

Observing the Unique Cepheid Variable AI CVn

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Introduction

AI CVn is a type of variable star called a δ Scuti. These stars oscillate via the Kappa mechanism, containing a layer of helium which is opaque at high temperatures [5]. This layer expands under radiation pressure and cools until it becomes transparent, at which point the star collapses again, the layer reheats, and the cycle repeats. We observe this oscillation as a change in brightness. AI CVn is a peculiar δ Scuti which has a superposition of multiple oscillation frequencies [3].

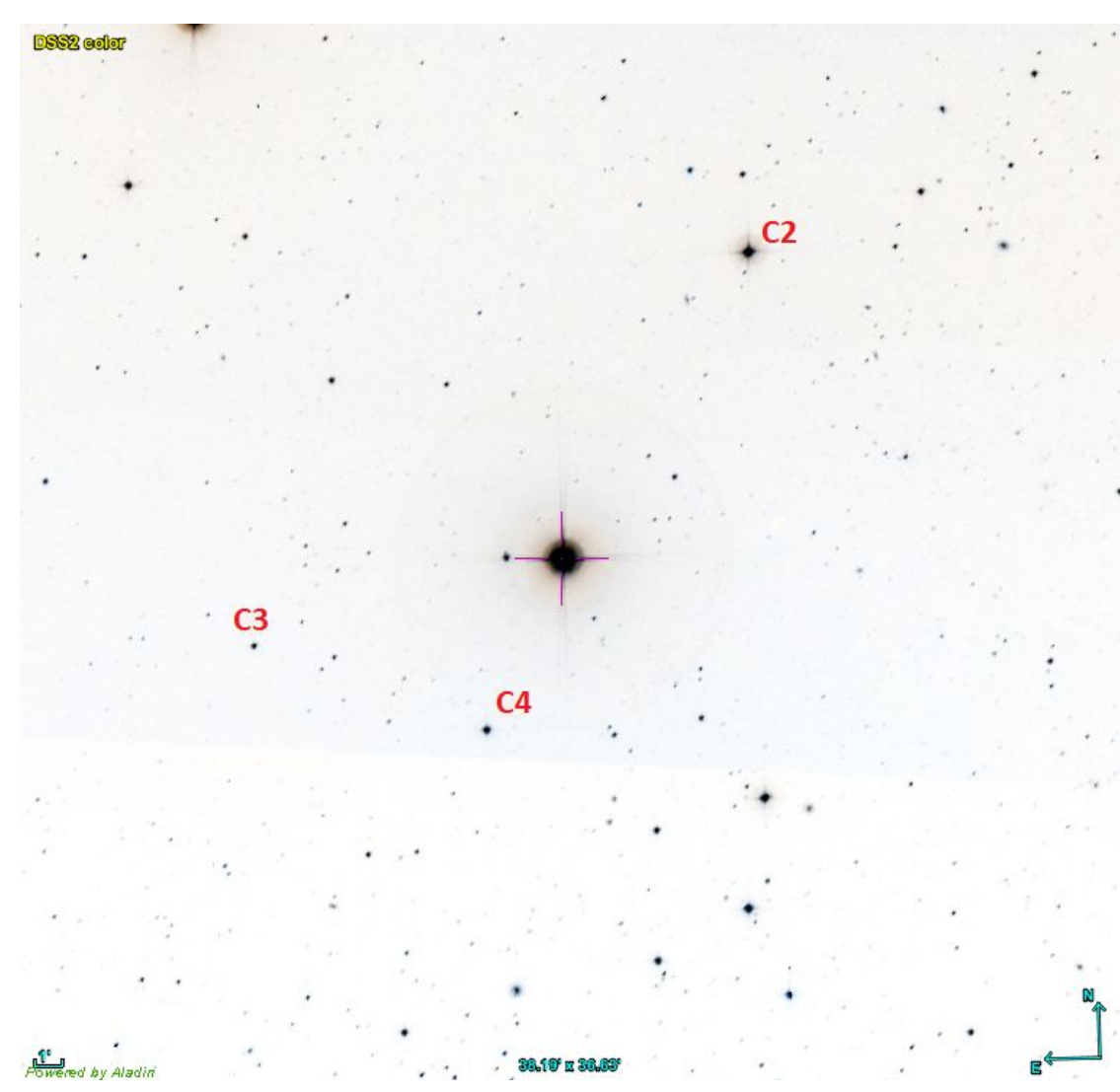
The 12-inch telescope at the RIT observatory was used to measure magnitudes in the B and V optical bands and processed for further analysis. AI CVn was expected to have 0.116 day period, but no periodic conclusions could be derived from this study.

Methodology

Our classmates used a 12-inch telescope at the RIT Observatory to capture images of our target star. We used AstrolmageJ to clean the images and extract photometric measurements in the B and V passbands.

For the temperature variation, we generated a plot of temperature vs. Julian date, ie. a temperature curve. For the frequency modes, we generated a light curve and input our light curve into a periodogram created by the NASA Exoplanet Archive.

A star finding chart for AI CVn (center) is displayed below, with HD 107824, BD+43 2213, and TYC 3020-1136-1 as C2, C3, and C4 respectively.



Processing

The analysis started by cleaning the raw images creating a master dark and flatfield image, which were subtracted and divided by to obtain unbiased DC count data. The values were measured in AstrolmageJ to measure the DC intensity values of the variable star. A reference star was chosen, and the DC values were converted to B and V-band magnitudes. In the plots below, star HD 107824 was chosen to be our reference star due to it's closeness on the sensor to our target, and having a close magnitude to the target.

Our measured magnitudes were within ± 0.05 magnitude range of an expected value, well within an acceptable margin.

Cepheid Temperature

For all emitting blackbodies, the temperature of the emitter can be calculated by using the spectral properties as a function of wavelength. For the case of this object, we are going to assume that this object is a main sequence, ideal blackbody star. Therefore, through a derivation of the blackbody emission equation, the temperature of AI CVn can be determined with the differences in the B and V-band magnitudes as shown:

$$T = \frac{5601K}{(B - V + 0.4)^{\frac{2}{3}}}$$

Equation 1 - Temperature derived for a Blackbody via color index [1].

For each recorded value, this temperature was found and plotted below. There is an average temperature value of 6570 Kelvin. Our temperature plot can be seen in Figure 2.

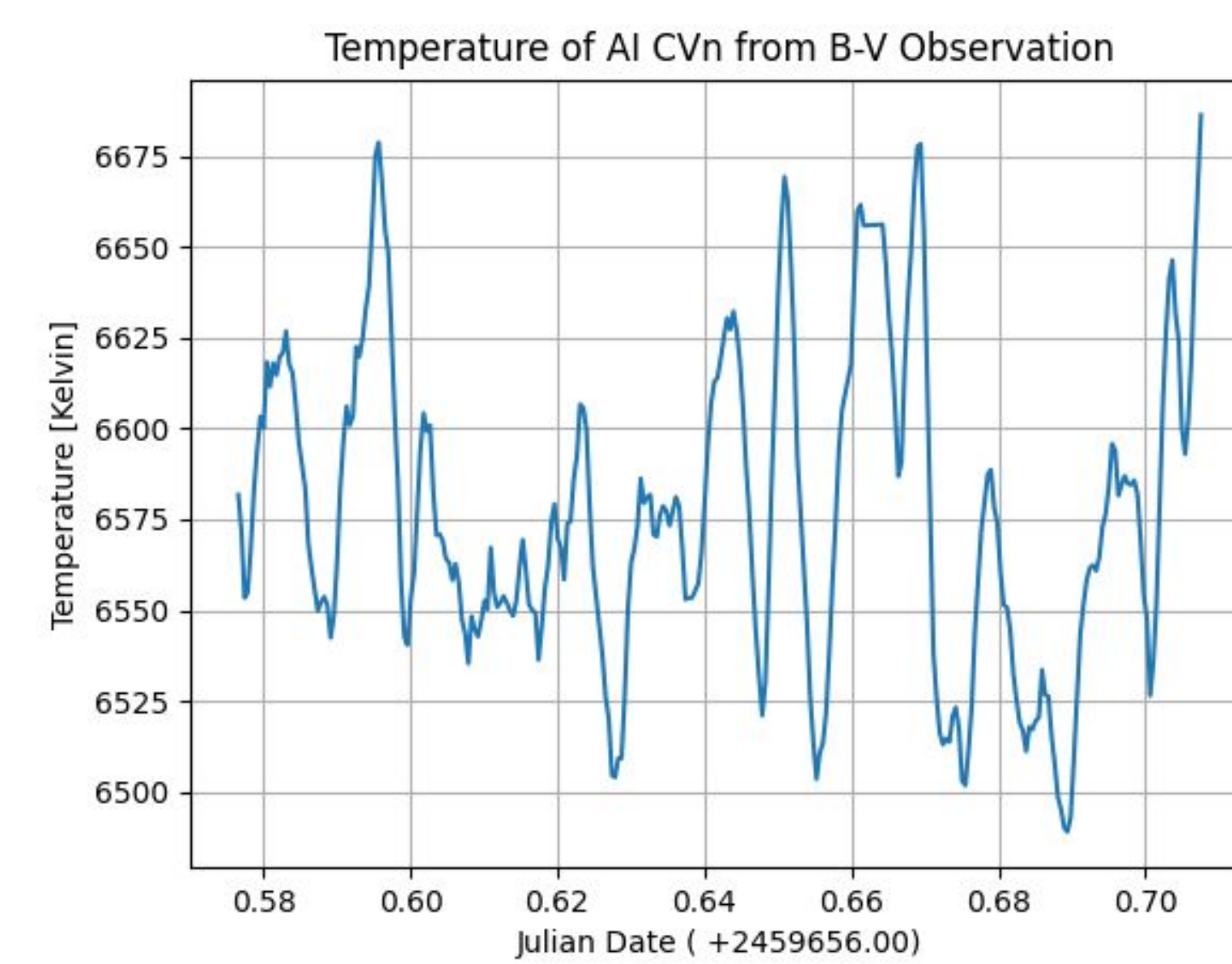


Figure 2 - Temperature Derived of AI CVn using Equation 1.

Yet, this may be a stretch of a conclusion to draw. According to the University of Colorado, Cepheid variables and their δ Scuti variants are not guaranteed to be main sequence stars [2] and are not subject to this blackbody property. Although, a paper on this topic discovered the temperature to be around 6,875 Kelvin, we must be skeptical of these measurements.

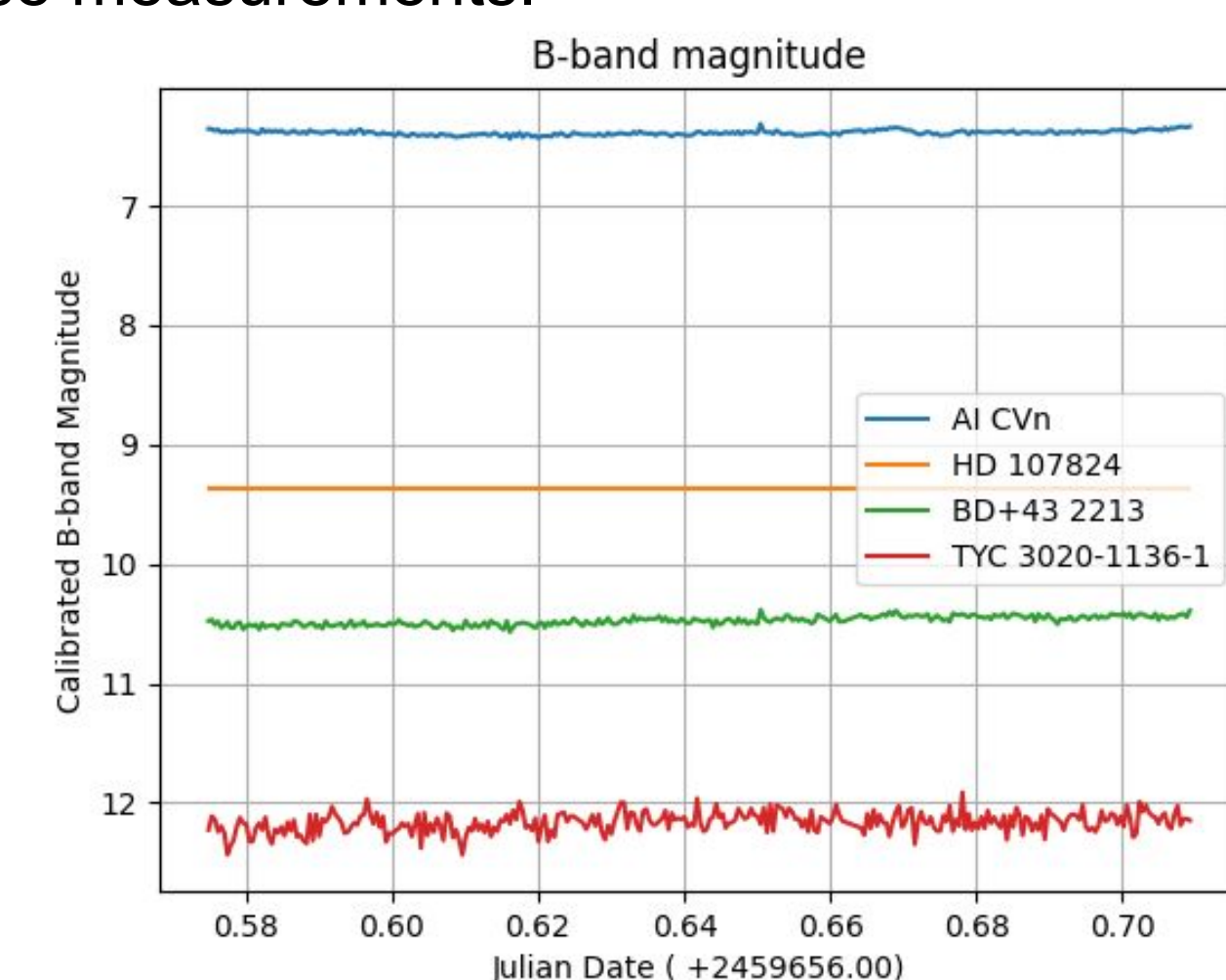


Figure 3 - B-band magnitudes of AI CVn as well as other target stars

Periodicity

Our initial attempt at measuring the periodicity had us put our measured magnitudes into the NASA Exoplanet Archive Periodogram tool, a special frequency decomposition tool. From the data collected, we can conclude that as there is an increasing bound on the longer period with no direct peak, we do not have complete data to draw conclusions about the frequency of magnitude spikes. Refer to Figure 4 to see our raw plots.

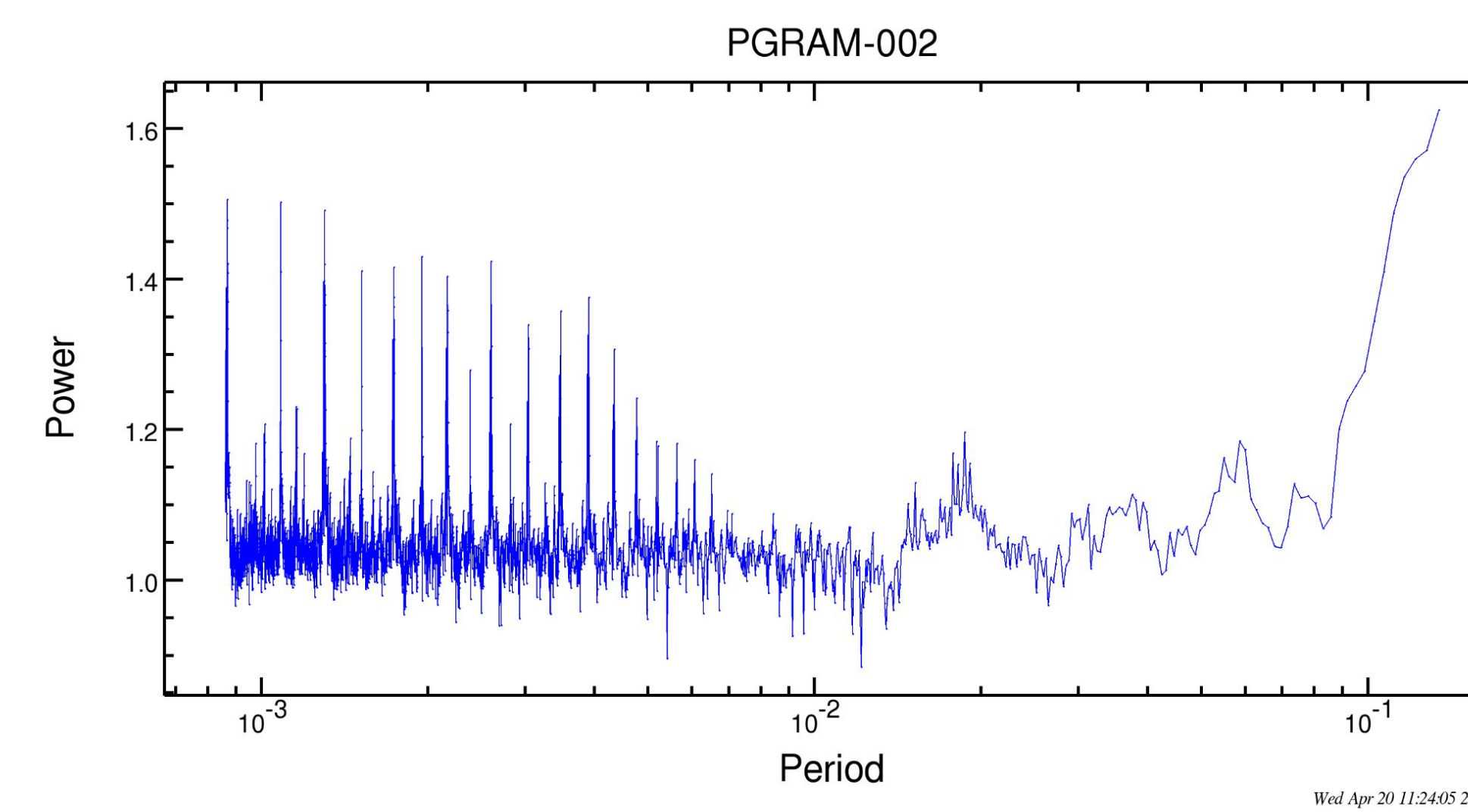


Figure 4 - Periodogram of the data collected of AI CVn on March 17th, 2022.

To supplement the missing data, we used publicly available data from TESS on AI CVn to further our research. The resulting periodogram can be seen in Figure 5. Note how the peaks start to be identifiable where our previous plot ended.

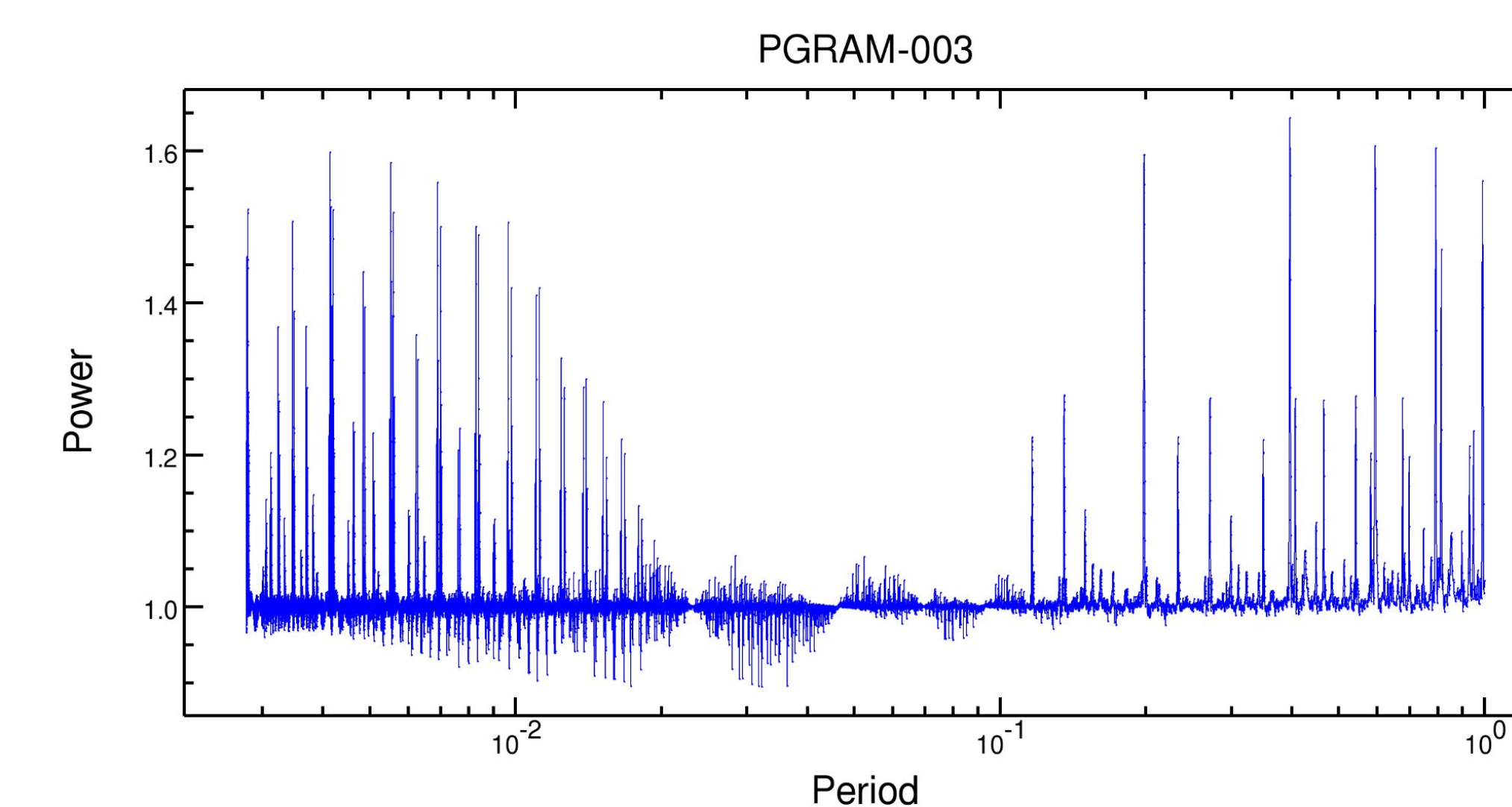


Figure 5 - Periodogram of TESS data on AI CVn.

The top 5 periods in terms of power are listed in Table 1. Our results for the top periods are not exact, but consistent with the values reported in Breger et al.

Period (Days)	Power
0.396	1.644
0.198	1.560
1.190	1.582
0.595	1.577
0.792	1.571

Table 1 - Peak period of the TESS data.

There were plans to incorporate a Non-Uniform Discrete Fourier Transform to analyze the magnitude and phases from our collected data, as they are superimposed and vary in phase. Due to limitations in our processing, we were not able to use these results

Conclusion

Our average temperature was less than the value quoted in the paper by 305 K. This suggests the possibility of our measurements having been taken during a part of AI CVn's period when it was cool and dim. However, our measured average magnitude is less, ie. brighter, than the value in SIMBAD, so we do not conclude this. Another possible explanation is that AI CVn is not an approximate blackbody due to non-MS properties, and therefore our calculation is incorrect.

Our measurements do not span an entire period in the fundamental mode of AI CVn. Therefore, the periodogram did not produce physical results from our measurements. However, from the TESS data, we observe five frequency modes consistent with previous work.

Recommendations

AI CVn is believed to be in a binary system [3,4]. Further observations over a longer interval of time may be useful in detecting the orbital period of the system photometrically, as well as the beating period of the orbital and pulsation modes.

Additionally, the phases of the frequencies could be determined using a non-uniform fast Fourier transform instead of the periodogram. We attempted this, but found non-physical results.

References

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