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Period Changes in LPV: MIRA and SR Stars

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Abstract: In this article, I present an analysis of long-term period variability in a sample of long-period variable (LPV) stars, including Mira(M) and Semiregular (SR) variables, using visual band observation data spanning approximately 70 years, from JD 2435259.5 to JD 2460687.5, obtained from the AAVSO International Database. I investigate temporal changes in the dominant pulsation periods of these stars. Period analysis was performed using the Weighted Wavelet Z transform (WWZ) method implemented in the VStar software package, which enables the detection of time-dependent period variations. The results show that several stars exhibit gradual period changes, with some increasing and others decreasing. In all cases, the observed period variations occur on long timescales and indicate slow secular evolution of pulsation periods rather than abrupt mode switching. These findings contribute to understanding the long-term pulsation behaviour and evolutionary effects in Mira and SR-type LPVs

1 Introduction

Long-period variable (LPV) stars are cool, evolved giants and supergiants that exhibit photometric variability on timescales ranging from tens to several thousand days. Most LPVs are located on the asymptotic giant branch (AGB) and include Mira variables, semiregular (SR) variables, and irregular variables. Their variability is primarily driven by radial pulsations**,** often accompanied by strong mass loss and extended circumstellar envelopes. Mira variables are characterized by large-amplitude light variations**,** typically exceeding 2.5 mag in the V band and relatively regular pulsation periods, whereas SR variables show lower amplitudes and less regular or multi-periodic behavior (Cahit YES ILYAPRAK*, et al,* 2008). Long-term monitoring of LPVs has revealed that, while many stars maintain stable pulsation periods over decades, some exhibit slow secular or cyclic period changes**,** which may be linked to stellar evolution, thermal pulses, or changes in pulsation mode. (Merchan-Benitez, P. et al 2023) Mira variables pulsate predominantly in the fundamental mode**.** These stars are typically single-mode pulsators; consequently, other LPVs exhibiting periods located on this sequence are also interpreted as fundamental-mode pulsators. In contrast, most semiregular variables (SRVs**)** show multi-periodic behavior, commonly with simultaneous excitation of the fundamental mode and the first overtone.(I. Soszy´nski , *et al*,2013) LPVs stars have been systematically observed by both amateur and professional astronomers for more than a century, resulting in extensive long-term datasets. These prolonged observational records enable investigations of secular variations in pulsation properties**,** which can yield valuable insights into the evolutionary processes of LPVs (Mira variables) and asymptotic giant branch (AGB) stars, including thermal pulses and pulsation-driven mass loss**.**

In this article, I investigate the period variability of six long-period variable (LPV) stars, consisting of three Mira variables, T Cep, S Cep, R Cas, one SRc variable, VX Sgr, one SRa variable, SS Vir and one SR variable, T UMi. For the majority of these stars, the pulsation periods are found to evolve slowly (increase and decrease) over time, indicating gradual long-term changes. Such slow period evolution may provide valuable insight into the underlying stellar evolution processes governing Mira and semi-regular variables.

2 Data and Methods

All observational data used in this study, spanning approximately 70 years (JD 2435259.5to JD 2460687.5), were obtained from the AAVSO International Database (AID). The analysis is based exclusively on visual-band observations, as this band provides long and densely sampled light curves that are particularly well suited for studying secular period changes in long-period variables. Their principal advantage is the availability of continuous records spanning several decades. However, visual estimates are characterized by larger uncertainties and increased scatter compared with CCD photometry, and seasonal gaps may also be present. Nevertheless, the large amplitudes of Mira variables and the exceptional temporal coverage of visual observations make them highly suitable for investigations of long-term period evolution. I examined data for the stars VX Sgr, SS Vir, S Cep, R Cas, T UMi, T Cep. All datasets are publicly available and were accessed directly through the VStar software for this work.

The AAVSO International Database (AID) contains nearly 50 million variable-star observations**,** including data collected over a timespan exceeding one hundred years. This open-access and publicly available repository offers extensive visual and Johnson V-band photometric measurements**.** The database is built from thousands of carefully vetted observations contributed by both amateur and professional astronomers**,** along with data from numerous organizations across the globe. (Kafka 2021). (Saini and Walker, 2021)

To examine period variability in the selected stars, I employed a wavelet-based analysis using the Weighted Wavelet Z-transform (WWZ), (Templeton, 2004). This tool is used by several other researchers for period and amplitude changes. (Bedding , T .R, *et al*, 1998). The long-term Visual time series of each star was subdivided into overlapping short time windows**,** enabling the temporal evolution of the dominant pulsation period to be followed. The window length and overlap were chosen to ensure a balance between temporal resolution. A decay constant of (c=0.001) and a period step of 0.01 day were used throughout the analysis, providing

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a suitable balance between temporal and frequency resolution and allowing the long-term evolution of the pulsation periods to be traced. The period search intervals were chosen individually for each star according to their expected minimum and maximum periods, ensuring adequate coverage of the dominant pulsation modes. These settings were found to be appropriate for identifying both secular and non-monotonic period variations. The complete analysis was performed using the AAVSO VStar application (Benn 2013). A similar approach to detecting period changes in long-period variables has been adopted by Templeton et al. (2005) and Neilson et al. (2016), allowing direct comparison with previous studies.

In wavelet analysis, a sinusoidal function of fixed frequency is fitted to the observational data using a Gaussian wavelet window (Foster 1996). This technique effectively performs a localized Fourier analysis on successive segments of the time series, providing estimates of the dominant period(s) and amplitude(s) and their temporal evolution. An implementation of this wavelet method is available within the VStar software package.

3 Results and Conclusion

Using sliding-window Fourier analysis and the WWZ method, the period evolution of a sample of long-period variable stars was investigated. Among the analyzed objects, six stars exhibit measurable period changes over multi-decade timescales, while the remaining stars show periods consistent with stability within the uncertainties.

VX Sgr: (SRc) -The time-dependent period analysis indicates that the dominant pulsation period of VX Sgr begins to increase around JD 2455566.5 and continues through JD 2460680.5. During this interval, the period rises from approximately 620.5 days to 670.0 days**,** representing an increase of about 50 days over ~14 years**.** While the variation is moderate in magnitude.

SS Vir: (SRa) - Time-dependent period analysis shows that the dominant pulsation period of SS Vir begins to decrease around JD 2453742.5 and continues through 2460687.5. Over this interval, the period declines from approximately 354.0 days to 340.5 days, corresponding to a net decrease of about 14 days over ~19 years. This modest variation indicates a slow and gradual long-term evolution of the pulsation period.

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S Cep: (M) - The period evolution of S Cep shows an increasing trend beginning from 2449727.5 and continuing until approximately 2456667.5. During this interval, the dominant pulsation period increases from about 478.5 days to 484.0 days, corresponding to a net increase of roughly 6 days over ~19 years.

R Cas: (M)- The dominant pulsation period of R Cas shows an increasing trend from approximately 427.5 days to 434.5 days between JD 2449722.5 and JD 2454467.5. Subsequently, the period decreases slightly by about 1.5 days over the following two years, reaching approximately 433.0 days by JD 2455207.5. Overall, the period increases by roughly 7 days over a timescale of ~14 years.

T Cep: (M)- The pulsation period of T Cep increases from approximately 376 days from JD 2433286.5 to about 400 days by JD 2447896.5. This is followed by a gradual decrease from the JD 2449360.5 to the JD 2458850.5, with the period returning to approximately 376 days, indicating a quasi-cyclic pattern. A renewed increasing trend is observed thereafter. Evidence for an earlier decreasing phase prior to JD 2435000.0 is also apparent and can be seen in figure 1. The pulsation period exhibits a quasi-cyclic variation with an amplitude of approximately 24 days, corresponding to alternating phases of period increase and decrease.

T UMi: The period evolution of T UMi spans approximately JD 2442000.0 to JD 2457000.0 and shows a pronounced long-term decrease. Over this interval, the dominant pulsation period declines from about 310 days to 200 days, corresponding to a decrease of roughly 110 days over 41 years. This change is significant compared to the other stars discussed in this sample. From the JD 2460000.0, the period exhibits a renewed increasing trend, suggesting a possible change in the star's pulsation behavior.

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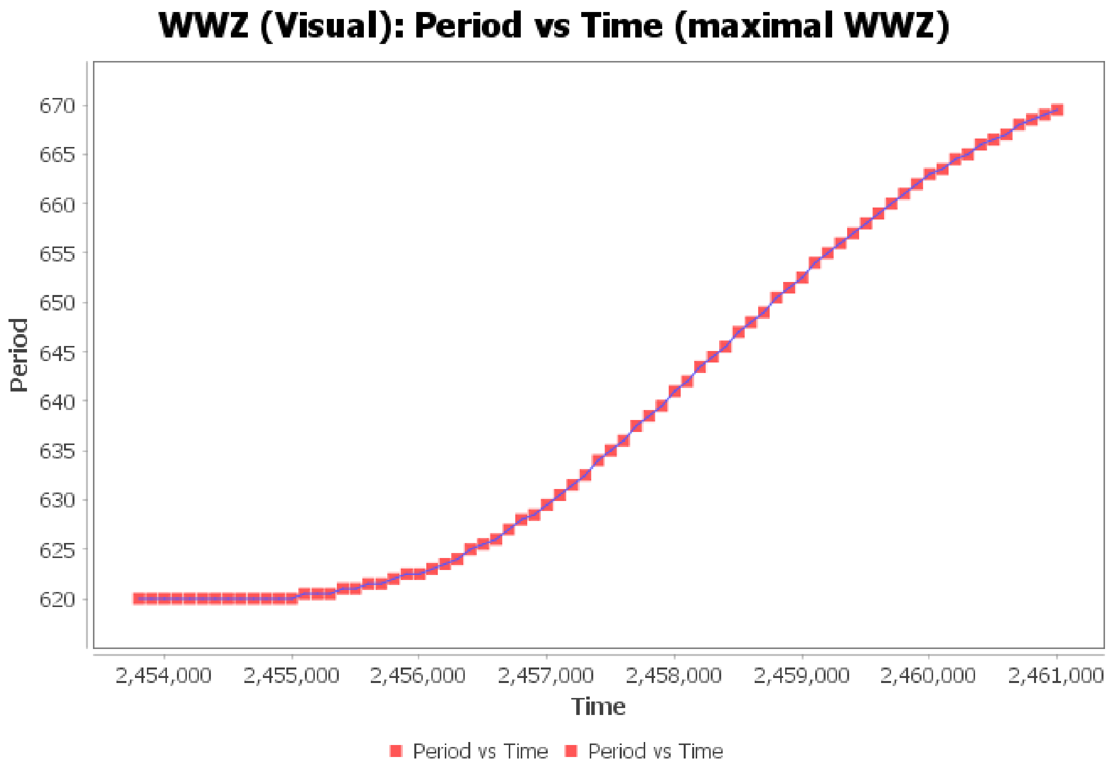

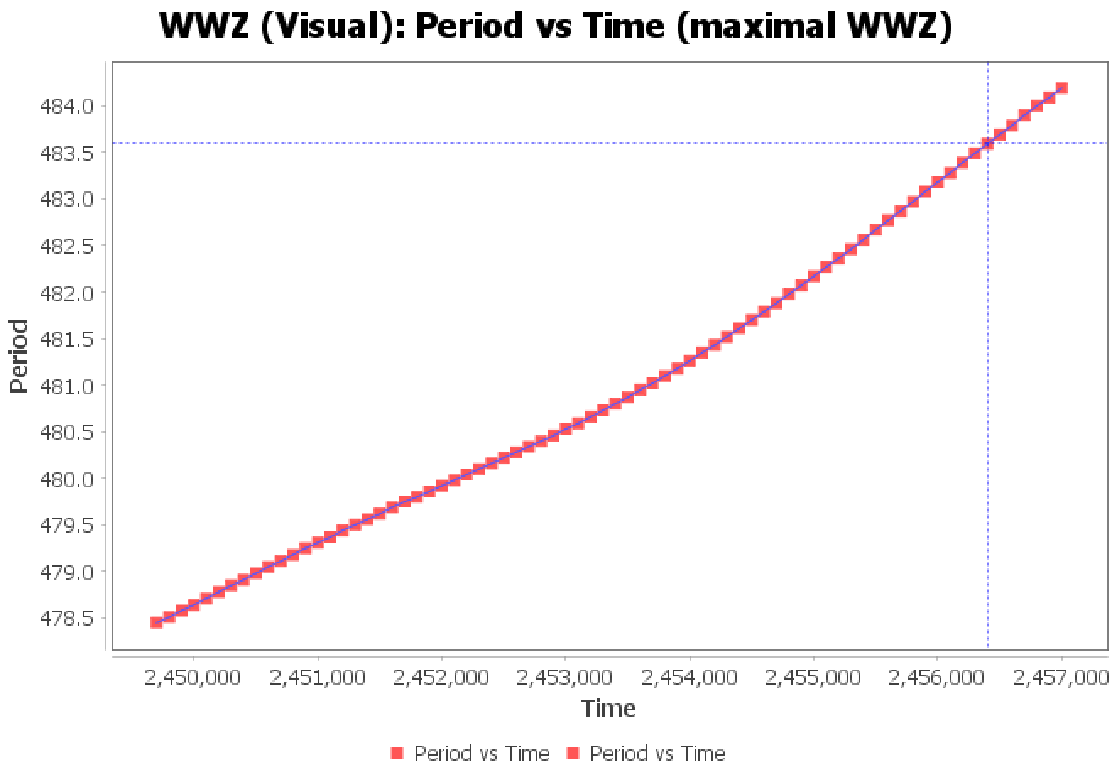

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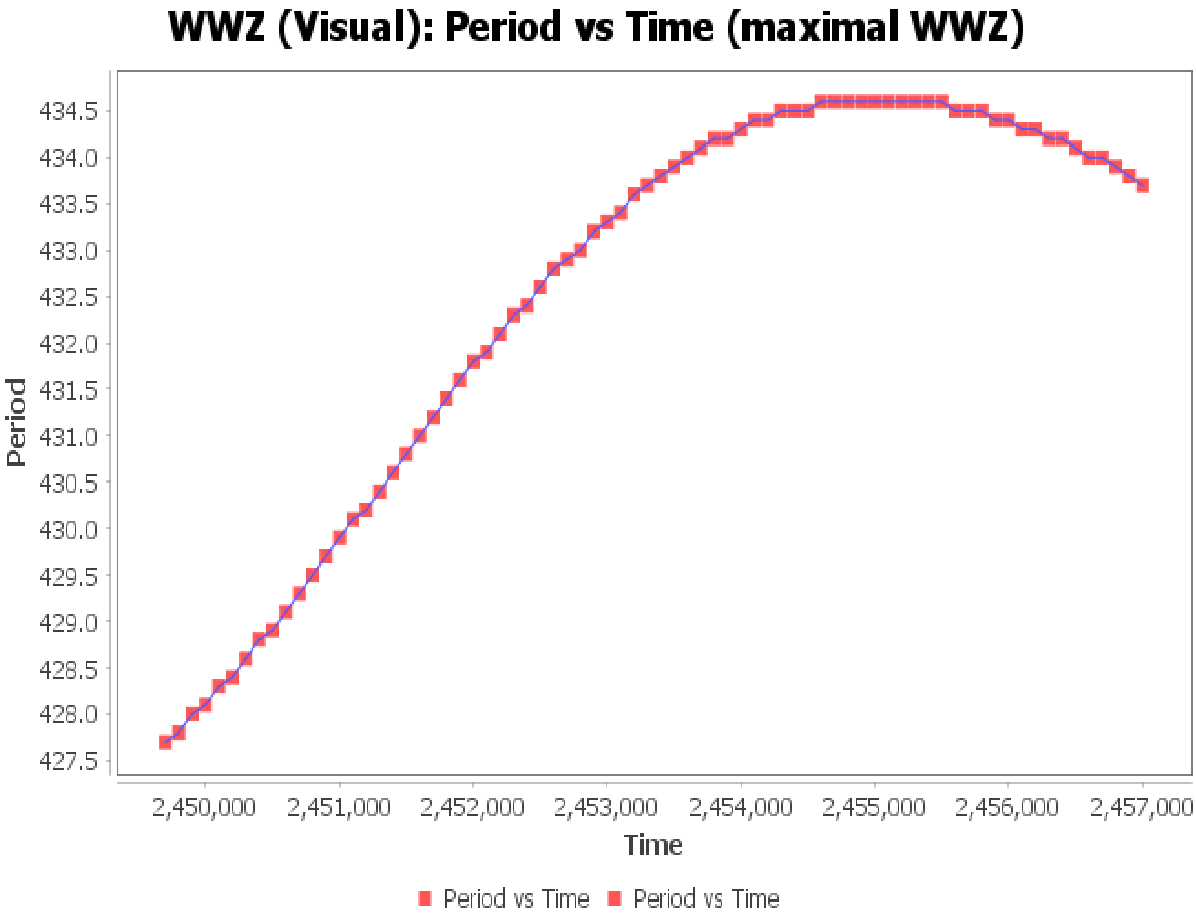

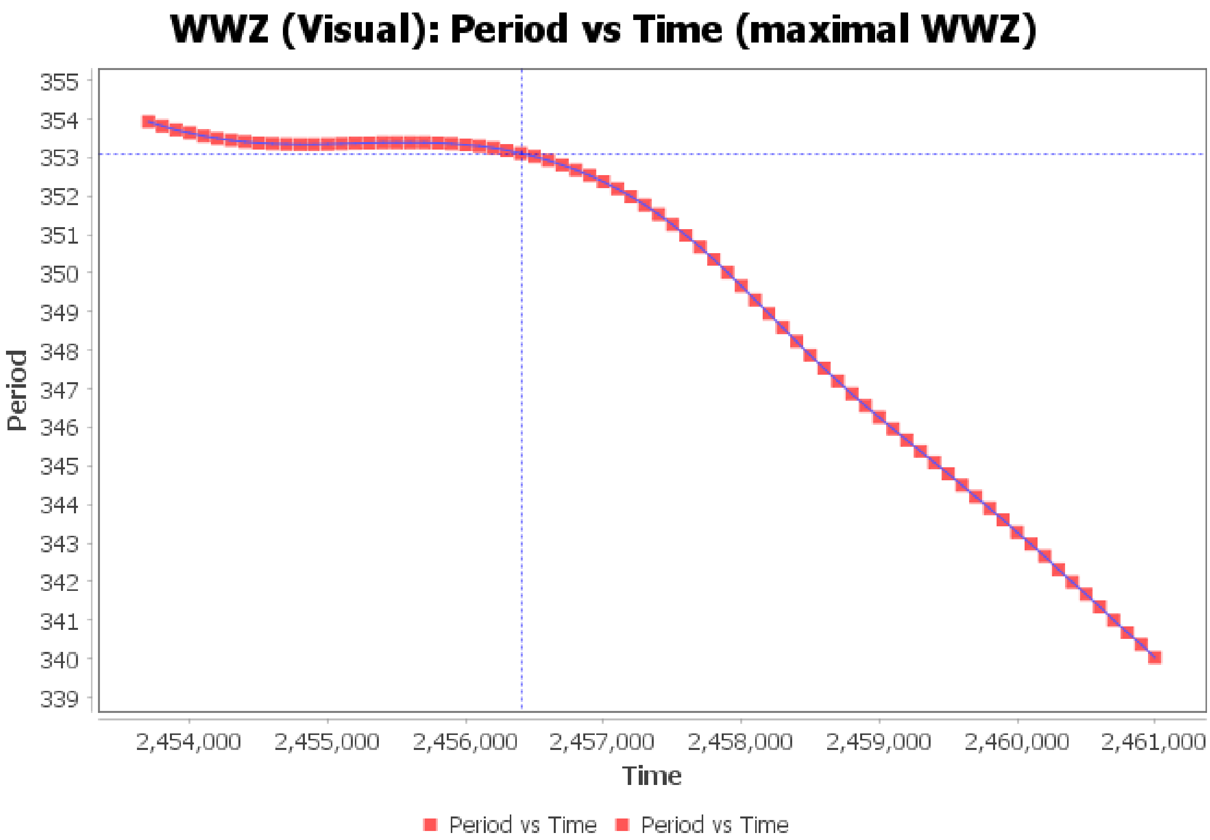

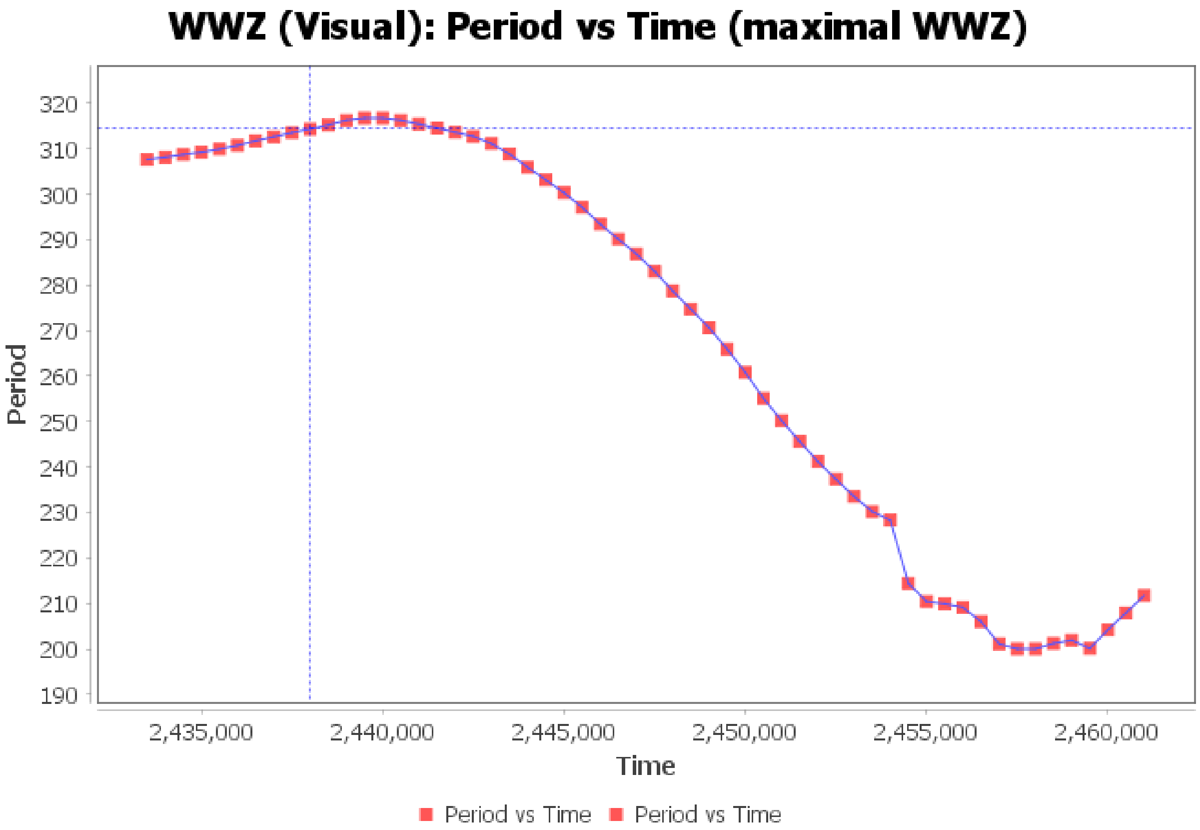
WWZ (Visual): Period vs Time (maximal WWZ)
320
310
300
290
280
270
260
250
240
230
220
210
200
190
Period
2,435,000
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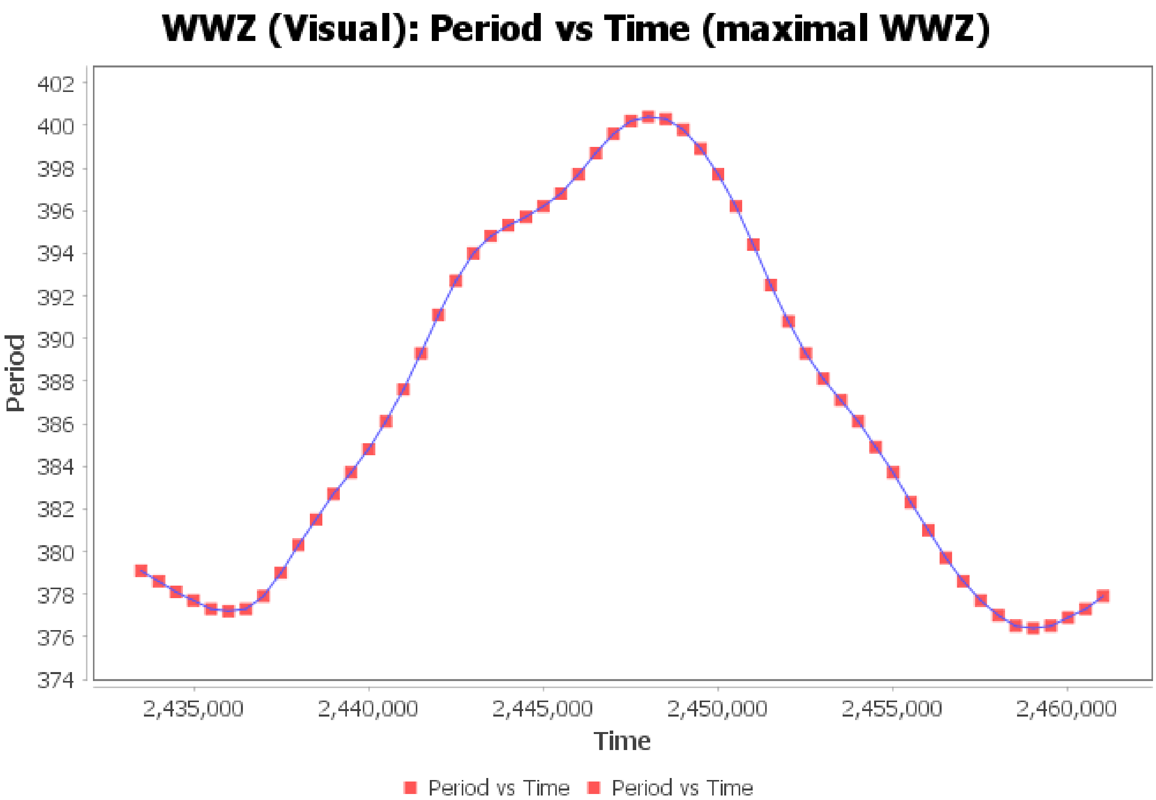
2,445,000
2,450,000
2,455,000
2,460,000
Time
Period vs Time
Period vs Time


WWZ (Visual): Period vs Time (maximal WWZ)
402
400
398
396
394
392
390
388
386
384
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380
378
376
374
Period
2,435,000
2,440,000
2,445,000
2,450,000
2,455,000
2,460,000
Time
Period vs Time
Period vs Time

Figure 1: 1st star VX SG 2nd star S Cep 3rd star R Cas 4th star SS Vir, 5th star T UMI, 6th star T CEP. All five stars show the evidence of secular period changes, except T CEP, which exhibits non-monotonic behaviour with alternating increase and decrease. T UMI appears to show a renewed increase in pulsation period beginning around 2460000.0.

Period uncertainties were estimated from the scatter among the periods derived from overlapping sliding windows. For stars with relatively stable periods, the uncertainties are typically a few days (≈ ±3–5 d), whereas stars exhibiting strong secular period evolution show somewhat larger uncertainties (≈ ±5–15 d). The corresponding uncertainties in period changes are generally several days and do not affect the overall trends discussed in this work.

Most stars display secular period evolution, characterized by either a gradual increase or decrease in pulsation period in contrast, T Cep show non-monotonic behavior, with periods increasing during one epoch and decreasing during another, indicating complex or cyclic period evolution. The relative period changes are generally small for most stars, consistent with slow evolutionary effects. However, T UMi shows a large and rapid decrease in period, significantly exceeding the typical values observed in Mira variables. Such behavior is consistent with previously reported cases of rapid structural changes in AGB stars.

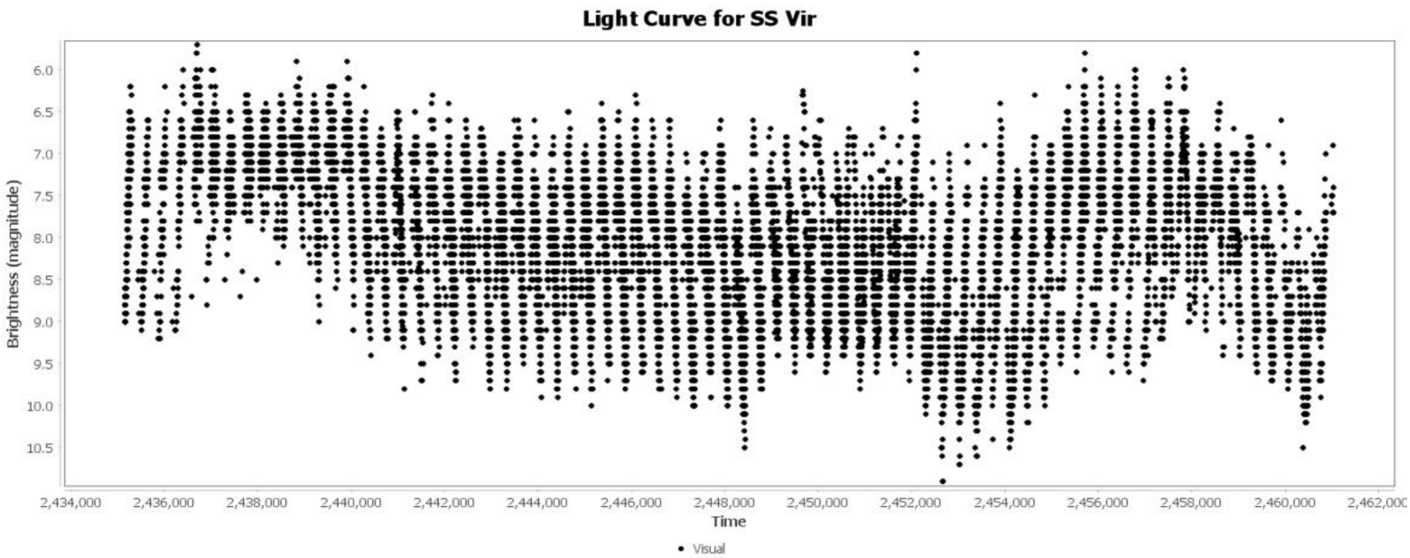
Table 1: This table summarizes the Max and Min Period, fractional period change (ΔP/P) and logarithmic period change rate (d ln P/dt) for the studied LPVs.

Star	P_{min} (Days)	P_{max} (Days)	ΔP / P(%)	d ln P/dt (day^{-1})	Trend
T UMI (1973-2014)	200	310	43.1	2.9×10^{-5}	Rapid Decrease
T UMI (2014-2025)	200	210	5.81	5.63×10^{-5}	Increase
VX SGR	620	670	7.75	1.41×10^{-5}	Increase
T CEP (1954-1994)	376	400	6.19	1.64×10^{-5}	Increase
T CEP (1994-2023)	376	400	6.19	2.14×10^{-5}	Decrease
SS VIR	339	354	4.33	9.7×10^{-6}	Decrease
R CAS	427	434	1.62	3.5×10^{-6}	Increase
S CEP	478	484	1.14	1.63×10^{-6}	Increase

Absolute period changes alone are inadequate for describing period evolution in long-period variable stars because their pulsation periods cover a wide range. Therefore, normalized parameters were used to characterize period variability in a consistent and comparable way. The relative period change, ΔP/P expresses the fractional variation of the pulsation period with respect to the mean period and provides a measure of the strength of period evolution.(Merchan

Benitez, P, et al, 2023) To account for the timescale of the variation, the logarithmic period-change rate *d* lnP/ *dt* was calculated. This quantity represents the normalized rate of period change per unit time and is widely used in studies of stellar pulsation and evolution. Periods at different epochs were determined using sliding-window analysis combined with Fourier and WWZ methods, and both parameters were used together to describe long-term, non-stationary period behavior.

T UMi exhibits two distinct phases of period evolution between 1973 and 2014, as reported in several studies. (Gal, J. et al, 1994, Neilson, H.R, et al, 2016, Merchan Benitez, P, et al, 2023) The pulsation period decreased rapidly from about 310 days to 200 days, corresponding to a large negative fractional change (approx −43%) and a logarithmic period-change rate of order 10^{-5}day^{-1}. In contrast, recent observations indicate that the pulsation period has begun to increase again, as shown in the present studies, rising from approximately 200 days in early 2023 to about 212 days by late 2025. Although the fractional increase during this phase is smaller (approx +5.8%), the associated rate of period change is significantly larger due to the much shorter time baseline. The opposite signs of the two trends clearly demonstrate a reversal in period evolution. This behavior may suggest that the rapid period decrease was followed by a phase of structural readjustment in the stellar envelope rather than a simple monotonic evolutionary process.



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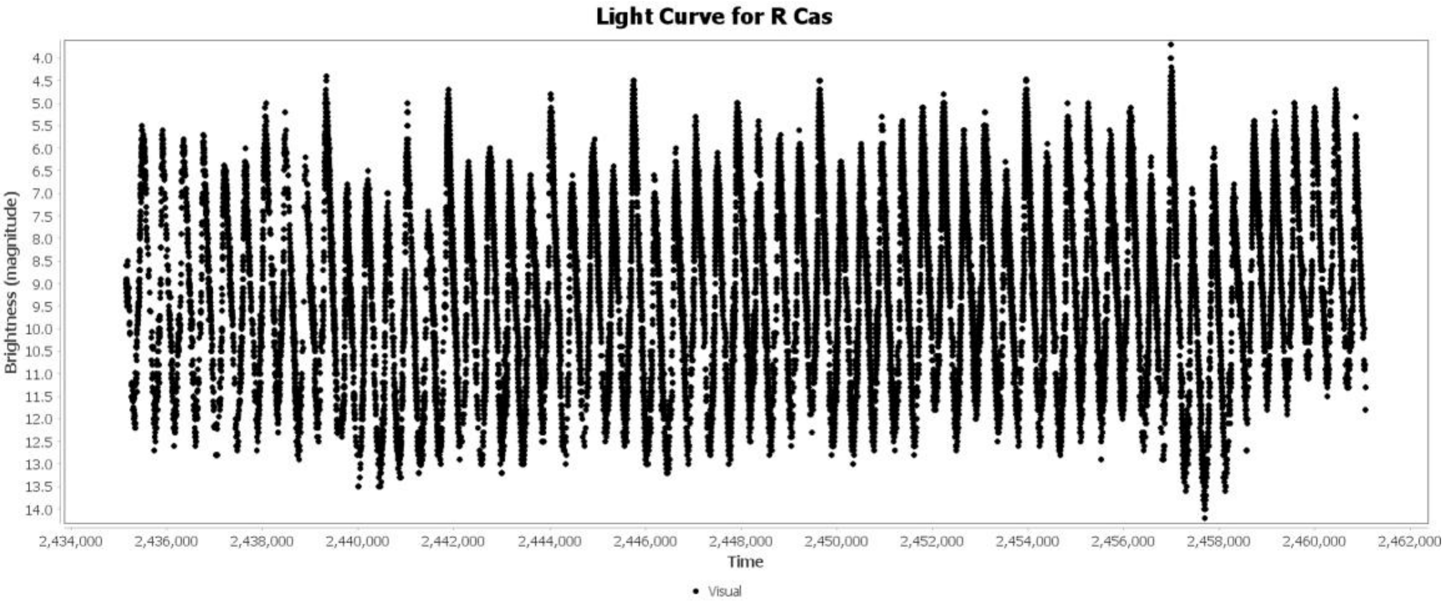

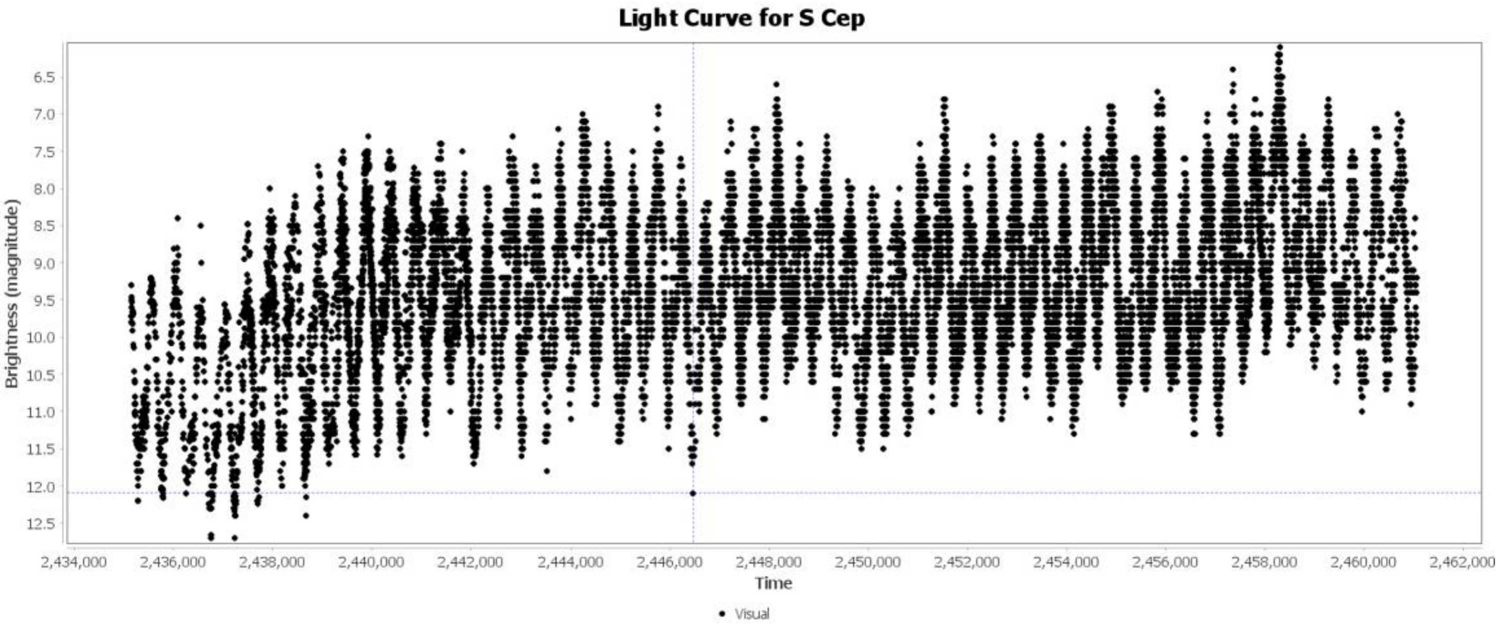

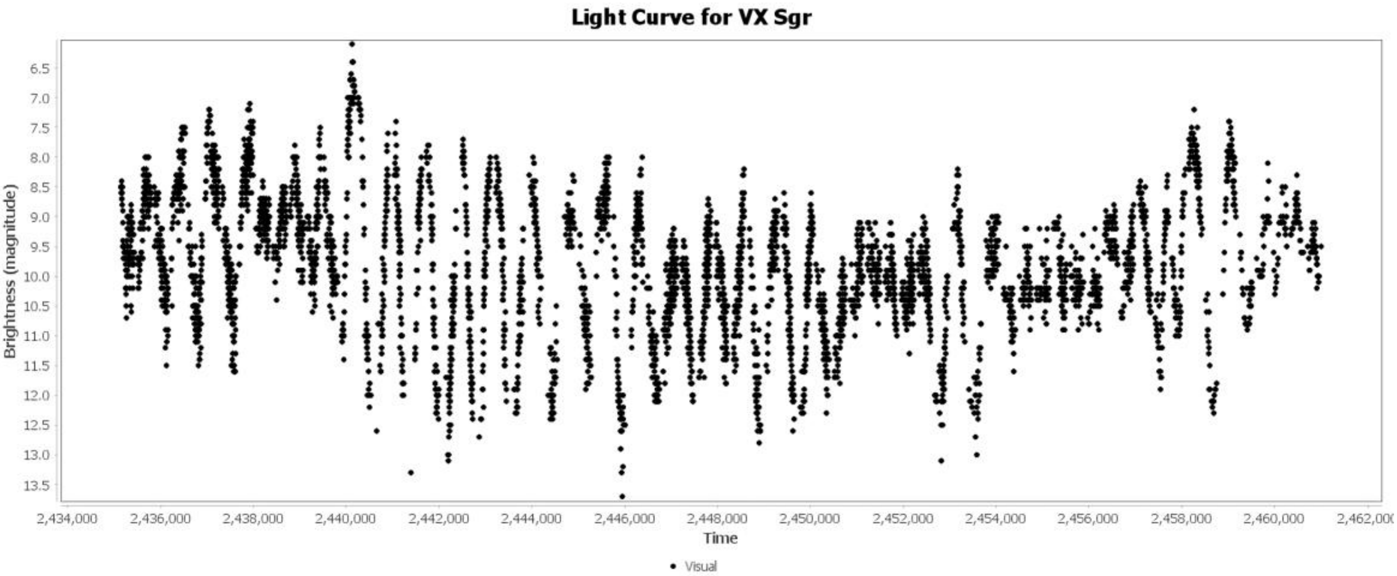

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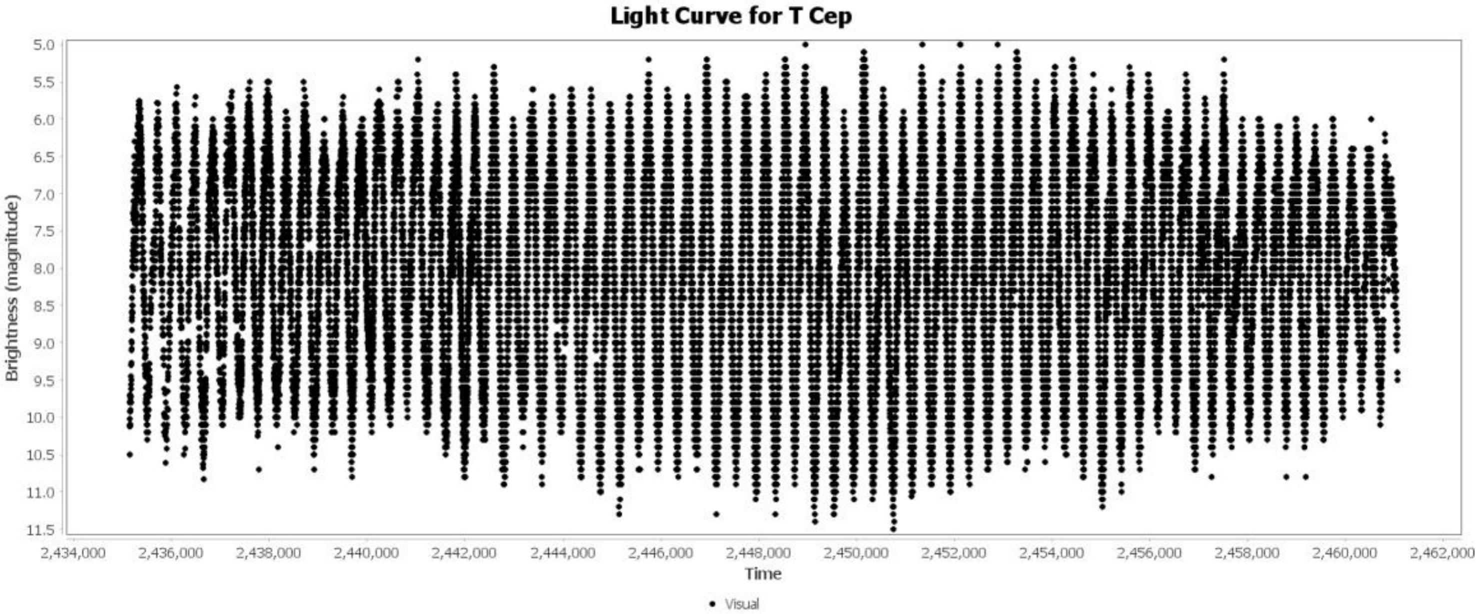

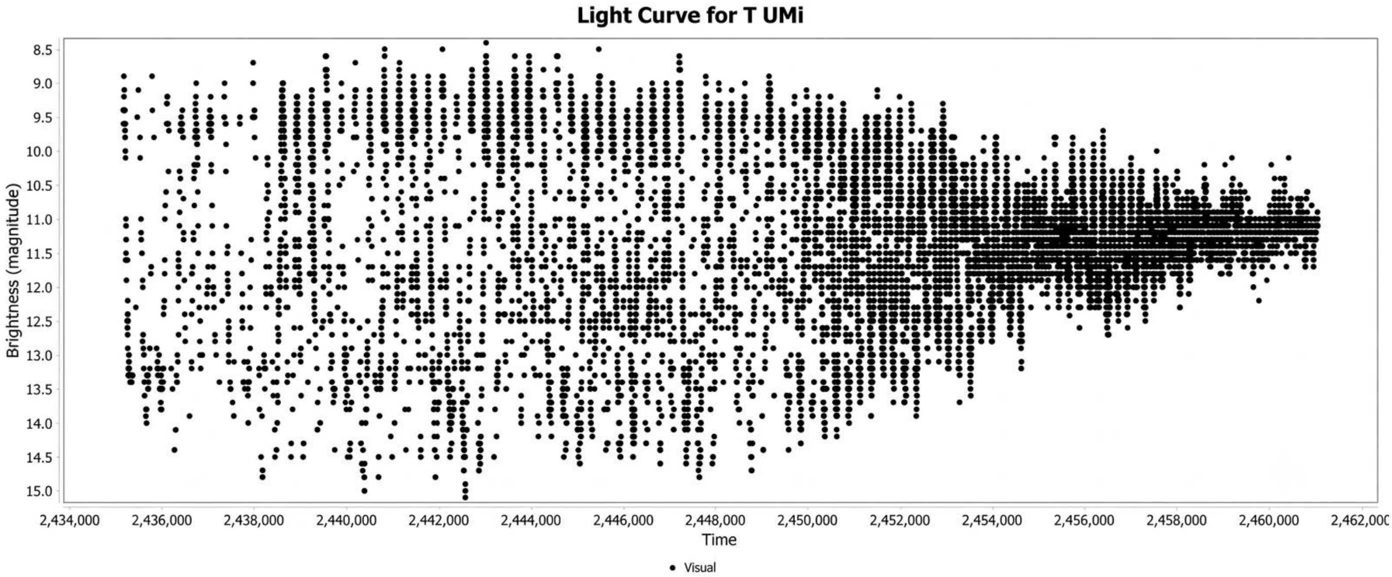

Figure 2: The raw visual light curve of the six LPVs covering the interval from JD 2435259.5 to JD 2460687.5. All stars exhibit noticeable variations in pulsation amplitude over time. VX SGR, S CEP, and T UMI show particularly large amplitude changes in visual magnitude, whereas R CAS and T CEP display comparatively more stable amplitude.

In this present study, long-term visual observations were analyzed to investigate pulsation period evolution in a sample of long-period variable stars, and highlighting the most recent changes observed in the period behavior of the investigated stars. In particular, the evolution of T UMi is especially interesting, as its pulsation period decreased from about 310 days to nearly 200 days and has subsequently begun to increase again, reaching approximately 210 days at present. Only minor period variations were found in R Cas. The maximum period reported in the present work is about 434 days, whereas Percy and Qiu (2019) reported approximately 430 days in a previous study. Some studies of VX Sgr (Lockwood, G.W and Wing , R.F, 1982 ;Dong Hwan Yoon et al. 2018) also indicate differences in the reported periods. Overall, the present work reveals the most recent variations in the pulsation periods of all the studied stars and provides updated estimates based on long-term observations extending to the present epoch. The results show that while most stars exhibit only small, gradual period changes consistent with secular stellar evolution, a subset displays significant or non-monotonic period variations.

These findings demonstrate that sliding-window and WWZ methods are effective tools for detecting and characterizing long-term period variability in LPVs. Continued monitoring and extension of long-baseline datasets will be essential for understanding the physical mechanisms driving period evolution in Mira-type stars.
Continued monitoring of all the studied stars, particularly T UMi and T Cep, is essential due to their sudden period decreases and subsequent increases. Further observations may provide deeper insight into possible amplitude variations and their influence on pulsation periods, as well as the underlying physical properties of these stars. A detailed investigation of these processes is beyond the scope of the present study.

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