Ginny Cunningham
ASTR630: Planetary Project Abstract
"Planetary Dynamics of PSR B1257+12"

The discovery of Earth-sized planets orbiting the pulsar PSR B1257+12 was monumental for both the field of pulsar research and that of the planetary sciences. Pulsars are famous for being extremely precise astronomical clocks which means that even minuscule aberrations in their signals can be detected and observed by astronomers. Under normal circumstances Earth-sized planets are difficult to detect due to their almost negligible effects on the host star but given the high precision of pulsar timing these effects can become visible. The planet introduces a gravitational perturbation to the pulsar which causes the pulsar to "wobble" around the center of mass. In turn this wobbling causes the pulsar's radio signal to arrive early or late. This delay in the signal is directly dependent upon the physical and orbital parameters of the offending planet.

In 1992 Wolszczan & Frail discovered at least two planets orbiting PSR B1257+12. The planets are designated "B", and "C" in order of increasing semimajor axis. (Planet "A" would be confirmed later.) Initially only planet B was discovered. A single planet in orbit around a host star provides very limited information about its physical and orbital parameters. However with the discovery of planet C and its 3:2 resonance with planet B more information could be gathered. Specifically the masses, semimajor axis, eccentricities, and orbital periods are known for each of the planets. Rasio et al. (1992) show that the gravitational effects that the two more massive planets have on each other actually result in periodic changes over time in their orbital elements. These changes should be easily detectable and would provide an additional confirmation of the pulsar planetary system.

For my project I will be exploring the three-body dynamics of the pulsar, planet B, and planet C system. The system can be modeled using the HNbody code, assuming that the effects of the planets on the pulsar are small. This is an appropriate assumption to make because for this case only the motions of the planets are important. The deviations of the pulsar only become relevant for the high precision methods of pulsar timing. The perturbations to the longitude of pericenter, eccentricity, and orbital period of the planets can be recreated to show how they evolve over time.

The effects of planet A on the two larger planets are generally negligible and Rasio et al. (1992) show that it can be ignored. However for this project I will explore just how little of an effect Planet A produces when it is included in the HNbody simulation. At the time the reference paper was written the inclination of the planets' orbital planes was unknown therefore an inclination of 0 degrees was assumed. The ramifications of introducing an inclined orbit will be another topic to evaluate. I will also examine the importance of the 3:2 resonance between the two more massive planets and how this allowed astronomers to derive their orbital properties. This planetary system around a pulsar provides a rich laboratory for testing and understanding several areas of physics and astronomy, including planetary formation, planetary dynamics, pulsar spin mechanisms, non-Newtonian gravity, and high-energy physics.

References:
Rasio, F. A., Nicholson, P. D., Shapiro, S. L., & Teukolsky, S. A. 1992, Nature, 355, 325
Wolszczan, A., & Frail, D. A. 1992, Nature, 355, 145