Collisions and Close Encounters within Globular Clusters

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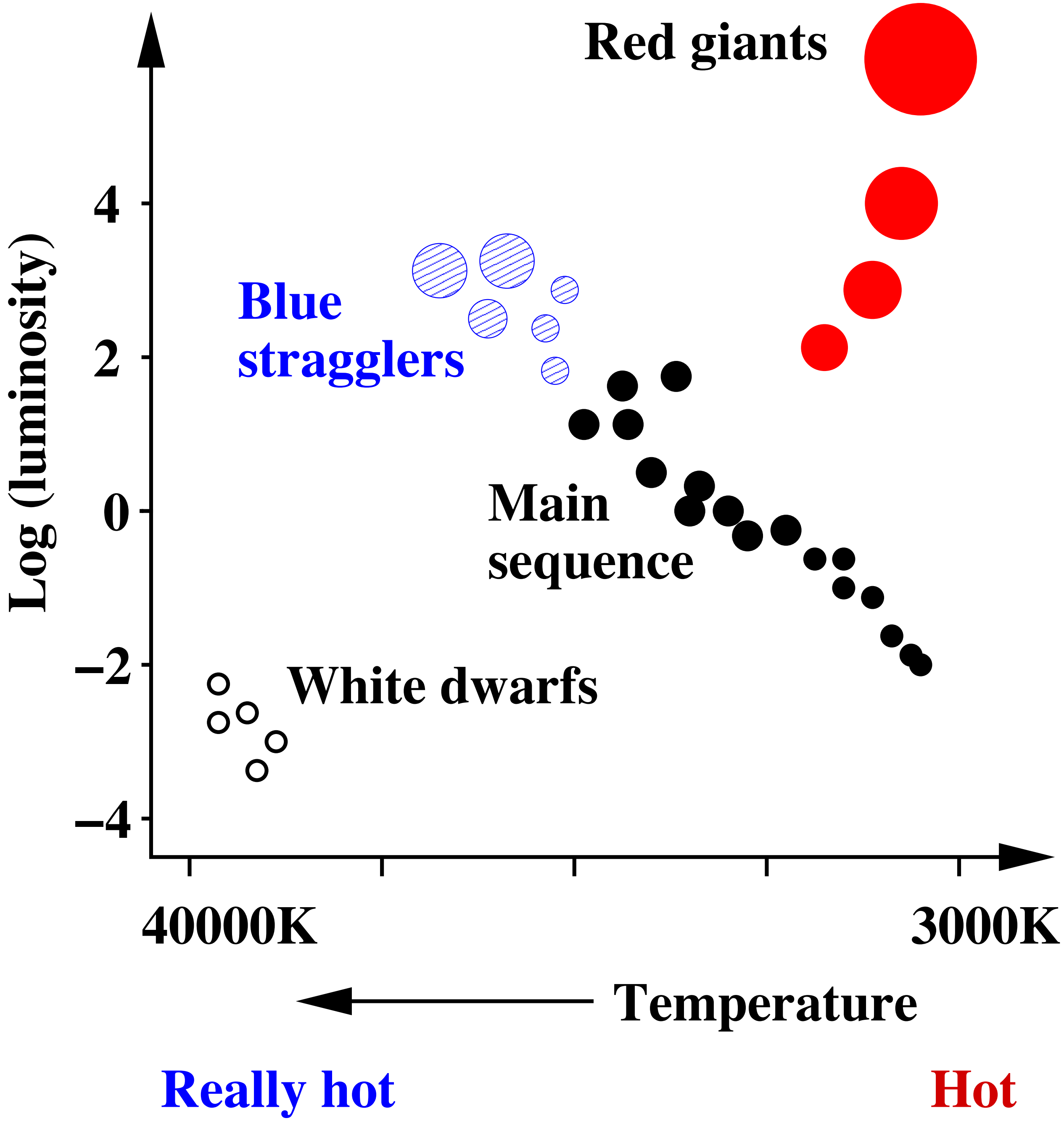
Lecture 2

- Production of blue stragglers (both from single-single collisions and encounters involving binaries)
- Explanation of observed blue straggler population
- Production of interacting binaries

H–R Diagram of a globular cluster



Two kinds of blue stragglers

Those produced in collisions/mergers between two single stars

Those produced via mass transfer within binaries

Stellar encounter timescales

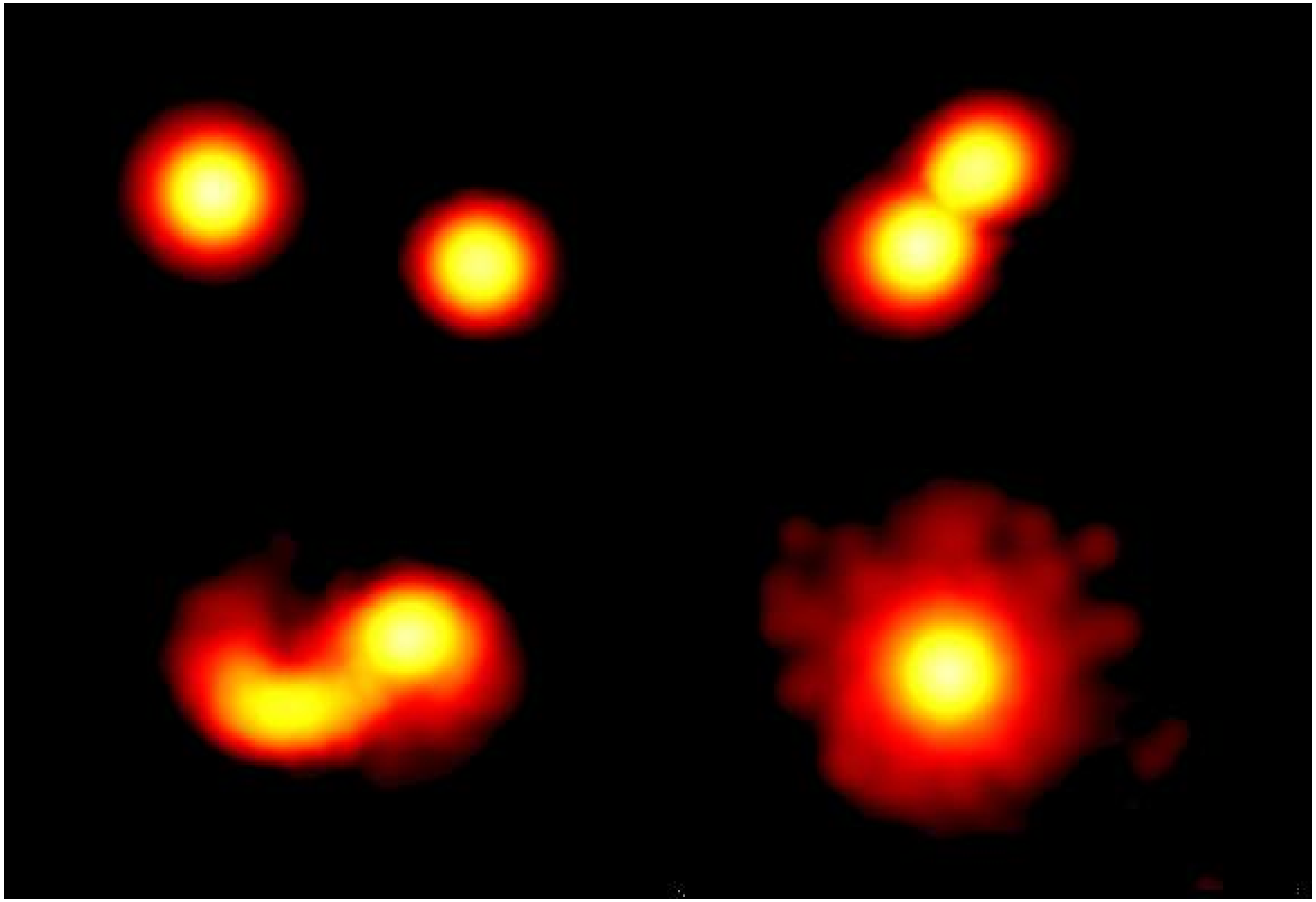
Cross section is given by

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

Timescale for a given star to undergo an encounter is

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

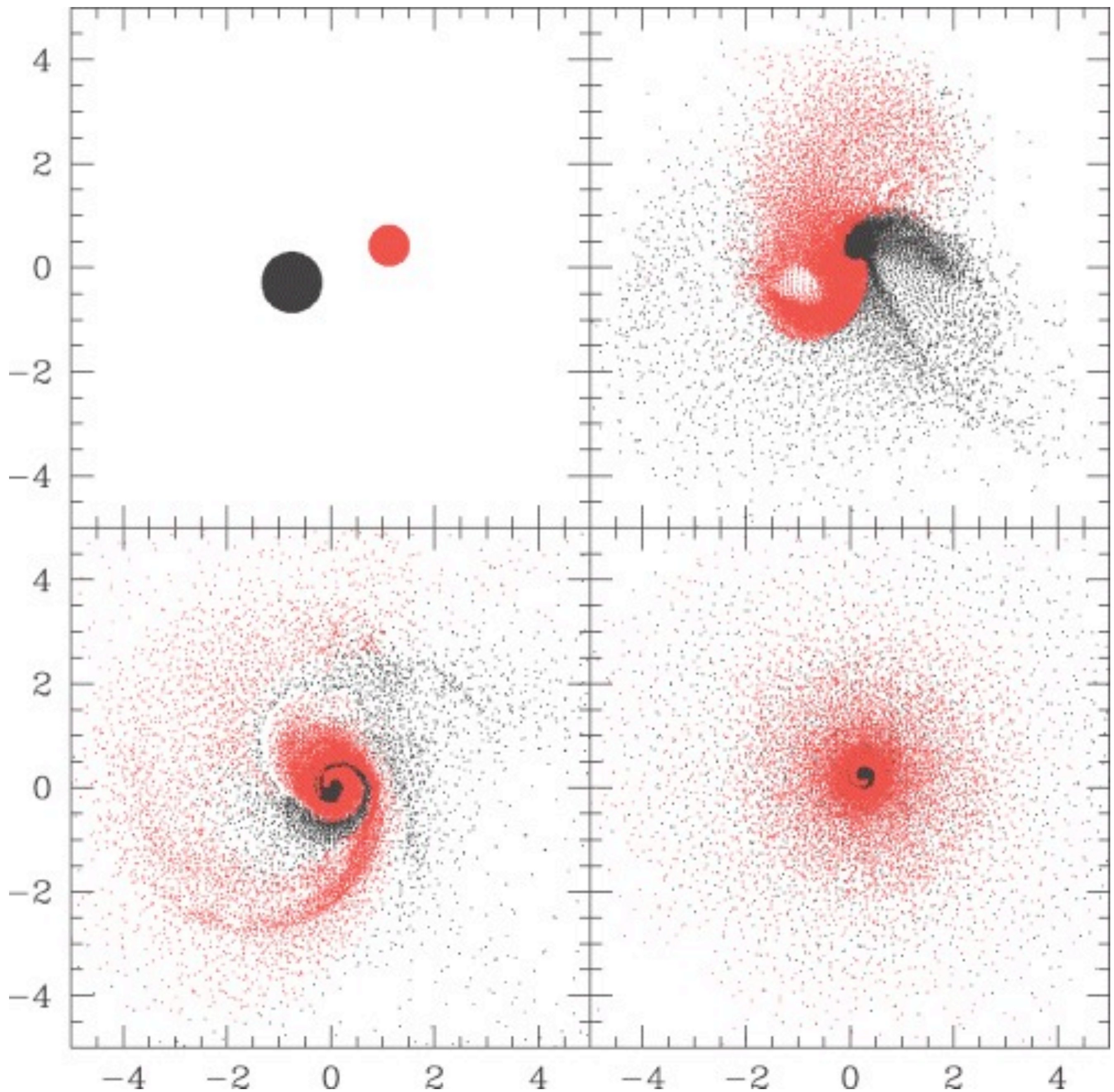
Stellar collision between two MS stars



Modelling post-collision evolution is very difficult

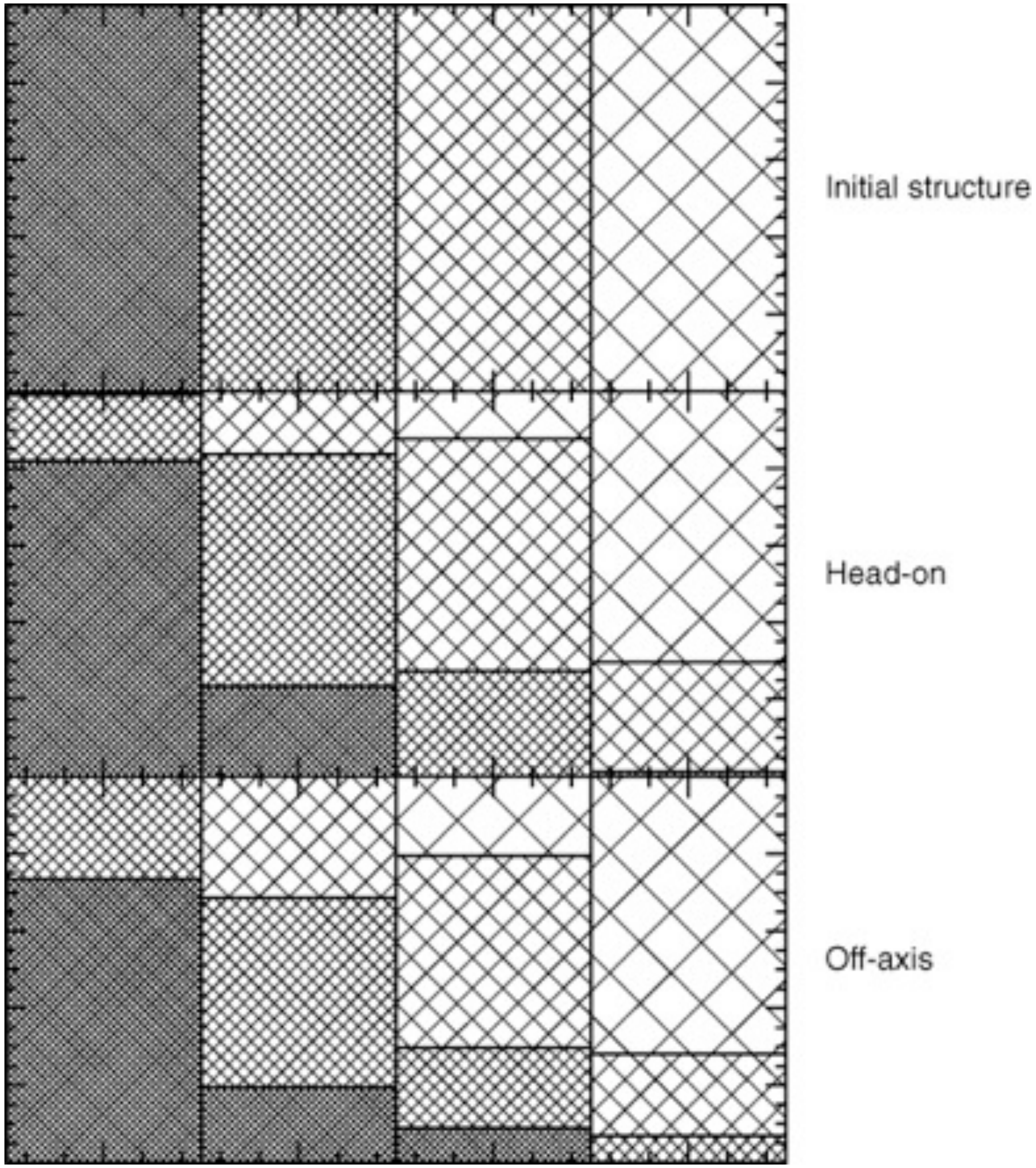
- Significant rotation
- Possible mixing of material
- Angular momentum loss?

(eg Sills et al 2005; 2009)



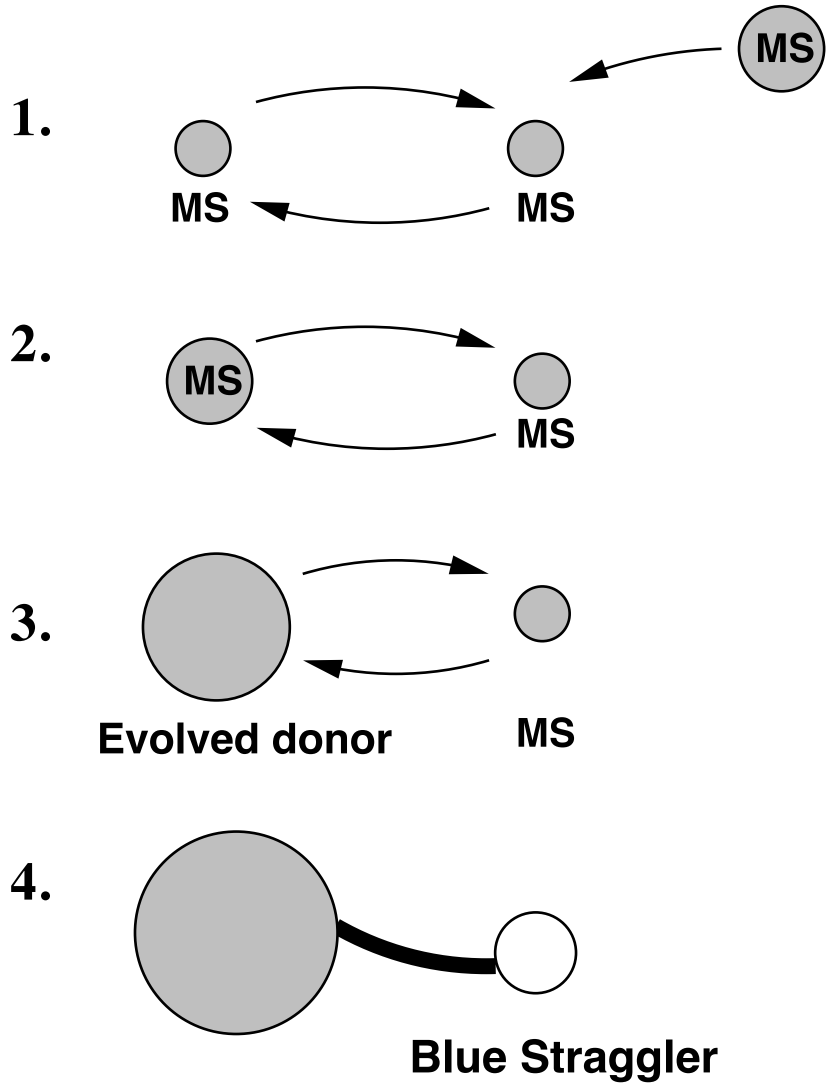
(Sills, Adams, and Davies 2005)

How much do stars mix during collisions?



(Sills, Adams, and Davies 2005)

Making blue stragglers through binary evolution



(Davies, Piotto, and De Angeli 2004)

How does blue straggler formation rate scale with cluster mass?

Collision rate between main-sequence stars given by

$$\Gamma_{\rm coll} \propto \frac{\rho^2 r_{\rm c}^3}{\sigma} \propto \frac{\rho^2 r_{\rm c}^3}{\sqrt{M_{\rm tot}/r_{\rm h}}} \propto \frac{M_{\rm c}^2 r_{\rm c}^{-3}}{\sqrt{M_{\rm tot}/r_{\rm h}}} \propto \frac{f_{\rm c}^2 r_{\rm h}^{1/2}}{r_{\rm c}^3} M_{\rm tot}^{3/2}$$

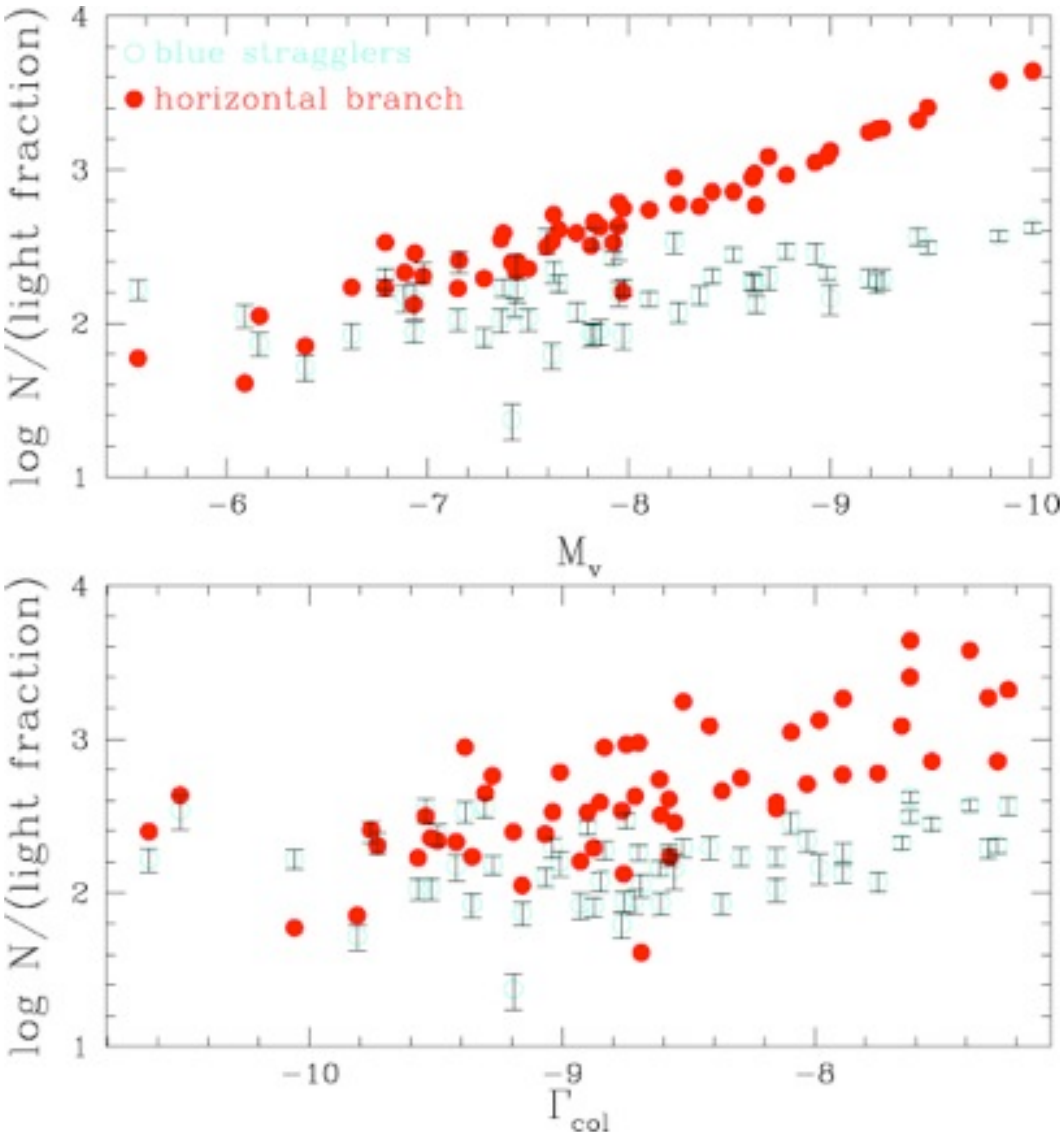
Number of blue stragglers made in collisions

$$N_{\rm bs,coll} \propto M_{\rm tot}^{3/2}$$

Number of blue stragglers made in binaries

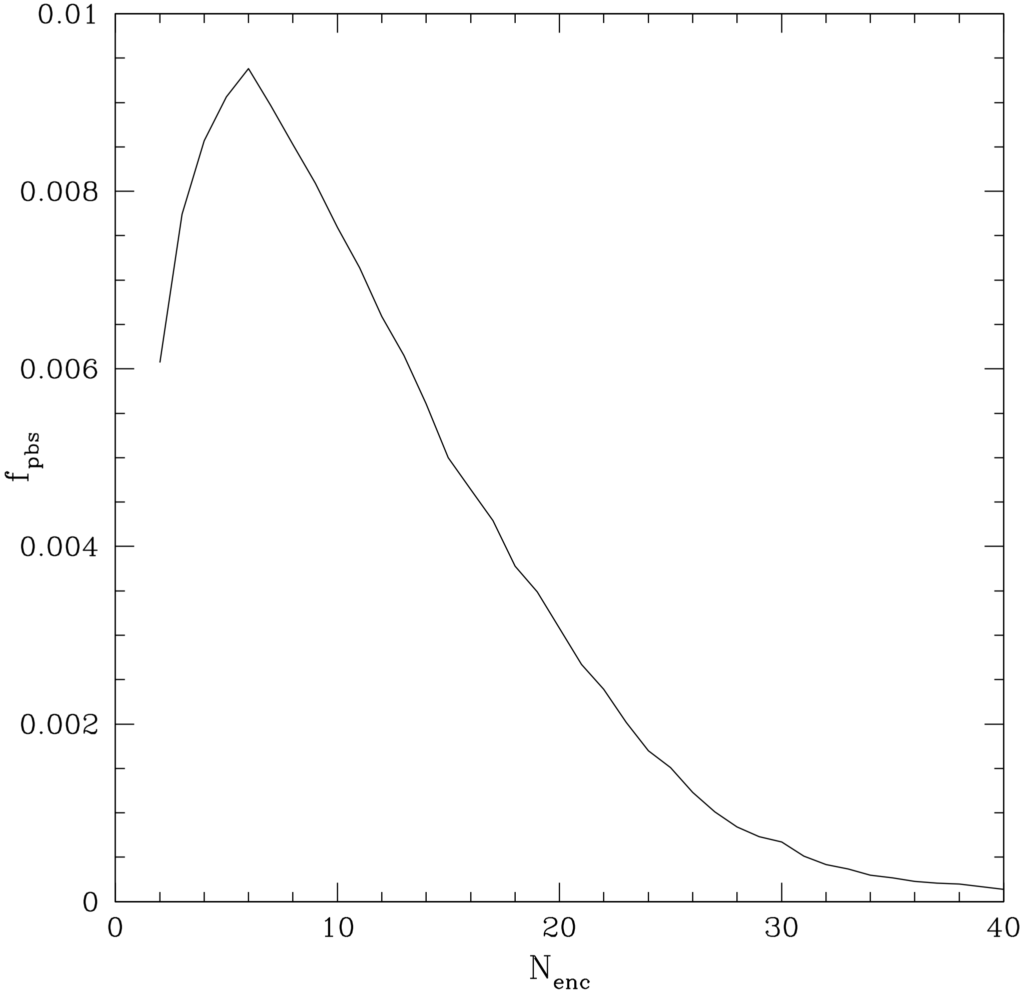
$$N_{\rm bs,bin} \propto M_{\rm tot}$$

There are roughly the same number of blue stragglers in all clusters!



(eg Davies, Piotto, and De Angeli 2004)

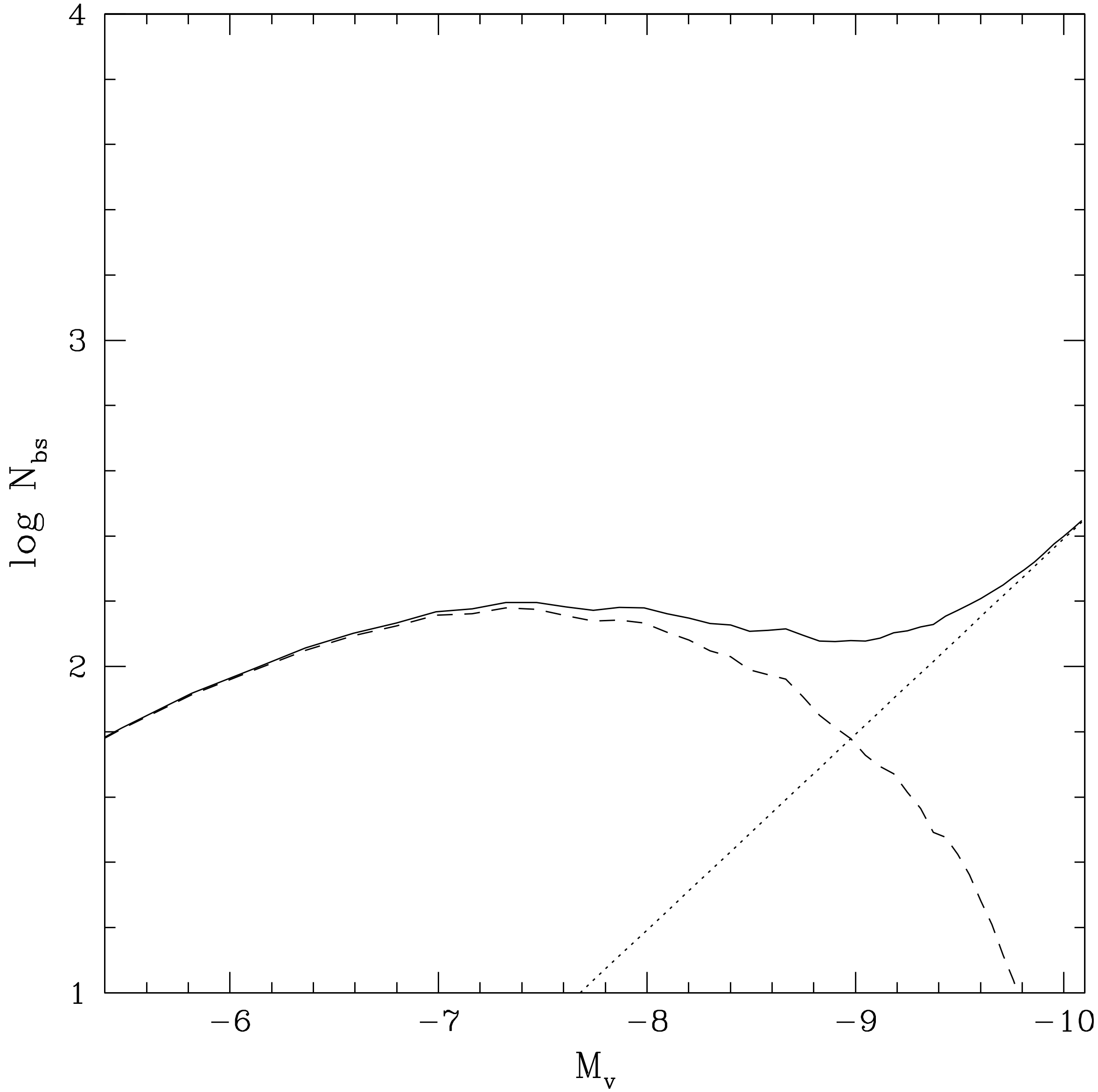
The effect of encounters on binaries



Encounters reduce the number of binaries which can make BSs today

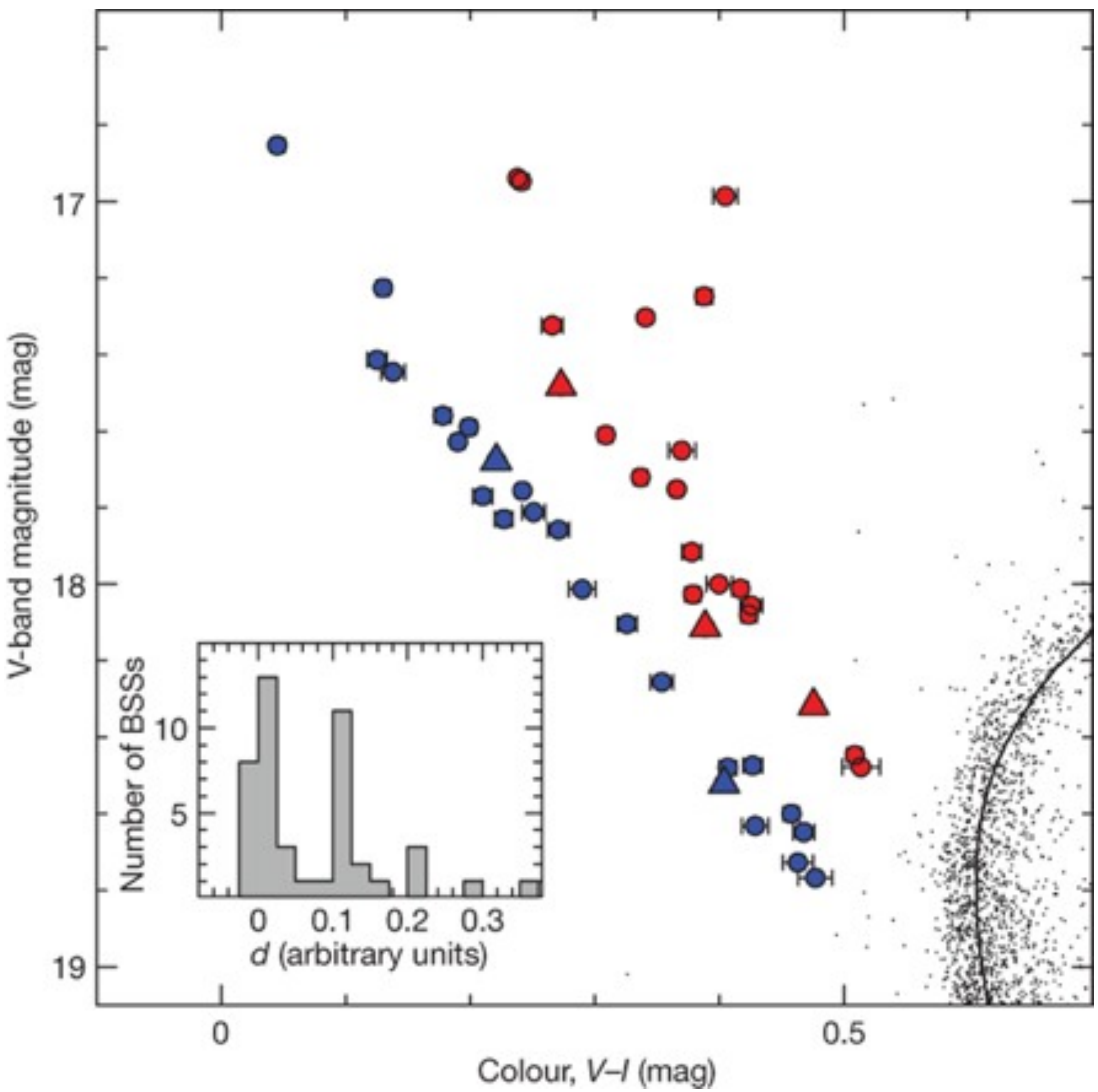
(Davies, Piotto, and De Angeli 2004)

Predicted BS numbers from both collisions and binaries



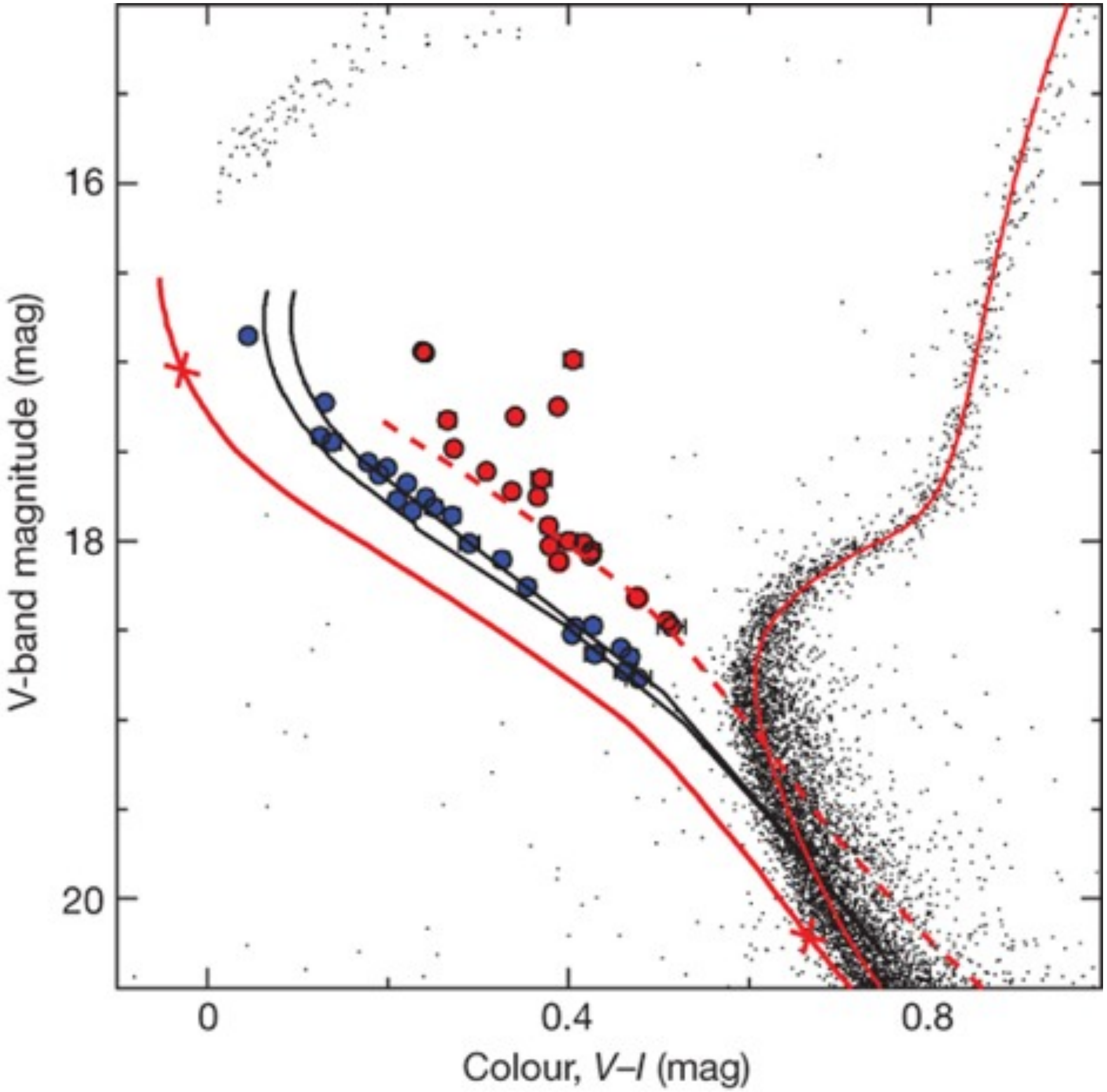
(Davies, Piotto, and De Angeli 2004)

Globular cluster M30



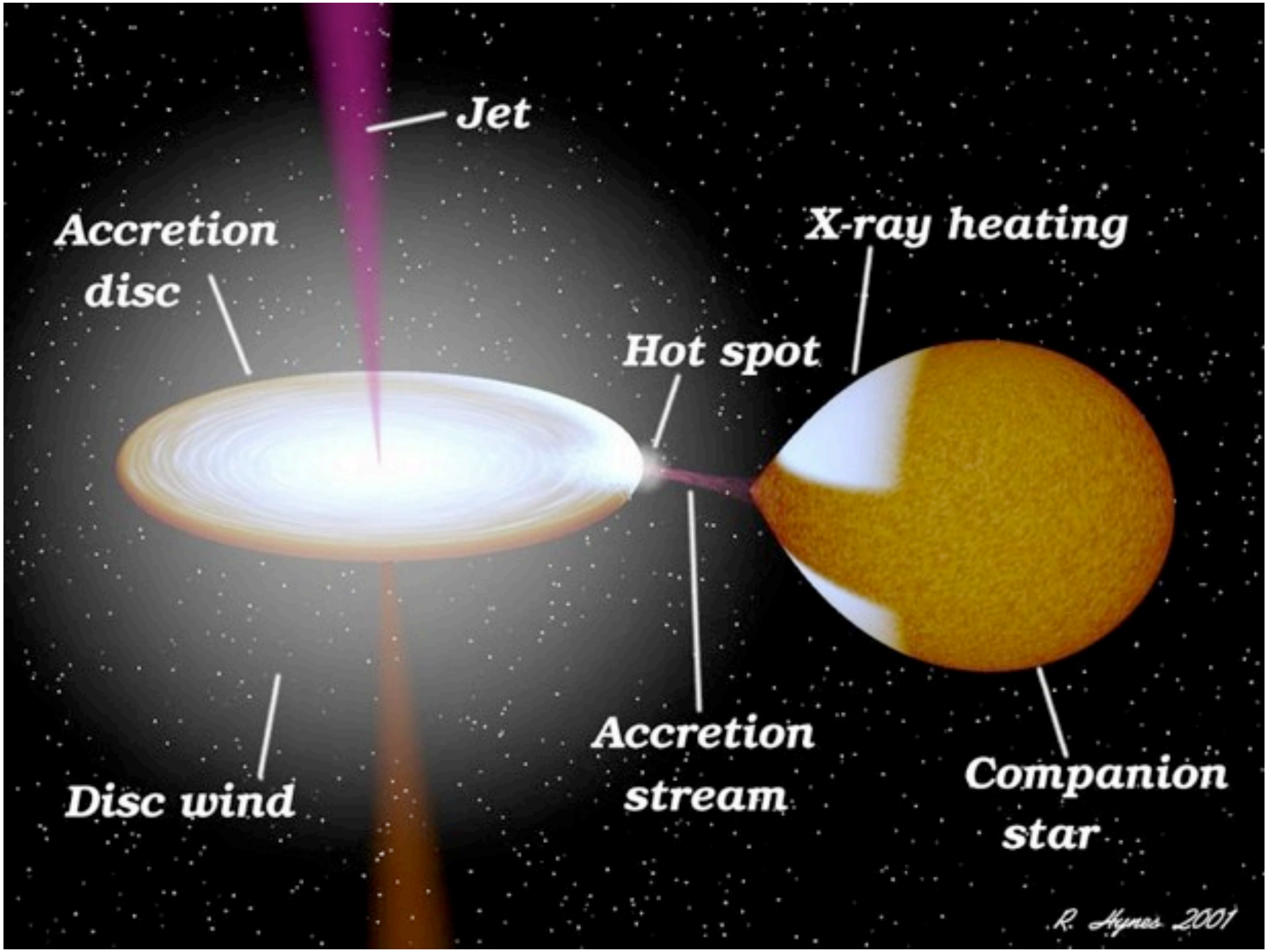
(Ferraro et al 2009)

Globular cluster M30

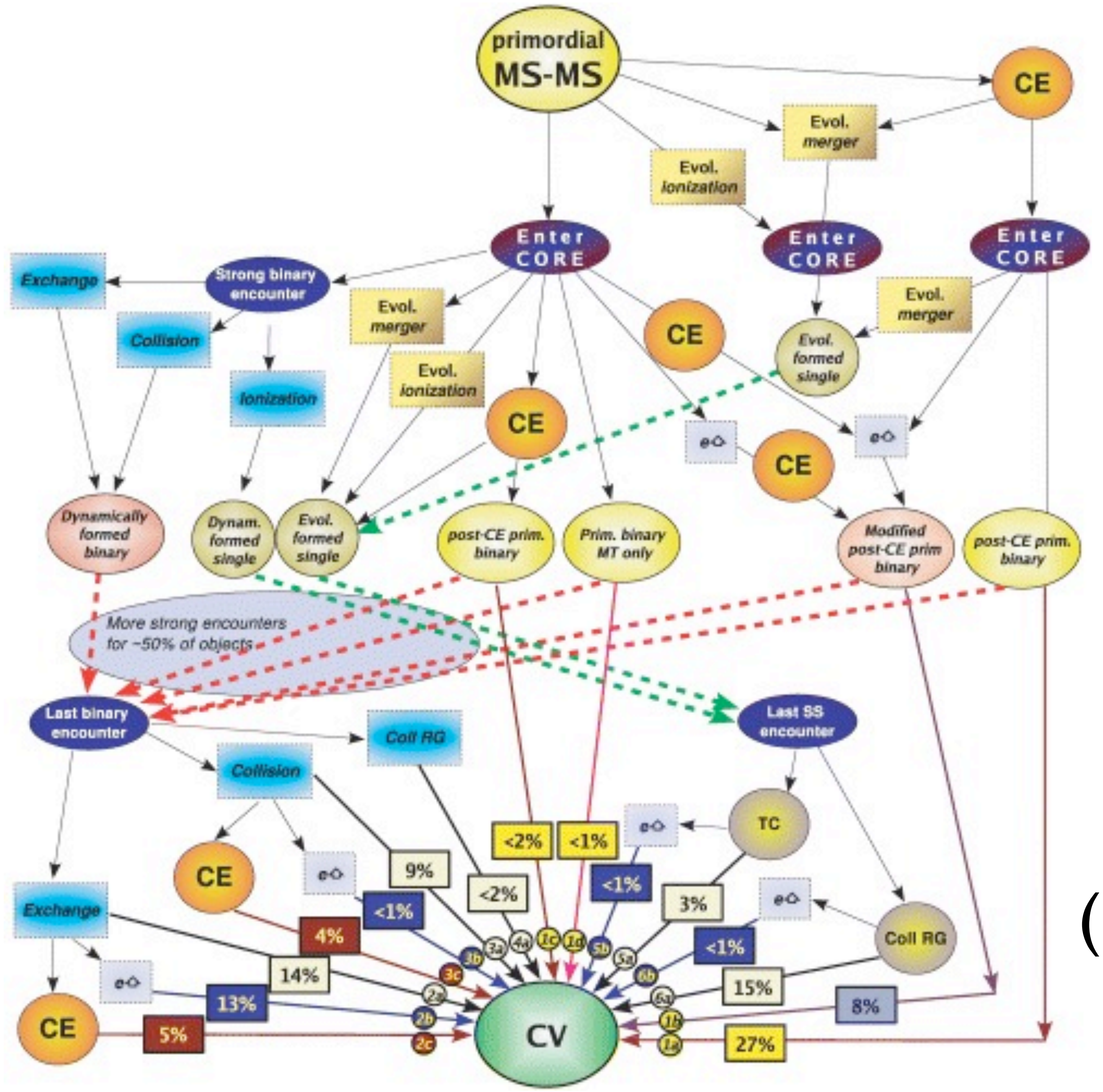


(Ferraro et al 2009)

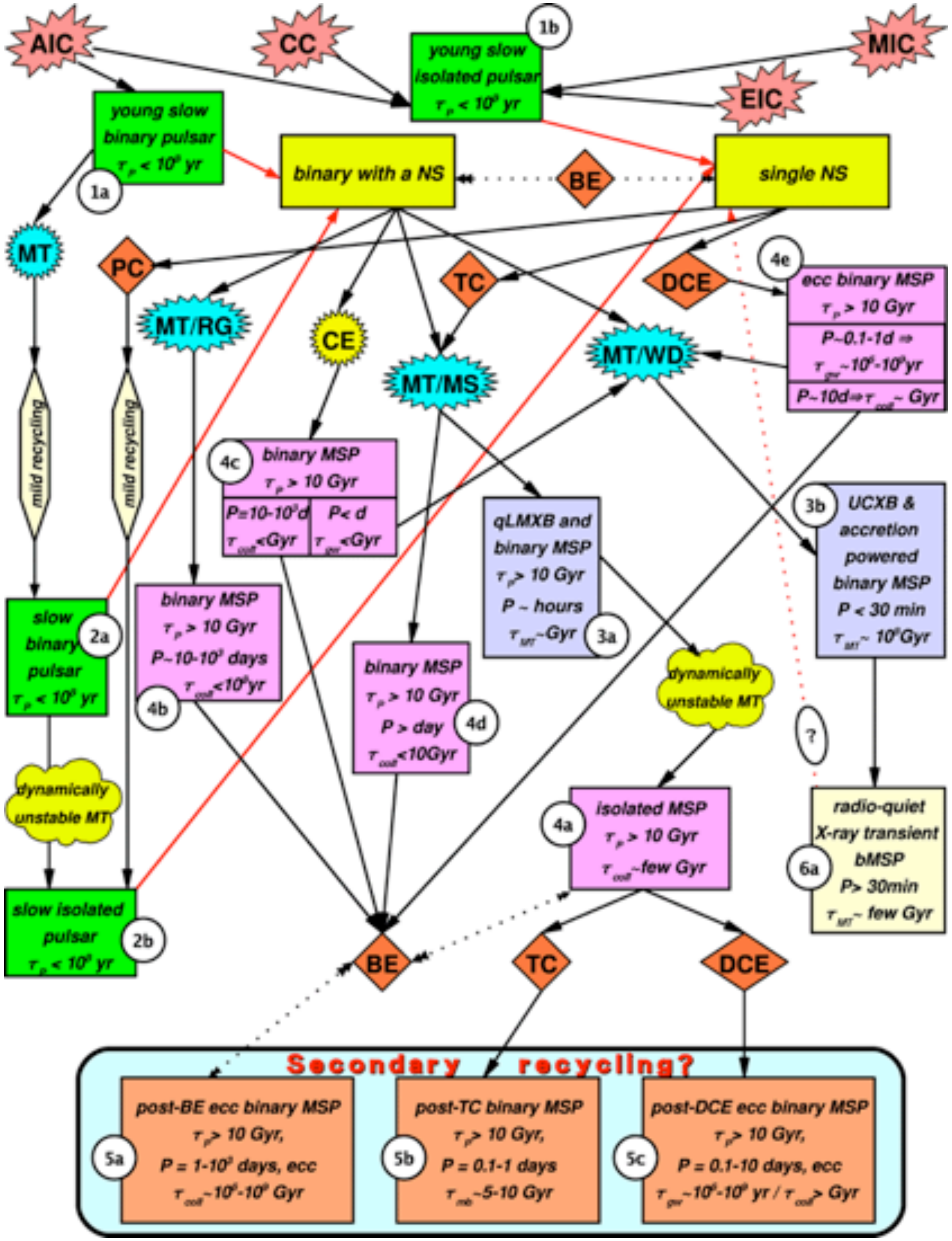
How to make an interacting binary



Making interacting binaries containing white dwarfs



(Ivanova et al 2006)



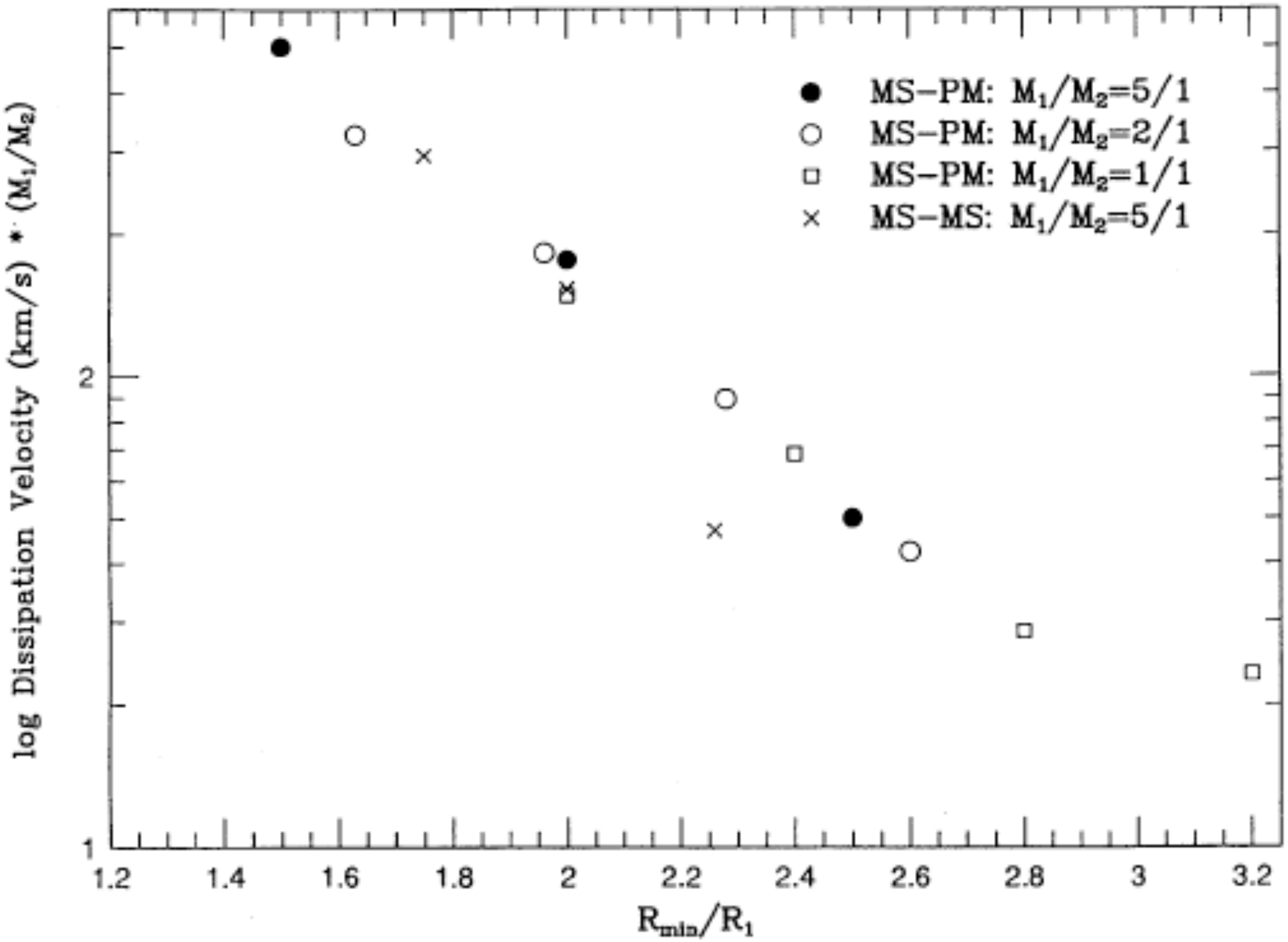
Making interacting binaries containing neutron stars

(Ivanova et al 2008)

How to make an interacting binary

- Tidal capture (single-single encounter)
- Collisions involving a red giant making a common envelope system
- Encounters between binaries and single stars which lead to clean exchanges

Tidal capture



Rcapt ~ 3Rstar

(Benz and Hills 1992)

Tidal capture II

Rcapt ~ 3Rstar (agrees with theoretical prediction of Fabian, Pringle and Rees 1975).

Post tidal capture, (might) get tidal circularisation. System put into circular orbit separation ~6 Rstar.

Problem: heating in star may cause it to expand forming a merged system rather than a binary.

A high-velocity collision between a red giant and a black hole

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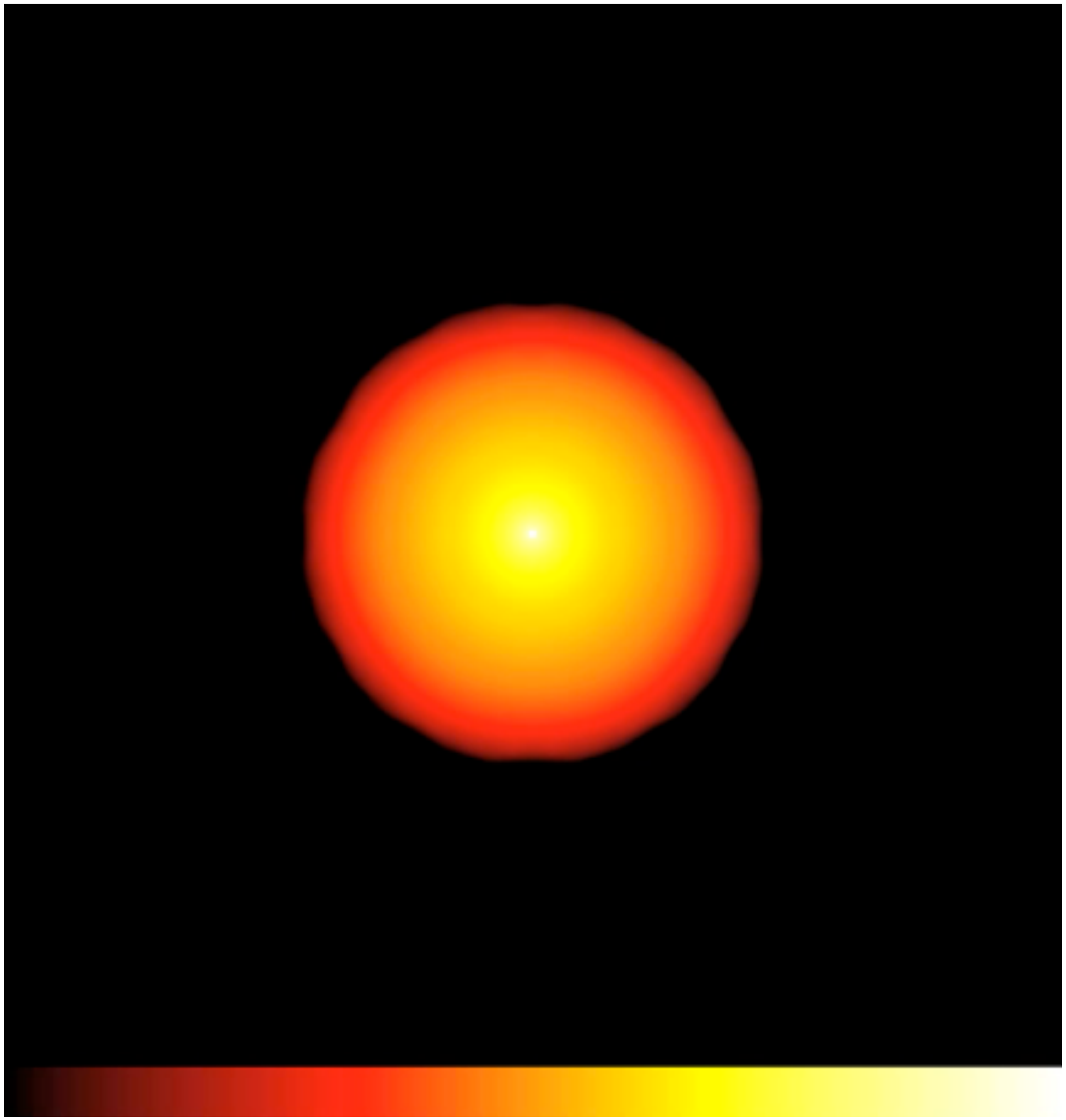
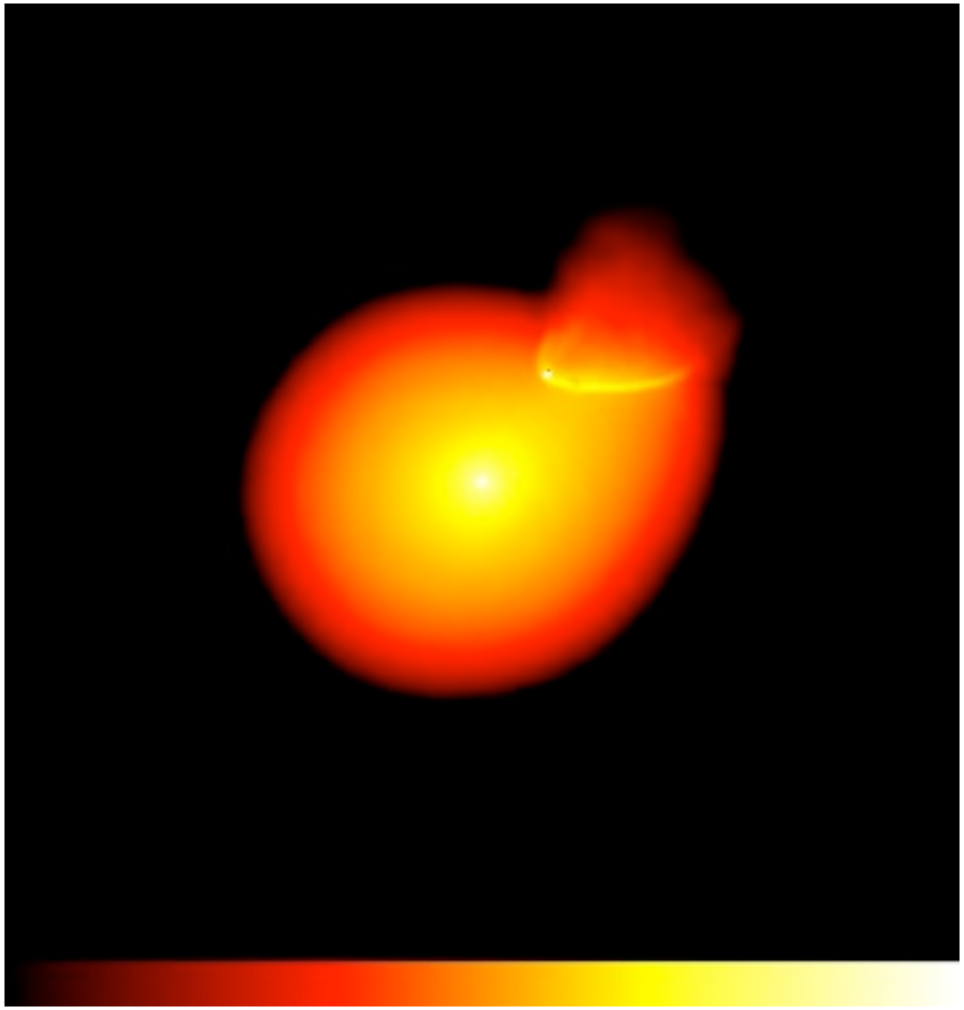
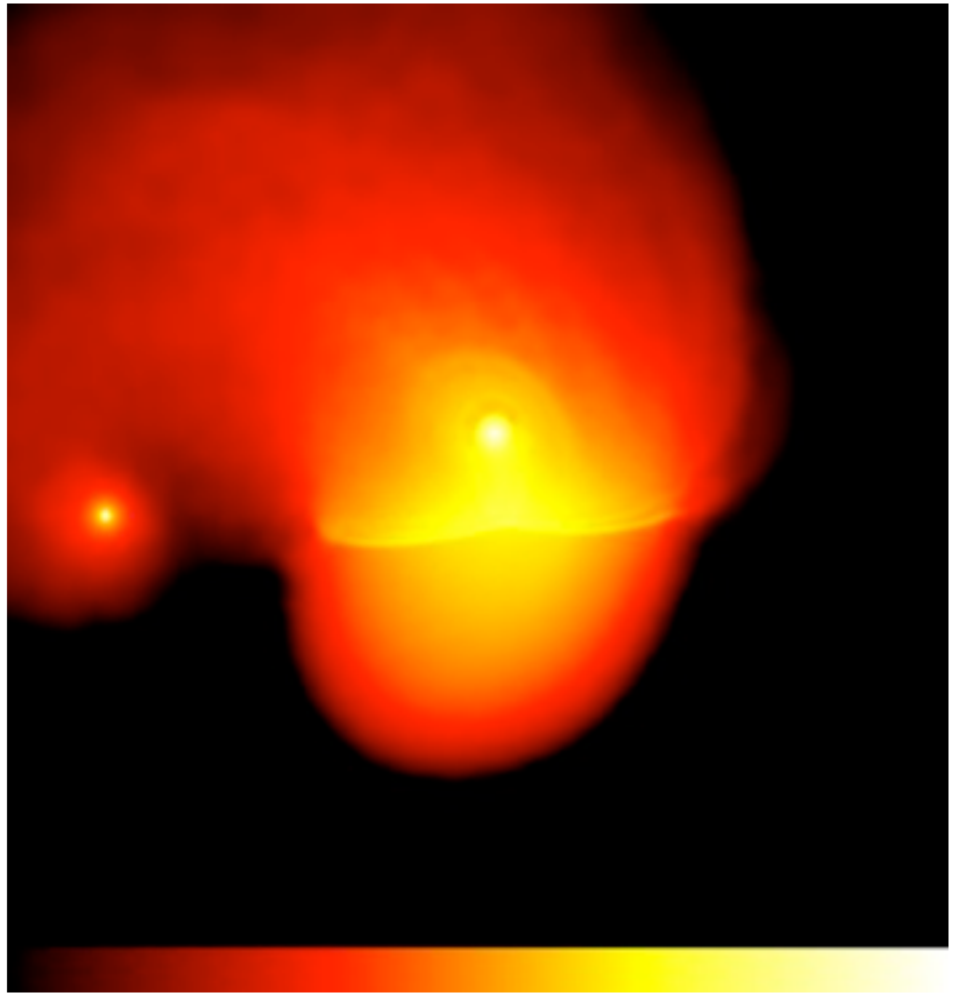


A high-velocity collision between a red giant and a black hole





Outcome of a lower-velocity red giant collision

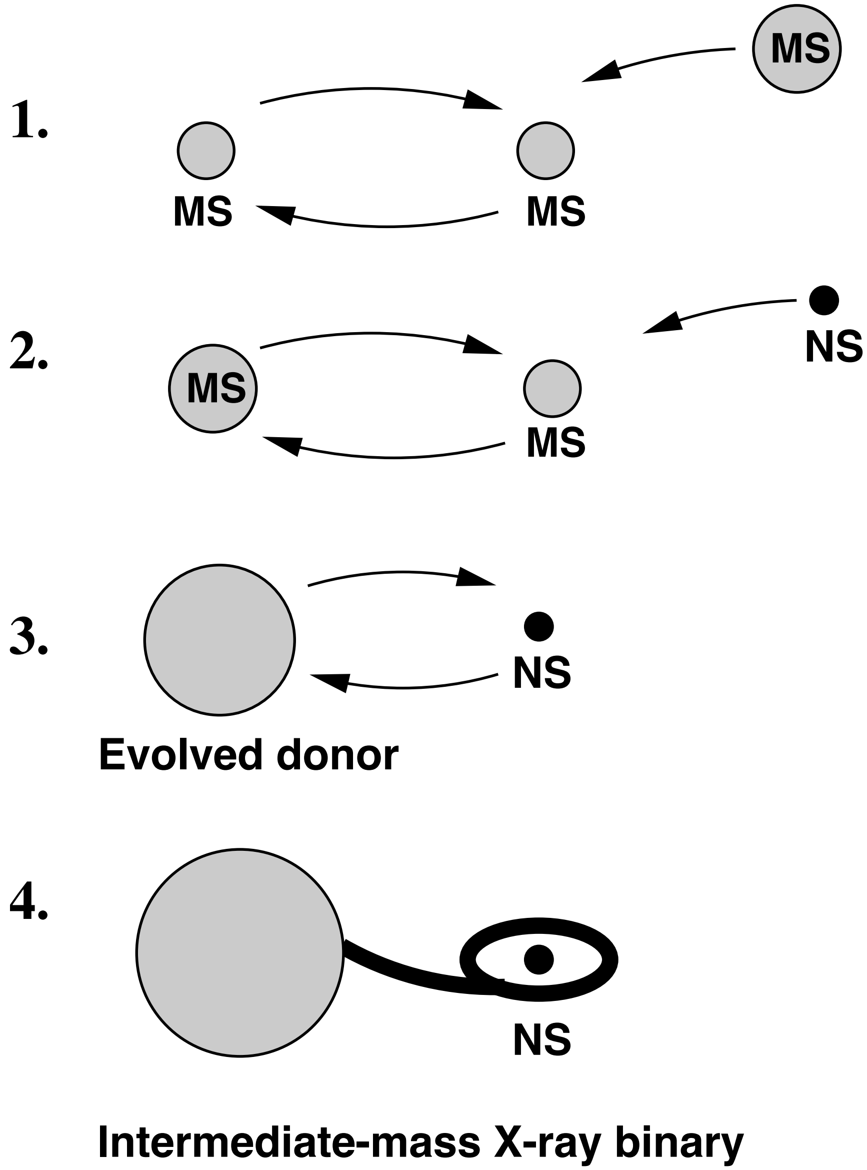
Collision leads to the formation of a *common-envelope system*, with intruder and red-giant core orbiting inside envelope of gas.

Intruder and red-giant core (effectively a white dwarf) spiral together as envelope is ejected.

$$\frac{G(M_c + M_e)M_e}{\lambda d_i r_l} = \alpha_{\rm ce}\left(\frac{GM_2M_c}{2d_f} - \frac{GM_2(M_e + M_c)}{2d_i}\right)$$

Final binary contains a white dwarf and the intruder star. Can reduce the separation from ~100Rsolar to ~10 Rsolar.

Making binaries via binary-single encounters



(Davies & Hansen 1998)