

Investigating the Stability of Trojan and Horseshoe Co-orbitals in **Extrasolar Multi-planet Systems**

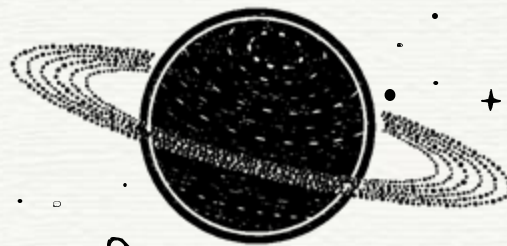
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National
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CO-ORBITAL CONFIGURATIONS

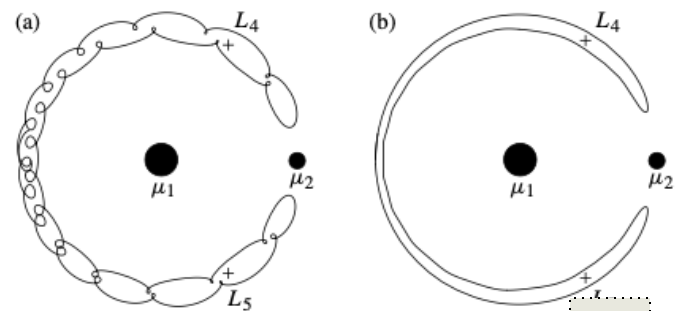
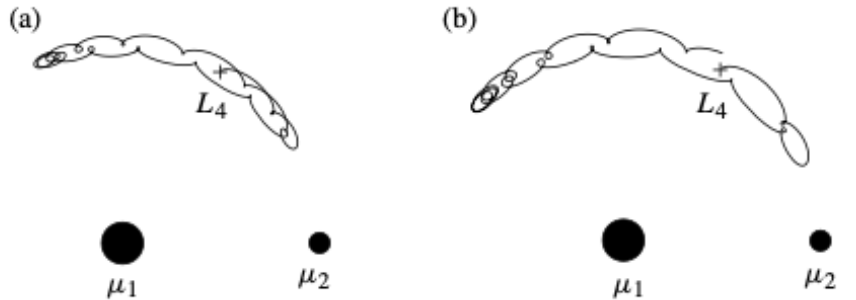
CO-ORBITALS

TROJANS

HORSESHOES

- Shared orbits with host
- 60° angular separation

- More complex paths than Trojans
- 180° apart in longitude



CO-ORBITALS IN THE SOLAR SYSTEM

STABLE:

- Mars
- Jupiter
- Neptune

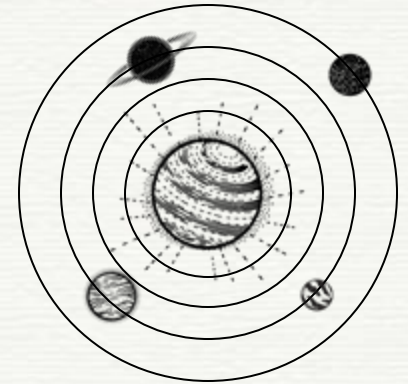
UNSTABLE:

- Saturn
- Uranus

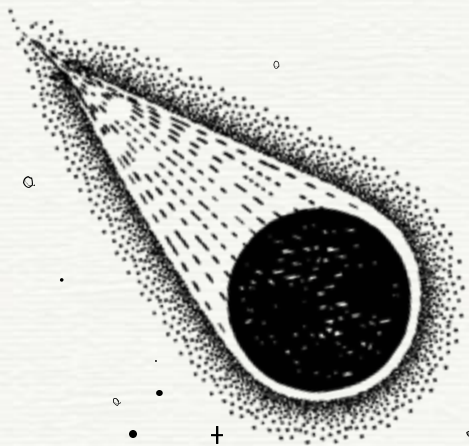


Reason for Instability:

Saturn and Uranus' **near-resonances** with Jupiter and Neptune, respectively



SATURN IS IN NEAR 5:2 RATIO WITH JUPITER



Does a system's resonance
influence long-term **co-**
orbital stability?

PROCESS

01



ACQUIRE

Initial conditions
from NASA
Exoplanet
Archive

02



SIMULATE

20 hypothetical
co-orbitals for
each exoplanet
using REBOUND

03



PLOT

Eccentricity,
inclination, and
difference in mean
longitude*

04



ASSESS

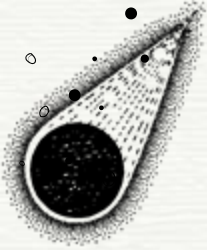
Stability of
systems using
lifetime plots

$$R_H = \left(\frac{m}{3M_{\odot}} \right)^{\frac{1}{3}} \text{ Hill radius}$$

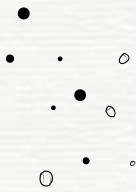
$a_i = a_{planet}$ First co-orbital's semi-major axis

$a_f = a_i * (1 + R_H)$ Last co-orbital's semi-major axis

*average angular
position along orbit



ASSESSING STABILITY



STABILITY THRESHOLD

Smallest difference in mean longitude able to remain stable

$$S_{threshold} = 5 \frac{R_H}{a}$$

LIFETIME PLOTS

Semimajor axis vs lifetime

$$t_{lifetime} = \frac{t_{stable}}{T_{host}}$$

VISUAL INSTABILITY

Added horizontal lines serving as stability indicators

$$S_{indicator} = \frac{t_{max}}{T_{host}}$$

Multi-Planet Systems



TRAPPIST-1

2-body
resonances



Kepler-11

Not in
resonances



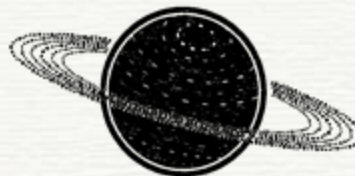
Kepler-80

3-body
resonances*



Kepler-90

Not in
resonances



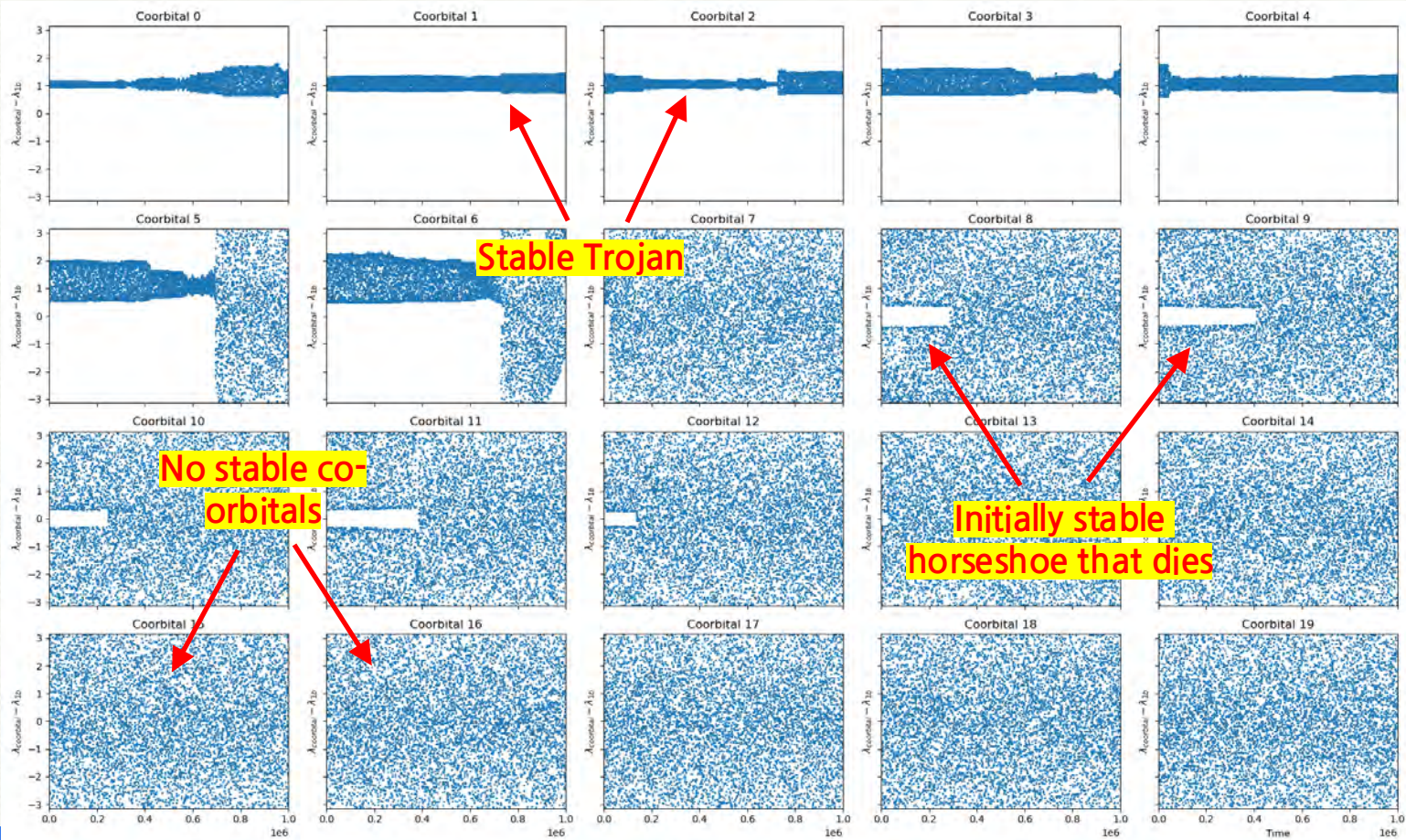
HD 110067

2-body
resonances

*weaker
than 2-body

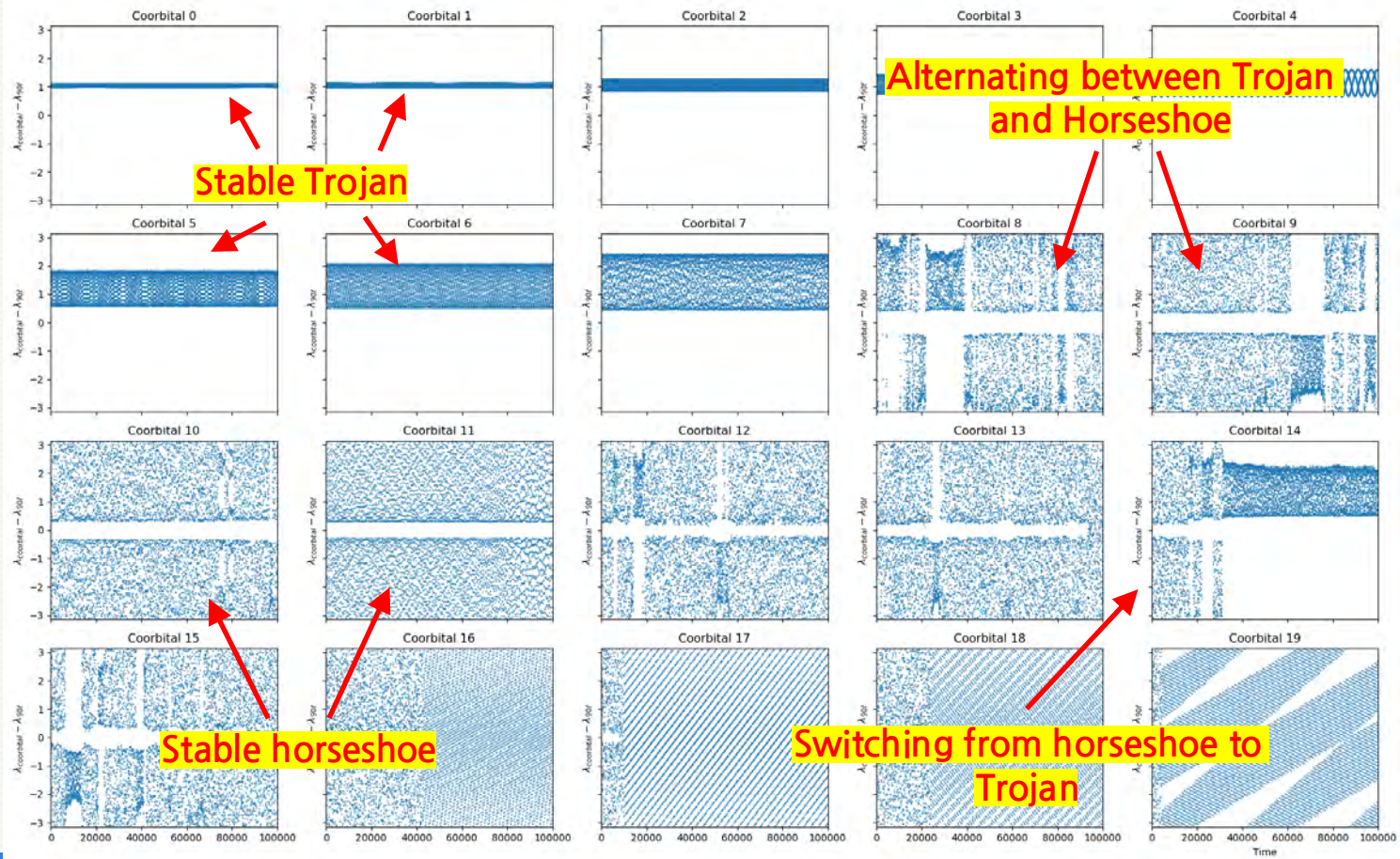
TRAPPIST-1b
over 10^6 years

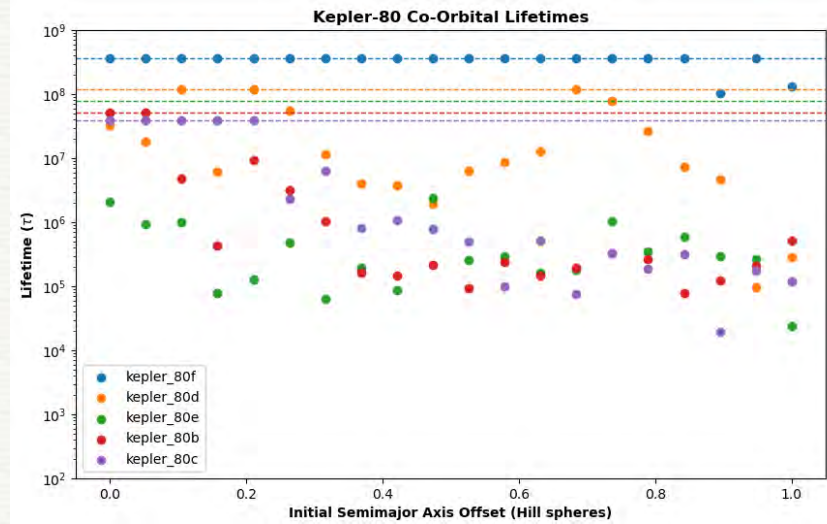
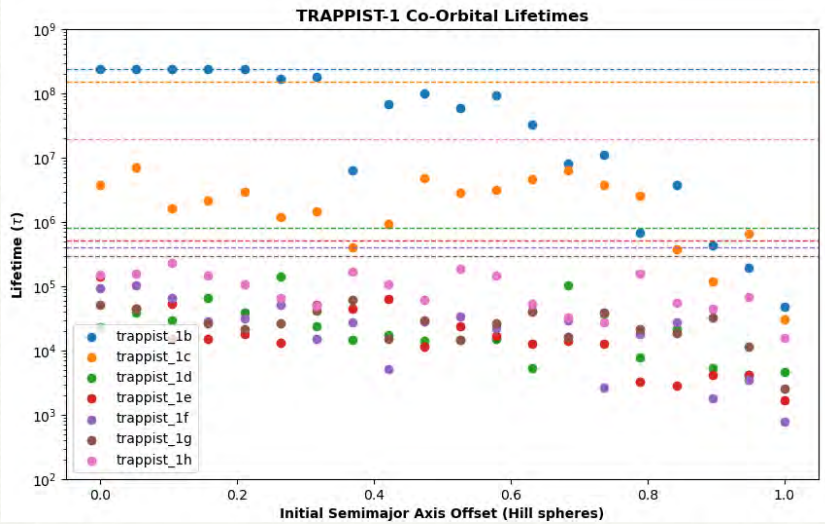
+ ✦ 2-BODY RESONANCES



Kepler-90f
over 10^5 years

+ ✦ NOT IN RESONANCES

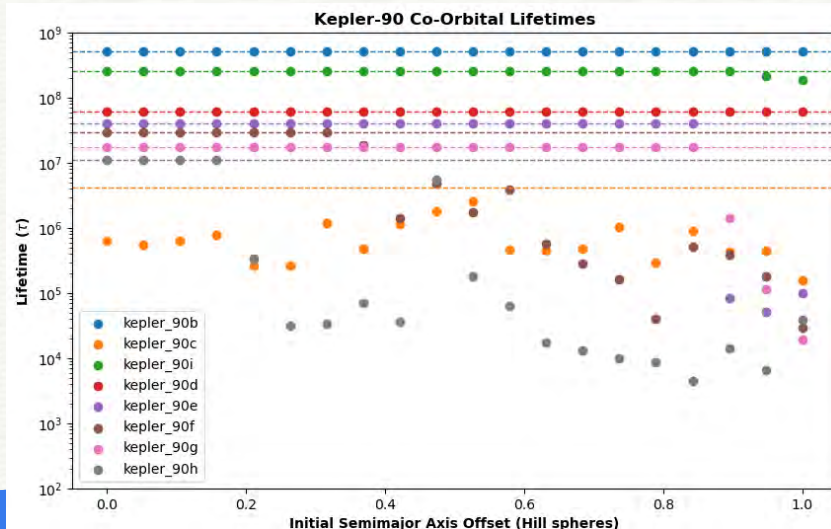




TRAPPIST-1: 2-body

Kepler-80: 3-body

Kepler-90: Not in resonances



CONCLUSIONS

ORBITAL RESONANCES IMPACT CO-ORBITAL STABILITY

- Co-orbitals less stable in resonant systems
- Trojans generally more stable than horseshoes

» BUT WHY ??? »

- Co-orbitals of one planet are also in or near resonance with other planets, potentially causing dynamical chaos
- Stability linked to dynamical interactions & resonances



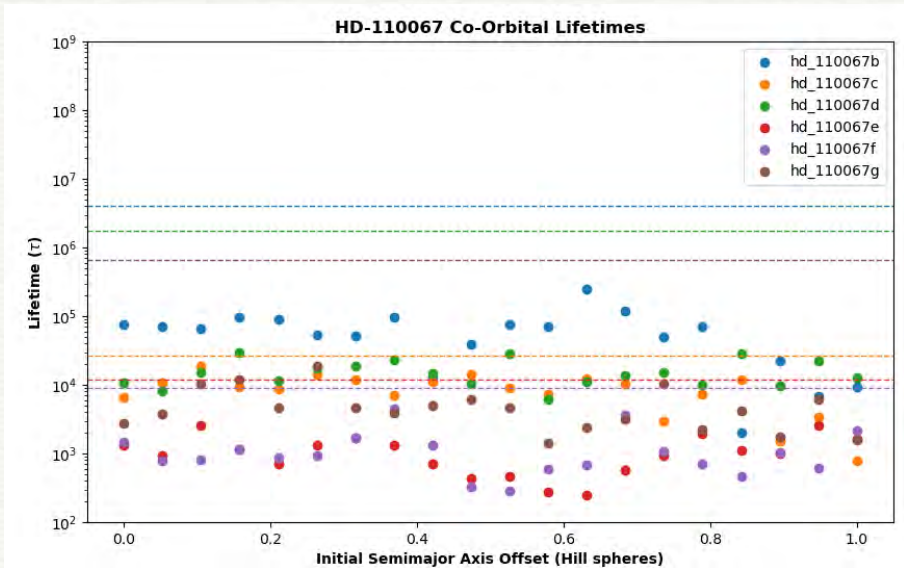
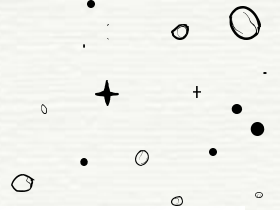
THANK YOU!

SETI Institute, Vassar College, National Science
Foundation, DPS Travel Grants, Xaria (my cat)

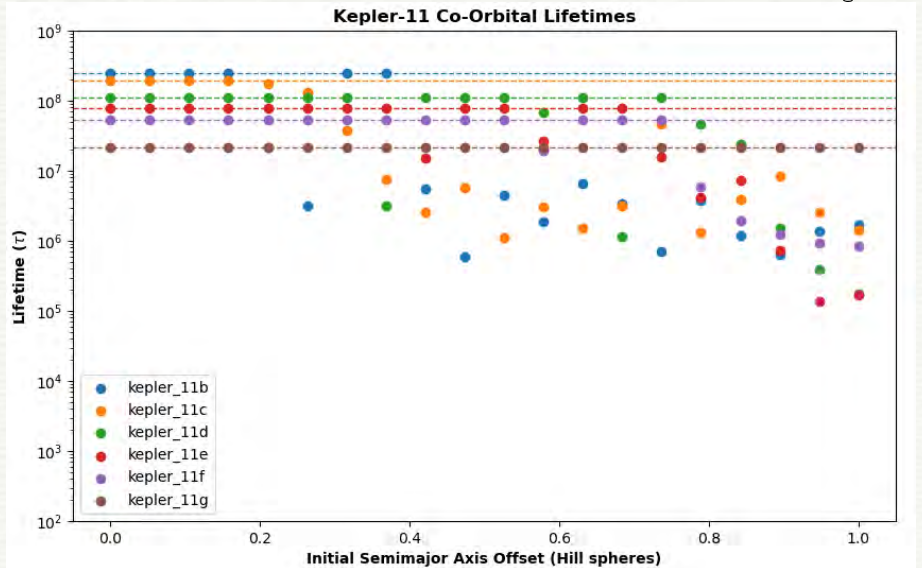


<https://github.com/mariahjones/orbitals>





HD 110067



Kepler-11

