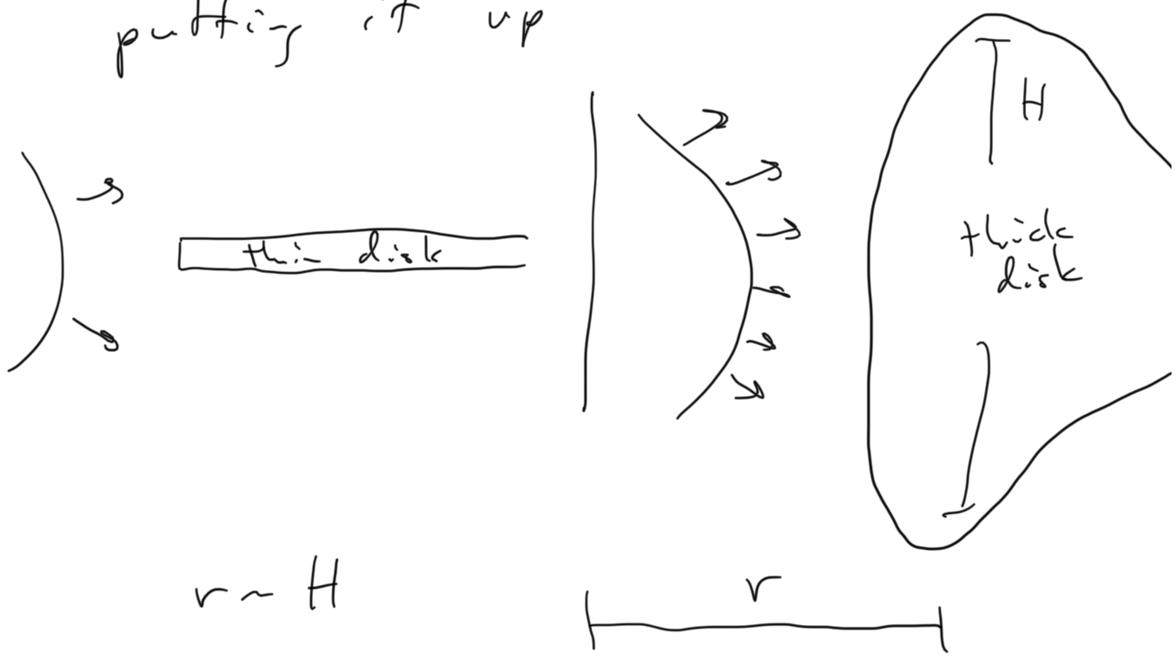
ASTR 5590 - Accretion III

Thick discs / Advective Flows

For $\uparrow \dot{m}$, radiation pressure in the inner part of the disk is high, "puffing it up"



In other words, L heats up inner part of disk until $\langle v \rangle$ comparable to rotational velocity

Disk being thick allows a funnel to be created ☆ See Fig 14.10

↳ help produce jets?

For thin disks, it's assumed energy & Λ is transported thru viscosity

E can also be transported by

- advection: transfer by large-scale fluid motions
- convection: advection where cells (entities of bulk motion) diffuse

These important for last phase of accretion onto object

- bulk flow hit object, heat released, not much different than if viscosity
- if bulk falls into BH, E lost!
  - ↳ likely important in SMBH acc

Accretion in Binaries

In a binary system, accretion is either

1) Bondi-like: fed by a stellar wind
2) Roche-lobe overflow: donor star evolve

★ Mode line slide

★ 2 accretion mode slide

How material accretes onto a compact object (at least for a WD or NS) also depends on the magnetic field

Only matters if its strength provides enough pressure to alter the accretion flow

$$P_B(r) > P_{ram}(r)$$

★ What is P_B for a given B?

$$\frac{B^2}{8\pi}\left(\frac{R_*}{r}\right)^6 > \rho v^2$$

dipole field

velocity of flow

$$v = \sqrt{\frac{2GM_*}{r}}$$ infall vel.

For a $M_\odot$ NS accreting @ L_{Edd}, these pressures equal @ $r \sim 10^3$ km,

100 ↑ th R

$100\times\uparrow$ than NS

For a WD (similar mass, $\downarrow B$, $\uparrow R_{WD}$), Edd. accretion gets $r \sim 6\times10^4$ km, $10\times\uparrow$ than $R_{WD} \sim 5000$ km

Seems like B can prevent accretion, but material experiences no P_B if it travels along B field lines

☆ Fig. 14.14

WD Binaries

Cataclysmic Variables

- classical novae
- dwarf novae
- recurrent novae
- symbiotic stars

- polars
- intermediate polars } $\uparrow B$ fields $> 10^3$ T (10^7 G)

Classical

Classical

- optical brightness ↑ by 6–19 mag
- only 1 outburst observed
- rate around $30\,yr^{-1}$ (MW) & $38\,yr^{-1}$ (M3
- get thermonuclear runaway b/c fusion v. temperature sensitive, so once critical amount of stuff accreted, it burns v. fast

Others

dwarf novae : 2–5 mag optical ↑
↳ WD — occurs regularly

recurrent novae : brighter, decades b/t outbursts

symbiotic stars : accretor is MS star, not WD

Magnetic accreting WDs

Polars : rotation of WD phase-locked to orbital period

- AM Herculis prototypical case
- material flows like in Fig. 14.14 and Fig. 14.16

Intermediate: $P_{rot}(WD) < P_{orb}$

Polars

↳ accretion rates highly variable, so emission (outbursts) also variable (hence, "cataclysmic")

Some cases, can see hot spot where Roche lobe overflow meets acc. disk

In mag. CVs, see soft X-ray/UV thermal emission from where column meets WD surface, and hard X-rays where column flow shock wave is

→ hard kT (~20 keV) depends on mass of WD

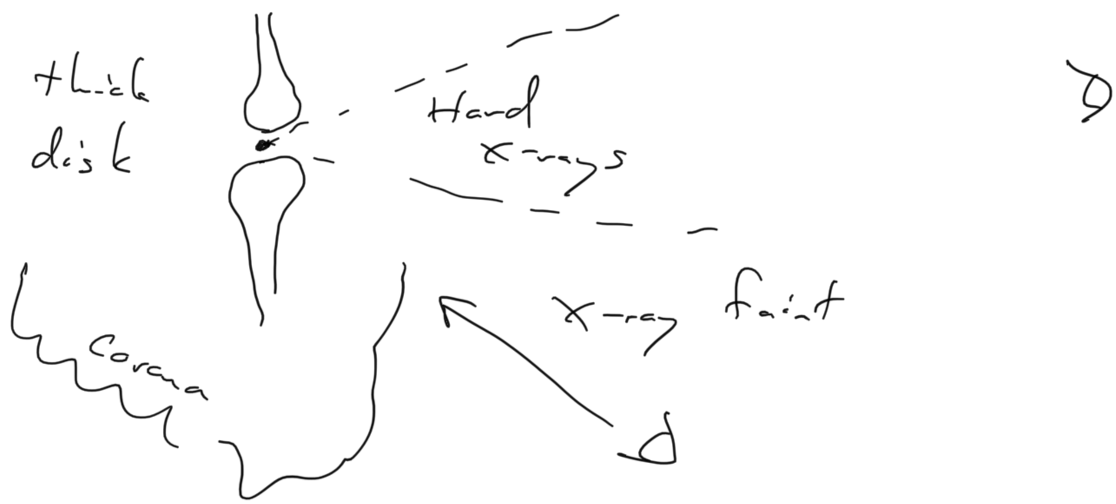
$\boxed{\text{NS/BH Binaries}}$

Low Mass X-ray Binaries (LMXBs)

- donor star $\sim M_\odot$ on MS evolving to red giant
- found in Galactic bulge (old

[10^{10} yr] population)

- binary origin unclear b/c X-ray emission inclination dependent



☆ Fig. 14.21

- Systems undergo outbursts

Type I / $L_x \uparrow$ by 10x over rise times of 1–10s, last ~ 1 min

- BB in nature
- amounts to only ~1% of quiescent L_x given duty cycle

Thought to occur in NS systems w/weak B fields, where material ... surface then undergoes accretes on su

runaway thermonuclear burning, just like in novae

Burst L_x (likely?) saturates @ L_{Edd}, so can use L_{max} to get r_{emit} via $L = 4\pi r_{emit}^2 \sigma T^4$

Type II

2 sources, bursts more rapid/often

Quasi-Periodic Oscillations (QPOs)

- short, but can change freq w/ L_x
- assumed to be near NS surface
  - ↳ perhaps beat freq. b/t P_{rot} NS + Keplerian P of disk close in
  - → other ideas

High Mass X-ray Binaries (HMXBs)

Donor star is O or B type star

Since lifetimes $\lesssim 100$ Myr, assoc. w/ recent star formation (locally)

<u>MW)</u> ~60% are known/likely

Be XRBs

↖ H emission lines

stars have debris disks, NS plows

thru them on elliptical orbits

~30% have supergiant donor stars

↳ Roche lobe overflow or wind

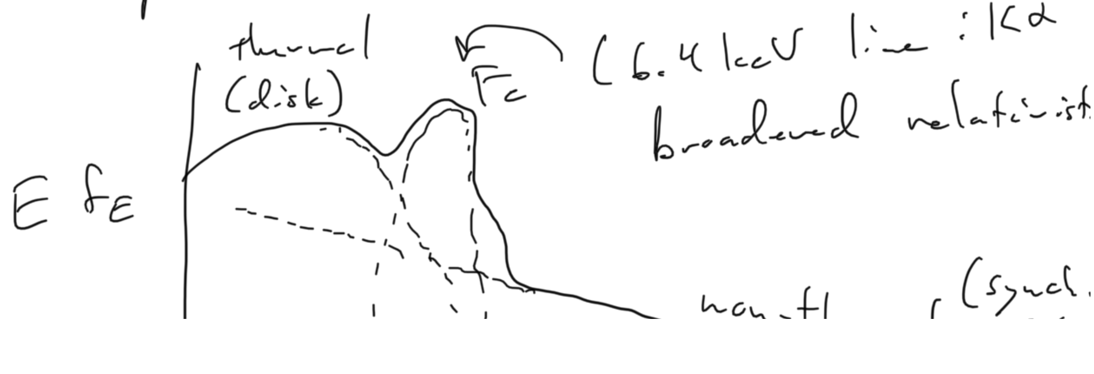
Black Hole CO in binaries

X-ray emission much more varied,

classified into distinct states

1st order, have thermal/non-thermal

components + broad Fe line



(soft)

Thermal State

$$\frac{F}{V} = \frac{2\cos i}{D^2} r_I^2 T_I^4$$

inclination

dist.

measure these

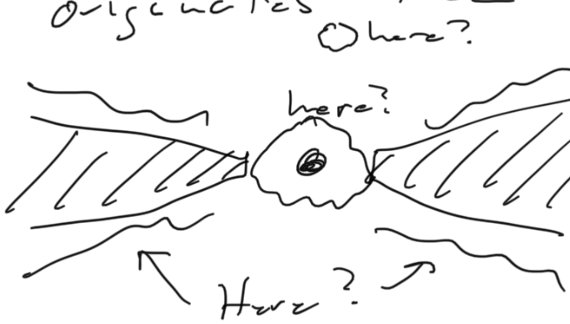
get $r_I \cos^{1/2} i$ if dist. known

→ agrees w/ r_I for ~10 $M_\odot$ BHs

Hard State

PL dominates spectrum

originates from Corona of some kind



non-thermal e^-, synch. or IC emitting

QPOs

40–450 Hz – similar to P_{ISCO}

– if associated w/ $3 r_g$ then freq. corresponds to BH mass!

$$\nu_{QPO} \sim 2.7\times10^{3}\left(\frac{M}{M_\odot}\right)^{-1} \text{Hz}$$

↳ generally give $M \sim 5-15\,M_\odot$

These QPOs fairly stable w/ L_x, so could be more physical

Fe Fluorescence lines

Broad Fe line from neutral Fe in cooler disk seen

→ excited by BH ↑ rad. environment, see de-excitation (fluorescence)

More redshifted than blueshifted, combo of Doppler + grav. redshifting of disk around BH (Interstellar-esque

★ can be used to estimate spin of BH (but requires modeling continuum well — could explain "broad line w/ warm absorber models)

~~A~~ Slides on states