The Companion Frequency and Orbital Distribution of M-Dwarf Binaries

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Motivation & Goals

- M-Dwarf multiplicity is not well constrained
- We seek to **fit a model to the surface density distribution** of M-Dwarfs using point estimates from surveys over a range of orbital separations
- **Calculate a constrained frequency**
  - Specific ranges of mass ratio (q) and semi-major axis (a) from sensitivity of data
  - Assume companion mass ratio distribution does not depend on orbital separation
  - Only account for binary systems (no triples, quadruples, etc.)
- **Extrapolate constrained frequency** to find new value covering broad ranges of mass ratio and semi-major axis
- Compare to other stellar multiplicity estimates

Methods

- Collected data from five M-Dwarf multiplicity surveys

Reference	Semi-Major Axis Sensitivity Range (AU)	Multiplicity Estimate (q ≥ 0.6)
Delfosse et. al. (1998)	0.00 - 4.63	0.04 ± 0.018
Fischer & Marcy (1992)	0.04 - 4.00	0.08 ± 0.034
Cortes-Contreras et. al. (2016)	2.60 - 29.5	0.07 ± 0.012
Janson et. al. (2012)	3.00 - 227	0.18 ± 0.016
Ward-Duong et. al. (2015) A	3.00 - 100	0.11 ± 0.022
Ward-Duong et. al. (2015) B	100 – 10,000	0.07 ± 0.017

- Used MCMC with chi-squared likelihood to fit a log-normal model to separation distribution with three parameters ($\log_{10}\mu, \log_{10}\sigma, A$)

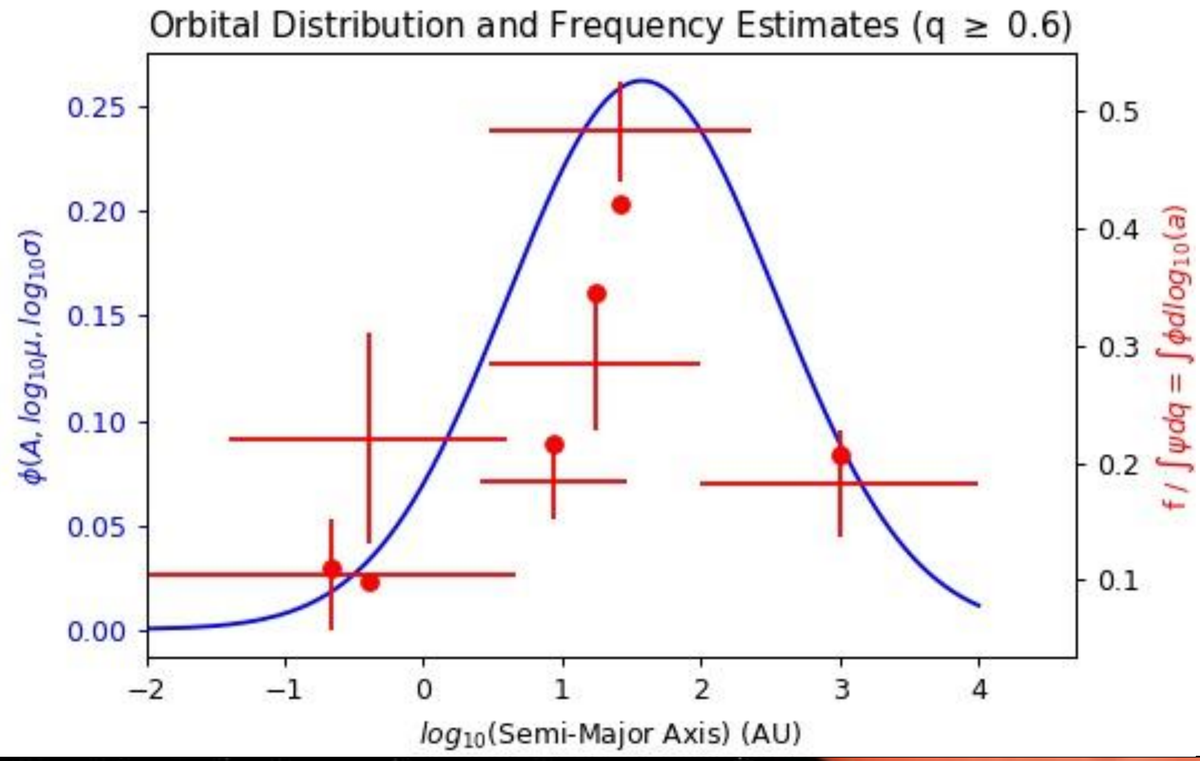
$$\phi = A * \frac{e^{-(\log_{10} a - \log_{10}\mu)^2/2\log_{10}\sigma^2}}{\log_{10}\sigma * \sqrt{2\pi}}$$

- Referenced mass ratio distribution from Reggianni & Meyer (2013) $\psi = q^{0.25 \pm 0.29}$
- Calculated frequency f = $\int_{q_{min}}^{q_{max}} \psi\, dq * \int_{\log_{10} a_{min}}^{\log_{10} a_{max}} \phi\, d\log_{10} a$
- Analyzed Goodness of Fit
  - $\chi^2_{red.}\,(3\ d.o.f.) = 2.14$
  - $P(X \geq \chi^2_{red.}) = 0.09$

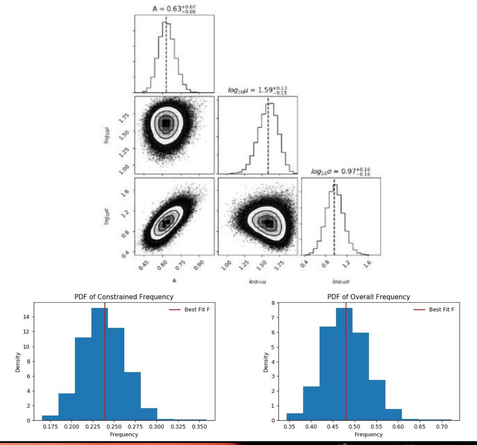
Despite this low probability, we do not reject the null hypothesis that the data came from this model

Results

- **Constrained Frequency** (0.60 ≤ q ≤ 1.00, 0.00 ≤ a ≤ 10,000): **0.239 ± 0.04**
- **Overall Frequency** (0.10 ≤ q ≤ 1.00, 0.00 ≤ a ≤ ∞): **0.481 ± 0.08**



Analysis of Fit



Conclusions

- Peak in orbital surface density distribution of M-Dwarf binaries occurs at about 40 AU (larger than the estimate from Winters et al. 2018 and slightly smaller than Raghavan et al. 2010 for FGK stars)
- **About half of all M-Dwarfs have a low mass companion**, many of which may be brown dwarfs after extrapolating down to this regime
- Comparisons
  - Extrapolated results from surveys of other spectral type over constrained regions of mass ratio and separation

Survey	Raghavan et. al. (2010) - FGK Stars	De Rosa et. al. (2013) – A Stars
Multiplicity Fraction q = [0.6, 1], a = [0.00, 10000 AU]	f = 0.230 +/- 0.032	f = 0.238 +/- 0.026

  - **Overall, multiplicity fraction does not vary significantly across spectral types** over q = [0.6, 1] and a = [0.00, 10000 AU]

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