EPSC Abstracts
Vol. 6, EPSC-DPS2011-542, 2011
EPSC-DPS Joint Meeting 2011


# Planetary System Disruption within Wide Binary Star Systems

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## Abstract

Because they are so weakly bound, the orbits of wide binary stars evolve greatly under the influence of the Galactic tide and impulses from passing field stars. Most systems eventually pass through phases of high eccentricity, and this can have catastrophic consequences for the planets orbiting within these binary systems. During these eccentric phases, close encounters between the two binary members occur, and any planets orbiting the stars can be strongly perturbed. We use numerical simulations to study the planetary dynamics within such wide binaries, and we find that dynamical instabilities are common. For planetary configurations like our own solar system, we find that a wide binary companion ($a > 1000$ AU) will trigger planetary ejections in 1/3 to 1/2 of all systems. Interestingly, these ejections and instabilities typically occur only after hundreds of Myrs or Gyrs of evolution, possibly generating events similar to the LHB instability that occurred in our own solar system.

## 1. Introduction

Although uncertain, it seems that at least ~10-15% of stars are born into wide binary systems with semimajor axes beyond ~1000 AU [1]. Such weakly bound orbits will evolve very similarly to orbits in our own Oort Cloud. In particular, it is inevitable that many of these binary systems will be driven into highly eccentric states due to the perturbations from the Galactic tide and other passing field stars. During these eccentric phases, the binary members will experience much closer stellar encounters than would be expected for an isolated star in the field. In this work we investigate the effect that this type of evolution will have on planetary systems that the binary members may possess.

## 2. Numerical Methods

To perform our simulations, we use the wide binary integrator in the Mercury package [2]. Each of our simulated systems consists of a 1 $M_\odot$ primary star orbited by a system of giant planets and a wide binary companion. The binary companion masses range between 0.1 and 1.0 $M_\odot$ and the binary semimajor axes are set between 1000 and 30000 AU. For each binary mass/semimajor axis combination, we perform 50 ten-Gyr simulations. For simplicity, the planetary configurations modeled in our initial runs all resemble the current configuration of giant planets in our solar system. In addition, perturbations from the Galactic tide and passing field stars are modeled using the current parameters of the solar neighborhood.

## 3. Results

We find that as wide binary systems approach a high eccentricity state, the close mutual encounters between binary members trigger instabilities within the primary's planetary system. Often this results in one or more planets being ejected from the system. An example of this type of behavior is shown in Figure 1. In this system, the binary companion's pericenter reaches minima at $t = 1$, 3.5, and 7.2 Gyrs. Consequently, the primary's planetary system becomes unstable during all of these times as well, with Uranus ejected at $t = 3.5$ Gyrs and Neptune lost at $t = 7.2$ Gyrs.

Interestingly, these instabilities are typically quite delayed because the binary system is unlikely to form in a highly eccentric state. This allows planet formation to take place in a relatively quiescent environment. Only hundreds of Myrs or Gyrs later will close encounters with the binary companion occur, possibly disrupting the planetary system.

For a given binary configuration, ~1/3 to 1/2 of our systems will eject one or more planets during their

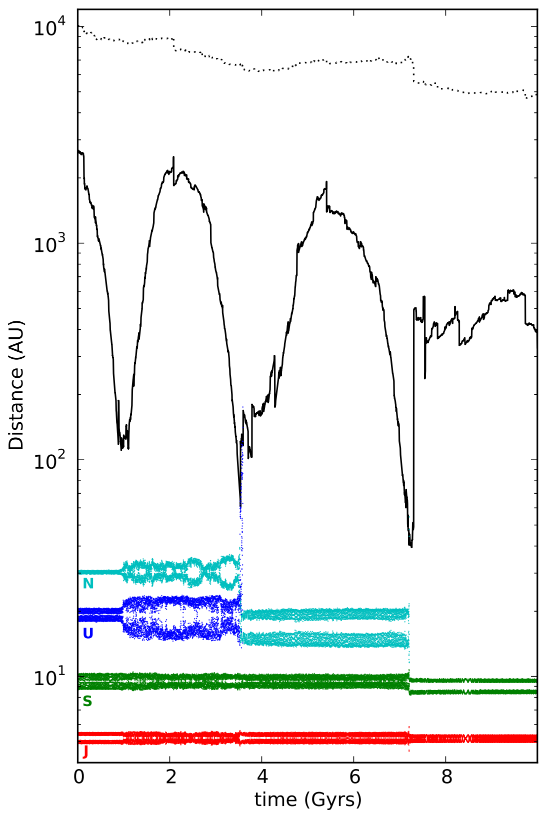


Figure 1: Typical evolution of a planetary system within a wide binary. Plotted are the perihelia and aphelia of Jupiter, Saturn, Uranus, and Neptune vs. time. Additionally, the solid line shows the pericenter evolution of a 0.1 $M_\odot$ binary companion. The dotted line shows the binary semimajor axis.

lifetimes. This fraction depends mostly on the binary companion's mass, with 0.1 $M_\odot$ companions disrupting fewer systems than 1 $M_\odot$ companions. Surprisingly, the disruption fraction is not as sensitive to the binary separation distance. Although tighter binaries evolve more slowly under the action of the galactic perturbations, they are more lethal to the primary's planets for a given binary eccentricity. This is because the binary companion will pass through pericenter at a much higher frequency in a tight binary than a wide one.

# Acknowledgements

This work was funded by NSERC and a CITA National Fellowship. Our computing was performed on the General Purpose Cluster provided by the SciNet consortium at the University of Toronto.

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