A New Low-Mass Eclipsing Binary: Absolute Dimensions of ROT1345

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Photometric observations of the low-mass eclipsing binary ROT1345 in the R and I bands, and subsequent analysis, are presented here. Absolute dimensions of the system were obtained from these data and combined with previously acquired radial velocities to produce values of: $M_1 = 0.539 \pm 0.003\ M_\odot$, $M_2 = 0.493 \pm 0.003\ M_\odot$, $R_1 = 0.51 \pm 0.01\ R_\odot$ and $R_2 = 0.54 \pm 0.01\ R_\odot$. Temperatures were also obtained, with 3510 K for the primary and 3476 K for the secondary. These results were compared to those obtained by Lopez-Morales, using the same radial velocities, but different photometry. While the masses for both results were in generally good agreement, the radii differed by as much as 2σ.

Introduction

Low-mass stars make up the majority of the stellar population, at least 70% (Lopez-Morales & Ribas 2005). Despite this, the sample of well-studied low-mass stars in eclipsing binaries is rather small, owing to the fact that low luminosities of these types of stars make them difficult to detect and obtain careful observations. Measurements of basic parameters such as mass, radius and temperature can only be determined from observing eclipsing binaries, and only half a dozen low-mass, M-type systems have been studied. Of these however, only four have accurately derived masses and radii (with uncertainties of less than 2%) with which to rigorously test low-mass evolutionary models: CM Dra (Metcalf et al. 1996), YY Gem (Torres & Ribas 2002), CU Cnc (Ribas 2003), and GU Boo (Lopez-Morales & Ribas 2005). The other two systems (BW3 V38 and TrES-Her0-07621) do not have measurements with uncertainties small enough to test the models (Lopez-Morales & Ribas 2003).

Though the sample is small, a statistically significant difference has been found to exist between the observed mass-radius law and that predicted by theory. Evolutionary models consistently predict radii that are smaller by up to 15% of those observed. It also appears that the temperatures are overestimated by as much as five percent. The reasons for this discrepancy are unclear at this time, but in a paper summarizing the problem, Ribas (2003) suggested that it is due to tidal interactions between the two stars, which increase the rotational velocities of the stars. This in turn would increase magnetic activity and the presence of spots on the surface, and lower the temperature. The stars then expand to conserve radiative flux (Ribas 2003). This, however, has not been confirmed, and further research is required to increase the sample size and further constrain the models.

Fortunately, as instrumentation is becoming more sensitive and the number of surveys is increasing, so sample of low-mass eclipsing binaries is getting larger. ROT1345 was first identified by the Robotic Optical Transient Search Experiment (ROTSE) database by Lopez-Morales and her collaborators. Lopez-Morales obtained spectroscopy and V-, R-, and I-band photometry over February, 2005 at the Kitt Peak Observatory. These measurements yield values for the masses of the primary and the secondary of $0.540 \pm 0.003\ M_\odot$ and $0.500 \pm 0.003\ M_\odot$, respectively, and values for the radii of $0.526 \pm 0.003\ R_\odot$ and $0.507 \pm 0.003\ R_\odot$, respectively. It was also determined that two spots existed on the primary: one covering the entire northern hemisphere of the star, and another, smaller spot on top of the larger spot. The goal of this project was to confirm the results of Lopez-Morales.

Observations and Reduction

R- and I-band images of ROT1345 were taken over the course of four nights (June 20, June 24, June 29, and June 30, 2006) using the SBIG STL-1001 1024×1024 pixel CCD camera mounted on the Smith 24-inch telescope at Mount Laguna Observatory. The images also included four other stars, two of which were chosen as comparison stars. Data taken on June 20 and June 24 were rejected for analysis due to inopportune weather conditions and unusually large systematic errors. An attempt was made on the other two nights to obtain measurements over both eclipses. In total, 364 images were taken in I band, and 366 images were taken in R band, along with sky flats and dark flats.

Standard IRAF tasks were used to apply dark current and flat field corrections. The images were aligned on IRAF so that the program star and the two comparison stars appeared in the same place on each image. IRAF phot was then used to obtain differential light curves.

Analysis

The R- and I-band light curves were fitted using the Eclipsing Light Curve (ELC) code (Orosz & Hauschildt 2000) in order to obtain values for the masses, radii and temperature of the individual stars. ELC uses intensities from model atmospheres and can take into account the presence of spots when creating the model light curve. The radial velocity curves obtained the Lopez-Morales spectroscopy were used. Within the code are several programs that use different routines, namely a genetic algorithm and a grid search routine, to refine the free parameters in order to find the minimum χ^2 value. In total, seven models were computed, each with different spot configurations: one on the primary, one on the secondary, one on each, two on the primary, two on the secondary, one on the primary with two on the secondary, and two on the primary with one on the secondary.

χ^2 is defined as the sum of the differences between the data points and the model, divided by the standard deviation, and squared. Ideally, if the model fits exactly, then χ^2 will be less than one. If the model fits the data well, then the χ^2 will be roughly equal to the number of data points. Neither is generally the case; if error bars exist on the data, χ^2 will not be equal to one, so models were run through several programs within ELC to determine the best χ^2 value for each individual model. A model was either rejected or accepted for further analysis based on its χ^2 value relative to those of the other models.

After several iterations of the models were produced by ELC, the best fit model was determined to be the model with a spot on both the primary and the secondary. Figure 1 shows the differential light curves with fits and residuals. The spot on the primary was located in the southern hemisphere, and was smaller than the spot on the secondary, located in the northern hemisphere. Both spots appear to be brighter than the rest of their respective stars. Our results yielded mass values for the primary and secondary of 0.539 ± 0.003 $M_{\odot}$ and 0.493 ± 0.003 $M_{\odot}$, respectively, and radii of 0.51 ± 0.01 $R_{\odot}$ and 0.54 ± 0.01 $R_{\odot}$, respectively. Temperatures for both stars were also obtained, with 3510 K for the primary and 3476 K for the secondary. Our results of for the primary radius differed by 0.026 ± 0.01 $R_{\odot}$, and for the secondary by 0.033 ± 0.01 $R_{\odot}$ with those of Lopez-Morales. Our results for the masses were generally in good agreement with the earlier results, though our mass for the secondary were outside the range of that value obtained by Lopez-Morales, differing by 0.007 ± 0.004 $M_{\odot}$.

The discrepancy between these results and those of Lopez-Morales is obvious, despite the fact that the light curves were well fitted by the model. A combination of experimental and systematic error can account for these differences. Lopez-Morales collected three times as many data points as were for this study, with could have a great affect on the accuracy and precision of the results. She also used a much larger and thus more sensitive telescope than the one that was used to collect this data. The existence and location of spots on the two stars could also have caused the results to differ. As noted above, in February of 2005, the entire northern half of the primary was a spot, while nearly a year and a half later, activity on the surface had decreased to a small spot on the southern hemisphere. Activity on the secondary increased from nothing to a large spot on the northern hemisphere in the same time span. It is probable, then, that the change in radii is not real, and simply a result of the changing dynamics of the system and the methods of data collection. The difference in masses, though slight, is somewhat unexpected, considering that the same radial velocity curves were used. However, because the ELC code takes into account model atmospheres, the solutions for radial velocity curves and the light curves are somewhat intertwined, so that systematic and experimental errors in one can and will affect the other.

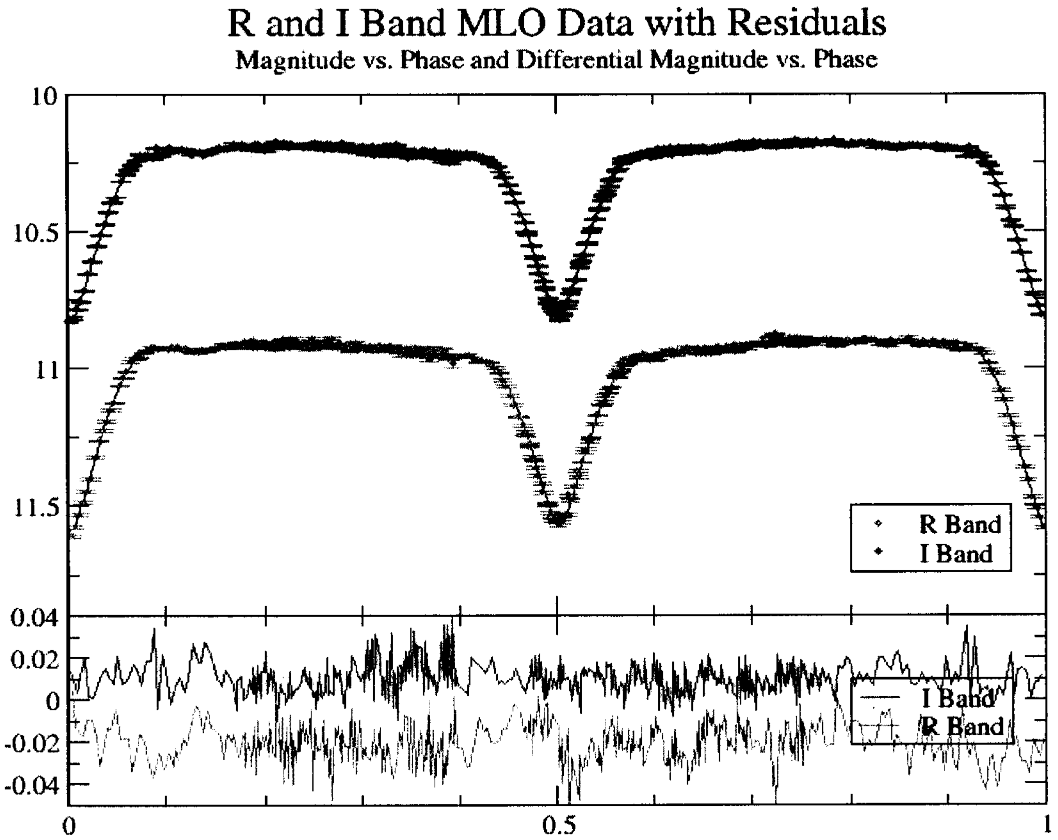

Fig 1: Magnitude vs. Phase and Differential Magnitude vs. Phase

Conclusions

The paper reports the results of photometric observations of ROT1345. Light curve modeling using the ELC code yielded results of 0.539 ± 0.003 $M_{\odot}$ and 0.51 ± 0.01 $R_{\odot}$ for the primary, and 0.493 ± 0.003 $M_{\odot}$ and 0.54 ± 0.01 $R_{\odot}$ for the secondary. The values for the masses confirmed the results obtained earlier by Lopez-Morales, though there was a slight discrepancy between the masses for the secondary. The values for the radii could not confirm those obtained by Lopez-Morales, though given the amount of data collected and the size of the telescope used, her results are more likely to be accurate.

Modeling on the data presented here and by Lopez-Morales continues to obtain greater precision and accuracy. The results will later be compared to the predictions of evolutionary models. Further observations of ROT1345 should be done to provide better confirmation of Lopez-Morales' results, and increase the accuracy and precision of the data.

Acknowledgements

I would like to thank Dr. Orosz for very patiently explaining everything to me, including stuff I really ought to have already known. I would like to thank my mom for patiently listening to me complain about my problems setting up the ELC program, even though I don't think she really knew what I was talking about. I would also like to thank fellow student Rose Matheny for working out several IRAF practice problems with me.

I would especially like to thank three teachers that have impacted my understanding of science and its place the search for knowledge: Tom Origer, who first introduced me to some of the most basic tenets of scientific thought and who mentored me for many years; Peter Menth, who was the first to tell me I should be a scientist; and Drew Kempiak, who for two years encouraged me in my exploration of the physical world and who provided moral support during my first few years of college.

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