

Exoplanetary System Dynamical Considerations for NASA Missions

Juliette Becker

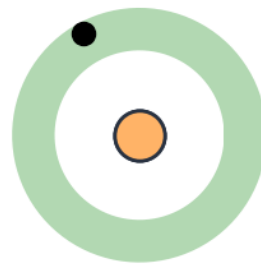
University of Wisconsin



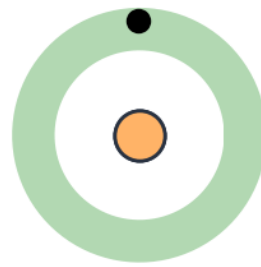
WISCONSIN CENTER
for
ORIGINS RESEARCH

HWO Goal: an Earth-like planet

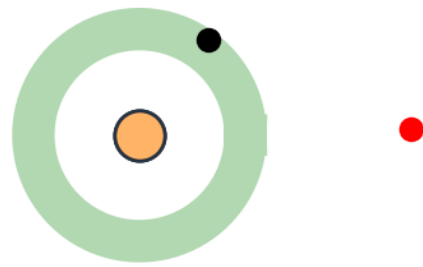




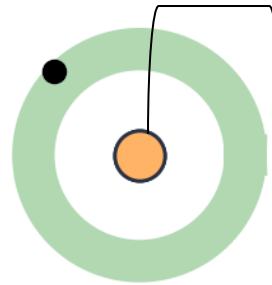
● Companion planet (Jovian-like)



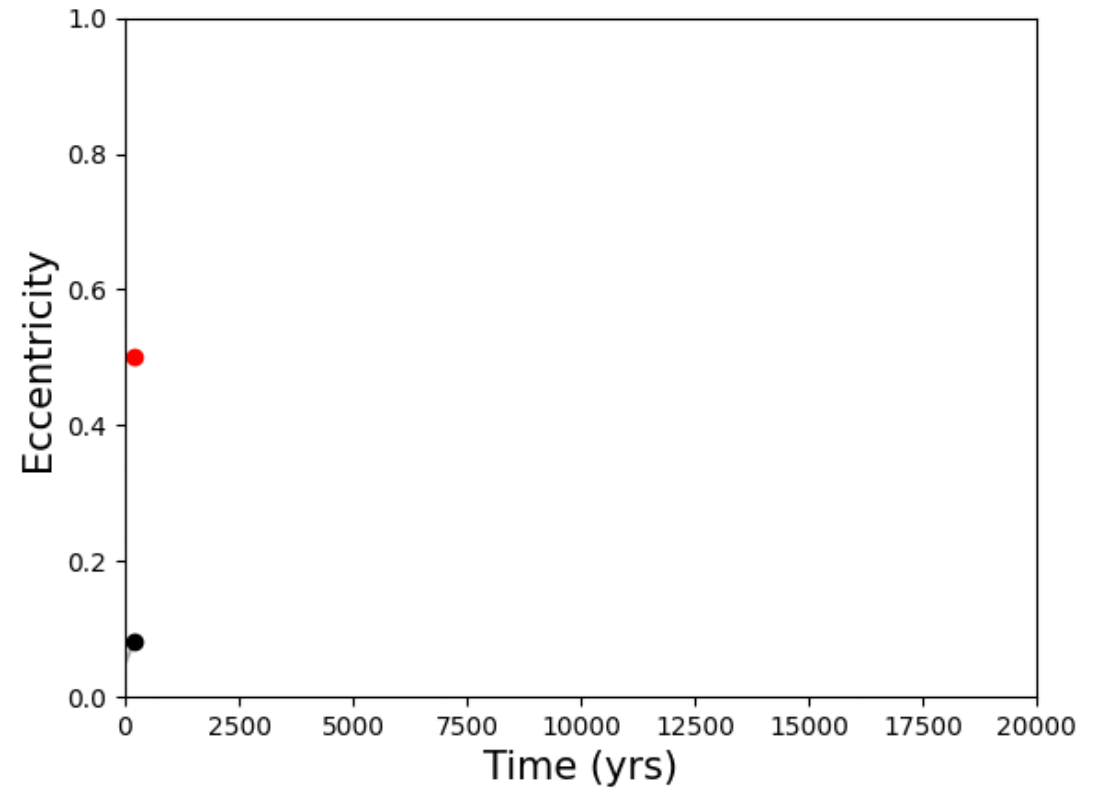
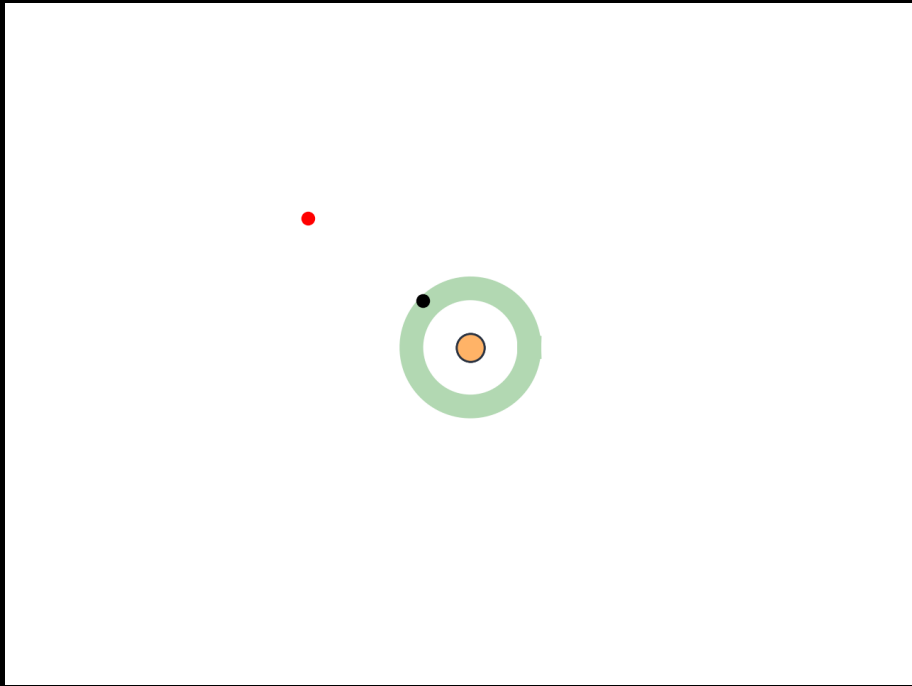
Habitable Zone

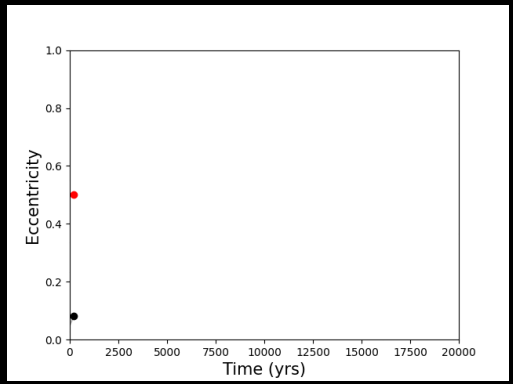


Planets pass close together – not good for long-term stability

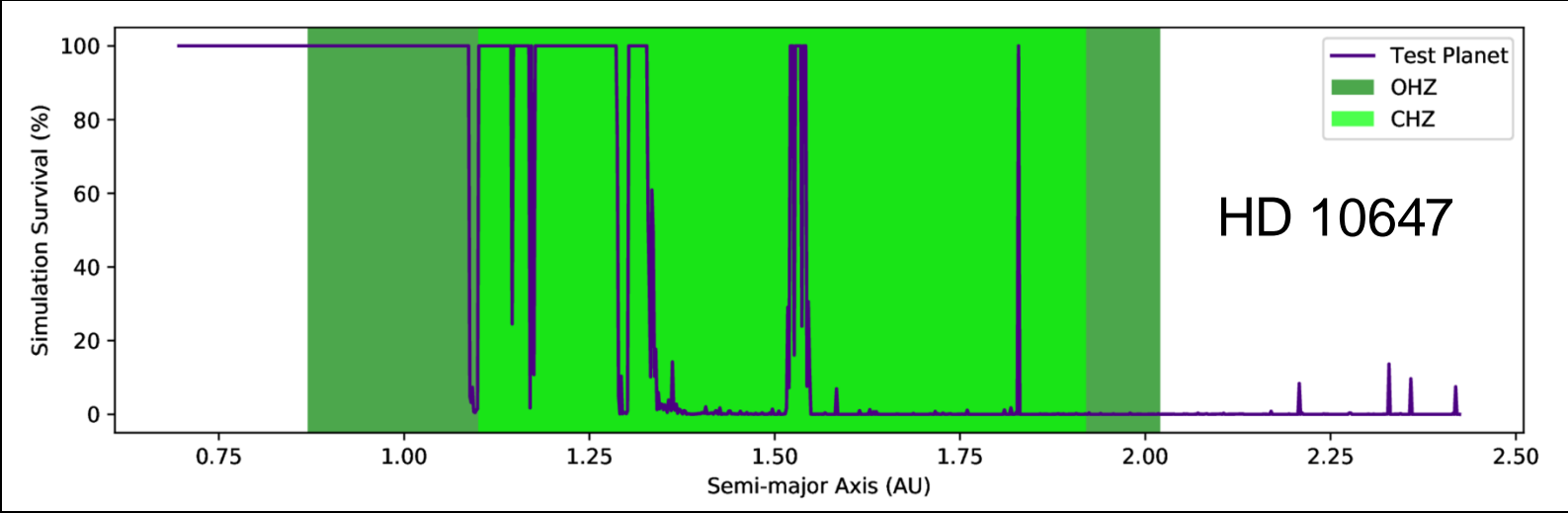


Over long timescales

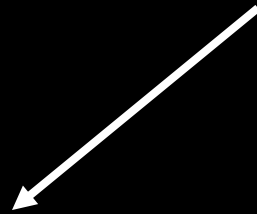
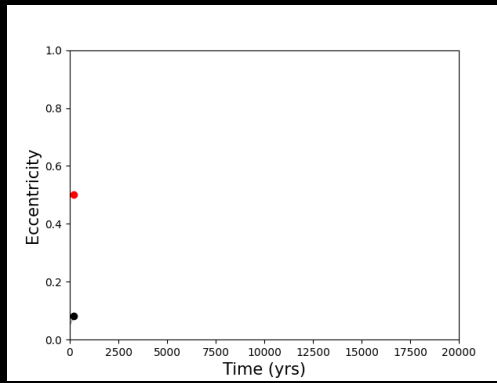




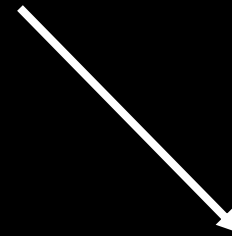
Dynamical
Instability (planets
are lost from
system)



Kane et al. 2024



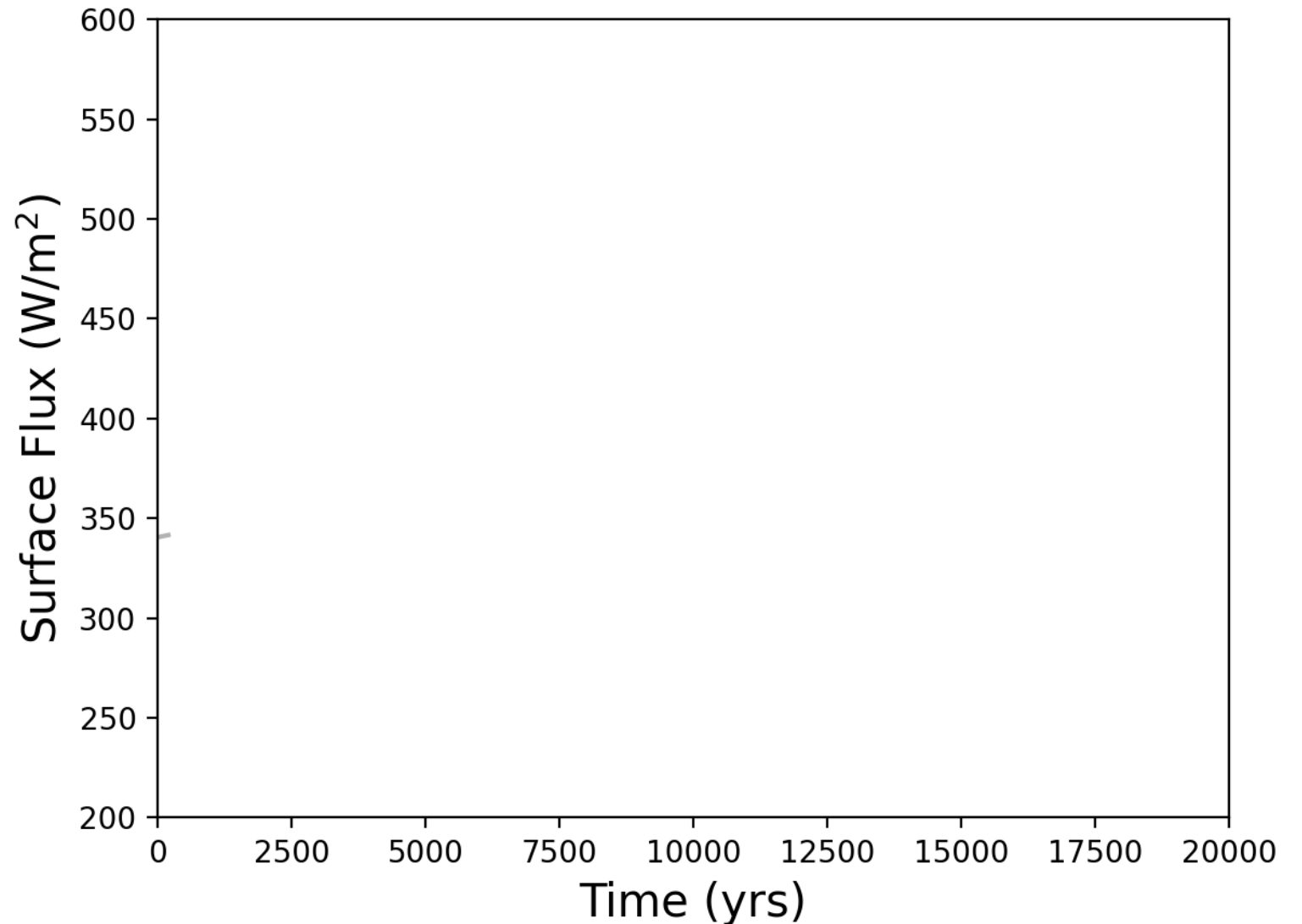
**Dynamical
Instability (planets
are lost from
system)**



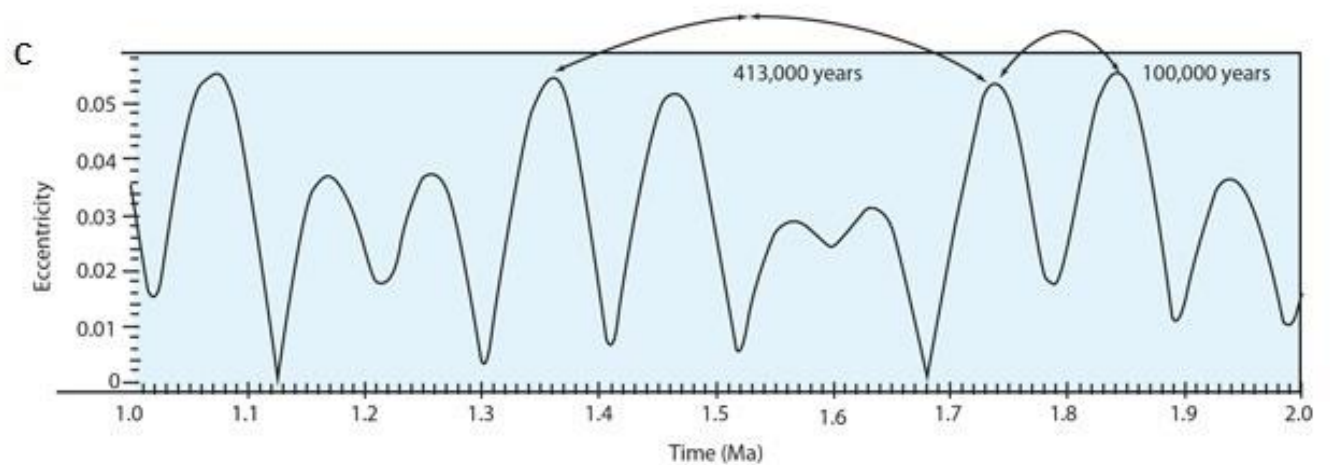
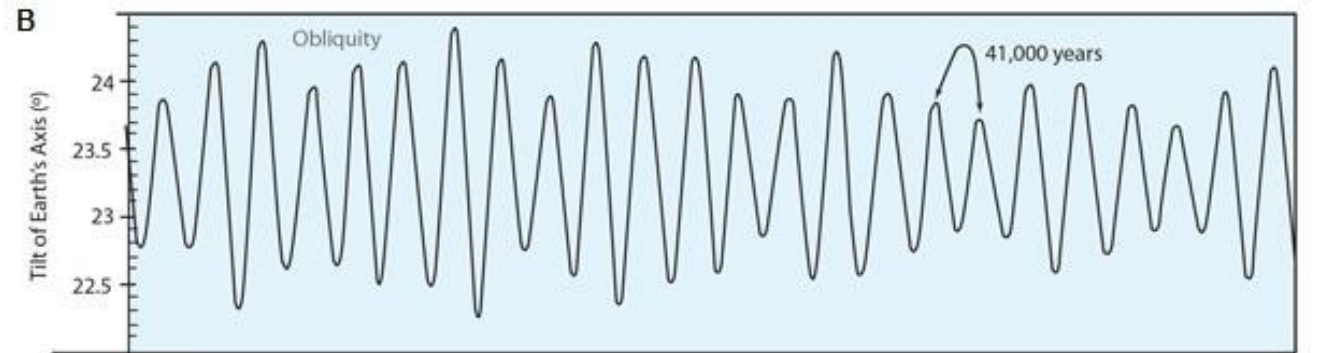
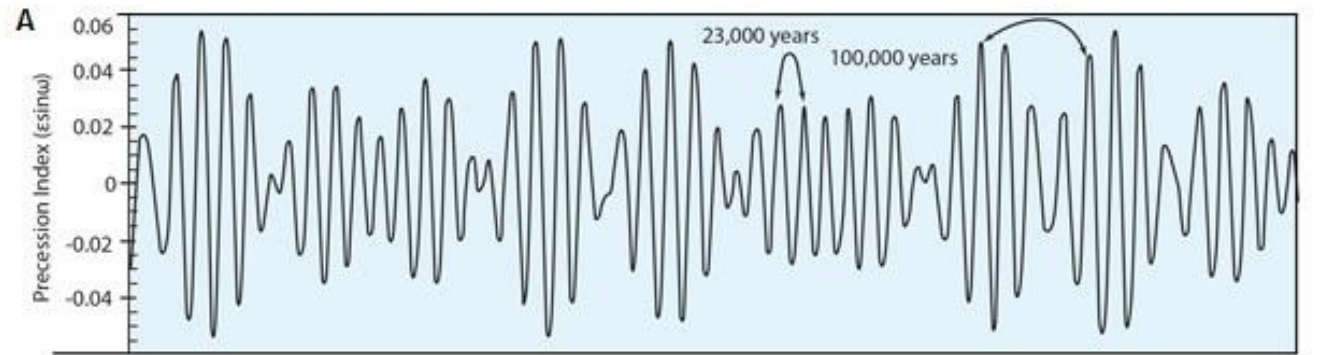
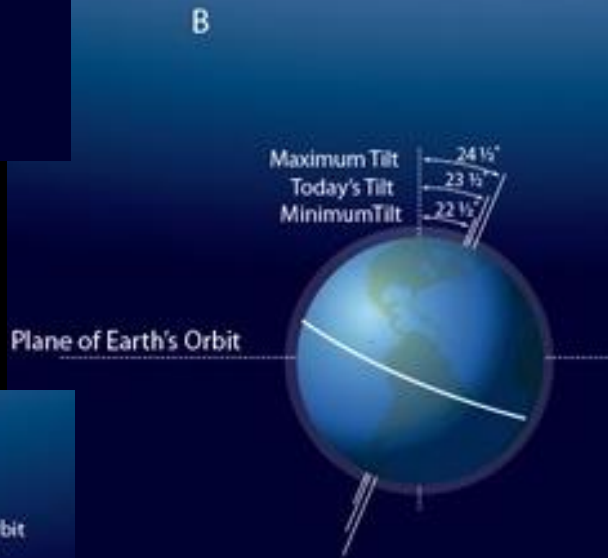
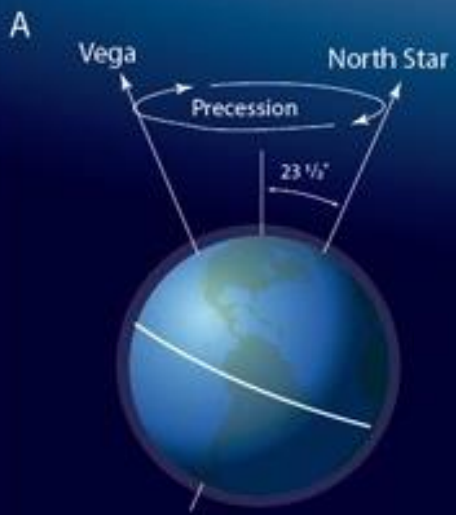
**System parameters
change significantly
over time**

System parameters
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over time

$$F_p(t) = \frac{F_p(t)}{\sqrt{1 - e^2}} = \frac{(1 - A)L_\star(t)}{4\pi a(t)^2 \sqrt{1 - e^2}}$$



Secular variations: Milankovitch Cycles





Horner 2008,
Batygin+Laughlin 2015,
Kane 2023

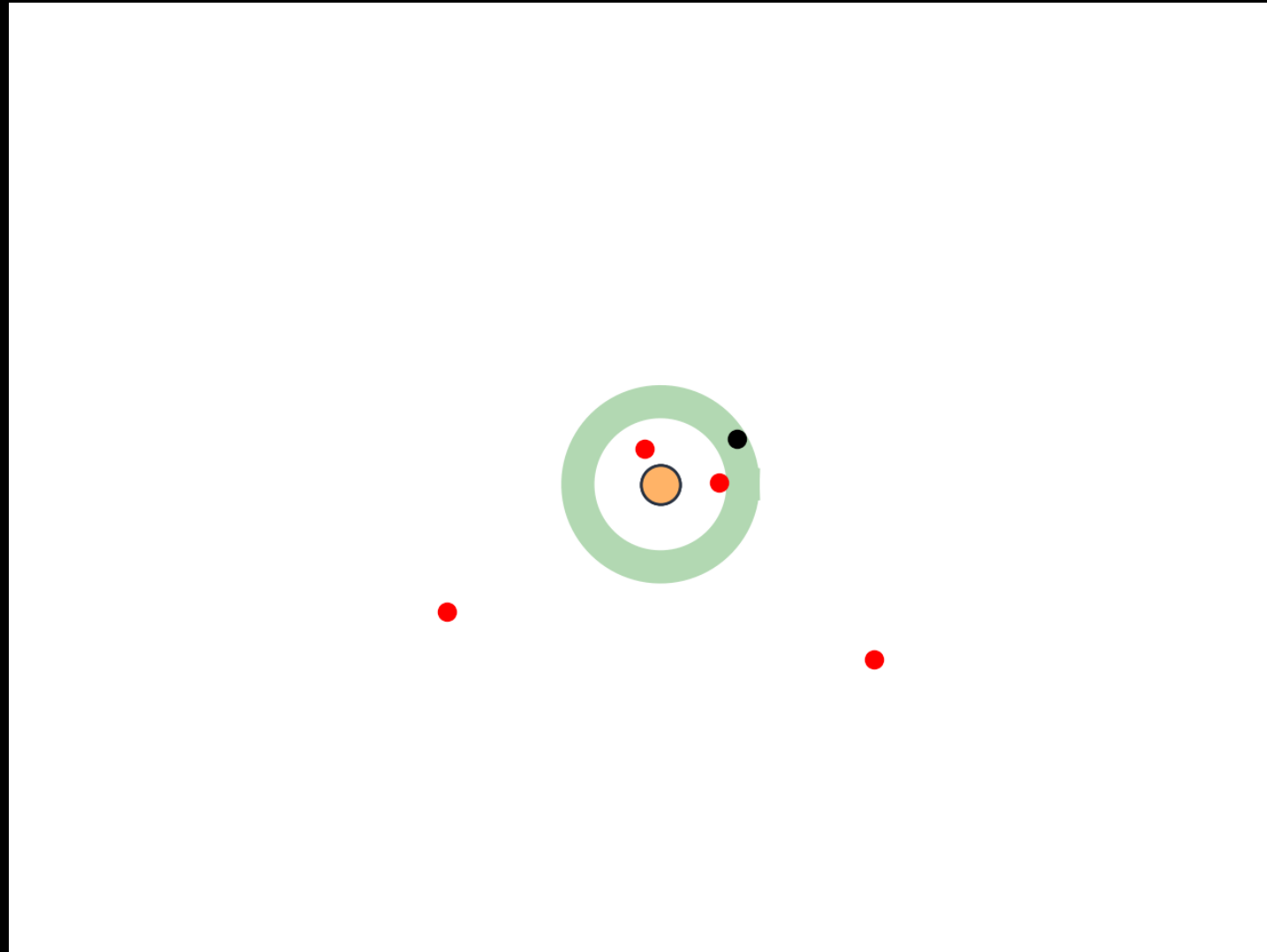
Roadmap to Maximizing HWO's Impact

- **Identify** planets that may be habitable. Ideally, HWO will do this
- **Characterize** them in detail to confirm if they truly can support life. We can start doing this now!
- **Investigate** their formation histories to understand planet formation more generally. We can start doing this now!

How can we set the stage for future missions like HWO?

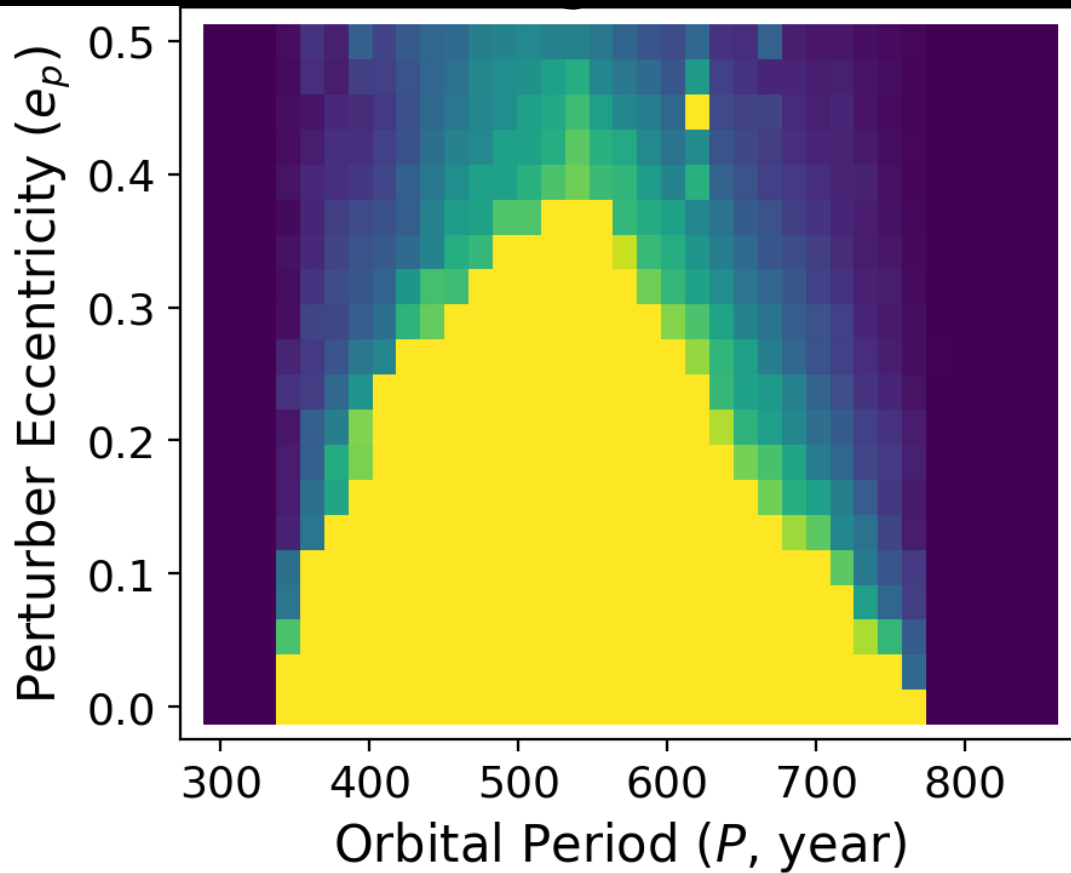
What should we be doing now?

Fully Characterize Dynamics of Target Systems

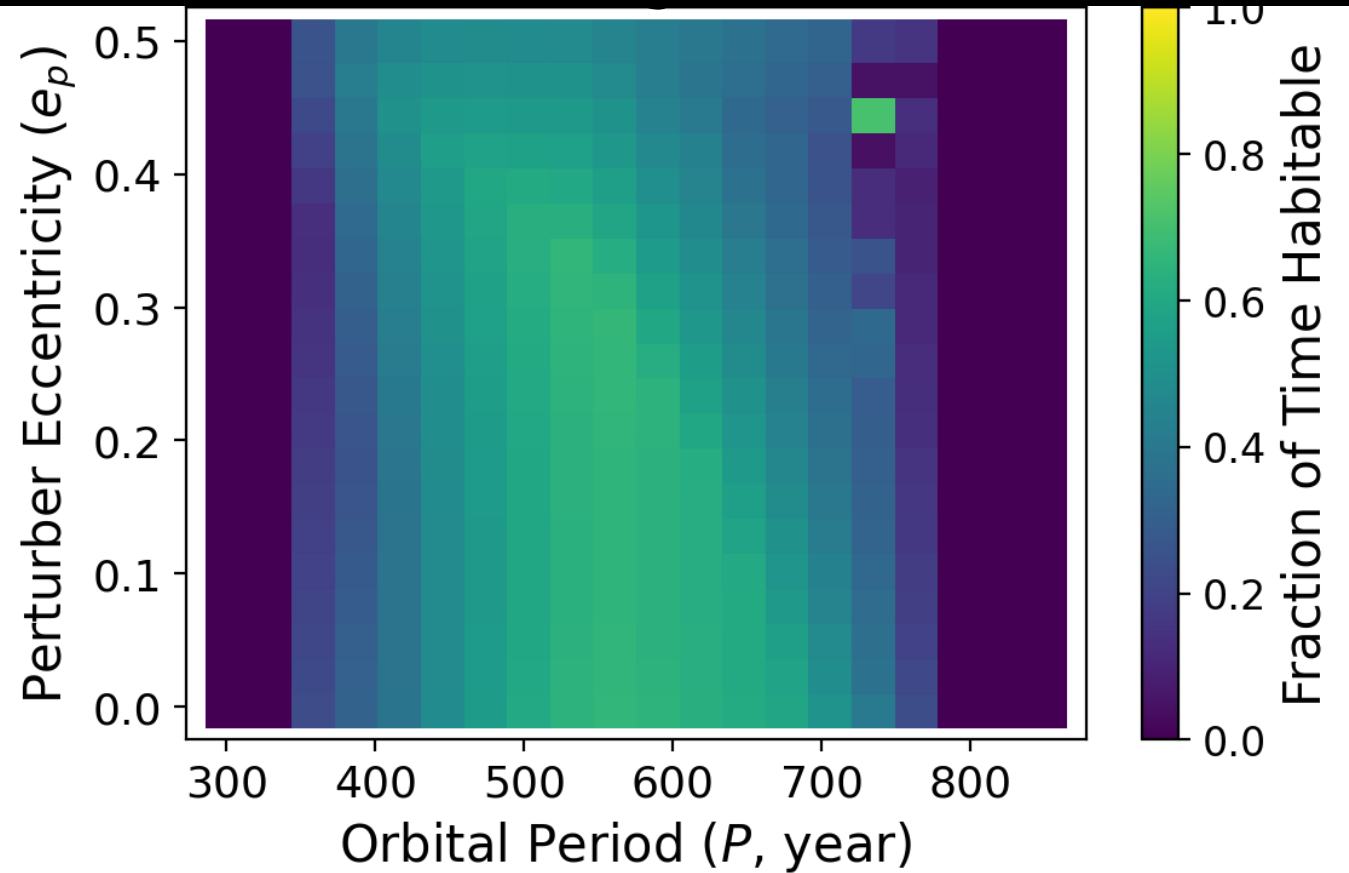


Why is this refinement important?

Coplanar with Earth-like planet

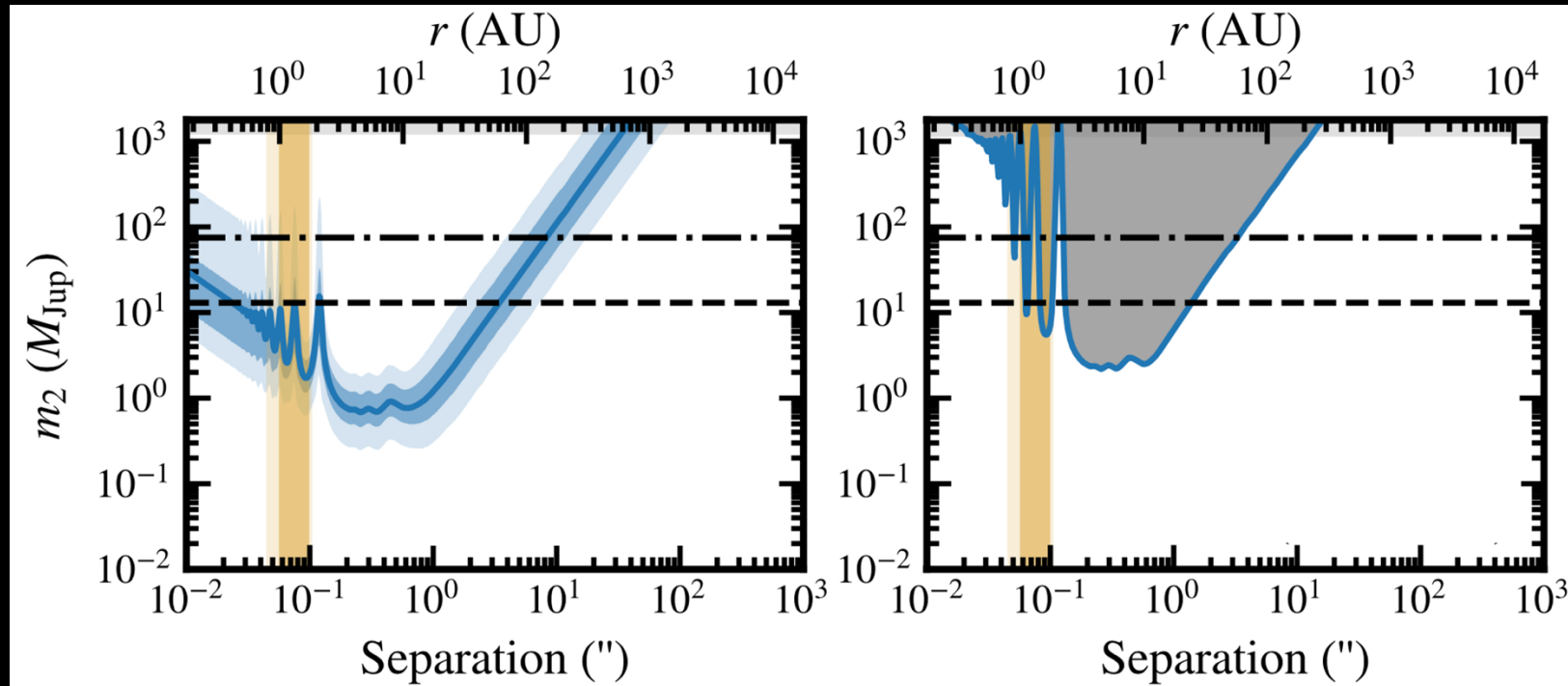


10 degrees misaligned



How do we set the stage?

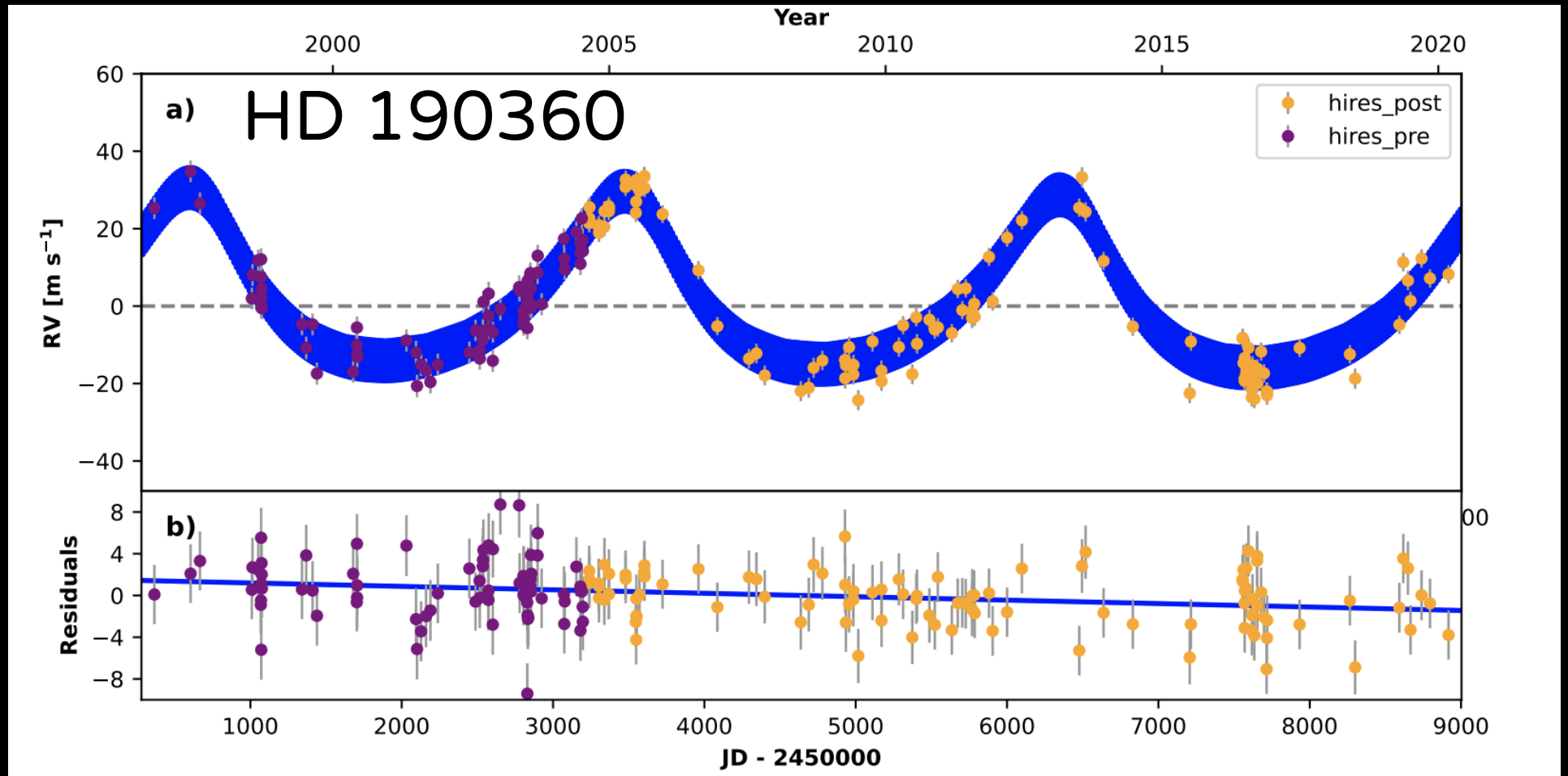
Katie Teixeira Painter
PhD Candidate,
University of Texas



Hipparcos
with Gaia
EDR3 - >
detection of
~Jupiters out
to ~10 AU

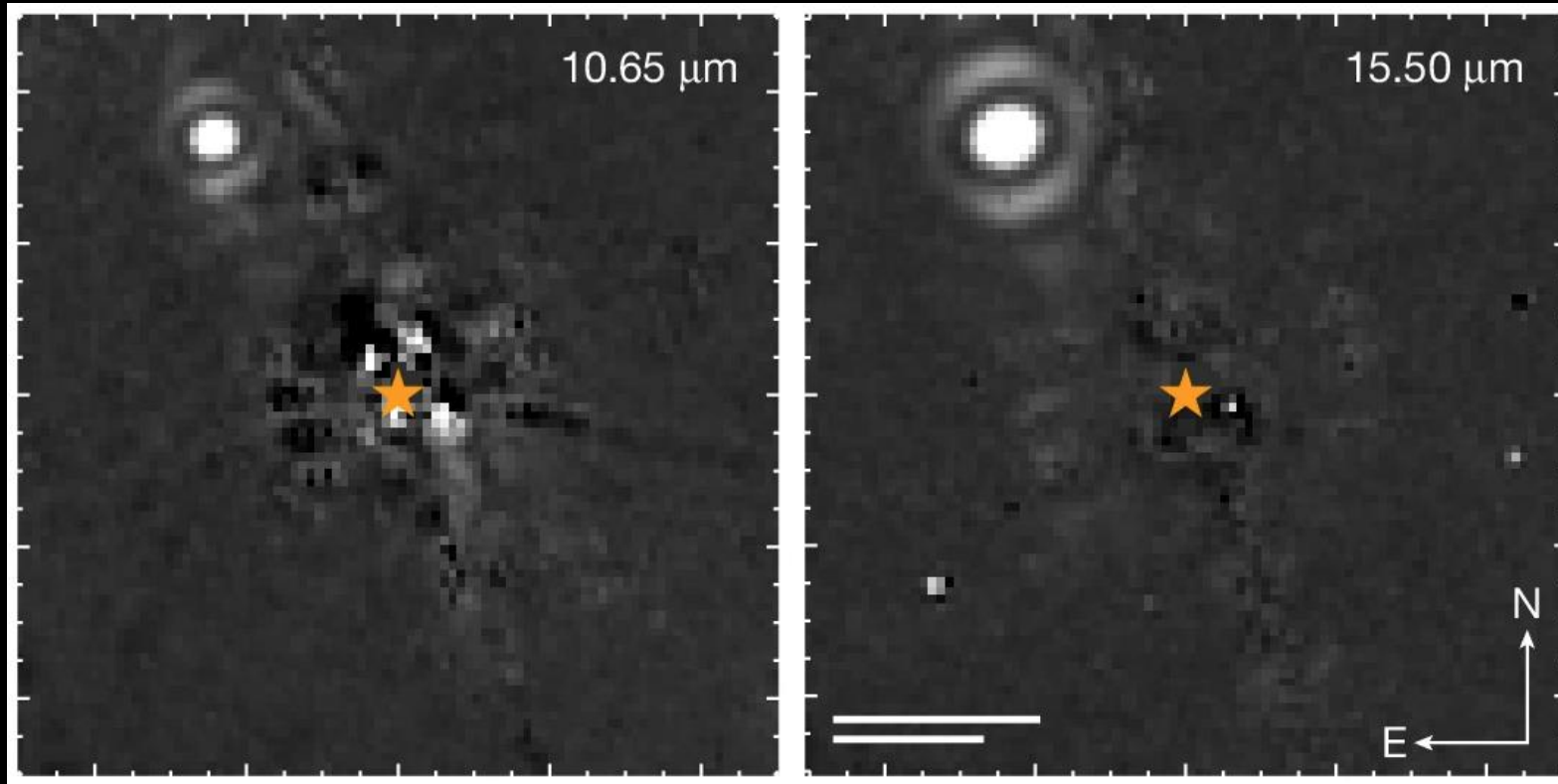
Painter et al. submitted

How do we set the stage?



Harada et al.
submitted

How do we set the stage?



JWST-MIRI can find cold, distant planets outside regions presently accessible – up to 100s of AU!

Matthews et al. 2024



Dynamical Considerations for Habitability

1. Secular cycles may alter orbital parameters over time, leading to heat budget alterations
2. The exoplanet sample is more densely dynamically packed than the Solar System – multi-planet dynamics relevant and giant companion planets may provide a stabilizing or destabilizing influence
3. HWO alone cannot capture the full range of constraints we need to characterize these systems – the time to start is now!

Questions?

