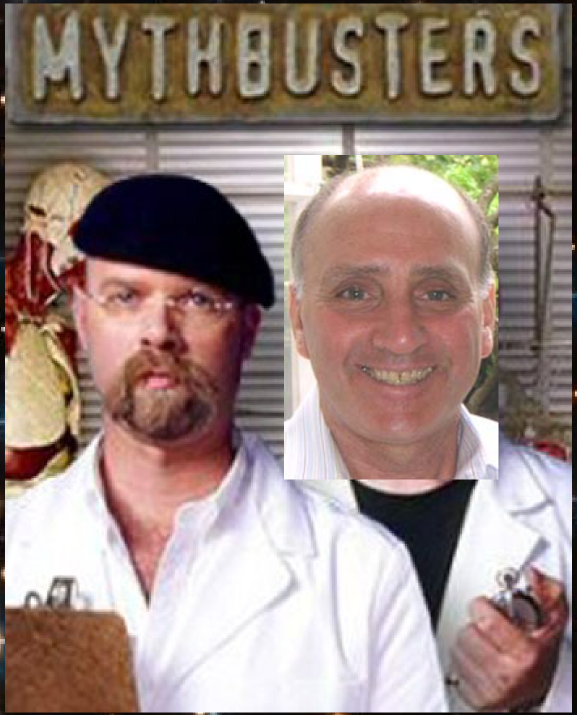
New Observations Related to the Dynamical Evolution of Globular Star Clusters



Harvey B. Richer
UBC
KITP January 12, 2009

S. Davis, R. Gagne, J. Heyl, A. Ruberg – UBC;
J. Kalirai, J. Anderson - STScI; A. Dotter - U Victoria;
J. Fregeau- KITP; I. King - U. Wash; B. Hansen, M. Rich - UCLA

Myth 1: The Primordial Binary Fraction in GCs is High

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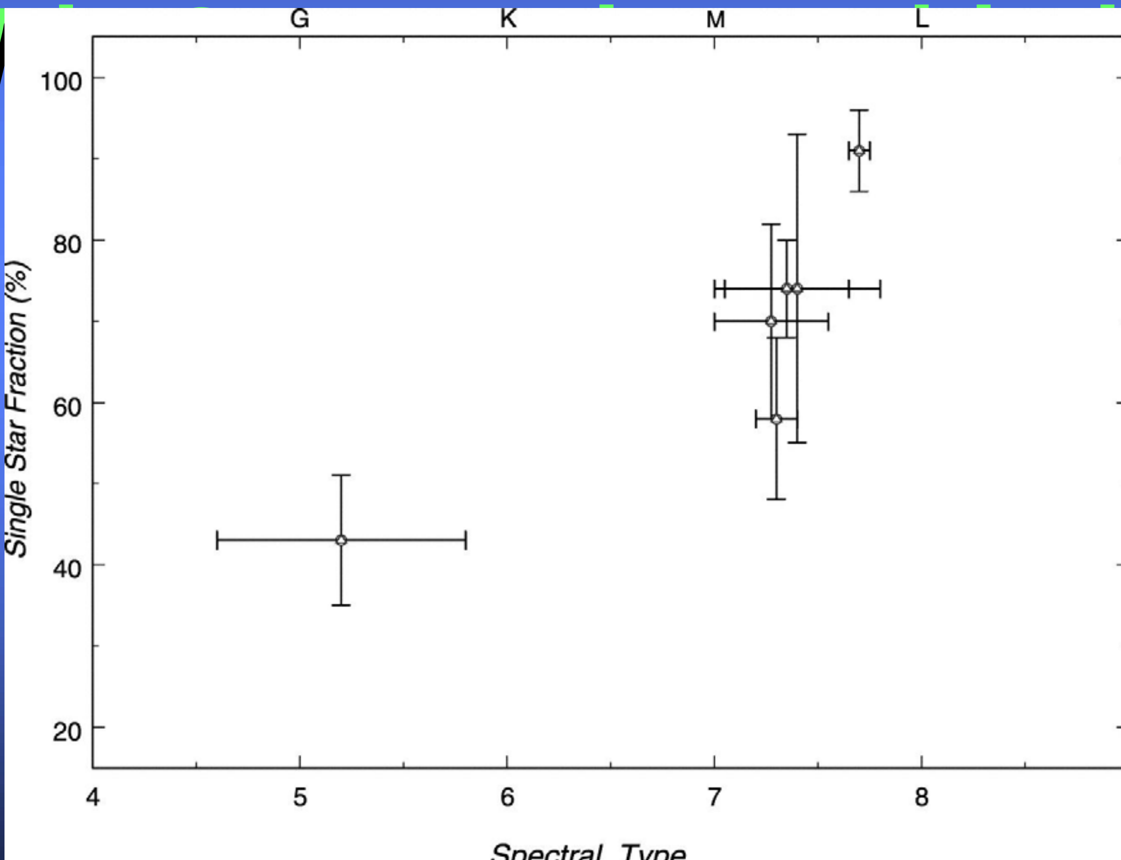
W … he field



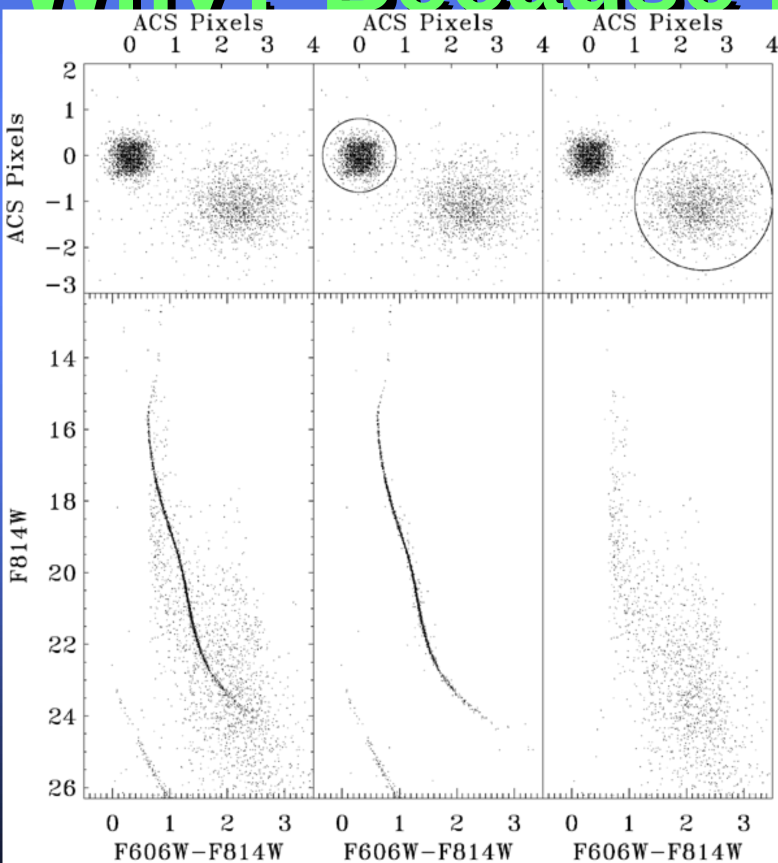
Most low mass stars are single: 70% M-stars single. This is for the disk - binary fraction is lower in the halo.

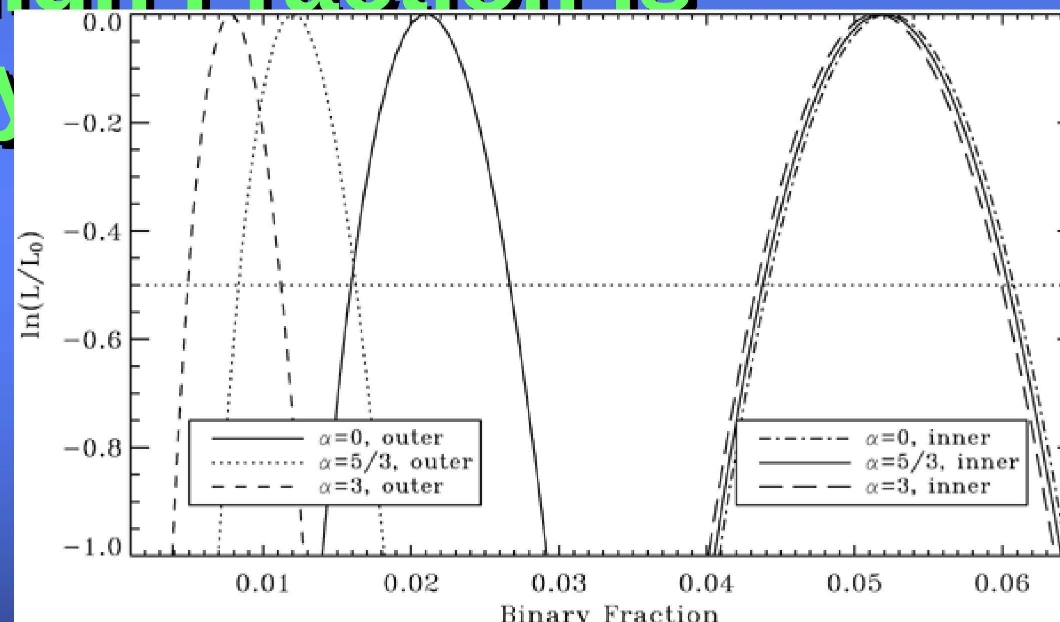
Lada 2006

Myth 1: The Primordial Binary Fraction in GCs is High

Why? Because High Fraction is

tly





Davis et al 2008

Myth 1: The Primordial Binary Fraction in GCs is High

Why? Because High Fraction is C [illegible] in Globulars

Table 1
Literature Binary Fraction Constraints

	Inside half-mass radius		Outside half-mass radius	
	f	Reference	f	Reference
NGC 288	0.15 ± 0.05	Bellazzini et al. (2002)	$0.0^{+0.1}_{-0.0}$	Bellazzini et al. (2002)
	>0.06	Sollima et al. (2007)		
NGC 362	0.21 ± 0.06	Fischer et al. (1993)		
NGC 2808			0.20 ± 0.04	Alcaino et al. (1998)
NGC 3201			<0.1	Cote et al. (1994)
NGC 4590	>0.09	Sollima et al. (2007)		
NGC 5053	>0.08	Sollima et al. (2007)		
NGC 5466	>0.08	Sollima et al. (2007)		
NGC 5897	>0.07	Sollima et al. (2007)		
NGC 6101	>0.09	Sollima et al. (2007)		
NGC 6362	>0.06	Sollima et al. (2007)		
NGC 6397	<0.07	Cool & Bolton (2002)		
NGC 6723	>0.06	Sollima et al. (2007)		
NGC 6752	0.27 ± 0.12	Rubenstein & Bailyn (1997)	$0.02^{+0.16}_{-0.02}$	Rubenstein & Bailyn (1997)
NGC 6792			"low"	Catelan et al. (2007)
NGC 6981	>0.10	Sollima et al. (2007)		
M3			"low"	Gunn & Griffin (1979)
			~ 0.04	Pryor et al. (1988)
	0.14 ± 0.08	Zhao & Bailyn (2005)	0.02 ± 0.01	Zhao & Bailyn (2005)
M4	$0.23^{+0.34}_{-0.23}$	Cote & Fischer (1996)	~ 0.02	Richer et al. (2004)
M15	~ 0.07	Gebhardt et al. (1994)		
M22			$0.03^{+0.16}_{-0.03}$	Cote et al. (1996)
M30			<0.05	Alcaino et al. (1998)
M55	>0.06	Sollima et al. (2007)		
M71	$0.22^{+0.26}_{-0.12}$	Yan & Mateo (1994)		
M92			$0.00^{+0.03}_{-0.00}$	Anderson (1997)
Arp 2	>0.08	Sollima et al. (2007)		
Terzan 7	>0.21	Sollima et al. (2007)		
Palmoar 12	>0.18	Sollima et al. (2007)		
Palmoar 13	0.30 ± 0.04	Clark et al. (2004)		
47 Tucane	0.14 ± 0.04	Albrow et al. (2001)	>0.05	de Marchi & Paresce (1995)
			~ 0.02	Anderson (1997)
ω Centauri			<0.05	Elson et al. (1995)

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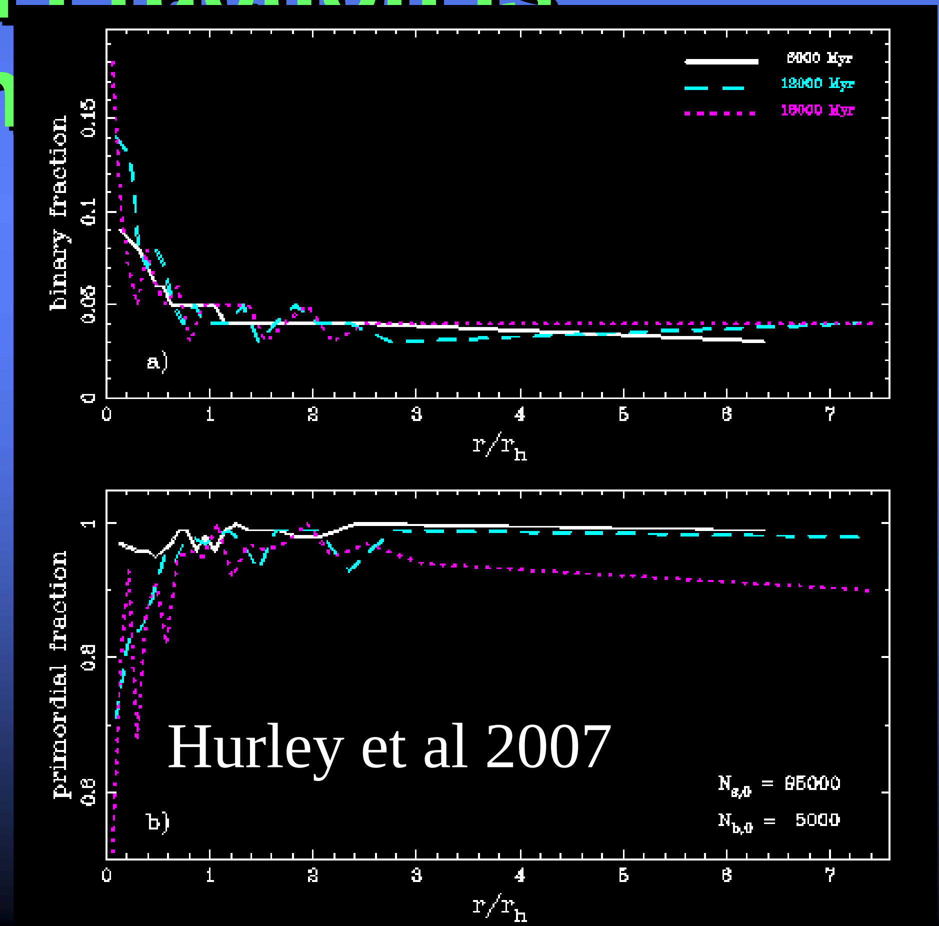

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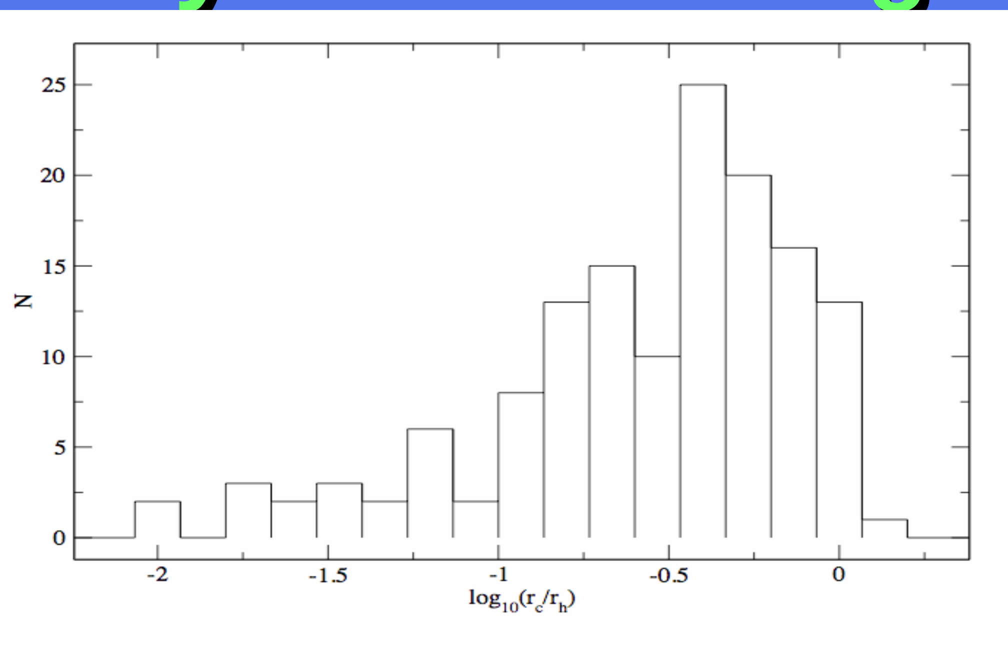

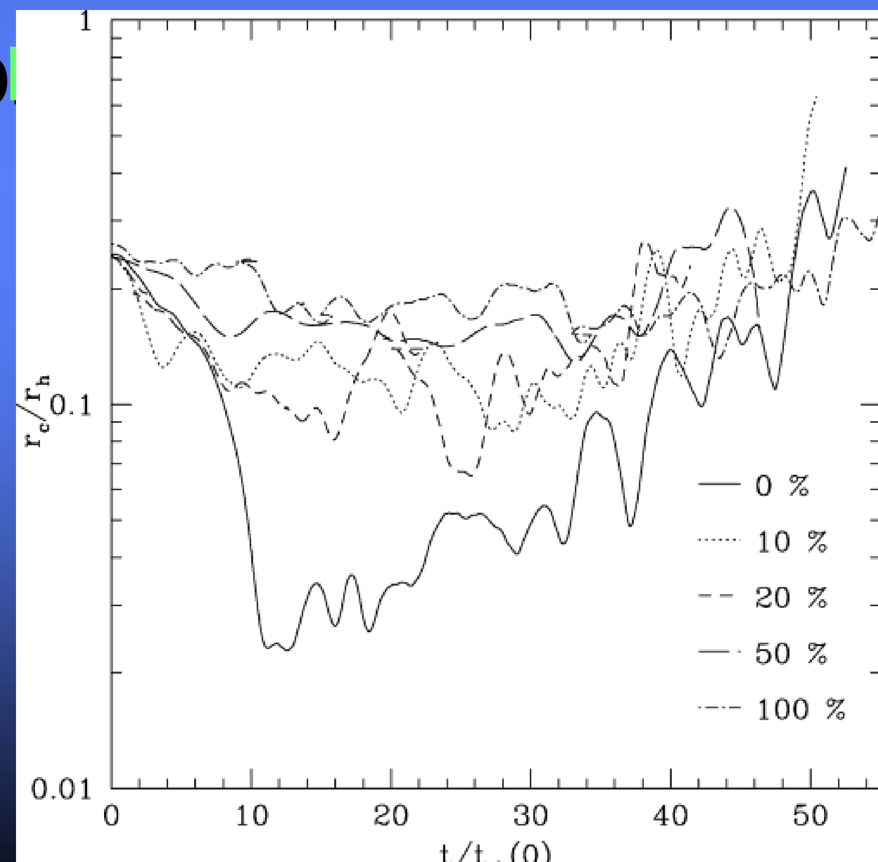

Trenti et al 2006

Myth 2: Occurrence IMBH in Globular Clusters is High

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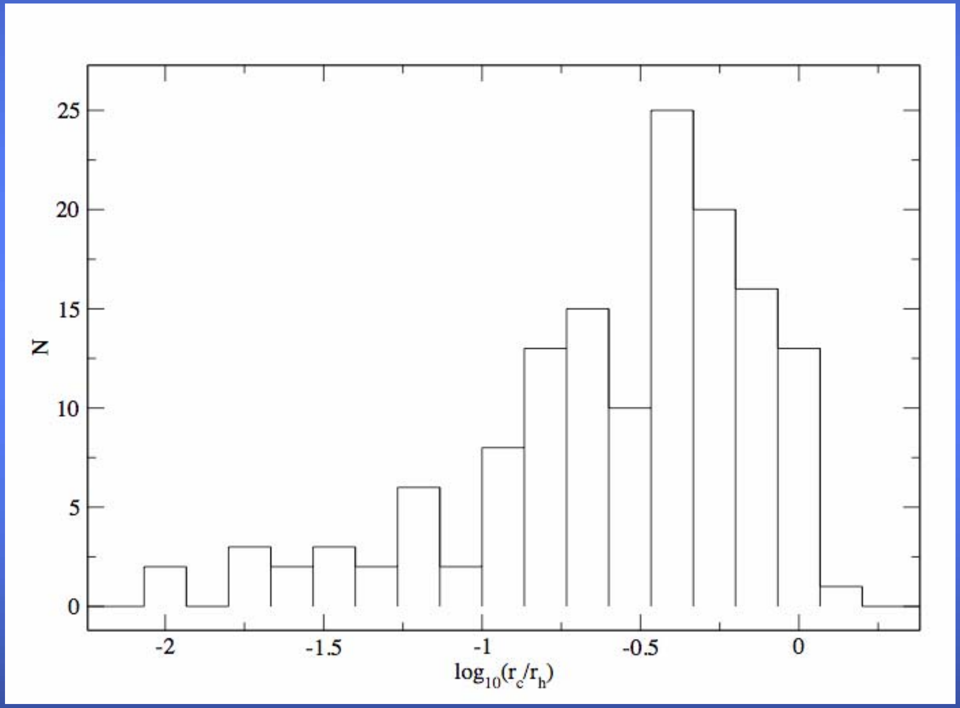
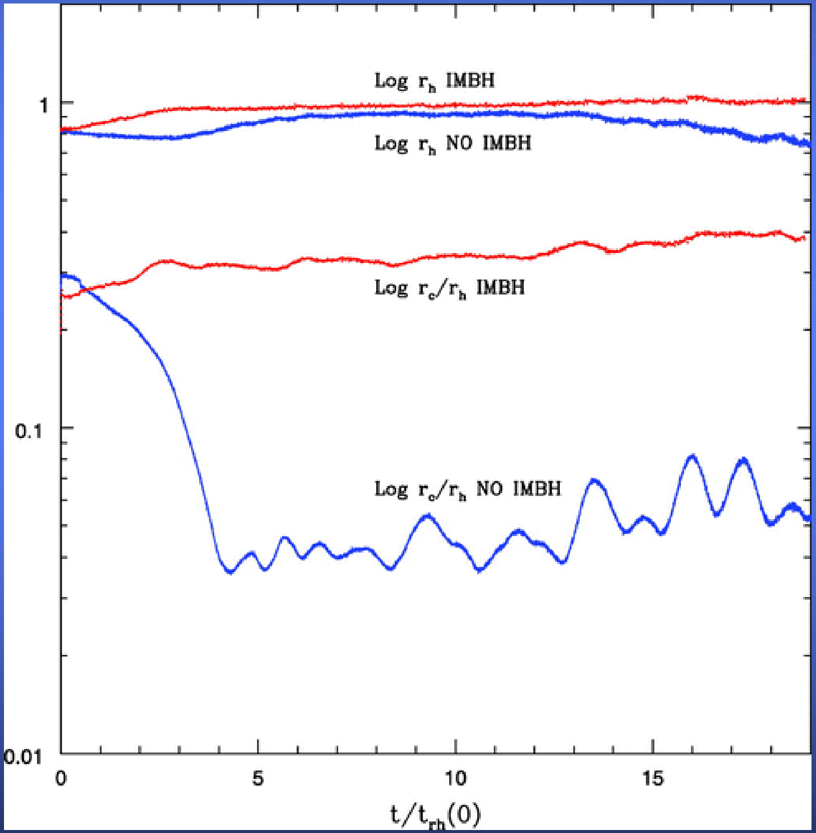
Why? Needed to understand r_c/r_h distribution



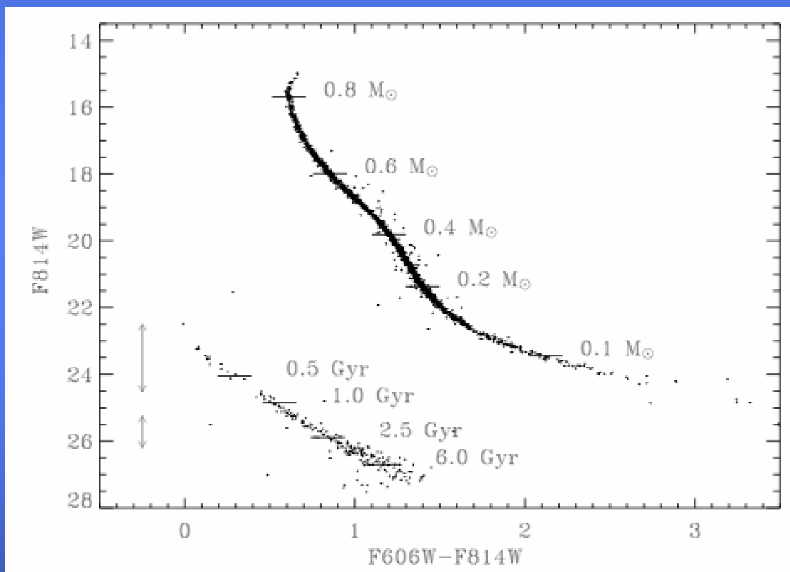
"Only presence of an IMBH appears to be consistent with such large core radius values" Trenti (2006)

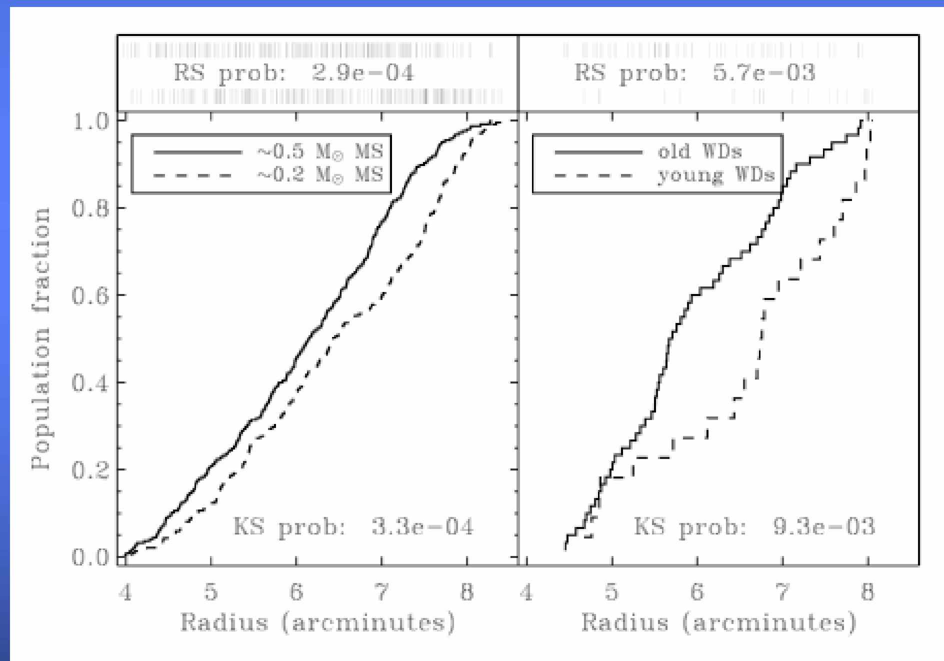


Gill et al 2008 "presence of an IMBH prevents core collapse"

A New Dynamical Scenario

High binary fraction & IMBHs suggested as another heat source ignored - "kicked" white dwarfs

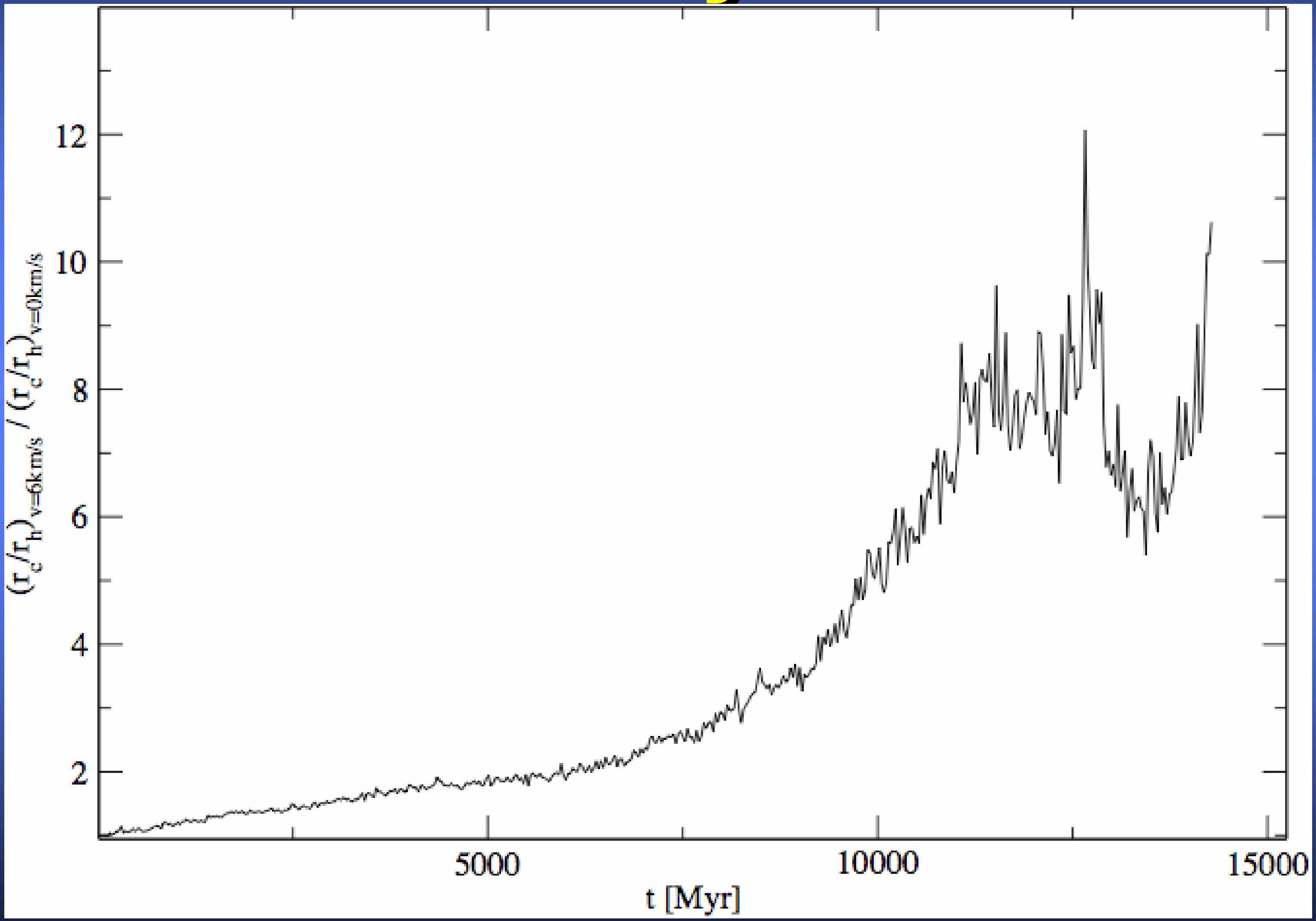




Davis et al 2008

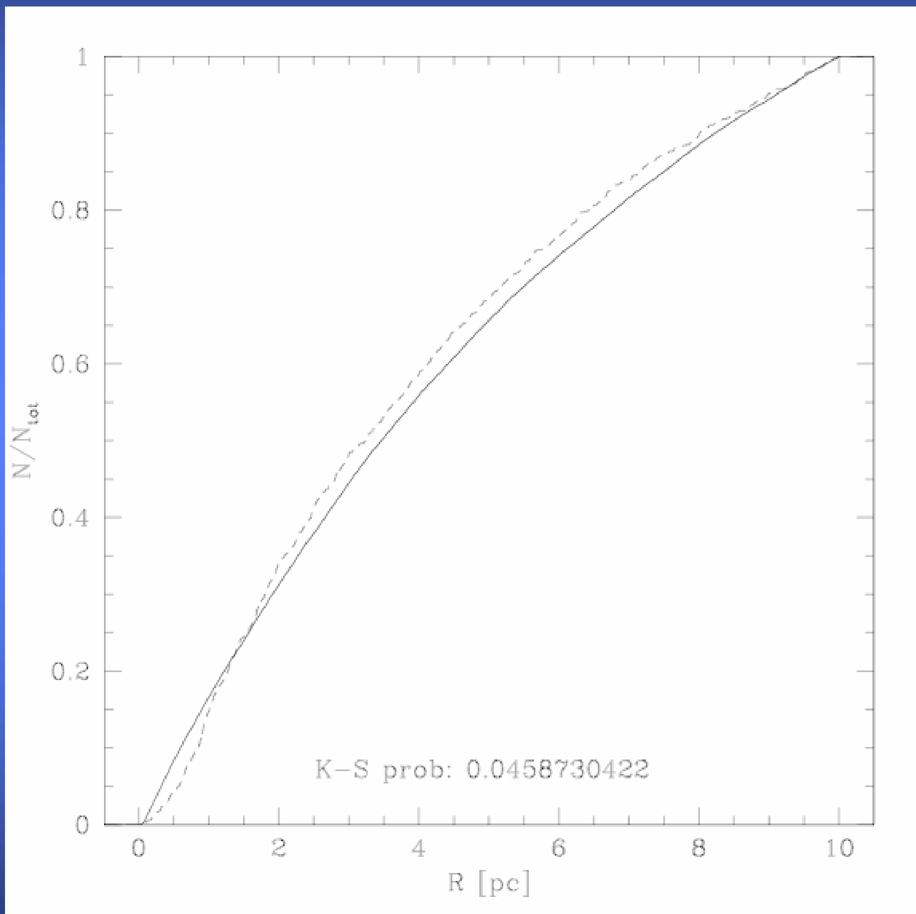
Examine WD radial distribution in cluster - suggests "kick" at birth 3 - 5 km/sec

Implication of WD Kicks
Core Heated by Kicked WDs

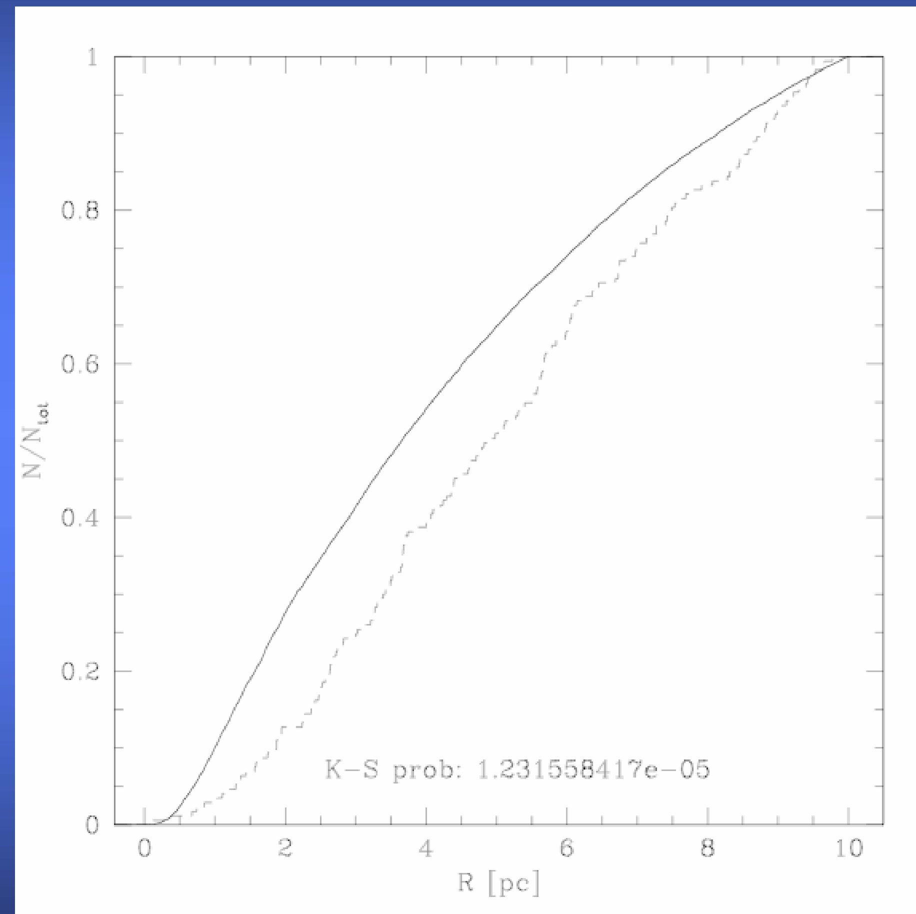


Fregeau et al 2009

Implication of WD Kicks
Young-Old WD Radial Distributions



No WD Kick



6 km/s WD Kick

Fregeau et al 2009

Other Implications of WD Kicks

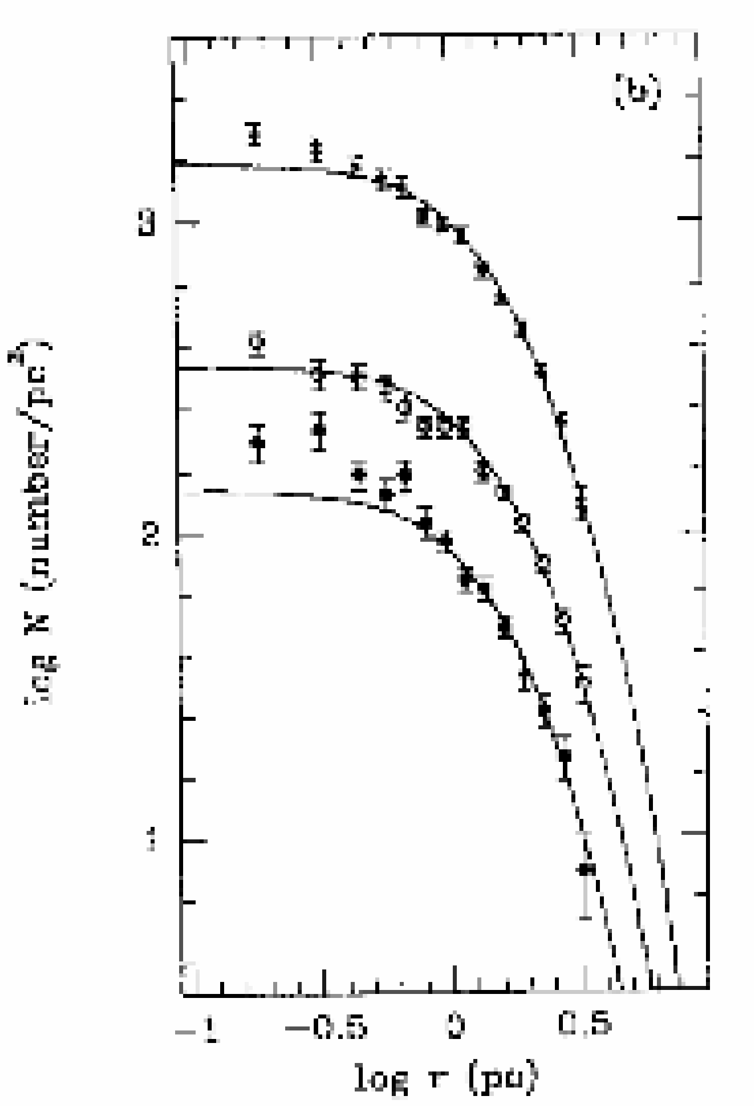
May explain shortage of WDs in open clusters

Reduces need for high binary fraction - new heat source

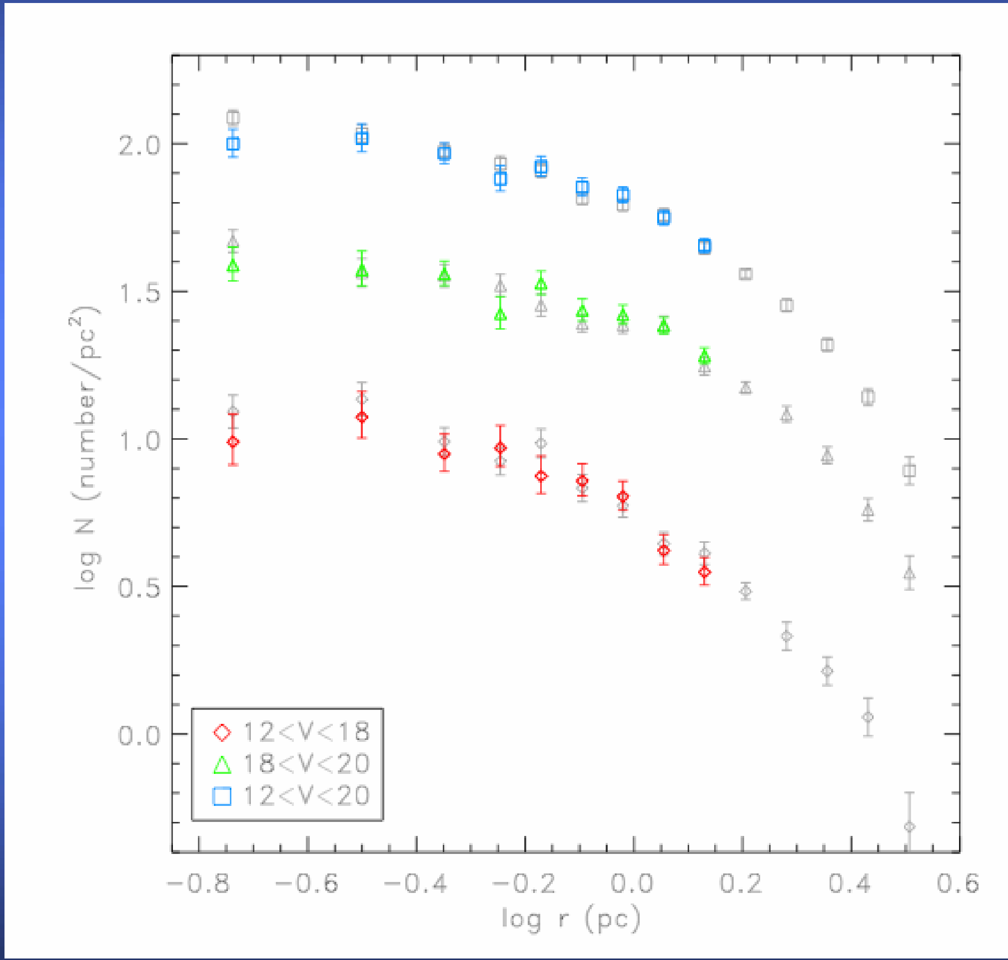
Prevent or delay core collapse

May explain large r_c/r_h ratio seen in many globular clusters - without need for Black Holes in most cases

Case Study: M71 r_c/r_h = 0.38 - possible candidate for IMBH



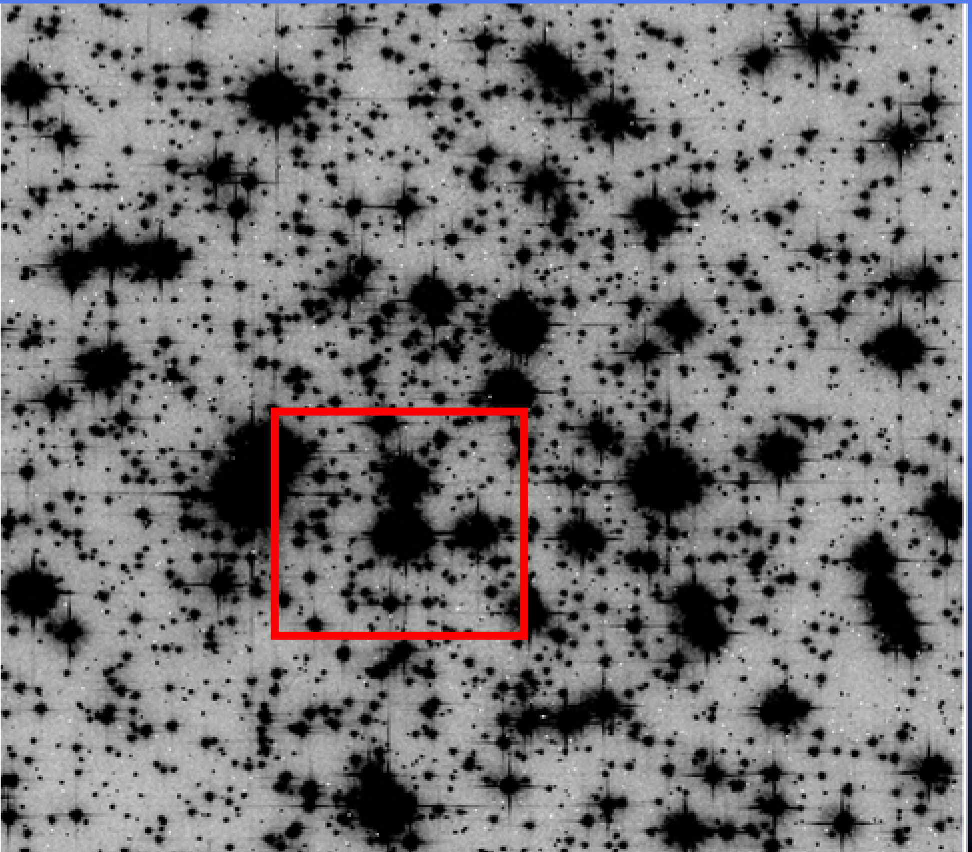
Drukier et al 1992

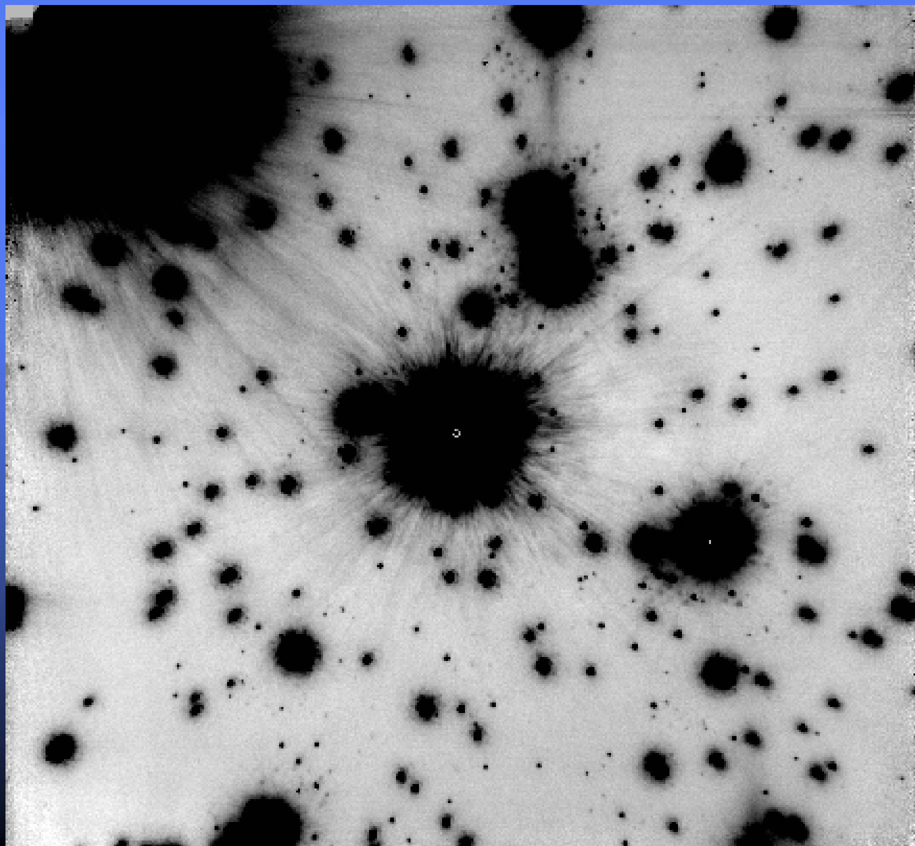


Richer et al 2009

Case Study: M71 $r_c/r_h = 0.38$

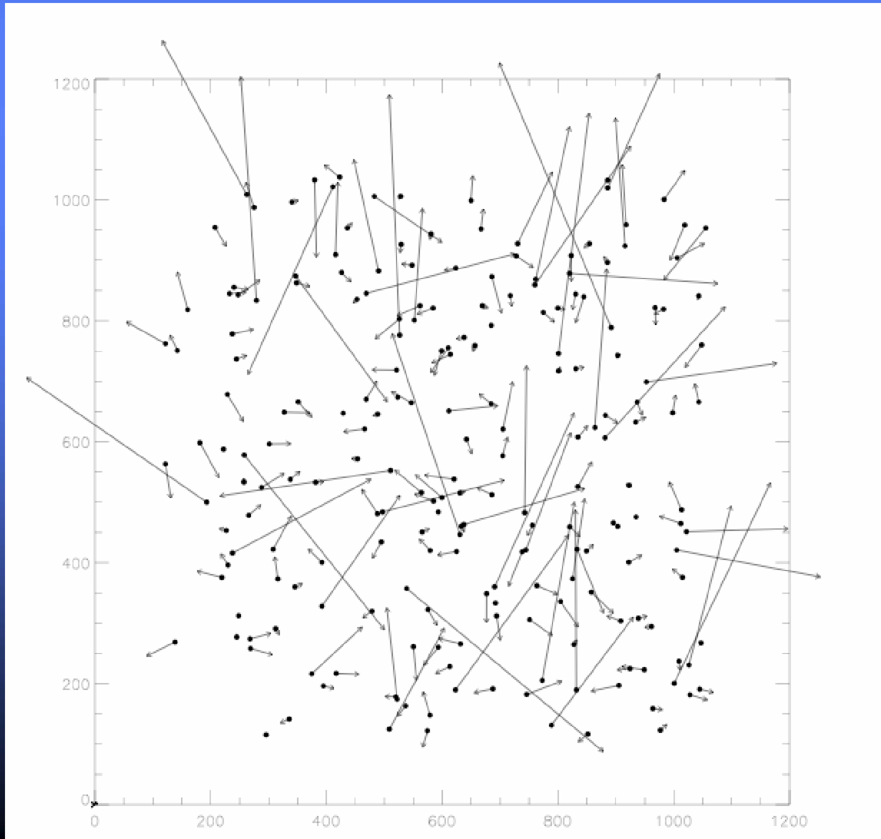
- Gemini AO Observations Core M71 in H & K
- Two Epochs separated by 1.8 years plus 1996 CFHT AO images
- Field 22” x 22” - Pixel 0.022” - FWHM 0.06” in K

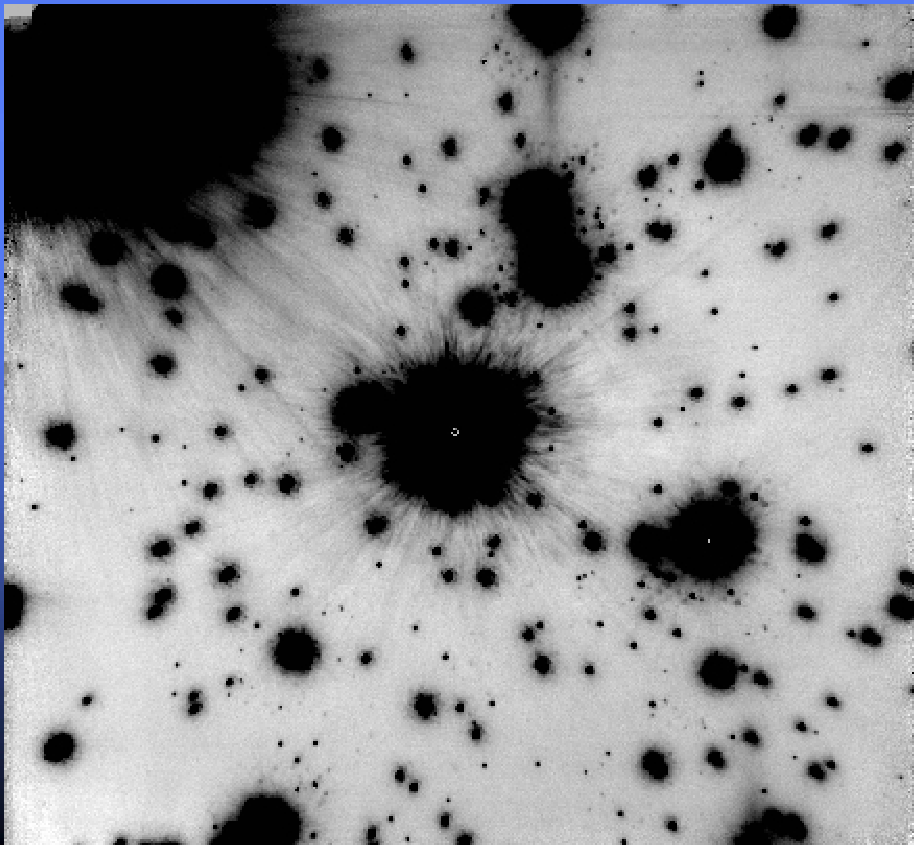




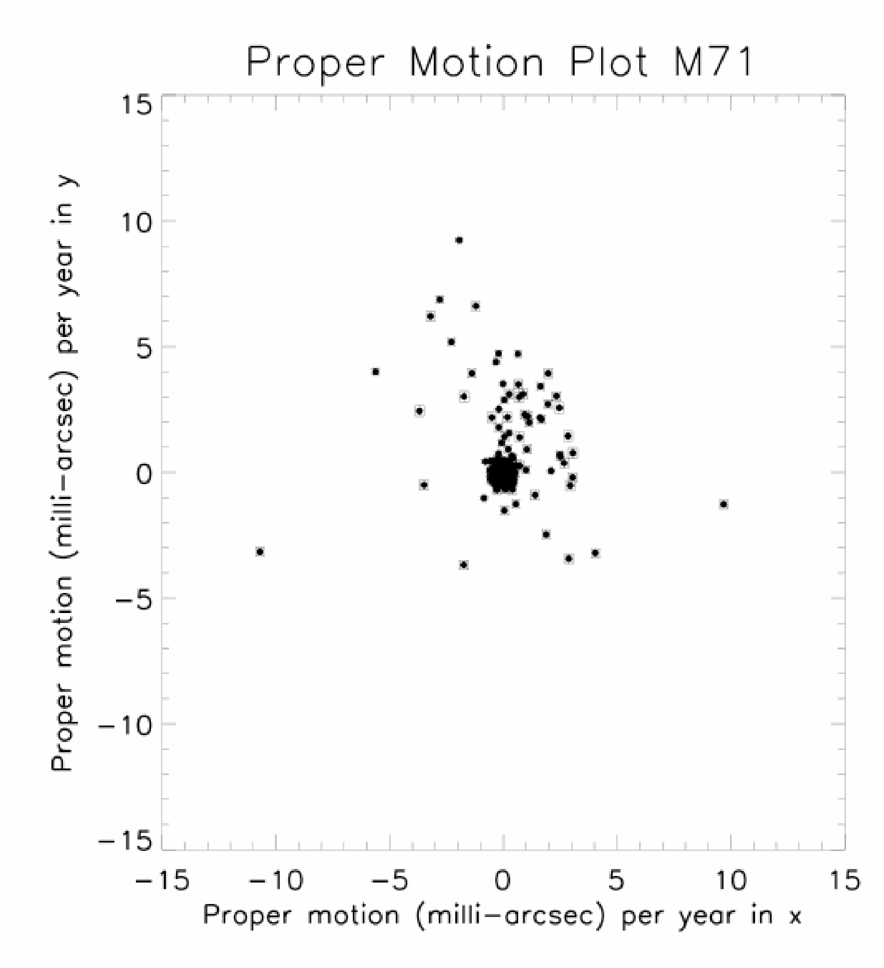
Case Study: M71 $r_c/r_h = 0.38$

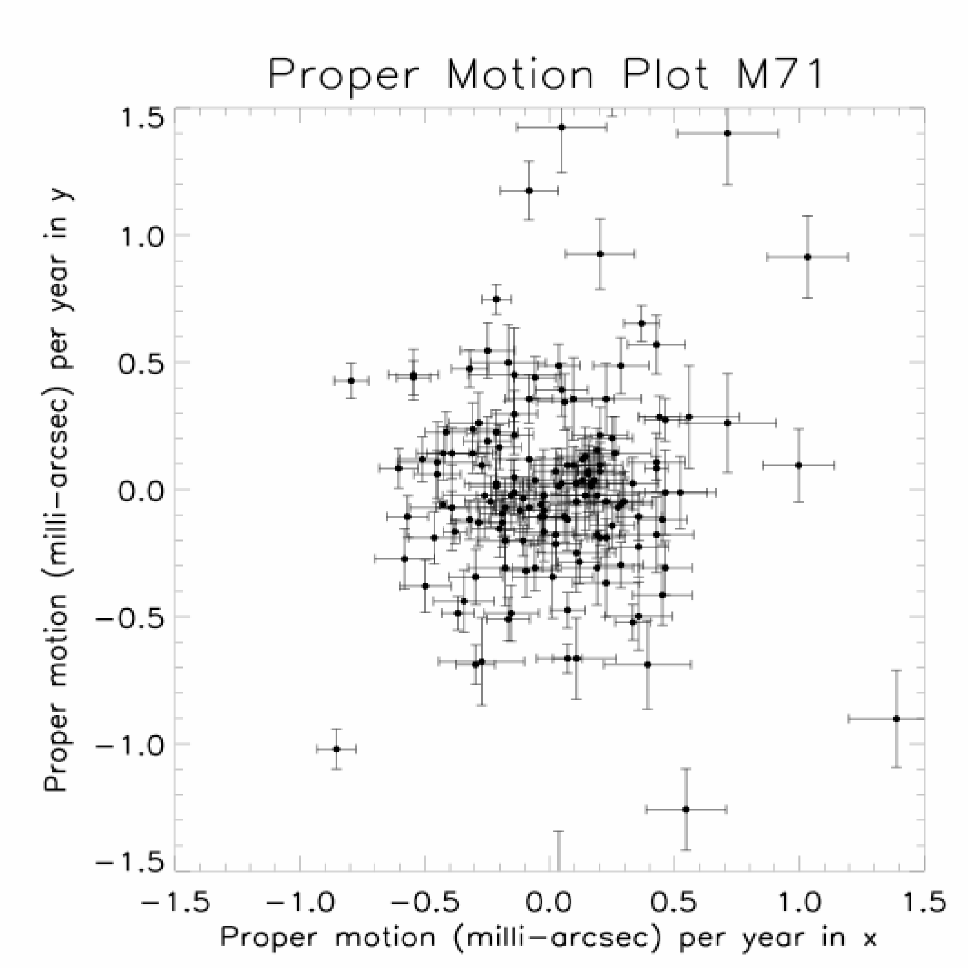
- Gemini AO Observations Core M71 in H & K
- Two Epochs separated by 1.8 years plus 1998 CFHT AO images (no obvious systematics in PMs)
- Field 22" x 22" - Pixel 0.022" - FWHM 0.06" in K





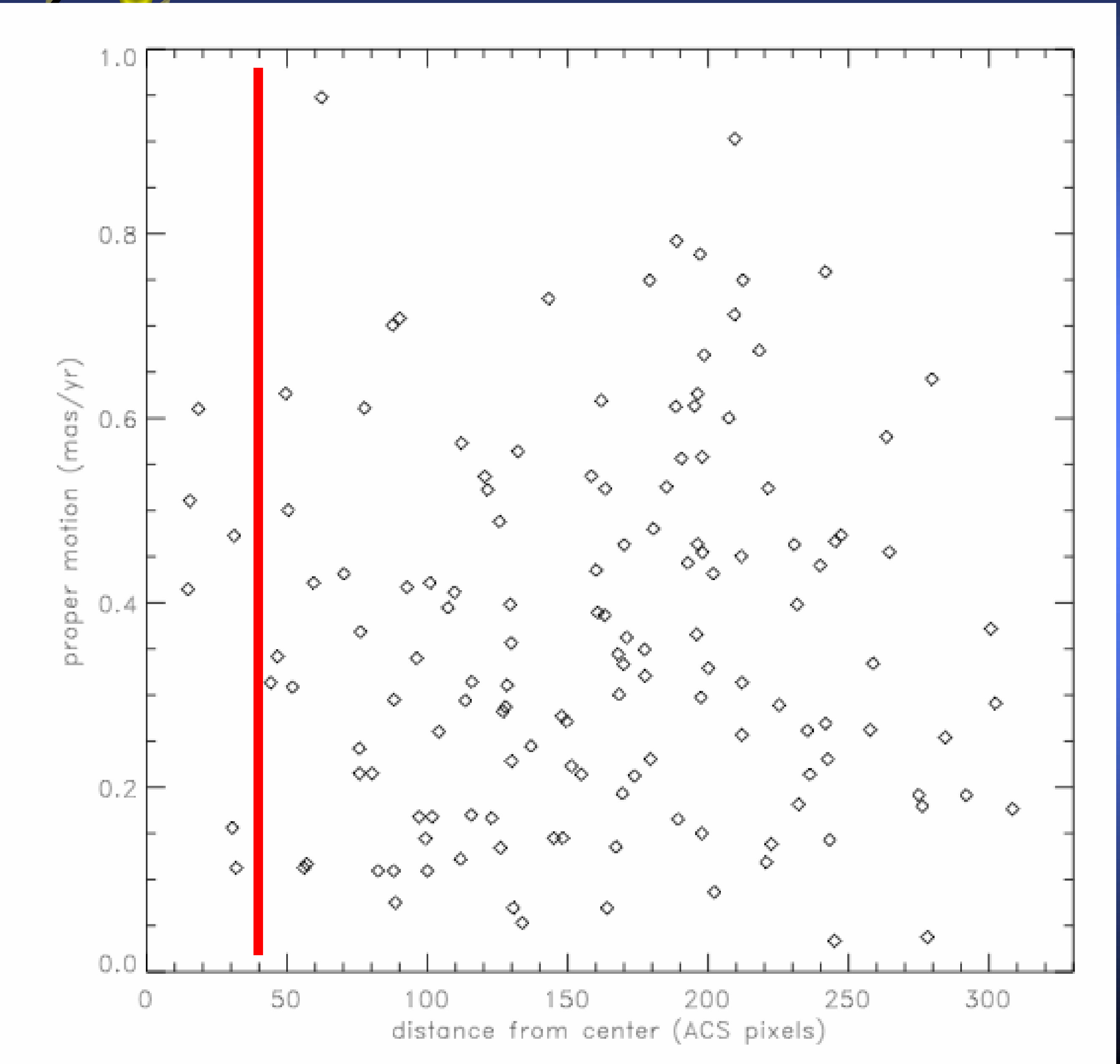
Observed PMs (note PM scale)





$\sigma_{\text{proper motion}}$ = 250+/-20 micro-arcsec / yr

No Evidence Excess Velocity in Core M71



Line is sphere of influence of $100\ M_{sun}$ black hole.

Some Thoughts

Primordial binary fraction appears to be low (few %) in globular clusters

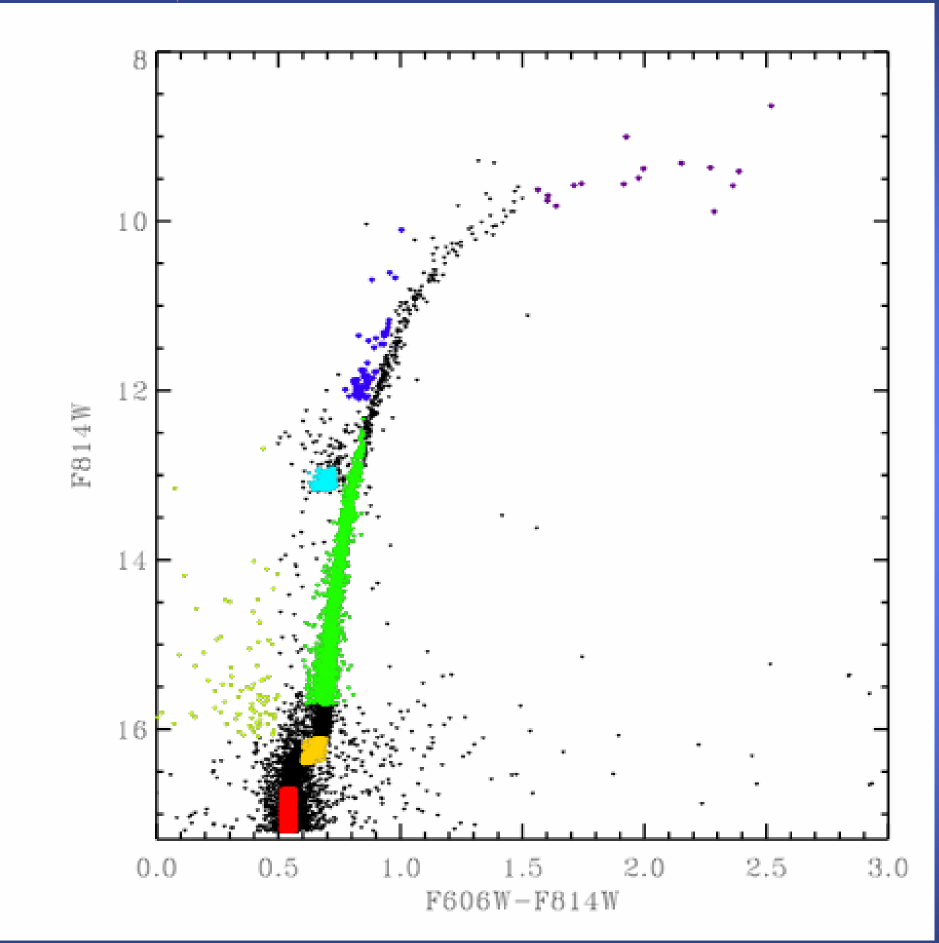
WD kick can provide a new heat source to delay core collapse

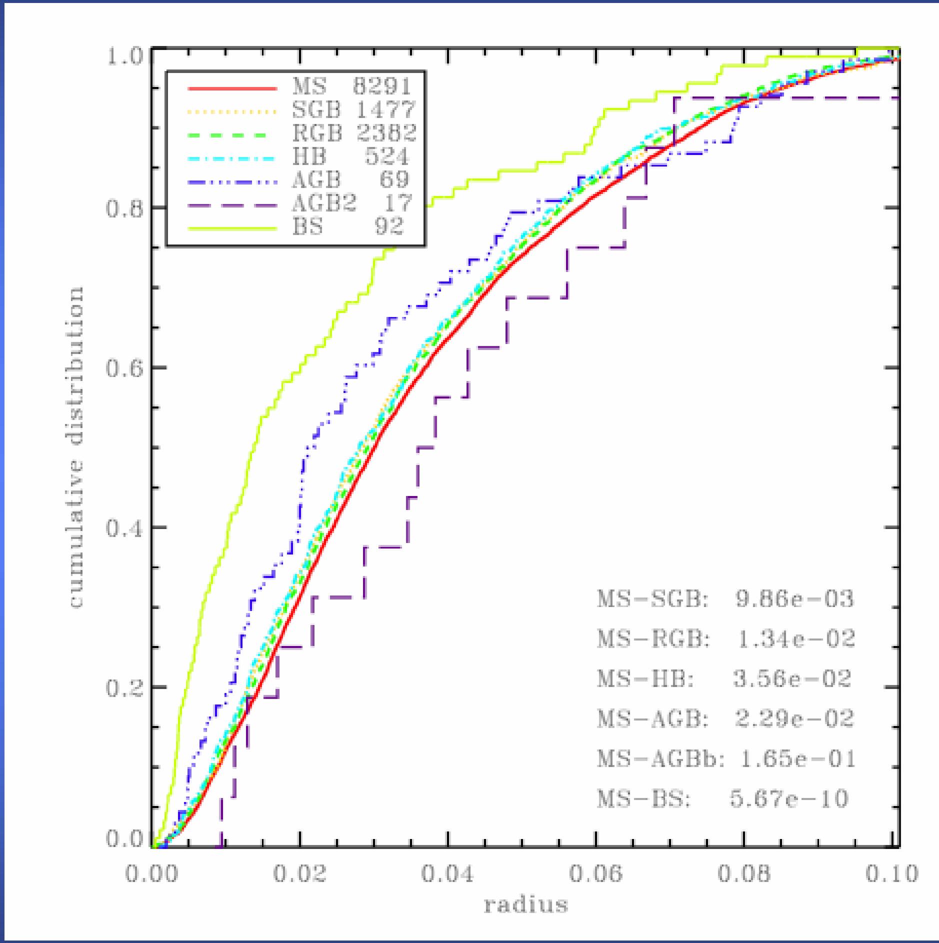
Monte-Carlo simulations with kick produce large r_c/r_h clusters

Soon - direct detection of young and old WD proper motion dispersions

Soon - good statistics on radial distributions various stellar populations in globular clusters to investigate source of kick

Where Does the "Kick" Occur?





Suggestive (but not conclusive) that it may occur late on the AGB.
New HST/ACS proposal will provide superb statistics.