Demographics of Giant Exoplanets from a Combination of Direct Imaging and Radial Velocity Surveys

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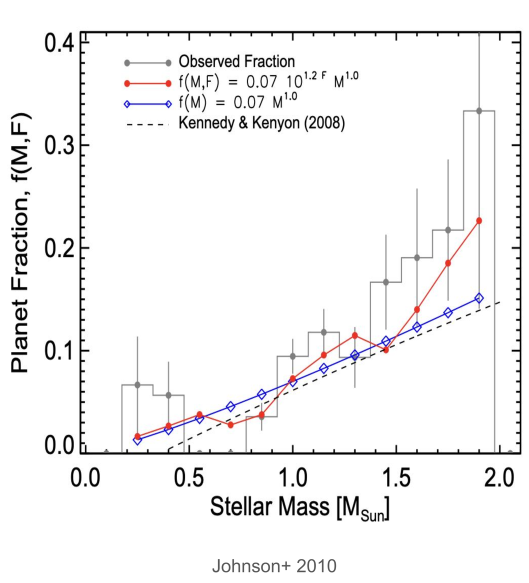
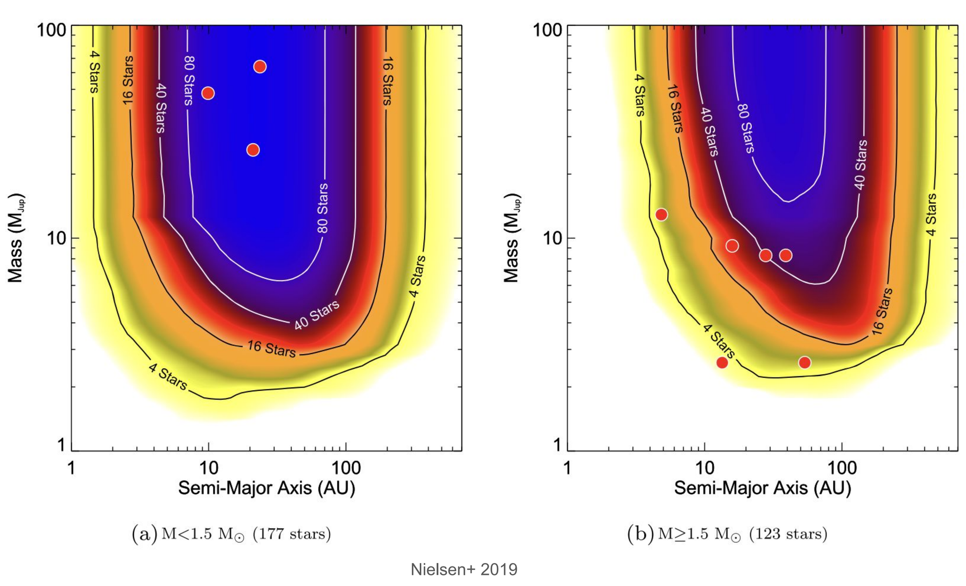
Abstract

Combining direct imaging and radial velocity techniques is a powerful approach to measuring the demographics of giant exoplanets from 0.01 au to 1000 au. These two techniques are highly complementary, with radial velocity being most sensitive to planets close to their host stars, while direct imaging is most sensitive to giant planets at larger orbital separations. We combine survey results from direct imaging (the Gemini Planet Imager Exoplanet Survey) and radial velocity (the California Legacy Survey) to more extensively probe the occurrence rates of giant planets across a wide range of semi-major axes. We fit a joint demographic population to the combined dataset and present early results from our analysis. Our findings echo previous work with a peak in giant planet occurrence rate near the snow line, consistent with predictions of pebble accretion. Additionally, we investigate the relationship between giant planet occurrence rates and stellar host mass.

More Massive Stars Have More Giant Planets

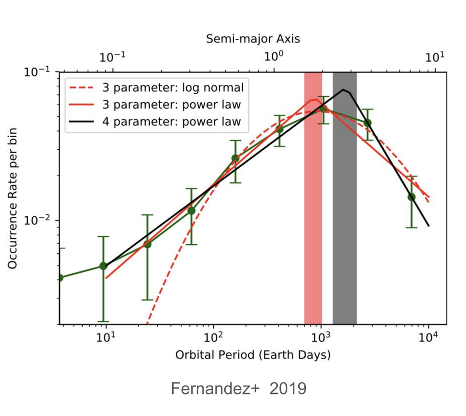


Johnson+ 2010

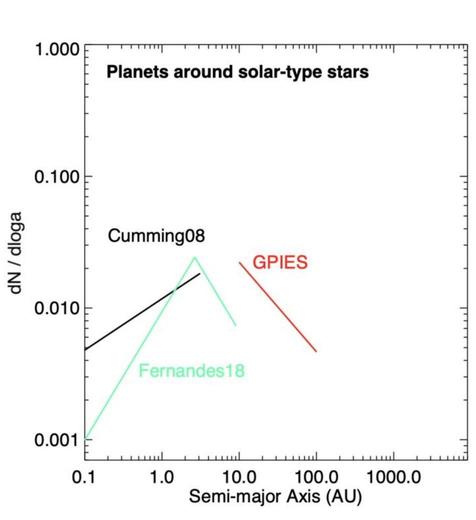


Nielsen+ 2019

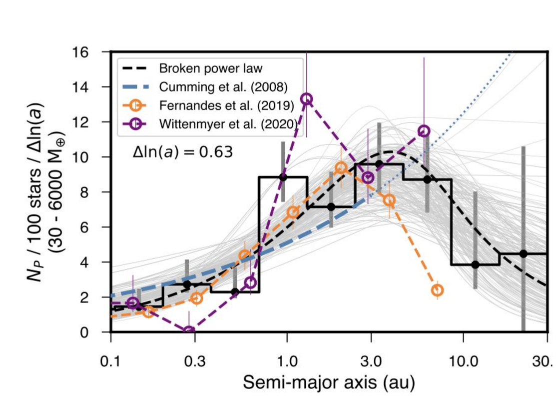
Previous Studies Suggest a Break in the Giant Planet Occurrence Rate Near the Snow Line



Fernandez+ 2019



Nielsen+ 2019

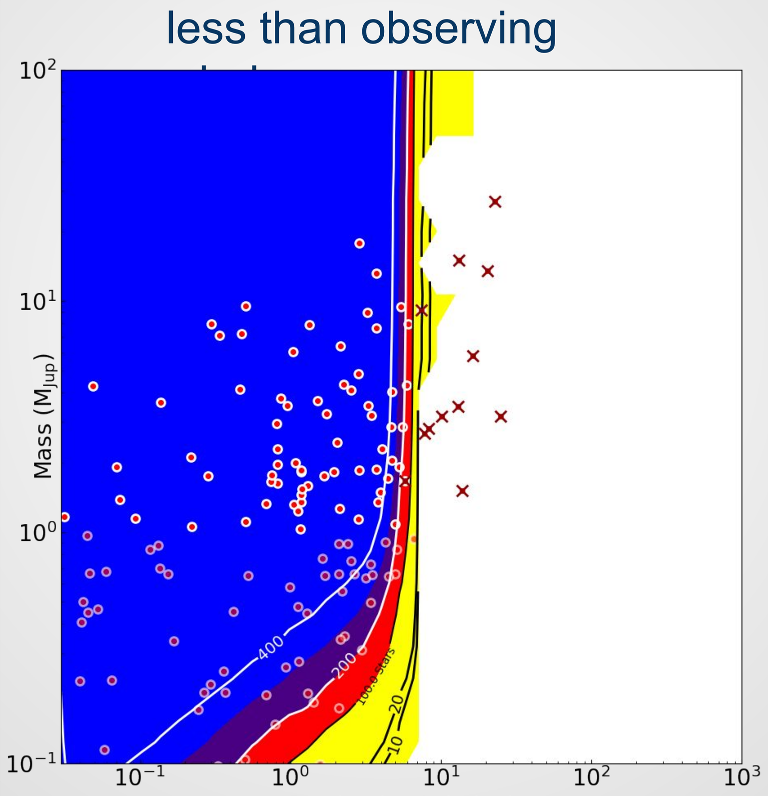


Fulton+ 2021

Combining Direct Imaging and Radial Velocity Demographic Results

California Legacy Survey (Rosenthal et al. 2021)

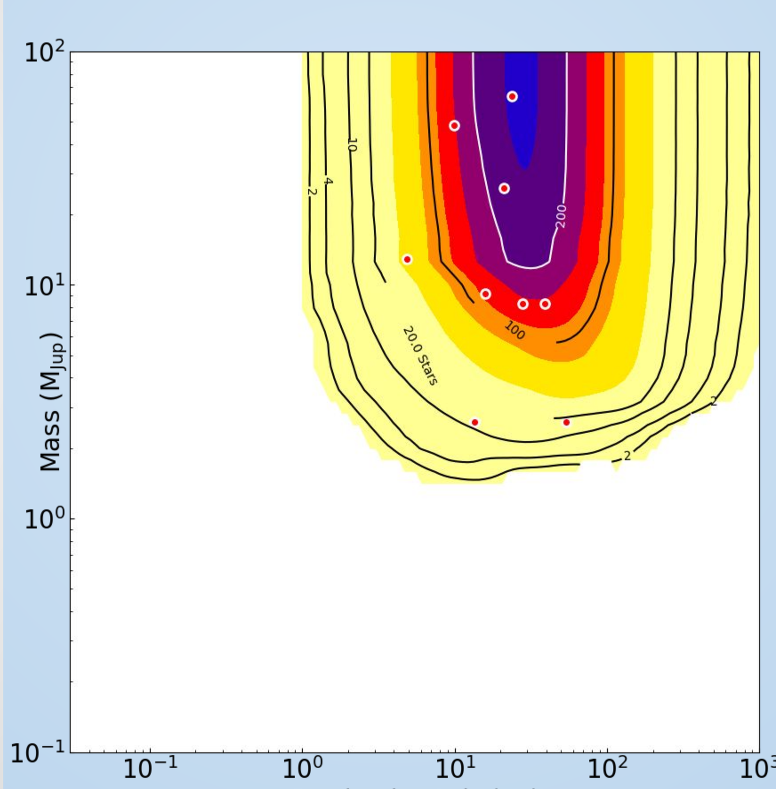
- 719 stars
- 66 planets 1-13 M_{Jup}
  - Consider only planets with orbital periods less than observing



- Radial Velocity Survey
- Most sensitive to giant planets between 0.03 - 8 au

GPIES (Macintosh et al. 2018)

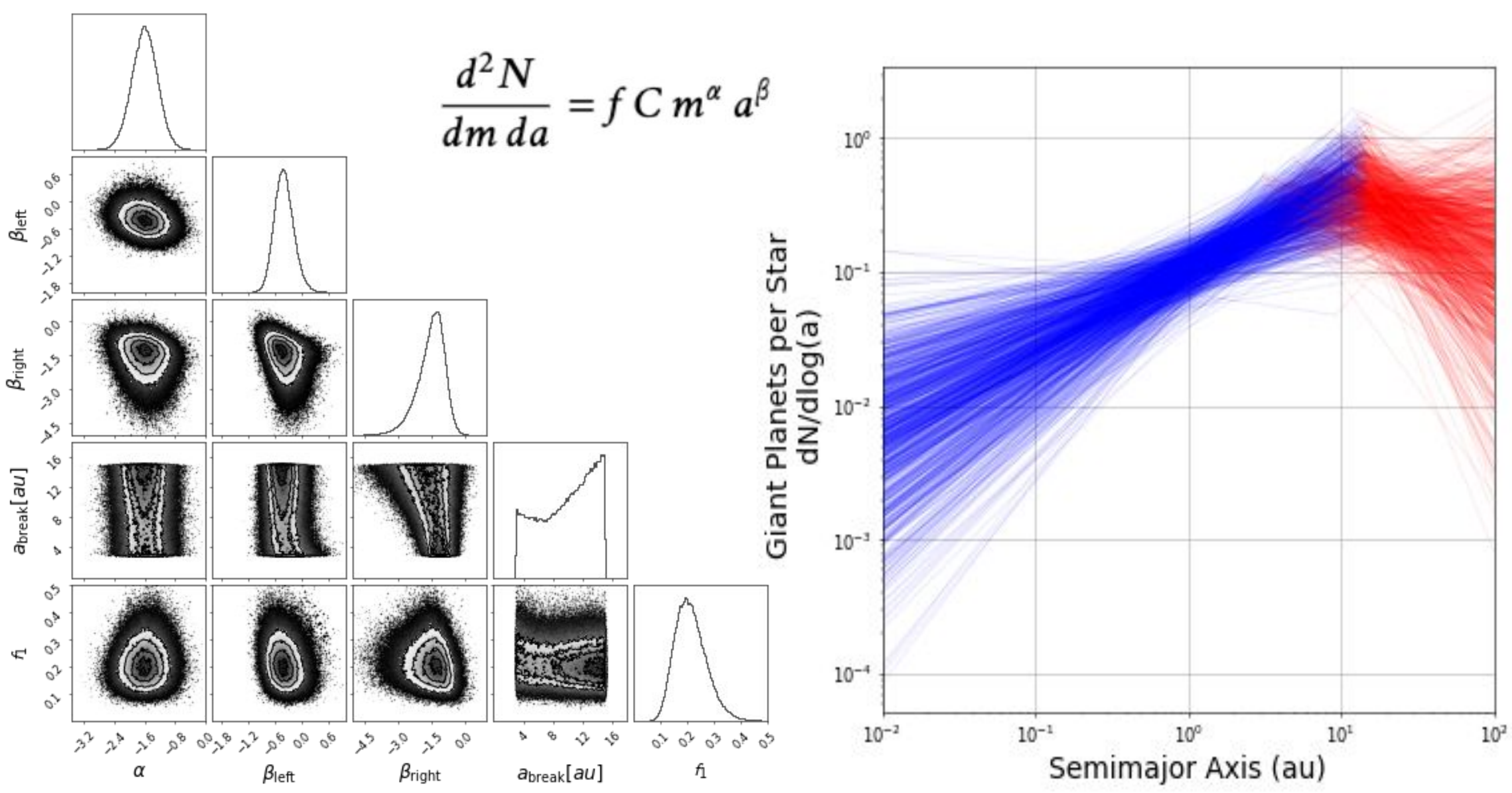
- 300 stars
- 6 planets between 1-13 M_{Jup}



- Direct Imaging Survey
- Most sensitive to giant planets between 10 - 100 au

Occurrence Rate of Giant Planets Around High Mass Stars Consistent with a Break

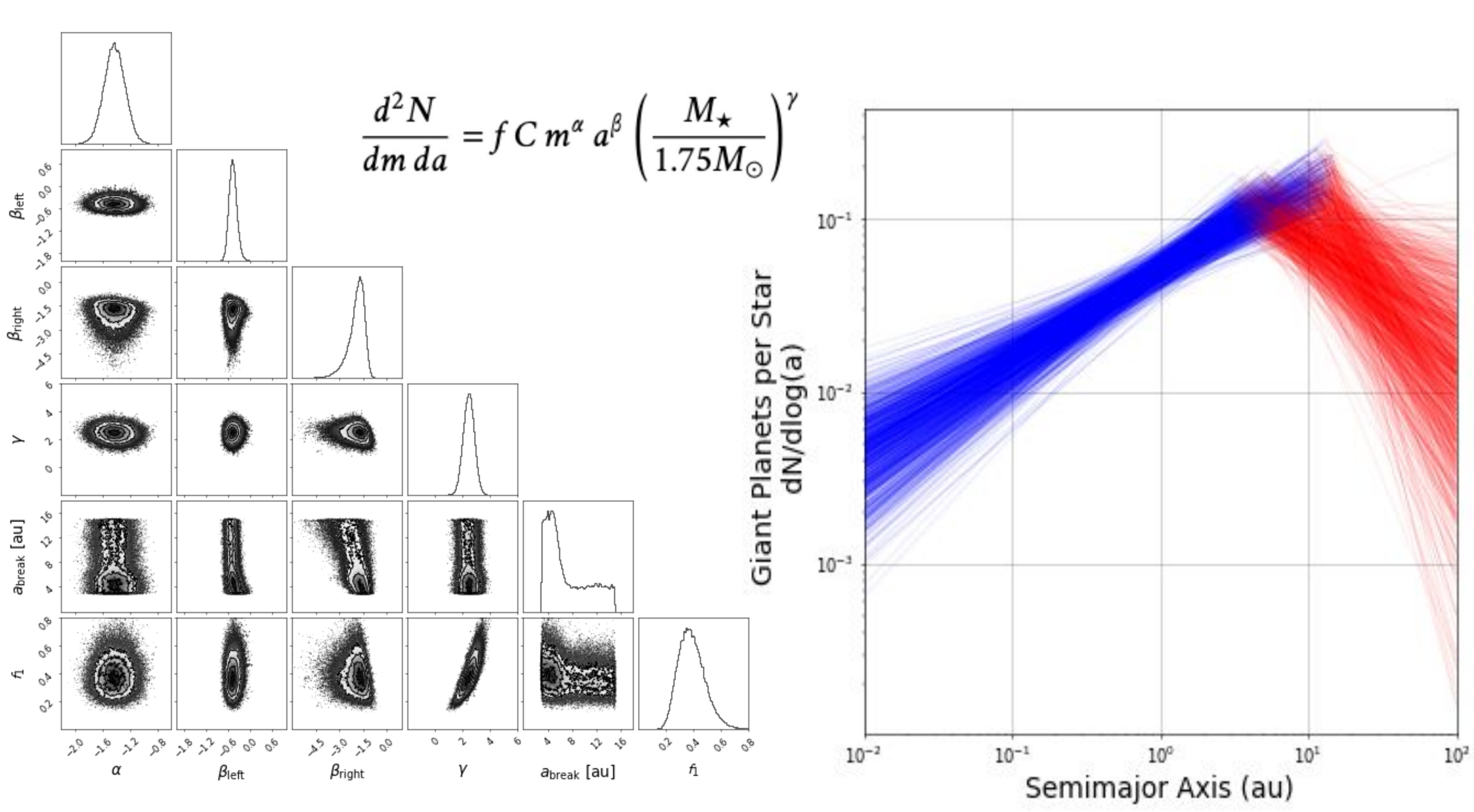
$$\frac{d^2N}{dm\,da} = f\,C\,m^{\alpha}\,a^{\beta}$$



- *Only stars > 1.2 $M_\odot$*
- *Location of the break is not well-constrained with these data*
  - *Uniform prior across 3 - 15 au*
- *Increasing occurrence rate for closer-in giant planets*
- *Decreasing occurrence rate for wider-separation giant planets*

A Positive Correlation Between Stellar Mass and Giant Planet Occurrence Rate

$$\frac{d^2N}{dm\,da} = f\,C\,m^{\alpha}\,a^{\beta}\left(\frac{M_\star}{1.75M_\odot}\right)^{\gamma}$$



- *Fit to all stars in the sample*
- *Occurrence rate scales with stellar mass*
  - $M_\star^{\gamma}$
- *More giant planets around higher-mass stars:*
  - γ = 2.4 +/- 0.4
- Other parameters similar to high-mass-only fit

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