A Photometric Analysis of the Eclipsing Binary RXJ0239.1-1028

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July 21, 2006
- Low Mass Binary Systems

- Photometric data

- Modeling and System Parameters

- Implications
Low Mass Binary Systems

Two gravitationally bound stars

$M < 1 \, M_{\text{SUN}} \rightarrow$ Spectral type $K$ or $M$

(possibly late $G$)
Low Mass Binary Systems

Spectroscopic: *Single-lined*

- Systems with high mass difference
- Yields mass function:

\[ f(m) = (1.0361 \times 10^{-7})(1 - e^2)^{3/2} K_2^3 P M \]
Low Mass Binary Systems

Spectroscopic: *Double-lined*

- Systems with comparable masses
- Yields mass ratio:

\[
q = \frac{v_1 \sin i}{v_2 \sin i} = \frac{K_1}{K_2} = \frac{M_2}{M_1}
\]
Low Mass Binary Systems

Photometric: *Eclipsing*

- Systems with high inclination
  \( (i \sim 90^\circ) \)

- Yields inclination,
  temperatures, and radius ratio
Low Mass Binary Systems

Photometric: *Non-eclipsing*

- Systems with low inclination
  \((i \ll 90^\circ)\)
- Tells us that the star exists
Low Mass Binary Systems

RXJ0239 is a *double-lined eclipsing* binary

→ Possible to obtain most of its critical parameters

**Masses** and **Radii** of both components!
Low Mass Binary Systems

Very few LMDLSEBS known to exist

http://www.le.ac.uk/physics/faulkes/web/images/hrcolour.jpg
### Photometric Data

<table>
<thead>
<tr>
<th>Epoch</th>
<th>Date</th>
<th>Filters</th>
<th>Observers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nov. – Dec. 2001</td>
<td>K</td>
<td>L. Marschall</td>
</tr>
<tr>
<td>2</td>
<td>Jan. – Feb. 2003</td>
<td>BVRI</td>
<td>L. Marschall</td>
</tr>
<tr>
<td>3</td>
<td>Oct. – Nov. 2004</td>
<td>VRI</td>
<td>M. Lopez-Morales</td>
</tr>
<tr>
<td>4</td>
<td>Nov. – Dec. 2005</td>
<td>BVRI</td>
<td>L. Marschall</td>
</tr>
</tbody>
</table>
Photometric Data

Ephemeris determination

- Mean eclipse times with corresponding cycle counts determined for each epoch
- Linear regression

$$E_0 = 2.07210095(59) \epsilon + 2450537.3436(7)$$
MLO (Epoch 4) images of RXJ0239.1-1028
Modeling and System Parameters

Eclipsing Light Curve (ELC) code utilized

- Genetic and grid search algorithms
- Four final solutions obtained:
  - Epoch 1
  - Epoch 3
  - Epoch 4 (Marschall)
  - Epoch 4 (MLO)
- $\chi^2$ minimization

\[
\chi^2 = \sum_{i=1}^{n} \frac{(x_i - m_i)^2}{\sigma_i^2}
\]
## Modeling and System Parameters

Final parameters taken as average of Epoch 1, Epoch 3, and Epoch 4 solutions:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period (days)</td>
<td>2.07200195 ± 5.9 x 10^{-7}</td>
</tr>
<tr>
<td>$M_{\text{primary}}$ (M)</td>
<td>0.733 ± 0.002</td>
</tr>
<tr>
<td>$M_{\text{secondary}}$ (M)</td>
<td>0.691 ± 0.002</td>
</tr>
<tr>
<td>$q$</td>
<td>0.942 ± 0.002</td>
</tr>
<tr>
<td>$R_{\text{primary}}$ (R)</td>
<td>0.751 ± 0.002</td>
</tr>
<tr>
<td>$R_{\text{secondary}}$ (R)</td>
<td>0.694 ± 0.003</td>
</tr>
<tr>
<td>$T_{\text{eff, primary}}$ (K)</td>
<td>4618 ± 14</td>
</tr>
<tr>
<td>$T_{\text{eff, secondary}}$ (K)</td>
<td>4258 ± 14</td>
</tr>
<tr>
<td>Inclination (°)</td>
<td>88.67 ± 0.04</td>
</tr>
<tr>
<td>$K_{\text{primary}}$ (km s^{-1})</td>
<td>91.13 ± 0.10</td>
</tr>
<tr>
<td>$K_{\text{secondary}}$ (km s^{-1})</td>
<td>96.73 ± 0.18</td>
</tr>
<tr>
<td>Semi-major axis (R)</td>
<td>7.69 ± 0.01</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0 (assumed)</td>
</tr>
</tbody>
</table>
Modeling and System Parameters

Spots

- Transient and migratory in nature
- Difficult to model
- One spot solution on primary
Implications

- Eclipse timing migration
- Parameters
Implications

Eclipse timing migration

Ephemeris

\[ T_c = P \epsilon + T_0 \]

O-C residuals generated

Mean residuals of zero imply no migration
Implications

Eclipse timing migration

- O-C nonlinearity
  - Apsidal motion ?
  - Errant O-C point ?
  - Third body ?
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More epoch eclipse timings needed
Implications

Parameters

- Mass-radius relation for low mass, main sequence stars
  - Empirical: \( R \approx M \)
  - Theoretical: \( R \approx 0.9 M \)
Summary

- RXJ0239
  - Multicolor photometry from four epochs
  - Double-lined radial velocity data spanning multiple epochs
  - Parameters modeled with ELC

- Nonlinearity in O-C residuals

- Stellar dimensions consistent with empirical mass-radius relation for lower main sequence
Summary

- RXJ0239
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