

Intermediate-Mass Black Holes and Gravitational Radiation

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IMBH in stellar clusters.

Rates and scenarios for interactions.

Amplitudes and eccentricities.

Information from 0.1–10 Hz.

Summary and future work.

Intermediate-Mass Black Holes

Hypothetical population with $M \sim 10^{2-4} M_{\odot}$.

Too large for stellar evolution.

Evidence is strong, but not conclusive.

Kinematic evidence in globulars.

Evidence for $\sim 10^{3-4} M_{\odot}$ BH in M15, G1?

BH may not be needed.

Analyses of other clusters ongoing.

Bright X-ray sources in several galaxies.

Bright, variable, off-center.

If quasi-isotropic, $M > 10^{2-3} M_{\odot}$.

If beamed, could have $M \sim 10 M_{\odot}$.

Several strong cases for $M > 100 M_{\odot}$.

Many candidates in dense stellar clusters.

Types of Interactions

Mass segregation causes massive objects to sink to the center of a dense stellar cluster.

Binaries, BH, neutron stars.

Three-body interactions tend to tighten hard binaries.

Gradual hardening can cause merger.

Inspiral time: $\sim 10^{6-7}$ yr.

Initial $e \sim 0.9 - 0.99$ (Gultekin).

Direct two-body capture by gravitational radiation.

Plunge orbits.

Pericenter $\sim \text{few} \times 10^2 M$.

Inspiral time: $\lesssim 10^5$ yr.

Initial eccentricity: $e \sim 1 - 10^{-5}$.

Rates of Interactions

Event rates depend on number density of IMBH, types of interactions.

Average number density of globulars:
 $\sim 2 \text{ Mpc}^{-3}$.

Energy release, merger mass affect LIGO-II detection rate.

$E/M = 0.1$, up to $\sim 10^3 \text{ yr}^{-1}$.

More realistic 0.01-0.02, tens per year.

What about at other frequencies? Assume:

10% of globulars have $1000 M_{\odot}$ BH.

Average 10^8 yr between mergers with $10 M_{\odot}$.

Observe for one year.

Compute h, e for three-body, two-body scenarios.

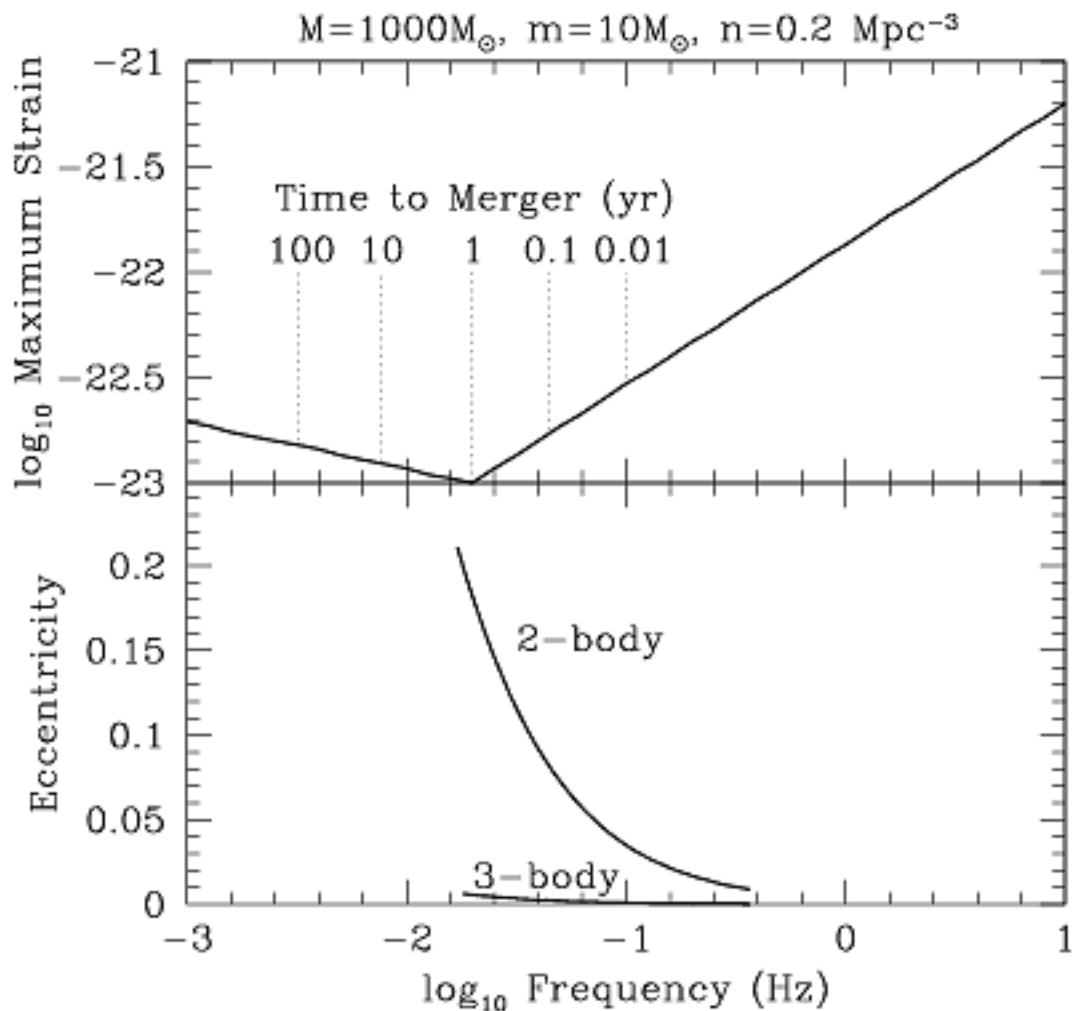


Fig. 1.— Typical strains and eccentricities versus frequency, for two-body and three-body scenarios in globular clusters. We consider a $10^3 M_{\odot}$ black hole in a binary with a $10 M_{\odot}$ black hole, and that there are on average 0.2 globular clusters per Mpc^3 with such a black hole in the center. In a year's observation, binaries less than a year to merger will be seen at their event rate, implying that typically the closest one will be ~ 500 Mpc away. In this realm, higher frequencies lead to larger observed strains. In the same 500 Mpc radius volume there are numerous binaries with longer times to merger than 1 yr, with the number increasing as the time to merger increases. Therefore, for a given $\tau_{\text{merge}} > 1$ yr, the typical distance to the closest such binary decreases as τ_{merge} increases, with the result that the strain observed from the closest such binary increases with increasing τ_{merge} and decreasing frequency.

Information in the 0.1-10 Hz Range

Inspiral, merger, ringdown for $1000 M_{\odot}$ BH.

Pericenter precession

For 2-body inspiral, $e \gtrsim 0.05$ at 0.1 Hz.

Above 1 Hz, essentially circular.

Lense-Thirring precession.

Orbits will be at random angles.

$a/M \sim 0.1$ expected.

Orbital decay.

If EM counterpart (e.g., Virgo Cluster), get distance or do self-consistency check.

Summary and Future Work

Active field, but lots to do!

Observational: masses, number density.

How common are IMBH?

What is their mass distribution?

In detail, what are their environments?

Theoretical: spins, eccentricities.

What are most common encounters?

What is distribution of e , a/M ?

In general, speculative but promising sources.