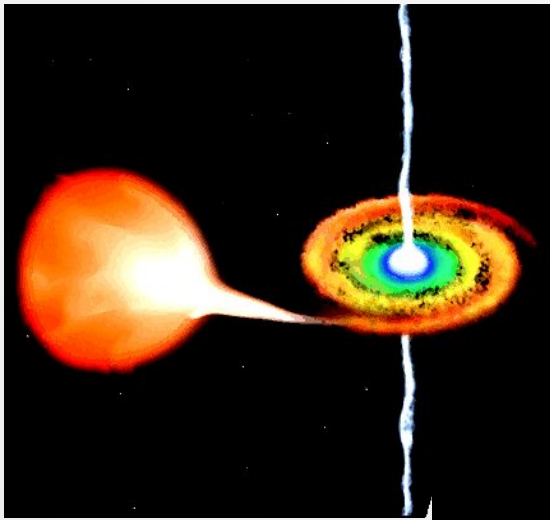
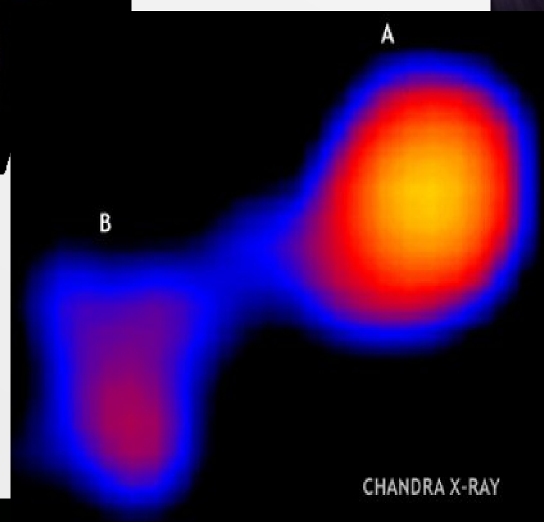
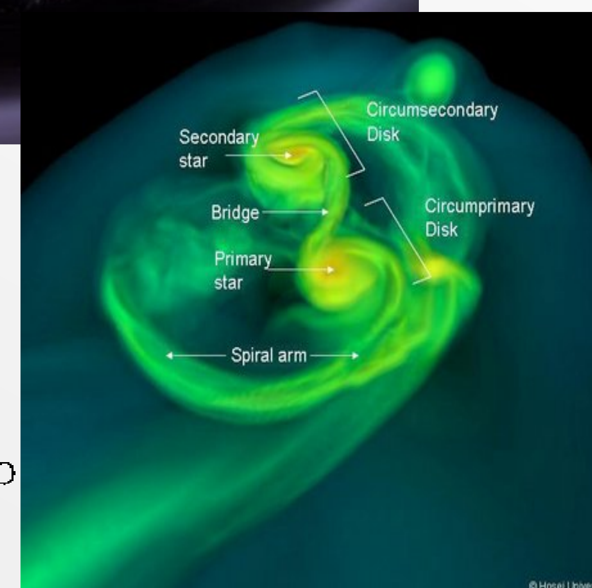
Binary Stars – Lecture 6







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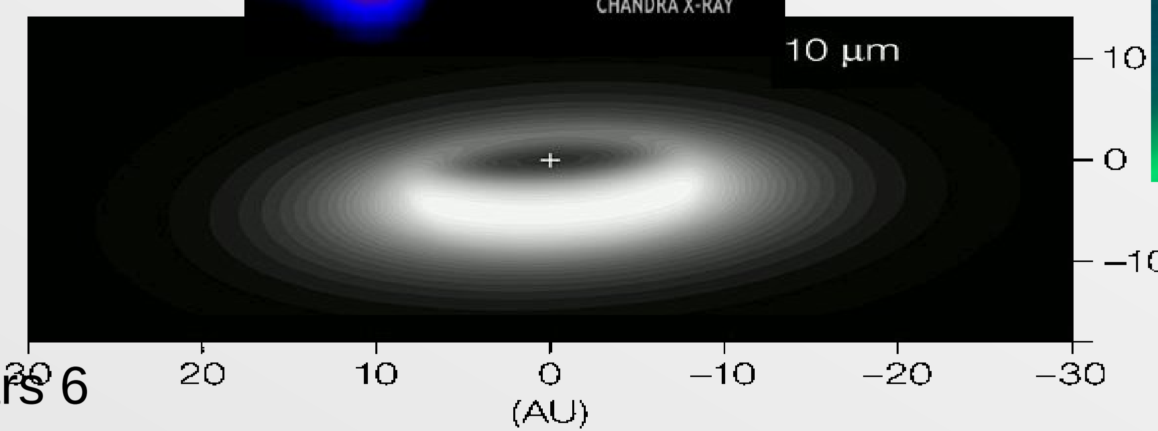

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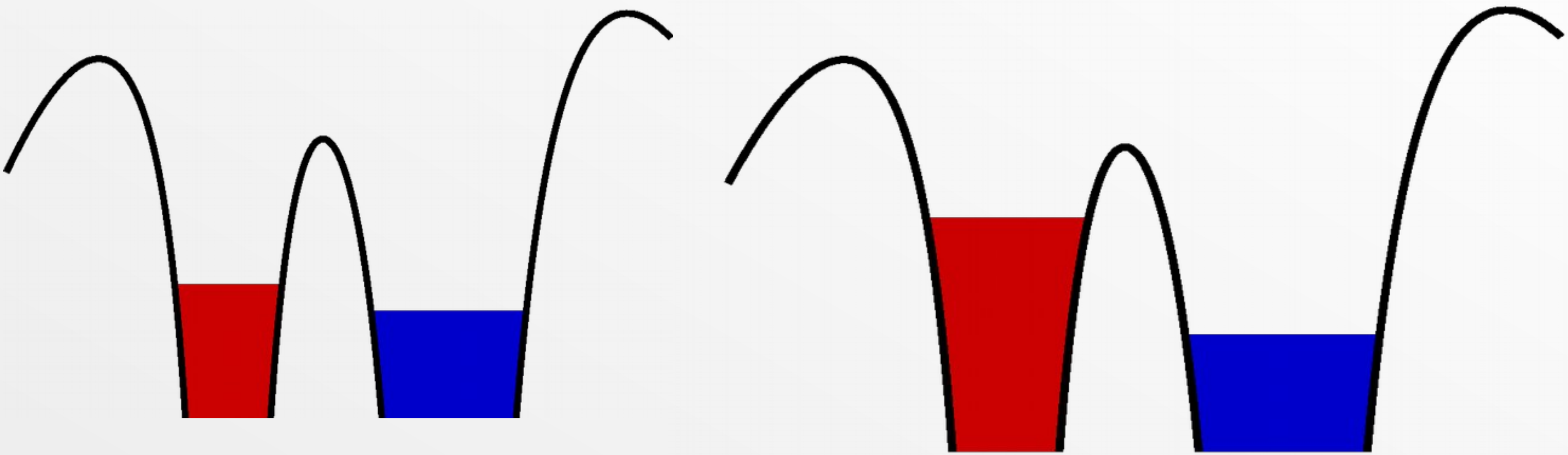
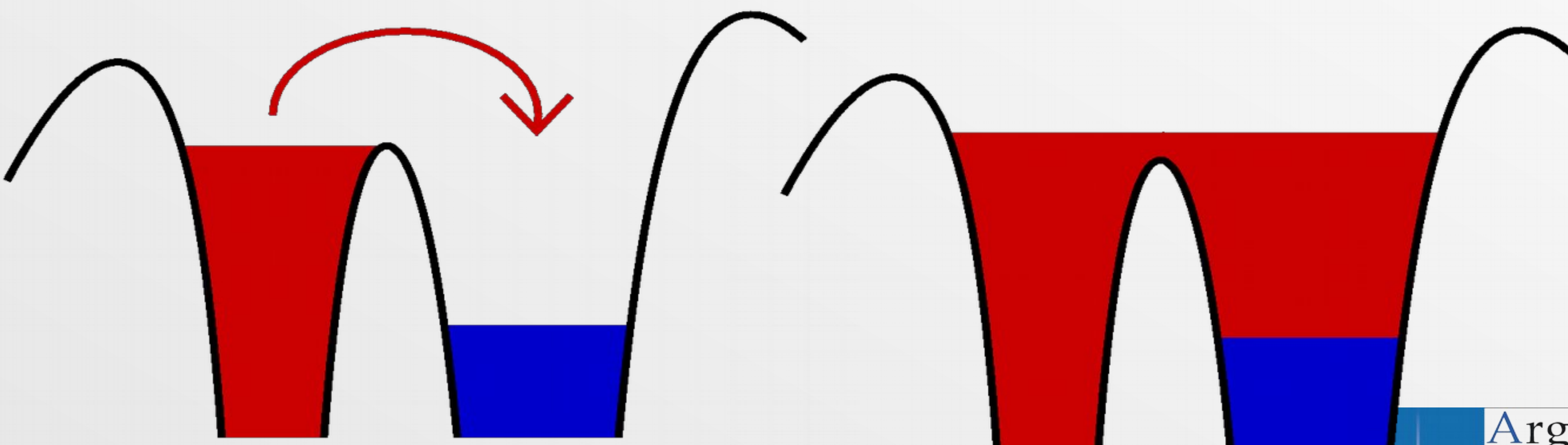
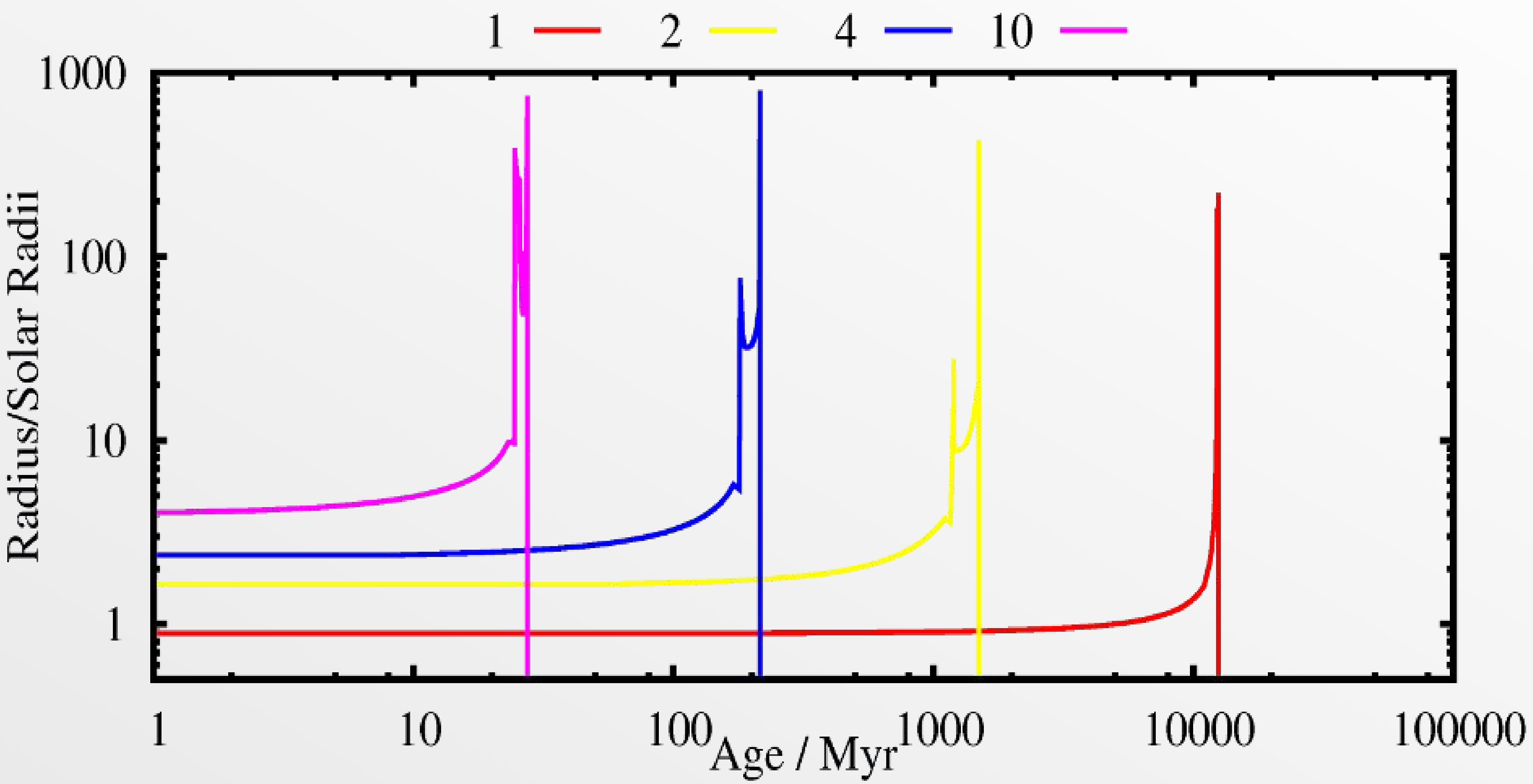
Roche configurations



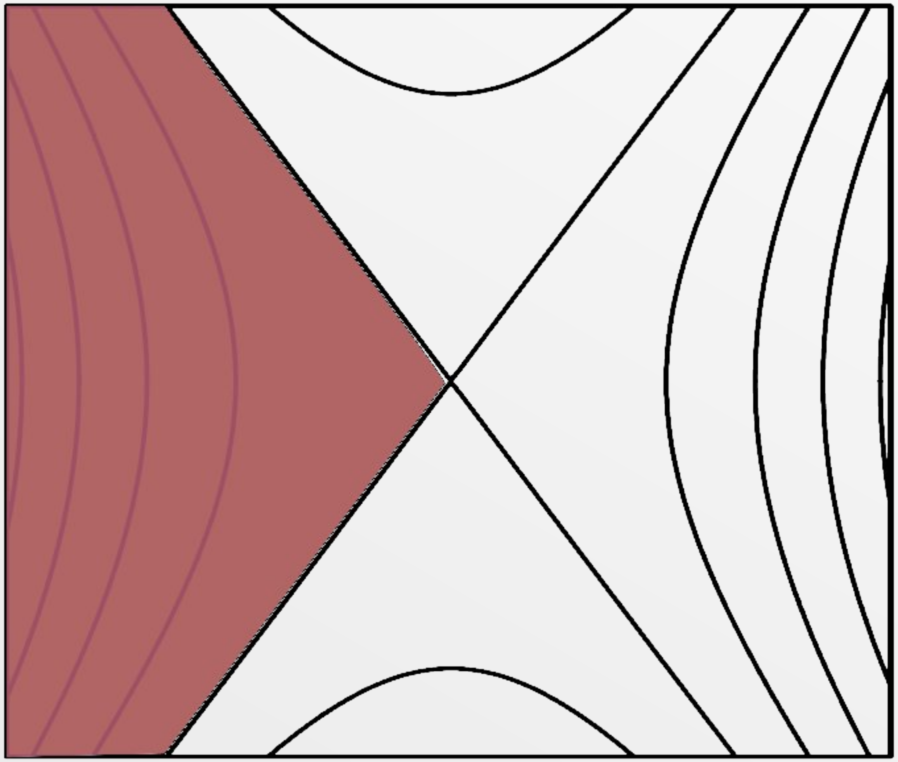
Roche Lobe Overflow

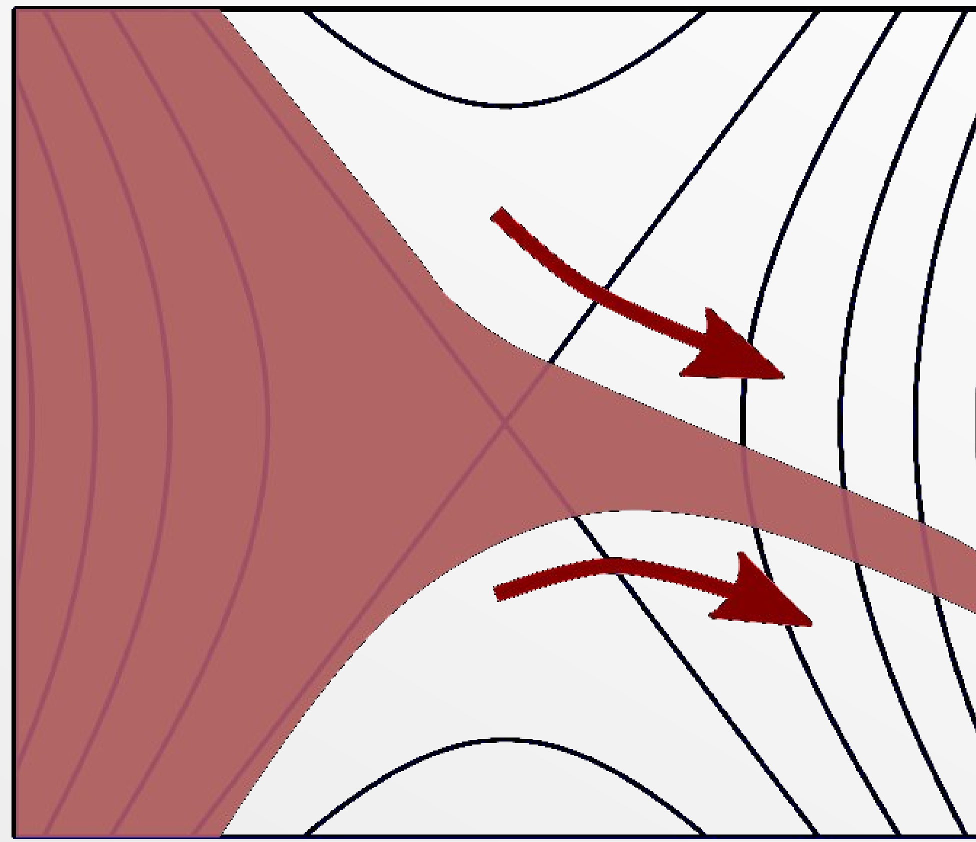


Stellar Evolution



Roche Overflow





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RLOF rates

- Always have $\dot{M}_1$ a strong function of ΔR

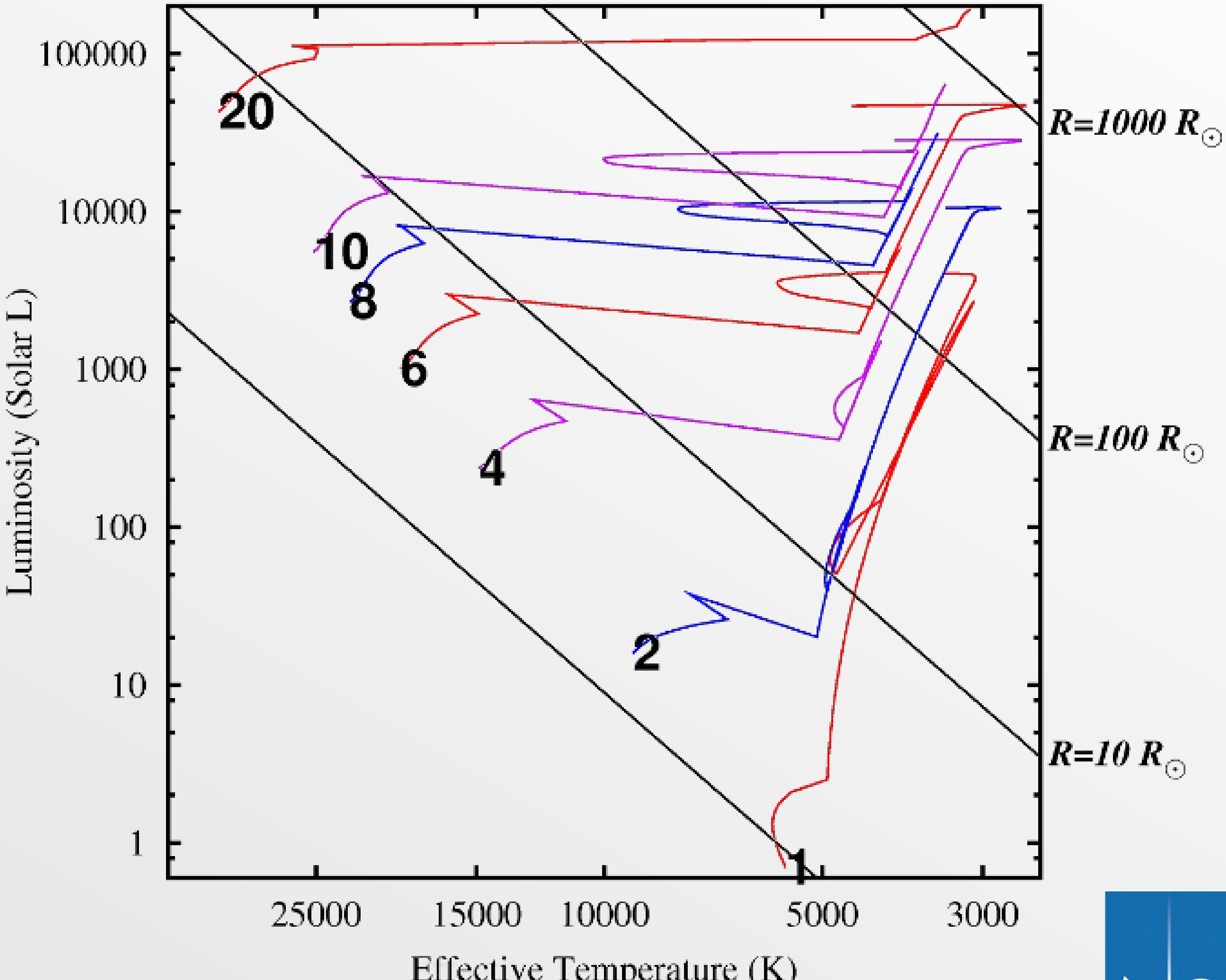
$$\Delta R = R - R_L$$

- Hence unless dynamical timescale expansion

  RLOF is self-regulating with small ΔR

- Supersonic (ballistic) flow through L_1
- Streamlines intersect: disc, eventually material hits secondary or direct impact

Stellar Evolution



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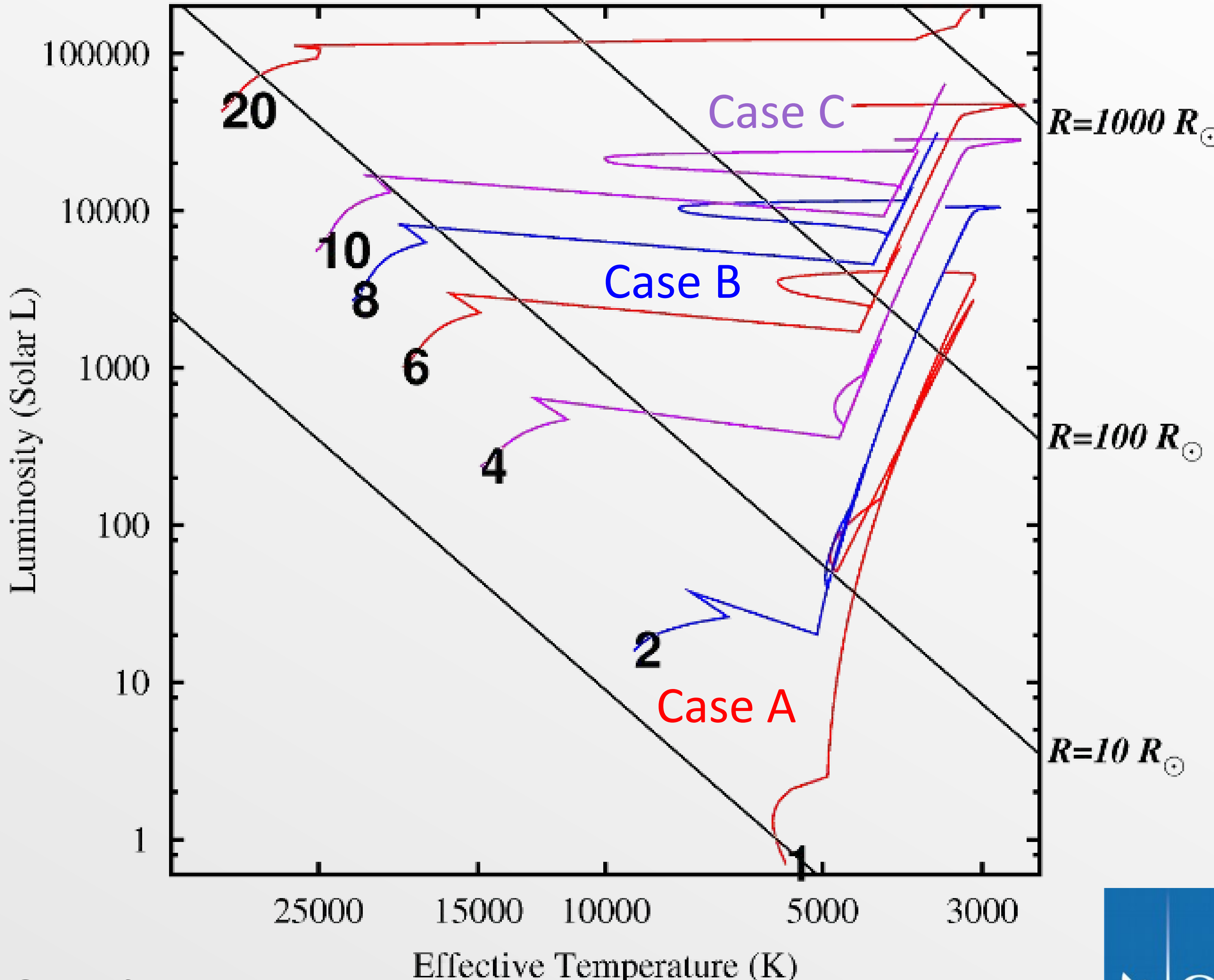
Cases A, B and C



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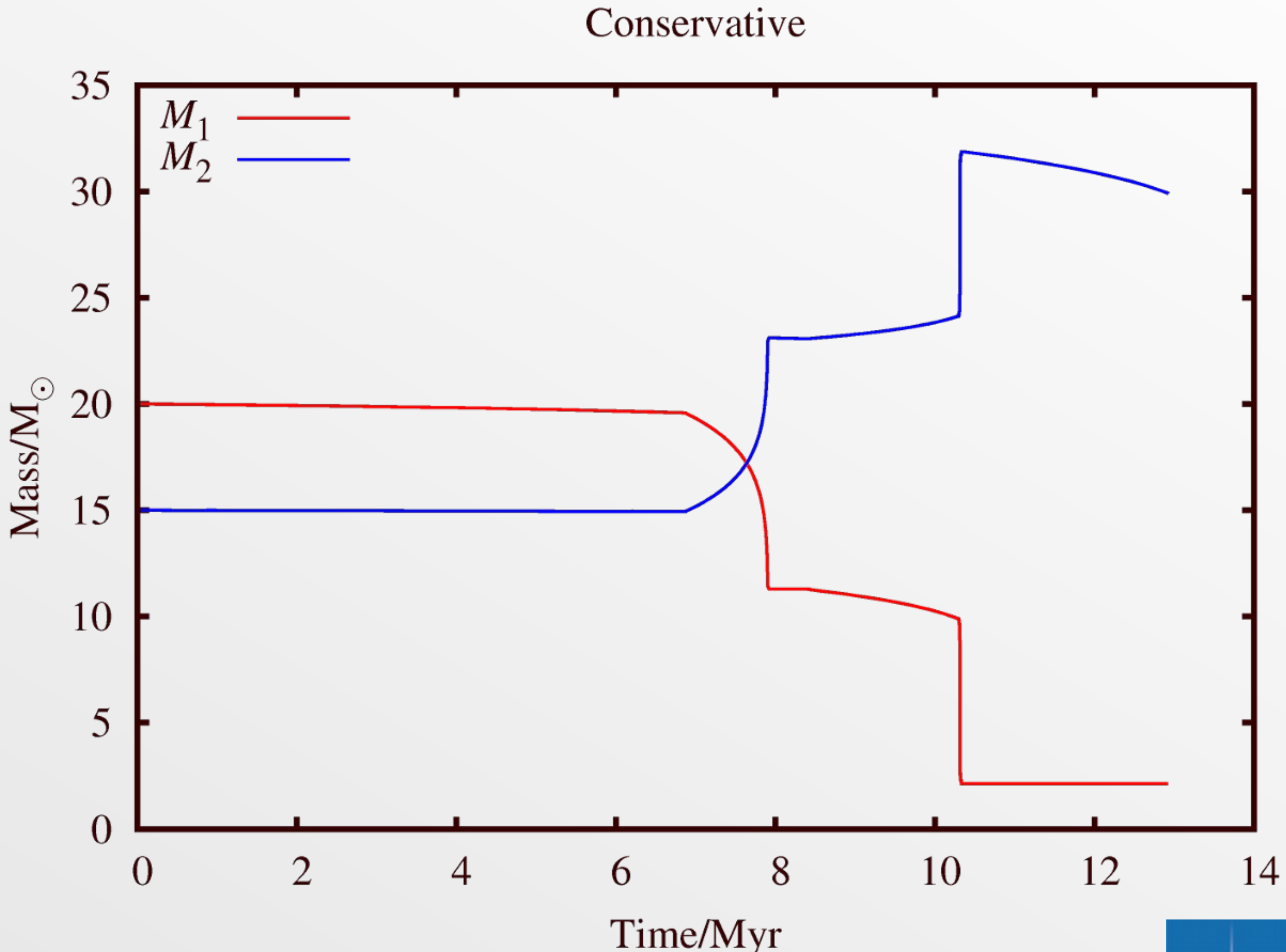
Stellar Timescales

- Three timescales are important
  - Dynamical: minutes-hours – fast
  - Thermal: (tens of) Myr - medium
  - Nuclear: Myr to Gyr – slow
- In mass transfer we need to know
- Timescale of mass transfer:
  - Change of radius R
  - Change of Roche lobe "radius" R_L
- Timescale on which accretor can react

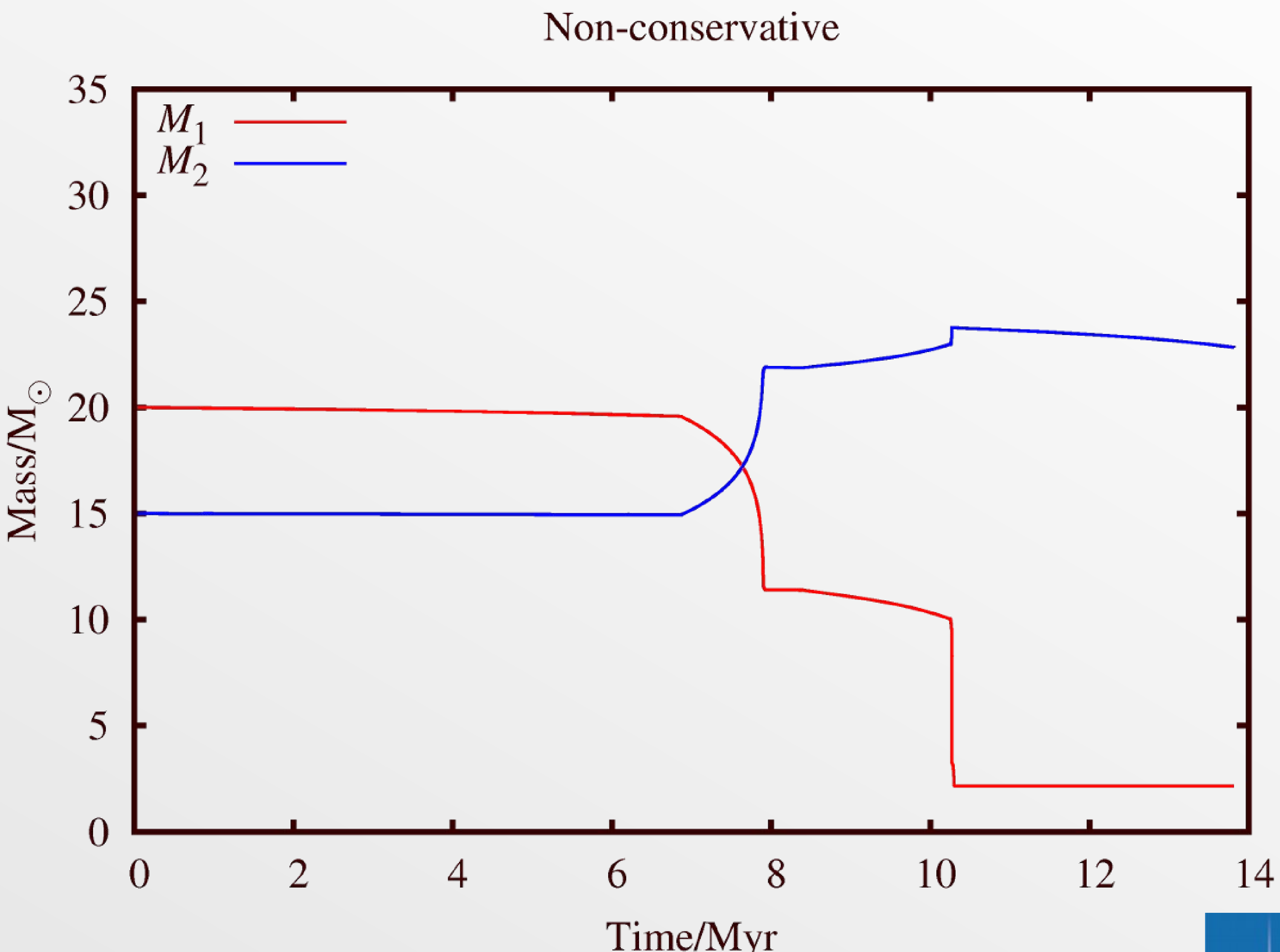
Conservatism

- Conservative RLOF: no change in system
  - Mass
  - Angular momentum
- Non-conservative:
  - Mass β
  - Angular momentum γ
- Physical conditions + a model give β and γ

20$M_\odot$ +15 $M_\odot$ (3 days)



20$M_\odot$ +15 $M_\odot$ (3 days)



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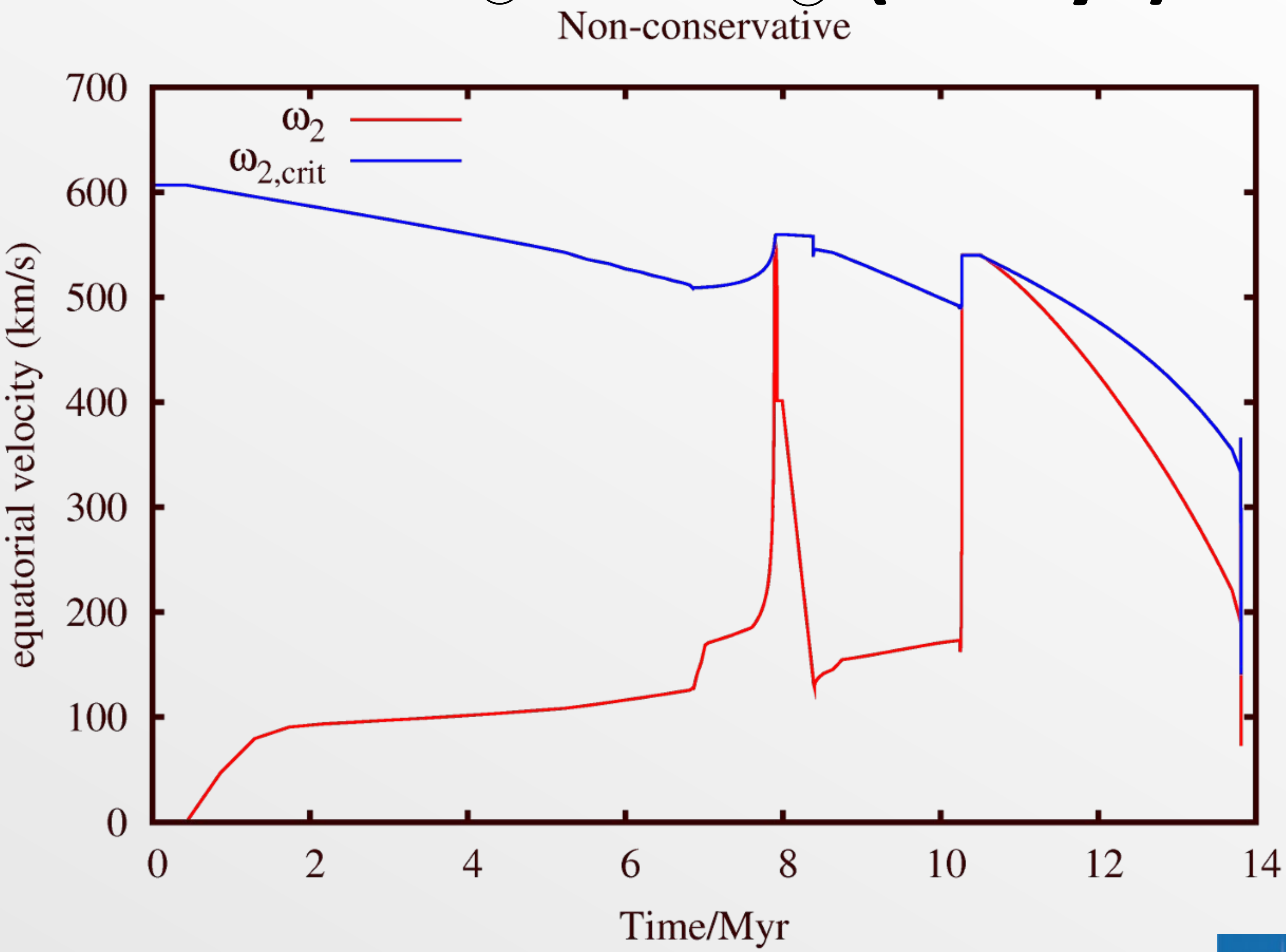

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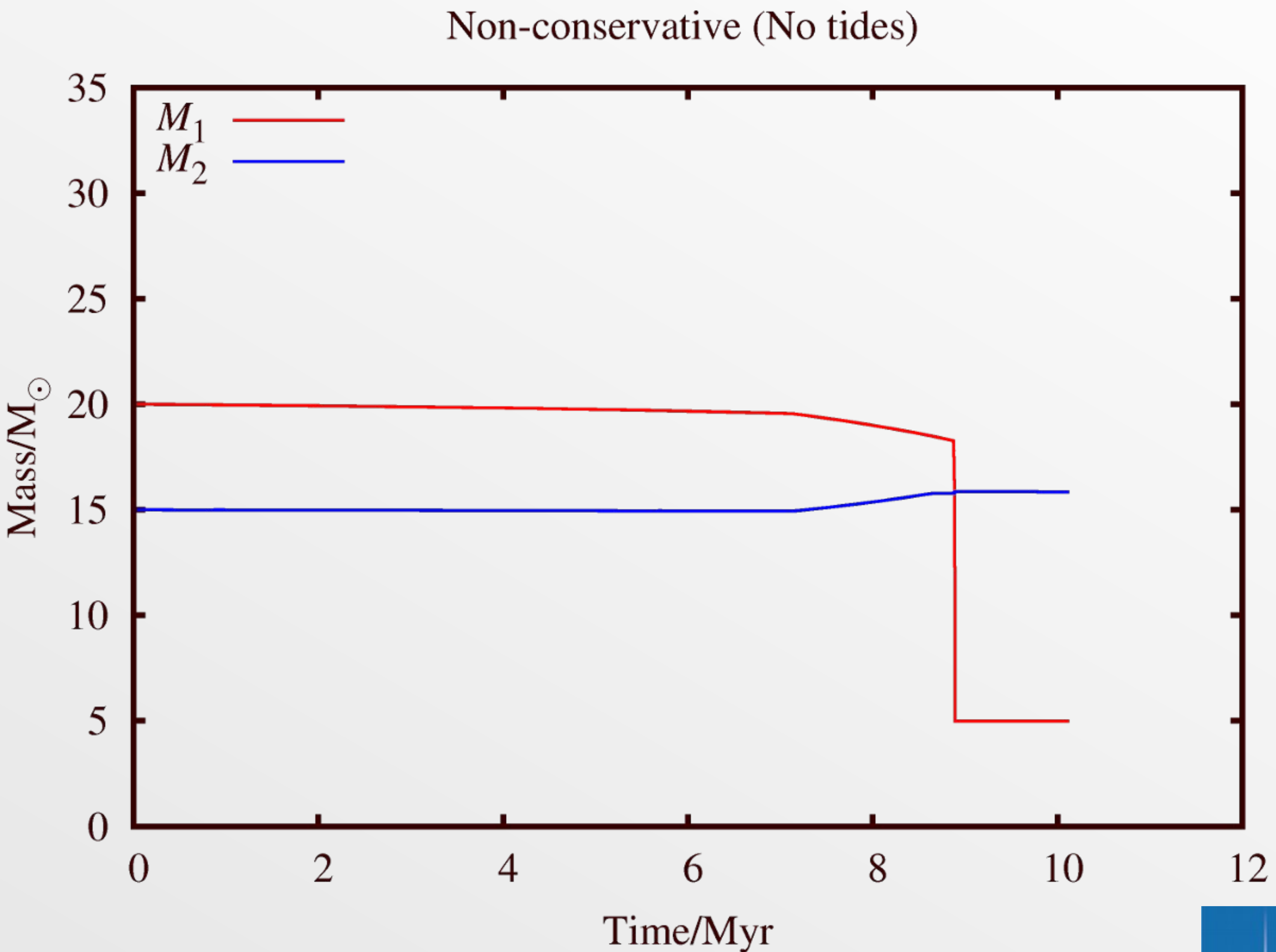

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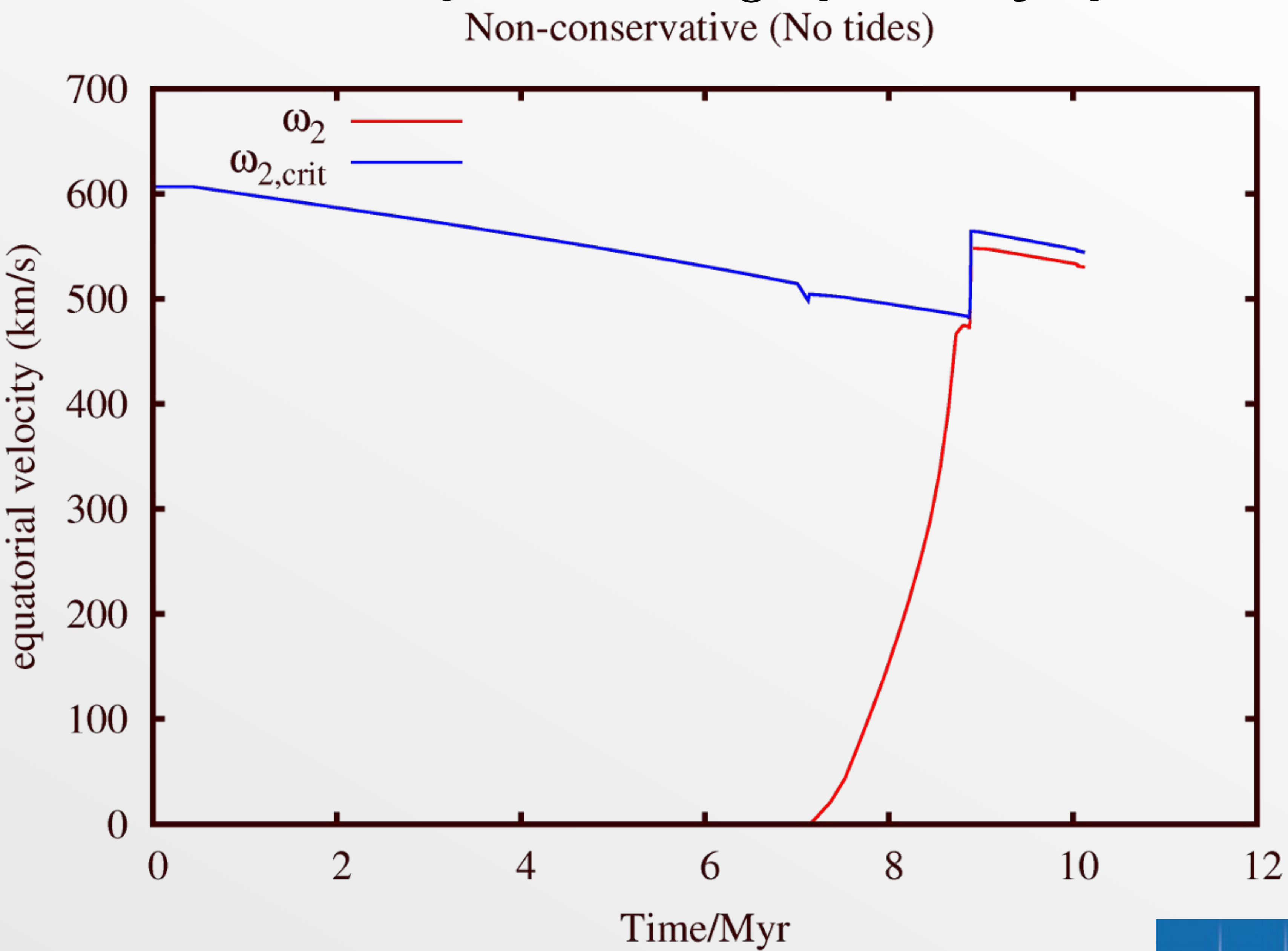


Stability

- What **stops** Roche-lobe overflow?
- Question of *stability* and **+** or **–** feedback
- Depends on:
  1. How R_1 responds to mass loss
  2. How the orbit (a) responds to mass transfer
  3. How the other star responds to accretion
- For now, neglect 3 and focus on 1 and 2

Response of the Donor Star

- Initial response: dynamical
- General rule:
- "Convective" stars expand (n=3/2 polytropes)
    - e.g. red giants, white dwarfs
- "Radiative" stars shrink
    - e.g. main sequence, core-He burning
- Later: thermal, nuclear response of star

Response of the orbit

- Orbit may widen or shrink
- Roche lobe size depends on separation *a*
- and mass ratio *q* $\zeta_{\mathrm{ad}} < 2.13q - 1.67$
- Dynamical instability if
- Mass transfer runs away!

Response of the accreting star

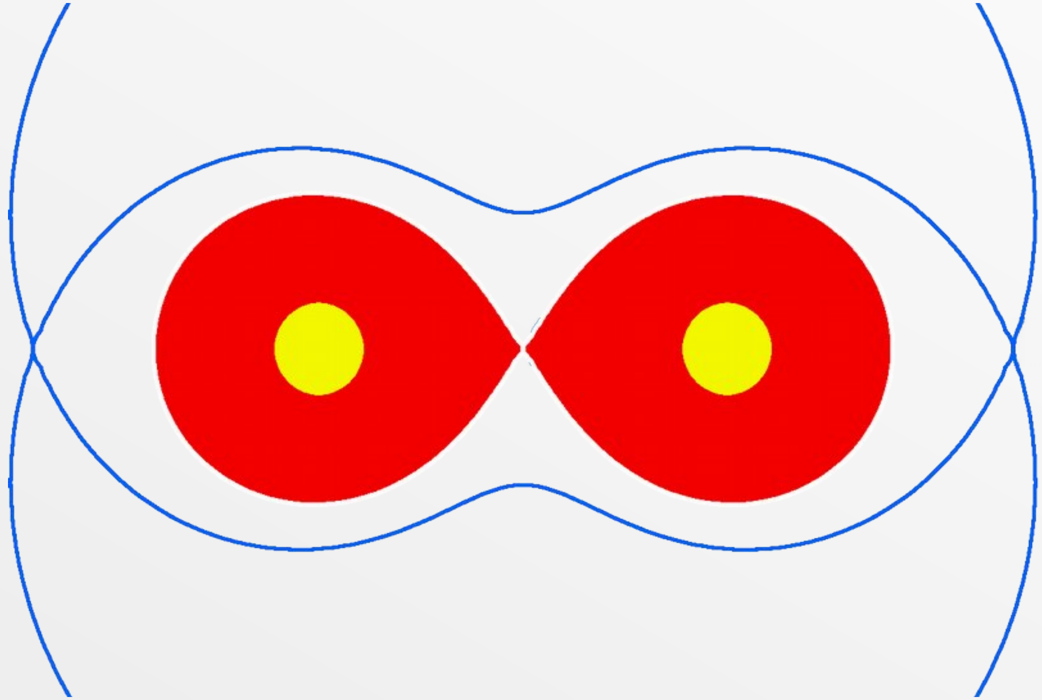
- Luminosity of accretion may exceed *Eddington*

$$L \sim \frac{GM\dot{M}}{R} > L_{\mathrm{Edd}}$$

- Hot spot?
- Spin up beyond breakup if $\Delta M \gtrsim 0.1M$
- Nuclear burning on surface? Novae or SNIa?
- mixing, rejuvenation, swelling of accretor
- *Contact* or *Common envelope evolution*

Common Envelope Evolution

- Both stars fill their Roche lobe



- Spiral in: friction, orbital shrinkage, eject or merge!
- Very poorly understood phase of evolution