Constraining the Secret Histories of Stars Using "Tatooine" Planets: Tidal Circularization and Migration in "Tatooine"/Circumbinary Systems

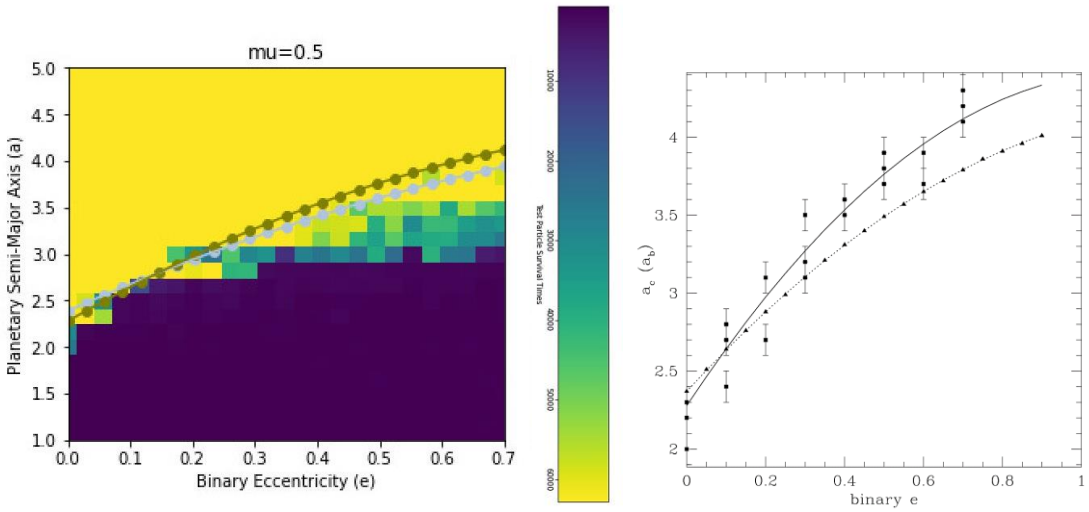
SURP Student: Kanah Smith
Supervisors: Janosz Dewberry and J.J. Zanazzi
Collaborators: Niharika Namulla

August 20th, 2021

The question our project works to answer is, why there is a lack of exoplanets orbiting binary star systems, particularly binary pairs with orbital periods that are less than 7 days. This observation comes from David V. Martin's paper (Populations of Planets in Multiple Star Systems, 2018) which noted that the then 2862 eclipsing binaries identified by the Kepler space telescope, showed circumbinary planets existing only for those with binary orbital periods greater that 7 days. We continued work on this question, which was originally proposed by Holman and Wiegert (Long-Term Stability of Planets in Binary Systems, 1999), by first reproducing their work with the addition of more advanced and accurate software tools. The work they did involved creating computer simulations to model these short period binary systems; through this, they were able to determine what they had called the stability criterion, the boundary upon which circumbinary planets could exist in stability around their binary host. Crossing the stability criterion and getting closer to the stars would result in ejection from the system due to gravitational forces between the stars pushing the planet out.

Our work involved using the programming language python, where we employed a package known as REBOUND (and its sub-package, REBOUNDx that hosts additional features) to create stellar simulations, remodelling the work previously conducted by Holman and Wiegert (1999). The simulations I created differed from their work mainly in the software advancements that are currently available; in addition, I was able to create simulations that hosted many non-interacting test particles as circumbinary planets in the system. All test particles had initially randomized positions to collect more robust and accurate data as to

the region in which these planets lose stability, considering their initial positions. Once ejected from the simulations, the test particles survival times were collected and plotted in comparison to the data collected by Holman and Wiegert (1999). The image shown below illustrates a colour plot of survival times from my simulation, which hosted 25 test particles, compared to the plot with similar orbital aspects created by Holman and Wiegert; both graphs also have the stability criterion plotted.



The next steps for this project will be focussed on investigating the effects of tidal forces, namely tidal circularization, and migration on the stability criterion of the binary orbit and determine if it is the reason for the lack of circumbinary planets in orbit of short period binary star systems. Circularization and migration of the binary pair in their evolution involves the stars migrating towards each other in addition to their orbits becoming increasingly circularized. Tidal forces between the stars cause internal gaseous mixing, dissipating orbital energy and decreasing both binary semi-major axis and eccentricity.

My work to integrate tidal components into the simulations has already begun, with the integration of REBOUNDx's tidal features, so we are hopeful and excited to compare the colour plots based on gravitational and tidal forces, in addition to analyzing the evolution of orbital parameters of both the binaries and the test particles throughout the simulation.

References

Holman, M. J., & Wiegert, P. A. 1999, AJ, 117, 621, DOI: 10.1086/300695
Martin, D. V. 2018, arXiv:1802.08693v1 [astro-ph.EP]