Binaries and Cluster Dynamics

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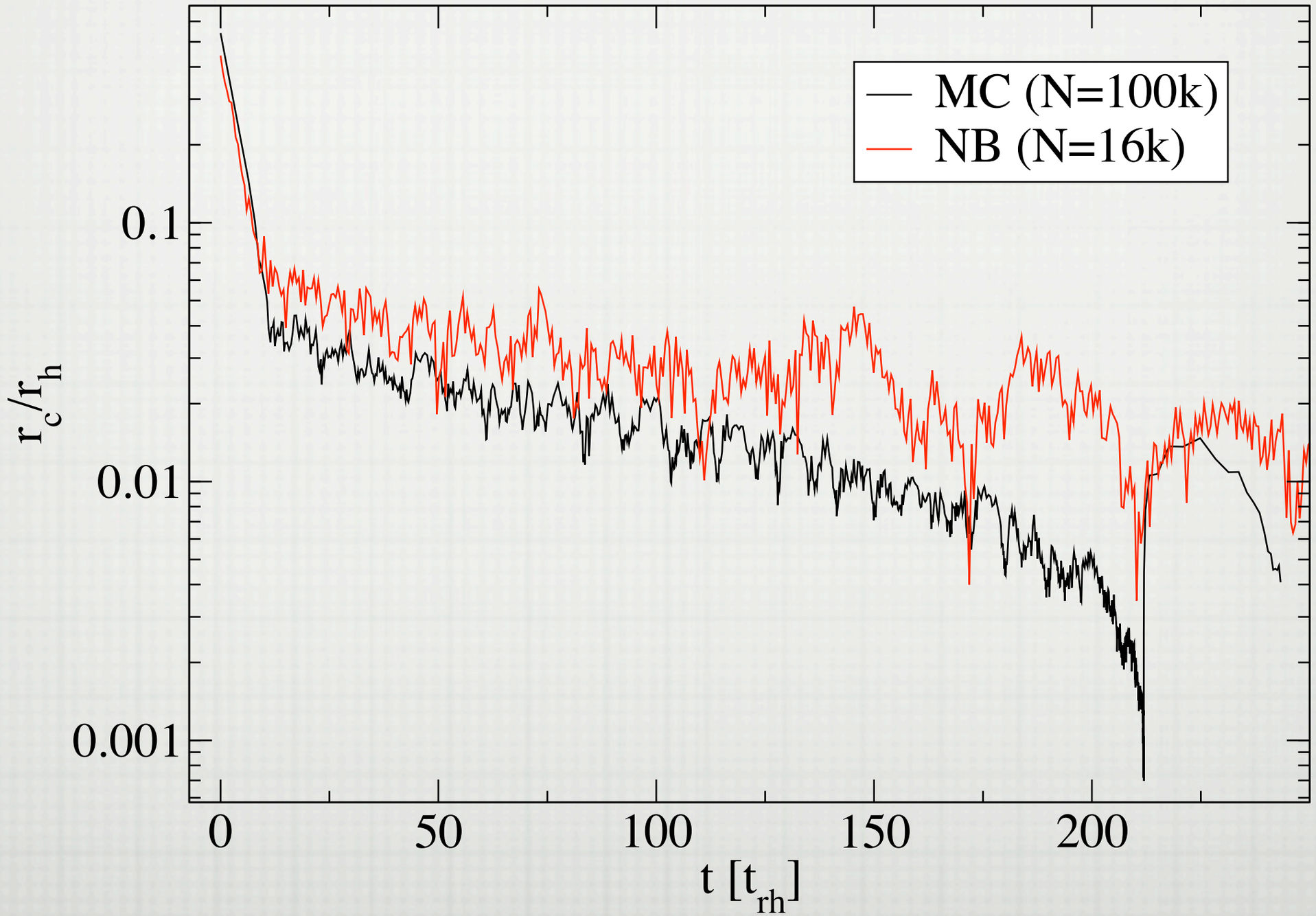
Facts

- In the point-mass approximation, primordial hard binaries (even a few percent) can postpone core collapse for tens of half-mass relaxation times (~tens of Gyr) in a long-lived binary burning phase.

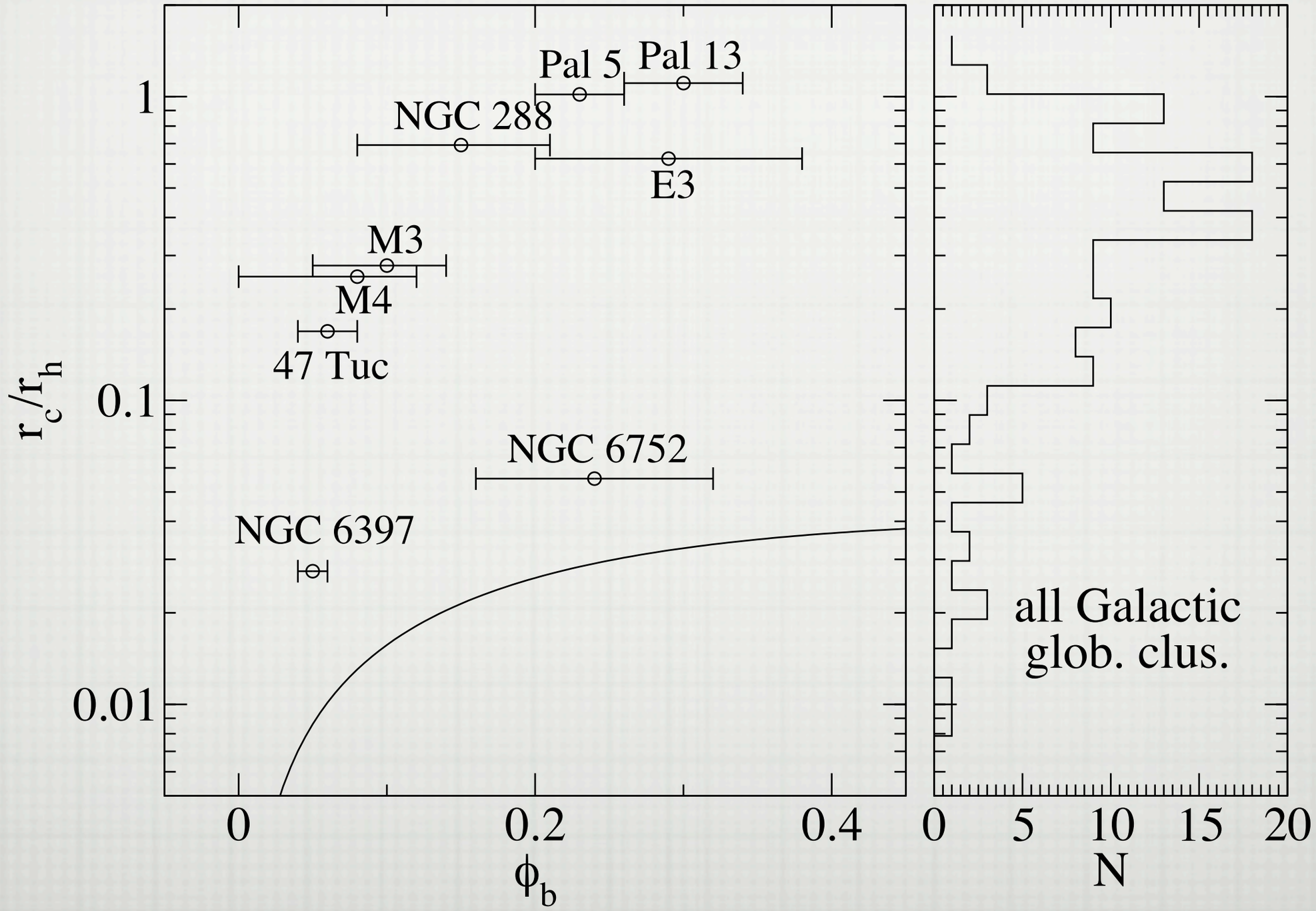
- Strong dynamical interactions are responsible for the formation and evolution of interacting binaries in clusters (LMXBs, CVs, etc.).

- Clusters are observed to have relatively small core binary fractions at present (generally <~10%, but sometimes up to ~50%).

Agreement Between N-Body and Monte Carlo



Disagreement Between Theory and Observations in Binary Burning Phase



Possible Resolutions of r_c/r_h Discrepancy

- Differing definitions of r_c/r_h can yield a factor of up to ~4 difference in the appropriate direction (Hurley 2007).
- Neglected physics in simulations important? Stellar evolutionary mass loss on long timescales (Hurley 2007), collisions of stars leading to expedited stellar evolution mass loss (Chatterjee, et al. 2007)?
- Additional energy sources: central IMBHs (Trenti 2006), prolonged mass segregation (Merritt, et al. 2004), evaporation of stellar-mass BH population (Mackey, et al. 2007)?
- Perhaps most clusters are simply not yet in the binary-burning phase (Fregeau 2008)?
- White dwarf birth kicks of ~5 km/s (Davis, et al. 2008; Fregeau, et al. 2009)?

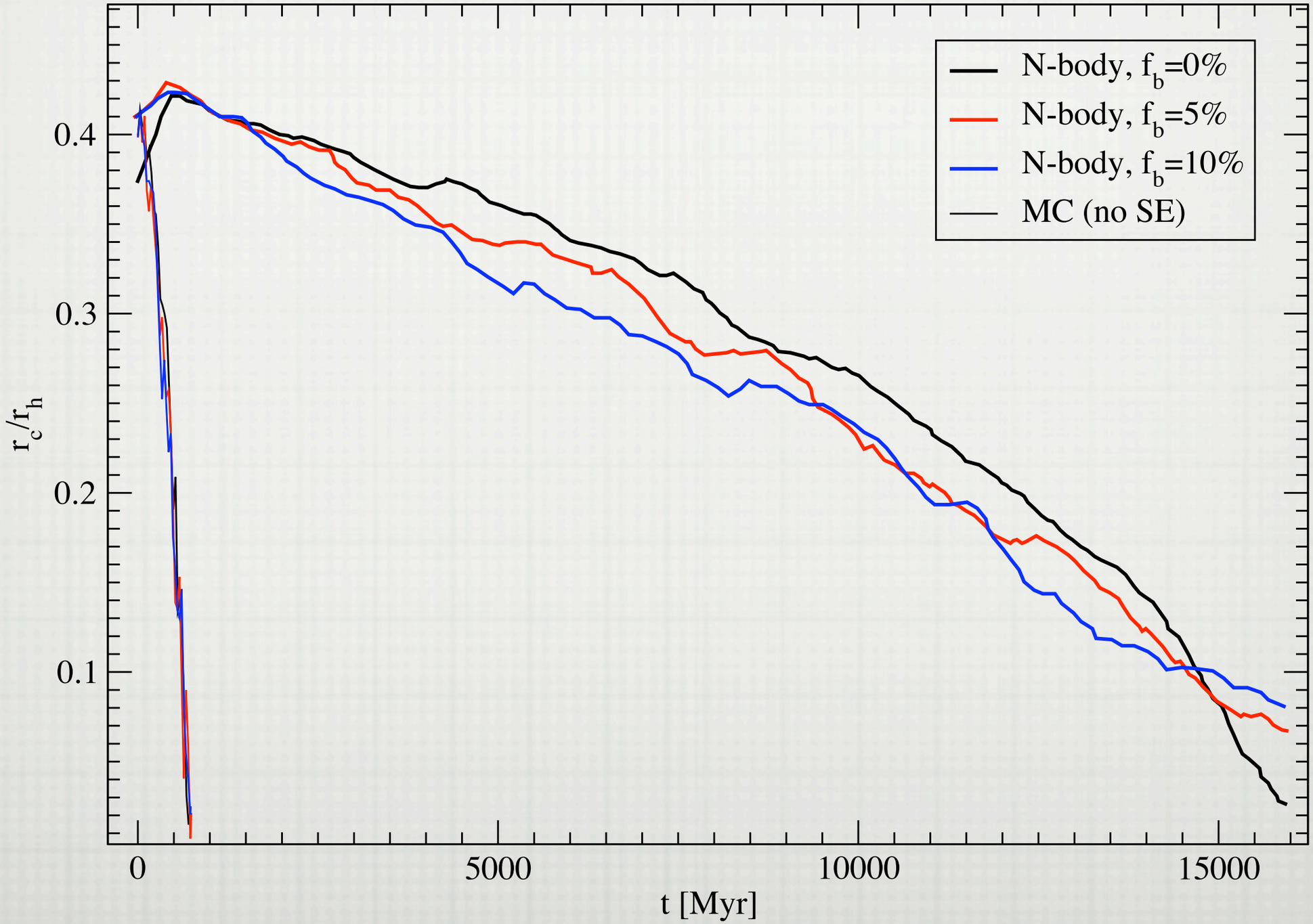
IMBHs to the Rescue?

- IMBHs are known to act as apparent energy sources for clusters, since they are essentially sinks of (negative) binding energy in the core (e.g., Baumgardt, et al. 2005), so they act to increase cluster core sizes.

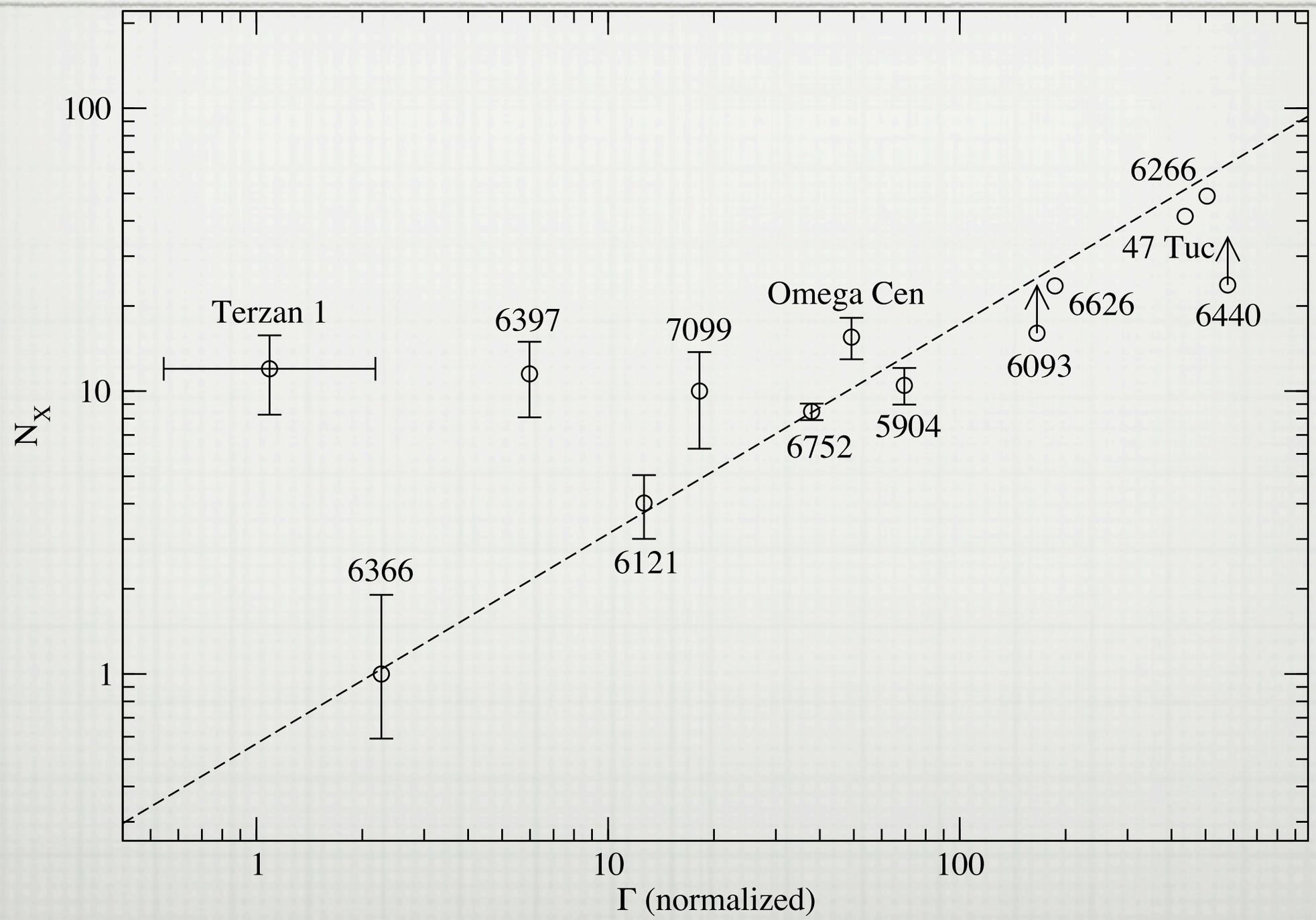
- There is some weak evidence for IMBHs in G1 and M15, via velocity dispersion profiles consistent with the presence of a central BH (Gebhardt, et al. 2002, 2005; van der Marel et al. 2002; Gerssen, et al. 2003).

- Taking those clusters that are not particularly tidally-truncated or elliptic, and which have sufficient large dynamical ages, Trenti (2007) finds that ~tens of Galactic GCs could host central IMBHs of mass 0.02 M_{clus}.

Stellar Evolution to the Rescue? (Hurley 2007)



Most Clusters Not Yet in Binary Burning Phase? (Fregeau 2008)



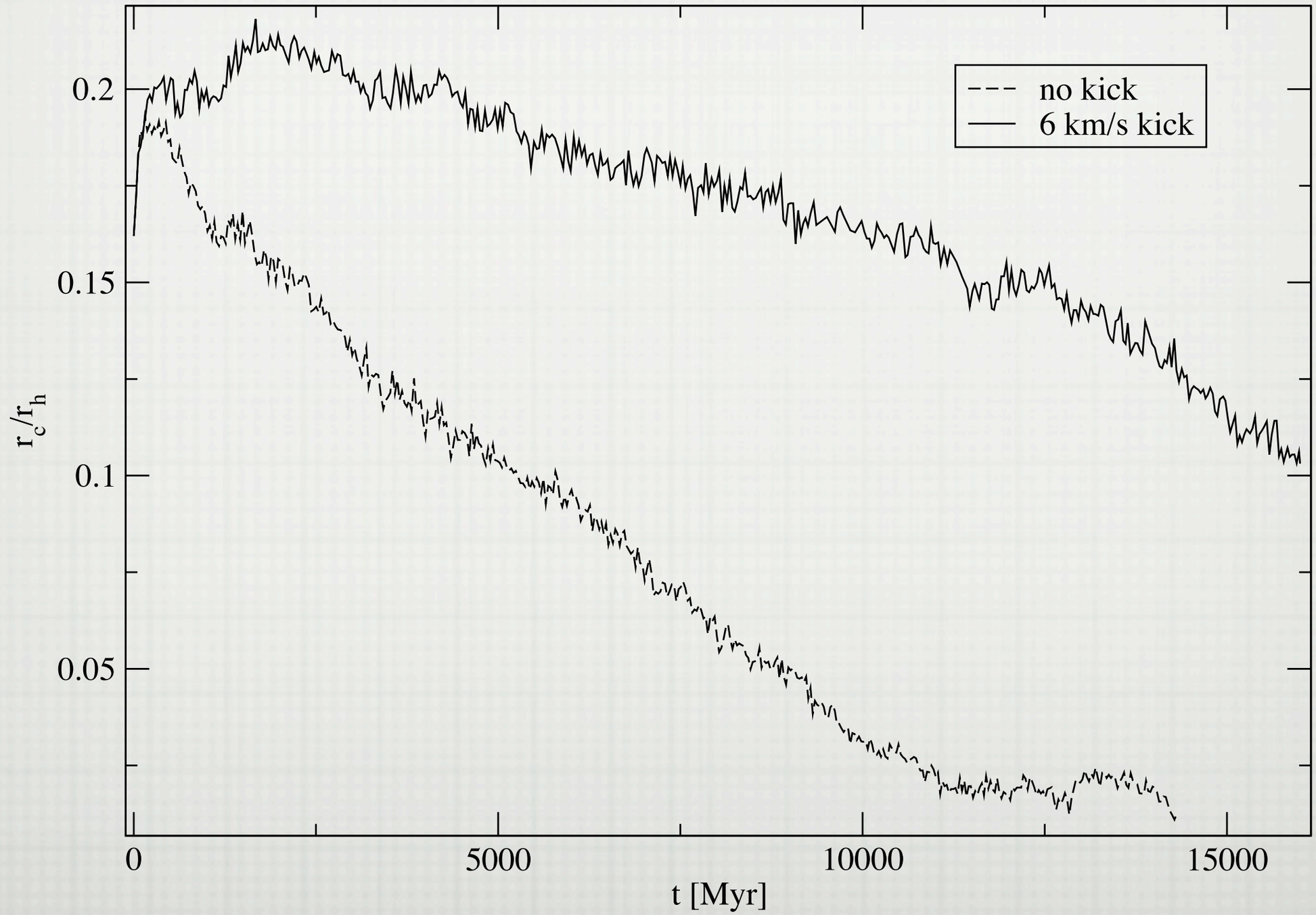
Most Clusters Not Yet in Binary Burning Phase? (Fregeau 2008)

- X-ray binaries (XRBs) shine as X-ray sources for a few Gyr after their formation, so the number of XRBs we see in a cluster should scale with the *time-integrated* core interaction rate over the past few Gyr, not with the *current* core interaction rate.

- Globular clusters should either be in an initial core contraction phase (meaning the core density was recently lower than it currently is), or in the binary-burning phase (meaning the core density has been roughly constant with time recently).

- Integrating the core interaction rate over time for the two phases reveals that binary burning clusters should have a number of X-ray sources that is a factor of ~2-20 above the Pooley, et al. scaling.

White Dwarf Kicks? (Fregeau, et al. 2009)



The Great Debate: Evolution of the Binary Fraction

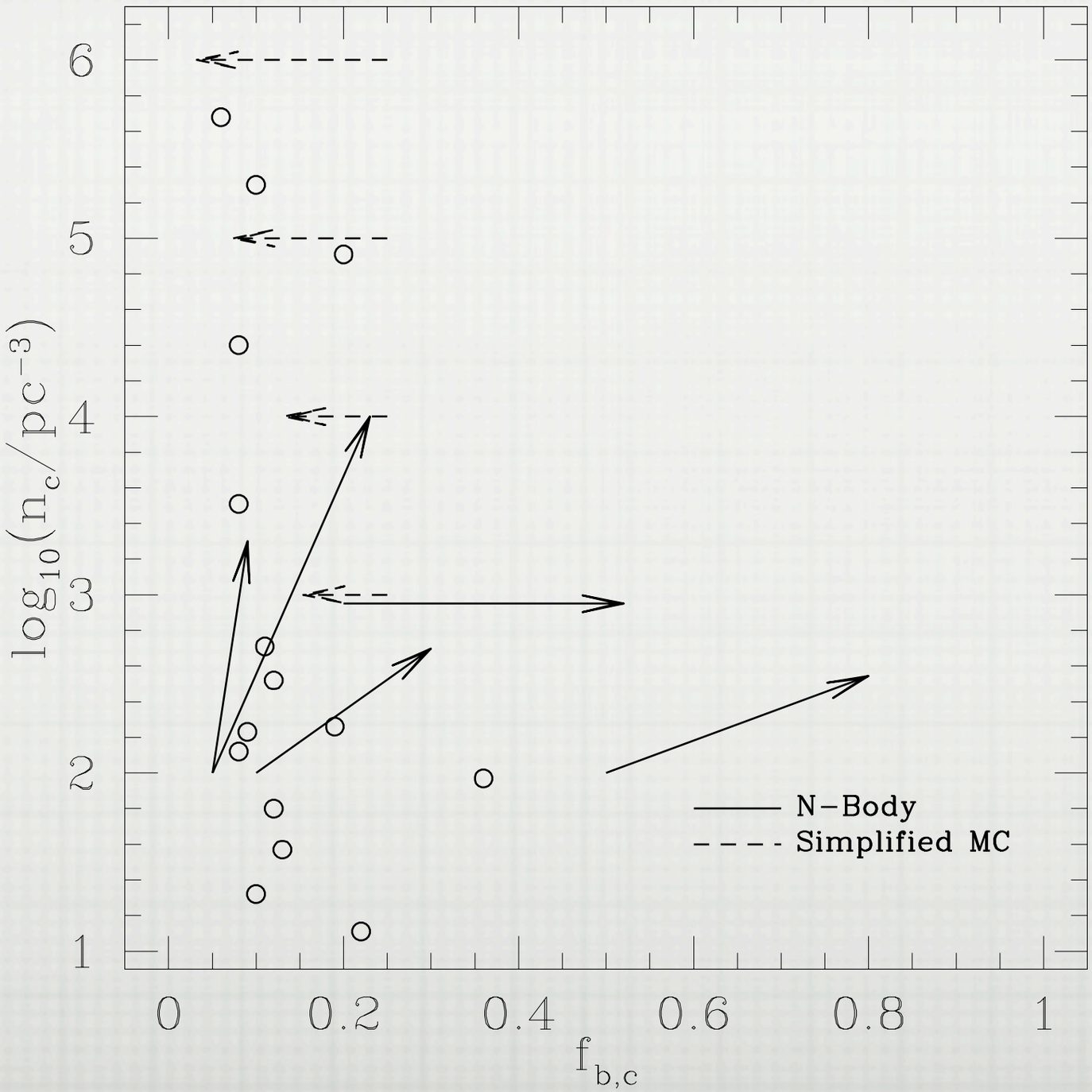
- Clusters are currently observed to have relatively small core binary fractions (<~20%). What does this say about their *initial* binary fractions?

- Ivanova, et al. (2005) generally find that the core binary fraction *decreases* greatly with time, and that 47 Tuc must have been born with ~100% binaries (~30% hard) to explain its current core binary fraction of ~10%.

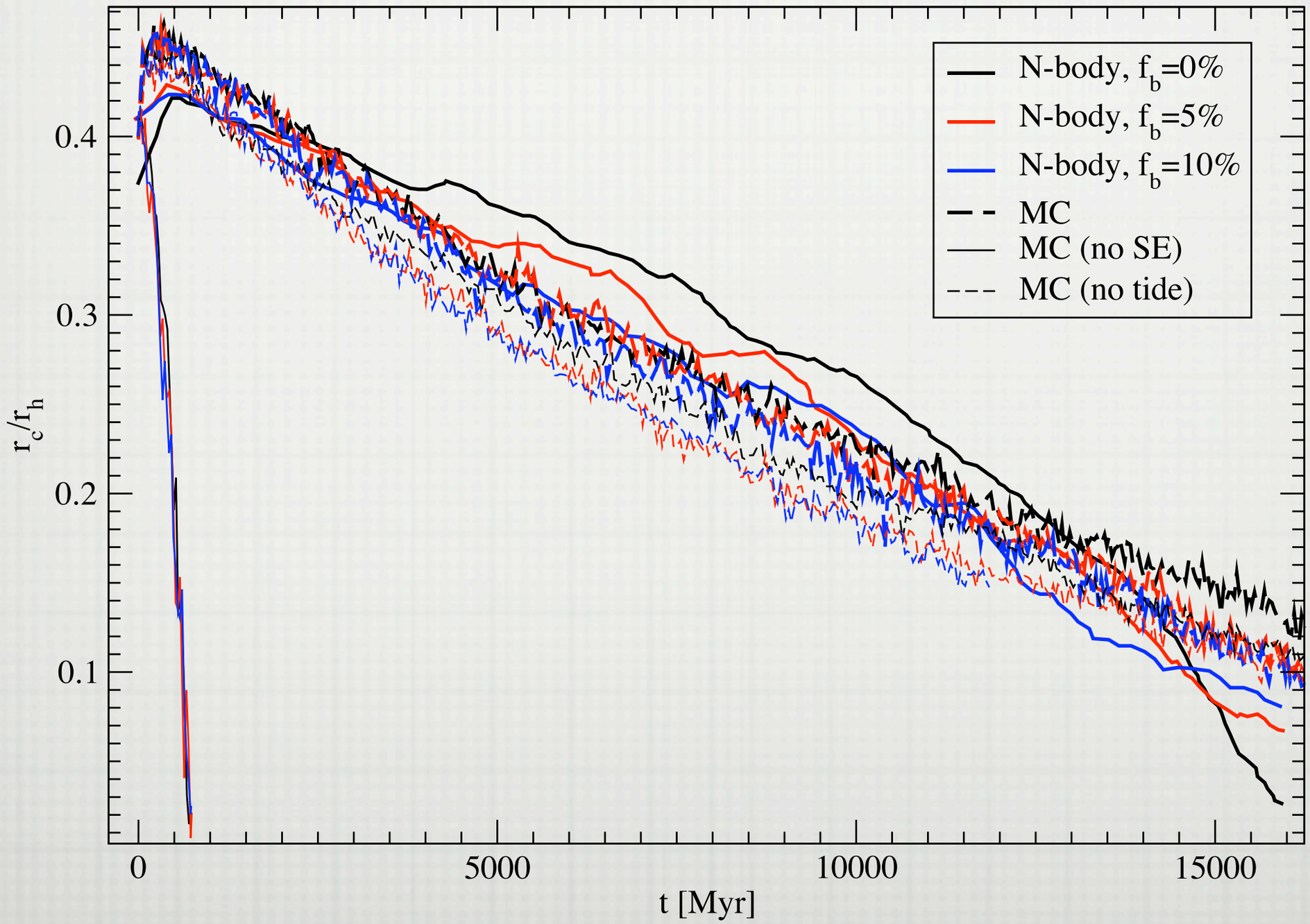
- Hurley, et al. (2007) generally find that the core binary fraction *increases* with time, and that the binary fraction at the half-mass radius stays roughly constant with time, implying that clusters were born with very small (<~10%) binary fractions.

- The methods are very different: direct N-body for Hurley, and simplified, static-density core Monte Carlo method for Ivanova.

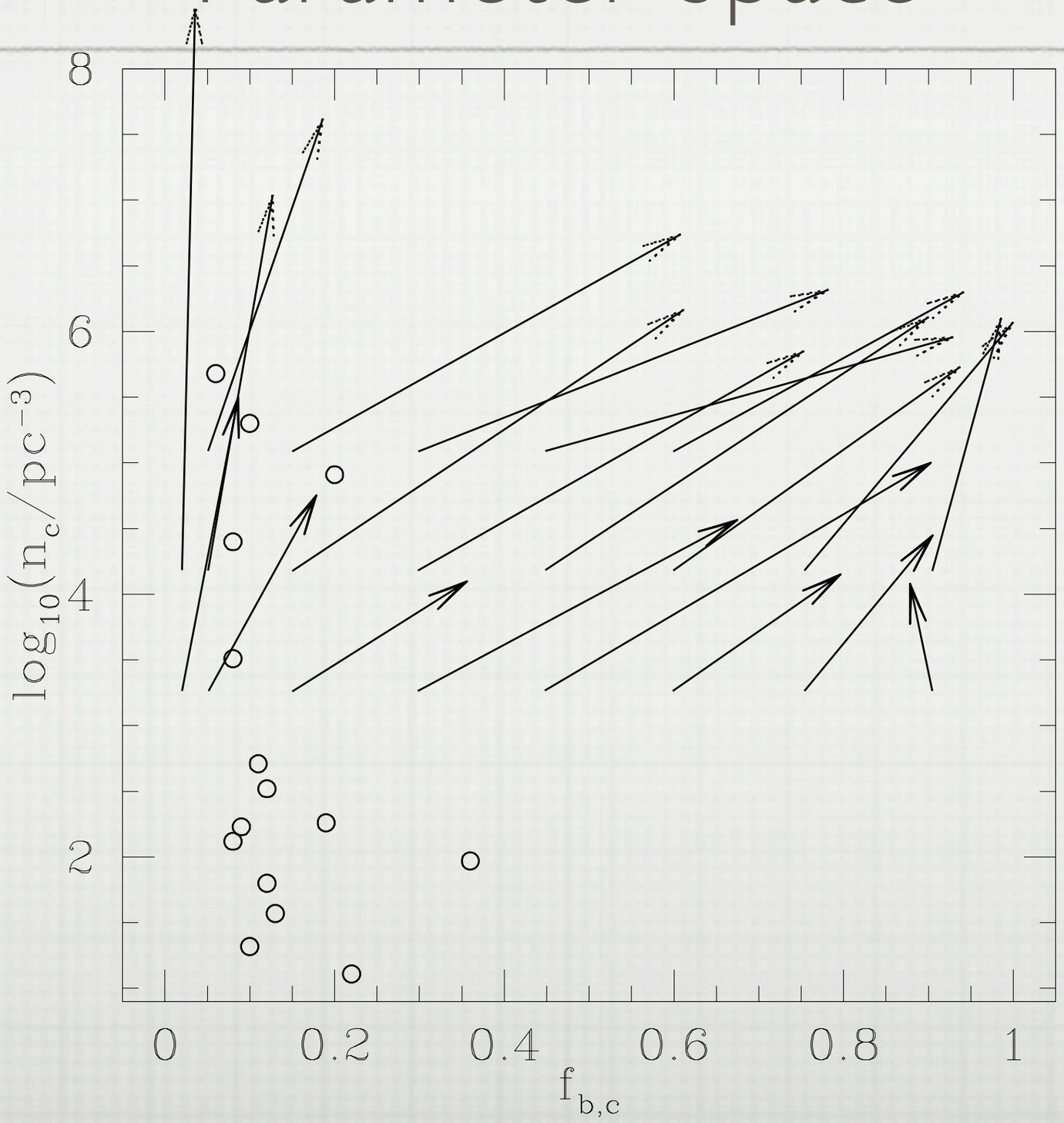
Binary Fraction Evolution in Parameter Space



MC Code: Now With Stellar Evolution!



Binary Fraction Evolution in Parameter Space

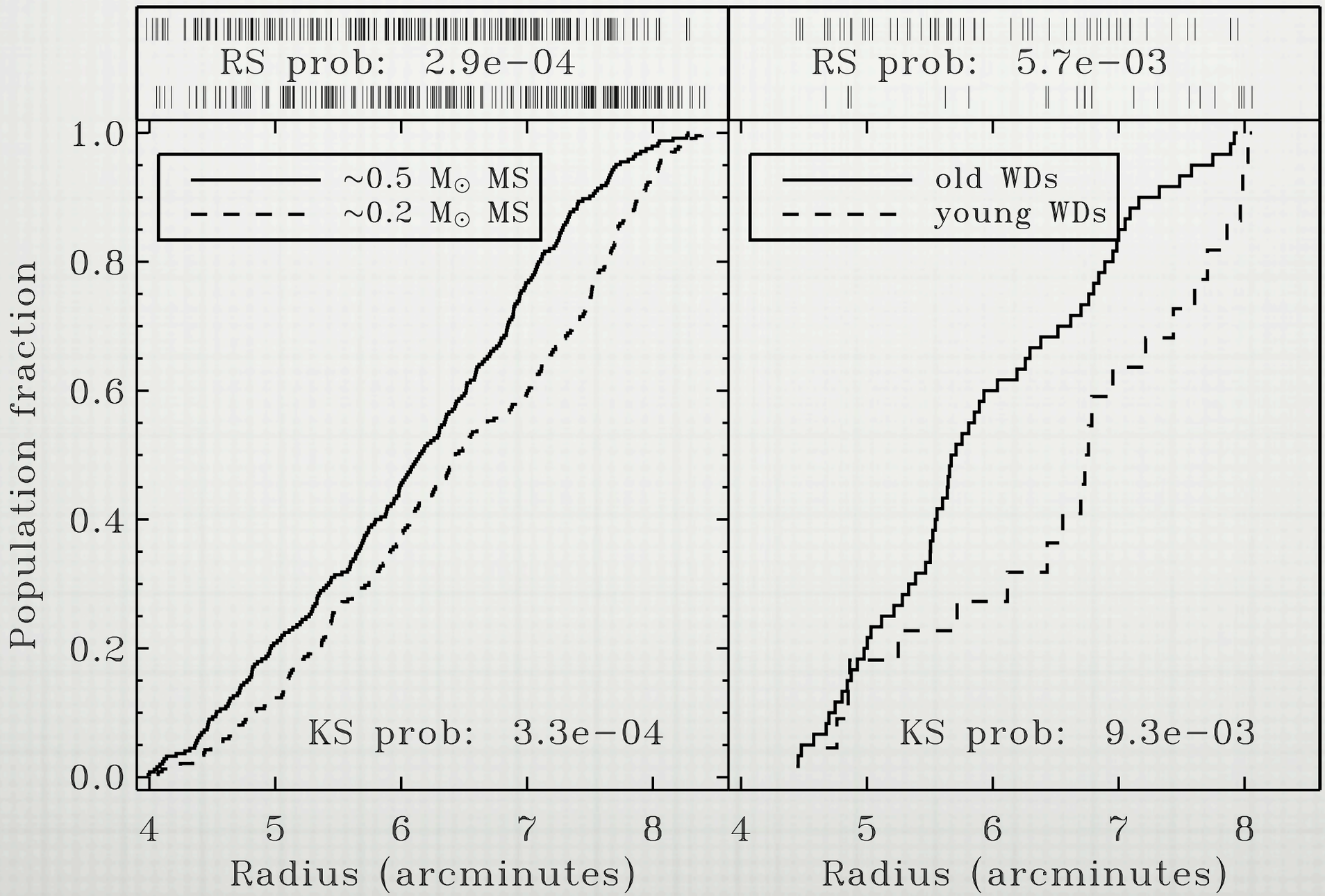


Conclusions

- There are several possible resolutions to the discrepancy between observations and theory in r_c/r_h. Recent improvements to the Monte Carlo code are yielding new clues on the theory side, but improved observations are likely required to test some hypotheses (IMBHs, WD kicks, etc.).

- Cluster core binary fractions generally increase with time, implying that clusters were "born" with small binary fractions (<~10%).

White Dwarf Kicks? (Davis, et al. 2008)



White Dwarf Kick Simulations (Fregeau, et al. 2009)