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KOI-13.01: A Spin-Orbit Misaligned Giant Planet Orbiting a Fast-Rotating Star

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Abstract of the Abstract

I report a measurement of the stellar spin-planetary orbit alignment in the KOI-13 system, the first such measurement to use transit photometry alone (i.e., not Rossiter-McLaughlin spectroscopy). The star's obliquity to the plane of the sky is 18.5°, and the planet's orbit normal is inclined 34.6° to the projected stellar pole, leading to a net spin-orbit misalignment of 40.3°. Given the much-lower inclinations of solar system planets, I invoke a possible Kozai resonance with the binary stellar companion of the KOI-13 host star as a possible explaination for the high measured inclination.

1. Abstract

Given the nebular theory of planetary system formation and our experience in the solar system, it is reasonable to expect the orbits of planets in extrasolar systems to show low inclincations with respect to their parent stars' equators. Indeed the mutual inclinations among the planets in the Kepler-11 system are much lower than those among solar system planets (Lissauer et al., 2011). On the other hand, the stellar spin-planetary orbit alignment of some other transiting extrasolar planets measured using the Rossiter-McLaughlin effect can be quite high, as in the case of planet XO-3 which shows a striking spin-orbit misalignment of $70^\circ \pm 15^\circ$ (Hébrard et al., 2009).

Barnes (2009) predicted that objects transiting fast-rotating stars would show unusual, asymmetric lightcurves if the transiter's orbit normal is not aligned with the stellar rotational pole – i.e. in the case of a spin-orbit misalignment. Recently Szabo et al. (2011) showed that KOI-13.01, one of the *Kepler* planet candidates announced by Borucki et al. (2011), rotates with $V \sin i$=65 km/s and shows a pronounced lightcurve asymmetry. Szabo et al. (2011) attributed this asymmetry to gravity darkening associated with rapid rotation, but did not measure the implied spin-orbit misalignment.

Using the algorithm that I developed for Barnes (2009), I fit the folded transit lightcurve for KOI-13.01. I found that the lightcurve asymmetry indicates a stellar obliquity of 18.5° relative to the plane of the sky (i.e., the stellar north pole is tilted away from the viewer by 18.5°), and that the longitude of the ascending node for the planet is 214.5° (*i.e.* that the planet transits the south pole of the star first while heading toward the equator at a 34.5° angle with respect to the stellar equator). The resulting net spin-orbit misalignment is 40.3°. This technique does not, however, resolve the degeneracy between prograde and retrograde solutions – hence the spin-orbit misalignment might then be 139.7° if the planet orbits retrograde.

The parent star of KOI-13.01 has a binary companion of similar mass with a separation of 1900 AU, which allows that the Kozai mechanism may be responsible for this system's spin-orbit misalignment.

KOI-13.01 thus represents the first system for which the spin-orbit alignment has been measured purely photometrically. The prograde/retrograde degeneracy notwithstanding, the photometric method removes the $\sin i$ degeneracy inherent in Rossiter-McLaughlin measurements and thus measures a fully accurate inclination of the planet orbit relative to the stellar equator. The photometric method can complement the Rossiter-McLaughlin effect to constrain spin-orbit alignment for planets orbiting fast-rotating stars.

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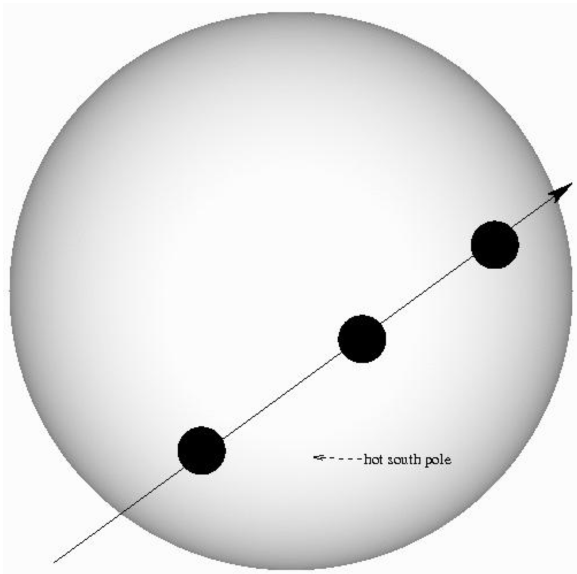

Figure 1: KOI-13.01 transit geometry.

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