Constraints on Transit and Eclipse Probabilities of Long-Period Exoplanets from Orbital Elements

NExScI NASA Exoplanet Science Institute

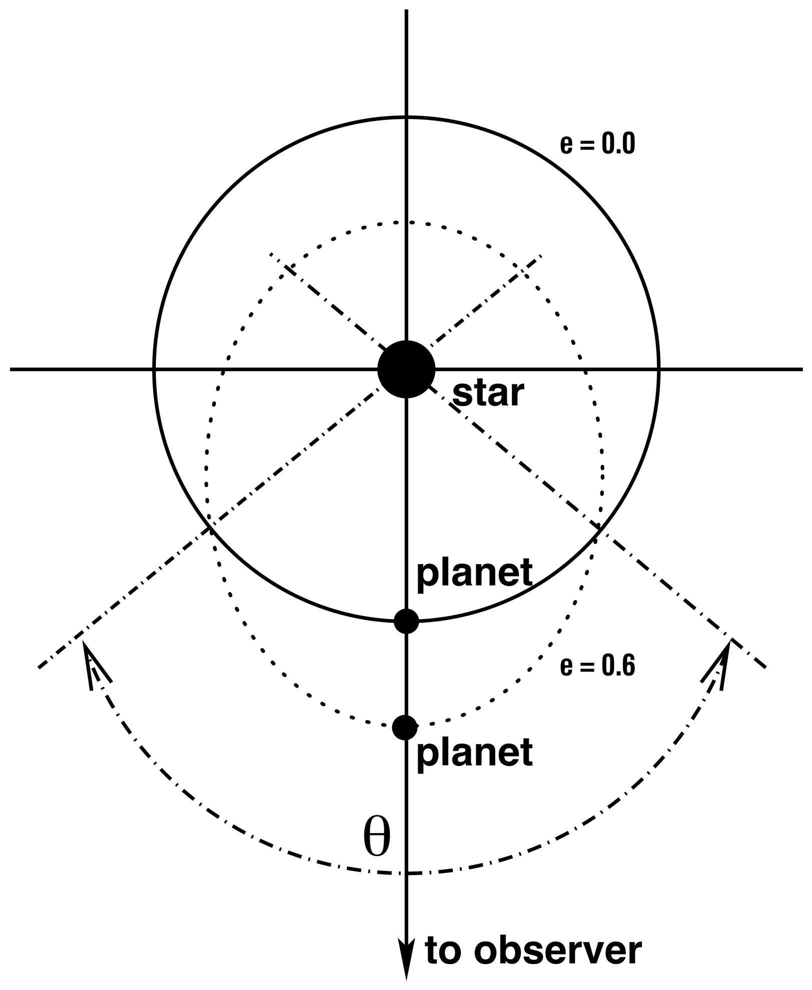
Kaspar von Braun & Stephen R. Kane

(NASA Exoplanet Science Institute, California Institute of Technology)

California Institute of Technology 1891

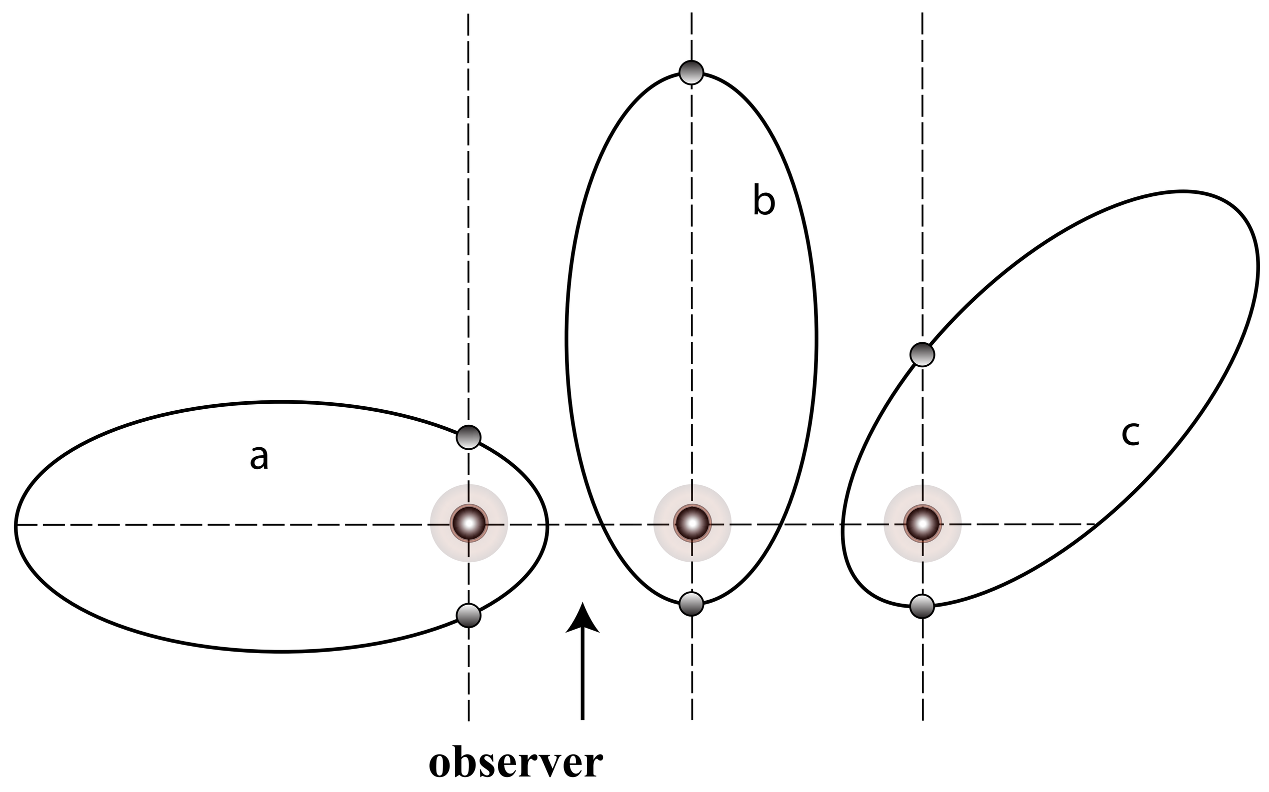
Abstract & Introduction: Transiting exoplanets provide an opportunity to study the mass-radius relation and internal structure of extrasolar planets. Long-period transiting planets in particular allow insight into planetary evolution akin to the Solar System where, in contrast to hot Jupiters, planets are not constantly exposed to the intense radiation of their parent stars. Observations of secondary eclipses additionally allow studies of exoplanet temperatures and large-scale exo-atmospheric properties. In our presentation, we show the dependence of transit and eclipse probabilities upon eccentricity and argument of periastron. We further illustrate resulting selection and observational strategies involved in our photometric survey of southern radial-velocity planets with the aim of detecting transit signatures **(Transit Ephemeris Refinement and Monitoring Survey – TERMS)**. In addition, we elaborate on the implication of the presence/absence of observed transits for the observability of secondary eclipses.

Fig. 1: Orbital Geometry



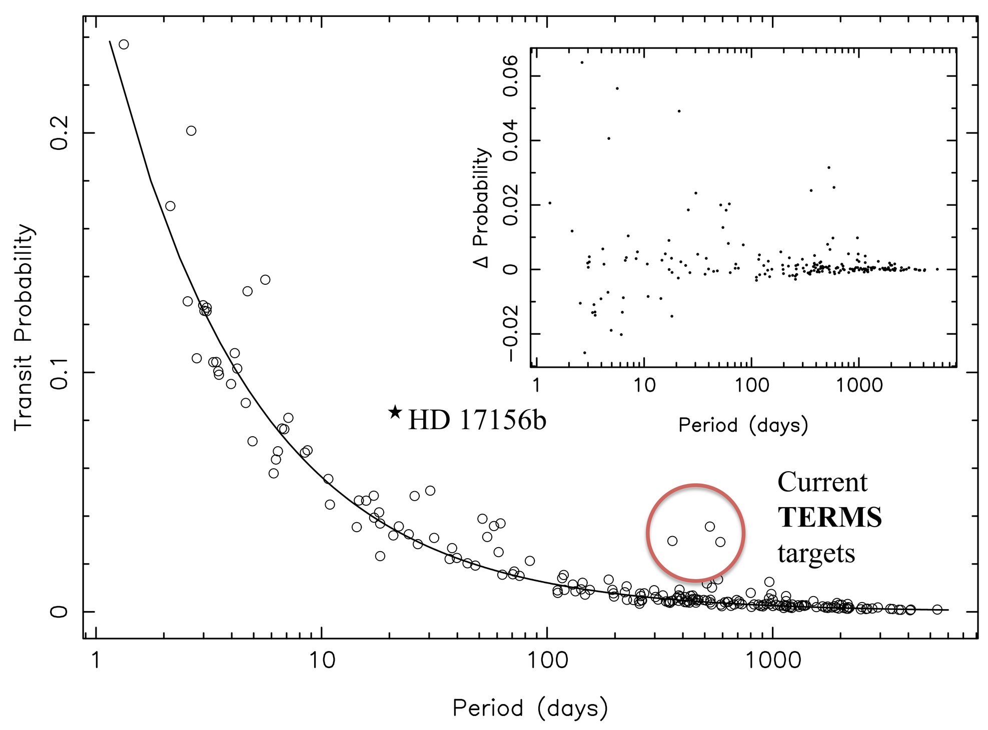
Left Panel: Transit and Eclipse Probabilities: Elliptical vs. Circular Orbit. View from above of circular (solid line) and elliptical (dotted line; e = 0.6) planetary orbits for ω = 3π/2. The angle Θ corresponds to the range of orientations of ω for which transit (eclipse) probability is lower (higher) for the elliptical orbit than for the circular one.

Right Panel: Exoplanet Transit and Eclipse Probabilities as a Function of Argument of Periastron. Top-down view of three different orbital configurations of an eccentric orbit, with the arrow indicating the line of sight of an observer. The periastron arguments of orbits a, b, and c are π, π/2, and π/4 respectively. The star–planet distances in front of and behind the star, and thus the transit end eclipse probabilities, are highly dependent upon the value of the argument of periastron ω.

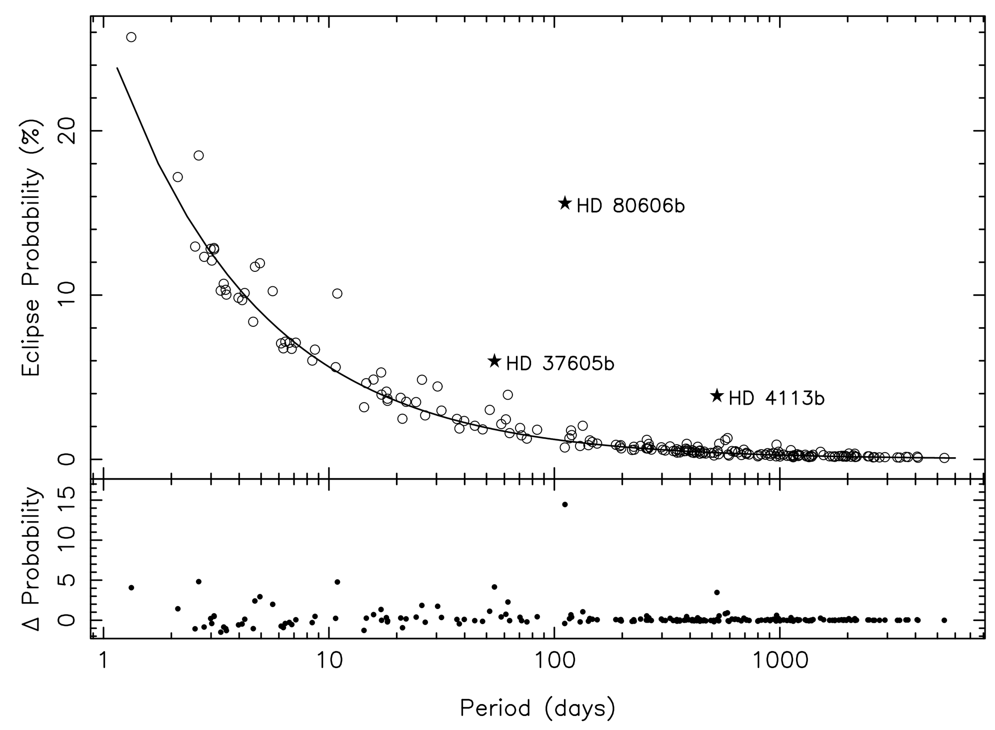


The eclipse and transit probabilities are sensitively dependent on e and ω.

Fig. 2: Transit/Eclipse Probabilities

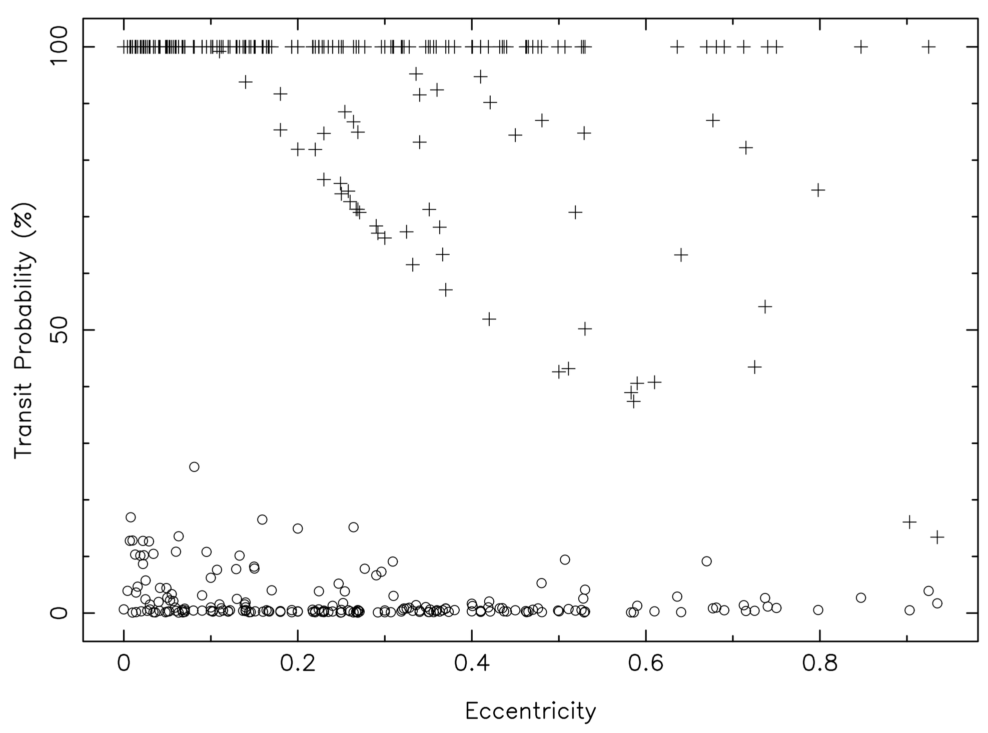


The **Left Panel** and **Right Panel** show the geometric transit and (secondary) eclipse probabilities, respectively, of a sample of 203 known extrasolar planets (Butler et al. 2006), calculated from their orbital parameters (open circles). The solid lines indicate transit/eclipse probabilities if the respective orbit of the given period were circular. We assume solar and Jupiter radii and masses for all stars and planets for the purpose of comparison. The star symbols indicate systems whose transit/eclipse probabilities are particularly enhanced by their combination of e and ω with respect to an equivalent circular orbit (also indicated by the residuals plots). The three systems in the right panel with enhanced transit probabilities and periods of around 1—2 years (HD 156846b, HD 4113b, and HD 20782b) are current **TERMS** targets.

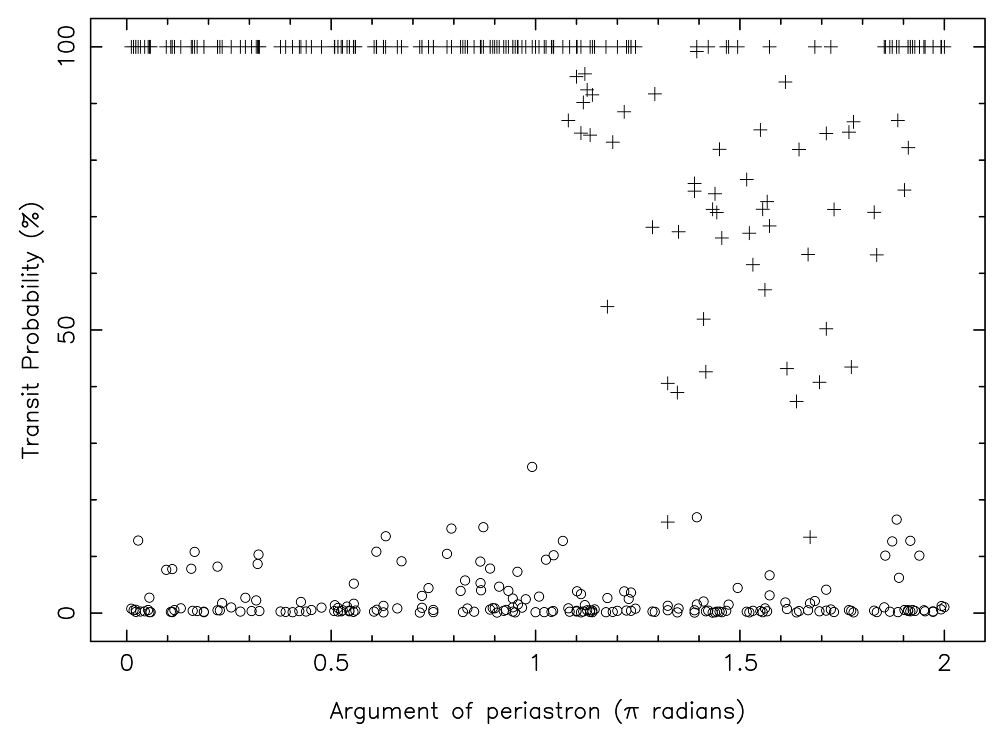


Combinations of e and ω can make long-period exoplanet systems viable targets for transit studies.

Fig. 3: Conditional Transit/Eclipse Probabilities



The **Left Panel** and **Right Panel** show the geometric transit probabilities as a function of e and ω, respectively, of the same 203 known extrasolar planets (Fig. 2), both *a priori* (solid circles – no knowledge of orbital inclination), and if a secondary eclipse has been detected (crosses), such as in the case of HD 80606b (Laughlin et al. 2009). We assume solar and Jupiter radii and masses for all stars and planets for the purpose of comparison. The left panel shows that, for low eccentricities, detection of a secondary eclipse guarantees the presence of a transit, whereas for higher eccentricities, this is not the case. The right panel shows that, for values of ω ~ π/2, the existence of a secondary eclipse guarantees the presence of a transit, whereas for ω ~ 3π/2, this dependence is much weaker (as expected from Fig. 1). The same general behavior is found in the inverse case where one calculates the eclipse probabilities a priori or with the know of the existence of a primary transit.



The presence of a transit or eclipse greatly affects the likelihood of existence of the respective counterpart.

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Contact:

Kaspar von Braun:
kaspar@caltech.edu