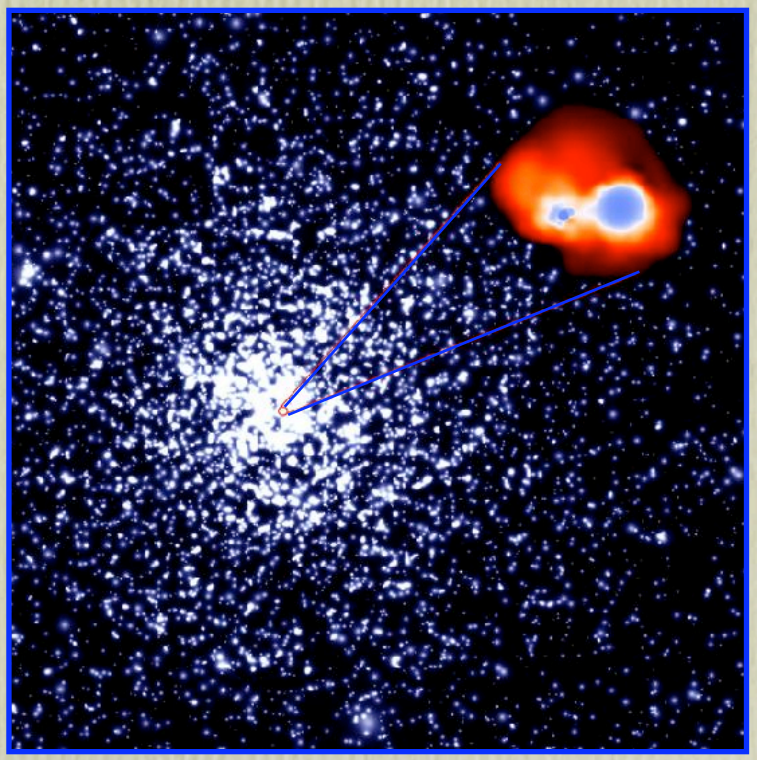
Stellar collisions in young star clusters



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Young star clusters

few Myr old

Mass $10^{4\text{-}5}$ M_{sun}

Density $10^{5\text{-}6}$ M_{sun}/pc^3

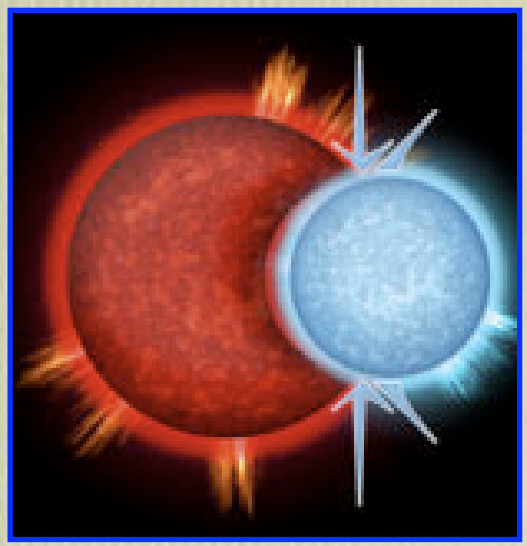
Arches cluster

Quintuplet cluster

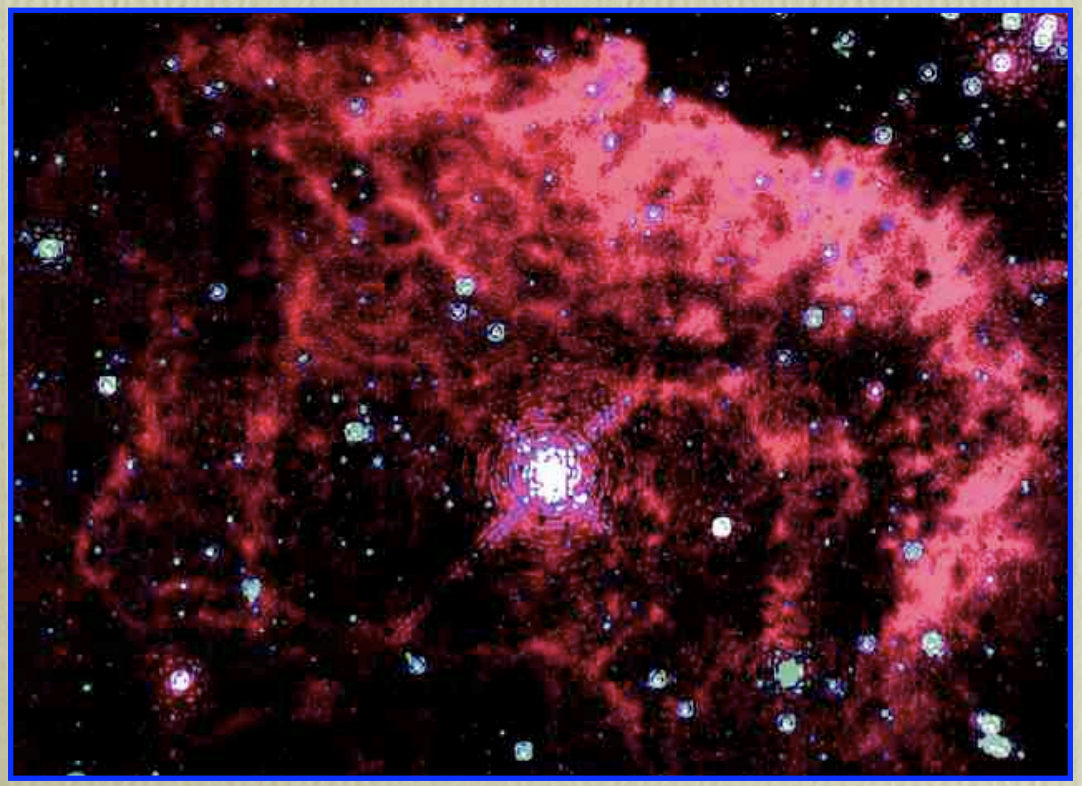
Presence of massive stars

Massive binaries

Stellar collisions



Pistol star



Massive blue stragglers

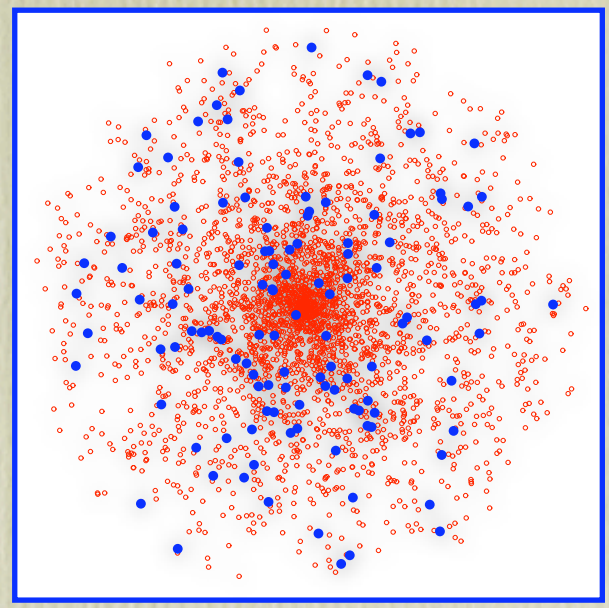
Runaway collisions

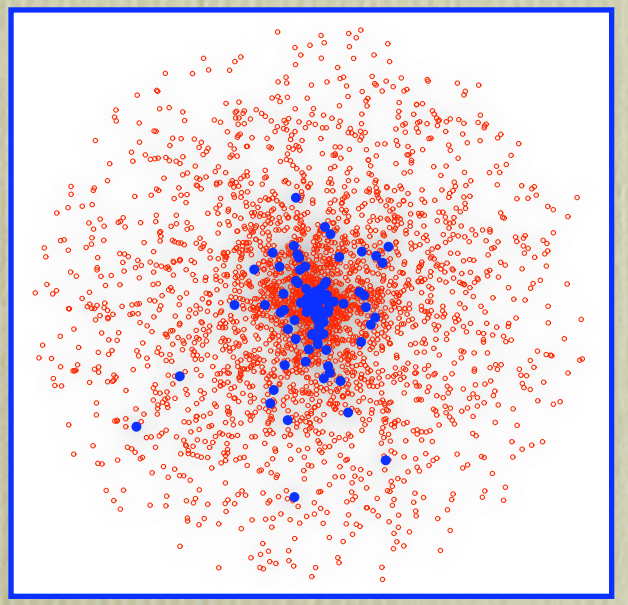
Formation of an IMBH

A route towards a collision

Young dense star cluster

Mass spectrum



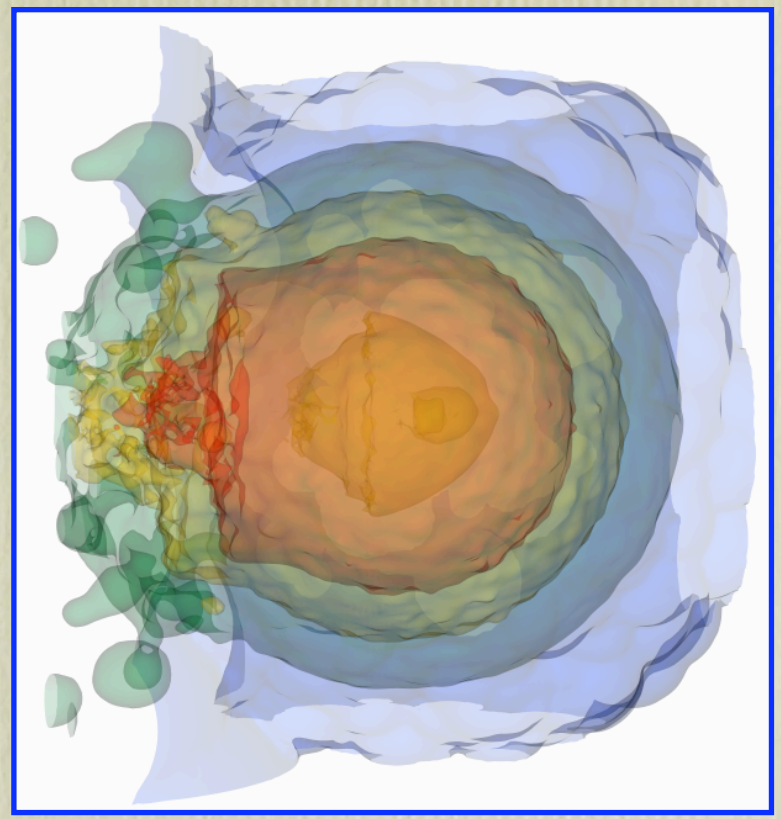


Mass segregation

Core enhanced with massive stars

The first collision

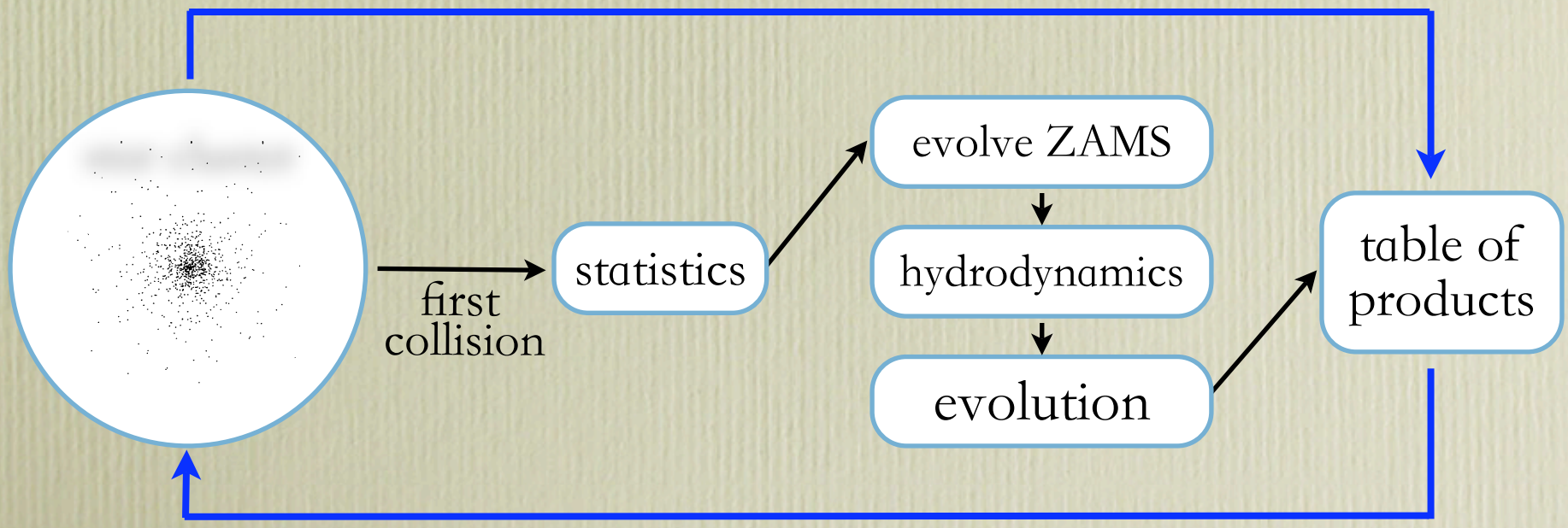
- Initial conditions
  - Configuration
  - Masses and ages of colliding stars
  - Relative velocity
  - Impact parameter
- Structure and evolution



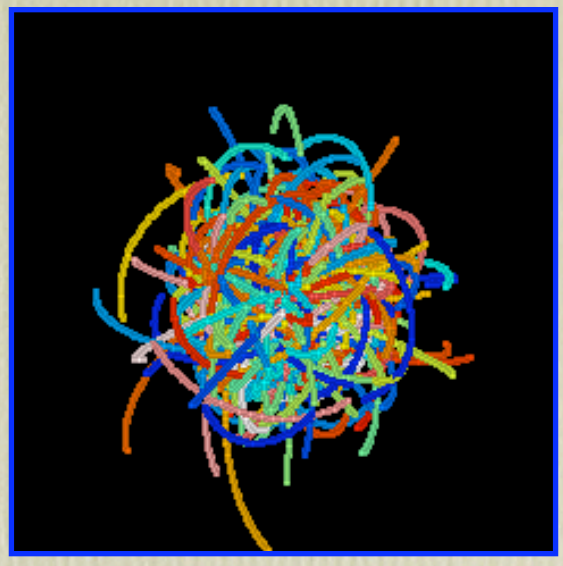
Studying the first collision

Tools

- N-body simulations
- Hydrodynamical simulations
- Stellar evolution



N-body simulations



N = 24576 stars

King model $W_0 = 9$

No primordial binaries

Mass function, 0.1 - 100 M_{sun} (Kroupa`01)

Range of half-mass radii (0.05 - 0.75 pc)

Stellar evolution

Time of the collision

Expected:

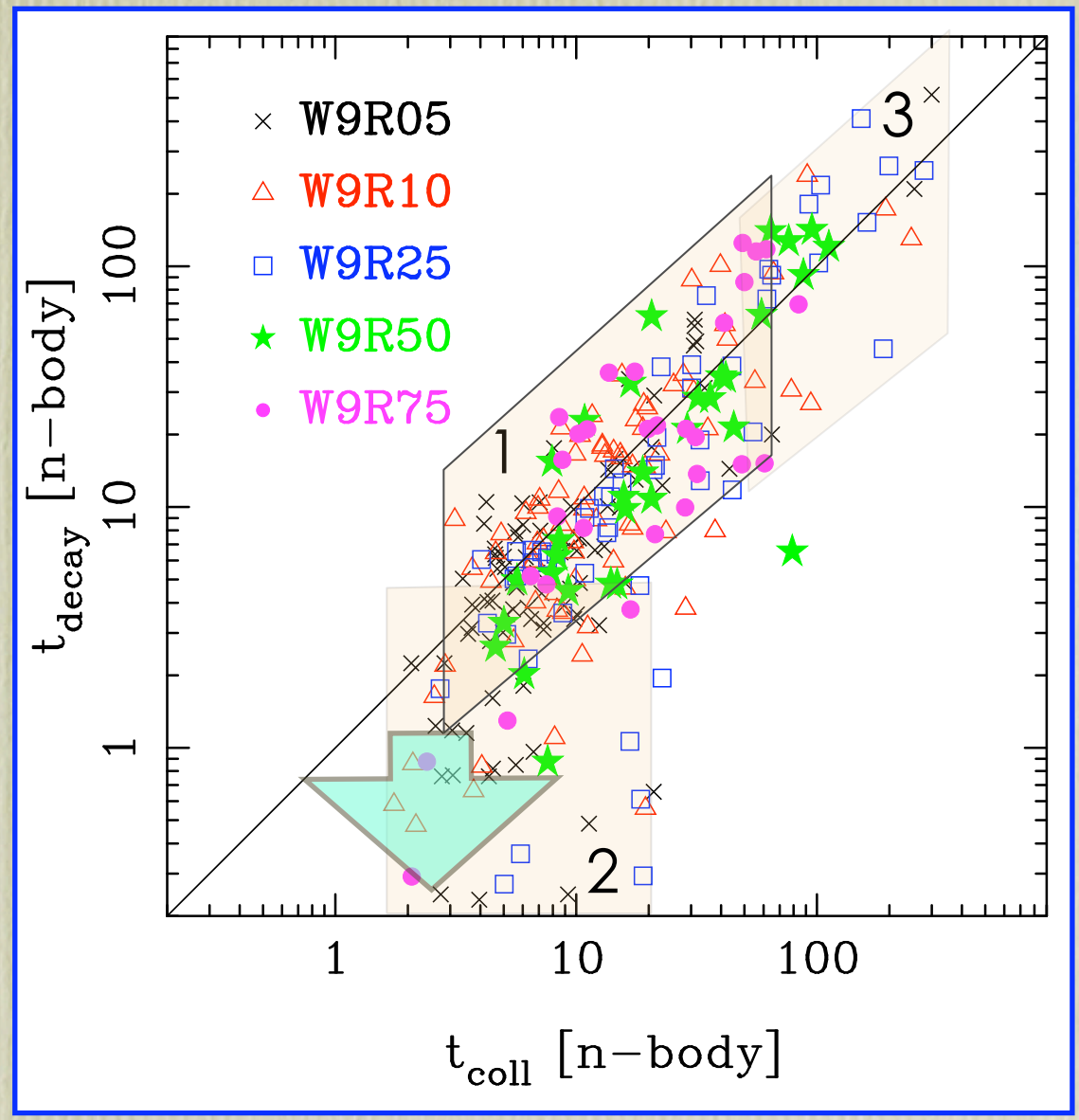
$t_{coll} \sim 100\ (R_{cl}/pc)$

Simulations:

Reg. 1: $t_{coll} \sim t_{decay}$

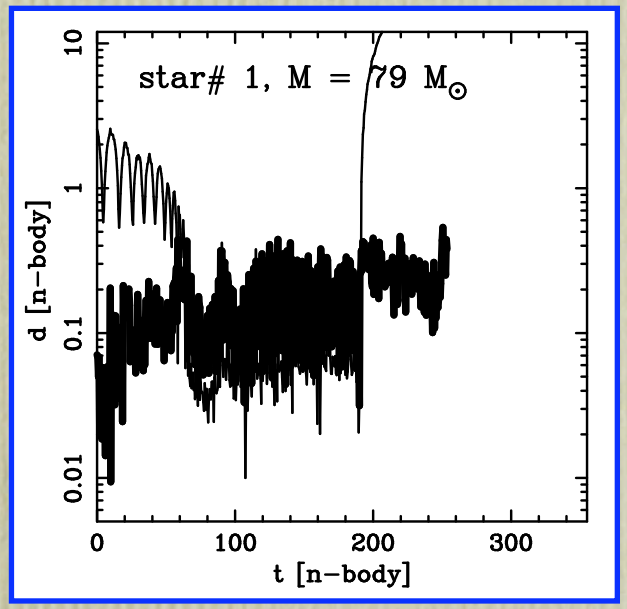
Reg. 2: $t_{coll} \sim$ const

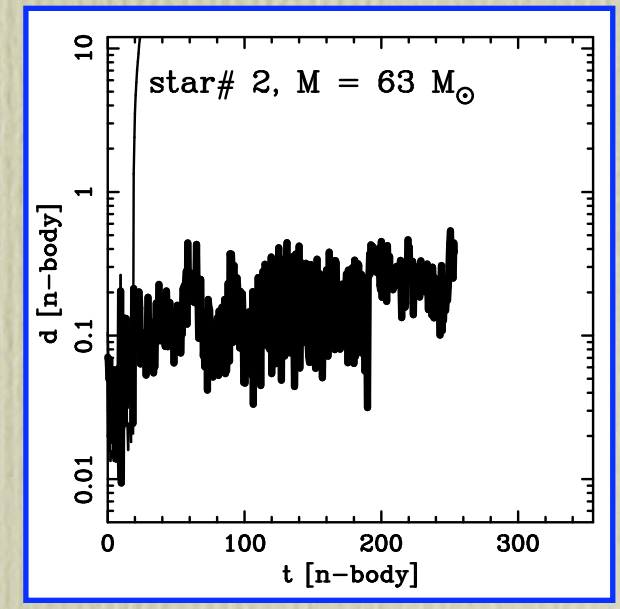
Reg. 3: binary ejection

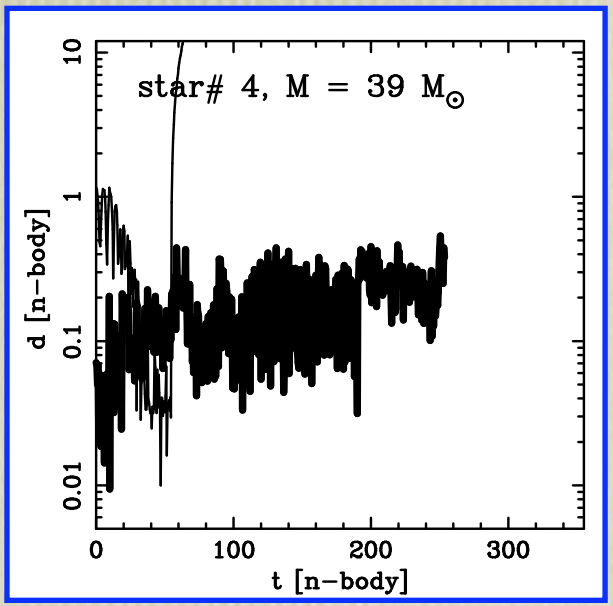


Ejection of massive binaries

When $M_{cl} > 10^4\ M_{sun}$ massive binaries are ejected







Collision is delayed

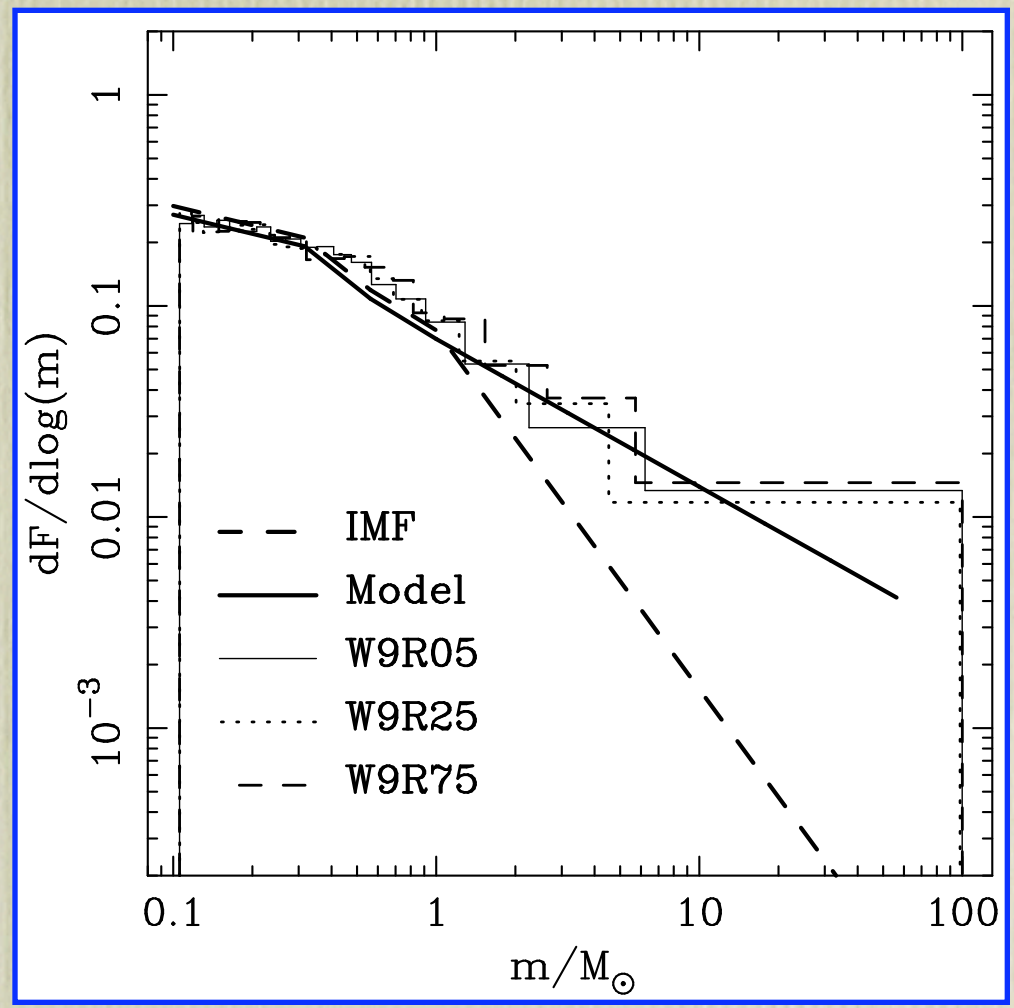
Mass function in the core

The core is enhanced with massive stars

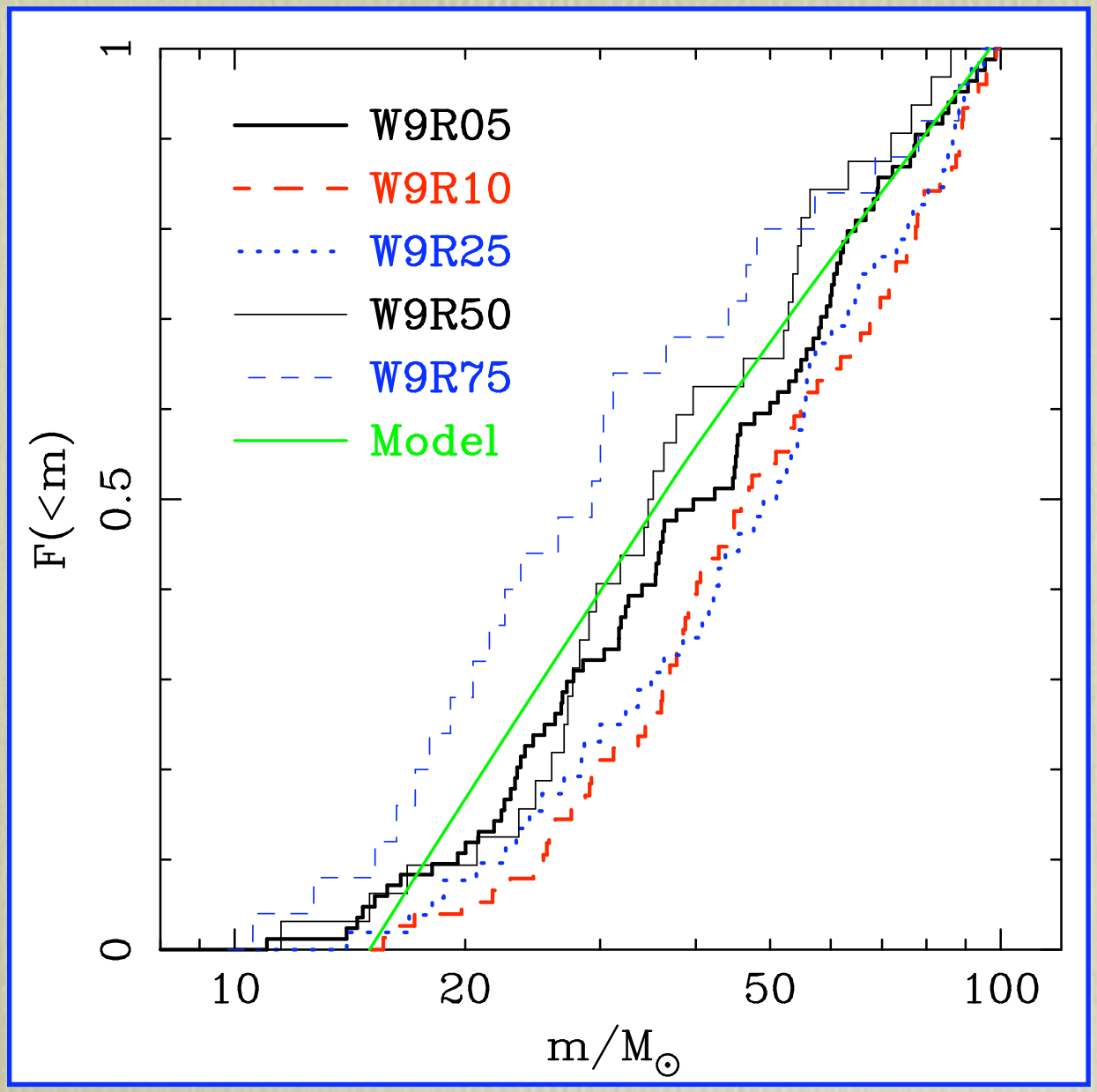
$$t_{\rm df} \propto \frac{1}{m}$$

Core mass function flattens

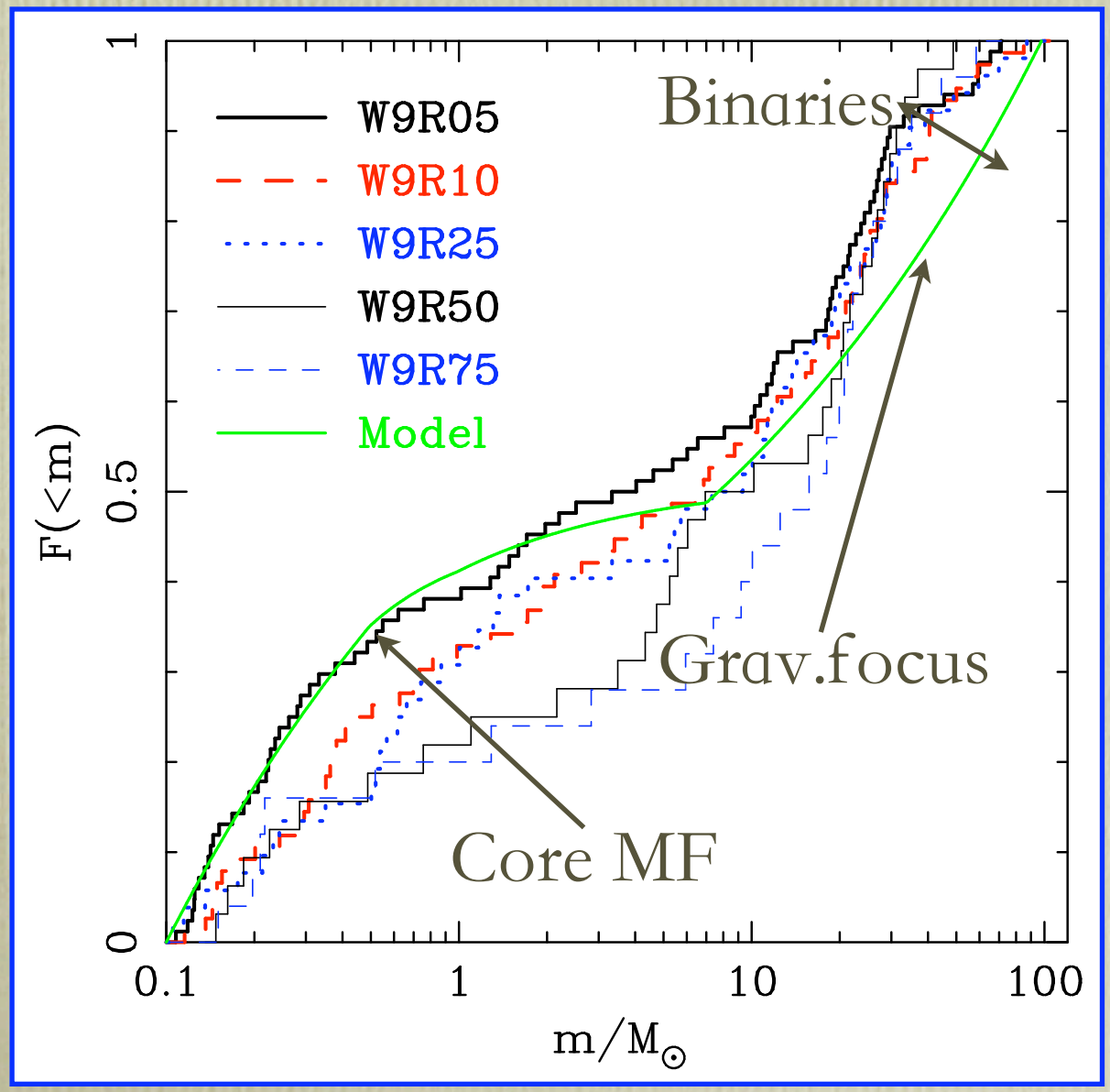
$$\mathcal{N}_{\rm c}(m) \propto \begin{cases} \mathcal{N}_0(m), & m < 2\langle m_0 \rangle, \\ m\mathcal{N}_0(m), & \text{otherwise.} \end{cases}$$



Colliding stars : primary



Colliding stars : bullet



Scenario:

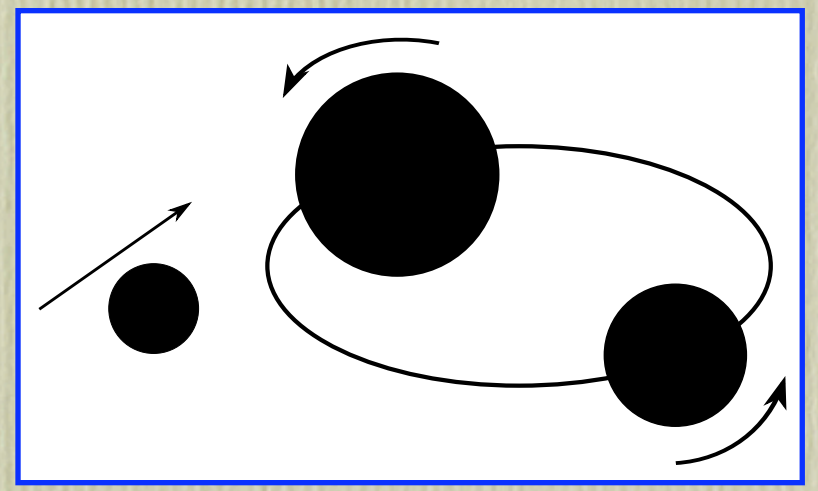
Mass segregation

Enhanced core mass function

Binary formation

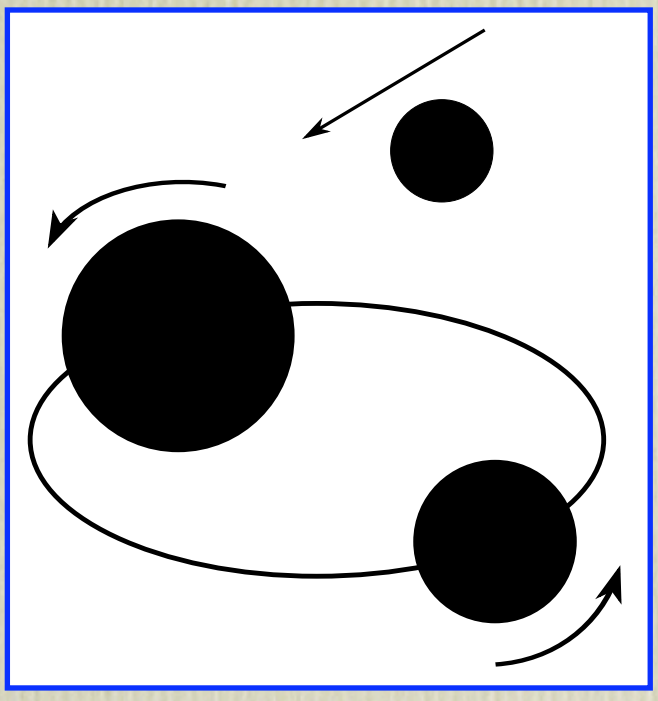
Bullet hits the primary

Collisions with binary

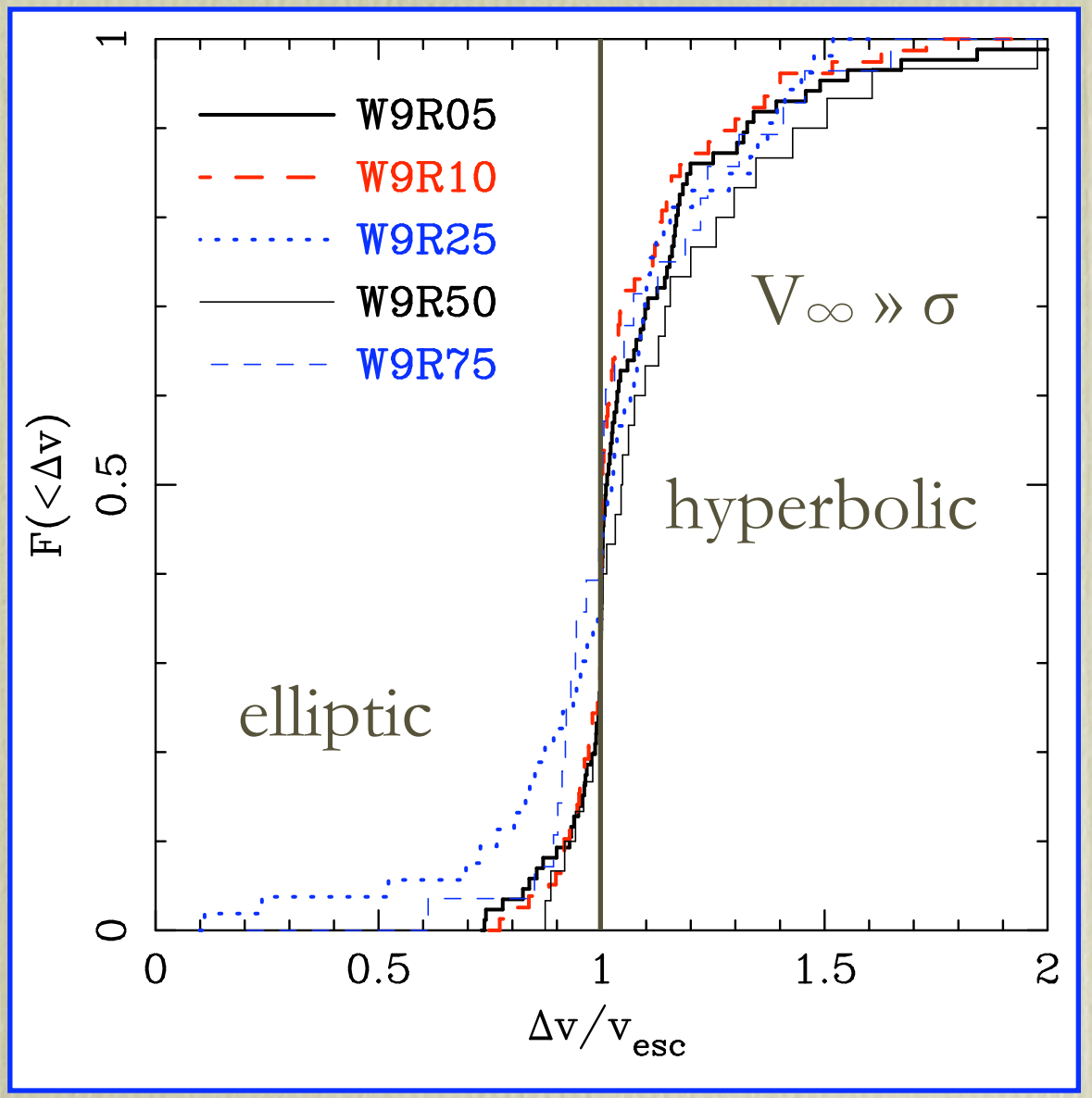


$V_{rel} > V_{esc}$
energetic or hyperbolic collisions

$V_{rel} < V_{esc}$
elliptic collisions



Collisions : relative velocity



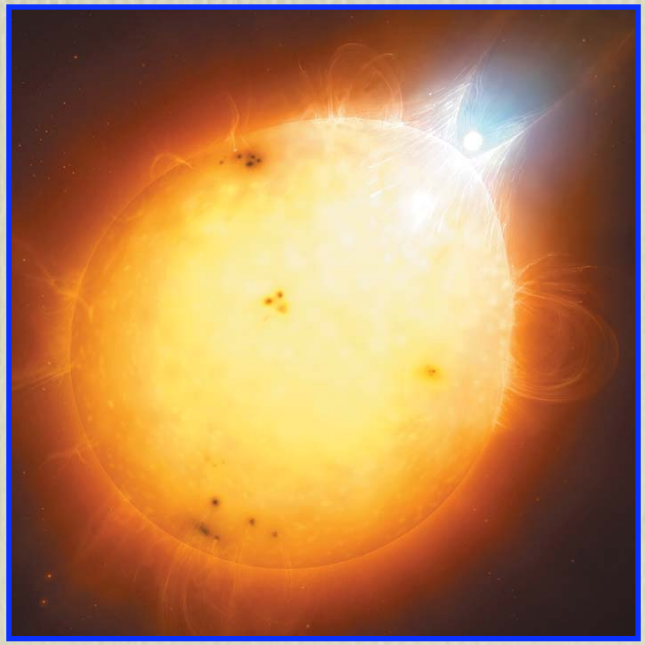
Conclusions

A cluster may experience at least one collision

Occur between a binary and a single star

Between massive stars

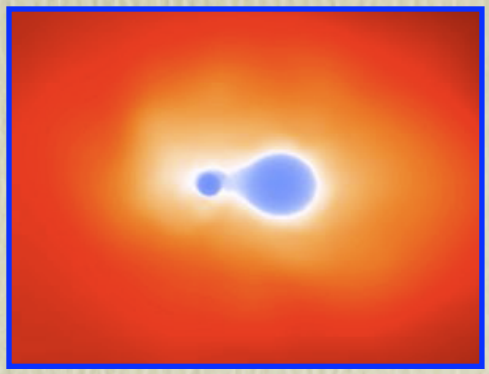
Are energetic

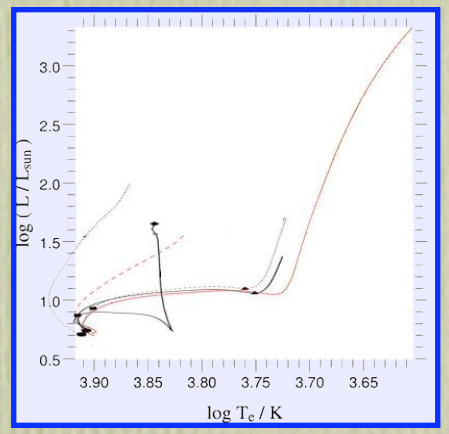


Future work

Hydrodynamical simulations

- Mass loss
- Structure of a collision product



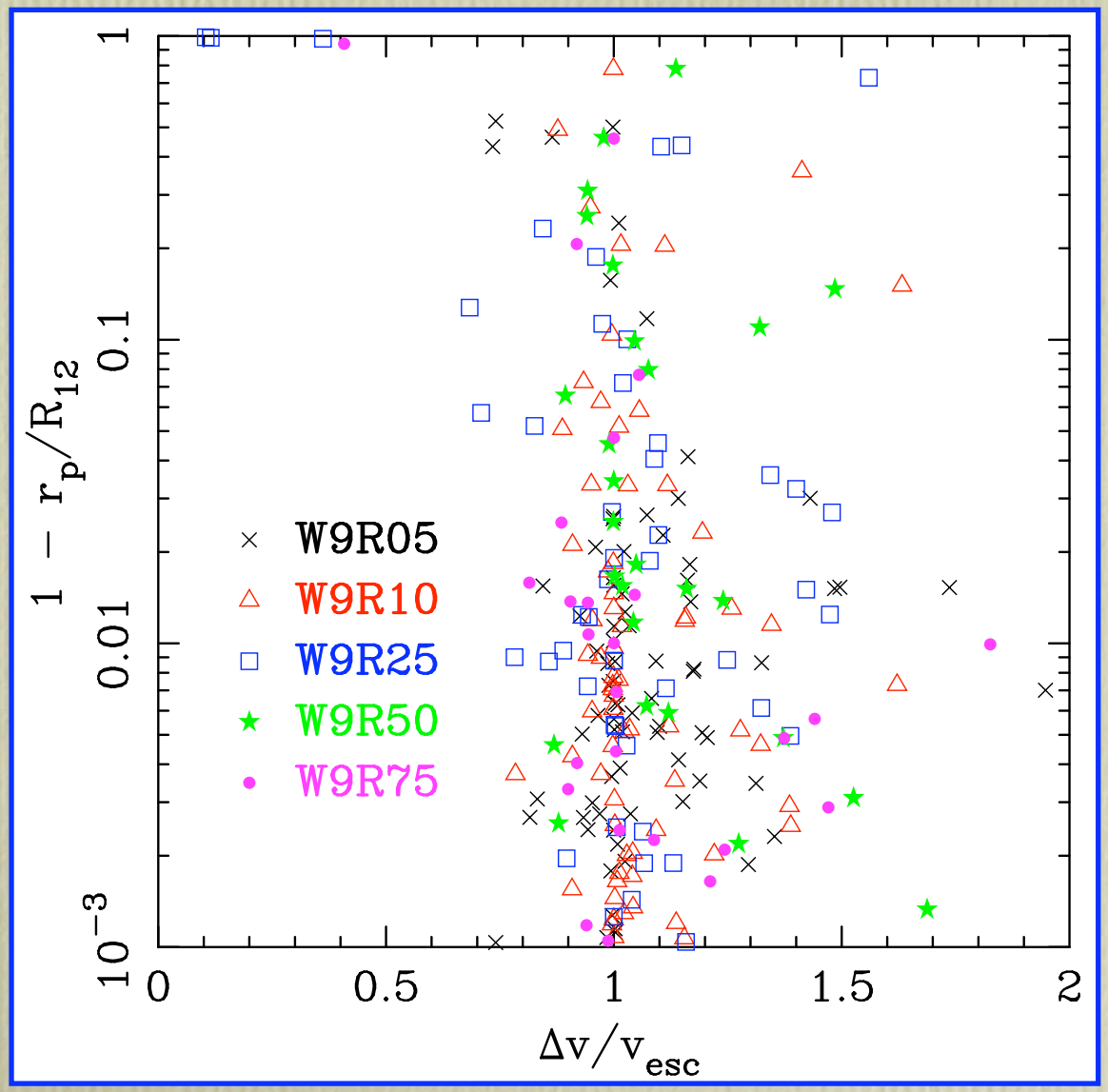


Evolution of the product

- Lifetime of the collision product
- Observational properties

Feedback to N-body simulations

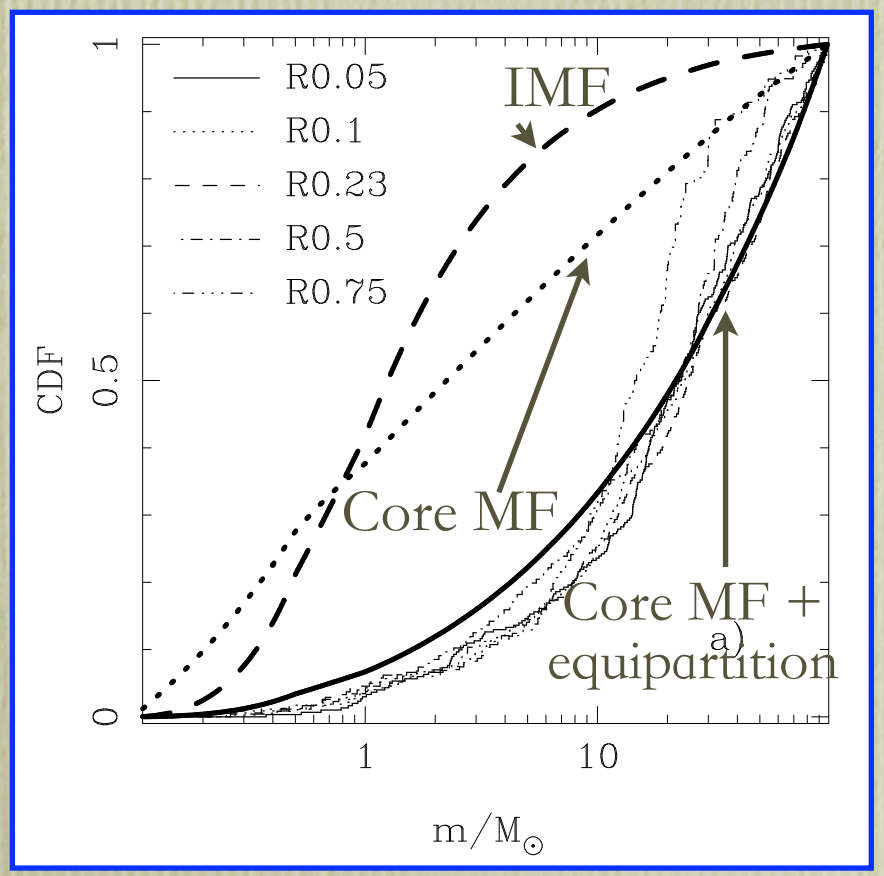
Collisions : impact parameter

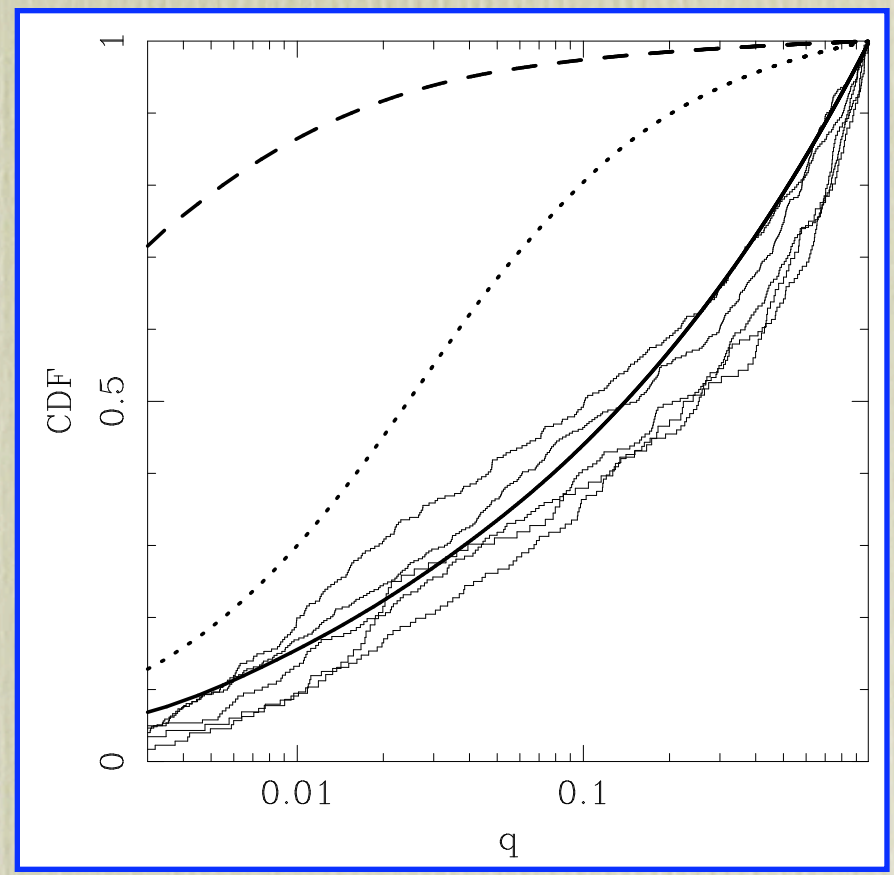


Collisions are both energetic and grazing

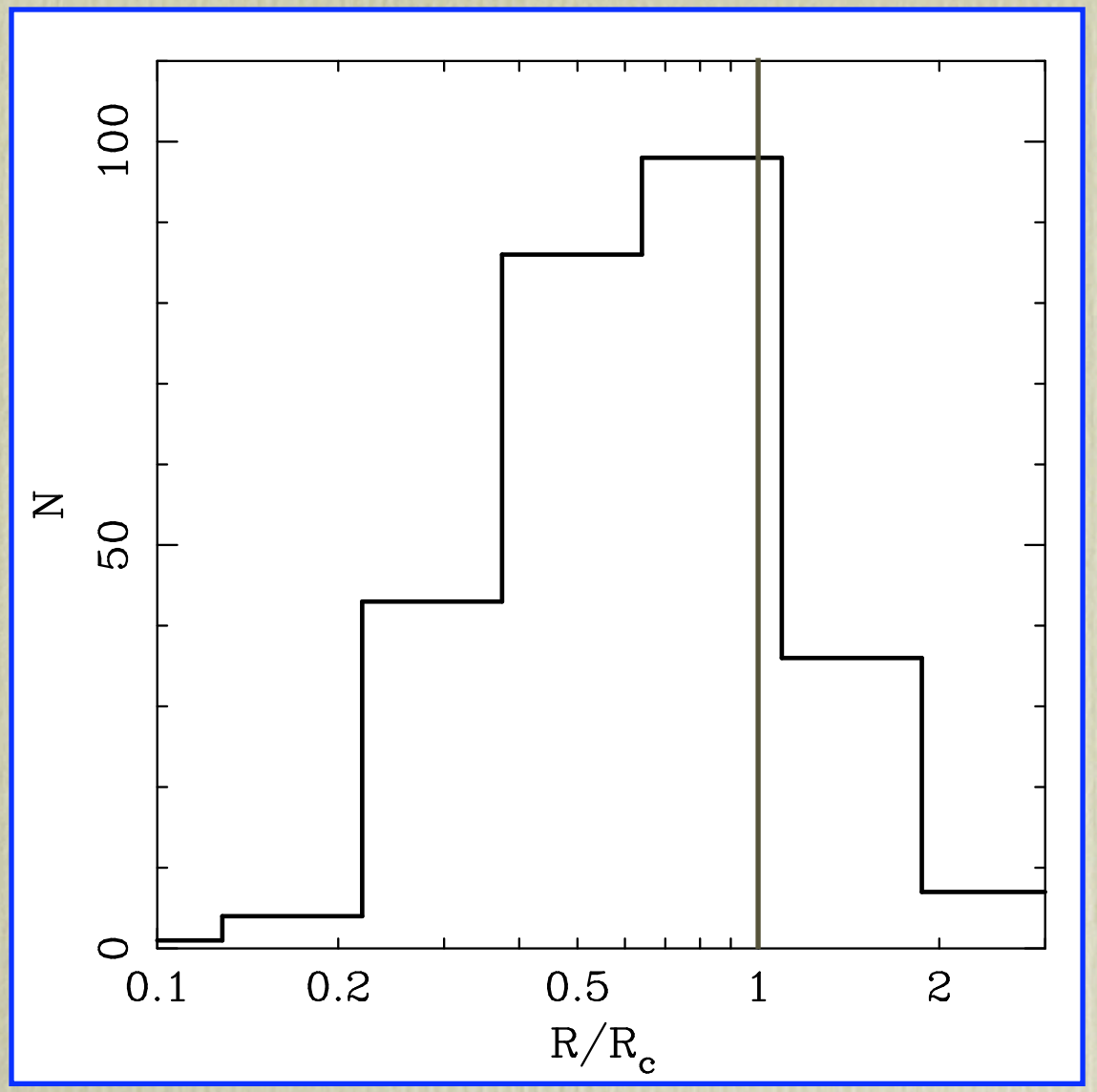
Binary formation

Binaries are formed by 3-body encounters





Location of the collision



Time of the collision