

Neutron-Star Retention in Globular Clusters

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Observed Neutron Stars

X-ray sources:

- Luminous — A dozen luminous X-ray sources.
- Low-luminosity — A ubiquitous class of X-ray sources. Many may be NSs (MSPs, quiescent LMXBs).

Radio pulsars:

- Now ~ 10 clusters with ≥ 2 pulsars detected.
- Difficult to detect, so many more than we see.

Theory and observation suggest that ~ 1000 neutron stars were retained in certain massive clusters, giving retention fractions of $\gtrsim 10\%$.

The Retention Problem

- Inferred NS kick speeds are $\gtrsim 100\text{--}200 \text{ km s}^{-1}$, distributed according to a Maxwellian:

$$p(v_k) = \sqrt{\frac{2}{\pi}} \frac{v_k^2}{\sigma_k^3} \exp(-v_k^2/2\sigma_k^2) .$$

- Globular cluster escape speeds are $\lesssim 50 \text{ km s}^{-1}$.
- These give retention fractions of $\lesssim 1\%$ for neutron stars with *single progenitors*.

Binary Neutron Star Retention

- A binary companion acts as an anchor for the neutron star.
- Drukier (1995) and Davies & Hansen (1998) suggested that binaries may alleviate the retention problem.
- A systematic population synthesis study is needed, treating the retention problem as one of *stellar evolution* rather than *stellar dynamics*.

Massive Binary Population Synthesis

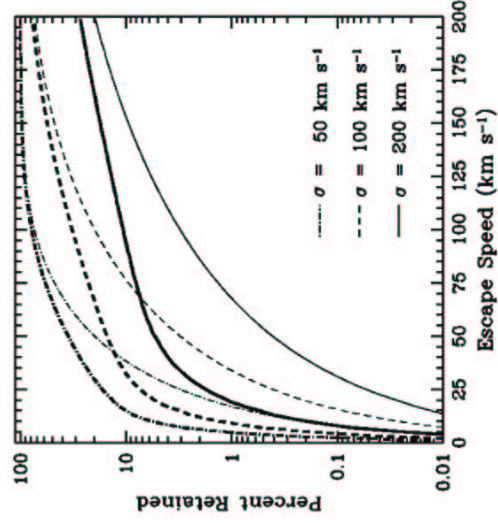
- (1) Choose the parameters of the primordial binary.
 - (i) primary mass: e.g., $p(M_1) \propto M_1^{-2.5}$
 - (ii) secondary mass: e.g., $p(M_2/M_1) = \text{constant}$
 - (iii) semimajor axis: e.g., $p(a) \propto a^{-1}$
- (2) Decide if mass transfer is stable or dynamically unstable, and evolve the binary parameters. Only the core of the primary remains.
 - (i) stable: a changes by, e.g., $\pm 50\%$, and the secondary accretes a substantial amount of material
 - (ii) dynamically unstable: a decreases by $\sim 99\%$, and the secondary accretes nothing
- (3) Compute the changes in orbital parameters that result from supernova mass loss and the NS kick.

Stable Mass Transfer

Following stable mass transfer . . .

- companion masses of $\gtrsim 10 M_\odot$,
 - orbital speeds of $\sim 100\text{--}200 \text{ km s}^{-1}$,
- and so . . .
- fraction of mass lost in the supernova is small ($\lesssim 20\%$),
 - systemic speeds of bound post-SN binaries are $\lesssim 50 \text{ km s}^{-1}$.

Retention Fractions



For $\sigma_k = 200 \text{ km s}^{-1}$...

- ~5% at 50 km s⁻¹
- ~8% at 100 km s⁻¹

For $\sigma_k = 100 \text{ km s}^{-1}$...

- ~15% at 50 km s⁻¹
- ~30% at 100 km s⁻¹

Probably optimistic.

Thin curves — Singles

Thick curves — Binaries

Possible Resolutions

Stellar evolution:

- Typical kick speeds $< 100 \text{ km s}^{-1}$.
- Low-kick NSs ($\lesssim 50 \text{ km s}^{-1}$) born in binaries.
- *But the outcome of TZOs is unclear.*

Cluster structure:

- Very concentrated 10^6 - M_\odot globular clusters, with $v_{\text{esc}} \sim 100 \text{ km s}^{-1}$ (*maybe unlikely?*).
- Very massive globular clusters ($M_{\text{gc}} \sim 10^7 M_\odot$).