# THE PUZZLING BEHAVIOR OF EM COMAE BERENICES

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**Abstract**

EM Comae Berenices is an RRab star which has a very complicated O-C diagram that cannot be described by any straightforward revision of the elements.

EM Comae Berenices was discovered by Kinman *et al.* (1966) at the Lick Observatory during a survey of metal abundances in galactic halo RR Lyrae stars. The published elements:

$$JD_{max} = 2437736.586 + 0.54253\ E \qquad (1)$$

were then revised by Butler *et al.* (1979) during a continuation of the Lick work to:

$$JD_{max} = 2437736.586 + 0.542555\ E. \qquad (2)$$

In addition to the data collected in these surveys, 536 photographic plates taken at the Maria Mitchell Observatory (MMO) from 1964 to 1990 were examined. Using phases calculated from the latter elements, folded light curves from Lick Observatory data and the data accumulated at the Maria Mitchell Observatory were produced. These graphs showed a degree of scatter inherent in photographic photometry, but it was obvious that several of the maxima were earlier or later than the predictions, indicating that adjustments to the elements would be needed if the deviations turned out to be systematic.

O-C diagrams are a powerful tool used to calculate corrections to a variable star's elements. One way to obtain precise values of O-C is to use an average folded light curve (magnitude plotted against phase) from a well-defined subset of the data, and then to compare it to light curves made from other subsets of the data. The fitting of one curve to all of the others makes it possible to define the position of maximum in a consistent way. The offset of maximum from phase = 0.0 is noted. If several of these shifts are plotted together against cycle count or Julian date, a trend is sometimes noted (line segments of positive or negative slope, for example, or parabolic curves), indicating that the elements need revision. From the parameters of these functions, e.g., slope, intercept, curvature, it is possible to adjust the star's elements to produce better predictions of the time of maximum. In this study the fitting was done using a non-linear least-squares technique (Belserene 1986).

For many stars, an O-C diagram will produce a nice curve, but the O-C diagram calculated from our data and from the Lick data is interesting to say the least (Figure 1). When I first looked at the graph I saw several short-term trends, but nothing could be said about a trend over the entire data set. Due to the nature of O-C diagrams, a particular point can be plotted in several places. When you calculate O-C, a particular maximum can be said to be 4/10 of a cycle late, for example, or 6/10 of a cycle early, so the point could be plotted at either +0.4 or -0.6. Thinking along these lines I moved the first point on the graph (Lick 1962-64 data) from -0.004 to -1.004. Of course doing this implies that when Butler *et al.* (1979) corrected the original period of 0.54253 (Kinman *et al.* 1966) they picked a spurious period that corresponded to a miscount of one cycle in 15 years, which is the time interval between their two sets of data.

Spurious periods are alias periods that are related to the true period. These periods arise from gaps in the data due to the interval between observations, e.g., the sidereal day, the synodic month, or a yearly period. These spurious periods are related to the true period by the relationship: $1/P_{spurious} = 1/P_{true} \pm 1/interval$. Assuming that Butler *et al.* had picked a spurious period, the first two thirds of Figure 1 resembles a parabola, when the point is moved to -1.004.

I found the best fitting parabola by the method of least squares, using a computer program developed for that purpose at the MMO. Due to the large error bars in the 1964-67 data, and the large deviations from the curve in the 1983-84 and 1989-90 data, I excluded these points from the fit. Using the relationship that the slope of the curve is the negative of the required change in 1/P, one can then calculate what the period should be at any time along the curve.

The calculated parabola turned out to be unsatisfactory for three reasons. First, the curve did not fit the points as well as I expected it to; it intersected only half of the error bars of the points used in the fit. Second, periods calculated from the parabolic equation for 1962, 1964, and 1979 gave a very poor fit to the Lick data for those years. Finally, even though the curve was fitted without the 1964-67, 1983-84, and the 1989-90 data points, there is no real reason to ignore those points. For these reasons I decided that the parabola did not give a good representation of the O-C diagram for EM Com. Therefore, I have no reason to move the Lick 1962-64 data point down on the O-C diagram.

Linear fits could be used on small portions of the O-C diagram to give an approximation to the period behavior during those time intervals. For 1968 through 1976 a linear fit indicated new elements of:

$$JD_{max} = \underset{\pm 0.002}{2441397.151} + \underset{\pm 0.000010}{0.542587}\,E. \qquad (3)$$

A linear fit on data from 1974 to 1982 indicates new elements of:

$$JD_{max} = \underset{\pm 0.003}{2444107.313} + \underset{\pm 0.0000017}{0.5425655}\,E. \qquad (4)$$

Although straight lines could be fitted on short time intervals it is obvious that no simple functional form will work for the entire data set. The behavior in JD 2438000-2440000 and near 2446000 is particularly puzzling. Unfortunately there was not a long enough trend in the last few years of the data to project a set of new elements for the future.

I thought it would be interesting to see whether the deviations on the O-C diagram were dependent with the way I grouped the data. Therefore I shifted the boundaries of the data sets one year and produced another O-C diagram. This graph was similar enough to Figure 1 to show that the points were not group-dependent. The shifted groups, however, showed that the years 1984 and 1990 were the culprits in causing the large deviations. I re-examined the plates for those years and double checked the calculated Julian dates to see if any errors were made in my initial survey. None were found, so I was back where I had started. I ran sets of the data through several period search programs, but found no promising periods other than spurious periods already rejected.

Perhaps the discordant points might be due to the Blazhko effect. The Blazhko effect is a variation in the shape and amplitude of the light curve. Conspicuous period changes are common in stars with the Blazhko effect (Szeidl 1975). This might account for scatter in the folded light curves and large deviations from the general trend in the O-C diagram in Figure 1. Unfortunately our data are too spread out in time to demonstrate variations in shape and amplitude.

After examining all of the available data and trying several different approaches, I have come to the conclusion that this star is behaving in no simple manner. Perhaps a pattern will emerge when more observations have been made. Equation (2) continues to provide an approximation to the average period. Equations (3) and (4) show that the actual period can differ from the average in the fifth decimal place.

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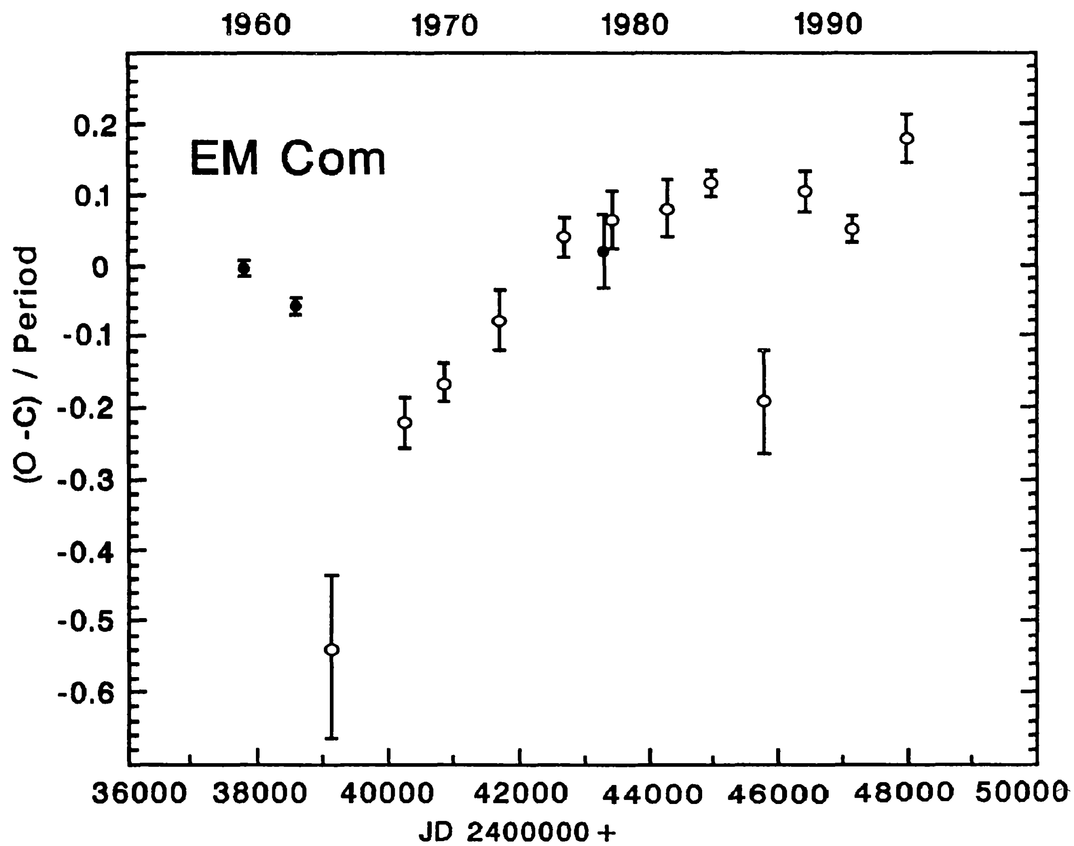


Figure 1. O-C diagram for EM Comae Berenices for 1962 to 1990. Solid points represent data from Lick Observatory; open circles are MMO data.