Testing Low Mass Stellar Models with M-dwarf Eclipsing Binaries from SDSS Stripe 82

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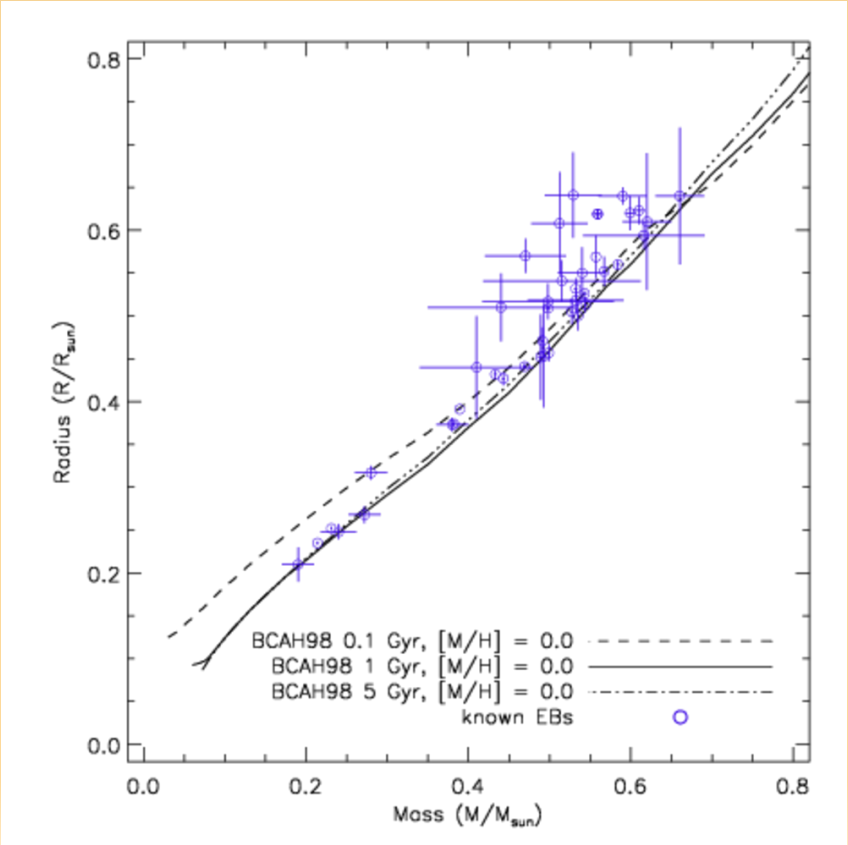
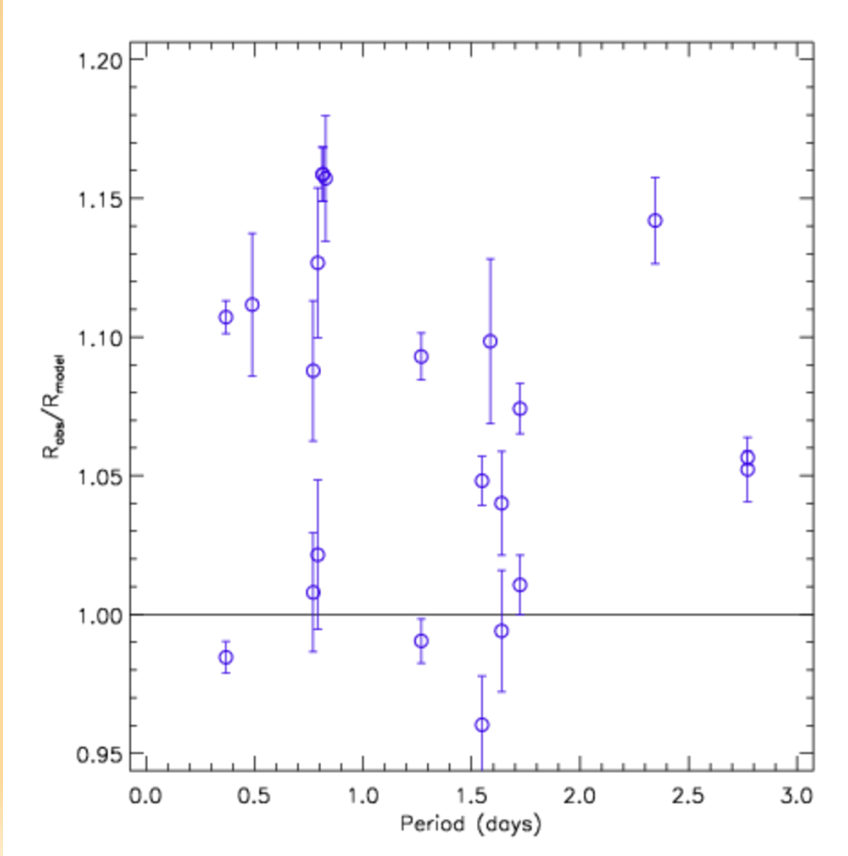
Low Mass Stars and Stellar Models

- Low mass stars in eclipsing binaries allow direct measurement of stellar properties
  - Mass, radius, effective temperatures, luminosities, chemical composition
- Observed stellar radii are ~ 10 – 15% larger than modeled radii
- Are tidally induced magnetic fields in close binaries the cause of this discrepancy?

Lower MS Mass – Radius Relation



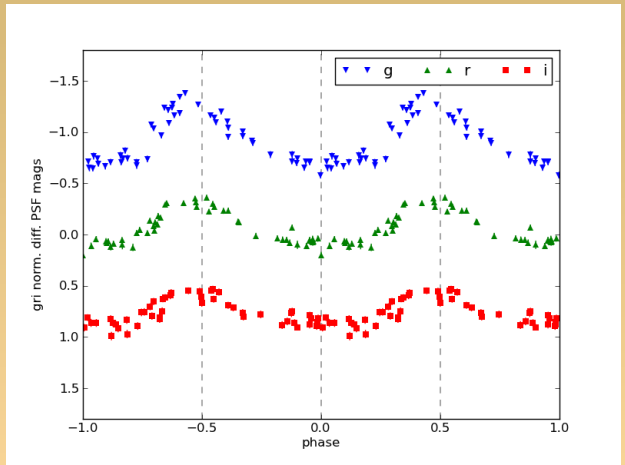
dM EB Orbital Period – Radius Discrepancy



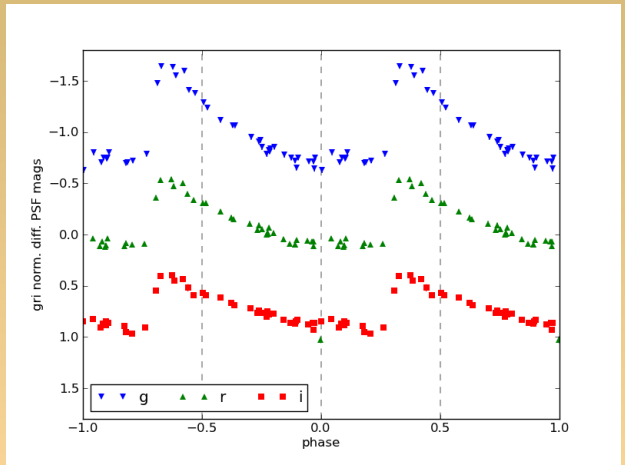
Outline

- Variability in SDSS Stripe 82
- Eclipsing binary systems from this dataset
  - Modeling
  - Parameter distributions
  - Follow-up candidate selection
- Follow-up observations
  - SDSS J2122 – dM0 + dM1 EB
  - SDSS J0211 – dM1 + dM2 EB
- Future work

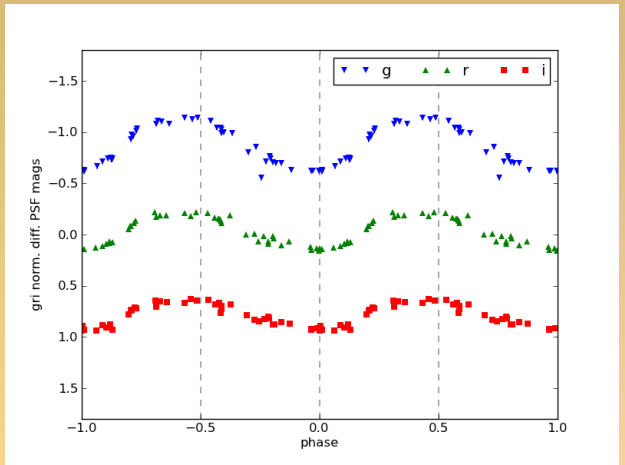
Variables from SDSS Stripe 82



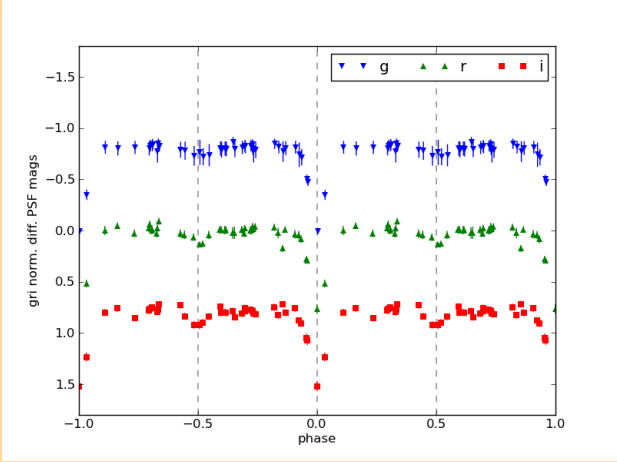
HADS – period: 0.049 days



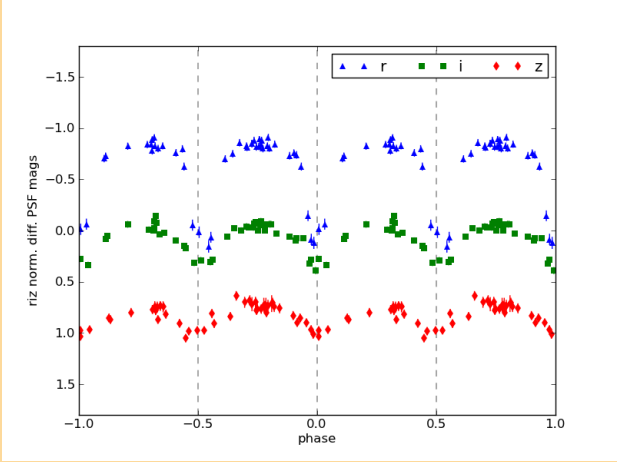
RRab – period: 0.595 days



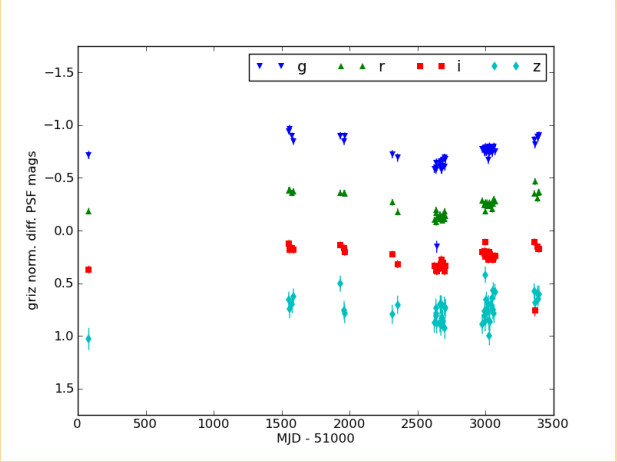
RRc – period: 0.357 days



A/BHB EB – period: 1.51 days



MS+WD EB – period: 0.143 days



SDSS QSO

- ~ **2 million** total point sources identified
- ~ **1.3 million** point sources with:
  - ≥ 10 detections, SDSS *r* < 22.0
- **16796** total variable point sources

- **781** periodic variables
  - **382** EBs
  - **288** RR Lyrae, **49** HADS
  - ~ **60** other (rotation, CV, ELL, etc.)

Search the variable point source catalog – Mozilla Firefox

Firefox | Search the variable point sourc... | shrike.pha.jhu.edu/cat-search/var-search | Google

Reset form | Search catalog

Output type

(•) HTML table ( ) CSV text

Sort output by

( ) PSF r mag (ascending) ( ) RA (ascending) ( ) Stetson variability index (ascending) ( ) Object tags (ascending) ( ) Periodic variable type (ascending)
( ) PSF r mag (descending) ( ) RA (descending) (•) Stetson variability index (descending) ( ) Object tags (descending) ( ) Periodic variable type (descending)

Object name constraints

( ) no object name constraints

( ) search by SDSS J name(s)
separate names by commas
use the form JXXXXXX.XX+/-XXXXXX.X

( ) search by object MB name(s)
separate names by commas
22982,140427,36,30313,25412

Position constraints

(•) no position constraints

( ) find object(s) in rectangle
use decimal degrees (J2000 coords)
min α [ ] max α [ ]
min δ [ ] max δ [ ]

( ) search around coordinates
use decimal degrees (J2000 coords)
α [ ] and δ [ ]
using a radius of [ ] arcmin

Magnitude constraints

[ ] use PSF u mag limits min [ ] to max [ ] mag
[ ] use PSF g mag limits min [ ] to max [ ] mag
[ ] use PSF r mag limits min [ ] to max [ ] mag
[ ] use PSF i mag limits min [ ] to max [ ] mag
[ ] use PSF z mag limits min [ ] to max [ ] mag

Color constraints

[ ] use PSF u-g color limits min [ ] to max [ ] mag
[ ] use PSF g-r color limits min [ ] to max [ ] mag
[ ] use PSF r-i color limits min [ ] to max [ ] mag
[ ] use PSF i-z color limits min [ ] to max [ ] mag

Object tag constraints

[ ] objects are tagged as **ANY** of the following...

[ ] SDSS QSO [ ] QSO color candidate [ ] SDSS white dwarf
[ ] SDSS hot subdwarf [ ] SDSS-I variable [ ] SDSS standard
[ ] RR Lyrae candidate [ ] white dwarf/sdO/sdB [ ] A/BHB
[ ] F-turnoff/sdF [ ] low-metallicity [ ] F/G
[ ] G dwarf [ ] K giant [ ] AGB
[ ] K dwarf [ ] sdM [ ] M dwarf
[ ] MS+WD pair [ ] brown dwarf [ ] unknown

[ ] objects are tagged as **ALL** of the following...
[ ] objects are tagged as **NONE** of the following...

Periodic variability constraints

(•) no periodic variability constraints
( ) object(s) are not tagged as periodic variables
( ) object(s) are tagged as periodic variables of any type
( ) object(s) are tagged as periodic variables of specific type(s):

[ ] eclipsing binary candidate [ ] high amplitude Delta Scuti
[ ] RRab RR Lyrae [ ] RRc RR Lyrae
[ ] ellipsoidal binary [ ] spot rotation
[ ] cataclysmic variable [ ] unknown

[ ] look for periodic variables with secure periods only
[ ] restrict periods to values min [ ] to max [ ] days

Search the light-curve catalogs > Search the variable point source catalog > Search results

Your query was translated to the following SQL statement:

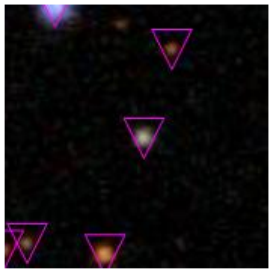
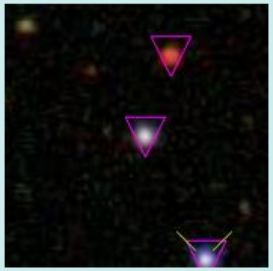
```
SELECT a.mb as mb, a.name as name, a.nobs as nobs,a.ra as ra, a.dec as dec, a.star_tags as star_tags, a.sdss_psfu as sdss_psfu, a.sdss_psfg as
sdss_psfg, a.sdss_psfr as sdss_psfr, a.sdss_psfi as sdss_psfi, a.sdss_psfz as sdss_psfz, a.lc_csv_fname as lc_csv_fname, a.lc_pdf_fname as
lc_pdf_fname, b.vartype as vartype, b.html_desc_fname as html_desc_fname, a.stet_ri as stet_ri, a.uid, b.period FROM probable_variables a LEFT OUTER
JOIN periodic_variables b ON (a.uid = b.uid) WHERE (((a.star_tags like %K dwarf%) or (a.star_tags like %M0%) or (a.star_tags like %M1%) or
(a.star_tags like %M2%) or (a.star_tags like %M3%) or (a.star_tags like %M4%) or (a.star_tags like %M5%) or (a.star_tags like %M6%) or (a.star_tags
like %M7%) or (a.star_tags like %M8%) or (a.star_tags like %M9%)) and ((a.star_tags not like %low-metallicity%) and (a.star_tags not like %K
giant%))) and ((b.vartype like %EB%)) AND (b.vartype not like %uncertain%) ORDER by a.stet_ri desc;
```

Notes:

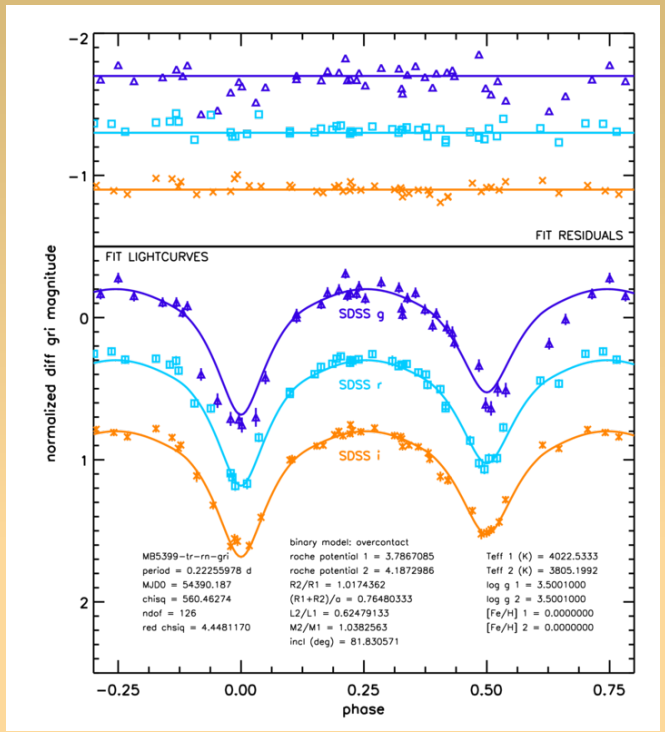
- Objects in the table below are sorted by decreasing Stetson variability index.
- Clicking on the cutout image will take you to the SDSS DR7 Object Explorer page for this object. If it is not present in DR7, then the object returned might not be the one you were looking for. This is because the Object Explorer searches a rather large 5 arcmin radius around the coordinates given.
- Detected periodic variable objects are noted by type below and links to their description pages are provided.
- The **LC CSV** column links to a tarball containing CSVs of the light-curves of the object. The **LC info** column links to a page with light-curves of the object.

Run another search query.

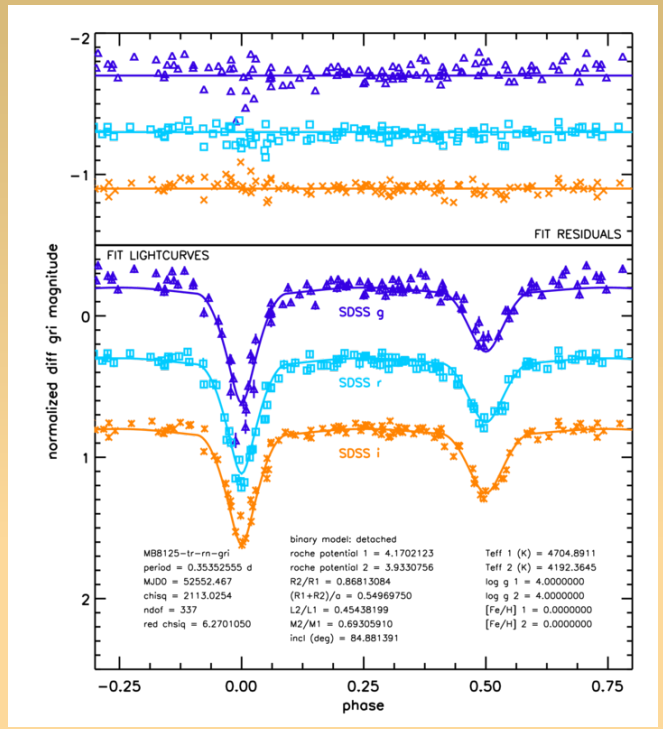
The following **59** object(s) match your search criteria:

object	RA [deg]	DEC [deg]	nobs	object tags	u	g	r	i	z	LC CSV	LC info	SDSS cutout
MB58833 SDSS J205650.83-005633.5 **periodic var: dK EB** **period: 0.274258 days**	314.212	-0.943	45	K dwarf / SDSS-I variable	21.15	19.40	18.69	18.50	18.31	get	view	
MB178470 SDSS J205122.50-010555.0 **periodic var: dK EB** **period: 0.263172 days**	312.844	-1.099	36	K dwarf / SDSS-I variable	19.87	18.30	17.72	17.53	17.42	get	view	
												

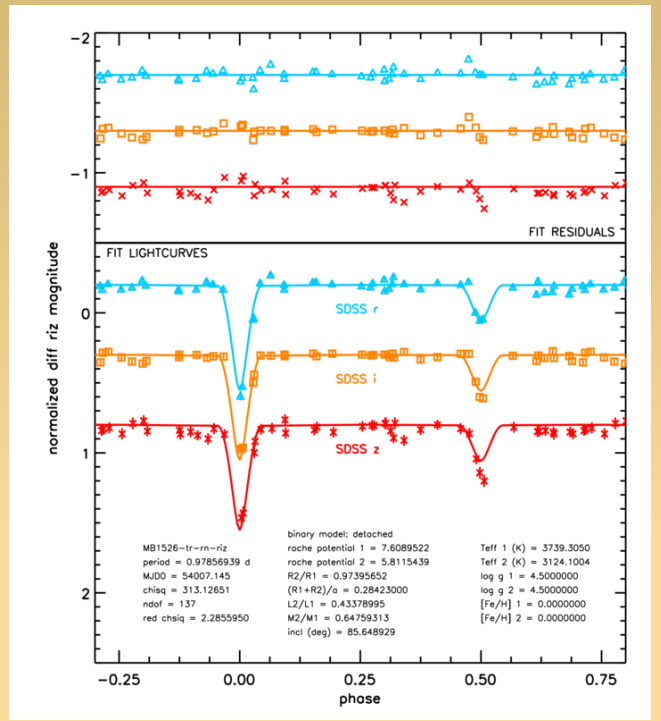
Stripe 82 Eclipsing Binaries



gK EB – period: 0.223 days



dK EB – period: 0.353 days



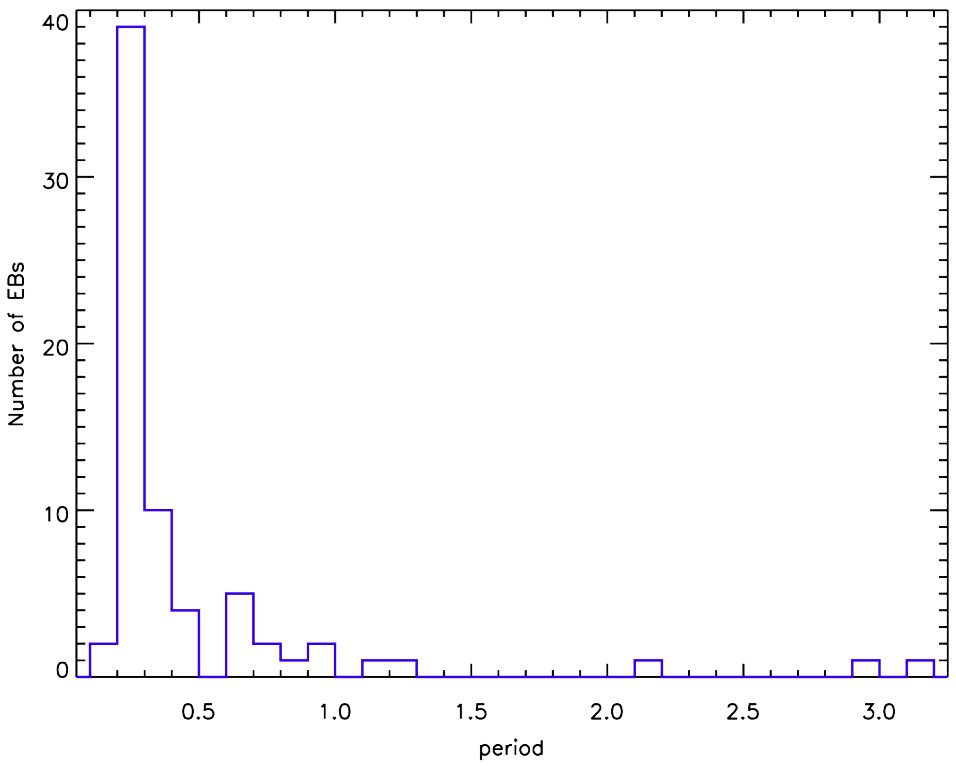
dM EB – period: 0.979 days

- **382** total EBs
  - **162** EBs with secure periods
  - **104** EBs suitable for LC modeling
- Use Wilson-Devinney model code
  - Fit SDSS *gri* LCs for *r-i* < 0.7
  - Fit SDSS *riz* LCs for *r-i* > 0.7

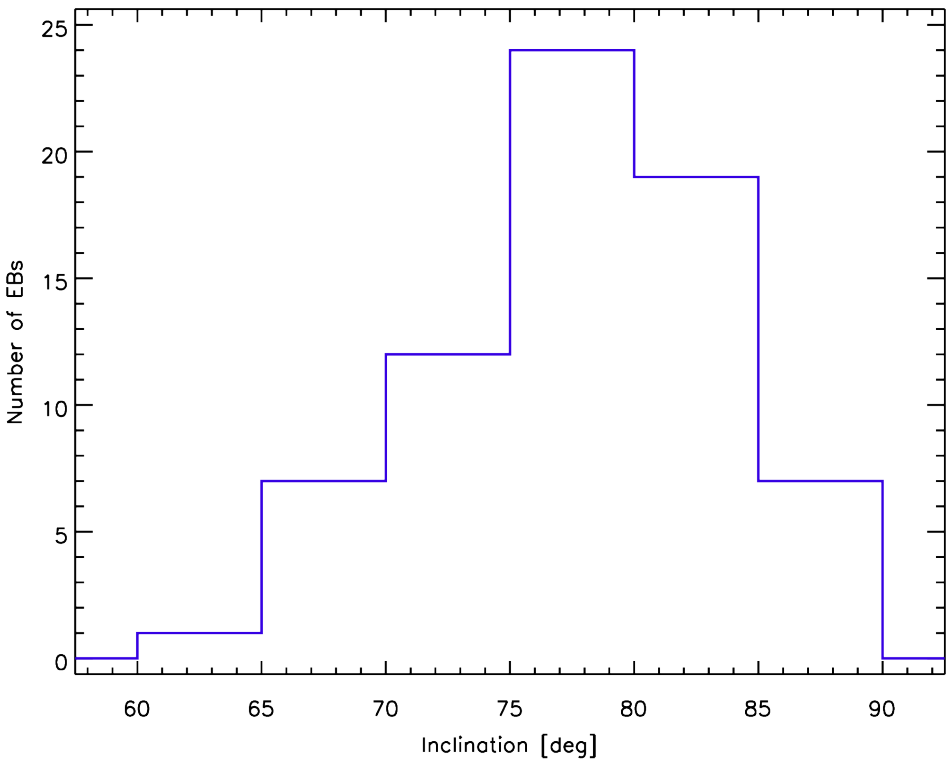
- Fix:
  - e = 0, no third light, no spots
  - log g, [Fe/H]
- Fit:
  - R2/R1, (R1+R2)/a
  - L2/L1, M2/M1
  - inclination
  - MJD0
  - effective temperatures

EB Orbital Parameter Distributions

Orbital Period

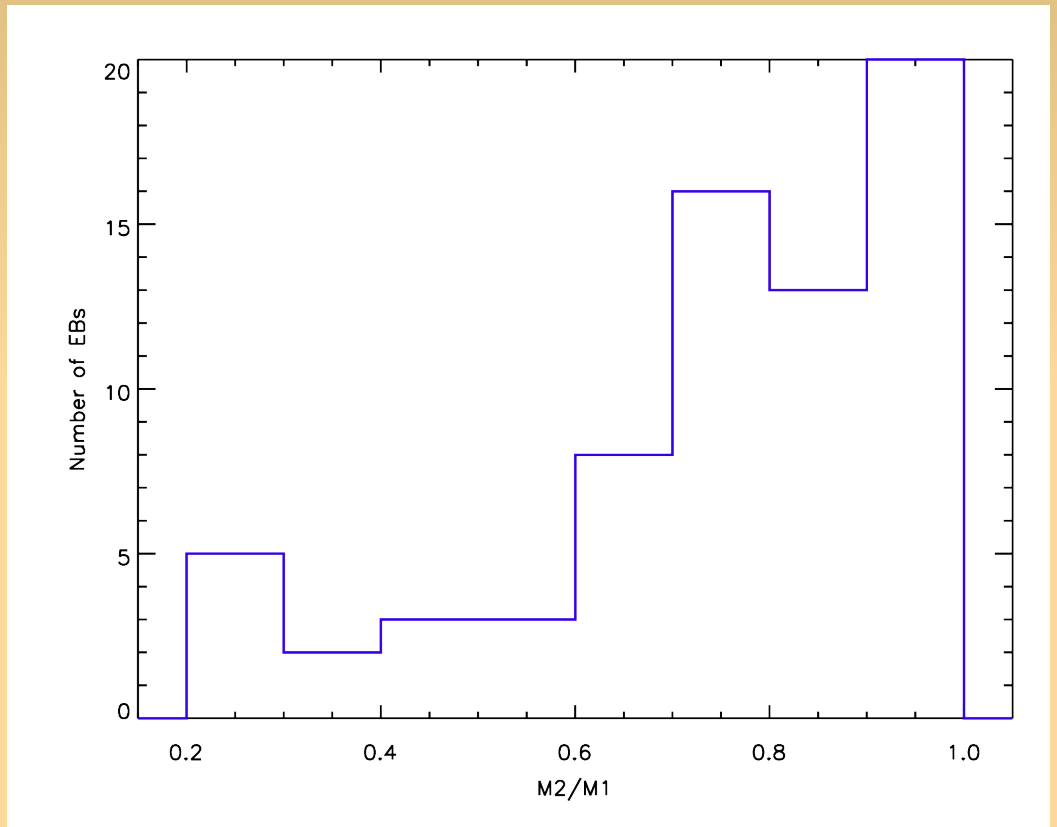


Orbital Inclination

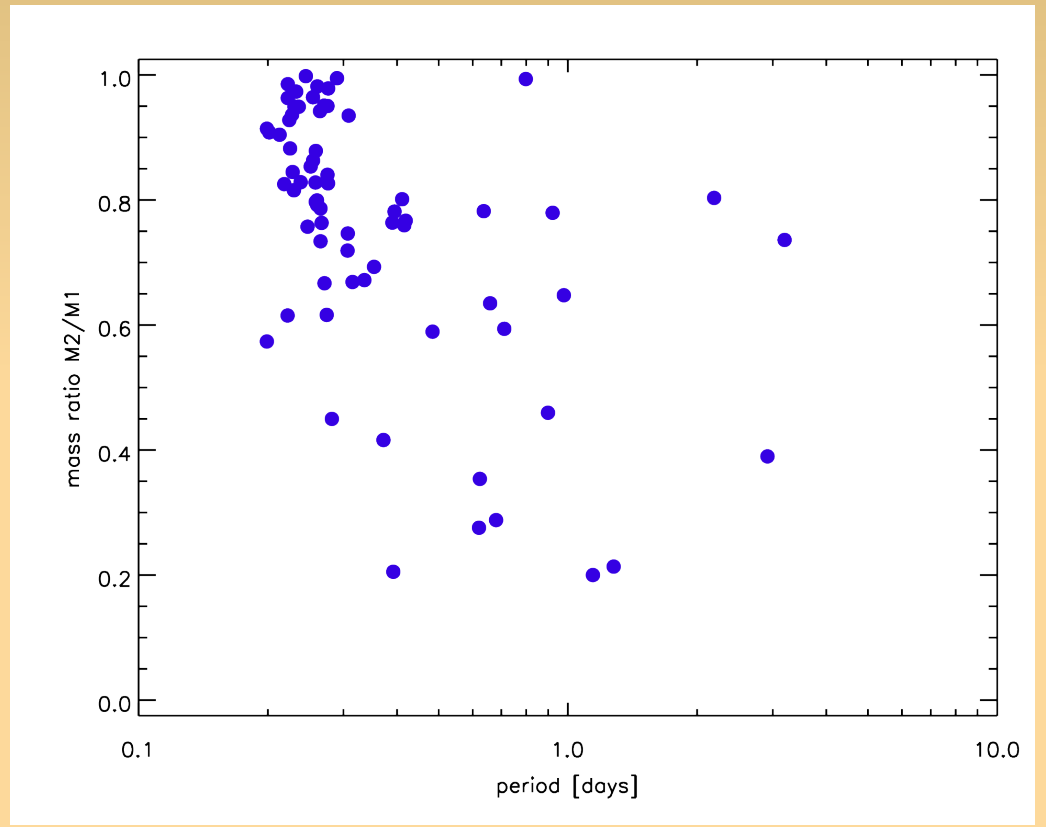


EB Stellar Parameter Distributions

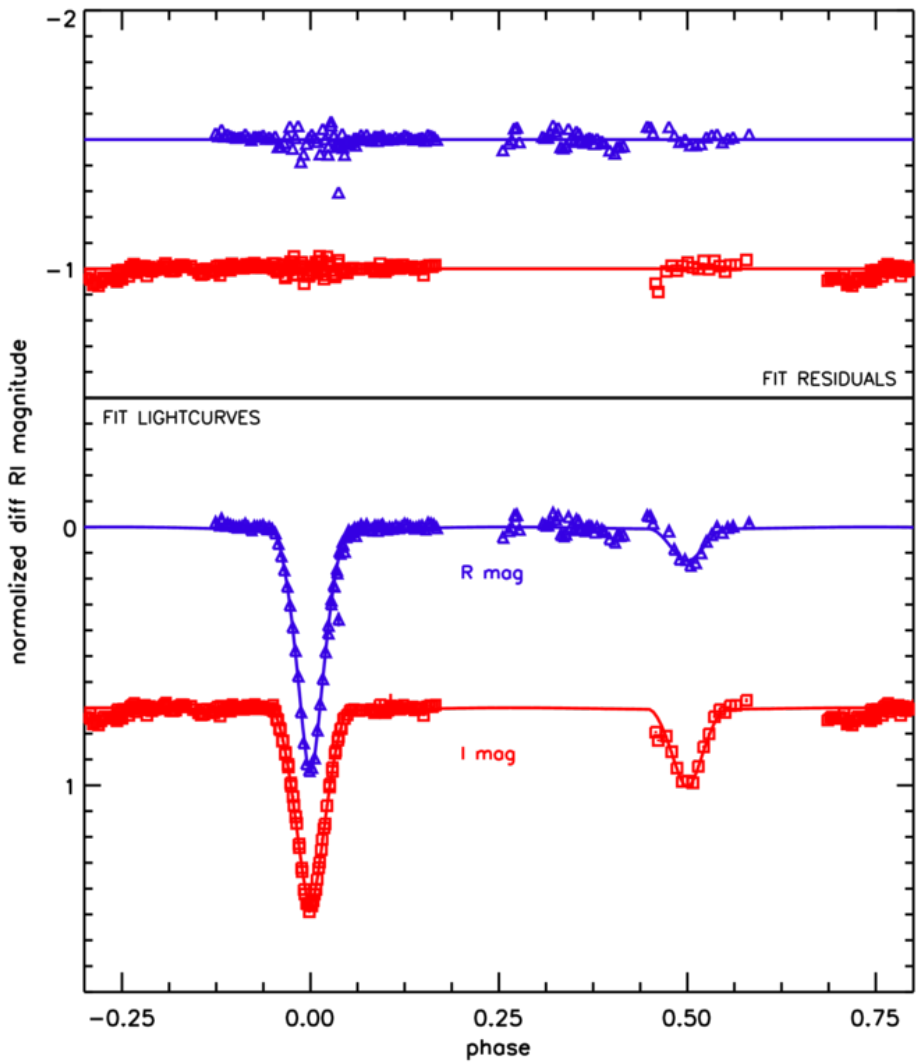
Photometric mass ratio M2/M1

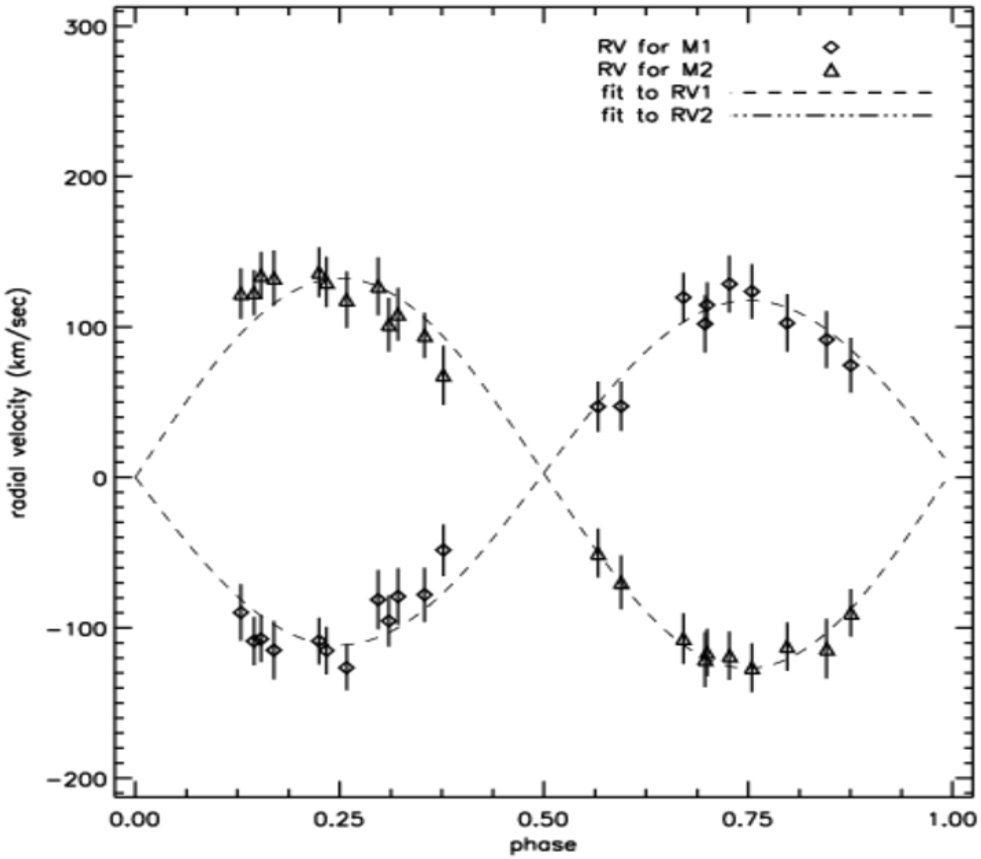


Photometric mass ratio vs. period



Two M-dwarf EBs – SDSS J2122



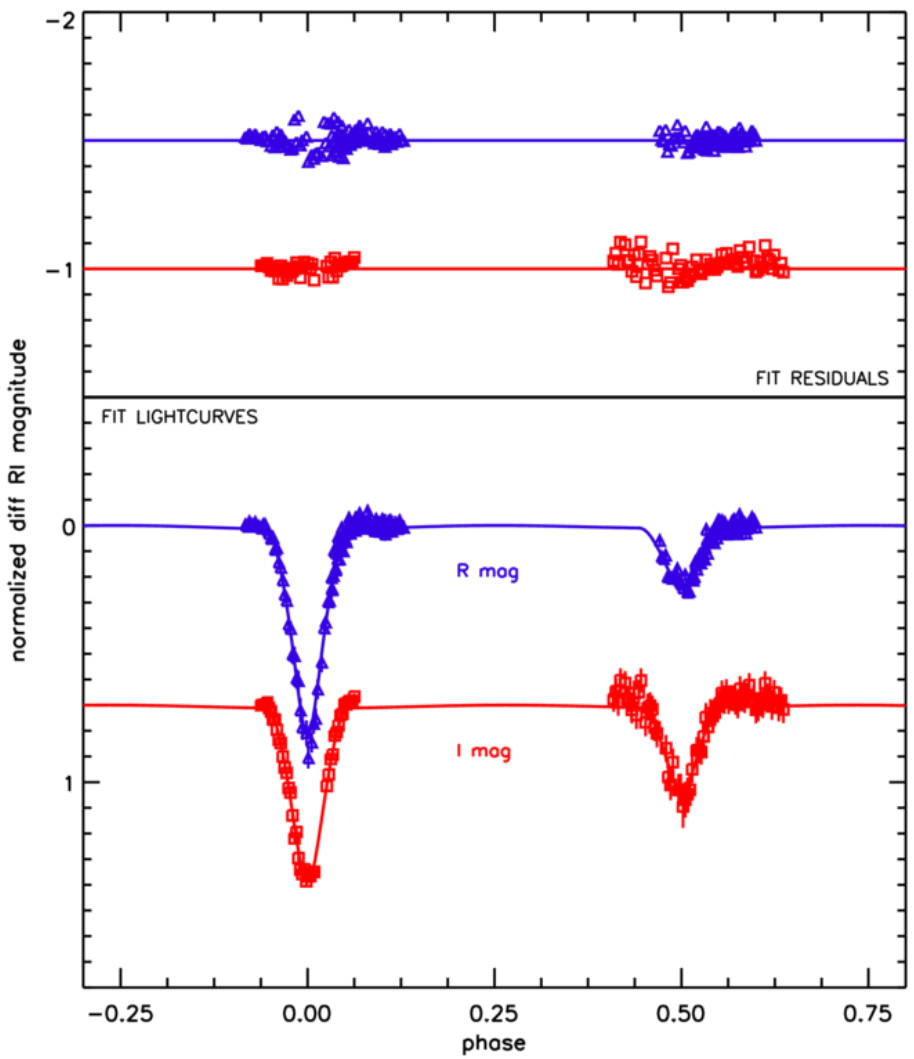


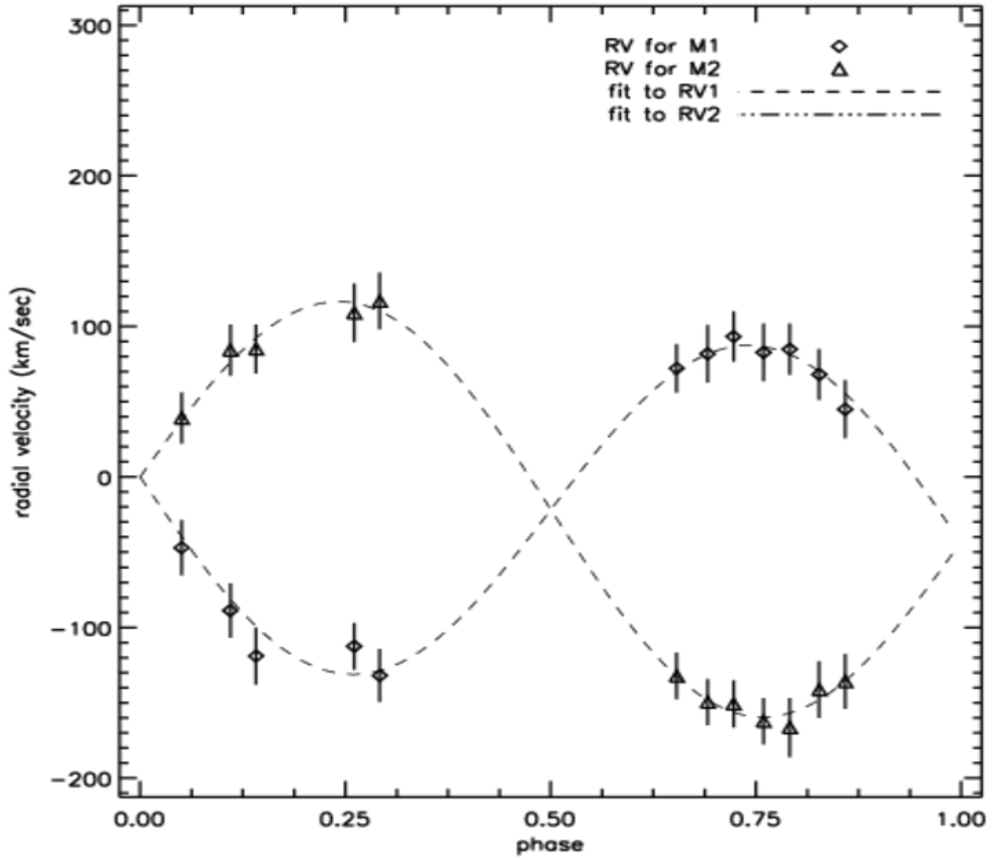
SDSS J212203.12-010053.3
Period: 0.791032 ± 0.000147 days
HJD0: 2455775.9743

M_1: 0.616 ± 0.075 $M_\odot$ R_1: 0.594 ± 0.016 $R_\odot$
M_2: 0.532 ± 0.059 $M_\odot$ R_2: 0.518 ± 0.014 $R_\odot$

$T_{eff,1}$: 3330 ± 338 K, SpT: dM0
$T_{eff,2}$: 2934 ± 510 K, SpT: dM1

Two M-dwarf EBs – SDSS J0211





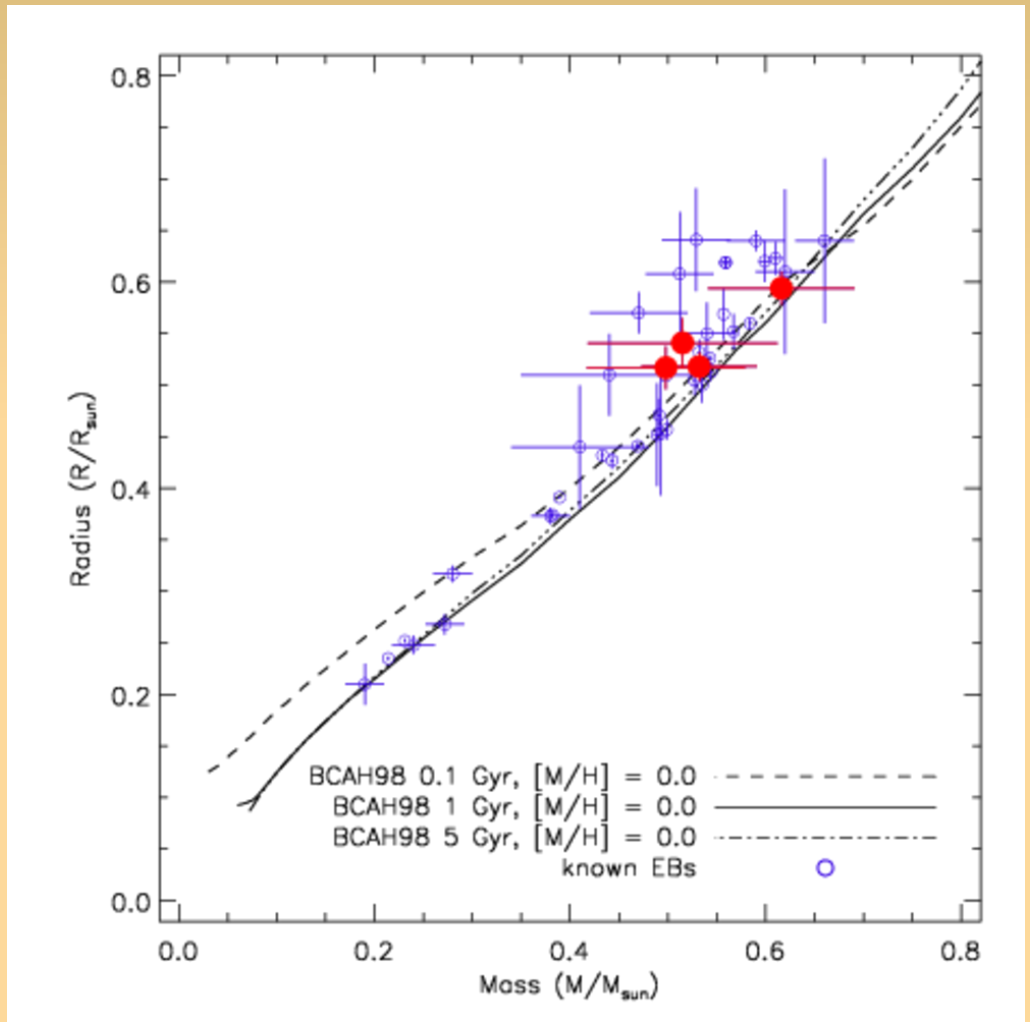
SDSS J021121.55-003808.3
Period: 0.623655 ± 0.000406 days
HJD0: 2455879.7346

M_1: 0.515 ± 0.097 $M_\odot$ R_1: 0.541 ± 0.024 $R_\odot$
M_2: 0.498 ± 0.082 $M_\odot$ R_2: 0.517 ± 0.021 $R_\odot$

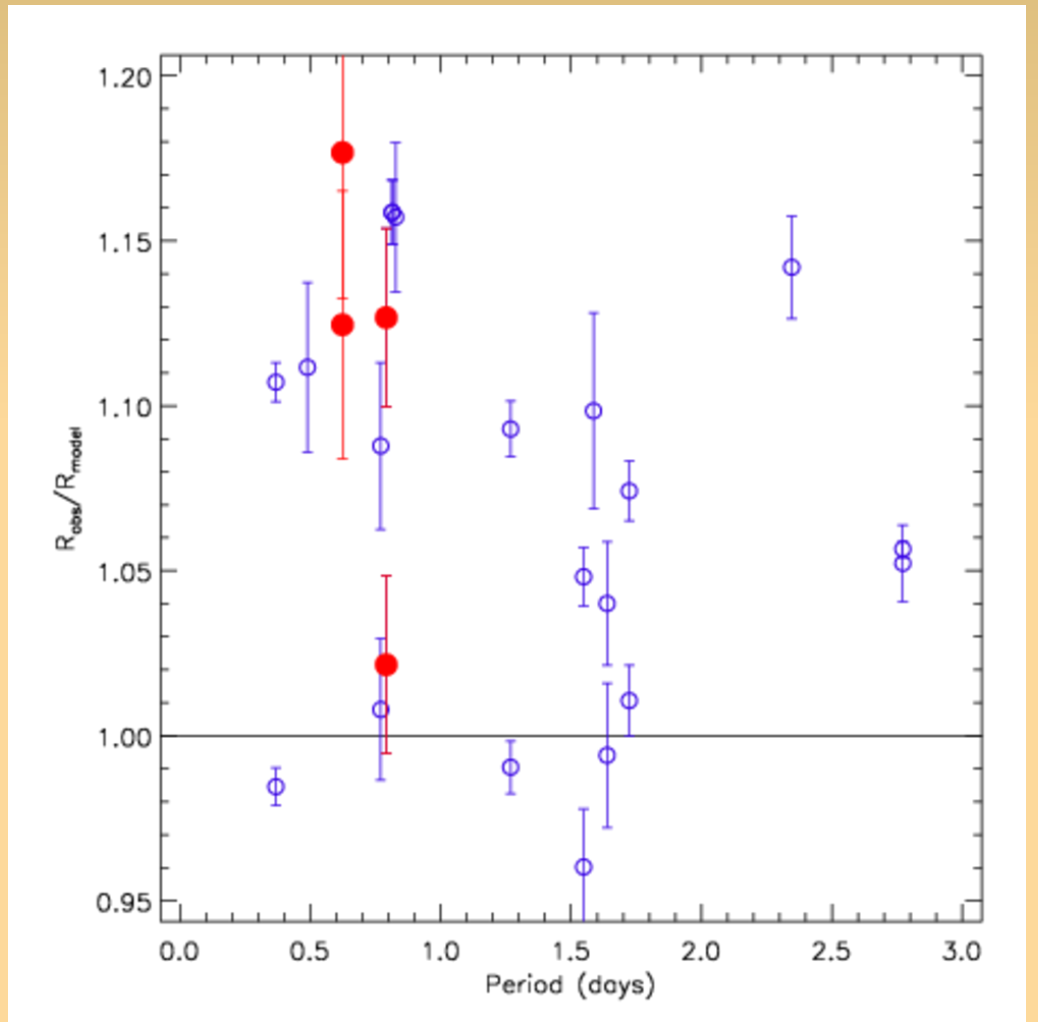
$T_{eff,1}$: 3192 ± 473 K, SpT: dM1
$T_{eff,2}$: 2836 ± 619 K, SpT: dM2

Low Mass Stellar Models Revisited

Lower MS Mass – Radius Relation



dM EB Orbital Period – Radius Discrepancy



Future Work

- More EB catalog science
- Estimate absolute masses and radii of Stripe 82 dM EB sample directly
  - cf. Coughlin et al. 2011 (Kepler sample of EBs)
- More follow-up light-curves and RVs for final target EBs
  - Observations this week
- Improve modeling of final two EB targets
  - Better mass estimates needed

Summary

- ~1.3 million point sources extracted from SDSS Stripe 82
- 16796 variable point sources
  - 781 periodic variable stars
  - 382 EBs, 288 RR Lyrae, 49 HADS, ~60 other
  - Search: http://shrike.pha.jhu.edu/cat-search/var-search
  - Browse: http://shrike.pha.jhu.edu/stripe82-variables
- 2 M-dwarf EBs with follow-up observations to get M + R
  - SDSS J2202 (dM0 + dM1):
    - M_1: 0.616 ± 0.075 $M_\odot$, R_1: 0.594 ± 0.016 $R_\odot$
    - M_2: 0.532 ± 0.059 $M_\odot$, R_2: 0.518 ± 0.014 $R_\odot$
  - SDSS J0211 (dM1 + dM2):
    - M_1: 0.515 ± 0.097 $M_\odot$, R_1: 0.541 ± 0.024 $R_\odot$
    - M_2: 0.498 ± 0.082 $M_\odot$, R_2: 0.517 ± 0.021 $R_\odot$
- Observed radii are larger than predicted radii from models