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Chapter 1

Introduction and Historical Overview

Chapter 2

Observations of Galactic Nuclei and Supermassive Black Holes

- 2.1 Structure of galaxies and galactic nuclei
- 2.2 Techniques for weighing black holes
- 2.3 Supermassive black holes in the Local Group
- 2.4 Phenomenology
- 2.5 Evidence for intermediate-mass black holes
- 2.6 Evidence for binary and multiple supermassive black holes
- 2.7 Gravitational waves

The amplitude, h , of a gravitational wave is a dimensionless quantity given by

$$h \approx \frac{G}{c^4} \frac{\ddot{Q}}{D} \approx \frac{GM_Q}{c^2 D} \frac{v^2}{c^2}, \quad (\text{Merritt 2.55})$$

where v is the internal velocity of the source, M_Q is the portion of the source's mass (in units of mass, not just 0–1) participating in the quadrupolar motions, and D is the distance to the source.

To understand the detector size needed to observe a gravitational wave, consider the ideal case, where the entire mass is participating in quadrupolar motions ($M_Q = M_{12}$), and the binary is located at a distance D from the observer and a from each other. Then we have $v^2 \approx GM_{12}/a$, and from (Merritt 2.55) we have

$$\begin{aligned}
 h &\approx \frac{GM_{12}}{c^2 D} \frac{GM_{12}}{ac^2} \\
 &\approx \frac{G^2}{c^4} M_{12}^2 a^{-1} D^{-1} \\
 &\approx 2 \times 10^{-16} \left(\frac{M_{12}}{10^{-8} M_\odot} \right)^2 \left(\frac{a}{\text{mpc}} \right)^{-1} \left(\frac{D}{100 \text{Mpc}} \right)^{-1} \quad (\text{Merritt 2.58})
 \end{aligned}$$