Gas Giants and Their Friends

How Gas Giant Properties Vary with Inner Companions

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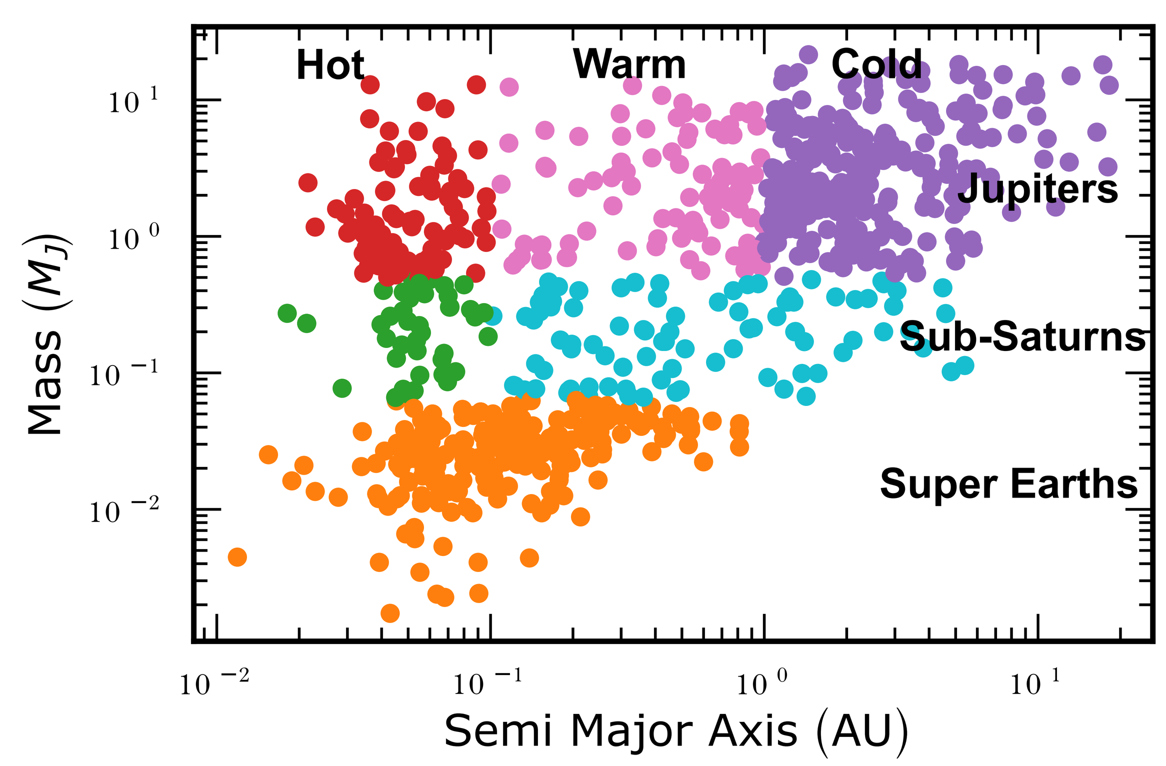
Introduction

One important aspect of exoplanet demographics is the composition of planetary systems. In particular, a prominent topic of study in the past decade is whether the occurrence rate of gas giants is affected by the types of inner planets in their host systems. This connection has been examined between outer gas giants and hot Jupiters[1-2], other gas giants [3] and super Earths [4-7]. We present a comprehensive and unified study of gas giant occurrence using one of the largest exoplanet samples assembled.

Planet Sample

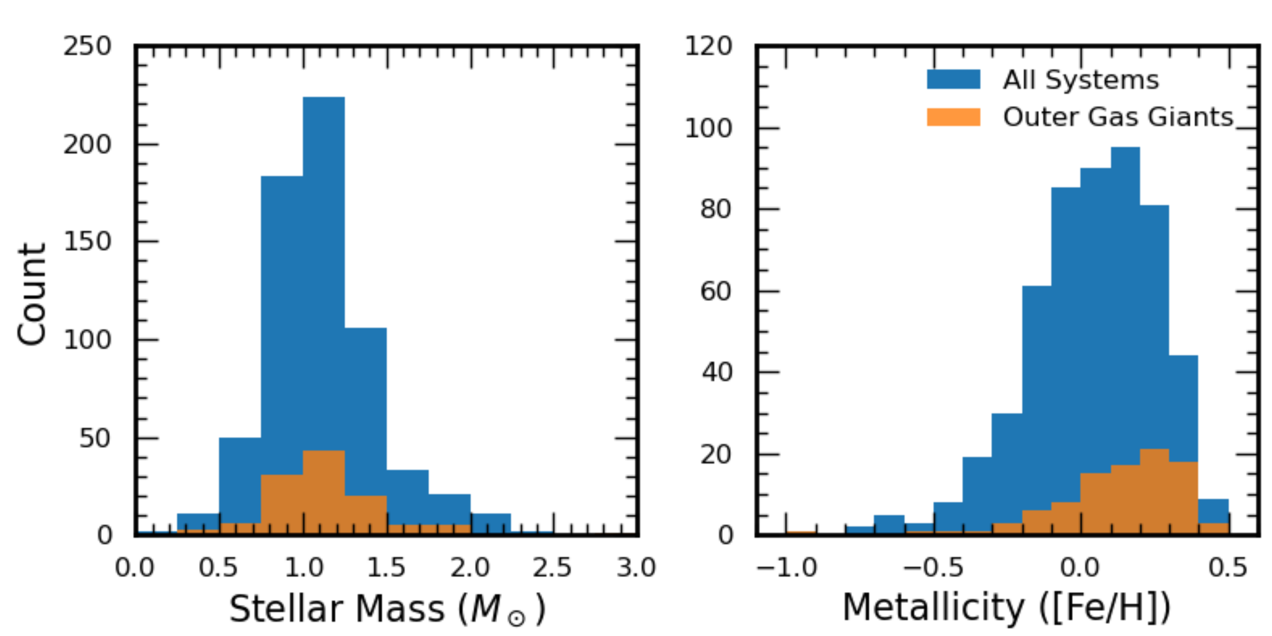
We examine this connection across many types of inner planets including hot and cold Jupiters, sub-Saturn sized planets and super Earths. We have assembled **one of the largest samples of exoplanets consisting of over 1000 planets and 600 systems**. Each system selected from the NASA exoplanet archive for meeting the following criteria

1) The system has a publicly available radial velocity (RV) data set with at least 20 data points
2) The RV baseline spans at least 1 year



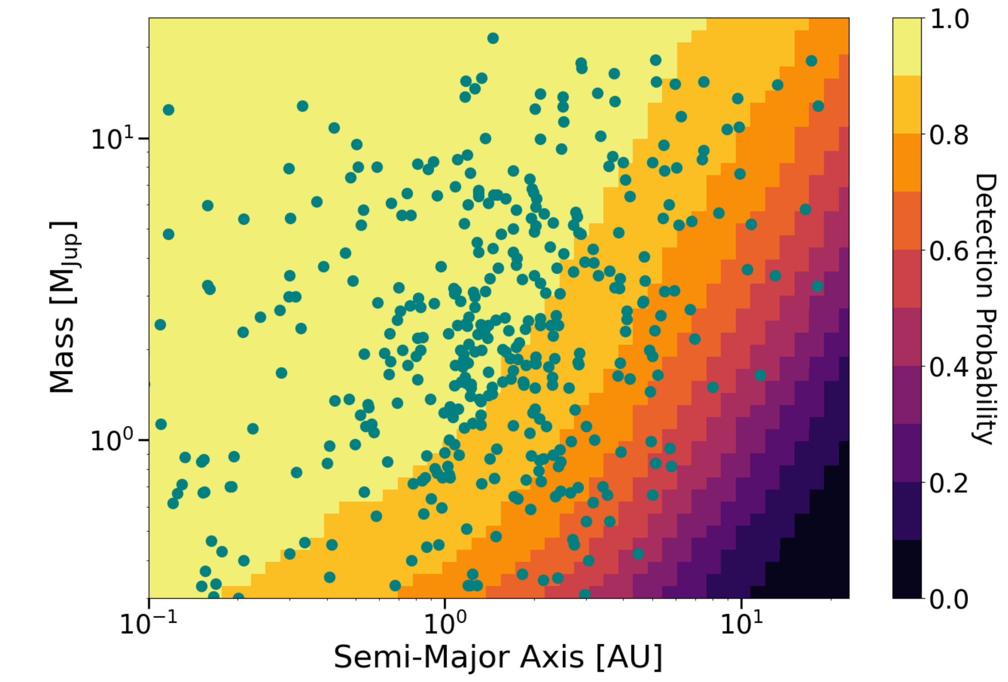
We classify planets into seven categories based on mass and semi-major axis. By mass, planets are divided into super Earth (SE), sub-Saturn and Jupiter planets. Sub-Saturns are further divided into hot and cold planets (HS, CS), and Jupiters are divided into hot, warm and cold Jupiters (HJ, WJ , CJ). These divisions are indicated by the color in the figure above.

We also examine how stellar properties affect the correlations between inner planets and the presence of outer gas giants. Our sample includes a wide range of stellar masses and metallicites, both roughly centred around solar values. The distributions of these properties for outer gas giant companions differ slightly, indicating their influence, but are not wildly different from the overall distributions.



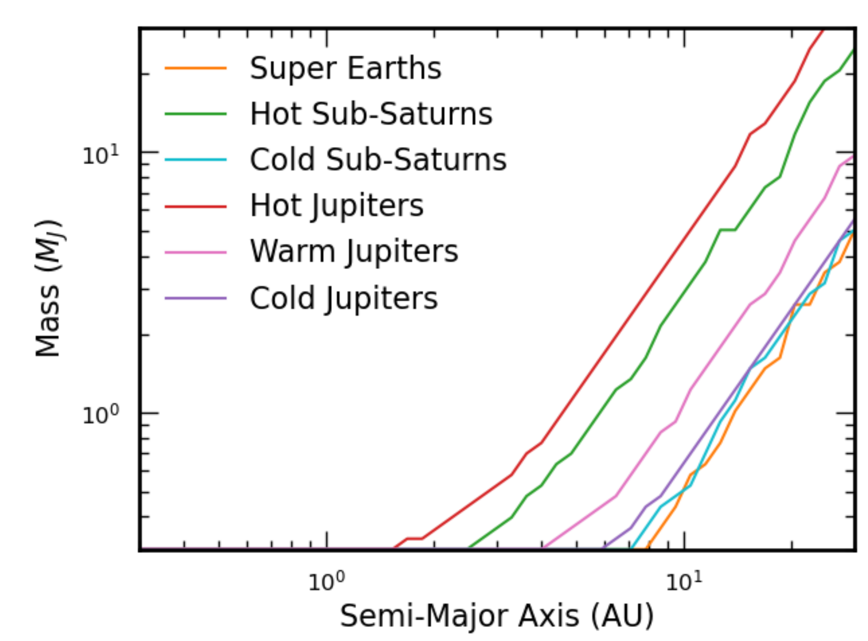
Completeness Correction

Different RV data sets have different detectability of planets depending on the period compared to the baseline and the RV semi-amplitude compared to the noise. To compensate for these differences, we construct completeness maps for each system based on the underlying data set.



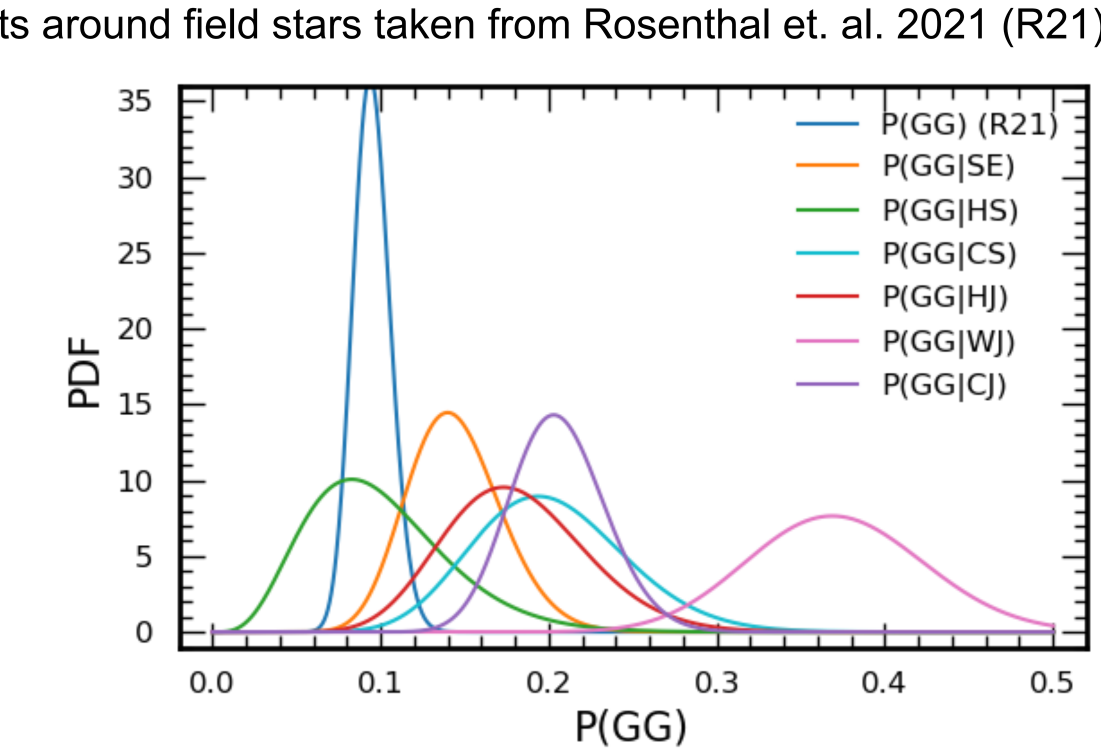
We use these completeness maps to correct our occurrence rates by effectively removing equivalent fractions of systems where outer companions could not be detected.

We also show the 50% completeness contour of each of our planet types. For our average hot Jupiter system, we could detect a Jupiter mass planet out to 4 AU. For our typical super Earth or cold Jupiter systems, it improves to 10 AU.



Occurrence Rates

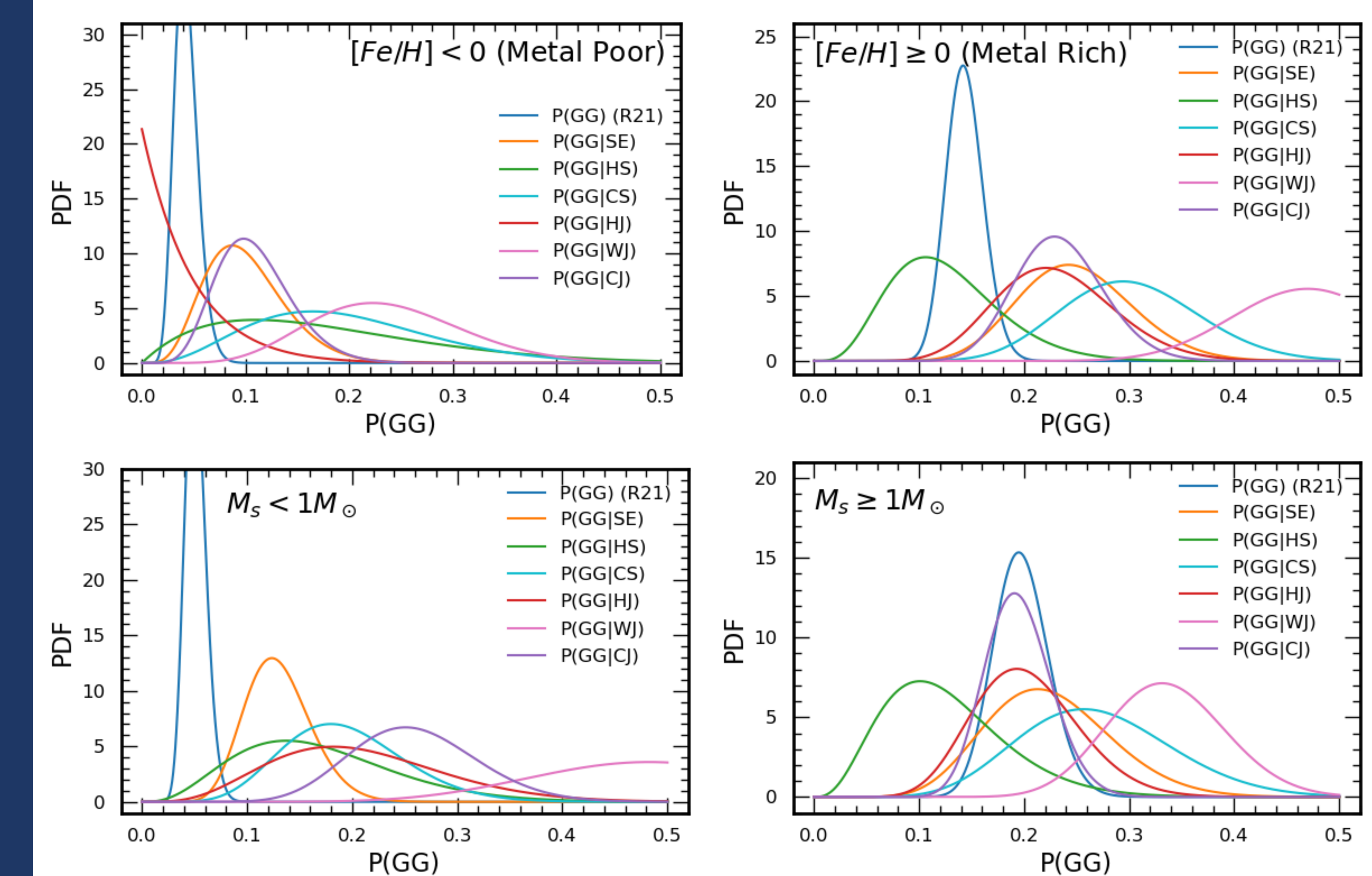
We compute the occurrence rate of gas giants around different types of inner planets. We compare these rates to the occurrence rate of gas giants around field stars taken from Rosenthal et. al. 2021 (R21) [8].



The typical star has a 9% chance of hosting a gas giant. Hot sub-Saturn systems have a similar likelihood. For super Earth, hot Jupiter, and cold Jupiter and sub-Saturn systems, it improves to 15-20%. For a warm Jupiter systems, it is 37%. We see that for almost all types of inner companions, their systems are **more likely to have a gas giant than the typical star.**

Stellar Properties

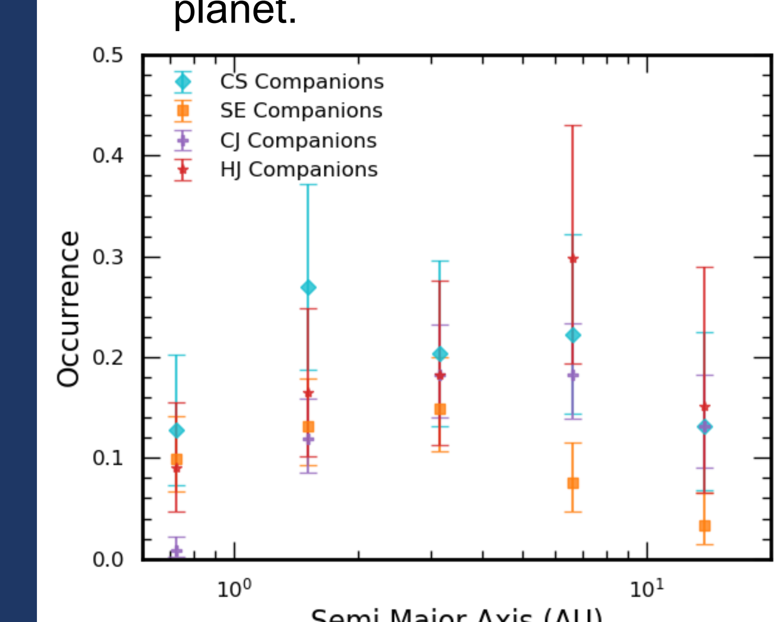
We examine how stellar mass and metallicity [6] affects these occurrence rates. When we compare occurrence rates for metal poor and metal rich systems, we see that metal rich systems typically have larger occurrence rates. Furthermore we see the gap in occurrence between generic gas giants and gas giants with other inner planets **widens for metal rich systems compared to metal poor systems**.



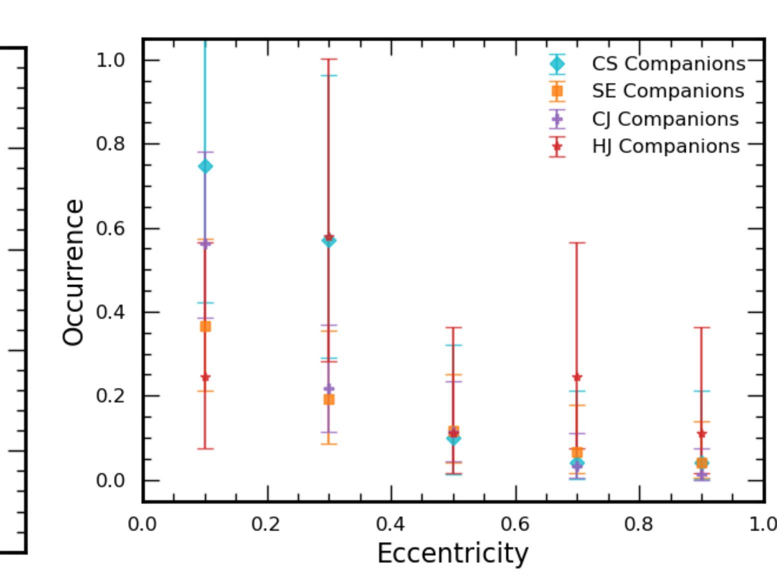
For stars larger than the sun, we see that they are more likely to host gas giants in general, but less likely to host gas giants and other planets together.

Future Directions

We plan to examine how gas giant properties, such as eccentricity, semi-major axis and mass, correlate with the presence of an inner planet.



For semi-major axis, for all inner planet types, we see a clear peak with the occurrence starting to drop off with higher semi-major axes.



For eccentricity, we see that gas giants around hot Jupiters are deficient in low eccentricity planets, possibly indicative of dynamical interactions being common.

References

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