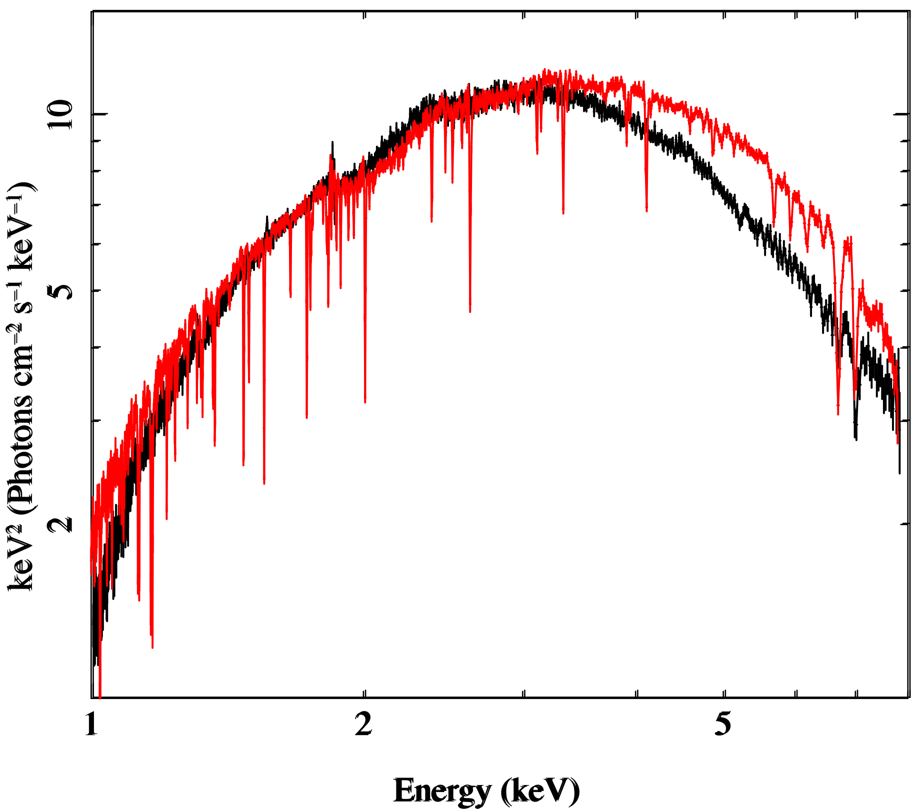
B winds? GRO J1655

- April 1st– very similar L/LEdd and spectral shape! Homan & Nielsen 2012, Higginbottom et al 2018



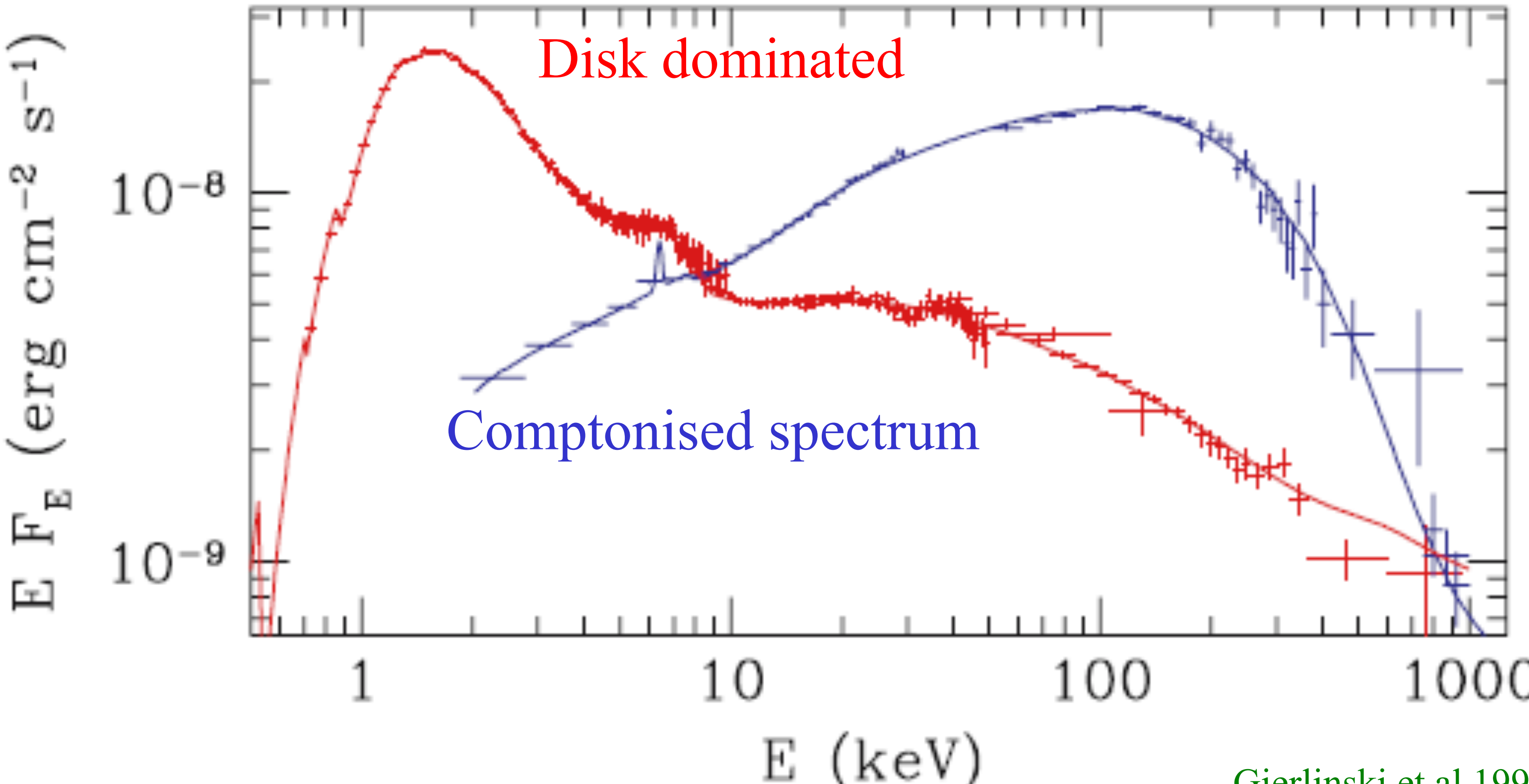
B winds? GRO J1655

- Not thermal wind at the observed L/Ledd (Miller et al 2006, 2008, Luketic et al 2010, Higginbottom et al 2014)
- Magnetic wind? If so, transient not ubiquitous as obviously not present on March 12??
- Or L>LEdd wind has gone optically thick?? (Shidatsu et al 2016)



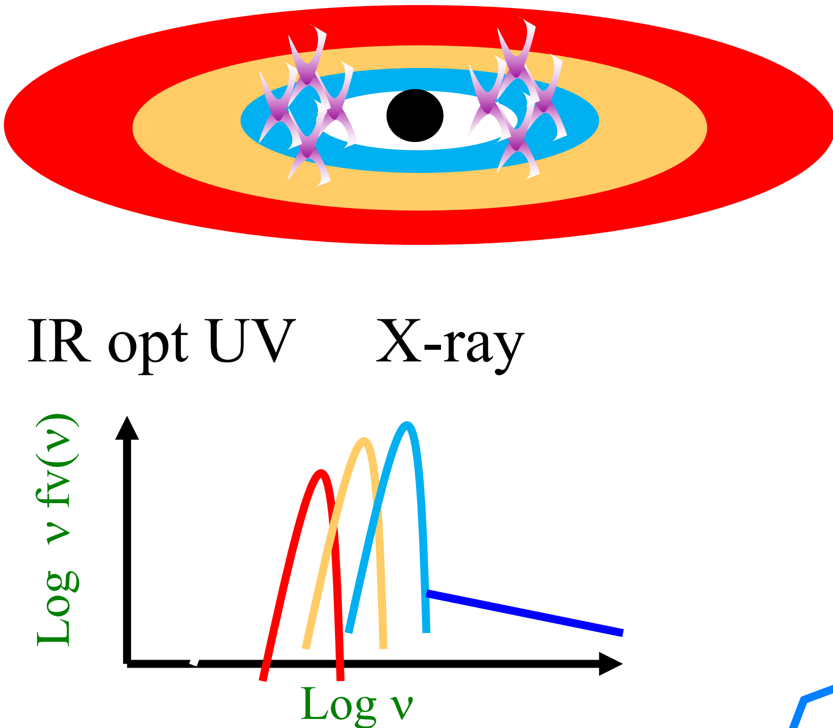
Two types of spectra in stellar BH

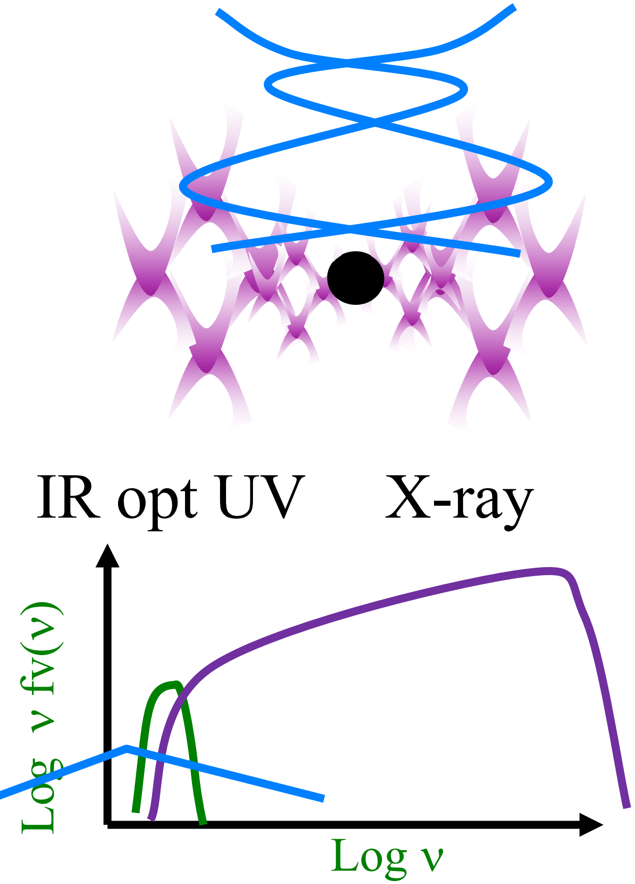
- Dramatic change in shape as well as luminosity at L~0.02 Ledd (for slow changes)



Gierlinski et al 1999

Models of accretion flows

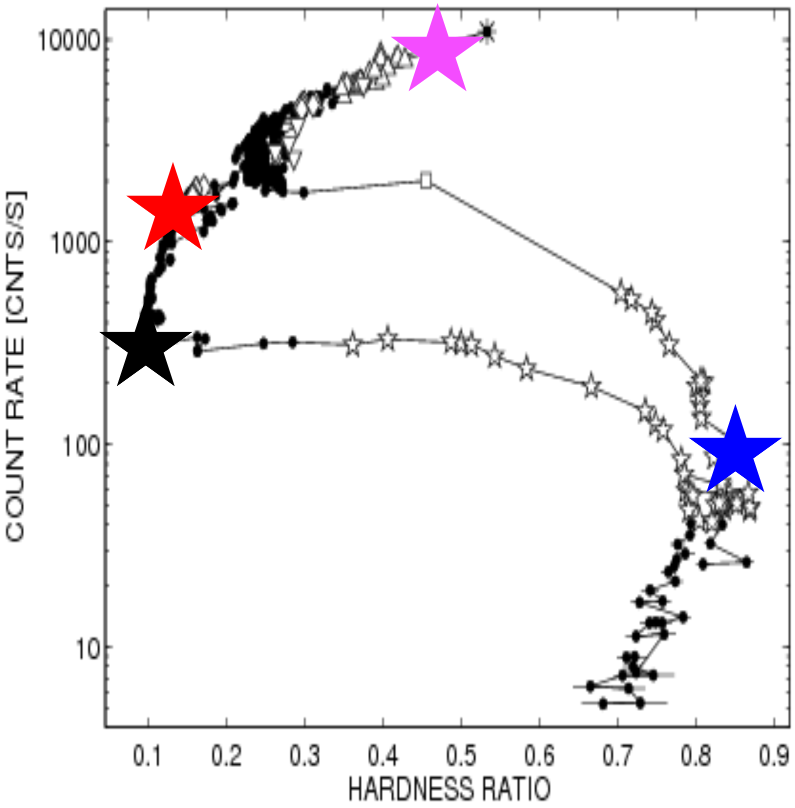




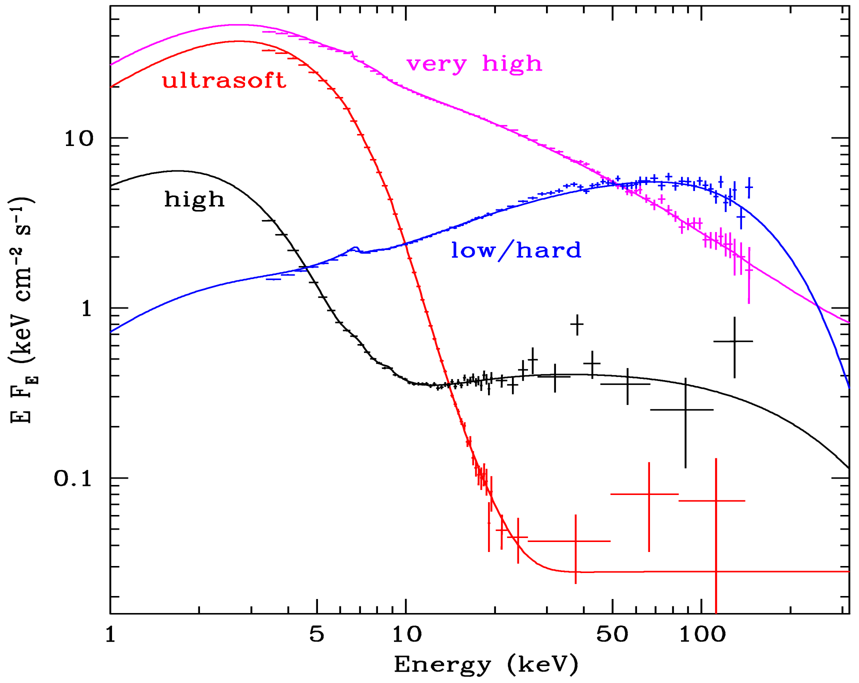
Discs – geometrically thin,
cool, optically thick SS73
Plus X-ray tail/corona
No jet

'ADAF'– geometrically
thick, hot, optically thin
Jet from hot flow $\Gamma \sim 1.5\text{-}2$
Only low L/Ledd

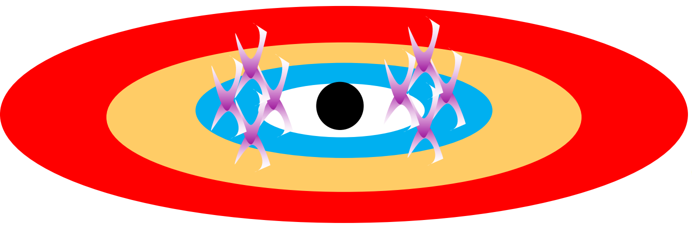
Black hole binaries: SPECTRA

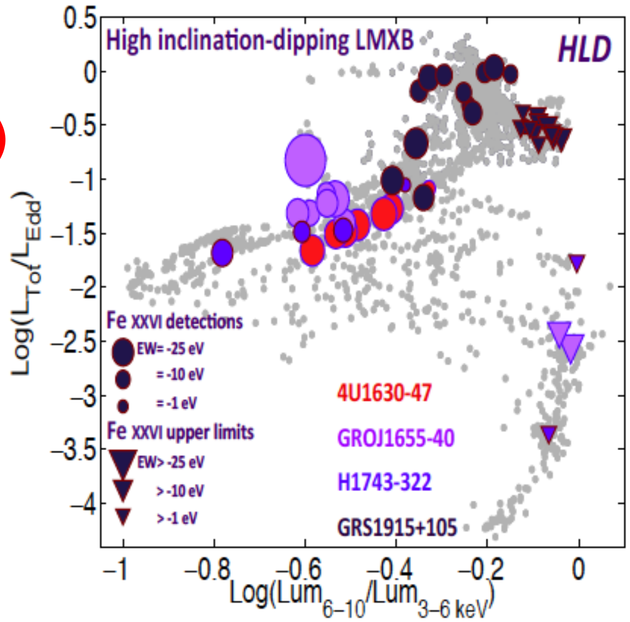


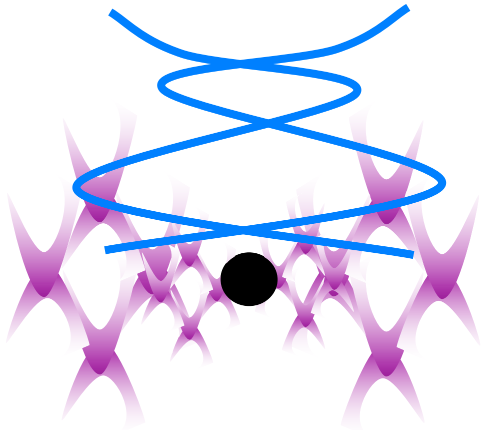
- Observe dramatic changes in SED with mass accretion rate onto black hole



Anticorrelates with jet: B wind? but spectra change:Radiative/thermal







Soft state

Disc

Winds, no jet

Hard state

Hot flow

No winds, jet

See Ryota Tomaru's talk

Conclusions

- Thermal-radiative winds explain what we see as X-ray absorbing winds in NS/BHB
- Predict wind responds to changing spectrum – harder SED means launch closer in, wind goes faster & more highly ionised so less visible (as well as changing photo-ionisation stability Chakrovorty, Bianchi etc)
- CAN'T HAVE UBIQUITOUS B WINDS AS STRONG AS NEEDED TO EXPLAIN APRIL 1st GRO J1655
- Slow thermal-radiative(dust) winds in AGN: warm absorbers
- Fast UV line driven disc winds in AGN: UFOs as well as BALs?