

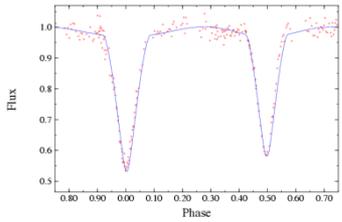
The VSS Southern Eclipsing Binaries Programme

astrophysical research for all

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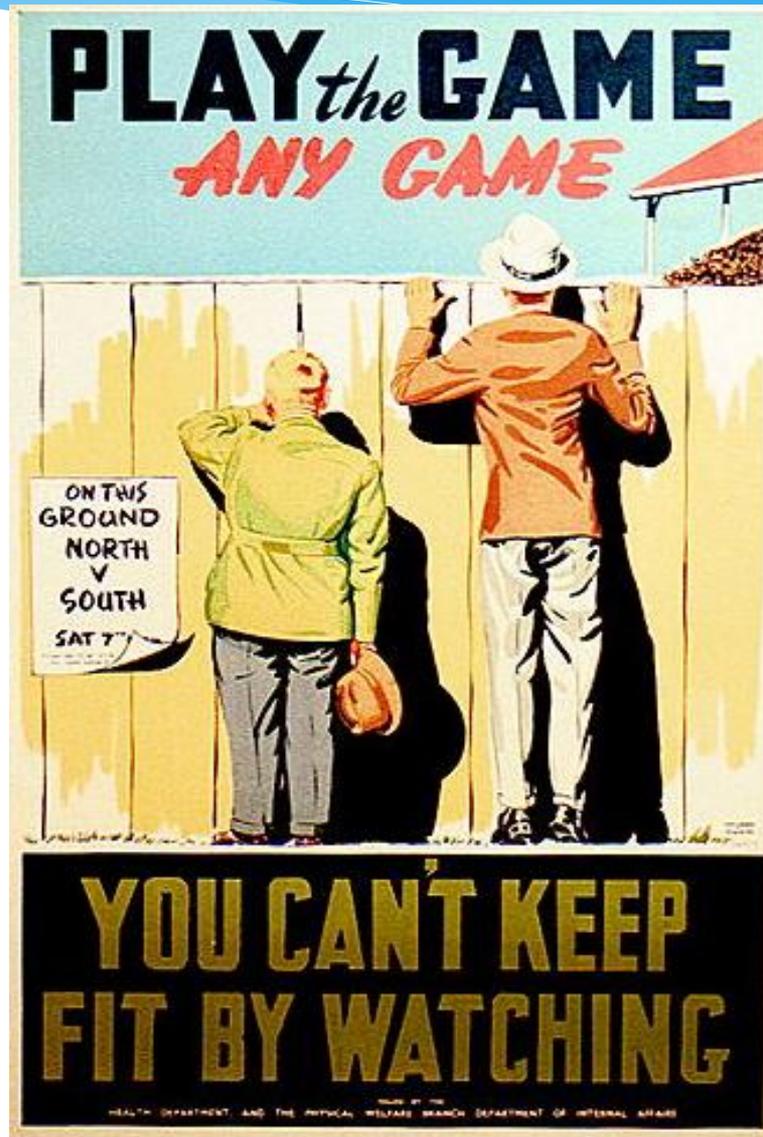


Sports and Stars

You can watch them,
you can read about
them.

But to really understand
them, to get the
excitement, to achieve
something, you have to
get down and dirty and
play the game.

*And Eclipsing Binaries are
one game you can play.*

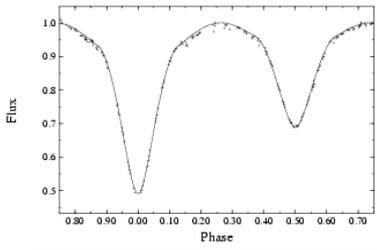


In the south:
"Too many stars,
too few
astronomers."

TJR

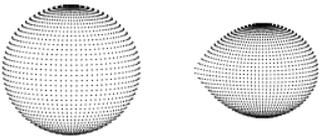


Why Study Eclipsing Binaries?



- * Easy targets for amateur research
 - * Also very good for analysis by amateurs (don't send off to an archive somewhere, do the research yourself!)
 - * Southern EBs usually badly under-studied
- Astrophysically vital to study:
- * Eclipses provide fundamental stellar parameters not obtainable directly otherwise
 - * Close binaries are born together then evolve differently from lone stars, providing unique astrophysical laboratories.





Research for everyone



OBSERVER, at the Telescope

Got a tracking telescope and camera?

- * Get a time series of images overnight
- * Do aperture photometry on them next day
- * Email photometry to the appointed analyst.

ANALYST, at the Computer

Become responsible for research on nominated targets, and do some or all of:

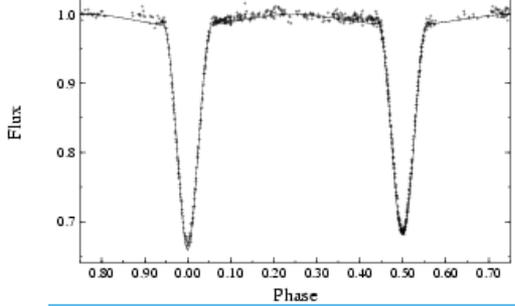
- * Find Times of Minima,
- * Find Light Elements,
- * Research Period Changes,
- * Search for Planets (SPADES),
- * Model the system,
- * Write research papers.



Let's look at all this more closely...

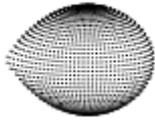


SEB Programme Aims



1. Observational and analysis work at all levels and types:
 - * Beginner to rusted-on old hand
 - * Embarrassingly easy work to seriously mind-stretching
 - * No prior knowledge of EBs to deep background reading
 - * Can't remember high-school maths, stats, physics; to can. (even unto the rarefied heights of university courses)
 - * Am and Pro
2. Close collaboration and mentoring
3. Serious research aimed at publication.

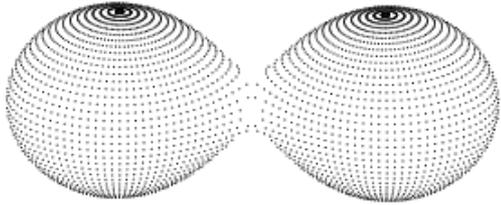




Main Research Goals

1. Finding Times of Minima
2. Deriving Light Elements
3. Obtaining a Phased Light Curve
4. Obtaining Spectra
5. Light Curve Analysis & System Modelling
6. O-C Diagrams
7. Search for a 3rd body (incl. SPADES)
8. Unexpected Opportunities



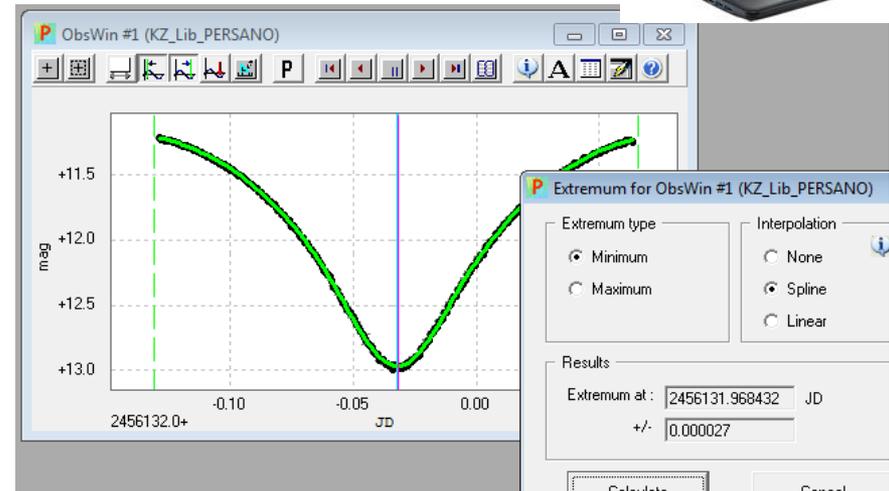
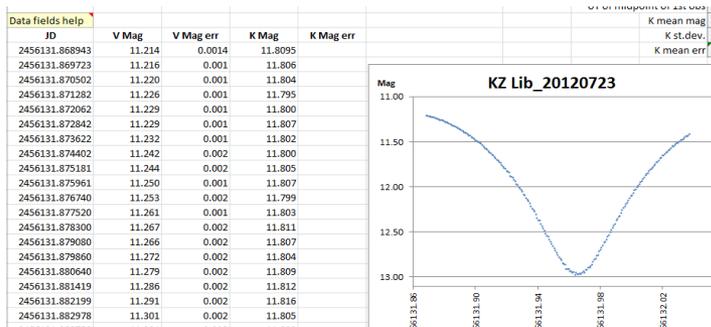


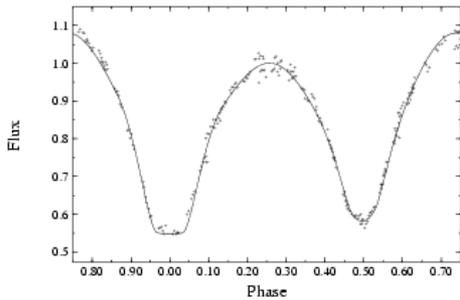
Goal 1: Minima

* **Observer** takes hours-long time series of target, then carries out photometry.



* **Analyst** puts data into PERANSO, measures minimum.





Goal 2: Light Elements

- * Analyst acquires several minima of a target, recording on a supplied *Excel Results Form*.

Minima							
Cycle	HJD (O)	error	Min mag	C	C error	O-C	O-C error
3501	2455883.053236	0.000170	10.43	2455883.052804	0.000000	0.00043	0.0002
3571	2455961.999949	0.000023	10.43	2455961.999084	0.000000	0.00086	0.0000
3807	2456228.16172	0.00033	10.44	2456228.160828	0.000000	0.00089	0.0003
3888.5	2456320.080362	0.000730214	9.97	2456320.076854	0.000000	0.00351	0.0007

- * The form automatically performs a regression to find period P and a “zero epoch” E_0 .
- * Then can predict future eclipses:

$$E_n = E_0 + nP$$

Linear Estimate			
P	1.9743188	2455750.90275	E0
se P	4.30178E-06	0.000759995	se E0
r^2	1.00	0.001076551	se E
F	2.10639E+11	1	df
ss_reg	244122.4593	1.15896E-06	ss_resid

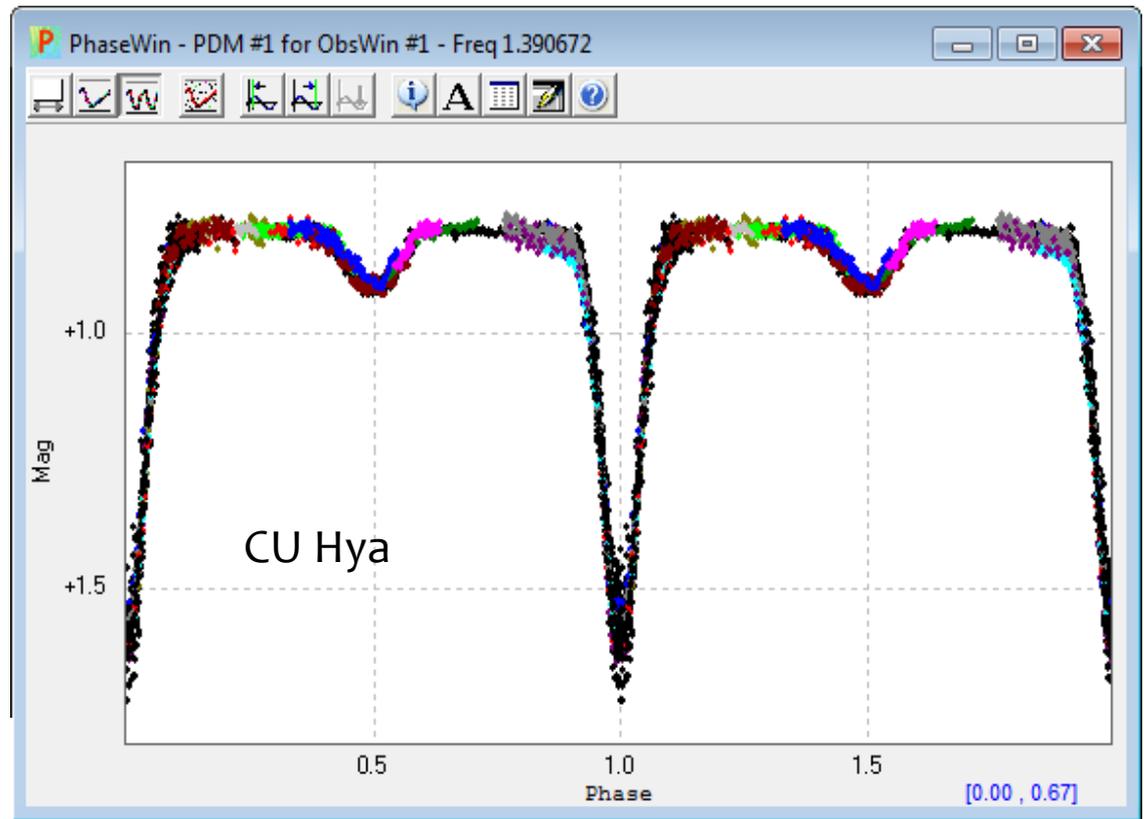


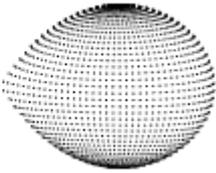
Goal 3: light curve



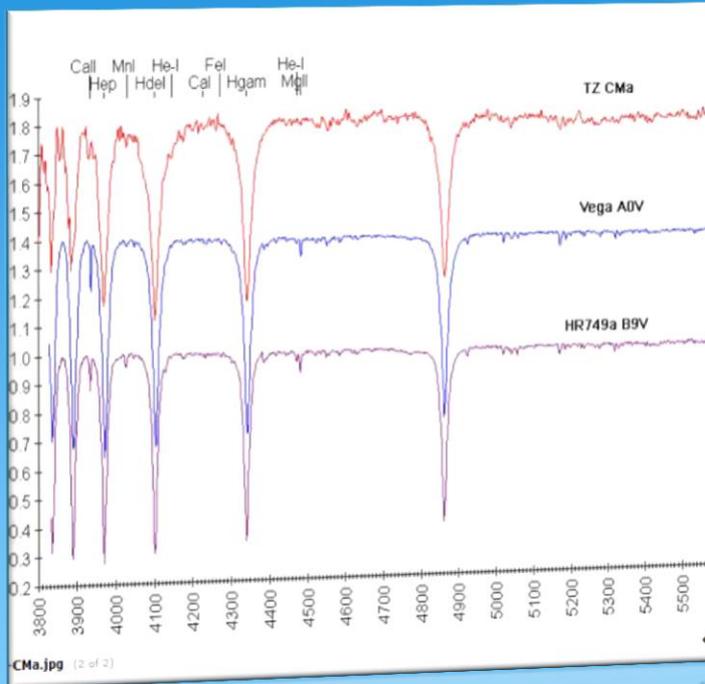
Observers do time series at all phases of target, not just eclipse

Analyst cobbles these together in PERANSO to produce a complete light curve.



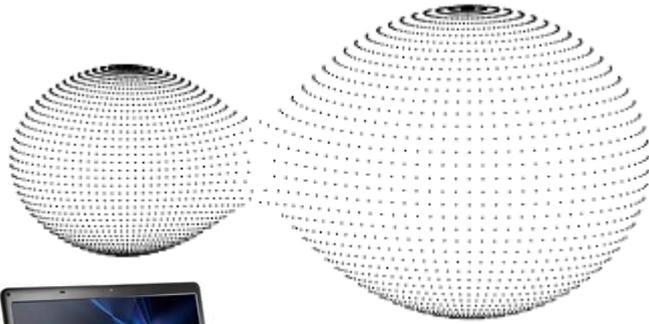


Goal 4: Spectra



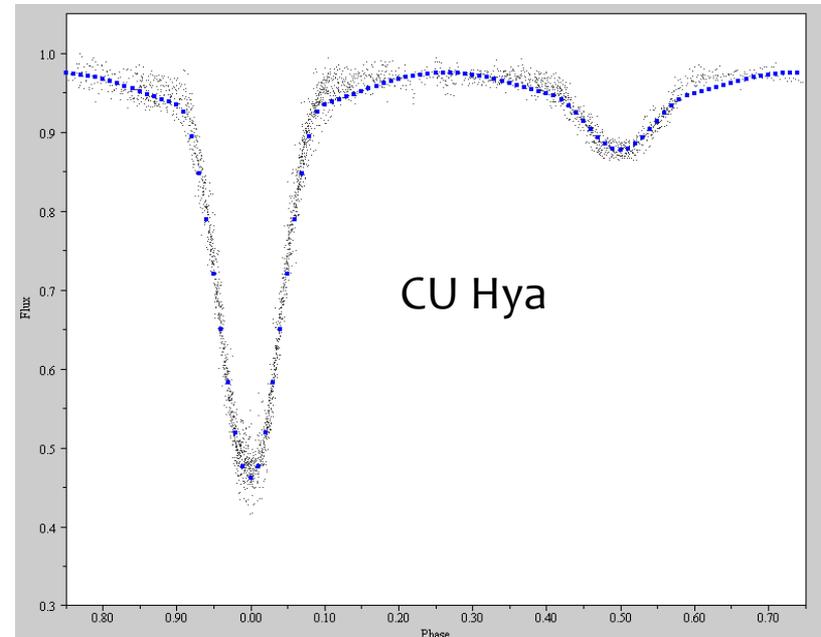
- Amateur equipment can determine spectral classifications of the brighter eclipsing binaries in the Programme.
- Radial velocities would be most helpful – if we can get time on Gemini South!

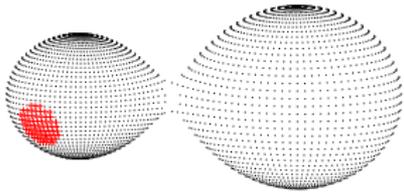




Goal 5: Light curve analysis

- * **Analyst** can use a “light curve analysis” program to try to fit a “synthetic” light curve generated by the program to the observed light curve.
- * You guess at various parameters of the system,
- * It draws a light curve for such a system.





Goal 5 Light curve analysis

Output is a 3D model and list of astrophysical parameters:

- the orbital inclination to our line of sight,
- the radii of the stars relative to the orbital radius,
- their shapes,
- the ratios of their masses, luminosities and temperatures.

... and much more

More still if we can determine the orbital velocities spectroscopically (anyone got an 8-metre class telescope?)

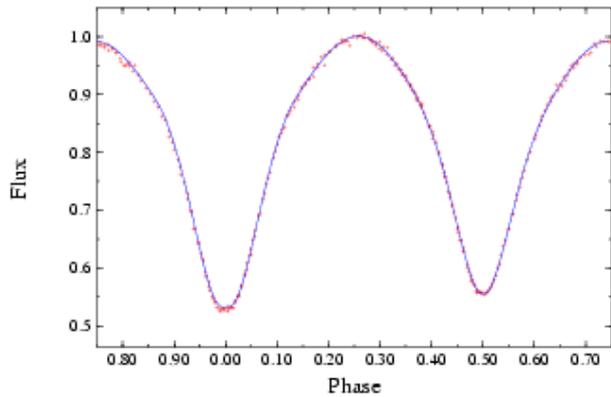
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p. 308
                                output from Binary Maker

mass ratio input = 0.500000      mass ratio < 1 = 0.500000
Omega 1 = 4.043948              Omega 2 = 2.928706
Omega inner = 2.875845          Omega outer = 2.577260
C 1 = 5.503041                 C 2 = 4.016053
C inner = 3.945571             C outer = 3.547458
Fillout 1 = -0.283020          Fillout 2 = -0.017550
Lagrangian L1 = 0.570752       Lagrangian L2 = 1.582381
AG = r1(back) = 0.290000       AS = r2(back) = 0.330000
BG = r1(side) = 0.285550       BS = r2(side) = 0.302496
CG = r1(pole) = 0.280698       CS = r2(pole) = 0.290948
DG = r1(point) = 0.292452      DS = r2(point) = 0.365511
Surface area 1 = 1.024883      Surface area 2 = 1.202942
Volume 1 = 0.076780            Volume 2 = 0.097885
Mean radius 1 = 0.285416       Mean radius 2 = 0.307815
Mean radius 1 (vol) = 0.263666 Mean radius 2 (vol) = 0.285897
Eccentricity = 0.00000         Longitude of Periastron = 0.0000
Phase of periastron = 0.00000  Phase of conjunction = 0.00000
Angular Rotation F1 = 1.0000   Angular Rotation F2 = 1.0000
Normalization Phase = 0.25000  Normalization Factor = 0.97500
inclination = 77.000           wavelength = 5500.00
temperature 1 = 7450.00        temperature 2 = 4650.00
luminosity 1 = 0.8789          luminosity 2 = 0.1211
gravity coefficient 1 = 1.000   gravity coefficient 2 = 0.320
limb darkening 1 = 0.580      limb darkening 2 = 0.720
reflection 1 = 1.000           reflection 2 = 0.500
                                Period = 0.00000000
                                00
```



agnitude	Distance	Rad Vel 1	Rad Vel 2	Mass Center 1	Mass Center 2
0.0275	1.0000	-0.3322	0.6459	-0.3333	0.3333
0.0273	1.0000	-0.3319	0.6450	-0.3332	0.3332
0.0271	1.0000	-0.3310	0.6429	-0.3324	0.3324
0.0273	1.0000	-0.3295	0.6395	-0.3310	0.3310
0.0277	1.0000	-0.3273	0.6350	-0.3289	0.3289





6 O-C Diagrams

- * **Analyst** can comb the literature to find Observed times of minima.
- * But by now the analyst has our light elements (P , E_0) so can Calculate when those minima should have occurred.

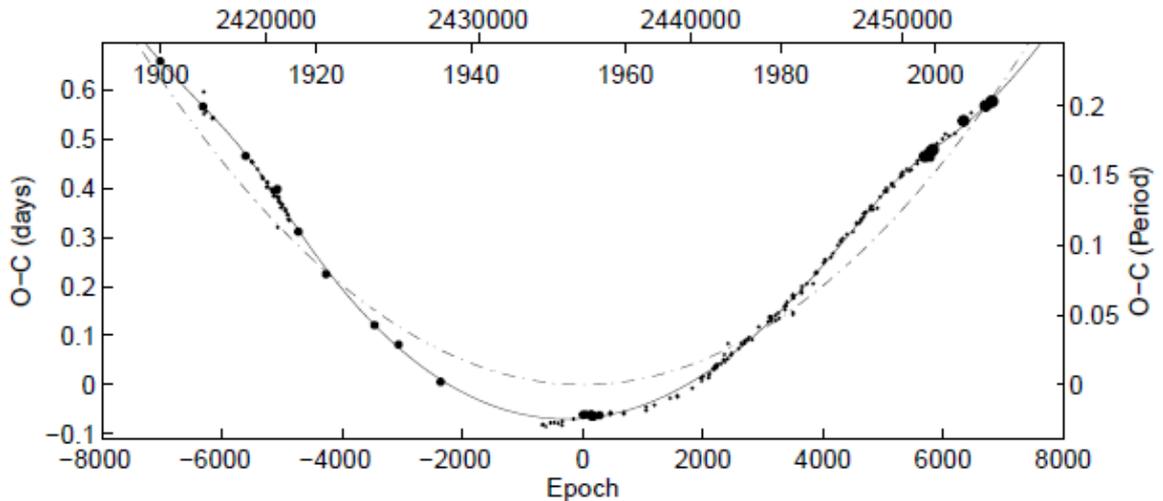
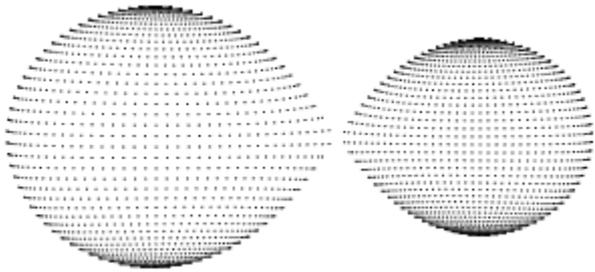


Figure 3: The $O - C$ diagram of RR Dra (for the description see Fig 1).

The period of RR Dra is lengthening.
Zasche et al, [2008NewA...13..405Z](#)





Goal 7 Third Body & SPADES

- * A wavy line in an O-C diagram may indicate a star or planet in orbit around the binary.
- * Search for Planets Around Detached Eclipsing Systems is a sub-project aimed at that.

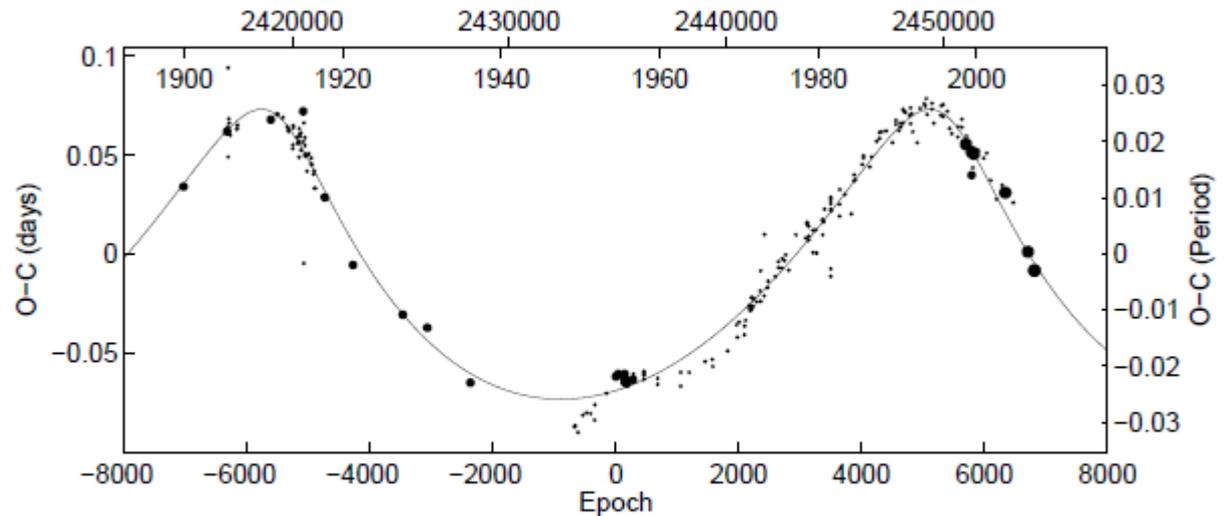
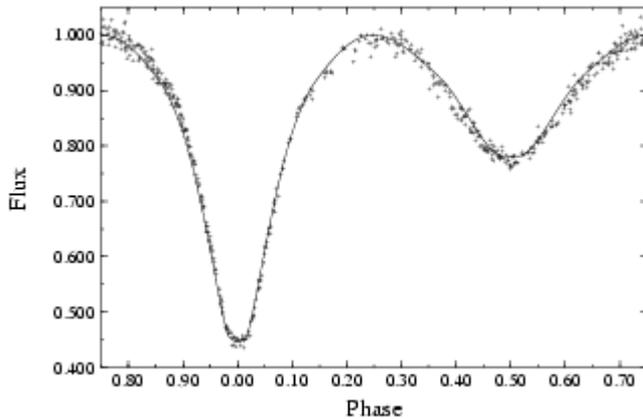


Figure 4: The $O - C$ diagram of RR Dra after subtraction of the quadratic term.

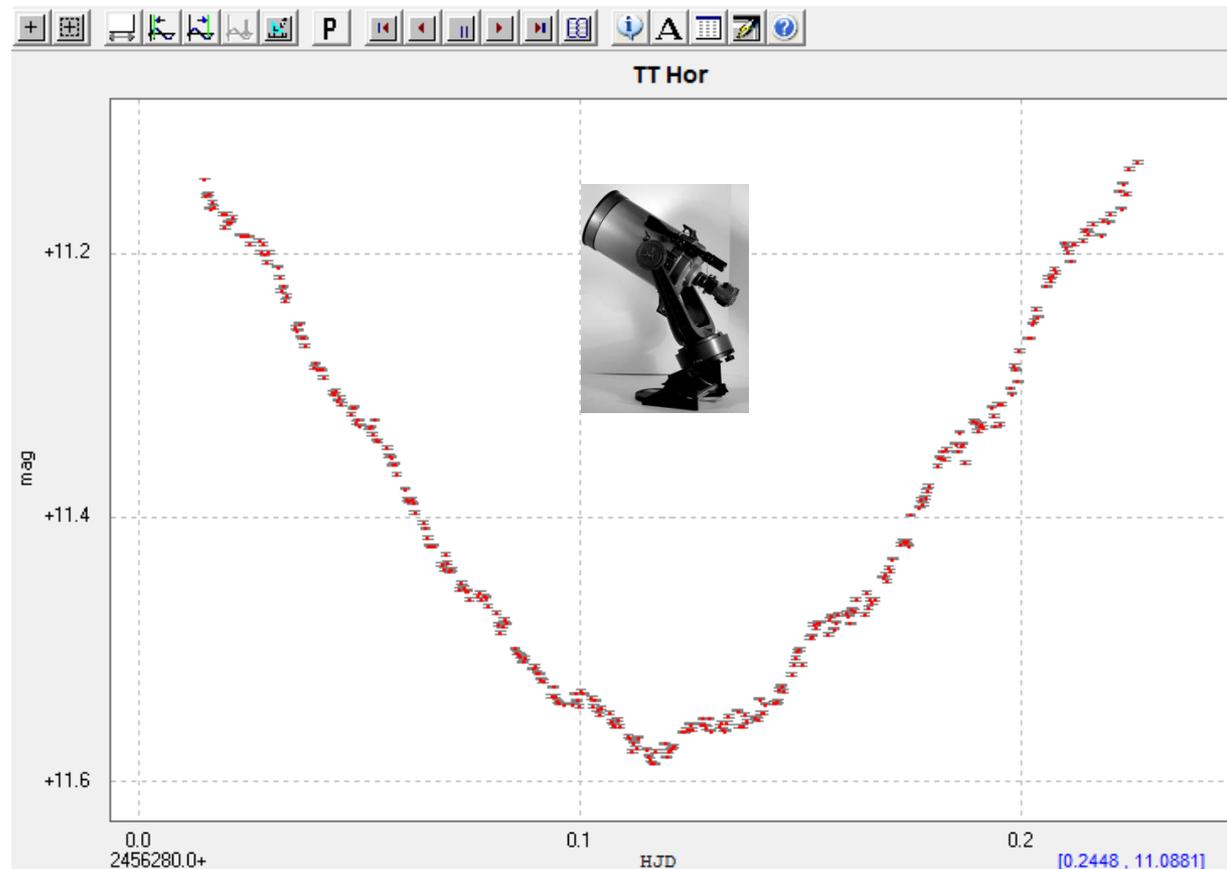
Signature of a third body – but in this case probably a star of $>1.85 M_{\odot}$

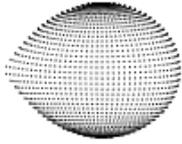


Goal 8 Opportunities



- * Rapidly evolving eclipsers need regular monitoring (V685 Cen, R Ara)
- * Some cataclysmics, novalikes, etc. are eclipsing, need monitoring (Z Cha, VZ Scl)
- * Poorly observed eclipsers may hold surprises





What do I need if I am to take part in the SEB Programme?

As Observer

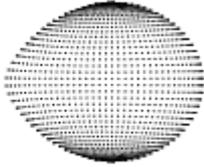
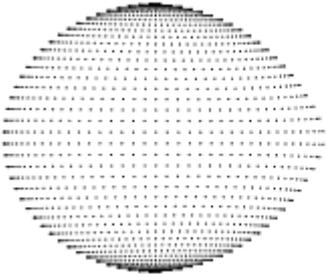


- * tracking telescope & CCD or DSLR camera
- * Photometric filters optional, depending on task
- * Camera software includes aperture photometry tool

As Analyst



- * Familiarity with Excel, learn PERANSO
- * Not scared of a little elementary statistics
- * Optional – light curve & O-C work, paper writing.



How do I take part?

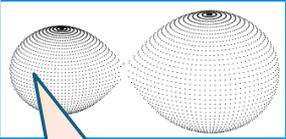
Contact me, tom.richards@variablestarssouth.org

Read all about it at www.variablestarssouth.org:

- * Full programme description, detailed step-by-step guide for observers and analysts
- * Target list, observing information for each
- * *Ephemerides* program to show what's eclipsing in your sky tonight
- * All data acquired so far with all analyses, target by target
- * Consolidated table of all minima, light elements and spectra obtained so far.

And... we provide mentoring for all observing and analysis work; So even the most timorous soul can join the Programme with confidence.





That's all, now join the fun!

Read more in *Southern Stars*, June 2013

Models & Light
Curves from
caleb.eastern.edu

CU Hya
rendered in
BinaryMaker 3

