The Changing Scene for Mira Star Observers

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ABSTRACT

We summarise the present state of Mira star research conducted by amateurs for more than a century. Various types of period change are illustrated and the physical nature discussed. We then suggest further observational ideas based upon the use of colour photometry with BVRI filters and CCD cameras, perhaps supplemented by spectroscopic radial velocity measures from amateur astronomers using the more sensitive equipment now generally available.

INTRODUCTION

Why Miras were attractive to amateur observing groups:

- Large amplitude means high accuracy not essential
- Long periods suit observers restricted by weather, other duties
- The field was relatively new and unexplored
- No complex or expensive equipment was required

These were the primary targets of groups such as the RASNZ VSS, BAA, AAVSO and many others. But after a century or more things have changed – we live in a world of personal computers, the Internet and almost unlimited astronomical information, instant communication, and so on.

So how do we attract new visual observers to maintain the long term record of what Mira stars are doing?

And if these measures by visual observers are no longer needed what stars are suitable for visual observers?

VARIABLE STARS SOUTH

Variable Stars South has changed from the old RASNZ VSS

- Our projects have a goal achievable in a reasonably short time
- We encourage analysis and understanding of the measures
- We encourage the publication of papers

In short, we follow the guidelines espoused by Ron McIntosh, an Auckland planetary observer who was instrumental in setting up the Auckland Observatory:

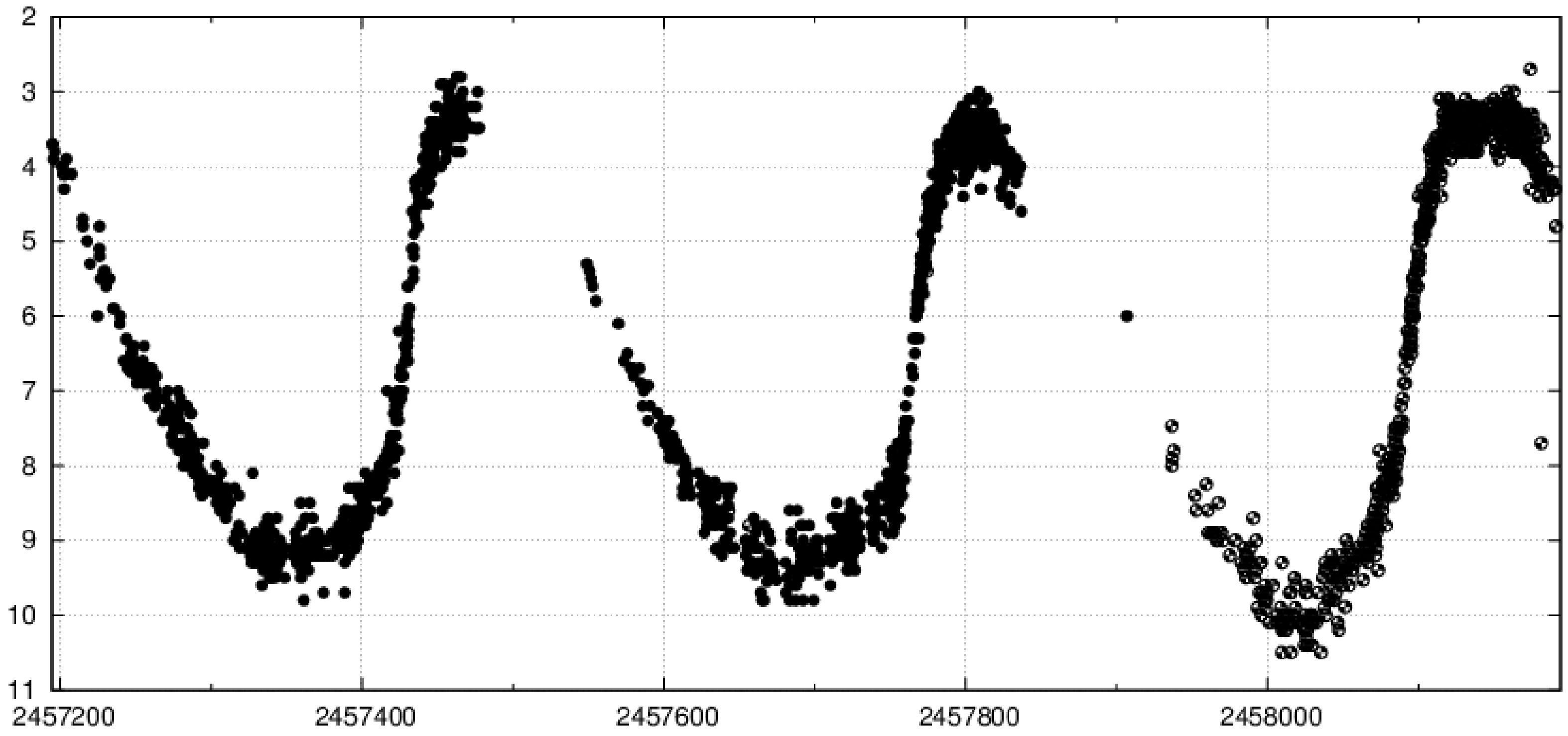
- Observe, record, publish

But in the Mira star field we are striking problems and need help and advice. The questions are:

- What can our visual observers usefully do, given the above guidelines?
- Our members do colour photometry and simple but good spectroscopy – what areas in the wider LPV field can these be used in? And how?

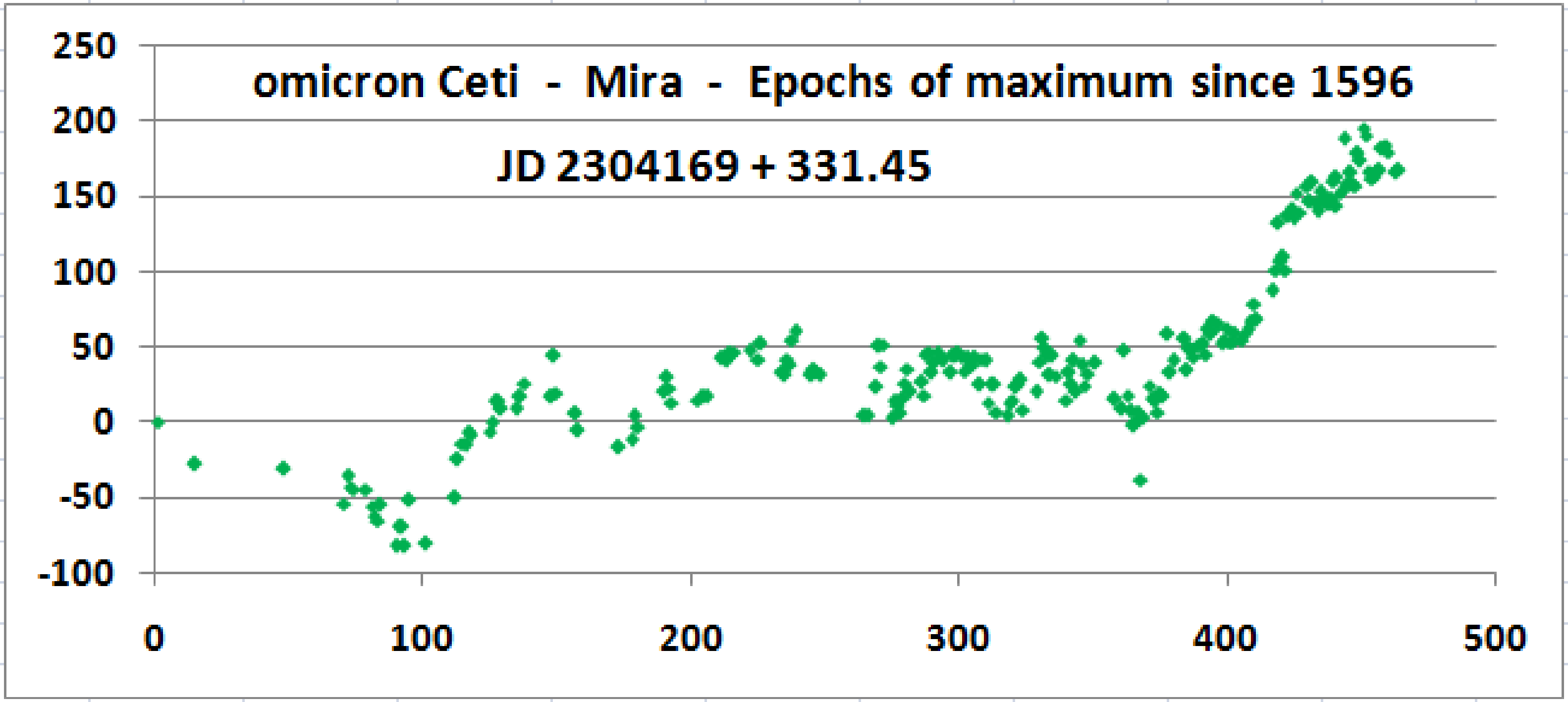
Without the light curves measured by visual observers other measures lose much of their value.

VISUAL LIGHT CURVE OF MIRA



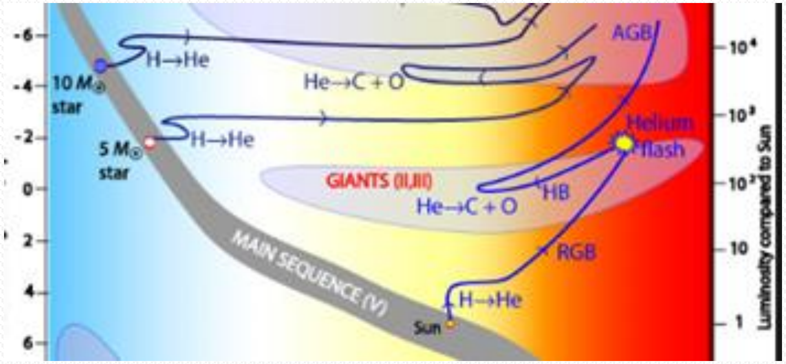
- Visual observations for 1000 days to 17 March – almost exactly 3 cycles
- Very popular star – wide scatter of measures
- Current maximum rather flat top – pulsations a little irregular

HISTORICAL MEASURES OF MIRA



This is an O-C diagram showing the observed epochs (dates) of maximum brightness of omicron Ceti as they differ from the calculated dates of the ephemeris. Late is positive on the vertical scale, early is negative. The horizontal scale shows cycles since 1596. There is a clear change in period about cycle 368 in 1929. The period since then is ~333.5 days. Why the change?

WHAT IS A MIRA STAR?



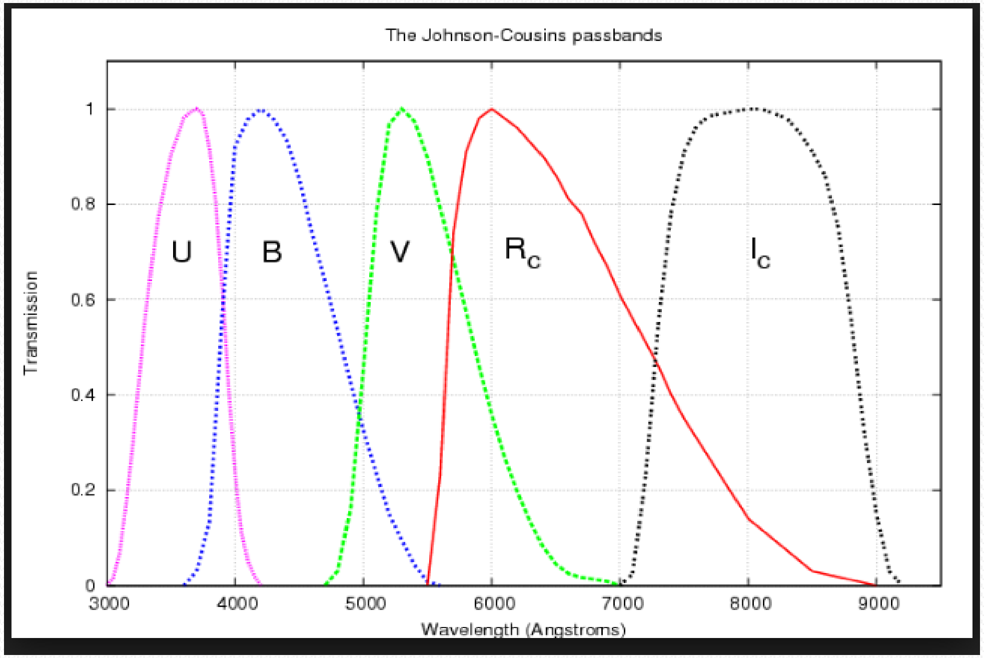
These stars initially had main sequence masses of between 2 and 7 solar. Much of this has been lost during the red giant branch expansion – now they are evolving up the asymptotic giant branch, AGB, and still losing mass.

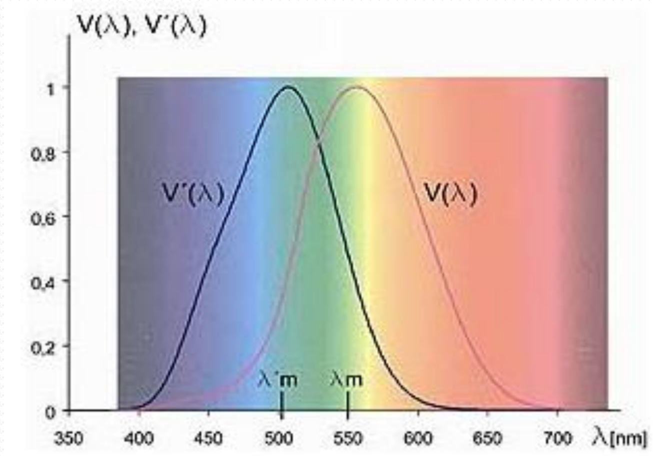
Miras appear to be deriving energy from the fusion of helium in the core and fusion of hydrogen somewhat further out from the core in a radiative shell. This is all surrounded by a convective zone

. Dependent upon the initial main sequence mass the overall evolution is measured in billions of years. So we must use the same techniques as for the Hertzsprung-Russell diagram. These involved mass, luminosity and temperature and compiling a plot from which evolutionary tracks and age could be determined purely by where stars are found in the diagram.

For Miras such an evolutionary history is reconstructed using mass loss rates and positions on the H-R diagram which show luminosity and temperature. Radius and other measurements are derived from all of this.

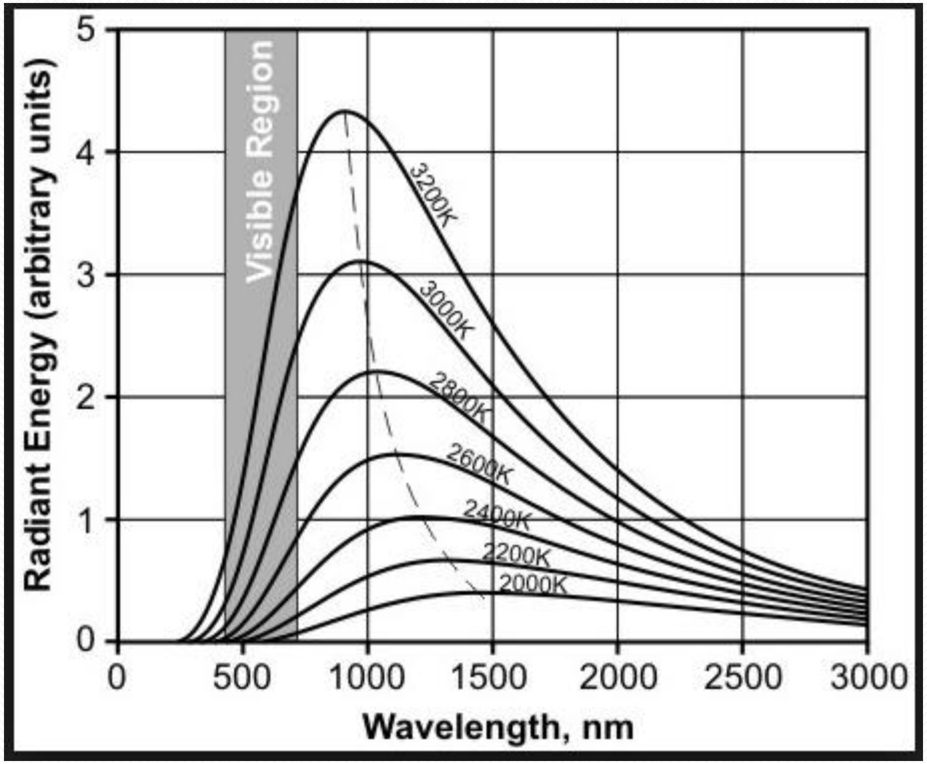
THE DETECTORS WE USE





The upper graph shows the wavelength s we can examine using various filters. The lower graph shows the average eye response to the same horizontal scale . The right hand curve is in normal light, the left shows a completely dark-adapted eye.

A REALITY CHECK



Are these observed values real? Why is there such a large range through different filters?

Miras are cool stars with temperature around 3000K. But amateurs are working in a narrow range of wavelengths .BVR filter s cover the visual range with U picking up the UV radiation from gas around the star, I looking at radiation from hot dust shells.

Some amateurs are using JH filters with wavelengths of ~1220 nm and 1630 nm but the photometers are quite slow and crude as compared to CCD equipment.

MIRA PERIOD CHANGES

The observed pulsations are similar to Cepheids but involve the ionisation and recombination of hydrogen, not helium, and seem to be affected by the deep convective atmosphere. During its evolution up the AGB a Mira star seems to undergo five types of period change.

- Normal evolution up the AGB – not directly observable – increasing period
- Helium flashes in the helium burning regions – decreasing period? What happens next?
- Abrupt changes in period other than evolutionary – Mira itself
- Large increases in period over several decades – BH Crucis, LX Cygni.
- Period alternations of 1-3% over several decades – almost all Miras.

Do the helium flashes result in a saw toothed period cycle – in this case we might observe a faster increase in period than expected How do we find out?

EVOLUTIONARY TIME SCALES

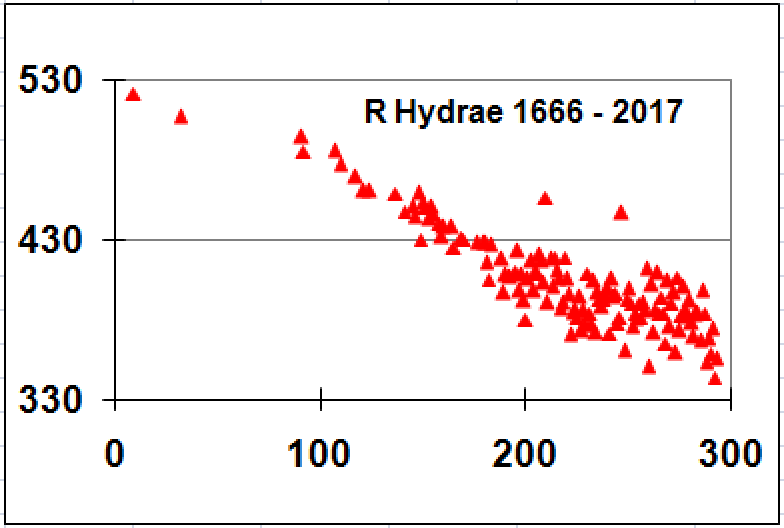
We cannot observe events which take place so slowly so must reconstruct event sequences as in the H-R diagram

Blocker, 1995, studied mass loss and its effect on times of events;

- Initial masses vary from 1 to 7 solar masses – more massive objects evolve faster – mass ^3.5~
- Evolutionary times on AGB from 1 x 10^6 to 5 x 10^7
- Thermal pulses occur during an interval of 4 x 10^4 years to 3 x 10^6
- Numbers of pulses range from 5 to 80
- Intervals between pulses range from 2,630 years to 95,000 years

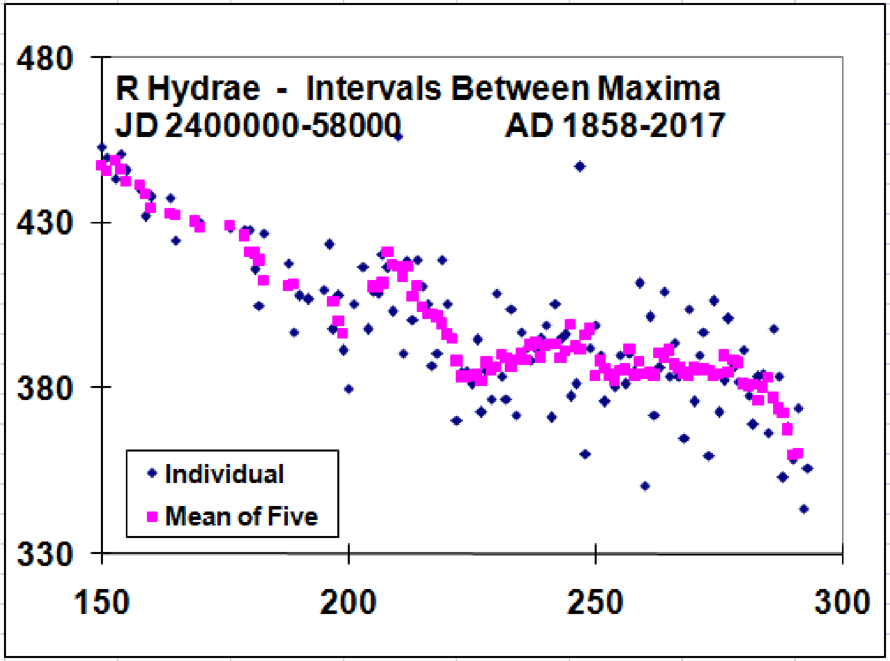
These times may vary widely dependent upon a number of factors but illustrate one main point – nothing happens very quickly. But let's look at the effects of some of these events.

THE HELIUM FLASH EVENT



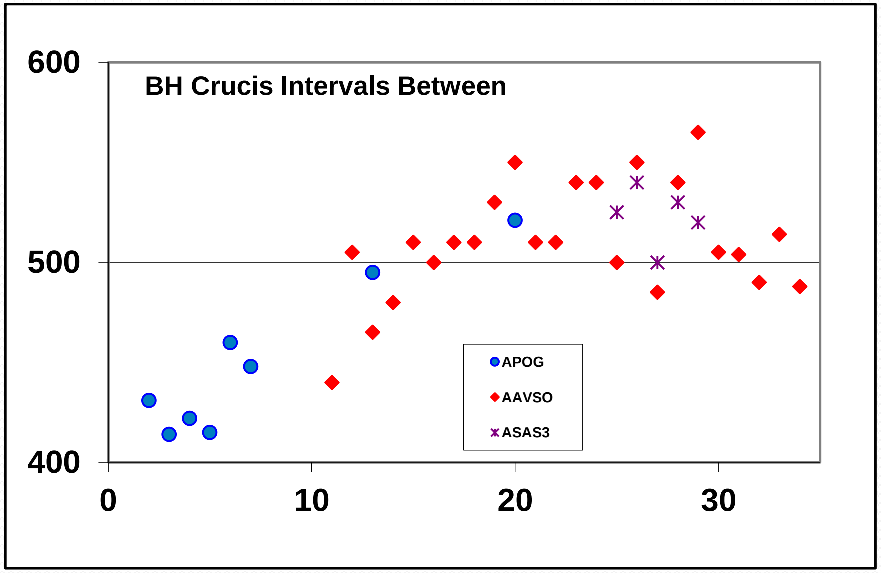
R Hydrae is probably the only star where we have measures over the complete helium flash or thermal pulse – but it is not entirely certain that the period decline is complete – the more detailed graph below shows a renewed decline since 2003

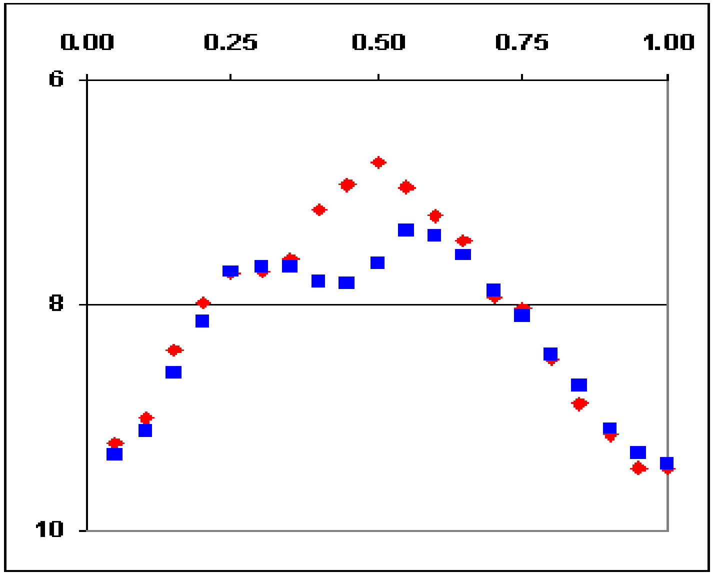
The above graph shows individual epochs from 1666 to 2017. At the right we show epochs over the last 159 years of that interval where the period changed from a steady decline to alternating. But is the period still becoming shorter?



THE THIRD DREDGE UP?

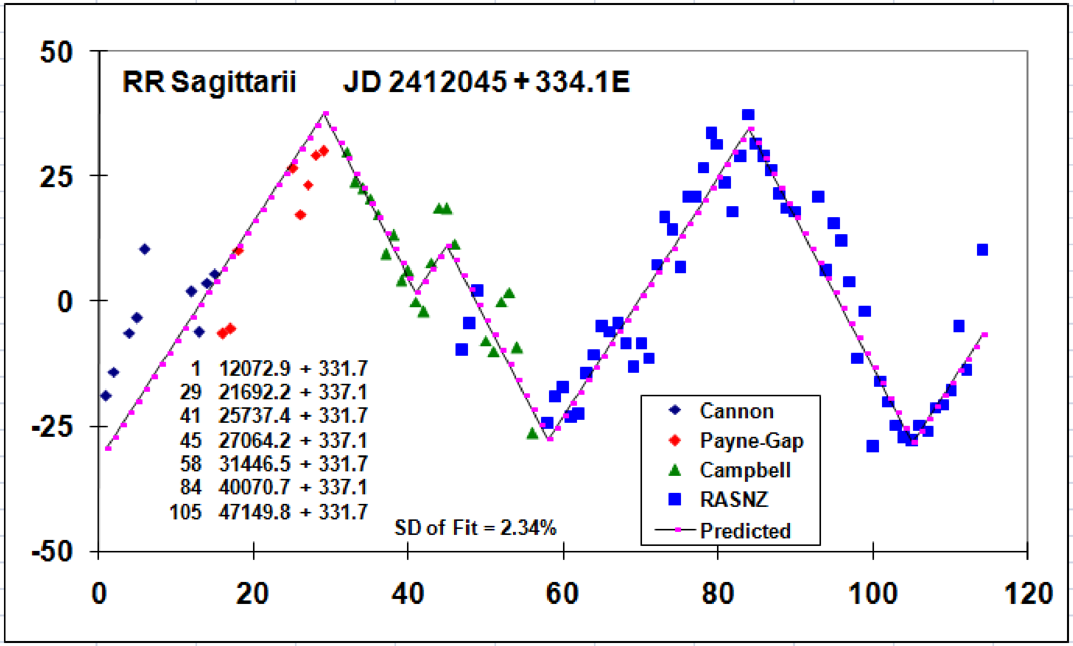
In recent years two Mira stars have shown a different type of period change BH Crucis and LX Cygni. This event has lasted only decades and the period has increased rather than decreasing. This is shown for BH Crucis in the left graph. Due to spectral changes it is possible that it is a by-product of the helium flash.





During this interval BH Crucis brightened although the B-V colour reddened indicating a cooler surface and consequently a considerably larger star. The visual measures are shown at the left. BH Crucis was measured in UBV at Auckland since its discovery until 2000 and then by di Scala. There are no such measures of the northern hemisphere star LX Cygni.

PERIOD ALTERNATIONS



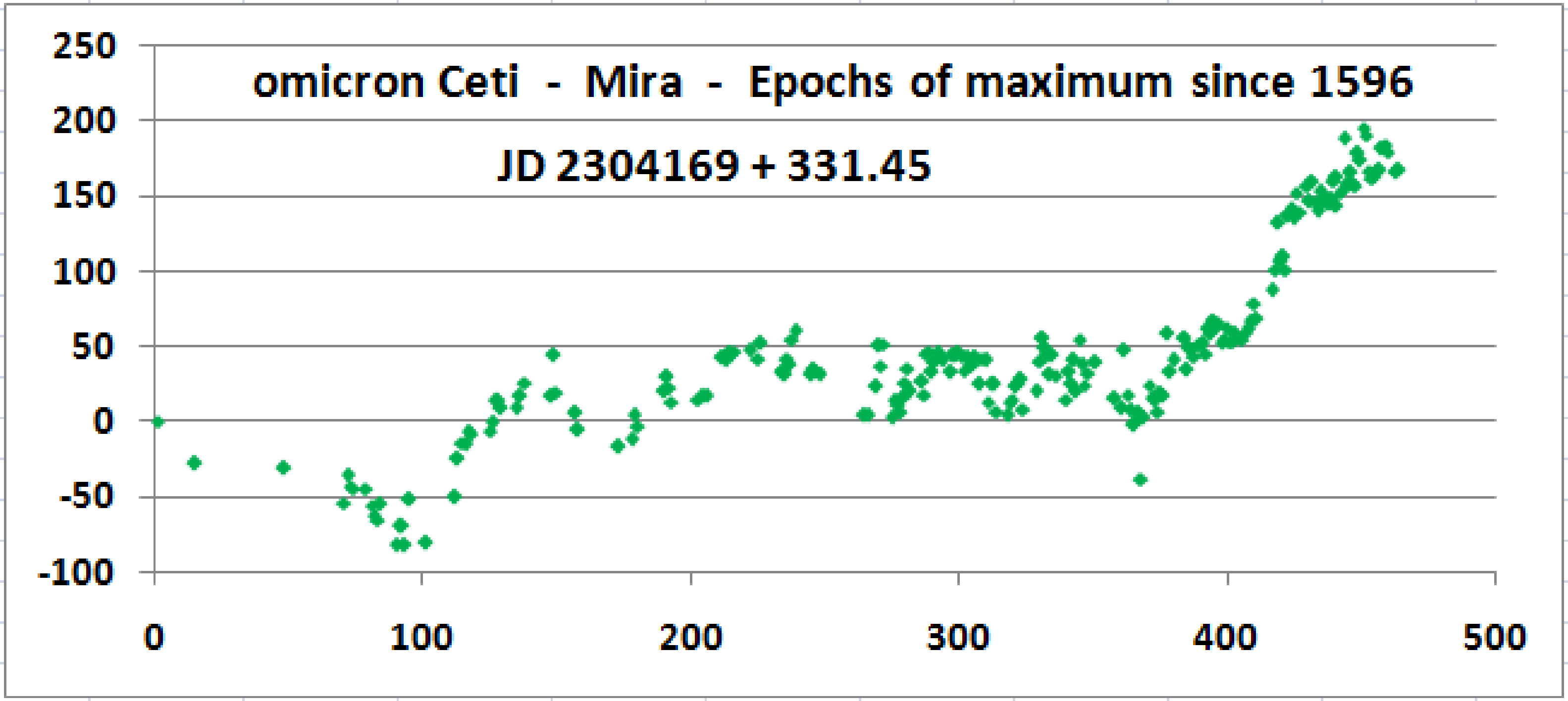
It has been realised for more than half a century that the periods are inconsistent. In 1995 we analysed 88 stars observed by the RASNZ and drew up graphs similar to this.

The periods alternate by 1-3% around a mean with occasional reversions.

The divergences seem to be limited – in this case to ~12% of the basic period.

Why do these occur? Some analyses favour the presence of a variety of periods, others effects of the convective envelope. The latter idea is supported by the fact that longer period Cepheids with convective envelopes also show these period alternations.

ABRUPT CHANGES



The prototype Mira star – omicron Ceti – shows a good example of an abrupt period change. Not large, but still real. There are also indications of period alternations but for reasons mentioned earlier the light curves are not as good as with many other Miras.

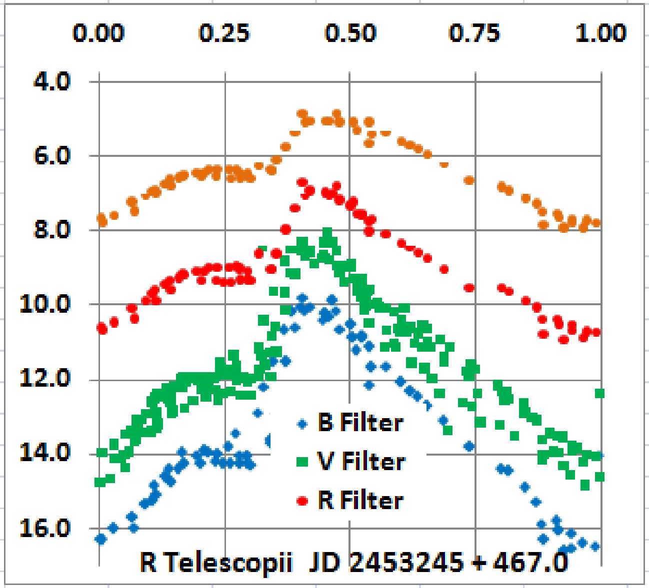
THE AMATEUR SCENE NOW

When I began observing variable stars in 1967 these were the primary targets . But in 2018 the scene is different.

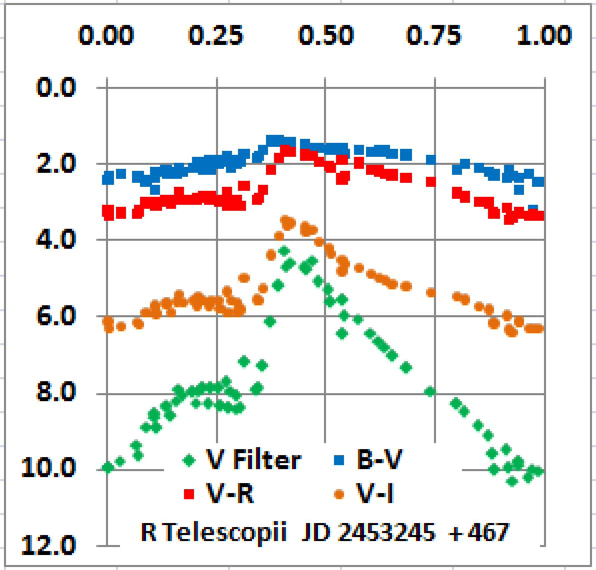
- Fewer visual observers, mostly elderly with few new observers
- CCD measures using BVRI filters
- Measures concentrated on a smaller number of objects
- Has time series photometry run its course in this field?
- Should the visual observer now follow the CV field and become more of an early warning device?

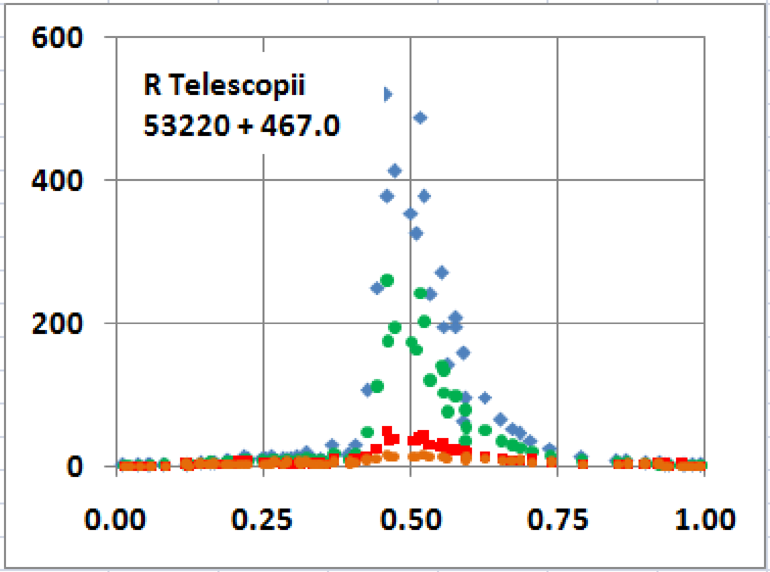
We mention some interesting research avenues shortly but let’s look at some BVRI examples first.

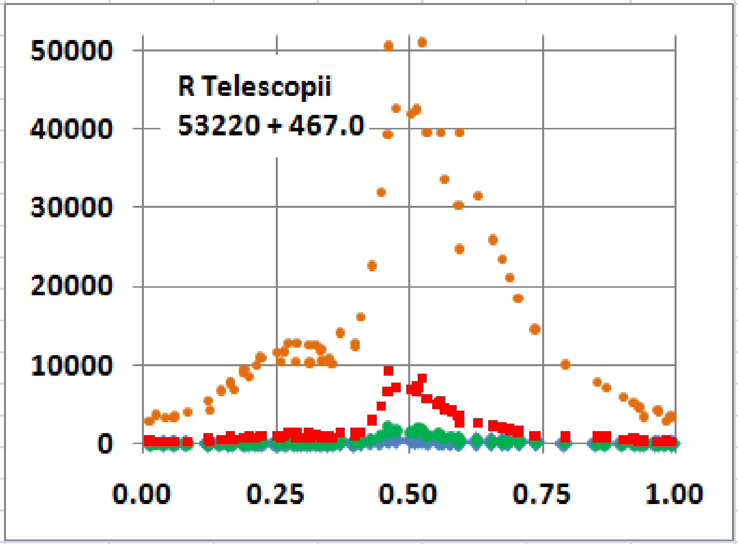
R TELESCOPII



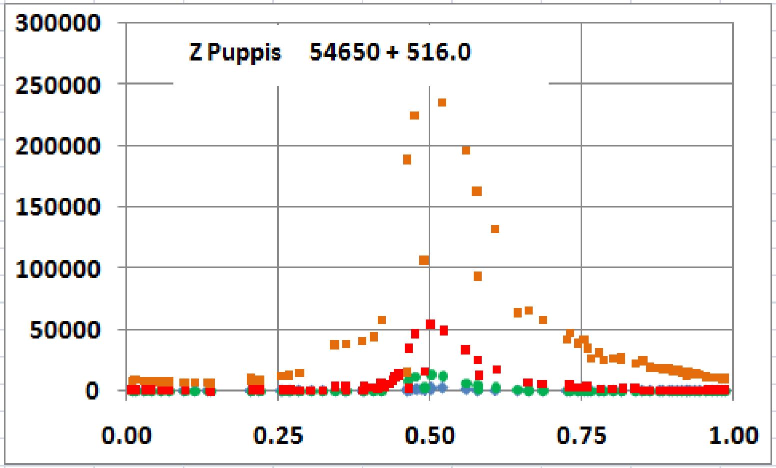
- Filter colours
- V, B-V, V-R, R-I
- Intensities by filters
- Intensities as against minimum B

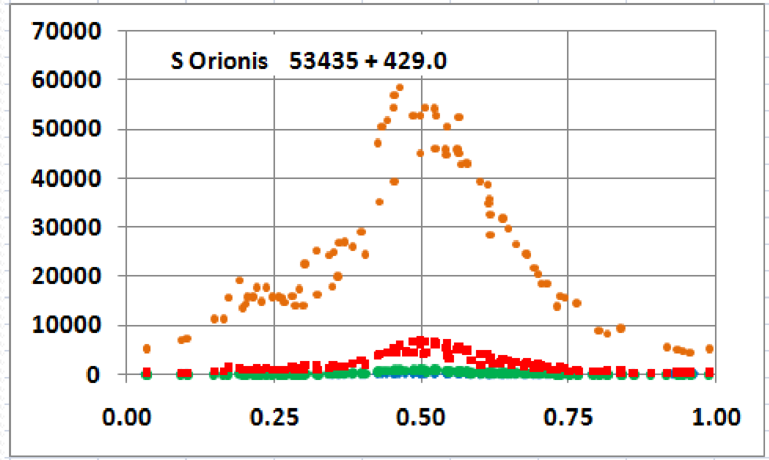


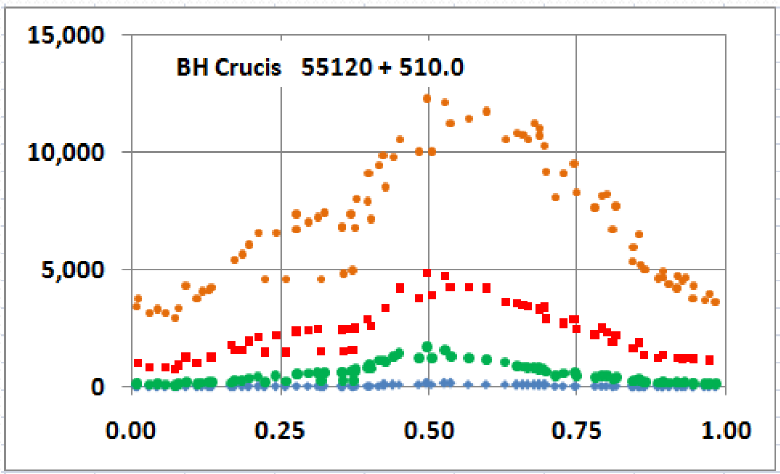


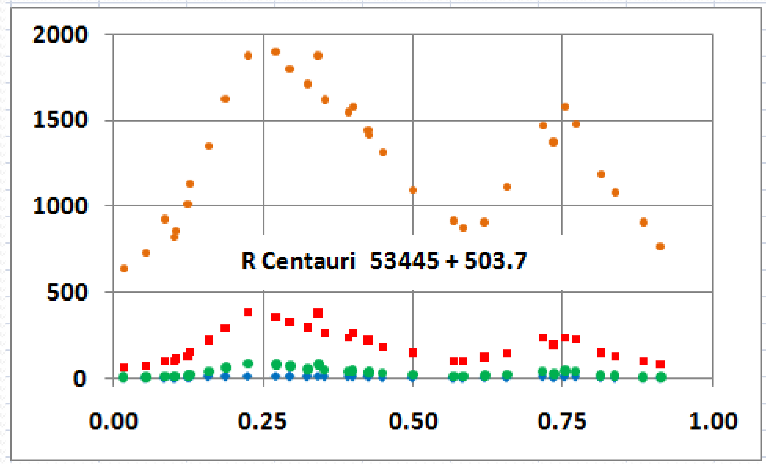


SEVERAL OTHER EXAMPLES









The Mira stars show here are Z Puppis, S Orionis, BH Crucis and R Centauri, the first with normal spectra, BH Crucis with SC and R Centauri, with dual maxima.

MIRA COLOUR PHOTOMETRY

The examples shown here indicate that amateurs can achieve good accuracy in BVRI measures of LPV stars. But which ones should be targeted and why? Stars near the end of the AGB with longer periods may be useful candidates. But T Leo Minoris shows that some shorter period stars may be interesting. Some thoughts:

- Some Miras show humps and bumps on light curves or dual maxima
- These seem to be better candidates for period changes
- Measure B and V with DSLR cameras to study temperatures
- CCD cameras can do BVRI – and U with patience if necessary.
- These stars are bright in J and H but the amplitudes are low. The cameras are sequential – star, sky, comparison, check – not simultaneous measures

Leave the standard TSP period change monitoring to the visual observers. Success rate ~1-5% perhaps, per century – not all that exciting. Also, period changes are not usually detected for many decades – we must try to foresee which ones are most likely to do this.

WE NEED SOME GUIDANCE

Variable Stars South measures are usually on projects where we can expect an observational paper on a reasonable time scale. In most areas this has been achieved but not so much with long period pulsating variables.

One possible area involves alternating periods – are there associated colour changes?

R Centauri, which will be discussed at the forthcoming symposium, is a dual maximum Mira star which apart from an ongoing reduction in the period shows other interesting changes. With this star and BH Crucis as examples useful targets would include R Normae, V415 Velorum, TT Centauri and a few others which have distorted light curves – flat or prolonged maxima, very pronounced humps and other features.

There may also be value in radial velocity measures of some stars with the increasing sensitivity of spectroscopic instruments in the amateur price range. BH Crucis and R Centauri both show features which would be usefully explored in this manner.

CONCLUSION

Quite clearly amateur measures of Miras and other cool, long period variable stars need some new goals. The decreasing number of visual observers has resulted in a decrease in coverage with some interesting stars not observed at all.

Amateurs have much greater access to accurate multi-colour instruments – CCD and DSLR cameras but have no clear picture of what can usefully be observed.

In particular, Variable Stars South needs guidance from one or two active professional astronomers. We are now actively seeking that but welcome suggestions from anyone with an interest in this field.