Plato and star clusters

Mark Gieles
The old ….

47 Tucanae (12 Gyr)
Plato 2.0 and globular clusters: the nearest = impossible

Asteroseismology

Messier 4 @2 kpc

Kanatas+ 1995
The complex stellar population of globular clusters

Multiple main sequences (in massive GCs)

Light element variations (in all GCs)

Products of hot-hydrogen burning

Piotto+ 2007

Carretta+ 2009
Hot-hydrogen burning

CNO
~15M K

NeNa
~40M K

MgAl
~70M K

 Arnould+ 1999

Review: Charbonnel 2016
Existing models

Polluters

- AGB stars
  - Ventura 2001

- Massive stars (10-100 M\(\odot\))
  - Prantzos & Charbonnel 2006

- Very/super massive stars
  - \(10^3-10^4\) M\(\odot\)
  - Denissenkov & Hartwick 2014

Enrichment scenario

- The “AGB scenario”
  - D’Ercole+ 2008; Maxwell+ 2014; Renzini+ 2015; D’Antona+ 2016

- Fast rotating massive stars (Decressin+ 2007)
- Interacting binaries (de Mink+ 2009)
- Early disc accretion (Bastian+ 2013)
- Interacting stars (Elmegreen 2017)

- TBD

see reviews by Bastian 2015; Renzini+ 2015; Charbonnel 2016
“Strange” (i.e. GC) stars in the bulge

\[ \sim 1\text{-}2\% \text{ of bulge stars} \]

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

Required ΔAge [Myr]

Niederhofer et al. YMC sample
Goudrooij et al. eMSTO sample
NGC 1856 - Milone et al.
NGC 1856 - Correnti et al.
Praesepe - Brandt & Huang

SYCLIST Model (Mv above hook)
SYCLIST Model (Mv at MSTO)
SYCLIST Model (minimum Mv)

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.
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

High fraction of Be stars

Line broadening

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

Bastian+ 2017

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

![Graph showing frequency vs. time for LIGO Hanford and LIGO Livingston](image-url)
The young ...
Multi-epoch survey of 6 young clusters: $f_{\text{bin}} = 0.69 \pm 0.09$
Multiplicity determines the evolution of massive stars

Sana+ 2012
Similar analyses in 30 Doradus: $f_{\text{bin}} = 0.50 \pm 0.05$
Dynamical processing of binaries?

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

0.0000 million years
Plato lightcurves: massive star multiplicity in field & clusters

Bonanos+ 2004

Sana+ 2010
& Plato