The asynchronous polar V1432 Aquilae and its path back to synchronism

The CBA consortium

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Cataclysmic variables are binary stars with a white dwarf (WD) and main sequence (MS) star

Matter is being drawn by gravity from the MS star onto the WD, usually through an accretion disc

Cataclysmic variables with magnetic white dwarfs
(aka magnetic CVs) come in two types:

1. WD magnetic field < ~10MG
    - known as intermediate polars
    - partial accretion discs truncated at the inner edge by the WD magnetic field
    - WD spin period is much shorter than the orbital period

Intermediate polar

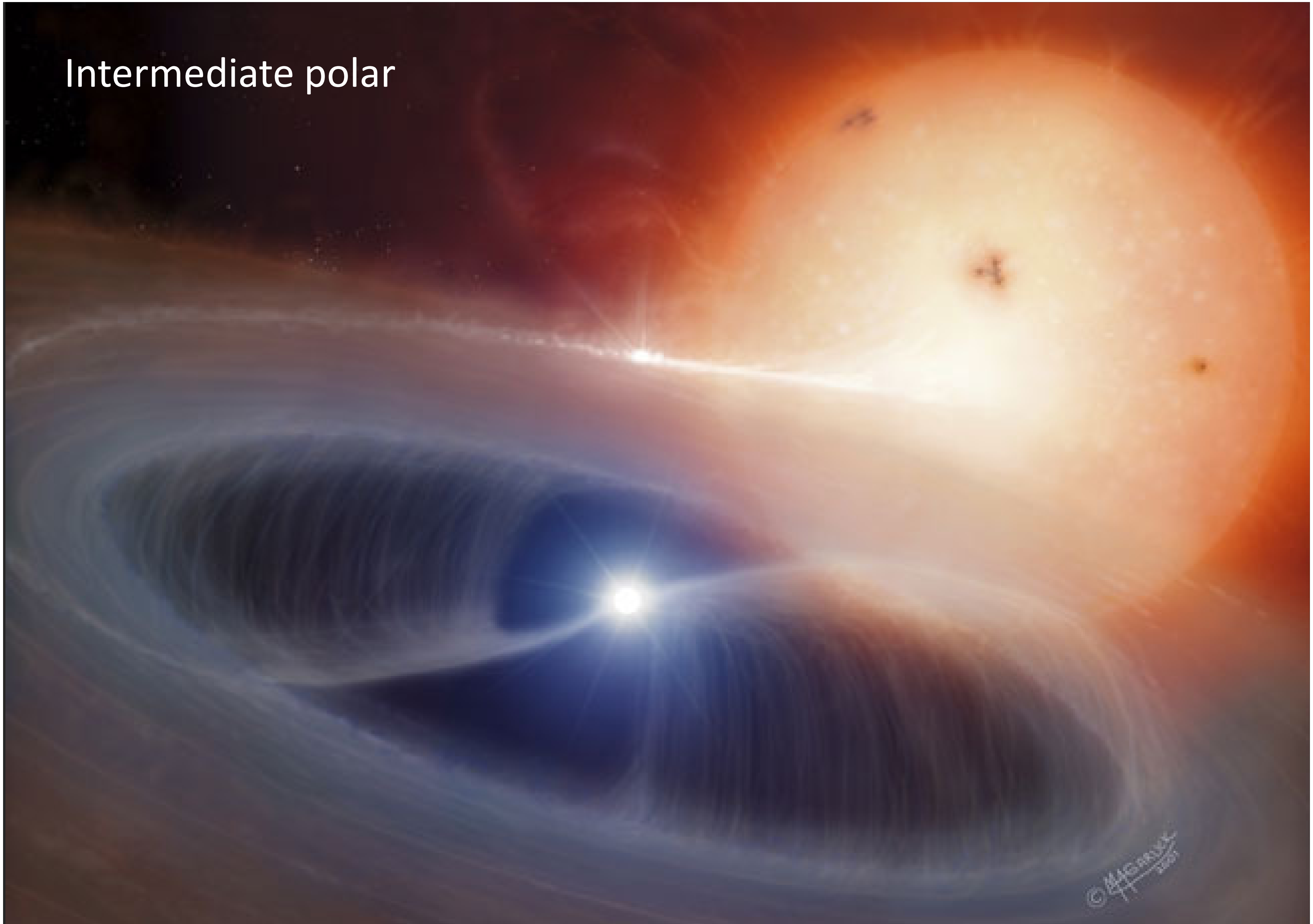

Image by Mark Garlick

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1. WD magnetic field < ~10MG
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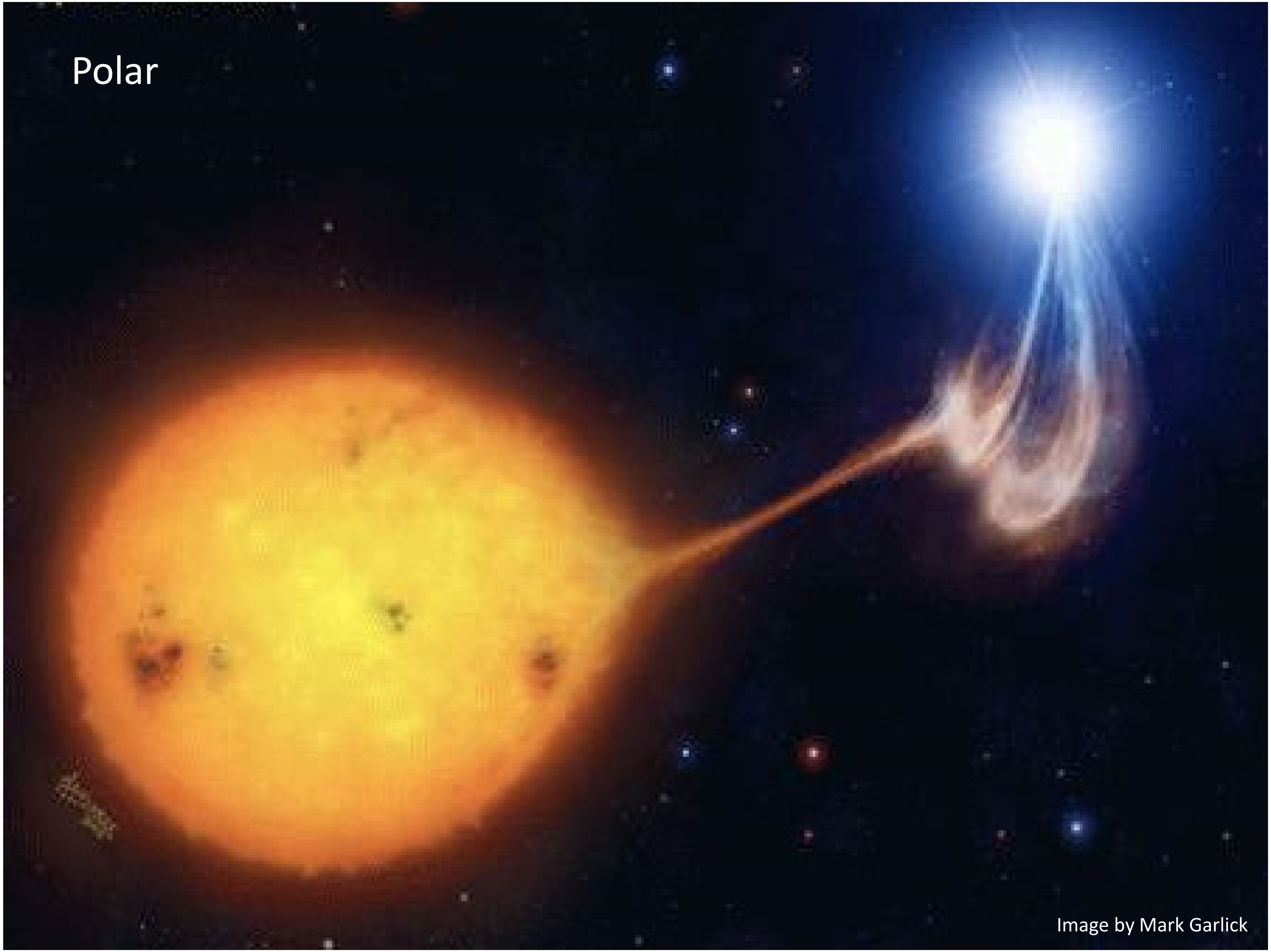
2. WD magnetic field > ~10MG
    - known as polars
    - no accretion disc as the WD field channels the accretion stream directly to the WD magnetic poles
    - WD spin period is the same as the orbital period


Polar
Image by Mark Garlick

In polars the WD spin is normally synchronised with the binary orbital period (i.e. the WD is stationary in the binary rest frame)

However there are 4 polars for which this is not quite true
- V1432 Aql, V1500 Cyg, BY Cam and CD Ind

Their WD spin is ~1% different from the orbital period

They are known as asynchronous polars

Why only 4 out of ~135?

We believe they get knocked out of sync during nova explosions but quickly get back into sync (~100-1000 years)

Why is V1432 Aql so interesting?

It is the only asynchronous polar in which the WD spins slower than the orbital period
– we don't yet know why

It is also the only asynchronous polar which shows eclipses
– these define a regular clock for measuring temporal changes

Because it is asynchronous, the accretion stream encounters a continually changing magnetic field

It is an ideal test-bed for understanding the accretion process
– if we can obtain the observational evidence to guide and constrain development of a physical model

Getting the evidence

Over the past 15 years the CBA has received >75,000 photometric measurements of V1432 Aql

These were contributed by 23 observers in 10 countries

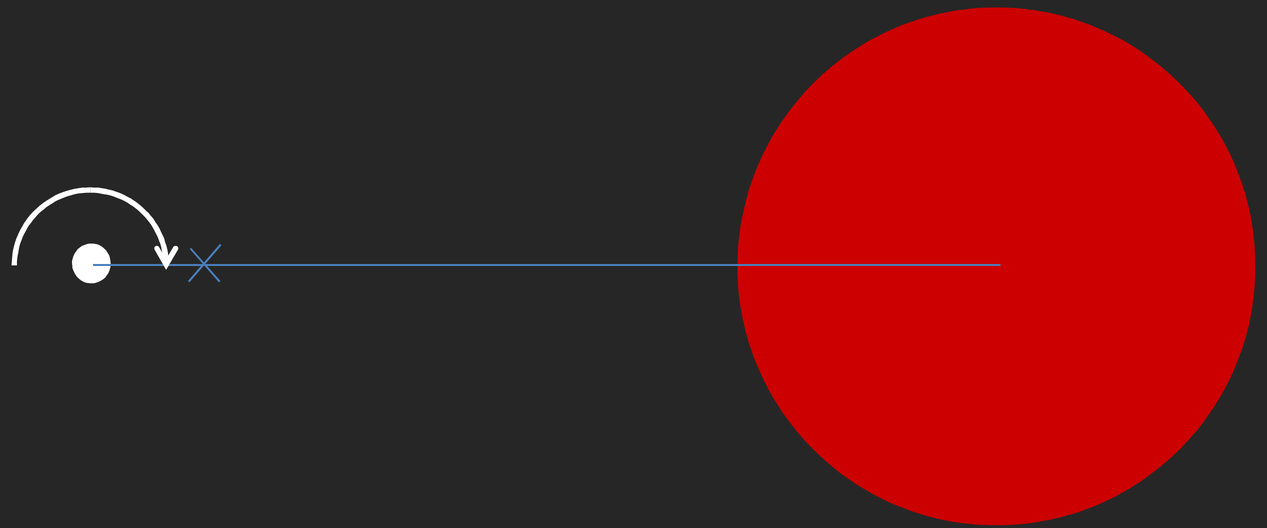
312 datasets, 1170 hours of observation

Times converted to HJD, magnitudes unfiltered so manually aligned to (usually much) better than 0.1 mag

The dynamics of V1432 Aql

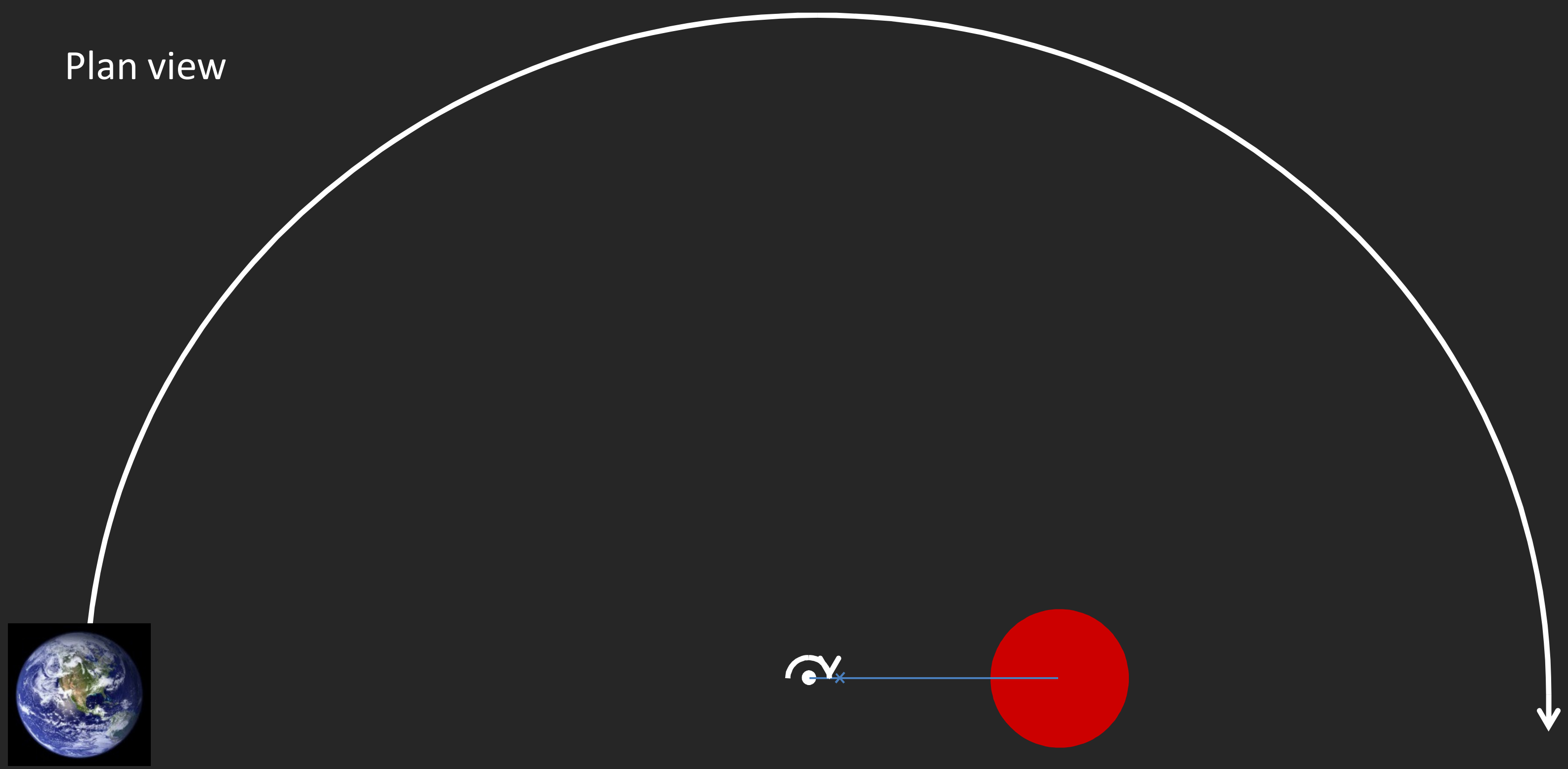
In the rest frame of the binary system the WD is slowly rotating, currently in about 62 days

Plan view



This rotation is gradually slowing down

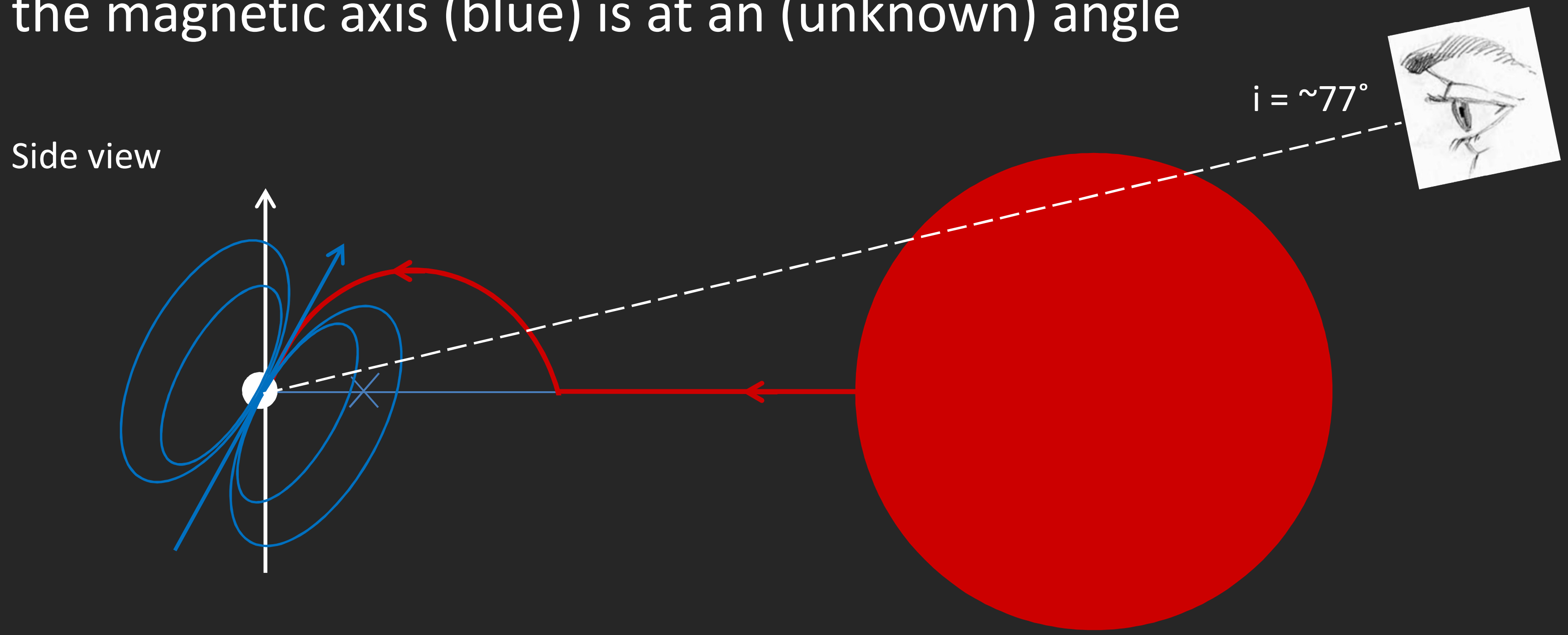
When it stops the polar will have re-synchronised



In the binary rest frame, our vantage point is orbiting the binary centre of mass every 3hr 22min

Because of the slow WD rotation, we see its apparent spin period as being slightly longer than the orbital period

Looking in the orbital plane,
the rotation axis (white) is perpendicular to the plane,
the magnetic axis (blue) is at an (unknown) angle



The accretion stream is diverted along the magnetic field lines onto the magnetic pole of the WD

As the WD rotates, the accretion stream follows the moving magnetic field lines

WD rotation period P_{rot} in the binary rest frame

This is what we really want to know

However we can only directly measure the orbital period P_{orb} and the apparent WD spin period P_{spin}

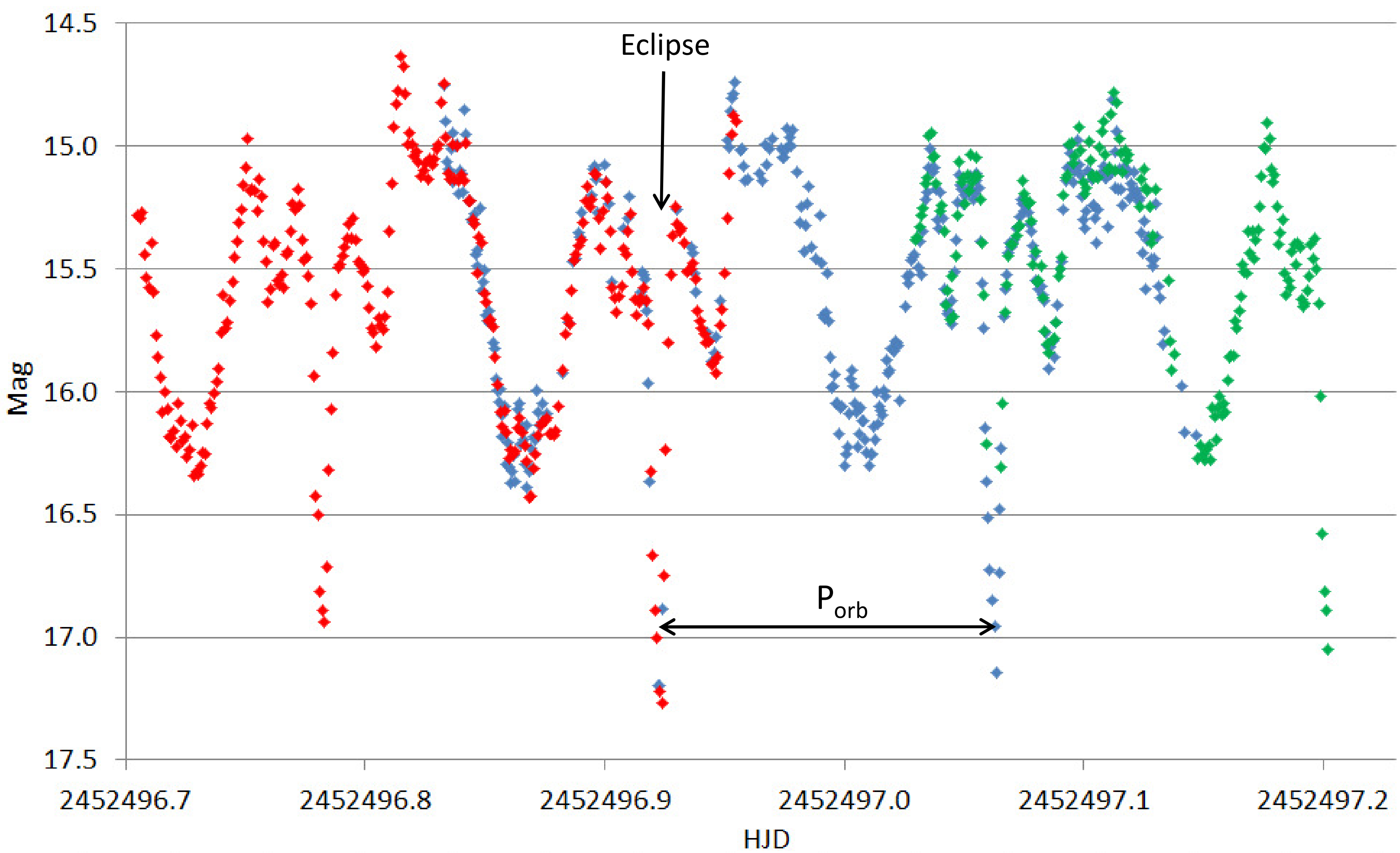
P_{rot} is the beat period between these

$$\frac{1}{P_{rot}} = \frac{1}{P_{orb}} - \frac{1}{P_{spin}}$$

Knowing this we can work out

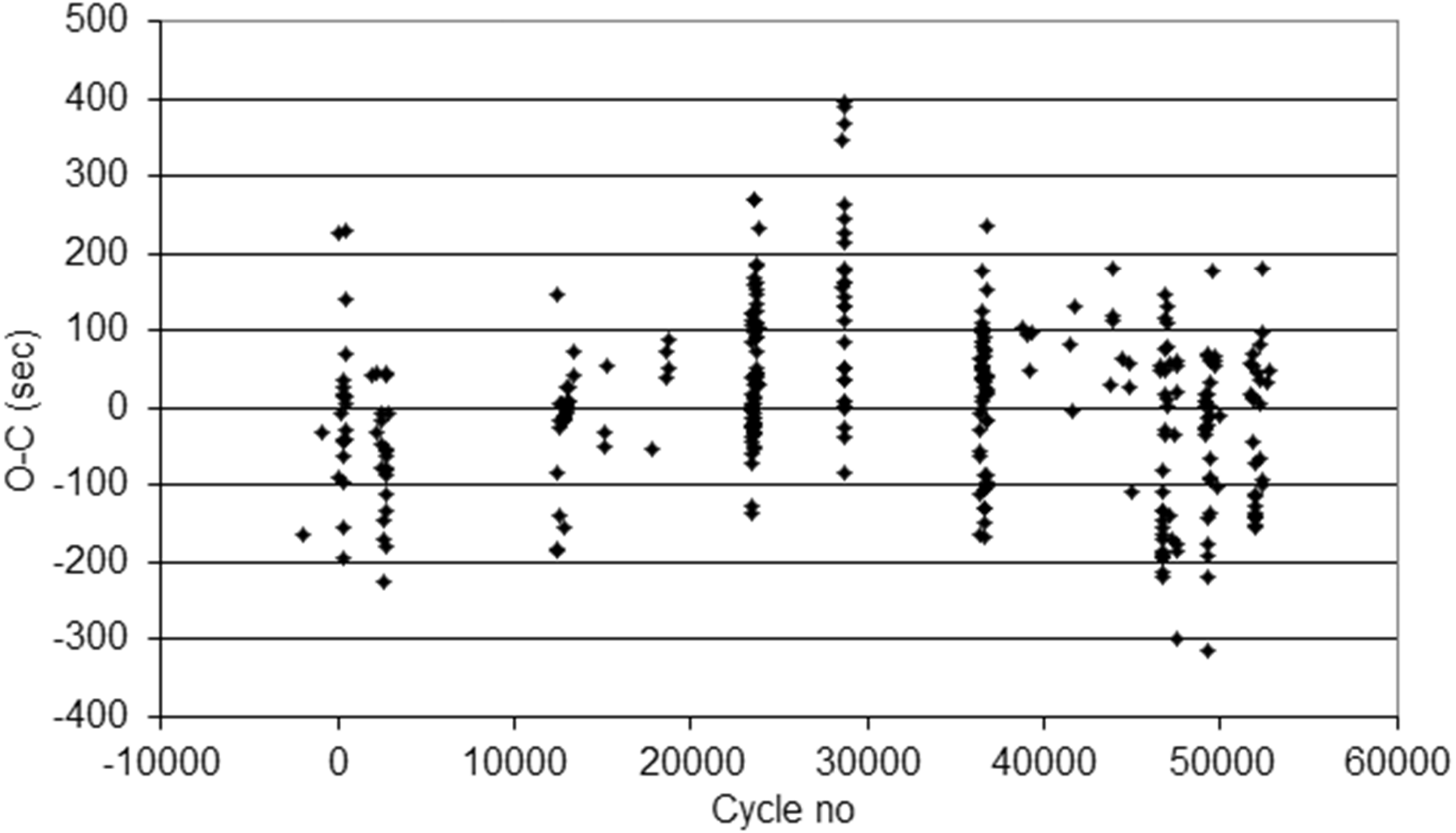
- the WD rotation phase (rotation angle) at any time
- when the polar will resynchronise

Measuring the orbital period P_{orb} (relatively easy)



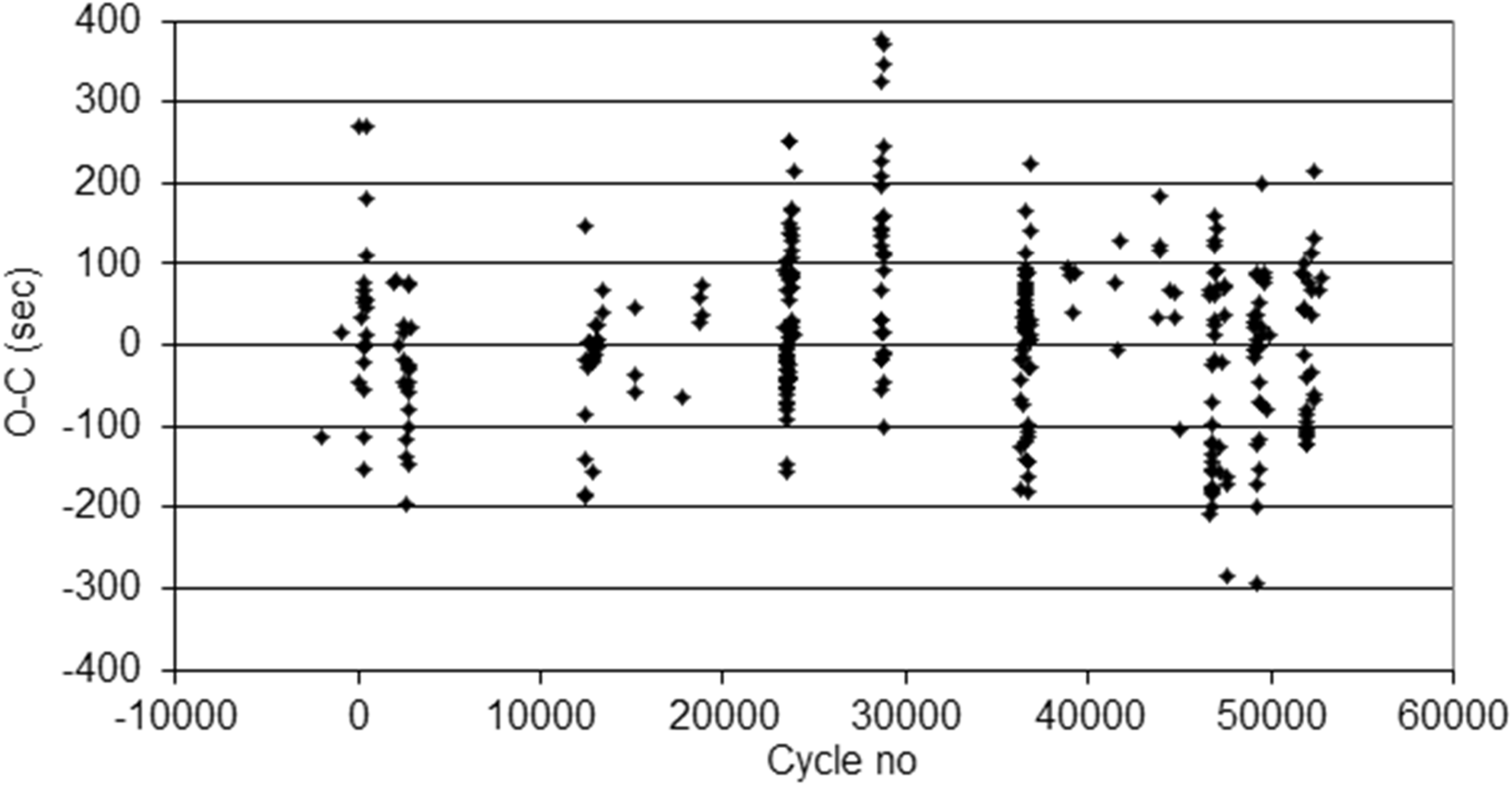
Eclipse O-C residuals to linear ephemeris

P_{orb} = 0.140234751d (12116.282s)

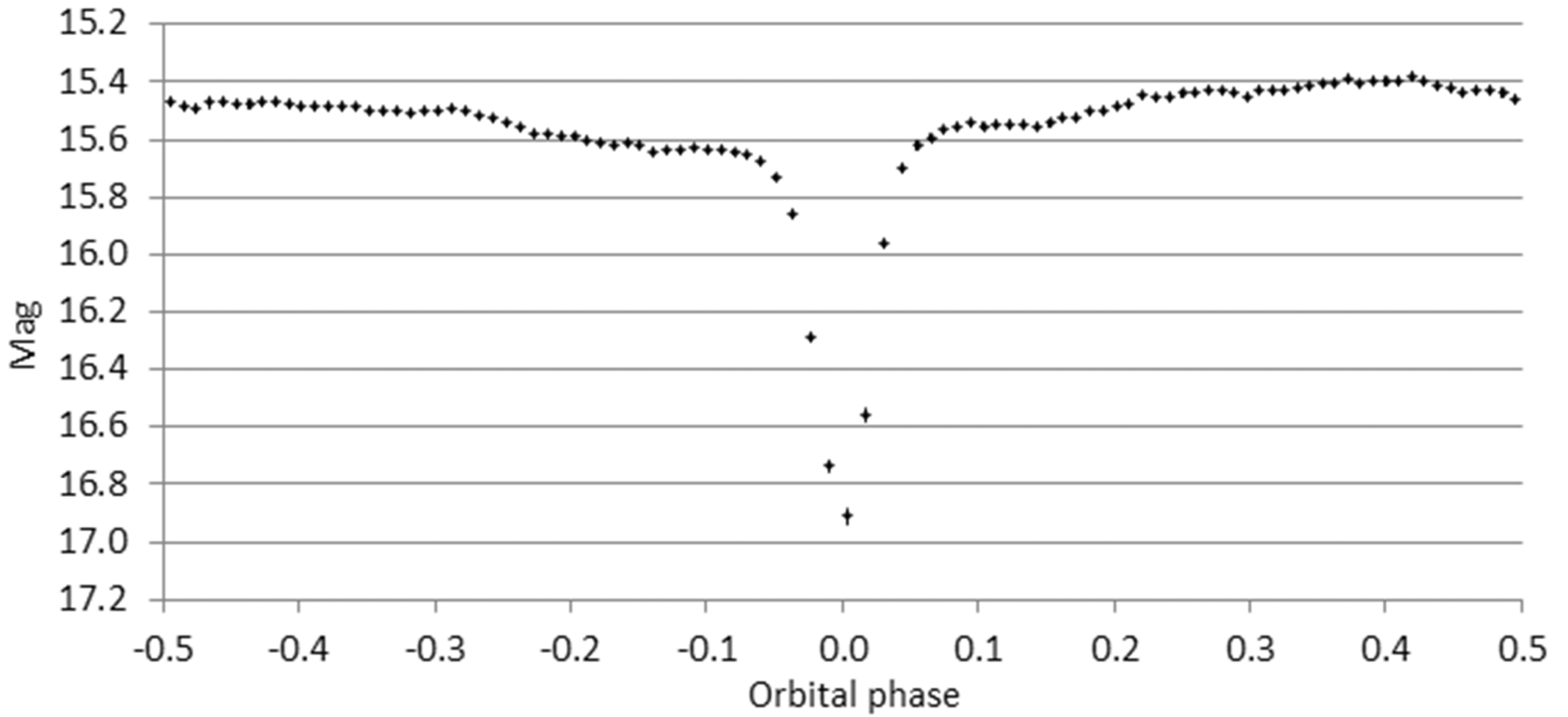


Eclipse O-C residuals to quadratic ephemeris

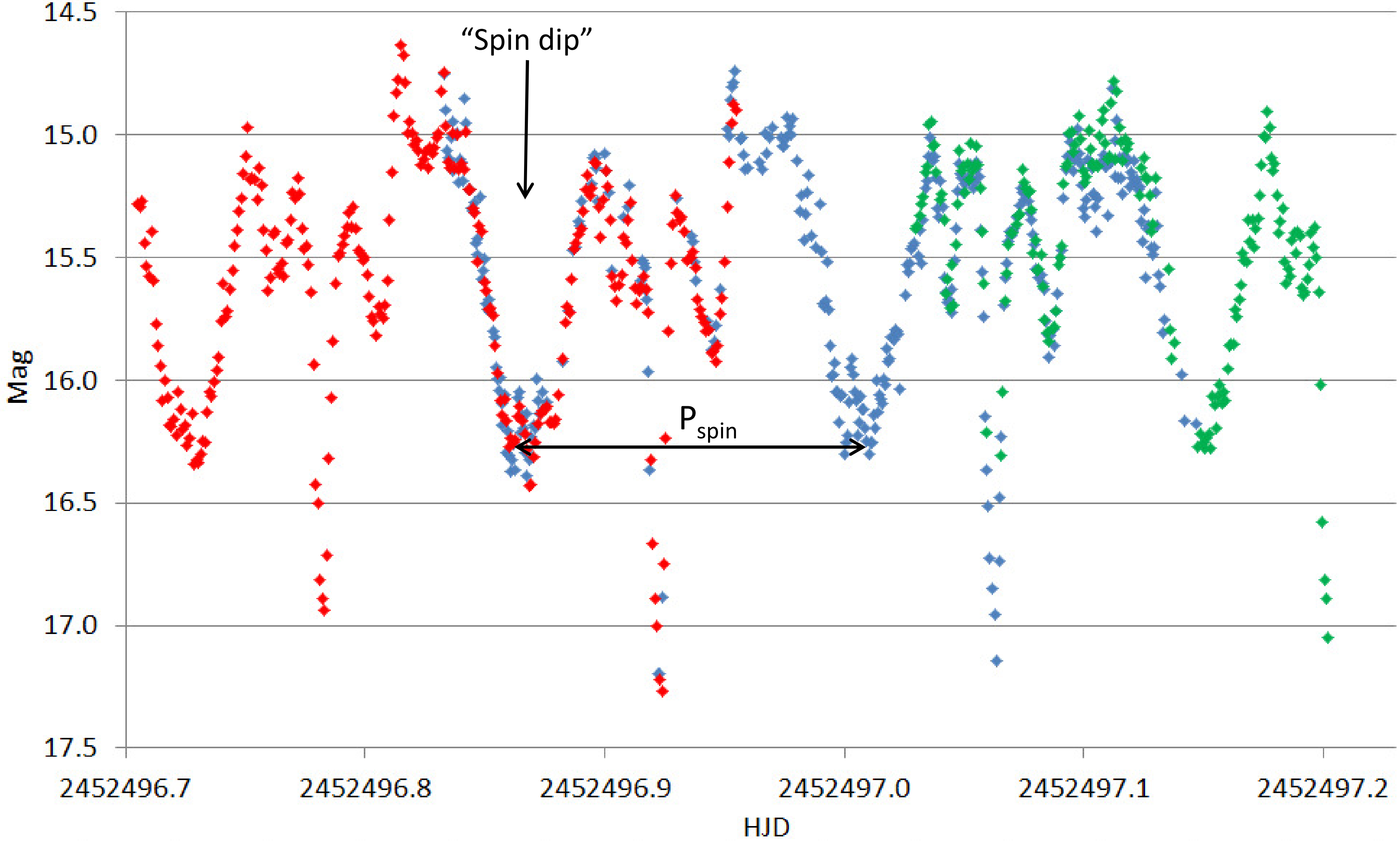
$dP_{orb}/dt = -1.38(29) \times 10^{-11}$ years/year



Mean 15-year light curve phased on the orbital period P_{orb}



Measuring the WD spin period P_{spin} (harder, it changes)



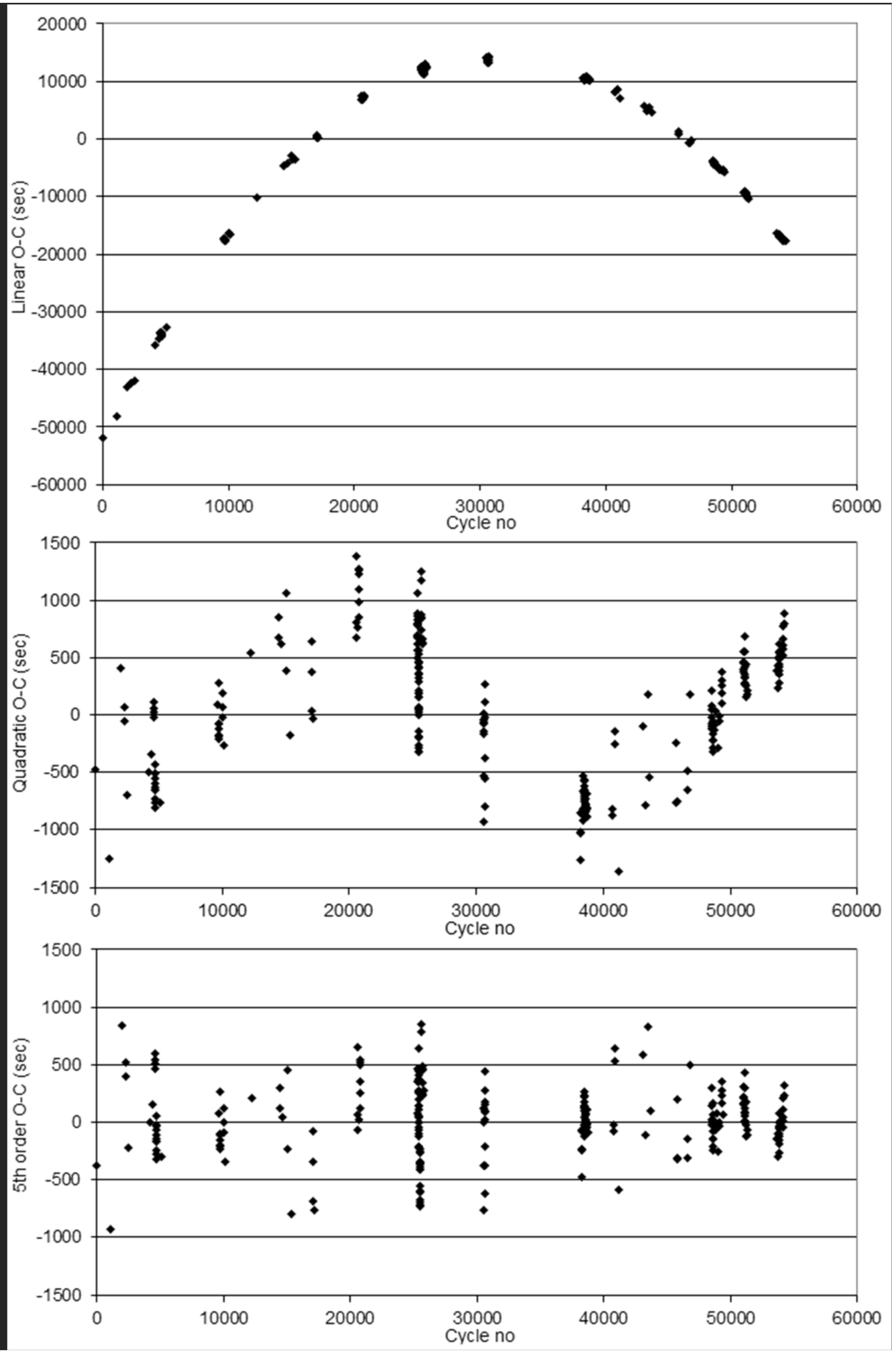
Spin dip O-C residuals for:

Linear ephemeris

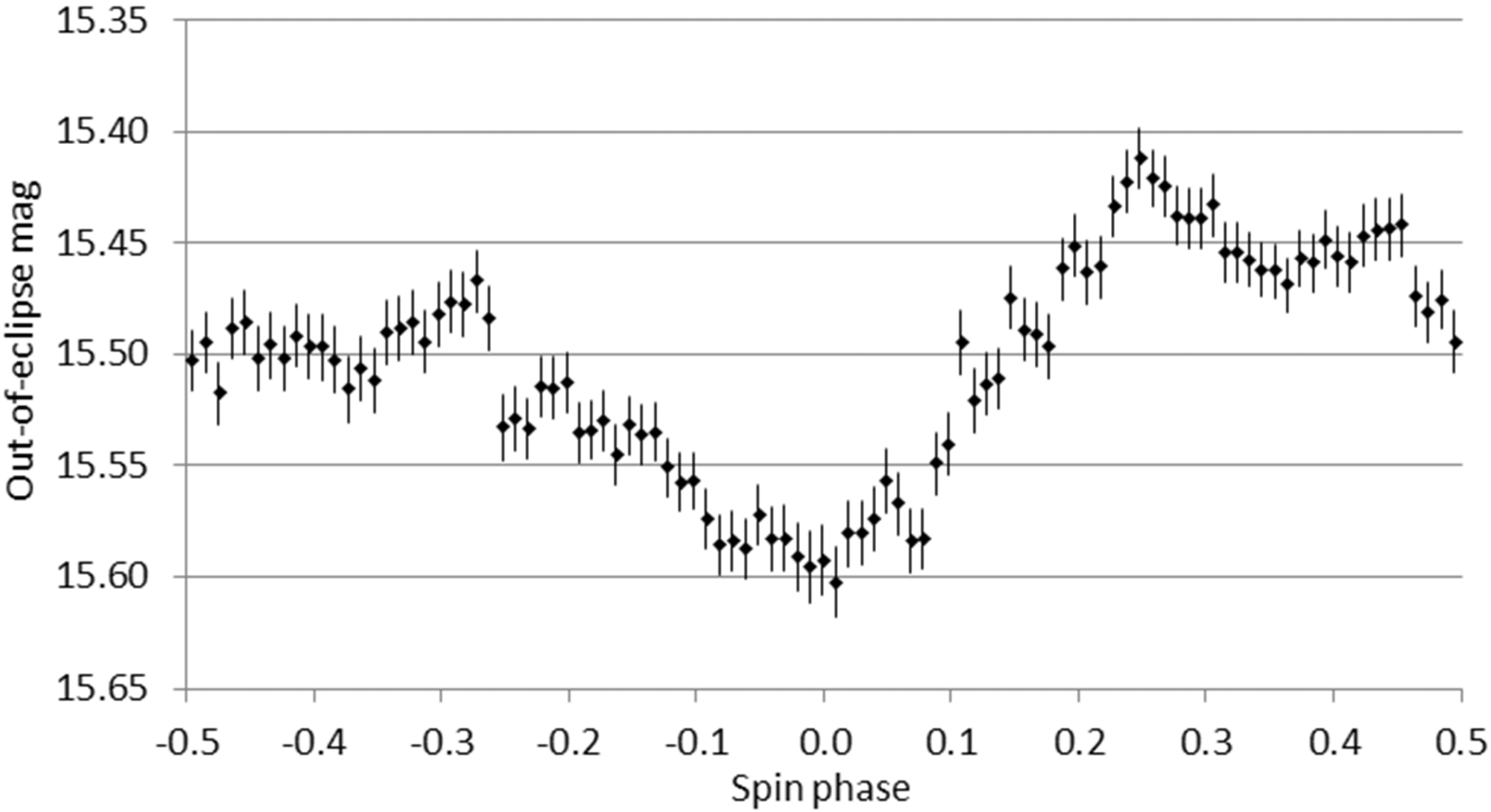
Quadratic ephemeris

5^{th} order ephemeris

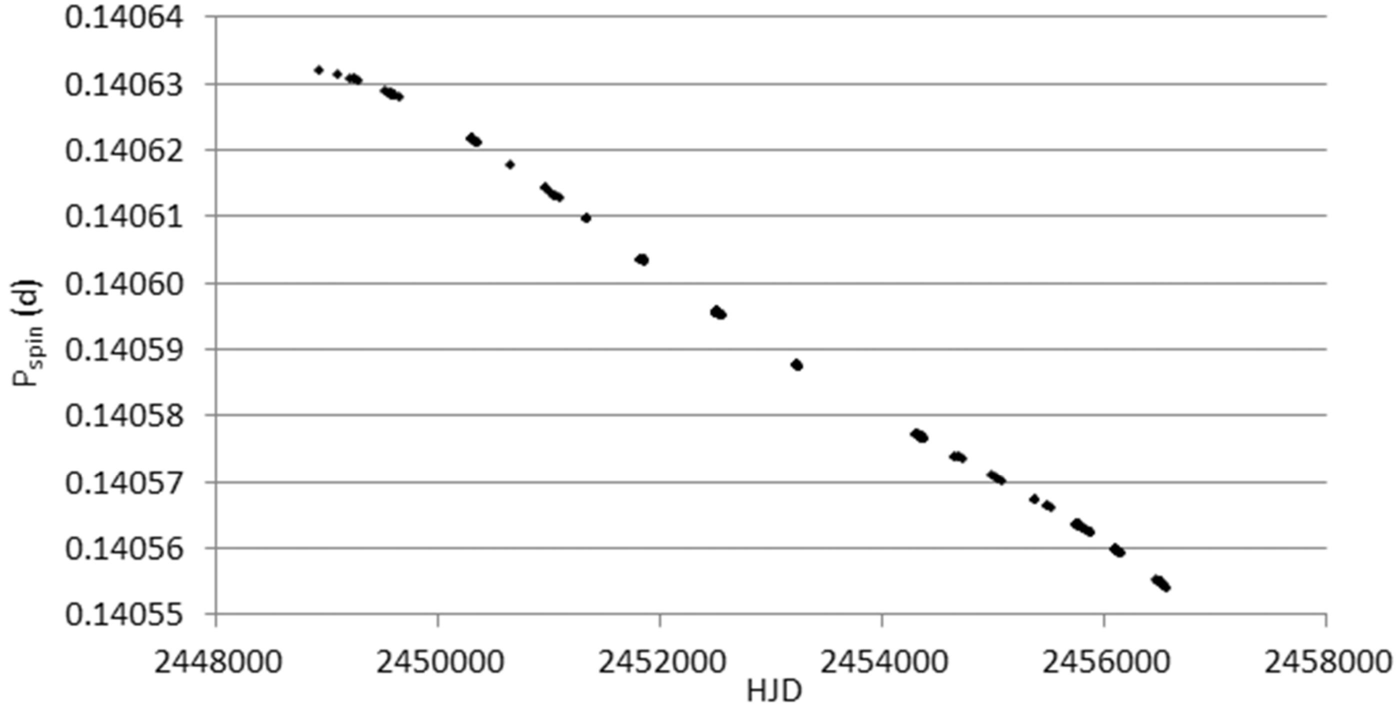
P_{spin} is best represented by a 5^{th} order polynomial in HJD



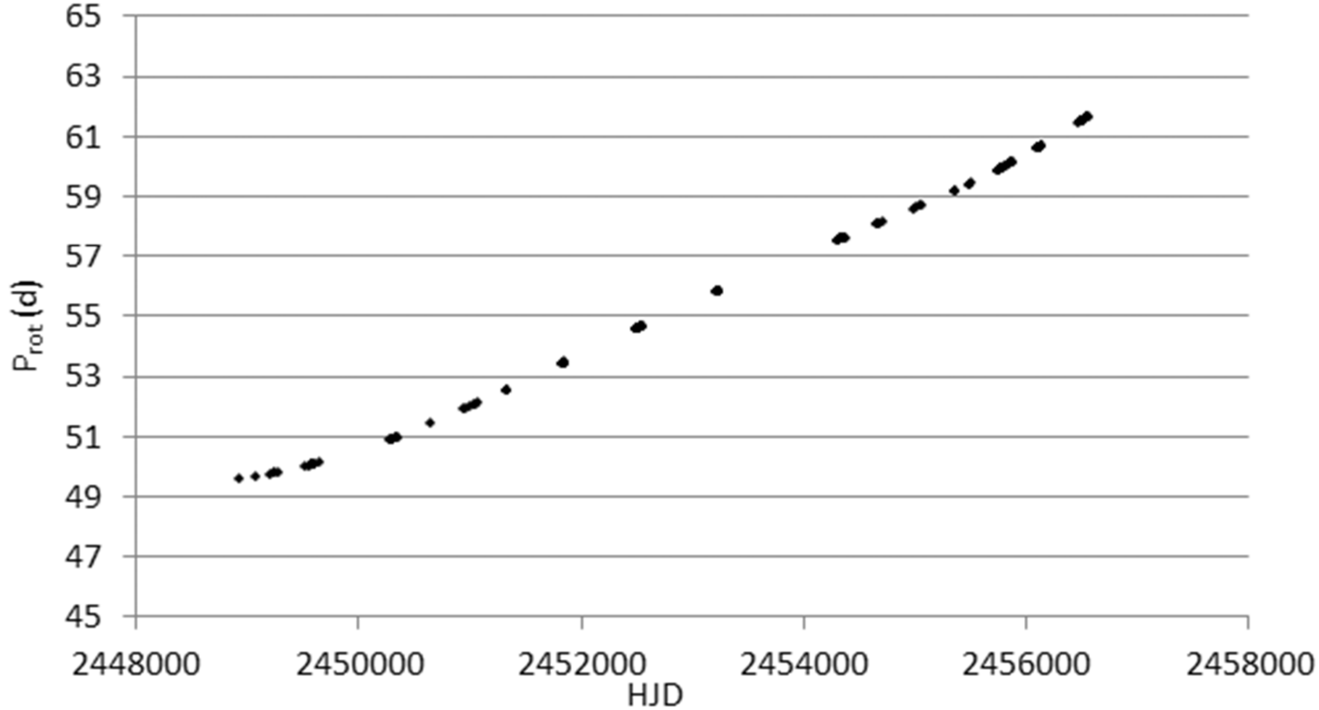
Mean 15-year out-of-eclipse light curve phased on the variable WD spin period P_{spin}



Variation of
WD spin period
P_{spin} and
WD rotation
period P_{rot}

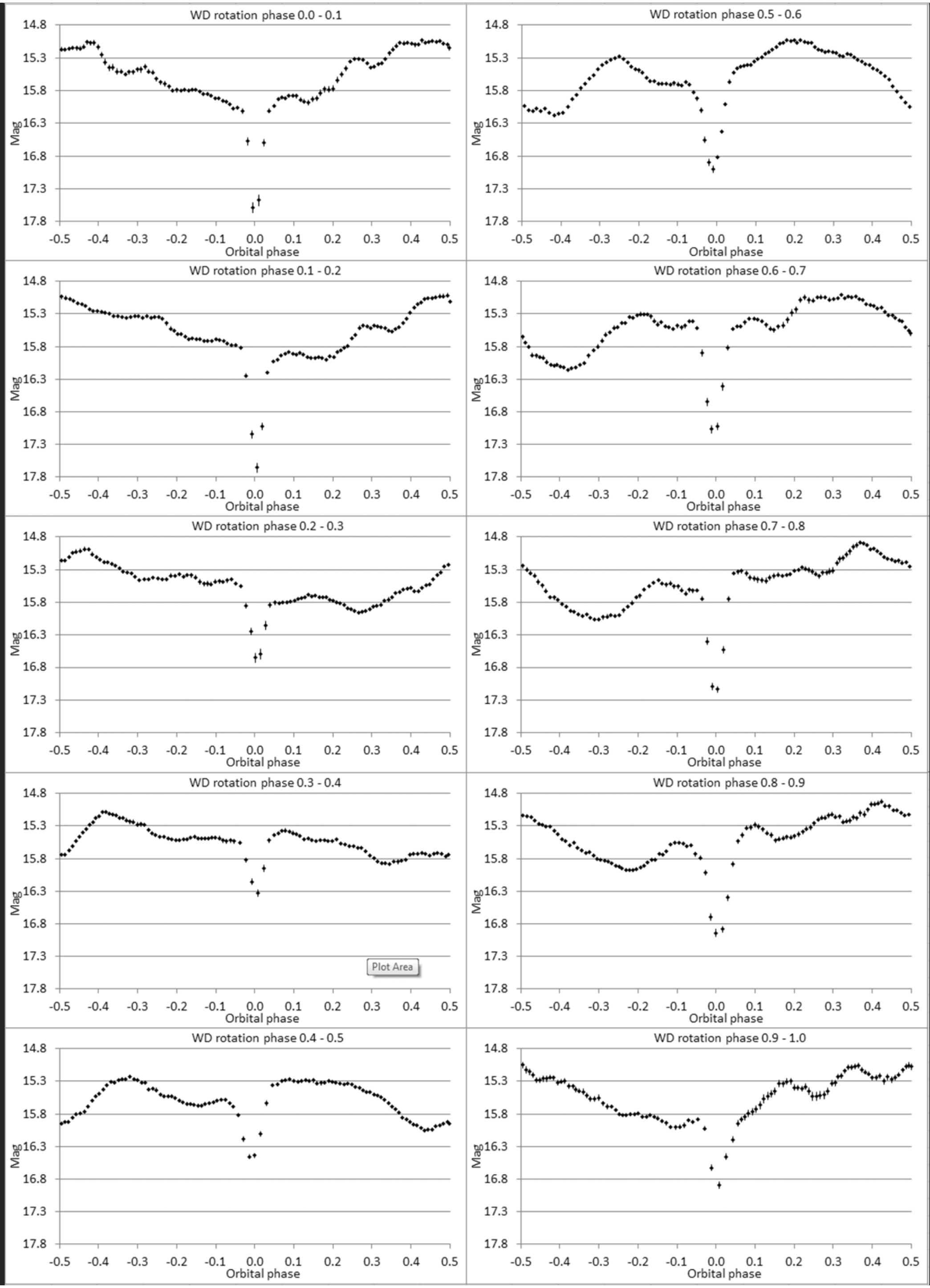


Synchronism
(i.e. $P_{spin} = P_{orb}$)
will be restored
around 2100



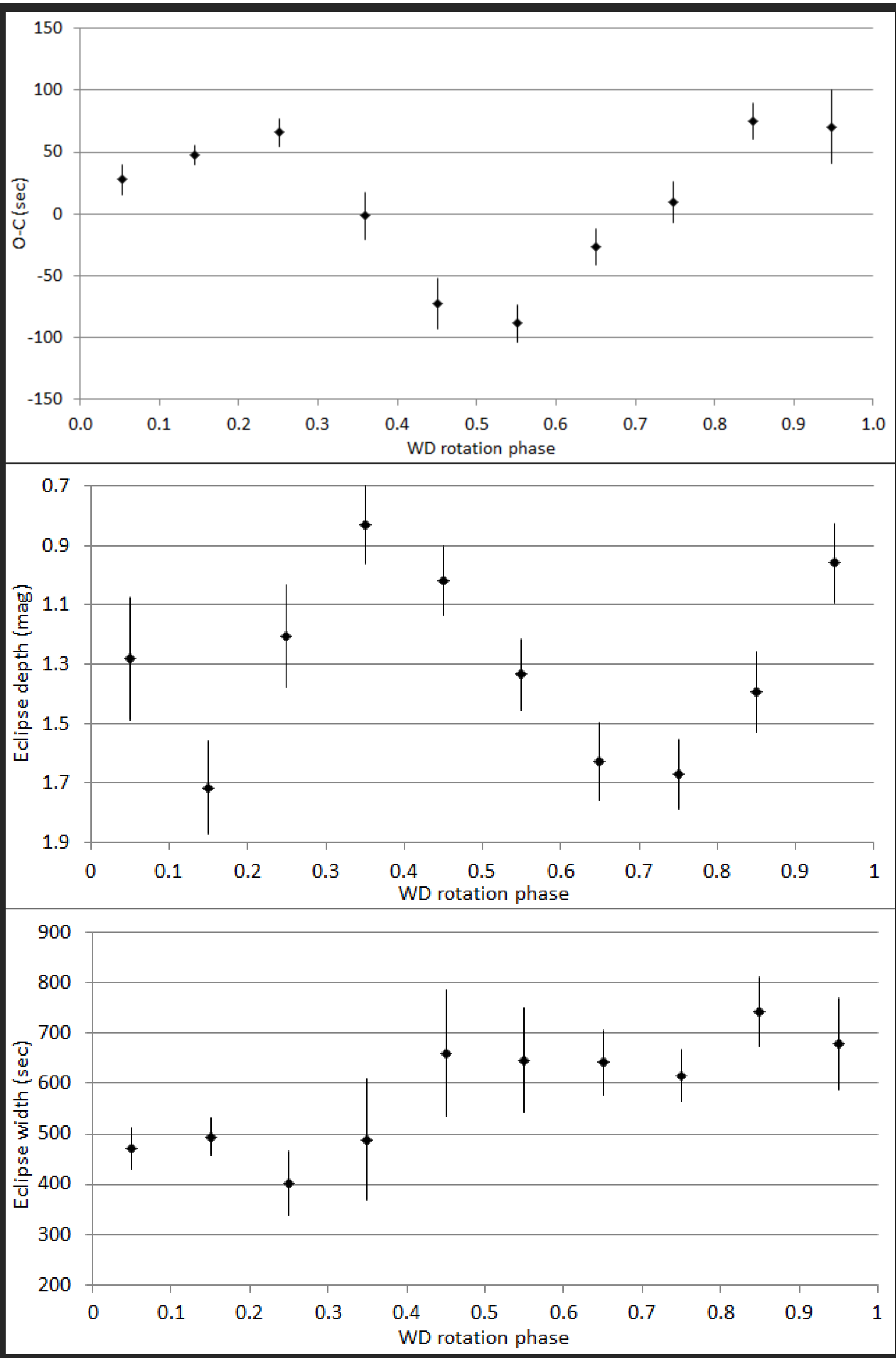
Knowing how P_{rot} changes we can now:

- calculate the WD rotation phase (angle) at any time by numerical integration
- look to see how various observable quantities change as the WD and its magnetic field rotate
- start to understand how the accretion stream moves as it encounters the continually changing WD magnetic field



Orbital light curve variation with the WD rotation phase

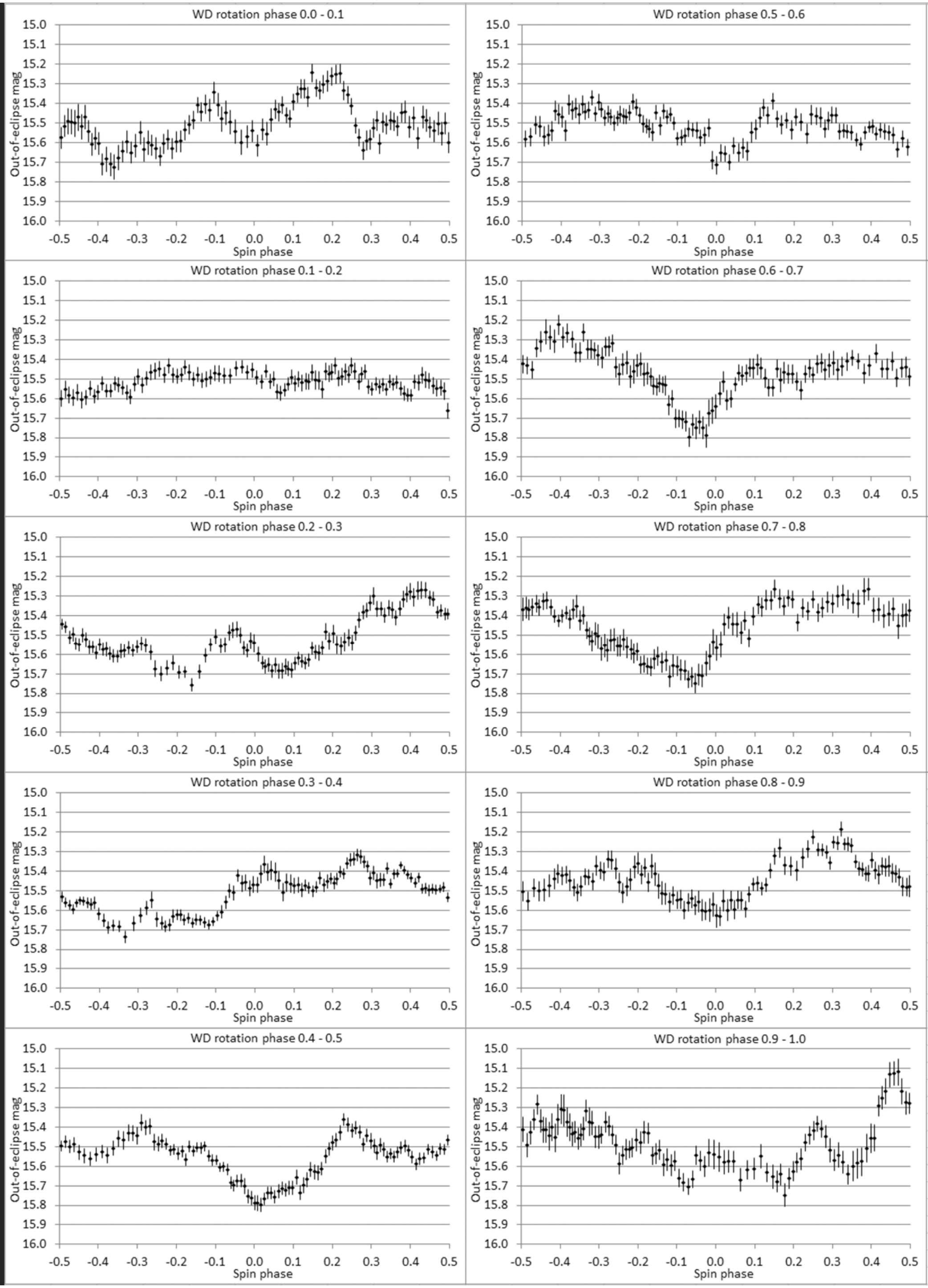
Eclipse variation with the WD rotation phase



Eclipse timing

Eclipse depth

Eclipse width



WD spin light curve variation with the WD rotation phase

We now do have the observational evidence to guide and constrain the development of a physical model of the accretion process in this magnetic CV

So it's over to the modellers to come up with a satisfactory explanation of this behaviour

Thank you