ASTR 2030 Black Holes Spring 2006. Project 5. Fri Dec 1.

Scribe's name:

Names of other members of the group:

Compact Binary

The following story is based on an original concept by Jonathan Spears in this class in Fall 2002.

In 2013, the Laser Interferometer Gravitational Wave Observatory (LIGO; `http://www.ligo.caltech.edu/`) completes its planned upgrade (`http://www.ligo.caltech.edu/advLIGO/`). Advanced LIGO is capable of detecting the merger of two stellar-sized black holes in a binary system out to almost cosmological distances. Optimistic members of the LIGO team had predicted that such events could occur as often as once a day; more conversative members expected mergers only once a year. Sadly, the first year data prove disappointing: no black hole mergers are detected.

In a last ditch effort, our hero (who bears a striking resemblance to Jodi Foster) pushes the data analysis well outside the instrument's nominal frequency range of 10–1000 Hz, and is rewarded with the detection of a sharp and surprisingly strong signal at 2 Hz, implying a compact binary system orbiting at 1 Hz, one cycle per second.

The one year of data show that the binary system is moving at a detectable rate across the sky, indicating that it must be quite close by, maybe in the distant outer reaches of the solar system! Woah.

Knowing only the period, one second, our hero cannot determine the mass of the compact binary, but she can make graphs of various useful quantities as a function of the possible mass M of the binary.

1. The objects in a compact binary system will spiral together as the binary emits gravitational waves. If the orbital period is 1 second, then the binary will merge on a timescale indicated on the attached graph. Can you use this information (on the merging timescale) to determine a probable upper limit to the mass of the binary?

2. Could the objects in the compact binary be planets (for example, the Earth has a radius of about 10^4 km)? White dwarfs (radius also about 10^4 km)? Neutron stars (radius about 10 km)? Black Holes?

3. Sketch how this compact binary might be used to gravitationally slingshot a spacecraft. To roughly what velocity could the spacecraft be accelerated? [Hint: In a gravitational slingshot, a spacecraft can be accelerated by a velocity comparable to the relative velocity between the spacecraft and the slingshotting object. If you are worried about the survivability of astronauts, then you should know that the tidal force turns out to be one gee per meter in an orbit where the orbital period is 1 second.]

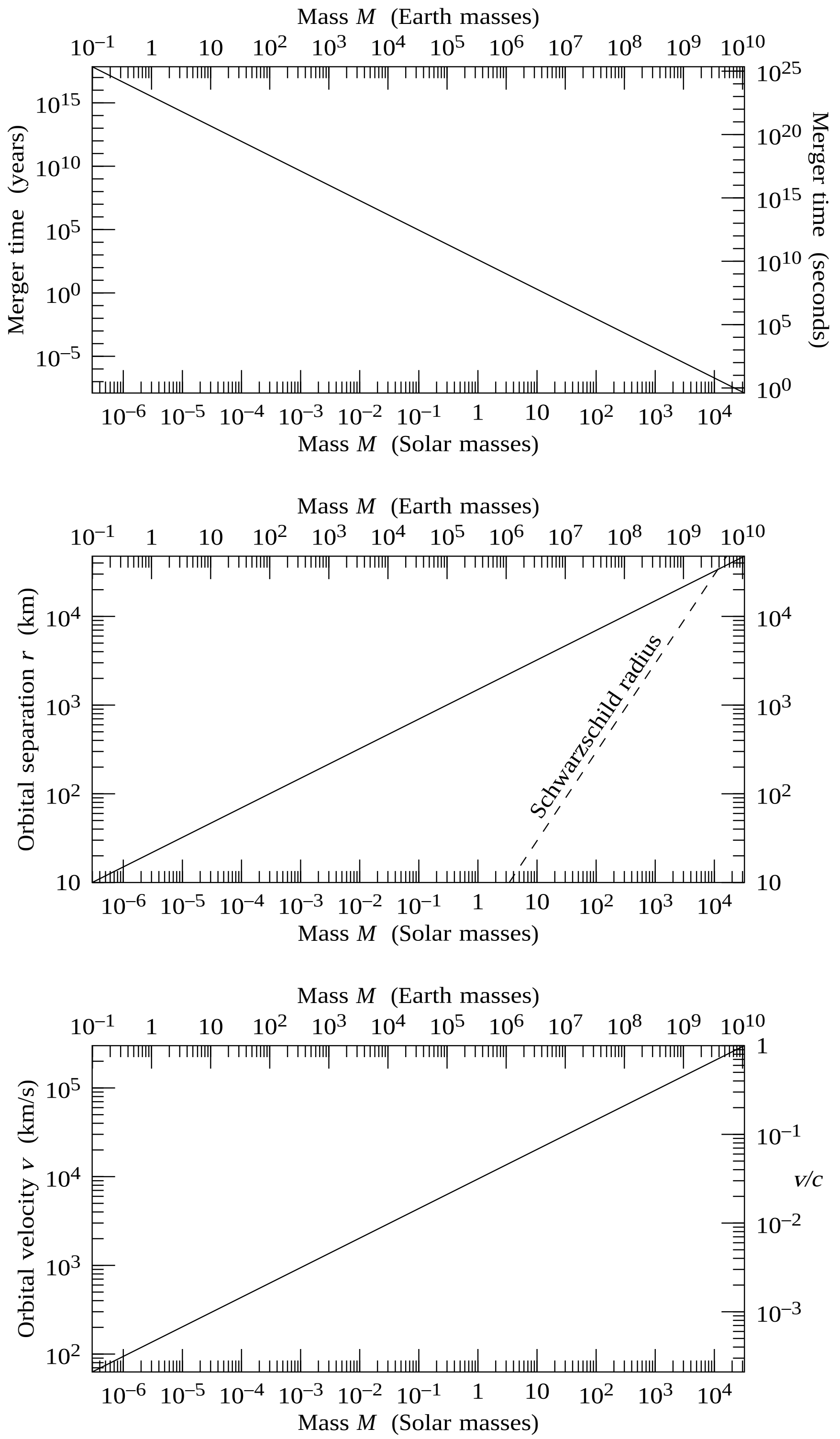

Figure 1: These graphs assume that the orbital period of the compact binary is 1 second.