Not-so-simple stellar populations in nearby massive star clusters

Young and middle-aged

Richard de Grijs
Macquarie University, Sydney, Australia

Main collaborators:
Chengyuan Li (Macquarie University, Australia),
Licai Deng (NAOC, China),
Yujiao Yang, Xiaohan Wu and Hao Zhang (PKU, China)
Simple stellar populations?

**Single age**: sharp, narrow MSTO
**Single metallicity**: narrow CMD
**Mass range** given by the IMF
... but for **single stars** only!

\[ M_V = -2.5 \log L_V [L_\odot] + \text{constant} \]

at \( D = 10 \) pc (**absolute magnitude**)

\[ (V-I) = m_V - m_i = -2.5 \log L_V / L_i \]

Subscript “0”: corrected for the effects of extinction (dust)

**Colour–magnitude (Hertzsprung–Russell) diagram**
Mackey et al. (2008)

Villanova et al. (2007); Piotto et al. (2007)

Milone et al. (2008)

NGC 2808

NGC 1783

LMC

NGC 1851
(Martocchia et al. 2018, MNRAS)
Broadening of the main sequence (turn-off) could be due to:

1. differences in helium abundances;
2. binary populations;
3. a range in stellar ages and/or metallicities; or ...
4. a population of rapidly rotating stars
1. Determine global binary fraction
2. Constrain maximum plausible age spread
3. Explore the effects of rapid rotation

NGC 1831

NGC 1868

550 Myr

830 Myr

850 Myr

1.2 Gyr
$\omega = 0.55$ stellar rotation for intermediate stellar populations: NGC 1831
Fig. 15.— $\omega$ (fraction of the critical break-up rate) distribution of rotating stars, with double Gaussian peaks at 0.10 and 0.50, and standard deviations of 0.05 and 0.15, respectively.
Fig. 16.— Steps to generate our simulated NGC 1831 CMD. From left to right: (1) We generate stars that exactly match the parameters given by the adopted isochrone. (2) For stars more massive than $1.2 M_\odot$, we randomly assign rotation velocities, based on the $\omega$ distribution of Fig. 15. (3) We assign ‘binary status’ to 70% of the artificial stars and adjust their photometry based on the adopted binary properties. (4) We adopt the appropriate photometric uncertainties according to Eq. (1).
Fig. 19.— Pseudo-color distributions of (red) the simulated MS TO stars and (blue) the observed MS TO stars for (top) NGC 1831 and (bottom) NGC 1868.
NGC 1651: An unexpected discovery
Hertzsprung–Russell diagram

Individual stars

Stellar density

Bright

Subgiant branch

Main-sequence turn-off region

Main sequence

Faint

Effective stellar temperature (at the surface)

Bright

Old age (model)

Young age (model)

Model age difference: 450 million years


**Core SGB sample:**

\[ R \leq 15 \text{ arcsec} \]
Maximum plausible age range allowed by the SGB width: 80 Myr

NGC 411
- Most extended MSTO known
- Lowest escape velocity of an MSTO cluster

NGC 419
Rotational deceleration?

At intermediate ages, extended Main-Sequence Turn-Offs imply the presence of an age spread or a population of rapidly rotating MSTO stars.

- A simple stellar population including rapidly rotating stars seems the “best” match to intermediate-age clusters.
- The presence of an extended MSTO does not necessarily imply an age spread.
- Our most recent results suggest that a major reassessment of the multiple stellar population paradigm is sorely needed!