QZ CARINAE – UPDATE IN 2018

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Variable Stars South

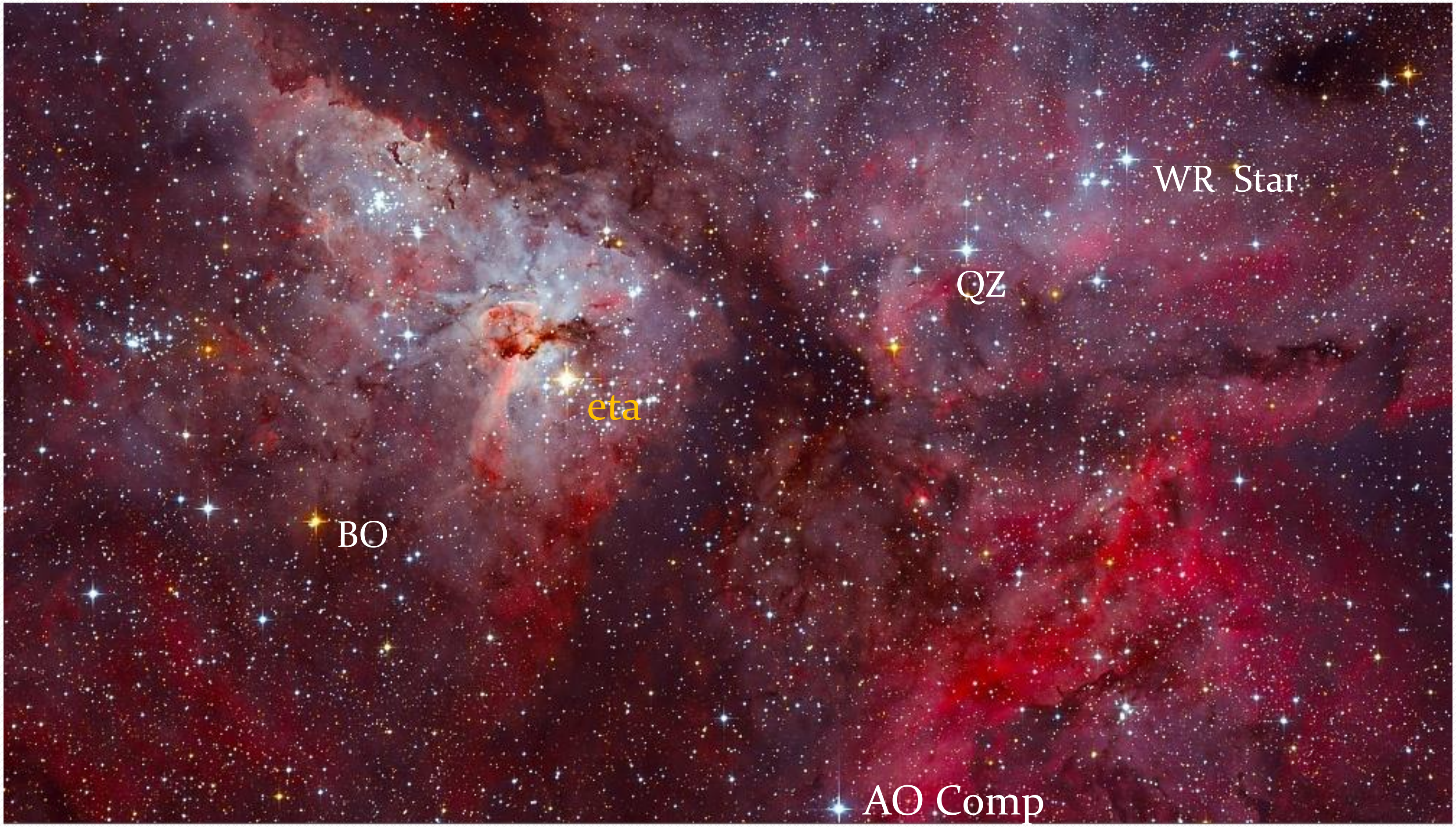
ABSTRACT

The quadruple system of QZ Carinae is interesting as one of the most massive multiple star systems in our galaxy, but also challenging due to the orbital period of the eclipsing component being only 124 seconds short of six days. As a result its phases at one particular longitude repeat only every 11.5 years.

Observations of the eclipsing pair began in 1971 and measures of the light time effects (LTE) which have an amplitude of ~12.7 hours show that the two pairs of stars have not yet completed one orbit of each other since then. With the help of observations from the BRITE satellite a better mean light curve has been prepared and the various LTE values recalculated to provide a more accurate picture of this orbit.

Measures of the primary eclipse by Variable Stars South members in 2017 and continuing in 2018 seem to indicate that the total phase may be slightly shorter than previously believed. Our present understanding of QZ Carinae is reviewed in this presentation.

ETA CARINAE REGION



This shows some stars of interest against the bright nebulosity of the region which makes photometry rather more inaccurate than we would like!

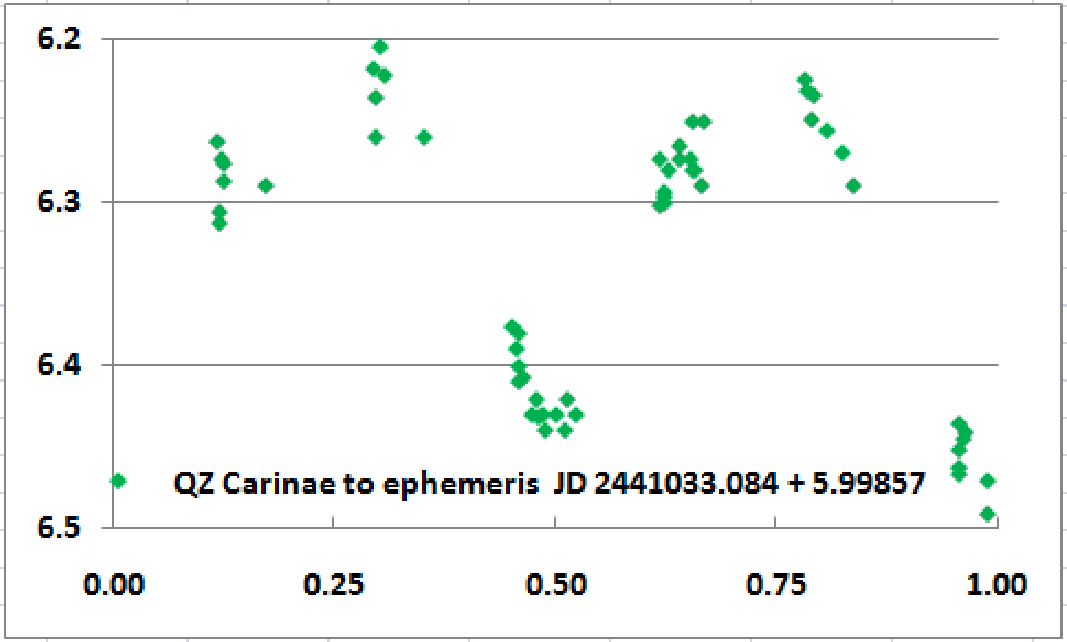
A LITTLE HISTORY

Eta Carinae is a star that all new variable star observers look at. Brian Marino and Stan Walker were no exceptions – but we began to doubt the accuracy of the two main comparisons used -with eta at that stage near sixth magnitude. Bateson, of course, scorned the idea.

When our new photometer was properly calibrated by March, 1971, these two stars were added to the target list. But HD 93206, now known as QZ Carinae, was a challenge. It was variable but gave the same readings every third night. It was a little reminiscent of a song popular about that time regarding a clock which always showed 12 30. This has caused no end of problems and it's only with the aid of the BRITE consortium that these have been resolved.

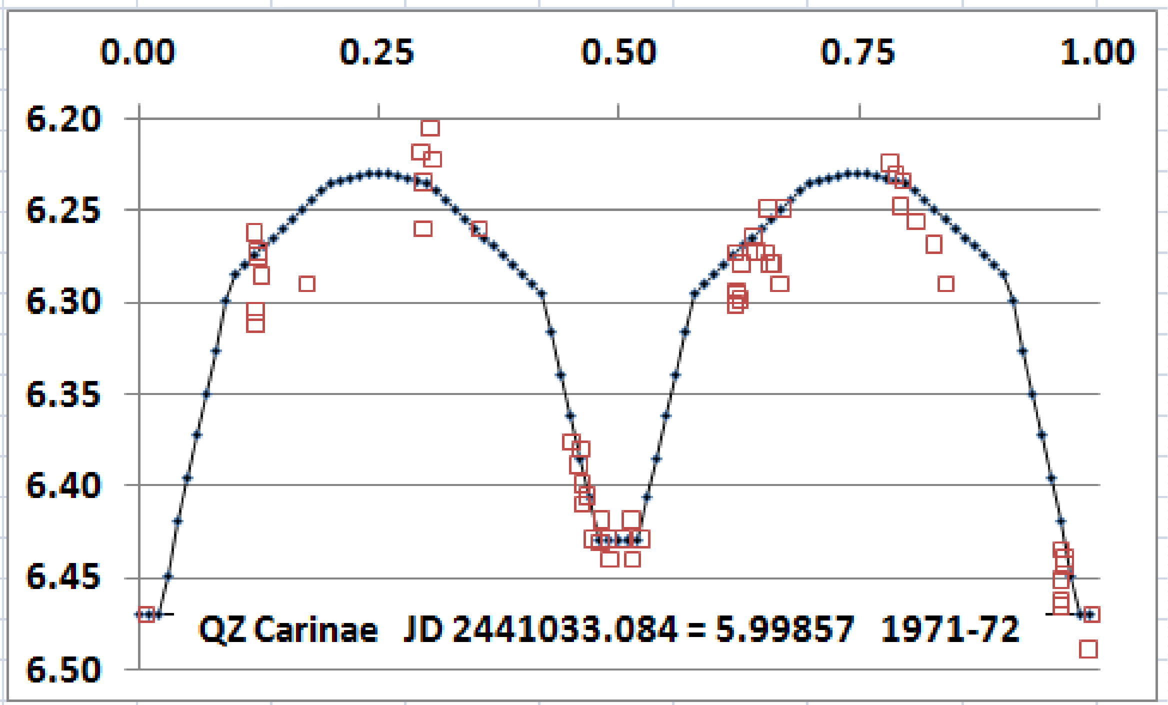
The ground based approach ideally called for a round the world collaboration but in the 1970s astronomy was not geared for such an effort, particularly on some anonymous star. Perhaps the first such project involved EX Hydrae, a puzzling CV, in 1979. One of the problems which has continued is that QZ Carinae at 6.3 or so is too bright for many installations.

THE LIGHT CURVE AND PERIOD



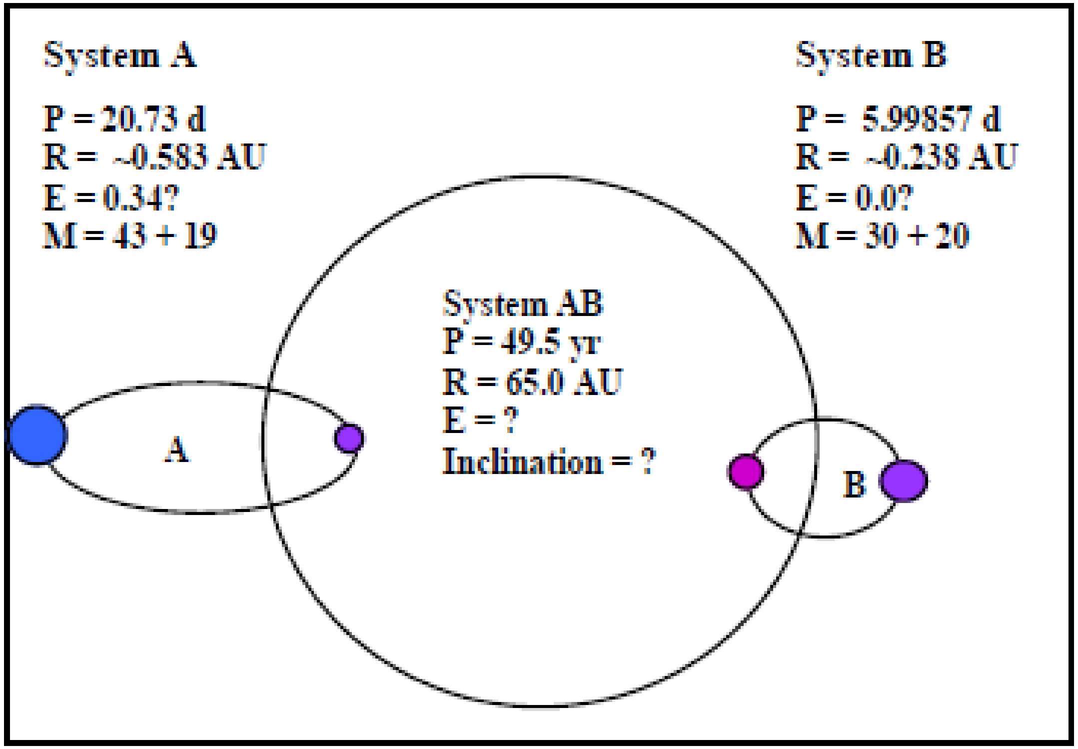
The first two seasons' measures were published in IBVS 681 with our determination of a period of 6.007 days and classification of the star as a beta Lyrae binary system. This caused other groups to study the star and it was soon resolved by spectroscopy into two pairs of massive stars, one eclipsing - one not, but with an orbital period of ~20.73 days. All very luminous objects with a total mass of ~95 times the Sun. The problems of the awkward period are clearly apparent in this graph.

THE ORIGINAL MEAN LIGHT CURVE



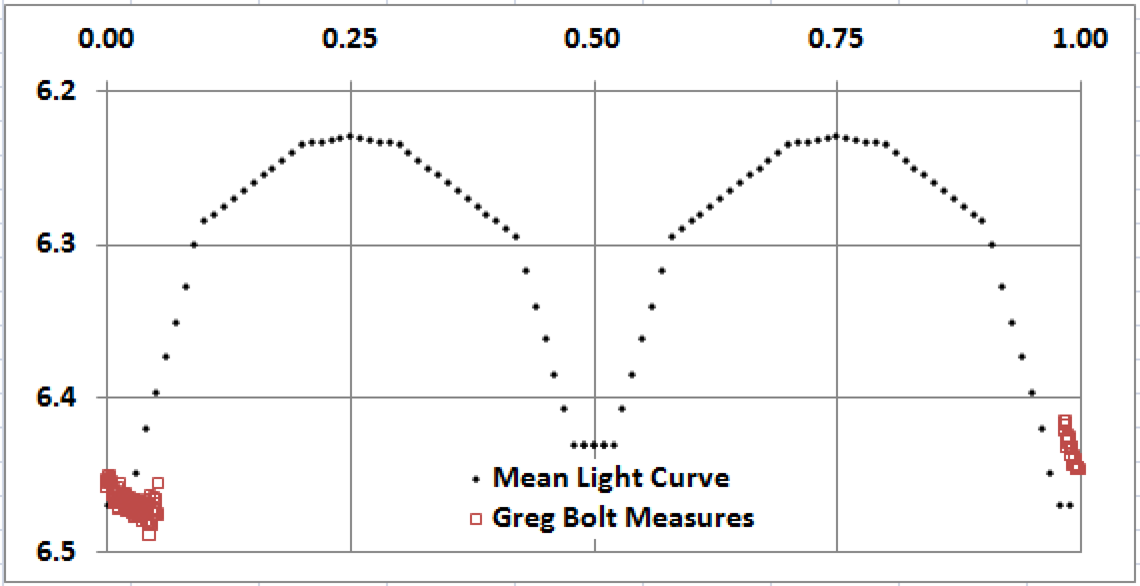
The measures made during 1971 and 1972 are shown fitted to a mean light curve as constructed by Leung et all from those measures. The amplitude is quite low at 0.24 or 240 millimagnitudes and the stars themselves are active – strong stellar winds, mass loss, perhaps interactions, possible ellipticity of the non-eclipsing orbit, so much of the scatter is real. The plot points are ~10 millimags in size.

PARAMETERS OF THE SYSTEM



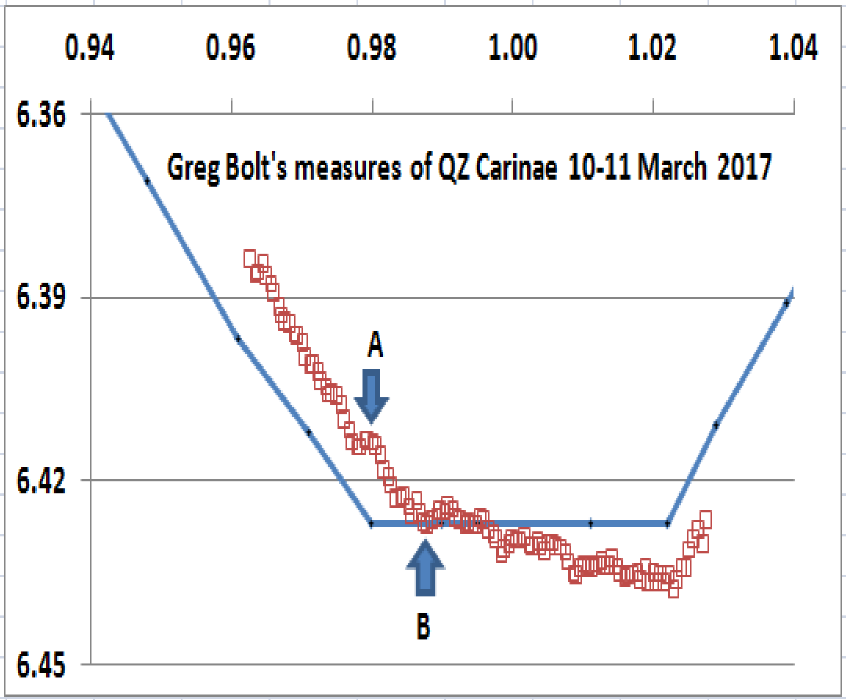
The graph above is based on the conclusions of our paper in 2017. The orbits are not to scale as this would be impossible to show but approximate sizes of the stars, with their temperatures denoted by colour, are shown . Some figures are questionable or unknown. Total mass estimated at ~112 solar.

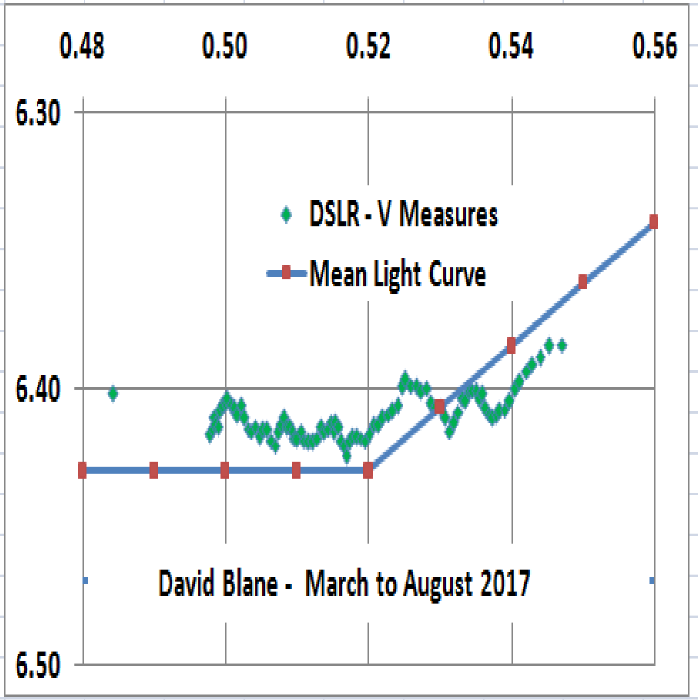
FITTING OBSERVATIONS TO MLC



The .orbital periods of each pair are simple to determine but the orbits of each of these pairs around the other is not as easy. So we turn to light time effects to do this. The seasonal epoch of the eclipsing pair serves as our marker. Here we show measures in 2017 by Greg Bolt of Perth in which mid-eclipse is occurring 0.1796 days, or 4.31 hours, too late. MLC by Leung et al.

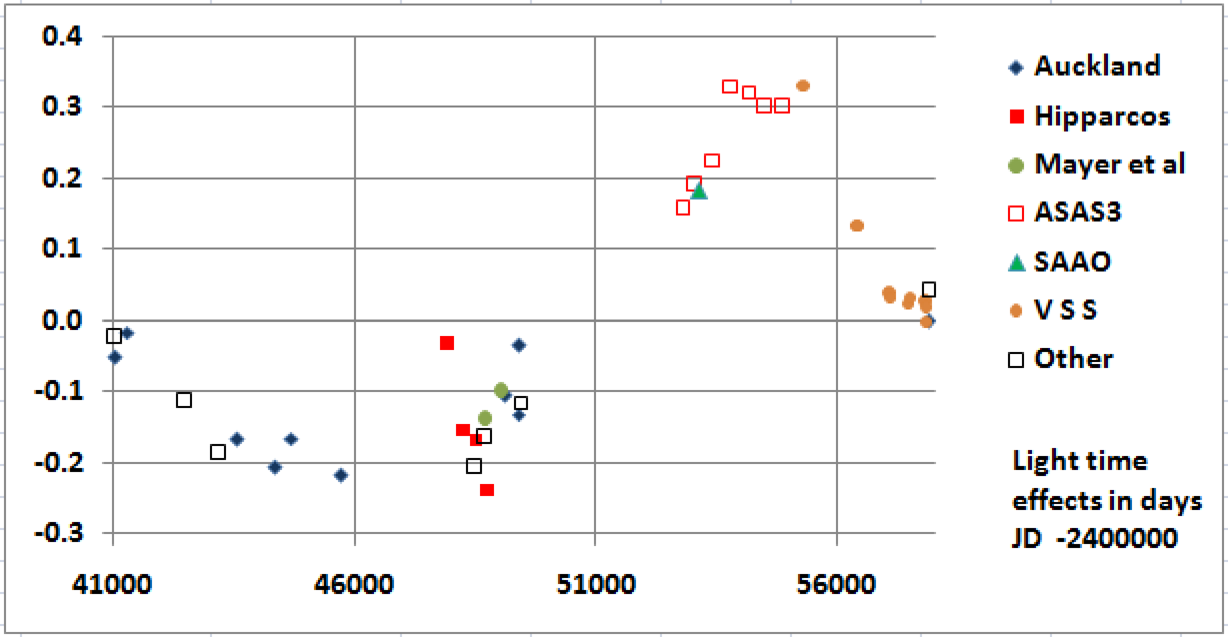
DETERMING CONTACTS OF ECLIPSE





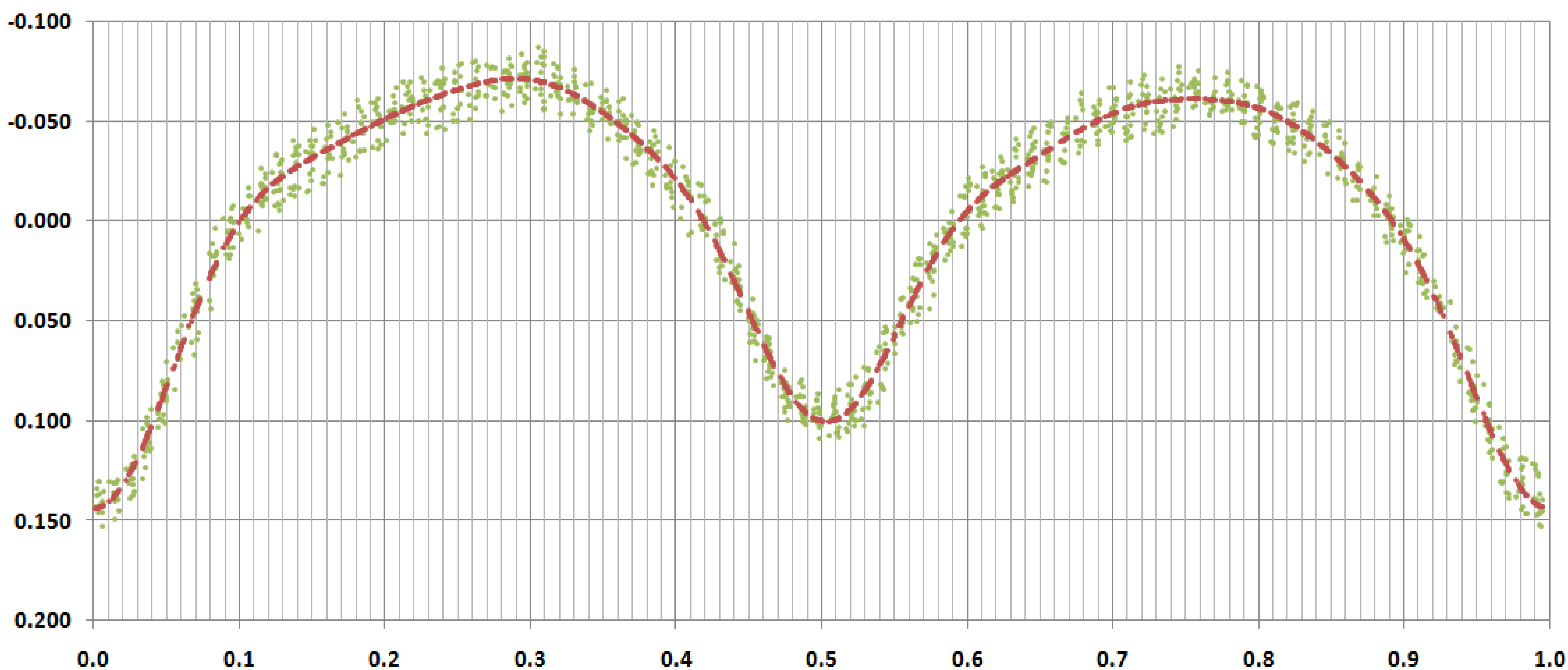
This same light curve is examined in more detail against the same MLC but corrected for the LTE. We are searching for the second and third contact points – the start and finish of totality – which helps in determining the size of the stars, as do the less easily observed first and fourth contacts, the beginning and end of the partial phases. But which of A or B is the second contact point? Dave Blane's measures from South Africa reveal erratic behaviour near third contact.

THE O-C DIAGRAM OF 2017



So let's put all of this together. The first information we derive is that the orbital period of the eclipsing pair is clearly affected by the amplitude of the light time effects, about 13 hours. So it's clear that we are using a tentative period which cannot be confirmed until more than one system orbit has been completed and the curve begins to repeat. But it's clearly at least 17,000 days or 46.5 years. A critical point is defined by the ASAS3 measures, which suffer from a degree of saturation, and three points in 2009, 2010 and 2013 by Terry Bohlsen.

BRITE TO THE RESCUE

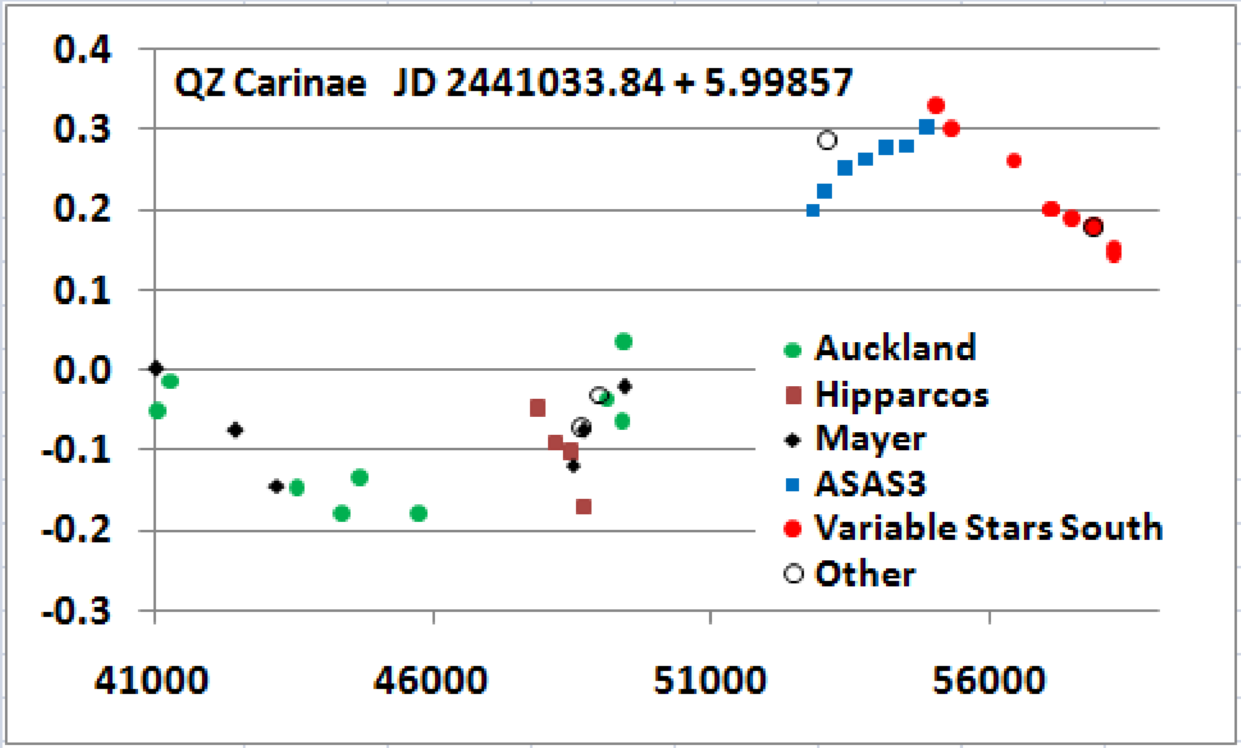


These measures were made by the BRITE-Heweliusz (BHr) satellite in 2017 and supplied to us by Andrzej Pigulski and the BRITE-Constellation Executive Science Team. They were made using a non-standard broad band red filter and each of the green points is the mean of all observations in one satellite orbit. An 8 harmonic Fourier fit to the measures was then translated into 100 points to make a MLC of a full orbit of the eclipsing pair. The fit obscures the totality of eclipses and this was adjusted (not here), as well as stretching the amplitude to fit the V light curve range.

BRITE-Heweliusz (BHr)

One of six nanosatellites launched as part of the Bright-star Target Explorer (BRITE) programme.

THE NEW O-C OF 2018



We have reworked all the observed epochs using the new MLC. They fall into two categories – PEP measures and CCD and it's not clear which values for comparisons were used. So some scaling is required. More about this problem in the next two slides. But the critical region of the early 2000s is now much smoother and more acceptable.

DISPARATE COMPARISON MAGNITUDES

Think about the scene in 1971 when these measures began.

- PEP since about 1954
- UBVRI system about the same time
- Hardie's articles on transformation in early 1960s
- No Internet
- Best available catalogue was Royal Observatory Bulletin of 1964
- E Region values since early 1980s was well in the future.

All of the Auckland measures have used the older ROB comparison values which now appear to be 0.043 too faint in V. So this has been corrected. But we have no idea what others were using and whether they have been consistent.

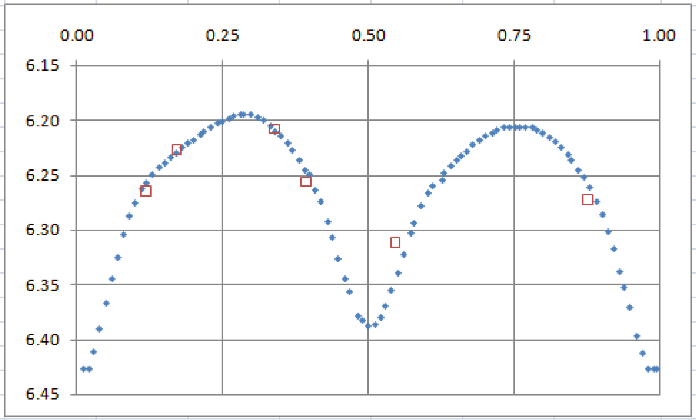
So we have a situation where random measures made only during ingress or egress are critically dependent upon the magnitude being correct. The classical method of observing totality is difficult due to its duration and the low eclipse amplitude.

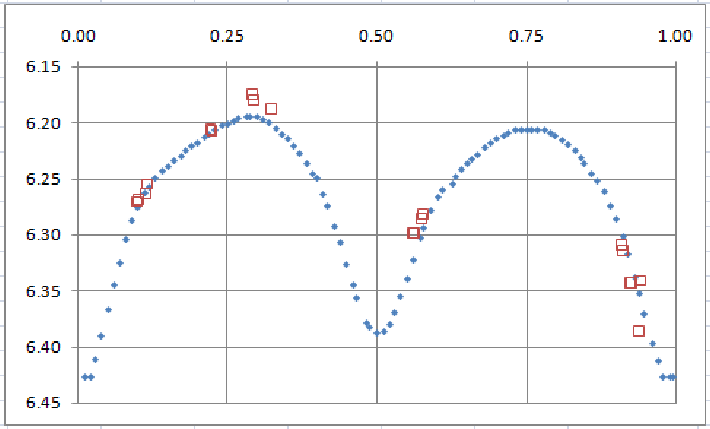
THE NEED FOR CONSISTENCY

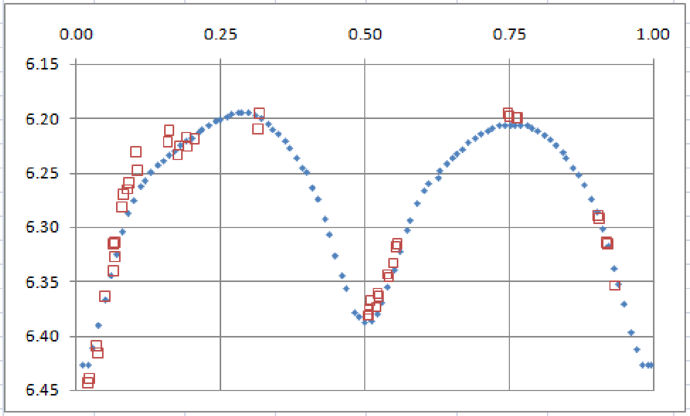
This problem still exists. There are now many catalogues in existence, many just accumulations of assorted magnitudes and colours from various published papers. Often they are prepared for a specific purpose, such as APASS which is primarily designed to provide good comparison values for visual observers. Magnitudes are published, with errors in most cases. For fitting observations to a mean light curve to determine an epoch of sufficient quality to be used in a high precision O-C diagram to allow derivation of orbital parameters they are not suitable . Mark has determined the following values by using multiple measures against E Regions and we hope observers will use these to achieve accurate results.

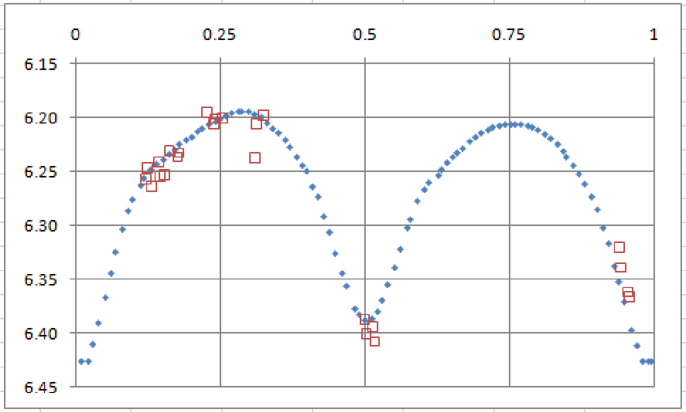
Star	Identity	R A	Dec	V	B-V	V-R	V-I
AUK A	HD 93131	10h44m31.840s	-60°12'23.54"	6.448	-0.011	0.119	0.234
AUK C	HD 93695	10h48m24.633s	-59°57'52.44"	6.427	-0.121	-0.048	-0.092
CCD 1	HD 93191	10h44m27.532s	-59°53'05.41"	8.537	-0.004	0.000	-0.072
CCD 2	HD 305523	10h45m09.241s	-60°02'37.99"	8.543	0.185	0.167	0.382
CCD 3	HD 93222	10h45m15.964s	-60°10'48.79"	8.119	0.094	0.120	0.266
CCD 4	HD 93028	10h43m54.777s	-60°17'23.43"	8.375	-0.019	0.039	0.065
DSLR 2	HD 93403	10h46m24.388s	-59°29'48.64"	7.265	0.234	0.198	0.435
DSLR 5	HD 92741	10h41m51.592s	-60°03'43.10"	7.241	-0.008	0.014	0.031
DSLR 6	HD 93843	10h49m18.064s	-60°18'47.49"	7.311	-0.021	0.043	0.098
DSLR 7	HD 93683	10h48m18.800s	-60°42'25.00"	7.889	0.128	0.161	0.373

A FEW EXAMPLES OF FITTING



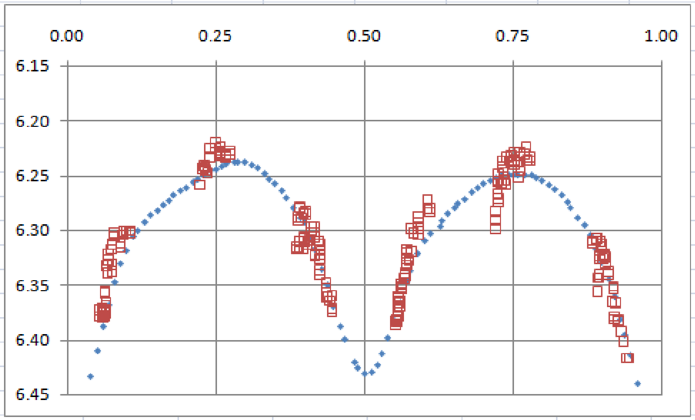


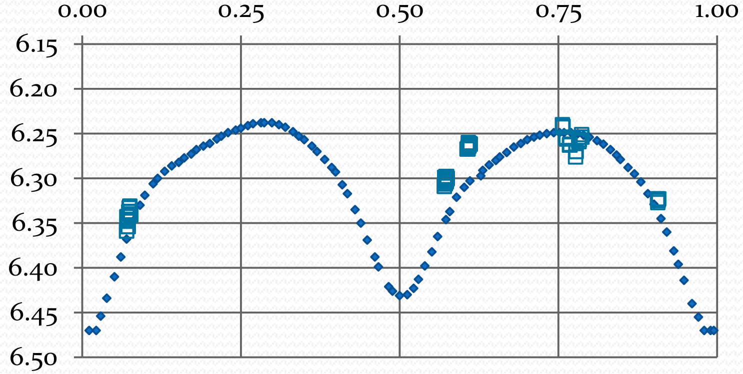


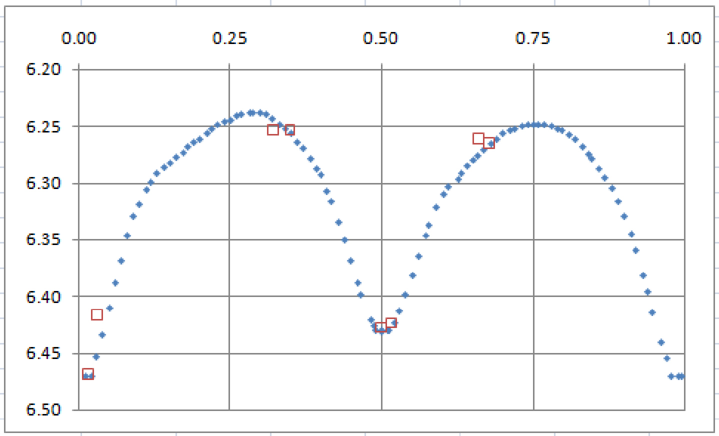


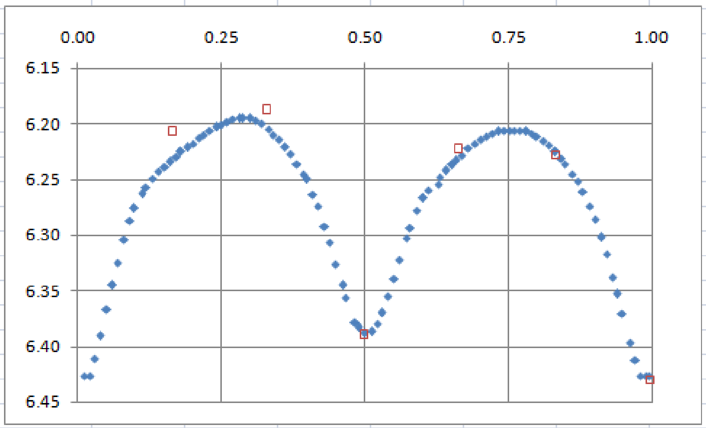
These four images are from Hipparcos measures in 1990 to 1992. A correction of 0.45 magnitudes was applied to the measures to match the MLC. The scatter at times is larger than quoted by them.

MORE EXAMPLES OF FITTING



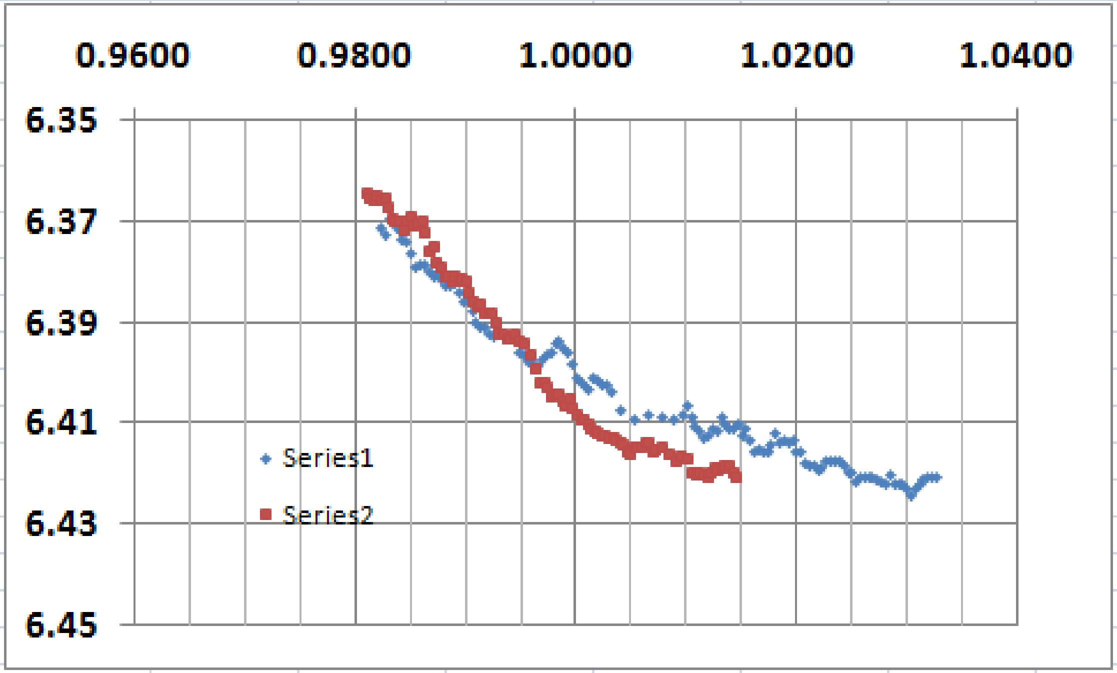






The top two show a mix of good and bad measures, the lower two show good fits of data which has been compressed by averaging blocks near the same phase. The last image makes us wonder at the regularity of the non-eclipsed peak magnitude.

ECLIPSES IN 2018



Returning to the eclipse duration this is the best area for CCD and DSLR observers in 2018. We need to be certain of its duration in order to put all of the derived epochs onto the same basis. Mark has observed second contact on two occasions in 2018 but we have nothing as yet on third contact. One thing which is noted from these detailed measures of the eclipse is the slope of about 15 millimagnitudes over six hours – also some activity at times around these two points which makes precise determinations difficult.

THE MESSAGES OF THESE IMAGES

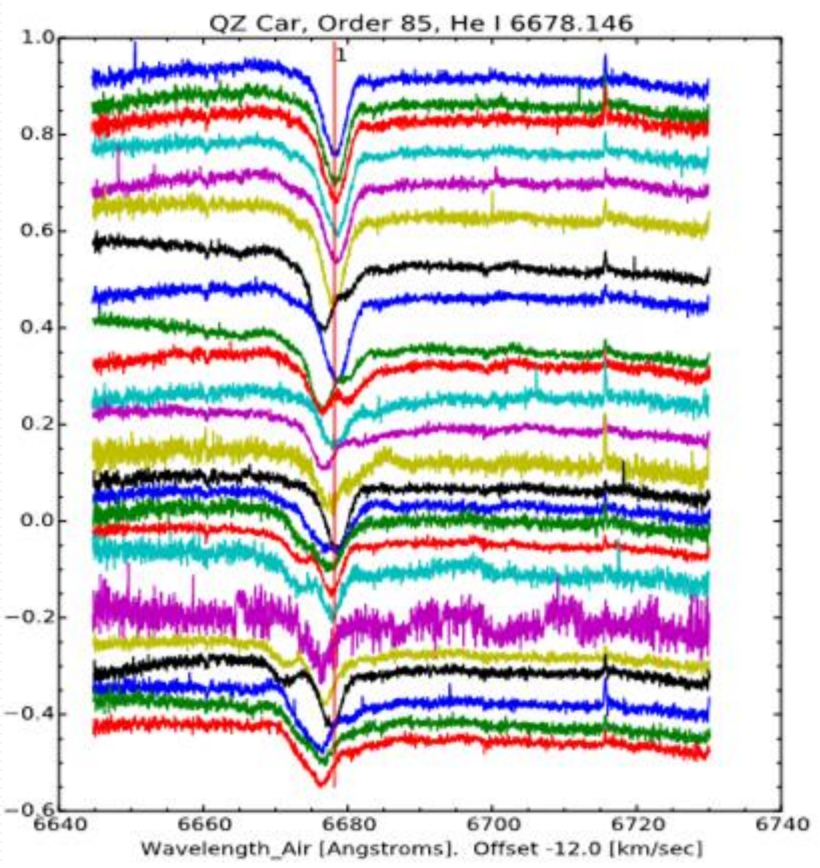
We mentioned earlier that these are very active stars. Is there other information to be found there? One concept is that the eccentricity of the more massive longer period system might leave a signature in the observations if the light curve of the eclipsing pair were to be subtracted. Previously there have not been enough measures to test this idea but with the volume of BRITE measures this may now be feasible. An analysis project for later this year.

The secondary eclipse seems slightly displaced, but subject to the primary eclipse duration which is still uncertain. This eclipse may be a little less than Leung et al's 0.04 phase

Unequal maxima and asymmetrical light curve need explanation.

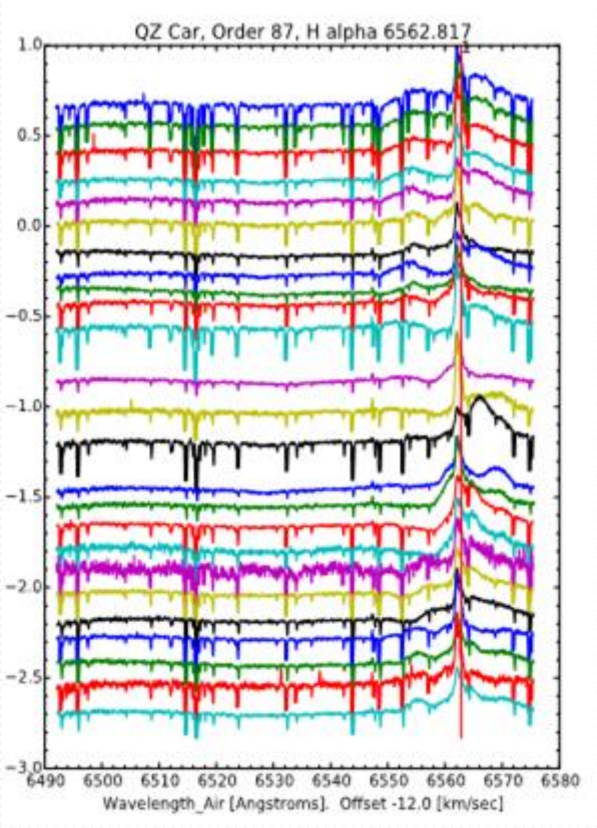
These measures and others have yet to be analysed in full due to the mean light curve being incomplete as the onset of the total stage of primary eclipse is uncertain and forms the primary target for 2018 measures.

SPECTRUM #1

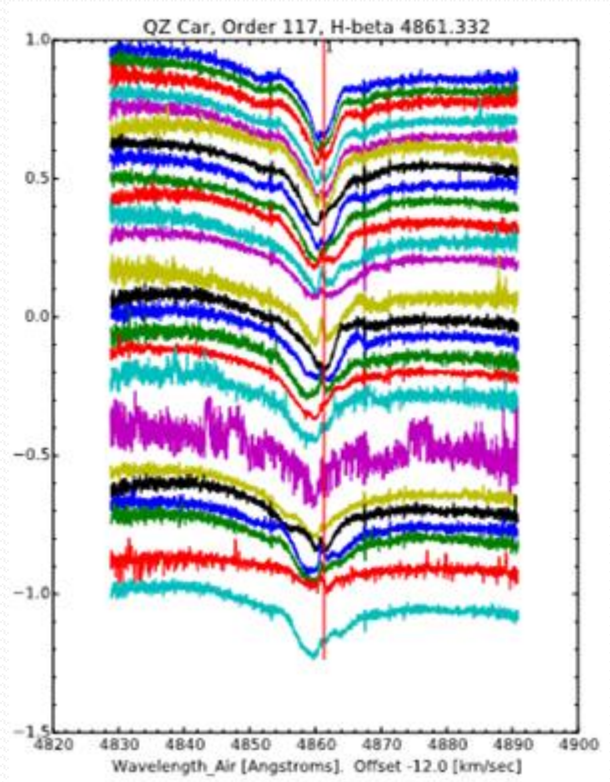


These spectra derived over a number of epochs observed at Mt John Observatory sow clearly various orbital RV measures, also variations in the strength and shape of the absorption lines.

MORE SPECTRA



Two selected sets of spectra at various epochs. Hydrogen alpha in emission on the left, beta in absorption on the right. Variations confirm that this system is very activ.



ACKNOWLEDGMENTS

We acknowledge substantial contributions to the material in this review from:

Greg Bolt in Perth who provided many observations during early 2017 which defined the primary eclipse and also other parts of the light curve.

Dave Blane in South Africa whose measures covered the end of the primary eclipse and the lower egress as well as numerous points on other parts of the light curve.

Terry Bohlsen in Queensland who provided images of his measures - 2009, 2010 and 2013 to allow revision to updated magnitudes and determination of three epochs at a critical part of the O-C diagram of the widely separated pairs.

Measures were made by the BRITE-Heweliusz (BHr) satellite in 2017 and supplied to us by Andrzej Pigulski and the BRITE-Constellation Executive Science Team.

University of Canterbury's HERCUKLES spectrograph at Mt John observatory, Tekapo, to obtain spectra over several seasons.

CONCLUSION

This project began in 1971 and is not yet concluded. But our understanding of the structure of this massive system of four stars has been significantly improved by the measures of 2017. We hope during this current season to define the shape and duration of the deepest part of the eclipses and remove any ambiguity from our mean light curve. This will allow an even more precise fitting of epochs to date.

It seems clear from the slopes of the declining curve of the O-C diagram that one orbit of the pairs around each other since discovery is as yet incomplete. This affects the true orbital period of the eclipsing period as well.

The BRITE measures have defined a mean light curve which is a better fit to other measures and thus the accuracy of the O-C curve is better.