

Binary evolution

* Differences w/ single stars

- Exchange mass (M) and ang. mom.
- Rotation → at formation; ang. mom. stored in binary
→ rotate slower?
 - tidal forces
 - in mass transfer
- SN explosion → impact on companion
→ unbind binary
- magnetic field → "slap" companion
→ Synchronize rotation

* When do we expect it?

- star expands & becomes "too big"
- shrink orbit → grav. radiation (short orbits, $\lesssim hr$)
 - magnetic braking + tides

* Which star generically transfers mass first? More massive

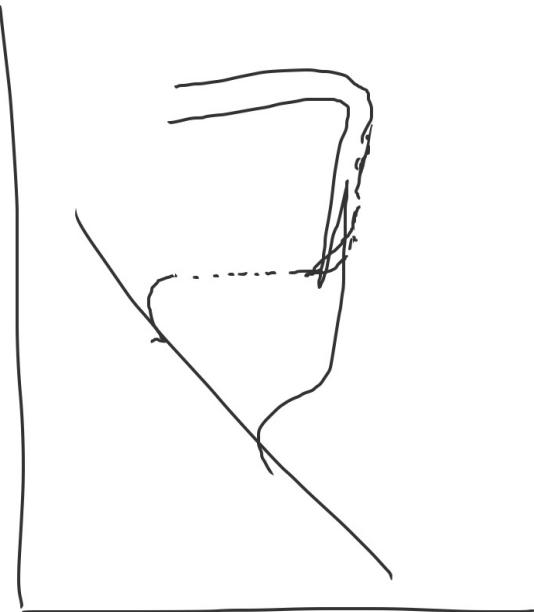
* When does mass transfer happen?

When does star expand most?

- main
- low-mass stars → red giant branch)
 - higher-mass seq: crossing the H α D
to become a red giant

alternatives

- on the main sequence case A
- on the AGB case C



Effect of mass transfer?

* What happens to orbit?

conservation laws!

- mass conservation: $M_1 + M_2 = \text{const}$

$$\Rightarrow \dot{M}_2 = -\dot{M}_1 = \dot{M}_T$$

- angular momentum \rightarrow ~~does not carry~~: radiation

- energy \rightarrow BAD: disk radiates ~~much~~ ang. mom.

lot of energy

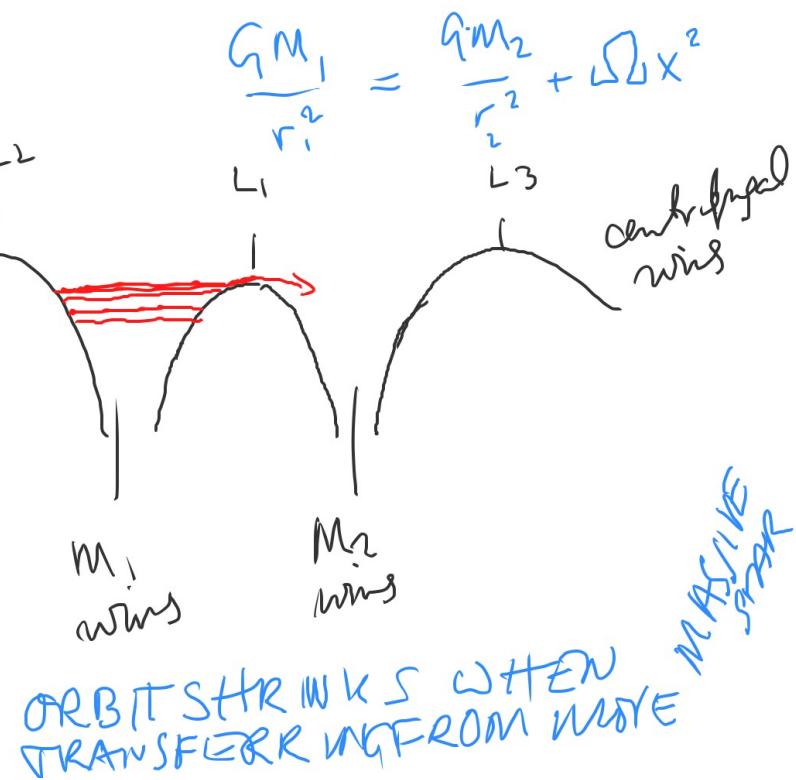
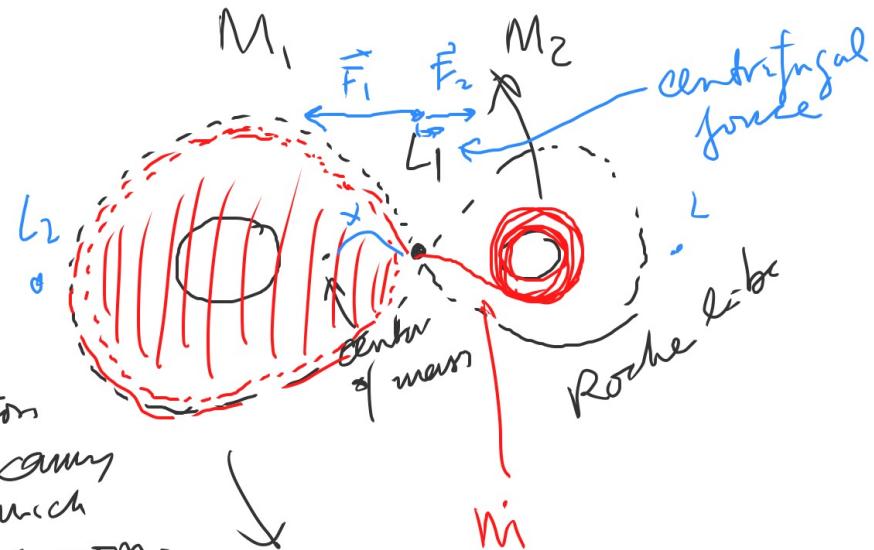
$$L = \frac{M_1 M_2}{M} \sqrt{GMa} = \text{const}$$

$$\frac{\dot{L}}{L} = \frac{\dot{M}_1}{M_1} + \frac{\dot{M}_2}{M_2} - \cancel{\frac{\dot{M}_T}{M}} + \frac{1}{2} \frac{\ddot{a}}{a} = 0$$

Centrifugal force

$$\frac{\ddot{a}}{a} = 2 \frac{\dot{M}_T (M_2 - M_1)}{M_1 M_2}$$

mass transfer rate from 1 \rightarrow 2



Effects on mass transfer?

- * What happens to Roche lobe \rightarrow generically shrink or hit faster
- * What happens to stellar radius?

I. Initially, radius decreases
(take off very outer layer)

II. Not in HE \rightarrow adjust back
gen., if not deg., still a bit
smaller

III. If convective \rightarrow on convective turn over timescale

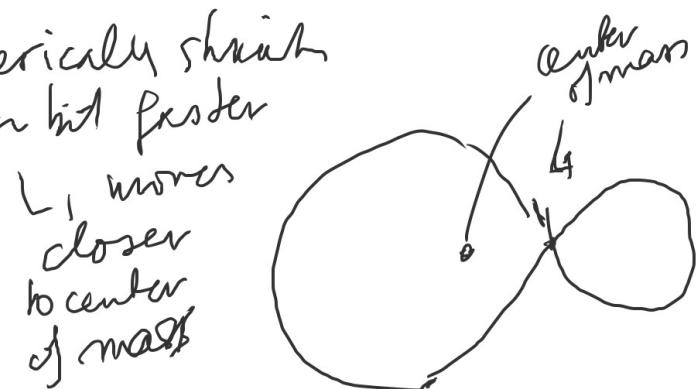
If radiative envelope \rightarrow on thermal timescale (slow) expand
back to original size

\Rightarrow unstable on thermal timescale

$$\frac{M_G}{\text{Mequiv}} \approx 10^{-6} M_\odot/\text{yr}$$

$$\frac{\text{Mequiv}}{t_{\text{KH}}} \approx 10^6 \text{ yr}$$

$$\textcircled{A} \dot{M}_T \approx \frac{M_G}{t_{\text{conv}}} = \text{day...month}$$



If deg: $R \propto M^{-1/3} \Rightarrow$ expand \rightarrow unstable
on dyn timescale

\rightarrow go back to \sim original size \oplus

\Rightarrow unstable on turn over time \oplus