The document appears to contain a scientific or technical text, possibly related to astrophysics or nuclear fusion. However, the text is not legible due to the image quality. The text includes references to research papers and appears to discuss topics such as the Intermediate Fusion Processes in an Intermediating Polar Candidate and the early appearance of Nova V442 Aqlule 1996. The document seems to be a research paper or a scientific report.
few years a few other novae have been so classified as well. Examples are V533 Her and GI Per, with white dwarf spin periods of 64 and 351 sec, respectively (Patterson 1994). The detected variations of V603 Aql in the optical, X-ray and ultraviolet regimes make it also a likely Intermediate Polar system (Udalski & Schwarzenberg-Czerny 1989, Schwarzenberg-Czerny, Udalski & Monier 1992). The presence of multiple periods in the light curve of HZ Pup supports the membership of this nova in the Intermediate Polar group, too (Abott & Shafter 1997). In V1974 Cygni, evidence was found to the presence of an accretion disc in the system, (Ritter, Ofek & Leibowitz 1995, Ritter, Leibowitz & Ofek 1996, 1997a, 1997b, Skillman et al. 1997), together with some indications for an intense magnetic field on the surface of the white dwarf (Chochel et al. 1997). The combination of these two properties makes V1974 Cyg another potential candidate for the Intermediate Polar group.

It would therefore appear that the Intermediate Polar phenomenon is not uncommon among classical nova CV systems.

2 OBSERVATIONS

We observed Nova Aquilae during three nights in 1995 May, and 18 nights during the interval 1996 April – August. Table 1 presents a summary of the observations schedule. We used the Tektronix 1K CCD camera, described in Kaspi et al. (1995) mounted on the 1-m telescope at the Wise Observatory. During the observations in 1995 we switched successively between the standard B, V, R and I filters, and in 1996 the photometry was carried out only in the I band. We note that our I filter is slightly redder than the standard bandpass. The exposures times of the observations in 1995 were 30 sec. (I), 40 (R), 50 (V) and 60 (B) with a repetition time of about 270 sec. In 1996 the integration time was 180 sec. The number of frames obtained in our programme in 1995 and 1996 are 522 and 1170, respectively.

Photometric measurements were performed using the DAOPHOT program (Stetson 1987). An IRAF* script was written by the first author for automatic reduction with aperture photometry. We chose star radii of five pixels, corresponding to angular diameter of about 3.5 arcseconds. Instrumental magnitude of the nova, as well as of a few dozens reference stars, depending on the image quality, were obtained from each frame. We finally used the Wise Observatory reduction program DAOSTAT (Netzer et al. 1996) for an internal consistent series of the nova magnitudes.

Fig. 1 displays a comprehensive visual light curve of the nova from discovery to 1996 September. The data were taken from AFOEV†. The marks in the figure indicate the times of our observations.

Fig. 2 presents the 1996 I light curve of the nova, as measured in our observing programme. One can see that

* IRAF (Image Reduction and Analysis Facility) is distributed by the National Optical Astronomy Observatories, which are operated by AURA, Inc., under cooperative agreement with the National Science Foundation.
† AFOEV (Association Francaise des Observateurs d'Etoiles Variables) operates at Strasbourg Astronomical Data Center (CDS), France.

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![Figure 1. Two years light curve of Nova Aquilae 1995. Data points are visual estimates of amateur astronomers, compiled by AFOEV†. The times of our observations are marked.](image-url)
3 DATA ANALYSIS

3.1 The apparent periodicities

During a few of our best nights in 1996, the light curve of the nova exhibits a small sinusoidal-like modulation with a peak-to-peak amplitude of about 1 - 2 per cent on a time scale of 1.5 hr. Sometimes a smaller dip at phase 0.5, relative to the main variation, was also seen. However, during most of the nights these variations were hidden in the noise. In a few nights a systematic brightness variation of a time scale of a few hours, with similar amplitude, could be recognized in the light curve as well.

The upper panel of Fig. 3 is a plot of the power spectrum (Scargle 1982) of most of the \textit{I} band points in 1996. We omitted from our analysis the night of May 11, because it had only a very few points, and the data points of August 27 and 31, when the light of the nova and the comparison stars varied by about 0.1 mag, due to reflected moonlight or instrumental problems. The inclusion of these three nights in the analysis doesn't affect the results in any significant way. Altogether we used 1046 points in our time series analysis. Before applying the power spectrum routines we normalized the data by subtracting the mean magnitude from each night.

The power spectrum shows three distinct groups of peaks. The left one is around the frequency \(3.900 \text{ d}^{\text{−1}}\), corresponding to the period \(P_1 = 0.2558 \pm 0.0001 \text{ d}^{-1}\). The uncertainty interval is a better than 99% confidence limit for the value of the period. It is derived with the Bootstrap technique (Efron & Tibshirani 1993) from a sample of 1000 pseudo-observed light curves. The second group near the center of the frame is around the frequency \(16.6518 \text{ d}^{\text{−1}}\), corresponding to the period \(P_2 = 0.06005 \pm 0.00001 \text{ d}^{-1}\), with the uncertainty derived as for the period \(P_1\). The third group of peaks at the right-hand side of the diagram is centered around the first harmonic of \(P_2\). All three groups are characterized by a central frequency and a pattern of peaks on both sides, corresponding to the 1, 1/2, 1/3 etc. day aliases of the central one.

We checked the reliability of the three major periodicities in the light curve of the nova by dividing the data

\textbf{Figure 2.} All the 1996 \textit{I} magnitudes of V1425 Aql that are presented in this work. The brightness of the nova decreased by about 0.6 mag during the time interval of these observations.

\textbf{Figure 3.} Upper panel - power spectrum of the \textit{I} light curve of 15 nights in 1996. The peaks marked as \(P_1\) and \(P_2\) represent the two major periodicities in the light curve, while peak \(P_21\) is the first overtone of \(P_2\). Each one is at a center of a pattern of peaks corresponding to the 1, 1/2, 1/3 etc. day aliases of the central one. The peak \(P_3\) is at the beat frequency between \(P_1\) and \(P_2\). Middle panel - power spectrum of the three nights in 1995. The data are a mixture of measurements in four bands. Within the large observational uncertainty, the group of high peaks at the left-hand side of the diagram (being aliases of each other) may be regarded as representing the same periodicity associated with the \(P_1\) peak in the 1996 power spectrum. Lower panel - power spectrum of the combined 1995-6 data. The \(P_1\) peak is significantly higher than in the 1996 data, while the other peaks are somewhat lower.

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1996
into two distinct parts (the first eight nights, and the remaining seven nights). A similar triple structure appeared in the power spectrum of each part separately. In a different test for the independence of the three periodicities, we subtracted from the data the fundamental harmonic of the lower frequency. The other two peaks remained almost unaltered in the power spectrum of the residuals. We repeated this treatment for the other two frequencies and found out that all three are indeed independent of each other. As a further check we created an artificial light curve on the times of the real observations, by superposing a sine wave of one of the three periodicities over a random distribution of points representing white noise. The power spectrum of each of these three synthetic light curves showed only the corresponding planted periodicity, surrounded by an alias pattern similar to the one of the real data, with no trace of the other periodicities.

### 3.2 A third Periodicity

In the power spectrum shown in the upper panel of Fig. 3 there is an additional group of peaks that stand out considerably above the noise level, although not to the height that makes them statistically significant. The central highest are at the frequency 12.70 d$^{-1}$, corresponding to the period $P_3 = 0.079$ d, and its one day alias at the frequency 11.72 d$^{-1}$. If we remove from the data the two periods $P_1$ and $P_2$, represented by the fundamental and the first harmonic of the corresponding periodicities, the group of these peaks remains almost unaltered in the power spectrum of the residuals.

The frequency of the beat between the $P_1$ and $P_2$ periodicities is 12.74 d$^{-1}$, corresponding to the period 0.0785 d. The near similarity between this frequency and the $P_3$ frequency in the power spectrum of the observed data strongly suggests the presence of the beat period in the 1996 light curve of the nova, in addition to the presence of the periods themselves. The fact that the beat frequency remains present in the power spectrum even after the removal of the other two periodicities indicates that this frequency is indeed modulating the nova light and that it is not a numerical artifact of the data reduction of the very uneven sampled light curve of the system.

We can estimate the statistical significance of the $P_3$ peak in the power spectrum in the following way. By the Bootstrap technique on a sample of 1000 pseudo-light curves, we found that a one Sigma (67%) and a 99% uncertainty intervals in the position of the $P_3$ in the power spectrum are 0.0004 and 0.001 d$^{-1}$, respectively. Thus it appears that the observed $P_3$ peak falls within one Sigma of the expected position of the beat frequency. Applying now again the Bootstrap routine on another sample of 1000, we found that the probability of a chance occurrence of a peak as high as the observed one within a 99% uncertainty interval around the beat frequency is less than 0.1%. Thus the combination of the height of the $P_3$ peak and the proximity of its position to that of the beat frequency, whose value is known a-priory, once the $P_1$ and the $P_2$ periods are known, makes the $P_3$ peak in the power spectrum a statistically highly significant feature. We therefore conclude that there exists a true third periodicity, the beat of the first two major ones, in the light curve of Nova Aql 95 during the 1996 observations.

### 3.3 Structure of the three periodicities

In the three panels of Fig. 4 we show the $I$ band data of the 1996 observations folded on to the periods $P_1$, $P_2$ and the beat period between them, $P_3$. The points are the average magnitude value in each of 40 equal bins that cover the 0.1 phase interval. The bars are the 1σ uncertainties in the value of the average values. Solid line represents the first two terms in a Fourier expansion around the corresponding fundamental periods, fitted to the data points by Least Squares. The full amplitude of the average variation in the upper curve is 0.012 mag., that of $P_2$ is 0.014 mag. and that of the third periodicity at the lower panel is 0.007 mag. These numbers were derived by binning the folded data into 30 equal intervals and by measuring the difference between the extrema. The error in the amplitude in all three cases is about 0.004, and it was calculated by samples of 1000 Bootstrap simulations. The double structure in the $P_2$ curve is responsible for the strong appearance of the first overtone of this periodicity in the power spectrum (Fig. 3 upper panel). It will be further discussed in section 4.

The best fitted ephemeris for the three periodicities are:

$$T_i(min) = HJD 2450202.566 + 0.2558 E.$$  
$$\pm 0.0002 \pm 0.0001$$

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\[ T_3(\min) = \text{HJD} 2450202.664 \pm 0.00005 \text{ E.} \]
\[ \pm 0.007 \pm 0.0001 \]

3.4 The 1995 light curve

In 1995 we observed the nova in only three nights, each run lasting about 4.5 hr. In these observations we used the four standard filters - \( B, V, R \) and \( I \) in a sequence. Inspecting the four light curves by eye we find no clear short scale variations of the order of 1.5 hr. The light curves do show, however, a long term variation, on time scale of the duration of the runs, i.e. of a few hours. The four power spectra of the bands (not shown here) have a few peaks, corresponding to periods of a few hours, all of them are, however, statistically nearly insignificant.

In order to improve the significance of the peaks in the power spectrum, we combined the four bands together and formed a united colour power spectrum. This was done by subtracting the mean from the points of each filter at the three nights, and then sorting the data by time. The power spectrum of the resulting light curve is shown at the middle panel of Fig. 3. The pattern of 1-d aliases peaks at the left-hand side of the diagram, which is many \( \sigma \) above the noise level, includes the frequency 4.01 \( \pm 0.17 \) \( \text{d}^{-1} \). Due to the scarcity of the 1995 data, the small amplitude of the variation (0.010 \( \pm 0.006 \) mag.) and the rather short duration of the observations in each night, the uncertainty in the position of this pattern of peaks on the frequency axis is large. Within this uncertainty it is consistent with the lower frequency peak (\( P_1 \)) in the power spectrum of the 1996 data.

In the 1995 power spectrum, however, there is no trace of the shorter periodicities identified in the 1996 data.

With the Bootstrap technique we found on a sample of 1995 pseudo-light curves, that the probability to obtain anywhere in the power spectrum a pattern of peaks as high as the observed ones is smaller than 0.1%. As a more severe test we checked also the probability to obtain peaks as high as the observed ones in data of correlated magnitudes. For that purpose we planted on the times of our real observations in each night a sinusoidal modulation with periods randomly chosen between 4-8 hr. This test shows that the observed pattern of peaks is significant at a 95% confidence level.

We also combined the data of 1995 with the 1996 points. In the power spectrum of the combined light curve (Fig. 3 lower panel), the peaks around \( P_1 \) gain a considerable amount of power. In particular the power at this frequency increases from \( \sim 35 \) in the 1996 data to \( \sim 45 \) in the combined 1995,96 data. This increase should be compared with a small decrease in the power in the other periodicities of 1996. For comparison we also combined with the 1996 data a pseudo 1995 light curve, namely, random magnitudes, distributed over the times of observations in 1995. No increase in power at the \( P_1 \) frequency is obtained in the power spectrum of this light curve, nor in the power spectrum of a light curve in which we added to the 1996 data a noisy sine wave of other periods that is planted on the 1995 times of observation.

We may summarize that while the 1995 observations are too scarce for establishing by themselves the presence of a few hours periodicity in the light curve, much less for determining its value, the data do suggest that the 6.14-h period identified in the 1996 light curve had already existed in the 1995 light curve. The 1.44-h periodicity and its first harmonic, as well as the beat period, do not seem to be present in the 1995 data.

4 DISCUSSION

4.1 Identification of the two periods

Three periodicities have been identified in the light curve of V1425 Aql 15 months after its outburst: one of them, \( P_1 \), was present in the light curve already three months after outburst. The three periods reflect three genuine modulations of the light emanating from this stellar system. They are not independent of each other as one of them is the beat between the other two. Thus it appears that in 1996 two independent clocks are operating in the nova system, each one modulates the light radiation directly and also indirectly through some combination with the other clock.

We suggest that the longest periodicity, \( P_1 \sim 6.14 \) h, is the orbital period of the nova underlying binary system. This is based mainly on the fact that this period was present in the light curve already in 1995, with no apparent change in its value. The observations by Mason et al. (1996), and their conclusion, that the dust shell of the nova was not optically thick at the time of their and our observations, make it indeed likely that the binary system could have seen with optical light at that time. Radial velocity measurements should confirm or refute our suggestion.

The amplitude of the 6.14-h variation, if indeed present in the 1995 light curve, is comparable, in magnitude units, to the amplitude of this variation in 1996. In 1996, however, the optical brightness of the system was some four magn. fainter than in 1995. This seems to us to suggest that the major source of the binary modulation in the light curve is the reflection effect. The amplitude of modulations by this effect depends on the inclination angle of the system and on the fraction of the radiation from the hot component, that is being intercepted by the companion, and reflected in the direction of the observer. The first parameter is clearly an invariant of the system. The second one may also be constant to first order, provided that the dimensions of the hot component did not change appreciably, relative to the radius of the companion, between the two years. This could be the case either because the size of the hot source, indeed did not change by a large factor from 1995 to 1996, or because in 1995, the size of the hot source, e.g. the white dwarf or the pseudo-photosphere of the white dwarf, was already small relative to the radius of the secondary star.

We further propose that Nova Aql 95 is an Intermediate Polar, in which the shorter period, \( P_2 \), is the spin period of the magnetic white dwarf in the system. Spin period that is shorter than the orbital is the rule in almost all known Intermediate Polars. There is only one exception, RX J1840+1025, but this is a nearly synchronous system, in which the spin period has only a marginal excess: \((P_{\text{spin}} - P_{\text{orbital}})/P_{\text{orbital}} \sim 0.3\%\) (Patterson et al. 1995).

The double structure shape of the 86.5-m period (Fig.
The accretion form - an Accretion Disc (?)

The fate of the accretion disc in a classical nova binary system during the outburst event and immediately following it is unclear. It is sometimes assumed that if an accretion disc is present in the pre-outburst system, it is being destroyed by this cataclysmic event. However, no theoretical effort was done in the direction of answering the question when is the accretion disc rebuilt in the scattered, slowly decaying system. Up to recent times there were little observational data concerning the existence of the accretion disc in young novae. In the last few years, however, observational data are being accumulated, indicating an early presence of an accretion disc in a few classical novae, already a few weeks or months after the outburst. Leibowitz et al. (1992) discovered an eclipse three weeks after maximum light in Nova V838 Herculis 1991. They interpreted it as the occultation of the accretion disc by the secondary star. Some 30 months after the outburst of the classical nova V1974 Cyg, Retter, Leibowitz & Ofek (1997a, 1997b, 1997c) and Skillman et al. (1997) detected permanent superhumps in the light curve of this system. Superhumps characterize the SU UMa class of CVs that are known to have an accretion disc in their underlying stellar system. Thus the observations in V1974 Cyg indicate the early presence of an accretion disc also in that system.

It is now believed that in nearly all known intermediate Polars, a major part of the accretion proceeds through an accretion disc most of the time (Patterson 1994, Helter 1995). In a few systems the accretion is partly maintained by a different mode - disc overflow, in which the accretion stream from the companion bypasses the accretion disc and interacts directly with the magnetic field of the white dwarf. (Heller 1993, 1995, 1996, 1997, Heller & Livio 1994). However, only one object (RX J1712-24) out of the 13 Intermediate Polars listed by Heller 1996 (see his Fig. 2) is believed to be a disc-less system. Based on this statistics, and ignoring the possibility that it is biased by a selection effect due to the excessive brightness of the disc, we may regard it as very likely that no later than 1996 May, Nova Aql 95 already contained an accretion disc within its binary system.

Unless the asymmetries in the system are large, the relative amplitude of the spin period to the beat period is a first order measure of the rate of accretion through an accretion disc relative to the rate of accretion via the disc overflow mode (Heller 1997). In N. Aql 95, if the 86.5-m period is indeed the spin period of the white dwarf, the dominant accretion is via the accretion disc, while a smaller part of it is maintained through the disc overflow mode. This is implied by the (peak-to-peak) amplitude 0.007 mag, of the beat period 0.079 day, that is a half of the amplitude 0.014 of the 0.00005-day spin period.

The 86.5-m spin periodicity in V1425 Aql is one of the longest among Intermediate Polars (Patterson 1994, Helter 1996), especially if the three nearly synchronous systems (Nova V1300 Cygni 1975, BY Cam and RX J19402-1015 - Patterson et al. 1995) are not counted in this class (Warner 1993 groups them with the AM Her systems). Heller (1996) and Allan et al. (1996) speculated that slow rotators accrete through accretion curtains. A 86.5-m spin cycle makes Nova Aquilae 95 a slow rotator and therefore a system with that type of accretion mode. In the accretion curtains model, the pulse structure is expected to consist of a single lump, because the two poles in this mode, act in phase. In the middle panel of Fig. 4 we see, however, that the pulse in N. Aql 95 has a structure of mid-way between one and two lumps. According to Heller, this would indicate that in this system polecaps are modulating the optical radiation to a large extent, in spite of the slow rotation of the white dwarf. If these ideas are correct, it is another evidence for the presence of an accretion disc in the system.

According to the spin-amplitude relation of Patterson (1994) the amplitude of the shorter, spin variation should increase as the nova continues to fade. Further confirmation for the Intermediate Polar nature of this system may come also from future X-ray and polarization measurements.

5 SUMMARY

(1) We found three periods in the power spectrum of Nova Aql 1995: 0.2558 day, 0.06005 day (with its first harmonic) and 0.079 day - the beat period between the first two periods.

(2) The longer period is seen in the power spectra of the observations in the two years 1995 and 1996, while the other two periodicities are absent from the 1995 data.

(3) The inter-relations among the frequencies of the three periods are characteristics of Intermediate Polar systems. Based on this we suggest that V1425 Aquilae belongs to this group.

(4) We interpret the longer 6.14-h period as the orbital period of the binary system, the 86.5-m period as the spin period of a magnetic white dwarf and the 1.9-h period as the beat period between them.

(5) These results imply that accretion (probably via an
accretion disc] was active in the system already some 15 months after the outburst of the nova.

6 ACKNOWLEDGEMENTS

We thank John Dan and the Wise Observatory staff for their assistance with the observations. We would also like to thank Shai Kaspi for taking for us a comparable spectrum of the nova.

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REFERENCES


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