Stellar Rotation of Kepler Exoplanet Host Stars

Scarcity of Short-Period Planets around Fast Rotators

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Using an algorithm based on the autocorrelation function (McQuillan, Aigrain & Mazeh 2013), we derived stellar rotational periods for 737 main-sequence exoplanet host stars. Comparing the stellar rotational period with the orbital period of the closest detected planet in each system, we have found that the spin-orbit distribution reveals a striking lack of close-in planets around fast rotators.

The Autocorrelation Function (ACF)

The ACF measures the degree of self-similarity of the observed light curve over a range of time lags. For rotational modulation, the repeated spot-crossing signature leads to ACF peaks at lags corresponding to the rotational period and its integer multiples. We adopt this technique of period detection over Fourier-based methods since the ACF has been shown to produce clear and robust results even when the amplitude and phase of the photometric modulation evolve significantly, and when systematic effects and long-term trends are present[1]. Kepler's long-baseline, high-precision light curves are revolutionizing the study of stellar rotation, and the ACF is the ideal way to exploit these data.

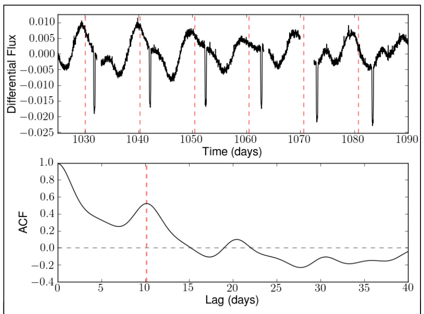

Figure 1. Example of a light curve and its ACF - KOI-805. The orbital period is 10.32d and the transits are clearly visible. The detected rotational period (10.14d) is marked on the ACF with a dashed line and corresponding period intervals are marked on the light curve as red dashed lines. It can be clearly seen that the rotational period detected matches the repeating flux modulations.

Application to the Full Kepler Sample

We applied the ACF to the full sample of 128,774 single, main-sequence stars below 6500 K observed by Kepler. We derived rotational periods for 31,995 targets, making it the largest sample of rotational periods to date. We are able to detect rotational periods for variability down to ~200ppm. See talk by Amy McQuillan.

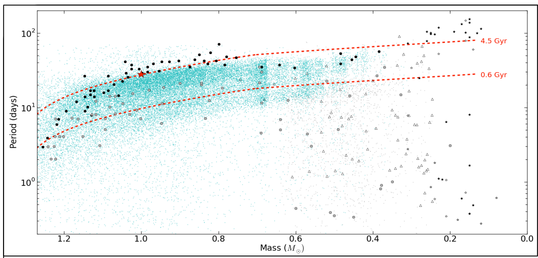

Figure 2. Detected rotational period as a function of mass for the full Kepler dataset (blue dots). Literature data from other surveys are marked as circles[2,3] (black/old, grey/young), stars[4], triangles[5] and grey dots[6]. The Sun is marked with a red star. The rotational isochrones from gyrochronology[7] are marked as red dashed lines.

Rotation of Planet Candidate Host Stars

Using the ACF we derived rotational periods for 737 Kepler planet host stars. Plotting the rotational period versus the orbital period of the closest observed planet in each system revealed a striking lack of short-period planets, in the range 1-3 days, around fast rotators, with periods shorter with 5-10 days[8].

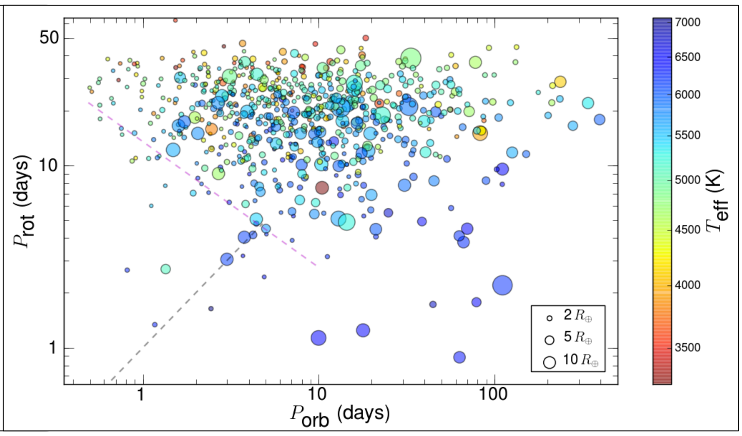

Figure 3. Host star rotational period vs. orbital period of the shortest period planet in each system. Stellar effective temperature is shown by the color scale and planet radius is indicated by point size. The grey dashed line marks the 1:1 ratio and the magenta line shows a fit to the lower envelope of the distribution of short-period planets.

Discussion

Slow stellar rotation is considered as indication for magnetic braking, either because of strong magnetic fields or due to stellar age. Therefore, fast rotators might be either young or have a weak magnetic field. But, in our case the fast rotation could be also due to spin-up processes through star-planet interaction, or even because the stellar envelope swallowed up a spiraling-in planet, which might explain the scarcity of short-period planets around fast rotators. To further study such possible alternative scenarios, we need to augment the stellar-orbital period distribution by derivation of stellar and activity characteristics of the planet host stars, and spin-orbit alignment of the planetary motion.

References:
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