

# *Evaluating the Merger Rate of Binary Black Holes Using the Milky Way Globular Clusters*



*Midwest Relativity Meeting 2020 Ilias Cholis, 10/24/2020* Kritos & Cholis, PRD 102, 8, 083016 (2020) (arXiv:2007.02968)

Very dense stellar environments where multiple dynamical interactions take place. Most stars are in binaries.

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Another channel to produce merging BH-BH binaries comes from direct captures.

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*There are about 150 Globular Clusters in the Milky Way. Significant enough sample for us to evaluate the BH-BH merger rates from globular clusters as a population.* 

*Most of which have well measured properties:*



Assume for simplicity that all BHs are 10  $M_{\odot}$  $B_{\rm eff}$  is the mass fraction of the mass fraction of the mass fraction of the GC that  $\sigma$ 

We can estimate the mass fraction of the GC that ends up in BHs, We can est ergy equipartition between the BH population and their enas up in <del>Bri</del>s,



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We can esti  $\bm{m}$  at a than mass fraction of than  $\bm{G} \bm{\bm{\cap}}$  that ands un in  $\bm{\mathsf{R}} \bm{\mathsf{H}} \bm{\mathsf{c}}$  $\sigma$  that errus up in Dr is,



From that we can estimate the maximum number of BHs that were born at  $n = 1$ any point in a GC, to that we can estimate the maximum number of RHs<sup>h</sup>  $\frac{1}{2}$ nal we can esumale were born at *MGC* 10 *M* imber of BHs that were born at

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N_{BH}^{\rm max} = f_{BH} \frac{M_{GC}}{10\,M_{\odot}}
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and increasing the natal mone that are reepond. escaping the clusters, the maximum number of retained pris,  $\frac{1}{2}$  for roughly 00% of the RHs central the kinetic energy (KE) of its neighboring objects its neighboring objects its neighboring objects its<br>External objects in the contract service of its neighboring objects in the contract of the contract of the con and including the natal kicks that are responsible for roughly 90% of the BHs escaping the clusters, the maximum number of retained BHs, and including the natal kicks that are responsible for roughly 90% of the BHs  $\overline{000}$   $\overline{01}$  $\delta$ ,

 $\Delta \tau$ ret-max  $\rho$  is  $\Delta \tau$ max  $N_{BH}^{\text{ret-max}} = f_{\text{ret}} \times N_{BH}^{\text{max}}$ 

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where the GW emission will dominate its evolution (see Sesana et al ApJ<br>2006).  $\int$ *b*<sub>c</sub> *.* (20) Hardéning rate, it takes ~15 encounters for the BH-BH to reach the point Z *<sup>r</sup>*max Hardening rate, it takes  $\sim$ 15 encounters for the BH-BH to reach the point where the GW emission will dominate its evolution (see Sesana et al ApJ 2006).

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#### *Example: Environment of 47 Tuc (NGC 104)*



#### *Connecting to the observed properties of Milky Way Globular Clusters*



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**About half of the BH-BH binaries (ecc. > 0.7) inside 47 Tuc have already merged** 





- Once averaging over the Milky Way sample third-body soft interactions give an averaged rate of  $\rm\,2-4\times10^{-10}yr^{-1}\,$  per cluster cluster.
- Accounting for direct capture events adds per cluster.  $0.3 - 5 \times 10^{-11} \mathrm{yr}^{-1}$
- The BBH mergers inside globular clusters can be responsible for  $\sim$ 100 mergers per year up to redshift of  $z=1$ .
- We have made a connection between the observed properties of clusters and the expected BH-BH merger events.
- Further observations of cluster properties on their total mass, density and velocity profiles and a better modeling of their cosmological distribution will allow us to more accurately evaluate those environments' contribution to the coalescence events observable from GW detectors.