Observations of BW Sculptor in Outburst

Abstract

Here we report observations of BW Sculptoris in super outburst. This is the first outburst ever recorded for this cataclysmic variable star.

Introduction

At least half of all stars are multiple star systems where stars orbit a common centre of gravity. Cataclysmic Variable stars are binaries and consist of a white dwarf primary star and a less massive red dwarf secondary star. They can have orbital periods ranging from an hour to several hours and the whole system can take a volume in space smaller than the Sun. As a result these systems can only appear as point sources. The close proximity of the stars causes the red dwarf to be misshapen in the direction toward the more massive white dwarf and causes it to fill its roche lobe. Gaseous material flows from the red dwarf's inner lagrangian point towards the white dwarf. An accretion disk forms around the white dwarf before material flows onto the surface of the white dwarf. White dwarfs that have a very strong magnetic field disrupt the accretion disk from forming, so material flows onto the poles of the white dwarf. These are called 'Polars'

Periodically, CVs increase rapidly in brightness (outburst) before dimming to its original magnitude (quiescence). This may repeat every few months. The outburst is thought to occur by an excess of material flowing through the accretion disk.

Novae and Recurrent Novae produce the brightest outburst where the magnitude can increase 16 magnitudes. Accumulated hydrogen fuses into helium on the surface of the white dwarf causing a runaway thermonuclear process.

Dwarf Novae (U Gem stars) undergo outbursts more often than Novae but the increase in brightness is less dramatic, up to 100 times. The period between outbursts varies from days to decades depending on the type of dwarf nova but its amplitude in brightness is proportional to the mean period between outbursts.

A subclass of U Gem stars called SU Uma stars periodically have a superoutbursts as well as normal outbursts. The superoutbursts are brighter and last longer than normal outbursts. They also exhibit superhumps with a period slightly different from the orbital period due to precession of the accretion disk. They have orbital periods of less than 2 hours. A type of SU Uma stars is the WZ Sge type. They only exhibit superhumps but in the order of decades apart. They have the shortest orbital periods of all the CVs. They also exhibit superhumps in quiescence.

Another type of CV are the nova like variables. These variables do not go into outburst as the transfer of material through the disk is stable. Only slight variations in brightness are observed.

BW Scl is listed as a nova like variable in the General Catalog of Variable Stars (GCVS). The AAVSO classify it as a UGWZ + ZZ star. ZZ refers a ZZ Ceti variable star which is a non-radially pulsating white dwarf star.

BW Scl was first observed as a soft x-ray source (RX J2353.0-3852) in the ROSAT all-sky survey. The optical counterpart was observed in 1992 as with a V magnitude of 16.5. Spectra showed broad double peaked balmer lines indicative of an accretion disk at high inclination and very similar to the short period SU Uma type cv, WZ Sge. SU Uma stars have periodic superoutbursts lasting a few weeks with normal outbursts inbetween lasting a few days. WZ Sge only has superoutbursts but are spaced 20 to 30 years apart. Subsequent photometry failed to show any eclipse however periodicity was observed at 87.4 minutes and at 38.0 minutes in 1993. These however were not observed in 1994.

The Hamburg / ESO Survey independently detected the object as a bright UV source, HE2350-3908, in 1995. Augusteijn & Wisotski, 1997, determined a period of 78.226 minutes with radial velocity measurements. Photometry also showed periodicity at 78 minutes. At the time this is the shortest period CV known, again similar to that of WZ Sge, having shorter periods than most SU Uma stars. X-ray observations suggest this is a CV with a low accretion rate.

It is a suspected WZ Sge cataclysmic variable star and until now has never been observed in outburst. It has quiescent superhumps with a period of 87.27 minutes.

BW Scl was identified with the aid of a finder chart from the AAVSO website. It lists its position as RA: 23:53:00.85, Dec -38:51:46.4. This also lists several comparison stars. The star referenced as ‘106’ was used as the reference star being of a similar colour to BW Scl.

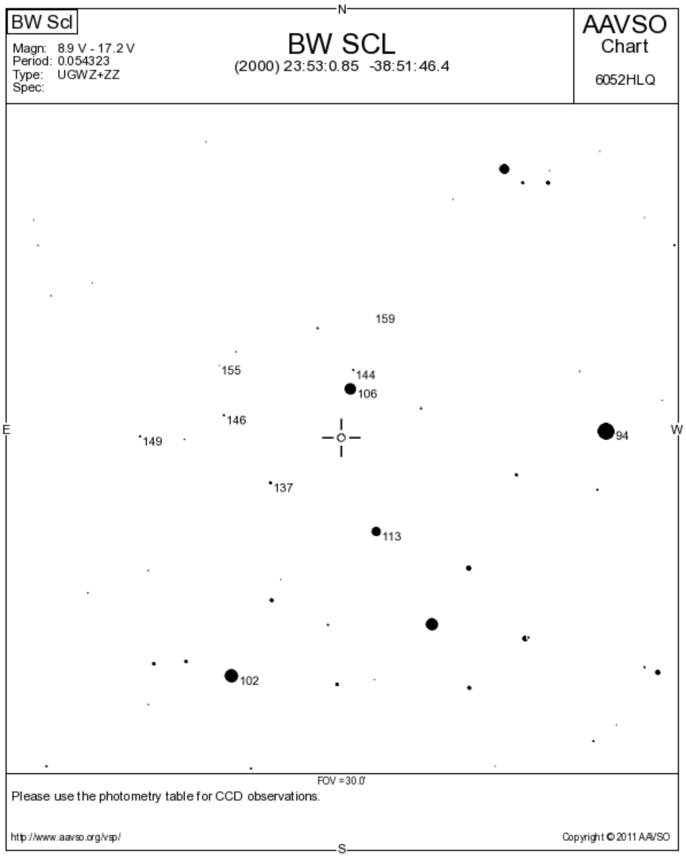


Figure 1: Chart for BW Scl [AAVSO]

A major outburst was observed on October 21 2011 reported by M. Linnol, USA, t at visual magnitude 9.6 and confirmed shortly after by A. Plummer, Australia, at visual magnitude 9.4 [AAVSO]. Maximum magnitude was reported on the same day, 8.91 by Peter Starr (author of this paper). Continuous observations were reported to the AAVSO for the following 2 months.

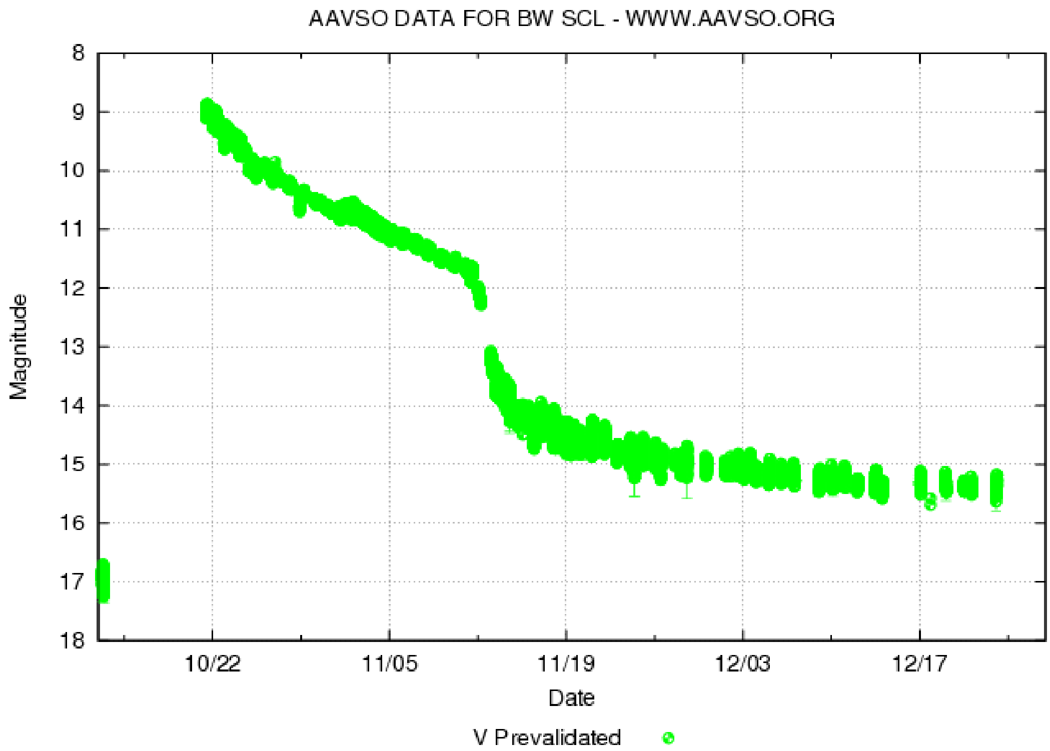


Figure 4: BW Scl V lightcurve from various contributors [AAVSO, 27/12/11)

BW Scl was monitored over several nights between October 21st 2011 and December 24th 2011 coinciding with the first day of the outburst announcement and settling down back to quiescence. All observations were filtered, predominantly with a Johnson V filter but some BRI observations were done as well. Exposure times varied depending on the brightness of the star (30 seconds to 120 seconds). Below are pictures of the field including comparison stars from the night of the outburst and near quiescence.

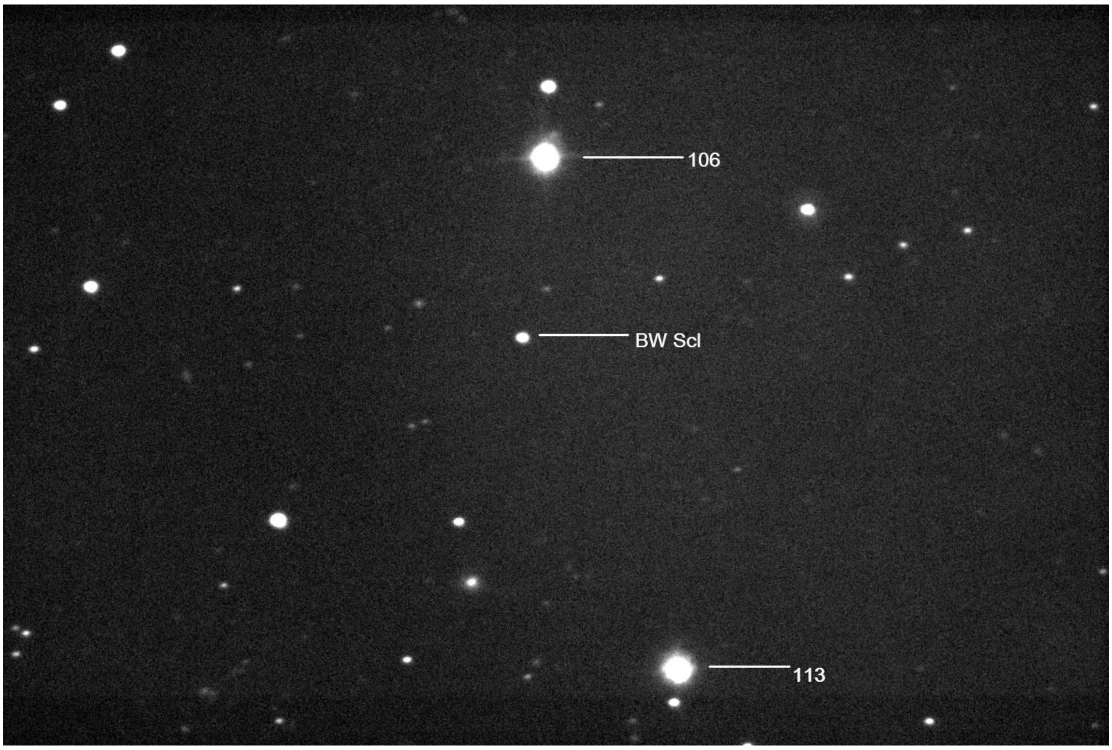


Figure 2: BW Scl near quiescence 24/12/2011, north is up

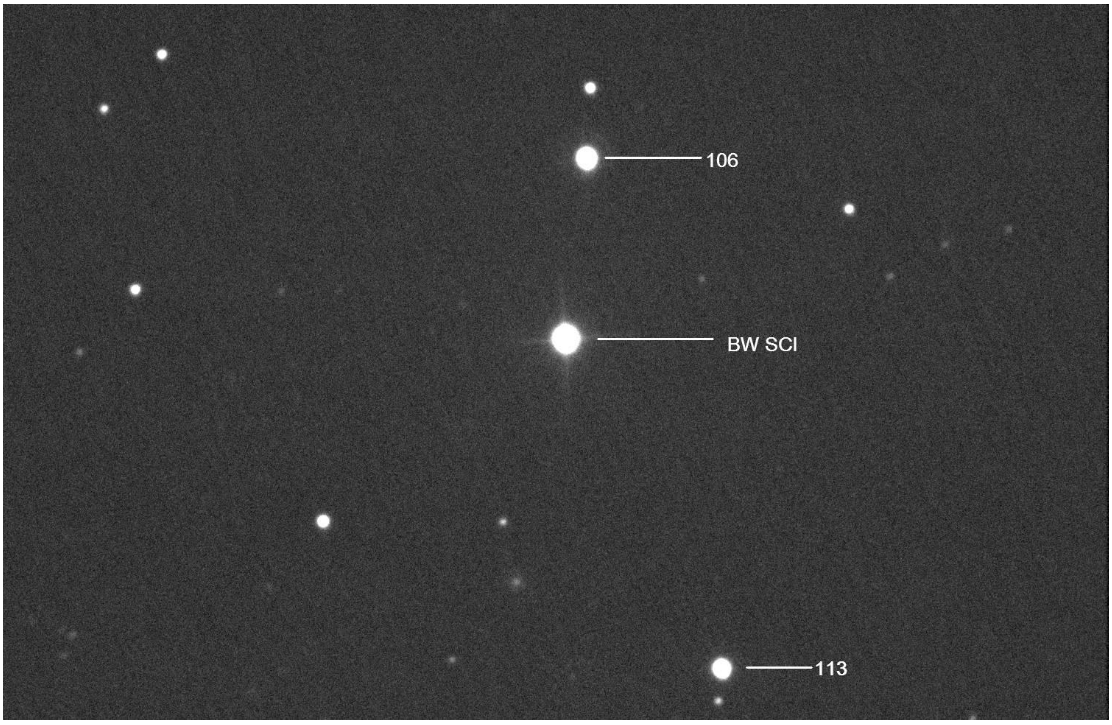
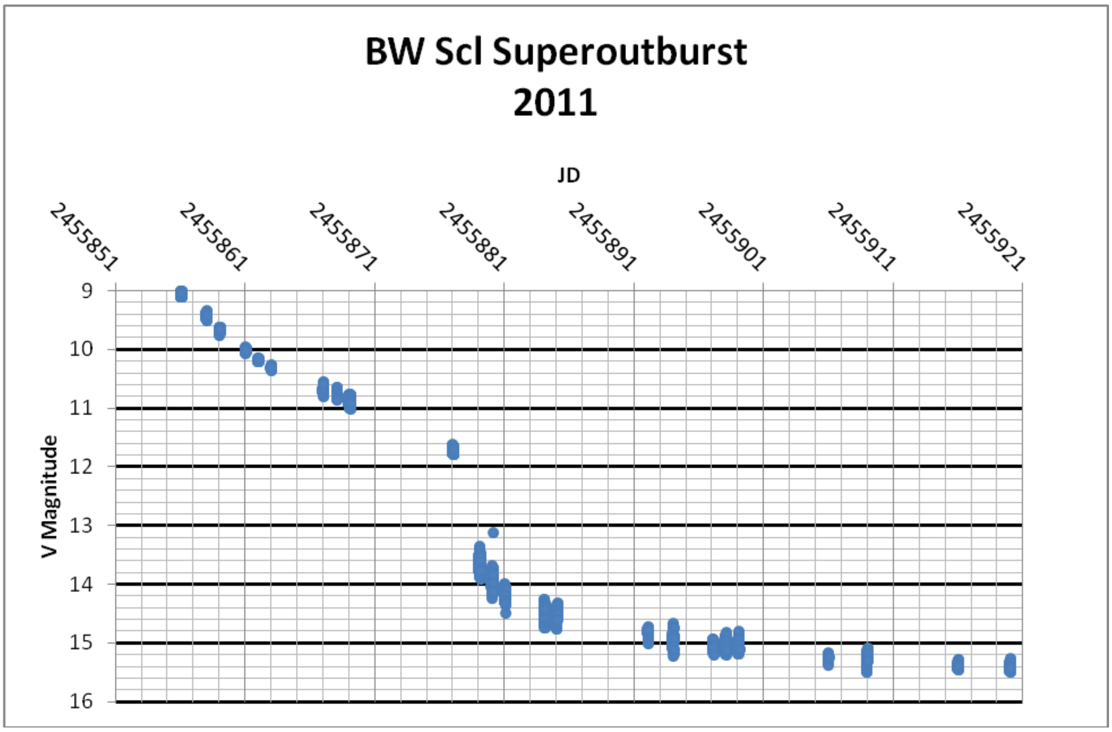


Figure 3: BW Scl in outburst and comparison stars, 21 Oct 2011, north is up.

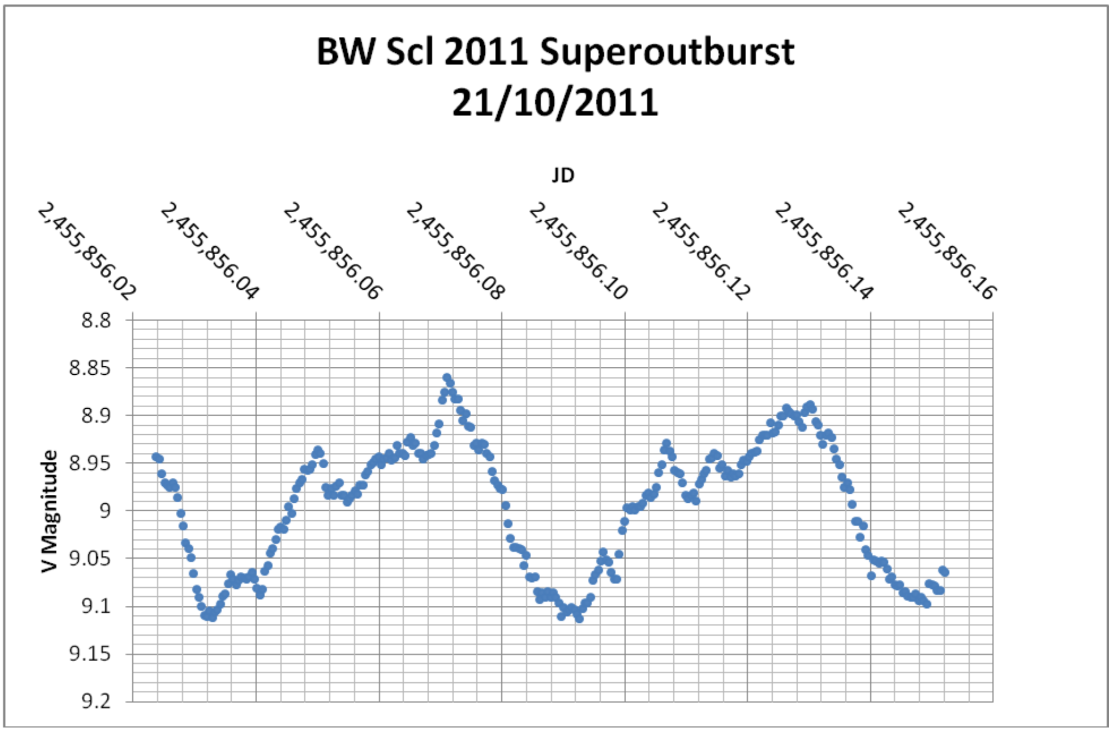
			B	V mag	R mag	I	BV
A	Target	BW Scl		16.2 – 16.54			
B	Reference	106	11.042	10.610			0.810
C	Check	113	12.193	11.309	10.812	10.348	0.884

- Sourced from AAVSO website, reference table 6052HHT.

A Chart of all my observations is depicted below. It shows the V magnitude ranging from 8.85 to 15.5. The magnitude drops at an exponential rate, before a sudden drop followed by another exponential decay to quiescence.



Below is a lightcurve of the first night of data on the 21/10/11 AEST. This includes the brightest magnitude recorded for this variable of 8.86. The lightcurve is complex and has many repeatable components.



The main components of dwarf nova systems are the white dwarf primary, red dwarf secondary, accretion disk, and bright spot. The white dwarf will be the smallest object so will give the fastest ingress and egress. The red dwarf will contribute little light to the whole system.

There are;

3 broad dips in brightness.

The centres of the first two dips are at JD 2455856.0367 and 2455856.0907. The time between the centres of the first two dips is 77.74 minutes.

The dips are likely to be partial eclipses of the accretion disk behind the secondary star.

2 broad humps. In other systems, this is due to the emergence of the bright spot. The 2 humps are quite differentand so no conclusions are drawn.

At the start of each dip there is a brief standstill followed by a sharp drop in brightness, with another brief standstill.

The first standstill is;
150 seconds ± 37 sec V magnitude = 8.97
74 seconds ± 37 sec V magnitude = 8.97
112 seconds ± 37 sec V magnitude = 8.97
The time between them are;
76.80 minutes and
81.35 minutes
(average 79.08 minutes)

The time to the second standstill is;
148 seconds, 0.06 magnitude drop
150 seconds, 0.06 magnitude drop
112 seconds, 0.03 magnitude drop

76.83 minutes and
80.08 minutes
Average 78.46 minutes

The timing between these successive standstills is similar to the published orbital period of the binary of 78.2 minutes

The sharp drop in brightness maybe caused by an eclipse of a relatively bright compact object. This could possibly be the eclipse of the primary white dwarf star. If the eclipse is total, the white dwarf would contribute 0.06 V magnitude.

The second standstill lasts for;
37 seconds ± 37 sec
111 seconds ± 37 sec
111 seconds ± 37 sec

After the last standstill there is a slower drop to minimum.
Each of the 3 minima have a different structure, maybe affected by noise.

There is a steady rise after each minimum followed by a standstill.

There is a small dip after the standstill followed by a sharp rise.

There is another standstill after the rise followed by another rise.

There is then another secondary dip before the hump appears.
JD 2455856.05 Magnitude 8.941
JD 2455856.06 Magnitude 8.945
14.22 minutes

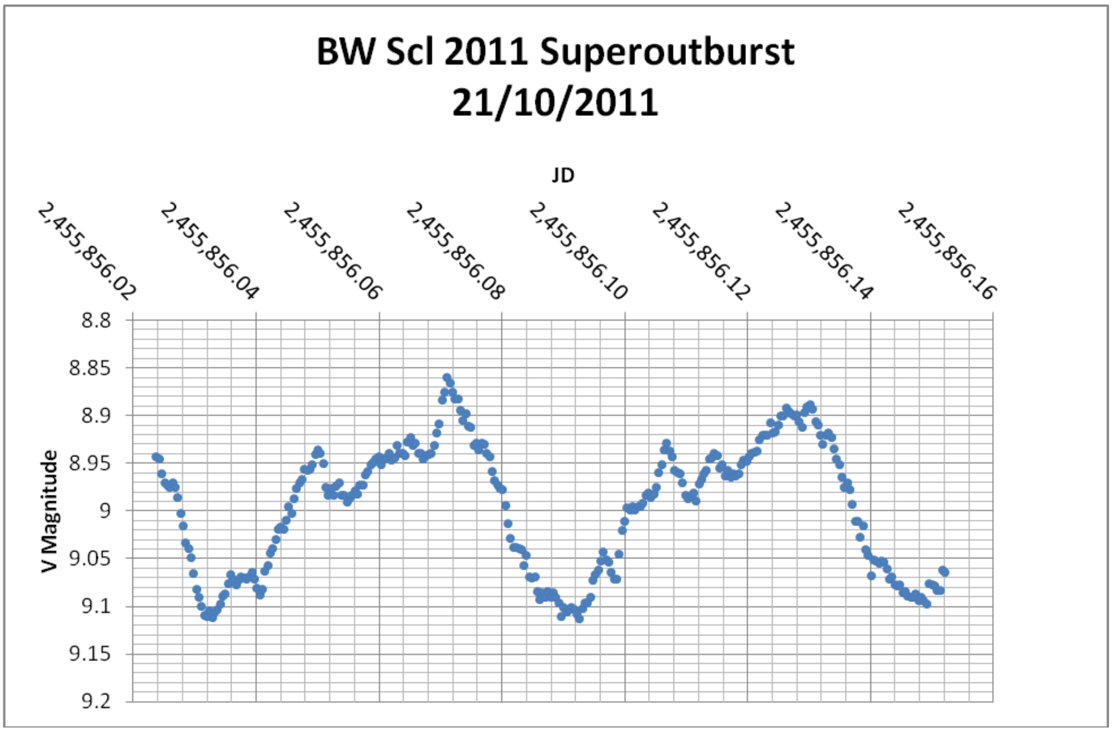
JD 2455856.106 Magnitude 8.936
JD 2455856.114 Magnitude 8.945
11.15 minutes

The period between the midpoints is 79.65 minutes. The depth of the dip is 0.05 and 0.04 magnitudes.

The lightcurve shows further repeatable structure. These will coincide with eclipses of different components of the system, eg, the white dwarf, bright spot, accretion disk and secondary star.
The sharpest drop appears on 3 successive eclipses at
JD 2455856.0268 to JD 2455856.029,
JD 2455856.060 to JD 2455856.082, and
JD 2455856.1362 to JD 2455856.1375.
This corresponds to 148, 150, and 112 seconds. This very short duration and implies a very small object being eclipsed. This can only be the primary, the white dwarf.
The drop in brightness is 0.06, 0.06, 0.041 magnitudes in both cases.
The time between the eclipses is 76.8 minutes, 80.7 minutes. This is an estimate of the orbital period of the binary system. This compares to radial velocity measurements giving an orbital period of 78.2 minutes.

The broad dips in brightness maybe due to the accretion disk being partially eclipsed by the secondary star.
The white dwarf maybe re-emerging from eclipse at JD 2455856.041, and JD 2455856.099. The eclipse lasts for 20.33 minutes and 27.28 minutes. The large discrepancy in eclipse times needs to be determined.
The end of each broad dip has a very distinct timing. There are 2 of these observed on the first night. The time between is 81.8 minutes.

The time between the first point of egress is 83 minutes. The difference in time suggests the white dwarf is emerging from behind the accretion disk which is changing angular size rather than emerging from behind the secondary star.



Available Equipment

Site:

All the data presented here was collected at my home observatory, a 2.3 metre diameter non-motorised Sirius Observatory, 9km from Coonabarabran, NSW, Australia. Longitude 149 11 33.99 east, Latitude 31 16 35.05 south, elevation 600m above sea level.

Telescope:
Planewave 20 inch aperture, Focal ratio f/6.8. The telescope is permanently mounted on a Paramount ME which sits on a 1.1 metre high cast iron pier bolted on a concrete slab. The telescope is polar aligned.

CCD: SBig ST8.
Filters used were a bessell set of B,V, R, and I.

Software:
Acquisition SBig software was used to drive the CCD for unfiltered observations. Whereas filtered observations were acquired with Maxim DL.
Raw data was calibrated using Maxim DL and photometry was done also using Maxim DL. Calibration involved taking several dark frames at the temperature and exposure time of the CCD. 5 Flats were taken every observing session for each filter. These were dark subtracted. The flats were a mixture of sky and dome flats.
Period analysis was done with Period 04 and excel spreadsheets.