Newsletter of the AAVSO Short Period Pulsator Section

Number 2

Northern Summer/Southern Winter 2024

We received enough encouragement to proceed to a second issue of the SPP Newsletter. Comments and suggestions remain welcome and can be emailed to Horace Smith (smithhh@msu.edu). This time we start with a short dive into O-C diagrams of pulsating stars, then look at two interesting variables with changing periods. SPP variables will also be discussed in the June 22 Section Spotlight Webinar. Register at the AAVSO website.

O-C Diagrams of Pulsating Stars

An O-C diagram tells us whether the period of a variable star is changing. Assuming that we are dealing with a pulsating star, and that the star has only a single period, or at least one dominant period, observed times of maximum light are often used as the O values in constructing an O-C diagram. There is, however, a correction to make first. Observed times are corrected from Julian Date to heliocentric Julian Date, or, if the highest accuracy is required, barycentric Julian Date, to compensate for the differing times it takes light to reach the Earth as our planet orbits the Sun. The C values are predicted times of maximum light, calculated according to an adopted period. Thus, $C = HJD_o + P \times E$, where HJD_o is an adopted initial time of maximum, P is the pulsation period (often given in days), and E is the number of pulsation cycles which have elapsed since HJD_o. The O-C value is just the difference between the observed time O and the calculated time C. Figure 1 shows the O-C diagram of a star with a constant period. Figures 2, 3, and 4 show O-C diagrams for hypothetical stars with changing periods.

For pulsating stars, the pattern of the O-C diagram not only tells how the period of the star is changing, but also how the density of the star is changing. Pulsating stars obey the basic pulsation equation: $P\sqrt{\rho} = Q$, where P is the period, ρ is the average density of the star, and Q is a constant. If the density increases, the pulsation period decreases. If the density decreases, the pulsation period increases, assuming the constant Q is unchanged.

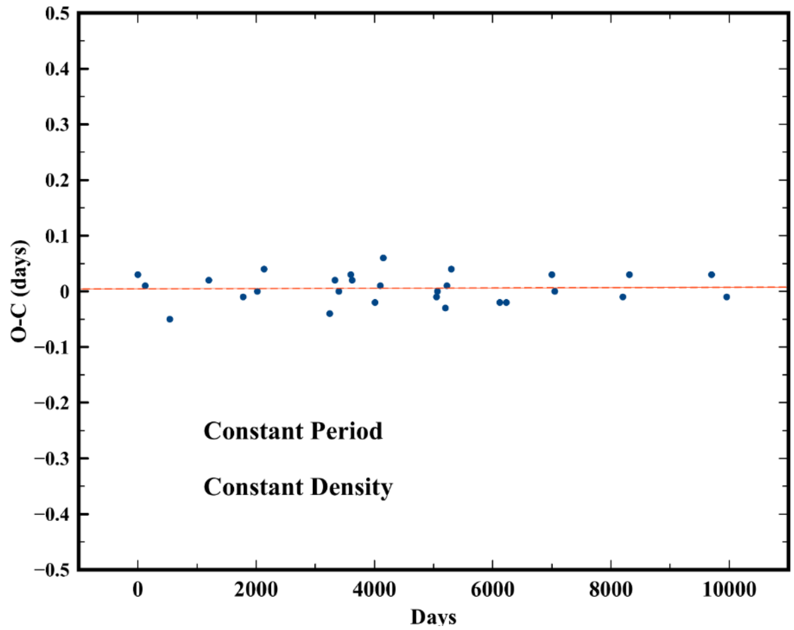

Figure 1. The O-C diagram of a star with a constant period is a straight line. The line will be horizontal if the adopted period is correct, Observational uncertainties will cause some scatter in the O-C diagram.

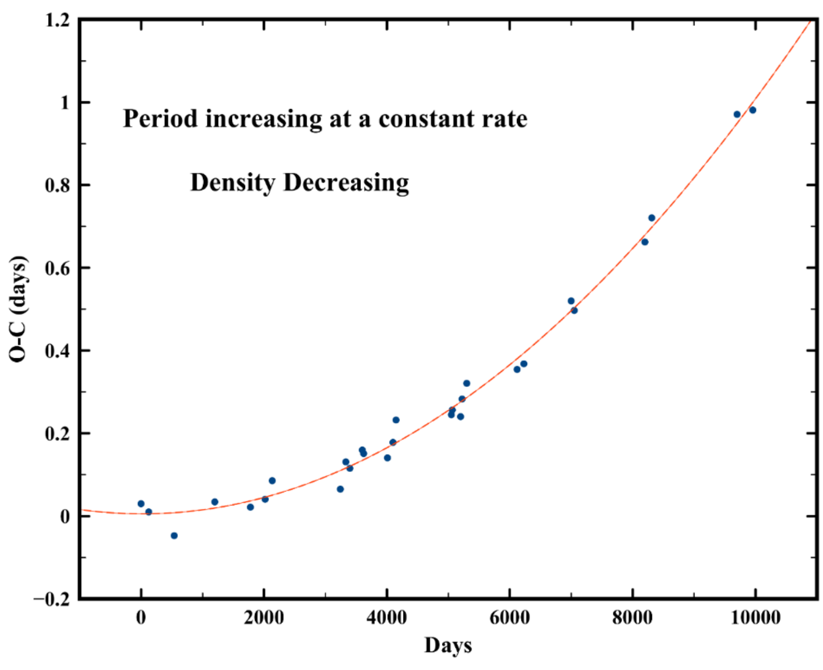

Figure 2. The O-C diagram of a star with an increasing period. In this case, the period is increasing at a constant rate. The pulsation equation tells us that the density of the star is decreasing as its period increases. The O-C diagram resembles a parabola.

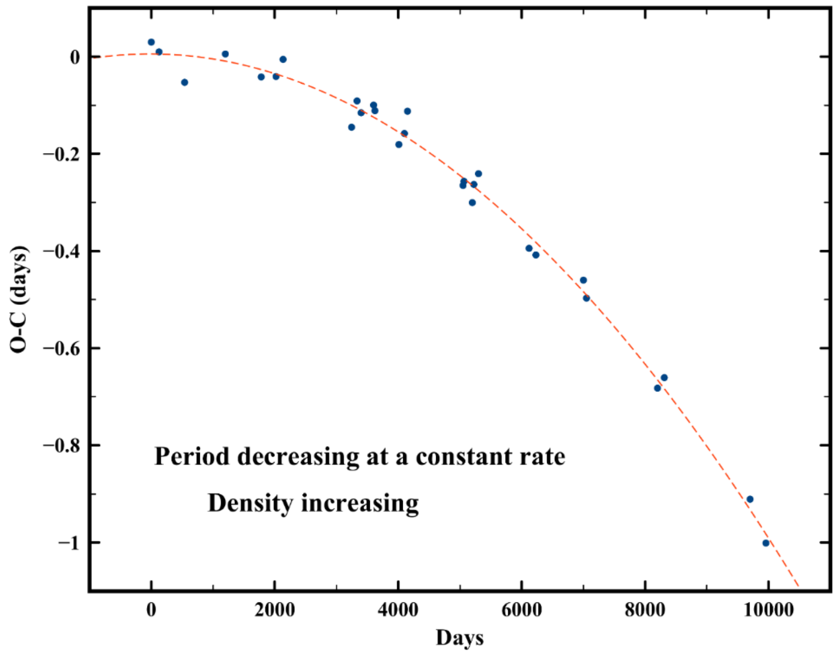

Figure 3. The O-C diagram of a star with a period decreasing at a constant rate. The pulsation equation indicates that the density of the star is increasing.

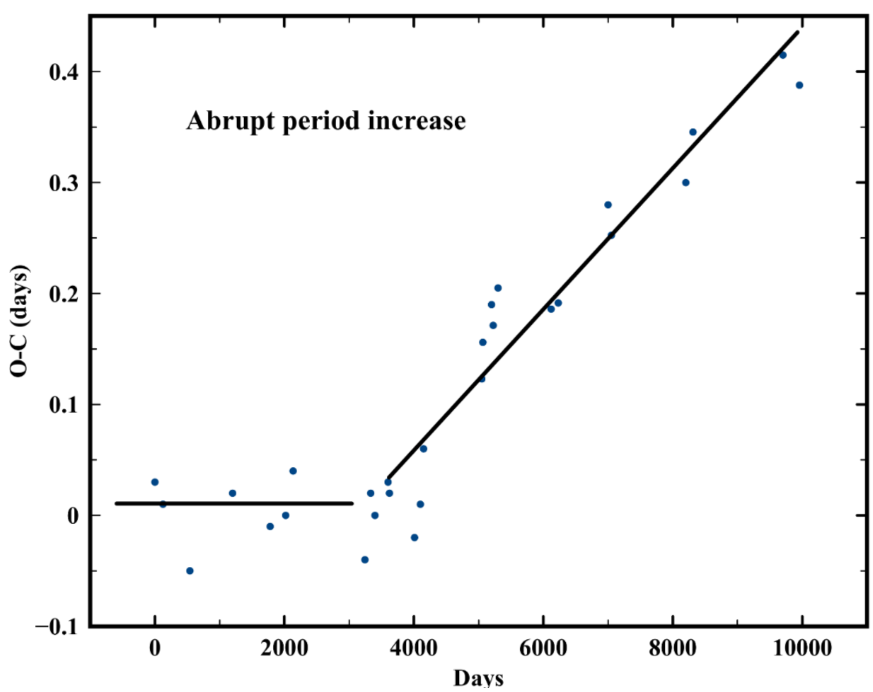

Figure 4. This star had a constant period until about day 3300. Then it suddenly increased in period, after which its period was once more constant. The O-C diagram is represented by two straight lines.

As RR Lyrae stars, Cepheids, delta Scuti variables, and other short period pulsators evolve though the HR diagram, their luminosities and effective temperatures will change, and so will their densities. For example, if a pulsating star of constant mass becomes larger in diameter as it evolves, its density will decrease and its period will become longer. While evolutionary changes in mean magnitude and mean color are almost always expected to be too small to detect in observations spanning a century or less, that is not necessarily true of the period changes resulting from stellar evolution. Pulsation periods for SPP stars can be determined to six or seven decimal places. Period changes thus have the potential to reveal changes due to stellar evolution long before they can be detected in any other way.

When evolutionary period changes are large enough to detect, they are ordinarily expected to yield O-C diagrams similar to those shown in Figures 2 and 3, with shapes resembling parabolas. However, we sometimes observe RR Lyrae variables and Cepheids acting in surprising ways. Some stars experience abrupt period changes. Others undergo both increases and decreases in period. Such changes are hard to explain in terms of smooth nuclear burning, and may indicate the occurrence of poorly understood instabilities within the stars. Mysteries remain, and unexpected period changes are certainly one motivation to keep watching pulsating variables! Our two target variables for this season illustrate this.

Two Variables with changing periods

Our featured variables for this newsletter are XZ Cygni and RV Cap. Both are RR Lyrae stars with changing periods. Both also show the Blazhko effect.

XZ Cygni (RA 19:32:30 DEC +56^{o} 23^{m} 17^{s} J2000)

The RR Lyrae variable XZ Cygni, with a period near 0.47 days, has long intrigued AAVSO observers. In 1971, Marvin Baldwin, who began the AAVSO RR Lyrae program, called attention to a recent large change in period for XZ Cyg. An updated O-C diagram for XZ Cyg is shown in Figure 5.

At the time that it came to Baldwin's attention, XZ Cygni was undergoing a period decrease. As Figure 5 indicates, that decrease would be followed by other period changes, both increases and decreases, before the star settled down to a calmer life. Since the 1990s, XZ Cyg had been relatively constant in period. However, recent photometry indicates that the period of XZ Cyg is decreasing again. Will there be a second episode of period instability, as was seen in the 1970s? Only more observations will tell.

As mentioned, XZ Cyg also shows the Blazhko effect. It has a primary pulsation period of 0.46659 days, but its light curve shape also changes with a 58-day (and possibly a 42-day) period, as shown in Figure 6. Its Blazhko period has also been observed to change in length and amplitude.

XZ Cyg is well-placed for northern observers through the summer and into the autumn.

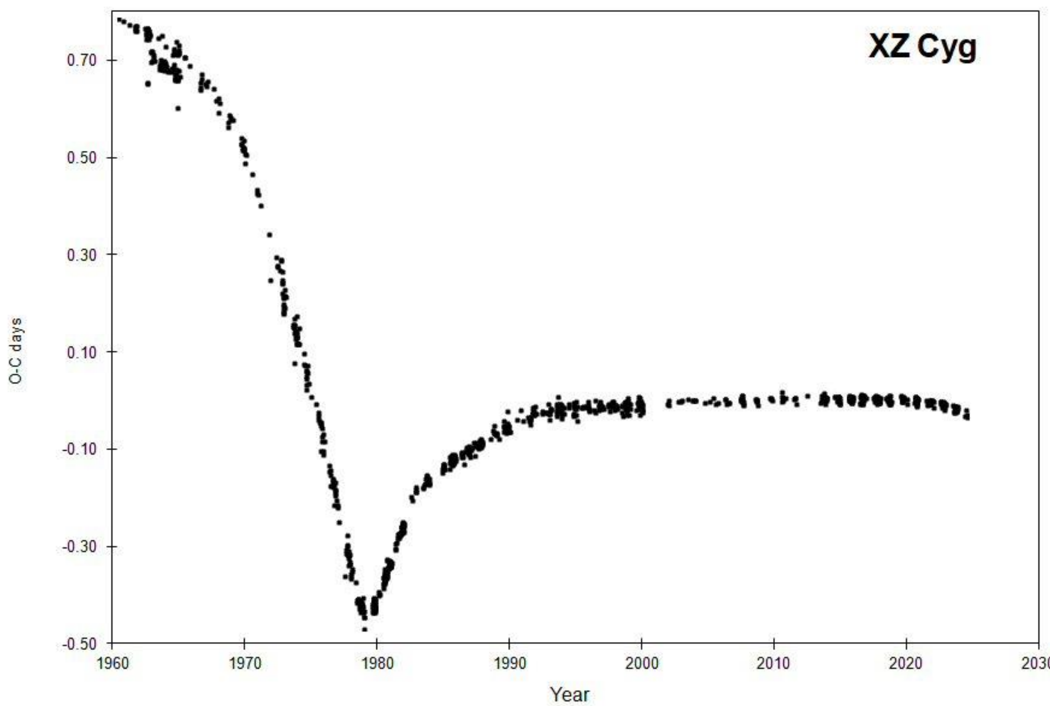

Figure 5. The long-term O-C diagram of XZ Cygni. Approximate times of maximum light are listed in the 2024 AAVSO RR Lyrae ephemeris, but period changes can gradually throw those predictions off. Courtesy of G. Samolyk.

Some sources for further information on XZ Cygni.

Baldwin, M. E. 1971, Journal of the Royal Astronomical Society of Canada, 65, 307. https://articles.adsabs.harvard.edu/pdf/1971JRASC..65..307M

Kaneshiro, D., Smith, H., and Samolyk, G. 2021, Journal of the AAVSO, 49, 19. AAVSO -- An Update on the Periods and Period Changes of the Blazhko RR Lyrae Star XZ Cygni

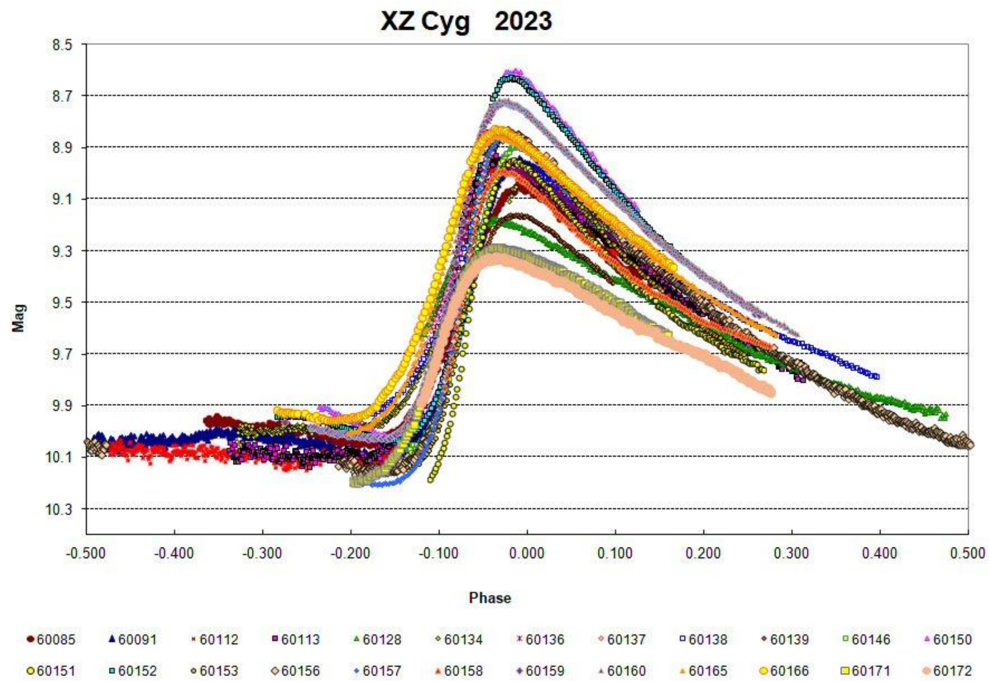

Figure 6. The change in the V light curve of XZ Cyg in 2023 because of the Blazhko effect. Series of observations lasting several hours per night are most useful. Courtesy G. Samolyk.

RV Cap (RA 21:01:29 DEC -15^o 13^m 46^s J2000)

RV Cap is a southern RR Lyrae which has also long been a target of AAVSO observers. As shown in Figure 7, RV Cap's 0.447744-day primary period has changed over time. Its O-C diagram illustrates the importance of keeping variables like RV Cap under observation. The gap in the O-C diagram means that we may not understand the full story of period changes for this star. Figure 7 made use of AAVSO observations and also data in the GEOS RR Lyrae database, where additional references on the photometry are listed: (http://rr-lyr.irap.omp.eu/dbrr/index.php).

Zinn et al. (2020 MNRAS 492, 2161) suggested that XZ Cyg and RV Cap belong to different small groups of RR Lyrae stars. Stars in each group belong to particular star streams in our galaxy. RV Cap is in a group with kinematics similar to the globular cluster NGC 3201. Such groups tell us about the formation of the Milky Way galaxy, if we can figure out what they mean.

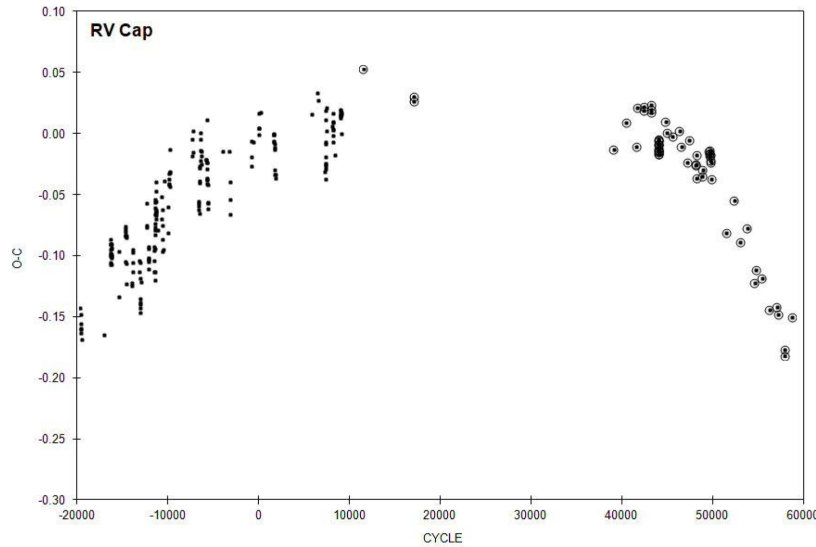

Figure 7. An O-C diagram for RV Cap, this time plotted against cycle number, E, instead of HJD. Courtesy G. Samolyk.

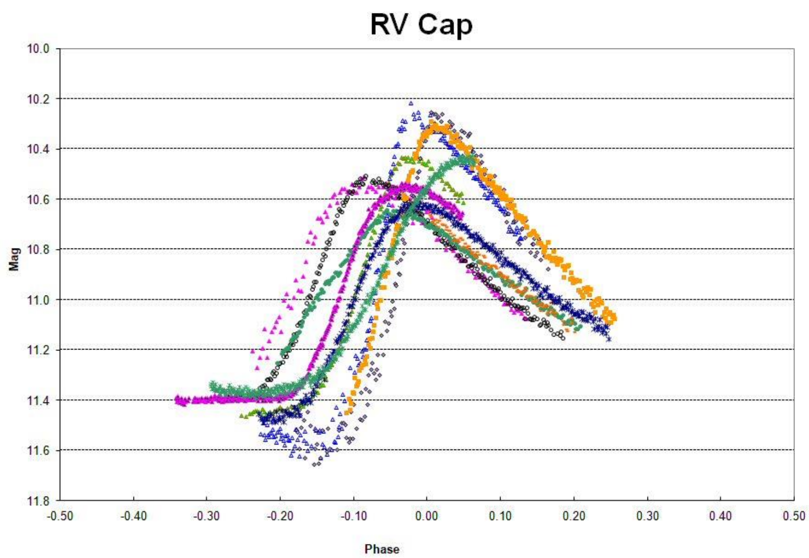

Figure 8. Changes in the V-band light curve shape of RV Cap because of its Blazhko effect. The Blazhko period of RV Cap is rather long, about 232 days. As with XZ Cyg, it is most useful if RV Cap can be followed for several hours on each night when it is observed. And as with XZ Cyg, observations through the V filter are very useful, while multi-filter observations have added value. Courtesy G. Samolyk.