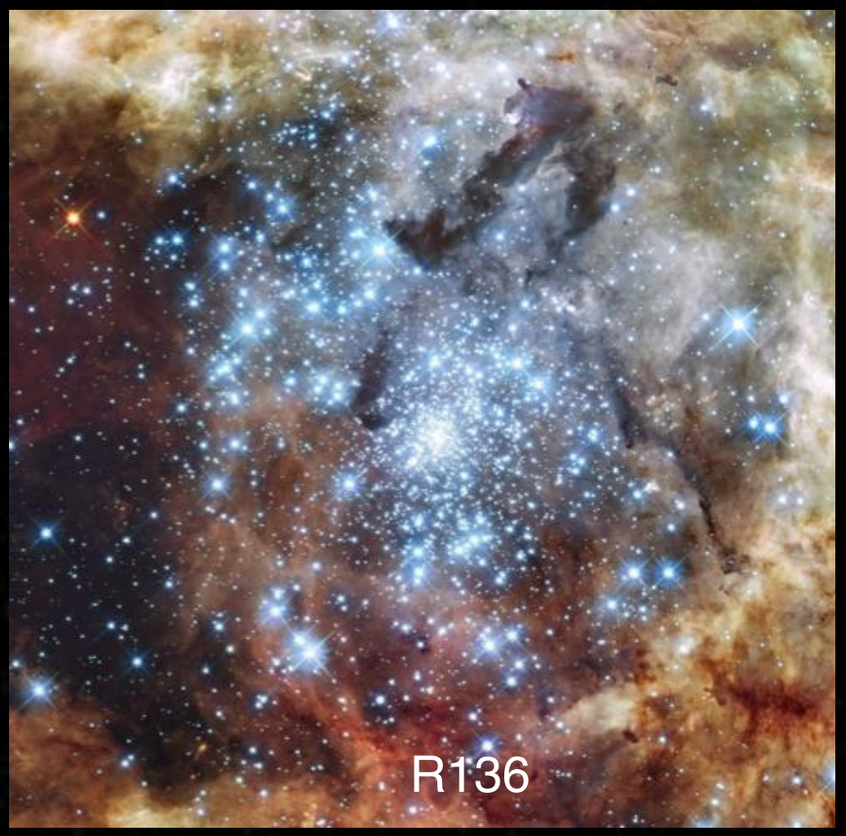


Plato and star clusters

Mark Gieles

erc European Research Council

UNIVERSITY OF SURREY

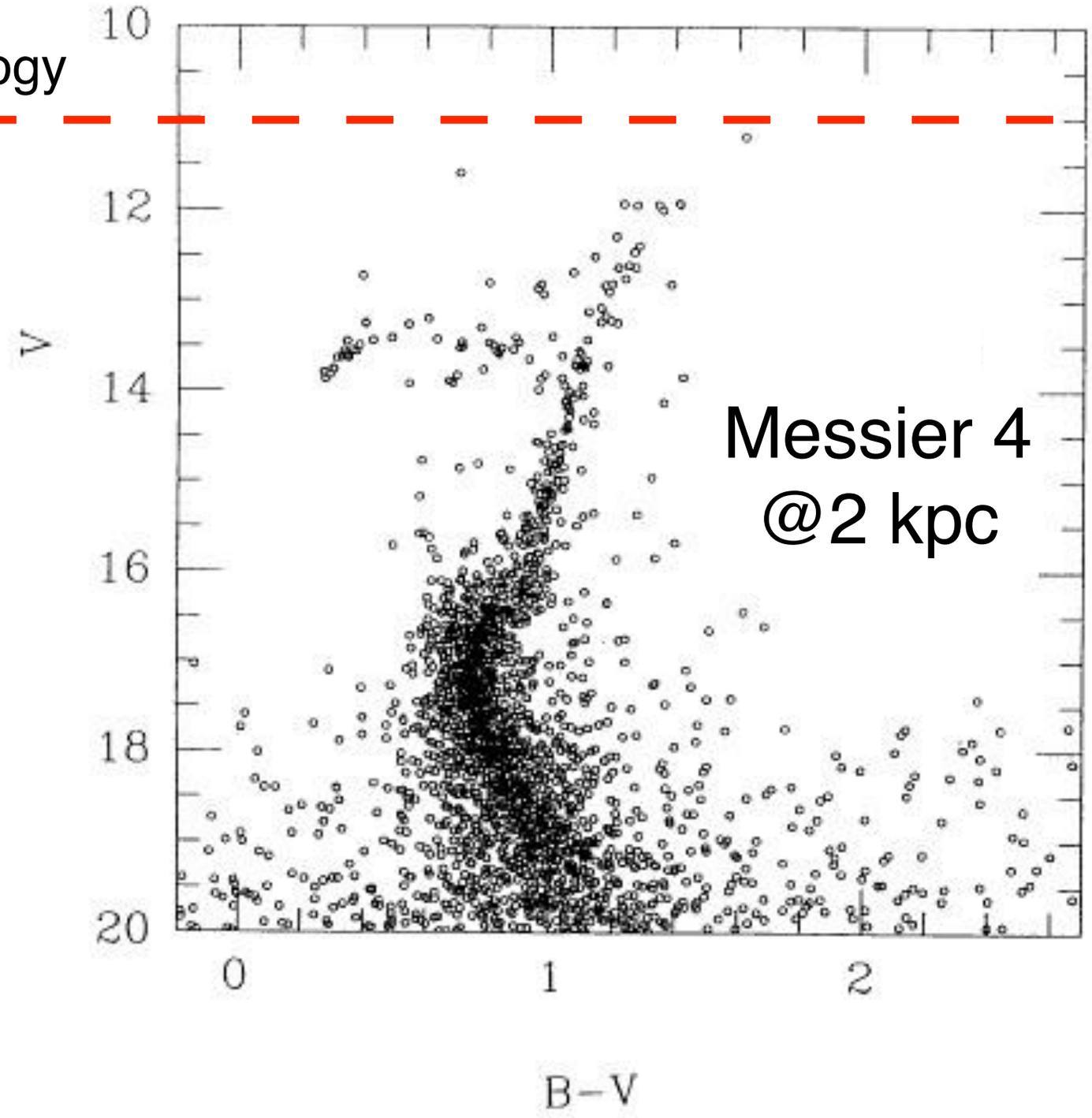
THE ROYAL SOCIETY

The old ….

47 Tucanae (12 Gyr)

Plato 2.0 and globular clusters: the nearest = impossible

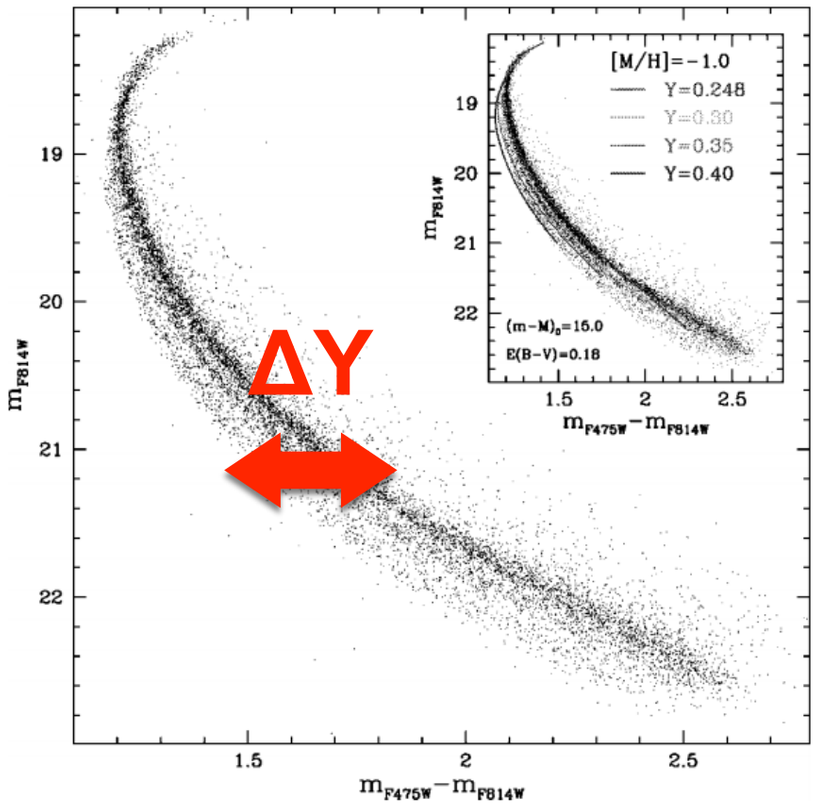
Asteroseismology



Kanatas+ 1995

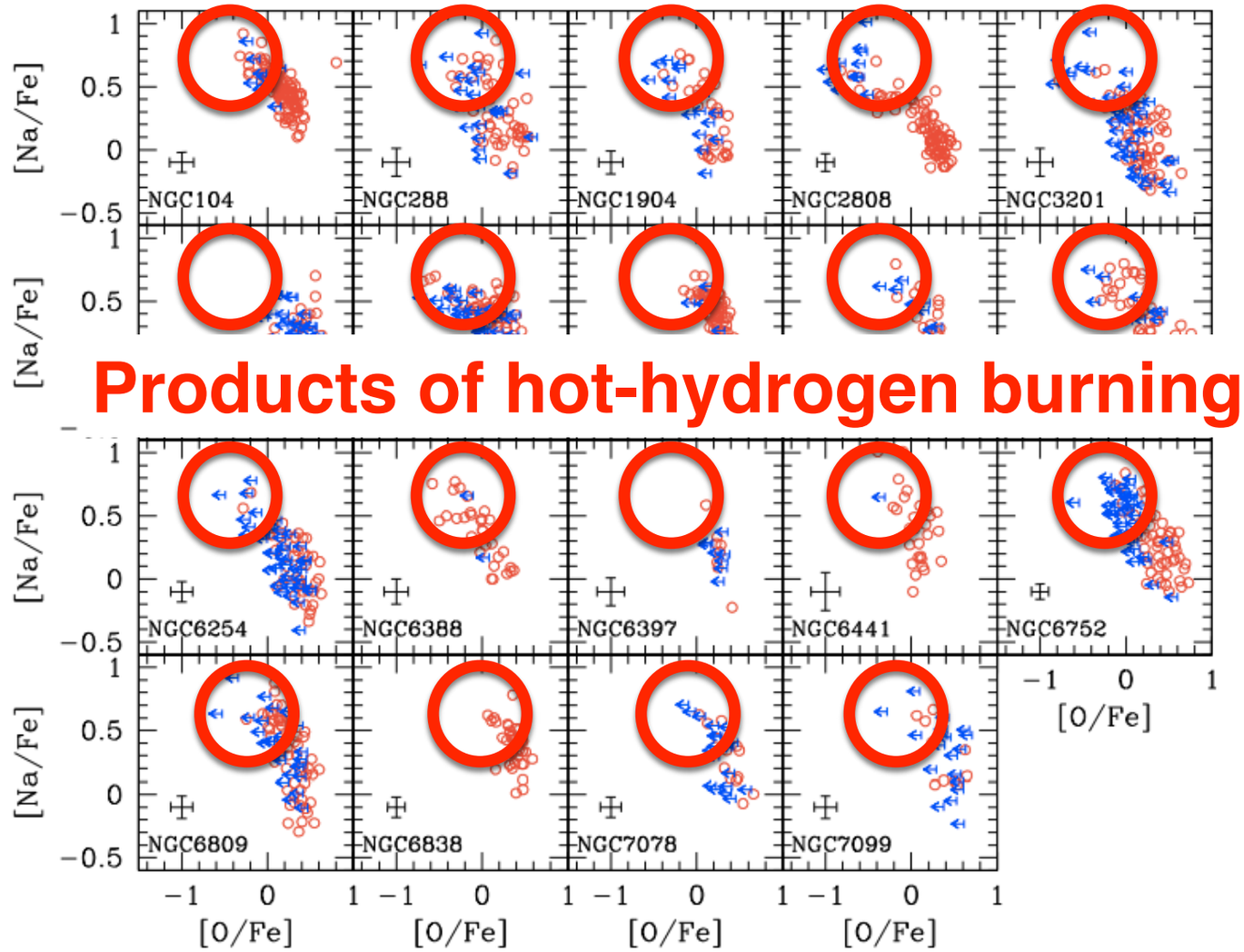
The complex stellar population of globular clusters

Multiple main sequences
(in massive GCs)



Piotto+ 2007

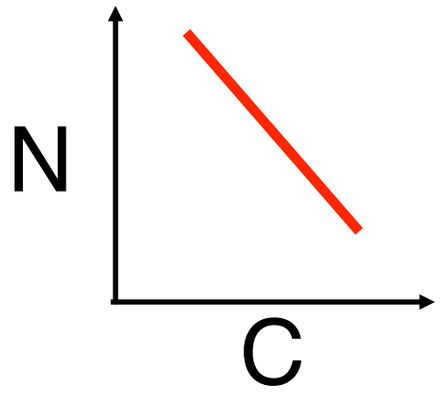
Light element variations
(in all GCs)

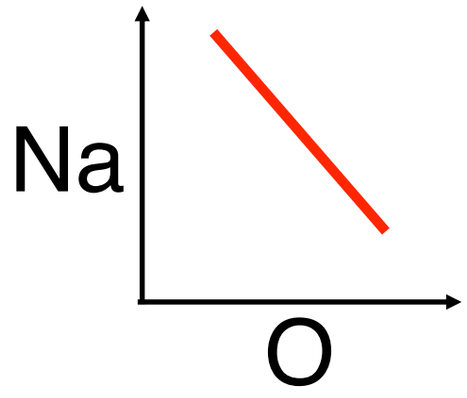


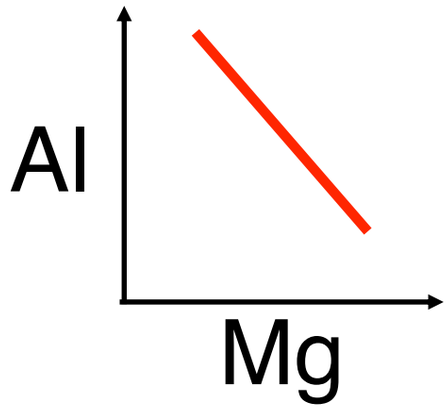
Products of hot-hydrogen burning

Carretta+ 2009

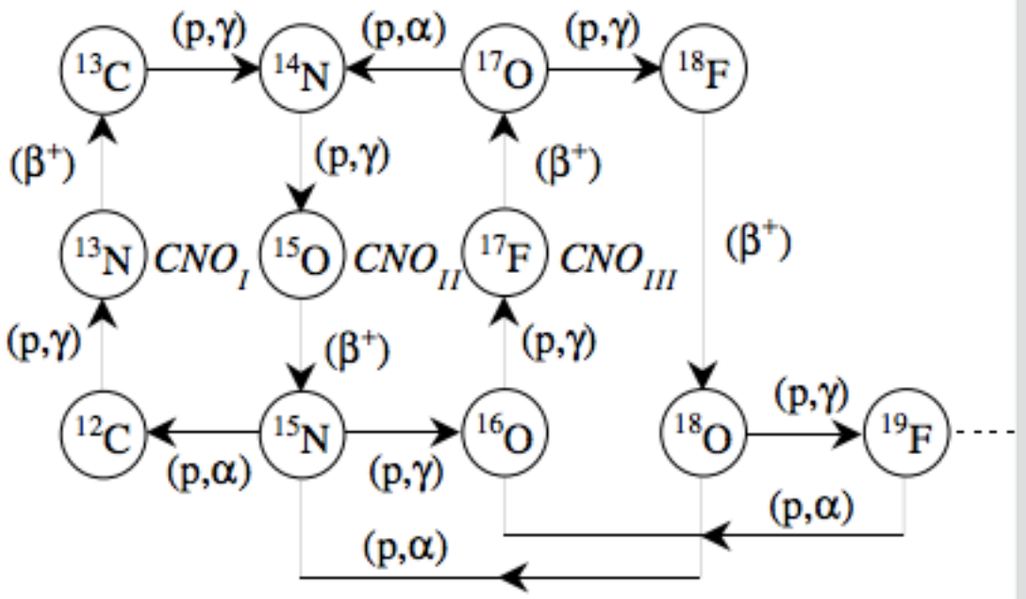
Hot-hydrogen burning





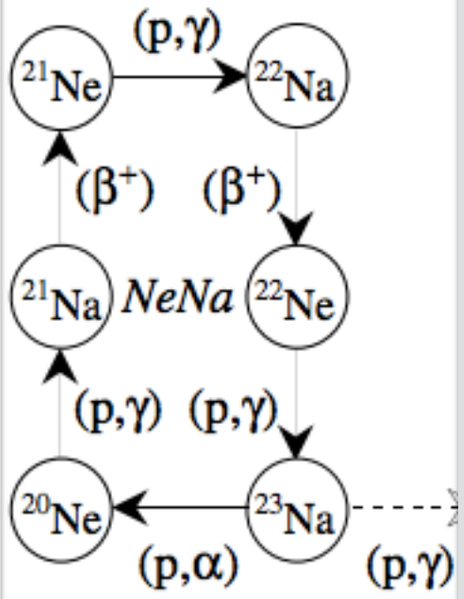


CNO
~15M K

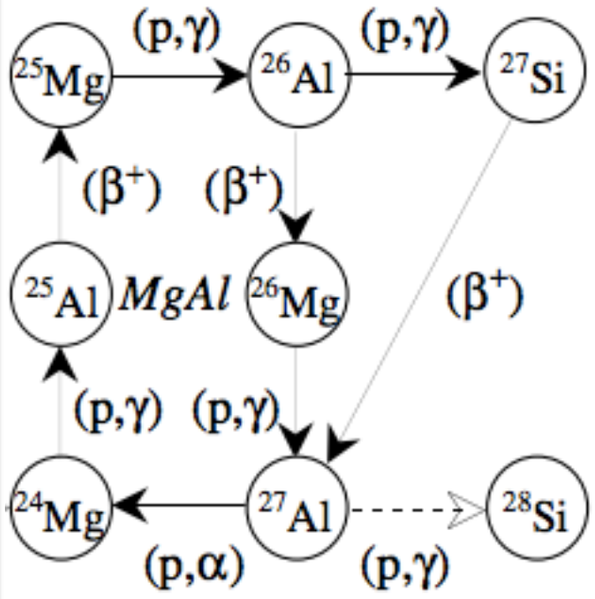


Arnould+ 1999

NeNa
~40M K



MgAl
~70M K



Review: Charbonnel 2016

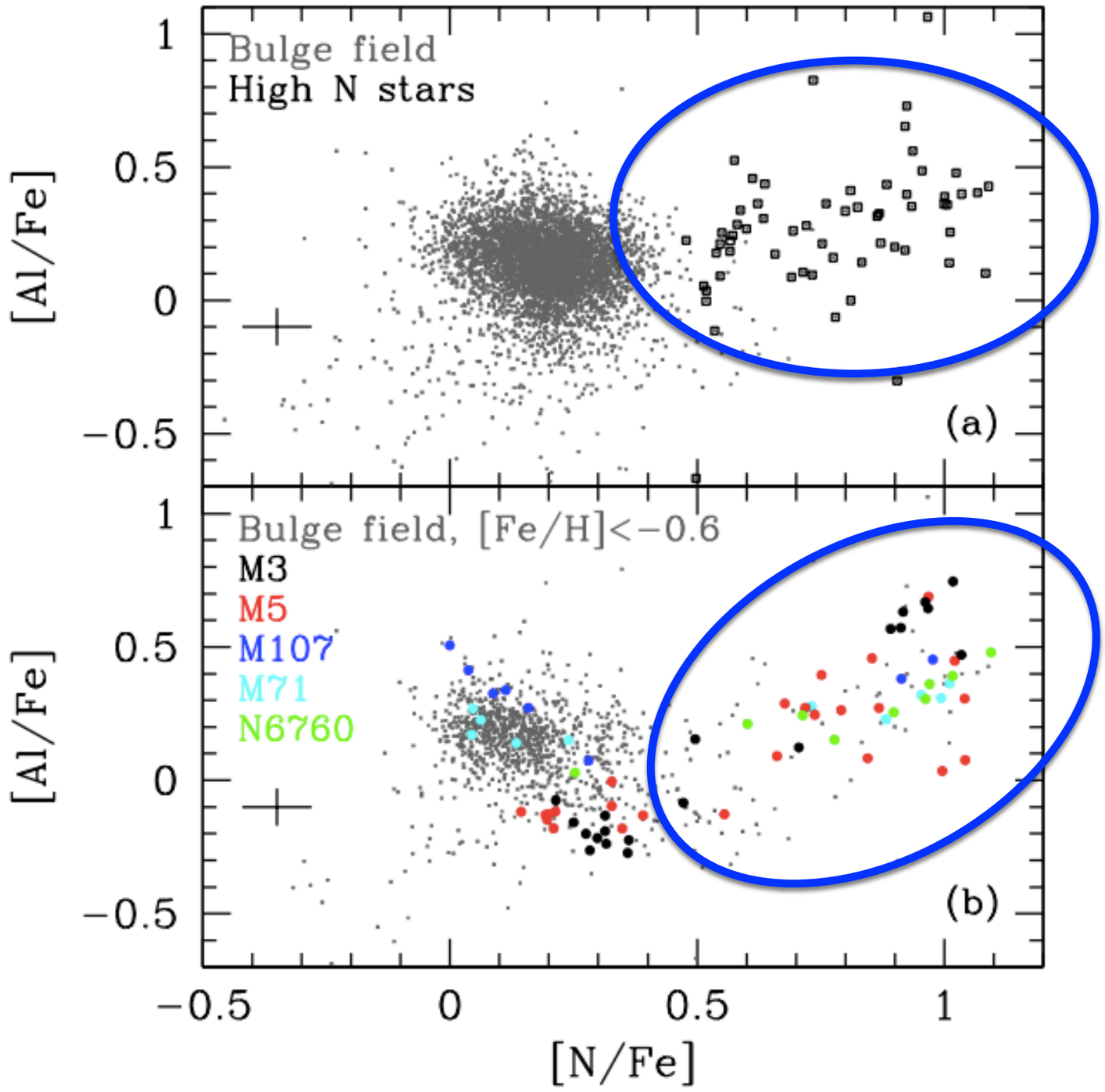
Existing models

Polluters	Enrichment scenario
 AGB stars Ventura+ 2001 R Sculptoris / ALMA	The "AGB scenario" D'Ercole+ 2008; Maxwell+ 2014; Renzini+ 2015; D'Antona+ 2016
 Massive stars (10-100 $M_\odot$) Prantzos & Charbonnel 2006 R136 (HST)	Fast rotating massive stars (Decressin+ 2007) Interacting binaries (de Mink+ 2009) Early disc accretion (Bastian+ 2013) Interacting stars (Elmegreen 2017)
? Very/super massive stars (10^3-10^4 $M_\odot$) Denissenkov & Hartwick 2014	**TBD**

see reviews by Bastian 2015; Renzini+ 2015; Charbonnel 2016

“Strange” (i.e. GC) stars in the bulge

~1-2% of bulge stars

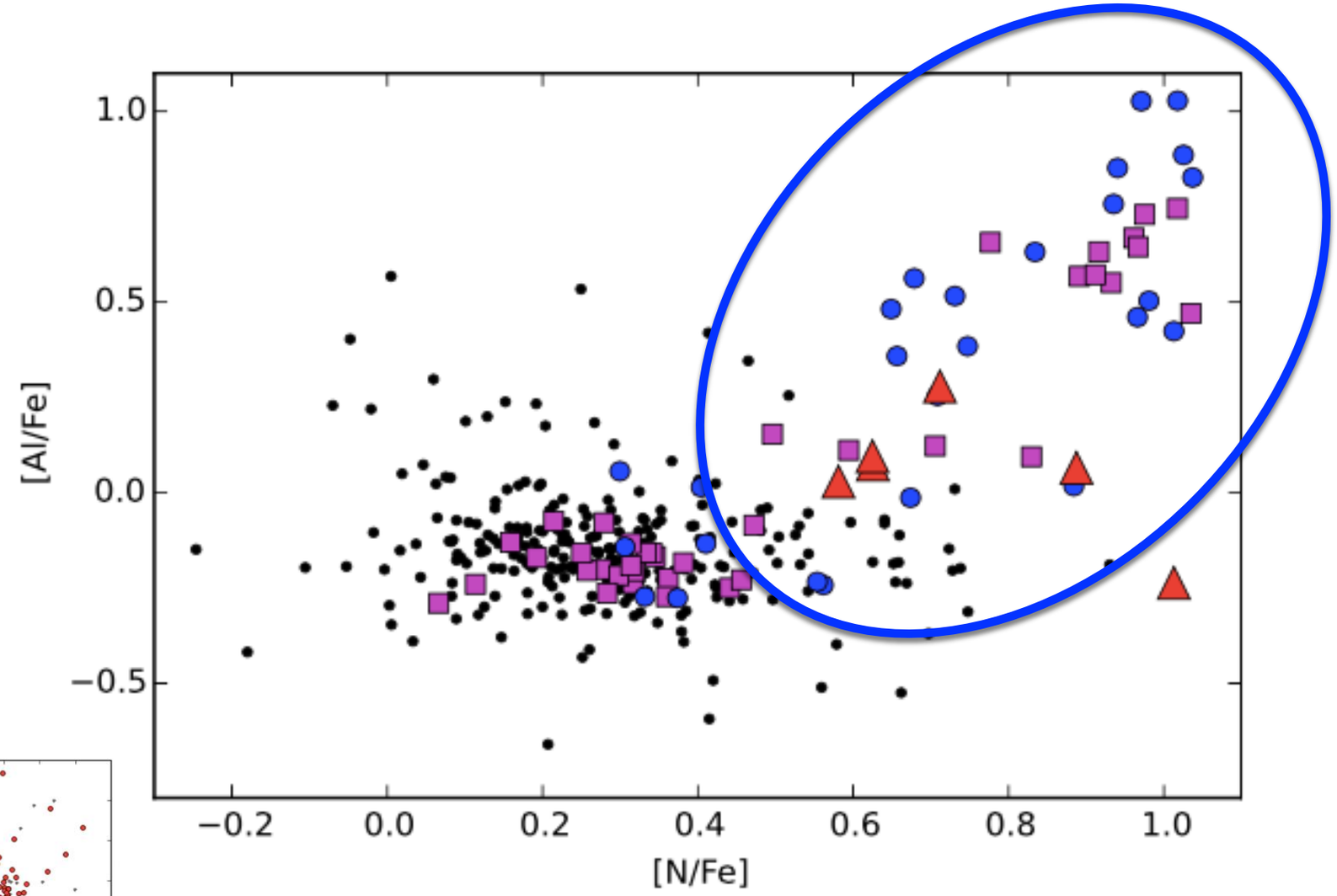


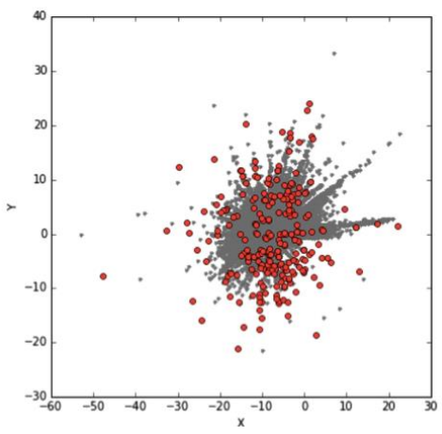
Schiavon+ 2016

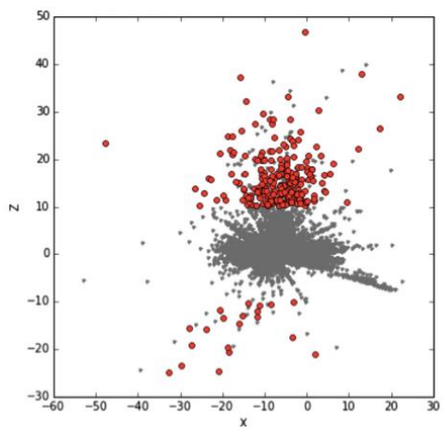
“Strange” (i.e. GC) stars in the halo

~1-2% of halo stars

SDSS-III/APOGEE



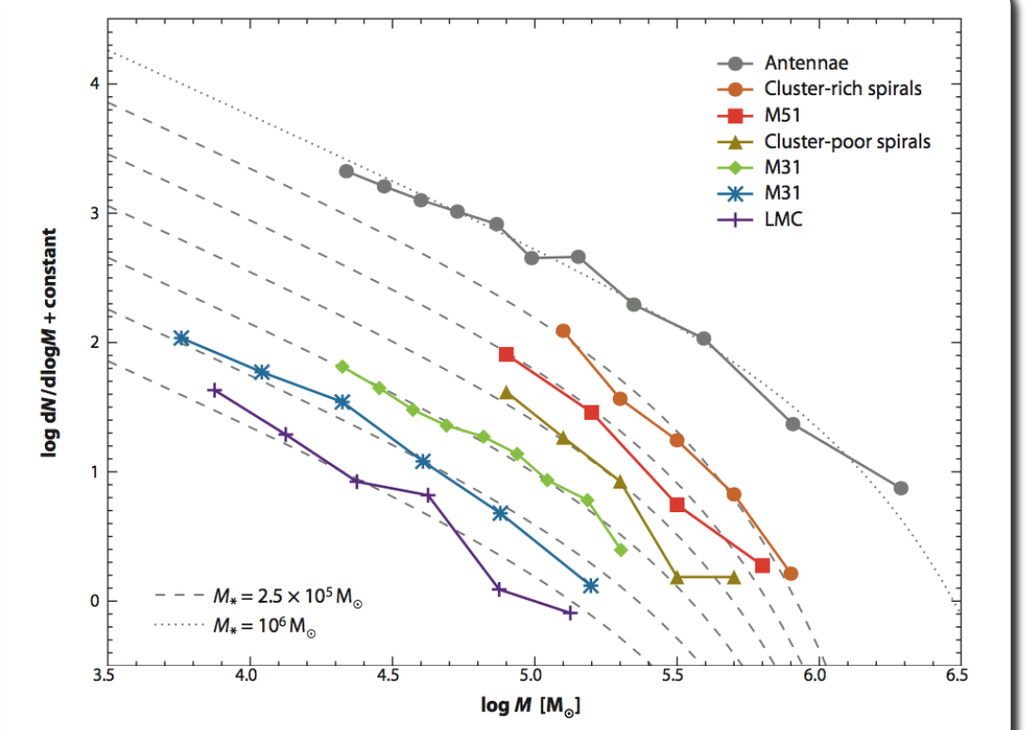




Martell+ 2016

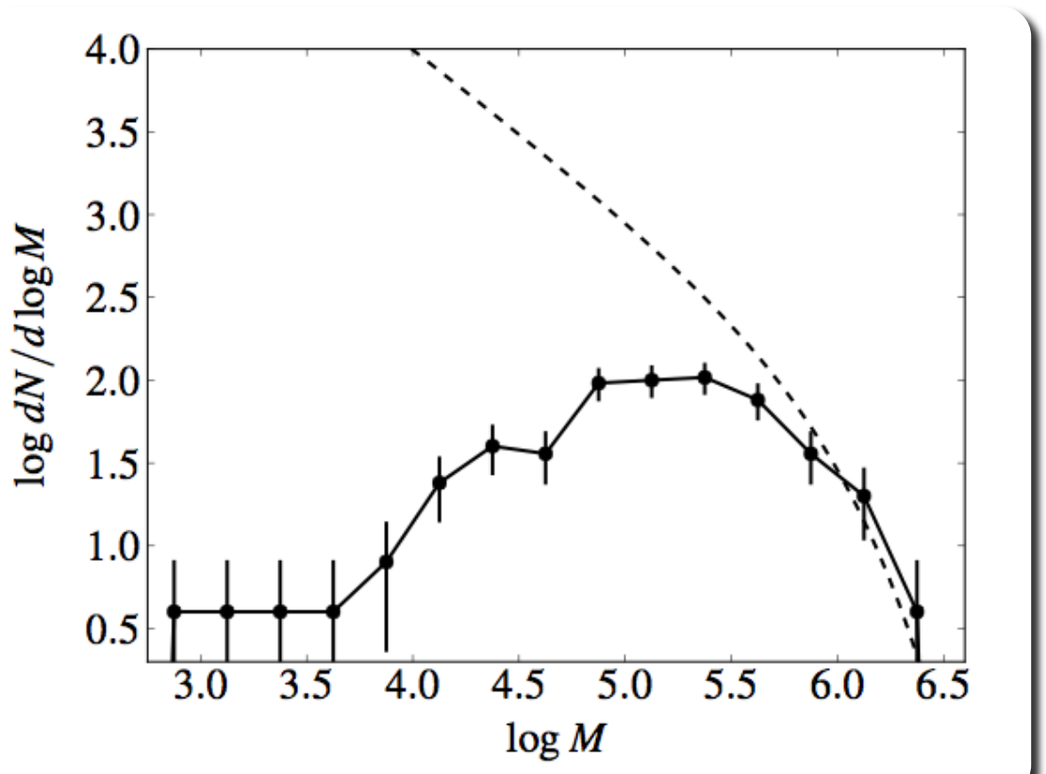
Globular cluster mass function: nature or nurture?

Young Massive Clusters (YMC)



Portegies Zwart, McMillan & Gieles (2010)

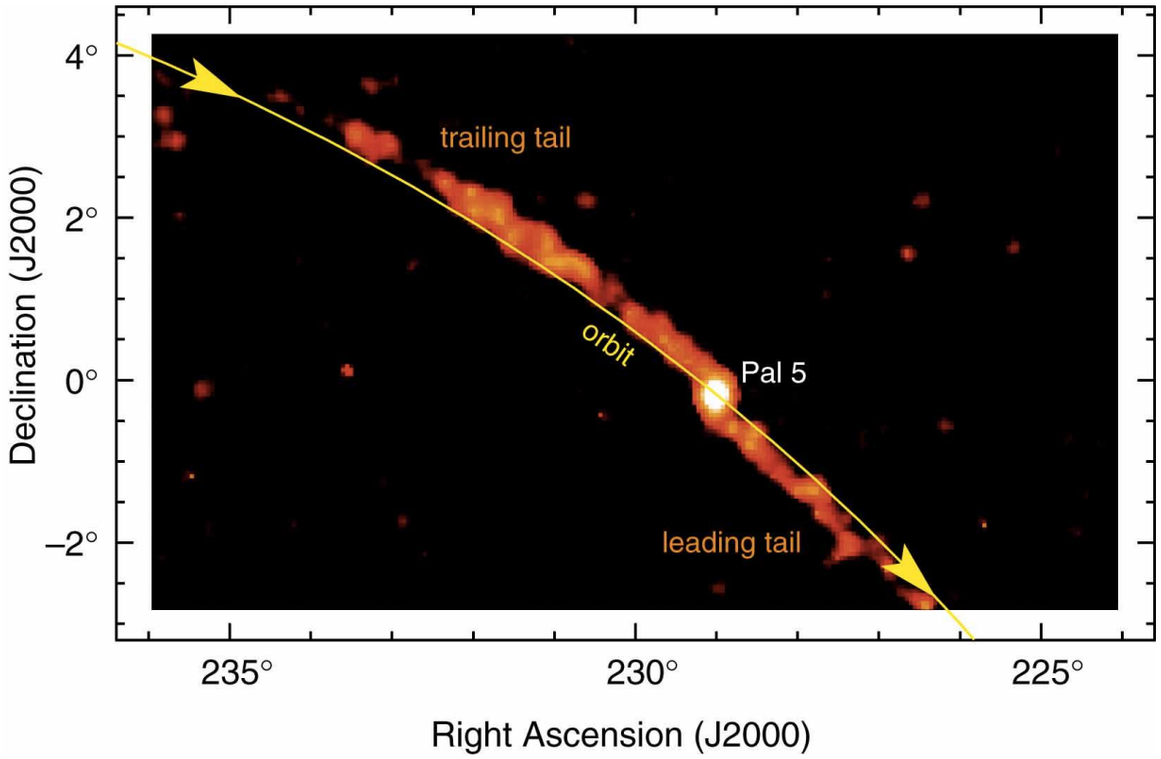
Milky Way Globular Clusters (GCs)



data from Harris (1996)

Constraining the building blocks of Galactic halo/disc

Accurate ages (Plato) and abundances allow us to find dissolved clusters



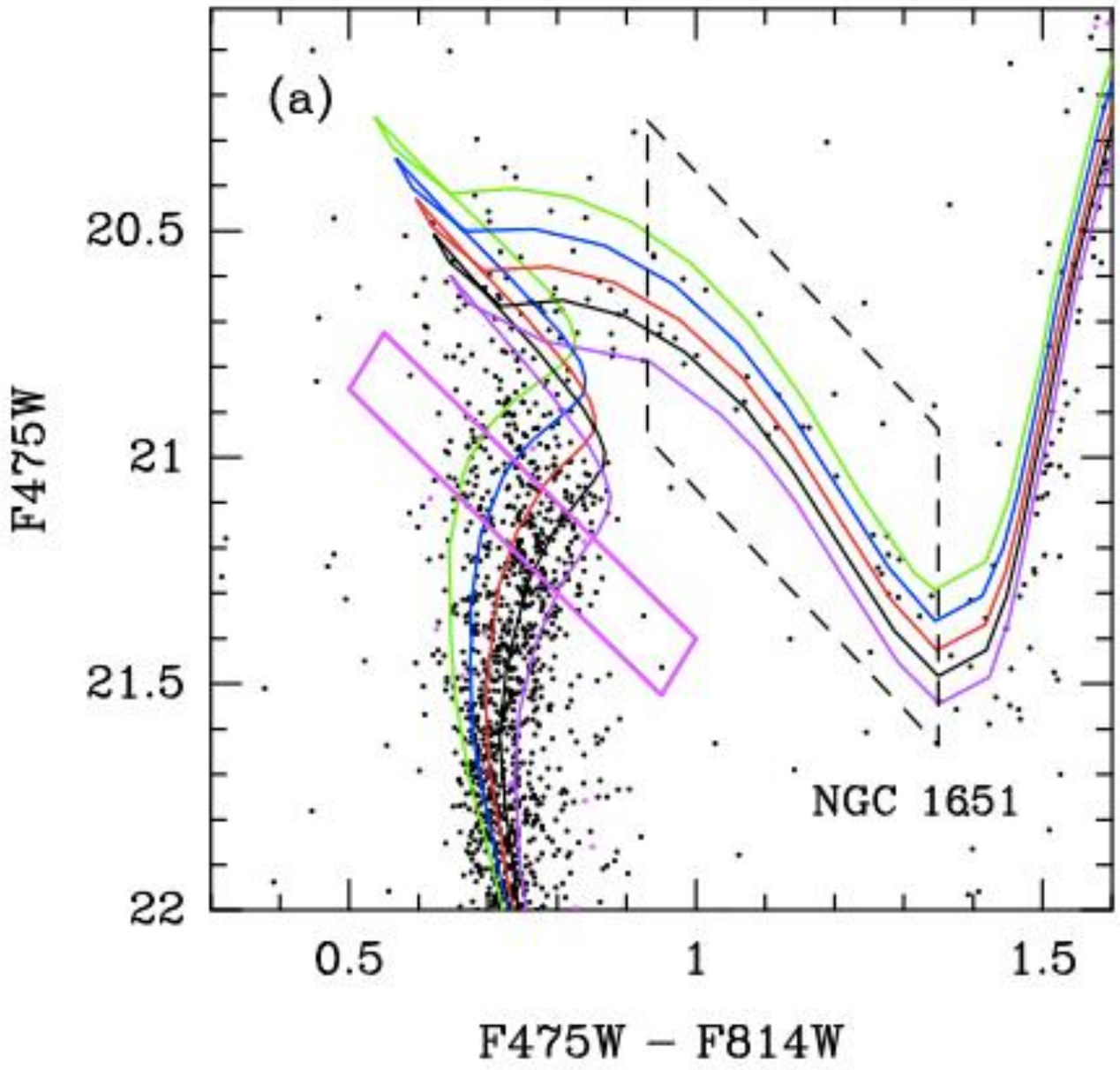
Odenkirchen+ 2001

The middle aged …

NGC 1783 (1.5 Gyr)

Extended main sequence turn off: age spread?

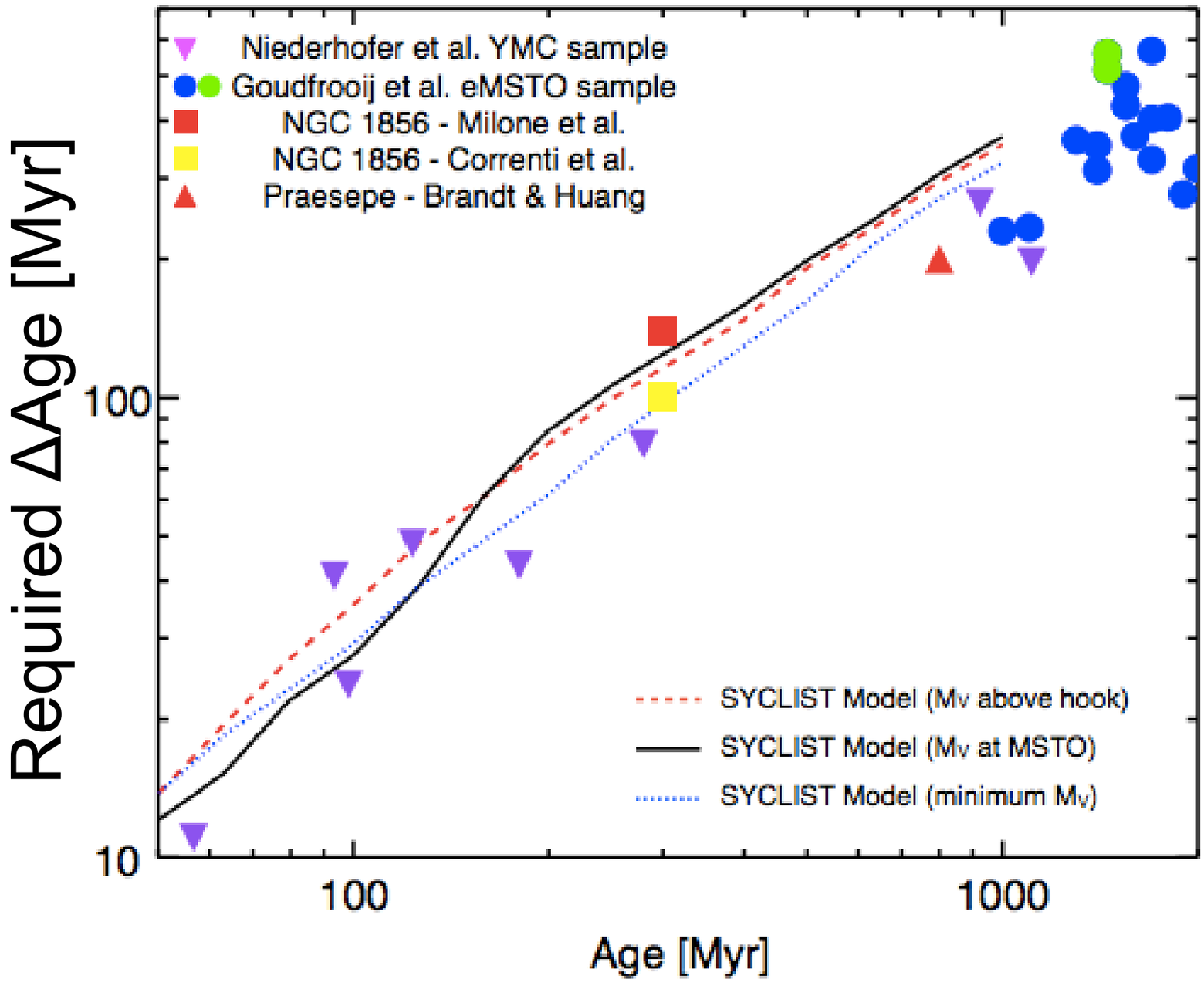
A common feature in intermediate age clusters in the Magellanic Clouds



Goudfrooij+ 2015

Bertelli+ 2003; Mackey & Broby Nielsen 2007; Glatt+ 2008; Milone+ 2009;

Age spread?



Niederhofer+ 2015

No evidence for Na-O anti-correlation

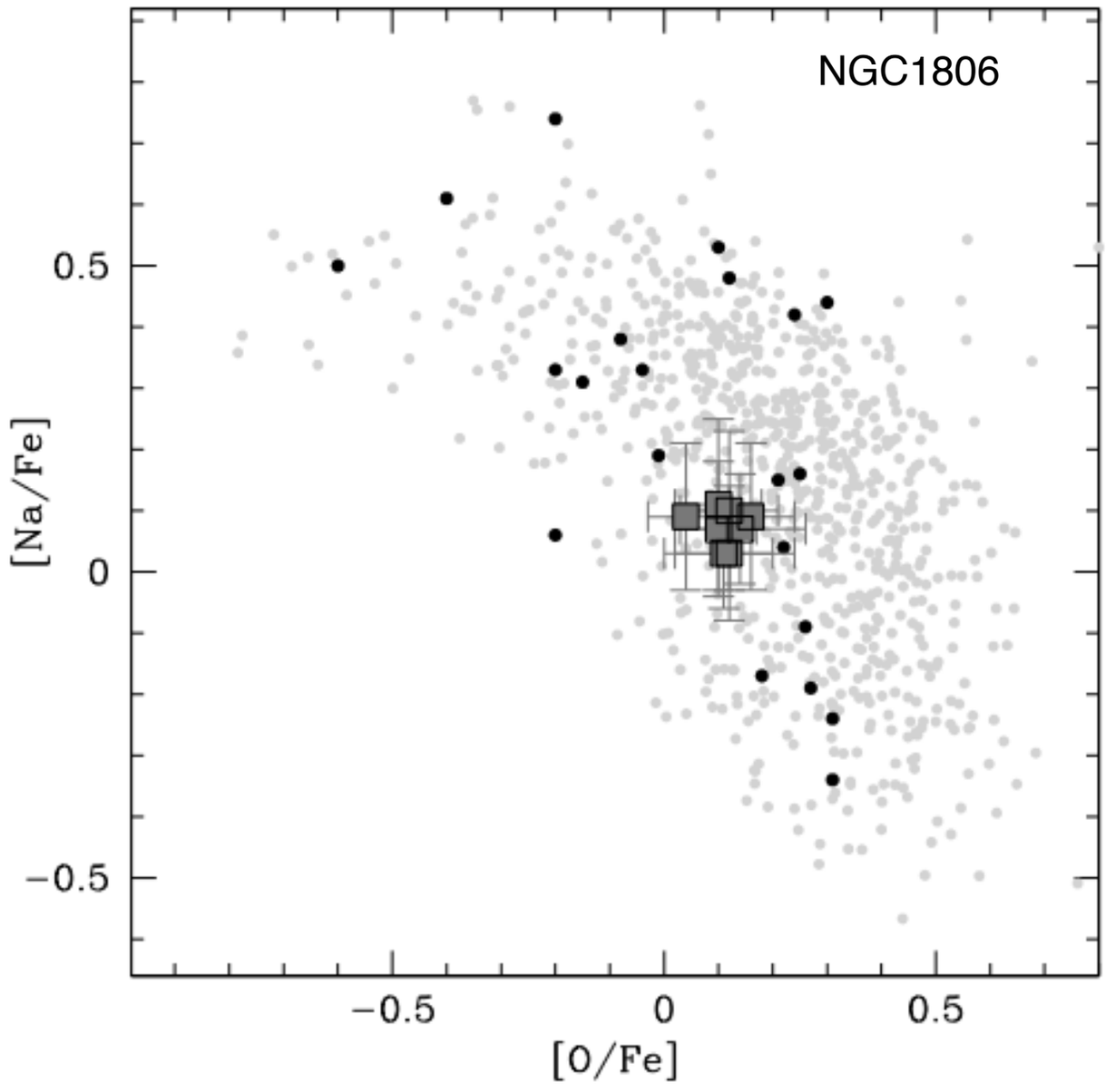
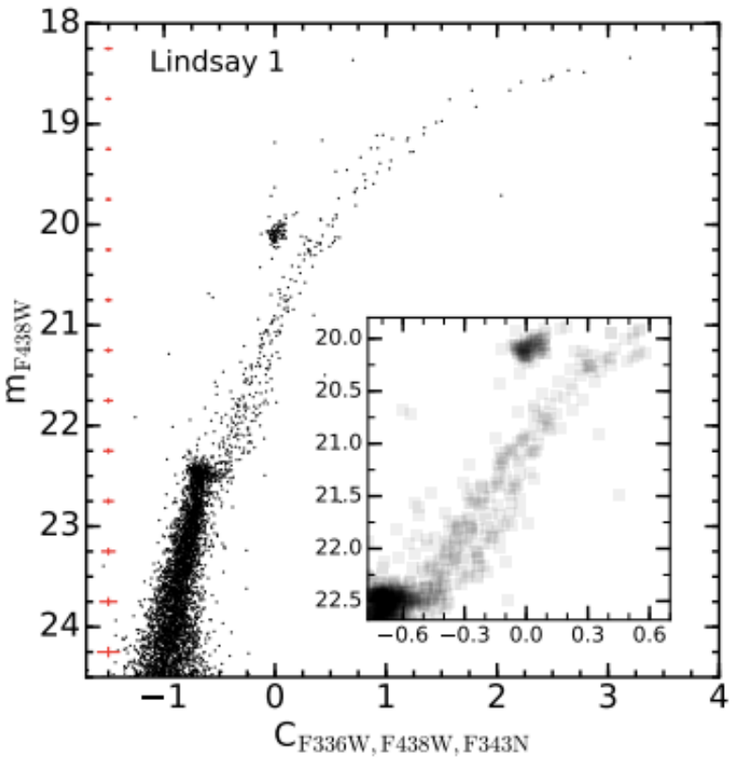
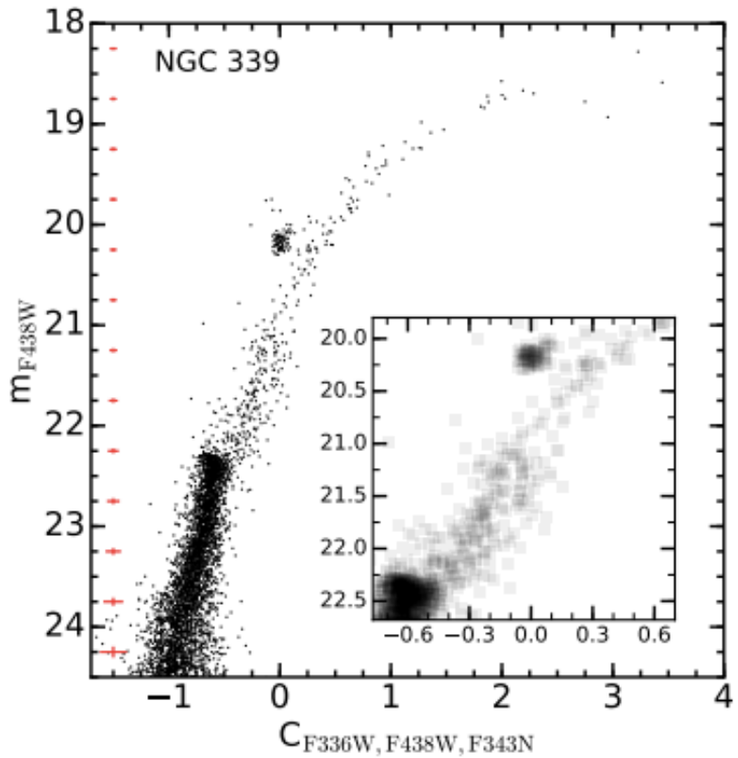


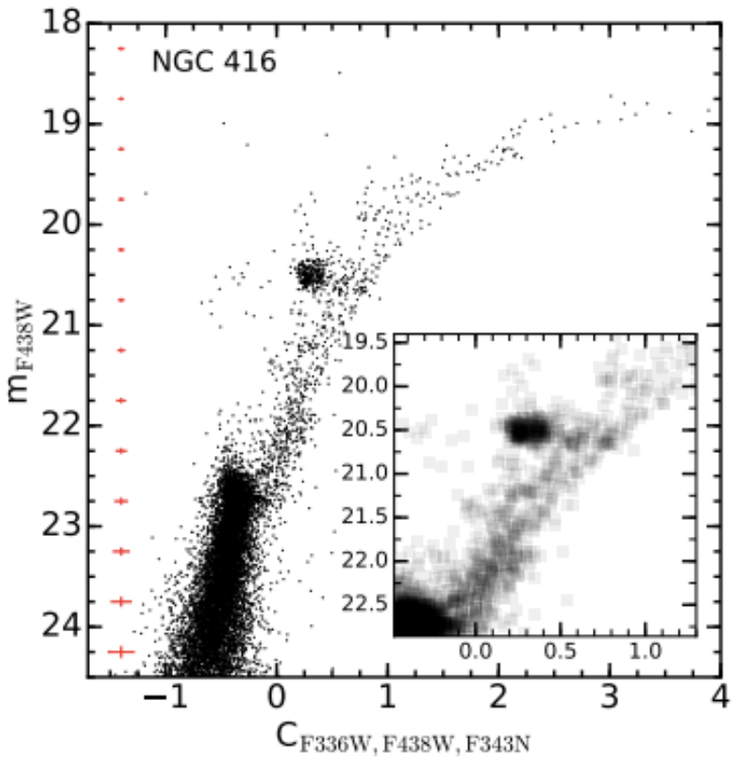
Figure 3. [Na/Fe] as a function of [O/Fe] for the eight members of NGC 1806 (dark gray squares), compared to the stars in old Milky Way (light gray points; Carretta et al. 2009a, 2009b) and LMC (black points; Mucciarelli et al. 2009) GCs.

Mucciarelli+ 2015

But: N spread at ages ~6-7 Gyr





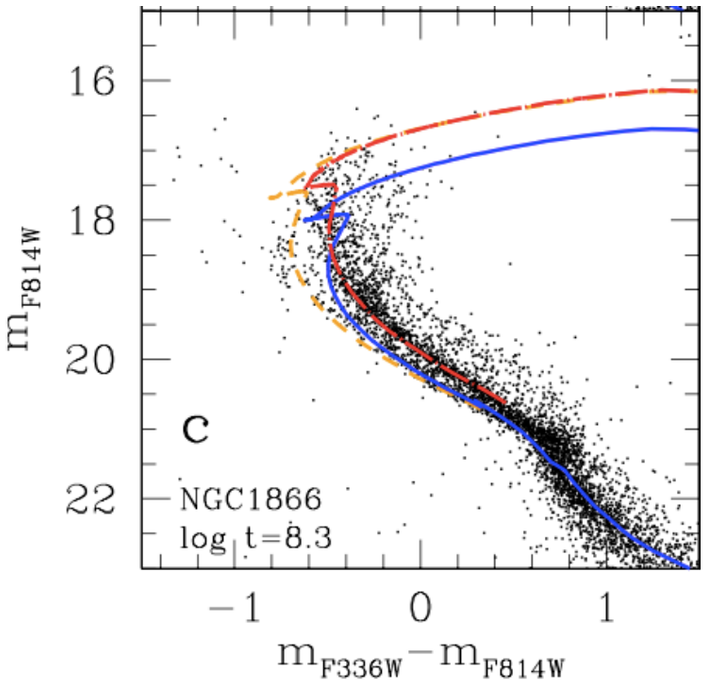


Niederhofer+ 2017

Spectroscopic confirmation of N spread in Lindsay 1 by Hollyhead+ 2017

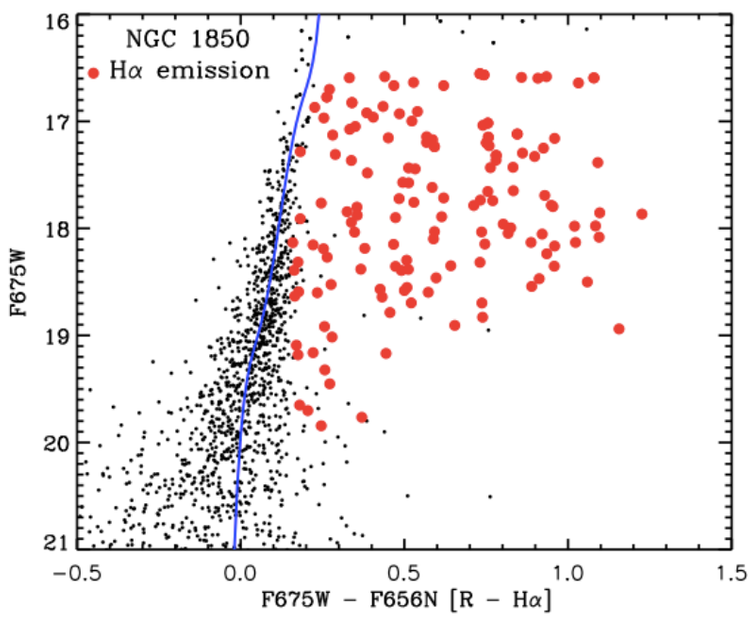
Rotation can do it: 80% of stars rotate near break up!

Stellar population modelling



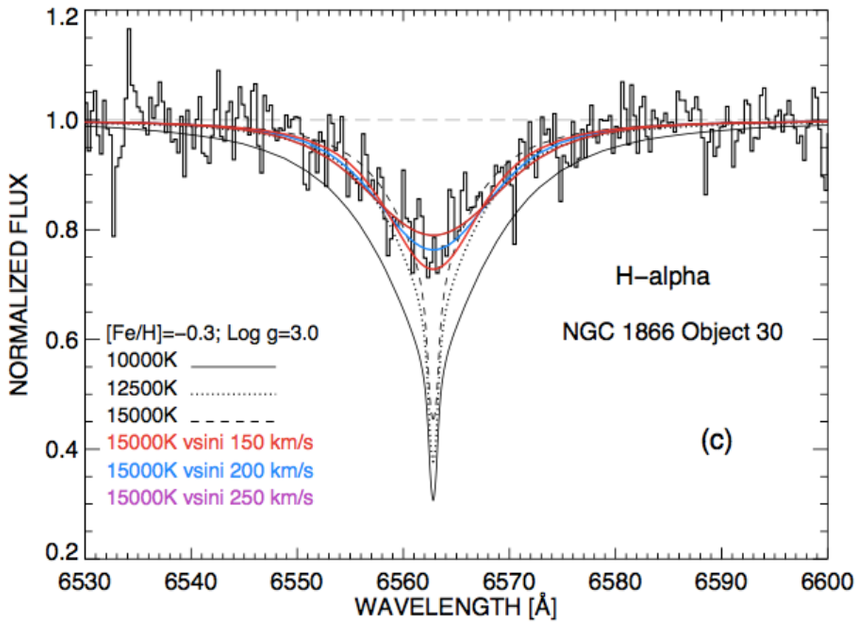
D'Antona+ 2017
see also: Bastian & de Mink

High fraction of Be stars



Bastian+ 2017

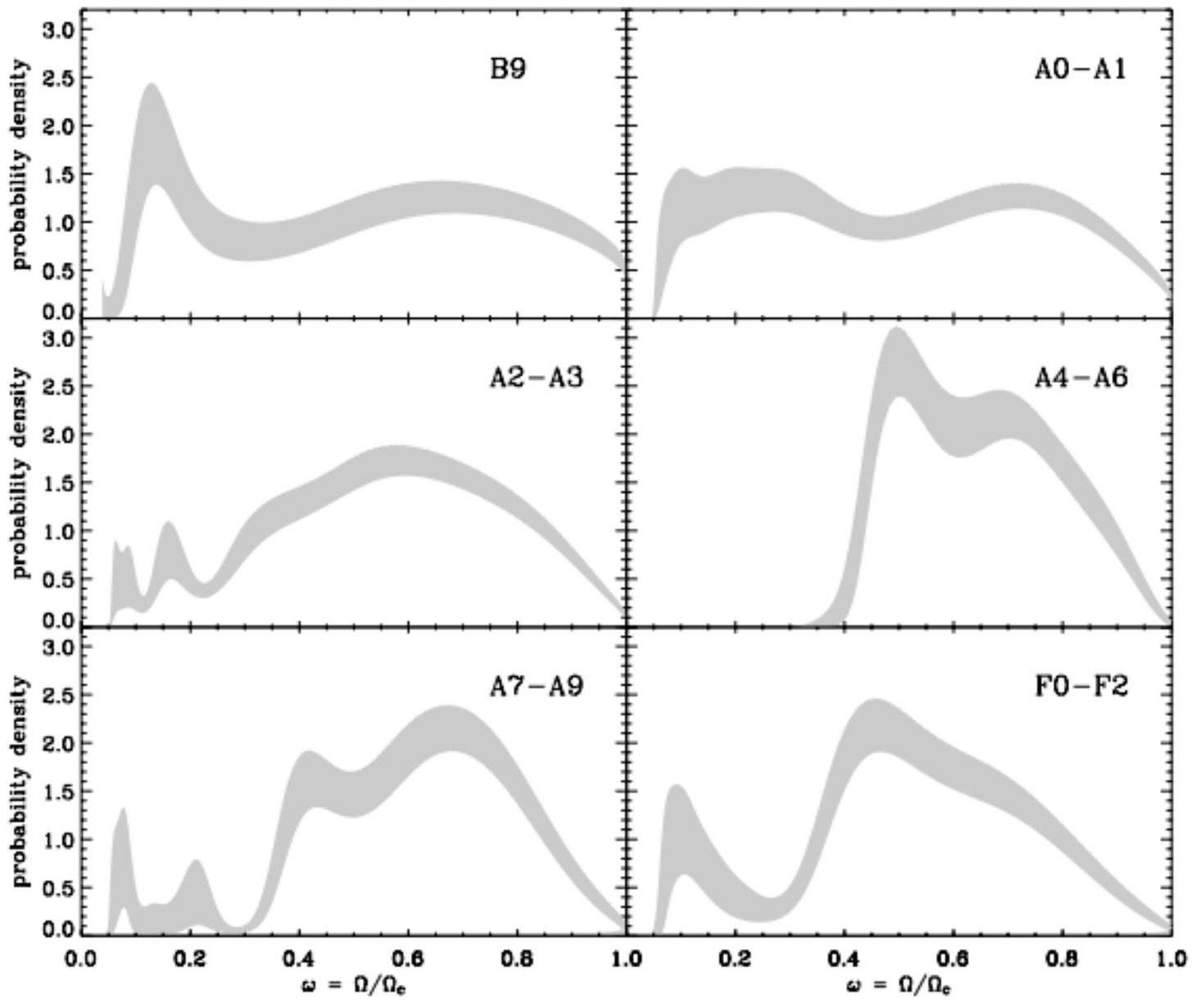
Line broadening



Dupree+ 2017

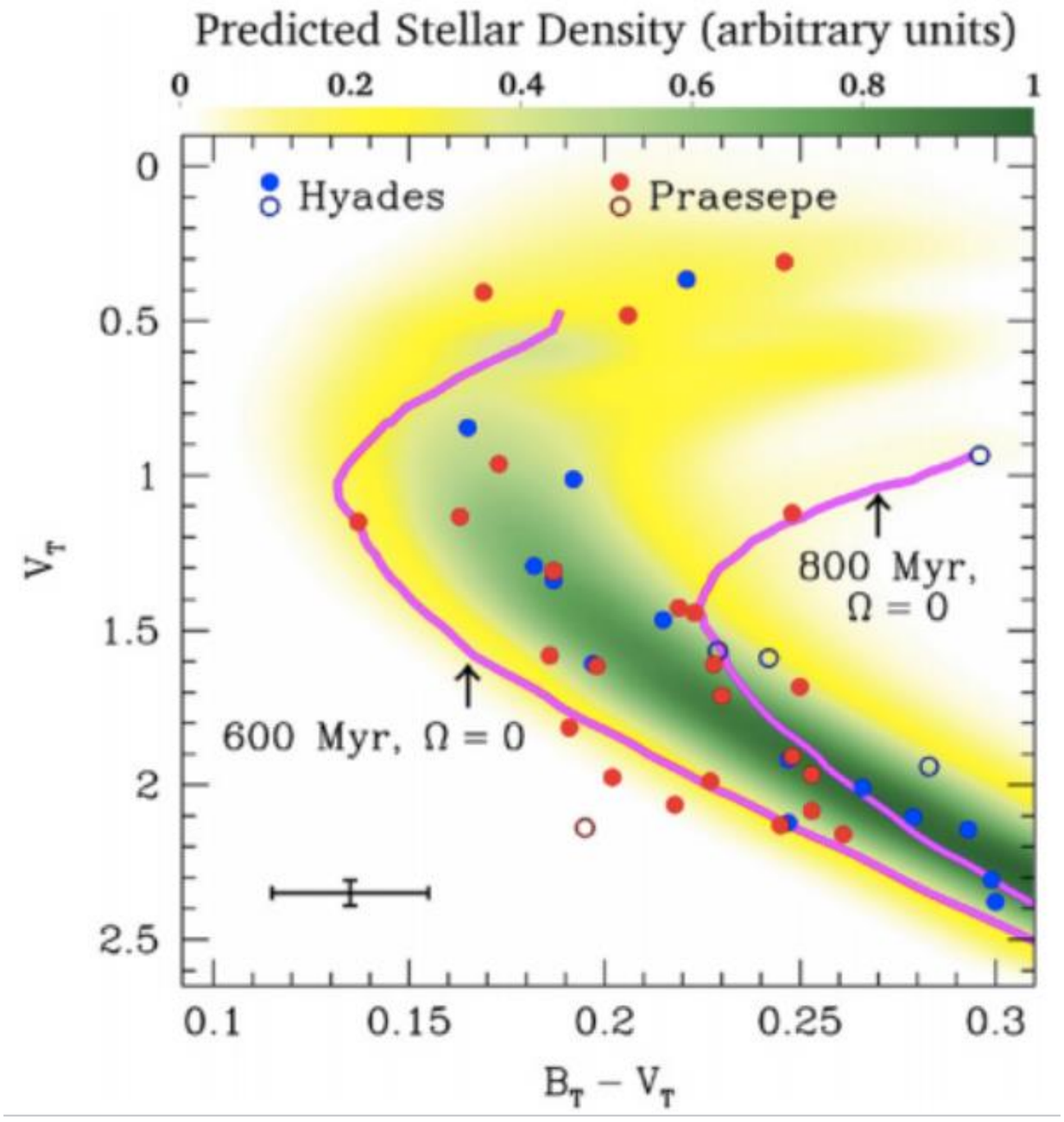
Cluster stars rotate faster than in field stars. Discs? Planets?

Galactic field stars



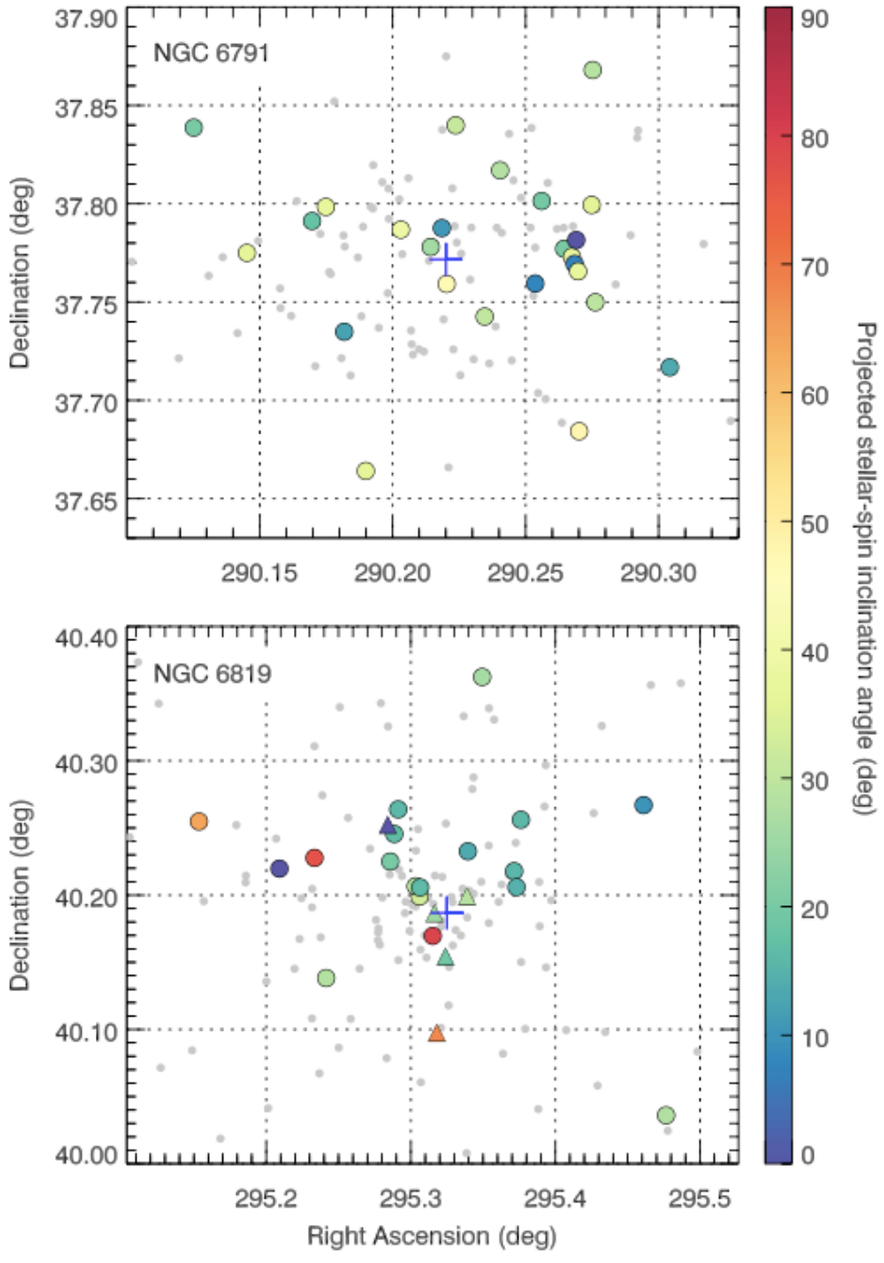
Royer+ 2007

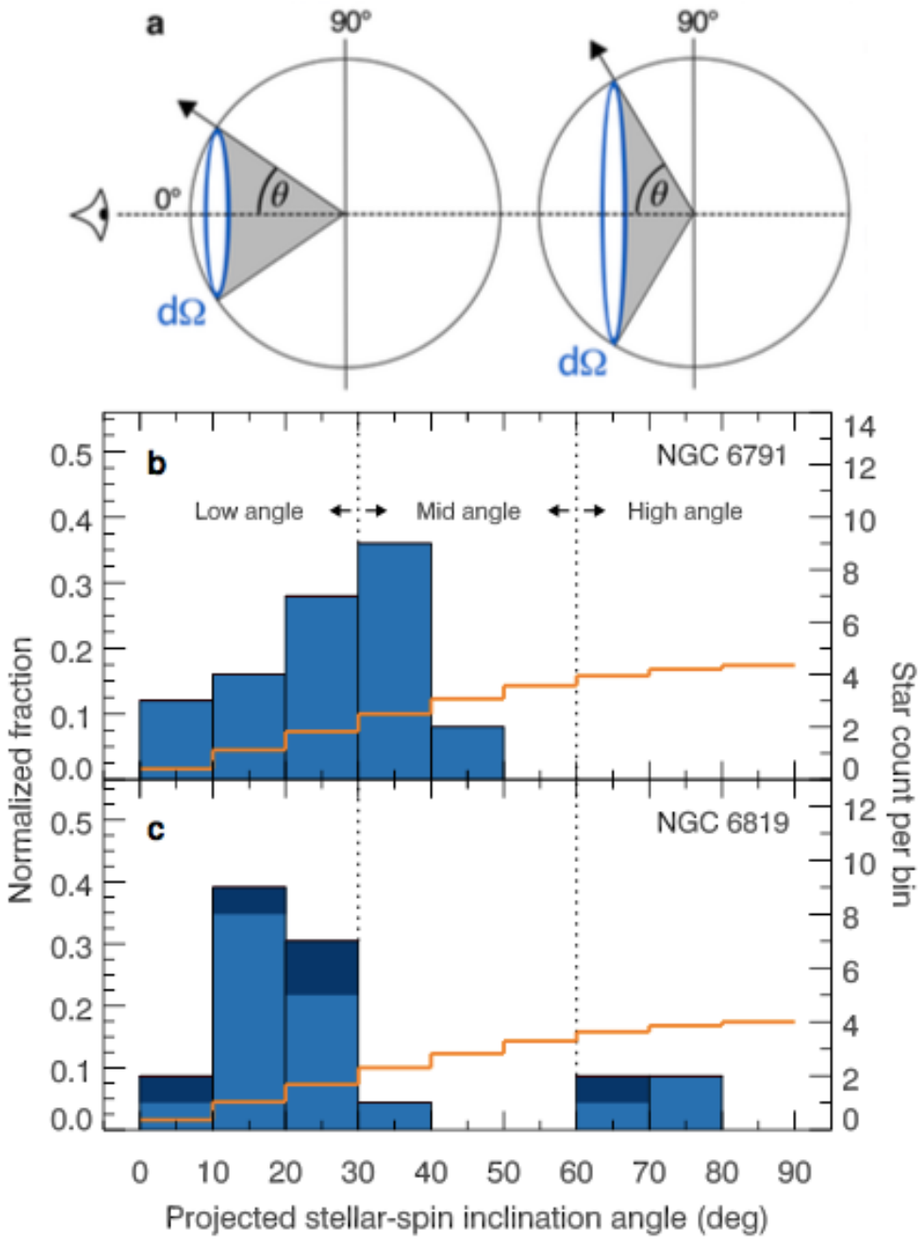
Stellar rotation in Galactic clusters



Brandt & Huang 2005

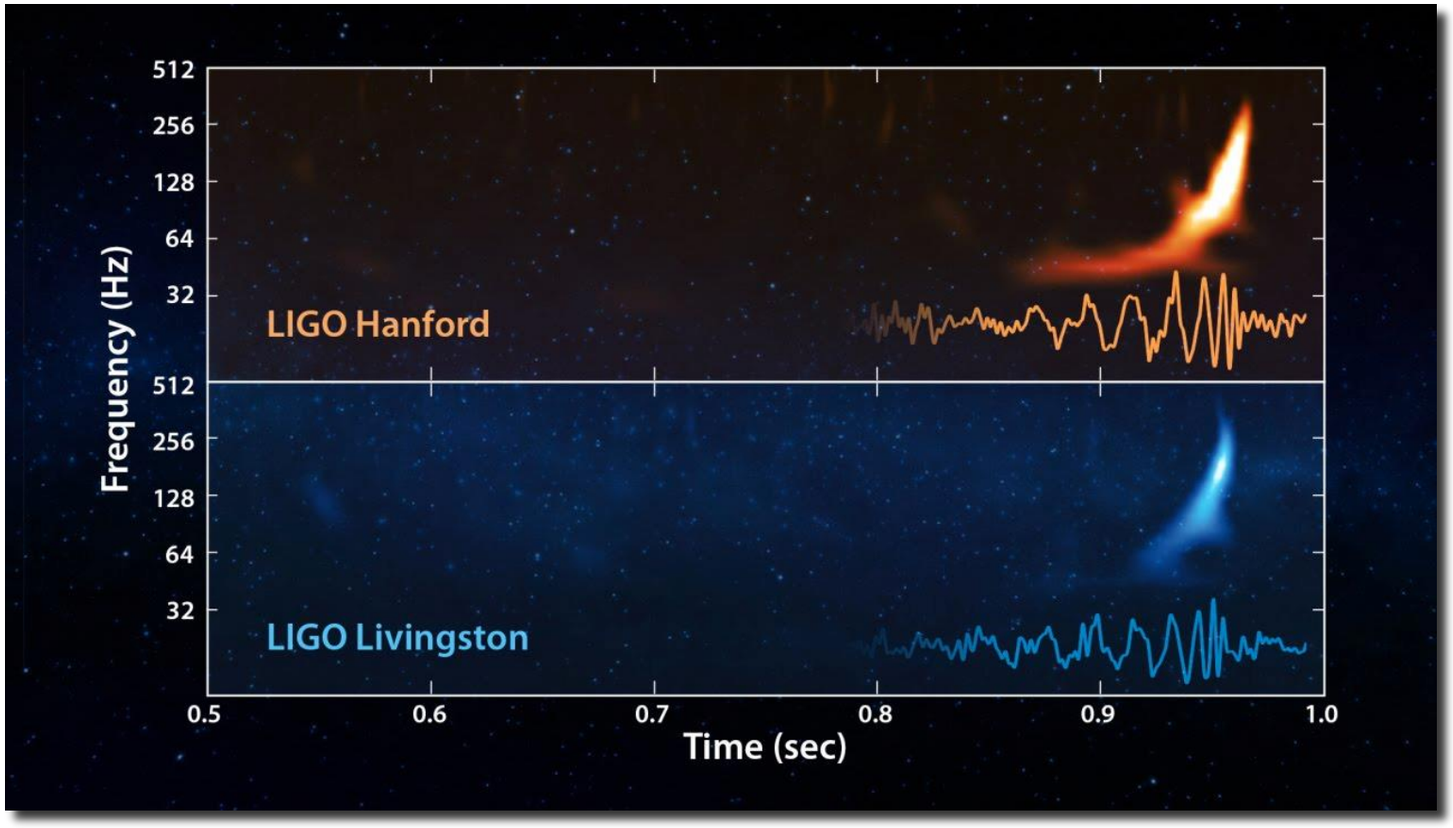
Kepler: spin alignment in 2 open clusters

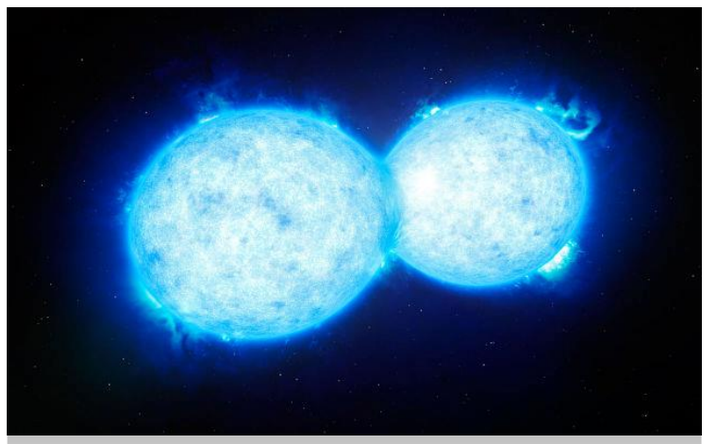




Corsaro+ 2017

Spin alignment: importance for gravitational waves

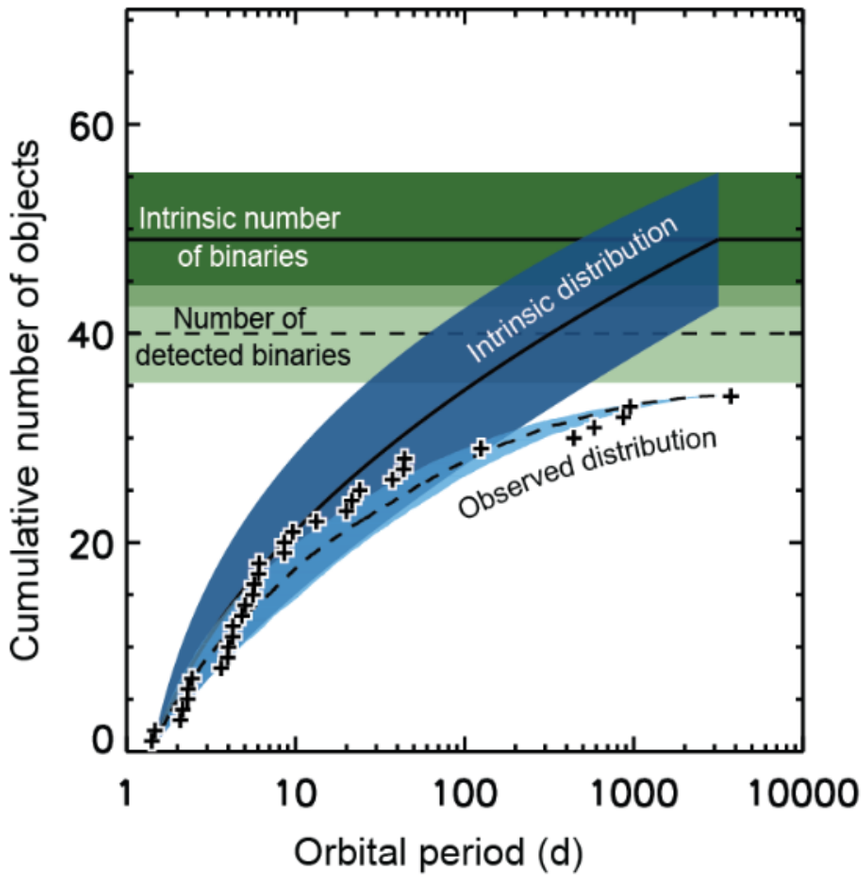


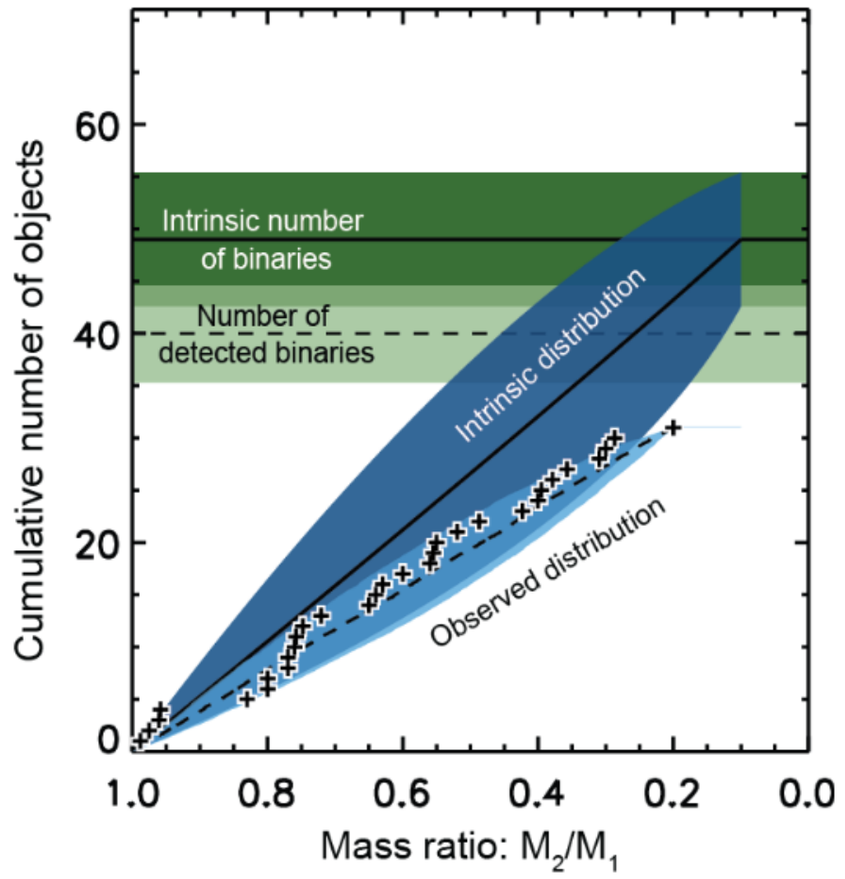


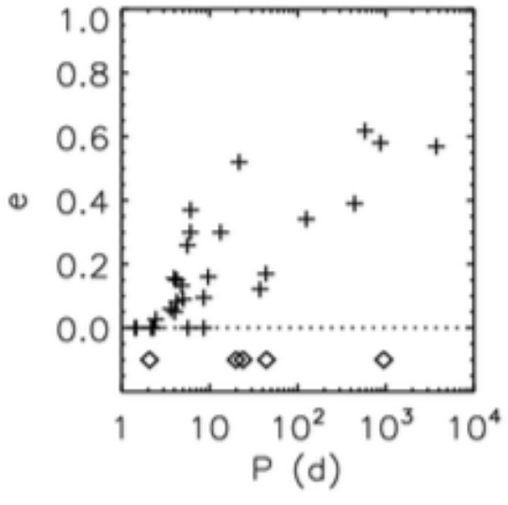
The young …

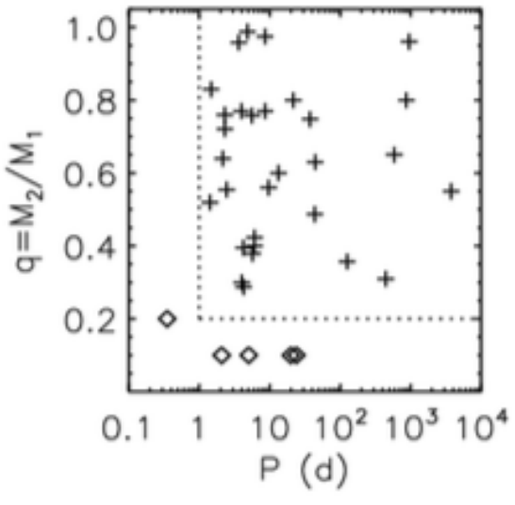
R136 (2 Myr)

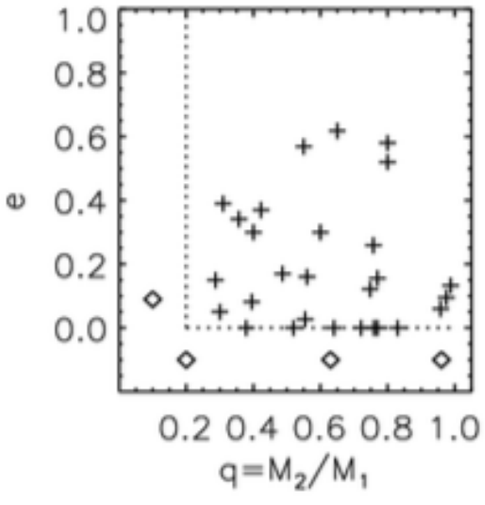
Multi-epoch survey of 6 young clusters: f_{bin} = 0.69±0.09





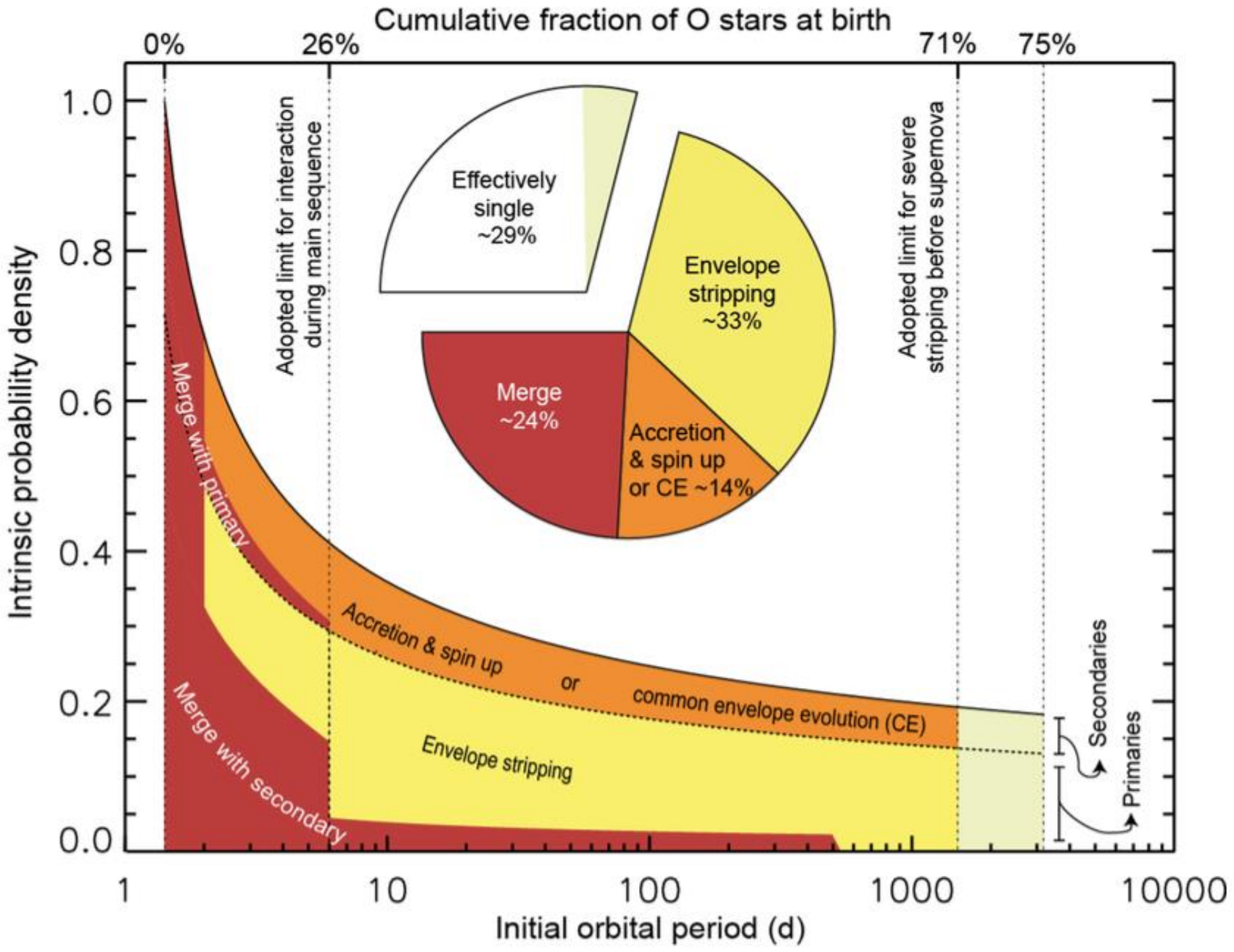






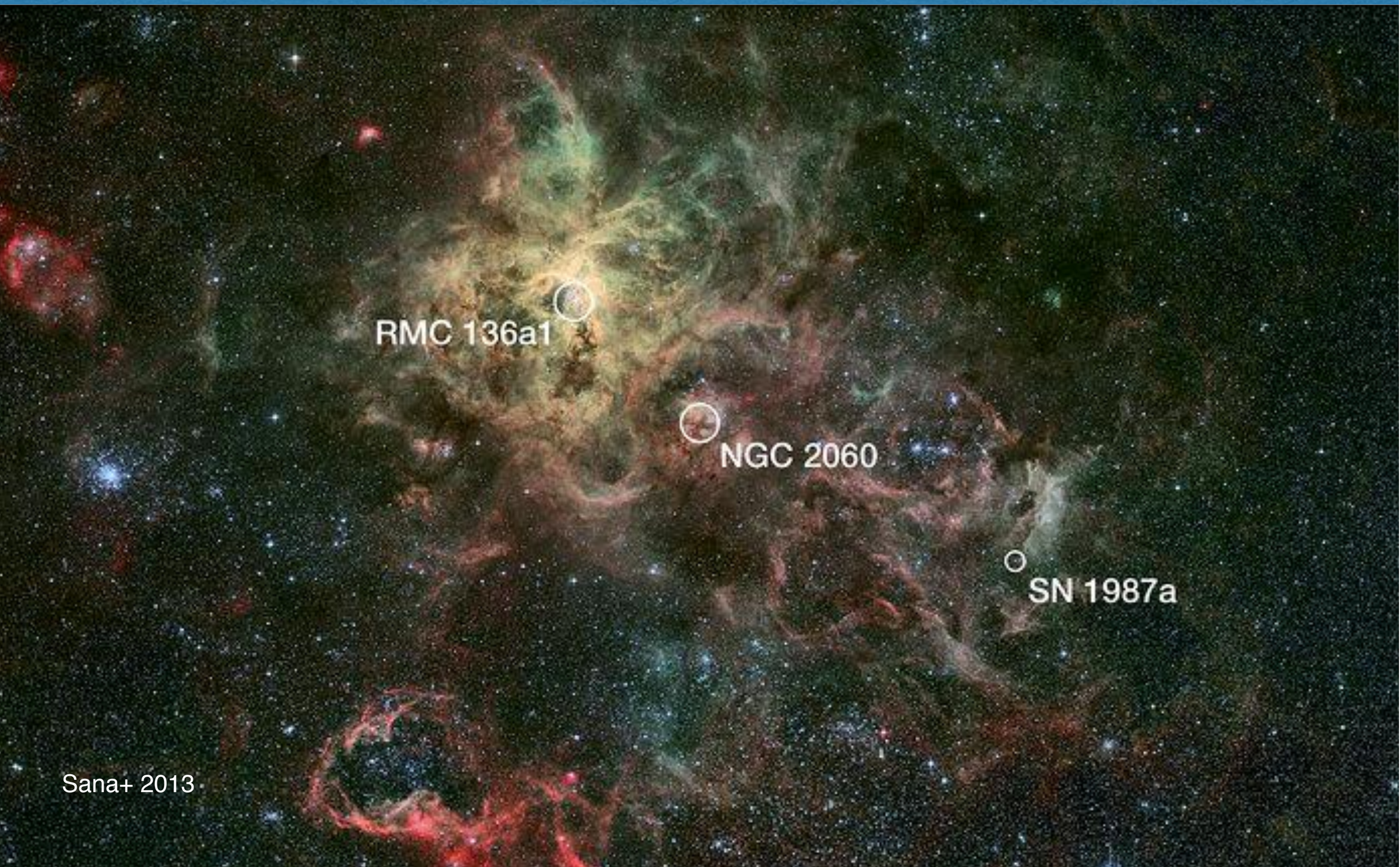
Sana+ 2012

Multiplicity determines the evolution of massive stars

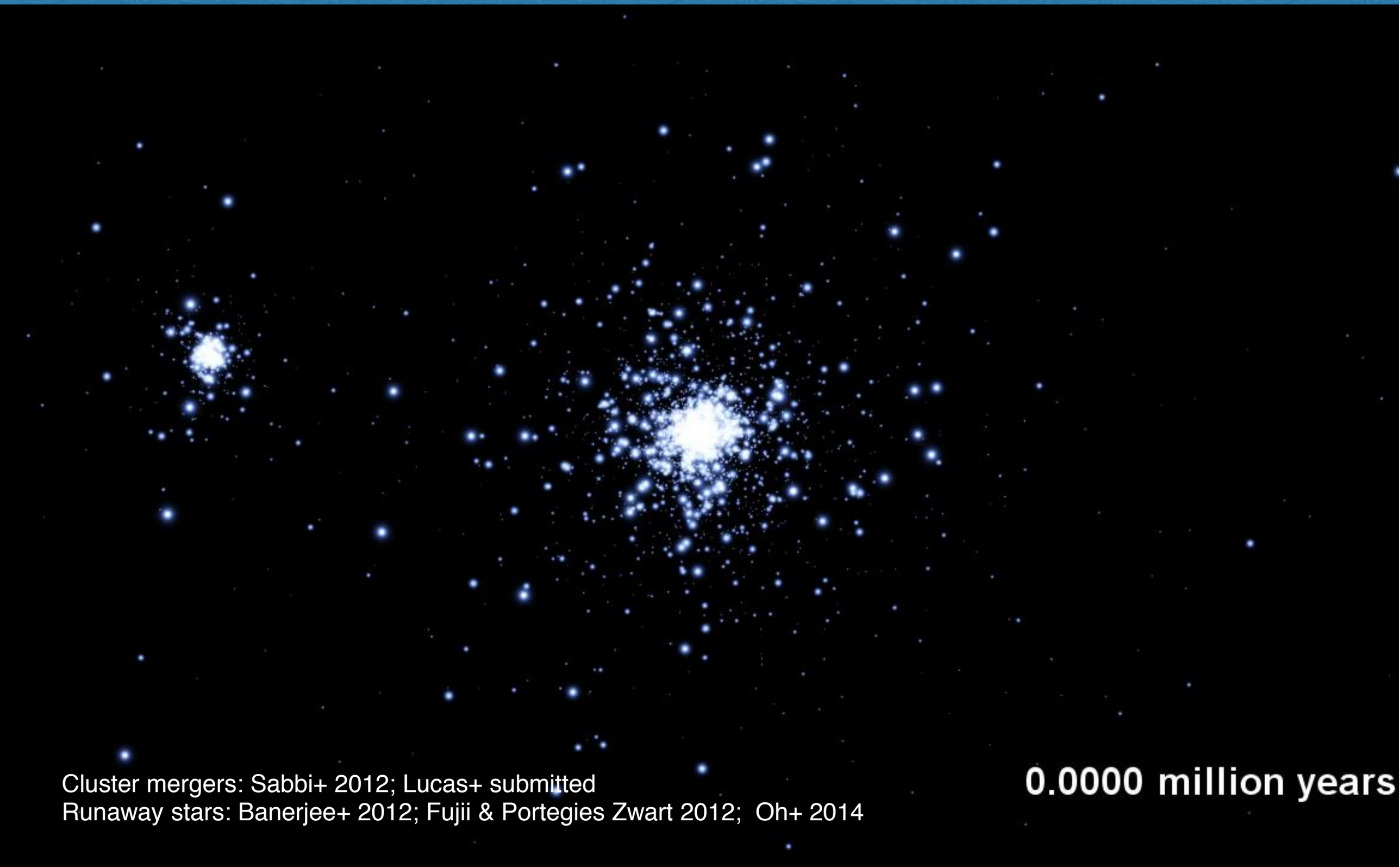


Sana+ 2012

Similar analyses in 30 Doradus: $f_{bin} = 0.50 \pm 0.05$

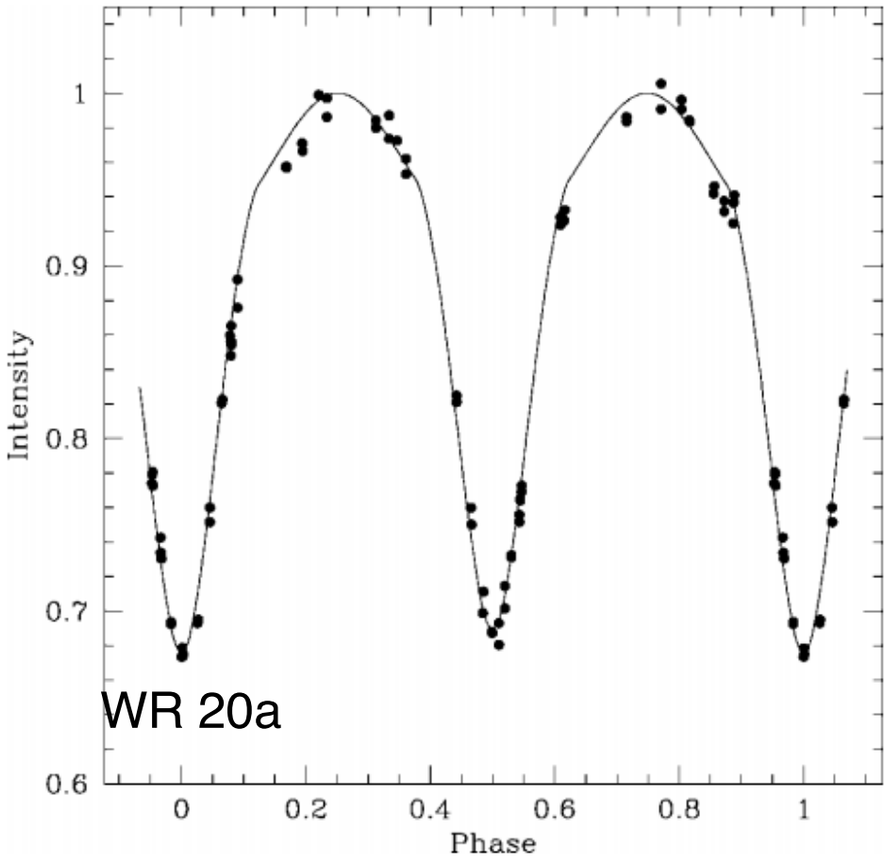


Dynamical processing of binaries?



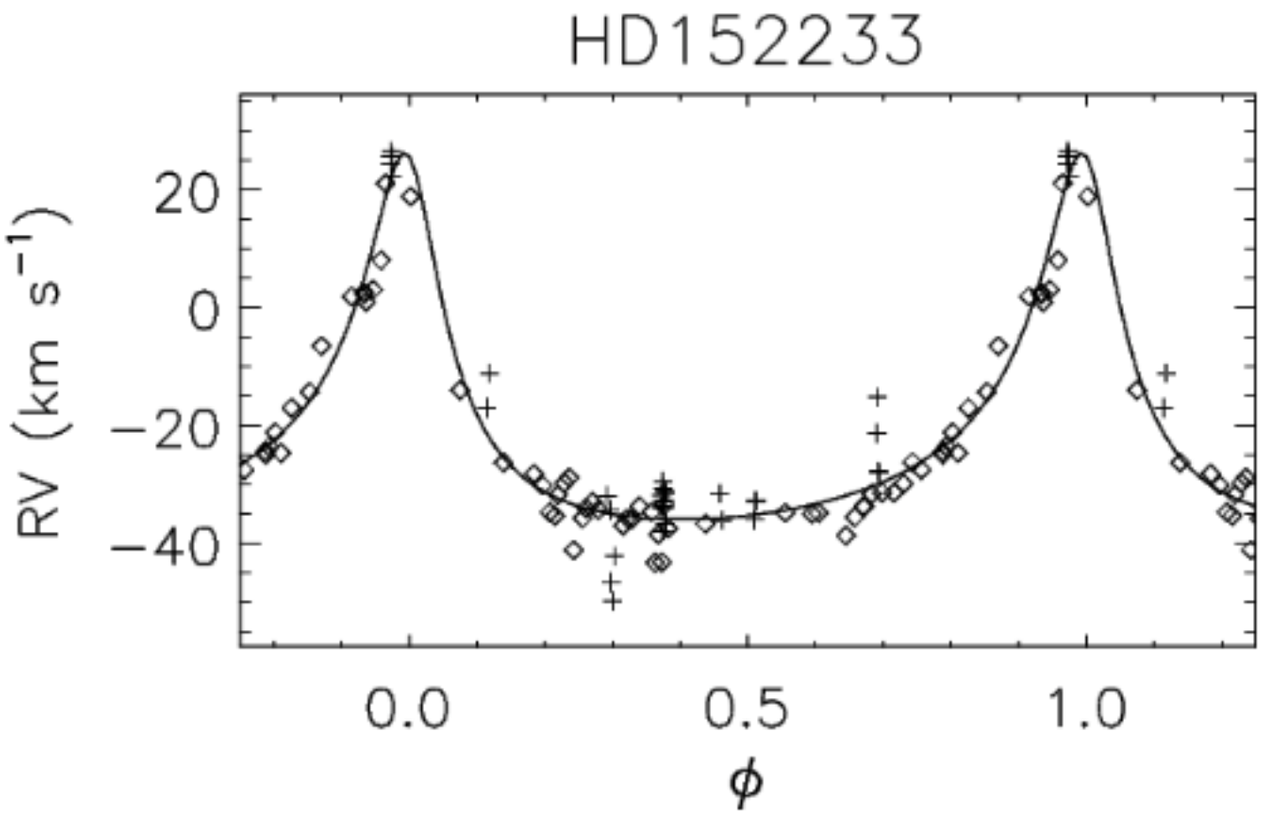
Cluster mergers: Sabbi+ 2012; Lucas+ submitted
Runaway stars: Banerjee+ 2012; Fujii & Portegies Zwart 2012; Oh+ 2014

Plato lightcurves: massive star multiplicity in field & clusters



WR 20a

Bonanos+ 2004



Sana+ 2010



& Plato