Mass segregation

A new role of binary, IMBH and stellar mass black hole

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1. Mass segregation

2. Measurement method and result
   ◦ isochrone fit
   ◦ completeness function
   ◦ measurement result

3. Mass segregation and energy sources
   ◦ binary stars
   ◦ intermediate mass black hole -- IMBH
   ◦ stellar mass black hole population
Mass segregation
what is mass segregation

Due to two-body relaxation effects in globular clusters (GCs), high mass stars are inclined to sink towards core regions, which causes the segregation of stars mass.

Typical relaxation time scales: 1~2 Gyr

Average GCs age: 12 Gyr

Most of the GCs should be mass segregated
Existence of low mass segregation GCs

Previous studies find several GCs lack of mass segregation: NGC 6101, ω Centauri, NGC 2419, NGC 5466, Ter 8 and Pal 2...

Flat radial profile of main sequence stars (MS) mean mass reveals the low mass segregation of NGC 6101, while NGC 6584 is a mass segregated sample.
Why low mass segregation

1. Not relaxed yet, Initial relaxation time scales are much larger than current, possible mass loss influences.

2. Dynamical collisions between main sequence stars and heavy objects can quench mass segregation. Those heavy objects are called energy sources (Gill et al. 2008 ; H. Baumgardt et al.2017)

1. Primordial binaries
2. IMBH – intermediate mass black hole
3. Stellar mass black hole population

In Beccari et al.2010 simulation, GCs with high binary fractions and IMBH are inclined to be less mass segregated.
Way to study mass segregation

- stellar mass function slope: Sollima & Baumgardt (2017)
- radial distribution of BSS: Ferraro et al. (2018)
- king models radii fitting: Goldsbury et al. 2013
- MS stars mean mass radial profile

Mean mass radial profile: Showing its ability to display energy sources influence on mass segregation but only applied to few GCs (NGC 6205, NGC 2298)

A comprehensive study is needed
Aim of this study

1. Measure GCs mass segregation through MS stars mean mass radial profile

2. Select low mass segregation GCs to find possible IMBH holders

3. Analyze binaries and stellar mass black hole population effects on mass segregation, construct a better understanding of dynamical evolution
Measurement method and result
Measurement method

Study object: \( \Delta m(0.7r_{hm}) \rightarrow (\langle m \rangle (r_{\text{core}}) - \langle m \rangle (0.7r_{hm})) \): Larger \( \Delta m(0.7r_{hm}) \) means stronger mass segregation

Observation data: Hubble ACS globular cluster survey

1. Fit isochrone model, select main sequence stars, transfer magnitude to mass
2. Calculate globular clusters observation completeness function
3. Apply completeness correction and calculate radial profile

NGC 6101 is a low mass segregation GC, which is consistent with Dalessandro et al. (2015)
1. Mass segregation of 33 GCs are measured through main sequence mean mass radial profile

2. Anticorrelation exists between core to half mass radius ratio and mass segregation—effects of energy sources (binaries, IMBH, et al)
Mass segregation and energy sources
This work selects 7 low mass segregation GCs

<table>
<thead>
<tr>
<th>name</th>
<th>$f_c$</th>
<th>$\Delta &lt; m &gt;$</th>
<th>$T_{rh}$ (Gyr)</th>
<th>$r_t/r_{hl}$</th>
<th>$L_z$ (km/s)</th>
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Possible IMBH holders selected in previous study:
*NGC 288, NGC 5466 Luźgendorf et al. (2013)
*NGC 4833 Sedda et al. (2019)
Low mass segregation GCs: IMBH

NGC 288: tidal shocks / extra-tidal structure / tidal tails?
NGC 5466: cold tidal stream ~45 degree
NGC 6362: loss 80% original mass possibly

High mass loss ratio $\rightarrow$ Much larger initial $T_{rh}$

Strong candidate standards:
1. Completely dynamical evolved
2. Binary fraction smaller than 5%
3. Low mass segregation, with $\Delta m(r_{hm}) < 0.07$

No strong candidates holding IMBH in this sample considering GCs core binary fractions and $T_{rh}$

NGC 288 extended tidal structures $\rightarrow$ NGC 5466 stellar stream
an anticorrelation between mass segregation and core binary fractions ($f_c$) when $f_c$ is below 0.1, then the quenching effect gets saturated at higher $f_c$.

Our results confirm that the binaries dynamical effects tend to saturate for $f_c \approx 0.1$ (Vesperini & Chernoff (1994); Heggie et al. (2006)).
Black holes can receive kicks during its formation, strong mass segregation may imply a small retention fraction of BHs. (H. Baumgardt et al. 2017)

Explaining low mass segregation GC NGC 6101 by varying retention fraction of BHs (Peuten et al. 2016)

1. There are GCs potentially having a stellar mass black hole population (Askar et al. 2018).
2. Those GCs are obviously located at the low mass segregation region with an average $\Delta m(0.7r_{hm})$ as 0.047 solar mass.

It is hard to distinguish stellar mass black hole and IMBH quenching effects.
Conclusion

1. Anticorrelation exists between mass segregation and core to half mass radius ratio, which reveals energy sources influence.

2. Binaries have a quench impact on mass segregation. The influence tends to saturate around 0.1.

3. No strong candidates of IMBH holders exist in data sample.

4. GCs potentially having stellar mass black hole population are less mass segregated.