Poster # 18.02 (Revised title)

Short-Term Changes in the Eclipse Timings and Light-Curve Shapes of W UMa Binaries

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and

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with

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Overall Purpose of the Program

The overall purpose of our program is to look for subtle short-term changes in the eclipse timings and light-curve shapes of short-period W Ursa Majoris binaries

Eclipse timing changes could be due to

*** Angular momentum loss**
*** The Applegate effect**
*** Third body light-time effect**
*** Micro-episodes of mass flow**

Light curve shape changes could be due to

*** Starspots or other photometric surface phenomena**
*** Flares (only in U—and not until a future observing season)**

Of course any changes in either eclipse timings or light curve shapes could also be due to observational errors

Research Approach

Concentrate on a few short-period binaries

* Select binaries at or near the 0.22 day "limit"
* Favor binaries with RV curves and known orbital parameters
* Obtain complete light curves (one orbit or more) nearly every night
* Observe same systems all season long for several seasons

Observational strategy

* Observe binaries simultaneously from two observatories
* Minimize photometric errors via ensemble photometry
* Transform all data to standard magnitude system
* Start with a trial pilot season of observations and analysis
* Follow with three full "industrial-strength" seasons

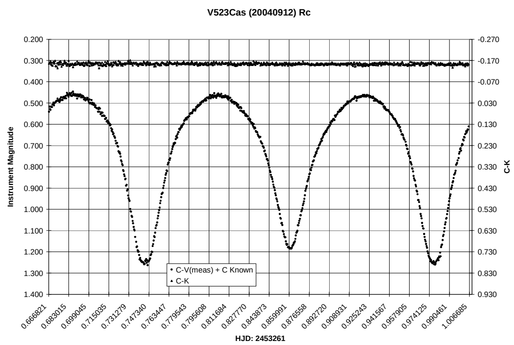
Complimentary analytic approaches

* Statistical—seasonal parameters and trends
* Nonparametric modeling—curve shape changes
* Parametric modeling—Wilson Devinney (with Dirk Terrell)

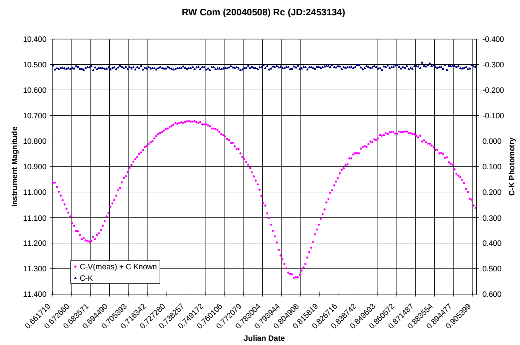
Pilot Season Observations

Binary	DRO	Orion	Total	Period	V_J Max	Delta Mag
V523 Cas	27	7	34	0.234	10.6	0.83
RW Com	18	8	26	0.237	11.0	0.70
V400 Lyr	7	10	17	0.253	12.7	0.65
TZ Boo	18	13	31	0.297	10.4	0.59
V1191 Cyg	22	39	61	0.313	10.8	0.33
GM Dra	14	3	17	0.339	8.8	0.27

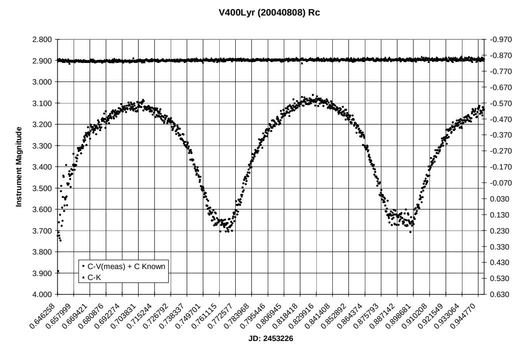
Sample Light Curves



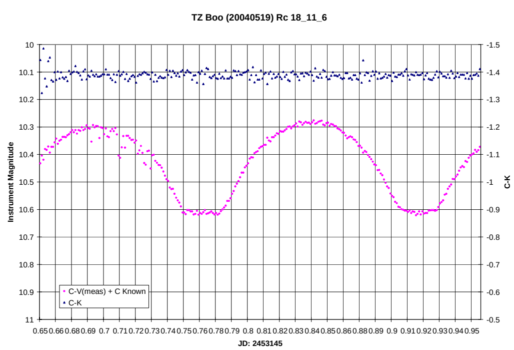
V523 Cas



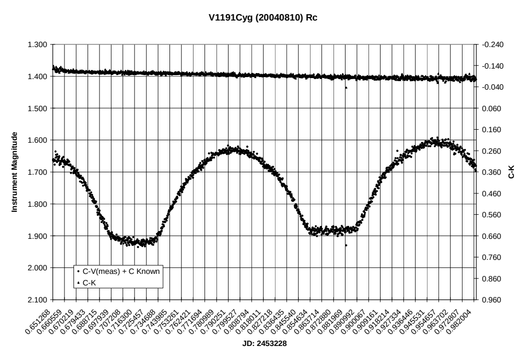
RW Com



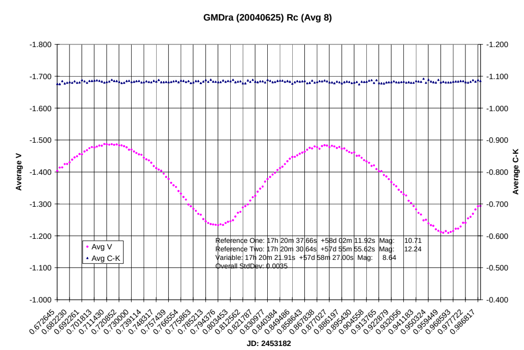
V400 Lyr



TZ Boo



V1191 Cyg



GM Dra

Statistical Analysis

Times of minima (and other parameters)

* Kwee van Woerden, Fourier, and Hertzsprung[1]
* Actual (external) errors (precision) based on simultaneous observations
* Other parameters—secondary minima, maxima, delta magnitudes, etc.

Seasonal ephemeris and O-C analysis

* Period (and epoch) derived solely from our seasonal observations
* Error of mean for seasonally-derived period less than one second
* Seasonal ephemeris used in seasonal O-C analysis

Photometric Precision

* Precision of classical variable minus single comparison photometry
* Precision of ensemble photometry (multiple comparisons)
* Relationship between times of minima and photometric precision

Analysis of variance (ANOV)

* Partition of variances between observatories, orbital cycles, nights, etc.

1. Hertzsprung, E., 1928, *Bulletin of the Astronomical Institute of the Netherlands,* 4, 178.

Nonparametric Light Curve Modeling

Nonparametric light curve models

* Make no physical assumptions / compliment parametric models
* Tsesevich[2] introduced concept of standard light curve for sparse data
* We extended Tsesevich concept to a season of dense-data light curves

Model formulations

* Models are magnitude as a function of phase (they can be piecewise)
* Points transformed to a function via smoothing spline or Fourier low pass
* Models formulated for every individual night (each observatory)
* Seasonal master model formulated from best nights (each observatory)

Quantitative differential analysis between models

* Compare single night models with seasonal standard model,
  or compare models from individual nights two at a time
* Use comparisons to evaluate quantitative changes in light curves
  with respect to magnitudes, colors, and asymmetries
* Converted phase shifts for best fits to whole-curve times of minima

2.Tsesevich, V. P., 1971, in *Variable Star Research Methods,* ed. V. B. Nikonov, p 70, Moscow: Naula.

Parametric Light Curve Modeling

Parametric light curve models

* Models provide physical representation / necessarily make assumptions
* Parametric models yield astrophysical interpretation at the cost of some fit to data if the underlying model is inadequate
* Wilson-Devinney model analysis (Dirk Terrell)

Model formulations

* Initial modeling develops a single set of orbital parameters for the season
* Using these, develop a model for each night with variations in time of minima, and in starspot numbers, lat/longs, diameters, and temperatures

Quantitative differential analysis between models

* Compare models from individual nights—two at a time
* Use comparisons to evaluate quantitative changes in light curves with respect to magnitudes, colors, and asymmetries
* Also use models to interpret variations as changes in starspots
* Converted phase shifts for best fits to whole-curve times of minima

Parametric / Nonparametric Model Comparison

Roles of each model type
* Nonparametric models are the empirical standards / reality checks
* Parametric models provide astrophysical interpretation

Comparing the two tells us
* How well the parametric models fit the empirical data
* What variation remains unexplained

This will suggest
* How complete our parametric models are in explaining reality
* And therefore whether they are in need of further explanatory parameters

Program Future Plans

Complete pilot season analysis

* Ensemble photometry reduction procedure
* Statistical analysis
* Nonparametric model analysis
* Parametric model analysis (Terrell)

Report pilot season results to the community

* IAU Commission 42 conference in Syros, Greece, 27-30 June, 2005
* Close Binaries in the 21st Century: New Opportunities and Challenges

Further out

* Select binaries for second season / some the same, some new
* Observe in V & I (sequentially) instead of R only
* Eventually add two new larger telescopes (one for each observatory)
* Equip these new systems with simultaneous UVI photometers
  (using dichroic beamsplitters and three CCD cameras)