The eclipsing AM CVn star, SDSS J0926+3624

Tom Marsh

Department of Physics, University of Warwick

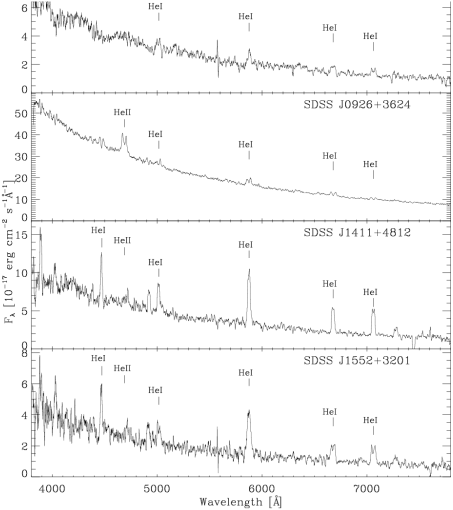
Co-Is: *Vik Dhillon, Stu Littlefair, Paul Groot, Pasi Hakala, Gijs Nelemans, Gavin Ramsay, Gijs Roelofs, Danny Steeghs*

Outline

1. The discovery of SDSS J0926+3624
2. ULTRACAM observations:
    - Phenomenology: superhumps and QPOs
    - Eclipses, parameters.
    - Testing Patterson's ϵ-q relation
    - Timing
3. Conclusions

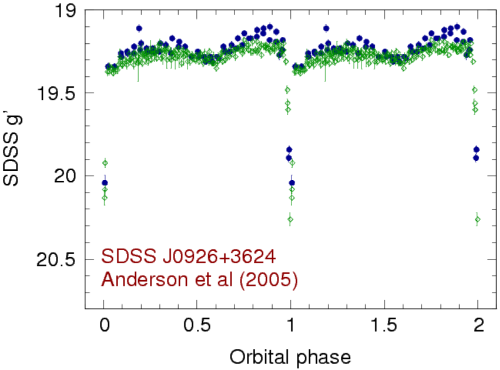
The discovery of SDSS0926+3624

- Anderson et al (2005) discovered 4 new AM CVn stars in the SDSS.
- SDSS J0926+3624 is eclipsing, the first and currently the only eclipsing AM CVn known.
- $P = 28$ minutes
- $g' = 19.3$ out of eclipse with eclipses lasting ~ 1 minute.

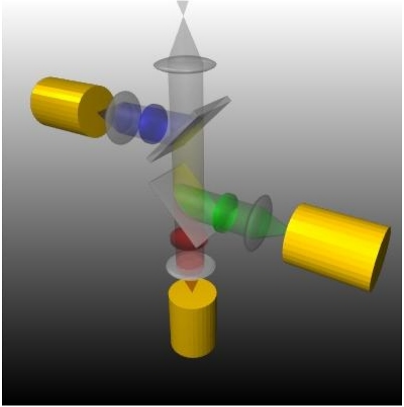


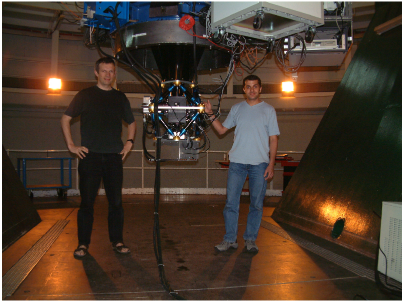
The discovery of SDSS0926+3624

- Anderson et al (2005) discovered 4 new AM CVn stars in the SDSS.
- SDSS J0926+3624 is eclipsing, the first and currently the only eclipsing AM CVn known.
- $P = 28$ minutes
- $g' = 19.3$ out of eclipse with eclipses lasting ~ 1 minute.



ULTRACAM: a high-speed CCD photometer

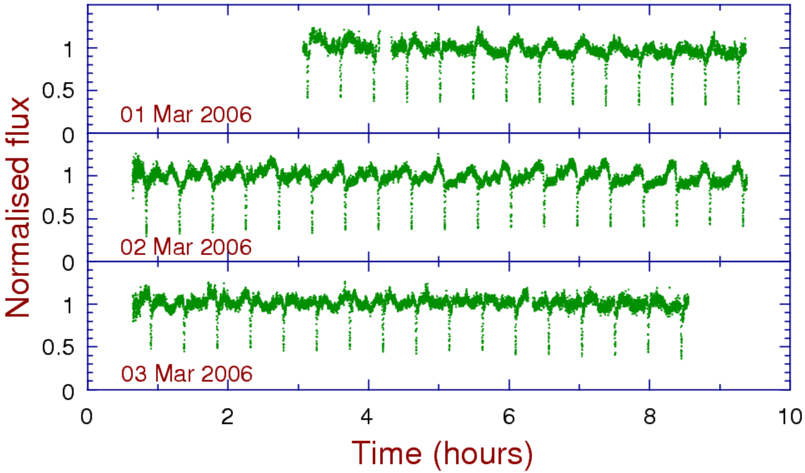




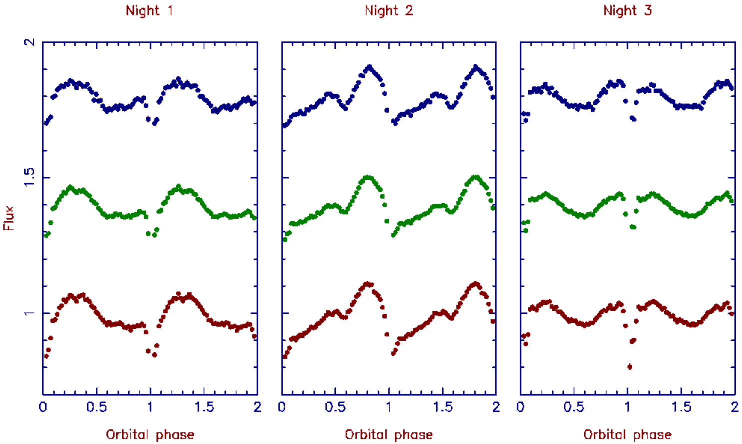
ULTR

at Cass on the 4.2m WHT

SDSS0926+3624 with 4.2m WHT & ULTRACAM



Superhumps – I.



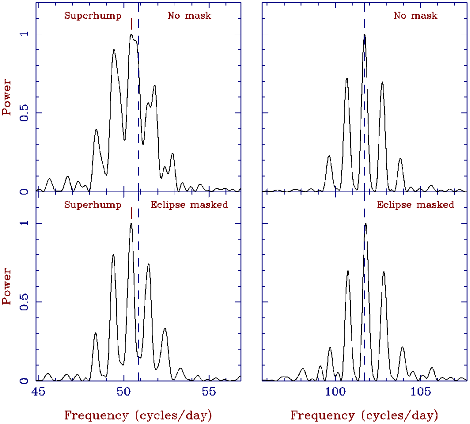
Gross changes of the light curve from night-to-night caused by superhumps, a changing, tidal distortion of the outer disc that occurs for $q = M_2/M_1 < 0.3$ (Whitehurst 1987).

Superhumps – II.

Superhump cycle time:

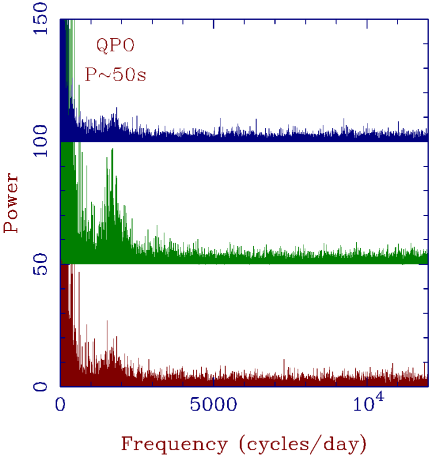
$$P_{\mathrm{Cyc}} = \frac{P_{\mathrm{Orb}} P_{\mathrm{SH}}}{P_{\mathrm{SH}} - P_{\mathrm{Orb}}},$$

$$= 2.26 \pm 0.26\,\mathrm{days}.$$



QPO

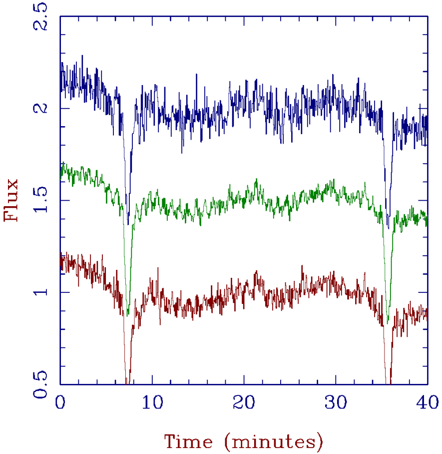
No high frequency oscillations, but a QPO with a period around 50 seconds.



QPO

No high frequency oscillations, but a QPO with a period around 50 seconds.

Peak-to-peak amplitude up to $\sim$ 10%



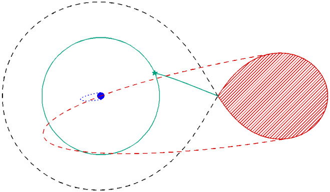
Eclipse analysis in CVs

Stream dynamics and Roche geometry ⇒the orbital inclination i and the mass ratio $q = M_2/M_1$

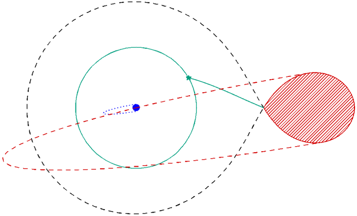
Accretor's eclipse gives R_1/a.

M-R relation and Kepler's 3$^{\mathrm{rd}}$ law ⇒M_1 and M_2.

Smak (1979); Cook & Warner (1984); Wood et al (1986)

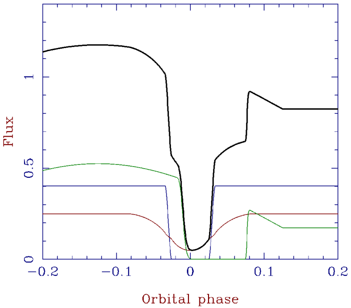


$q = 0.2,\ i = 80^\circ$

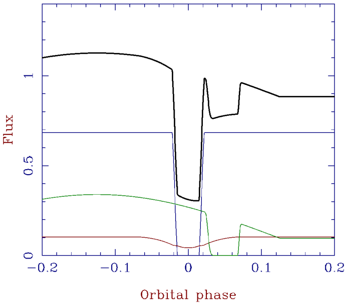


$q = 0.1,\ i = 83.9^\circ$

Example models

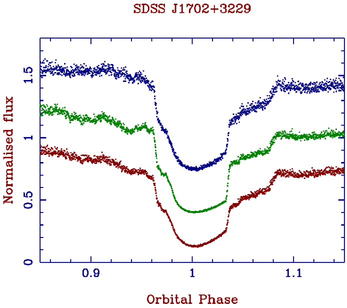


$q = 0.15$

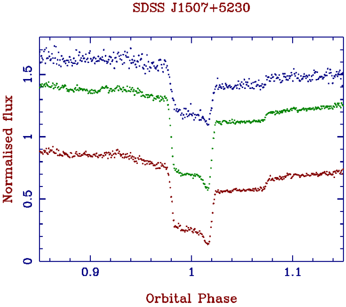


$q = 0.03$

Example data, courtesy Stu Littlefair



$P = 144\,\text{min},\ q = 0.215$

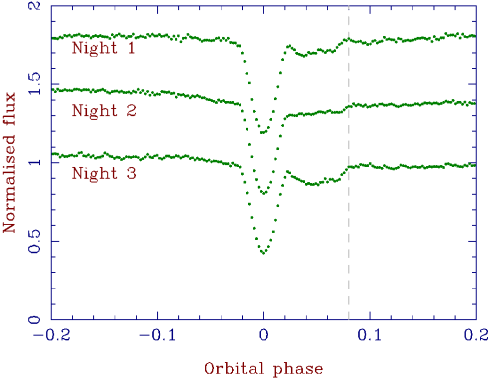


$P = 67\,\text{min},\ q = 0.05$

SDSS0926, mean data, night-by-night

In SDSS0926, the bright-spot starts its eclipse after the white dwarf has come out of eclipse. q is clearly small.

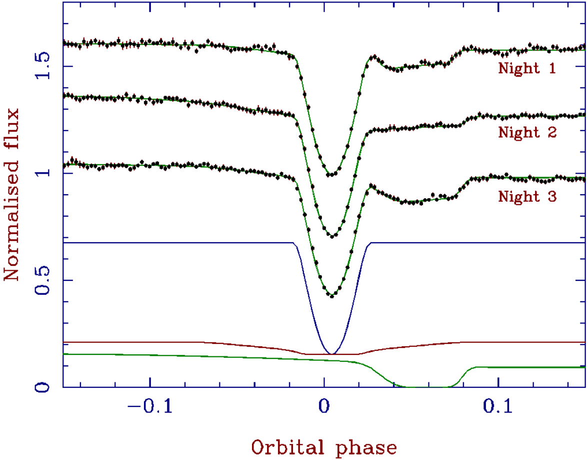
Disc radius variable from night-to-night (tidal instability of outer disc).



Light curve fits

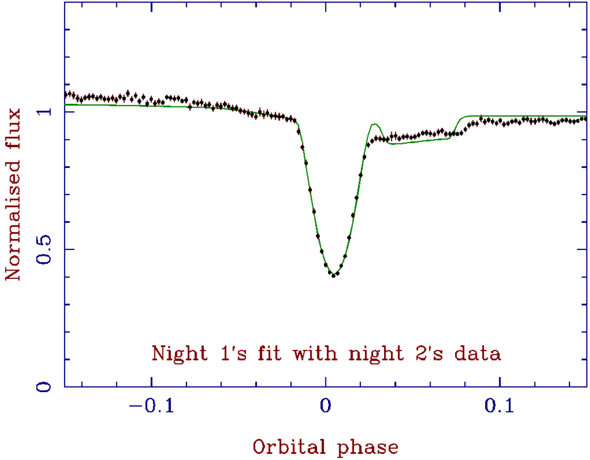
White dwarf $\sim 70\%$ of flux; disc and bright-spot $\sim 15\%$ each.

Typical of quiescent systems.



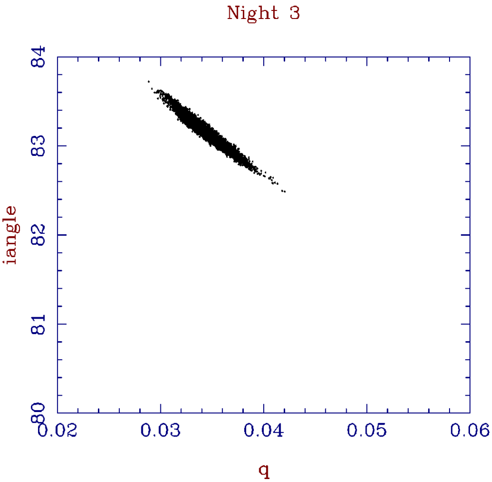
Distorted outer disc

From night 1 to night 2, the bright-spot's distance from the white dwarf changes from 0.33*a* to 0.42*a*.



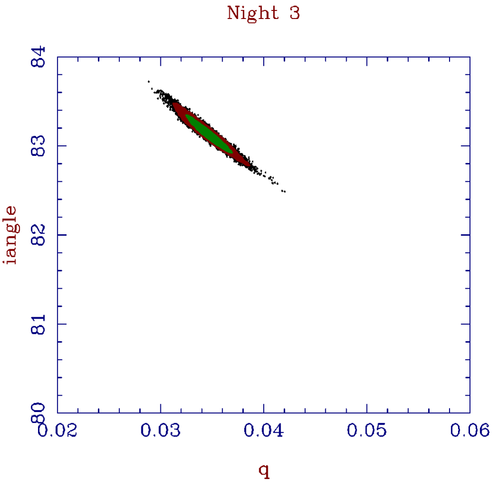
Fit parameters

Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the "Monte Carlo" method).



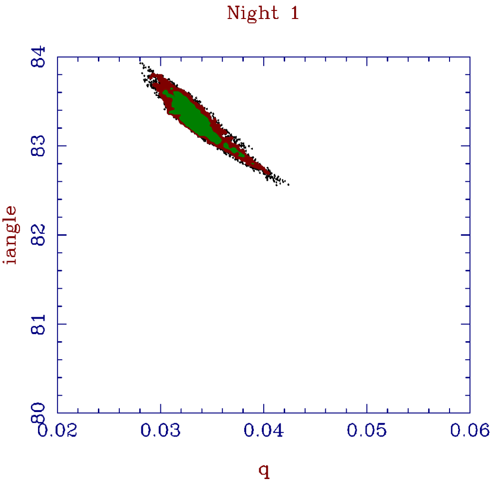
Fit parameters

Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the "Monte Carlo" method).



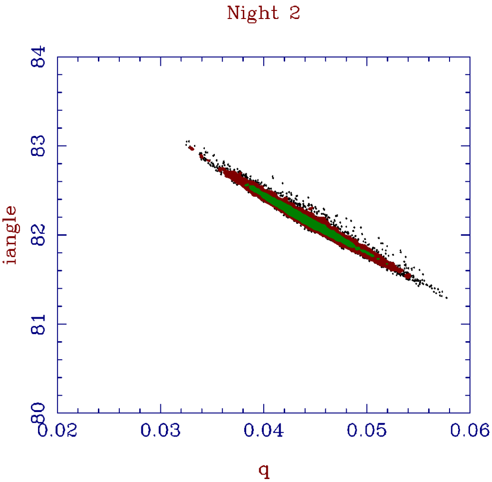
Fit parameters

Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the “Monte Carlo” method).



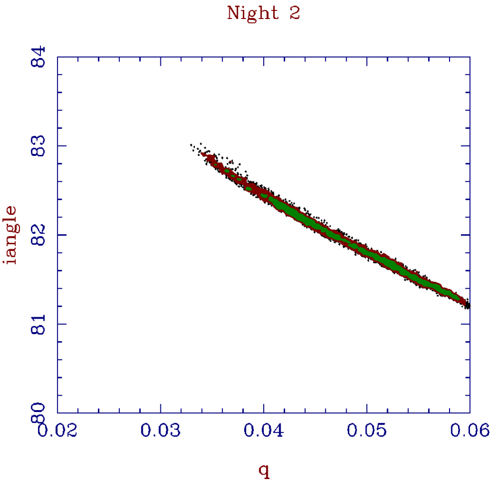
Fit parameters

Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the "Monte Carlo" method).



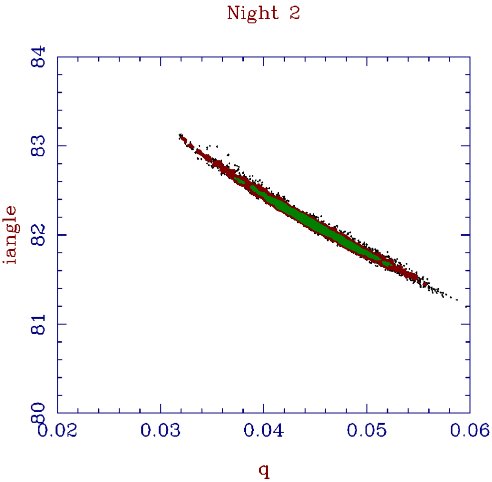
Fit parameters

Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the "Monte Carlo" method).



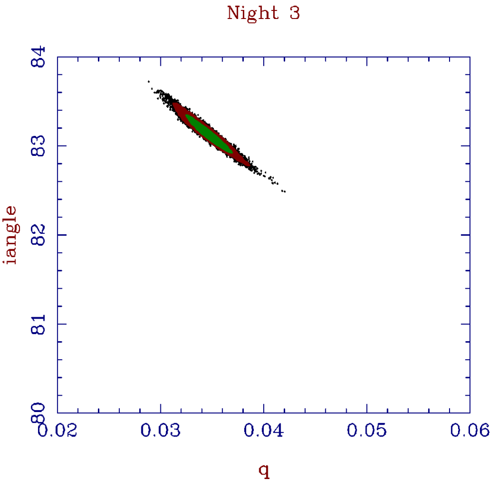
Fit parameters

Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the "Monte Carlo" method).



Fit parameters

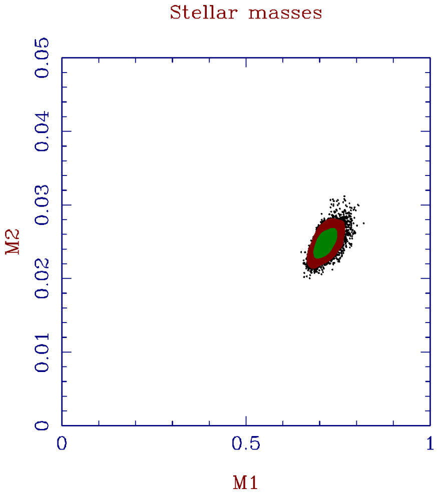
Many parameter fits; uncertainties best derived using Markov Chain Monte Carlo (MCMC method, not equivalent to the "Monte Carlo" method).



Component masses

Donor mass
$\sim 0.025\,\mathrm{M}_\odot$

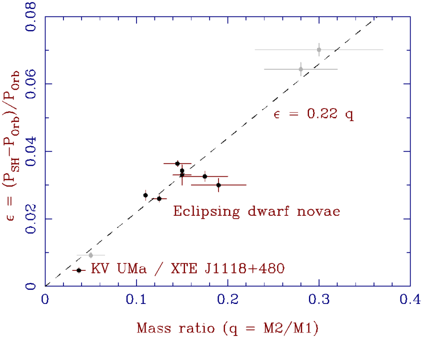
Smaller than reported earlier ($\sim 0.029\,\mathrm{M}_\odot$), and thus closer to fully degenerate $0.020\,\mathrm{M}_\odot$. I have not resolved why yet.



Patterson's ϵ–q relation for superhumps

Whitehurst (1987): at small $q = M_2/M_1$, outer disk distorts and precesses → superhumps.

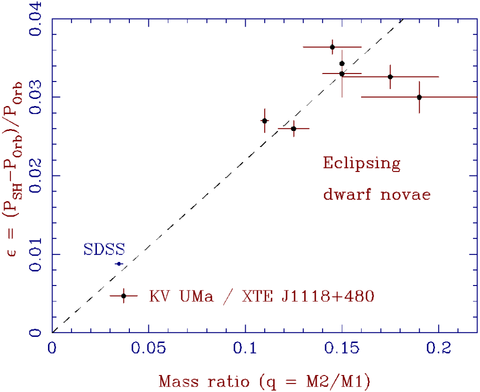
Patterson (2001) presented evidence for an empirical relation between $\epsilon = (P_{\mathrm{SH}} - P_{\mathrm{orb}})/P_{\mathrm{orb}}$ and q.



Potentially simple way to measure q in AM CVn stars, but poorly constrained at very small q.

Patterson's ϵ–q relation for superhumps

SDSS0926 lies within $\sim$ 15% of Patterson's (2001) relation and is by far the most secure calibrator at small q



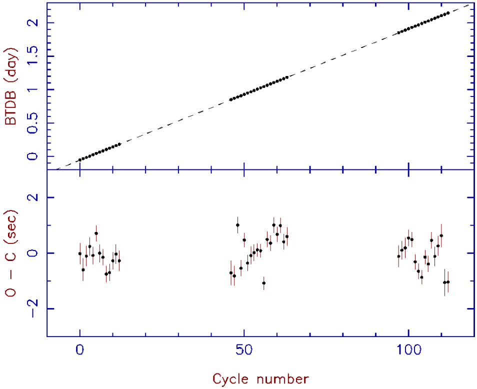
Timing

Mean eclipse time over 3 nights has RMS uncertainty $\approx 0.2\,\mathrm{sec}$.

Time delay due to GWR-driven orbital evolution over 10 years $\sim 5\,\mathrm{sec}$.

$\Rightarrow$predicted evolution will be detectable within ~ 5 years.

Any enhancement from magnetic braking should be obvious.



Conclusions

1. The first eclipsing AM CVn star, SDSS 0926+3624, does not disappoint and has already the most secure parameters of any AM CVn star.
2. Patterson's (2001) ϵ–q relation survives SDSS0926 remarkably unscathed.
3. Future observations can (a) map out the shape of a superhumping disc, (b) firm up the parameters, (c) directly measure the period evolution, and (d) test whether magnetic braking operates in AM CVn stars.
4. *An eclipsing system in hand is worth ten in the fynbos; let's find some more!*