SURP Research Summary

Constraining the Secret Histories of Stars using Circumbinary "Tatooine" Planets

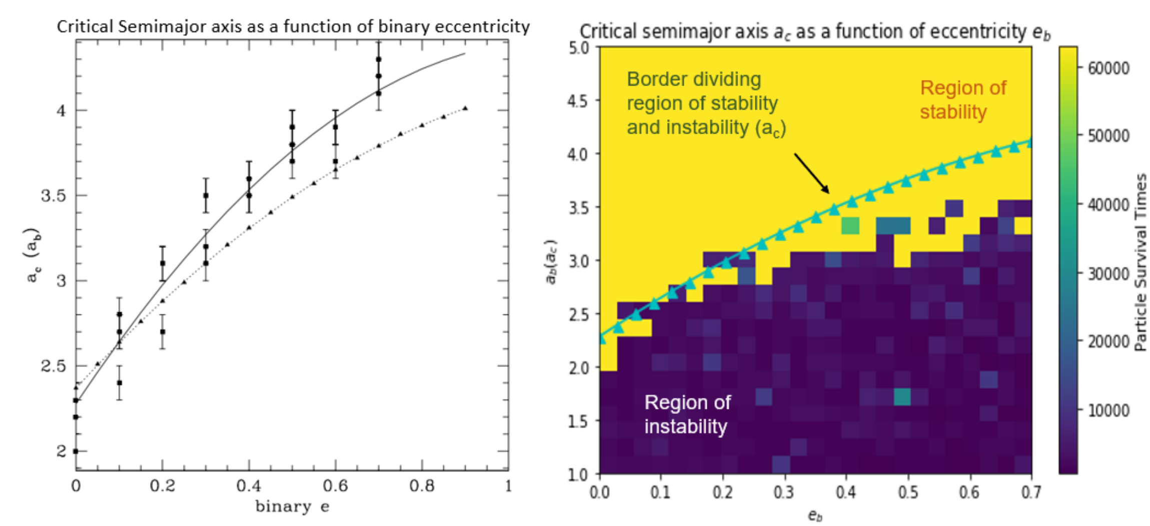
Niharika Namulla

Our research this summer focused on constraining regions of stability near binary star systems with the help of circumbinary(p-type) test particles/planets. We then aimed to improve this estimation through survival analysis. We first started by building N-body simulations of binary star systems and test particles under varying orbital constrains, noting their respective survival times. A survival time is simply the duration that the test particle is observed to orbit the binary system before possibly being ejected from the system (due to orbital instabilities). We then plotted the survival times for all test particles in a colour map (Figure 1b.), overlaid by the critical semi major axis (Eq 1.) derived from Holman & Wiegert(1999). The critical semi major axis is simply a region in phase space near a binary system beyond which test particles are observed to have stable orbits at larger times as opposed to within. Finally, to constrain for right-censored data, we used survival analysis, mainly the survival function and the hazard function to improve our estimation of survival times.

$$\frac{a_{\mathrm{crit}}}{a_{\mathrm{bin}}} = 1.60 + 5.10 e_{\mathrm{bin}} - 2.22 e_{\mathrm{bin}}^2 + 4.12 \mu_{\mathrm{bin}} - 4.27 e_{\mathrm{bin}} - 5.09 \mu_{\mathrm{bin}}^2 + 4.61 e_{\mathrm{bin}}^2 \mu_{\mathrm{bin}}^2,$$

Holman & Wiegert (1999) (1)

Comparing the results obtained from H&W(1999) (Figure 1a.) and the colour plot from our simulations (Figure 1b.), we see a clear resemblance among the two. We see that the pattern of survival times clearly follows Eq 1.(lined in blue) and there does appear to be a critical semi major axis limit beyond which all test particles have improved stability as opposed to within. We see that beyond the blue line, most if not all test particles survived the entire duration of simulation(yellow region), while below this region we see many particles being ejected at earlier times.



1. (a) Holman & Wiegert (1999) **1. (b)** Courtesy: Niharika Namulla

Figure 1. **(a)** The critical semi-major axis as a function of binary eccentricity obtained by Holman & Wiegert (1999). For the following orbital ranges: μ_{bin} ($0.1 < \mu < 0.9$), e_{bin} ($0.0 < e < 0.7$-0.8), Duration: 10^4 orbital periods. **(b)** Our results: Obtained using REBOUND programming package. For the following orbital ranges: e_{bin} = 0.0 – 0.7 , a_p = 1.0 – 5.0, μ_{bin} = 0.5 (constant for all simulations), Duration: 10^4 orbital periods. Total number of simulations run: 625.

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There are several avenues of further work that we aim to pursue:

1. So far, we have applied survival and hazard functions to only a few data sets obtained. Thus, the next logical step is to apply these functions to all data sets obtained to improve our estimation of all survival times.
2. Moreover, we aim to include survival regression as part of our statistical analysis.
3. We also hope to conduct simulations for a larger range of binary mass ratios to observe the relation between binary mass ratio and binary stability
4. Lastly, we aim to include tidal dissipation in our simulations to study how tides affect our results.