Constraining Orbital Parameters of Extrasolar Planets Through Transit Monitoring

NExScI — NASA Exoplanet Science Institute

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Abstract & Introduction: The orbital parameters of extra-solar planets have a significant impact on the probability that the planet will transit its parent star. This was recently demonstrated by the transit detection of HD 17156b whose favorable eccentricity and argument of periastron dramatically increased its transit likelihood. We demonstrate how these two orbital parameters affect the geometric transit probability as a function of period and apply our insights to known radial velocity planets to show that in some cases, due to the values of eccentricity and argument of periastron, long-period planets have comparatively high transit probabilities. Finally, we calculate the expected transiting planet yield for a photometric monitoring campaign to look for transits of radial velocity planets.

Orbital Geometry and Transit Probability

Argument of Periastron: The transit probability of elliptical orbits can be much higher than for circular orbits for certain orientations of the argument of periastron.

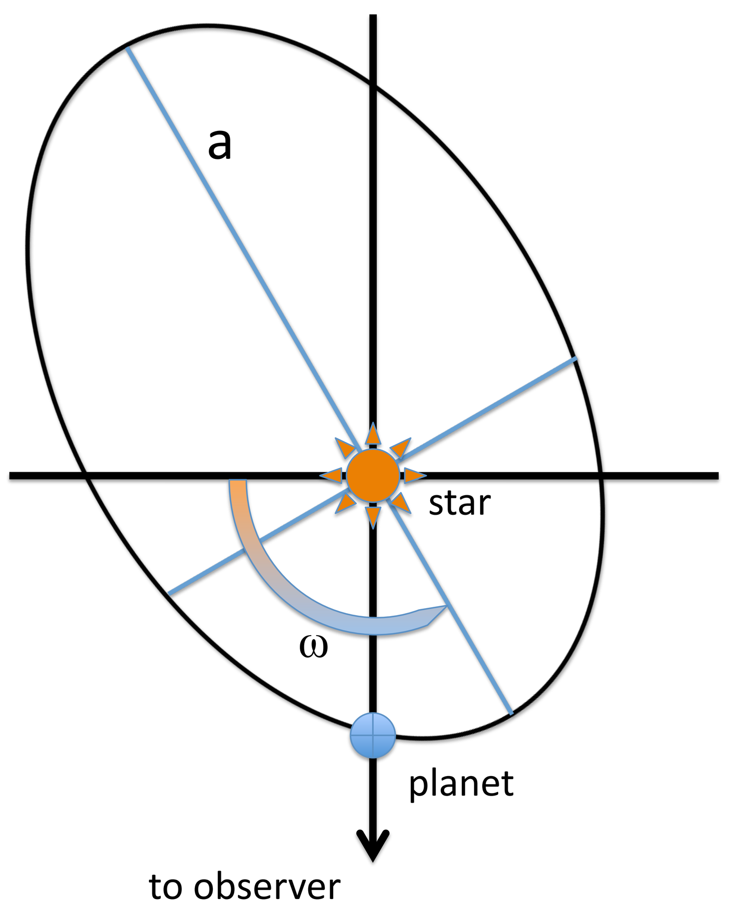

Fig. 1: Orbital Geometry of an Elliptical Orbit of a Transiting Exoplanet. **a** indicates the semi-major axis, and **ω** the argument of periastron. The maximum likelihood for a transit to occur is at **ω** = π/2.

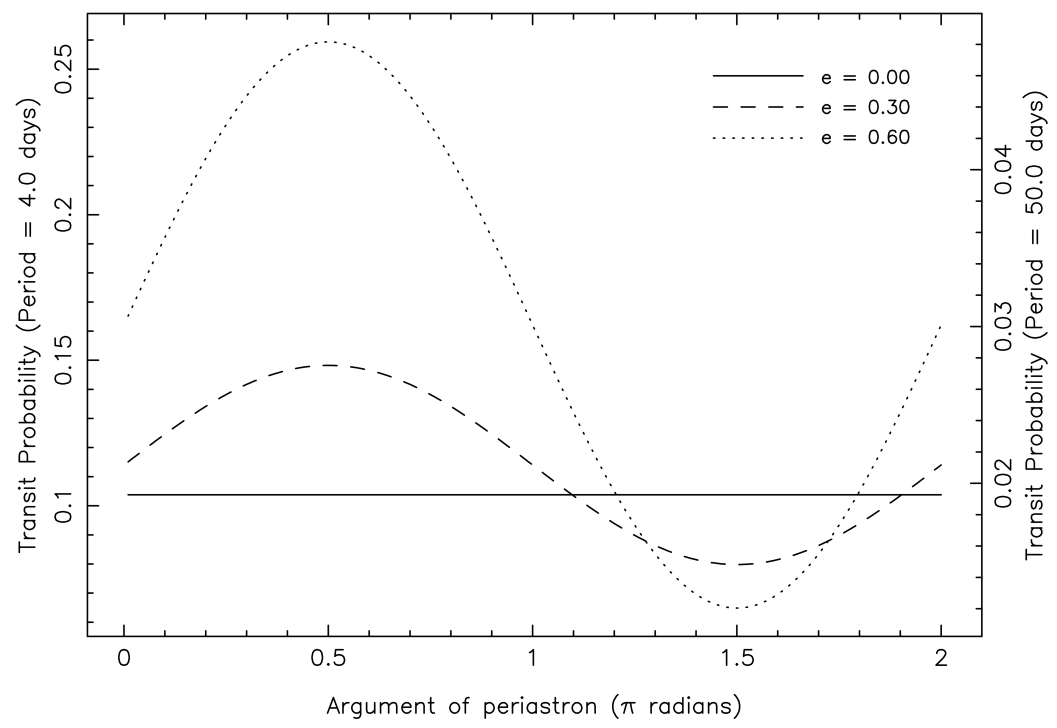

Fig. 2: Exoplanet Transit Probability as a Function of Argument of Periastron. This figure shows the transit probability for elliptical orbits (dotted line: e = 0.6; dashed line: e = 0.3) as a function of ω, along with a comparison to the corresponding probability for a circular orbit (solid line). Stellar and planetary radii are assumed to be one solar and Jupiter radius, respectively. The left and right ordinates illustrate this dependence for different periods.

Ellipticity: The transit probability of planets in elliptical orbits, averaged over all possible orientations of argument of periastron, is higher than for planets in circular orbits.

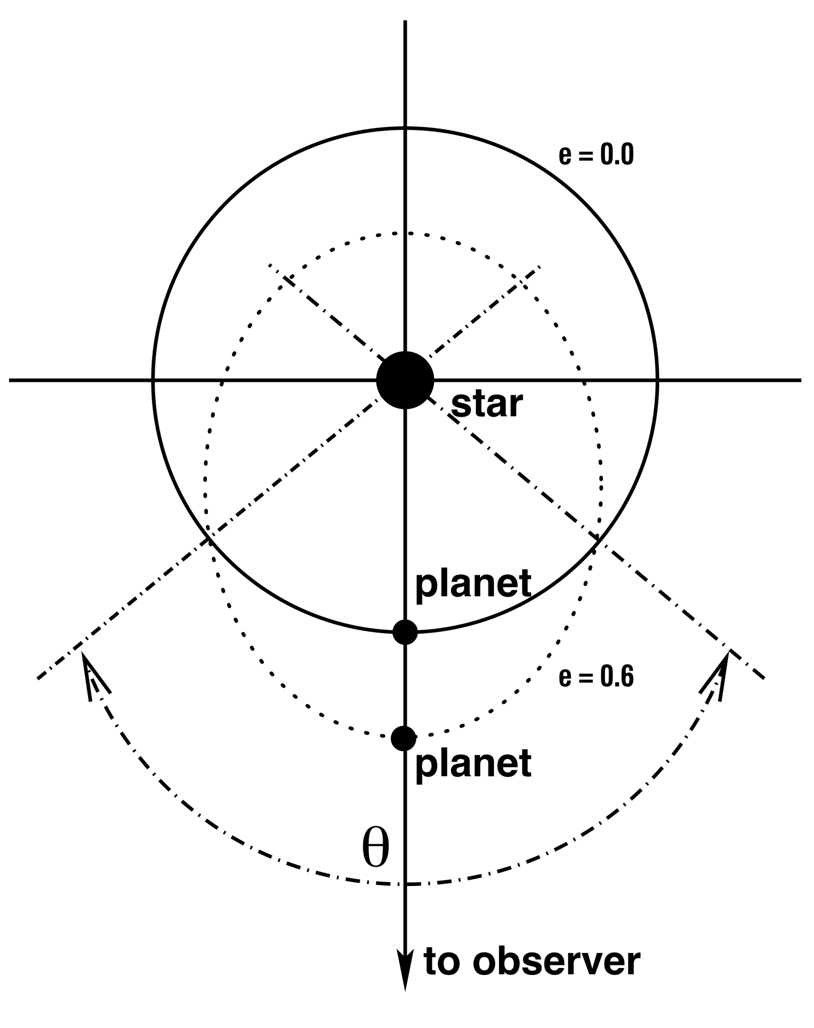

Fig. 3: Transit Probability: Elliptical vs. Circular Orbit. View from above of circular (solid line) and elliptical (dotted line; e = 0.6) planetary orbits for ω = 3π/2. The angle Θ corresponds to the range of orientations of ω for which transit probability is lower for the elliptical orbit than for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

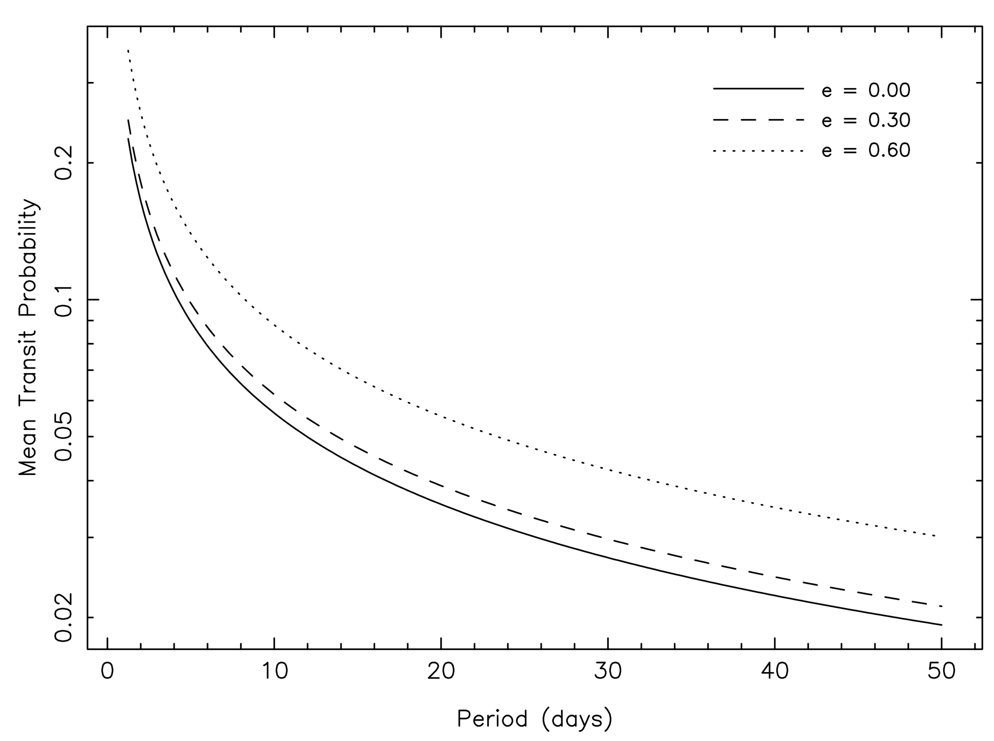

Fig. 4: Exoplanet Transit Probability as a Function of Ellipticity. This figure shows transit probability, averaged over all values of ω, for elliptical planetary orbits (dotted line: e = 0.6; dashed line: e = 0.3; solid line: circular orbit) as a function of period. Stellar and planetary radii are assumed to be one solar and Jupiter radius, respectively.

Application to Known Exoplanets

Better Than One May Think: Measured values for e and ω make searching for transits viable for planets with long orbital periods (such as HD 17156b).

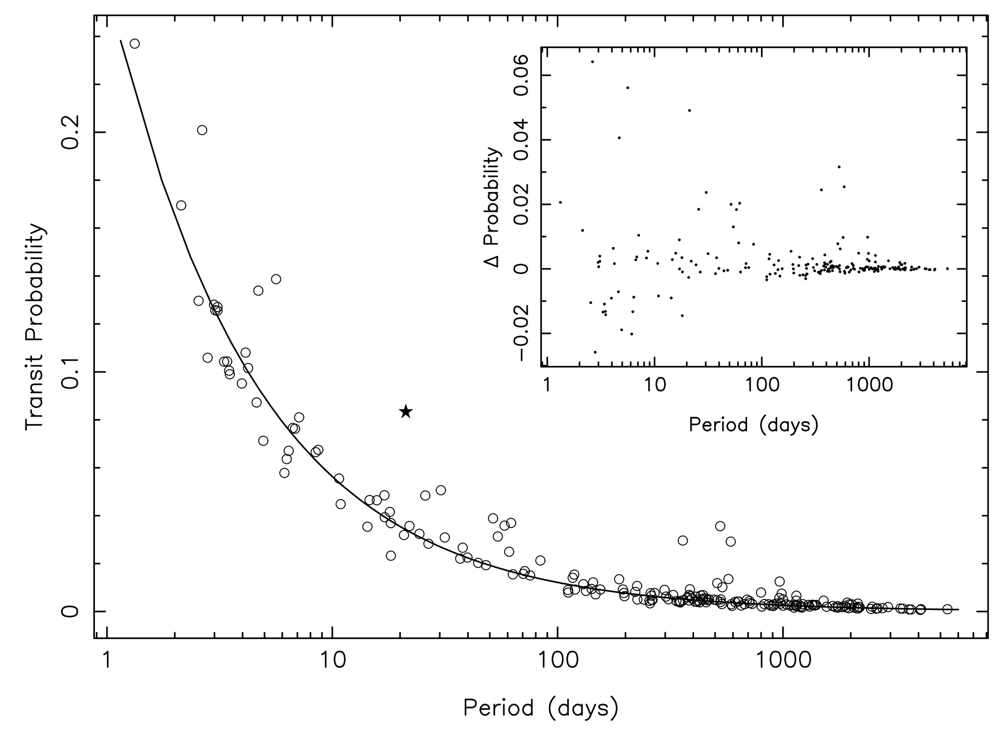

Fig. 5: Geometric Transit Probabilities of Known Radial Velocity (RV) Planets. Transit probabilities as a function of period of 203 known RV planets (Butler et al. 2006) based on their orbital parameters (open circles). The solid line corresponds to the transit probability of a circular orbit with the same period. The transiting planet HD 17156b (21.2 day period, e = 0.67) is indicated by a star. The sub-panel shows the probability difference between open circles and solid line as a function of period.

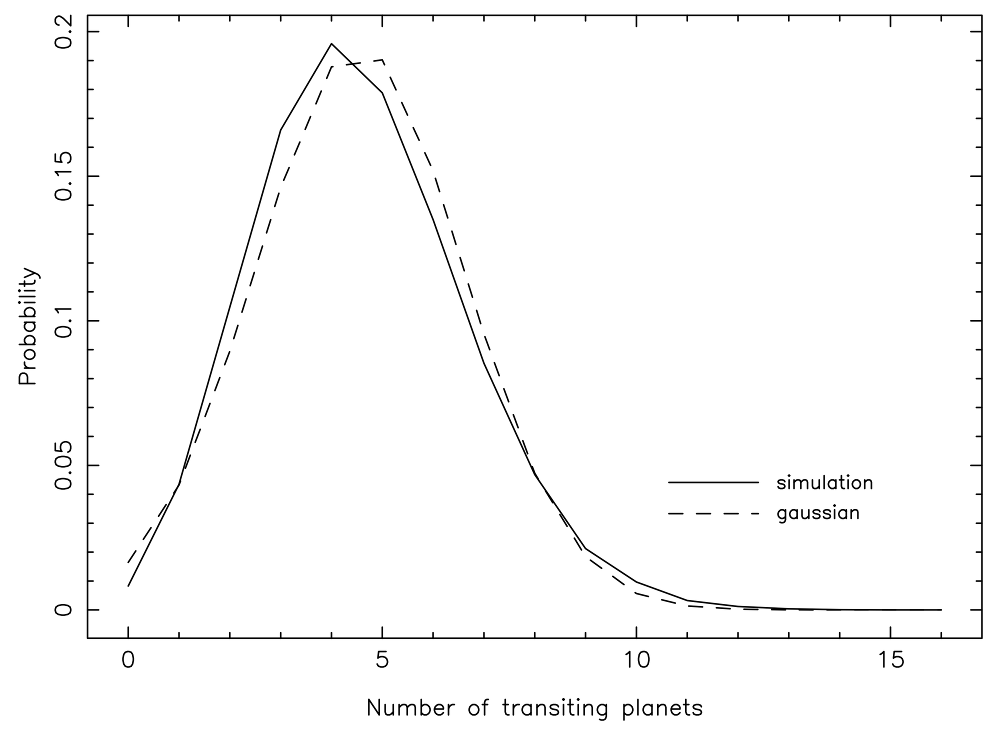

Fig. 6: Probability Distribution for RV Planets. Based on orbital elements of the 203 RV planets from Butler et al. (2006), and assuming one solar and Jupiter radius for star and planet, respectively, a Monte-Carlo simulation (solid line) predicts the number of expected planets from the sample. A Gaussian distribution with μ = 4.5 and σ = 2.0 is overplotted as the dashed line. Three of the planets in this sample are (thus far) known to transit.

Examples of Orbital Parameter Constraints Through Transit Monitoring

If a Planet is Found NOT to Transit: What can be said about its orbit?

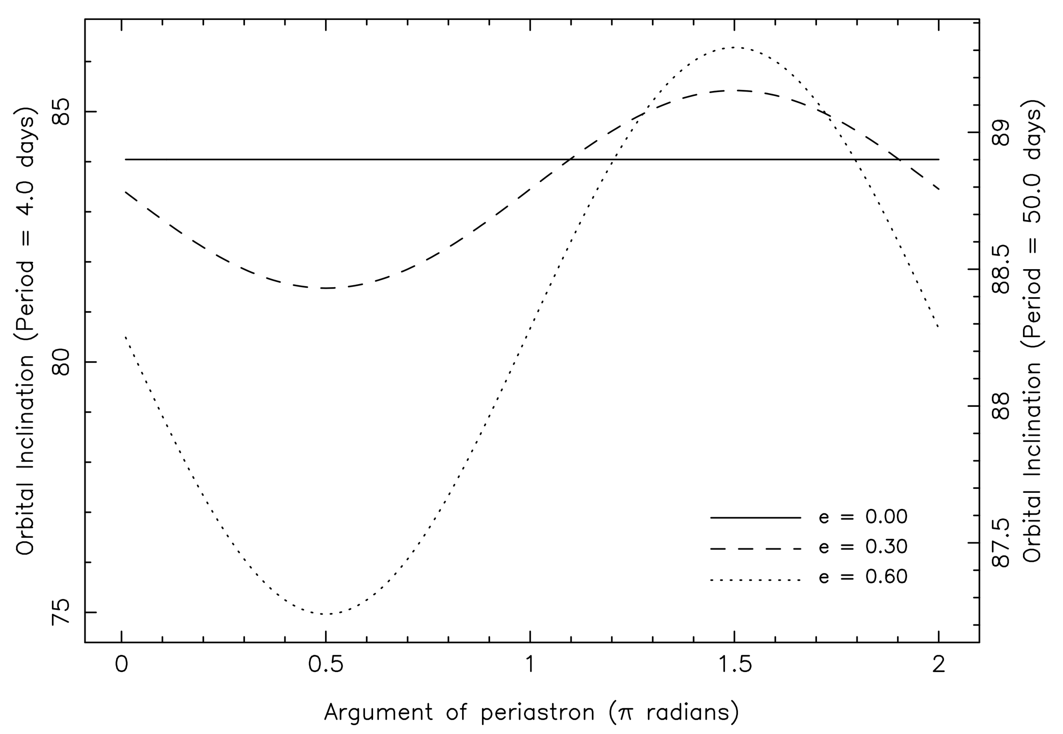

Fig. 7: Maximum Orbital Inclination. Maximum orbital inclination as a function of ω, for a non-transiting planet (dotted line: e = 0.6; dashed line: e = 0.3; solid line: circular orbit). Stellar and planetary radii are assumed to be one solar and Jupiter radius, respectively. The left and right ordinates illustrate this dependence for different periods.

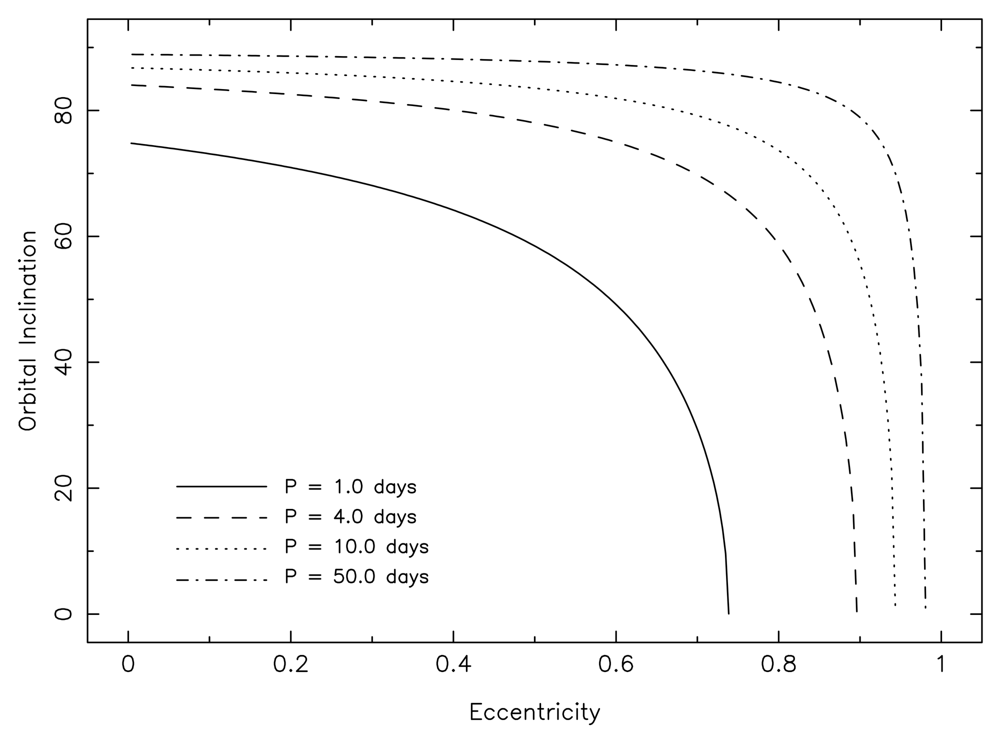

Fig. 8: Maximum Orbital Inclination. Maximum orbital inclination as a function of e for a non-transiting planet for four different periods for the case ω = π/2 (periastron passage in front of star; see Fig. 1). For example: a non-transiting planet with a 4-day orbit and e = 0.4 will have i < 80°. For higher values of e, the range of possible values of i will decrease (for no observable transit).

References:

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