Photometric Followup Observations of M-dwarf Eclipsing Binaries in SDSS Stripe 82

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M-dwarf Eclipsing Binaries from SDSS Stripe 82

We present preliminary results from followup observations of five M-dwarf eclipsing binaries (EBs) found in sparsely sampled *ugriz* time-series photometric data from SDSS Stripe 82. These objects were discovered during the course of a general search for variable point sources (concentrating on periodic variables) in this data-set (described in Bhatti et al. 2010). A light-curve catalog of all variable point sources detected is available at http://shrike.pha.jhu.edu/stripe82-variables.

The small number of observations (median ~30) per object and the long time-base of the data-set (1998 – 2007) pose significant challenges for accurate period determination. We used two independent 'string-length' algorithms (Dworetsky 1983 & Stetson 1996) to identify periods, and subsequently generated phase-folded light-curves and ephemerides to plan followup observations.

As of December 2009, we have identified 54 M-dwarf eclipsing binary candidates, ranging from M0 to M5 in subtype, with periods of ~0.14 to ~2.1 days. A large fraction of these are short-period (< 0.5 day) binaries.

Observations with the KPNO 2.1-m

Five M-dwarf EBs were selected for followup; these are examples of early to mid-M dwarf subtype objects with periods < 1.0 day. We observed these objects over a period of 7 nights (Sept 22 – 28, 2009) with the 2.1-m telescope and the T2KB CCD camera at the Kitt Peak National Observatory (KPNO).

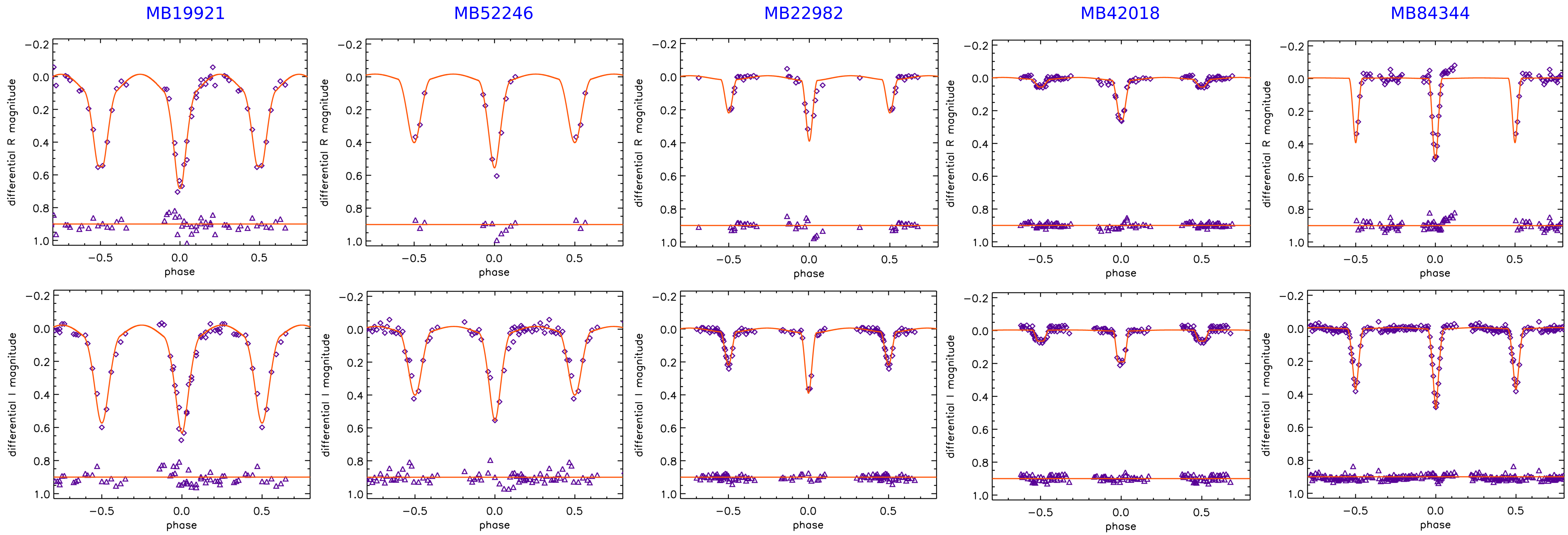
We used *R* and *I* filters and an exposure time of 240 seconds to obtain high S/N light-curves of our targets near and during the eclipse phases of their orbits. Landolt standard stars were also observed at various airmasses for transformations to a standard magnitude system.

The data was reduced in the standard manner and aperture photometry was carried out on the target and four comparison stars. These measurements were used to obtain differential magnitude light-curves in both filters. Some objects were observed multiple times, resulting in improved phase coverage (mostly in the *I* band).

Modeling the Light-curves – I

We first use the light-curves obtained during these observations to verify, and if necessary, correct the period *P* and time of minimum light t_0 obtained from the Stripe 82 data. All but one of our objects (MB22982) have no significant corrections. Once *P* and t_0 have been determined, we hold them fixed for all subsequent fitting.

We use quadratic limb darkening coefficients from Claret (2004) and a gravity-darkening parameter $\beta = 0.32$, suitable for convective interiors of cool stars. The light-curve model is parametrized by: the ratio of the sum of the radii to the semimajor axis $(R_1+R_2)/a$, the ratio of the radii R_2/R_1, the inclination i, the surface brightness ratio L_2/L_1, and the amount of third light L_3. We assume an eccentricity $e = 0$ keeping in mind the small periods of these objects. We do not yet take starspots or reflection effects into account. Light-curve models are generated using JKTEBOP (Southworth et al. 2004), and fits to the observed light-curves are then calculated.



Modeling the Light-curves – II

We use the downhill simplex method (AMOEBA; Press et al. 1992) to iteratively minimize the χ^2 value while simultaneously fitting all of the variable parameters. The *R* and *I* light-curves are fit independently, and the process of fitting is repeated until parameters obtained from both light-curves agree with each other. In case of poor phase coverage, we adopt parameter values calculated using the best light-curve available.

We do not yet obtain robust estimates for the errors on the derived parameters. These will be calculated using Monte Carlo simulations of synthetic data. A further improvement will be to use the Wilson-Devinney EB model (Wilson & Devinney 1971) to take into account starspots, reflection effects, and model atmospheres.

Binary Properties from Light-curve Fits

Object	R	I	Period [days]	R_2/R_1	L_2/L_1	i [deg]	Type
MB19921	18.7	17.8	0.235549	0.671	0.844	85.1	M1
MB52246	19.4	18.3	0.245626	0.723	0.767	81.2	M3
MB22982	18.6	17.2	0.371841	0.775	0.558	81.8	M4
MB42018	18.0	16.8	0.394514	0.621	0.176	87.4	M2
MB84344	18.4	16.9	0.672371	0.711	0.816	85.0	M3

NOTES: (1) MB42018 is a blend and was fit using a third-light contribution of ~0.47 mag, (2) spectral type reported above is for the composite system, (3) the subscript 1 refers to the larger binary component, while subscript 2 refers to the smaller binary component.

Future Work

The sparse phase coverage and low cadence of our observations points to the need for additional photometric monitoring of these targets. Once well-sampled light-curves in both *R* and *I* bands have been obtained, fitting to binary models will be far more robust. Spectroscopic observations will provide absolute scales for these systems, and enable the calculation of their fundamental properties, most importantly, the masses and radii of the binary components.

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