“Rage Against the Dying of the Light”

The Declining Period of MU UMa

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RR LYRAE STARS

RR Lyrae stars are low-mass giants that have evolved off the main sequence, up the red giant branch, and into the zero-age horizontal branch (ZAHB). They typically remain in this stage for about 10^8 years, and stars that reside in the instability strip pulsate. Eventually, they’ll return to the red giant branch for a second time (Neilson et al. 2016). RR Lyrae stars are similar to Cepheids in that they’re both old, low-mass, pulsating stars, but RR Lyrae stars are typically too faint to be used as standard candles.

MU UMa

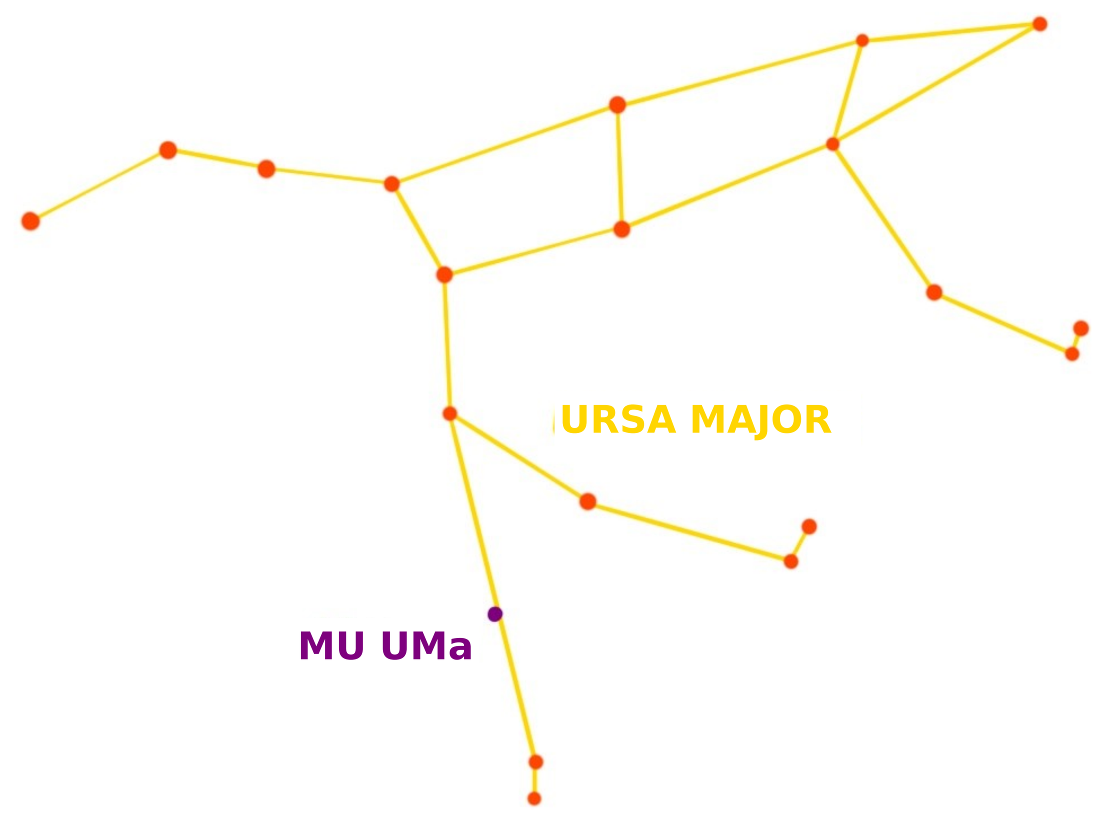

Figure 1: Constellation Ursa Major, with star MU UMa highlighted. MU UMa is located at 11h 35m 36.724s, +38° 45′ 57.816″.

MU UMa, located within Ursa Major (Figure 1), is a type C RR Lyrae star. It has a short period and is located next to easily found stars – the Big Dipper – and is thus an ideal candidate for taking sufficient data in one sitting. Its spectral type is A0 and absolute magnitude, though variable, is on average around 12 magnitudes.

EXPERIMENTAL PROCESS

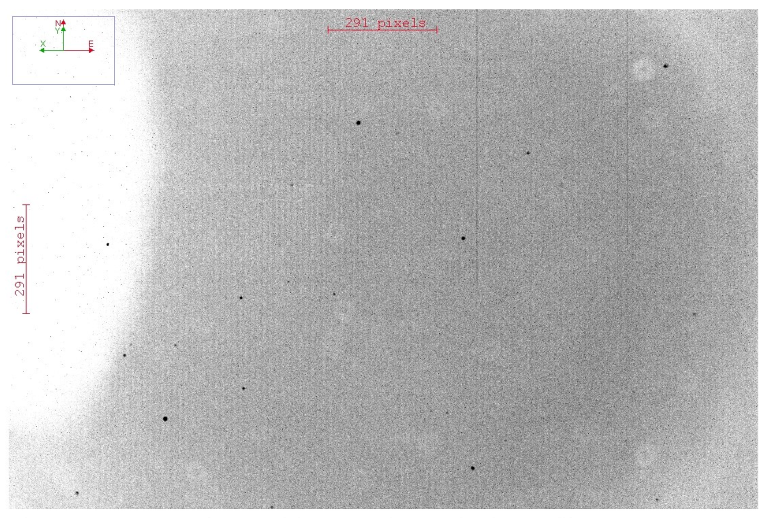

Figure 2: An uncleaned image through the B filter. Many disruptive visual elements can be seen, such ‘dust donuts,’ vertical lines, and the large aberration to the left side.

Because MU UMa resides near the Ursa major constellation, aligning the telescope for data collection was quite easy using the well-known stars nearby. After conducting observations in both the B and V filters for approximately 6.5 hours, we cleaned the images and began the process of extracting intensity data using AstroImageJ. We selected three nearby stars, detailed in the Tycho-2 Catalogue, to use as reference stars for our analysis.

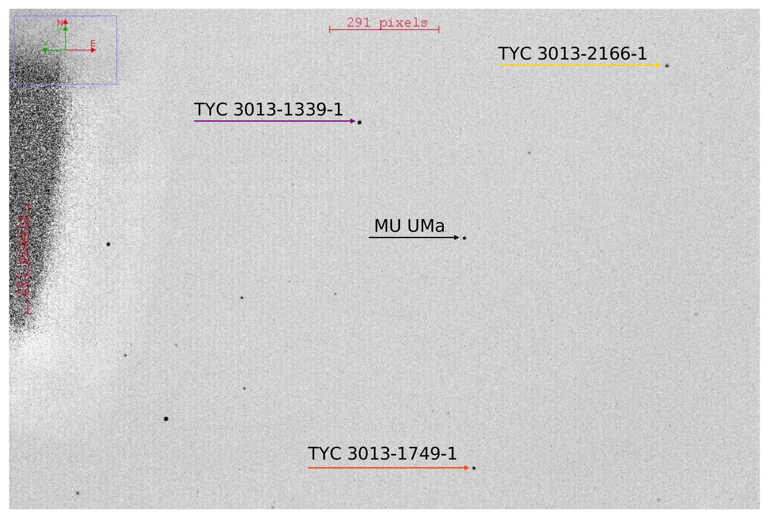

Figure 3: The same image with B filter, now cleaned using AstroImageJ. Our target star and reference stars are indicated.

LIGHT CURVE ANALYSIS

We used the star TYC 3013-1749-1 as our reference star with which to calibrate the conversion from intensity to absolute magnitude. We chose this specific star as it appeared to have a similar brightness to MU UMa, and was physically close enough that any possible sources of error would likely affect both. We calculated absolute magnitudes for both V and B filters. For MU UMA, these were, respectively, 11.6898 and 12.0419 magnitudes. The TYC catalog has these listed as, respectively, 11.554 ± 0.106 and 12.010 ± 0.108 magnitudes. Thus, our calculated values had percent errors of 1% and 0.3%, and fell within 2 and 1 sigma of the accepted values.

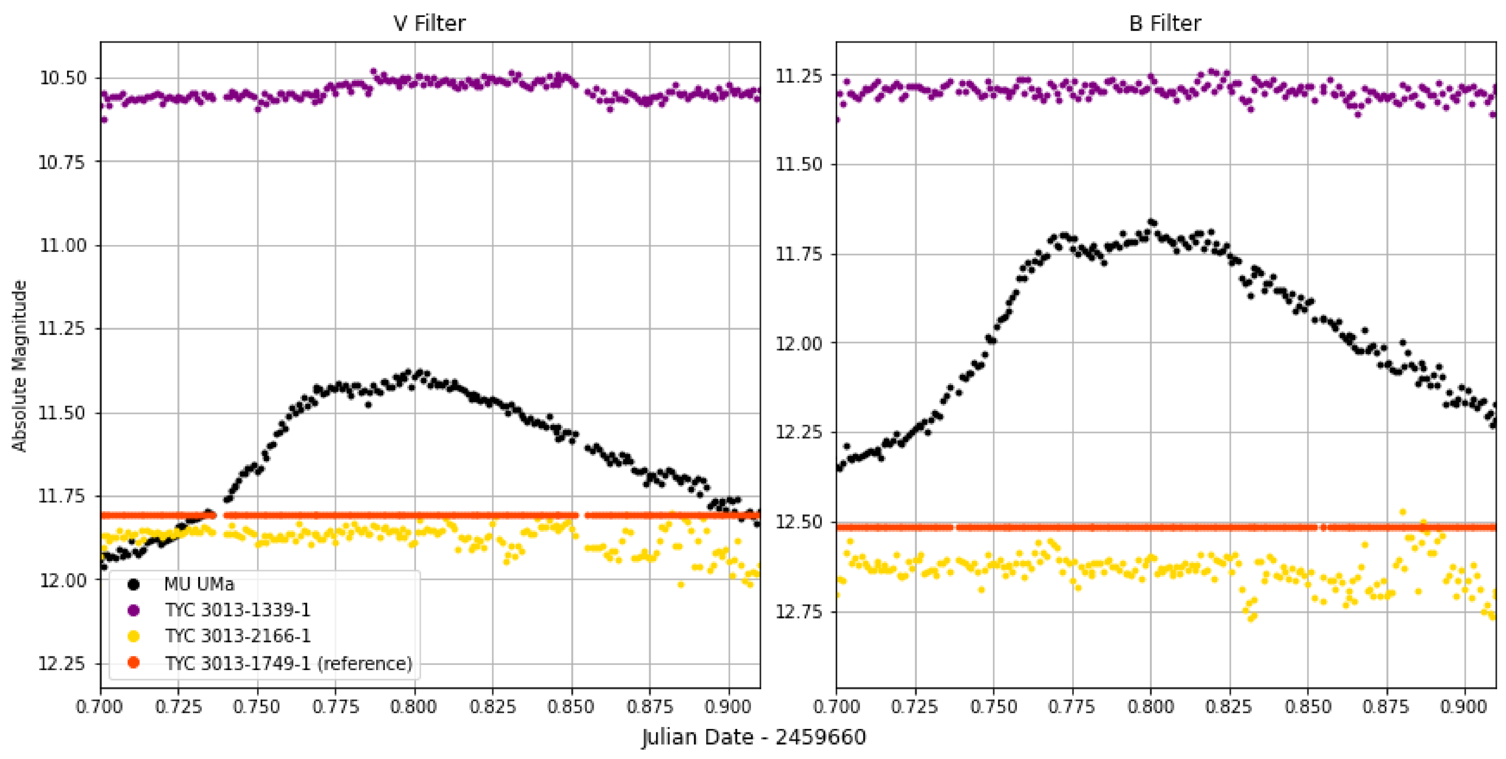

Figure 4: Light curves of the target and reference stars over the course of around 6.5 hours. TYC 3013-1749-1 was used as the reference star for converting from simple intensity to relative magnitude to absolute magnitude. The calculated magnitudes of the other stars are consistent with accepted values. MU Uma is seen to have a non-constant magnitude over time — not surprising as this is a variable star. It appears that our data covers nearly a full period.

PERIOD ANALYSIS

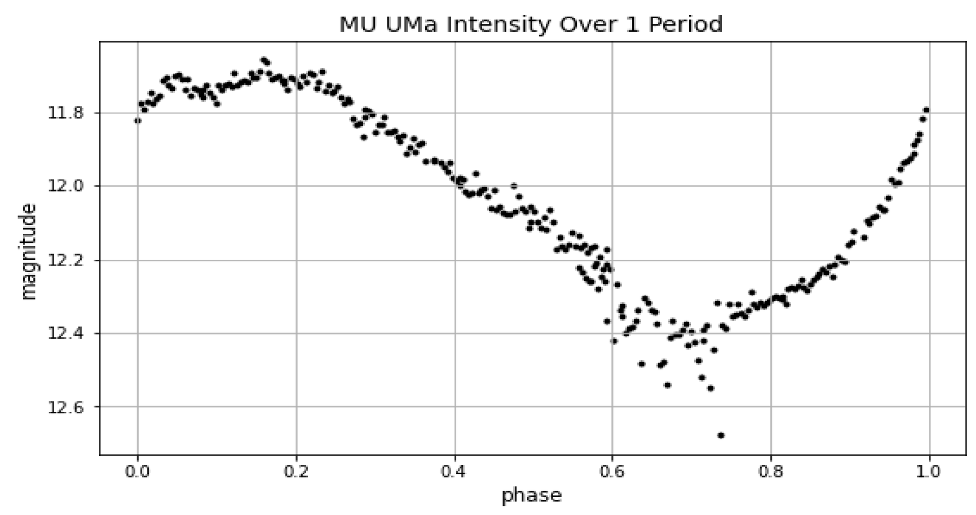

Figure 5: The Julian Date is converted to phase, where the phase at time t over a period P is the fractional portion of t/P. This plot is the smoothest representation of B filter magnitude over time we were able to find. The calculated period used is 0.25332 days.

We began our analysis using the epoch of maximum and period given in the GCVS catalog. However, these predicted that at the beginning of our data collection process the intensity of the star would be decreasing. At that time, it was increasing, which alerted us to a potential change in the period. Our measured maximum happened about 20 minutes before the predicted time. By converting the Julian Date to a phase, we were able to vary the period until striking upon a value that made the intensity a fairly smooth function of phase (Figure 5). This calculated period was 0.25332 days, or about 6.5 hours. Using this new period and the previously established epoch of maximum, we predicted a maximum about 2 hours after ours ended up happening. This inconsistency in predicted maxima leads us to believe that the period is decreasing over time (Figure 6).

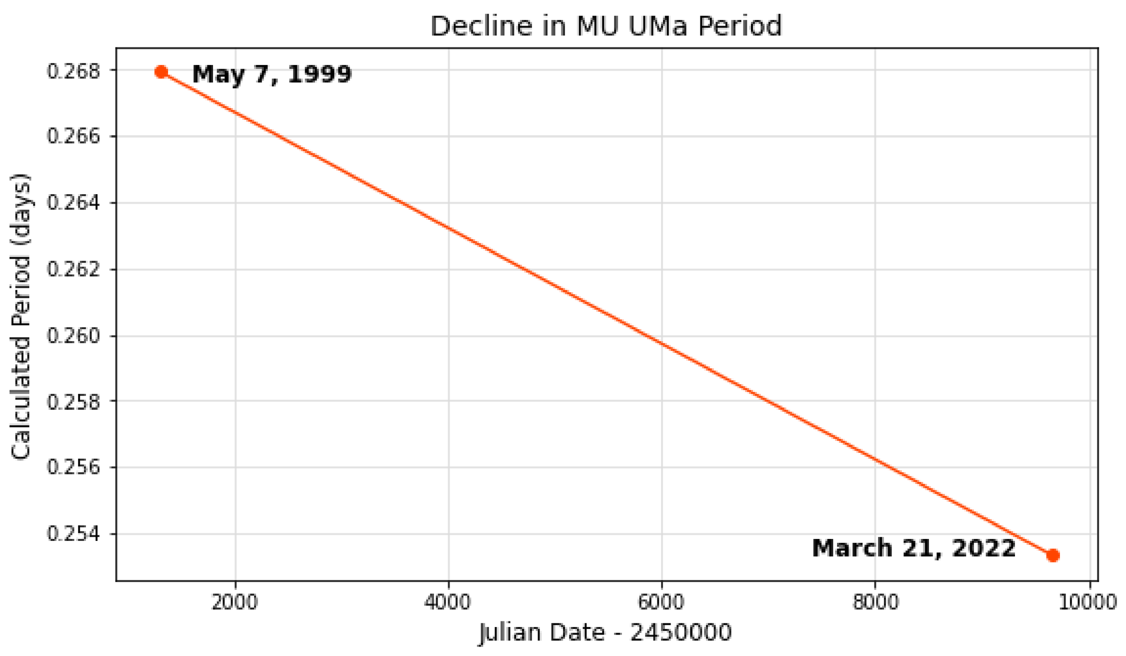

Figure 6: There is a marked decline in calculated period from the GCVS catalog, found in 1999, to our calculated period in 2022. We find that the period decreases by 0.000639 days each year.

CONCLUSIONS

RR Lyrae stars, when in the horizontal branch, are expected to decrease slowly in density, which would then lead to an increase in period. This change is typically less than 0.1 day per million years and tends to be linear in nature. We determined the period to have decreased, and at quite a large rate which, assuming our calculated period in 2022 is correct, contradicts this notion (Neilson et al. 2016). There is, however, evidence that some RR Lyrae stars that are about to but have not yet begun the core helium burning process may experience a period decrease at a greater rate (Silva Aguirre et al. 2010). While this is unlikely, there is a chance our star, MU UMa, falls within this category. Because we were unable to observe a completed cycle of MU UMa, our conclusion must remain a theory.

REFERENCES

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