Evolution of the Binary Fraction in Globular Clusters

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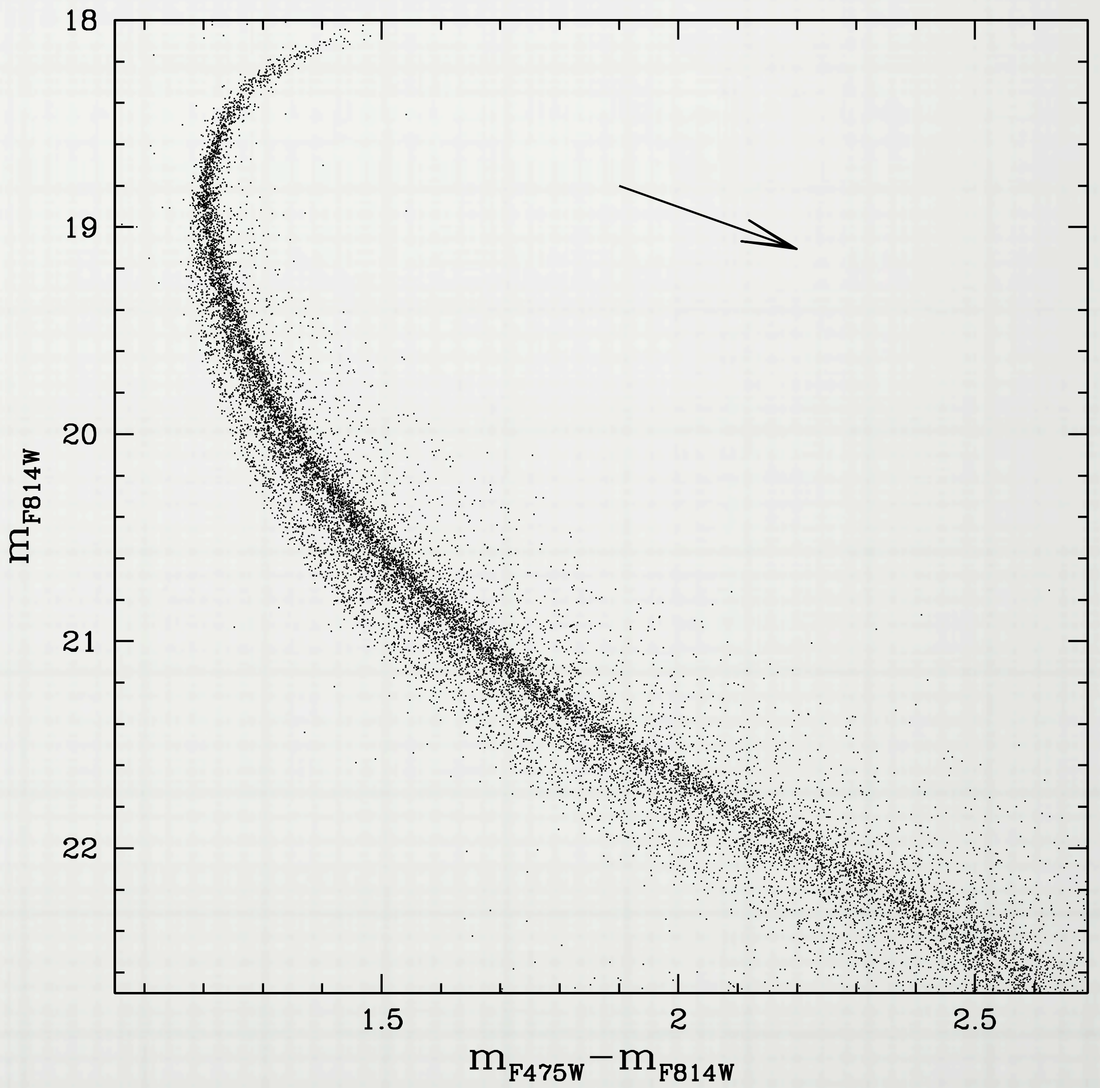
Globular Cluster Formation

- The properties of globular clusters encode details of the galaxy formation process (Ashman & Zepf 1992).
- Unfortunately, many seemingly fundamental properties of globular clusters lack convincing explanations (c.f. multiple He abundance in some clusters).



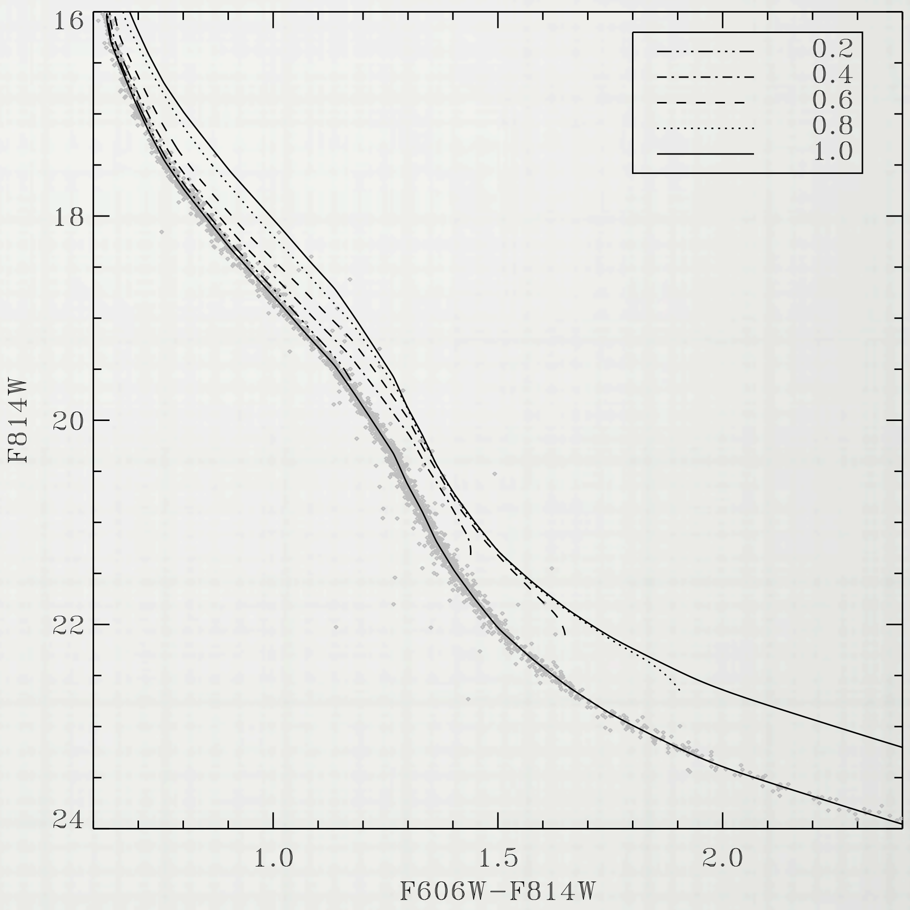
Triple MS of NGC2808 (Piotto 2008)

Initial Conditions?

- Ideally, one would like to know the properties of globular clusters at formation, since these properties relate directly to galaxy formation (and, of course, star formation in clusters).
- The clusters that can be observed best (those in our Galaxy), are almost universally *old*.
- Young super star clusters in other galaxies (as well as Westerlund 1 in our own Galaxy) yield some clues, since they are thought to be analogs of proto-globulars.
- A promising path is to perform "population synthesis" of cluster populations, via direct simulation of their evolution.

Cluster Core Binary Fractions

- *Current* cluster core binary fractions are difficult to determine, but can be measured via, e.g., main-sequence fitting, radial velocity surveys, and extrapolation from observations of a few key populations (e.g., BY Dra, W UMa binaries).



MS method in NGC 6397 (Davis, et al. 2008)

- While the observed binary fraction in low stellar density environments like the field and open clusters is rather large (>~50%), the binary fraction observed in globular cluster cores ranges from a few % to ~30%.

- Is this low *current* binary fraction consistent with a relatively large *initial* binary fraction?

Binary Fraction Evolution

Many strongly coupled processes affect the binary population in a cluster.

- Internal to cluster: binary scattering interactions, binary stellar evolution, stellar collisions, mass segregation.
- External to cluster: tidal stripping due to host galaxy, disk shocking.
- Possible, but likely irrelevant: tidal capture, three-body binary formation.

The binary fraction is thus a good test of the degree of our understanding of cluster evolution.

N-Body vs. Simplified Monte-Carlo

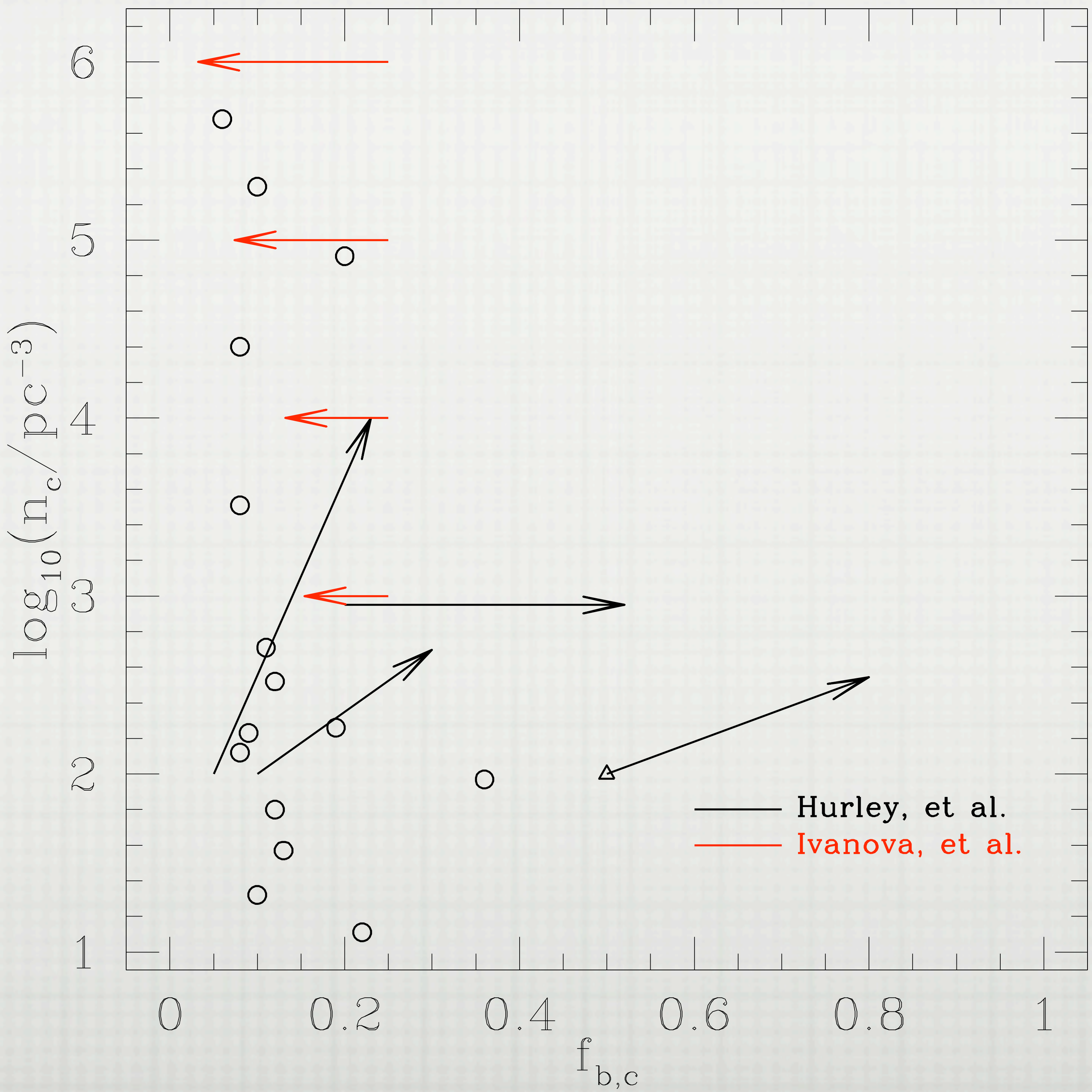
N-Body (Hurley, et al.)

- "Kitchen sink" model since it includes all relevant physics and makes no simplifying assumptions.
- Computationally very expensive and requires special-purpose hardware.
- Finds generally that cluster core binary fraction *increases* (greatly) with time.

Simplified MC (Ivanova, et al.)

- Simplified dynamical model (constant density cluster core with extended halo), coupled with detailed treatment of stellar evolution, collisions, scattering interactions.
- Computationally less expensive, allowing parameter space studies.
- Finds generally that cluster core binary fraction always *decreases* (greatly) with time.

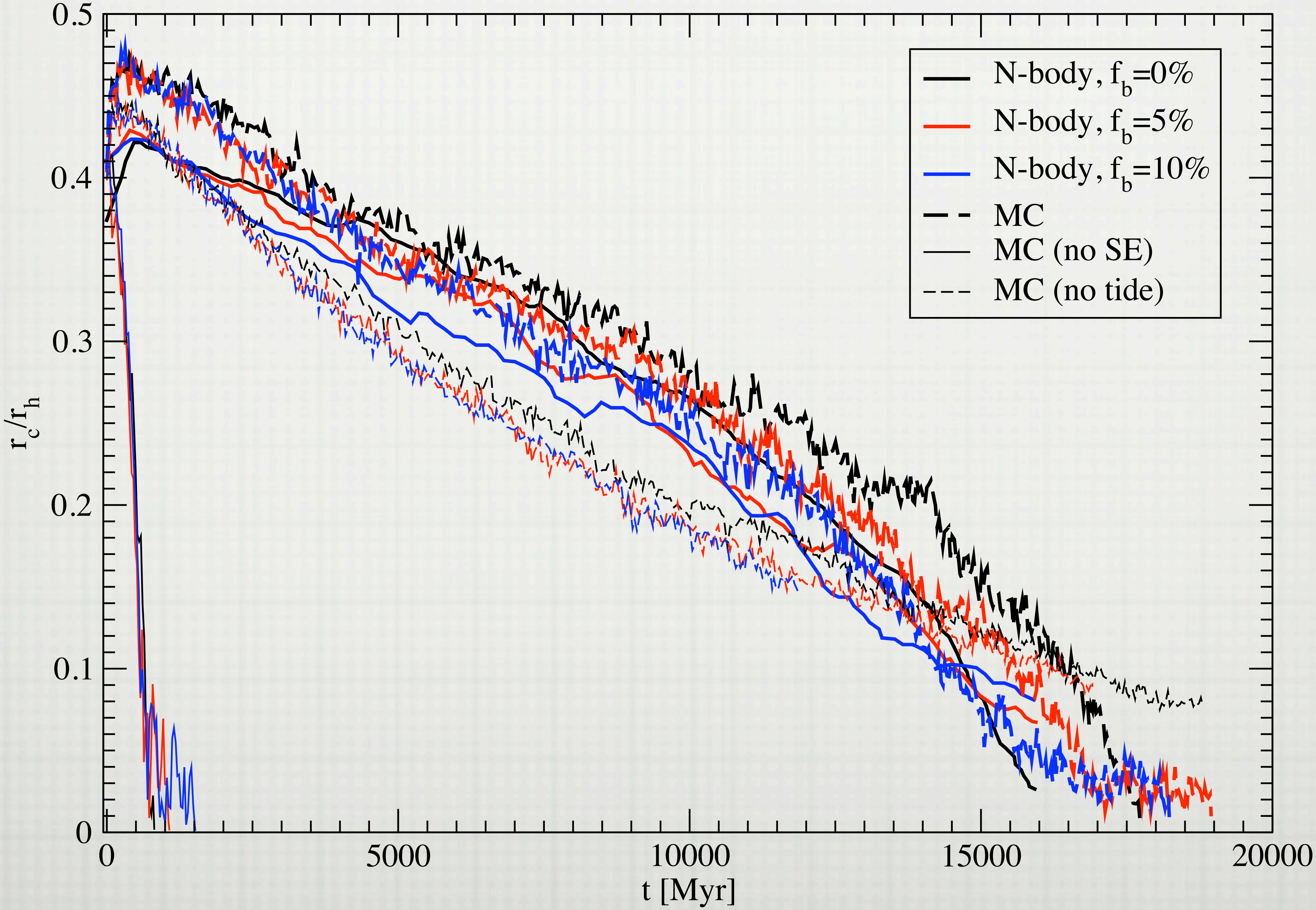
Apples vs. Oranges



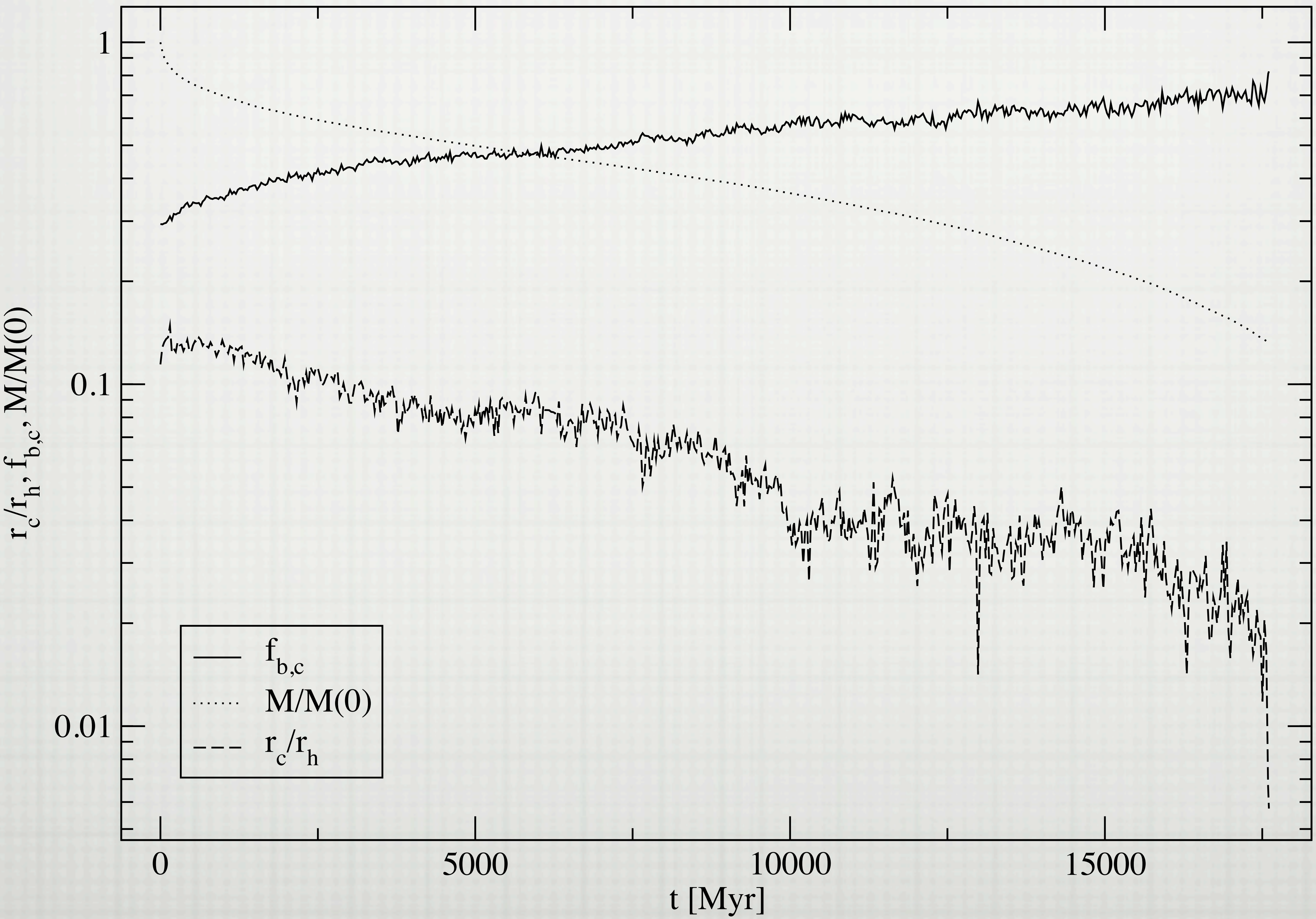
A Modern MC Code

- Monte Carlo method: stochastic solution of the Fokker-Planck equation using discrete representation of distribution function.
- Computation cost scales as N log N (N-body scales as N^2).
- Yields physical realization of cluster at each time step, allowing for inclusion of additional physics (binary interactions, stellar evolution, collisions, etc.)
- Have recently incorporated single and binary stellar evolution via "BSE" code (Hurley, Pols, & Tout 2000; Hurley, Tout, & Pols 2002).

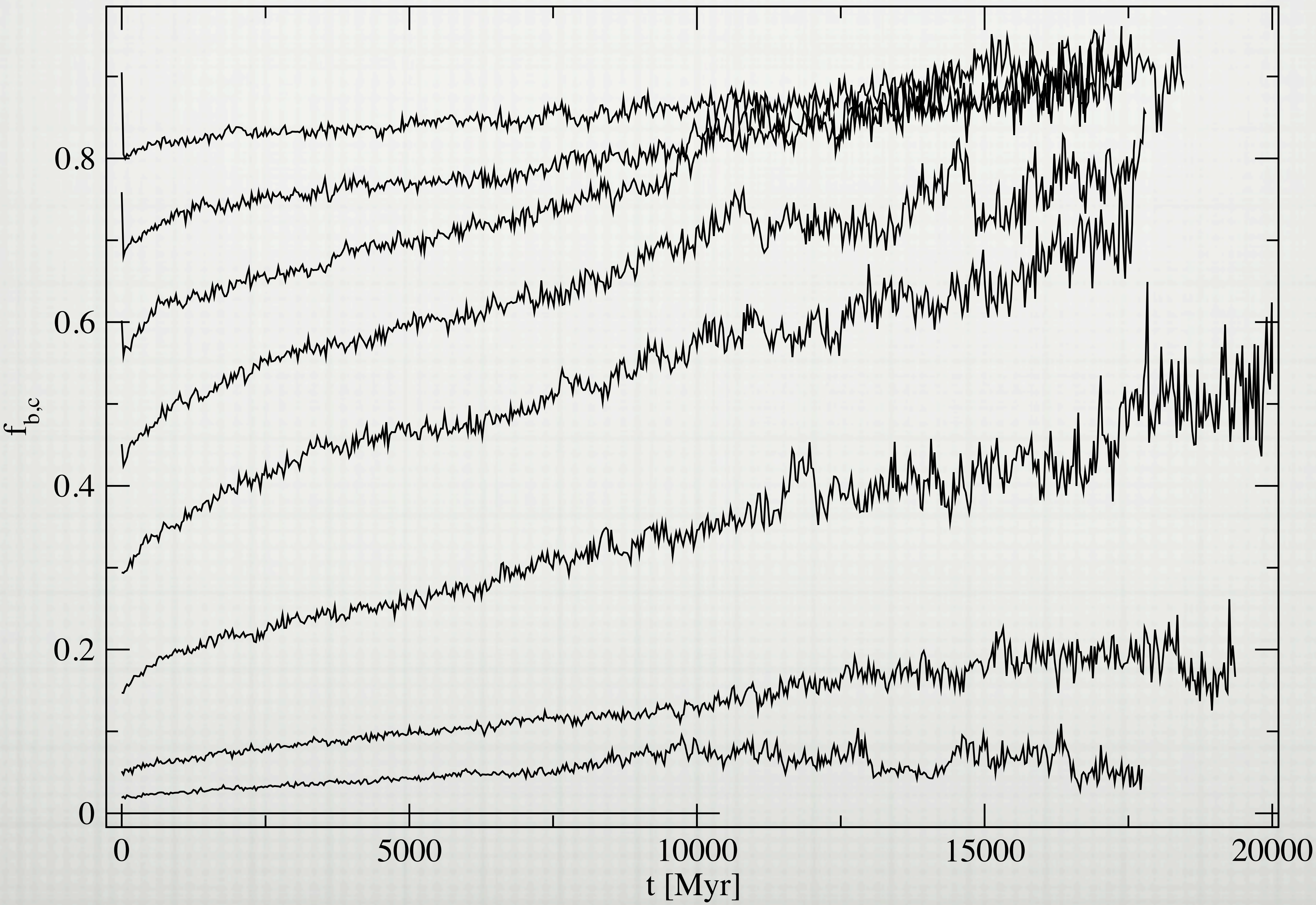
Comparison w/ N-body (Hurley 2007)



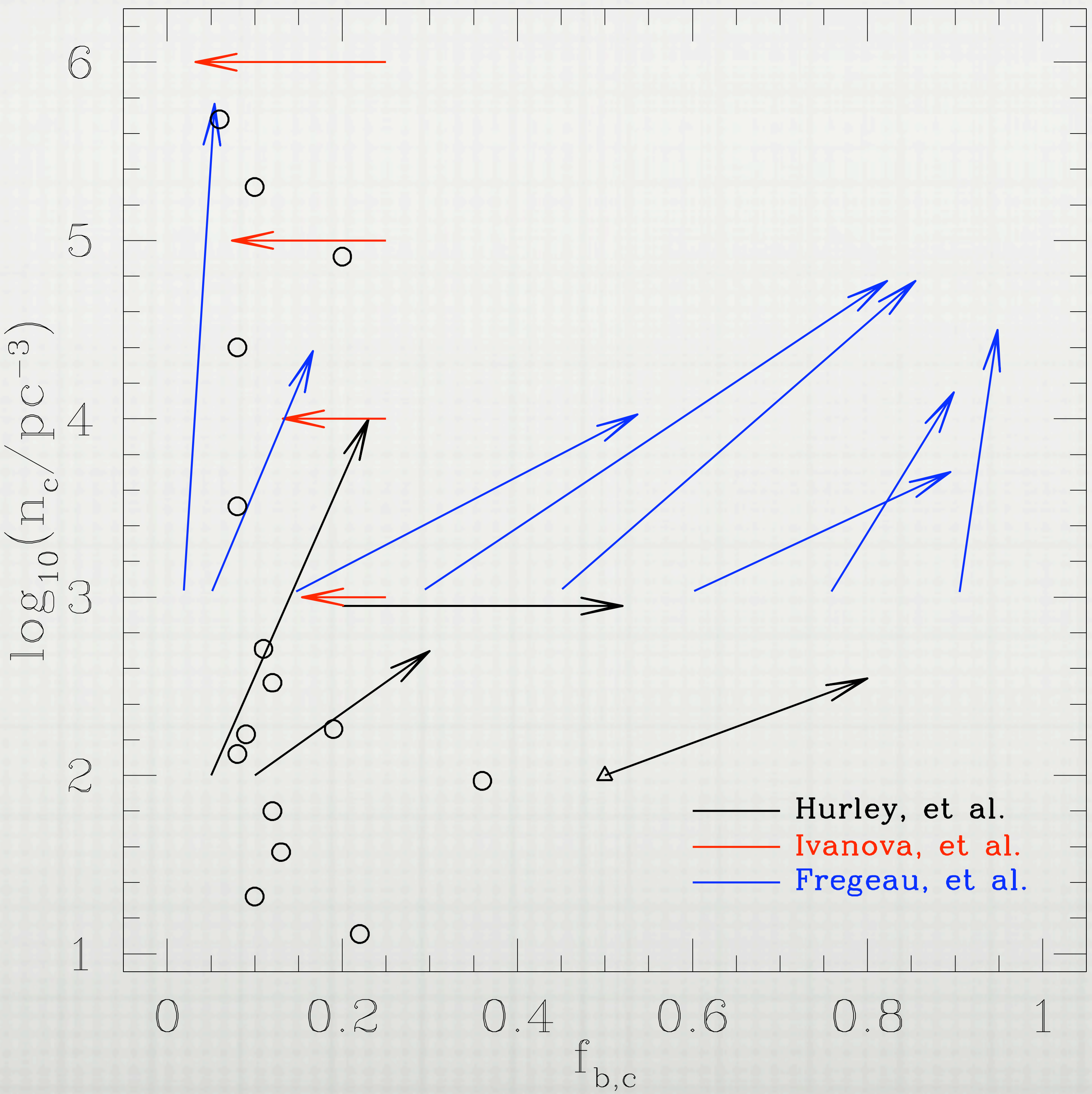
Typical Evolution (R=8pc, fb=0.3)



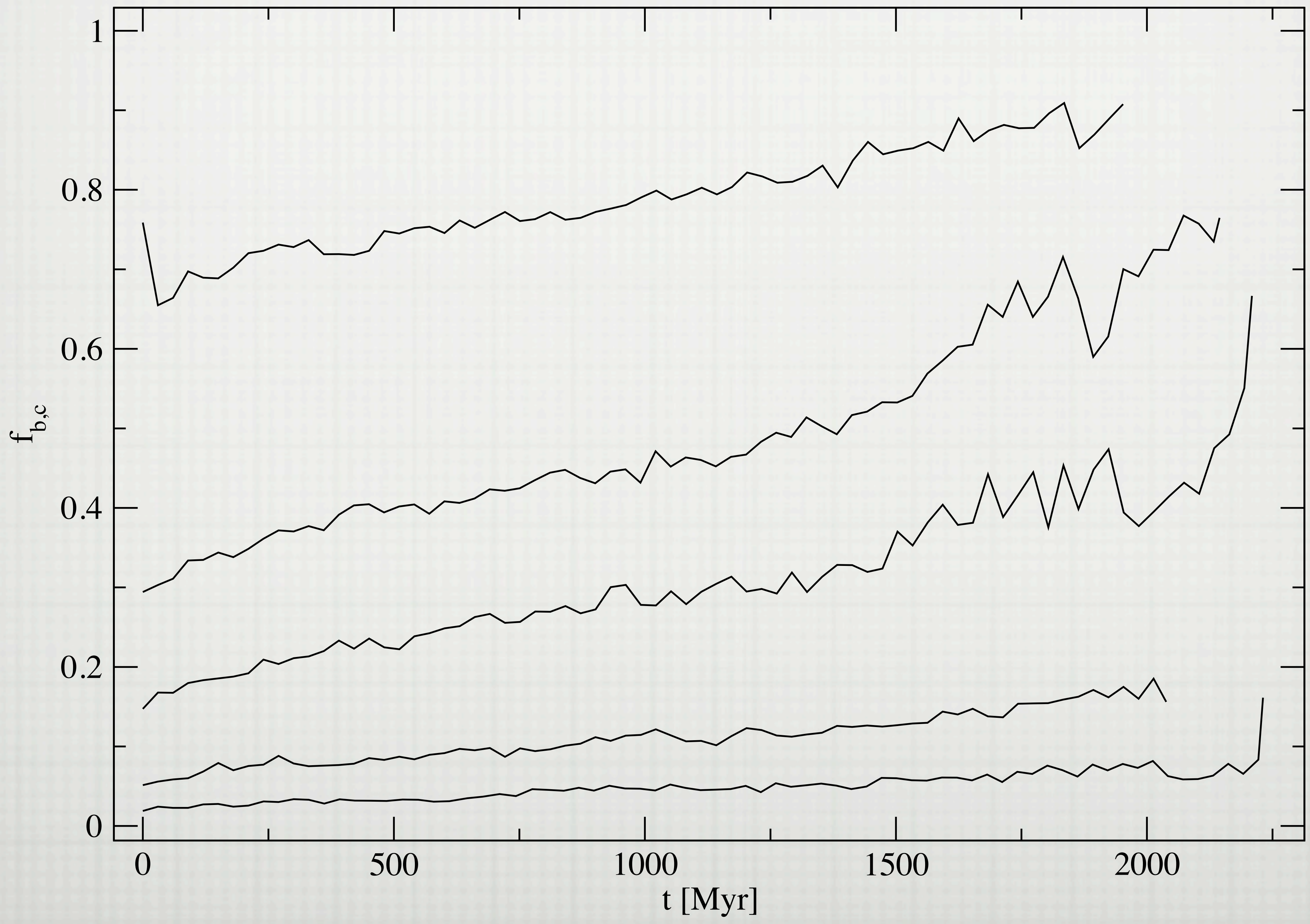
General Evolution (R=8pc)



Comparison to Apples and Oranges?



General Evolution (R=2pc)



Preliminary Conclusions

- As suggested by earlier N-body calculations, the quasi-equilibrium, binary burning phase is certainly not generic.
- Core binary fraction generically increases with time, suggesting that either: 1) globular clusters were "born" with very small numbers of binaries, or 2) we simply haven't found the appropriate cluster initial conditions.
- Although we haven't exhaustively sampled parameter space, it appears difficult to create clusters which survive a Hubble time.

Forthcoming Studies

- Central BH: loss cone physics added; comparison with new HST observations showing a range of weak central density cusps; hints for the existence of IMBHs?

- Dynamical influence of stellar collisions: the accelerated mass loss due to collisions *may* provide enough energy to produce core sizes compatible with observations.

- Detailed study of production of individual species (LMXBs, CVs, BSSs, MSPs): first to compare with semi-analytical study of Fregeau (2008), then to model individual clusters (e.g., M4, 47 Tuc, NGC 6397).

- Synthetic observables: H-R diagrams, surface brightness profiles, etc.