Mass transfer

Several regimes of mass transfer:

- If the binary is detached, but one of the components has a strong stellar wind, then gravitational capture of the wind by the other star may be significant.

  Relevant mainly to high mass X-ray binaries:

  High mass donor → strong wind +

  Neutron star or black hole accretor → high accretion efficiency.

- For a semi-detached binary:

  (i) If the mass transfer occurs in the stable regime, expect a stream of gas from the L_1 point and (probably) formation of a disk around accretor.

  (ii) If the mass transfer occurs on a dynamical or thermal timescale, expect large accretion rate → common envelope evolution.

Wind accretion

Most relevant to high mass X-ray binaries – early type (O or B) star with a neutron star or black hole in a close orbit.

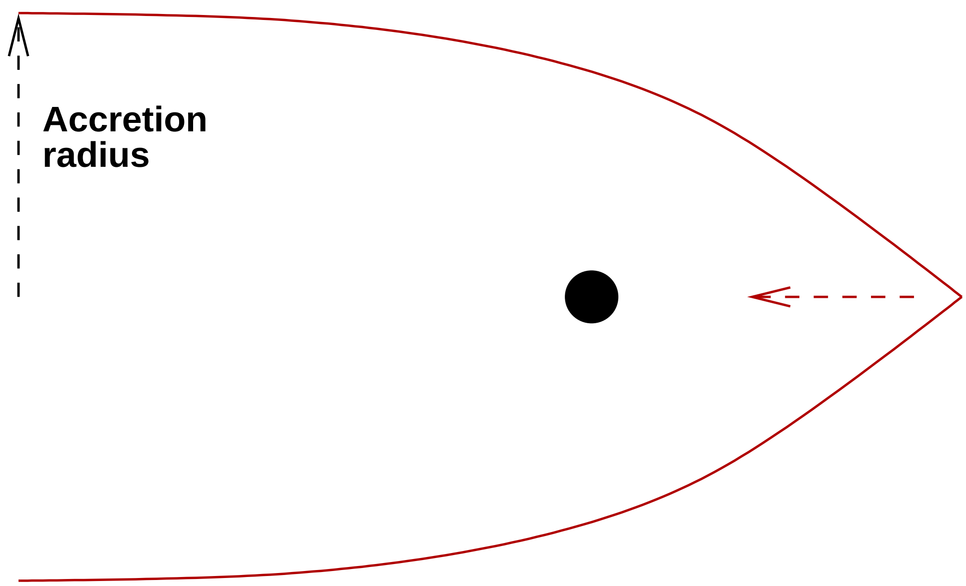
General properties of the wind:

- High mass loss rate $\sim 10^{-6} - 10^{-5}\ M_\odot \mathrm{yr}^{-1}$.
- Wind velocity,

$$v_w \sim v_{esc} = \sqrt{\frac{2GM_*}{R_*}}.$$

  Unless the compact companion is *very* close, $v_w \gg v_K$, where v_K is the Keplerian velocity of the neutron star or black hole.

Accretion flow is highly supersonic $\rightarrow$ Bondi-Hoyle-Lyttleton accretion regime. All gas within an accretion cylinder of radius R_{acc} is accreted.



Capture radius is simply the maximum distance at which the gravitational potential energy exceeds the kinetic energy:

$$R_{acc} = \frac{2GM_{acc}}{v_\infty^2}$$

where M_{acc} is the mass of the accreting object and v_∞ is the relative velocity of the accretor relative to the wind at large distance.

Resulting accretion rate is,

$$\dot{M}_{acc} = \pi R_{acc}^2 \rho_\infty v_\infty = 4\pi \rho_\infty \frac{(GM_{acc})^2}{v_\infty^3}$$

where ρ_∞ is the density at large radius from the accretor.

What fraction of the stellar wind is gravitationally captured by the compact object?

$$f \simeq \frac{\pi R_{acc}^2}{4\pi a^2} = \frac{(GM_{acc})^2}{a^2 v_\infty^4}.$$

Substituting for the stellar wind velocity,

$$f \simeq \frac{1}{4} \left(\frac{M_{acc}}{M_*}\right)^2 \left(\frac{R_*}{a}\right)^2.$$

Typically a small fraction – 10^{-3} or 10^{-4} of the wind flux.

For a neutron star accretor,

$$L \sim \frac{GM_{acc}\dot{M}_{acc}}{R_{ns}}.$$

Because of the large mass loss rates, even a small capture fraction produces a significant luminosity,

$$L \sim 10^{37} \left(\frac{f}{10^{-4}}\right) \left(\frac{\dot{M}_w}{10^{-5}\ M_\odot \mathrm{yr}^{-1}}\right)\ \mathrm{erg\ s^{-1}}.$$

Will the accreted gas have enough angular momentum to form a disk around the neutron star? Two simple analytic arguments:

- Average the specific angular momentum over the face of the accretion cylinder. This gives,

$$l \sim R_{acc}^2 \Omega_B.$$

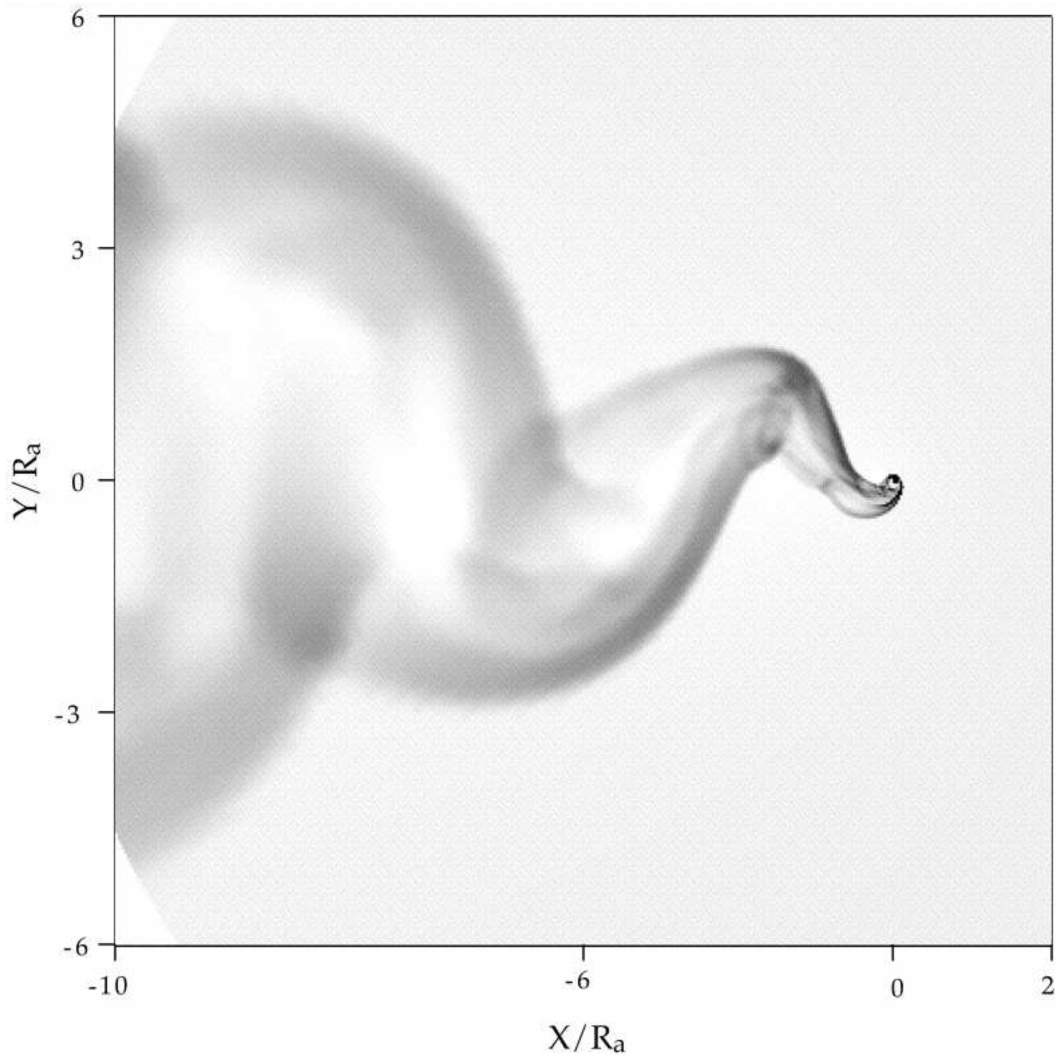
- Assume that accretion occurs via an accretion line (as in the original Hoyle-Lyttleton description), implying,

$$l \sim 0.$$

Even in the first case the resulting specific angular momentum could be smaller than the specific angular momentum of a Keplerian orbit at the neutron star surface.

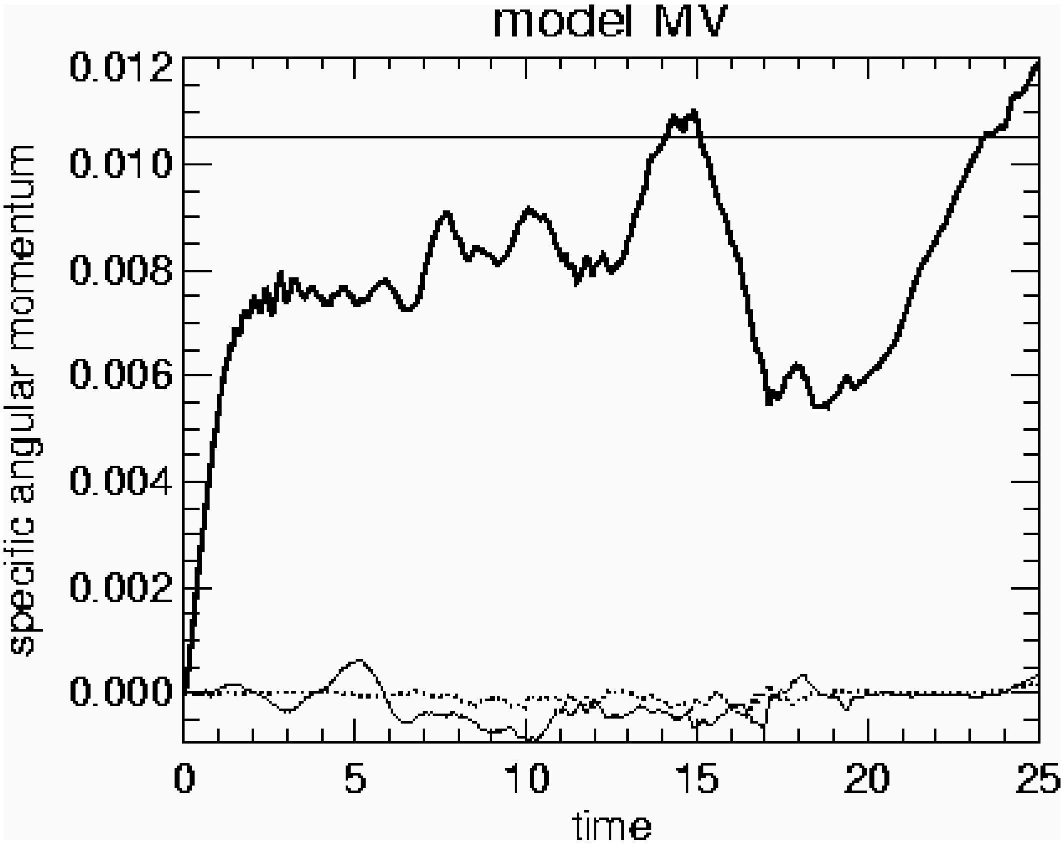
→ marginal whether a disk forms in all cases.

Numerical simulations add an additional complication: flow may not reach a steady state. Strong 'flip-flop' instability seen in 2D calculations eg Benensohn, Lamb & Taam (1997):



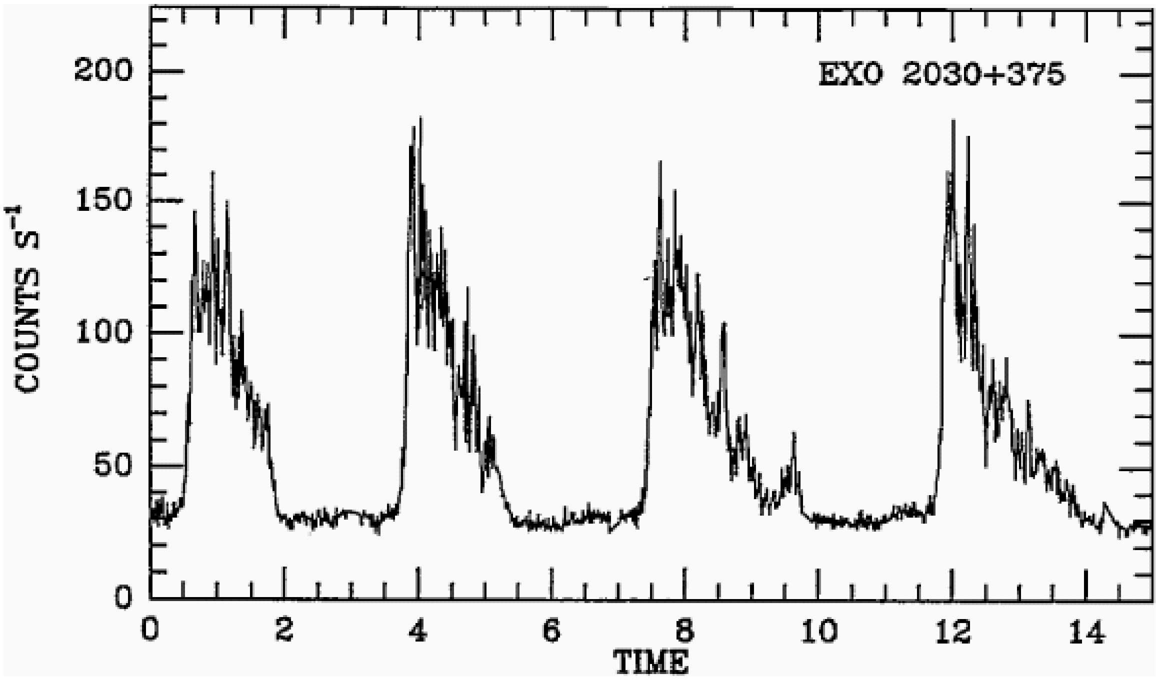
Probably less pronounced in 3D (Ruffert 1999).

Specific angular momentum of accreted gas (Ruffert 1999):



Large fluctuations, which may sometimes be strong enough to reverse the *sign* of the accreted specific angular momentum.

Accretion flow is definitely not steady in these systems, eg X-ray lightcurve (time units are in hours),



Dynamical timescale at the surface of a neutron star is,

$$\Omega_K^{-1} = \left(\frac{GM_{acc}}{R_{ns}^3}\right)^{-1/2} \sim 10^{-4} \text{ s}$$

$\rightarrow$ variability on hour timescales suggests instabilities at $R \gg R_{ns}$.