# R CENTAURI – AN INTERESTING & PERHAPS UNIQUE MIRA STAR

Stan Walker & Giorgio di Scala
Variable Stars South

# ABSTRACT

The first recorded maximum of R Centauri was in 1871 but reasonable coverage dates from only 1891. It displays two clear maxima, which characteristic is shared by less than a dozen others of the thousand or so well studied Mira stars. We present observations of the changing light curve shape and amplitudes with supplementary UBV and BVRI measures which appear to differ dramatically from other Miras. The pulsation period is also changing, believed to be the result of a helium flash, the onset of this period change in 1922 being perhaps the only one observed.

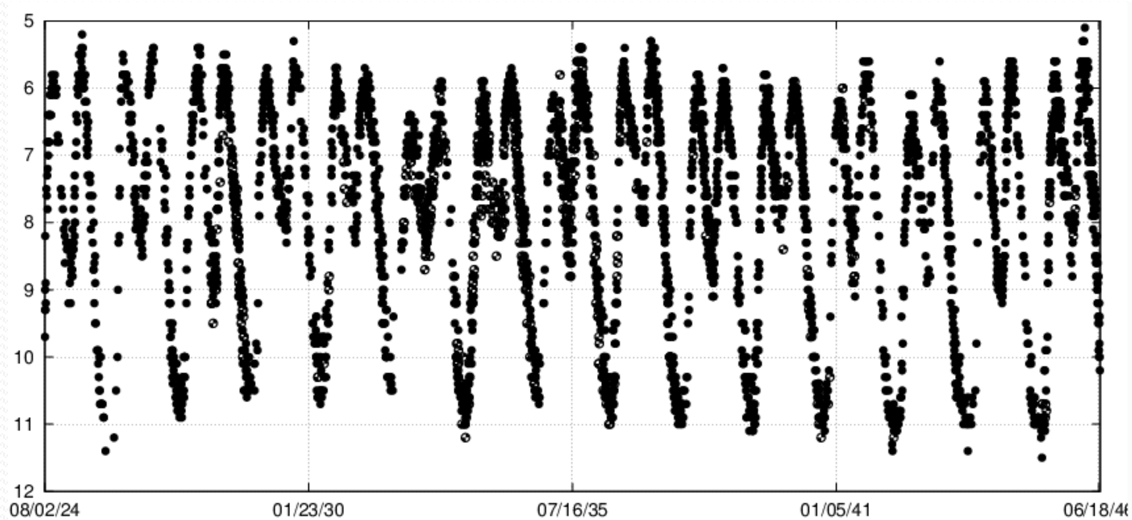
# INTRODUCTION

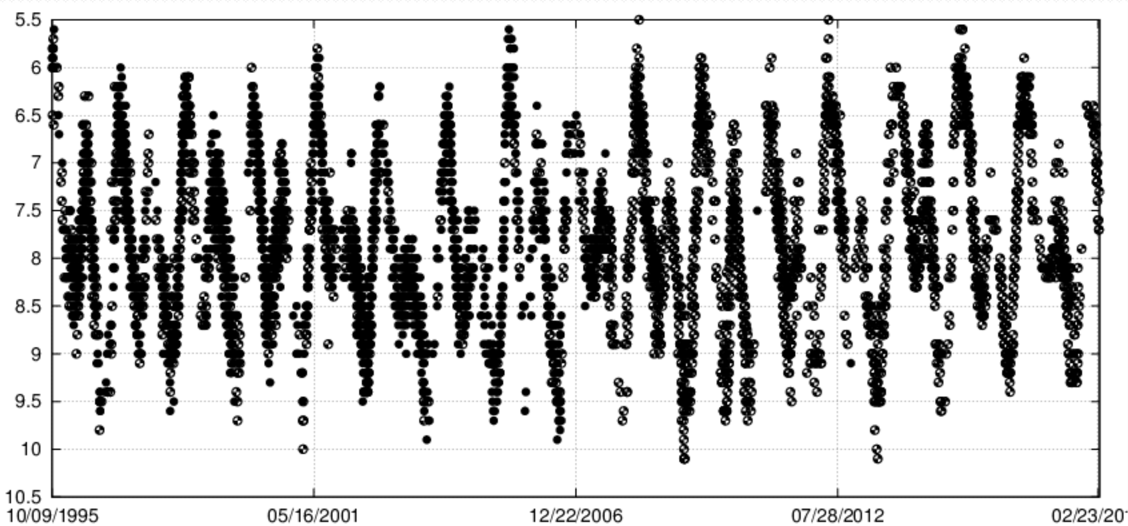
Mira stars have been the mainstay of amateur visual observing for well over a century. They have large amplitudes of up to ten magnitudes or so – an intensity change of 10,000 times – and their periods suit occasional measures at weekly or fortnightly intervals. The emphasis is on time series photometry and monitoring periods and a few period changes.

We can also divide the visual and near visual range into a series of wavelength blocks using filters – mainly UBVRI where the available measuring instruments are relatively inexpensive with an extension into the near infra-red using J and H filters with about 5% of the speed. K,L and M work in regions which require much more complex equipment than amateurs generally have access to.

But the vast majority of the historical data is in the visual and near-visual regions.

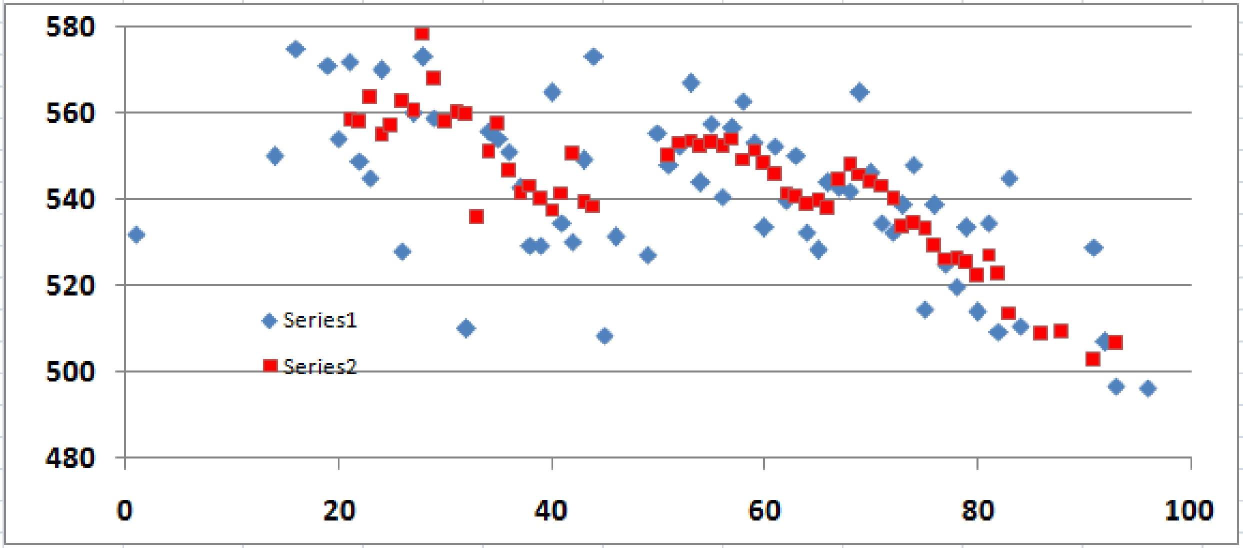
# THE LIGHT CURVE THEN & NOW

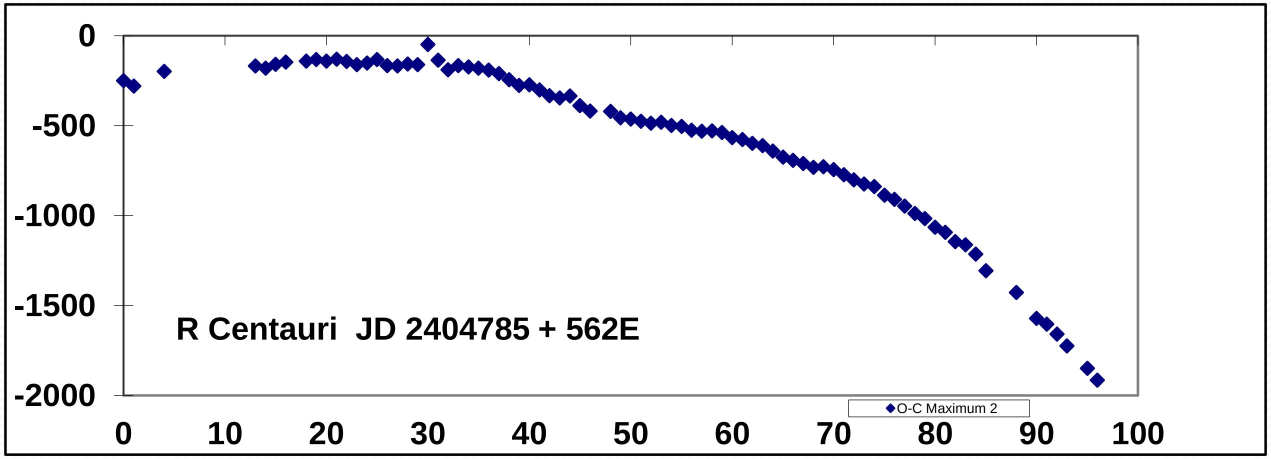



The upper graph shows the light curve from 1924 to 1945. Below from 1995 to 2018. During this period of 94 years the period changed by more than 10% and the overall shape of the light curve changed dramatically.

# CHANGES IN THE PERIOD




The upper graph shows individual intervals between epochs of primary maximum in blue, with a 5 point running mean superimposed in red.

The lower graph shows an O-C diagram – the cumulative deviations from an ephemeris describing the original period.

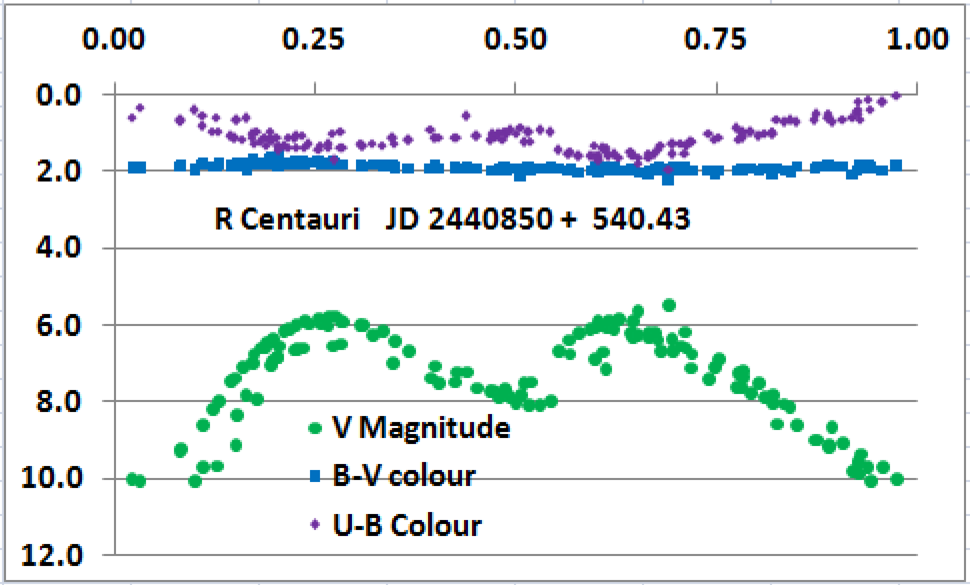
# WHY HAS THE PERIOD CHANGED?

During its evolution up the AGB a Mira star seems to undergo five types of period changes:

- Normal evolution up the AGB – not directly observable
- Helium flashes in the helium burning regions – decreasing period over two or three centuries?
- 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.

In this paper we concentrate on what appears to be a helium flash event in R Centauri.

# THE LIGHT CURVE IN THE 1970s



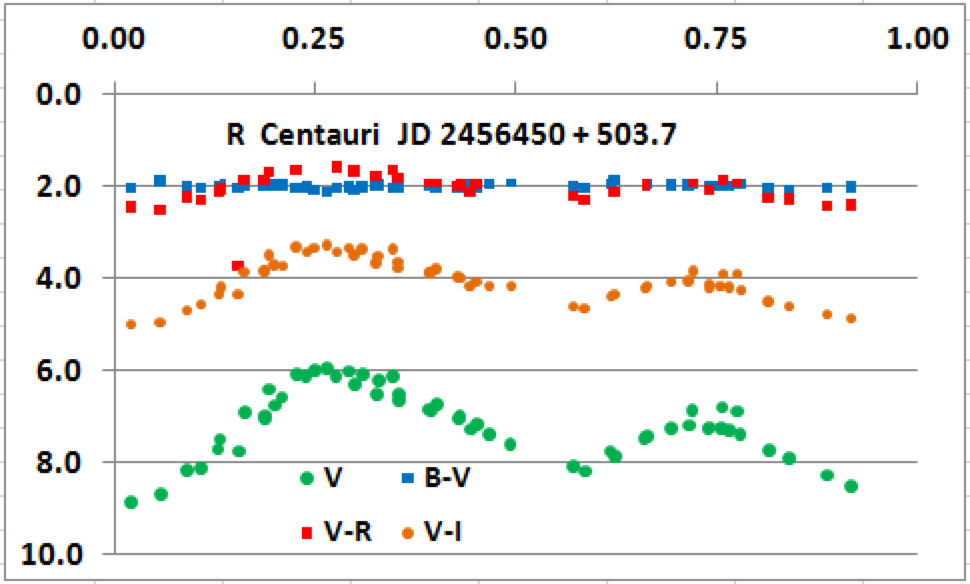

The inverted U-B colour curve suggests either a hot companion or a strong shell of gas in emission.

The B-V colour, brightest near the first maximum, indicates that the second maximum is overbright for its temperature. This suggests a larger radius for the second maximum.

During the interval from 1924 to 1971 when UBV measures began at Auckland Observatory the period became shorter by 22 days

The hotter and now clearly more stable first maximum has been used as an epoch marker – thus our epochs differ from many earlier analyses.

# THE LIGHT CURVE IN THE 2010s

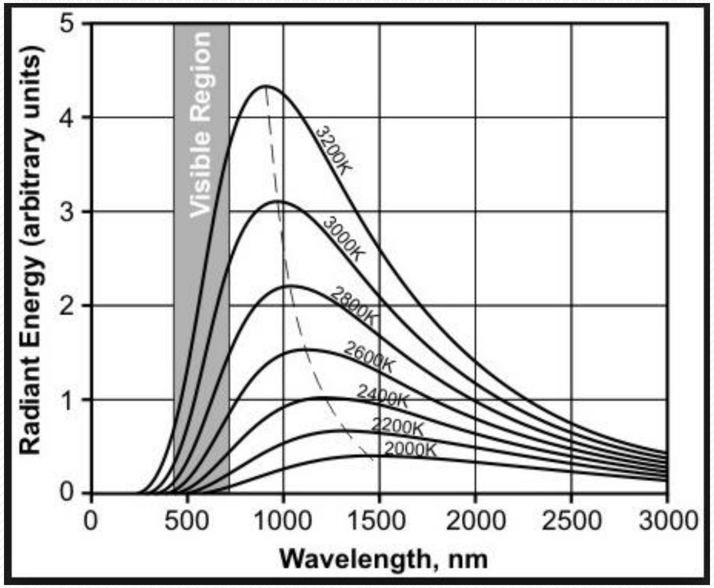


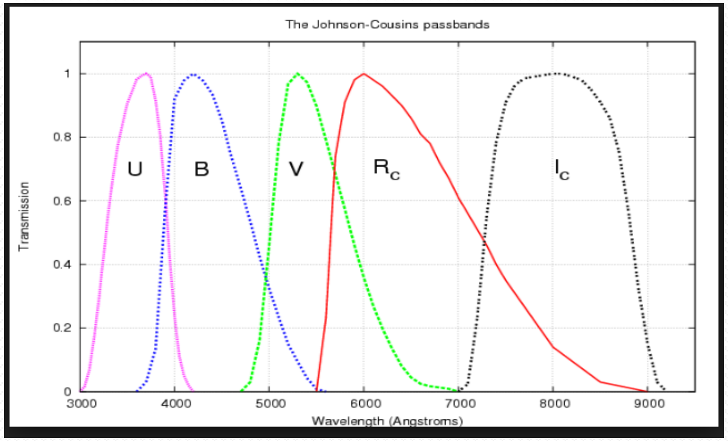

This shows a variety of changes. The V amplitude of the first maximum has decreased from 4.3 to 3.0 magnitudes, the amplitude of the second maximum from 4.3 to 2.0.

Whilst the first maximum is static at phase 0.26 the second maximum has shifted from phase 0.63 to 0.72.

The B-V colour is fairly similar but shows almost no amplitude. The period used was derived from ASAS3 measures made at a similar time to the di Scala measures.

# WHAT ARE WE MEASURING?



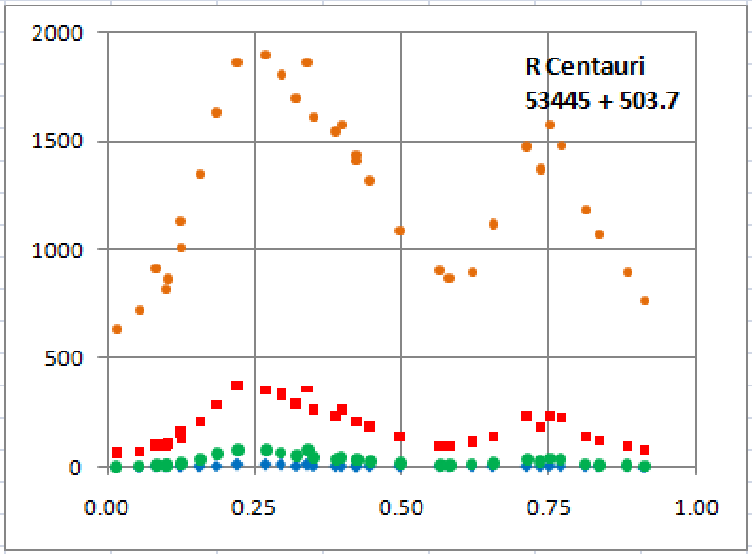



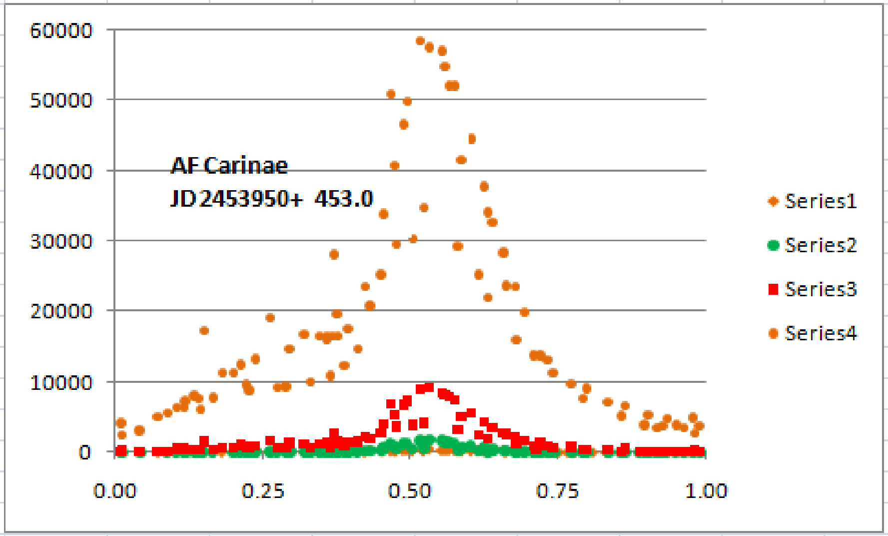

Are these values real? Why is there such a large range through different filters?

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.

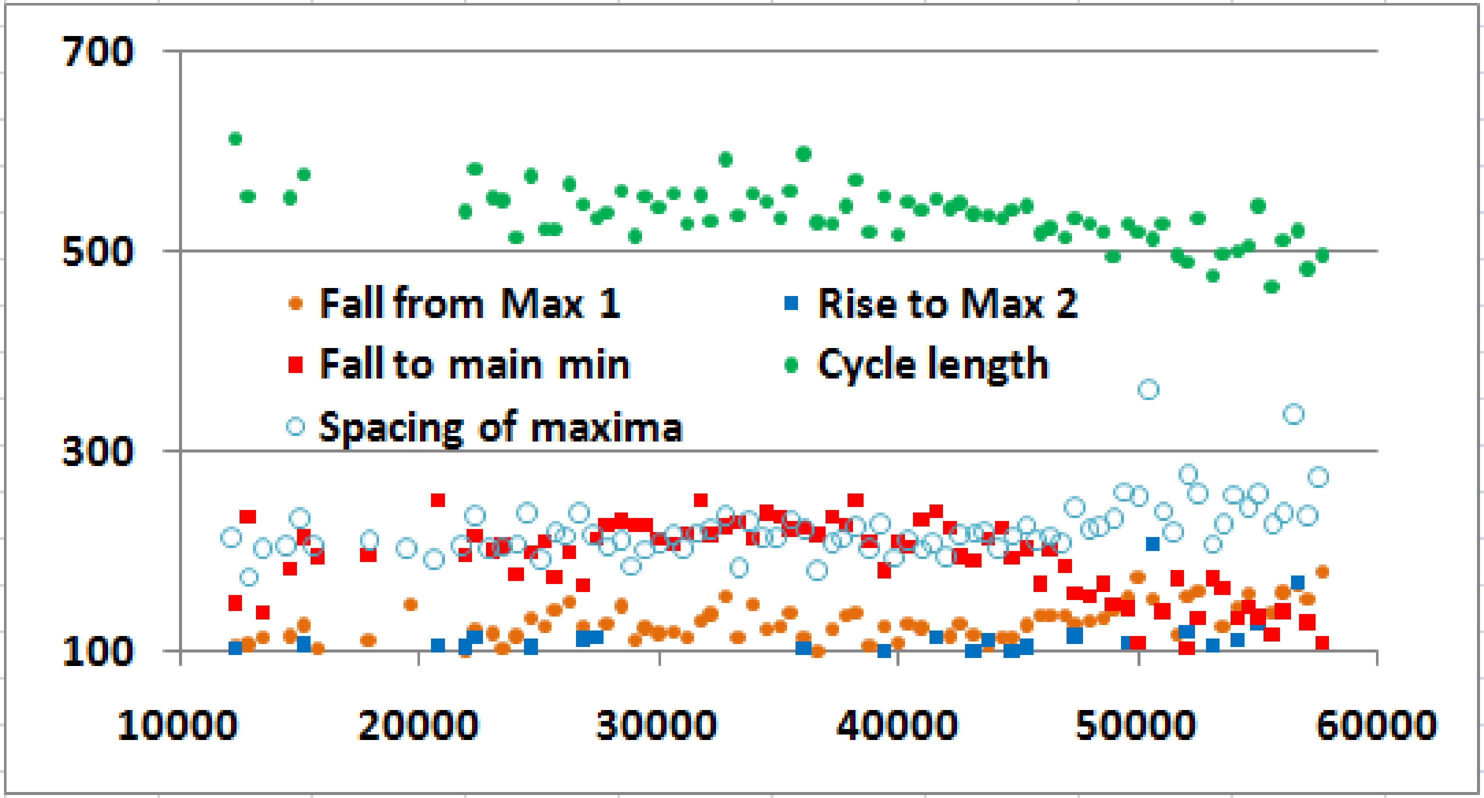
# A COMPARISON OF LIGHT CURVES




Apart from the shapes the amplitudes are interesting. That of R Centauri is much less in the I filter than AF Carinae and half a dozen other Miras, even the carbon star BH Crucis has a greater amplitude.

# LIGHT CURVE FEATURES




1. These data are fairly noisy – partly from secondary maximum instability
2. Shortening period clearly shown
3. Spacing of maxima increases
4. Final decline from second maxima shorter as a result of 2 and 3 ?????

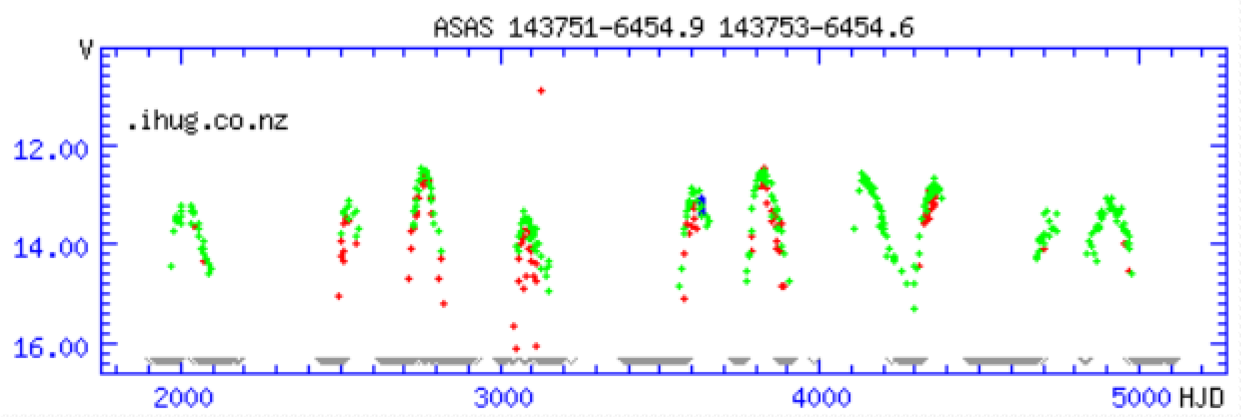
# DUAL MAXIMA MIRAS TO WATCH

| | | | | | |
|---|---|---|---|---|---|
| V415 Velorum | 10 03 30 | -46 49.2 | 9.6 | 11.8 | 410~ |
| BH Crucis | 12 16 17 | -56 17.2 | 6.5 | 9.8 | 530: |
| R Centauri | 14 16 34 | -59 54.8 | 5.8 | 9.0 | 500: |
| R Normae | 15 35 57 | -49 30.5 | 6.4 | 12.0 | 507 |
| BX Carinae | 10 52 06 | -62 29.0 | 11.7 | 13.8 | 427 |
| TT Centauri | 13 19 35 | -60 46.7 | 9.0 | 13.4 | 462 |
| UZ Circini | 14 20 52 | -67 30.8 | 9.0 | 14.0 | 538 |
| BN Scorpii | 17 54 10 | -34 20.4 | 9.7 | <15.0 | 616 |
| FK Puppis | 08 07 19 | -36 08.3 | 8.0 | 9.5 | 502 |
| CK Carinae | 10 24 25 | -60 11.5 | 7.2 | 8.2 | 525 |
| CL Carinae | 10 54 00 | -61 05.6 | 8.0 | 9.0 | 513 |
| | | | | | |
| R Hydrae | 13 26 58 | -23 01.4 | 3.5 | 10.9 | 389 |
| R Aquilae | 19 06 22 | +08 13.8 | 6.0 | 10.2 | 284.2 |
| | | | | | |
| T Cassiopeia | 00 23 14 | +55 47.6 | 6.9 | 13.0 | 444.83 |
| U Canis Minoris | 07 38 38 | +08 29.6 | 8.0 | 14.0 | 413.88 |

This was our original listing. Four of these stars are DMM, two or three may be but the light curves are not as repetitive as those of R Normae. Others on this list have interesting features which may be related.

# OTHER MIRAS TO WATCH

Sebastian Otero drew our attention to another star in 2017. The light curve from ASASA3 appears below. From this a search of ASAS3 and the International Databaserevealed a few other stars which might be DMM objects but the measures are too scattered to be certain.




| | | | | | |
|---|---|---|---|---|---|
| AS Circini | 15 13 39 | -60 20.3 | 8.85 | 10.75 | 517.9 |
| NSV20070 | 14 15 50 | -58 59.3 | 10.9 | 13.2 | 608 |
| V552 Nor | 16 30 13 | -53 28.8 | 10.7 | 13.2 | 445 |
| 93517-3930.0 | 09 35 18 | -39 30.0 | 11.6 | 15.0? | 620 |
| KS Pup | 07 37 53 | -33 29.8 | 11.8 | 15.1 | 400 |
| HR Pup | 07 52 58 | -20 52.8 | 11.05 | 13.3? | 509.8 |
| 65106-1103.1 | 06 51 06 | -11 03.1 | 11.0? | <15 | 537 |
| RU Tauri | 05 52 37 | +15 58.2 | 10 | <14V | 611 |
| Circinis star | 14 37 51 | -64 54.9 | 12.4 | 18.0 ? | 536 |

# USEFUL B-V PHOTOMETRY

B-V colour photometry provides a useful indicator of temperature changes during a pulsation cycle. With Miras exhibiting a smooth rise and falling light curve this probably will not reveal anything unusual and is best performed as part of BVRI or even UBVRI measures.

Miras are not simple stars, however. They have emission spectra, indicative of a surrounding gas halo almost certainly associated with mass loss, a shell or disc of dust which may create a degree of obscuration. This latter type of event plays a major role in R Coronae Borealis fades, probably with the fades of $L^2$ Puppis and in the collapse of the disc in dwarf novae.

Perhaps this plays a part in R Centauri and others of these stars. The early rise of R Telescopium and other Miras with humps on the rise may be in part due to the interference of ejected material.

# RADIAL VELOCITY MEASURES

Very few such measures have been made on Mira stars . A few of R Centauri were made but in a semi-random manner. With these dual maxima stars (DMM) and the unusual B-V colours of R Centauri this suggests that such measures would be valuable in their case.

Such measures are best confined to the brighter objects and with the long periods involved a good measure every 30 days when they are near minimum, changing to every 10-15 days when bright.

Another area for this type of attention is found in stars with humps. Does the star continue its normal surface contraction at this stage but become somewhat dimmed by absorption of an ejected dust halo? It was interesting that in the 1970s one explanation of Xray emission was suggested as arising from interaction with a dust shell I some manner. With Miras most humps occur not long after maximum radius/lowest gravity/maximum opacity when the star is faint

# MIRA COLOUR PHOTOMETRY

Study of Miras by RASNZ VSS, BAA, AAVSO  TSP study of period changes
Success rate ~1-5% perhaps, per century – not all that exciting

Some Miras show humps and bumps on LC 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

These stars are bright in J and H but the amplitudes are low

Leave the standard TSP period change monitoring to the visual observers

# CONCLUSION

There are many areas where amateurs can make very useful contributions to astronomical research beyond visual measures of stars.

The simplest area is BVR photometry of brighter stars using DSLR cameras with inbuilt filters

More expensive but able to reach fainter magnitudes is CCD photometry or classical photometry  using single star detectors.

BVRI photometry is suited to cooler objects,  JH photometry extends this into the infra red. UBV photometry is suited to hot and often massive stars. Emission objects often require full UBVRI filters.

Variable Stars South has many projects with realistic short time scales for results.  Members exchange advice or mentor newcomers and cooperate on specific targets.  See our posters around this room.