Stellar Collisions

Blue Stragglers and other Anomalies

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Motivation for Stellar Collisions

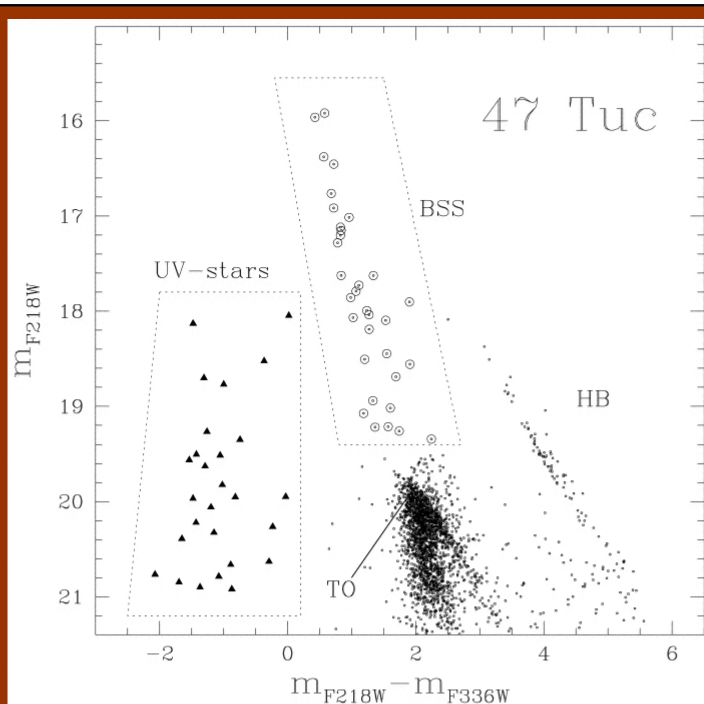
- Densities high, velocities low → theoretically feasible, numbers work out to 100’s to 1000’s per cluster
- Observationally motivated by blue stragglers, sdB stars, millisecond pulsars, LMXBs…
- All these objects can be produced by standard binary evolution as well – what happens when? How can we tell?

What's possible?

	MS	RG	WD	NS
MS	BS	RG sdB	RG CV	LMXB MSP
RG		RG He WD	CV sdB He WD	TZ LMXB MSP
WD			CV He WD	GRB
NS				GRB

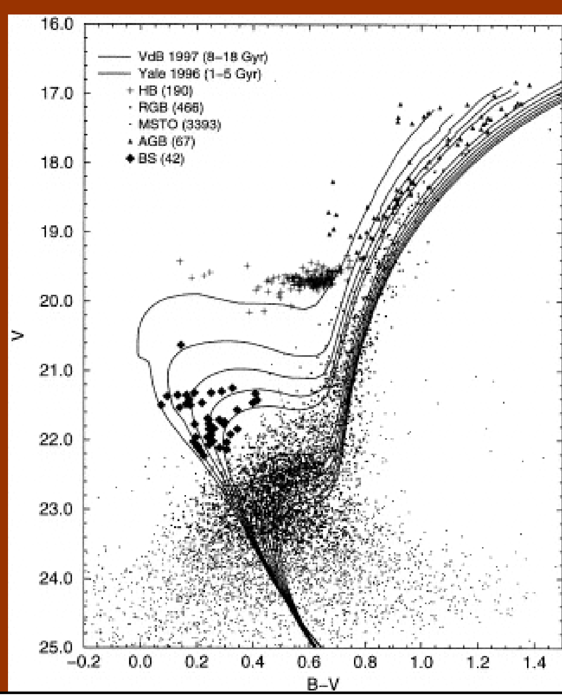
Blue Stragglers – HST Observations

- Photometry – can probe cores of dense clusters
- Ferraro, Guhathakurta, Gilliland …
- Using UV filters is useful for distinguishing blue stragglers from MS stars
- Can get variability, luminosity functions, radial distributions
- Even get blue stragglers in extragalactic globular clusters (Shara et al 1998)
- Database: Piotto et al 2002 (astro-ph/0207124) → HST observations of 74 globular clusters



Ferraro et al 2001

NGC 121
in SMC



Shara et al 1998

Blue Stragglers – HST Observations

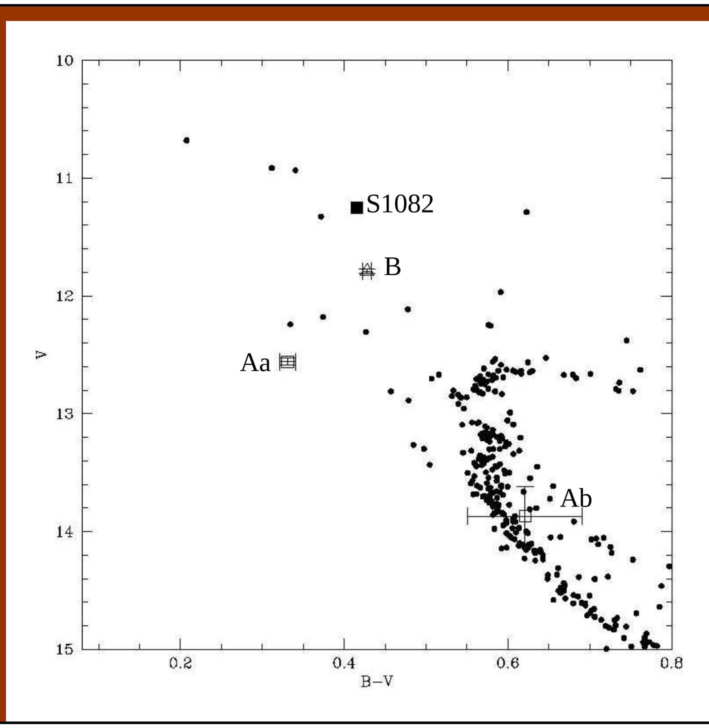
- Spectroscopy – almost none.
- 1 blue straggler in 47 Tuc: M=1.7±0.4 M_{υ}; v sin i = 155 ± 55 km/s (Shara, Saffer & Livio 1997),
- Preliminary results in NGC 6397 (Saffer et al 2002) suggest that the brightest blue straggler in the centre of the cluster has $M > 2 M_{to}$
- More to come in 47 Tuc, NGC 6397, M3, NGC 6752

Environmental Effects

- Field blue stragglers are spectroscopic binaries in long period, low eccentricity orbits. The primary is deficient in lithium and the secondary is a normal mass white dwarf. (Carney, Latham & Laird 2001) – binary merger
- Sparse clusters (e.g. NGC 288, Bellazzini et al 2002): high blue straggler frequency (N_{BS}/N_{HB} = 1.35), high binary fraction in core (10-30%) – binary merger

Environmental Effects II

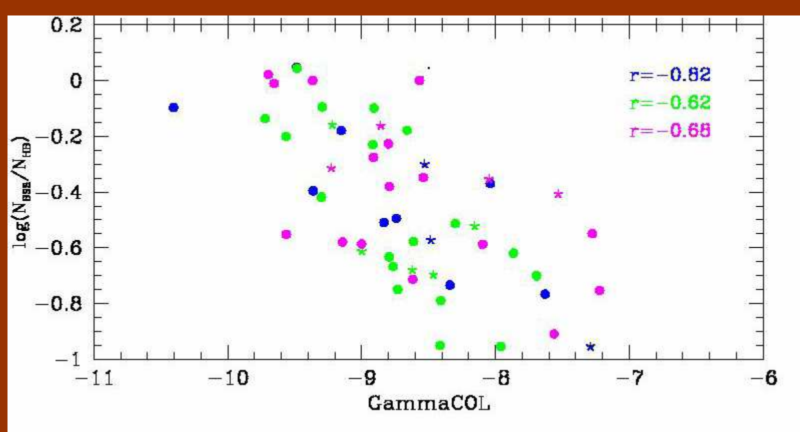
- Intermediate density clusters: a mixture
  - Consider S1082 in M67: triple system
  - Outermost star is a blue straggler, probably in orbit around the close binary
  - One component of close binary is blue straggler, other is normal main sequence star
  - Derived radii suggest stars are not coeval
- Need FIVE stars to explain this system – binary merger plus dynamical interaction



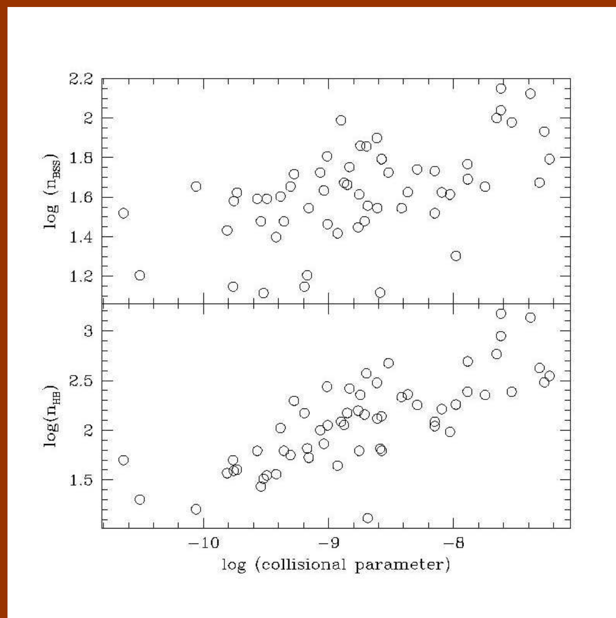
Sandquist et al. 2002

Environmental Effects III

- Dense clusters: collisions and close encounters must occur (e.g. Hills & Day 1976).
  - Direct collisions of two unrelated stars
  - Binary-mediated collisions
  - Mass transfer in a modified binary system (Davies)
    - Massive star transfers into a binary through an encounter, fills its Roche lobe, secondary becomes blue straggler → unless this happened in the last T_{BS}, these blue stragglers have evolved away
    - Could explain anti-correlation between current cluster collision parameter & N_{BS}



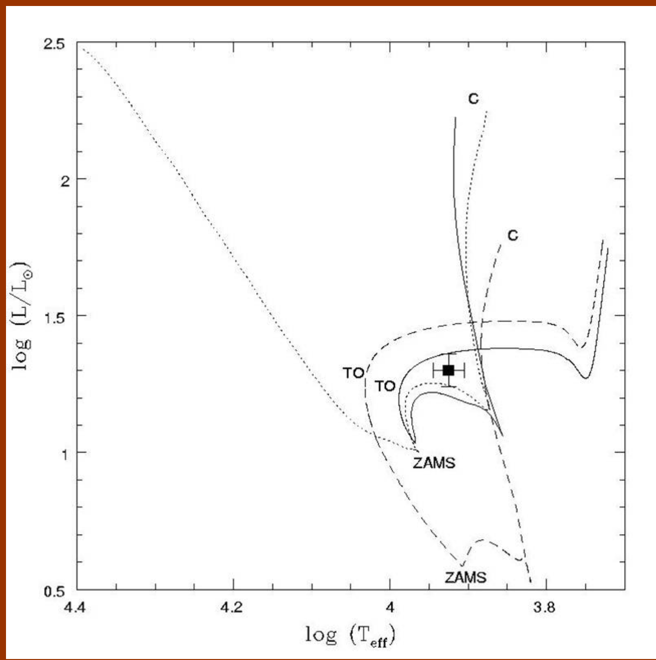
Piotto 2002



Piotto 2002

Evolution of Collision Products

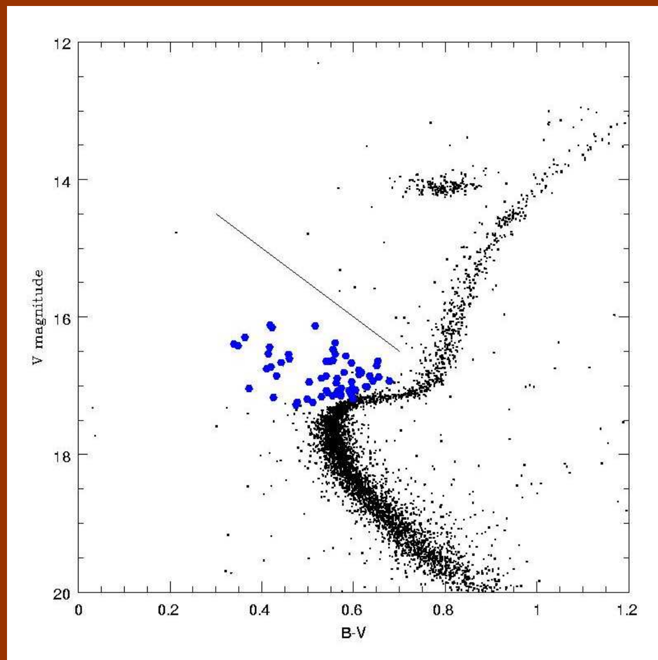
- SPH simulations of collisions (e.g. Lombardi et al 1997) as starting models for stellar evolution calculations of blue stragglers
- Reasonably good results for head-on collisions
- Still issues with offaxis collisions → rotation
  - Blue stragglers rotate too quickly – need to lose angular momentum. Through a disk?



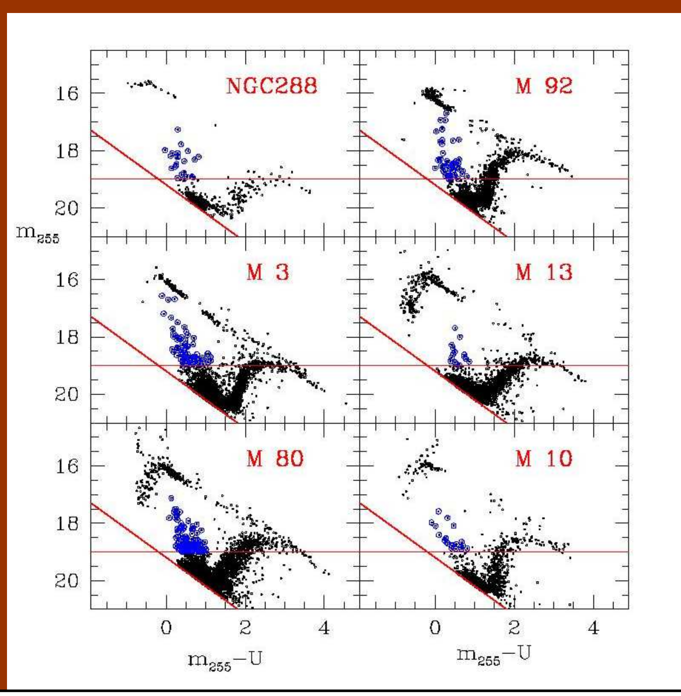
Sills et al. 2001

Uses for Blue Stragglers

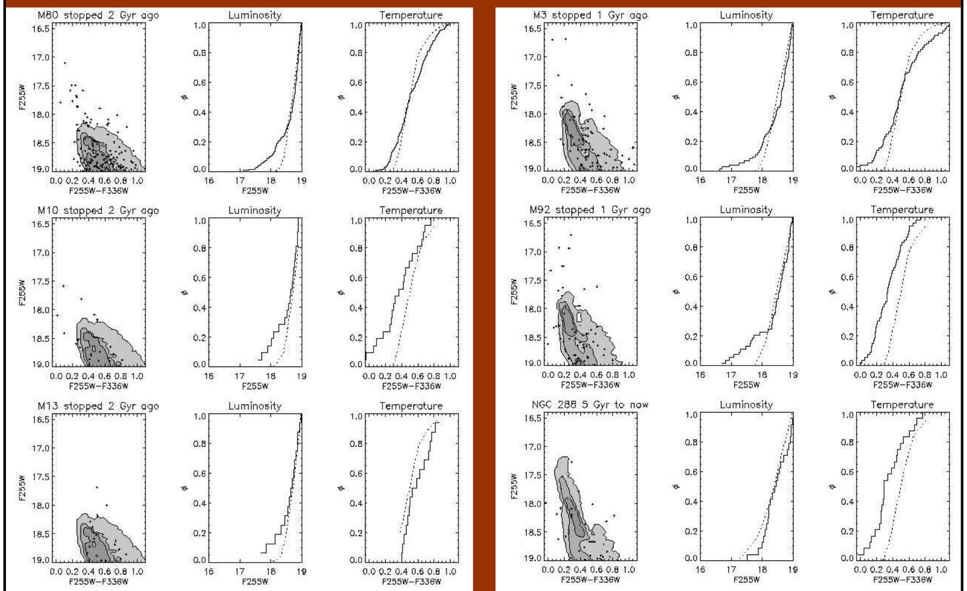
- Population studies – numbers and distribution of blue stragglers (radially and in CMD) can tell us about dyanmical history of cluster.
- 47 Tuc: Old blue straggler distribution at few arcmin from centre (none younger than about 3 Gyr, Sills et al. 2000). HST observations of core show younger population (Ferraro et al. 2001, Guhathakurta 2003)
- Ferraro et al 2003 – comparison of distributions in 6 clusters



Sills et al. 2000



Ferraro et al 2003



Ferraro et al 2003

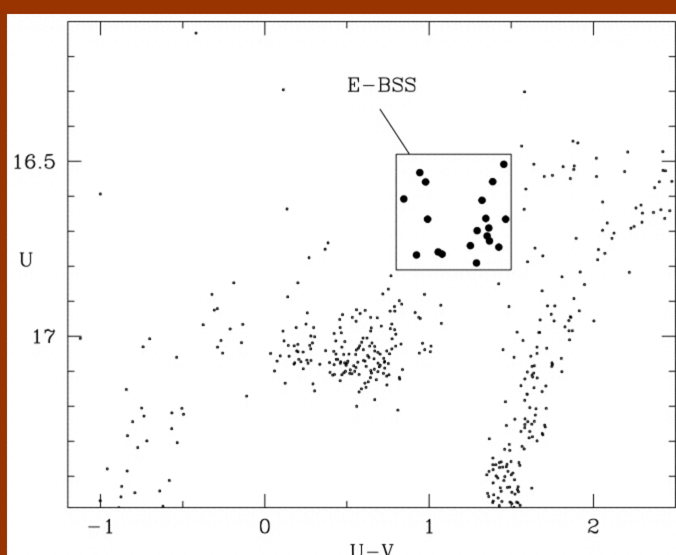
Blue Straggler Distributions

- Blue stragglers formed over last 5 Gyr at least
- Probably more blue stragglers between 2-5 Gyr ago than last 2 Gyr.
- Possibly a connection between blue straggler luminosity function shape and HB morphology?

Beyond Blue Stragglers

- Where do the blue stragglers go when they leave the main sequence? Can we see them?
- Possibly on the horizontal branch

M80



Ferraro et al 1999

Collisions involving giants

Possible explanation for following observations:

- Cores of dense clusters seem to be lacking bright giants (e.g. Bailyn 1994)
- Core collapse clusters show colour gradients (blue centres) (e.g. Djorgovski 1991)
- EHB/sdB/He WDs seem to be concentrated towards the centres of clusters (e.g. Ferraro et al 1992)

- Need detailed SPH simulations of these kinds of collisions, plus stellar evolution calculations to follow subsequent evolution.

But…..

- All of the previous objects can (and are) made through normal binary evolution processes
- How can we tell the difference between a "real" collision product and a binary merger?
- What about the grey area – a binary was hardened by or exchanged components through an encounter, and THEN underwent mass transfer. Is that a collision or not?

Summary

- Collisions happen.
- Definitely produce BS (at least sometimes)
- May produce other things (sdBs, LMXBs, MSPs…)
- What about binary mergers? How can we tell the difference?
- More work to be done on both observations & theory