# Decreasing Orbital Period of the BX Pegasi Binary System

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**Abstract**

BX Pegasi is a W-type Ursae Majoris (W UMa) overcontact binary star system sharing a common atmospheric envelope. This study investigates the system's complex orbital periodicity by analyzing V-band photometric data from the AAVSO International Database (AID) spanning Julian Dates (JD) 2452496.57564 to 2461001.662662. A rigorous cleaning process, which removed inaccurate or invalid observations, resulted in 13,595 data points being analyzed using the astronomical analysis software Peranso version 3.1.05. We also applied the Analysis of Variance (ANOVA) algorithm, which was used to identify patterns in the system's sharp brightness peaks. The Observed-Computed (O-C) charts revealed parabolic relationships within the timing of eclipses, showing that the orbital period of BX Peg is decreasing at a rate of $(-2.28 \pm 0.45) \times 10^{-9}$ days per cycle, or $(-0.257 \pm 0.051)$ seconds per year, indicating that the stellar components are speeding up as they orbit one another, similar to comparable research conducted by Alton and Lee (Alton 2013, Lee 2004) which also discuss a decreasing orbital period.

## 1. Introduction

BX Pegasi (Right Ascension (RA): 21h 39m 3.95s, Declination (Dec): 16° 54' 7.8") was first noted for its variable activity by Shapley and Hughes (1934) and was subsequently studied by numerous astronomers (Shapely & Hughes 1934). BX Peg is classified as a W-type UMa system (Williams 2000). These two stars are part of an overcontact binary system, which means the stars share a common envelope, or atmosphere, and/or share matter. Each star component takes between 6 to 7 hours to complete an orbit. Previously collected data of BX Pegasi's complex behavior were analyzed with the use of an O-C (Observed-Calculated) diagram. The primary objective of this research is to determine the rate and direction of orbital period change of these stars. A decreasing orbital period could be a sign of potential mass transfer, angular momentum loss via magnetic braking, or eventual merging of components, which would be a significant topic for future study.

## 2. Methods

We used the AAVSO International Database; the initial dataset spanned Julian Dates from 2452496.57564 to 2461001.662662.

The analysis was performed on Peranso version 3.1.05. Data points with V magnitudes brighter than 9.0 were removed, as BX Peg's known magnitude is approximately 10.1-10.7; brighter measurements are inconsistent with the target. Furthermore, a group of data points collected by Peranso user BHOB was removed for being out of the general range and bright enough to be considered outliers, which were concluded to be most likely an observation error. There was one single data point collected by user RRO, which was also identified as an outlier for the same reason and removed. Our final main deletion was erasing data captured using any light other than type V, the only light we're using for study. This left us with 13,595 data points.

Later in the process, a second clean-up was performed to remove data points that were too bright or too dim. We used the Analysis of Variance (ANOVA) method to analyze our data (Paunzen 2024). ANOVA is viable when looking for peaks or when dealing with fluctuating data. This is used to find the patterns, or lack thereof, in the data by breaking each section of peaks up and overlapping them to find what is changing or what is consistent. While on Peranso, we used the PeransoLeft/Right Margin Cursors on each maxima, and had it calculate the minima of the curve. Peranso then calculated the Observed Julian Date (JD) and times of minimum using the ANOVA algorithm. We used this information to calculate the Cycle Number, Computed JD, Observed-Computed, Observed Error, and Observed Magnitude. This data was then used to get the Period and Epoch.

After the data cleanup, we found the exact Time of Minimum (ToM) to be Julian Date (JD) 2454650.611. The O-C calculator was created using the ROUND function. We then used Period + (Cycle Number * Period) to find the Computed Julian Date (JD) for each observation of BX Pegasi, and (Observed JD - Computed JD) to calculate the Observed-Computed value (O-C) for specific observations.

The formula for the Cycle Number (E) was refined from =INT((Observed JD - Epoch)/Period) to =ROUND((Observed JD - Epoch)/Period, 0) (Used in Fig. 1). This refinement was necessary to mitigate rounding bias, and the cycle calculation was updated from integer truncation to a nearest-integer rounding function. The orbital period was also revised to 0.280422 days, consistent with previously published values from Kreiner (Kreiner 2004).

The data points in Fig. 2 exhibit the downward trend that is finalized in Fig 3. Several data points initially appeared as outliers in the upper right quadrant of the chart due to a phase-shift where late-occurring minima were misinterpreted as early, which were corrected in Fig. 3. The data was also normalized to the half period to account for primary and secondary eclipses. This downward trend is core evidence of our studies; the orbital period of the BX Pegasi is decreasing, meaning that the stars are orbiting each other faster over time.

## 3. Results

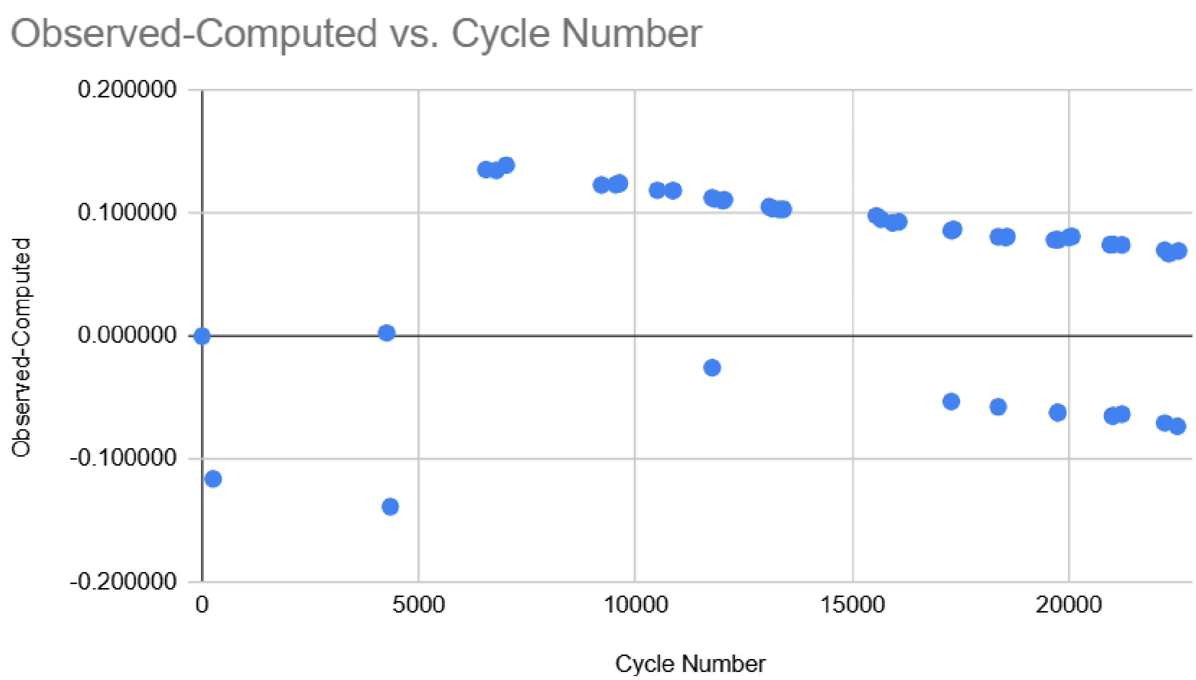


Figure 1: A downward curve, made up of primary and secondary eclipse data points.

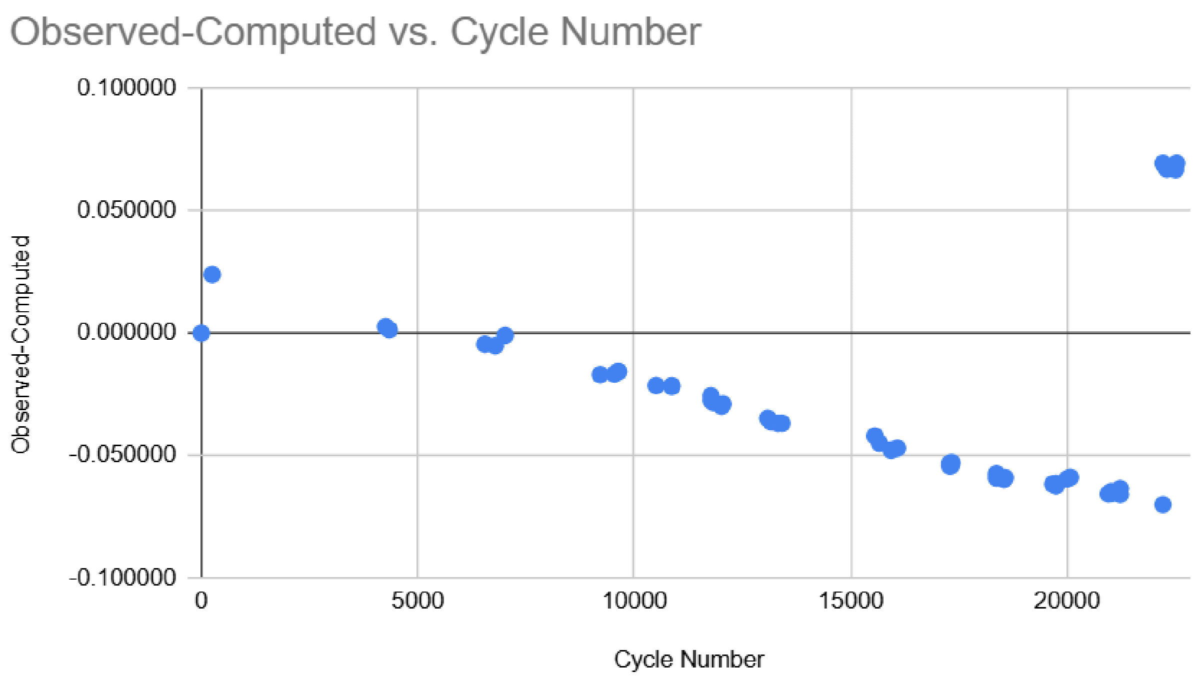


Figure 2: The downward trend finalized in Fig. 3, with a few outliers that require correction (see Sec. 2).

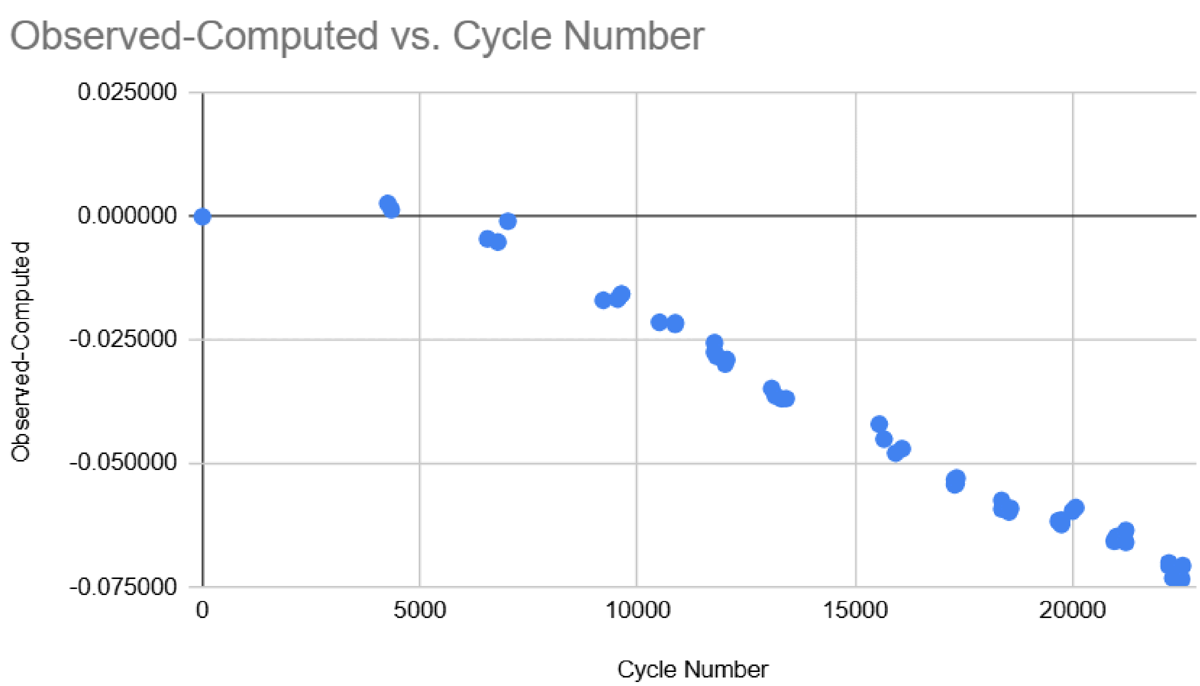


Figure 3: A stabilized set of data points that follows a distinct and continuous downward trend.

## 4. Discussion

BX Peg appears to have a decreasing orbital period, which can be seen in Fig. 3 with a clear downward parabolic trend. The data collected in Fig. 3 reveal that the orbital period of BX Pegasi is decreasing at a rate of $(-\ 2.28 \pm 0.45) \times 10^{-9}$ days per cycle, or $(-\ 0.257 \pm 0.051)$ seconds per year, which means the stellar components are speeding up. This result is consistent in sign with previous studies of BX Peg's period evolution (Lee et al. 2004; Alton 2013), which also report a long-term decreasing trend. This secular decrease may be attributed to mechanisms such as mass transfer, angular momentum loss via magnetic braking, or eventual merging of stellar components.

## 5. Conclusions

This analysis of the W UMa-type contact binary system BX Pegasi confirms a secular evolution in its orbital period, similar to those observed by other astronomers, namely Alton and Lee (Alton 2013, Lee 2004). By refining the reference epoch to 2454650.611 days and the orbital period to 0.280422 days (as mentioned in Sec. 2), the Fig. 3 O-C chart reveals that the BX Peg overcontact binary system has a decreasing orbital period of $(-\ 0.257 \pm 0.051)$ seconds per year. This continued period decrease is consistent with the expected evolution of overcontact systems, where angular momentum loss through mass transfer drives the stars to spiral inward over time (Henneco et al. 2024).

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