Collisions and Close Encounters within Globular Clusters

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Lecture 3

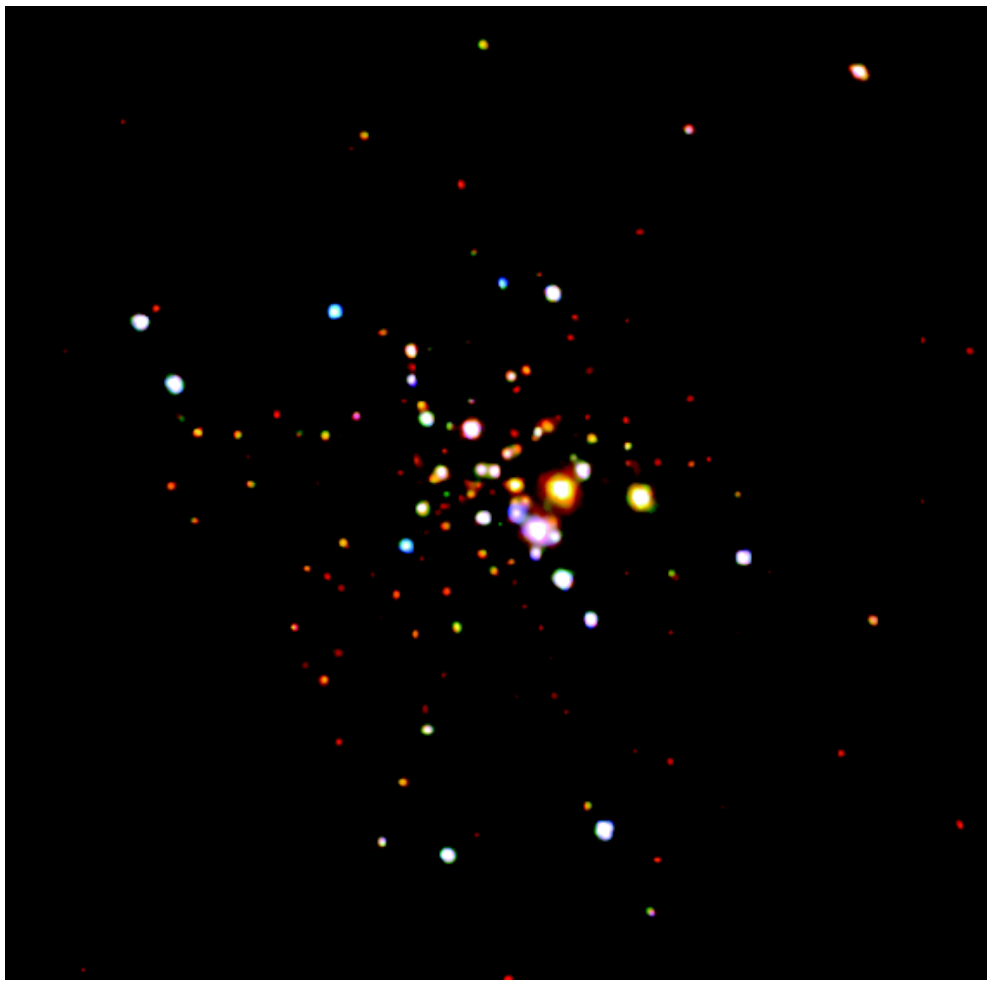
- Production of stellar exotica
- Cataclysmic variables
- X-ray binaries and millisecond pulsars
- Compact binaries

Optical image of 47 Tuc

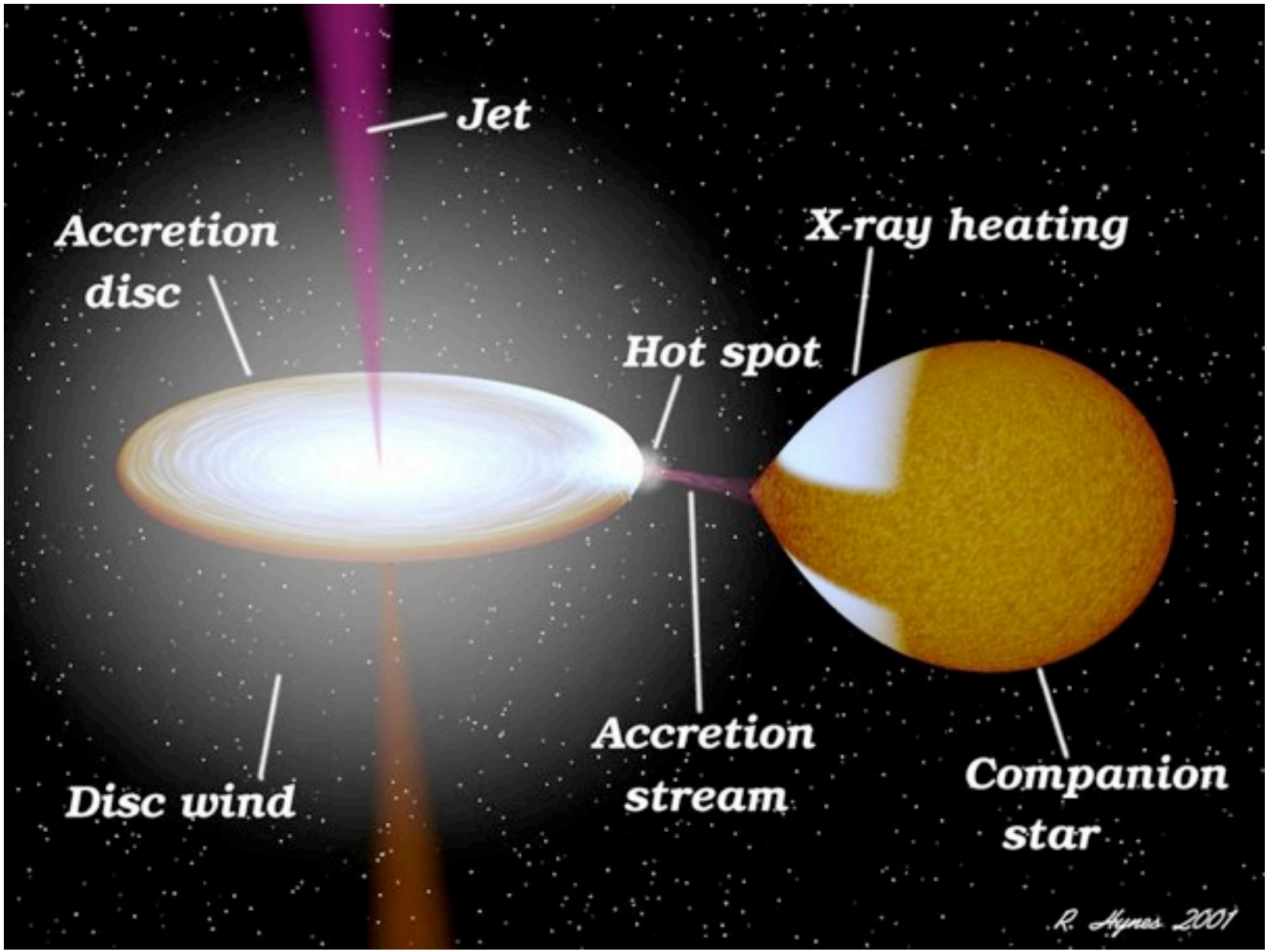
Globular Cluster 47 Tucanae
(FORS/VLT)

ESO PR Photo 20/06 (8 June 2006)

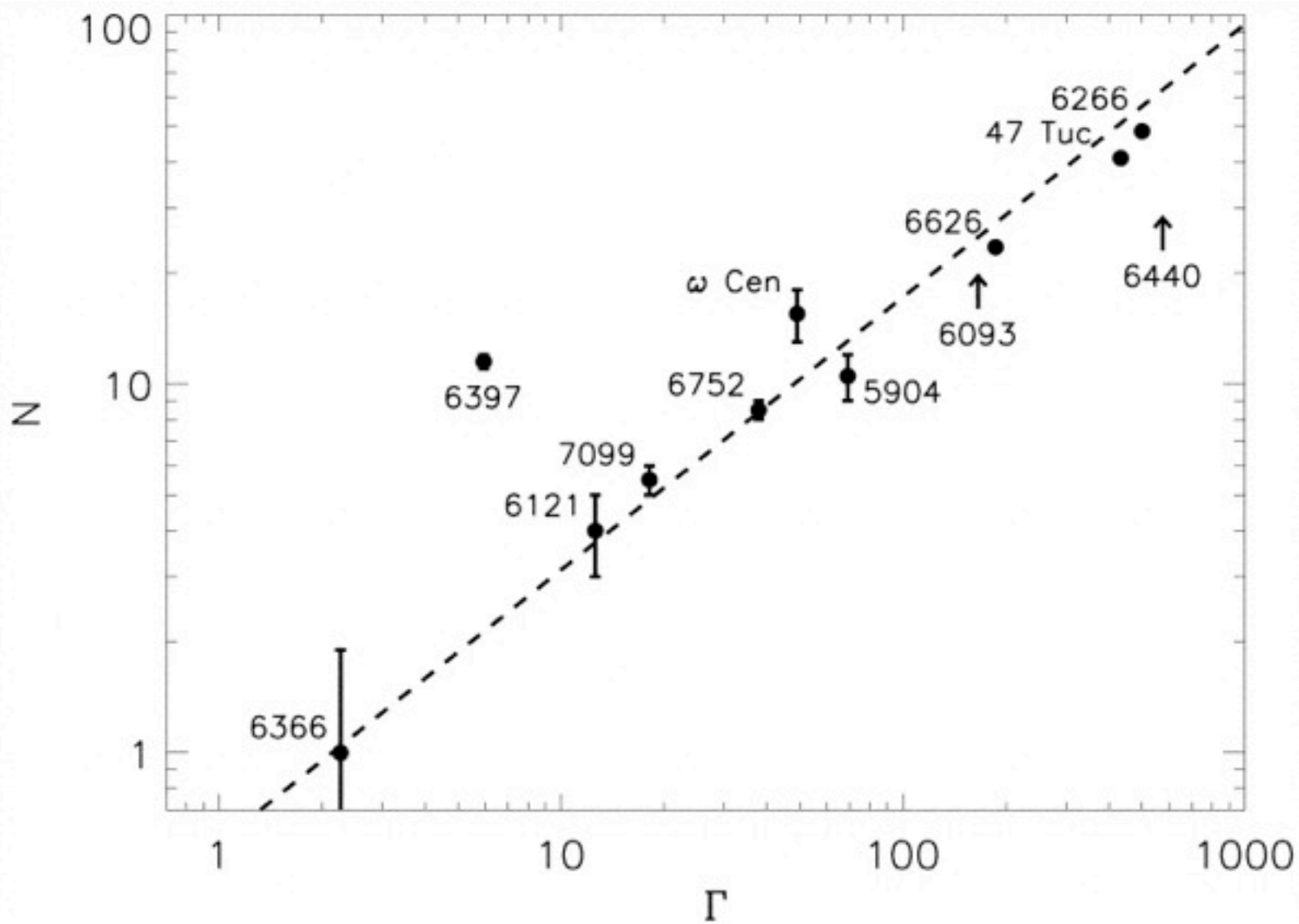
X-ray Image of 47 Tucanae (Heinke et al 2005)



An interacting binary

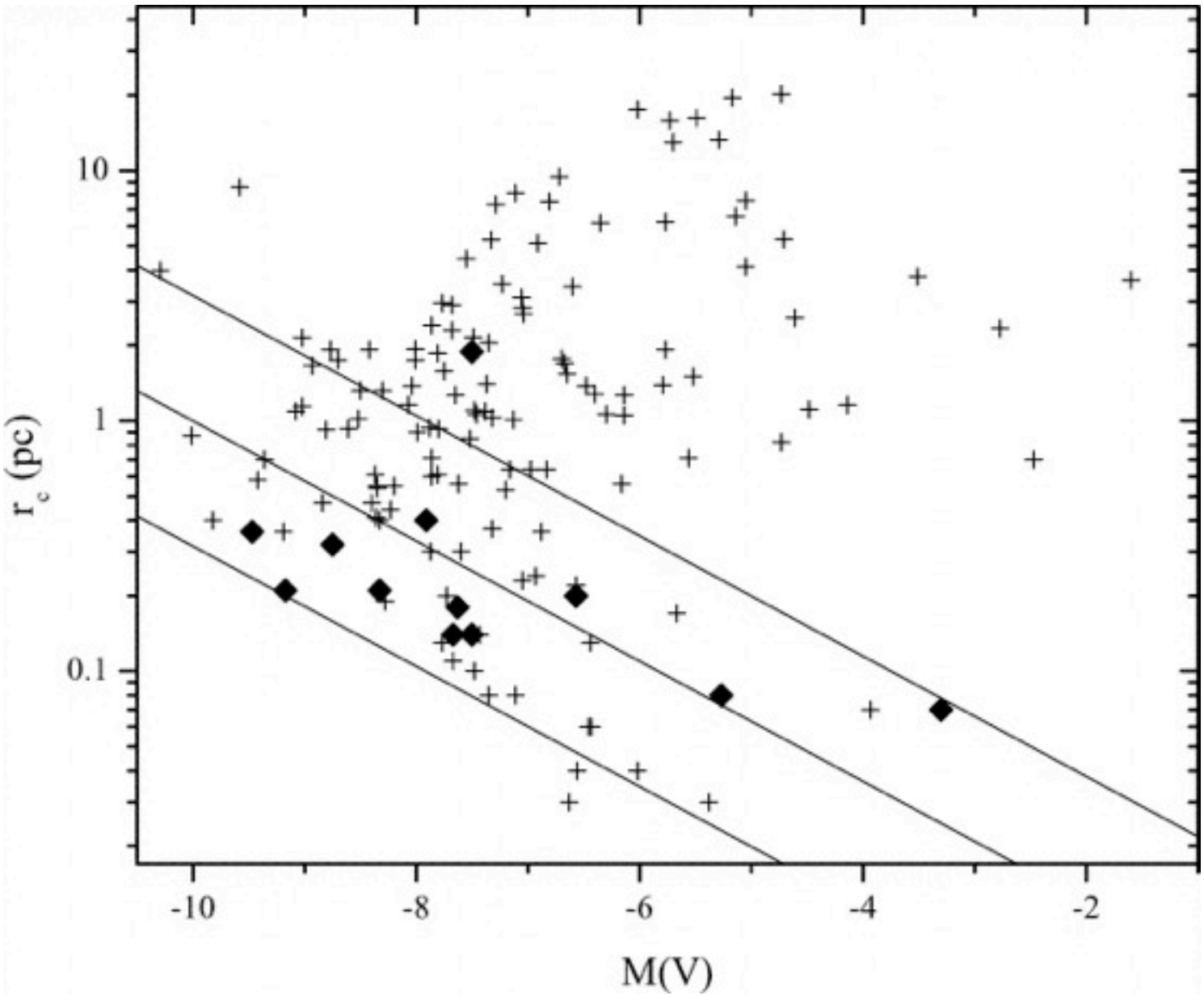


Evidence that interacting binaries are made dynamically



(Pooley et al 2003)

Clusters containing LMXBs have dense cores

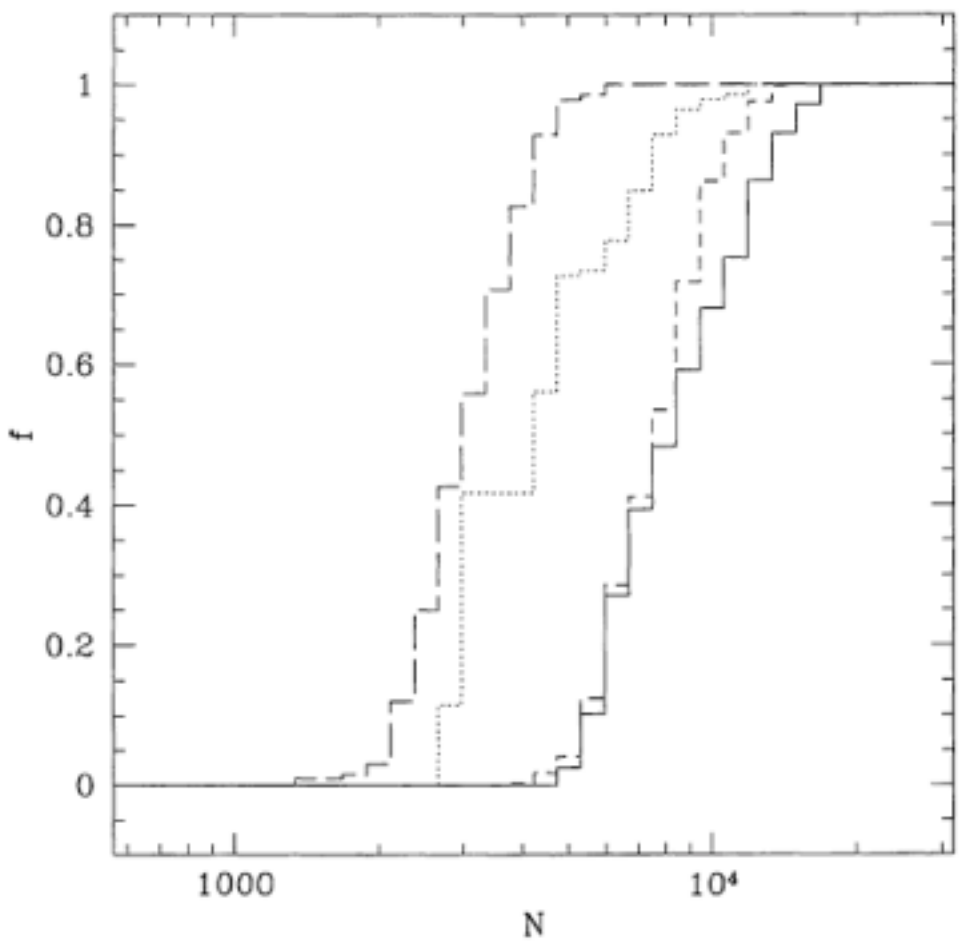


(Bregman et al 2006)

CVs

Are CVs primordial or made dynamically?

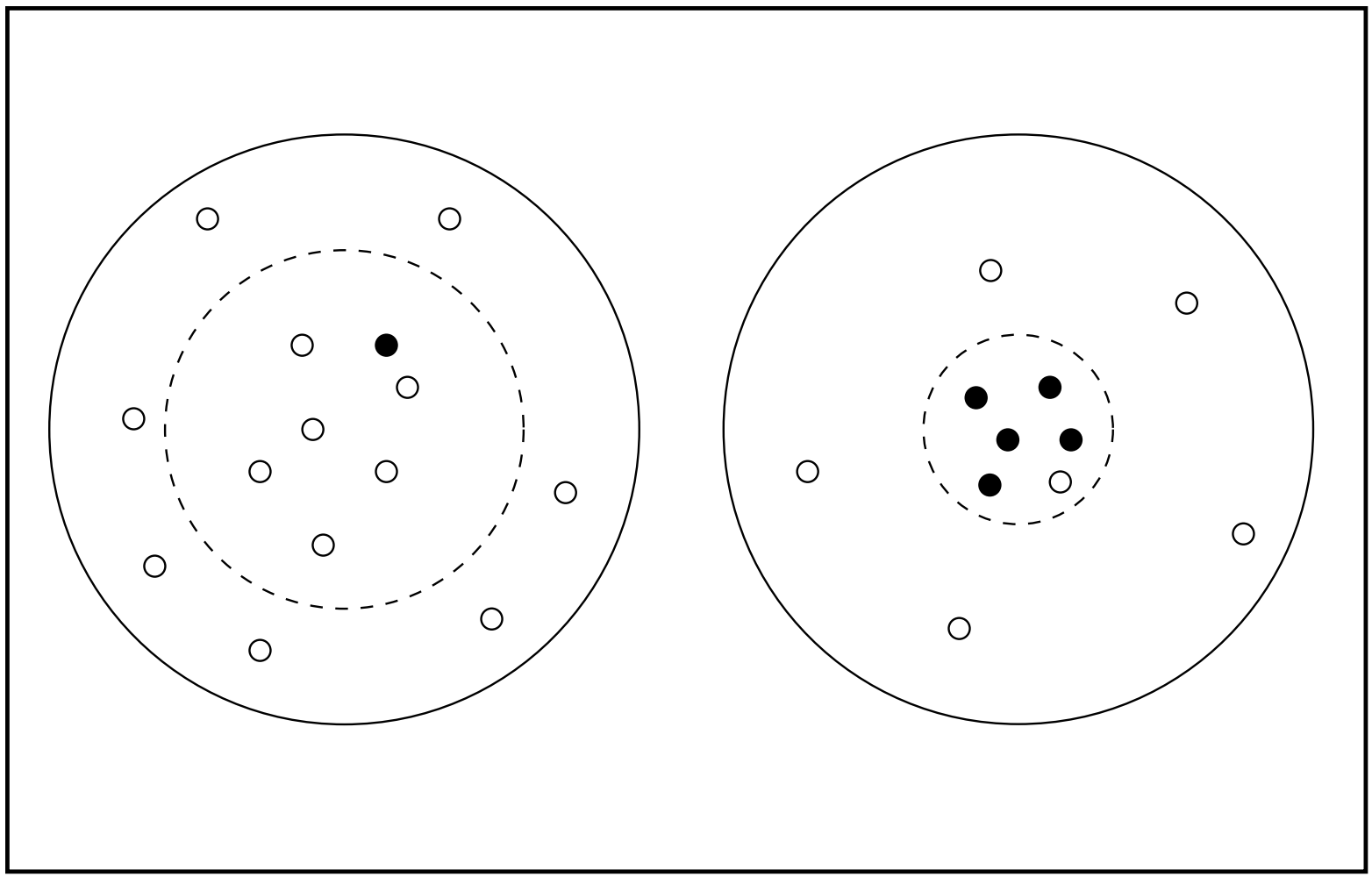
The binaries which would evolve into CVs on their own are soft binaries in globular clusters.



(Davies 1997)

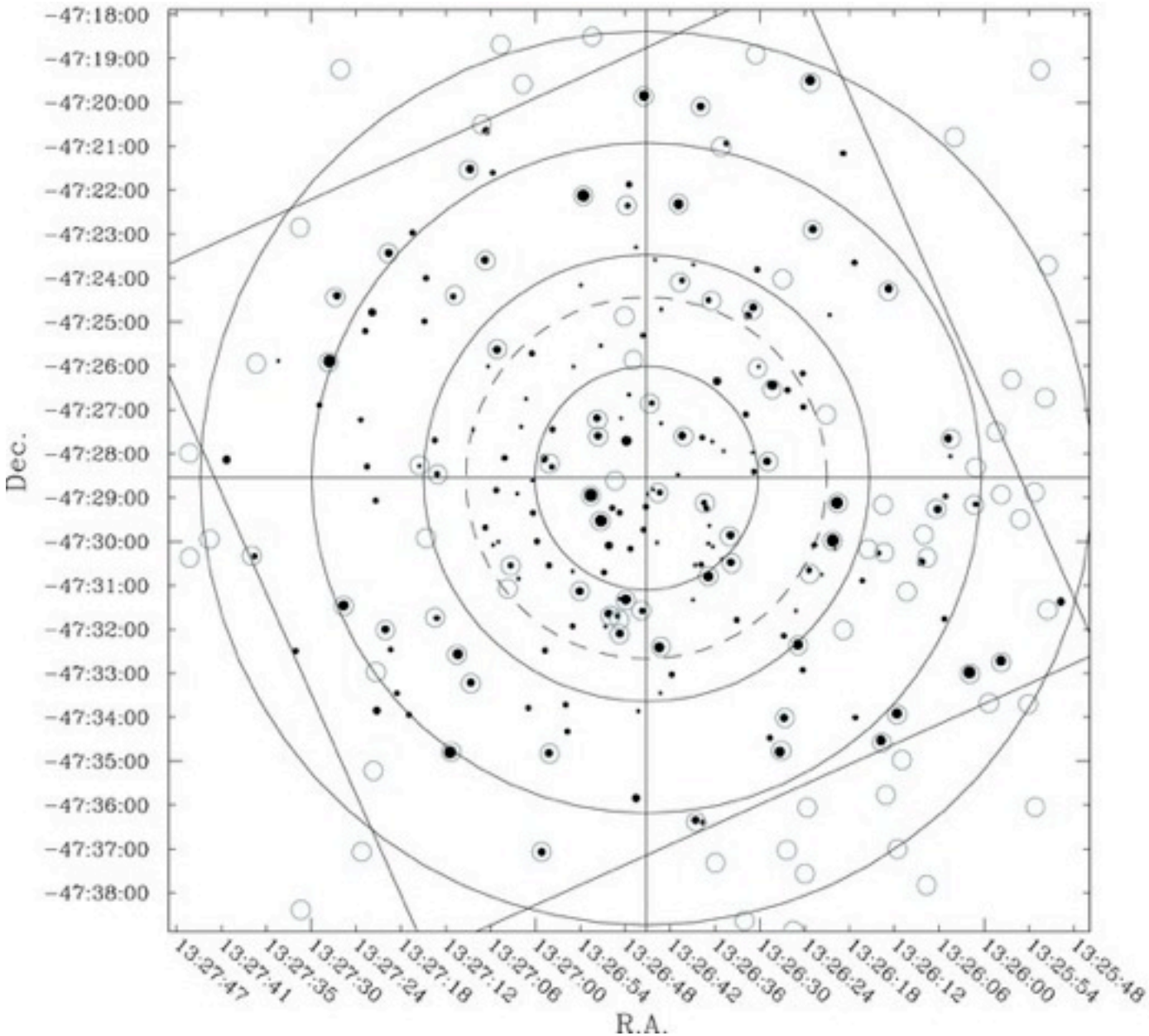
Alternatively, CVs may be produced through tidal capture of WDs or clean exchanges in binary-single encounters.

Possible distribution of CVs in globular clusters



white dots are primordial CVs, black dots are made dynamically

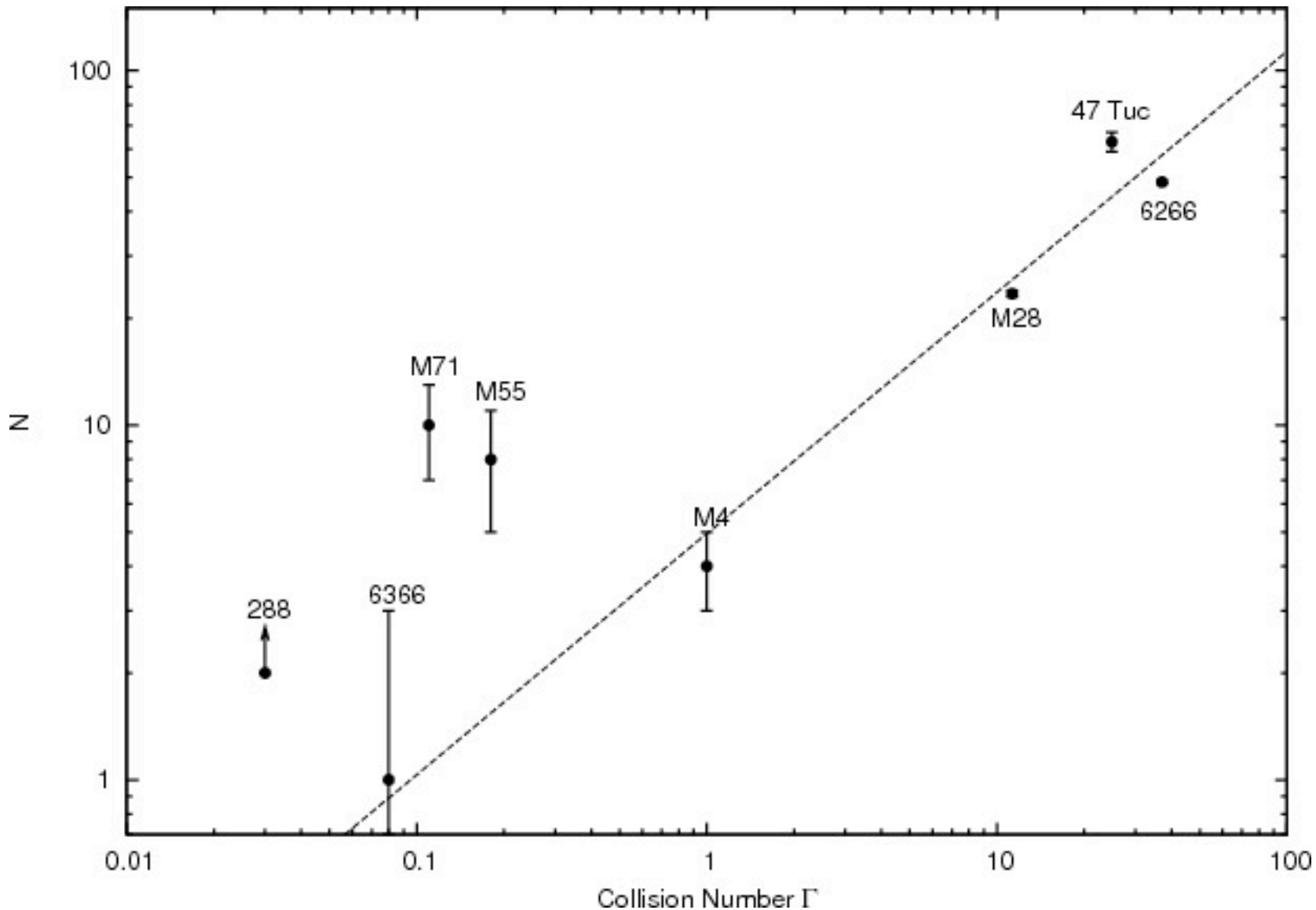
Chandra study of Omega Centauri



Number of CVs per unit mass is 2-3 times lower than in the field indicating that PCVs are being destroyed.

(Haggard, Cool, and Davies 2009)

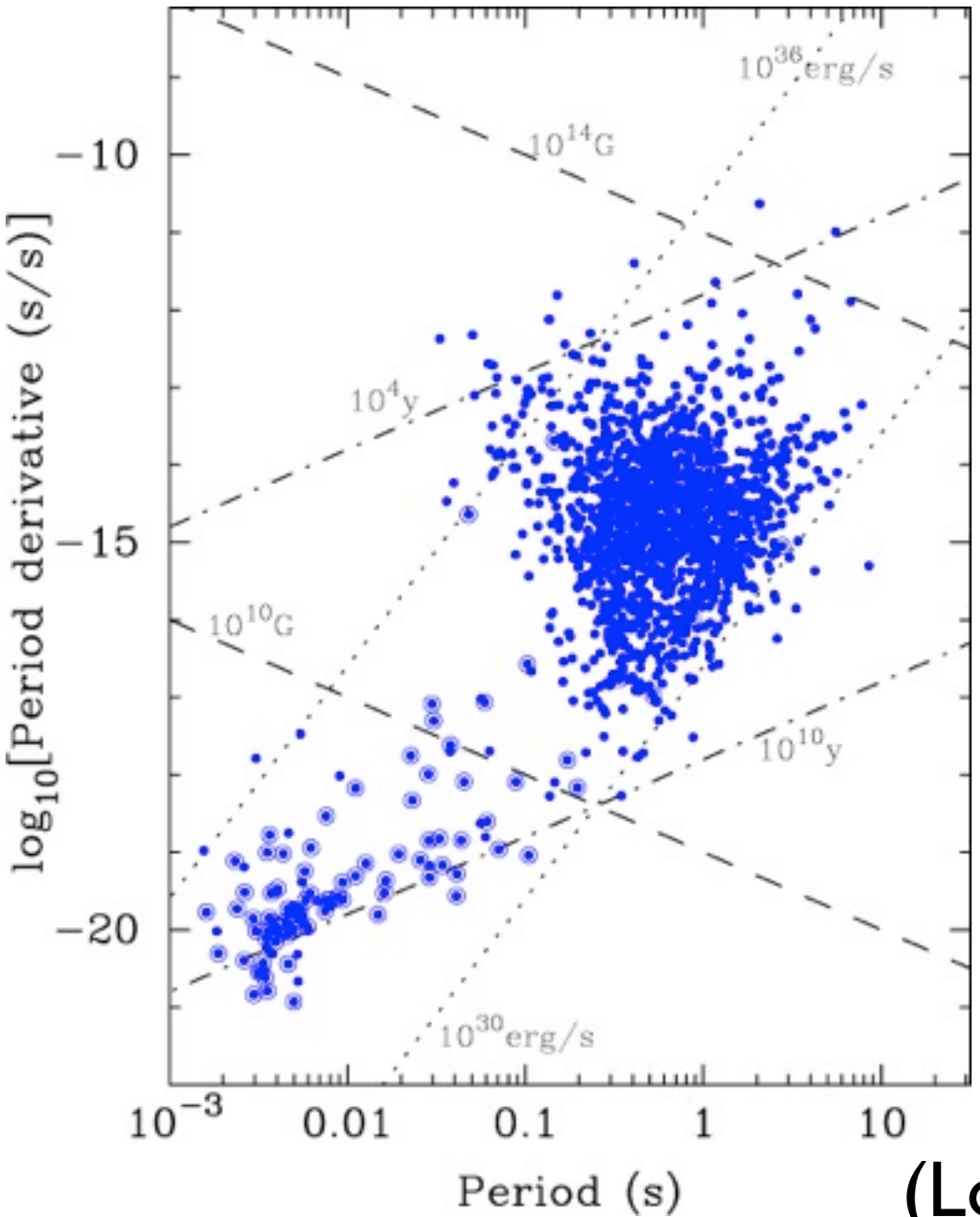
Evidence for primordial CVs in M71 and M55



(Huang et al 2010)

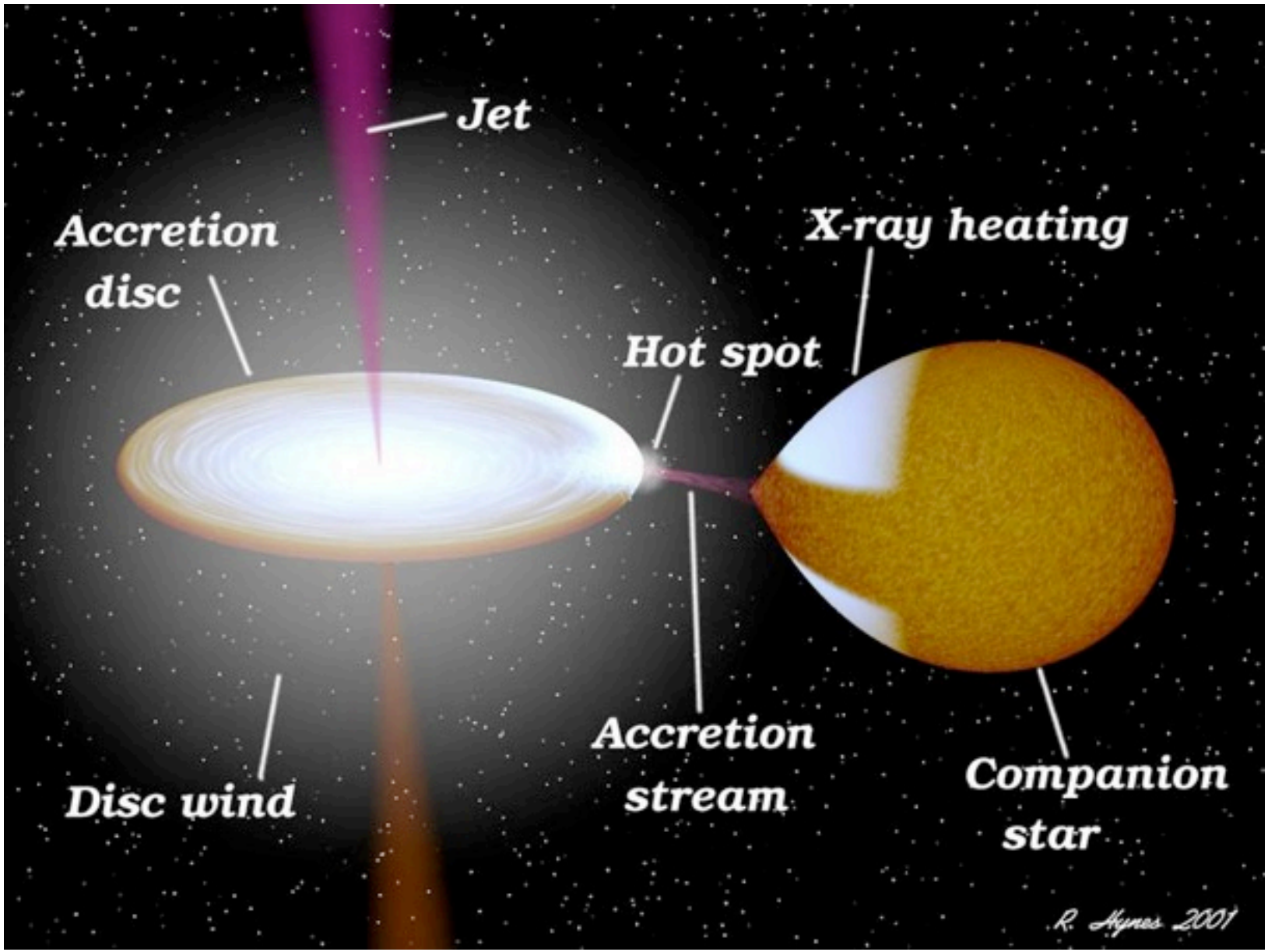
MSPs

Period derivative vs period for observed pulsars

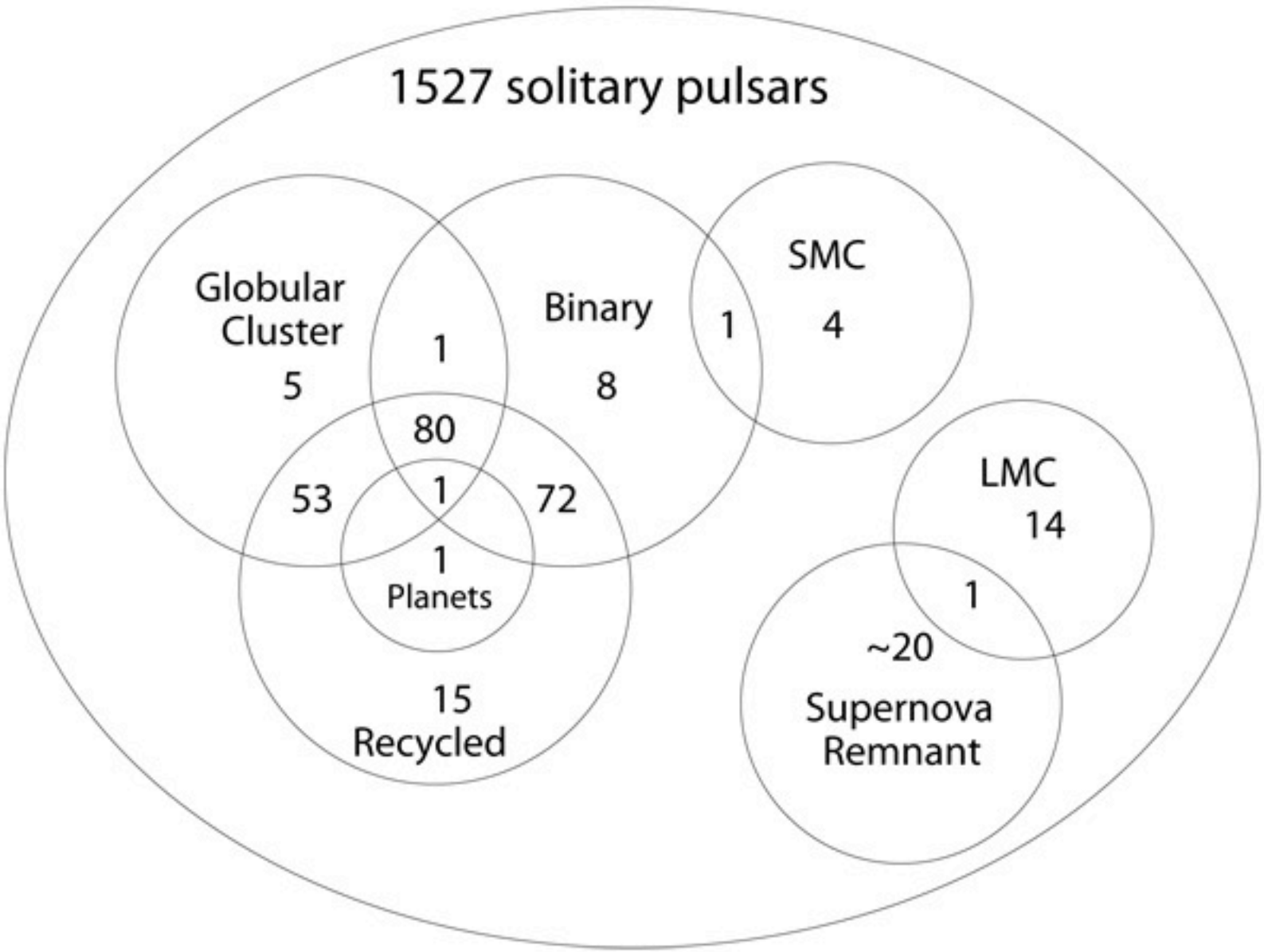


(Lorrimer 2008)

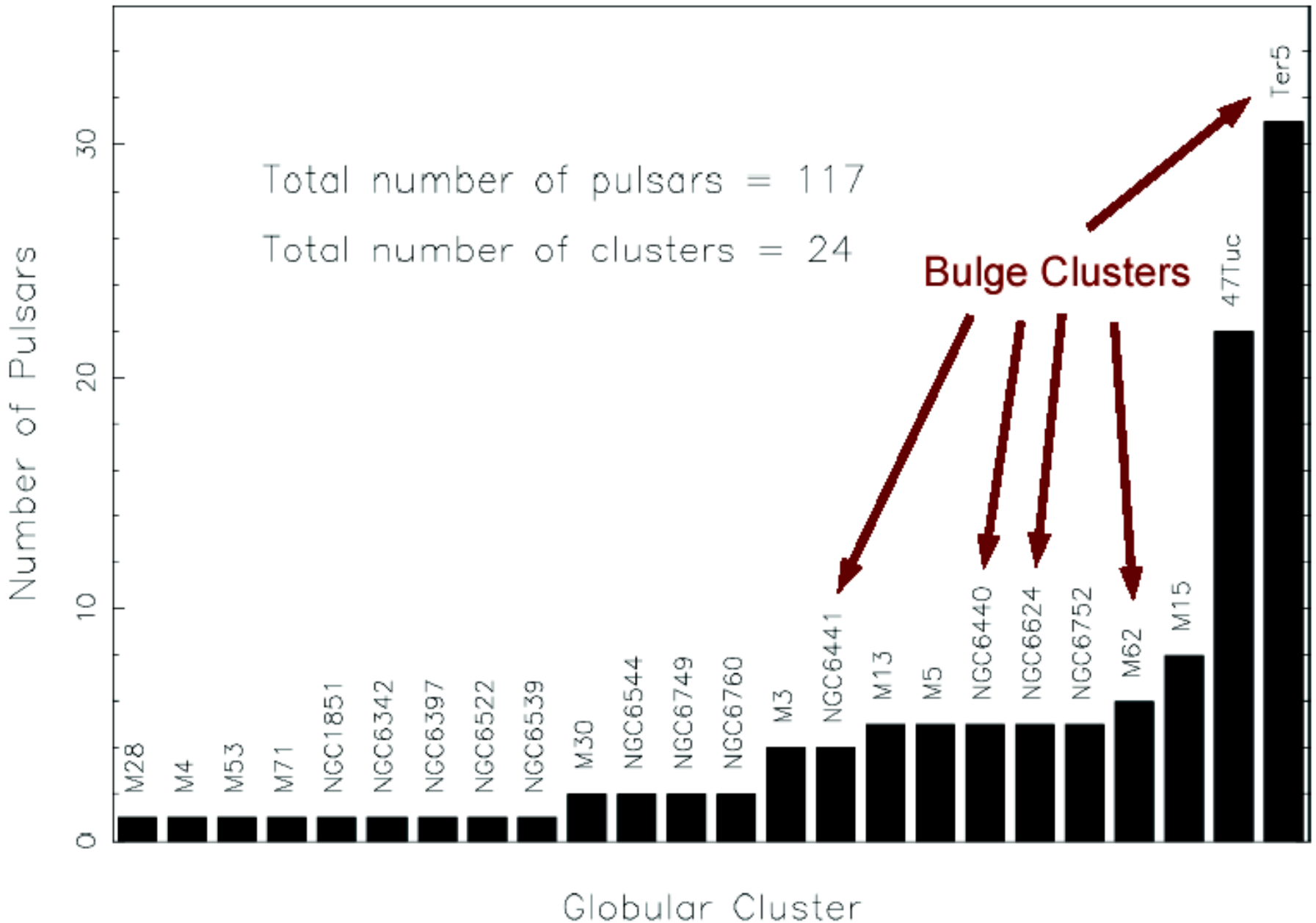
MSPs are produced in LMXBs



A Venn Diagram of Pulsars



(Lorrimer 2008)


Total number of pulsars = 117
Total number of clusters = 24
Bulge Clusters
Number of Pulsars
Globular Cluster
0
10
20
30
M28
M4
M53
M71
NGC1851
NGC6342
NGC6397
NGC6522
NGC6539
M30
NGC6544
NGC6749
NGC6760
M3
NGC6441
M13
M5
NGC6440
NGC6624
NGC6752
M62
M15
47Tuc
Ter5

(Ransom 2005)

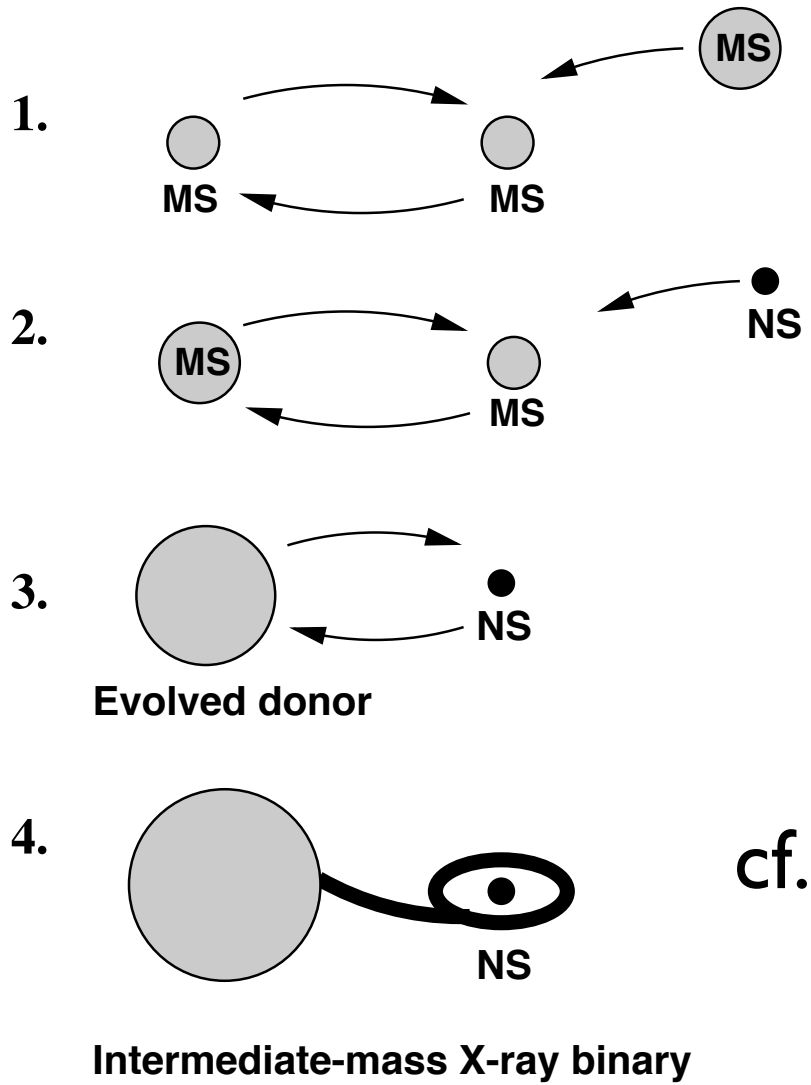
The MSP Enigma

Millisecond pulsars (MSPs) produced in low-mass X-ray binaries (LMXBs)

but

Globular clusters contain many more MSPs than LMXBs

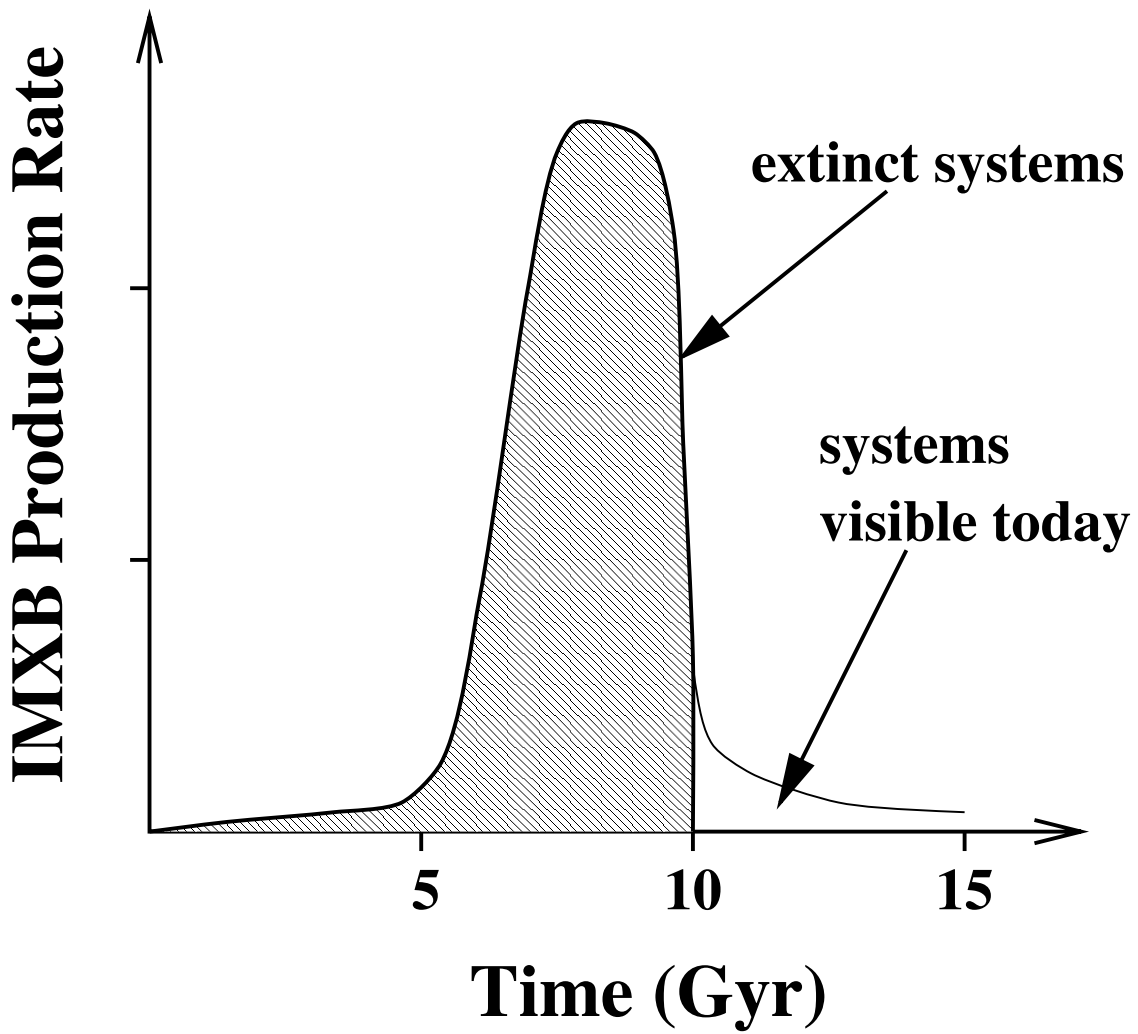
How to make IMXBs within stellar clusters



cf. Cygnus X-2

(Davies & Hansen 1998)

IMXBs make MSPs in the past



Compact Binaries

Neutron-star binaries

Neutron-star binaries are a source of gravitational radiation.

Tight binaries will merge in < 10 billion years.

Mergers may produce short gamma-ray bursts.

May also be sites for heavy element production.

They are rare: fewer than 1 in 1000 neutron stars are found in tight neutron-star binaries.

Simulation of a neutron-star binary merger

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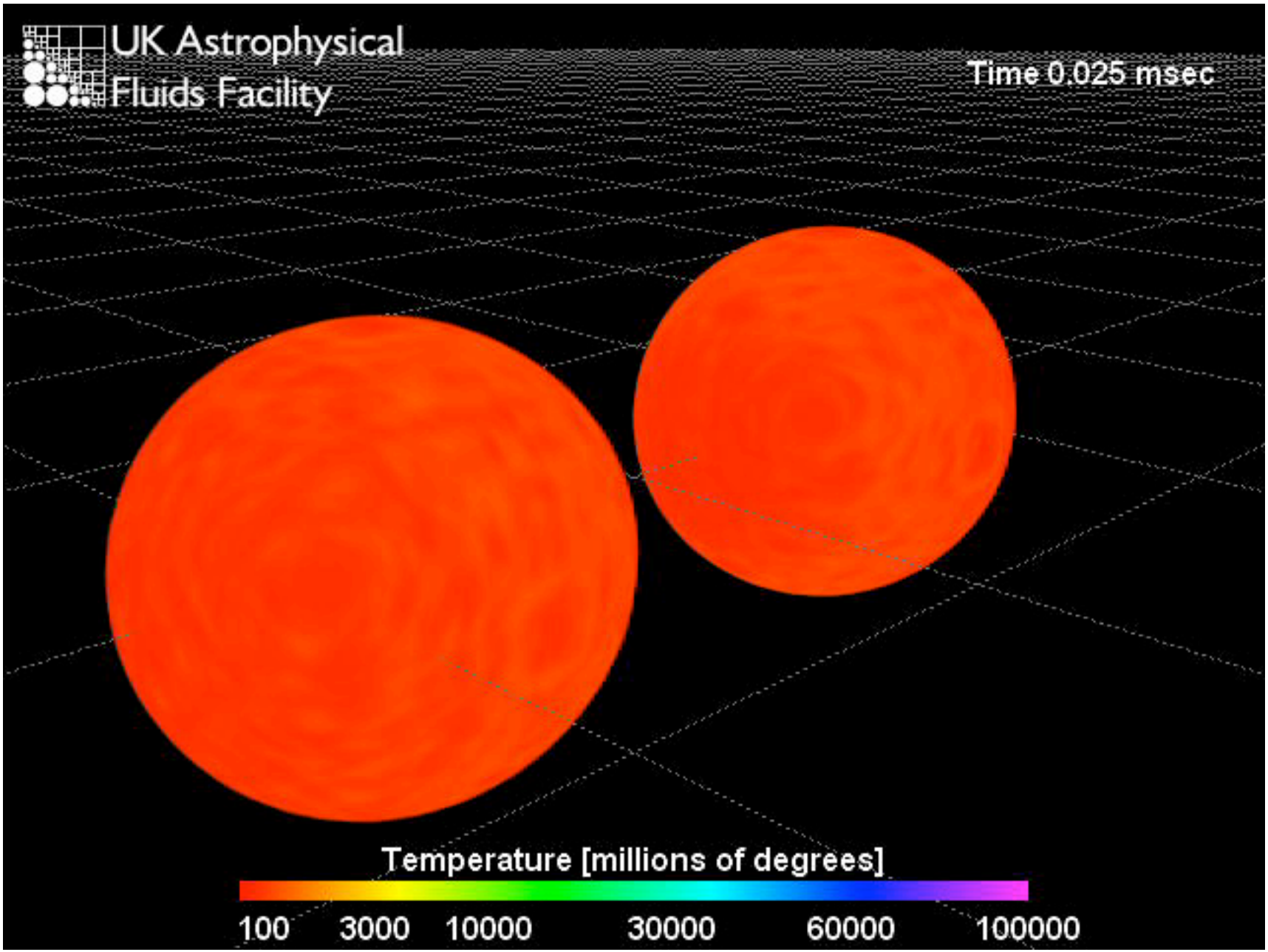
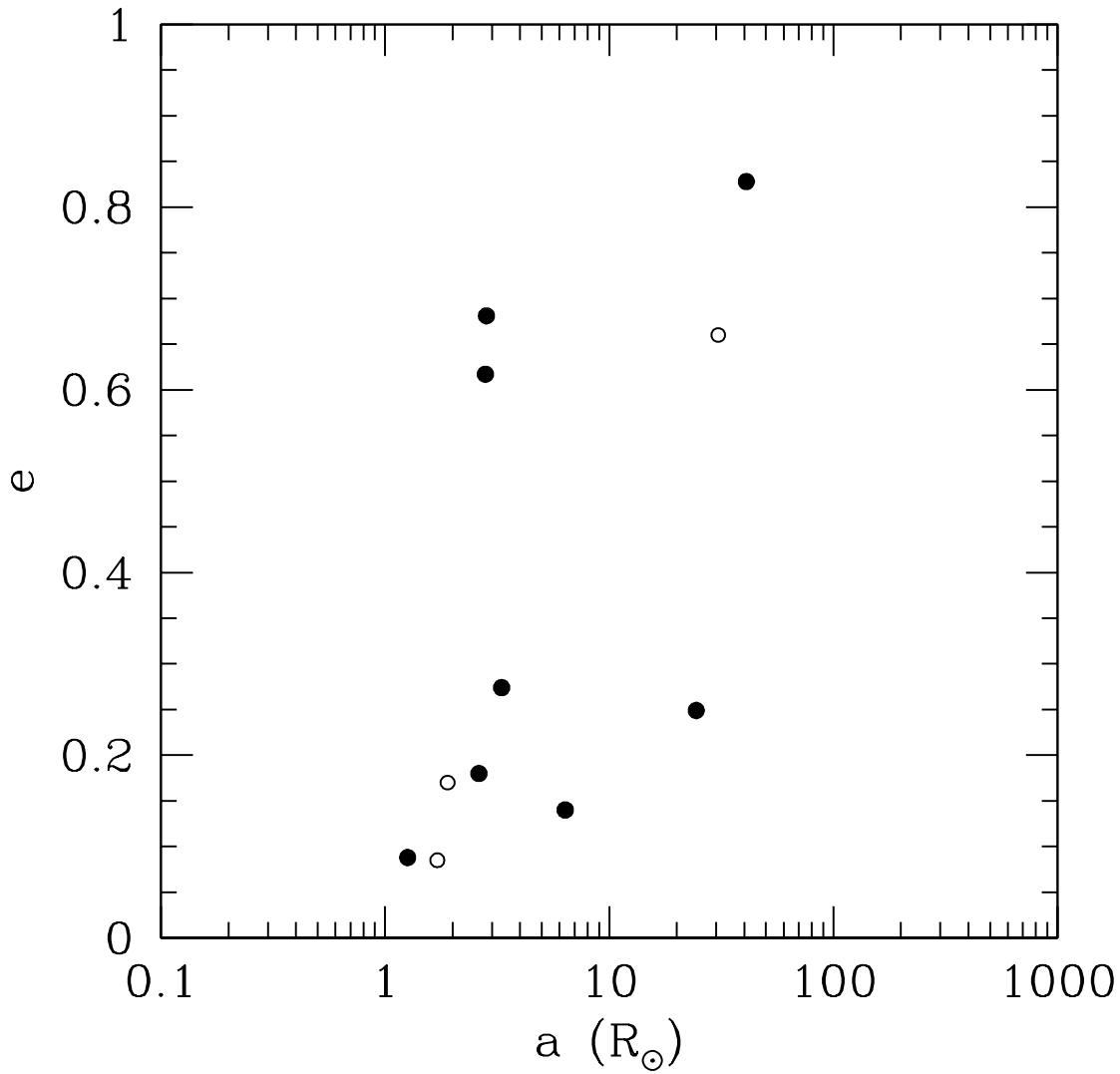


Properties of binaries observed outside of clusters

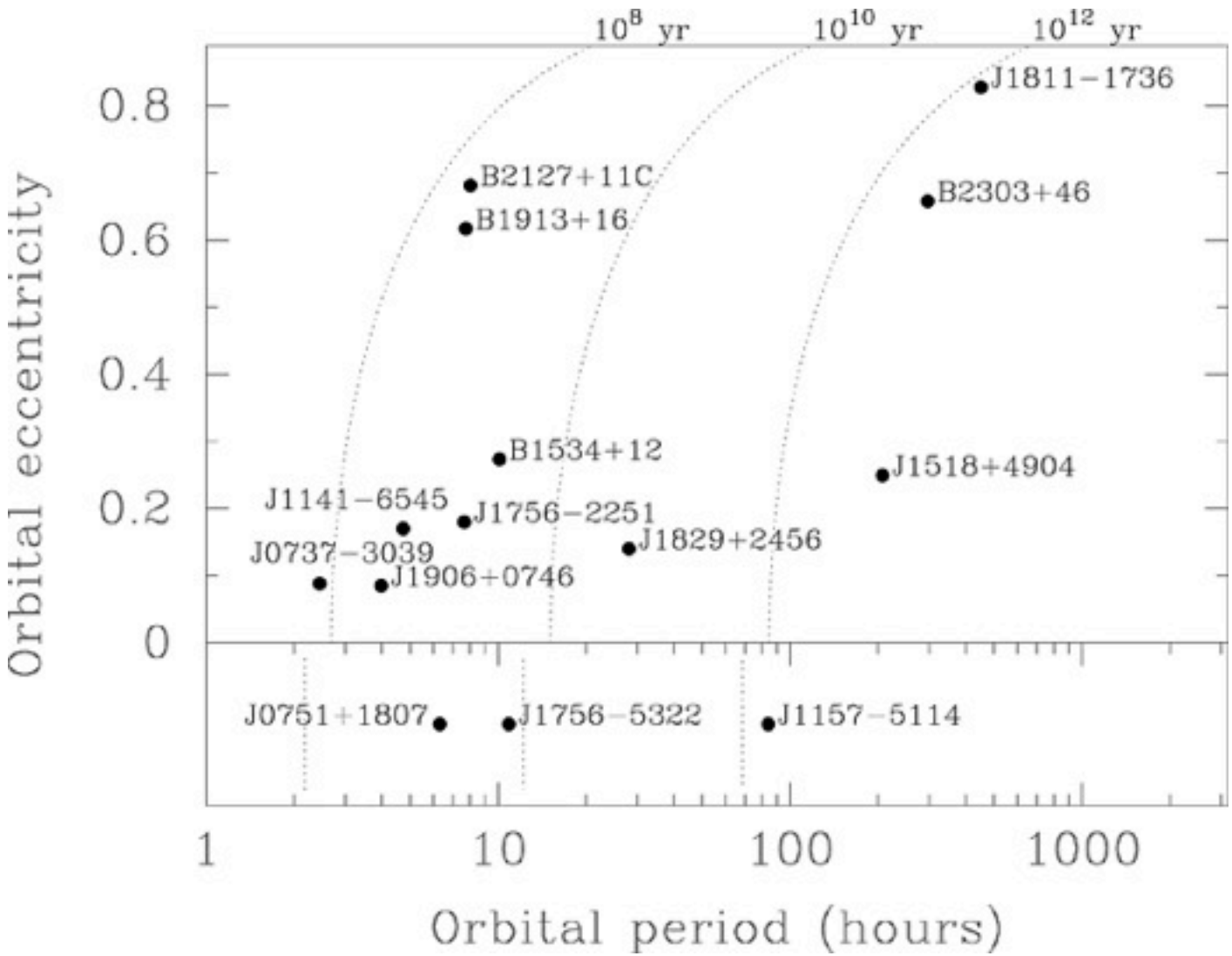


Inspiral timescale

Timescale for a circular binary of separation a to merge by gravitational radiation is

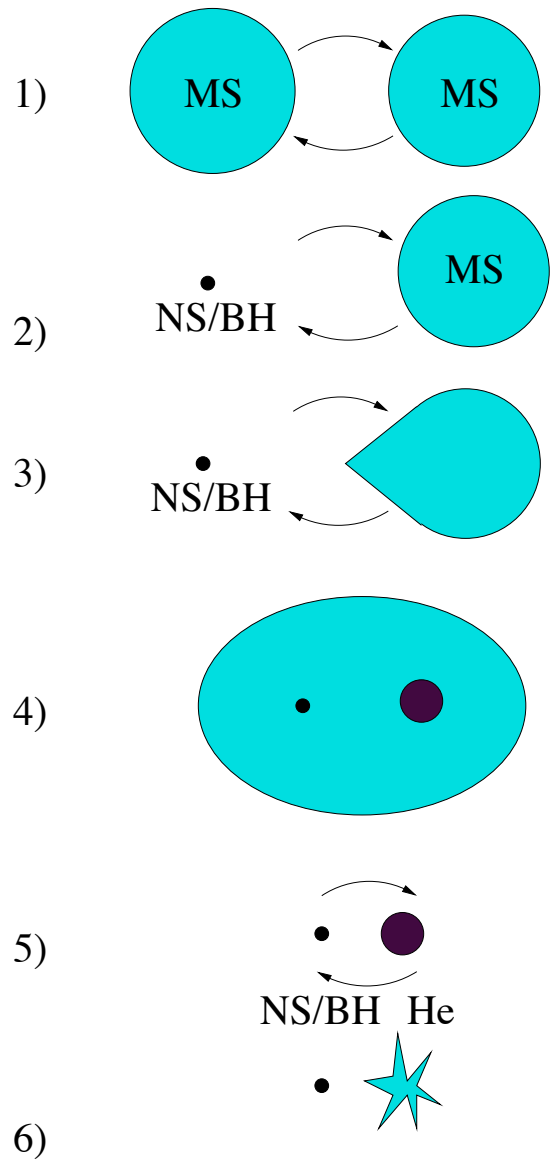
$$\tau_{gr} = 3 \times 10^8 \; yr \left(\frac{M_\odot}{M_1}\right)\left(\frac{M_\odot}{M_2}\right)\left(\frac{M_\odot}{M_1+M_2}\right)\left(\frac{a}{R_\odot}\right)^4$$

Properties of binaries observed outside of clusters



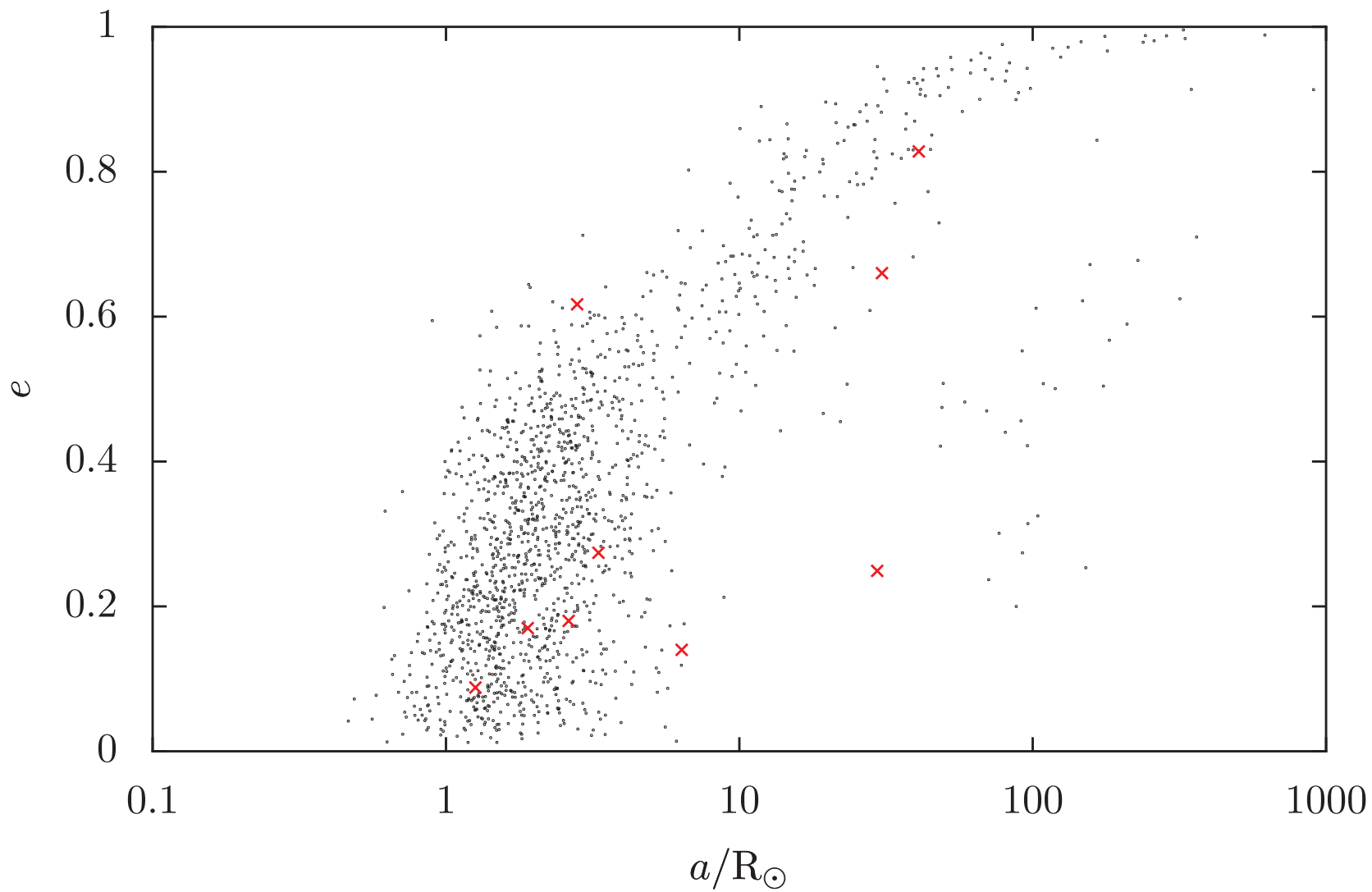
(Lorrimer 2008)

Producing compact binaries outside of clusters



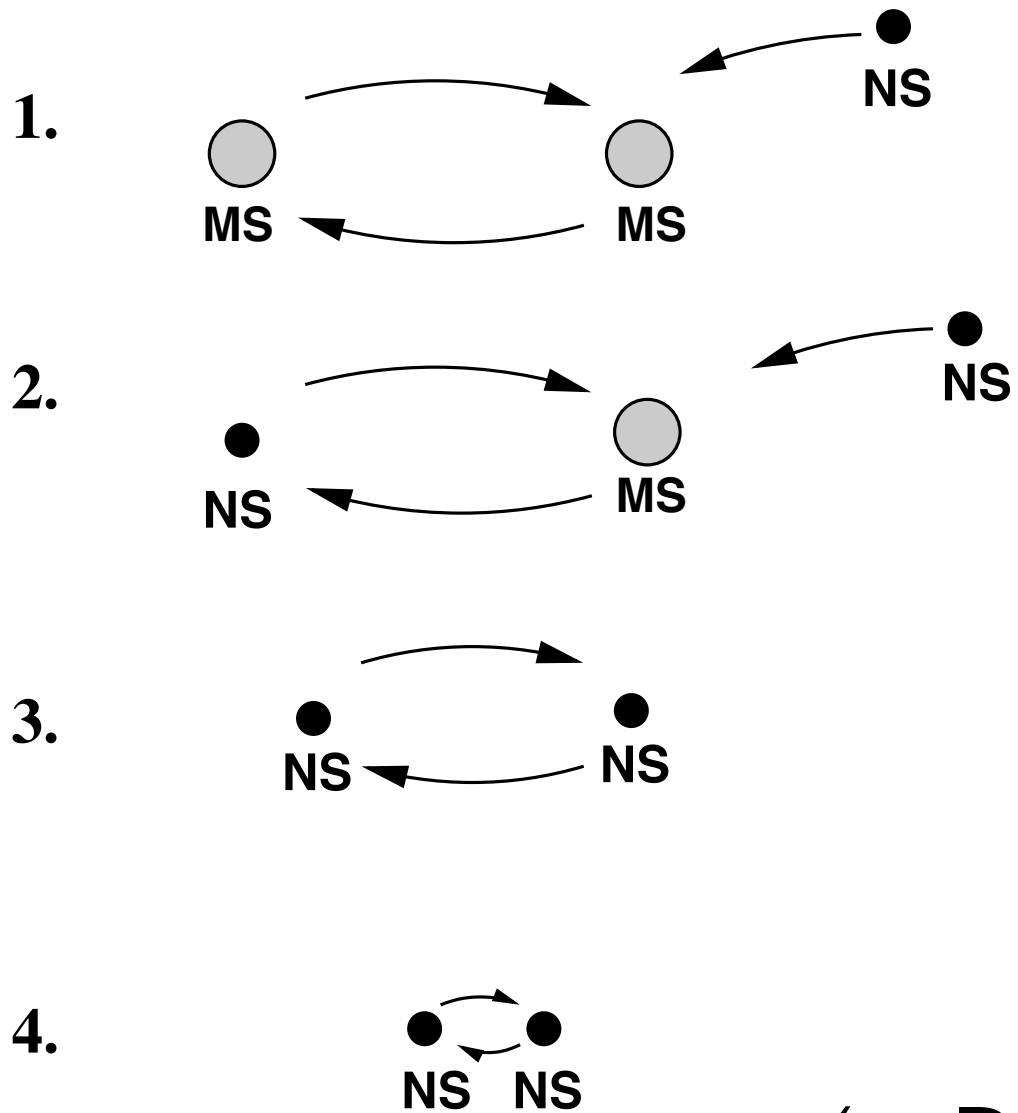
(Levan, Davies and King 2006)

A synthetic population of NS binaries



(Church et al 2011)

Producing compact binaries within clusters



(eg Davies 1995)

Where are gamma-ray bursts seen within galaxies?

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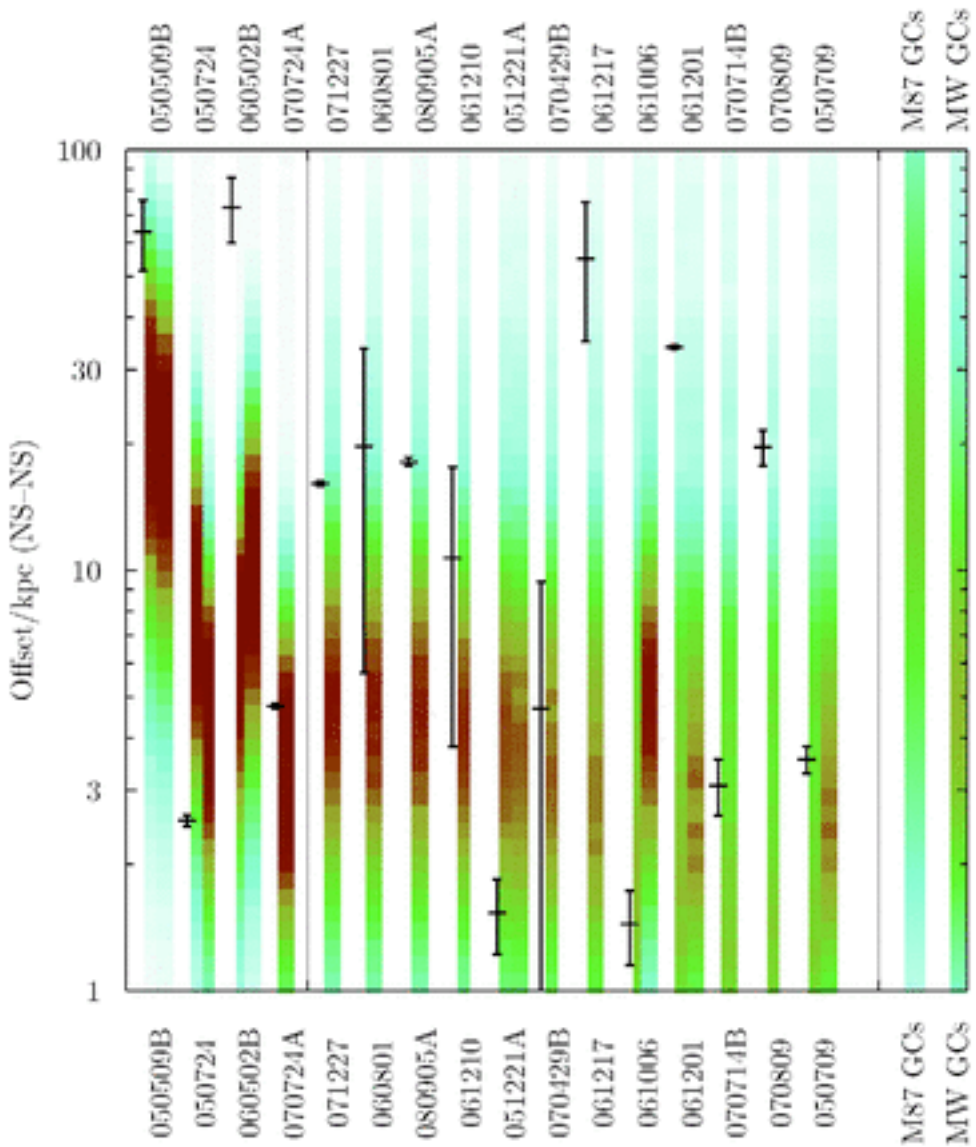
Evidence for NS-NS binaries in globular clusters



In some cases, SGRBs seen to occur a large distance from host galaxy but at distances consistent with observed globular cluster populations around other galaxies.

(Church et al 2011)

NS-NS binaries

Monte Carlo calculations show roughly 10 NS-NS binaries produced per dense cluster (cf Grindlay, Portegies Zwart, and McMillan 2006).

Next step: perform full N-body calculations including binary evolution.

Globular clusters may turn out to be very important factories producing NS-NS binaries emitting gravitational waves as they spiral together, and producing GRBs.