Companions to the NGC 188 Blue Stragglers

Aaron M. Geller

Lindheimer Postdoctoral Fellow
Northwestern University Department of Physics and Astronomy
Center for Interdisciplinary Exploration and Research in Astrophysics

Collaborators
Jarrod R. Hurley — Swinburne Centre for Astrophysics and Supercomputing
Robert D. Mathieu — University of Wisconsin - Madison

Outline

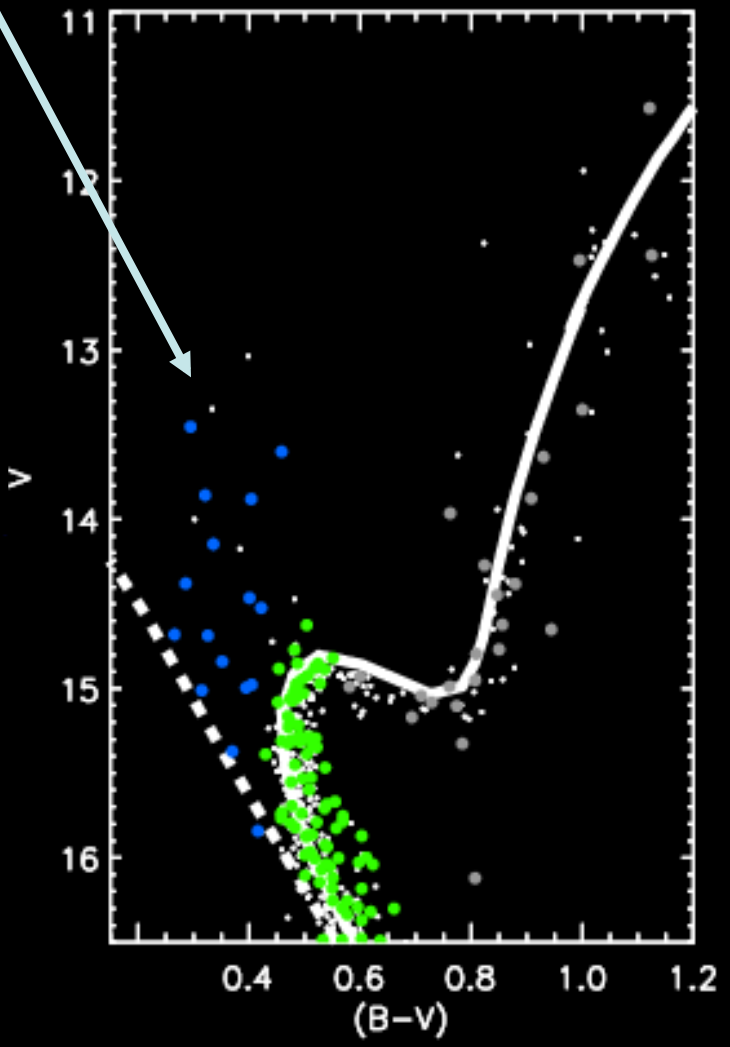
- What are blue stragglers?
- Observations of the NGC 188 blue stragglers
  - Binary frequency
  - Distributions of P, e, M_2
- Predictions from theoretical formation mechanisms
  - Correspondence with observations
- Origins of the NGC 188 blue stragglers

Blue Stragglers

Blue Straggler Population

- Generally brighter than MS turnoff
- Bluer than normal stars of similar mass
- Shouldn't these be giants or WDs?
- Believed to be more massive than normal MS stars of same age
- Form from a MS star that gains mass via: collision(s), mass-transfer, and/or merger(s)

Which mechanism(s) dominates in open clusters?



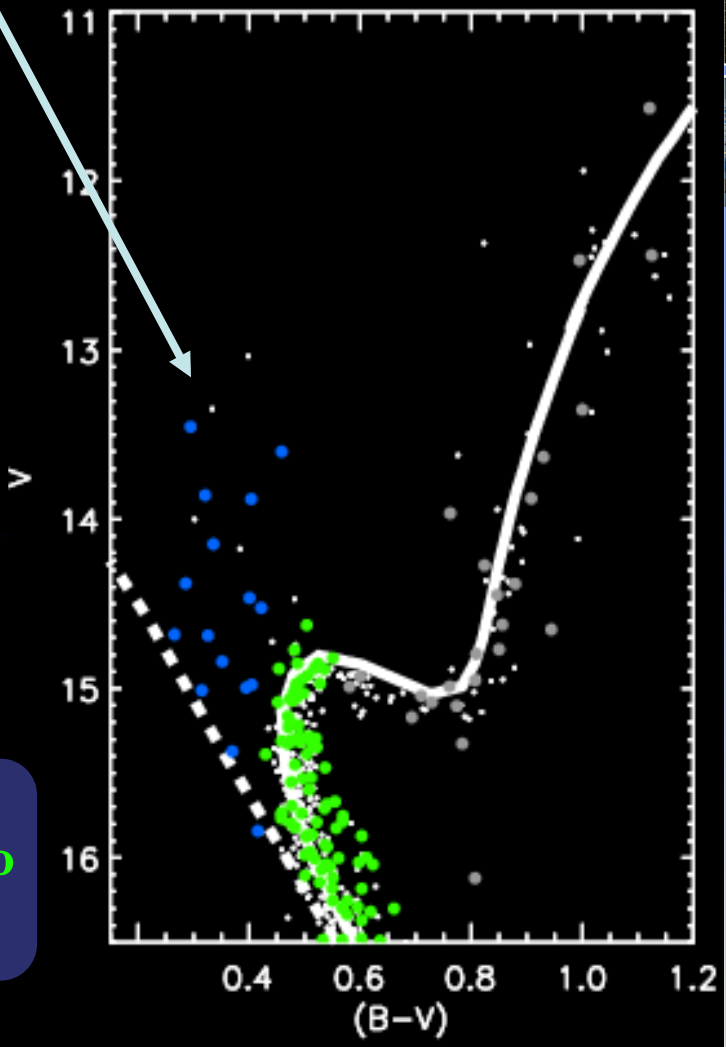
NGC 188 Blue Stragglers

Blue Straggler Population

Binary Frequencies :

MS	86 / 376	23 ± 2 %
Giant	21 / 70	30 ± 7 %
BS	16 / 21	76 ± 19 %

Completeness: 89% of binaries with P<10^3 days
63% of binaries with P<10^4 days



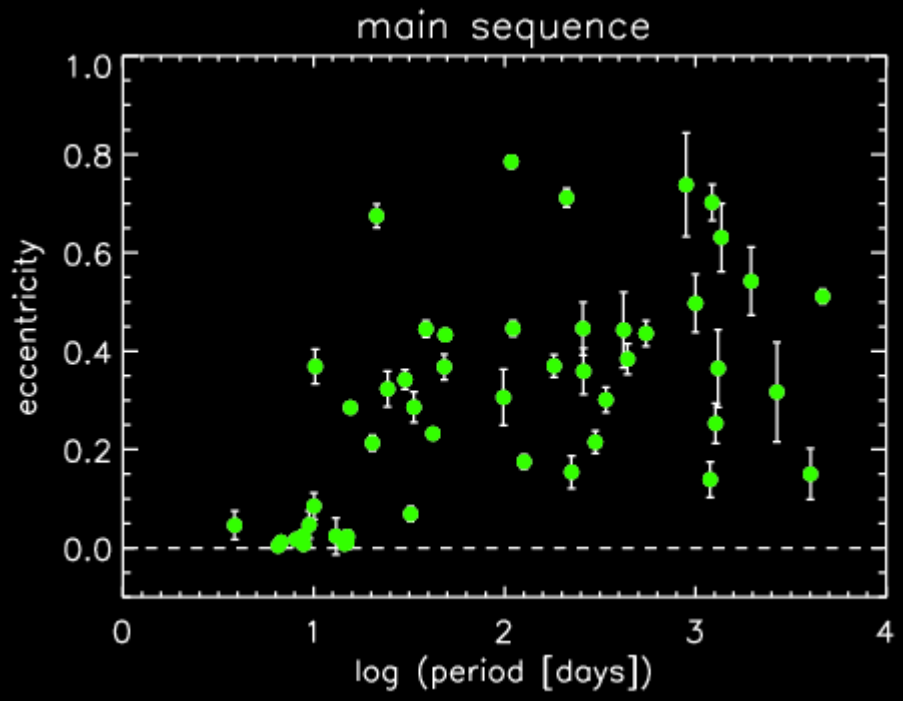
BS binary frequency of **76 ± 19%**
3 x normal MS binary frequency

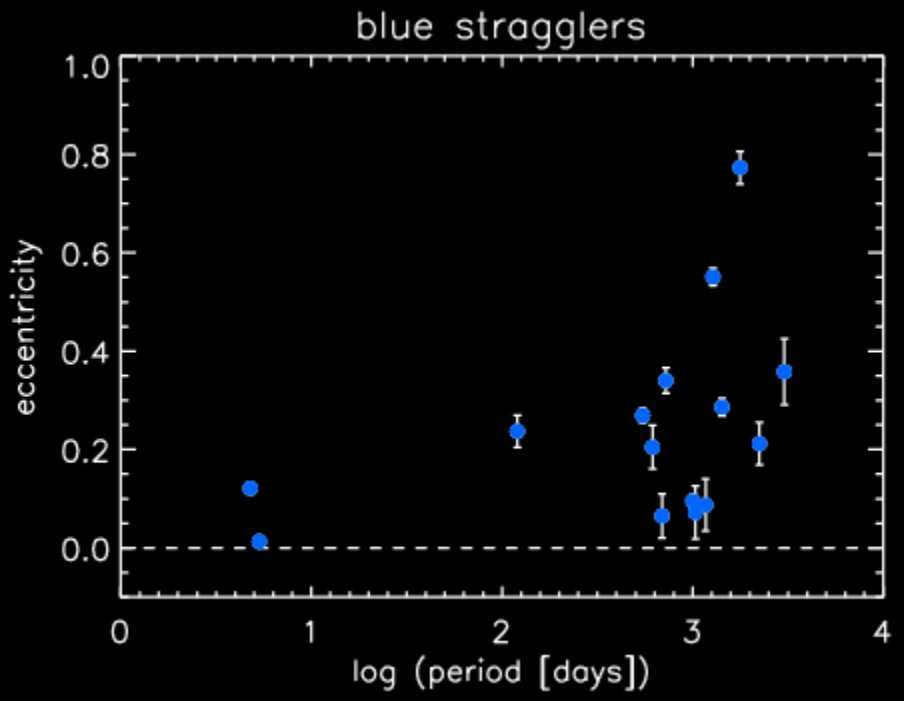
Mathieu & Geller (2009 *Nature*)

Aaron M. Geller

WOCS
WIYN Open Cluster Study

NGC 188 Blue Stragglers





BS binaries are concentrated at **~1000 day periods**.

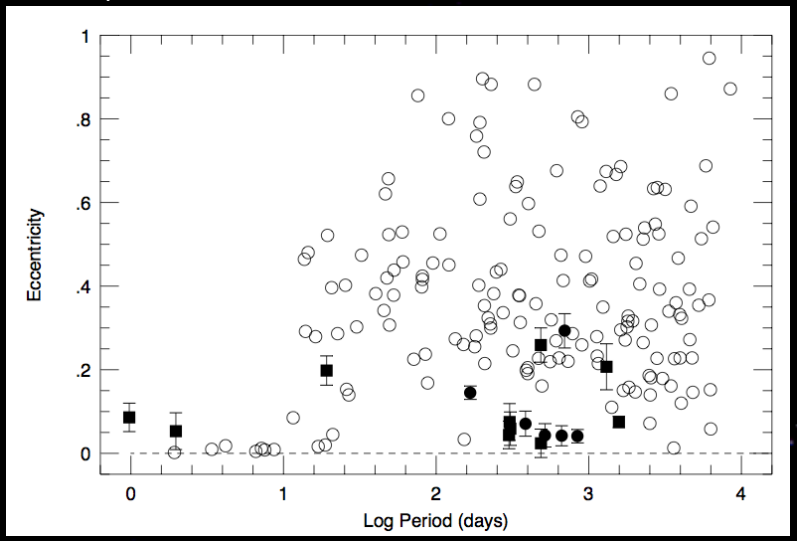
2D K-S test : 99% confidence that MS and BS drawn from distinct parent distributions.
All long-period blue straggler binaries are single lined (SB1s).

Mathieu & Geller (2009 *Nature*)

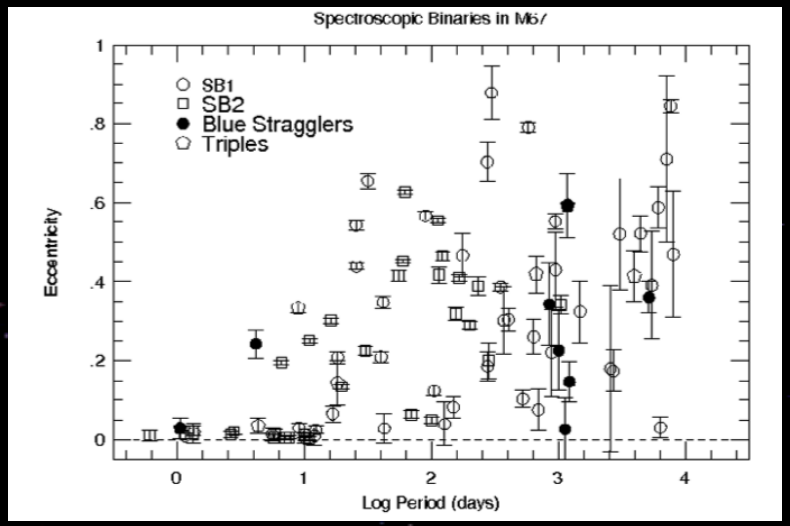
Aaron M. Geller

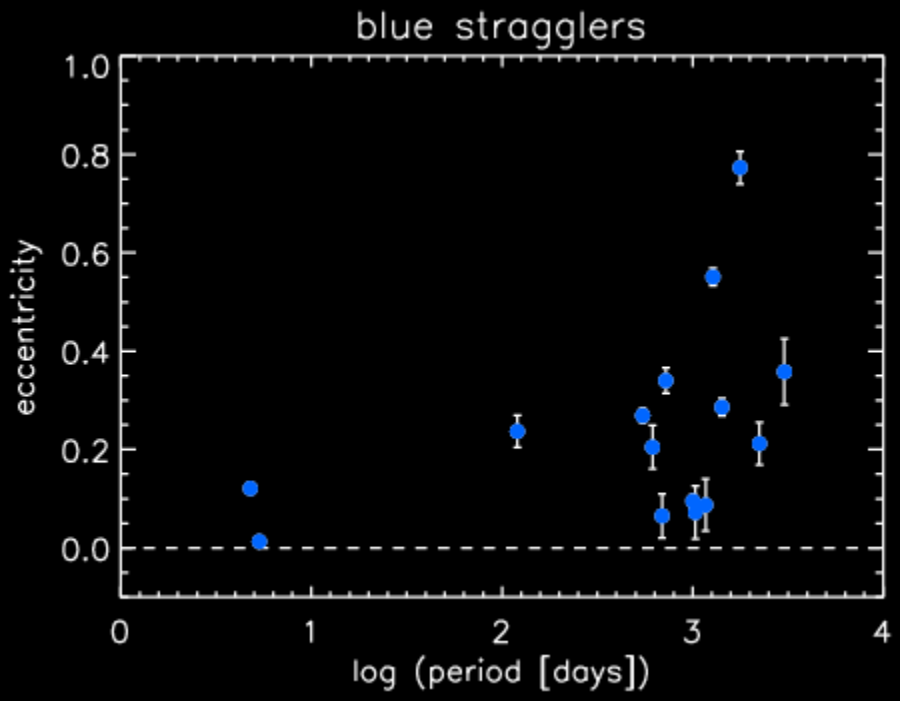
NGC 188 Blue Stragglers

Carney et al. 2001 field BS binaries



Latham 2007 M67 BS binaries



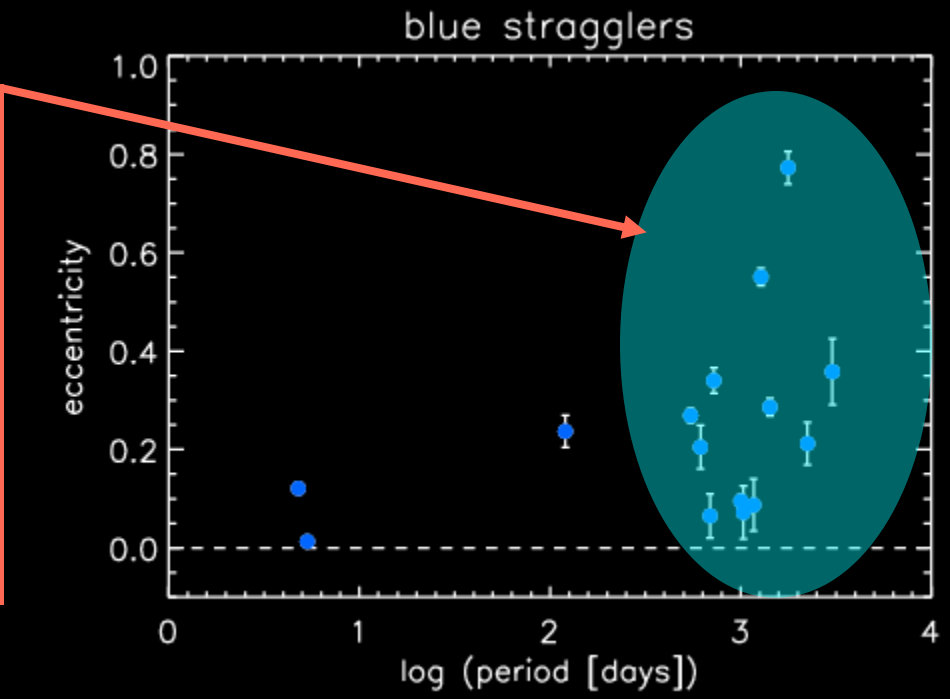


Is this a typical e – log P distribution for blue stragglers?

Aaron M. Geller

NGC 188 Blue Stragglers

Burning question:
12/21 BSs have periods of ~1000 days, all SB1s. Where did they come from?

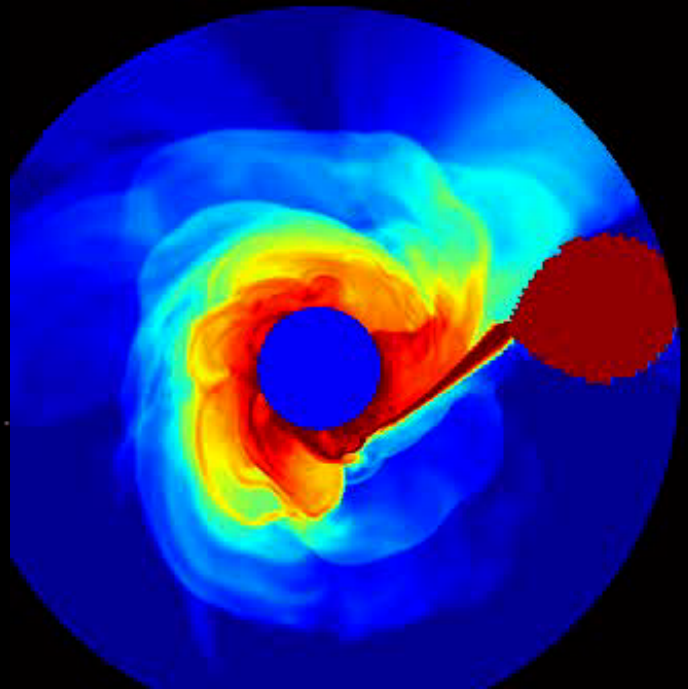


Formation Scenarios

for 1000d-period blue straggler binaries

Hypothesis	Secondary Star
Mass transfer (Case C – AGB)	C/O white dwarf

McCrea (1964), Chen & Han (2008), etc.



Movie from Blondin et al. NCSU

Formation Scenarios

for 1000d-period blue straggler binaries

Hypothesis	Secondary Star
Collision during binary encounter	Main-sequence star*

Leonard (1996), Leigh & Sills (2011), etc.

Dynamical model from FEWBODY (Fregeau et al. 2004); movie from A. Geller

Formation Scenarios

for 1000d-period blue straggler binaries

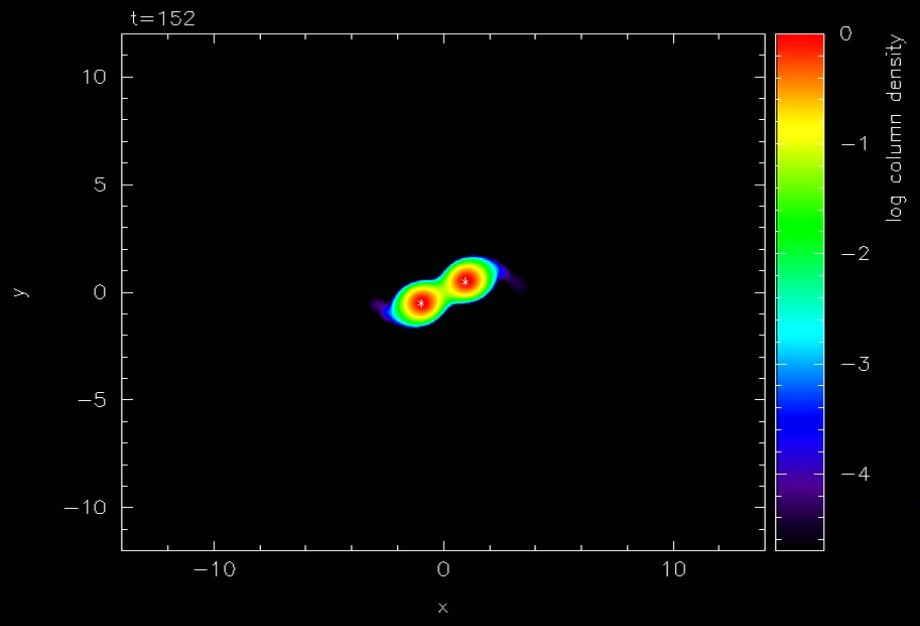
Hypothesis

Kozai-driven merger of close binary in triple

Secondary Star

Main-sequence star*

Ivanova (2008), Perets & Fabrycky (2009)



Movie from Lombardi, et al. (2011)

Formation Scenarios

for 1000d-period blue straggler binaries

Hypothesis	Secondary Star
Mass transfer (Case C – AGB)	C/O white dwarf
Collision during binary encounter	Main-sequence star*
Kozai-driven merger of close binary in triple	Main-sequence star*

McCrea (1964), Chen & Han (2008), etc.

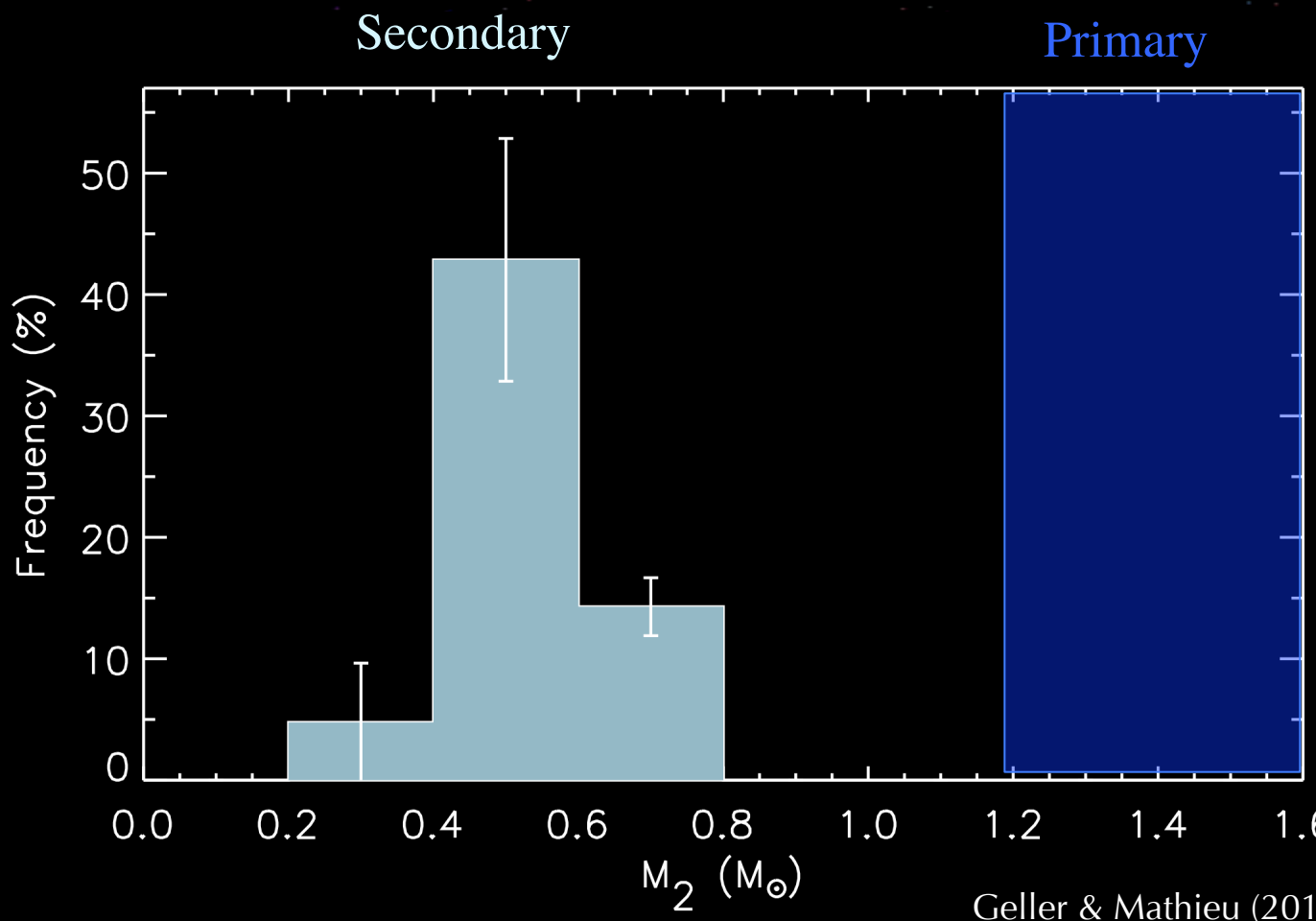
Leonard (1996), Leigh & Sills (2011), etc.

Ivanova (2008), Perets & Fabrycky (2009)

*caveats

NGC 188 Blue Stragglers

Secondary Mass Distribution



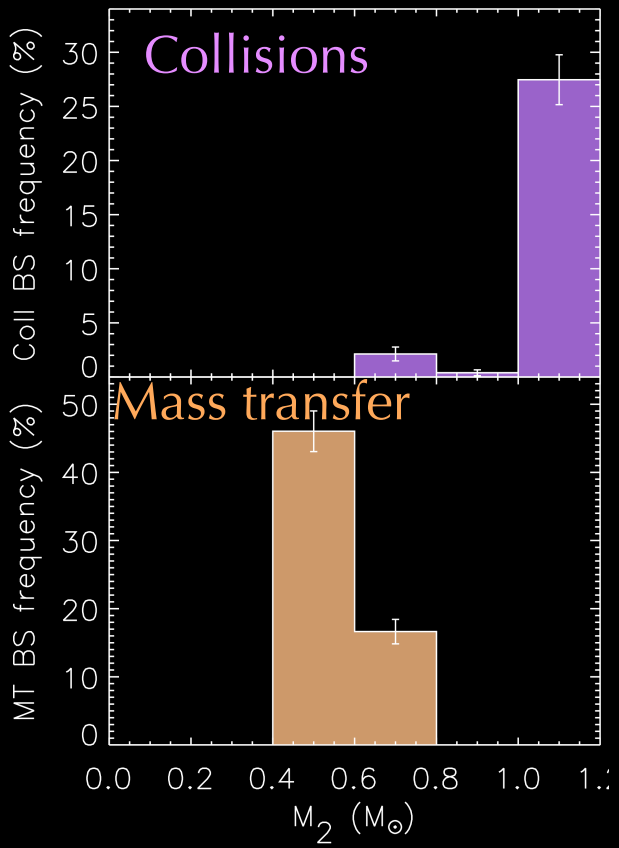
Geller & Mathieu (2011, *Nature* in press)

Aaron M. Geller

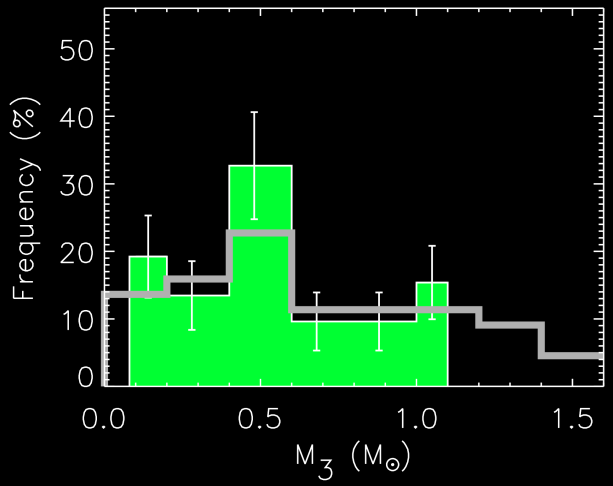
NGC 188 Blue Stragglers

Secondary Mass Distribution

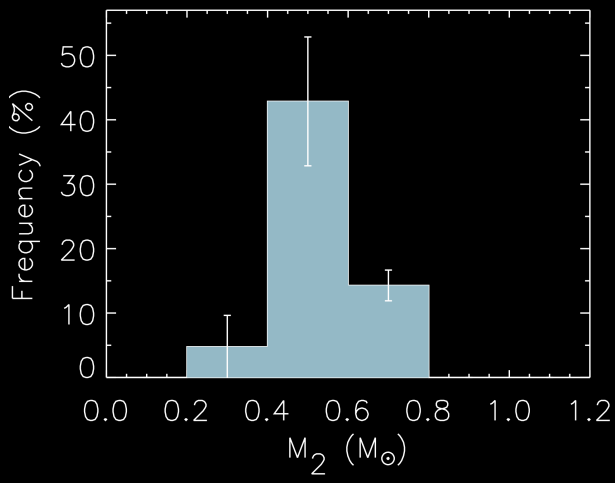
N-body Simulation of NGC 188



Tertiaries in MSC (Tokovinin 1997, 2008)



Observed



Triples have inner binaries with :

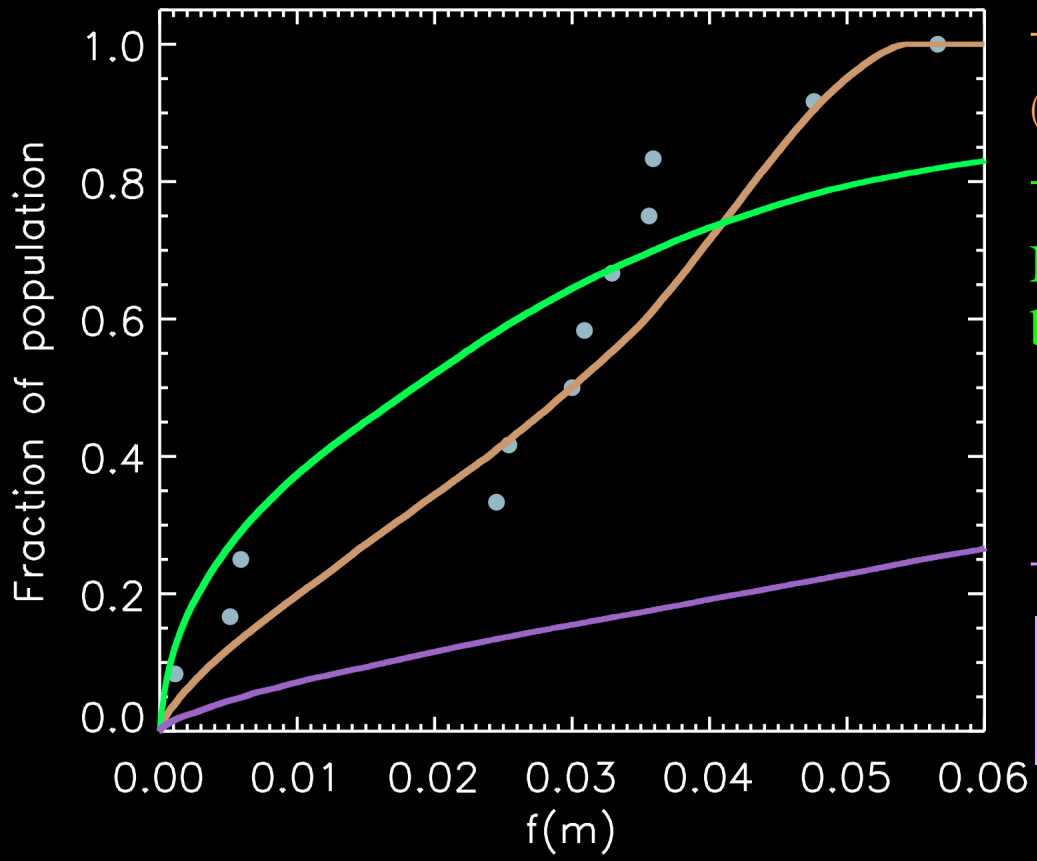
- Total mass between 1.2 -2.2 $M_\odot$
- Periods < 10 days

Geller & Mathieu (2011, *Nature* in press)

Aaron M. Geller

NGC 188 Blue Stragglers

Mass Function Distribution



Observations

Theoretical mass transfer
(0.55 $M_\odot$ WDs)

Theoretical mergers in triples
Not formally ruled out here,
but…

Theoretical collision from *N*-body

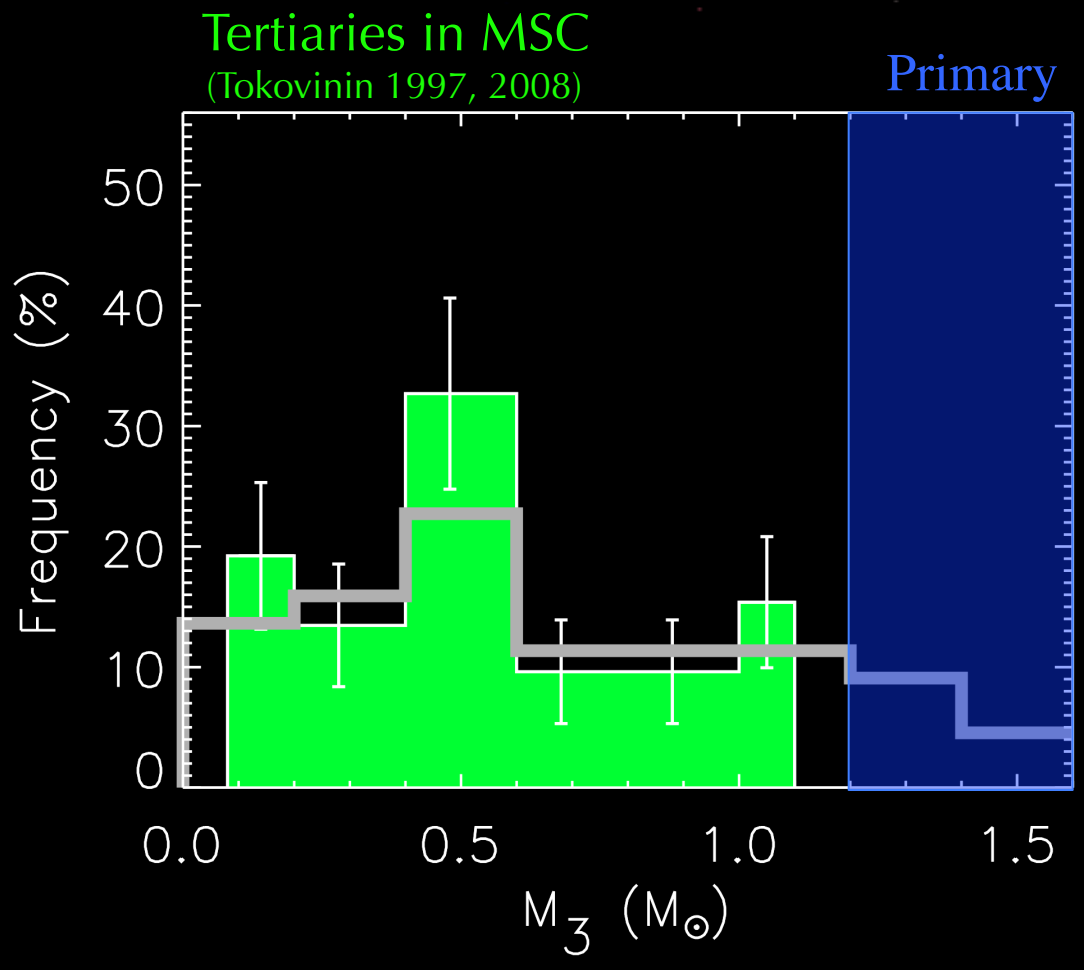
Ruled out at the >99% confidence level

Geller & Mathieu (2011, *Nature* in press)

Aaron M. Geller

NGC 188 Blue Stragglers

Secondary Mass Distribution



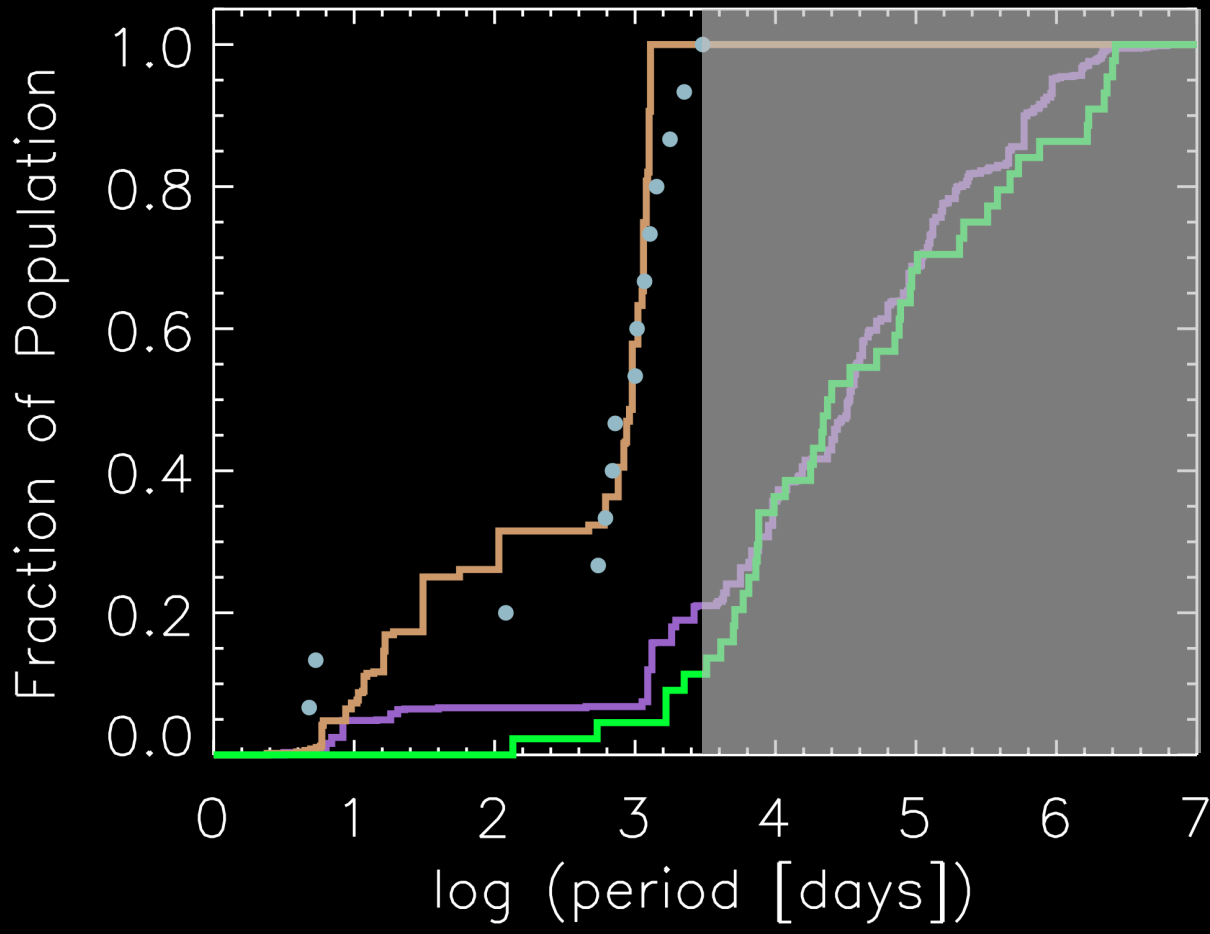
One more constraint:
all SB1s

- 6.6% chance to detect zero secondaries
- 1.8% change to also realize the observed mass-function distribution

Geller & Mathieu (2011, *Nature* in press)

NGC 188 Blue Stragglers

Period Distribution



Observations
Mass transfer from *N*-body
Collisions from *N*-body
Triples (outer period)

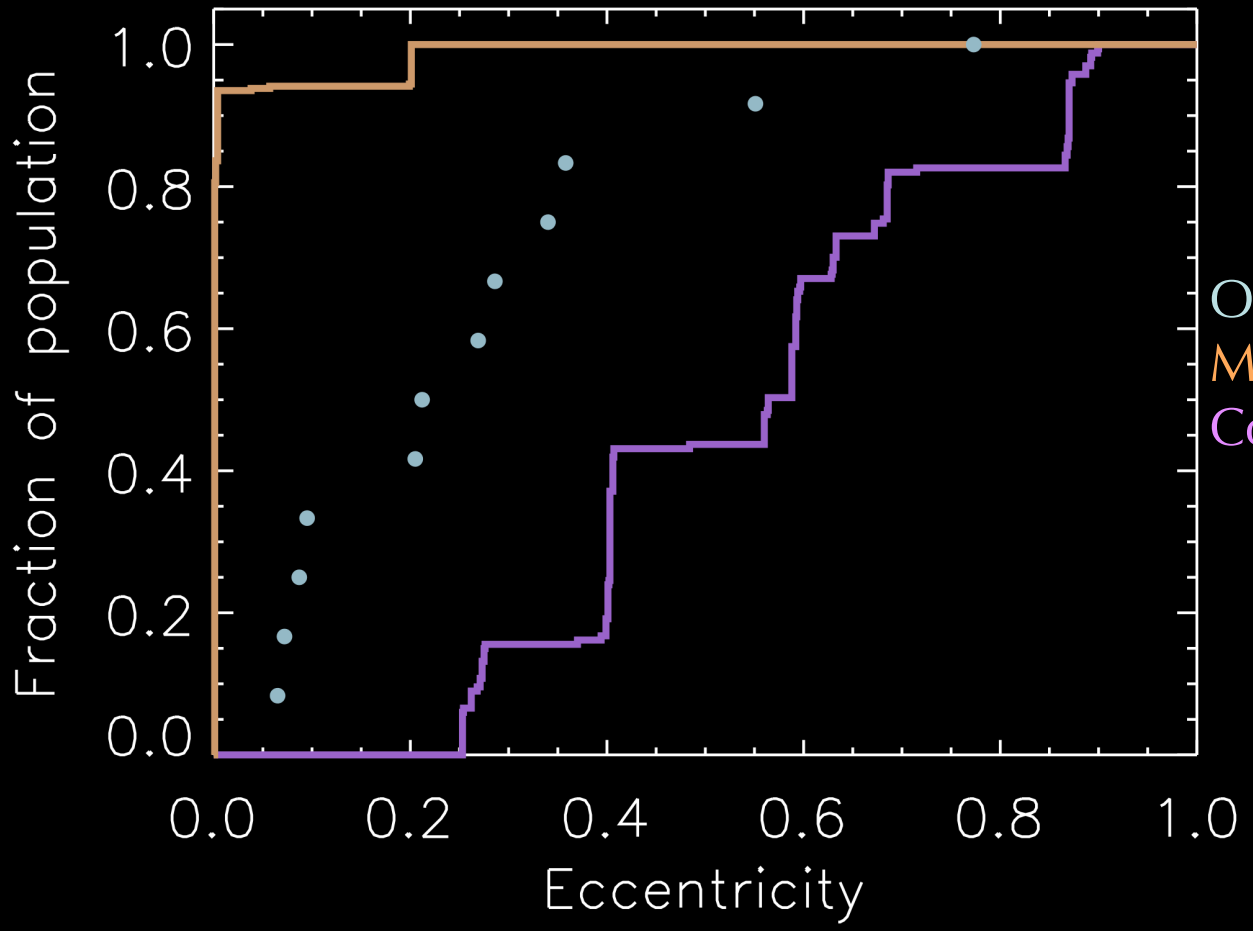
Collisions ruled out

Geller & Mathieu (2011, *Nature* in press)

Aaron M. Geller

NGC 188 Blue Stragglers

Eccentricity Distribution



Observations
Mass transfer from *N*-body
Collisions from *N*-body

Collisions ruled out

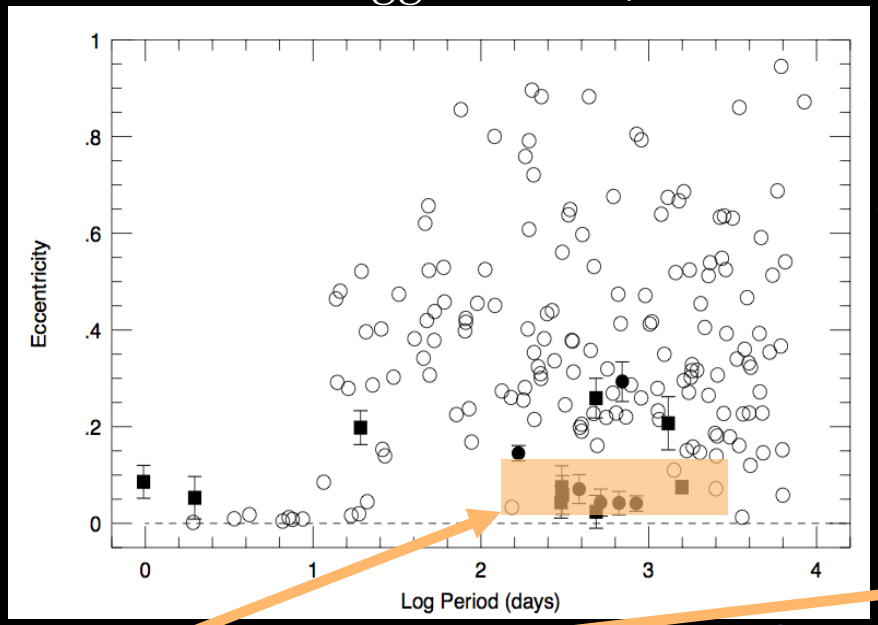
Geller & Mathieu (2011, *Nature* in press)

Aaron M. Geller

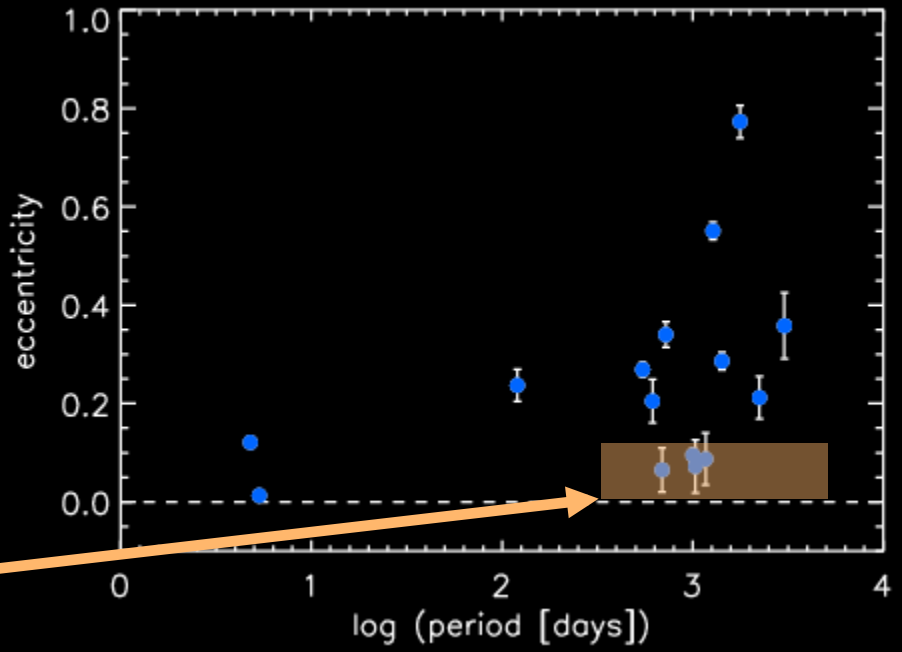
NGC 188 Blue Stragglers

Eccentricity Distribution

Field Blue Stragglers (Carney et al. 2001)



NGC 188 Blue Stragglers



Mass transfer (Case C) origin likely

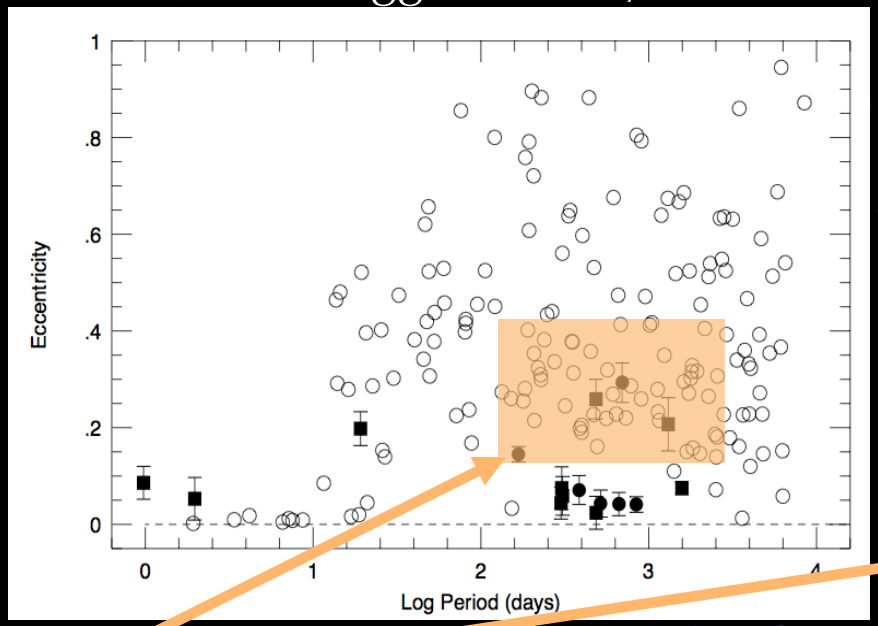
-no long-period circular MS binaries

Aaron M. Geller

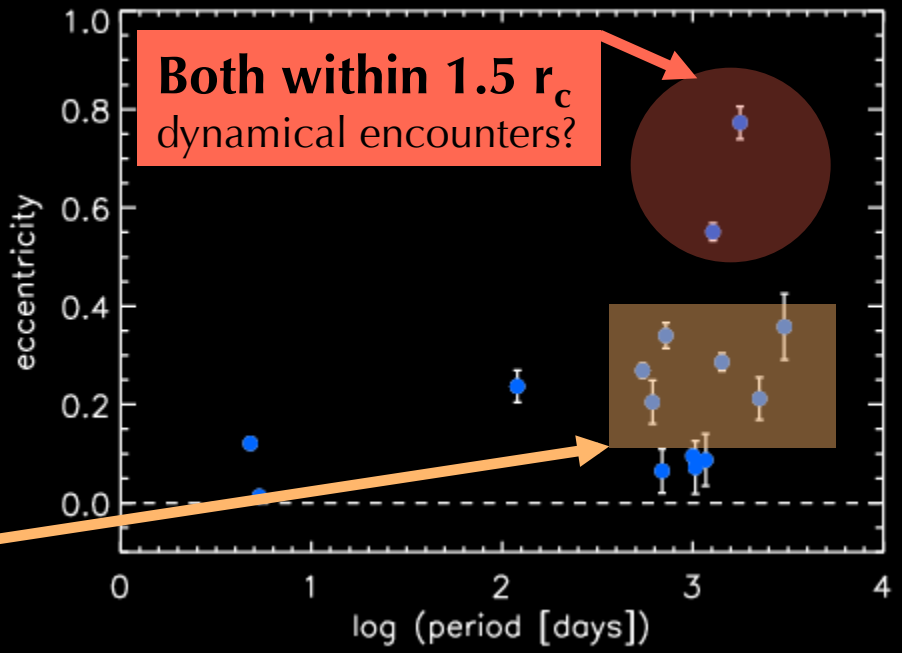
NGC 188 Blue Stragglers

Eccentricity Distribution

Field Blue Stragglers (Carney et al. 2001)



NGC 188 Blue Stragglers



Mass transfer (Case C) + "eccentricity pumping" ?

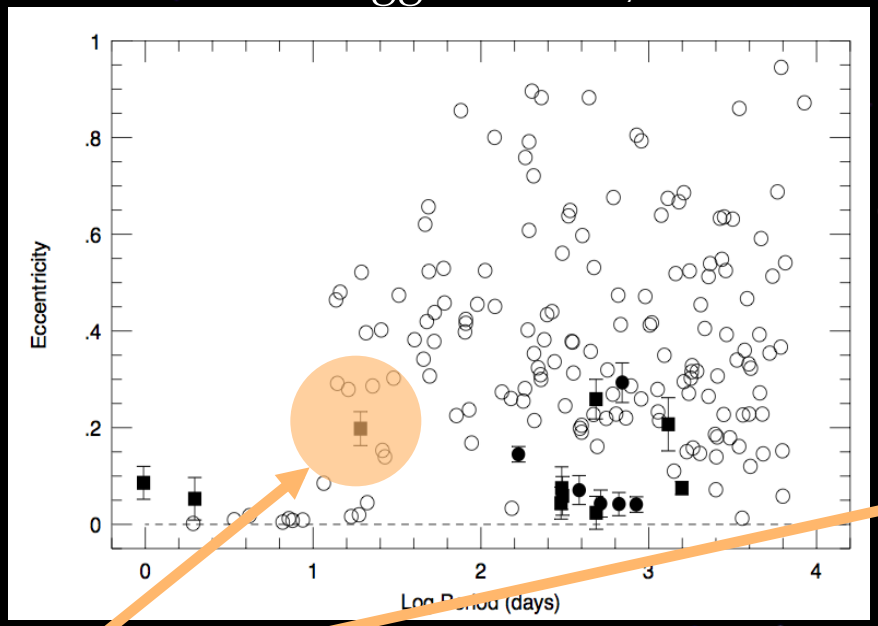
(Soker 2000, Bonacic et al. 2008, Sepinsky et al. 2009, etc.)

Aaron M. Geller

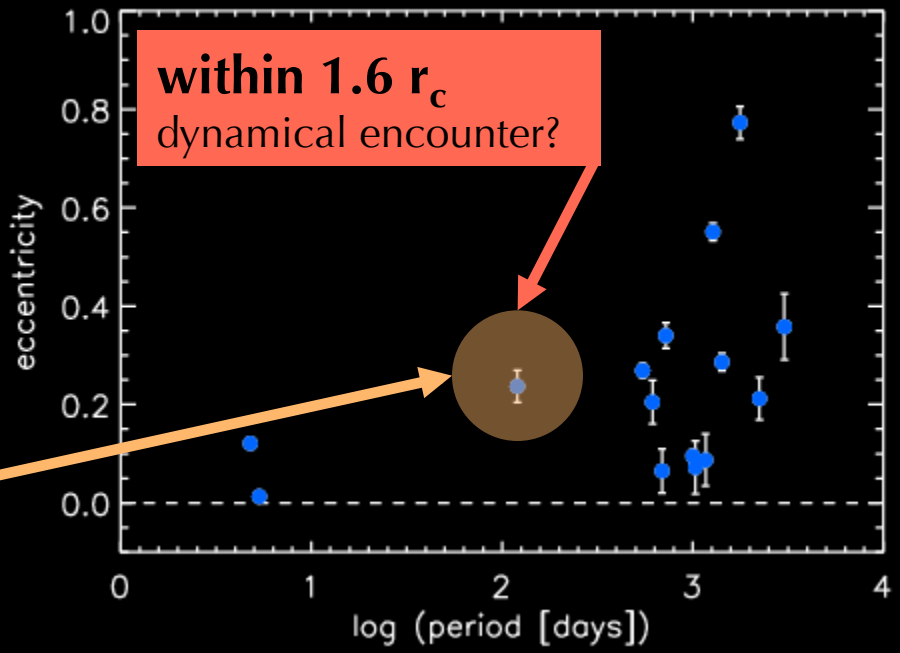
NGC 188 Blue Stragglers

Eccentricity Distribution

Field Blue Stragglers (Carney et al. 2001)



NGC 188 Blue Stragglers



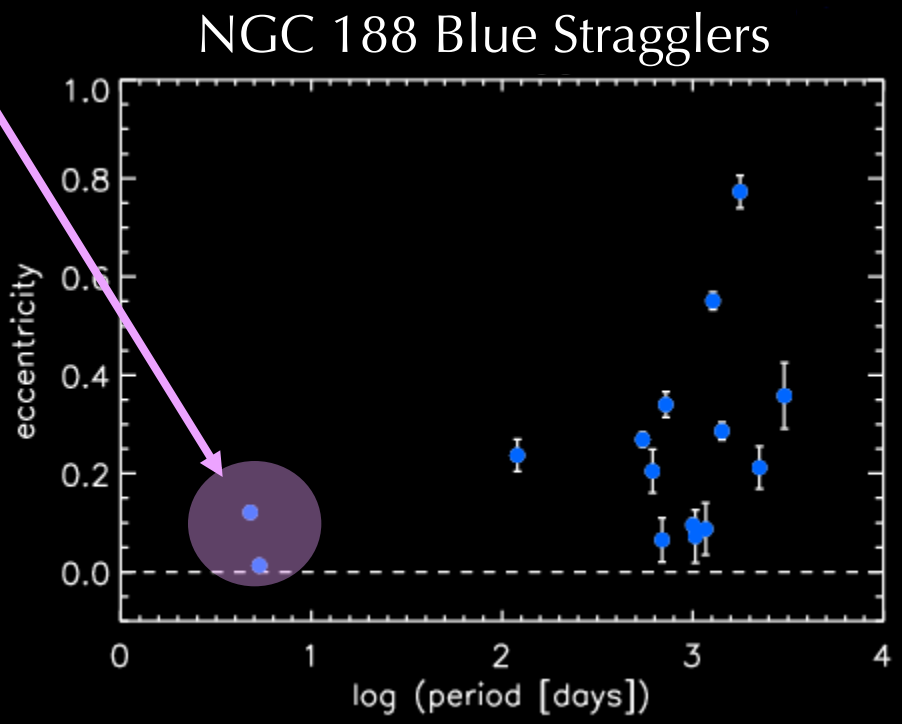
Mass transfer (Case B)+ "eccentricity pumping" or dynamical encounter?

Aaron M. Geller

NGC 188 Blue Stragglers

Origins

Short-period blue stragglers
- Both SB2s
- Origins involving dynamical encounters with binaries
- **Collisions**?



Aaron M. Geller

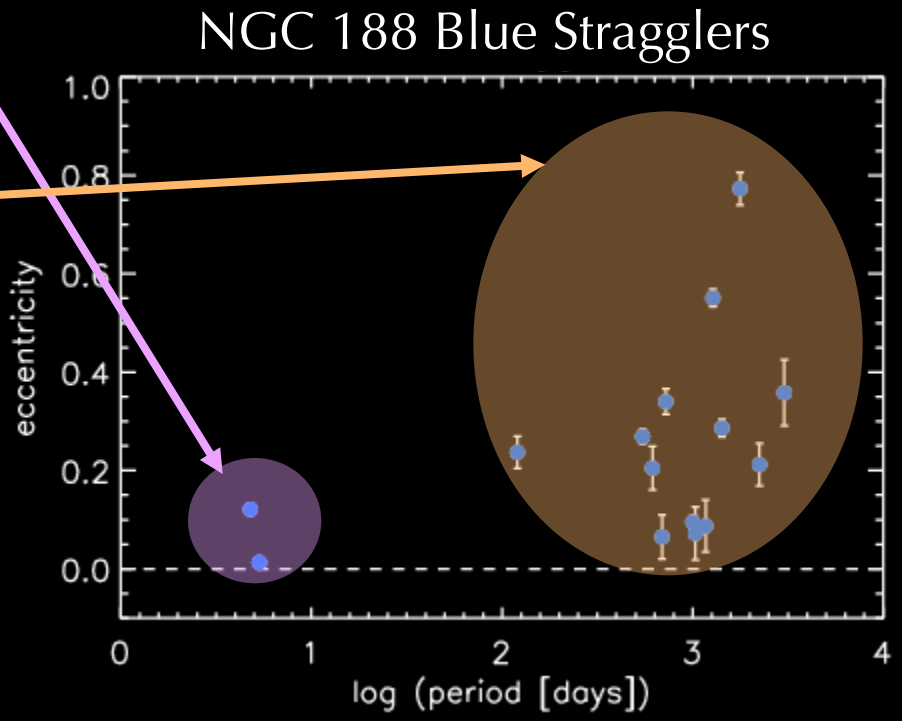
NGC 188 Blue Stragglers

Origins

Collisions, dynamical encounters, exchanges?

Long-period blue stragglers

- All SB1s
- Collisions cannot reproduce their binary properties
- Predictions from mass transfer are closely consistent with data
- But cannot definitively rule out mergers in hierarchical triples



NGC 188 Blue Stragglers

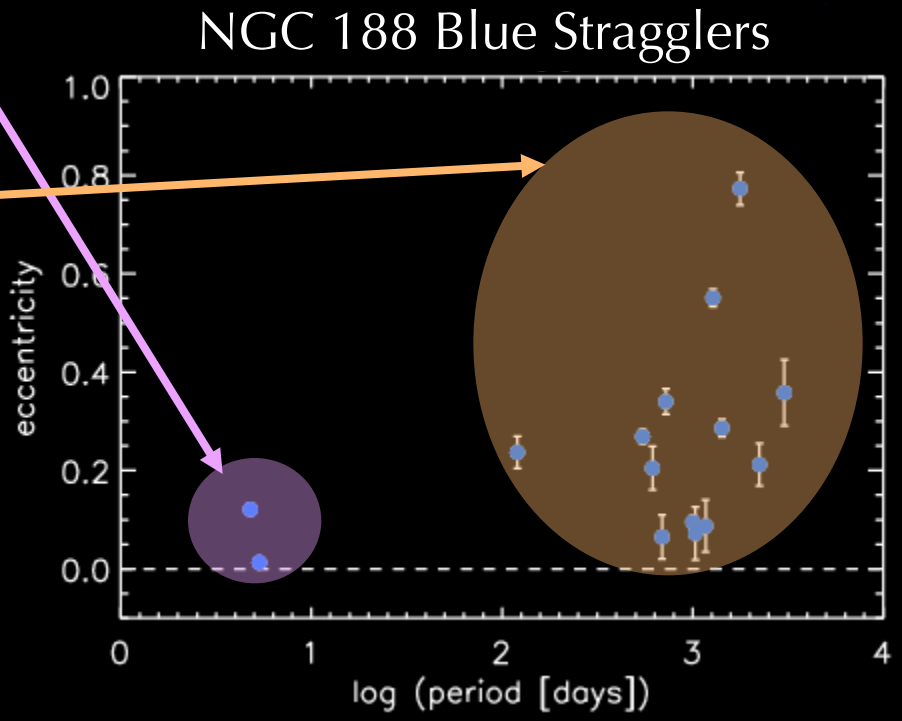
Origins

Collisions, dynamical encounters, exchanges?

Case C (& B) Mass Transfer
(+ dynamical encounters/"e-pumping")

And don't forget the 5 blue stragglers with constant RV (singles?)

Multiple formation mechanisms, but mass transfer dominates



We have upcoming HST Cycle 19 fUV observations aimed at detecting WD companions to SB1s predicted by mass transfer hypothesis

Aaron M. Geller