# Evidence for a Peak at ~0.3 in the Eccentricity Distribution of Typical Super-Jovian Exoplanets


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submitted to ApJL (today I hope)

# $0^{th}$ order planet formation physics is still unclear, and makes very different predictions at 0.1-5 au

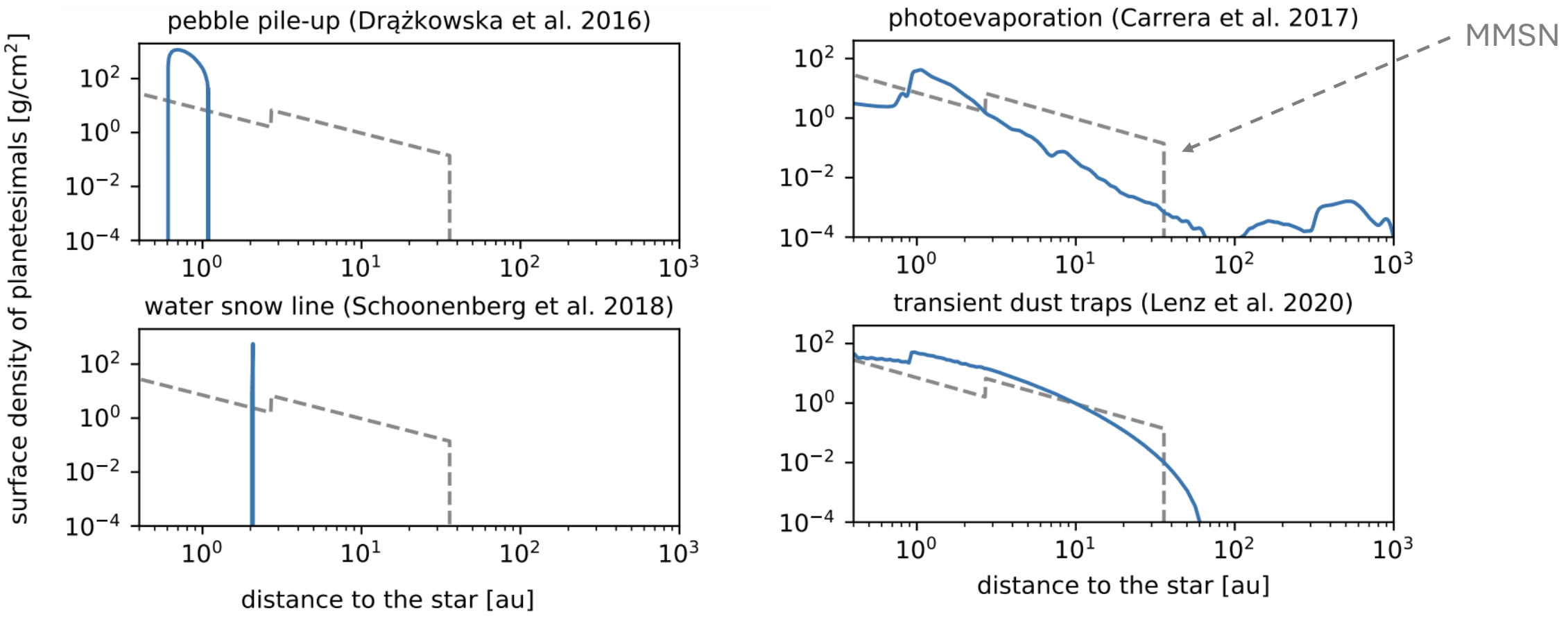



Figure from Drążkowska et al 2024

# $0^{th}$ order planet formation physics is still unclear, and makes very different predictions at 0.1-5 au

1st order post-formation physics is also unclear! Planet-planet scattering, secular interactions??

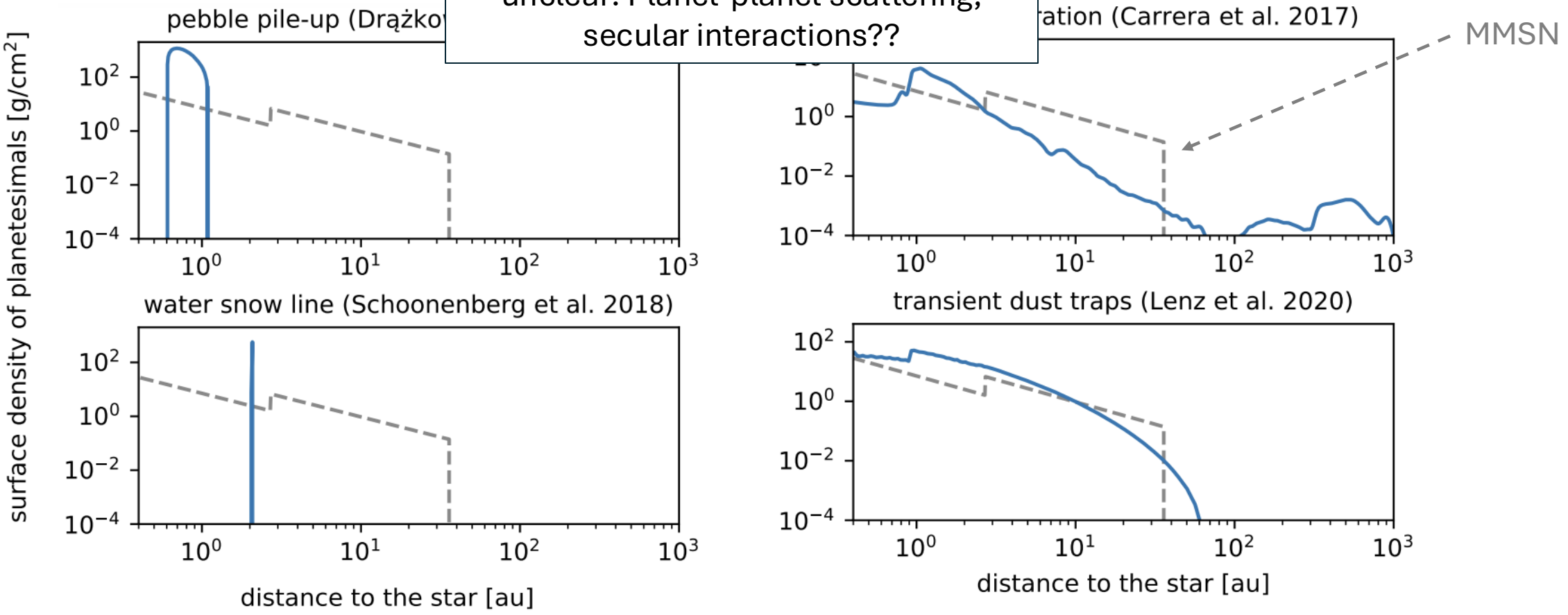
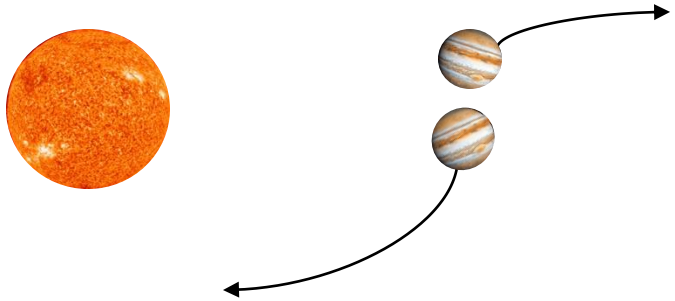


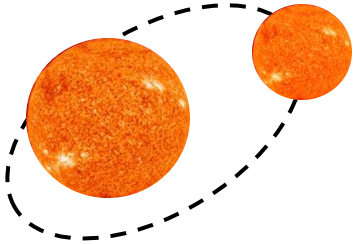

Figure from Drążkowska et al 2024

# Eccentricities for this critical 0.1-5au population can help unravel formation history.

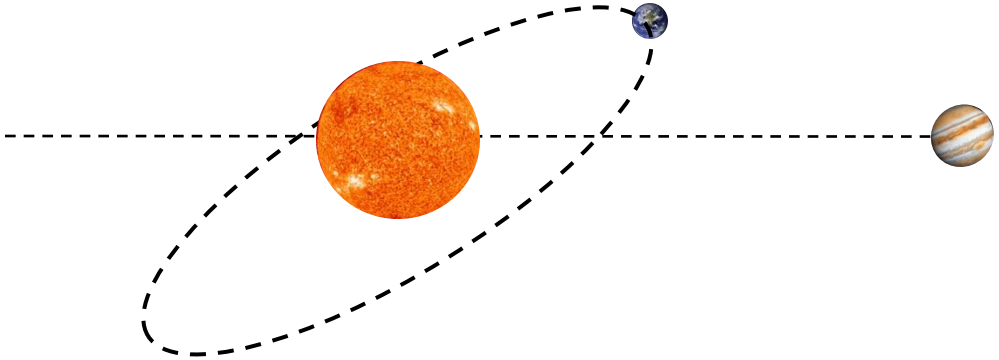
scattering events



formation mechanism

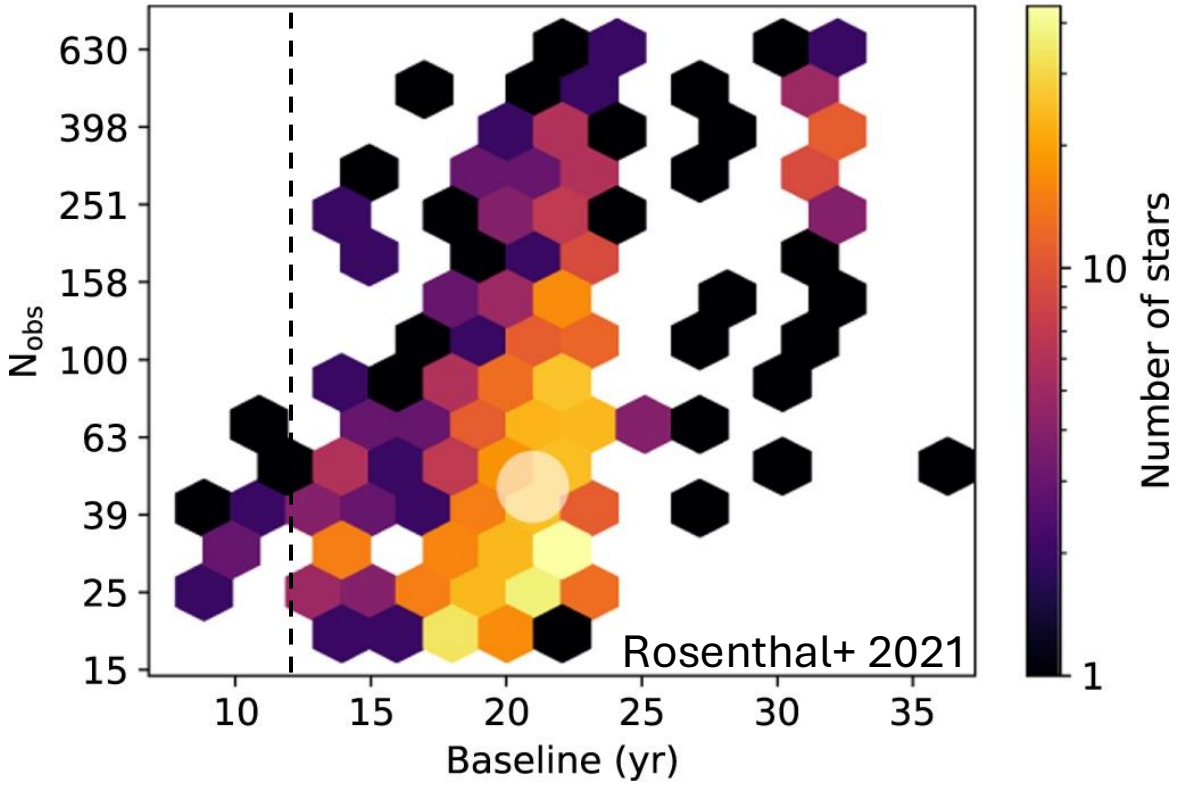


secular interactions



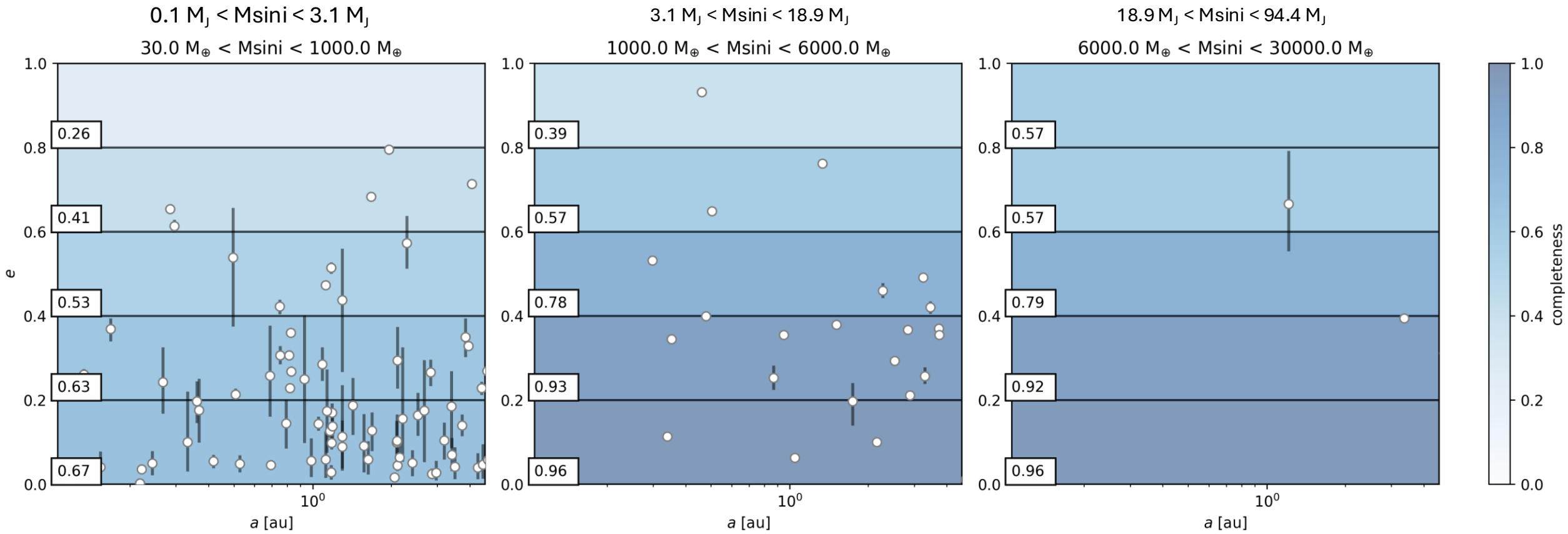
# As RV survey baselines increase, we can start to learn about the demographics of widely-separated giant planets.

Observing baselines for stars in the California Legacy survey:



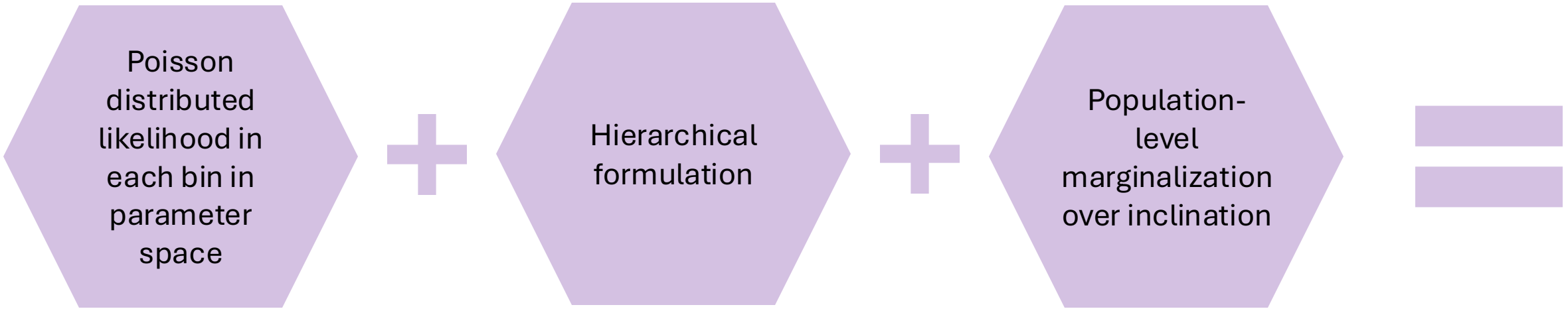
# We set out to model the eccentricities of “typical giant planets” at 0.1-5au.

## We started by modeling survey sensitivity:




Injection-recovery tests performed by BJ Fulton

# Next, we accounted for different types of uncertainty.



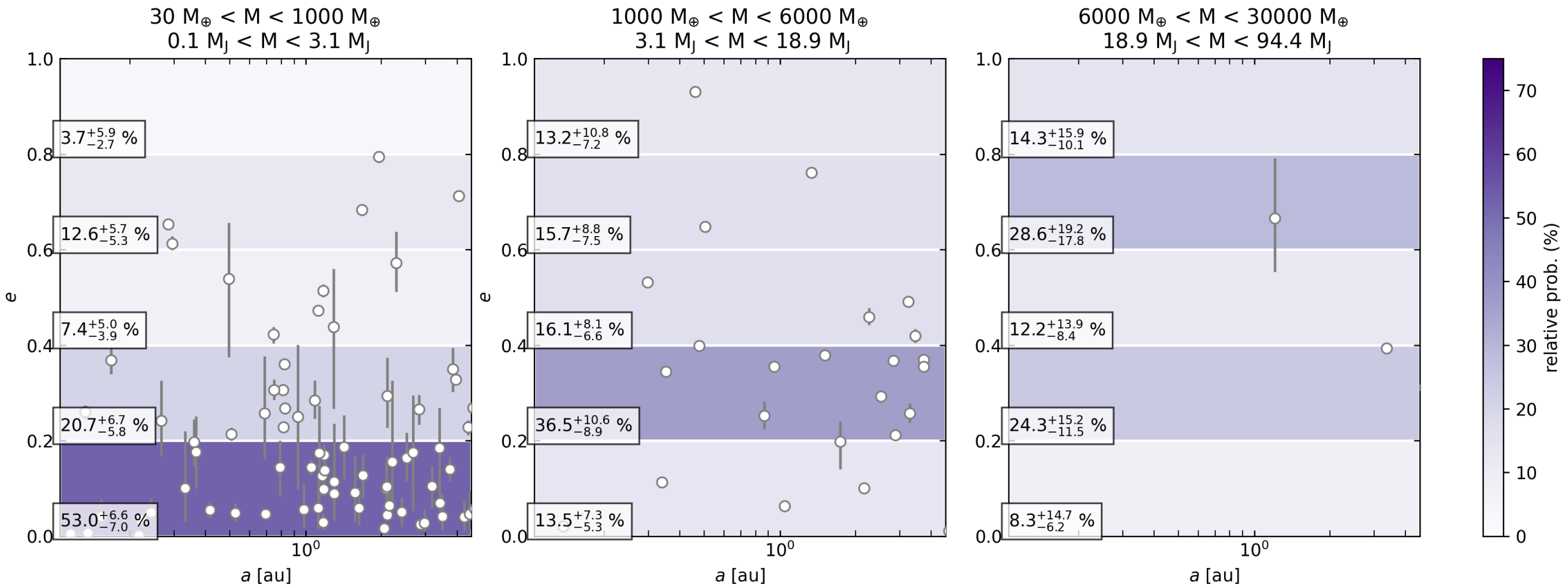

Accounts for counting statistics in observed sample

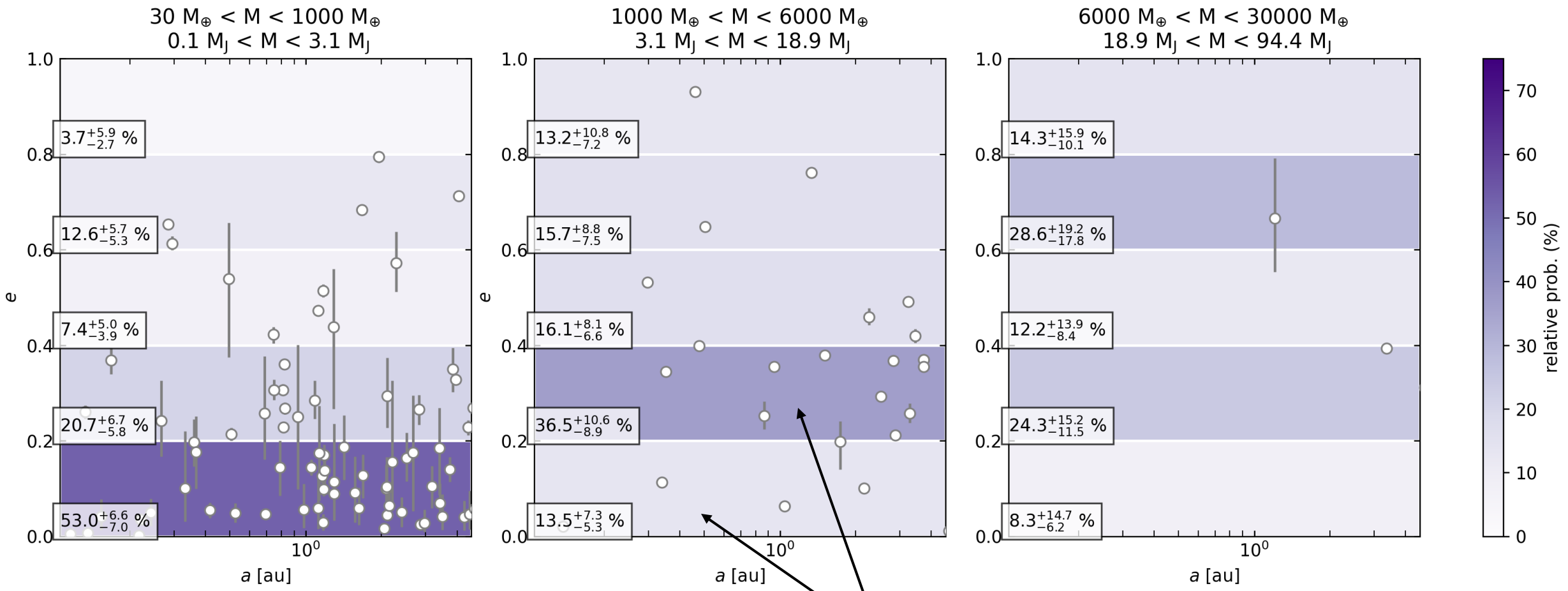
Accounts for uncertainty in individual planet parameters

Allows us to measure occurrence rates as a function of mass, even though we measure Msini



Based on methodology developed by Hogg+ (2010) and Foreman-Mackey+ (2014)


30 M⊕ < M < 1000 M⊕
0.1 MJ < M < 3.1 MJ
1000 M⊕ < M < 6000 M⊕
3.1 MJ < M < 18.9 MJ
6000 M⊕ < M < 30000 M⊕
18.9 MJ < M < 94.4 MJ
3.7+5.9−2.7 %
12.6+5.7−5.3 %
7.4+5.0−3.9 %
20.7+6.7−5.8 %
53.0+6.6−7.0 %
13.2+10.8−7.2 %
15.7+8.8−7.5 %
16.1+8.1−6.6 %
36.5+10.6−8.9 %
13.5+7.3−5.3 %
14.3+15.9−10.1 %
28.6+19.2−17.8 %
12.2+13.9−8.4 %
24.3+15.2−11.5 %
8.3+14.7−6.2 %
e
a [au]
relative prob. (%)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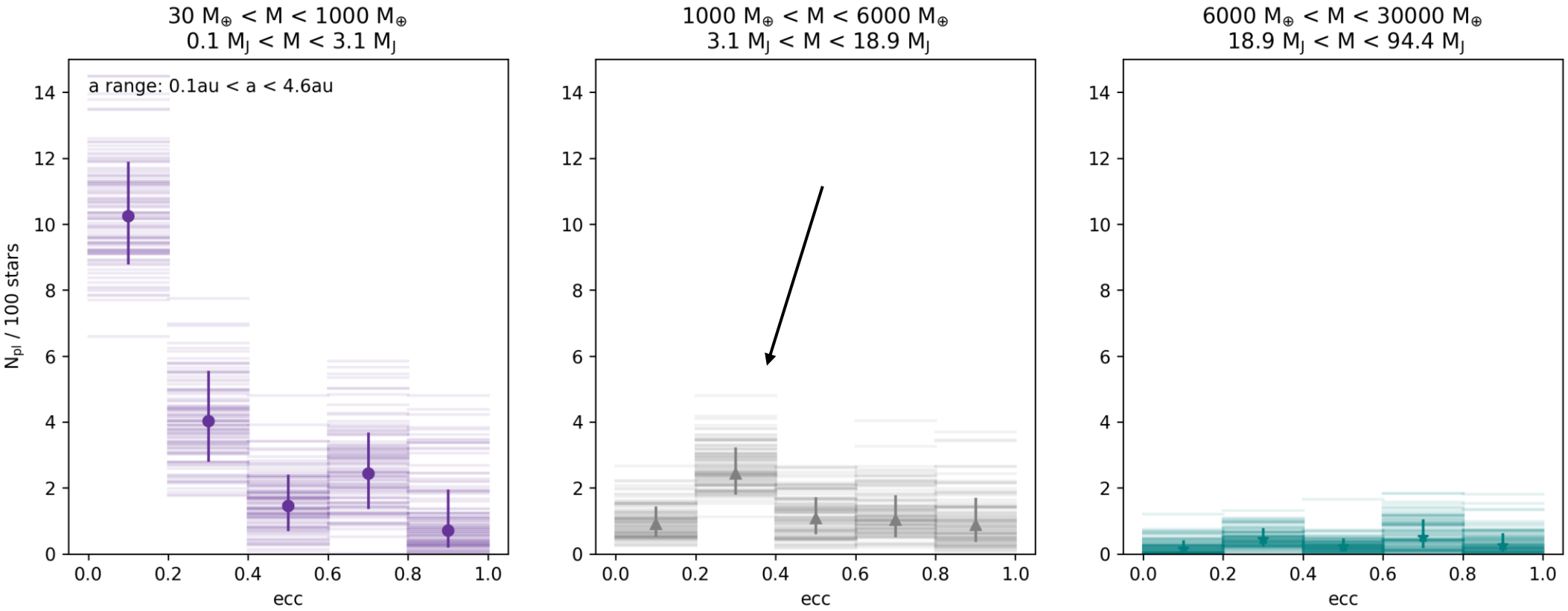
28.6+19.2−17.8 %
12.2+13.9−8.4 %
24.3+15.2−11.5 %
8.3+14.7−6.2 %
e
a [au]
relative prob. (%)
p(bin 2 > bin 1) = 98.7%

# Here are the same results in 1D:



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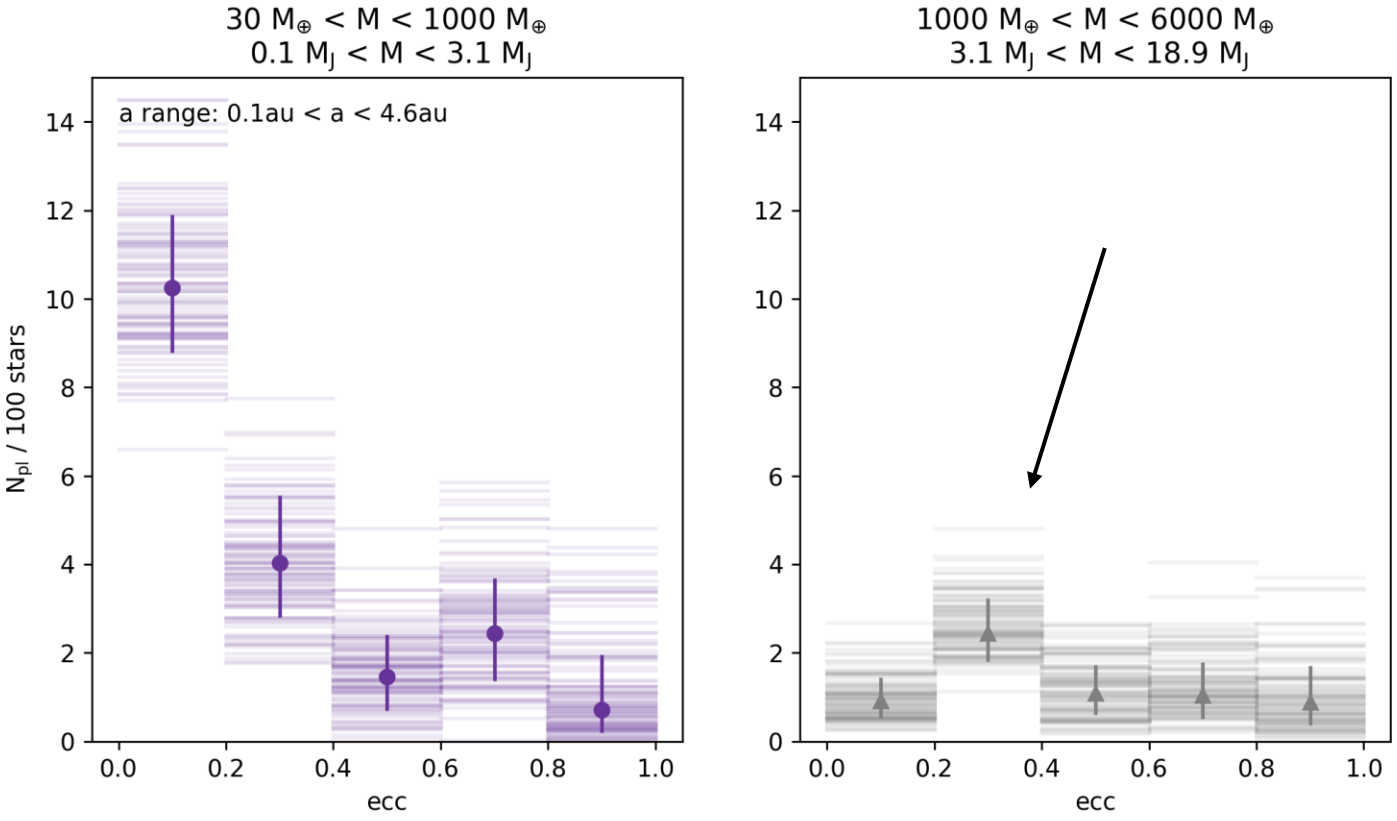
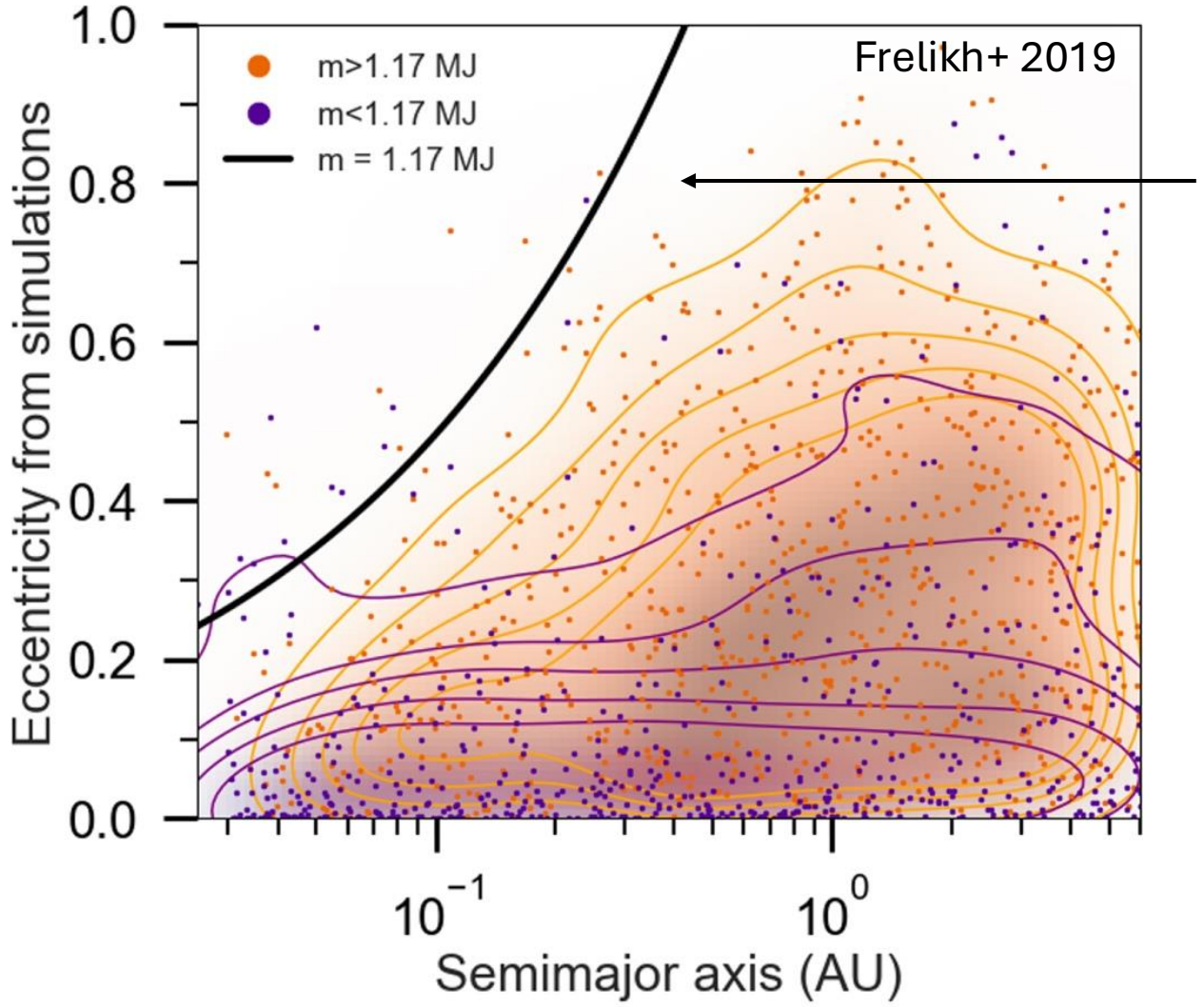
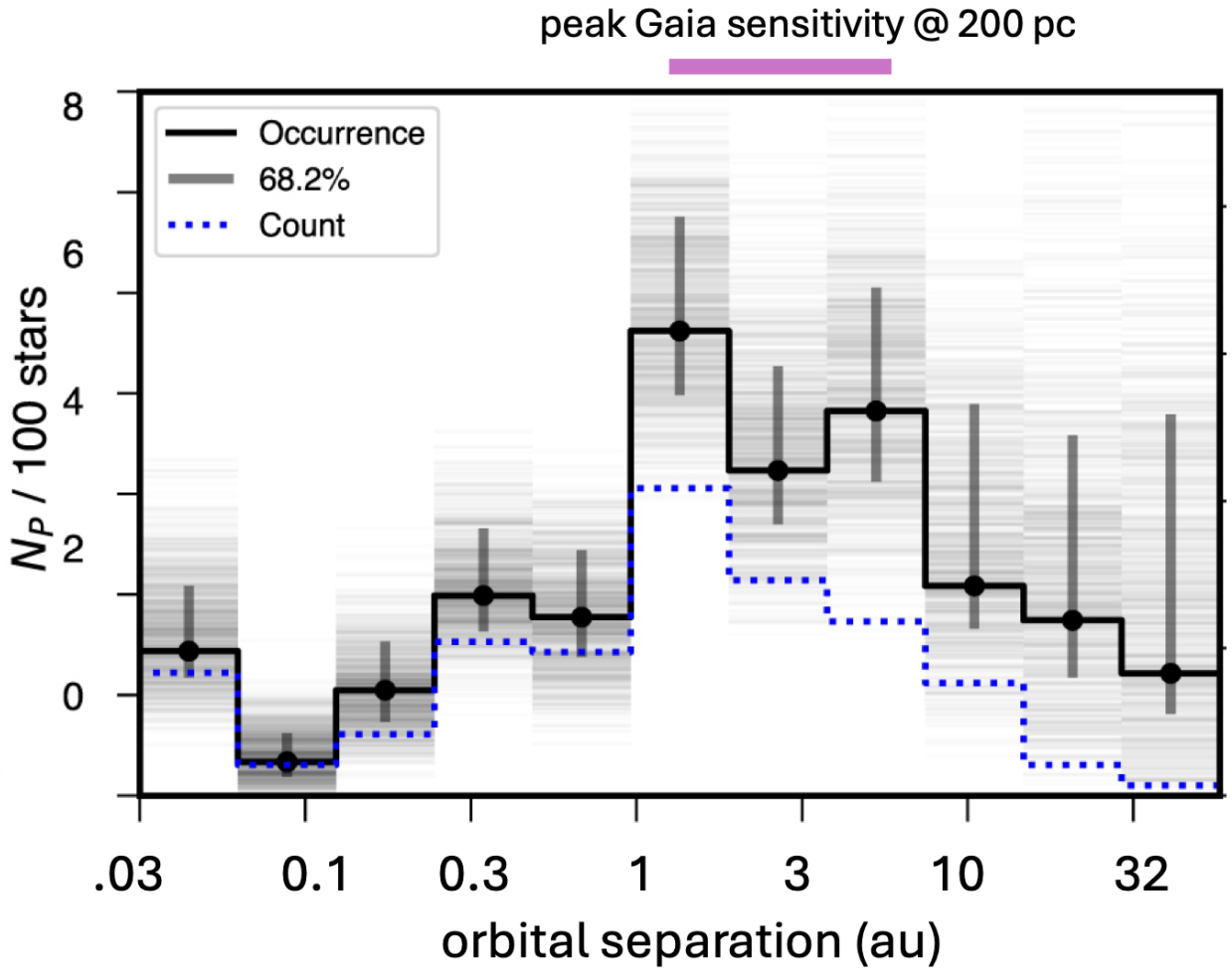



# The elevated eccentricities of giant planets ~1-5 au may point to a giant impacts phase.




Maximum eccentricity achievable before collision

# These trends are still coarse. We're excited for Gaia DR4, which should blow these statistics out of the water.



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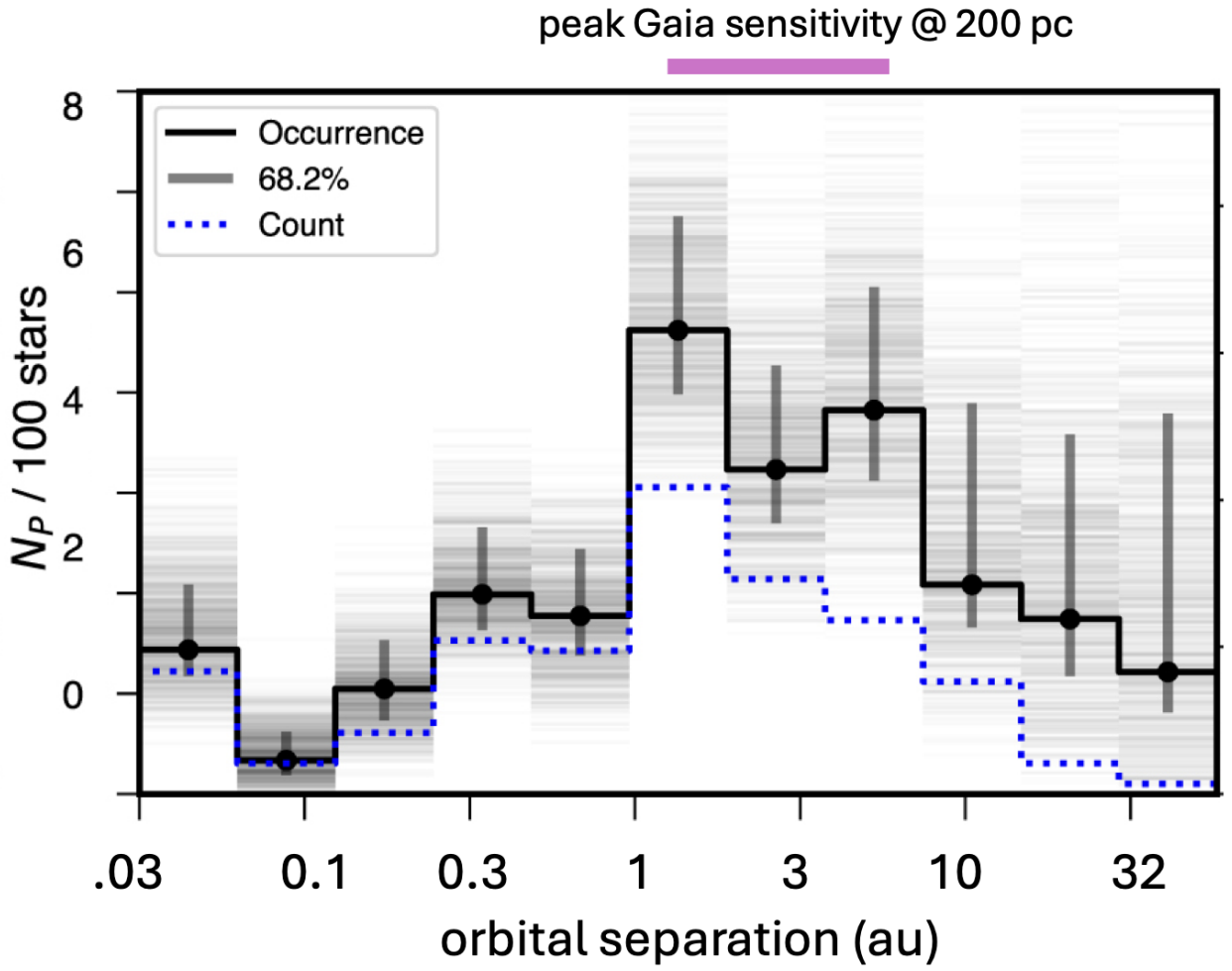
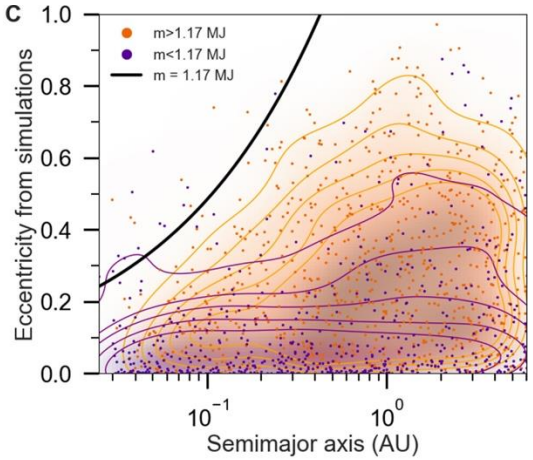
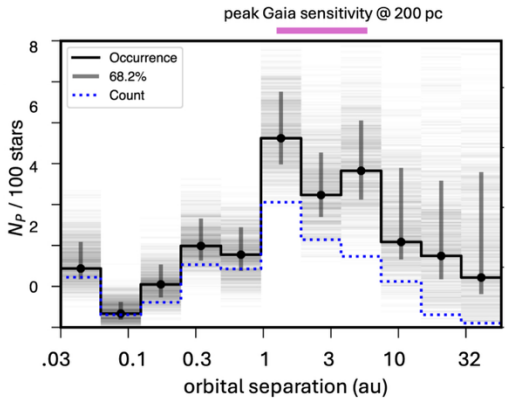


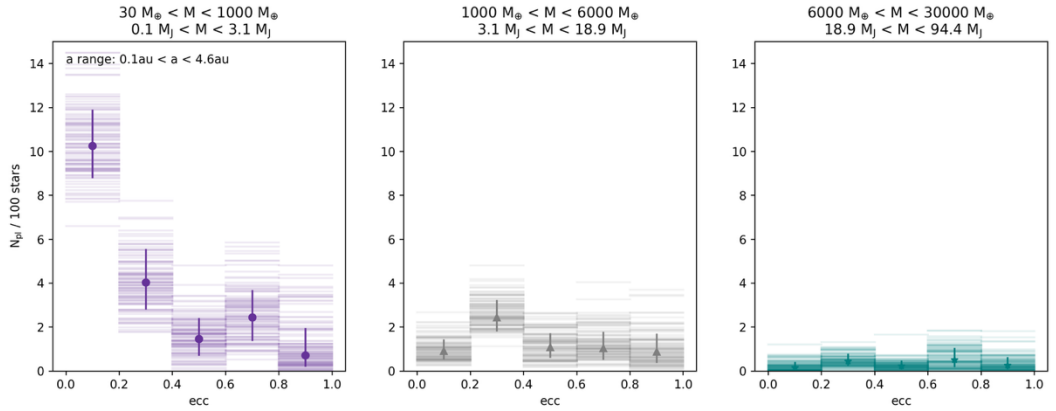

Estimated sensitivity to **21,000 ± 6,000** giant planets out to 500 pc.
(Perryman+ 2014)

# Summary:

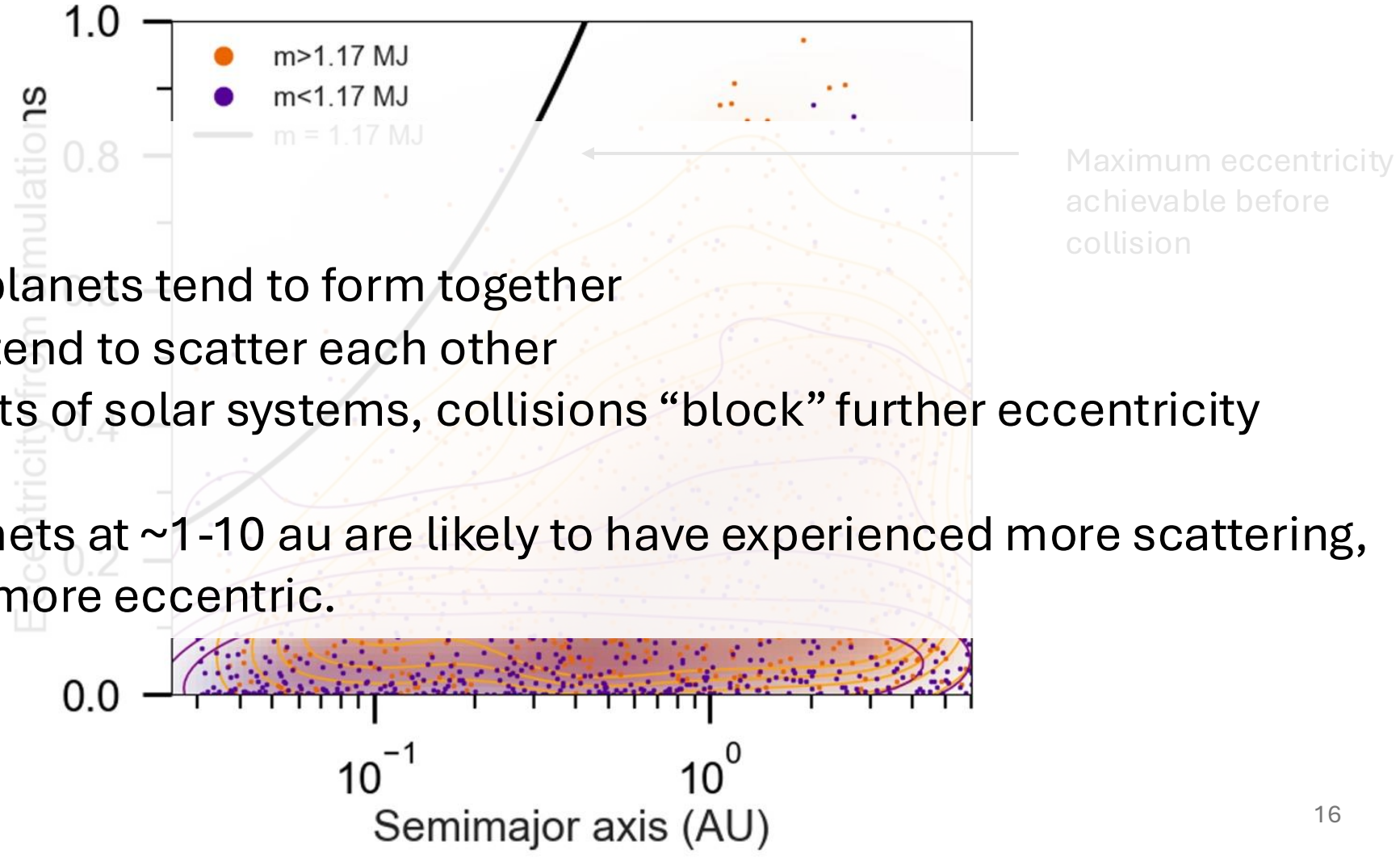
- Planet formation is very uncertain
- Most known giant planets are atypical
- Long-baseline RV surveys are beginning to discover the most commonly occurring giant planets
- The eccentricities of these most common planets will give us insight into planet formation overall
- We used the California Legacy Survey, a public, approx. uniform sample to measure occurrence rates of typical giant planets as a function of eccentricity, mass, and semimajor axis
- We observed a peak in the eccentricity distribution of super-Jovian exoplanets at their peak of occurrence, potentially pointing to a scattering/giant impacts phase.



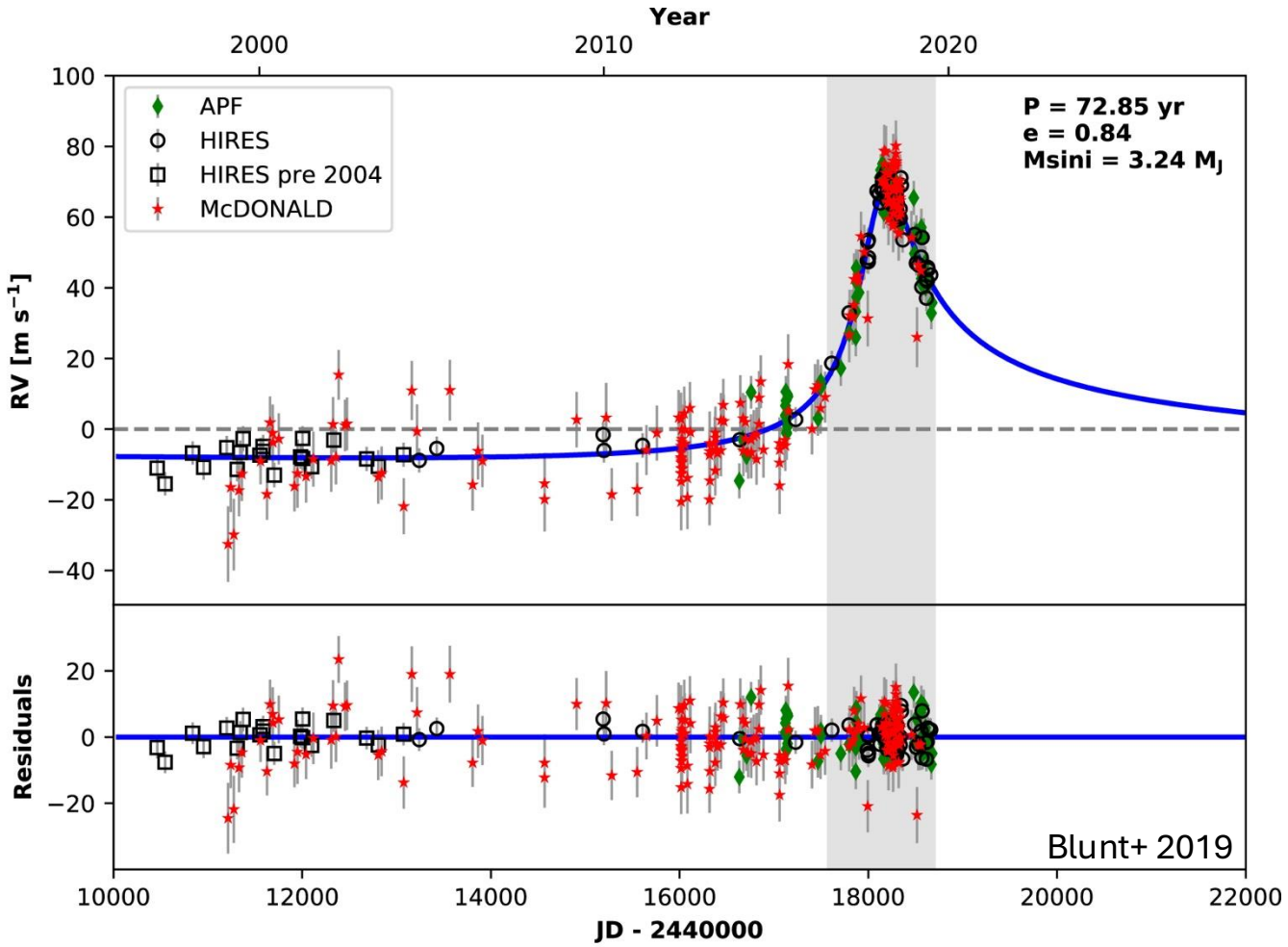
# The elevated eccentricities of giant planets ~1-5 au may point to a giant impacts phase. (Frelikh+ 2019)

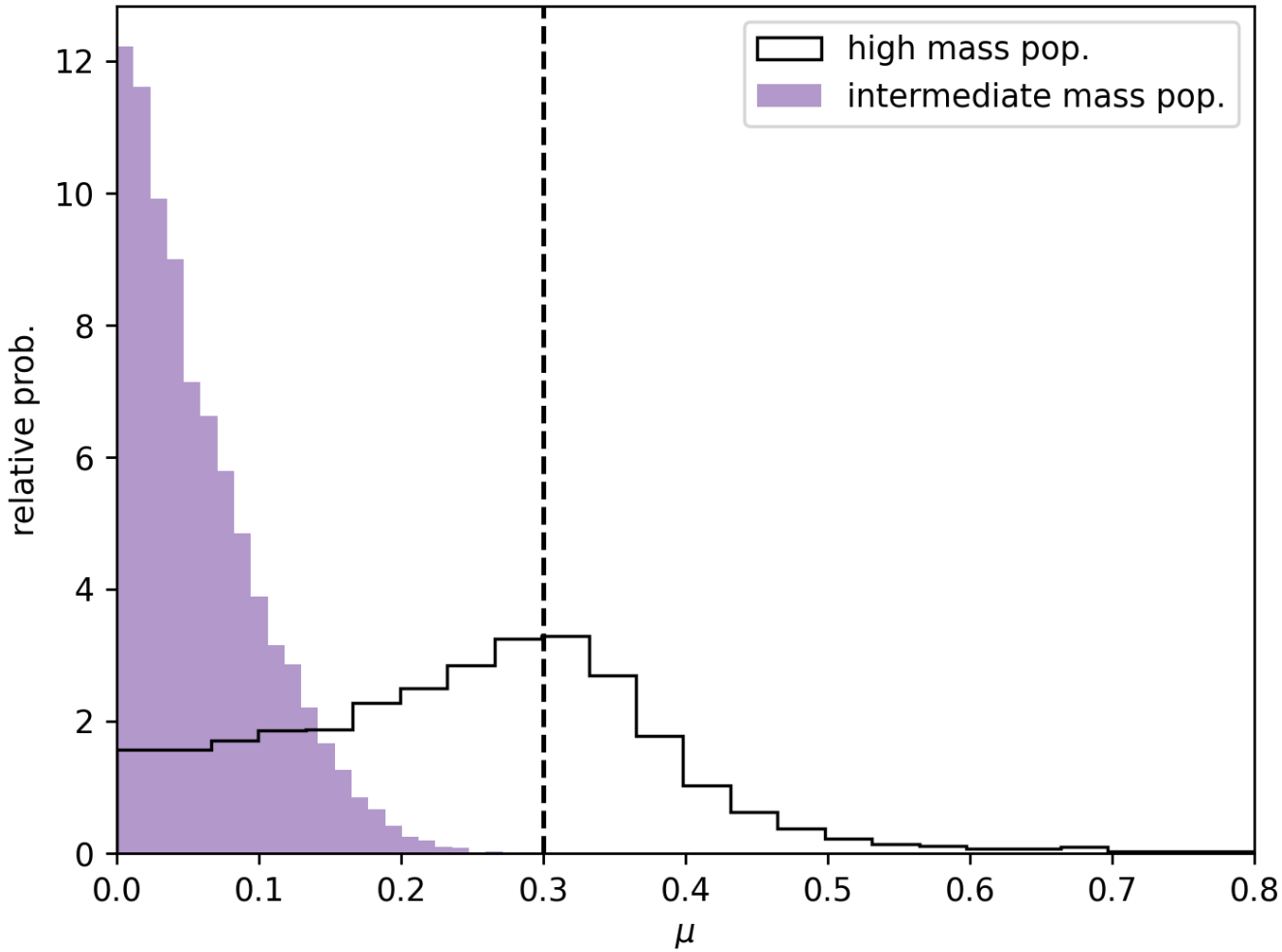


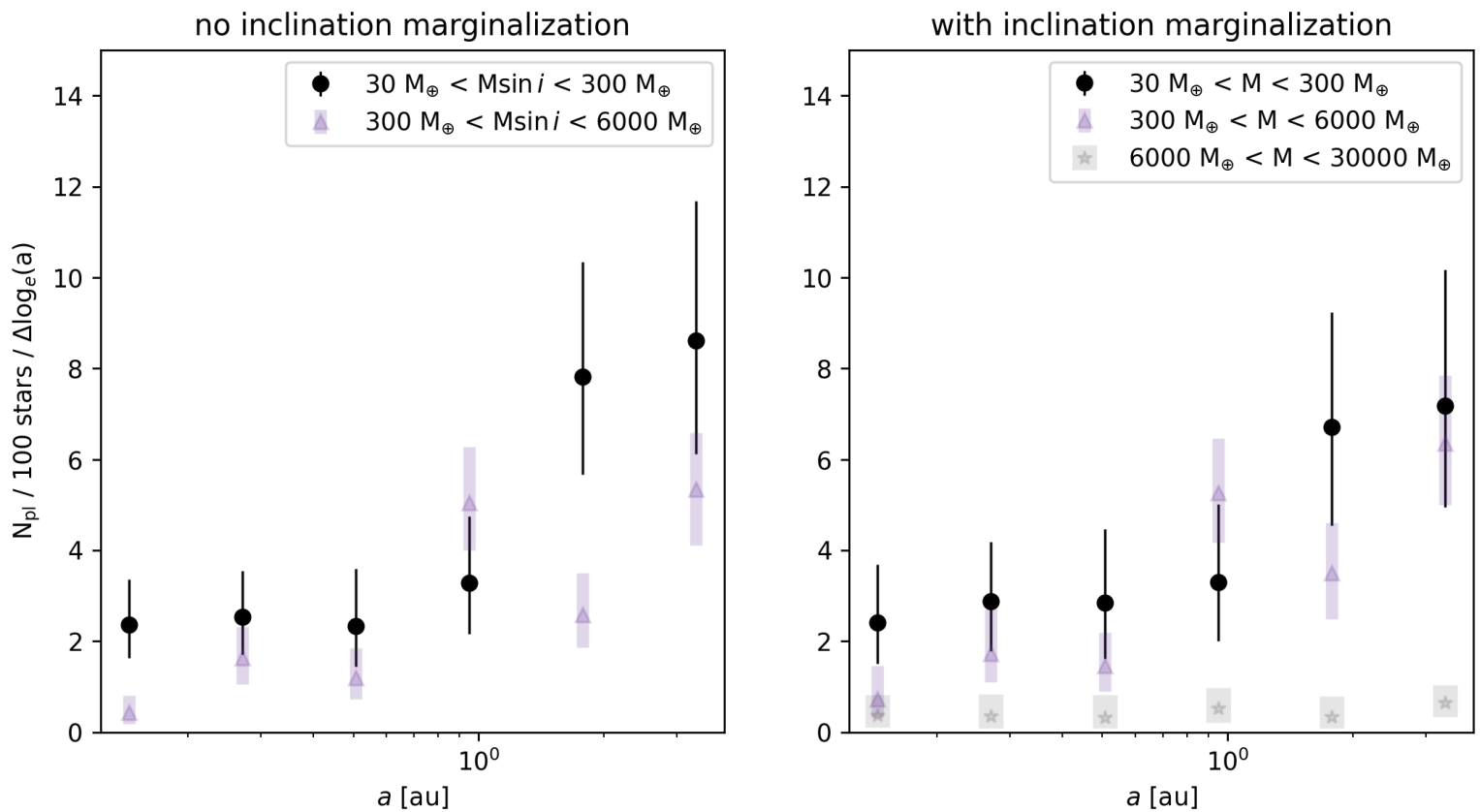

Here's the logic:

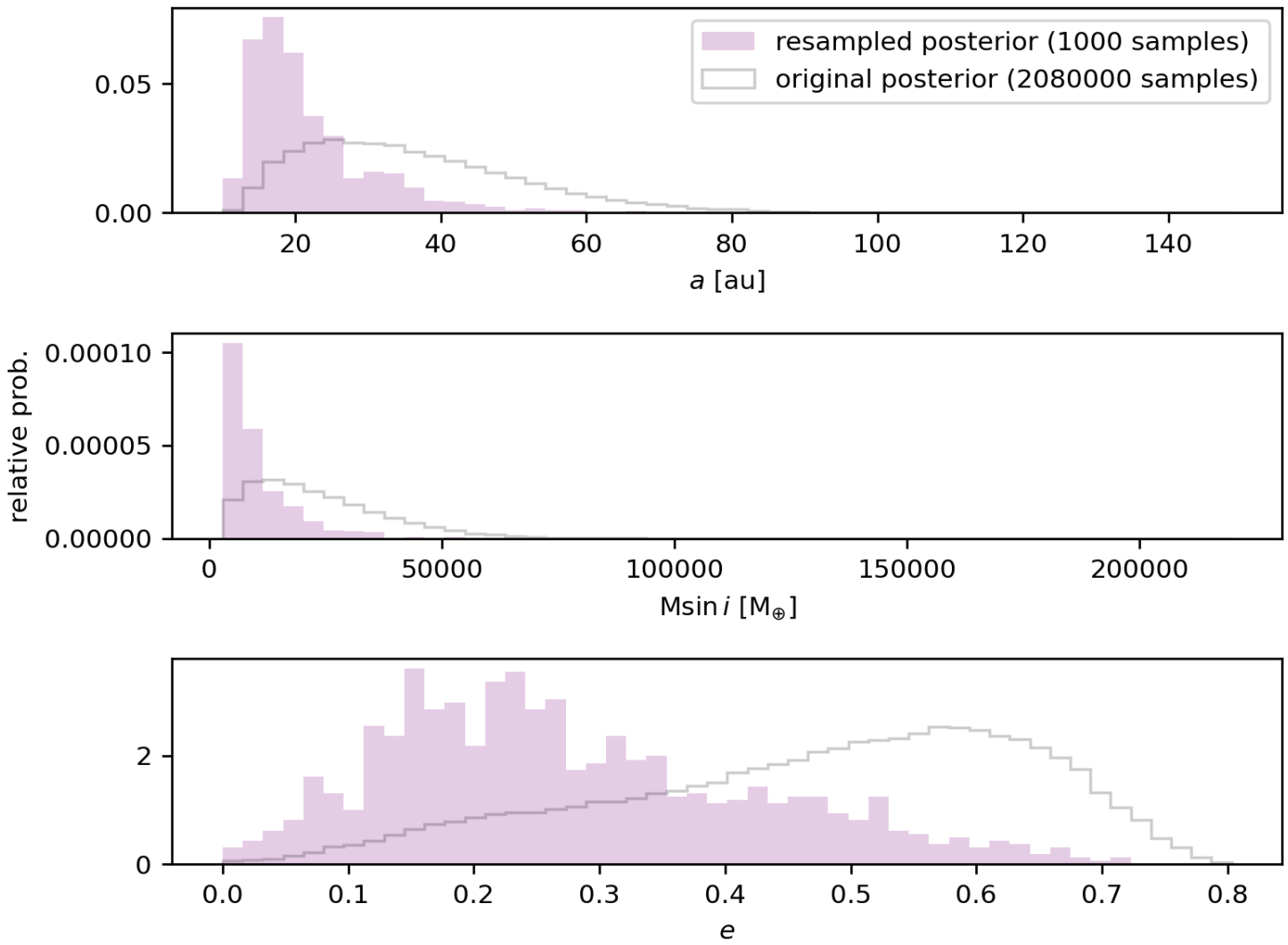
1. Multiple giant planets tend to form together
2. These planets tend to scatter each other
3. In the inner parts of solar systems, collisions "block" further eccentricity excitation
4. High mass planets at ~1-10 au are likely to have experienced more scattering, and therefore be more eccentric.

# How to measure the eccentricity of a planet at >1au: wait.




high mass pop.
intermediate mass pop.
relative prob.
0
2
4
6
8
10
12
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
$\mu$


no inclination marginalization
with inclination marginalization
30 M⊕ < Msin i < 300 M⊕
300 M⊕ < Msin i < 6000 M⊕
30 M⊕ < M < 300 M⊕
300 M⊕ < M < 6000 M⊕
6000 M⊕ < M < 30000 M⊕
N_pl / 100 stars / Δlog_e(a)
a [au]
0
2
4
6
8
10
12
14
10^0


resampled posterior (1000 samples)
original posterior (2080000 samples)
0.05
0.00
20
40
60
80
100
120
140
a [au]
relative prob.
0.00010
0.00005
0.00000
0
50000
100000
150000
200000
Msin i [M⊕]
2
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
e

# 2-for-1 effect is unlikely: