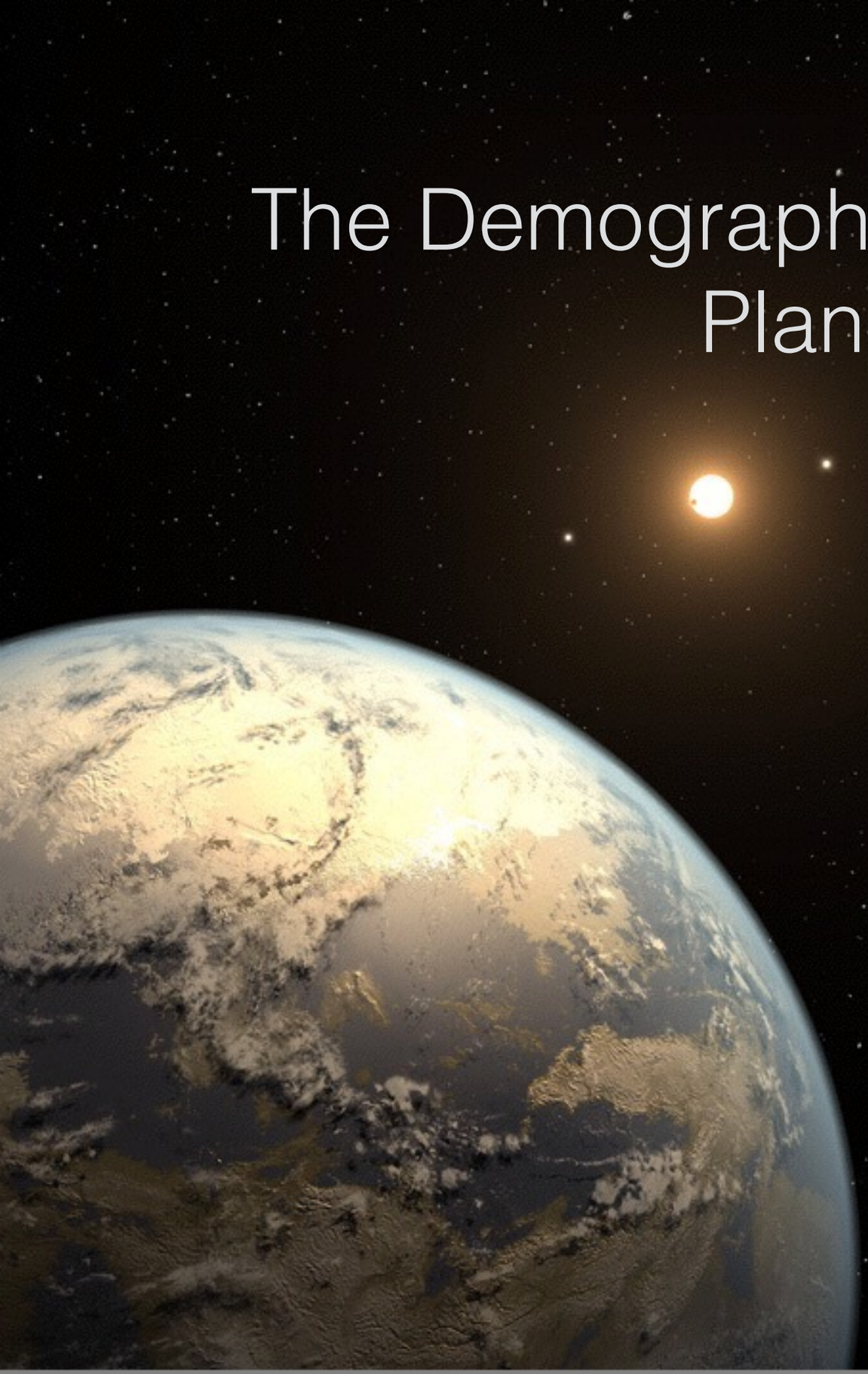
The Demographics of Rocky Free-Floating Planets and Their Detectability by WFIRST



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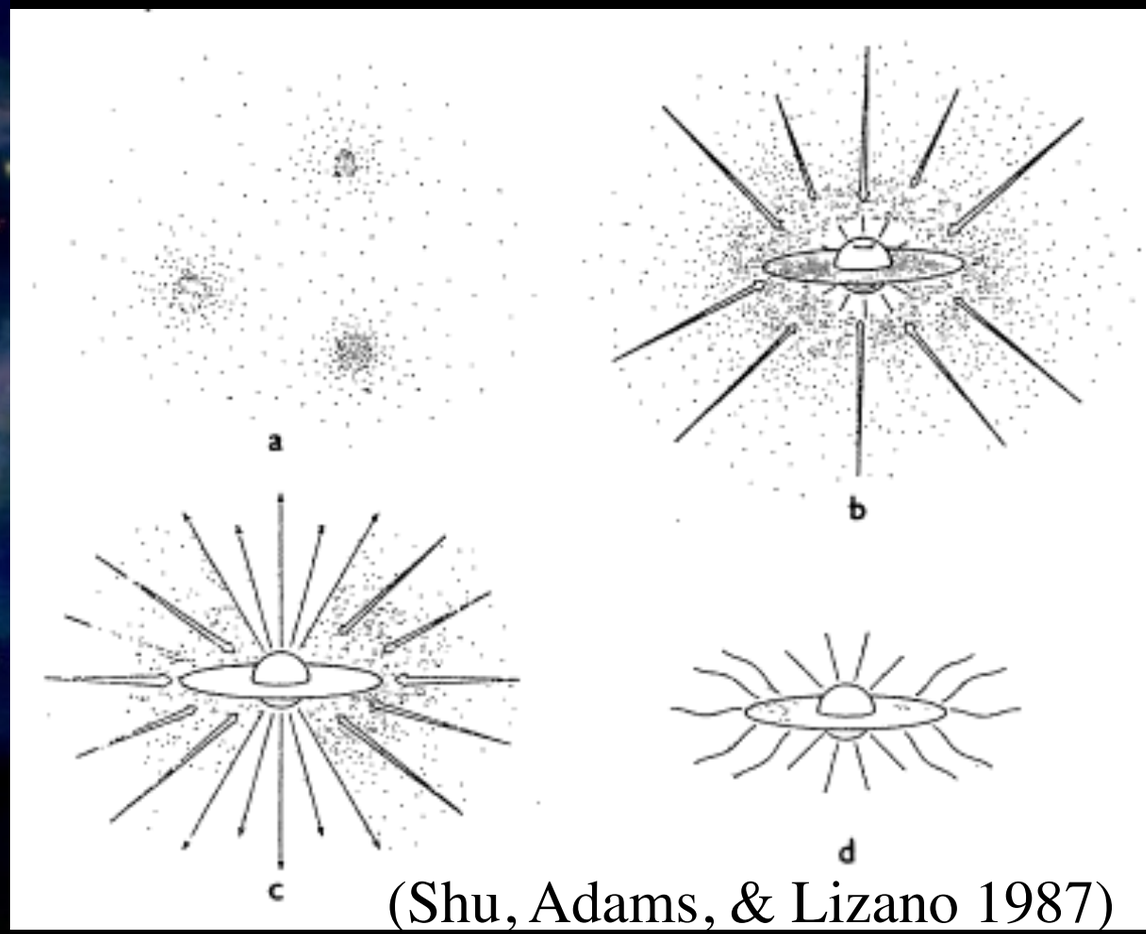
Planets Form From Disks



(Shu, Adams, & Lizano 1987)

Collapse of molecular cloud core ⟶ proto-star + disk

Classical Solar Nebular Theory

Early stage

dust grains ⟶ planetesimals

~ μm ~1-10 km

Middle stage

planetesimals ➡ planetary embryos

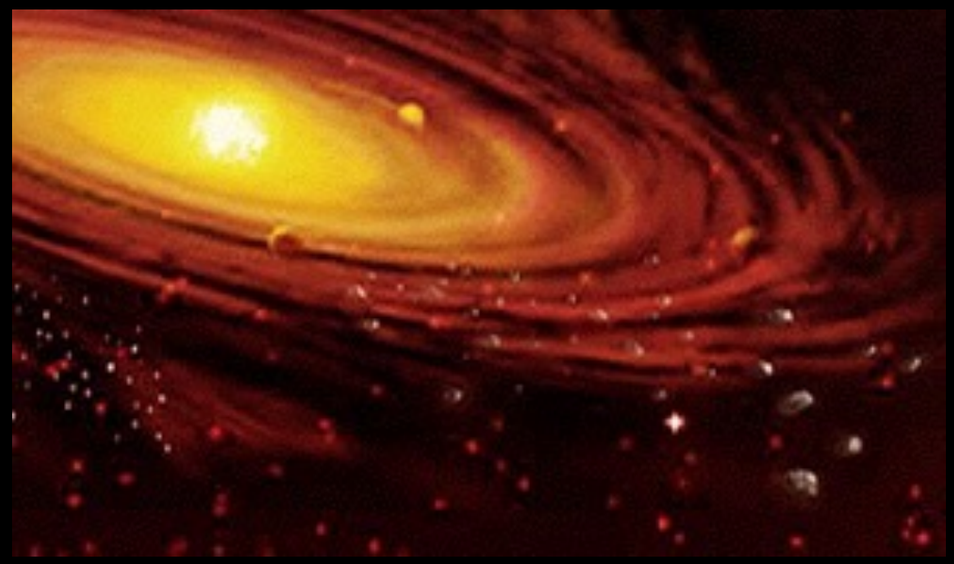
~10^3 km

Late stage

embryos ⟶ planets

Hundreds of Simulations

Sun + Jupiter + Saturn
(at present orbits)



Bimodal protoplanetary disk:
26 embryos (0.1 M_{Earth})
260 planetesimals (0.01 M_{Earth})
Smallest fragments = 0.5 lunar mass

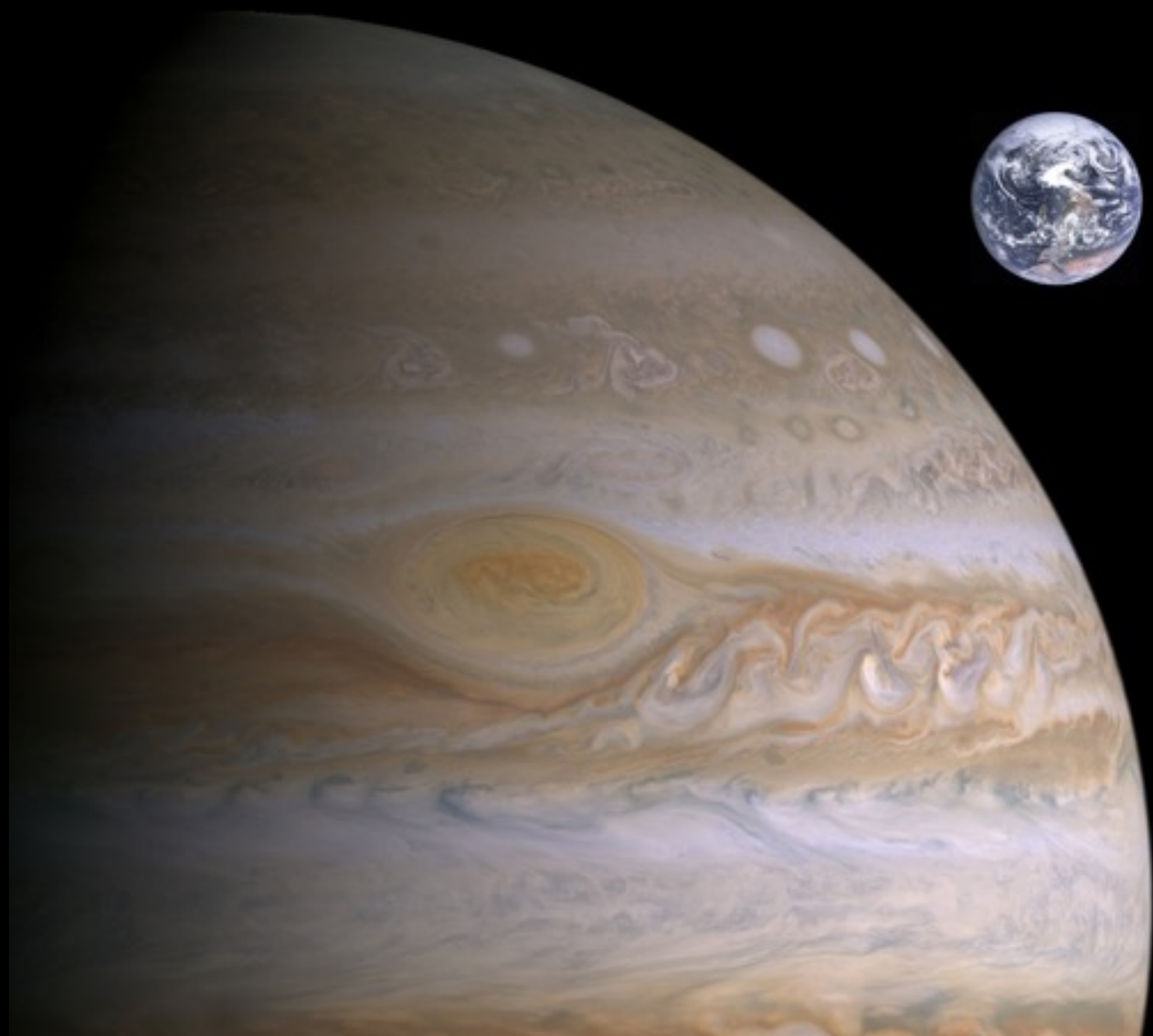
Small change in initial conditions in each simulation

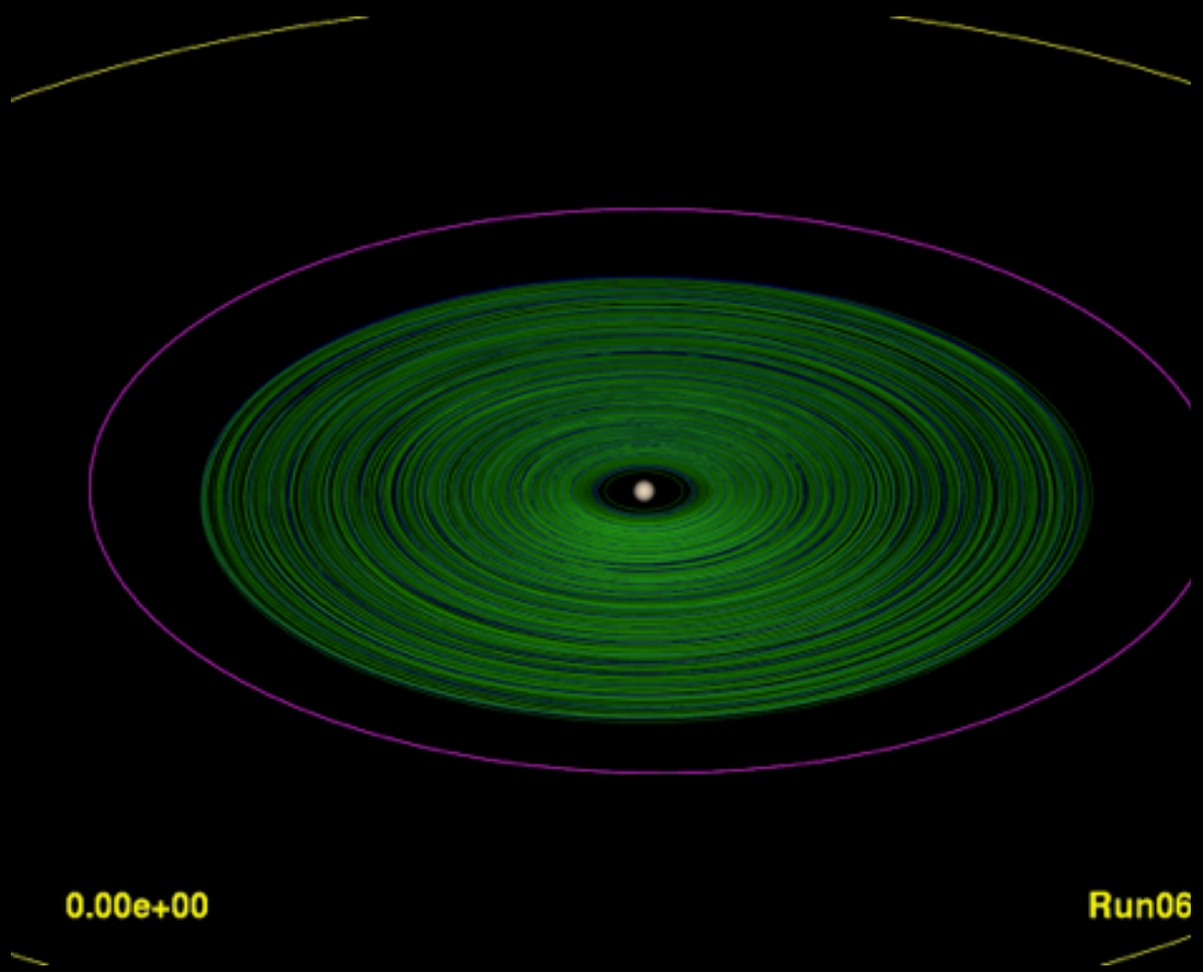
2 Gyr simulations, where all bodies fully interact gravitationally and collisionally

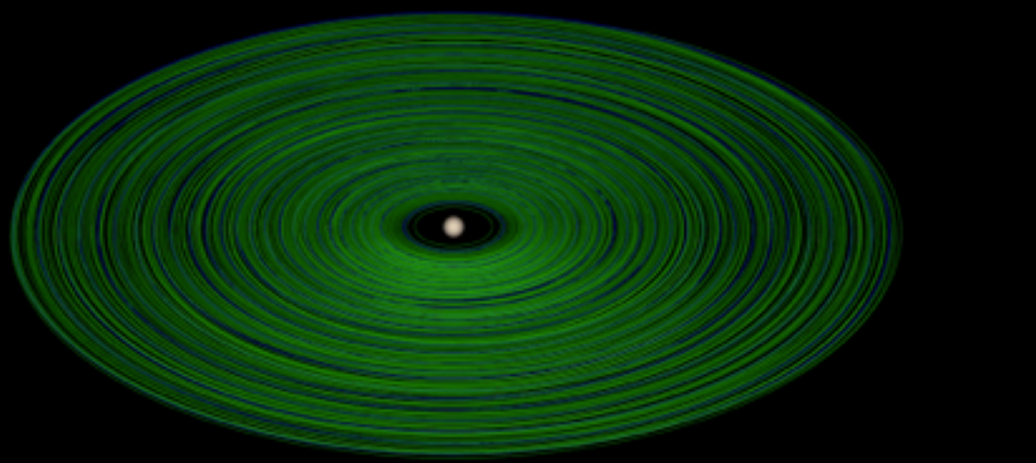
Jupiter analogs are likely scarce!

Occurrence Rates of Jupiter (RV + Transits) ~ 6%

(Wittenmyer et al. 2016)



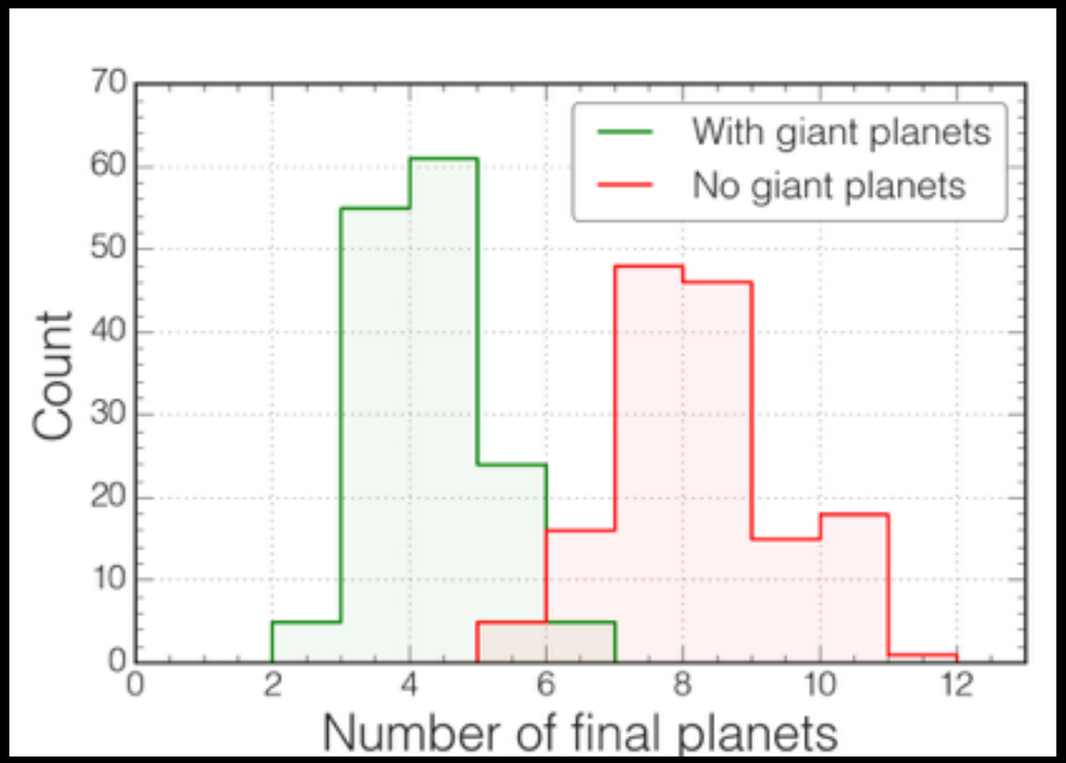




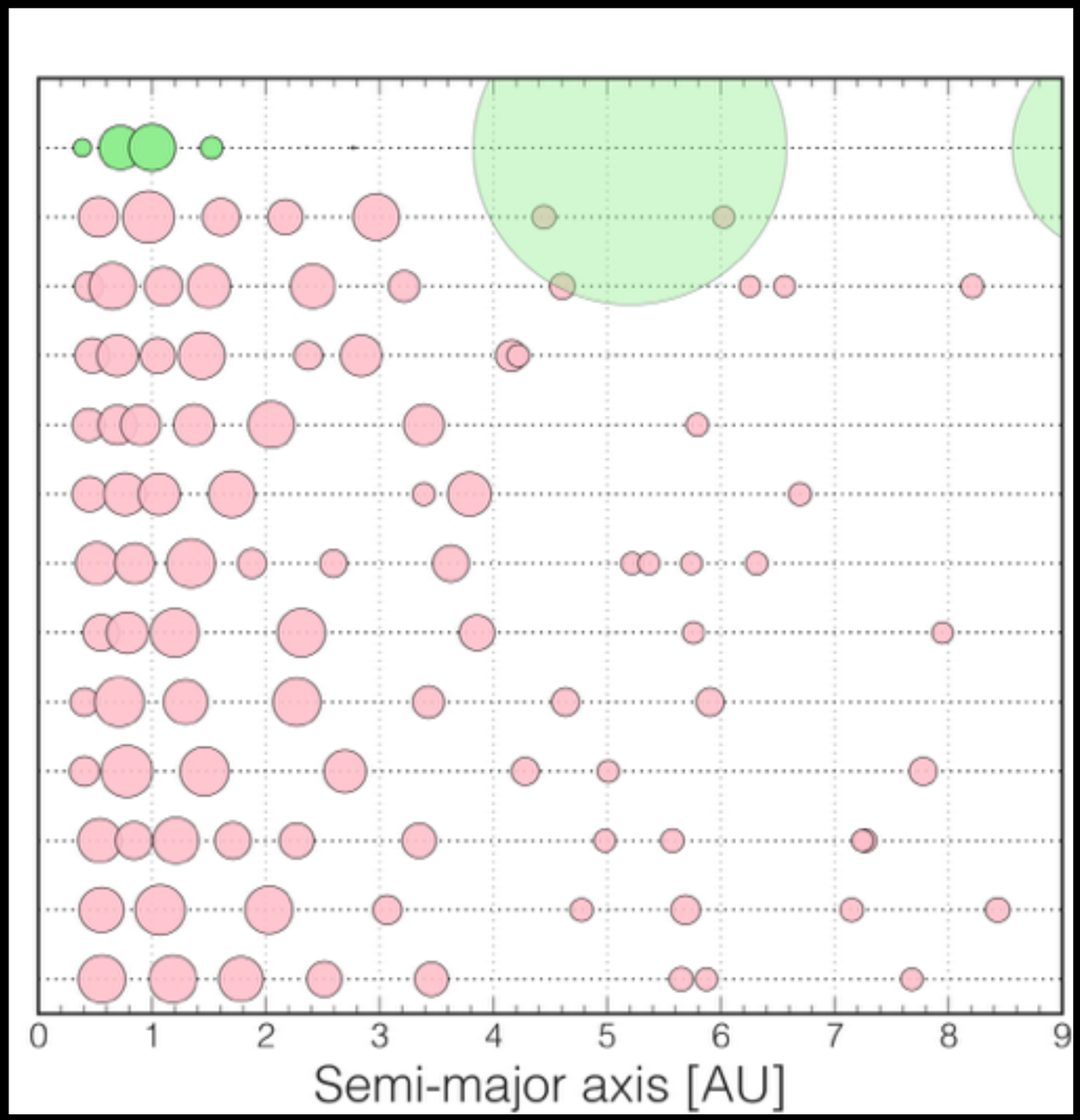
Jupiter+Saturn

No giant planets

Effect of Giant Planets



With no giant planets, more planets are formed but inner systems looks similar



WFIRST's microlensing program is going to be searching for free-floating planets.

How many will it find?

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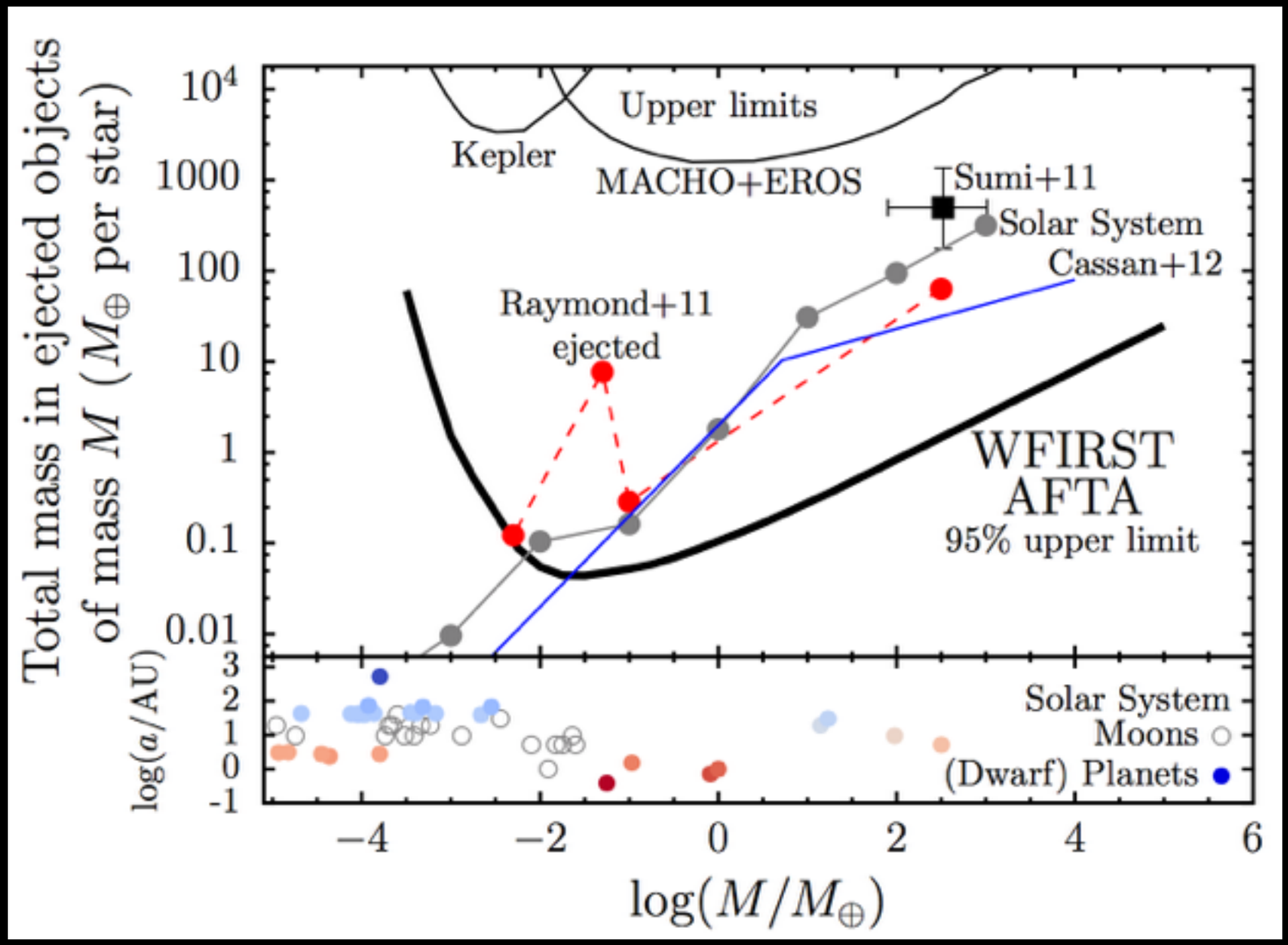
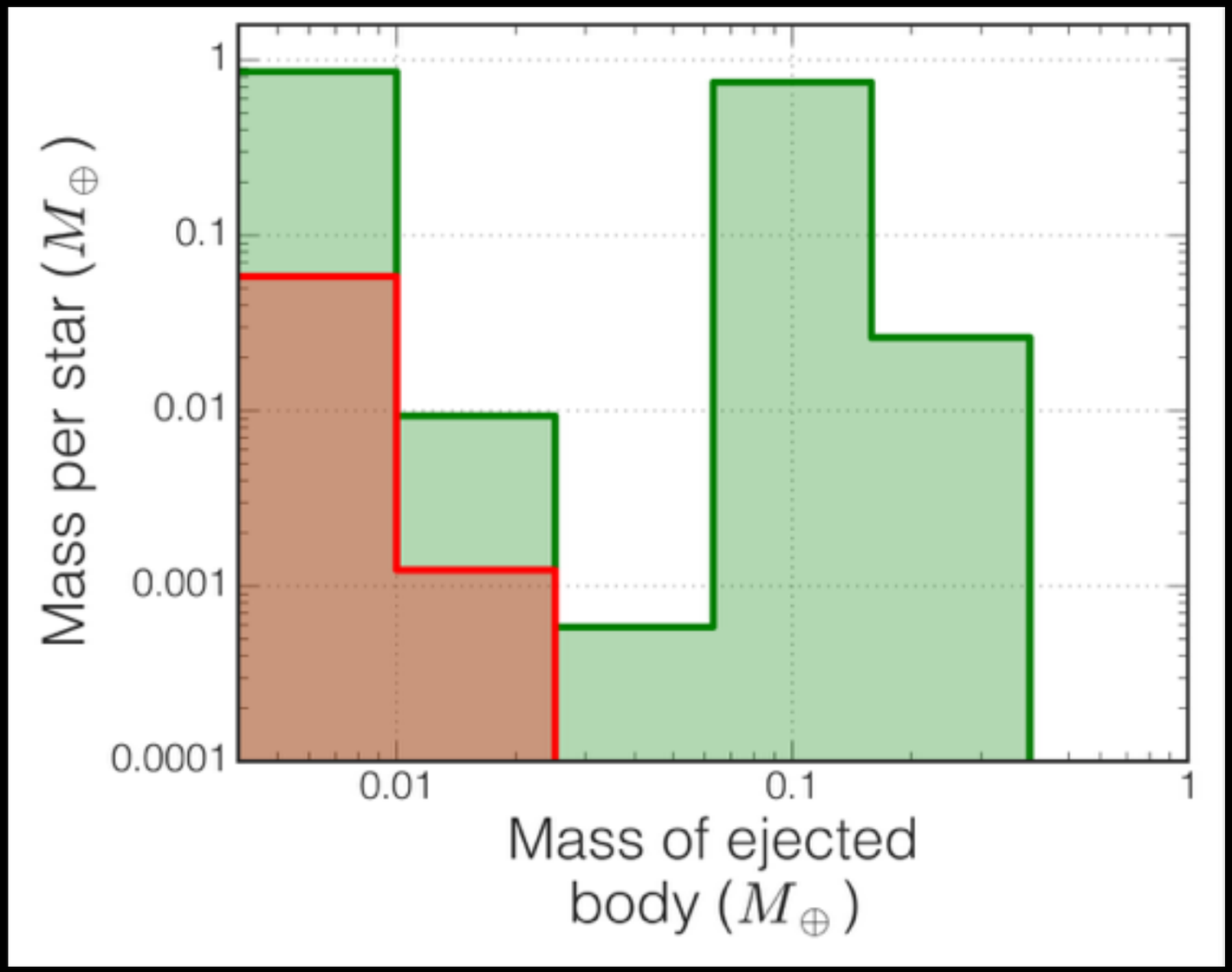


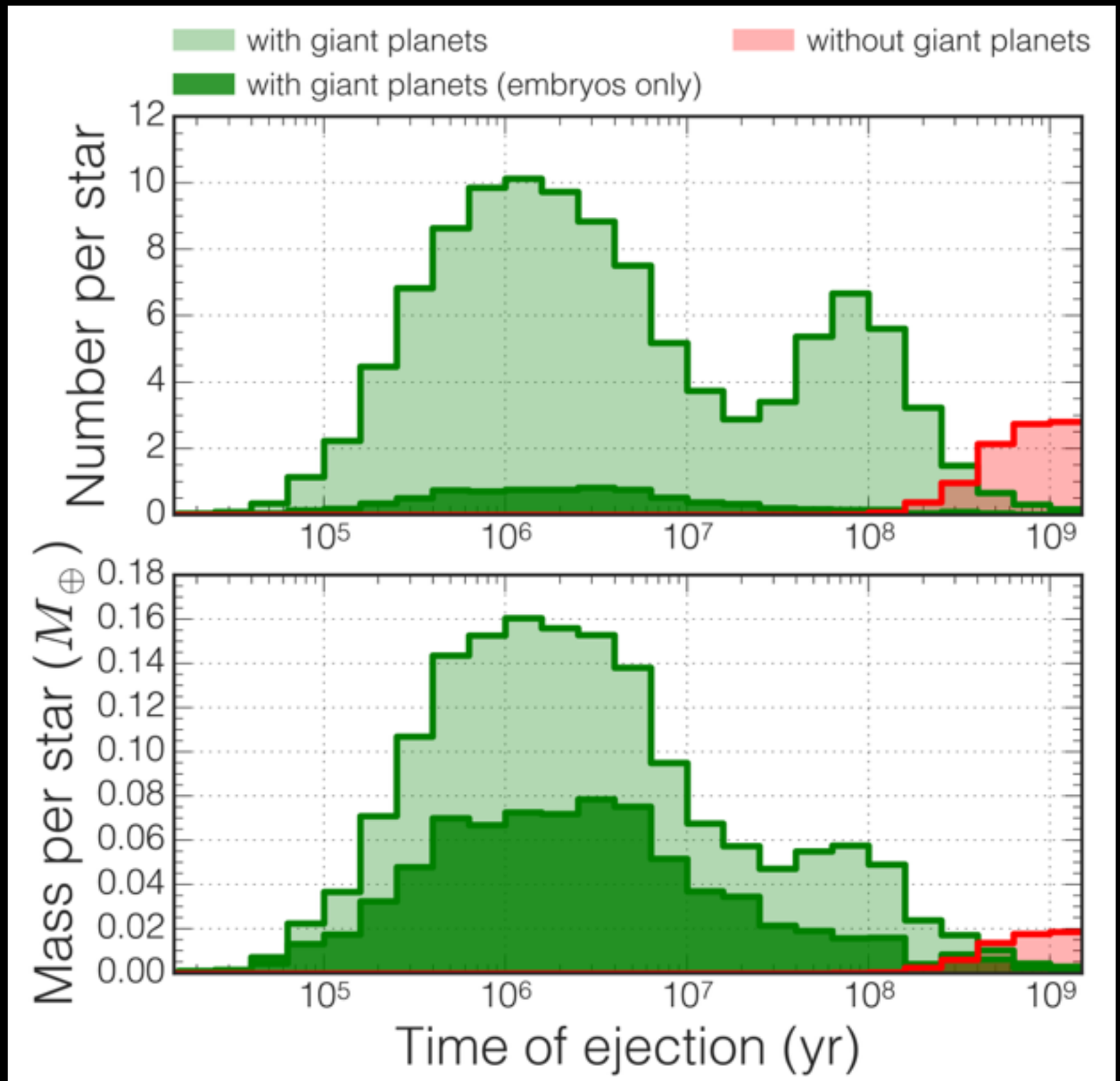
Mass in Ejected Material



1.6 Earth-masses per star in simulations with giant planets
Half the mass is in planets half in low-mass material

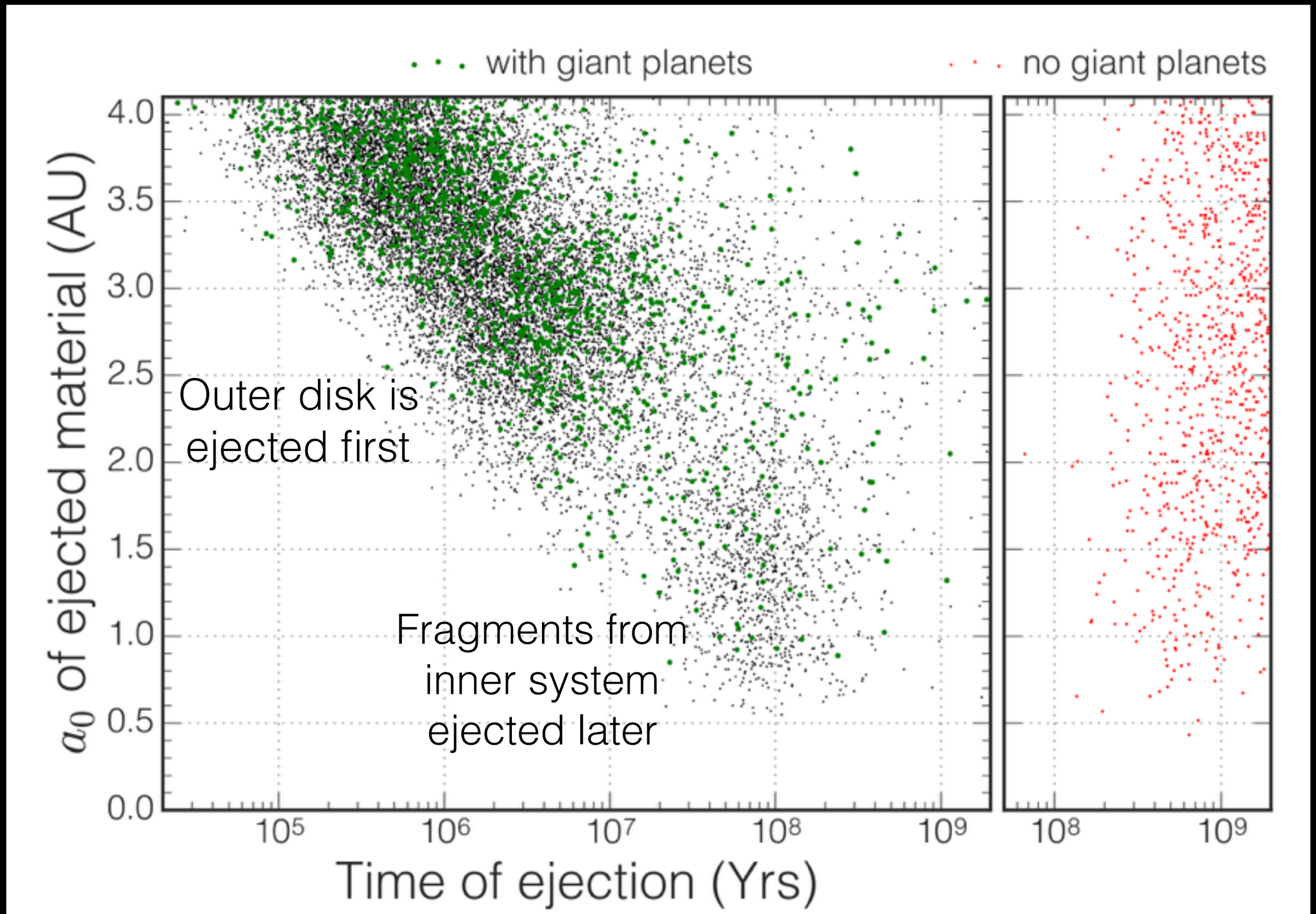
0.07 Earth-masses in systems without giant planets

Times of Ejections

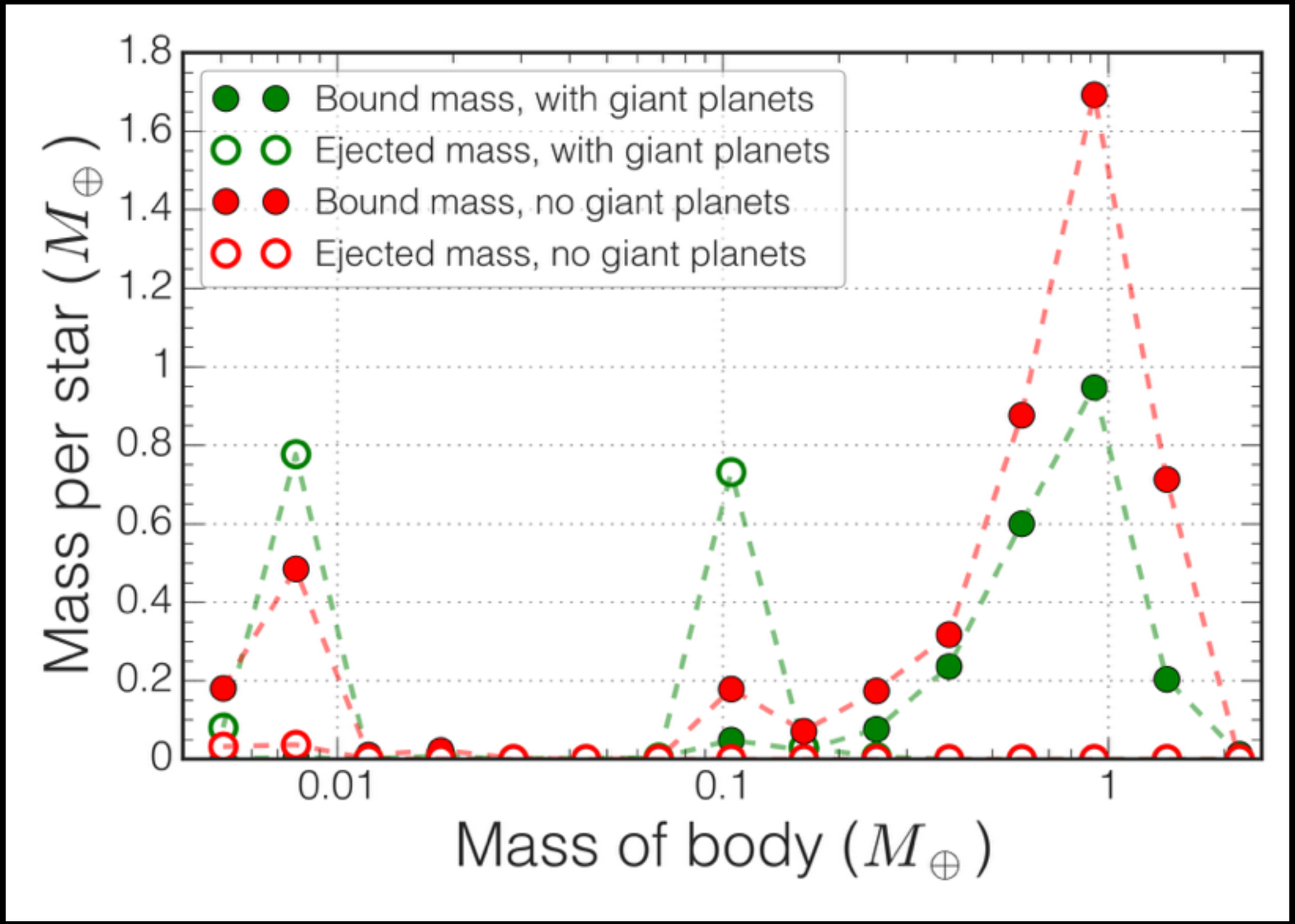


With giant planets, ejections happen early and often

Dependence on Initial Semimajor Axis



The Bound Population is unlike the Free-Floating Population

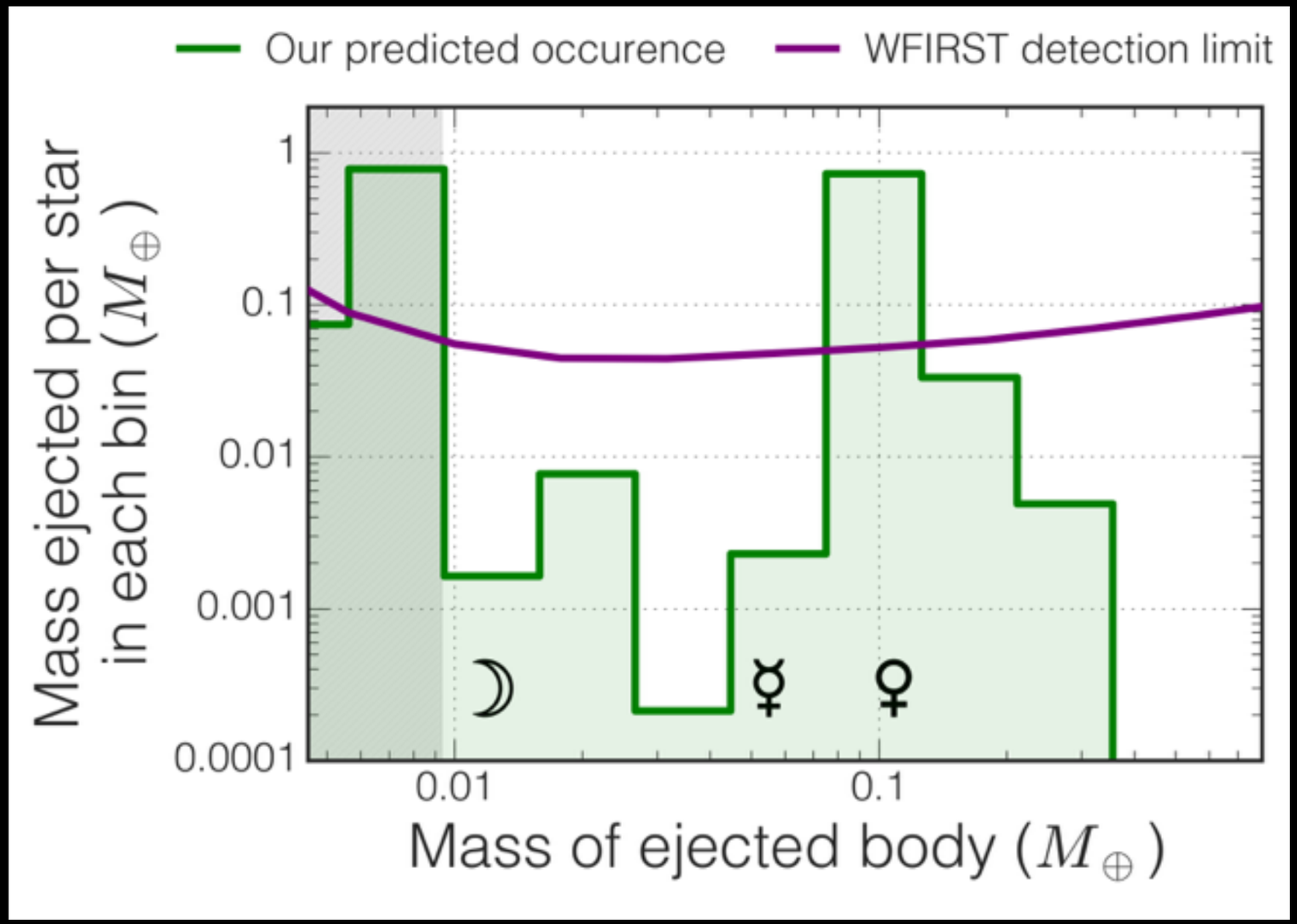


Predicting the WFIRST Yield

- Presume there are three populations of planets
  - Systems like our own with giant planets on stable orbits (6% of stars)
  - Systems with giant planets on unstable or executrix orbits (12% of stars), ejections from Raymond et al. 2011, 2012
  - Systems without giant planets (78% of stars)

- Multiplying these occurrence rates by the number of things ejected implies 3.2 Mars-mass embryos per star

WFIRST Detections



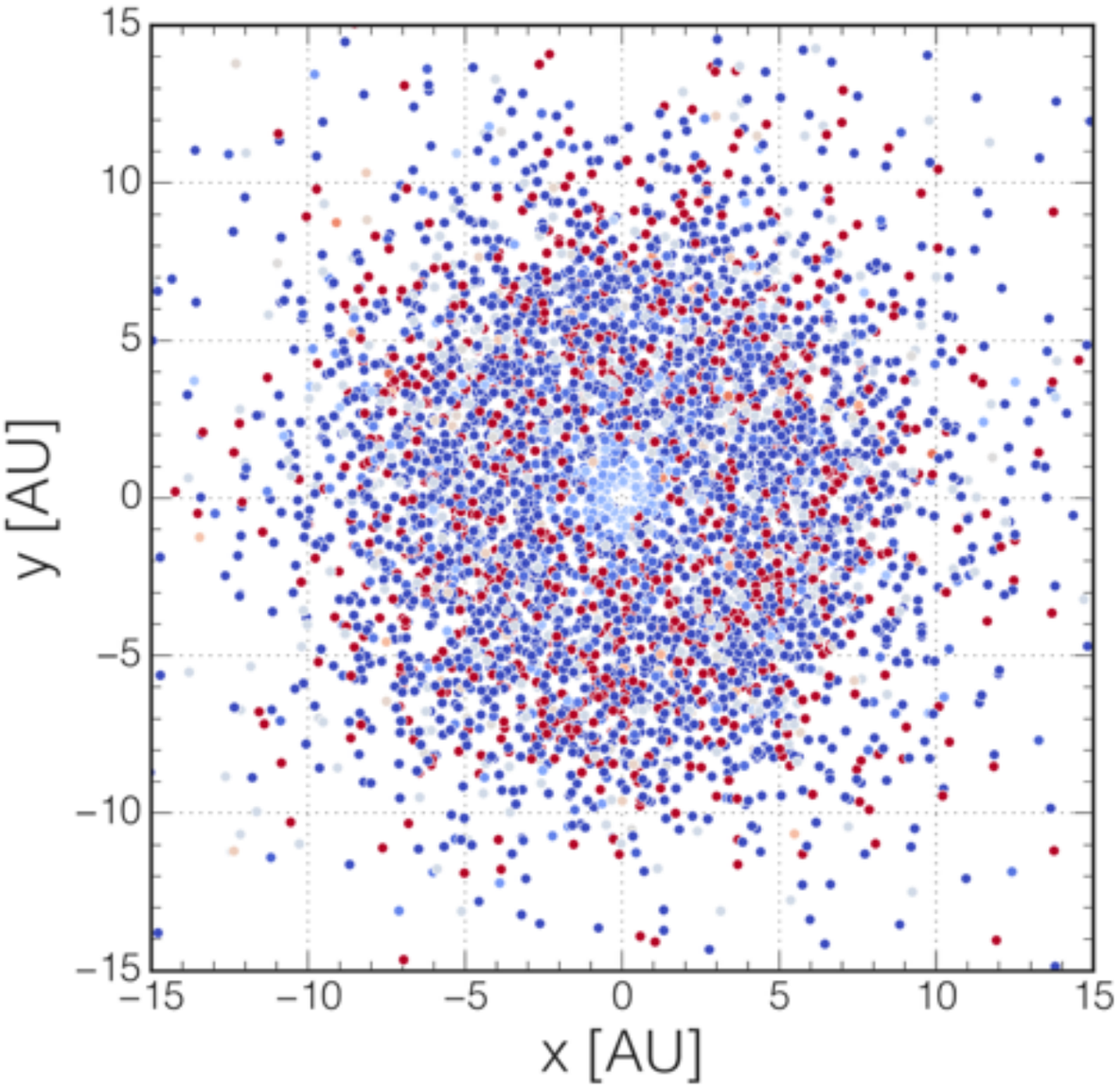
WFIRST will find a Mars' but few Earths

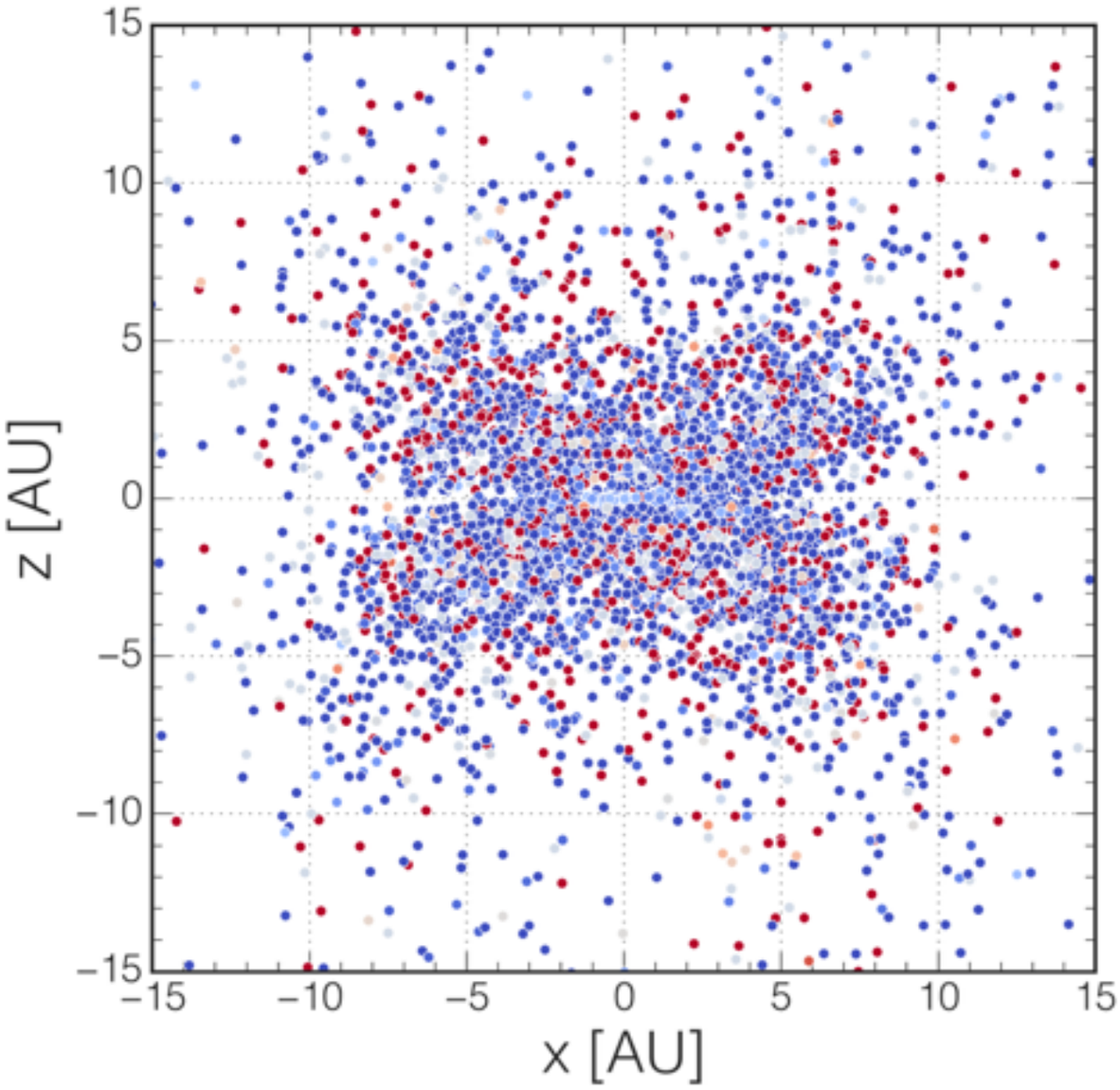
We predict that WFIRST will find 5.7 rocky free-floating planets

1.800e+09

Run028

Micro-Oort Clouds?





Conclusions

We modeled ejections from planetary systems with and without giant planets

With giant planet

- Around 1.0 Mearth of material is ejected but in bodies no larger than 0.3 Mearth
  - i.e. lots go Mars', no Earth's
- Ejections happen in two stages, an early stage of primordial material followed by a stage of process material

With no giant planet, almost very little mass is ejected

WFIRST will likely find a half dozen Mars', but only if giant planets are not uncommon