Sculpting Planetary Systems: Constraining Stability Timescales for Systems around FGK Dwarfs with Kepler Observations

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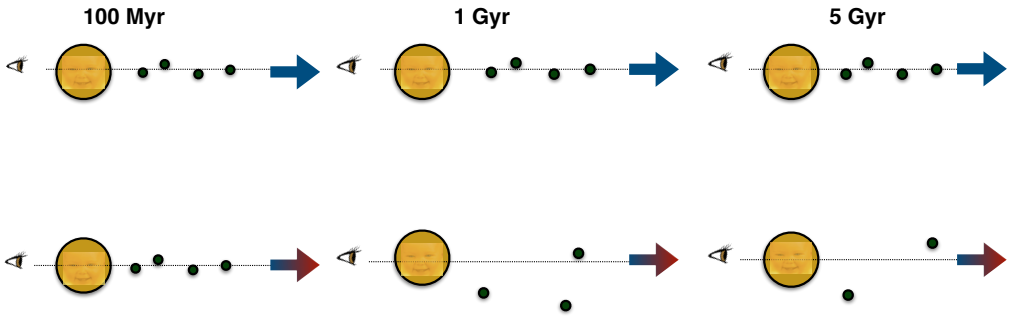
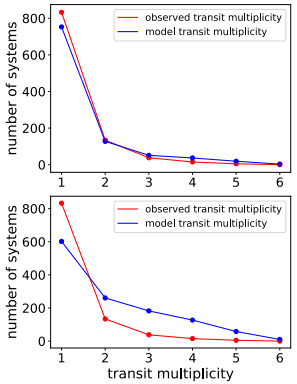


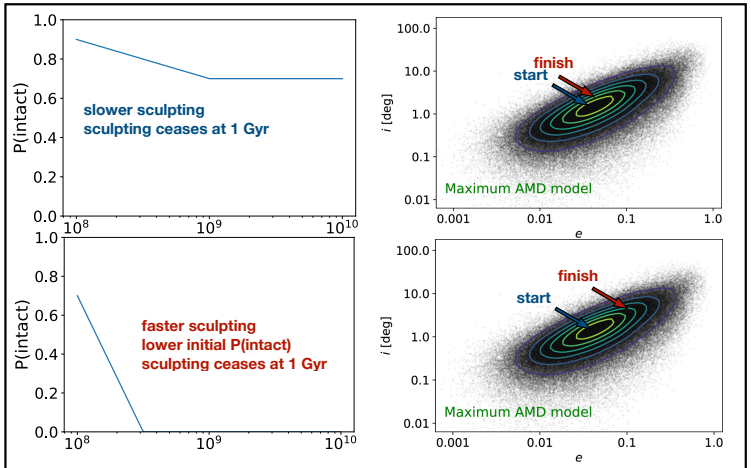


Motivation

- *Kepler* gave us constraints on planetary system demographics, including transit multiplicity Where do these observed transit multiplicities come from?
- The story of their provenance can tell us about the Solar System's dynamical history and the ease with which life on worlds around Sun-like stars can evolve. It can also give us better constraints with which to design expensive dynamical N-body simulations.

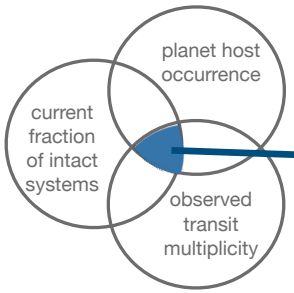
Methods

1. Use *Gaia-Kepler* crossmatch to get ages of planet-hosting stars (Berger et al. 2020b) and observed *Kepler* transit multiplicity
2. Simulate systems based on observed stellar properties, changing only the model, P(intact)
3. If intact, draw inclinations and eccentricities from a narrower and smaller distribution, respectively
4. Calculate observed transits and tally up model transit multiplicities
5. Evaluate models using Poisson log likelihood



Left: P(intact) is the fraction of FGK systems that are dynamically cool ("intact"), versus dynamically hot ("disrupted"). **Right:** Eccentricity and inclination distribution from Millholland et al. (2021). Over time, dynamical sculpting would push systems up in eccentricity, inclination, and angular momentum deficit (AMD).

A consistent dynamical sculpting model can reproduce…

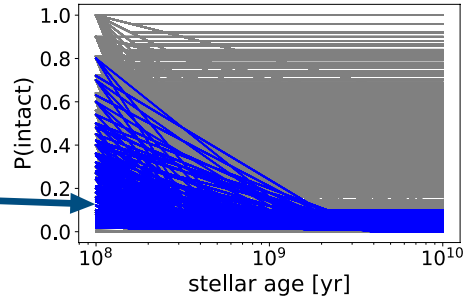


Results and Discussion

- Models with fractions of planet-hosting stars between 10% and 40% are strongly favored.
- Models with initial fractions of dynamically cool systems over 20% are disfavored.
- Limitations on sample size and age errors for younger stars in the sample mean that we can more confidently comment on Gyr+ timescales than on timescales shorter than 1 Gyr.

Example models:

- Favored: early period of rearrangement; architecture becomes frozen in before 1 Gyr
- Disfavored: all systems start intact and undergo sculpting over 10 Gyrs
- Disfavored: half of systems start intact; no sculpting occurs



Sculpting laws colored by whether they are strongly favored by the observed transit multiplicity and present-day fraction of intact systems of ~8% (blue; Ballard 2019), or not (gray).

Acknowledgments

This material is based upon work supported in part by the National Science Foundation GRFP under Grant No. 1842473. We wish to thank Jamie Tayar, Matthias He, and especially Sarah Millholland for their helpful comments and suggestions.

Citations

Ballard 2019 AJ 157 113.
Berger et al 2020 AJ 160 108
Millholland et al 2021 AJ 162 166