28 Astro notes 2018/10/31 - Wed - Close Binaries: accretion

28.1 Nomenclature of semi-detatched binaries with a compact object

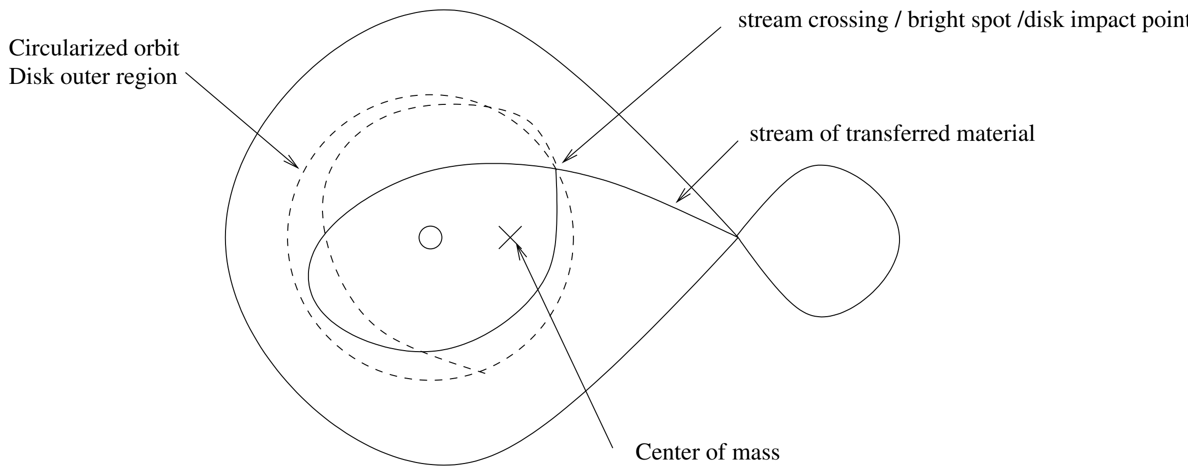
For semi-detached binaries that are transferring matter onto their primary star, the name depends on the type of primary compact object.

- White dwarf star - called Cataclysmic Variables
  Types of Outbursts:
  - "Classical" Novae - Thermonuclear outbursts - hydrogen-rich material accreted on surface leads to re-ignition of shell burning and mass ejection
  - "Dwarf" Novae - Thermal instabity in accretion disk - accretion disk is only actively putting matter on the primary star periodically in bursts
- Neutron star - called low-mass X-ray binaries
  These also have the same two types of "outburst", but the thermonuclear outburst is called an "X-ray burst", and the disk outburst doesn't have a particular name, typically called "high state".
- Black hole - still called an X-ray binary
  no thermonuclear bursts since there is no surface causally connected to the outside spacetime

There are also high-mass X-ray binaries where the primary star is the high-mass star and the lower mass star is the neutron star or black hole. These are typically not roche-lobe filling, so that the mass transfer is not unstable, and therefore are wind-accretion.

28.2 Impact point and circularization

When material leaves the L_1 point, it is not in the disk. It is on a non-circular and non-closing orbit that will cross itself due to the irregular potential in the binary. This leads circularization of the orbits of the material and eventually to a disk impact point – sometimes called the "bright spot" on the disk. This is near the outer edge of the disk and is where material is added to the accretion disk from the companion star



28.3 accretion disk and its temperature profile

Accretion disk moves material toward the star by moving its angular momentum outward. (so material can move inward) Angular momentum is thought to be coupled back into the orbit through unclear means (disk tidal effects). The overall disk luminosity from gravitational potential energy

$$L_{disk} = \frac{GM\dot{M}}{2R}$$

Where R is the inner edge of the disk.

The temperature profile of the disk is given by equating the gravitational energy release to the local energy emitted by the disk for mass flowing through at some rate $\dot{M}$.

$$dL_{ring} = 4\pi r \sigma T^4 dr = G\frac{M\dot{M}}{2r^2}dr$$

This gives a profile that looks like

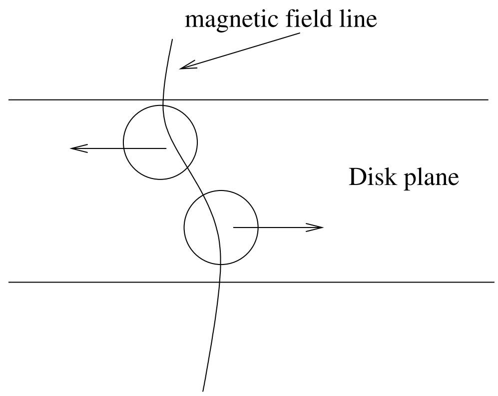
$$T = \left(\frac{GM\dot{M}}{8\pi\sigma R^3}\right)^{1/4} \left(\frac{R}{r}\right)^{3/4}$$

where R is the radius of the central object - the hottest part of the disk.

28.4 Disk viscosity and instability

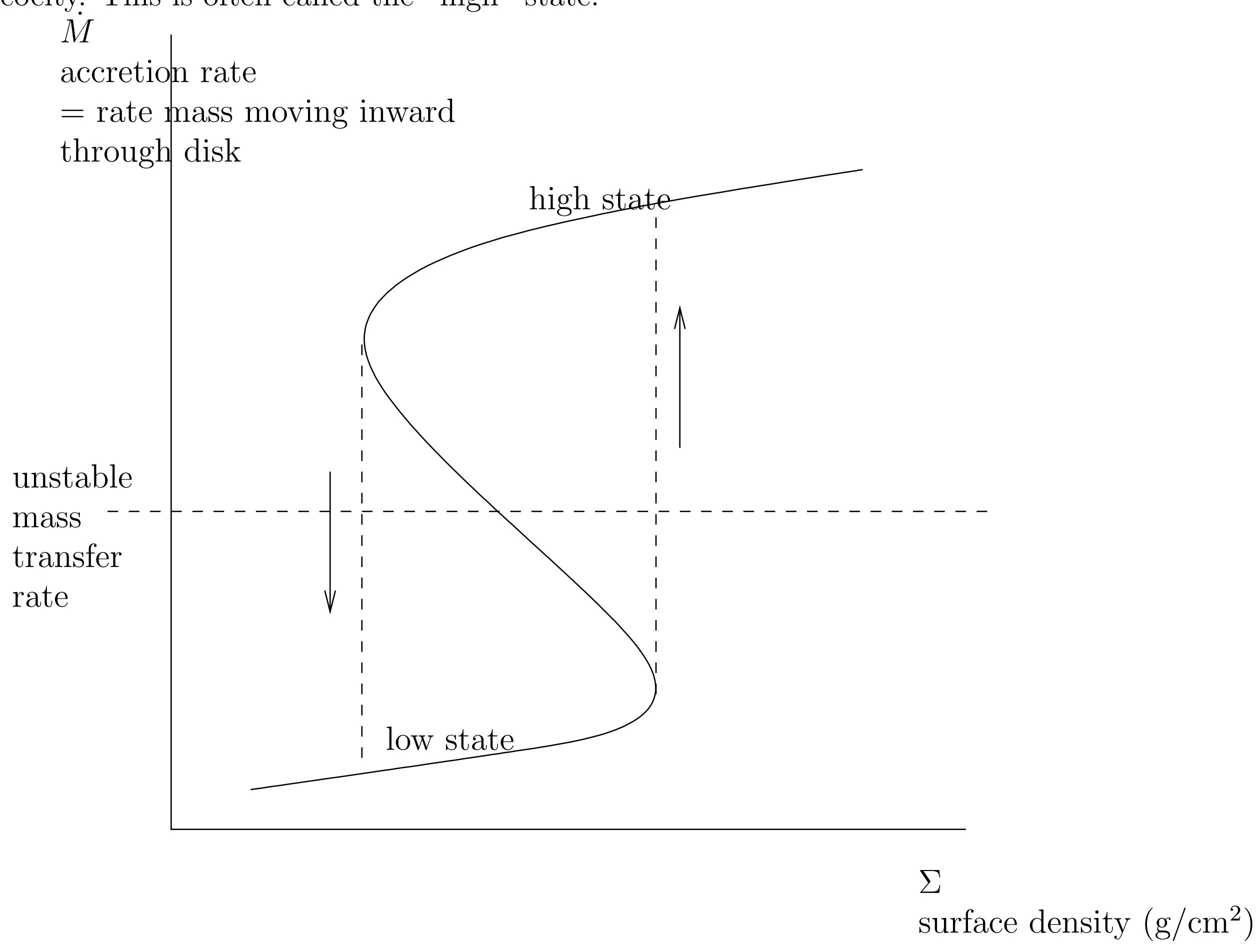
Disk viscosity is what transfers angular momentum in the disk. This is believed to be driven by something called the magneto rotational instability or MRI.

If a fluid parcel in the disk moves to larger radius, it will want to rotate more slowly. If this parcel is magnetically connected to a more inner parcel, this will have two effects: first, it will impart angular momentum to the outer parcel - causing it to move outward even more; second it will stretch and strengthen the magnetic field lines.



However, the MRI requires a hot disk in order to sustain the plasma that hosts the magnetic field. This can lead to instability, which leads to dwarf novae.

The disk needs enough surface density Σ to stay optically thick and "hold" heat to maintain an ionized plasma. Here Σ is the mass per area when considering a column passing vertically through the accretion disk. When Σ is large, the disk is optically thick and can stay hot and ionized, therefore hosting a magnetic field and having a high effective viscocity. This is often called the "high" state.



If the mass transfer rate from the companion star into the outer disk is in the intermediate (unstable) range, this leads to instability and limit-cycle behavior. The disk will build up matter, increasing surface density Σ until it is able to hold heat (become optically thick) and then become ionized. At that point the disk becomes magnetically active and the fields begin to allow material to lose angular momentum and move inward. This continues until Σ is too low to sustain the temperature for ionized plasma, at which point the disk switches back to the low state and begins accumulating surface density again.

For a WD primary star, this type of outburst, caused by a thermal instability in the disk, and the accompanying magnetic activity, is called a dwarf nova. For neutron star systems it doesn't have a particular name but is observed as a transience of the mass transfer onto the neutron star.