Things That Go Bump In The Transit

Using Kepler Transit Observations to Measure Stellar Spot Belt Migration Rates

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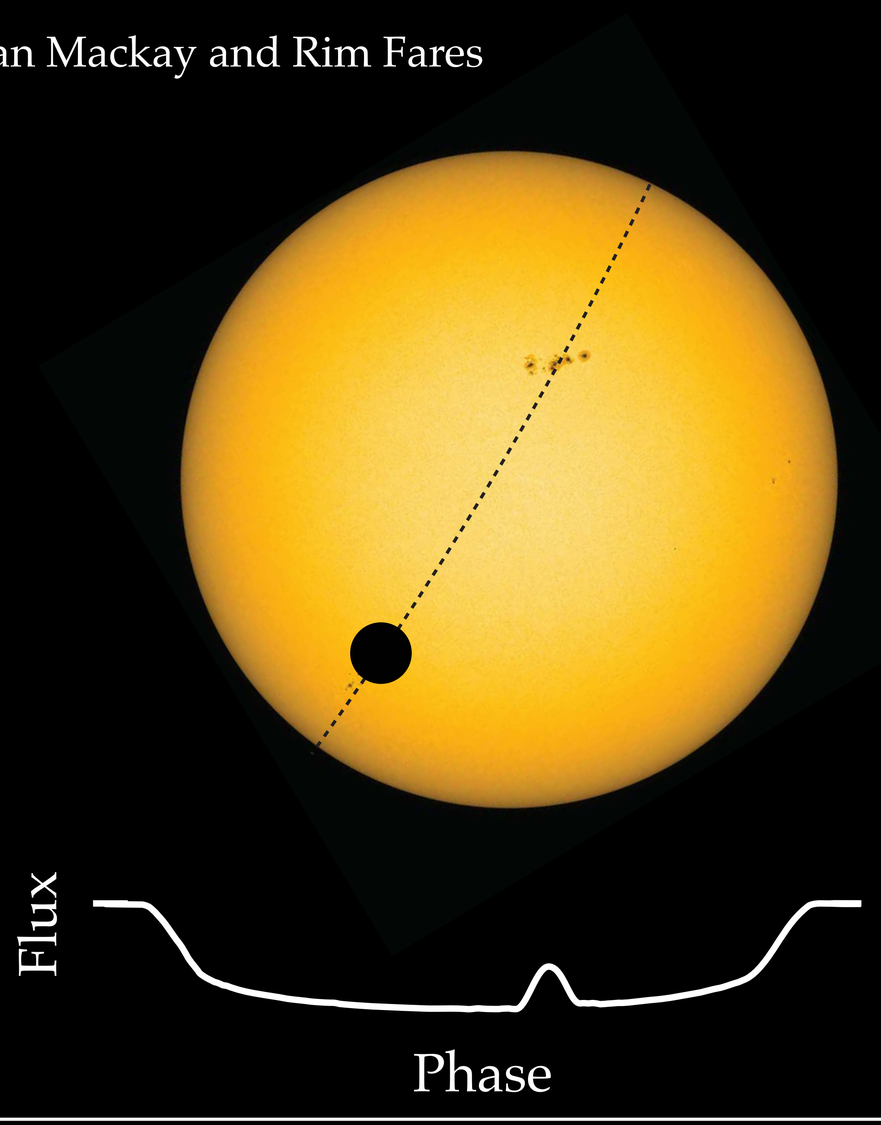
1. Introduction

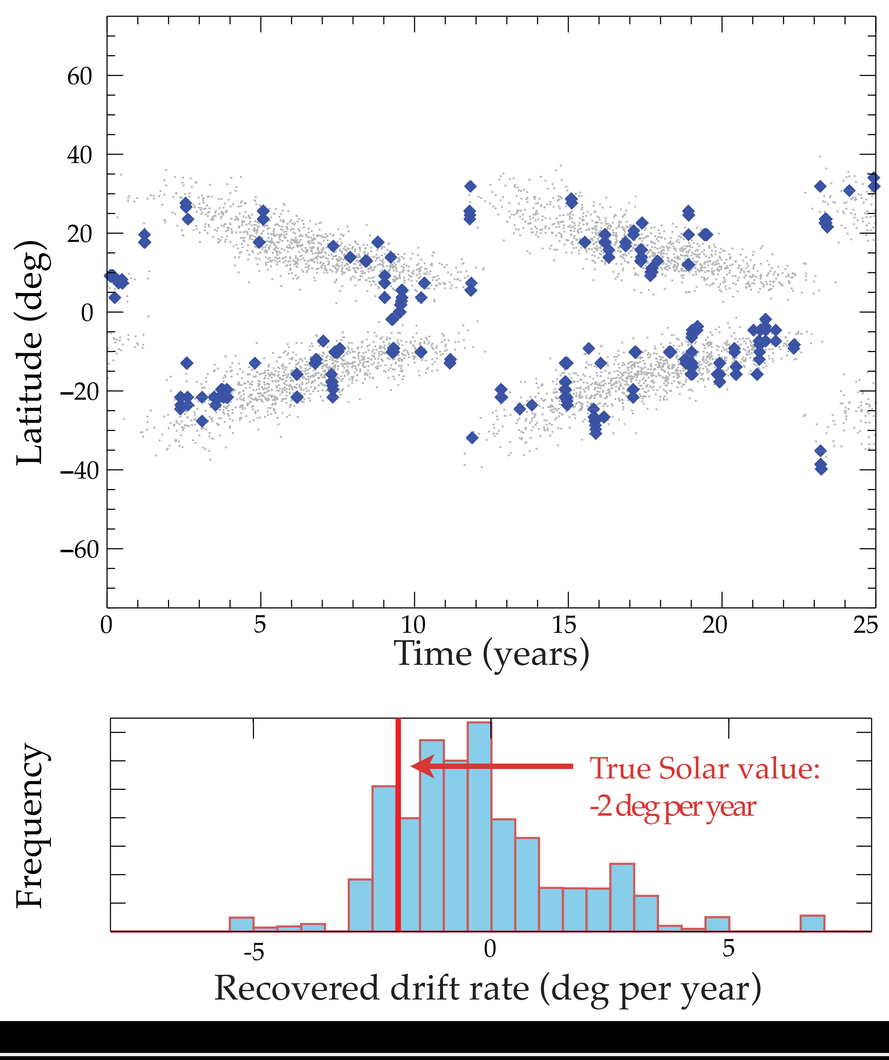
- Transit observations of planetary systems that show spin-orbit misalignment provide a new method for investigating the location and distribution of star spots over time.
- Systems such as Hat-P-11, HD 189733, Tres-1, WASP-4b have reported spin-orbit misalignment and the presence of spots in the transit lightcurves.
- When a planet transits over a star spot the fractional loss of light becomes less and a bump is registered in the light curve, from which we can determine the latitude of the spot on the star.
- A misaligned orbit means the planet will transit over a range of latitudes, providing insight into the distribution of star spots over the stellar disk.
- With continuous observations, such as provided by Kepler we can build a picture of any time-latitude variations of the spot locations, with the aim of detecting stellar butterfly patterns like that seen on the Sun and be a further test for stellar dynamo theories.



2. The Model

- We use Solar surface flux transport simulations to determine the evolution of star spots through the cycle, accounting for Differential Rotation, Meridional flow and surface diffusion. A butterfly pattern is specified as input. We use a Solar pattern (van Ballegooijen et al. 1998) and also patterns for describing magnetic cycles on the rapid-rotator AB Dor (McIvor et al. 2006).
- In our simulation, limb-darkening and also foreshortening of the spots on the stellar disk are accounted for. The planet is taken to be a hot-Jupiter (providing a 1% drop in light) with the obliquity taken to be 60º. The planet transits once every 5 days.

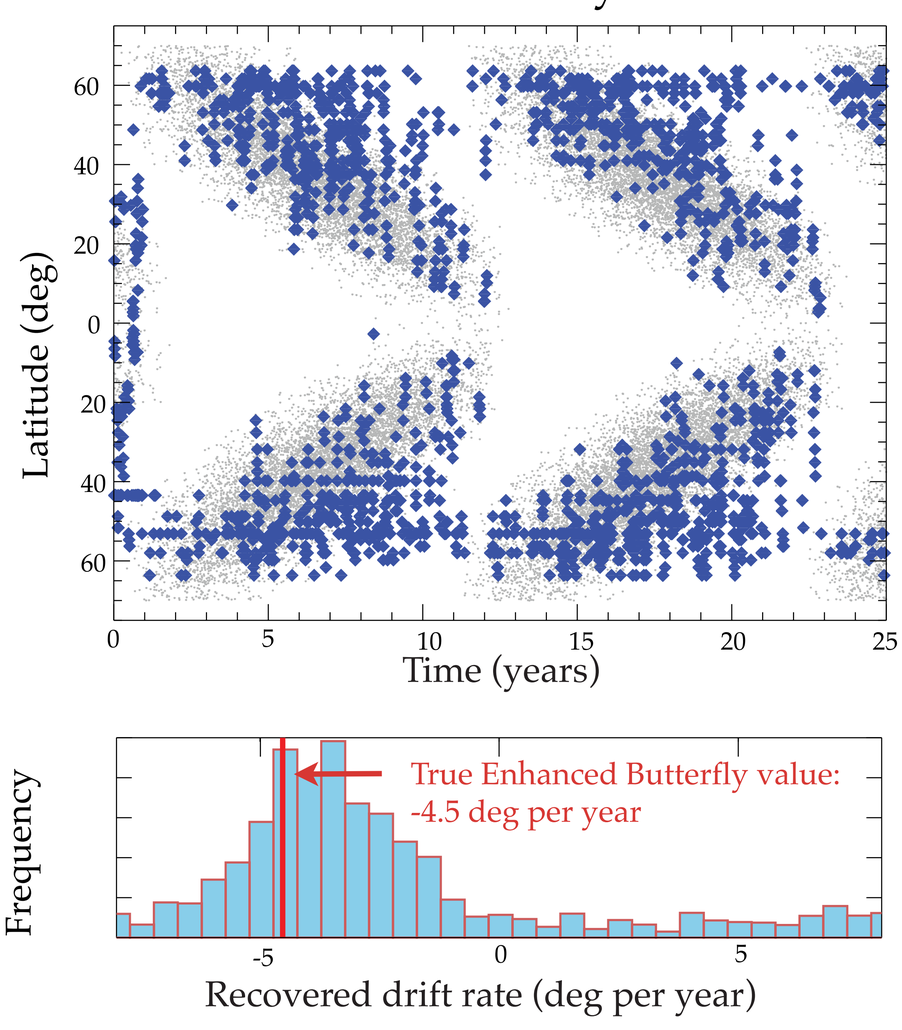
Solar Butterfly Pattern



Input butterfly patterns (grey dots) and recovered spot location (blue diamonds)

Recovered spot drift rates (Northern hemisphere) from random 3.5 year Kepler observation windows

Enhanced Butterfly Pattern



3. Conclusions and Prospects

- 3.5 years of Kepler observations may not be long enough to recover a drift rate for a star with an activity level similar to the Sun. However, for more active stars where the planet is more likely to occult a spot, we find that it may be possible to determine spot belt drift rates.
- Should the Kepler mission be extended, then we would be more likely to discover drift rates for stars whose planets show spin-orbit misalignment.

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