What does 15 years of data tell us about DW UMa?

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CBA: Center for Backyard Astrophysics

- Informal group of amateur astronomers
- Distributed around the world
- Focused on the time-varying behaviour of cataclysmic variables
- Coordinated by Prof Joe Patterson at Columbia University in New York and Dr Enrique de Miguel at Huelva University in Spain

Joe Patterson asked me in 2014 if I would be willing to analyse and write up their data on DW UMa

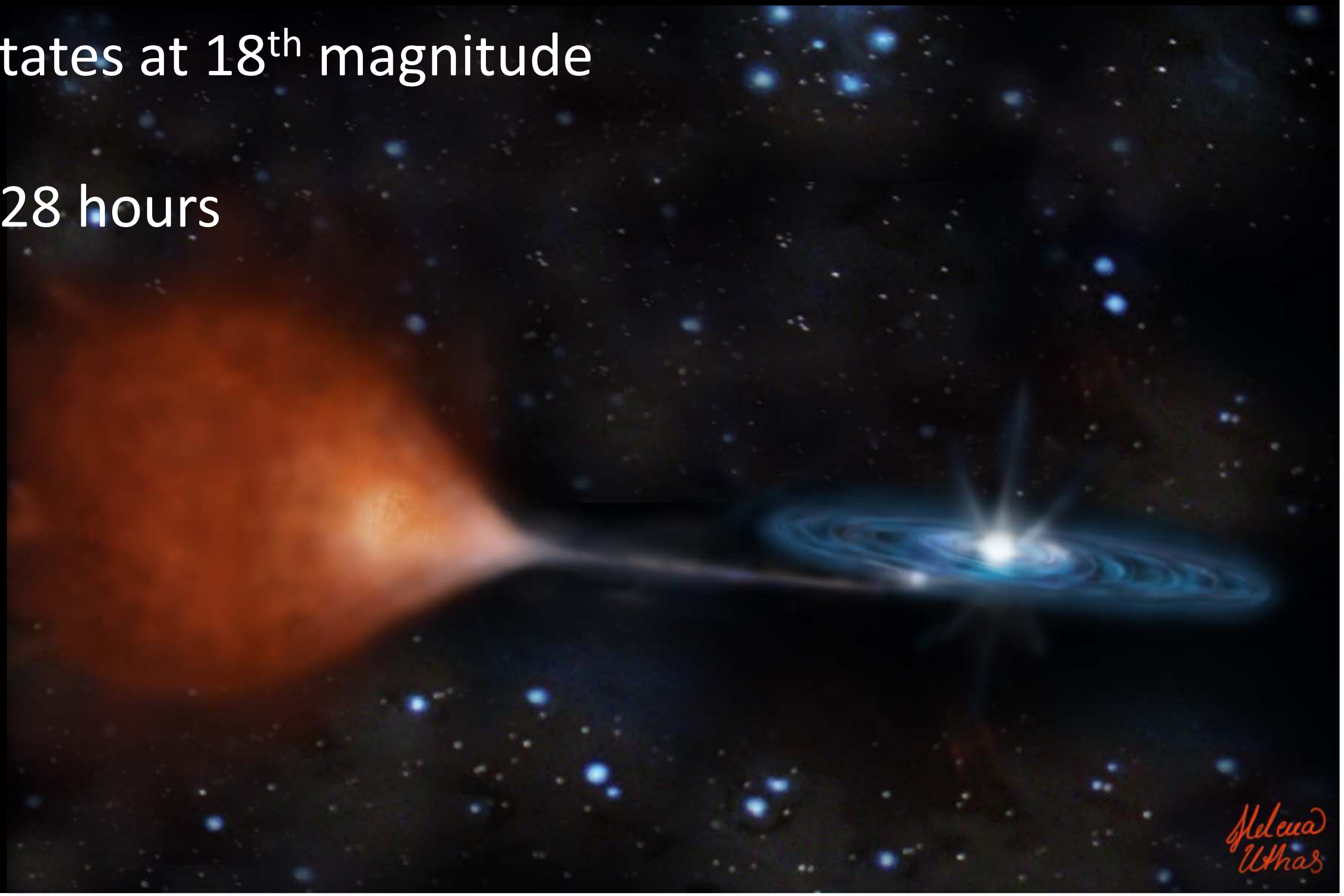
DW UMa

Eclipsing novalike (NL) cataclysmic variable and SW Sextantis star

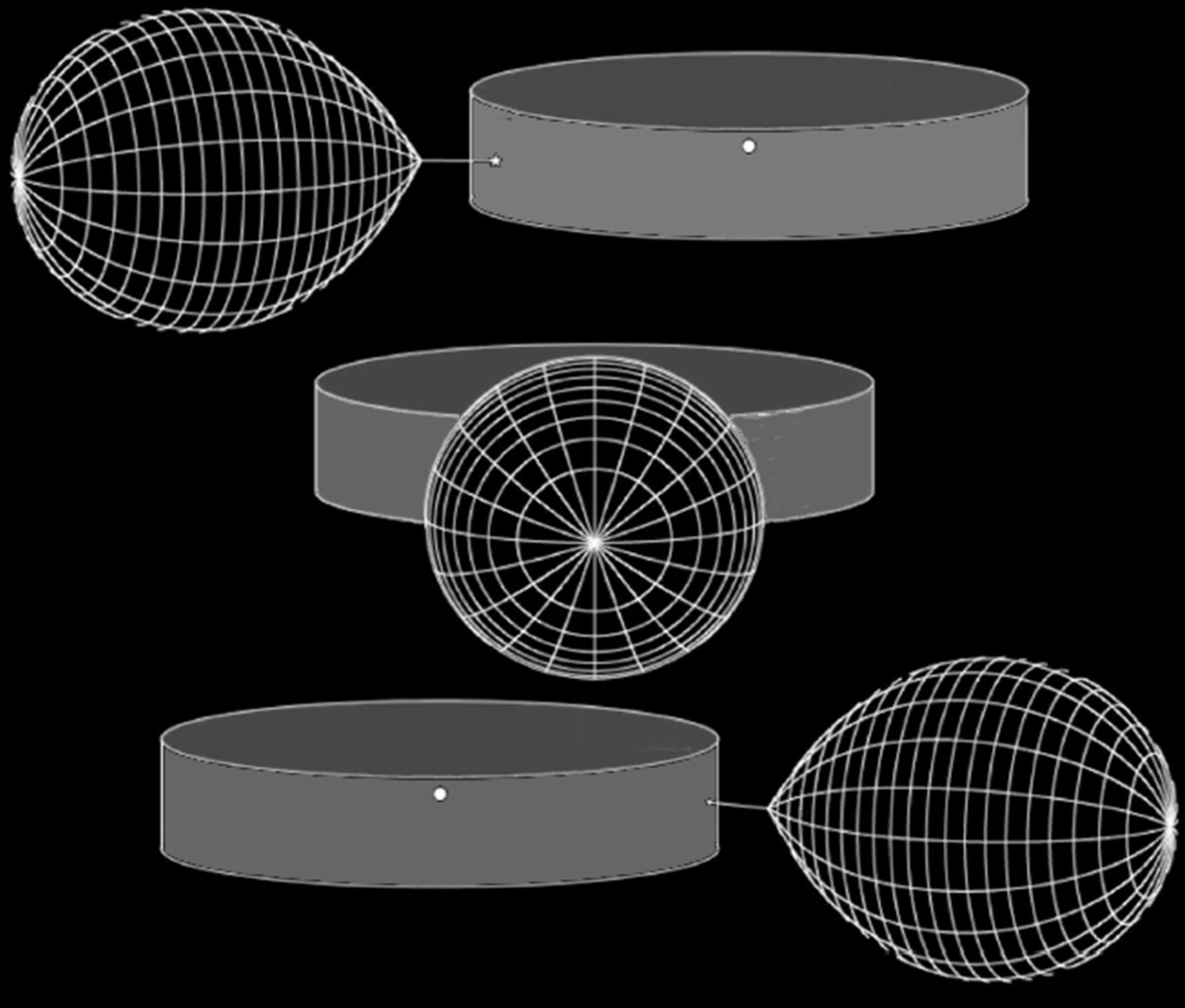
Normal magnitude V=14.2

Occasional low states at 18^{th} magnitude

Orbital period 3.28 hours



Schematic of DW UMa adapted from Dhillon et al. (2013) based on binary parameters from Araujo-Betancor et al. (2003)



$R_{WD} = 0.012\ R_{\odot}$
$R_{MS} = 0.34\ R_{\odot}$
$R_{AD} = 0.64\ R_{\odot}$

$M_{WD} = 0.77\ M_{\odot}$
$M_{MS} = 0.30\ M_{\odot}$

$a = 1.14$ AU
$i = 82°$

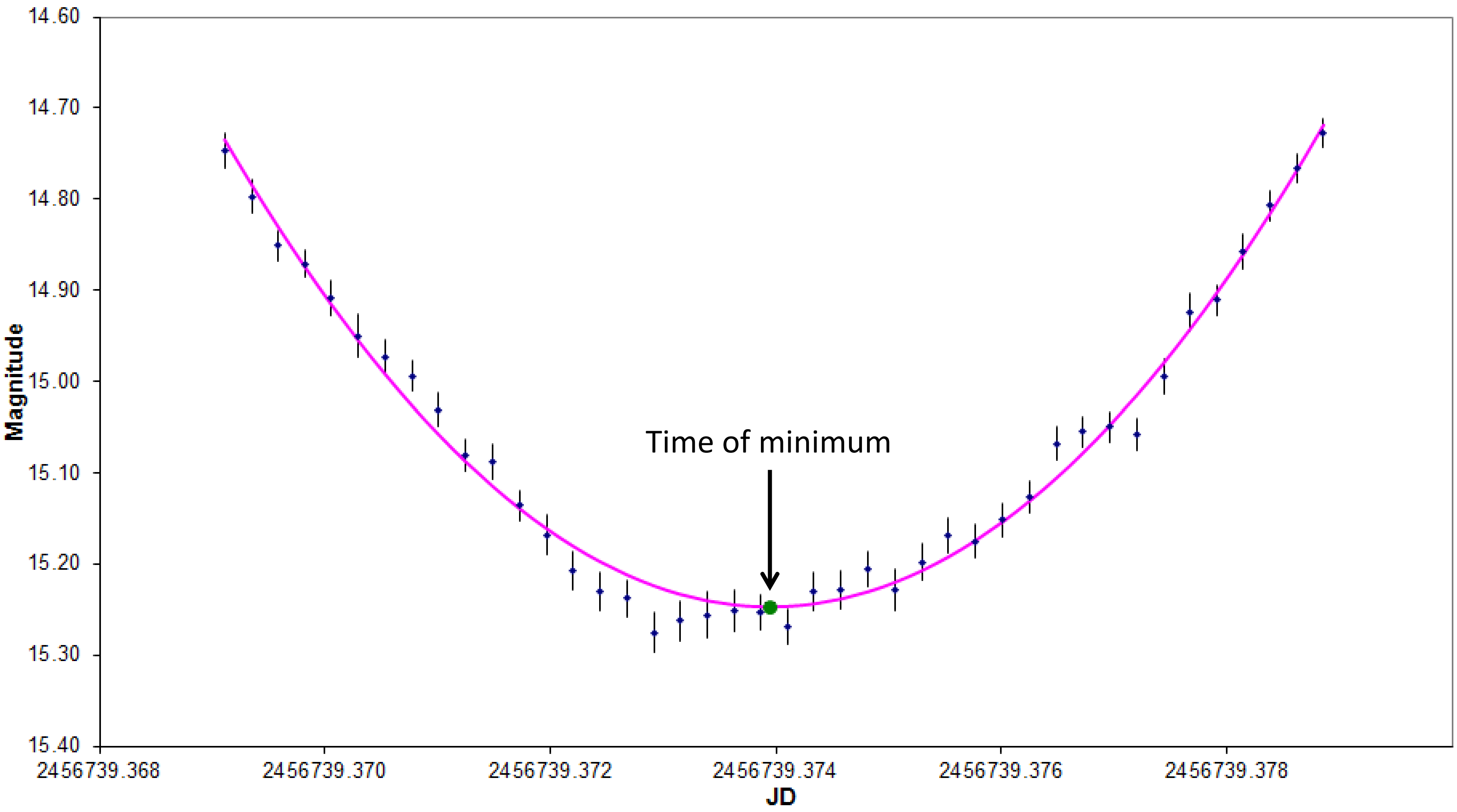
Note the wide rim of the accretion disc which hides the white dwarf in the high state

Year	Runs	Images	Eclipses	Time (hrs)	hrs/run	Observers
1999	11	1267	6	30.66	2.79	Kemp
2000	17	5530	25	93.24	5.48	L Cook, Fried, Kemp, Martin, Skillman
2001	23	4975	25	84.70	3.68	Krajci, Skillman, Vanmunster
2002	19	6761	33	124.66	6.56	Brettman, Foote, Fried, Kemp, Skillman, Vanmunster, Wood
2004	38	11787	51	215.54	5.67	L Cook, Foote, Kemp, Koppelman, Martin, McClusky, Messier, Robertson, Vanmunster
2007	4	196	3	3.35	0.84	Boyd
2008	6	1962	8	19.42	3.24	Boyd
2009	2	142	2	2.54	1.27	Boyd
2010	4	306	4	2.32	0.58	Boyd
2011	10	2678	10	34.36	3.44	Boyd, de Miguel, Krajci, Roberts
2012	19	4106	26	85.13	4.48	Boyd, Collins, Hambsch, Sabo, Ulowetz
2013	9	2226	9	22.81	2.53	Boyd, de Miguel
2014	78	29162	114	429.65	5.51	Boyd, Cejudo, Collins, M J Cook, de Miguel, Gomez, Jones, Koff, Menzies, Rock, Ulowetz
2015	30	13079	56	192.95	6.43	Barrett, Boardman, Boyd, de Miguel, Jones, Lemay
Total	**270**	**84177**	**372**	**1341.33**	**4.97**	

I will concentrate on 3 aspects of the analysis today

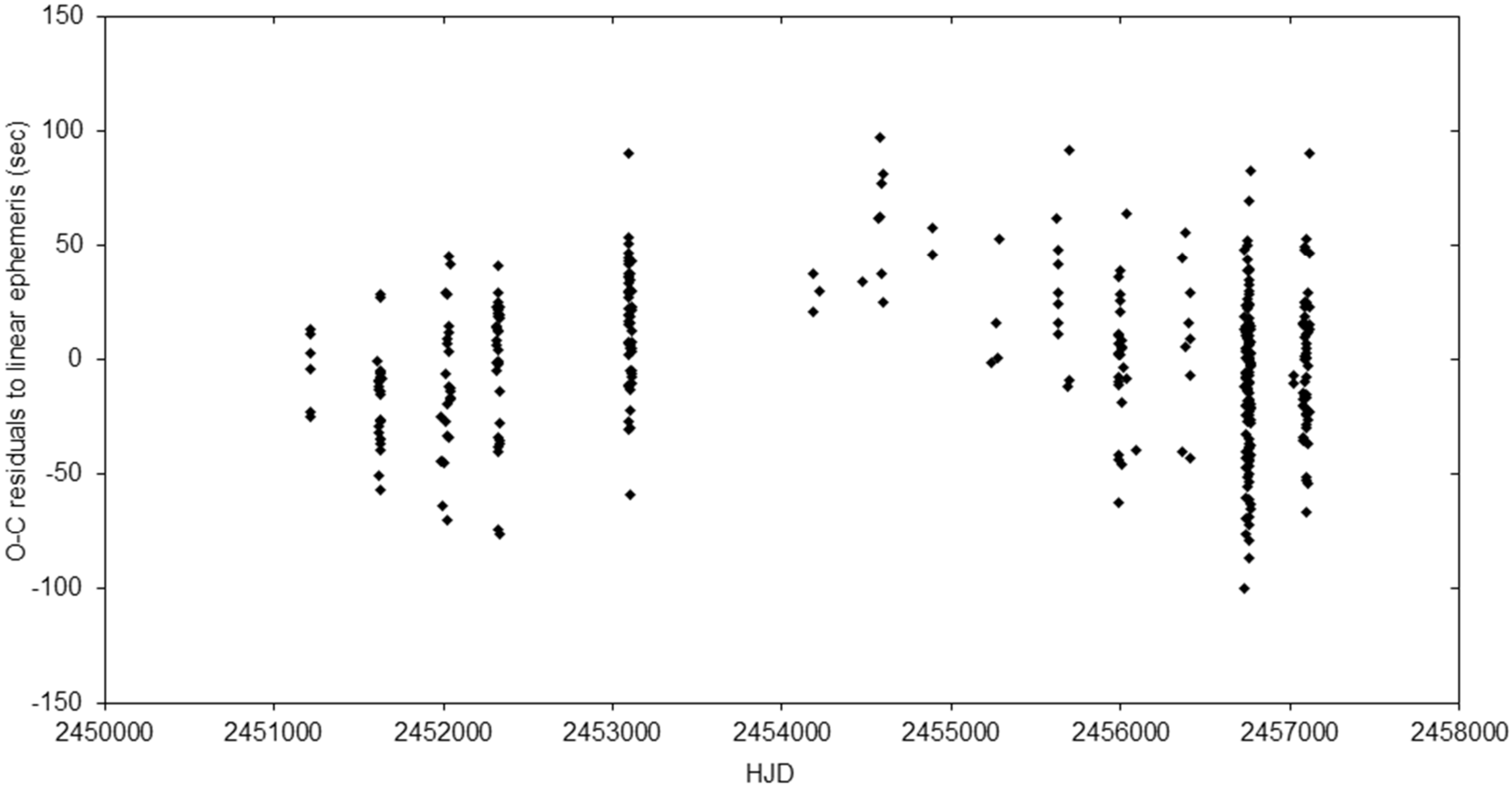
- times of eclipses
- periodic signals
- low state and recovery

Times of eclipse minima found from polynomial fits to eclipse profiles



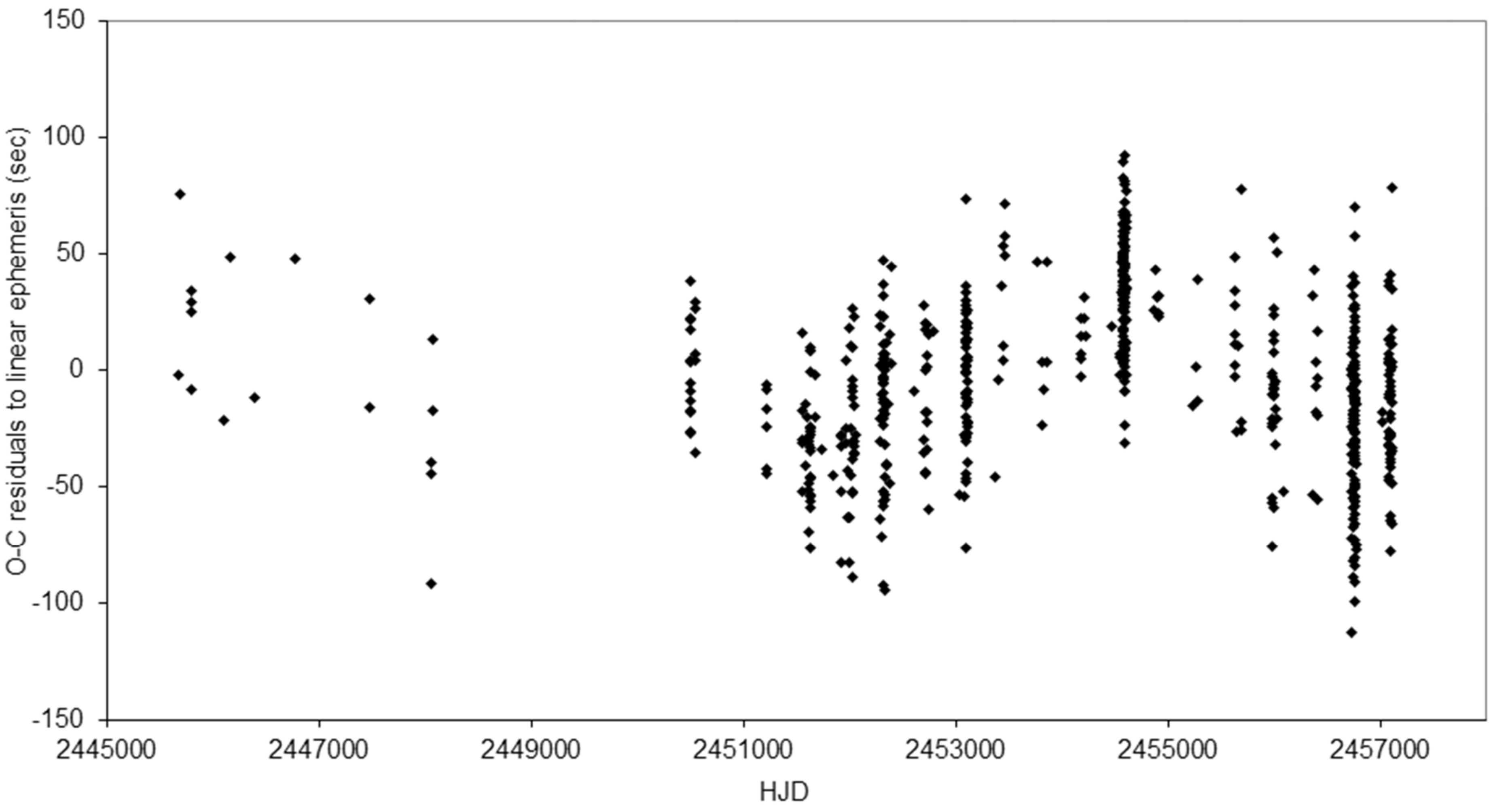
Observed – Calculated (O-C) times found wrt a linear ephemeris

Eclipse O-C residuals for 372 CBA measured eclipse times



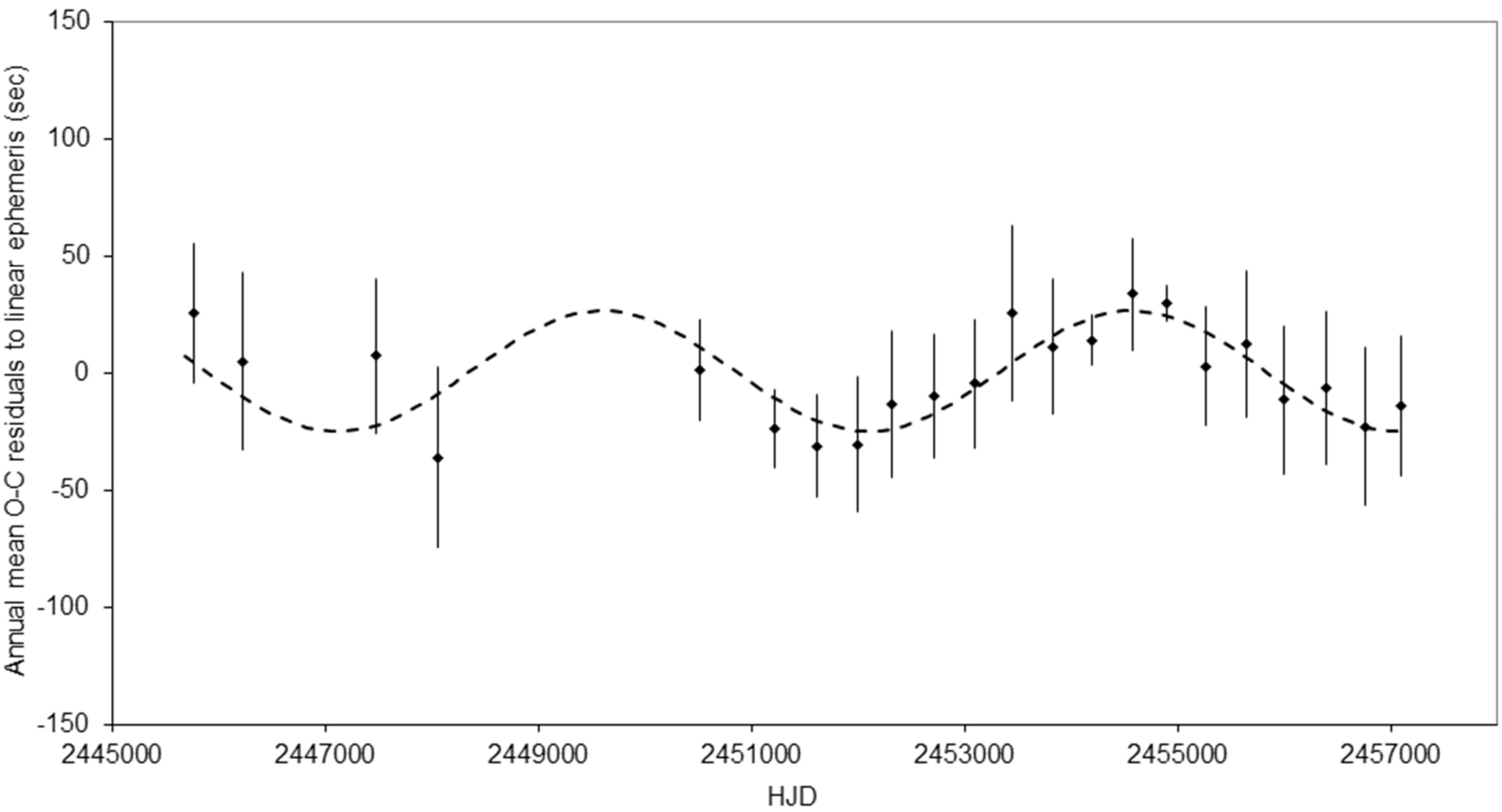
Possibly a reducing orbital period over this time interval?

Eclipse O-C residuals including 260 published eclipse times



Ephemeris: HJD (min) = 2451605.97651(2) + 0.1366065324(7) * E

Eclipse O-C residuals for annual mean eclipse times



Sinusoidal modulation with period 13.6 years and amplitude 25.7 secs

Two possible causes of this modulation

1. A third body orbiting the DW UMa binary

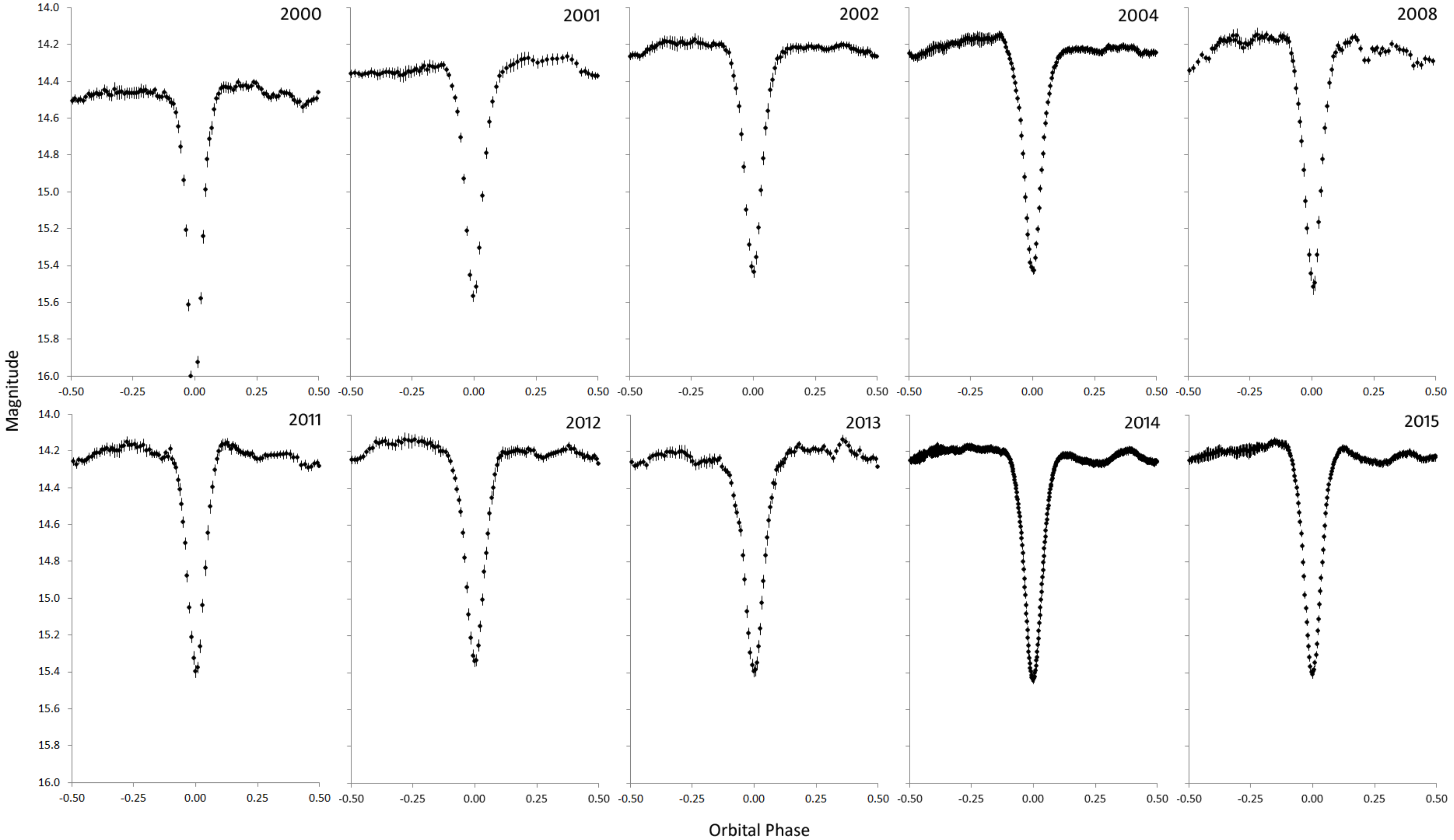
   – most probably mass 10.1 M_{jup} and orbital radius 5.8 AU

2. Magnetic cycles in the secondary star (Applegate effect)

   – there is more than enough energy in the star to power this

So we cannot say which mechanism is at work,
only lots more data would enable us to decide

Mean light curves phased on the 3.28 hr orbital period

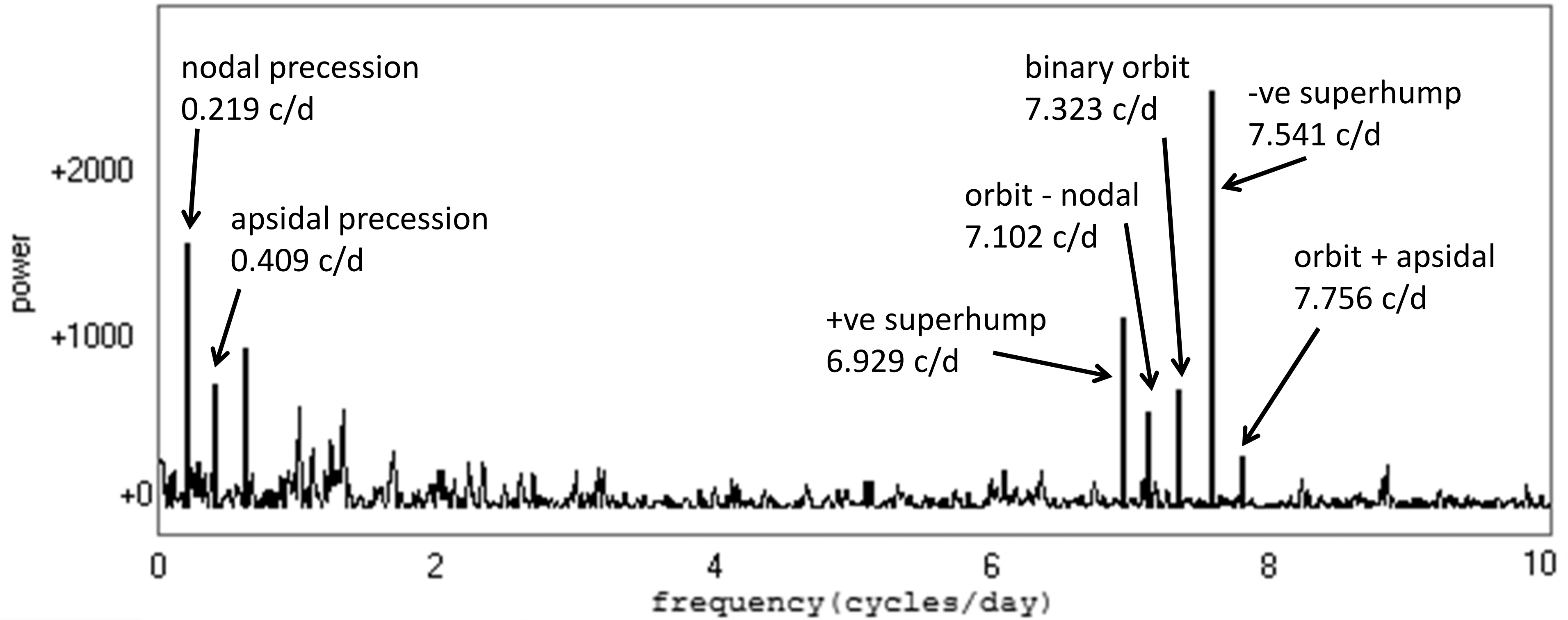


Signals to look for in the light curve outside the eclipses

- binary orbit
- apsidal disc precession (prograde)
  (elliptical disc due to 3:1 resonance with secondary)
- nodal disc precession (retrograde)
  (tilted disc due to pressure from accretion stream)
- +ve superhumps (orbit – apsidal frequencies)
- -ve superhumps (orbit + nodal frequencies)
- anything else?

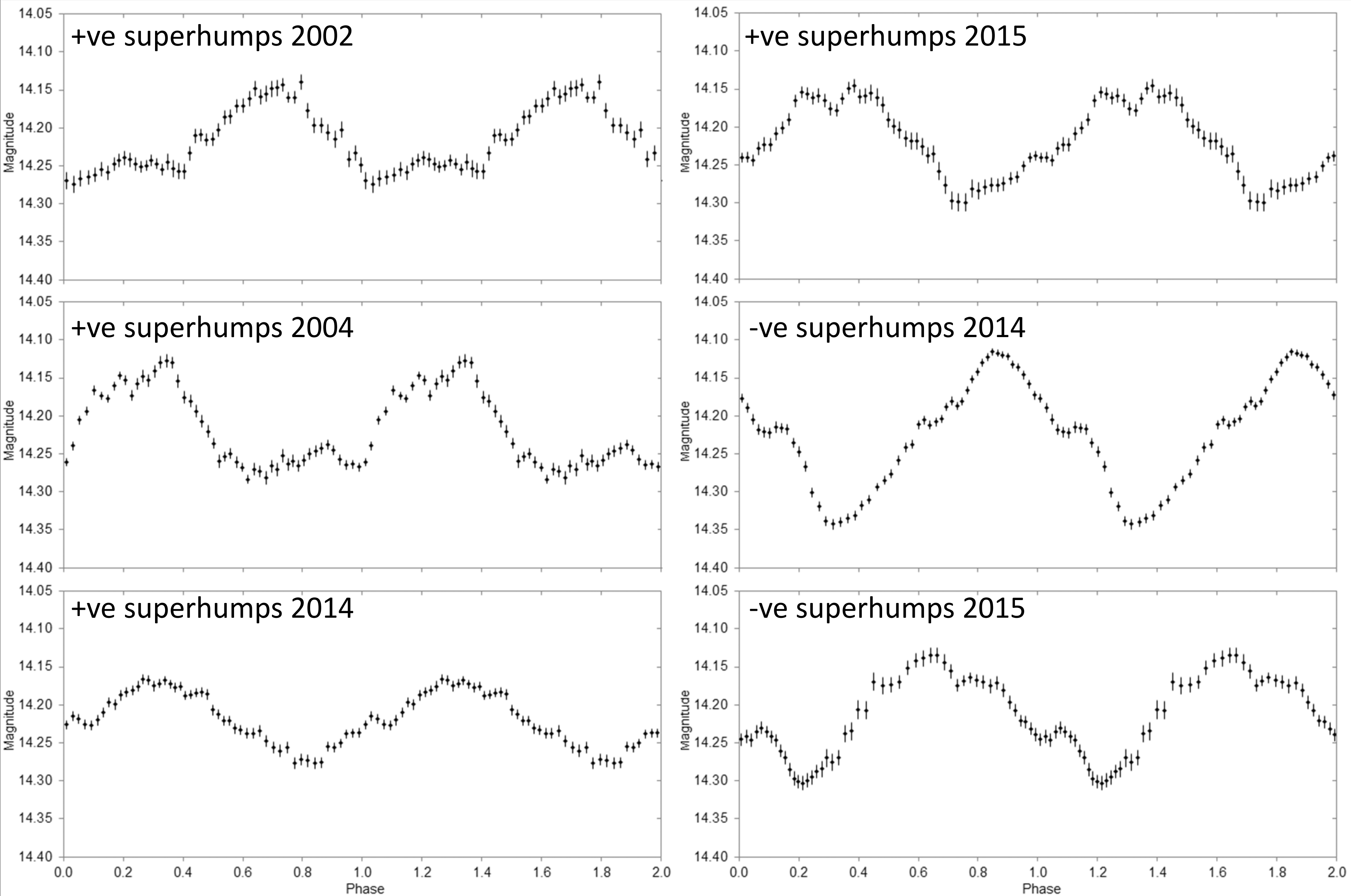
Frequency analysis using CLEANest algorithm (Peranso)

Power spectrum of 2014 light curve outside eclipse

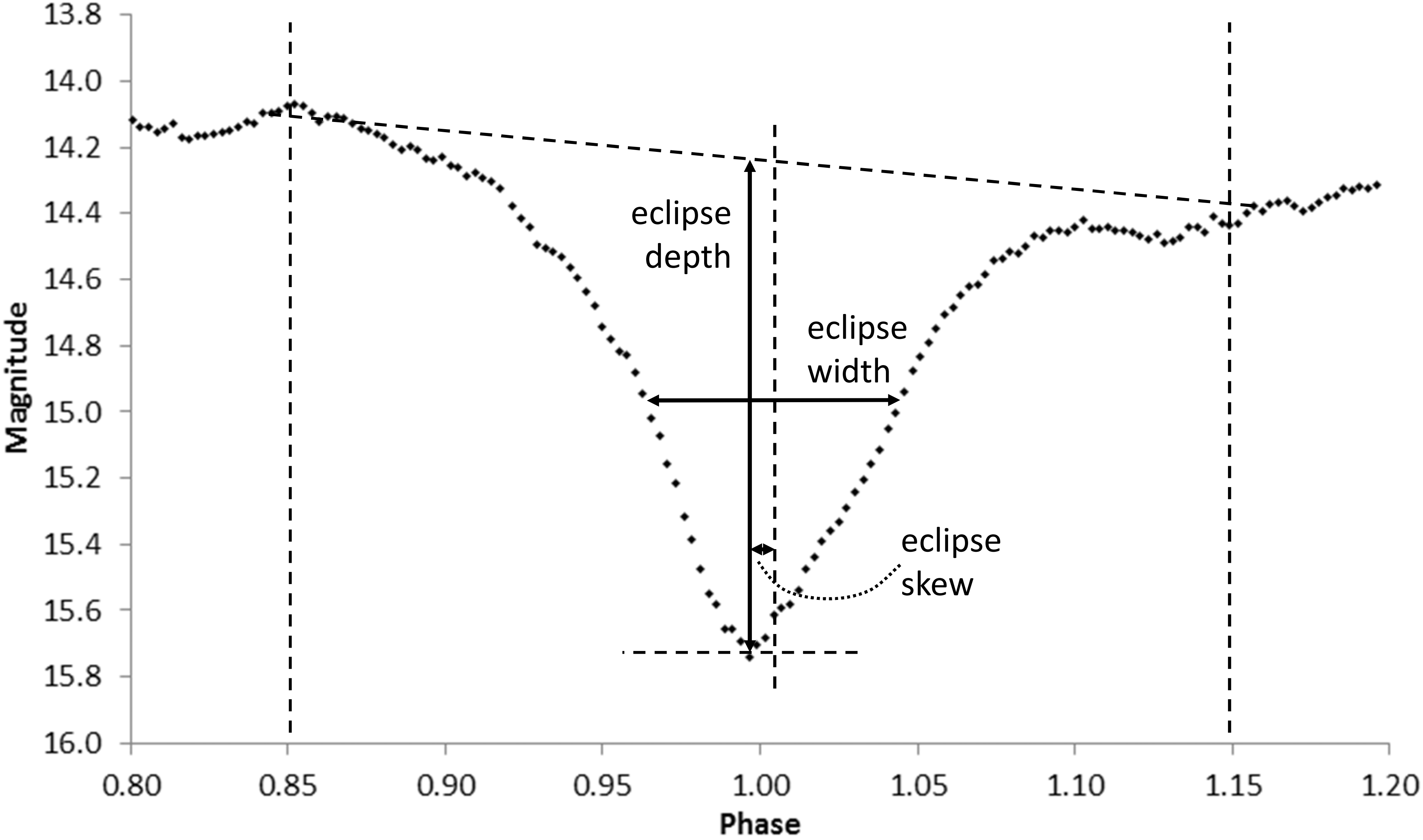


All the expected signals plus two unexpected ones!

Phased superhump plots



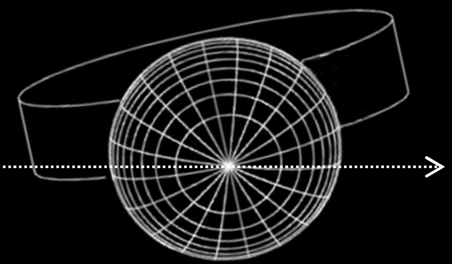
Parameters of the eclipse profile – do these vary?

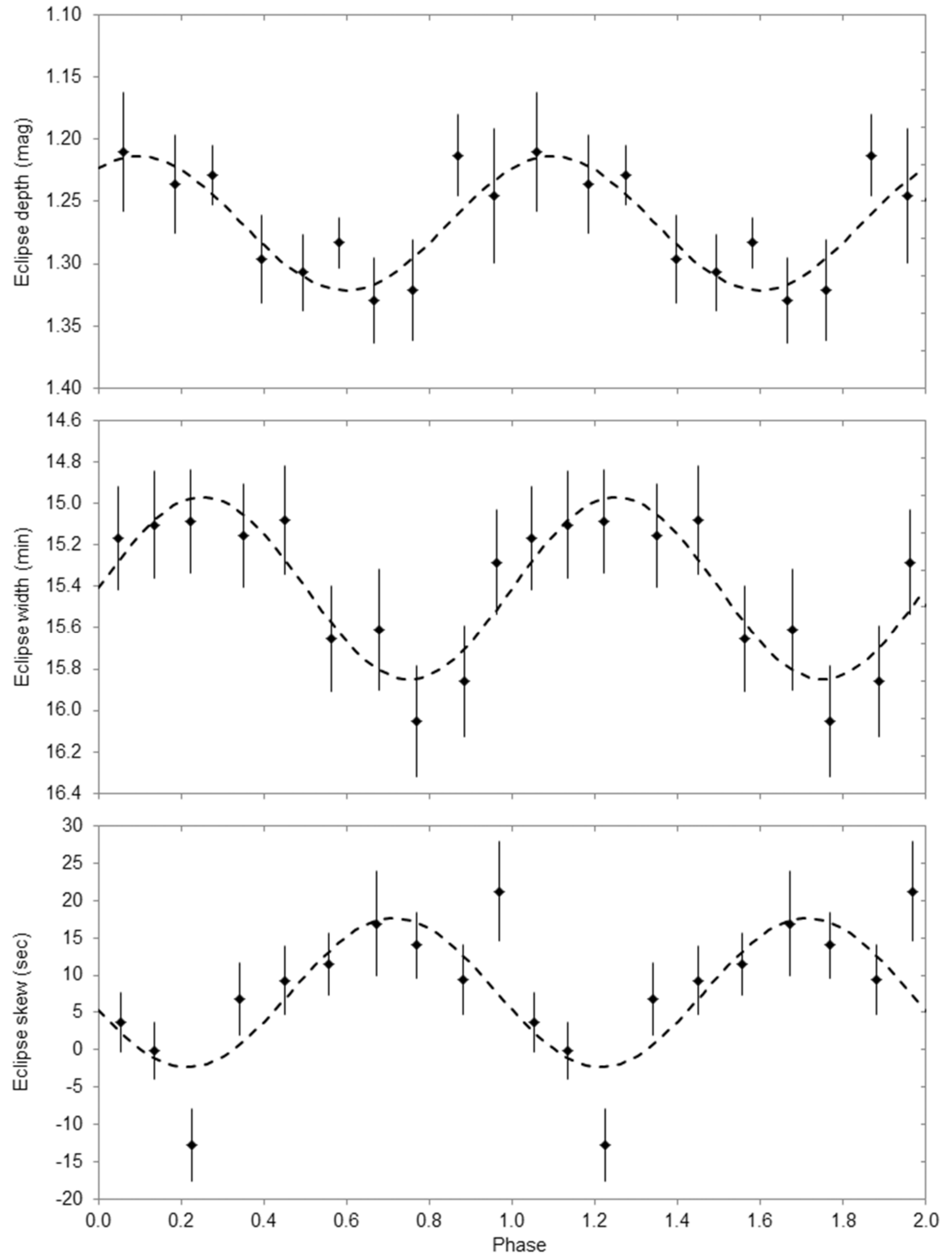


All 3 eclipse parameters appear to vary with the phase of the disc nodal precession period

Why?

Because as the tilted disc slowly precesses it is in a slightly different orientation at each eclipse

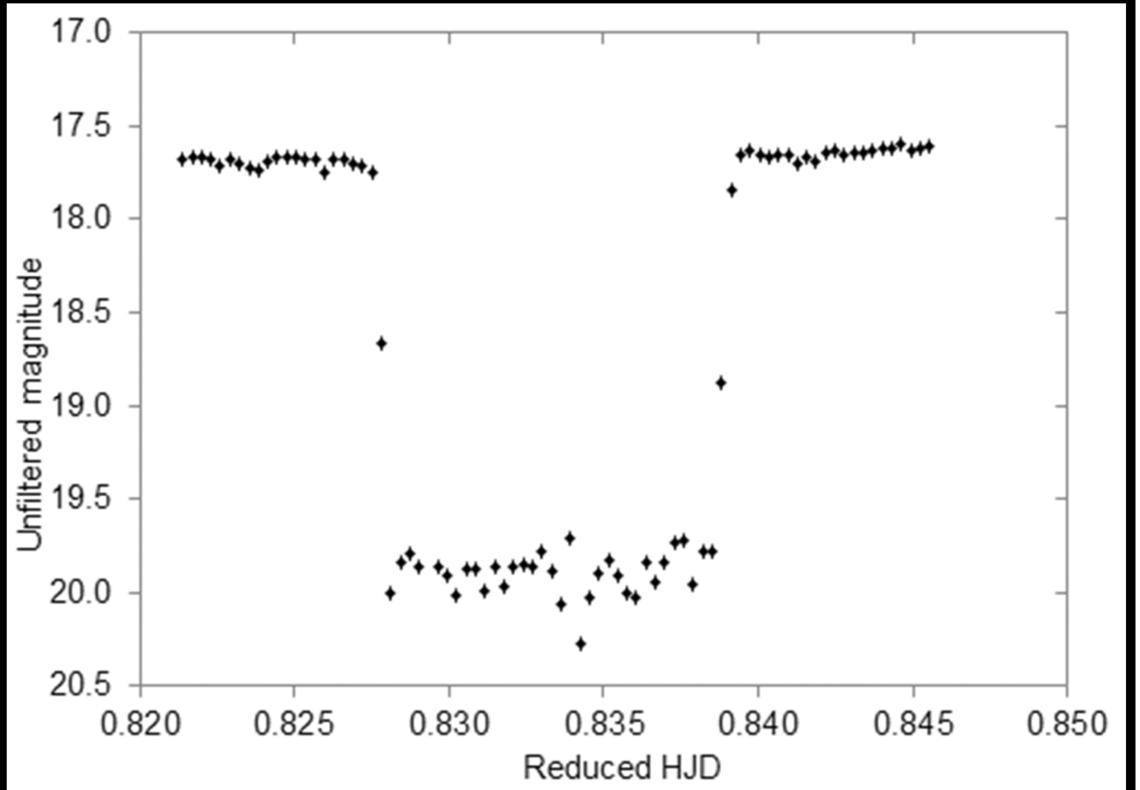


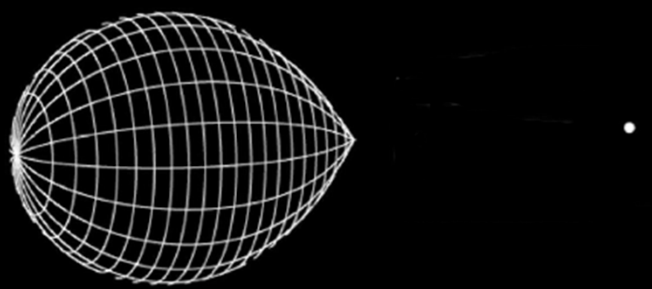


Low state in 1999

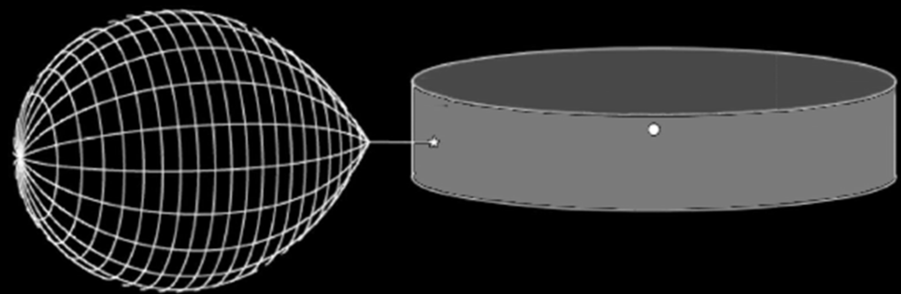
The steep-sided eclipse observed in 1999 points to the complete absence of an accretion disc

This is believed to happen because the accretion stream shuts off (caused by a cool starspot at the inner Lagrange point?)

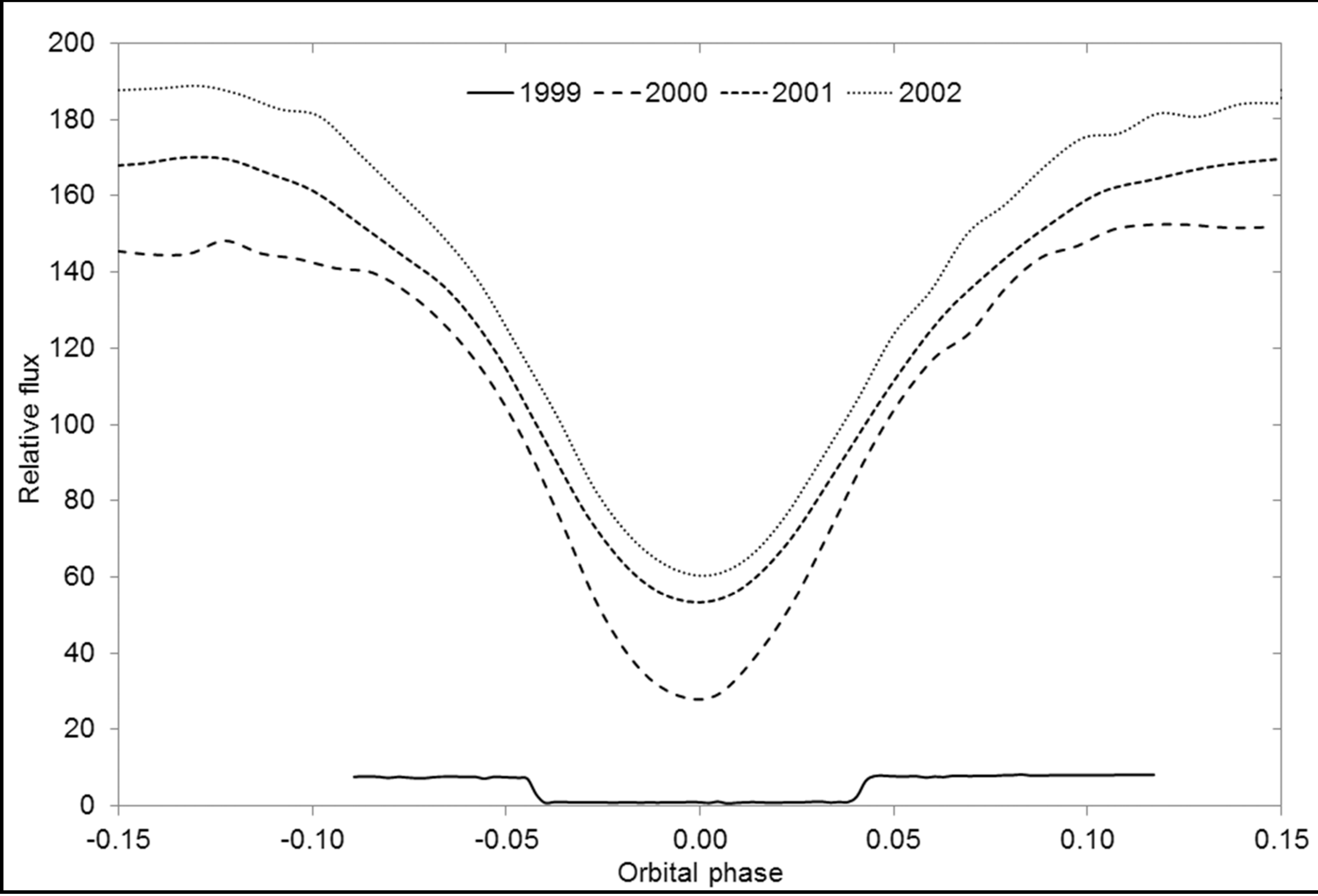




vs



Recovery from low state to high state – mean eclipse profiles



From the change in flux as the disc reforms between 1999 and 2002, we can calculate the (clear) magnitudes of the 3 components:

Accretion disc	14.2	(in its normal high state)
White dwarf	17.8	(hidden by disc rim in high state)
Main sequence star	19.9	

This correspond to a flux ratio 1 : 6.8 : 184

So when you look at DW UMa in its normal high state, all you are seeing is the accretion disc!

This demonstrates the potential of the amateur community when it works together on a common goal

Thank you for listening