Collisions and Close Encounters within Globular Clusters

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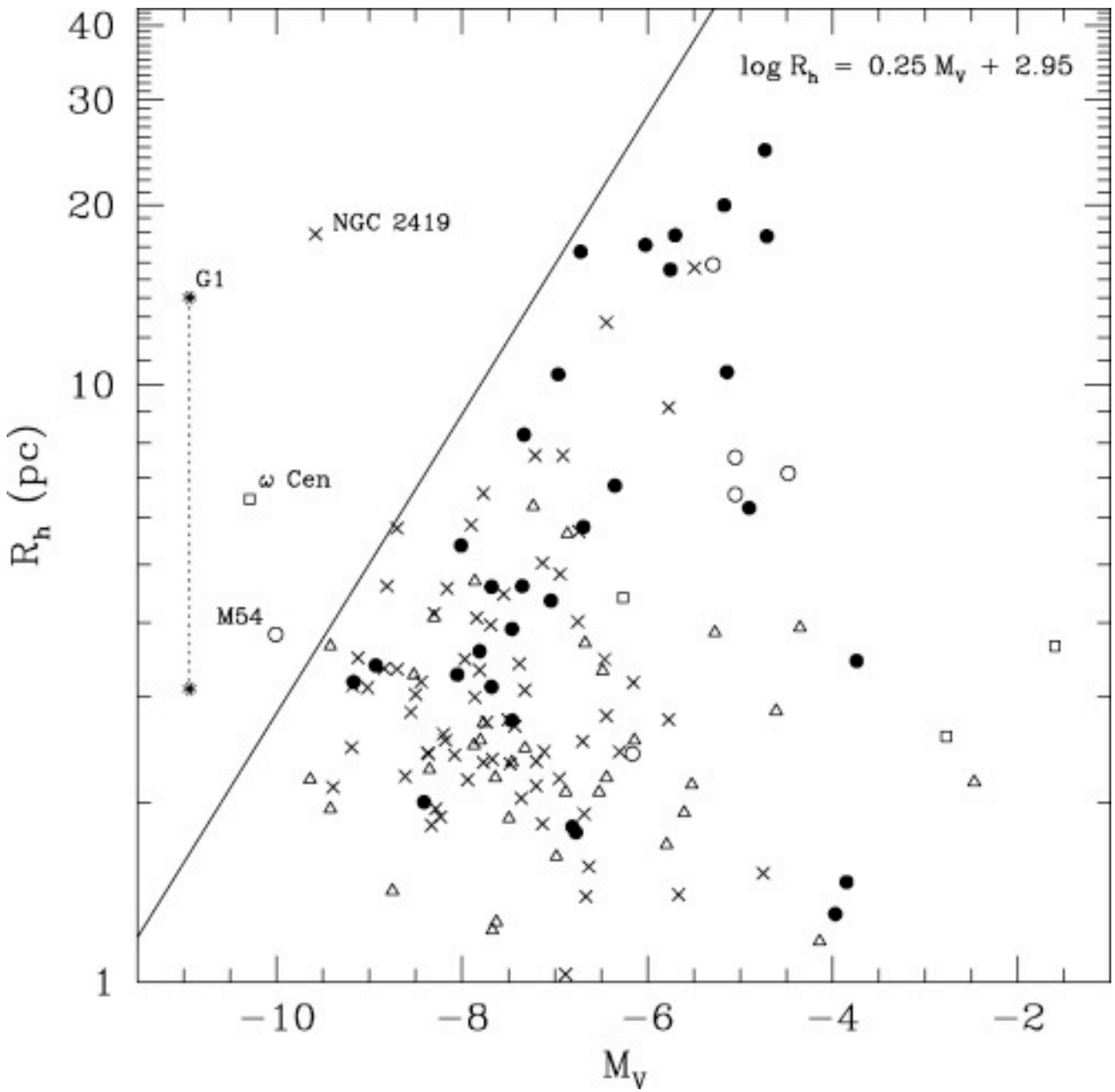
Lecture 1

- Introduction to collisions within clusters
- Collision rates as a function of cluster properties and stage of stellar evolution
- Outcomes of collisions
- Single-single vs binary-single encounters

An old globular cluster

Globular Cluster 47 Tucanae
(FORS/VLT)

ESO PR Photo 20/06 (8 June 2006)

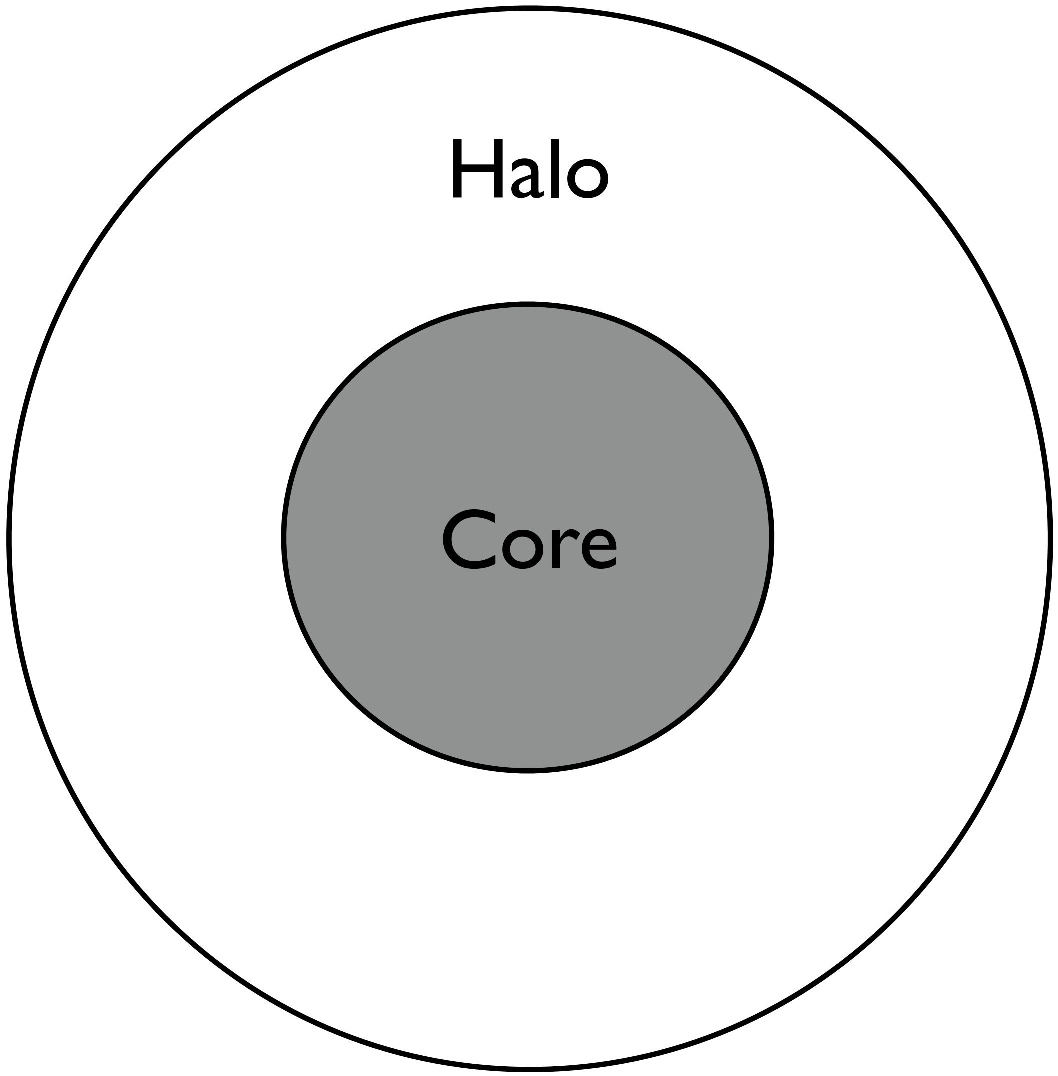


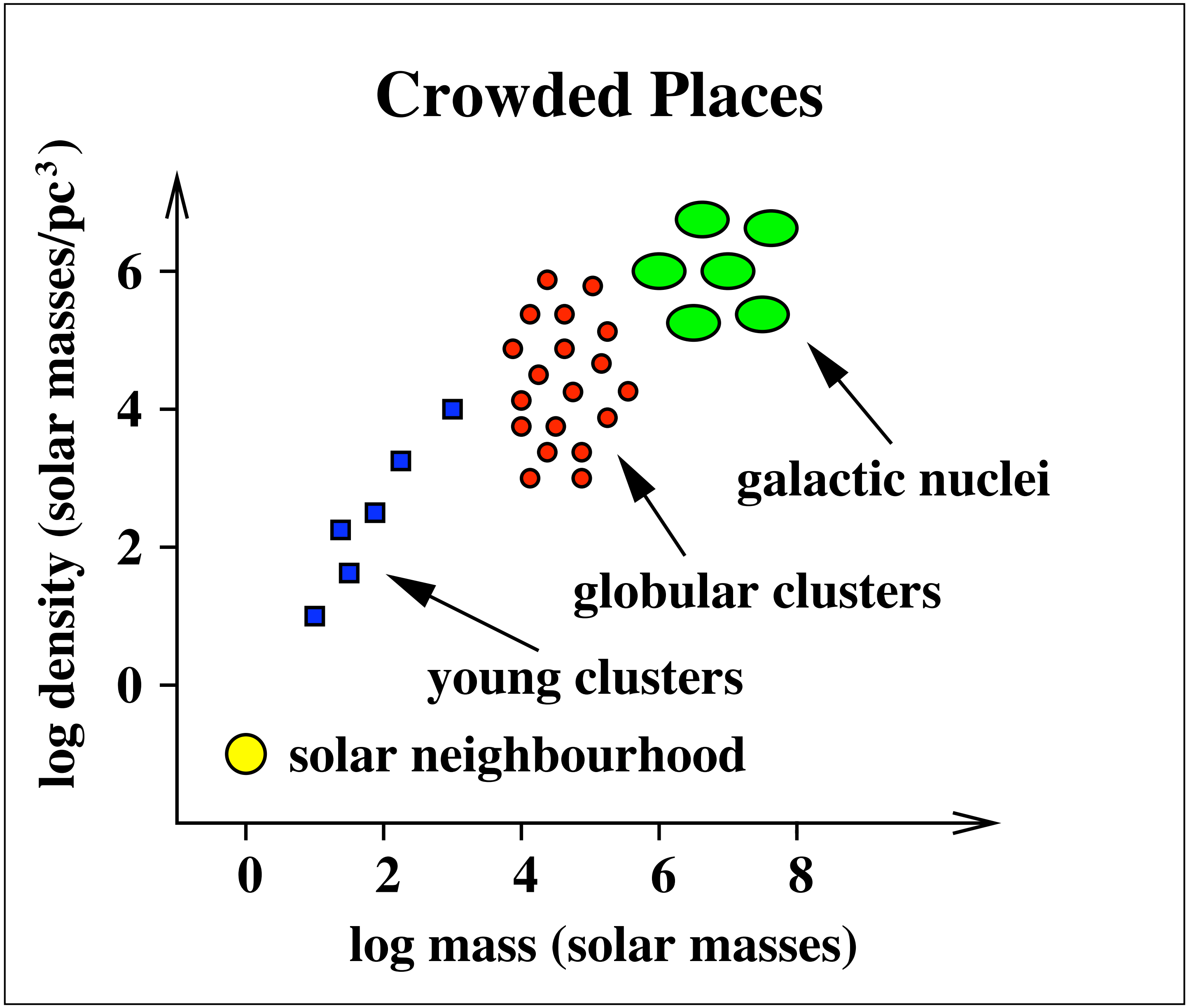
(Mackey & Van Den Bergh 2005)

Some useful information about clusters

- Cluster mass ~ up to one million solar masses
- Cluster half-light radius ~ 1-10 pc
- Typical velocity dispersion ~10 km/s (cf surface escape speed of sun ~600 km/s)
- Large range in core radius (but can be smaller than half-light radius)
- Cluster age: all clusters are old

A model stellar cluster





Crowded Places
log density (solar masses/pc^3)
6
4
2
0
galactic nuclei
globular clusters
young clusters
solar neighbourhood
0
2
4
6
8
log mass (solar masses)

Stellar encounter timescales

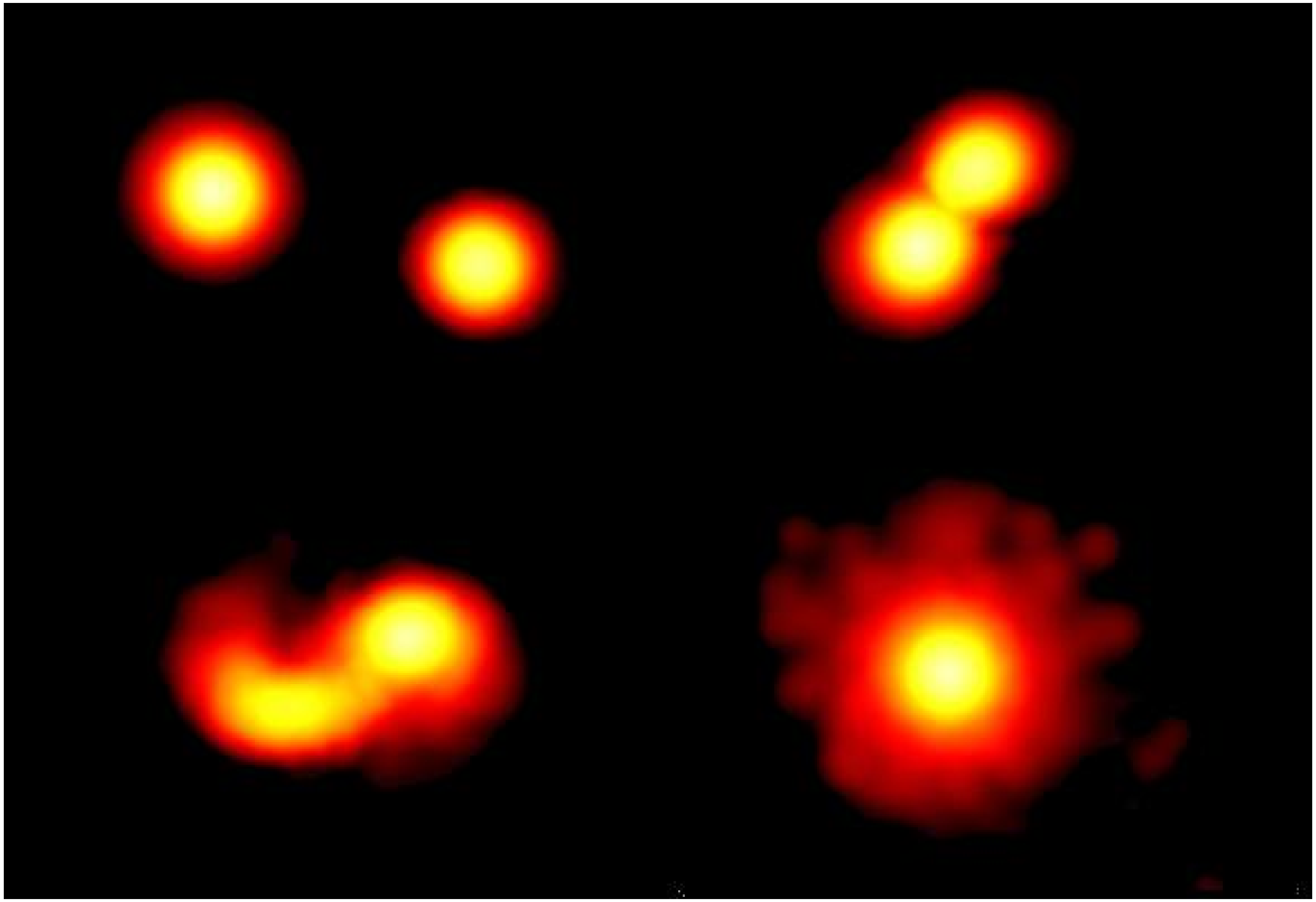
Cross section is given by

$$\sigma = \pi R_{min}^2 \left(1 + \frac{2G(M_1 + M_2)}{R_{min} V_\infty^2}\right)$$

Timescale for a given star to undergo an encounter is

$$\tau_{enc} \sim 10^{11} yr \ \left(\frac{10^5/pc^3}{n}\right) \cdot \left(\frac{M_\odot}{M}\right) \cdot \left(\frac{R_\odot}{R_{min}}\right) \cdot \left(\frac{V_\infty}{10km/s}\right)$$

Stellar collision between two MS stars



Outcomes of collisions in globular clusters

- Mass loss: 1-10 % (more for MS-CO)
- Typical delta V ~100km/s for collisions, so collisions lead to mergers
- Capture for Rmin ~ 3 Rstar (Fabian, Pringle, and Rees 1975)

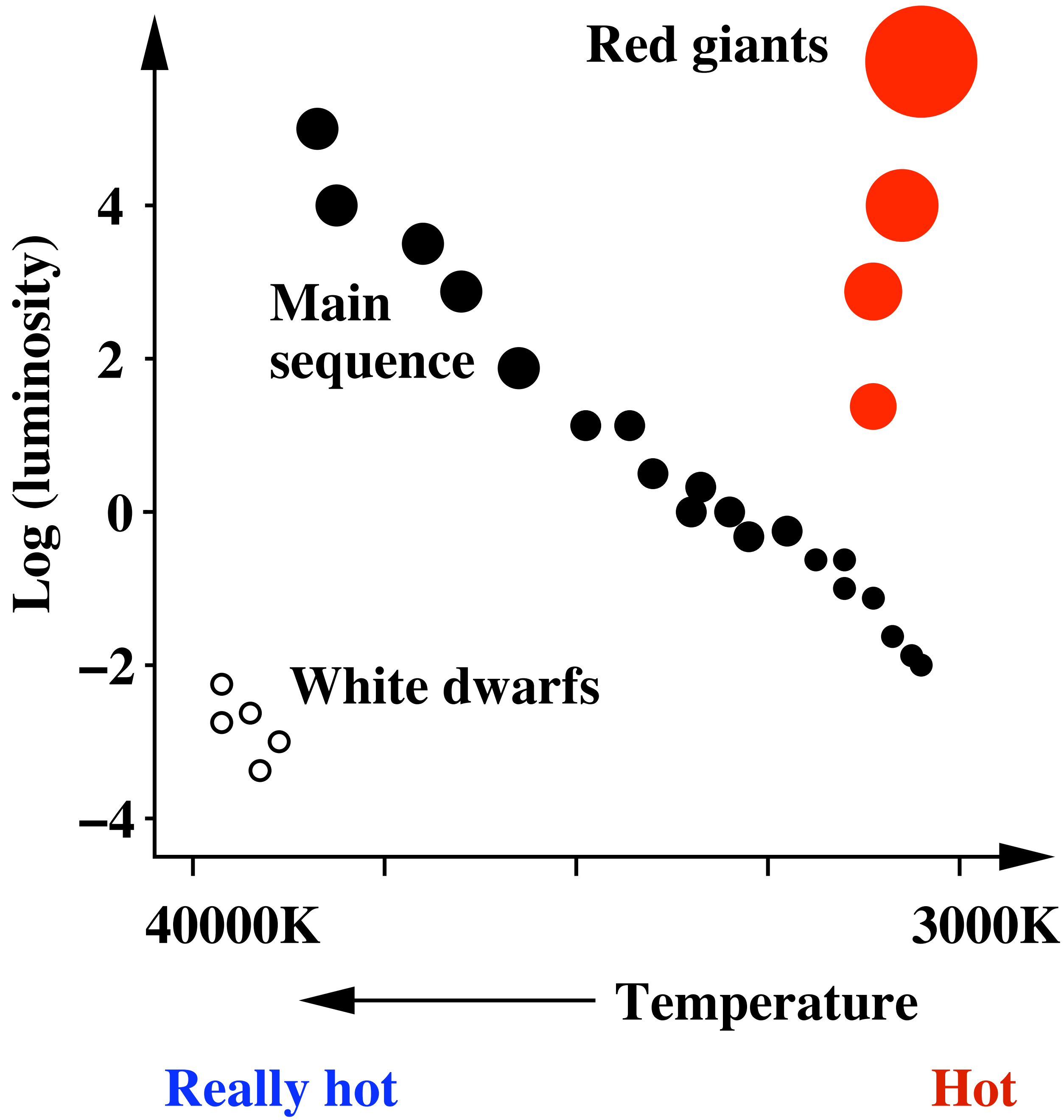
IDEA:

Collisions and close encounters between stars in cluster cores can produce EXOTIC objects.

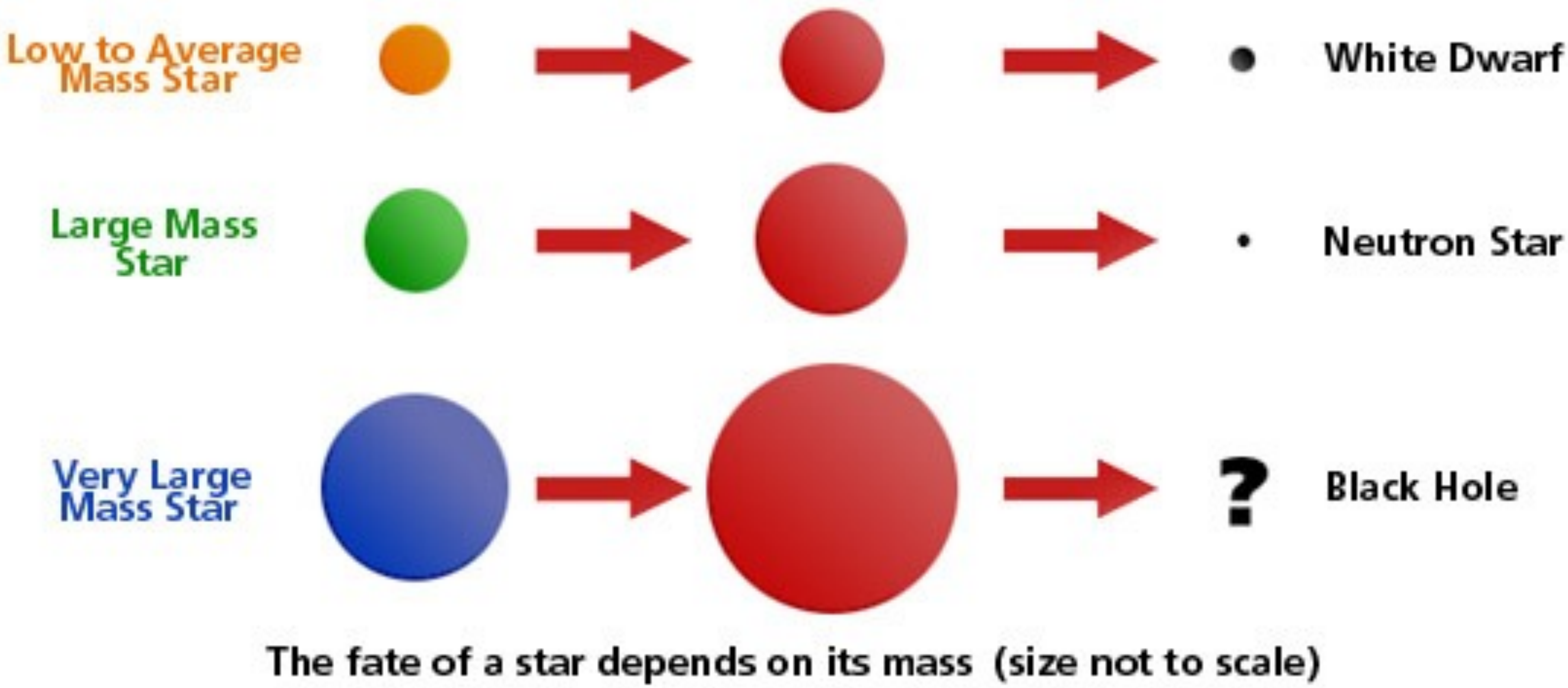
What collides with what?

...first quickly review stellar evolution

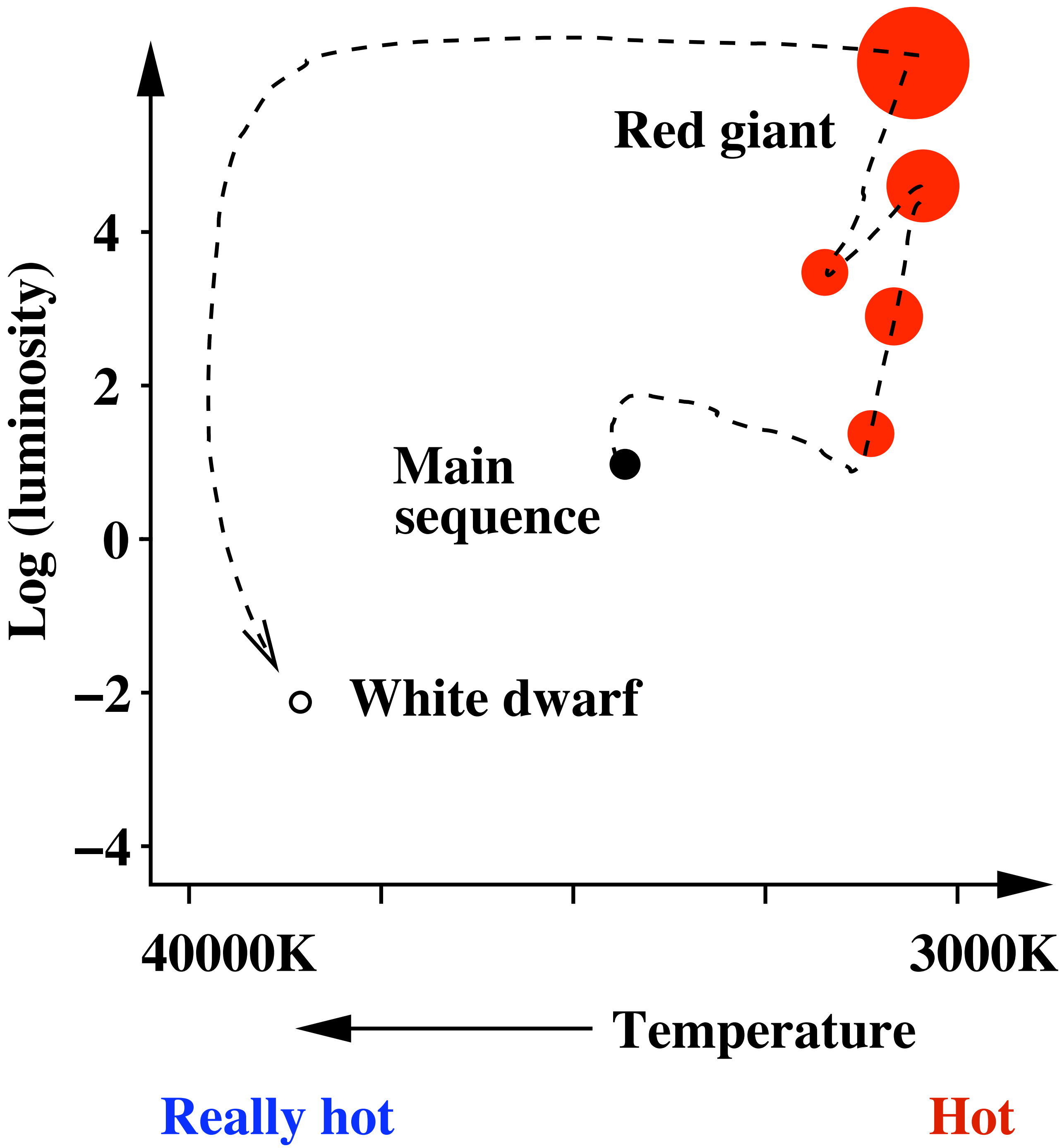
Hertzsprung–Russell Diagram



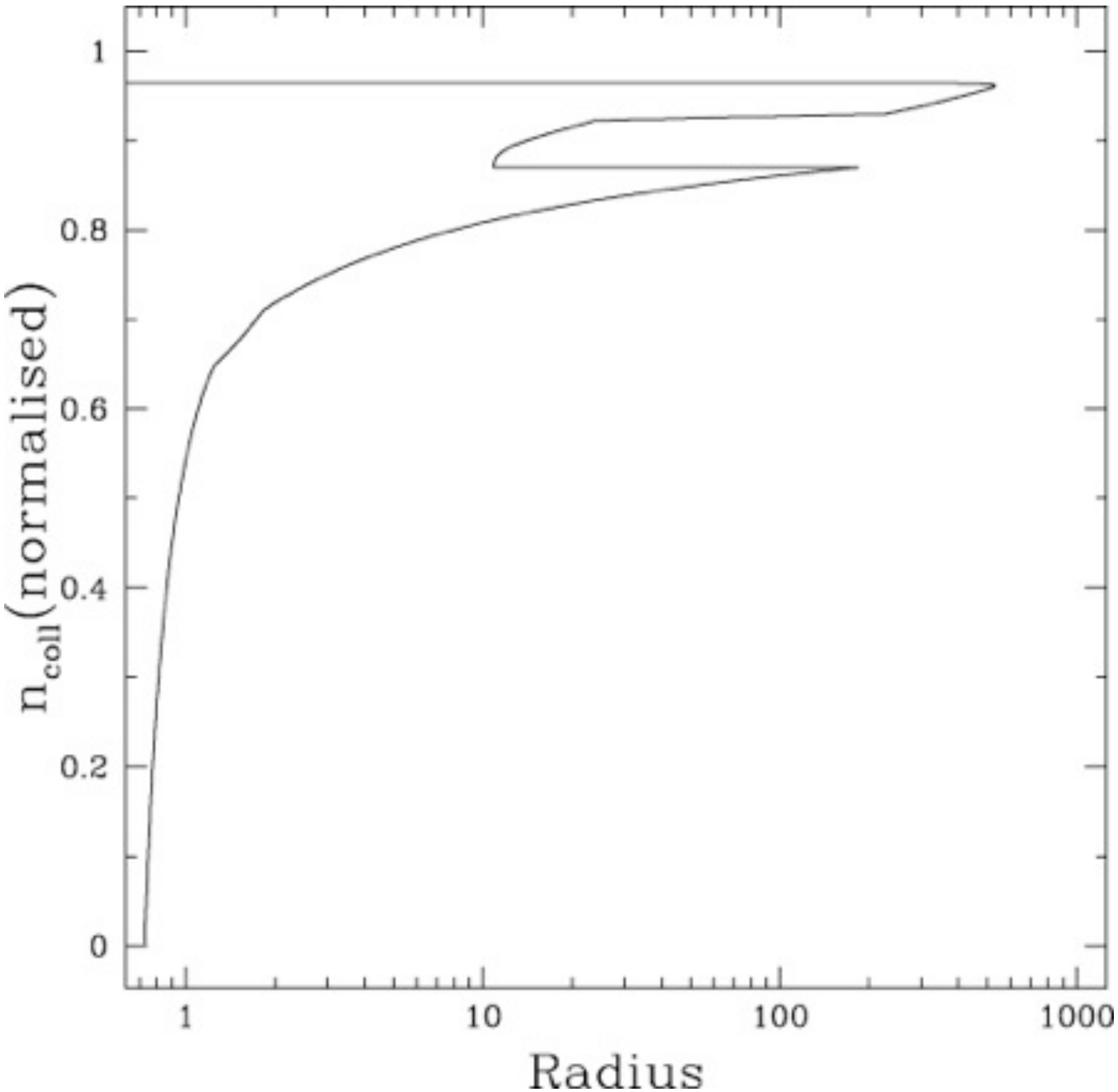
The lives (and deaths) of stars



Evolution of a low–mass star



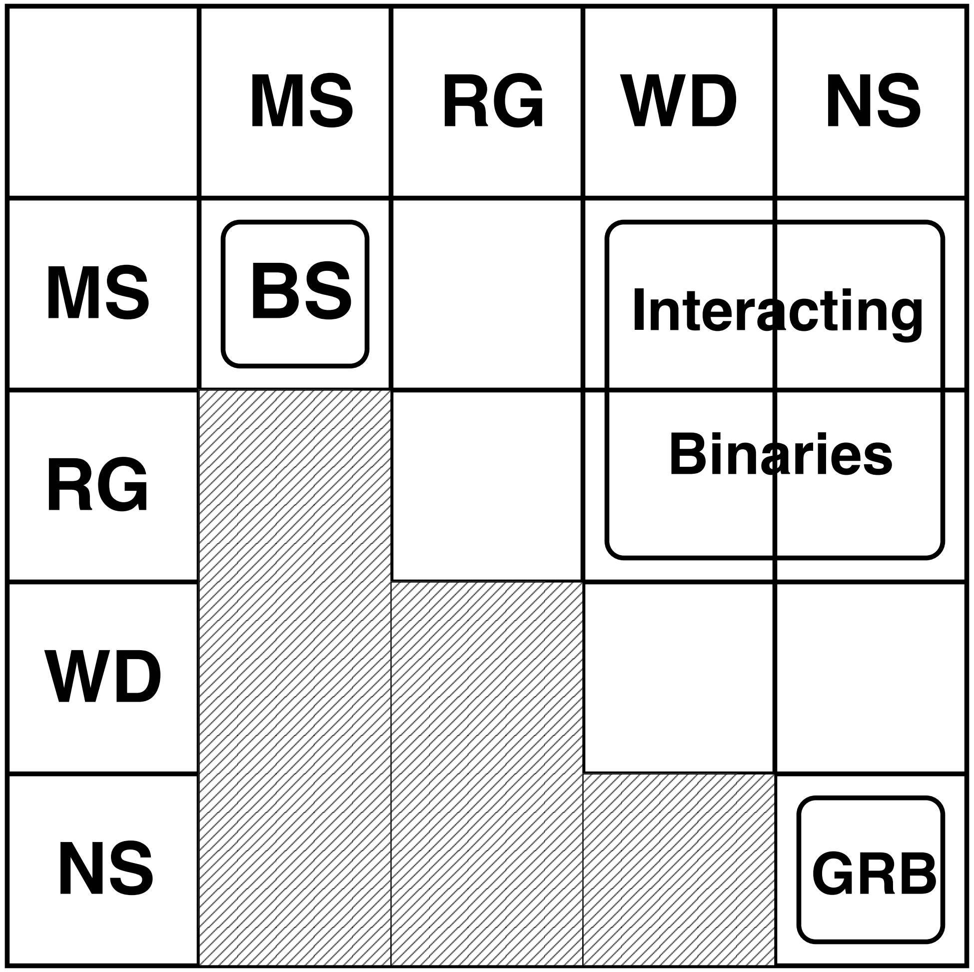
Stellar radius vs cumulative number of collisions



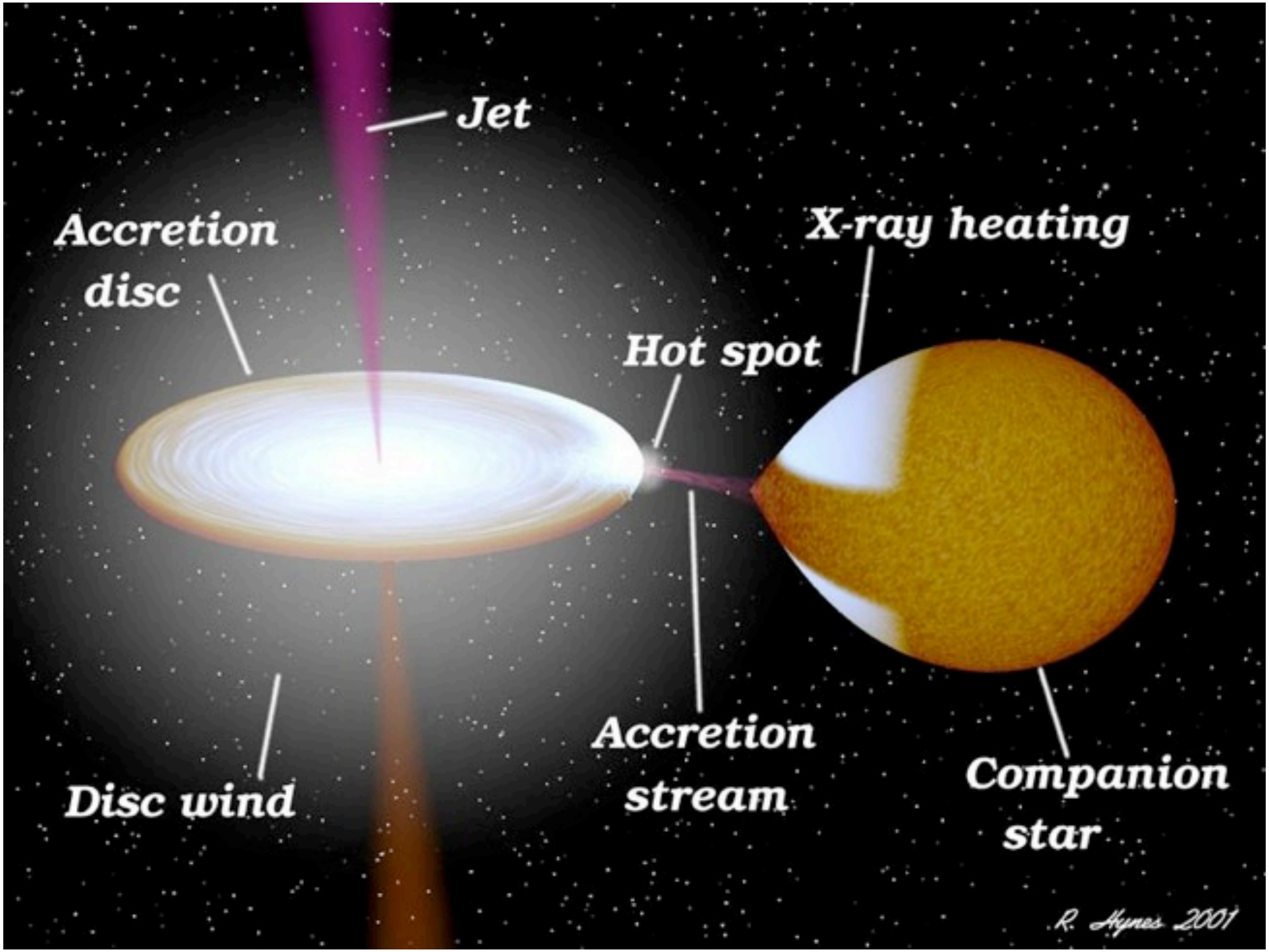
low-mass star in a globular cluster

(Sills, Adams, and Davies 2005)

What can collide with what?



An Interacting Binary



Now consider encounters involving binary stars

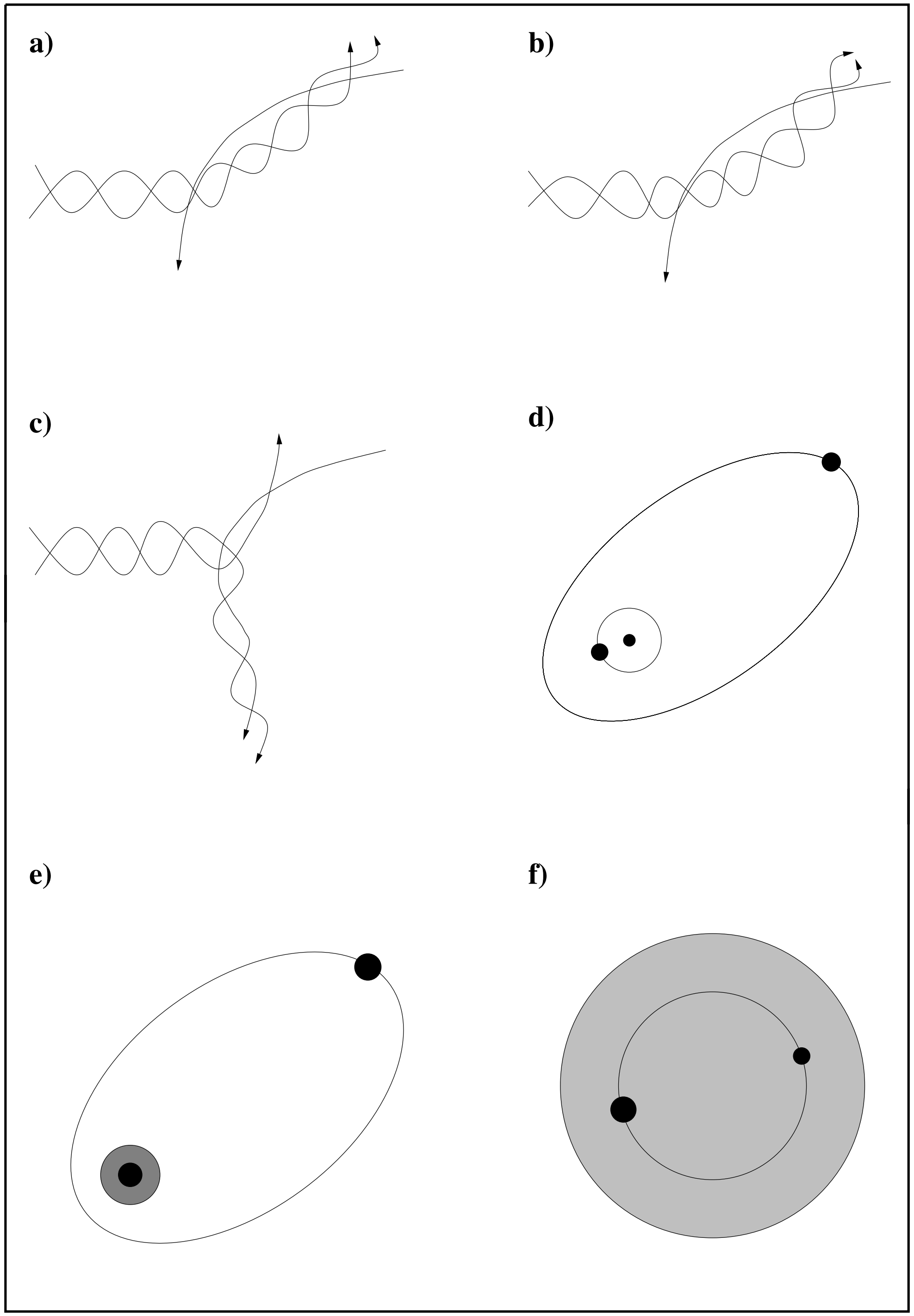
Encounter timescales involving binaries

Timescale for a given star to undergo an encounter with a binary is

$$\tau_{enc} \sim 10^{11} yr \left(\frac{10^5/pc^3}{n} \right) \cdot \left(\frac{M_\odot}{M} \right) \cdot \left(\frac{R_\odot}{R_{min}} \right) \cdot \left(\frac{V_\infty}{10 km/s} \right)$$

Where now Rmin is roughly the size of the binary, which can be much larger than the radius of a star.

Possible outcomes of encounters between a binary and a single star.



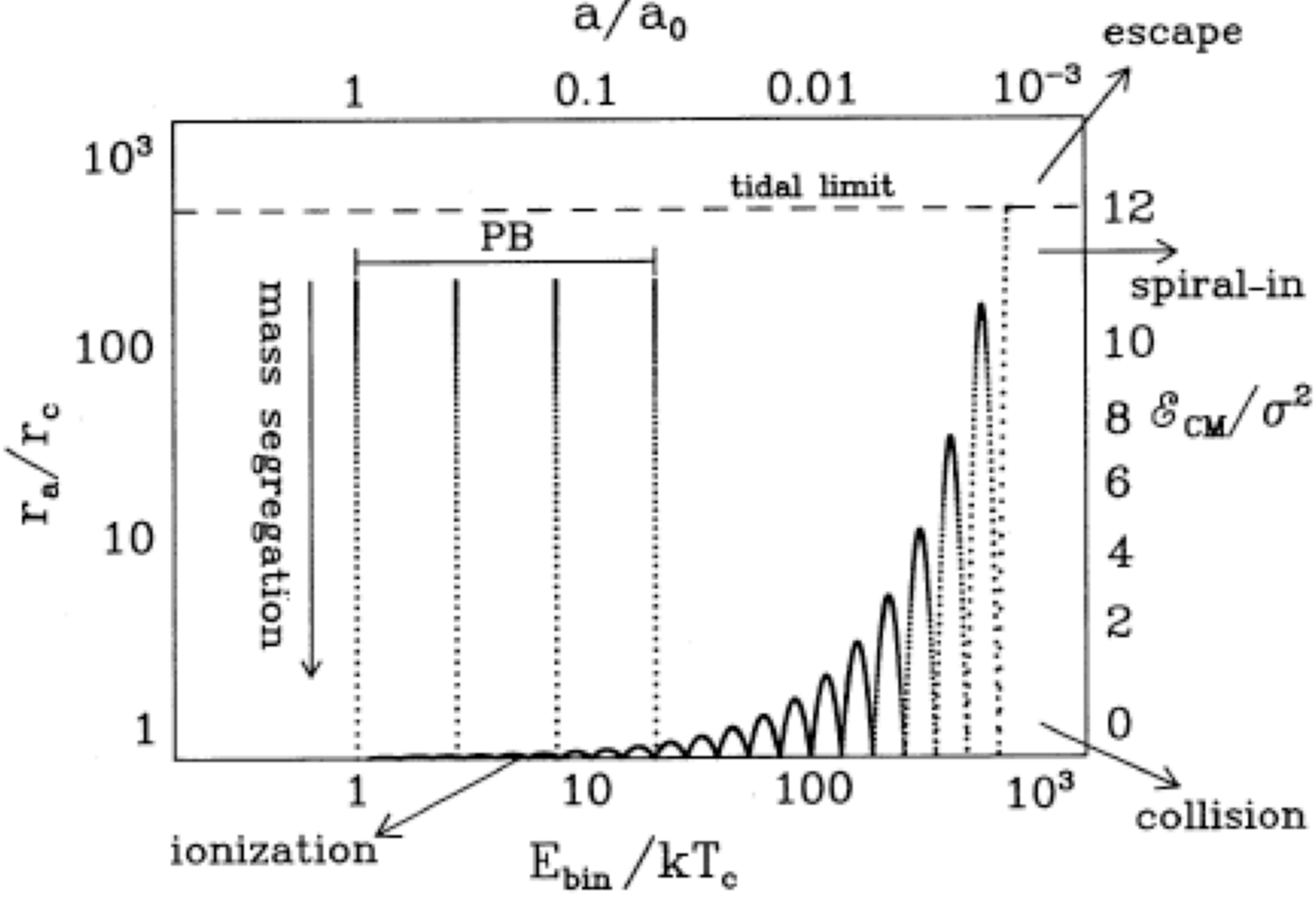
Concepts concerning binary-single encounters

- Hard-soft boundary

$$d_{\rm hs} \simeq 5{\rm AU}\left(\frac{V_\infty}{10km/s}\right)^{-2}$$

- Soft binaries get broken up
- Hard binaries get harder
- Clean exchanges: lowest-mass star ejected
- Stellar collisions occur during encounters

Using up binaries in a cluster

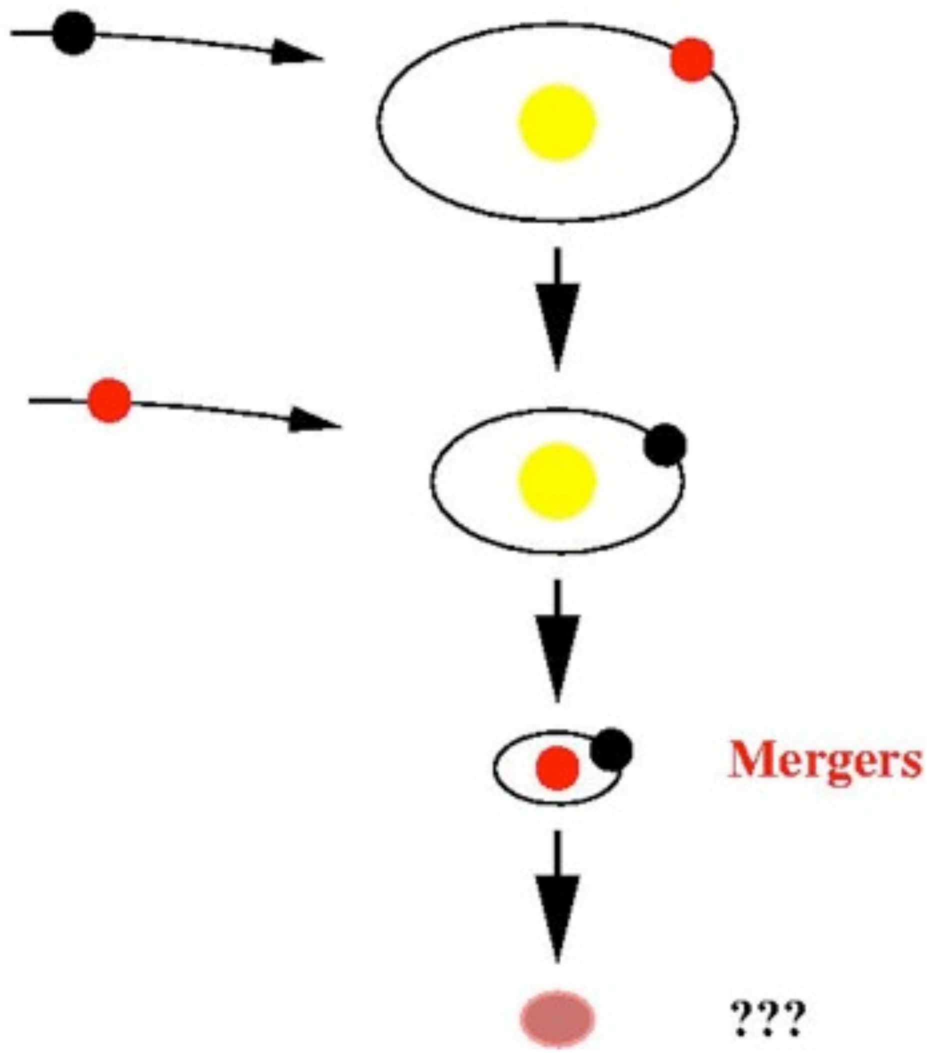


(Hut, McMillan, and Romani 1992)

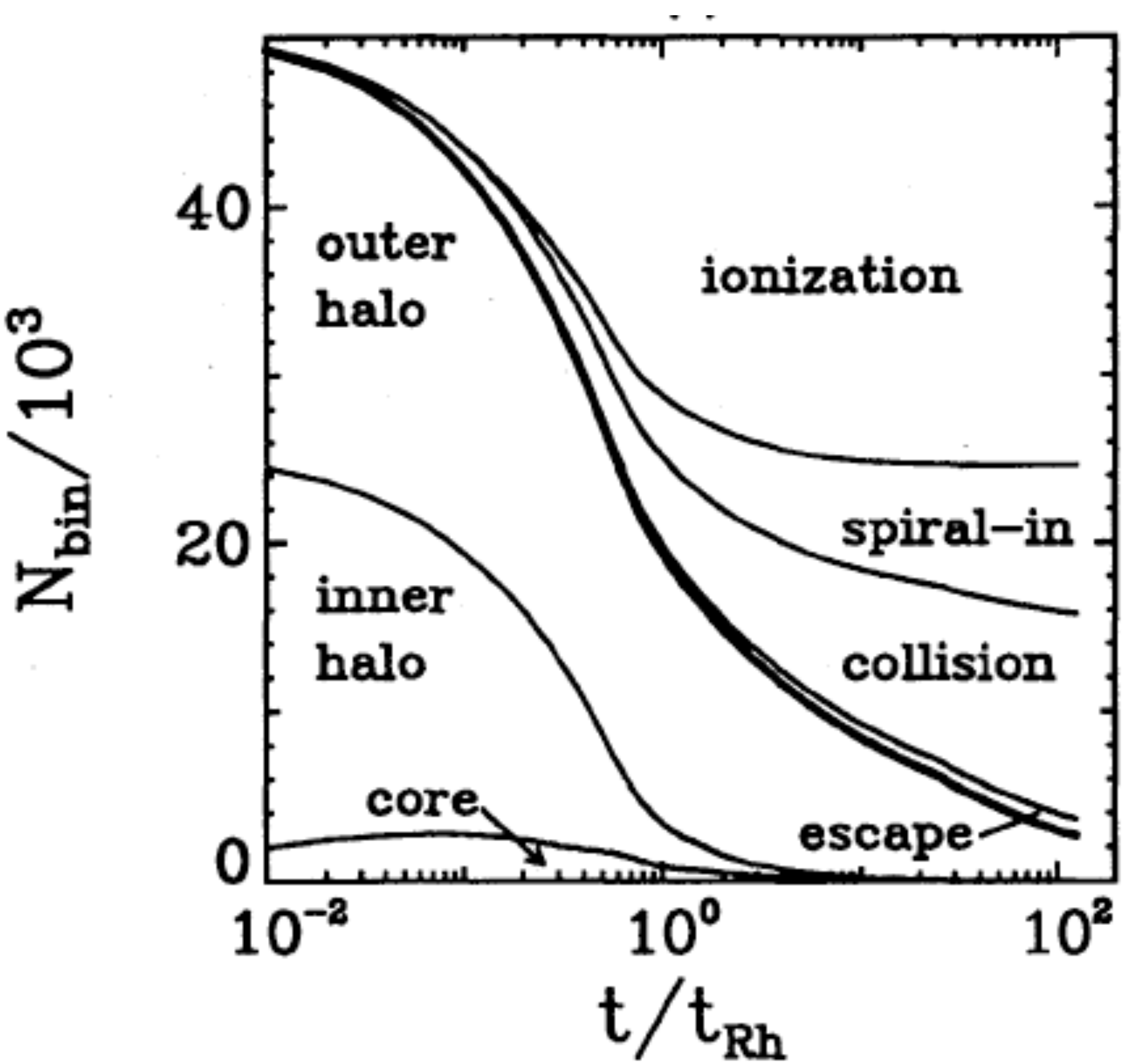
Binary Digestion

Wide binaries get broken up

Hard binaries get harder



Fate of binaries



(Hut, McMillan, and Romani 1992)