Kanah Smith
kanah.smith@mail.utoronto.ca

Tidal Circularization and Migration in "Tatooine" Systems

A research project conducted in collaboration with Niharika Namulla and under the supervision of Janosz Dewberry and J.J. Zanazzi

AFFILIATIONS

UNIVERSITY OF TORONTO

CITA ICAT Canadian Institute for Theoretical Astrophysics / L'institut Canadien d'astrophysique théorique

01. Motivation

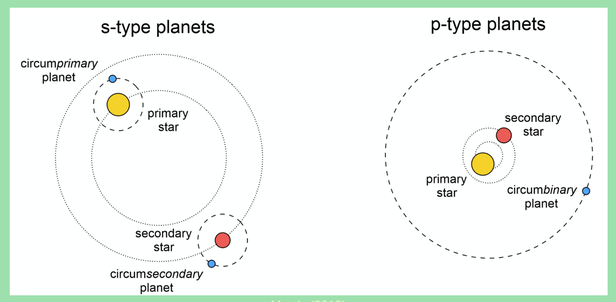
The question our project works to answer builds on the work of Holman and Wiegert[1] who were investigating why there is a lack of exoplanets orbiting binary star systems, particularly those with orbital periods less than 6 days.
Martin[2] shows that for these short period binaries, no planets have been detected within the system, an anomaly since exoplanets are easiest to detect in these systems.

02. Context

As most stars exist in binaries,[3] and with the Kepler Space Telescope's nearly 4500 exoplanet discoveries[4] (of which had uncovered the commonality for stars to host exoplanets) it can be assumed that binaries should exist in "Tatooine" systems.
Martin's[2] lack of detection leads us to believe that during the tidal circularization and migration stage of binary evolution, something is causing the planets to be ejected from the system.

02.1 What is a "Tatooine" Planet?

Planets in orbit with a binary star system in one of two orbital configurations:
- S-Type: individually orbits one of the binary stars
- P-Type: orbits both stars in the binary system



Martin (2018)

02.2 What is Circularization and Migration?

This stage of binary evolution involves the stars migrating towards each other in addition to their orbit becoming increasingly circularized.
Tidal forces between the stars causes internal gaseous missing, dissipating orbital energy and decreasing both binary semi-major axis and eccentricity.

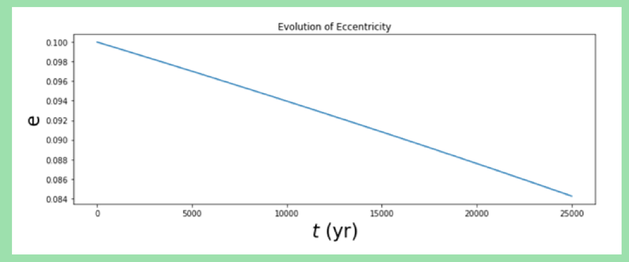
References
1. Holman, M. J., & Wiegert, P. A. 1999, AJ, 117, 621, DOI: 10.1086/300695
2. Martin, D. V. 2018, arXiv:1802.08693v1 [astro-ph.EP]
3. Australian Telescope National Facility (https://www.atnf.csiro.au/outreach/education/senior/astrophysics/binary_intro.html)
4. NASA Exoplanet Archive - NASA-JPL/Caltech (https://exoplanetarchive.ipac.caltech.edu/docs/counts_detail.html)
5. Python Graphic (https://commons.wikimedia.org/wiki/File:Python-logo-notext.svg)
6. REBOUND Graphic (https://rebound.readthedocs.io/en/latest/)
7. University of Toronto Graphic (https://www.logo.wine/logo/University_of_Toronto)
8. CITA Graphic (https://www.cita.utoronto.ca/)

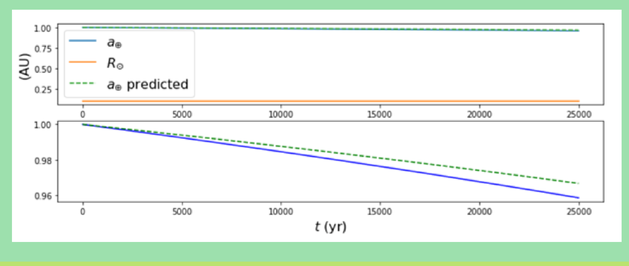
03. Methods

With more advanced and accurate software, we recreated a modified version of the simulations that Holman and Wiegert[1] used for their work, to analyze the survival times of planets given varying values of planetary semi-major axis, binary eccentricity, and mass ratio.

Python REBOUND

Preliminary simulations using the REBOUNDx python package assessed the affects of a small tidal force between the binaries, which showed deterioration of eccentricity and semi-major axis, the aforementioned circularization and migration, a signature of tidal dissipation.





Secondary work (excluding tides and focussing on recreating results) was conducted using the python package REBOUND and multiprocessing software, for simulations that each host 25 non-interacting particles/planets and ejects individual particles, collecting their survival times once they have reached a specified distance from the binary.

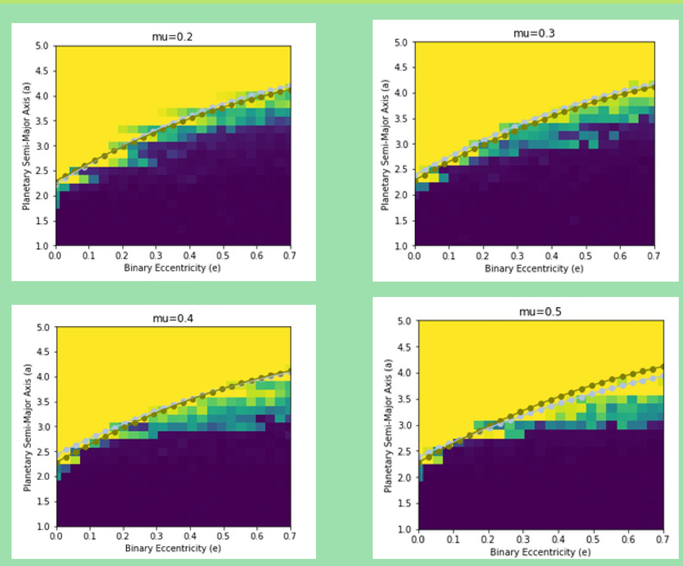
Survival times were collected and plotted using colour maps overlain with Holman and Wiegert's[1] stability criterion for p-type orbits to evaluate if we had successfully recreated their work.

$$\frac{a_c}{a_b} = 1.6 + 5.1e - 2.22e^2 + 4.12\mu - 4.27e\mu - 5.09\mu^2 + 4.61e^2\mu^2,$$
$$\approx 2.278 + 3.824e - 1.71e^2.$$

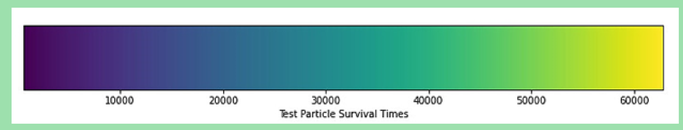
Holman & Wiegert (1999)

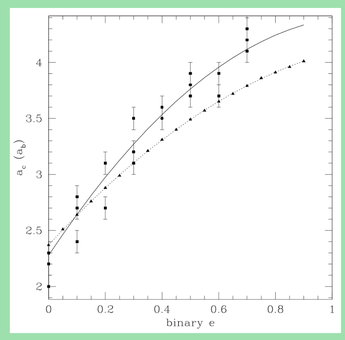
04. Results

Successfully recreated Holman an Wiegert's[1] results well and were also able to confirm that the stability criterion is roughly independent of mass ratio by comparing our survival time colour maps that have different mu values and seeing no significant difference.



Green Line: stability criterion with mass ratio Blue Line: stability criterion approximation without mass ratio





Holman & Wiegert (1999) Fig. 4

05. Future Work/Next Steps

Will include tides in the most recent simulations to focus on analyzing the effect of 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.