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 significant fraction may be NSs (MSPs, qLMXBs).

Radio pulsars:

- Now $\sim$10 clusters with $\geq$2 pulsars detected.
- Difficult to detect, so many more than we see.

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

Other Channels

Wide, noninteracting binaries:

- NS + main-sequence star
- NS + white dwarf
- NS + NS

Most double NS binaries are *completely undetectable*.

The Retention Problem

- Inferred NS kick speeds are $\gtrsim$100–200 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 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 seconday 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

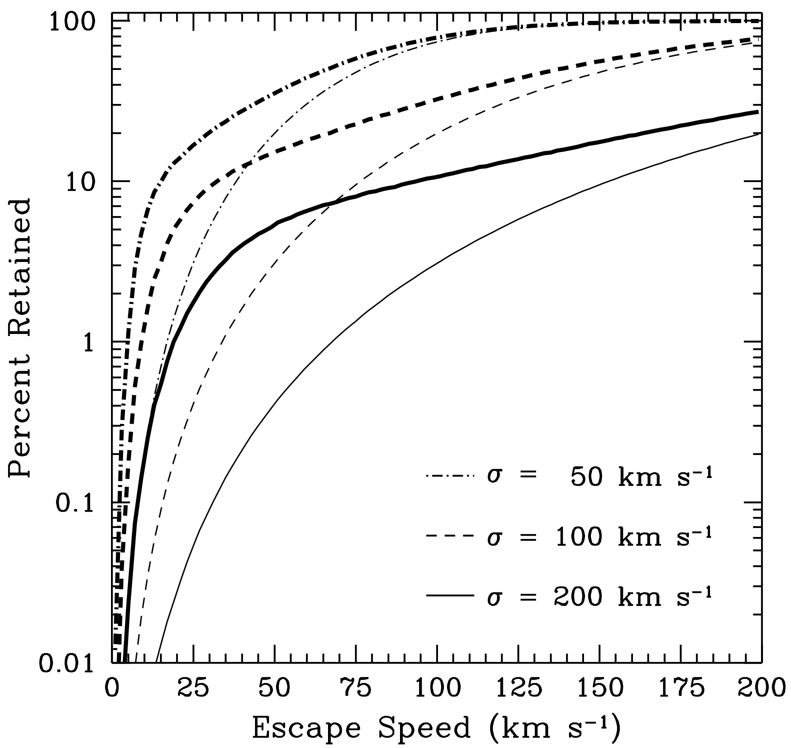
Following stable mass transfer . . .

- companion masses of $\gtrsim$10 $M_\odot$,
- orbital speeds of $\sim$100–200 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 km s^{-1}.

Retention Fractions



Thin curves — Singles

Thick curves — Binaries

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

- $\sim$5% at 50 km s^{-1}
- $\sim$8% at 100 km s^{-1}

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

- $\sim$15% at 50 km s^{-1}
- $\sim$30% at 100 km s^{-1}

Probably optimistic.

Possible Resolutions

Stellar evolution:

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

Cluster structure:

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