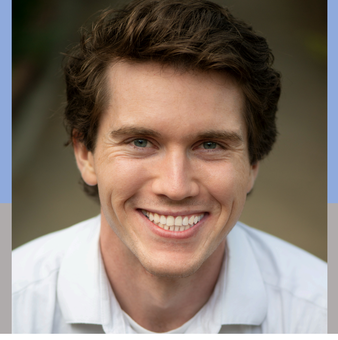

The Distant Giants Survey: Finding the connection between outer giants and inner small planets

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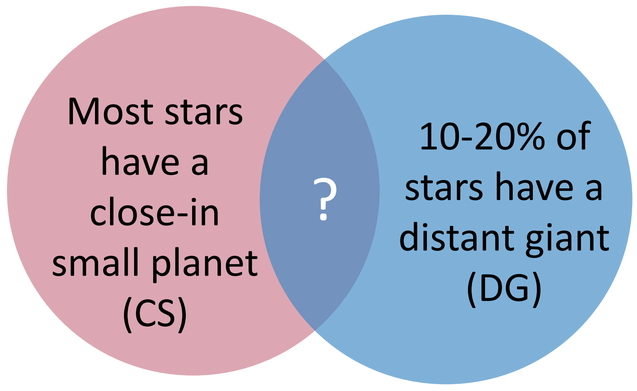
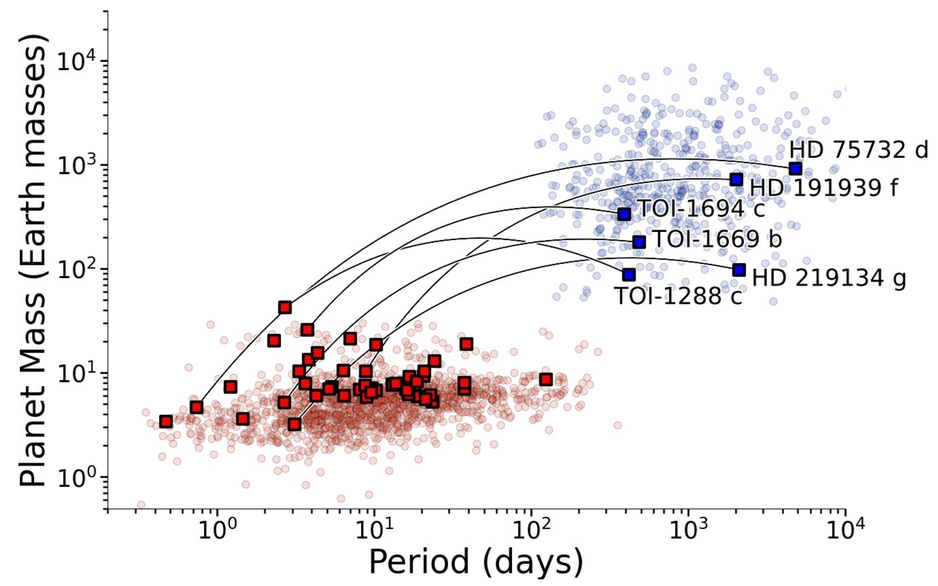


Why does this connection matter?

NASA's Kepler Space Telescope taught us that **small planets with short orbital periods are ubiquitous** (~1 per star; Petigura+2018). Meanwhile, ground-based radial velocity (RV) surveys have found that **10-20% of Sun-like stars host a Jupiter analog** (Rosenthal+2022). While we have made great strides in understanding these two populations *separately*, the connection *between* them remains uncertain because our detections come from nearly-disjoint stellar populations. **Uncovering the relationship between these planet types will inform our understanding of inner vs. outer planet formation**, teaching us about the evolution of our own solar system and others like it.

The Distant Giants Survey is measuring P(DG|CS)

To find the connection between these two populations, we began a 3-year Keck/HIRES RV survey to search for evidence of long-period giant companions in a sample of 47 Sun-like TESS targets hosting small transiting planets. A measurement of P(DG|CS) > 10-20% will indicate that distant giants and close-in small planets are positively correlated, and vice verse if P(DG|CS) < 10-20%. As of March 2023, **we have found evidence for giant companions in 16/47 systems** (~34%), 6 as fully resolved orbits (Van Zandt+2023) and 10 as partial orbits, a.k.a. RV trends. This preliminary result suggests a positive correlation, but hinges on the nature of the objects responsible for the RV trends.

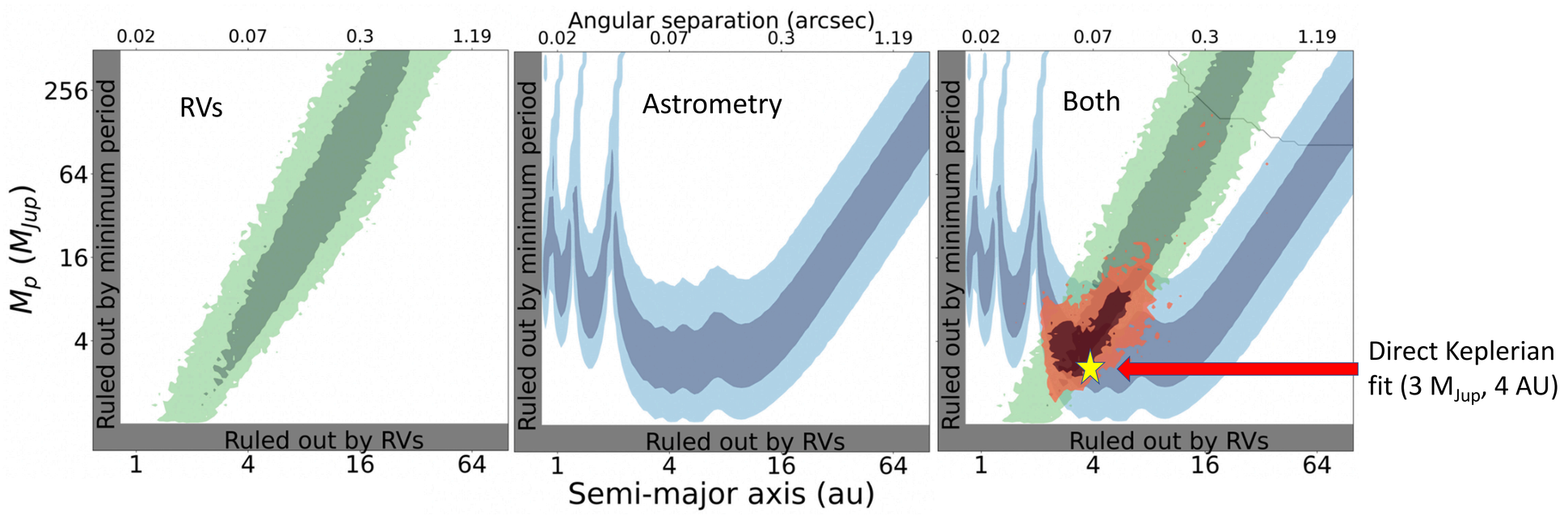


Red/blue planets were discovered with transits/RVs. Squares show the Distant Giants sample. ***We have measured masses of 6 gas giants so far.***

Partial orbit analysis is crucial to our final measurement

Because 10/16 of our possible detections come from partial orbits, disambiguating between planets, brown dwarfs, and low-mass stars in these systems is a central part of our survey. We combine our RV data with astrometric accelerations from the Hipparcos-Gaia Catalog of Accelerations (Brandt 2021) and high-resolution imaging to constrain the companions in our partially resolved systems. The procedure is as follows:

1. Randomly sample a set of orbital parameters
2. Forward model the sampled orbit's RV trend and astrometric acceleration
3. Compare the calculated values to their measured counterparts to compute a likelihood. Models with greater likelihood are shaded darker.
4. Repeat ~10^8 times to derive a posterior surface



The panels above show our analysis of HD 191939, a system in which we discovered a long-period super-Jupiter through partial orbits (Lubin, Van Zandt, et al. 2022). After obtaining greater phase coverage, we confirmed our prediction with a direct Keplerian fit to the RVs. We caution that despite this technique's utility in some systems, it finds limited success in others. For example, systems without available astrometric accelerations suffer from the mass-separation degeneracy in the left panel, while those with shallow RV trends and baselines ≳25 yr. benefit little from the inclusion of astrometry. Nevertheless, coupling direct imaging with RV trends can efficiently rule out many stellar companions.

Takeaway #1

The Distant Giants Survey is measuring the conditional occurrence of long-period giant companions to close-in small planets. Approximately 6 months of our 3-year survey remain, and so far we have found tentative evidence for an enhancement of giant planets in the presence of inner small ones. Our final result is dependent on a complete statistical analysis of our observations.

Takeaway #2

Combining RVs, astrometry, and direct imaging is a powerful technique for identifying long-period companions using only fractional orbit coverage. We have deployed our computational framework as Ethraid, a pip-installable Python package that can help ***you*** disentangle the RV trend in your system of choice!

Want more info. on the Distant Giants Survey? Visit my website!