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

SURP Student: Niharika Namulla

Collaborations: Kanah Smith Supervisors: J.J Zanazzi & Janosz Dewberry

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

UNIVERSITY OF TORONTO

INTRODUCTION

What are binary star systems?

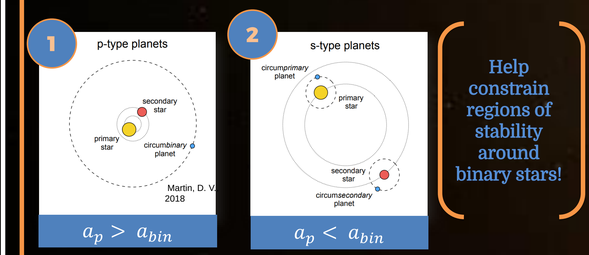
A Binary Star System is a system consisting of 2 stars orbiting a common center of mass

Why are they important?

- Most observable stars are in binaries[1]
- Serve as one of the best methods to determine mass of distant stars[2]
- Provide important clues about the conditions under which stars are formed[2]

Two main planetary orbital configurations:

1) Circumbinary planets (p-type orbitals)
2) Circumstellar planets (s-type orbitals)



Help constrain regions of stability around binary stars!

OBJECTIVE

Conduct survival analysis to obtain a more reliable stability criterion for circumbinary planets/test particles in N-body simulations

METHODOLOGY

How did we study these systems?

- Run N-body simulations
  REBOUND software package
- Observe long term stability of test particles under different orbital constraints (time of particle ejection)

Orbital elements:
- Binary eccentricity (eb): 0.0-0.7
- Test particle semi major axis (ap): 1.0-5.0
- Binary reduced mass (mu): 0.05 - 0.5
- # of test particles/simulation(Np): 10-30

- Compare to results from previous studies:
  Critical Semimajor Axis (a_{crit}) [3]

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

Holman & Wiegert (1999) (1)

How do we constrain particle survival times?

- Survival Analysis (SA) : deals with estimation of right-censored data
  LIFELINES software package
- Two (2) main functions:

1. Survival Function (SF): ← Probability of surviving past time t

$$S(t) = Pr(T > t)$$

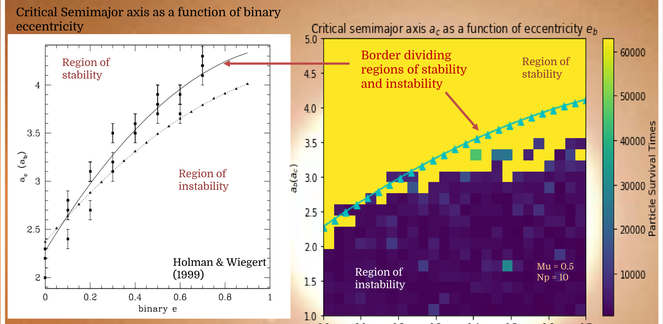
← Probability of ejection at time t, given the ejection has not occurred yet

2. Hazard Function (HF):

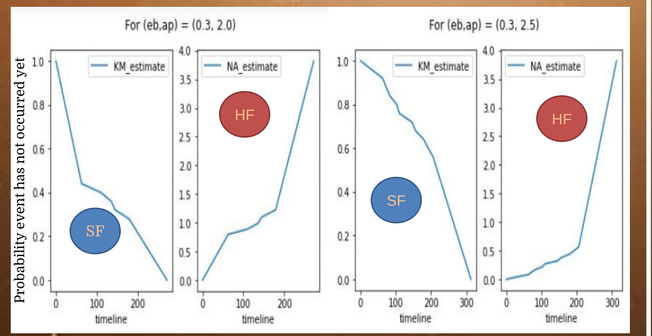
$$h(t) = \lim_{\delta t \to 0} \frac{Pr(t \le T \le t + \delta t \mid T > t)}{\delta t}$$

FINDINGS THUS FAR...

Trend line of orbital stability agrees with previous studies (Holman & Wiegert 1999)



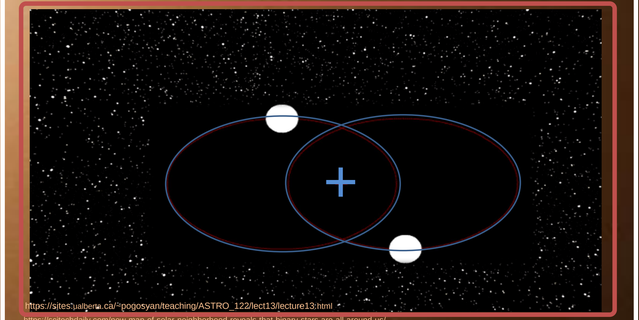
Survival & Hazard functions for specific orbital elements (provide a better estimate of test particle survival times)



NEXT STEPS

In the future we aim to:

1) Apply survival and hazard functions to all data sets obtained
2) Incorporate Survival Regression in our statistical analysis of survival times
3) Conduct simulations for a larger range of binary mass ratios
4) Study the effects of Tidal dissipation on binary stability (See Kanah Smith's poster!)



https://sites.ualberta.ca/~pogosyan/teaching/ASTRO_122/lect13/lecture13.html
https://scitechdaily.com/new-map-of-solar-neighborhood-reveals-that-binary-stars-are-all-around-us/

REFERENCES

1) Martin, D. V. (2018). *Populations of Planets in Multiple Star Systems* (pp. 2035-2060). Springer International Publishing. http://dx.doi.org/10.1007/978-3-319-55333-7_156

2) Milone, E. F., Leahy, D. A., & Hobill, D. W. (2008). *Short-Period Binary Stars: Observations, Analyses, and Results* (1st ed. 2008.). Springer Netherlands. https://doi.org/10.1007/978-1-4020-6544-6

3) Holman & Wiegert (1999)

Image Credit: NASA/Goddard Space Flight Center