Modeling and Fitting Exoplanet Transit Light Curves
Sarah Millholland and Dr. Gerry Ruch

Abstract
We present a numerical model along with an original fitting routine for the analysis of transiting extrasolar planet light curves. Our model employs Keplerian orbital dynamics about the system's center of mass to properly account for stellar wobble and orbital eccentricity, uses a unique analytic solution derived from Kepler's Second Law to calculate the projected distance between the centers of the star and planet, and uses a numerical limb darkening technique. We have also devised a novel Monte Carlo style optimization routine for fitting the light curve model to observed transits. We show that our results are in agreement with the published system parameters of planet WASP-42 b (Lendl et al. 2012).

Transit Light Curve Model
- Orbital modeling based on Kepler's Laws of Planetary Motion
- Kepler's second law allows for a method of finding the star and planet positions at any time
- The image above gives an exaggerated depiction of the orbital model: the star and the planet orbit elliptically with the center of mass of the system at one focus. Their position vectors each sweep out equal areas in equal intervals of time.
- In calculating the eclipsed intensity of the star, we use a numerical integration technique instead of analytic formulae such as those of Mandel and Agol (2002).
- Divide the stellar face into concentric shells of uniform intensity within each shell.
- Calculate and sum the intensities of the eclipsed portions of the shells.

Parameter Extraction Results

**Comparison of System Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Published Parameters</th>
<th>Deduced Parameters</th>
<th>Standard Deviation(^2)</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planet radius (R(_\odot))</td>
<td>1.040 ± 0.007</td>
<td>1.070</td>
<td>0.0025</td>
<td>9.26</td>
</tr>
<tr>
<td>Planet mass (M(_\odot))</td>
<td>0.5 ± 0.005</td>
<td>0.329</td>
<td>0.242</td>
<td>44.2</td>
</tr>
<tr>
<td>Stellar radius (R(_\odot))</td>
<td>0.863 ± 0.002</td>
<td>0.849</td>
<td>0.0039</td>
<td>3.48</td>
</tr>
<tr>
<td>Stellar mass (M(_\odot))</td>
<td>0.884 ± 0.02</td>
<td>0.879</td>
<td>0.0165</td>
<td>15.56</td>
</tr>
<tr>
<td>Semi-major axis (AU)</td>
<td>0.0548 ± 0.0017</td>
<td>0.0547</td>
<td>N/A</td>
<td>18.2</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0.06 ± 0.0013</td>
<td>0.069</td>
<td>0.0186</td>
<td>15.00</td>
</tr>
<tr>
<td>Argument of periastron (deg)</td>
<td>167 ± 26</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Inclination (deg)</td>
<td>88.25 ± 0.12</td>
<td>88.28</td>
<td>0.03797</td>
<td>0.034</td>
</tr>
</tbody>
</table>

The comparison between our deduced parameters and the published parameters (Lendl et al. 2012) is shown above.
1. The standard deviations are those of the parameter distributions of the five hundred best approximations at the convergence of the fitting algorithm.
2. The semi-major axis is constrained by the orbital period and stellar and planet masses in the fit.
3. The argument of periastron was left fixed for this fit.

Conclusion and Further Research
We have demonstrated that our original model and Monte Carlo fitting algorithm provide a reliable analysis of extrasolar planet transit light curves. We have also illustrated the impacts of stellar wobble and the error caused by not properly accounting for it. Currently, we are in the process of preparing a paper for publication that details our methods.

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References