Quantifying the Habitable Histories of Stellar Systems

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Introduction

What type of stars are the best targets in a search for Biosignatures?

- Astronomers have a qualitative understanding of which stars make good targets
  - Not massive stars, giants, neutron stars, white dwarfs?
  - Yes: Sun-like, older FGK stars
- We want to quantify and formalize this intuition
- Potentially useful for prioritizing target stars for future missions

Formulation for Long-term Habitability Metrics

$$B = \int \int H(a,t)\Gamma\left(a, R_p\right) da\, dR_p$$

- **Γ(a,R)** is the distribution of planets in semimajor axis and radius
- **H(a,t)** is the probability of biosignature emergence as a function of distance and time.

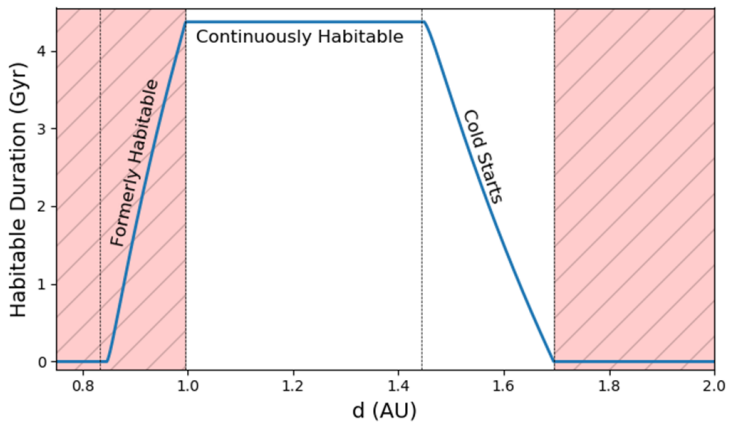
Possible Forms of Gamma

- Can use any realistic form for distribution of Earth-like planets
- We consider two contrasting forms:
  - Uniform in a
  - Uniform in ln(a)

Possible Forms of H

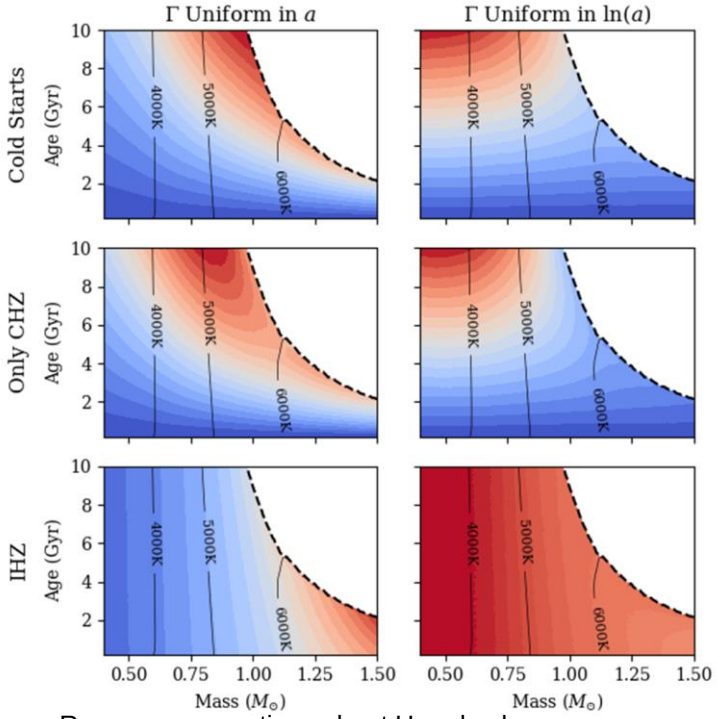
- All planets in current instantaneous habitable zone (IHZ) have same chance of hosting biosignatures (naïve, often implicitly assumed)
- More physical assumptions depend on the time spent in the habitable zone (see section below)
  - Probability of hosting biosignatures is proportional to time spent in the continuously habitable zone (CHZ)
  - H is proportional to time spent in the habitable zone (including Cold Starts)

Habitable Duration



- Time spent in habitable zone as a function of distance
- Continuously Habitable planets stay in habitable zone for duration of stars lifetime
- Cold starts enter habitable zone after forming outside of it

Comparison of Different Metrics



Row are assumptions about H and columns are assumptions about Gamma

Major Findings

- Different assumptions about H and Gamma affect what populations of stars are preferred
- Using only the current day habitable zone leads to misleading priorities in a search for biosignatures
- To assess long-term habitability one requires precise stellar evolutionary tracks
- This work served to introduce a framework for calculating biosignature yields that we will use in future studies.