Building part of the Galactic halo from globular clusters

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Collaborators

<table>
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<tr>
<th>Geneva</th>
<th>Bonn</th>
<th>Montpellier</th>
<th>Paris</th>
<th>Bruxelles</th>
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<tbody>
<tr>
<td>C. Charbonnel</td>
<td>H. Baumgardt</td>
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Chemical properties of GCs

Heavy elements

Low scatter and same trends as field stars

Heavy metals come from pre-enrichment of the galactic halo (i.e., are not produced in situ) 

Harris & Pudritz (1994)
Chemical properties of GCs

Heavy elements

Low scatter and same trends as field stars

⇒ Heavy metals come from pre-enrichment of the galactic halo (i.e., are not produced in situ) (Harris & Pudritz 1994)

Light elements: Li to Al

- C-N, O-Na, Mg-Al and Li-Na anticorrelations
- C+N+O nearly constant
- in TO and giants stars

(see eg. Carretta et al. 2010)

He content

- Multiple main sequences (NGC 2808, ω Cen...)
- Blue HB

⇒ need He-increase

(see eg. Piotto et al. 2009)

⇒ Complex history for GCs evolution
O-Na anticorrelation

Carretta et al. 2009
Overview: fast rotating massive stars

Early main-sequence

Decressin, Meynet, Charbonnel, Prantzos & Ekstrom 2007
Overview: fast rotating massive stars
Main-sequence to early He-burning

Decressin, Meynet, Charbonnel, Prantzos & Ekstrom 2007
Overview: fast rotating massive stars

End He-burning

Decressin, Meynet, Charbonnel, Prantzos & Ekstrom 2007
Evolution of globular clusters

Scenario I (Cluster evolution at constant mass)
- Formation of globular clusters
- Slow winds of massive stars form new stars
- Today

Scenario II (Mass segregation)
- Massive stars (1st gene)
- Low-mass stars (1st gene)
- Low-mass stars (2nd gene)

Decressin, Charbonnel & Meynet (2007)
Evolution of globular clusters

Scenario I
(Cluster evolution at constant mass)

Standard IMF
($x = 1.35$)

Formation of globular clusters

Slow winds of massive stars form new stars

Today

Scenario II
(Mass segregation)

Massive stars (1st gene)
Low-mass stars (1st gene)

Low-mass stars (2nd gene)

Decressin, Charbonnel & Meynet (2007)
Evolution of globular clusters

Scenario I
(Cluster evolution at constant mass)

Flat IMF
($x = 0.55$)

Standard IMF
($x = 1.35$)

Formation of globular clusters

Slow winds of massive stars form new stars

Today

Scenario II
(Mass segregation)

Loss of 95% of 1st gene

Massive stars (1st gene)

Low-mass stars (1st gene)

Low-mass stars (2nd gene)

Decressin, Charbonnel & Meynet (2007)
Effect of gas expulsion

N-body models
Baumgardt & Kroupa (2007)

- 20 000 stars
- gas = additional potential + time dependent

Physical inputs

- SFE ($\epsilon$) amount of gas
- $r_h/r_t$ concentrated cluster
- $\tau_{gas}/t_{cr}$ timescale of GE
Decressin, Baumgardt, Kroupa & Charbonnel (2010)

Efficient way to expel 1st gene. stars
Total mass of GC system

About 2.5% of halo stars are 2G stars (Martell et al. 2010, 2011)

Initial/Actual mass

For a given GC

\[ M_{\text{ini}} = 10 \times M_{\text{today}} \]

Schaerer & Charbonnel (2011)

Loss of 2G. stars: 0, 43, 65%
Total mass of GC system

About 2.5% of halo stars are 2G stars (Martell et al. 2010, 2011)

For a given GC
\[ M_{\text{ini}} = 10 - 30 \times M_{\text{today}} \]

For whole population of GC
IMFGC \( \propto \) lognormal
\[ \rightarrow 40\text{-}50\% \text{ of Halo} = \text{GC stars} \]
IMFGC \( \propto \) slope
\[ \rightarrow \text{GC stars } \gg \text{ Halo} \]

Schaerer & Charbonnel (2011)
Loss of 2G. stars: 0, 43, 65%
Conclusions

Chemical properties of GCs
- Complex history
- First generation similar to fields stars
- Second generation recycles slow wind of massive stars

Dynamical consequences
- Strong ejection of stars due to gas expulsion
- Initial mass of GC much higher

Stars loss from GC: important part of the halo