Blue Stragglers

A Theoretical Overview

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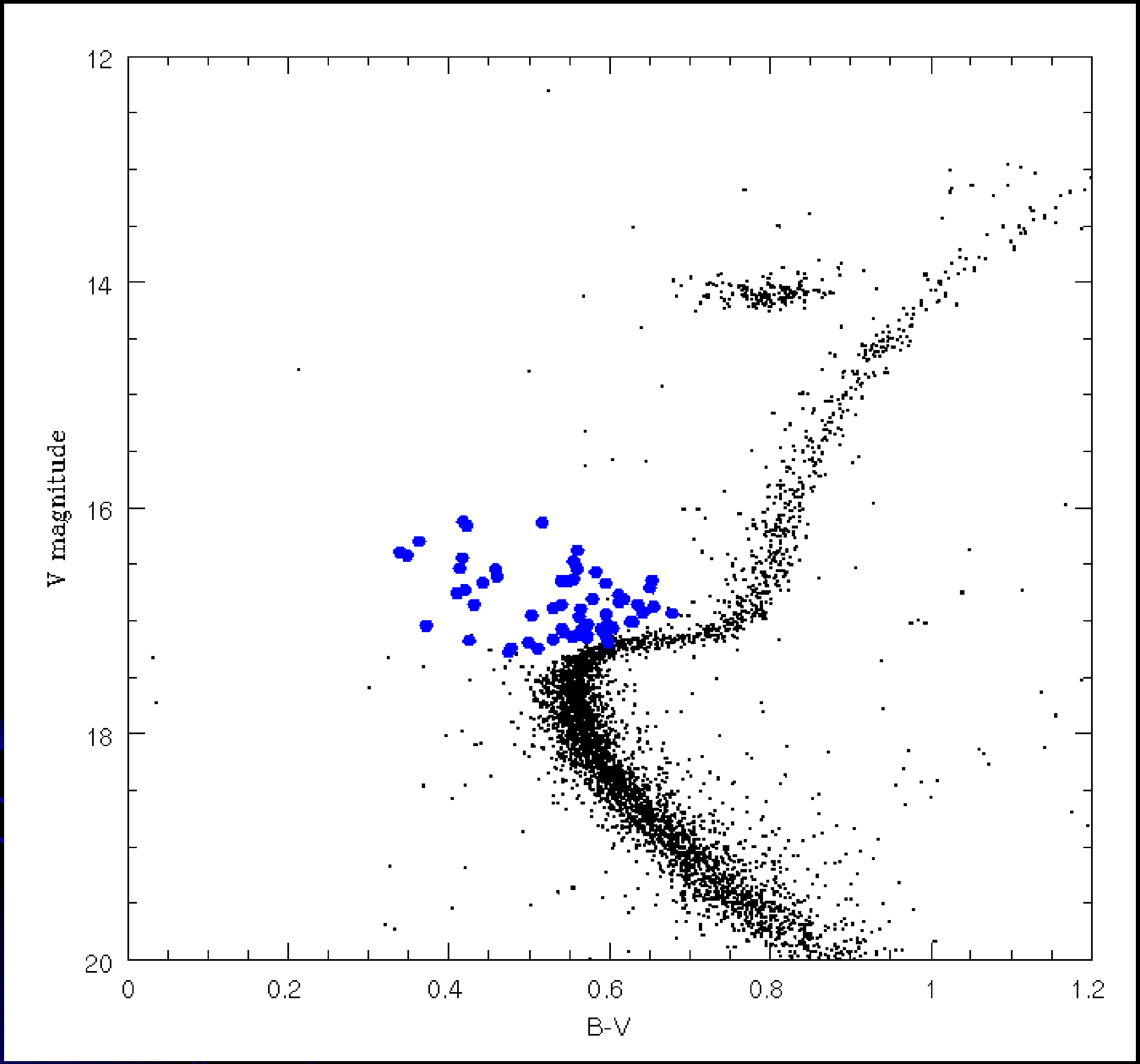
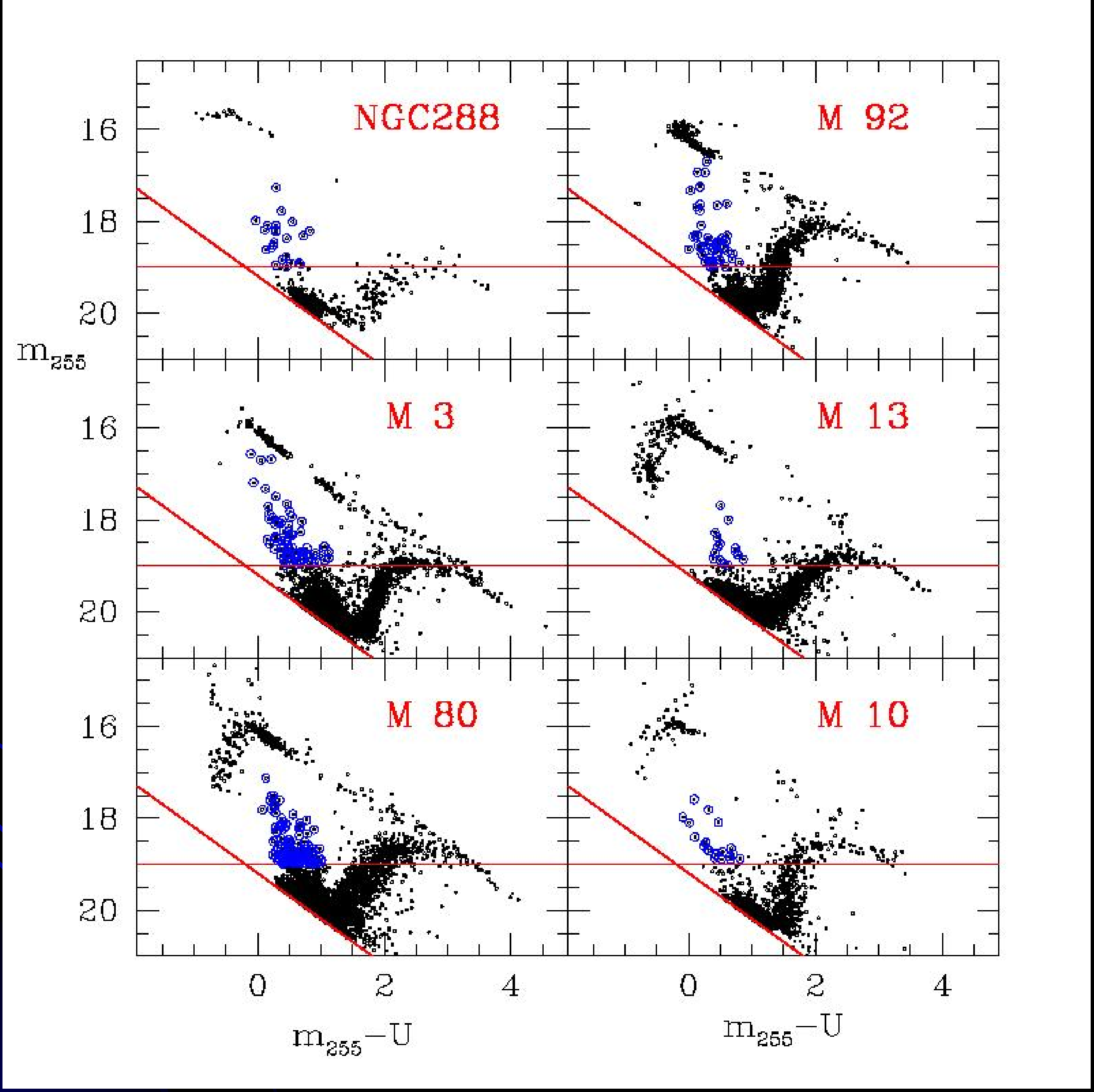
Inspiring Innovation and Discovery



47 Tucanae   Sills et al. 2000



Ferraro et al. 2003

Why should we care?

- Well, puzzles are fun
- May provide probes of cluster dynamical history
- May affect SEDs of extragalactic clusters, dwarf galaxies → implications for age & metallicity determinations from integrated light

So – where did they come from?

Formation Mechanism I

Direct stellar collisions between two unrelated stars

- Can be modeled using hydrodynamics for the collision, and then put result into stellar evolution code (e.g. Sills et al. 1997, Glebbeek et al. 2008)
- Also "sort by entropy" approach (Lombardi et al. 2002)
- Results so far pretty good, minor problems with angular momentum, little info on surface abundances

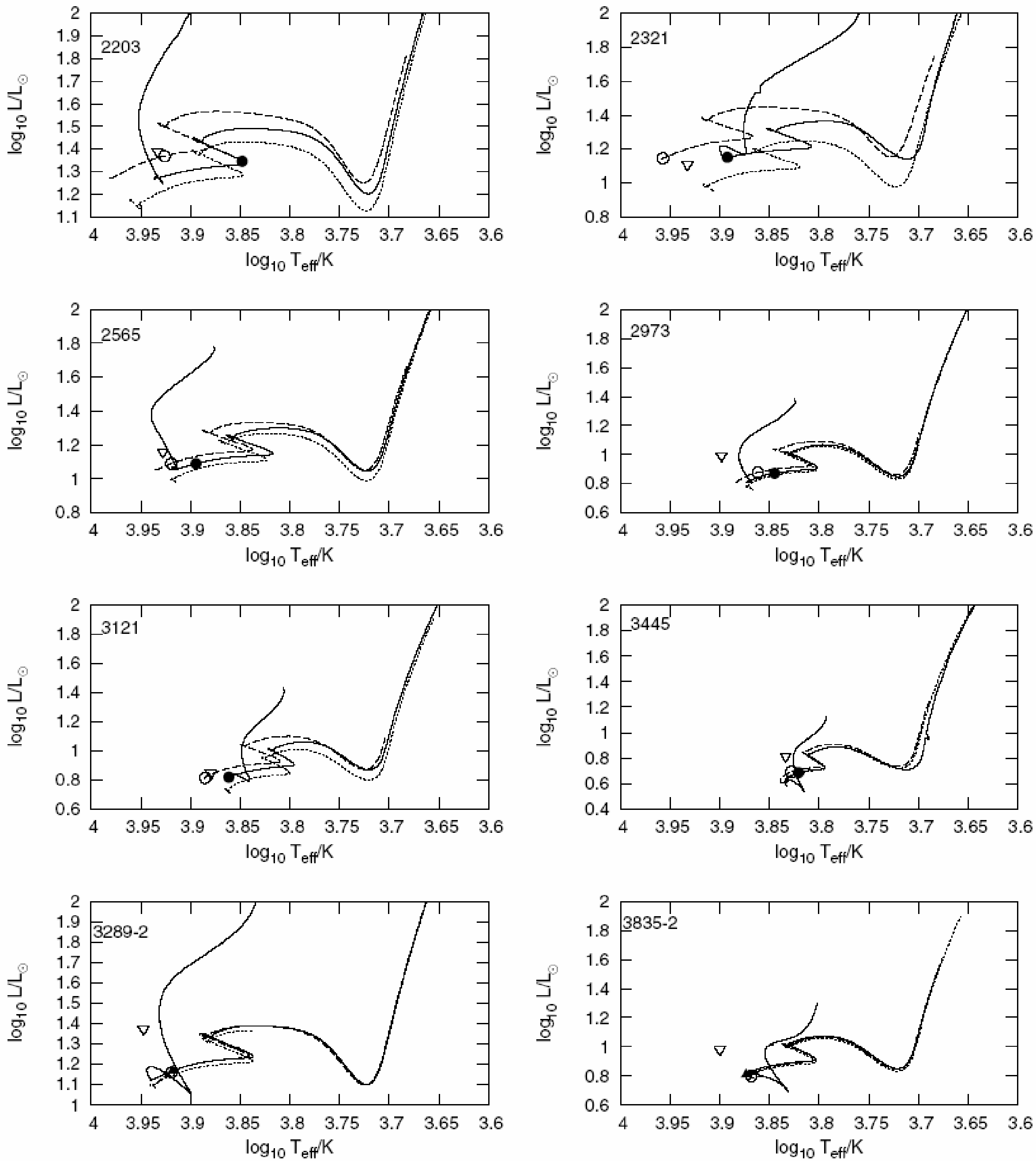


Fig. 2. Evolution tracks for the collision products (solid lines) compared to tracks for homogenised models (dashed lines) and a main sequence star of the same ZAMS mass (dotted line). Also marked are the positions at 4 Gyr for the detailed models (● for remnants of a single collision and ▲ for the remnants of two collisions), the homogenised models (⊙) and the BSE prescription (▿).

Evolutionary tracks for collision products (solid) compared to normal stars (dotted) and fully mixed stars (dashed)

Glebbeek et al. 2008

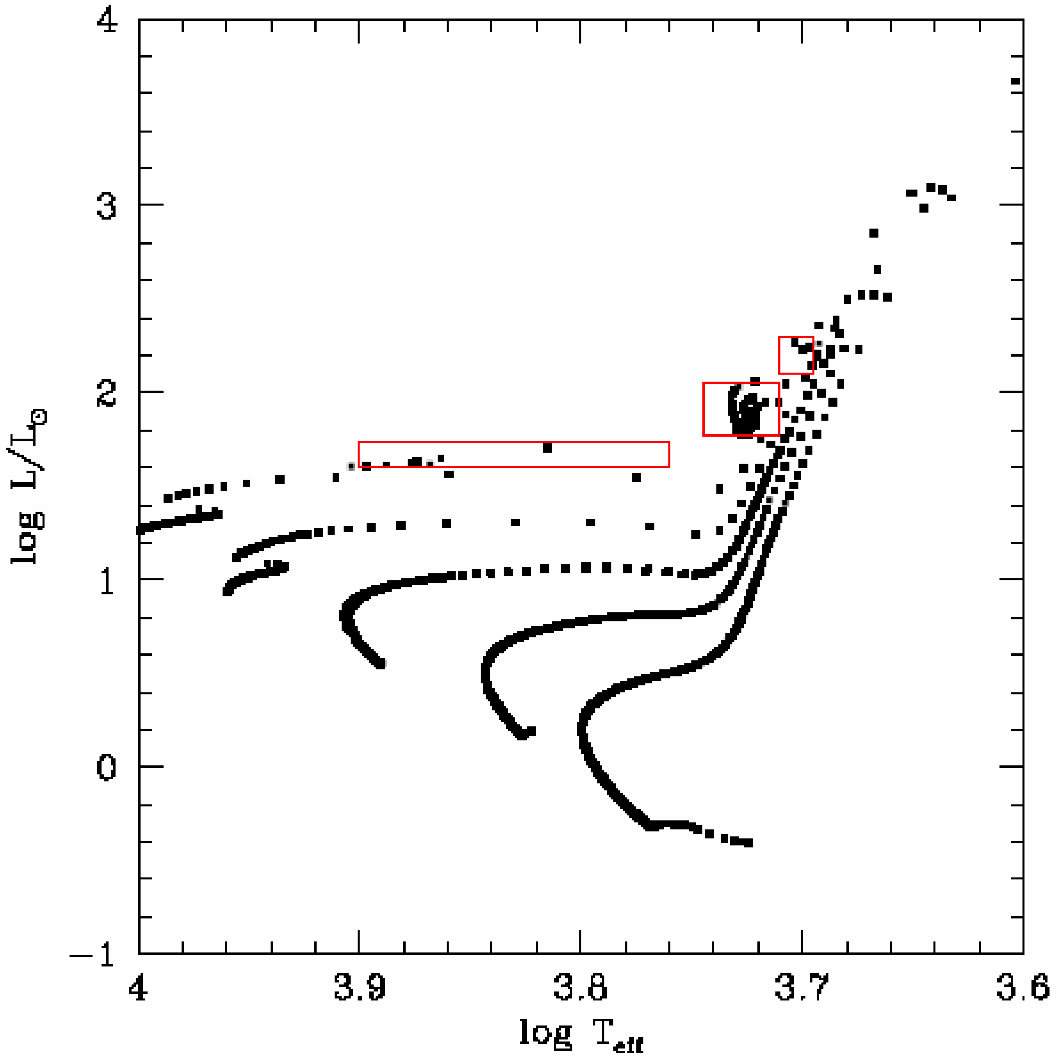


FIG. 11.— Evolutionary tracks for all collision products for collisions which occurred at time D, 10 Gyr after the cluster was formed. The points are equally spaced at 10^7 year intervals. The boxes outline the HB, E-BSS and AGB regions of the CMD.

Post-main sequence evolution of collision products – agree with observations of "E-BSS" stars

Sills, Karakas & Lattanzio 2009

Formation Mechanism II

Mass transfer in a binary system

- Detailed modeling of Roche-lobe mass transfer & concurrent stellar evolution (Chen & Han 2008a, 2008b, Tian et al. 2006)
- Not necessary that both stars are main sequence stars
- Lots of parameter space, need independent confirmation of results

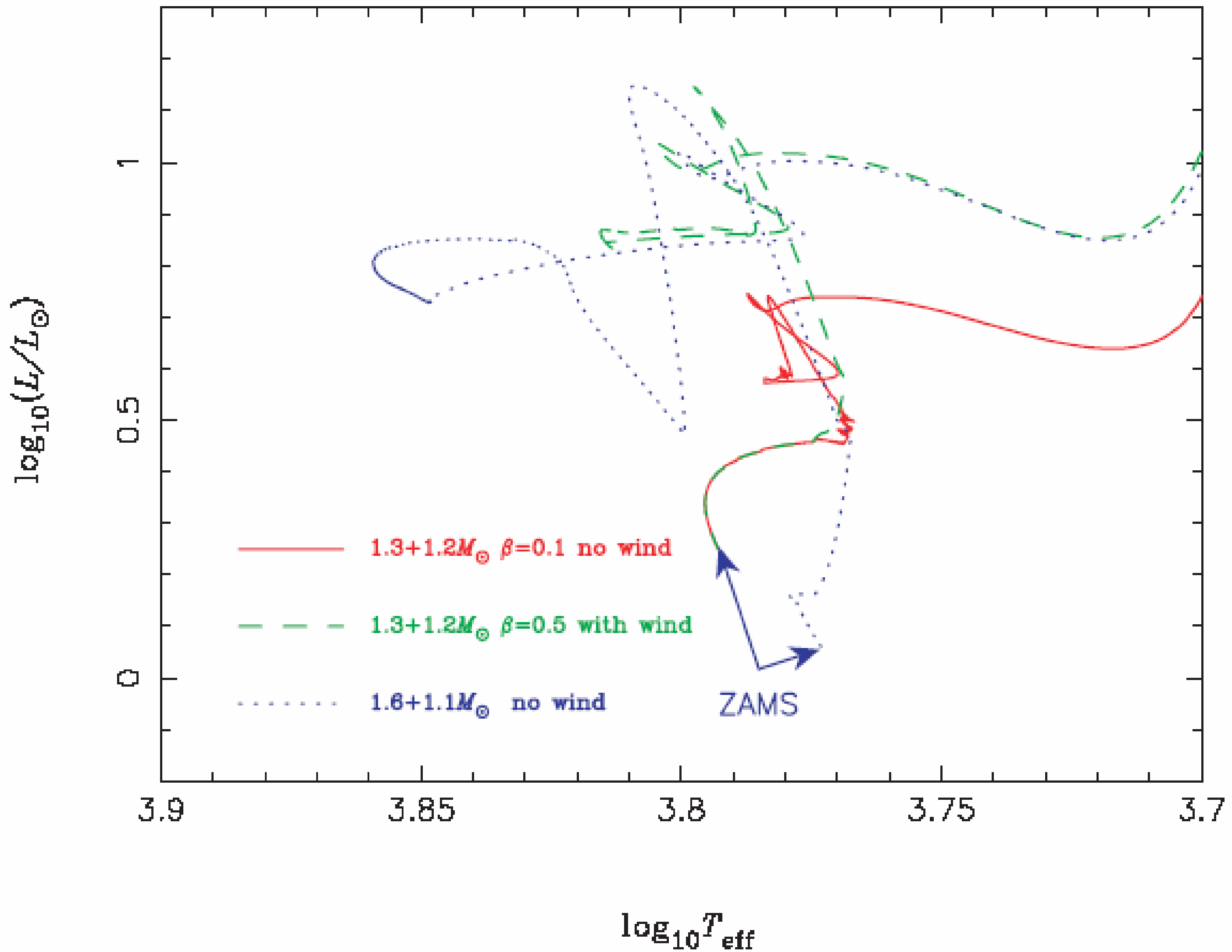


Figure 11. The evolutionary tracks for the secondaries of the three binaries we examined in the text.

Main sequence stars accreting from a giant companion

Chen & Han 2008

Formation Mechanism III

Dynamically modified binary evolution

- Invoked for oddballs (e.g. Knigge et al 2006 – X-ray source + BS in 47 Tuc)
- No detailed (hydrodynamic + binary + stellar evolution) models to date
- Did someone say "parameter space"!
- Dominant mechanism? (e.g. Hurley et al 2005)

Table 4. Details of the blue stragglers (BSs)
and $(B - V)$ colour (that of the BS or unreso
If the BS is in a binary, the companion type
classification of the evolution history of the B
B mass transfer; C = Case C mass transfer; c

ID no.	$M / M_{\odot}$	V	$(B -$
3289	2.10	10.95	0.
1418	2.09	10.82	0.
2203	2.08	10.94	0.
2411	1.97	11.61	0.

Blue stragglers in M67 Hurley et al. 2005

Population Synthesis ?

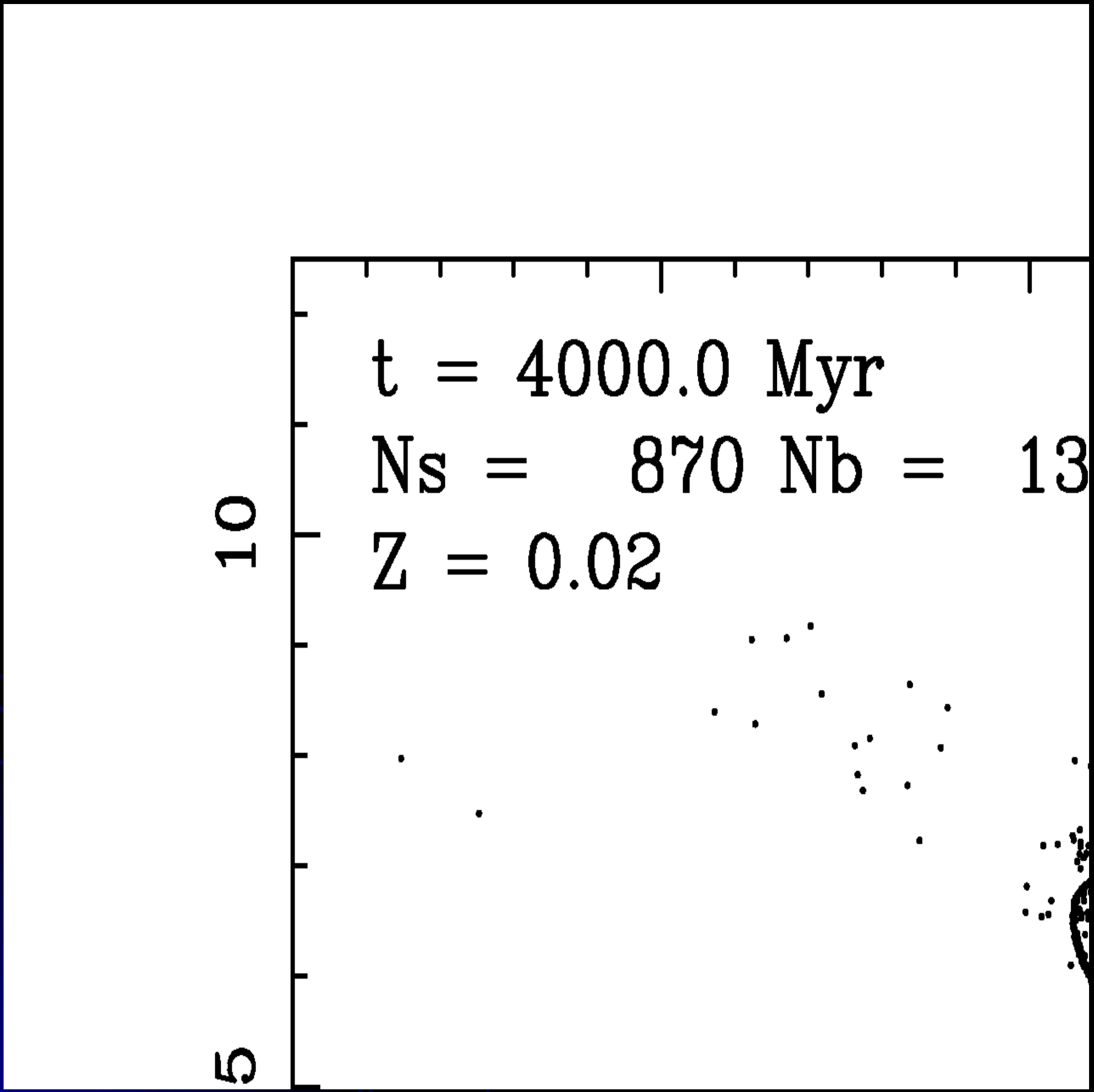
1. Figure out how to get one point in the right place in the CMD at the right time ✓
2. Figure out how to get THE RIGHT NUMBER of points in the right place in the CMD at the right time

Population Synthesis I

Do everything all at once -- cluster dynamics, stellar evolution, binary evolution

e.g. Hurley et al. 2001, 2005

Just a tad time-consuming, and hence strongly dependent on choices for prescriptions, initial conditions, etc.



M67 model Hurley et al. 2005

Population Synthesis II

Do something well, and something else badly:

e.g. good dynamics, simplistic treatment of formation mechanisms (Mapelli et al 2004, 2006)

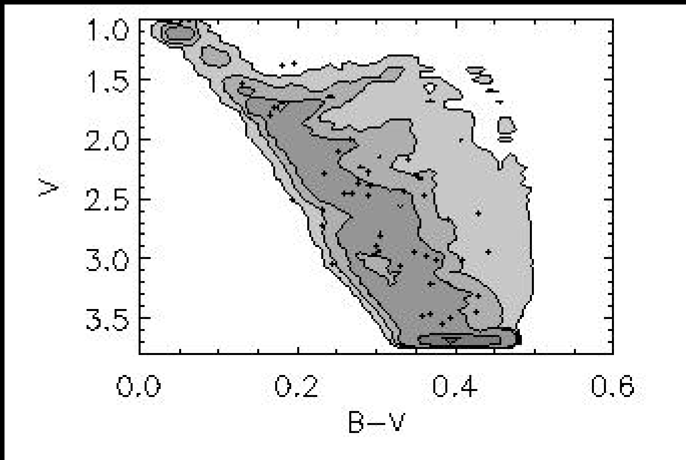
e.g. include lots of processes in an analytic model (Davies et al. 2004)

(for more details see C. Knigge's talk in about 45 min)

Population Synthesis III

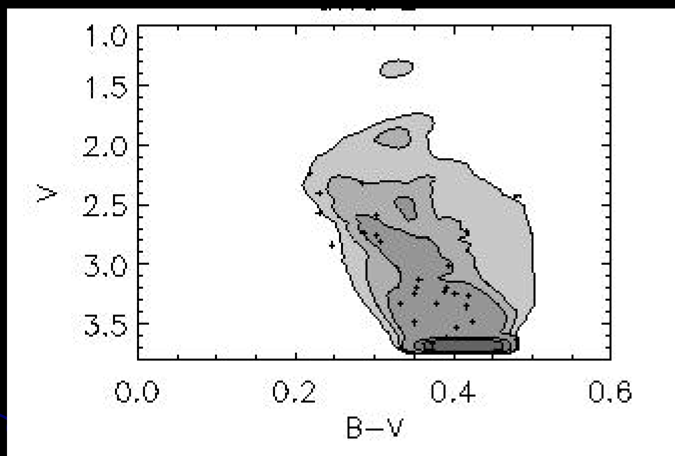
Do something well, and something else badly:

e.g. good blue straggler evolution, very simplistic model of cluster populations & dynamics: Monkman et al 2006



Core: 0 – 23″
Mass function x = -8
Formation time: 7 Gyr ago to now
KS test: 93%

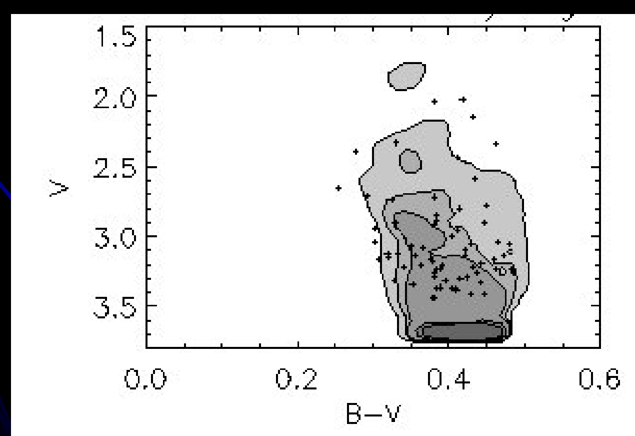
young, massive !



Mid: 23 – 130″
Mass function x = -3
Formation time: 7 – 0.6 Gyr ago
KS test: 44%

older, less massive ?

47 Tuc data from Ferraro et al & Piotto et al
HST + ground-based



Outside: 130 – 1200″
Mass function x = 1.35
Formation time: 7 – 1.2 Gyr ago
KS test: 35%

old, light ??

Monkman, Sills, et al. 2006

The Story So Far

- Models of collision products are fairly well understood
- We need more models of binary coalescence products
- Too much parameter space in dynamically modified binary evolution
- Population synthesis of blue stragglers just beginning

My Wish List

- Better observations of individual blue stragglers – masses, rotation rates, surface abundances, binary properties.
- More models of mass transfer blue stragglers – are they different from collision products?
- Should we just think about dynamically modified binary evolution? Where should we start?
- Binary properties of globular cluster populations