# PERIOD HUNTING IN LONG-TERM LIGHT CURVES OF CATACLYSMIC VARIABLES

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**Abstract**

Recent interest in long periods which may be present in cataclysmic variables has been motivated principally by the idea that solar-like magnetic cycles might be important. For the brighter members of the class, AAVSO light curves are an ideal resource for testing the presence of such periods. The detection limits are much more sensitive than could be achieved by any feasible photographic or photoelectric means. But, artifacts are found to be present in the Fourier spectra of the light curves of novae, caused by the lunar synodic period, the lunar sidereal period, the Earth's rotation period, and the round-off errors made by observers in recording the time.

## 1. Introduction

Visual data made available by the AAVSO can be extremely useful to professional astronomers. The visual data provide a very long baseline of observations otherwise impossible for professionals to obtain. It serves as an ideal data base for studying long term variations in light curves of cataclysmic variables that may be due to magnetic cycles which are on time scales of many years. Furthermore, eyeballs tend to be more uniform than phototubes over long periods of time and from one observer to the next.

## 2. Artifacts in the Data

Figure 1 exhibits the light curve of Nova Aqulae 1918 (V603 Aql) from 1918 to 1991 compiled from AAVSO visual data. V603 Aql is a cataclysmic variable which experienced a nova outburst in 1918, reaching a peak brightness of magnitude -1.1. From the figure, it is clear that the brightness fell off dramatically from 1918 until approximately 1950.

The AAVSO provided me with over 5067 observations taken between 1965 and 1991. Figure 2 shows the resulting light curve over this 26-year interval. The data in Figure 2 were averaged in twenty-observation intervals. In support of the possible existence of a magnetic cycle in the system, the light curve (Figure 2) does exhibit a long term modulation over 11-12 years. It should also be noted that the light curve shows evidence of an annual variation on the average of roughly 0.2 magnitude. Of the 24 full years represented in Figure 2, 14 show a slight increase in brightness over the course of a year, whereas none show any evidence of a decrease in brightness. This annual variation in brightness may be due to the object appearing more faint in the morning sky, which corresponds to the beginning of an observing season, than in the evening sky.

The data are most useful if we can first understand several inherent artifacts produced by sampling, round-off errors, etc. In my research, I have analyzed the origins and nature of these effects.

In analyzing the data, I performed Discrete Fourier Transforms (DFTs) to search the unevenly spaced data for periodic signals. The output of the DFT is a plot of power versus frequency in which a strong peak indicates the existence of a period.

Figure 3 is the result of a DFT performed to search for periodicities of V603 Aql between 0.1 and 2 days. There is an obvious peak at a period of one day which is a sampling effect caused by observers taking their data at one day intervals. Smaller spikes occur at periods of (1 day/n), for which n = 2, 3, ..., 10, which are caused by round-off errors made by observers when recording time to an accuracy of one tenth of a day. These effects are enhanced by the lack of observations taken approximately half way around the globe.

When searching for periods of V603 Aql between 2 and 750 days, as seen in Figure 4, a significant peak is apparent at a period of 1 year. The peak at one year is a by-product of the earth's revolution about the sun. This can be further proven by performing a synchronous summation, folding the data, over the period of one year, which results in empty bins when V603 Aql is not observable. As exhibited by Table 1, V603 Aql was never observed during the time of year mid-January through mid-April, which corresponds to bins 26 through 30.

Table 1. V603 Aql data folded at P = 365.25 days.

| *Bin* | *Number of Observations* | *Average Visual Magnitude* |
|---|---|---|
| 1 | 127 | 11.43 |
| 2 | 142 | 11.41 |
| 3 | 133 | 11.42 |
| 4 | 180 | 11.42 |
| 5 | 183 | 11.43 |
| 6 | 169 | 11.42 |
| 7 | 177 | 11.43 |
| 8 | 178 | 11.42 |
| 9 | 214 | 11.41 |
| 10 | 157 | 11.44 |
| 11 | 206 | 11.45 |
| 12 | 191 | 11.39 |
| 13 | 161 | 11.41 |
| 14 | 158 | 11.41 |
| 15 | 194 | 11.38 |
| 16 | 170 | 11.37 |
| 17 | 135 | 11.40 |
| 18 | 111 | 11.38 |
| 19 | 104 | 11.39 |
| 20 | 90 | 11.40 |
| 21 | 60 | 11.43 |
| 22 | 39 | 11.43 |
| 23 | 22 | 11.38 |
| 24 | 11 | 11.37 |
| 25 | 5 | 11.36 |
| 26 | 0 | - |
| 27 | 0 | - |
| 28 | 0 | - |
| 29 | 0 | - |
| 30 | 0 | - |
| 31 | 1 | 11.50 |
| 32 | 5 | 11.38 |
| 33 | 7 | 11.40 |

Table 1 continued.

| *Bin* | *Number of Observations* | *Average Visual Magnitude* |
|---|---|---|
| 34 | 5 | 11.46 |
| 35 | 12 | 11.58 |
| 36 | 16 | 11.52 |
| 37 | 14 | 11.46 |
| 38 | 19 | 11.58 |
| 39 | 24 | 11.44 |
| 40 | 30 | 11.45 |
| 41 | 34 | 11.46 |
| 42 | 29 | 11.44 |
| 43 | 40 | 11.48 |
| 44 | 44 | 11.42 |
| 45 | 47 | 11.41 |
| 46 | 41 | 11.41 |
| 47 | 52 | 11.48 |
| 48 | 72 | 11.44 |
| 49 | 90 | 11.48 |
| 50 | 101 | 11.46 |

There are two plausible explanations for the two peaks in Figure 4 corresponding to the synodic and sidereal periods of the moon. First, as shown by Table 2, which lists the data folded at the lunar synodic period, there is a dearth of observers when the moon is full (bins 23 through 26). Secondly, the moon seems to have systematic effects on the estimated brightness of the star. I believe that the latter explanation is more influential on the resultant Fourier transform. From a synchronous summation over each of the lunar periods, (Figures 5 and 6), it is clear that the brightness varied by 0.088 magnitude over the period of the moon. The synchronous summation corresponding to the lunar synodic period, P = 29.550 + 0.026 days, (Figure 6), shows that the star appeared brightest near full moon.

I verified my conclusions in several ways. Synchronous summations were performed and inspected at every obvious period. Data sets were recreated with random dates paired with true magnitudes and vice versa. For example, I took the true times of observations and paired each time with a randomly selected magnitude. All sampling effects still appeared in the DFT's. The spike corresponding to P = 1 year was still very strong, as well as the P = 1 day spike.

To confirm that the conclusions were inherent in all visual data sets, I compared my results with those from V603 Aql with data on other stars. I looked at GK Per from 1966 to 1991, for which the AAVSO supplied 10,676 data points. The data were averaged in twenty-observation intervals. The averaged light curve of GK Per, as seen in Figure 7, may also exhibit evidence of long term modulation which may be due to solar-like magnetic cycles. The long term wiggle is more clearly seen in Figure 8, the averaged light curve of GK Per in which the "dwarf nova" outbursts have been omitted. As seen in Figure 9, the DFT of GK Per from 0.1 to 2 days shows the same spiky features exhibited by the V603 Aql data (although with different values of power) at a period of 1 day as well as the 10 harmonics in the one day interval. From the DFT taken at 0.2 < P < 750 days, (Figure 10), we see spikes occurring at periods very nearly equal to the lunar periods. It should be noted that the period of one year is lost in the region which is densely populated by the noise which results from the "dwarf nova" outbursts evident in the light curve (Figure 7).

Table 2. V603 Aql data folded at the lunar synodic period of P = 29.550 days. Bin 24 corresponds to a full moon.

| *Bin* | *Number of Observations* | *Average Visual Magnitude* |
|---|---|---|
| 1 | 113 | 11.43 |
| 2 | 117 | 11.42 |
| 3 | 85 | 11.45 |
| 4 | 108 | 11.38 |
| 5 | 93 | 11.44 |
| 6 | 114 | 11.45 |
| 7 | 85 | 11.44 |
| 8 | 98 | 11.40 |
| 9 | 90 | 11.43 |
| 10 | 80 | 11.44 |
| 11 | 67 | 11.46 |
| 12 | 85 | 11.46 |
| 13 | 72 | 11.43 |
| 14 | 62 | 11.48 |
| 15 | 60 | 11.44 |
| 16 | 55 | 11.40 |
| 17 | 48 | 11.41 |
| 18 | 50 | 11.38 |
| 19 | 51 | 11.38 |
| 20 | 30 | 11.38 |
| 21 | 36 | 11.40 |
| 22 | 31 | 11.45 |
| 23 | 21 | 11.43 |
| 24 | 22 | 11.38 |
| 25 | 25 | 11.40 |
| 26 | 28 | 11.39 |
| 27 | 37 | 11.43 |
| 28 | 49 | 11.38 |
| 29 | 65 | 11.42 |
| 30 | 82 | 11.38 |
| 31 | 83 | 11.43 |
| 32 | 77 | 11.40 |
| 33 | 84 | 11.43 |
| 34 | 105 | 11.44 |
| 35 | 92 | 11.38 |
| 36 | 95 | 11.43 |
| 37 | 107 | 11.41 |
| 38 | 102 | 11.40 |
| 39 | 125 | 11.40 |
| 40 | 110 | 11.42 |
| 41 | 96 | 11.42 |
| 42 | 109 | 11.41 |
| 43 | 103 | 11.42 |
| 44 | 104 | 11.44 |
| 45 | 102 | 11.43 |
| 46 | 103 | 11.39 |
| 47 | 109 | 11.42 |
| 48 | 100 | 11.43 |
| 49 | 110 | 11.41 |
| 50 | 125 | 11.43 |

### 3. Conclusion

The artifacts described in this paper are inherent in the current data although they can be reduced in the future by a better distribution of observations. Researchers must be cautious in drawing conclusions about such periodicities.

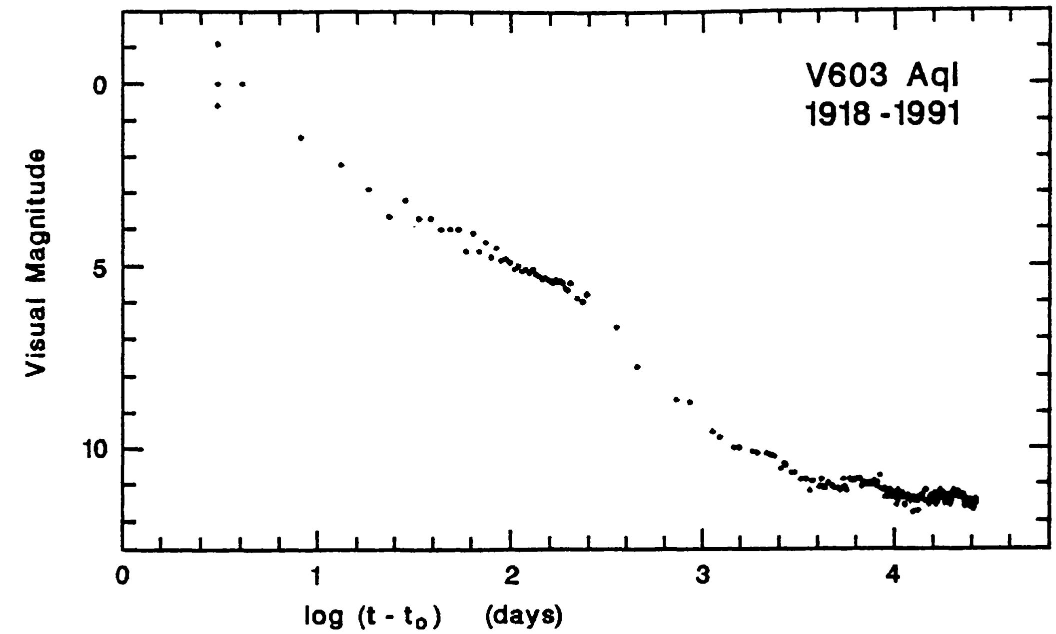


Figure 1. Long-term AAVSO visual light curve of V603 Aql since the nova outburst in 1918.

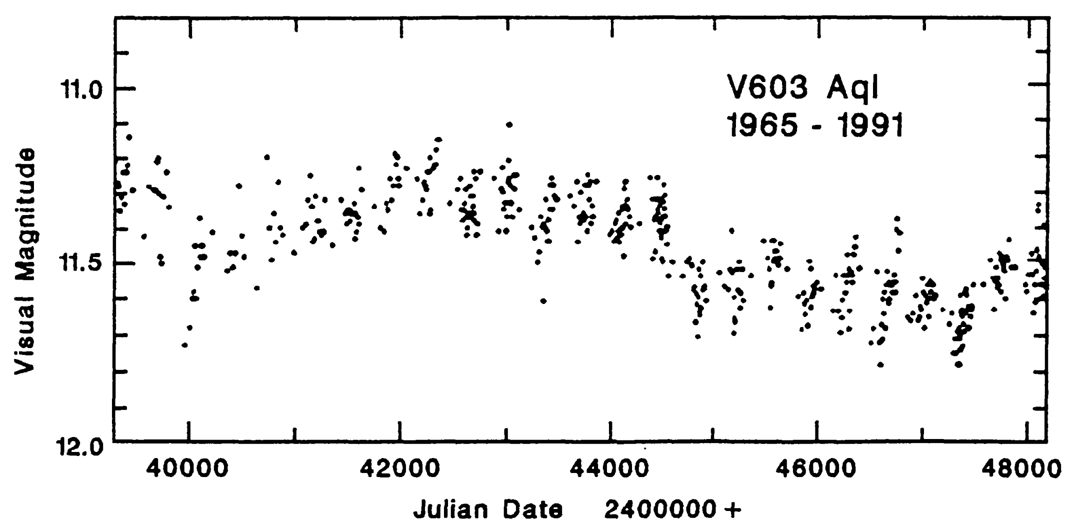


Figure 2. An expanded view of the AAVSO light curve of V603 Aql for 1965-1991. Each dot represents the mean of 20 visual estimates.

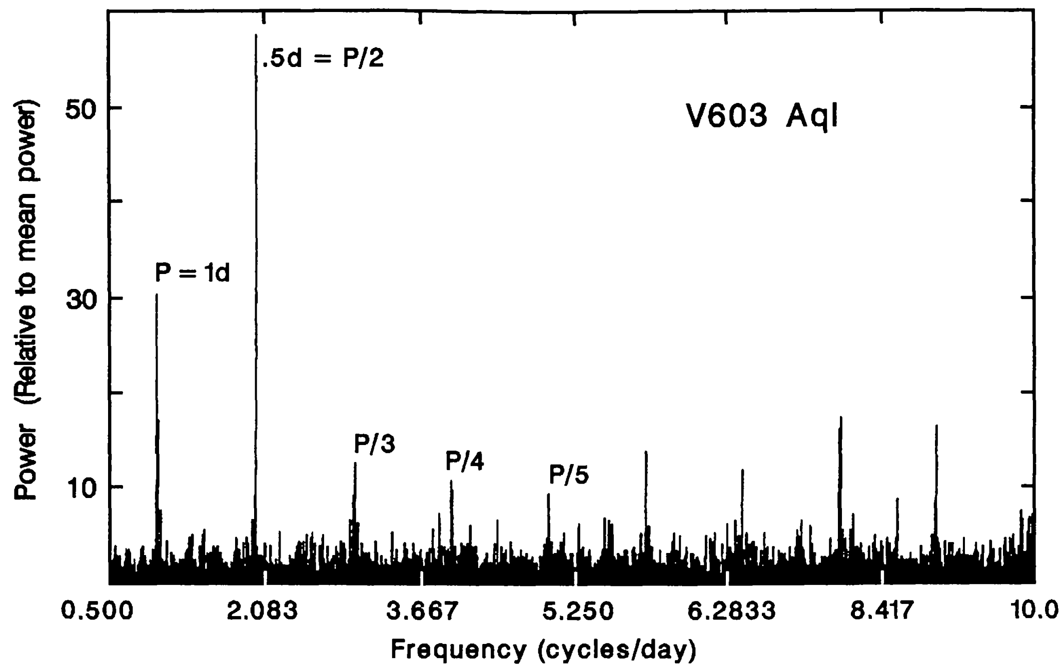


Figure 3. Power spectrum of V603 Aql over the frequency interval 0.5-10 cycles/day. The spikes indicate the existence of a period. The most prominent spikes in this range occur at period of (1 day)/n, for n = 1, 2, 3, ..., 10.

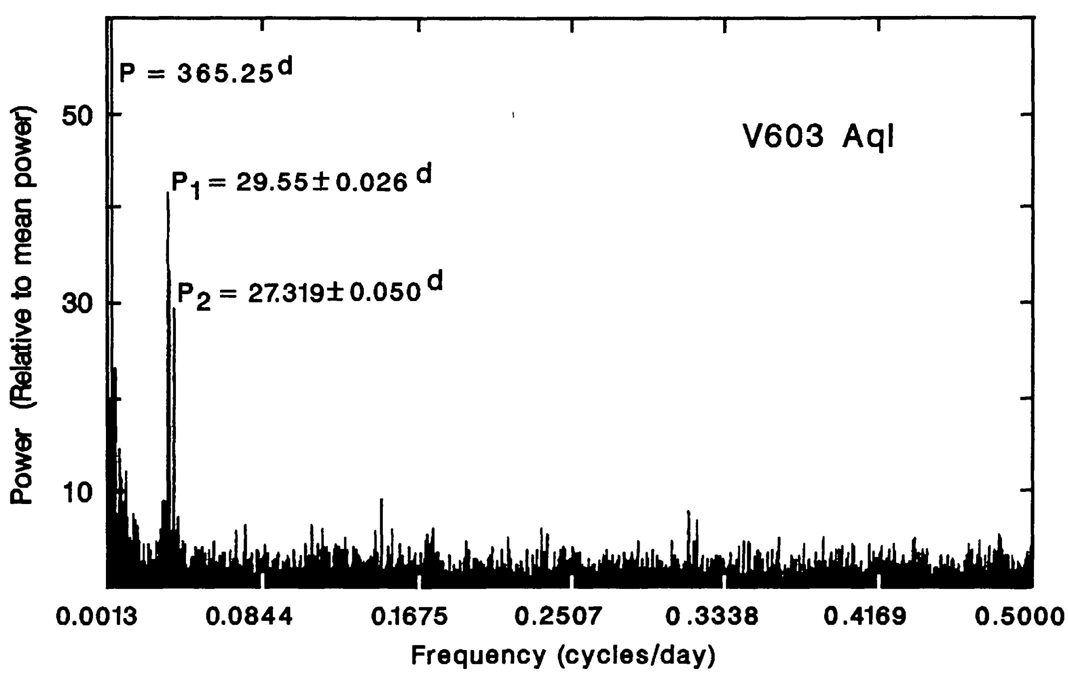


Figure 4. Power spectrum of V603 Aql over the frequency range 0.0133-0.5 cycle/day. The 3 most prominent spikes correspond to the earth's rotation period, the lunar synodic period ($P_1$), and the lunar sidereal period ($P_2$).

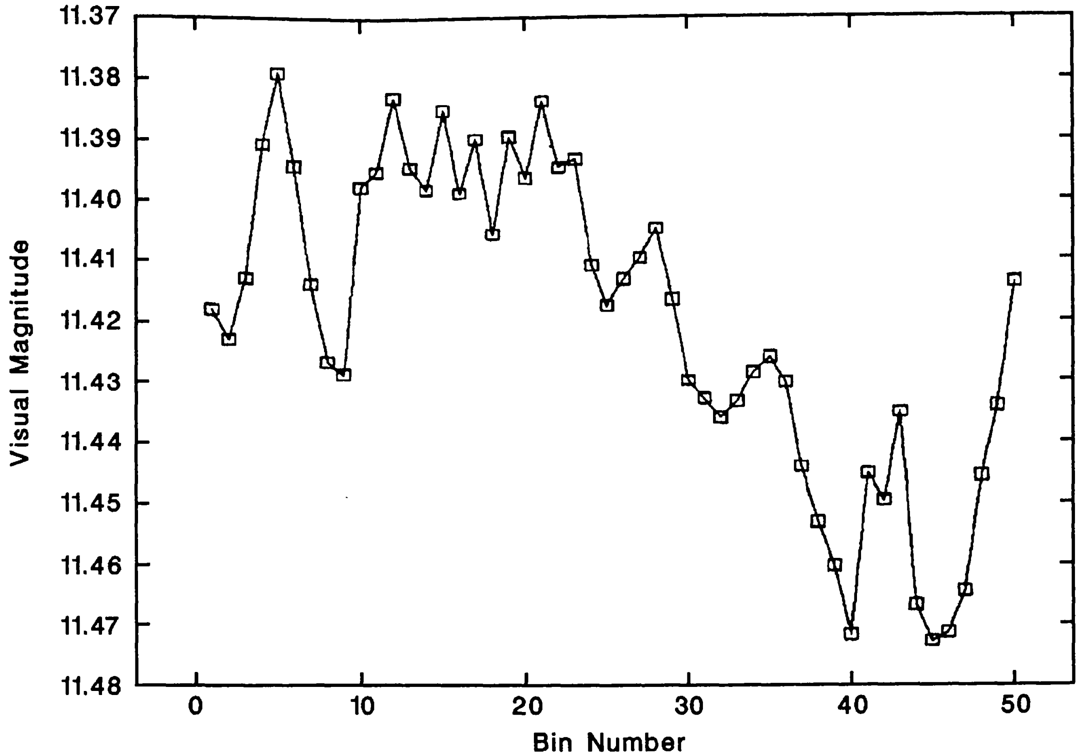


Figure 5. The light curve of V603 Aql folded about the lunar sidereal period. Bin 16 corresponds to the closest approach of the moon to the object.

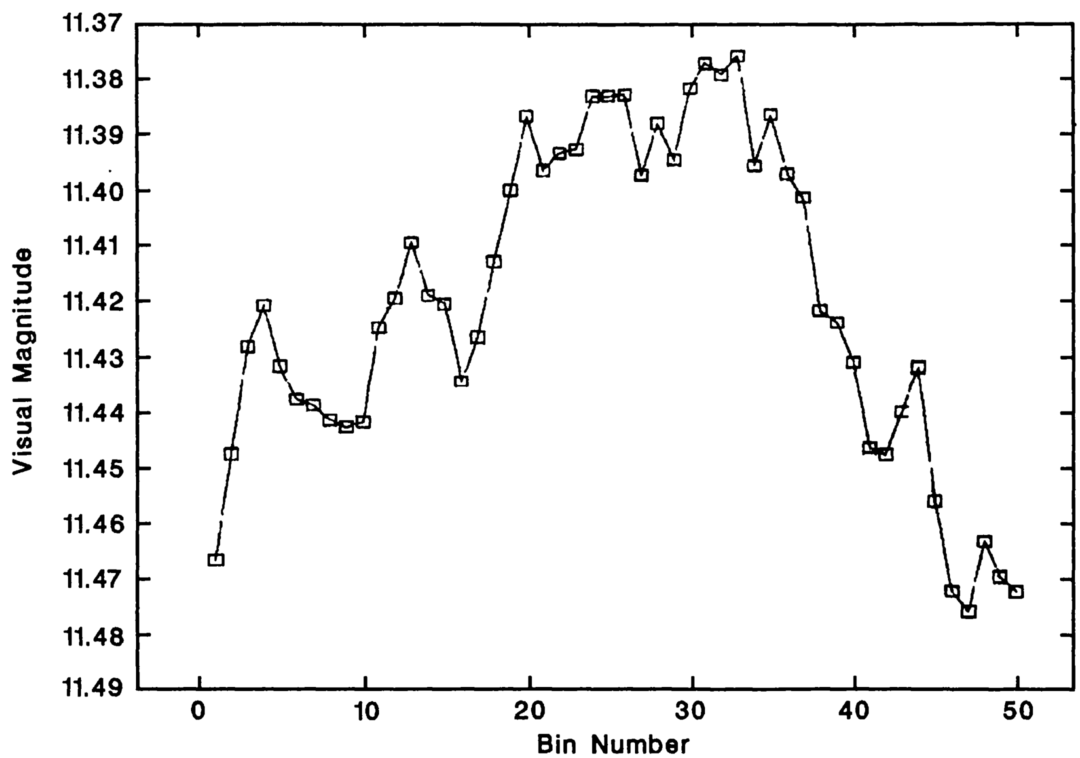


Figure 6. The light curve of V603 Aql folded about the lunar synodic period. Bin 24 corresponds to a full moon.

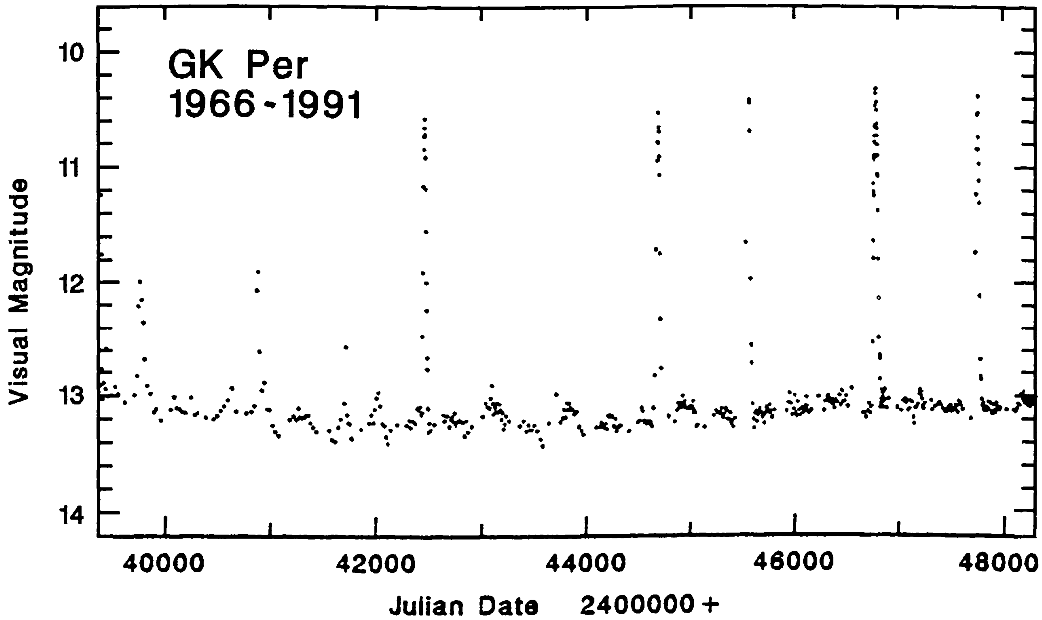


Figure 7. Long-term visual AAVSO light curve of GK Per. Each dot represents the mean of 20 visual observations.

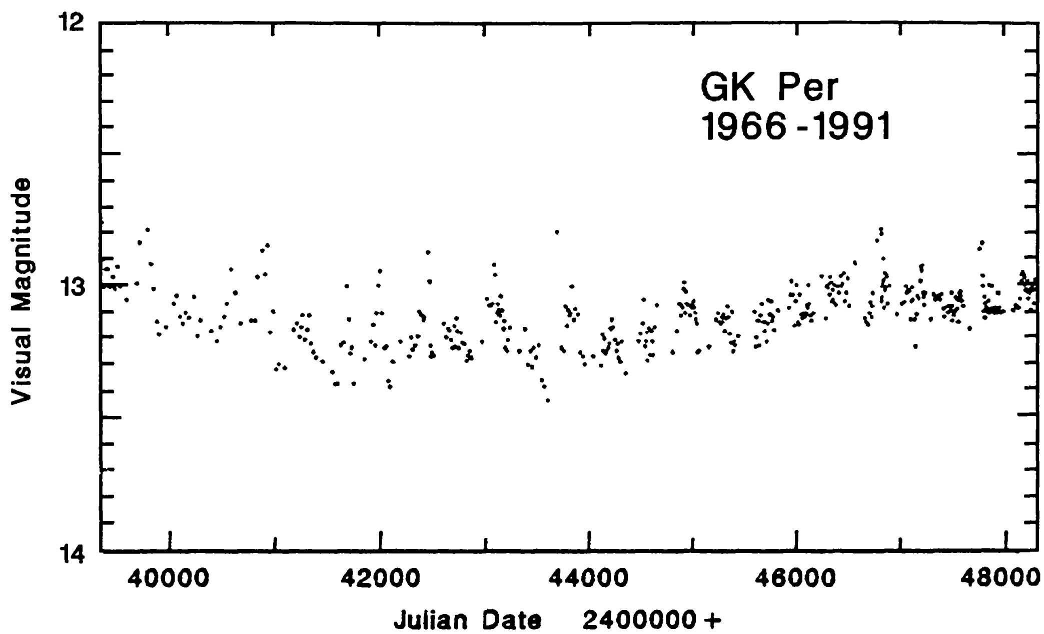


Figure 8. Long-term AAVSO visual light curve of GK Per with the "dwarf nova-like" spikes removed. Each dot represents the average of 20 visual estimates.

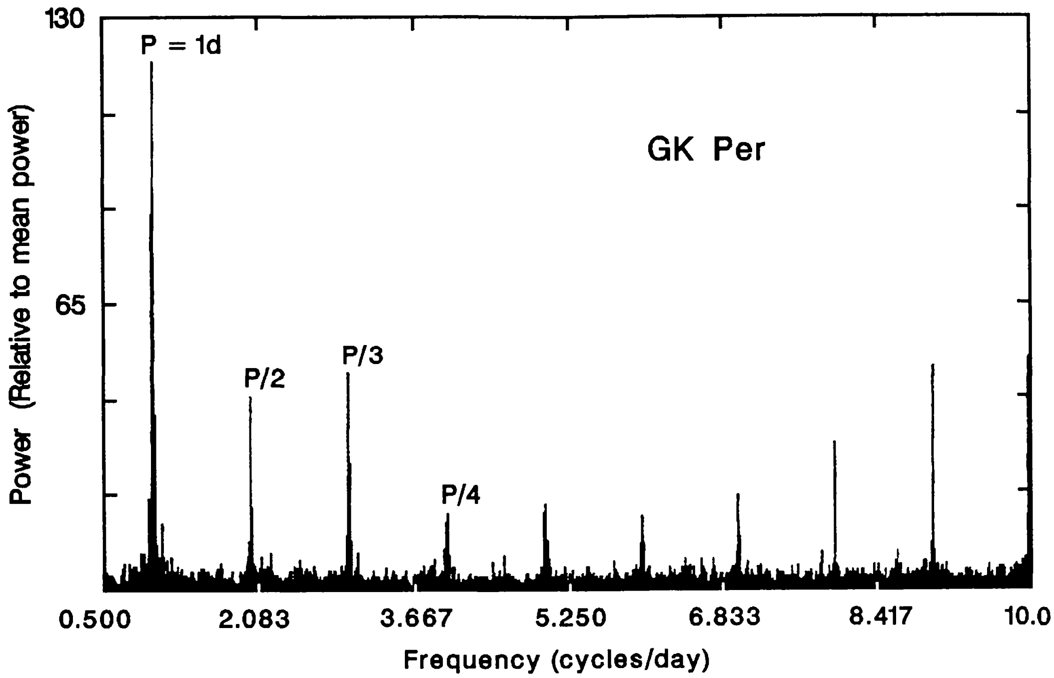


Figure 9. Power spectrum of GK Per over the frequency range 0.5-10 cycles/day.

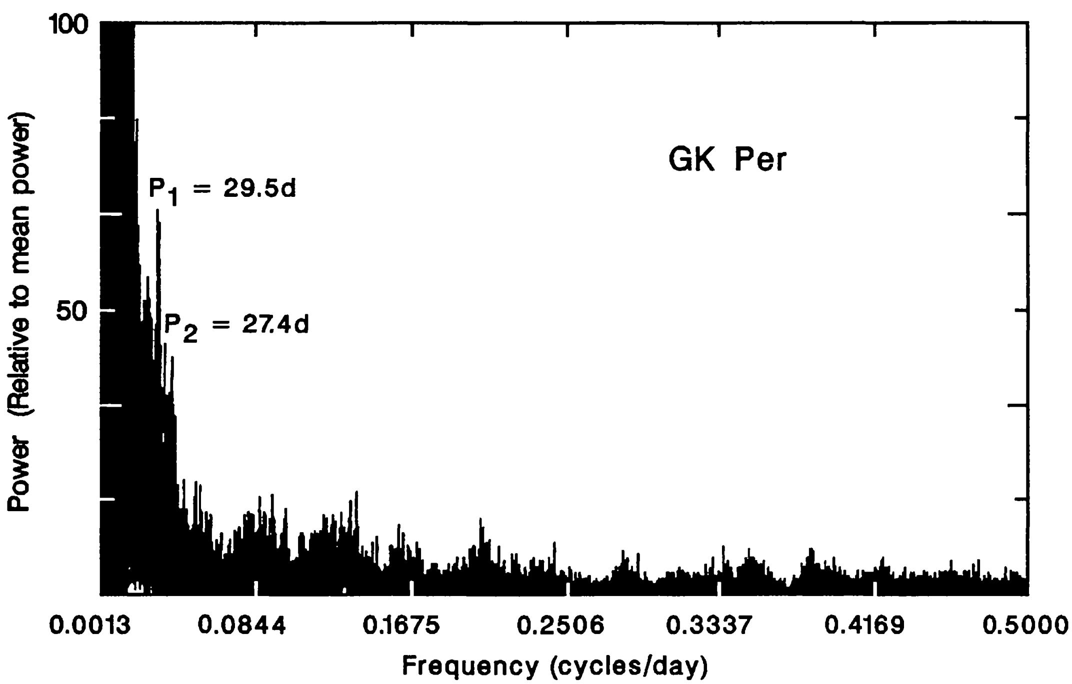


Figure 10. Power spectrum of GK Per over the frequency range 0.0133-0.5 cycle/day.