How Black Holes Shape Globular Clusters

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Motivation

Globular clusters (GCs) are of fundamental importance in theoretical astrophysics. They provide significant information about both star formation and galaxy formation. In the past few years, studies have suggested that GCs can retain a large number of stellar-mass black holes (BHs) at late times (~12 Gyr). An increasing number of BH X-ray binary candidates have been observed within GCs. Most recently, a stellar-mass BH candidate was found with a main-sequence star (MS) companion using radial-velocity observations in the Milky Way (MW) GC NGC 3201.

Our group has developed Cluster Monte Carlo (CMC) code for modeling star clusters. CMC contains all of the relevant physics, e.g. binary evolution, few-body scattering. The results from CMC have been compared to the state-of-the-art N-body simulations and agree excellently.

- *Can we produce GC models using CMC that are similar to the observed NGC 3201 with similar observed BH-MS systems?*
- *How do BHs shape GCs?*
- *How do BHs influence other compact objects like neutron star X-ray binaries (NS-XRB)?*

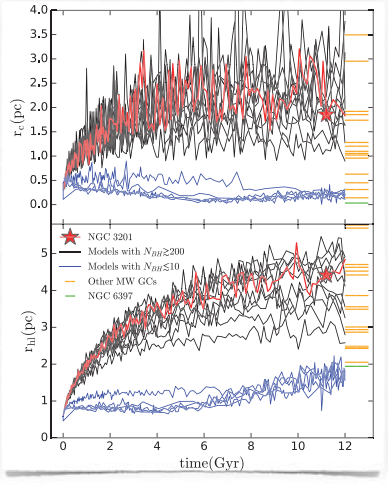
BHs Shape GCs

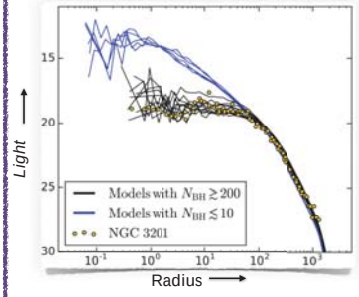
BHs can alter the evolution of GCs dramatically. Through mass segregation, BHs dominate the cluster centers.

With more BHs, the clusters have larger observed core radii; while clusters with only a few BHs are most likely core-collapse clusters with small cores.

The observed core radius of NGC 3201 suggests that it is a cluster with a large number of BHs . We predict that it contains more than 200 BHs.

The results from our models also agree well with other MW GCs. Among them is NGC 6397, which is observed to be a core-collapsed cluster. It falls in the range of models with less than 10 BHs.





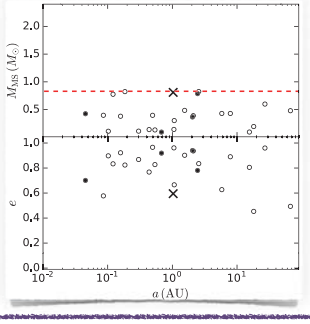
The correlation between BH populations and the observational features of GCs is also shown in the surface brightness of clusters. Clusters with a small number of BHs have brightness profiles with a 'cusp'-like structure; while clusters with many BHs do not.

BH dominant cluster centers are less luminous than star dominant cluster centers.

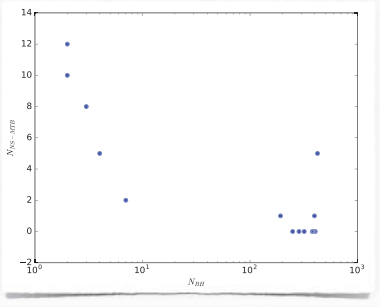
BH-MS Binary

The observed BH candidate in NGC 3201 has a MS companion. These kind of binary systems are produced naturally in our models.

The models also suggest that BH-blue straggler star (BS) binaries are unique to core-collapse clusters. In clusters with a large number of BHs, strong and frequent interactions between BSs and BHs can easily push outward and even eject massive BSs. In core-collapse clusters, however, BSs can be closer to the high density central region and form binaries with BHs.

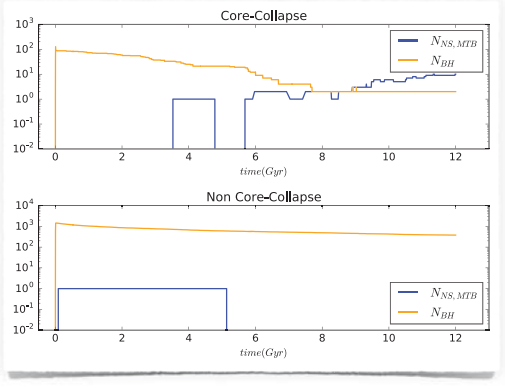


BHs Influence NS-XRB



The populations of BH are anti-correlated to the populations of mass transferring NS, which are potential NS-XRBs.

A large number of BHs means that most of the NSs are scattered out of the cluster central regions to where star densities are low. Low density leads to low number of encounters with other stars, and therefore low chances of forming binary stars.



Strong interactions between BHs and NS binaries may also break the binary systems and leave behind only single NSs.

In non core-collapse clusters like NGC 3201, there are only a few potential NS-XRBs; however, in core-collapse clusters, there can be more than 10 mass transferring NSs.

Conclusion

1. BHs have significant influence on the evolution of the host globular clusters, and thus shape their observational features.
2. We predict that NGC 3201 contains more than 200 stellar-mass BHs.
3. Our models show that BH-BS binaries are unique to core-collapse clusters.
4. The populations of retained BH are anti-correlated with other compare object populations like NS-XRB.

Reference

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