FGK Star Gas Giant Surface Density Distribution: A Log-normal Fit from 0.05-100 AU

Michael R. Meyer[1], Adam Amara[2], and Avery Peterson[1]

[1] Department of Astronomy, U. Michigan; [2]Institute for Particle and Astrophysics, ETH Zürich

What Motivated Us:

Exoplanet demographics (constraints on the frequency of planetary mass companions as a function or orbital radius, or the planet mass function) can place fundamental limits on planet formation theory (e.g. Mordasini et al. 2012). By combining several exoplanet detection techniques, we can constrain the surface density of gas giant planets as a function of orbital radius. Past attempts to explore this have fit power-laws to the data (e.g. Cumming et al. 2008). It is clear that there is an outer cur-off radius to these trends (e.g. Clanton & Gaudi, 2016). We have previously fit a log-normal distribution to the surface density of gas giants around M dwarfs (Meyer et al. 2018). Here we combine results for FGK stars with this approach.

The Method to our Madness:

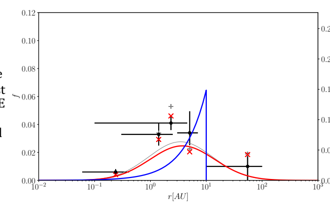
We collected point estimates of the frequency of gas giant planets surrounding FGK stars from the literature, as integrated between 1-10 $M_{jupiter}$ over a clearly defined range of separation. When necessary we adjusted the quoted frequency using the planet mass function from Cumming et al. (2008) and propagated the quoted errors from the original source. These data are shown in Table 1.

We followed the approach outlined in Meyer et al. (2018) but adapted our study for FGK stars. Using constraints from these data and our assumption of a log-normal functional form, we explore allowed values of three parameters (amplitude (A), mean of the lognormal (μ) , and square root of the variance (σ), all restricted to be positive) using a Markov Chain Monte Carlo approach to survey the landscape of the likelihood function with the publicly available package CosmoHammer (Akeret et al. 2013).

Orbital Separation Range (log {semi-major axis})	Estimated Frequency (1-10 $M_{jupiter}$)	Reference
-1.22 to -0.38	0.006 +- 0.002	Petigura et al. (2013)
-1 to 0.66	0.041 +- 0.005	Mayor et al. (2011)
-0.52 to 0.4	0.0329 +- 0.008	Cumming et al. (2008)
0.48 to 0.85	0.034 +0.0154/-0.0088	Wittenmyer et al. (2016)
1 to 2	0.01 +- 0.01	Preliminary SHINE/GPI results.

Here is what we found:

Figure 1 – The Maximum Liklihood Estimator (MLE) from our fitting is shown in red as a probability density function (PDF) along the right y-axis. The observed data are plotted against the left y-axis along with the MLE integrated estimates. The range of the observations are indicated as well as errors in y. The PDF for M dwarfs from Clanton and Gaudi (2016) is shown in blue.



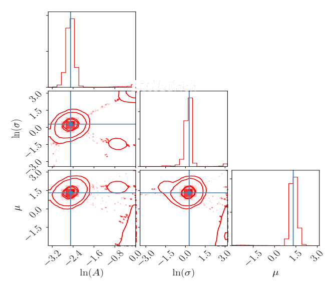
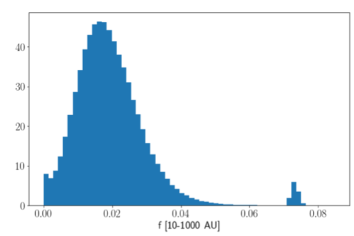


Figure 2 – Here we show the PDF of each fit variable in our log-normal function as well as the correlations between the variables.

Figure 3 – Here we show the integrated PDF of the frequency of 1-10 Mjupiter planets between 10-1000 AU predicted from our fit, marginalizing over the uncertainties of all fit variables above. We think the secondary peak in the PDF is due to boundary effects of the MCMC which are hinted at in Figure 2.



Implications:

- The surface density of gas giants around FGK stars is fit by a log-normal function (cf. Meyer+ 2018).
- We think this function makes more sense than a power-law + cut-off.
- Comparison of these results with those for M dwarfs is on-going, but supports the notion that the gas giant planet mass function is a power-law relative to M_*.
- Our results plus Raghavan et al. (2010) indicate the local minimum in the combined companion mass function (CMRD) depends on orbital separation (cf. Sahlmann et al. 2011; Reggiani et al. 2016).

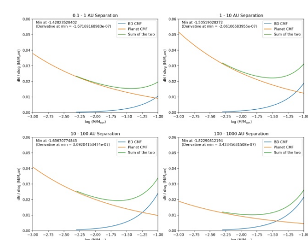


Figure 4 – CMRD versus orbital separation for FGK stars.

Acknowledgments

We are greatly to Maddalena Reggiani, Sascha P. Quanz, Veenu Suri, Nicholas Susemiehl, and Alexandra Greenbaum for helpful discussions. For more info please visit our website at U. Michigan: https://sites.lsa.umich.edu/feps/

Literature cited

Akeret et al. 2013, Astronomy & Computing, V2, 27.

Clanton & Gaudi 2016, ApJ, 819, 125.

Cumming et al. 2008, PASP 120 531.

Mayor et al. 2011, https://arxiv.org/abs/1109.2497.

Meyer et al. 2018, A&A, V612, L3.

Mordasini et al. 2012, A&A, V547, 111.

Petigura et al. 2013, PNAS V110, 19273.

Raghavan et al. 2010, ApJ, V190, 1.

Reggiani et al. 2016, A&A, V586, 147.

Sahlmann et al. 2011, A&A, V525, 95.

Wittenmyer et al. 2016, ApJ, V819, 28.

LSA ASTRONOMY UNIVERSITY OF MICHIGAN

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich