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Title: Detection of superrotation in Kepler light curves of hot Jupiters
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Abstract: Kepler-76b was identified as a grazing hot Jupiter by detection of the BEaming, Ellipsoidal and Reflection (BEER) phase modulations, combined with V-shape transit and occultation, in the light curve of its host star. The mass of such a transiting planet can be estimated from either the beaming or the ellipsoidal
amplitude. The ellipsoidal-based mass estimate of Kepler-76b is consistent with the spectroscopically measured mass while the beaming-based estimate is significantly inflated. We explain this apparent discrepancy as evidence for the superrotation phenomenon, which involves eastward displacement of the hottest atmospheric spot of a tidally-locked planet by an equatorial super-rotating jet stream. This phenomenon was first observed for HD 189733b in the infrared.
To investigate how common superrotation is, we analyzed the latest Kepler light curves of Kepler-76 and three additional transiting hot-Jupiter systems: KOI-13, HAT-P-7 and TrES-2, which show BEER phase modulations. For the four systems, we find that the beaming-based planetary mass estimate is significantly larger than the mass estimated from the ellipsoidal amplitude. As with Kepler-76b, this was previously noticed also for KOI-13b and TrES-2b.
Following the Kepler-76 reasoning, we explain these apparent discrepancies by equatorial superrotation, that displays itself in the star light curve as an angle shift of the planet reflection/emission phase modulation.
We propose a modified BEER model that includes superrotation and provides a photometry-consistent estimate of the planetary mass. Our analysis shows that the superrotation BEER model fits the data better than a zero phase-shift null model in a very significant way for HAT-P-7 and Kepler-76, and with marginal significance for KOI-13 and TrES-2.
The model mass estimates are in excellent agreement with the planetary masses derived from radial-velocity measurements, available for HAT-P-7, TrES-2 and Kepler-76. This makes the analysis a viable method for estimating hot-Jupiter masses from the photometric BEER modulations of their host stars.
We conclude that hot-Jupiter superrotation may be a common phenomenon that can be detected in the Kepler visual band light curves of planets that show significant BEER phase modulations.