Transit Detection of Radial Velocity Planets

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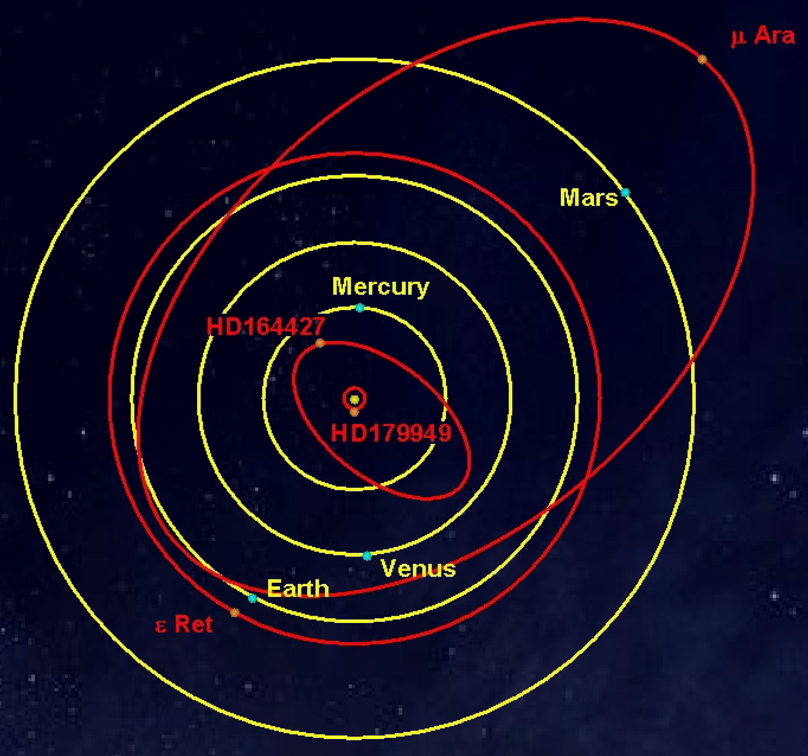
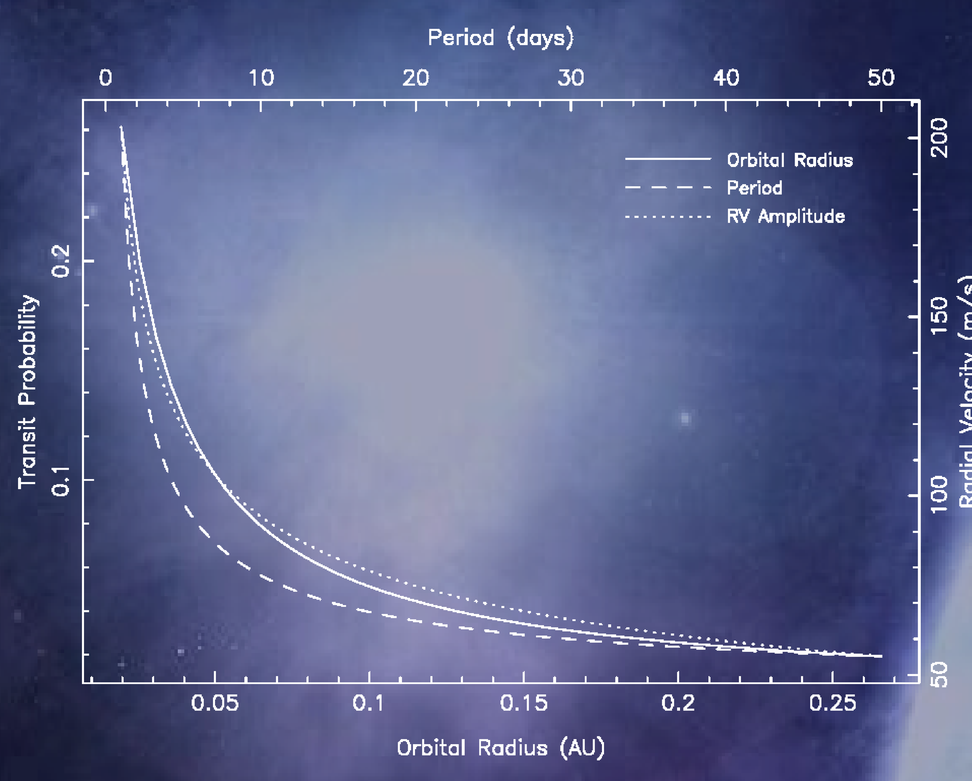
1. Introduction



In addition to the period, the orbital parameters of eccentricity, e, and argument of periastron, ω, have a significant impact on the probability that the planet will transit the host star, as well as on the ephemerides calculations. The radial velocity information can be used to construct an effective photometric follow-up strategy which will provide optimal detection of possible transits. We present the results of studying these effects and apply them to the known radial velocity planets.

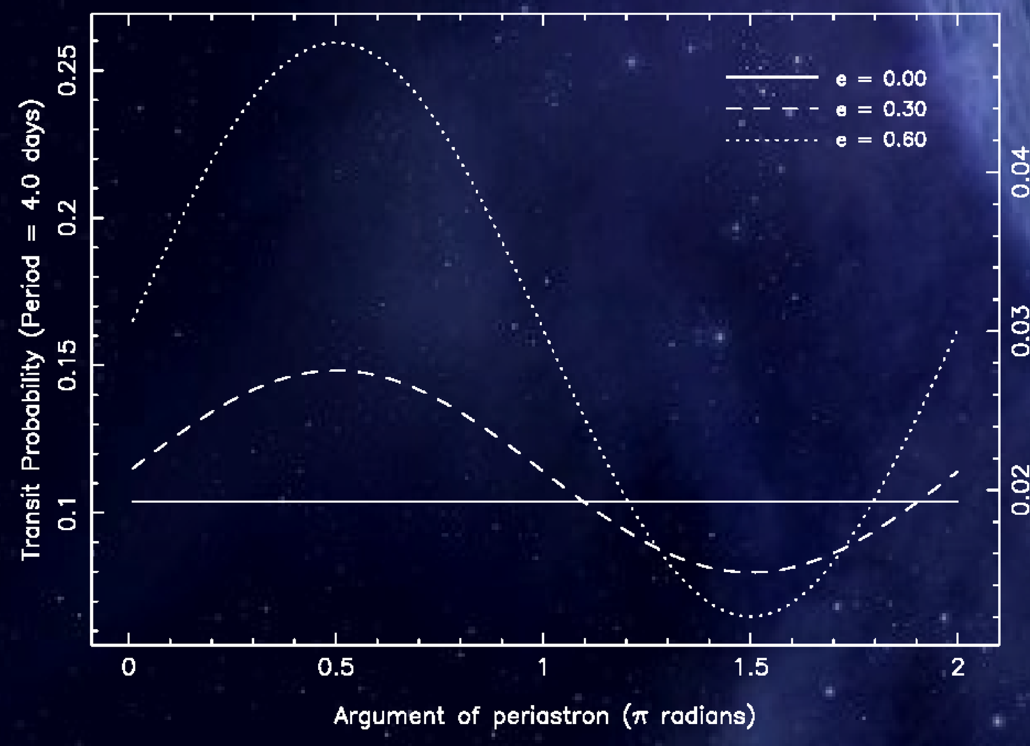
2. Transit Probability

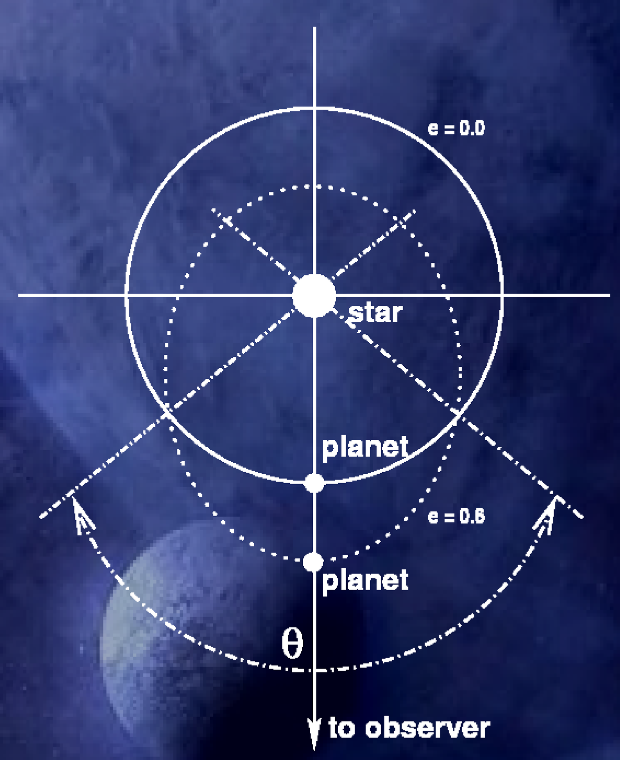


This figure illustrates the dependence of the transit probability (left axis) on orbital radius (solid line, bottom axis) and period (dashed line, top axis) for a Jupiter-sized planet in a circular orbit around a solar-type star. The associated radial velocity is displayed by the dotted line. This does not include the effect of the argument of periastron or eccentricity.

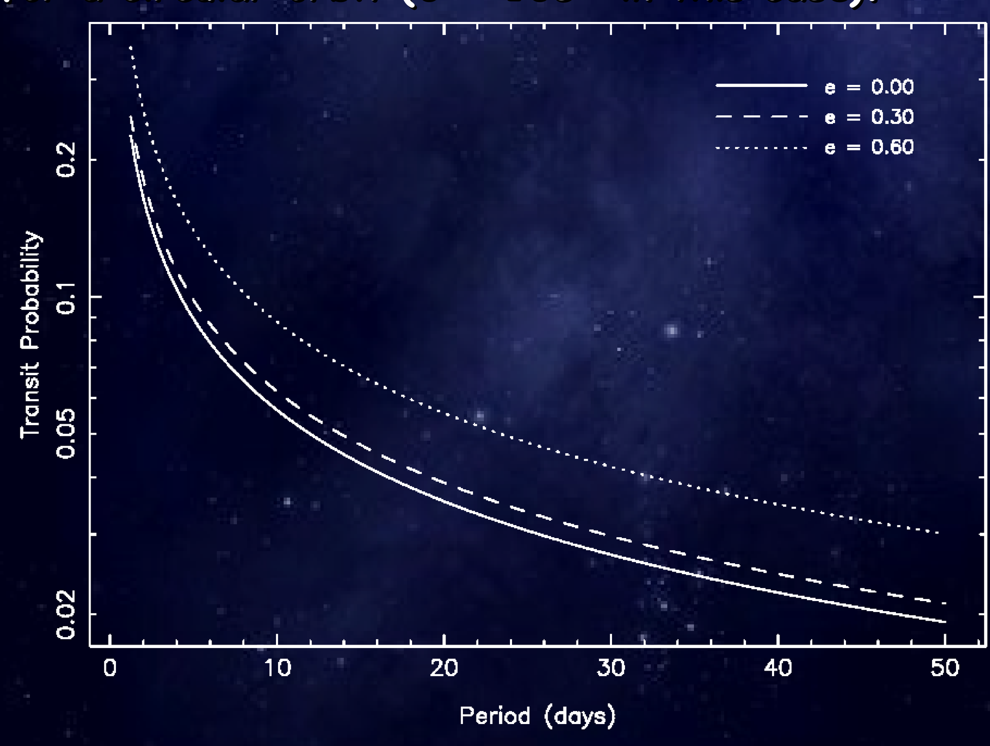
3. Argument of Periastron

Recent work by Barnes (2007) and Burke (2008) has shown that analysis of the eccentricity distribution can produce a higher predicted planet yield for transit surveys. Here we show the combined effect of the eccentricity and the argument of periastron on the transit probability.





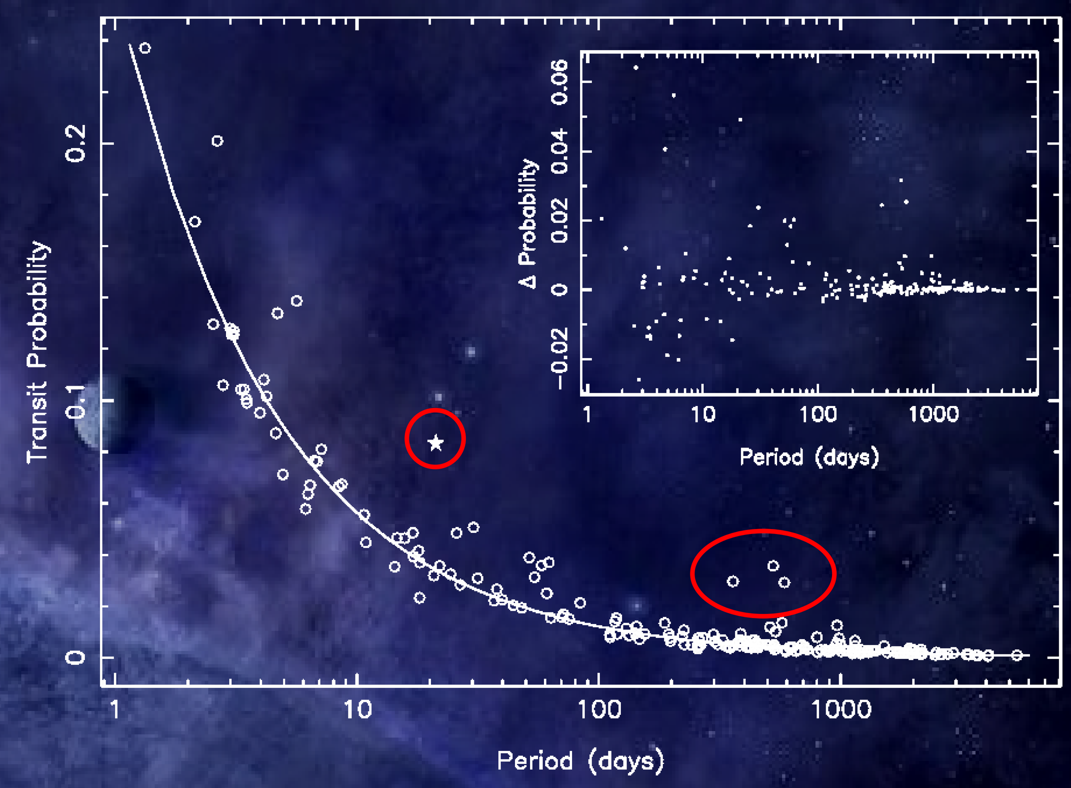
The above-left figure shows the effect upon the transit probability as we rotate the semi-major axis around the star for eccentricities of 0.0, 0.3, and 0.6. The angle θ in the above-right figure corresponds to the range of ω for which the elliptical probability is less than for a circular orbit (θ = 105° in this case).



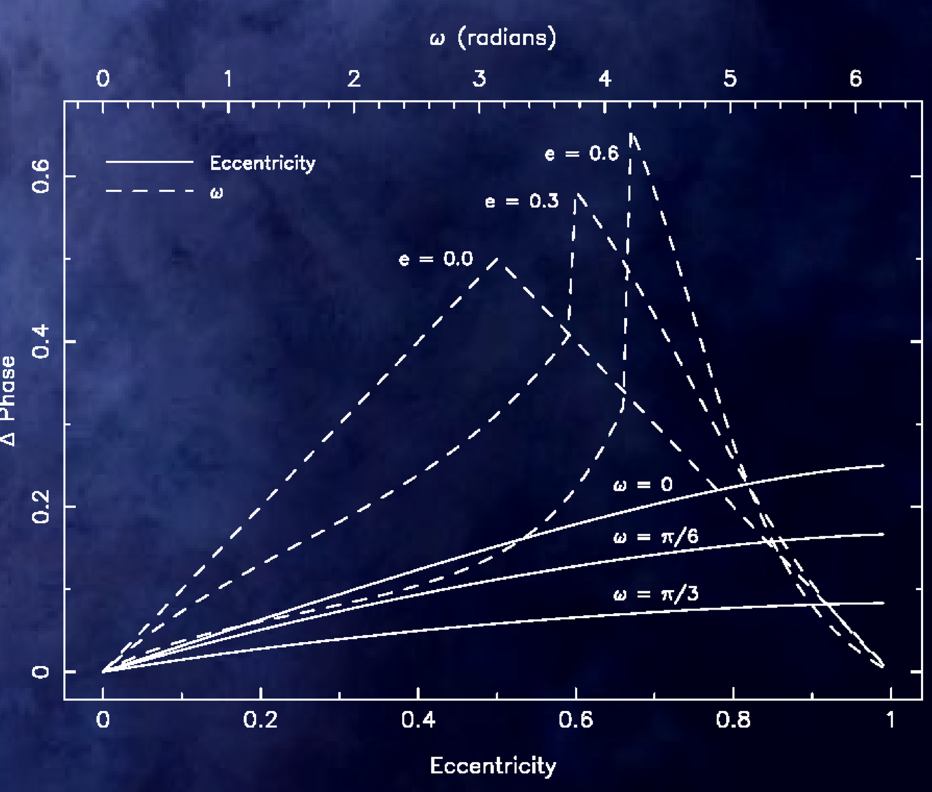
This combined effect (mean probability) is shown in the right figure as a function of period. As expected, doubling the eccentricity (0.3 to 0.6) creates a significant increase in the mean transit probability. The eccentricity of longer period planets can raise their likelihood of transiting to a statistically viable number for detection.

4. Application to Known Planets

Applying the orbital parameters of e and ω should in general lead to an overall more favourable situation for transit detection. The below figure shows the transit probability for 203 exoplanets calculated from orbital parameters provided by Butler et al (2006). The solid line indicates the transit probability for a circular orbit and the sub-panel in the plot shows the difference between the two values (residuals). The 21.2 day transiting planet, HD 17156b, is shown as a 5-pointed star and has a clear advantage due to its orbital parameters. Three long period planets (P > 350 days) also stand out, for which the probability residuals are ~0.03. The effect of this is to increase their transit probabilities to the same level as HD 17156b if it were in a circular rather than eccentric orbit.



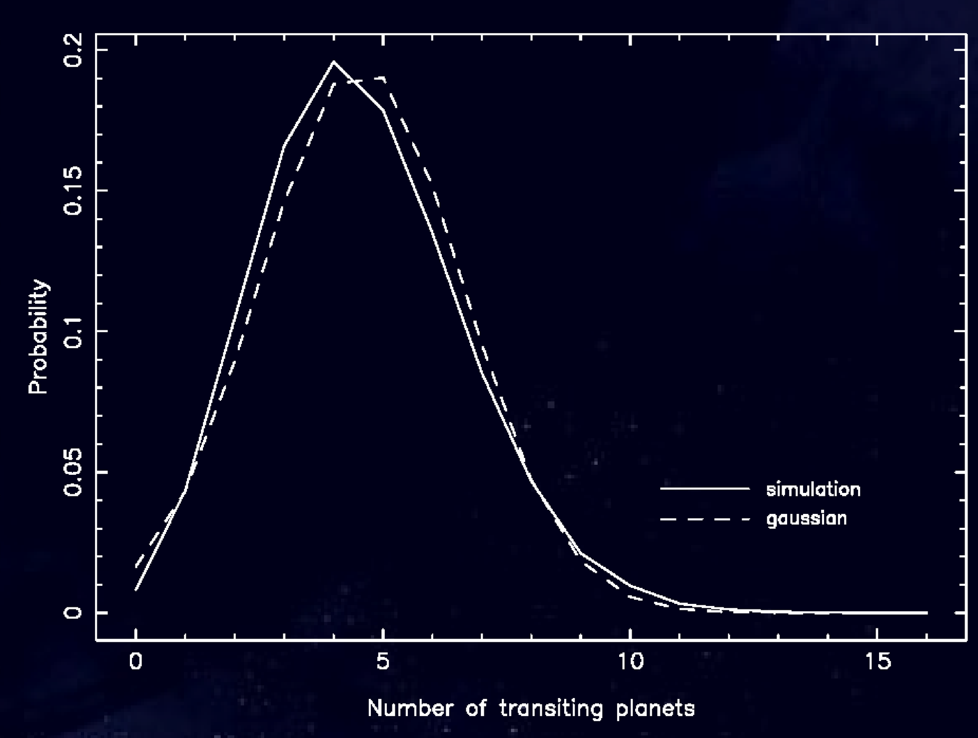
5. Epoch of Planetary Transit



Transit ephemerides calculations are heavily influenced by uncertainties in e and ω. This figure illustrates the offset between calculated and actual time of transit (as a fraction of the period) when varying e and keeping ω fixed (solid lines) or vice versa (dashed lines). For e = 0.0 and P = 4 days, a shift in ω of 10° leads to a 3 hour shift in the predicted time of mid-transit.

6. Photometric Follow-up Strategy

The majority of radial velocity planets have been detected around V < 14 stars. Kane (2007) shows that 1.0m class telescopes are ideal instruments to photometrically monitor these targets. By selecting observable targets with well constrained transit windows and high transit probabilities, an optimised campaign can be constructed. This figure shows the probability distribution for the 203 planets in the Butler et al (2006) sample, predicting the number of transiting planets based on their estimated orbital parameters. We have begun an observing campaign of known southern host stars at predicted planetary transit times using the CTIO 0.9m and 1.0m telescopes. The significance of a null result from such an observing campaign, as well as subsequent constraints on orbital parameters, is discussed in detail by Kane & von Braun (2008).



References

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- Burke, C.J., 2008, ApJ, 679, 1566
- Butler, R.P., et al., 2006, ApJ, 646, 505
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