Hot Jupiters, Cold Kinematics

Alexander J. Mustill[1], *Michiel Lambrechts*[1], *Melvyn B. Davies*[2]
[1]Department of Astronomy & Theoretical Physics, Lund University, Sweden
[2]Centre for Mathematical Sciences, Lund University, Sweden
alex@astro.lu.se

Introduction

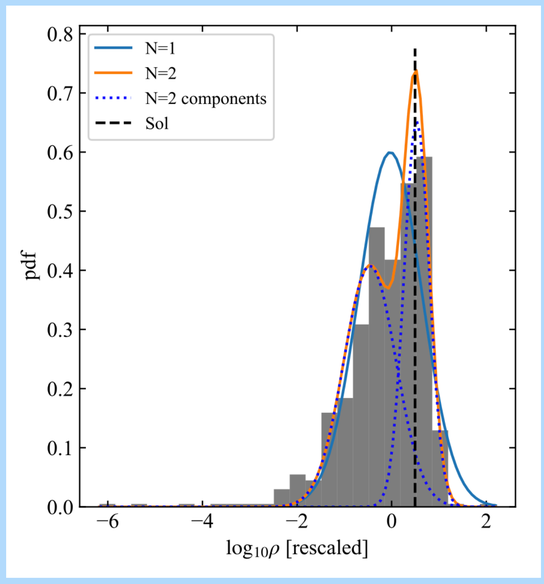
Recent work (Winter *et al.*, Nature, 586, 528) has revealed relations between the Galactic phase space densities of exoplanet host stars, and the properties of the planetary systems. Here we investigate the origin of one of these relations: the fact that stars hosting Hot Jupiters (here, $a < 0.2$ au) tend to have higher phase space densities than stars hosting Cold Jupiters ($a > 0.2$ au).

The Galactic phase space density may reflect:

- The birth environment of the host star, if a high density at birth persists into an above-average density when the star is old (1–4.5 Gyr)
- The age of the host star, as older stars are kinematically heated by matter inhomogeneities in the Galaxy

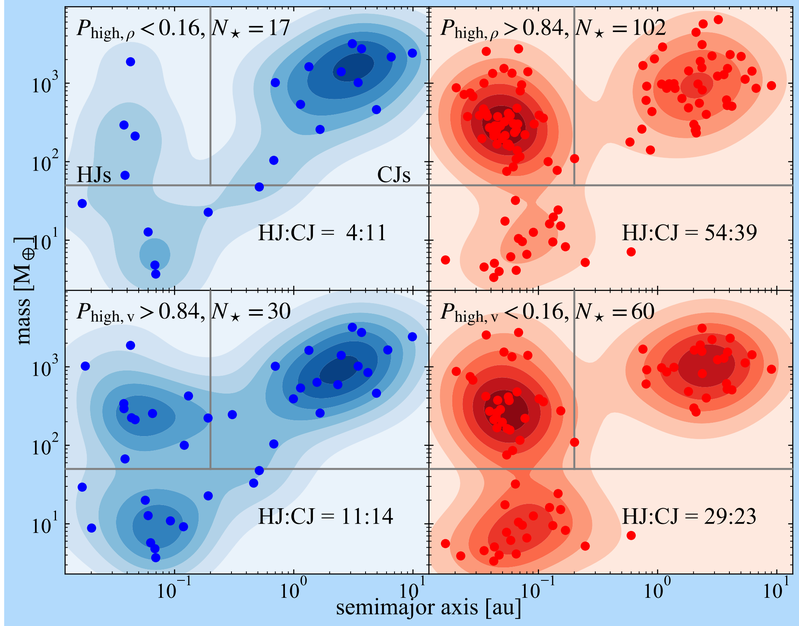
Hence, observed differences between populations of planets orbiting stars of high and low phase space density may reflect either the influence of the birth environment on planetary system formation, or the evolution of planetary systems with age.

Method



We follow Winter *et al.* (2020) in determining the host stars' phase space densities. We use 6D *Gaia* EDR3 kinematics to calculate each star's 20th nearest neighbour in 6D phase space, and compare it to neighbouring stars within 40pc. We then use a two-component Gaussian mixture model to find the probability that each star belongs to a high-density component or to a low-density component. The example of the Sun is shown above.

Hot Jupiters are indeed more common around stars in high-density regions of phase space…but also around stars with lower velocities relative to the Local Standard of Rest



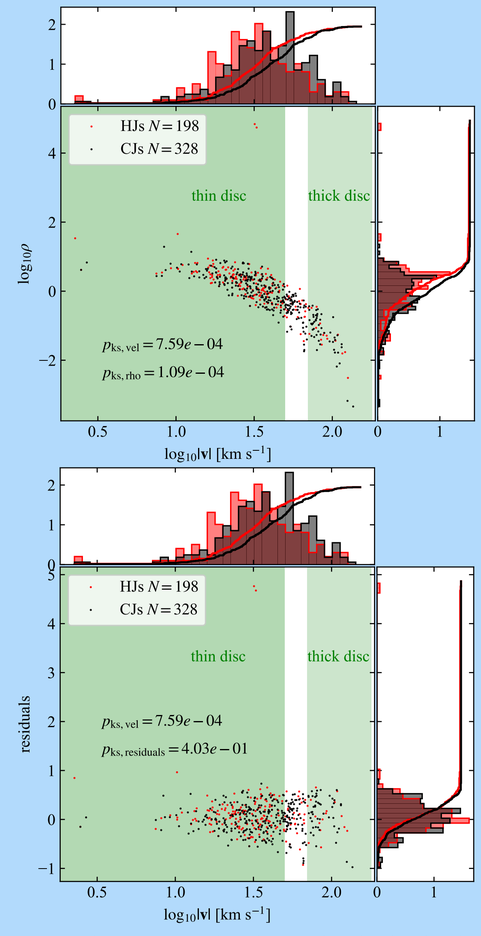
For stars that can be assigned confidently to either the high-density or the low-density population, we recover the result that Hot Jupiters are more common around the high-density hosts (top panels).

However, we also find that Hot Jupiters are more common around the stars with lower velocities relative to the Local Standard of Rest (bottom panels).

When investigating what determines a star's phase space density, we found that, for stars not in clusters, it is mainly set by the velocity relative to the LSR. Hence, the dependence of Hot Jupiter presence on phase space density may reflect a dependence on the star's random motion (and hence, on the age). We therefore next attempted to see whether the correlation persisted after detrending for velocity.

https://arxiv.org/abs/2103.15823

Hot Jupiter hosts have low velocities, but normal phase space densities for their velocity



The relation between phase space density and velocity is shown in the top panel. After detrending, we see no residual difference in the phase space densities between the hosts of Hot Jupiters and Cold Jupiters (bottom panel). **This suggests that the presence of Hot Jupiters is dependent on a star's age, which may be expected if Hot Jupiters are depleted on timescales of ~Gyr by tidal inspiral** (Collier Cameron & Jardine, 2018, MNRAS, 476, 2542, Hamer & Schlaufmann, 2019, AJ, 158, 190). Our work gives a hint of the relations that PLATO may uncover when it provides precise and accurate ages for a large number of main-sequence exoplanet hosts.