What Fraction of Small Stars Have Friends?

Companion Frequency and Orbital Distributions of M-Dwarfs

Nicholas Susemiehl[1], Prof. Michael Meyer[1]

1 - University of Michigan

Introduction

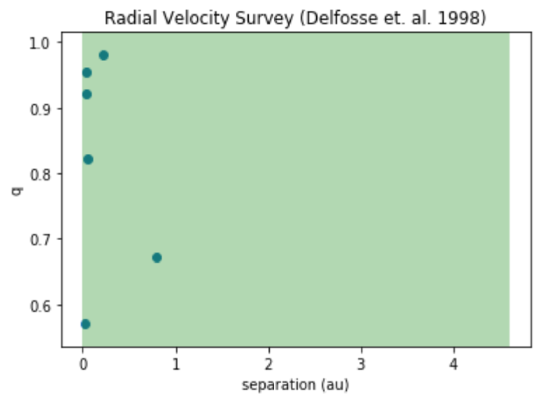
- Understanding stellar multiplicity is key to understanding star and planet formation
- Multiplicity fraction for M-dwarf stars is not well defined
- Assumed form for companion mass ratio (q, secondary mass / primary mass) distribution (Reggiani & Meyer 2013): $\frac{dN}{dq} \propto q^{-.25}$
- Assumed form for total stellar multiplicity:

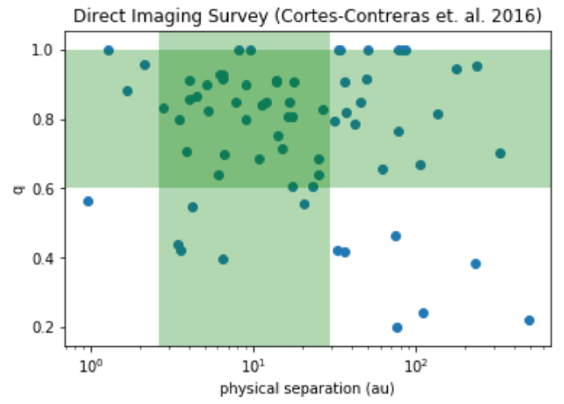
$$f = \int dN = \int_{-2}^{4} \int_{0}^{1} \phi(log(a)) \cdot q^{-\beta} \, dq \, dlog(a)$$

- Assume double integral is separable – dN/dq does not depend on orbital separation

Survey Data

- Sources
  - Radial Velocity (RV) - Delfosse et. al. 1998
  - Direct Imaging (DI) - Cortes-Contreras et. al. 2016
- Completeness Limit
  - Mass Ratio (q)
    - RV: q > 0
    - DI: q > .6
  - Separation (semi-major axis, a)
    - RV: .01 < a < 4.612 AU
    - DI: 2.6 < a < 29.5 AU





References

- Cortes-Contreras et. al. 2016, *Astro. & Astrophys.*, FC23
- Delfosse et. al. 1998, *Astro. & Astrophys.*, 344, 897–910
- Reggiani & Meyer 2013, *Astro. & Astrophys.*, 553, A124
- Janson et. al. 2012, *The Astrophys. Journal,* 754, 44
- Duchene & Kraus 2013, *Annu. Rev. Astron. Astrophys.*, 51

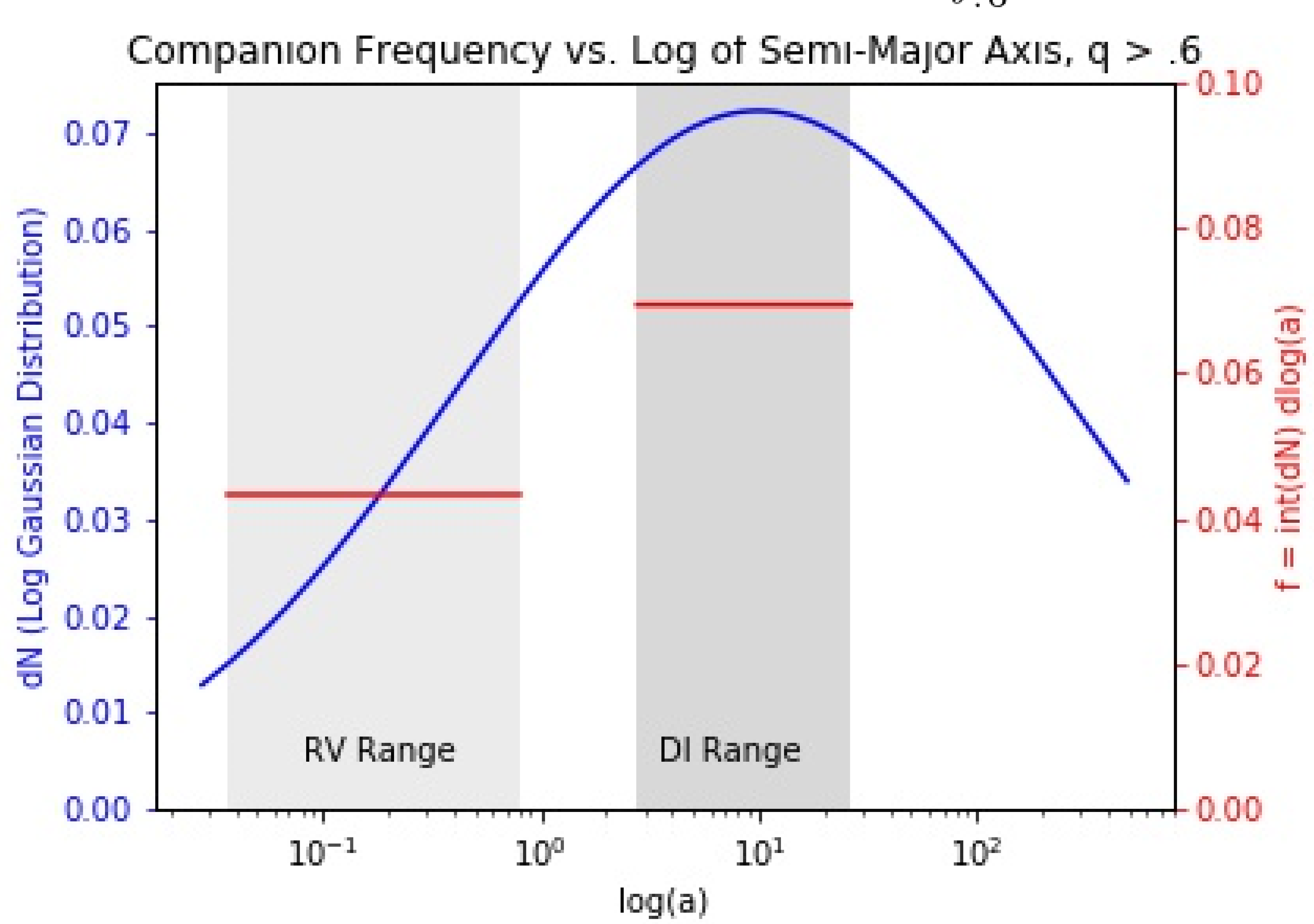
Abstract

This research explores nature of M-dwarf binaries by comparing the companion frequency derived from two surveys which used different detection methods. This is done over a fixed mass ratio (q > .6) and the ranges of separations (semi-major axis, a) these surveys are complete for. We were able to fit a model to the point estimates of the frequencies and use this to extrapolate a **total multiplicity fraction over all q [0,1] and a[0,∞] of .60**.

Results

- KS Test – statistical value of .48 and p value of .19 allow us to accept the null hypothesis that both mass ratio distributions (q>.6) were drawn from same parent population **regardless of orbital separation**
- Analysis – **Log-normal distribution** fit over point estimates of frequencies (q>.6), f (radial velocity) = .043, f (direct imaging) = .069. Using known data points, **found σ (standard deviation) of 1.375 and normalization constant (A) of .249**, while **holding $\overline{log(a)}$ to 1** (10 AU)
- Multiplicity – **total multiplicity fraction of .60** from integration over all q[0,1] and a(0,∞)

$$f = \int_{0}^{\infty} A \cdot \frac{e^{-\frac{(log(a)-\overline{log(a)})^2}{2\sigma^2}}}{\sqrt{2\pi\sigma^2}} \, dx \cdot \frac{\int_{0}^{1} q^{-.25} \, dq}{\int_{.6}^{1} q^{-.25} \, dq}$$



Conclusions

- KS test suggests **mass ratio and orbital separation distributions are independent**
- Comparison of σ
  - Duchene & Kraus 2013 suggest σ ~ 1.3
  - We found σ ~ 1.375
- Comparison of multiplicity fraction
  - We found a **total multiplicity fraction of .60 over all log(a) and q**
  - Janson et. al. 2012 found multiplicity fraction of .27
    - Only for .4<q<1
    - When we constrain q to this range, we find fraction of .30

Next Steps

1. Refine process with more data
   1. **Include more surveys,** such as microlensing, Janson et. al. 2012, Fischer & Marcy 1992
   2. Fit new variables to log-normal model, **including $\overline{log(a)}$**
   3. Recalculate total multiplicity fraction
2. Asses reliable error estimates
3. Compare to multiplicity of FGK stars as defined in other work
4. Search for further evidence that dN/dq does not depend on orbital separation

Further Information

nsusemiehl.com

sites.lsa.umich.edu/feps/