U DELPHINI: THE LAST 100 YEARS

Raymond R. Thompson
Maple Observatory
7 Welton Street
Maple, Ontario L6A 1R8
Canada

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Abstract

Using archival visual data from the AAVSO, photographic data from the Harvard College Observatory plate collection, and the author's photoelectric (V) data, an attempt was made to see how far back the 1100-day period of the semiregular variable U Delphini could be traced.

1. Introduction

The fourth edition of the *General Catalogue of Variable Stars* (GCVS) (Kholopov *et al.* 1985) lists U Delphini as HD 197812, HR 7941, type SRb, and spectral class M5 II-III.

During 7 years of observing U Del for the AAVSO photoelectric program (Percy *et al.* 1996), the author noticed a change in brightness of greater than one magnitude superimposed on the smaller and more typical variations present in a single season's observations. Last year the complete 7-year set of data was fed to a spreadsheet and graphed (Figure 1), revealing a very strong 3-year period. *Sky Catalogue 2000.0* (Hirschfield and Sinnott 1985) lists only a period of 110 days with a range of photographic magnitude 7.6 to 8.9.

A SIMBAD search produced two references to U Del's periodicity (Percy *et al.* 1993; Schult and Lehmann 1990). Percy found the 1100-day period to be "quite conspicuous," with "little or no evidence for minima at $\Delta t = 110$ days." Schult obtained 1160 days from 1442 observations in B and V. Percy also mentioned (Percy 1997) that the 1100-day period is added as a note to the entry in the *Bright Star Catalogue* (Hoffleit 1982). While the GCVS lists the 110-day period, a note refers to periods of 160–180 days and 1100 days.

When discussing this extremely long and unusual 1100-day period with Dr. Janet Mattei, AAVSO director, she suggested that it would make an interesting project to see how far back it could be traced and to determine if this unusual period was the result of a recent change in the star's behavior. Accordingly, arrangements were made with Mattei to obtain AAVSO visual data from as far back as possible and with Dr. Martha Hazen, curator of the Harvard College Observatory (HCO) photographic plate collection, to examine the relevant plates, back to the 1800's, if available.

2. Procedures

Analysis was carried out using the AAVSO period search program TS (Foster 1996), which employs a date-compensated discrete Fourier transform. Five separate data sets were used:

1. Set AV1: archival AAVSO visual observations from 1916 to 1961 (1911 observations).
2. Set AV2: fully-computerized AAVSO visual data from 1961 to 1997 (17759 observations).

3. Set HP: photographic estimates made visually from selected HCO blue plates from 1898 to 1952 (355 observations).

4. Set 40+: AAVSO visual observations from 1941 to 1950, a subset of AV1 (156 observations).

5. Set PE: the author's own photoelectric data from 1990 to 1996 (135 observations).

For set AV2, it was necessary to take 5-day means to fit the data to the capacity of the computer program.

In the HP set, patrol plates from the AC, AM series were used. These plates are 7 x 10 inches with a 35-degree field. U Del was included on two sets: 20 hours centered on +15° and 21 hours centered on +15°. Estimates were made visually. The main difficulty encountered derived from the fact that almost all of the plates are blue, but U Del is an M5 star which actually emits most of its energy in the infrared. Images were therefore not as dense as one would expect from a star this bright. In addition, the only comparison stars available were from the *AAVSO Variable Star Atlas* (Scovil 1980), which has mostly V magnitudes. To attempt to offset the effect of this mismatch, (a) set HP was analyzed separately, with the understanding that there would probably be differences in zero-point and amplitude, but which should not influence the validity of the period search; and (b) where all data were combined (see Figure 5), mean magnitudes were taken for sets AV1, AV2, and HP. That of HP was 0.6 magnitude lower than the other two, and all points in the HP set were adjusted upward by that amount.

3. Results and discussion

The photoelectric observations (Figure 1, data set PE) show two sets of contiguous minima and maxima. These suggest the sort of period one expects to find in a semiregular pulsating star. The data for 1993 show a half-cycle of 84 days; those of 1994 show one of 46 days, giving periods of 168 and 92 days, respectively. Although it was not possible to locate the source of the 110-day period listed in the GCVS and *Catalogue 2000.0*, it is conceivable that it was derived from short-term observations of the star, when small-amplitude, comparatively rapid variations dominate the data. These variations presumably originate in the star's actual pulsations. For the majority of SR stars, the value listed in the catalogues is usually a mean period about which the star varies more or less erratically. SR stars seldom, if ever, vary with the sinusoidal regularity of many Mira type stars.

The purpose of this research, however, was to see how far back the long, 1100- to 1200-day period could be traced, and to attempt to establish whether it was the result of a recent change in behavior or whether it was a relatively permanent feature. Hoffleit, in the *Bright Star Catalogue,* refers to the effect as a variation in mean magnitude with a period of 1100 days. A very similar and well-known phenomenon occurs with the much-observed SR star α Orionis. But its long, 2100-day period is much more elusive than that of U Del. All five of the power spectra published with this paper exhibit the 1100- to 1200-day peak as the major feature.

In Figure 2, based on data set HP, the 1170-day peak towers above a very noisy background, most of which probably originates in the scatter resulting from the difficulties encountered in obtaining the data, as described in section 2 above. Figure 3, from data set AV1, has a very similar noisy appearance. Reference to Figure 5 shows that up to the 1950's, the data lack the order and clarity of more recent years and exhibit much more obvious scatter, which is most likely observational in nature.

By contrast, in the power spectrum of observations made since 1961 (Figure 4, data set AV2), the peak, this time at 1150 days, dominates the scene, with the noise at very low power levels. Inspection of Figure 5, the graph of the complete data set, shows clearly the arch-like pattern of the 3-year cycle beginning to appear from 1960 on.

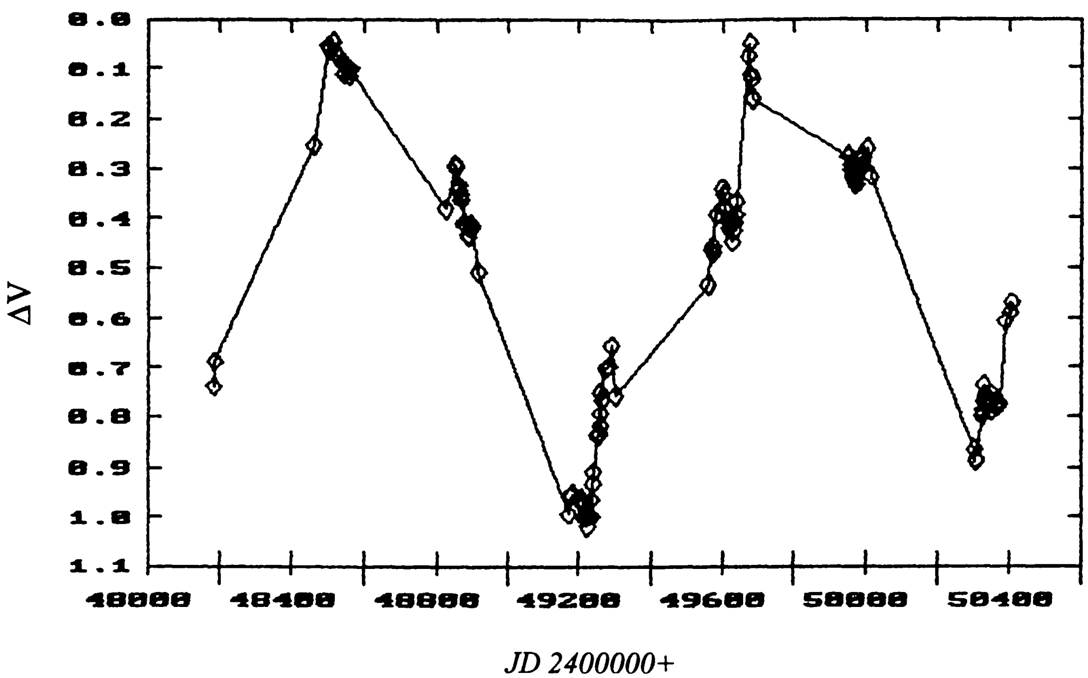

Figure 1. Data set PE; the author's photoelectric observations of U Del, 1990–1996. The AAVSO search program TS (Foster 1996) finds a period of 1210 days in these data.

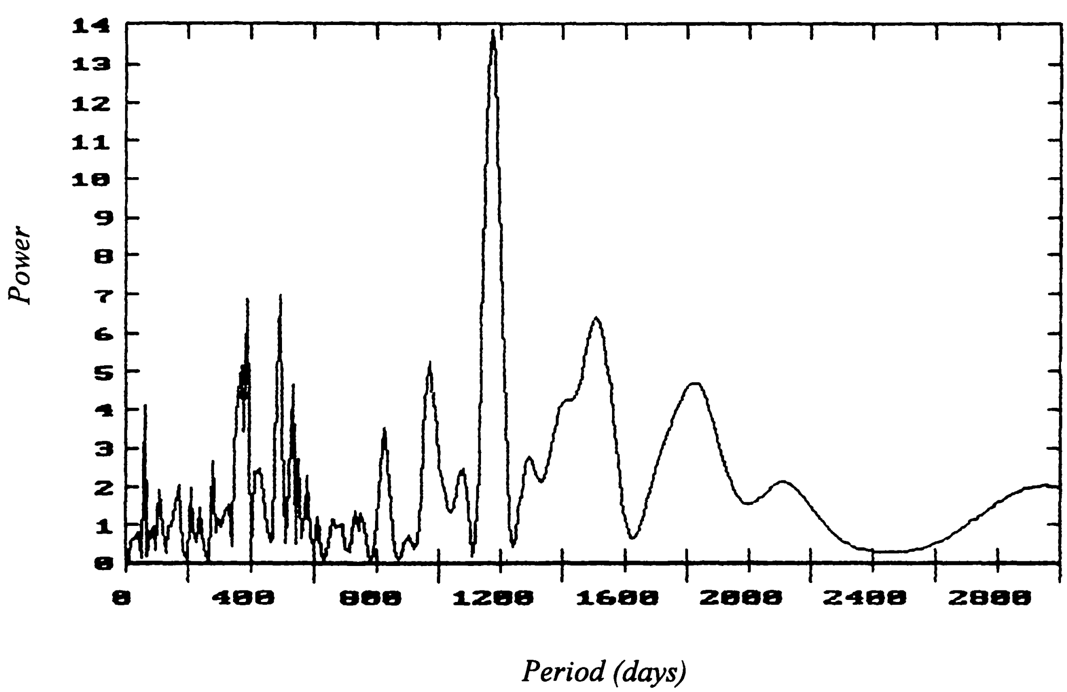

Figure 2. Dataset HP; power spectrum of U Del, derived from data taken from HCO photographic plates, 1898–1952. The primary peak is at 1170 days.

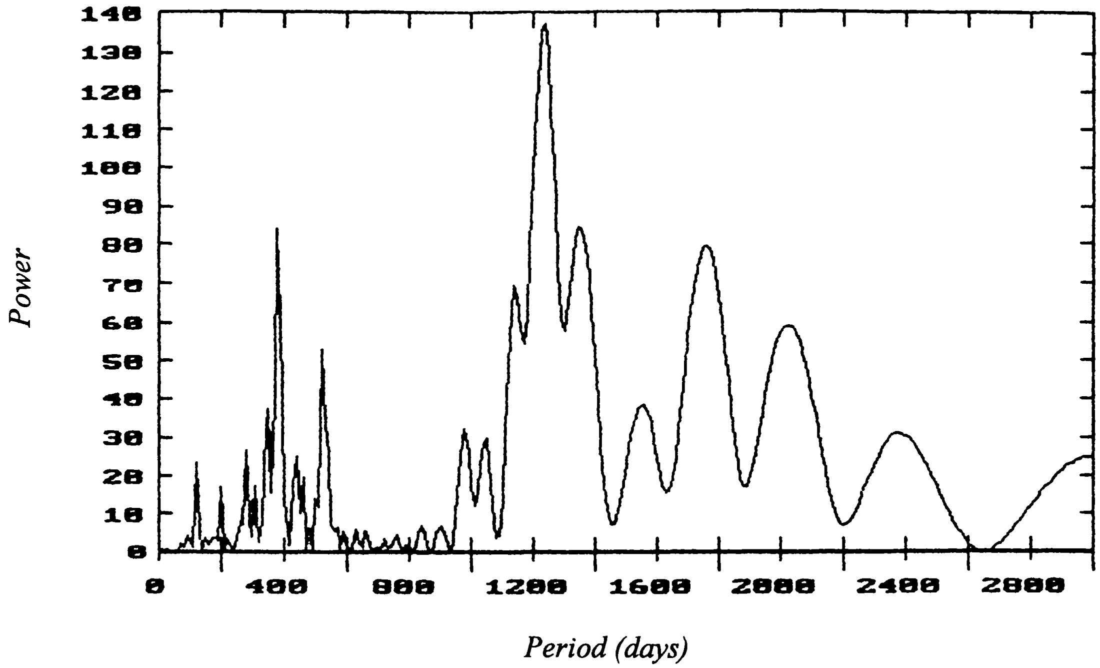

Figure 3. Data set AV1; power spectrum of U Del based on AAVSO archival visual data, 1916–1961. Here the primary peak is at 1240 days.

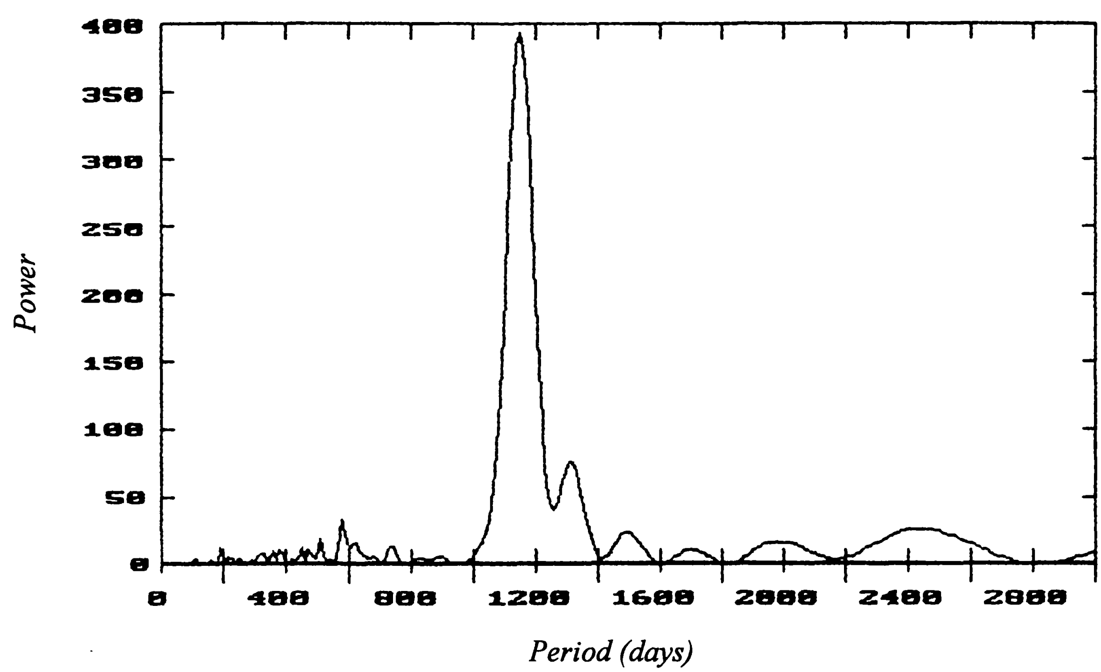

Figure 4. Data set AV2; power spectrum of U Del using 5-day means calculated from recent AAVSO visual data, 1961–1997. The 1150-day period dominates the spectrum, with noise at a very low level.

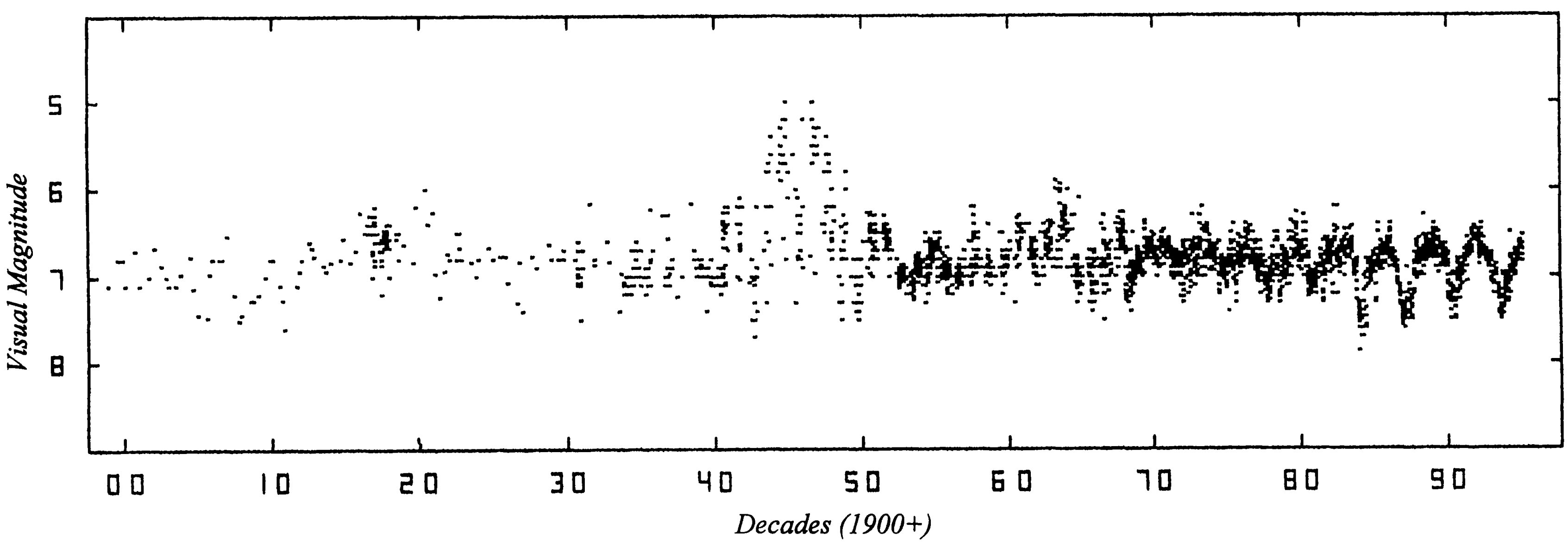

Figure 5. 100-year light curve for U Delphini (by decade since ~1900); all data sets combined, visual, photographic, and photoelectric. Of note is the intense activity of the 1940's, and the increasing dominance of the 1100-day period from 1968 on.

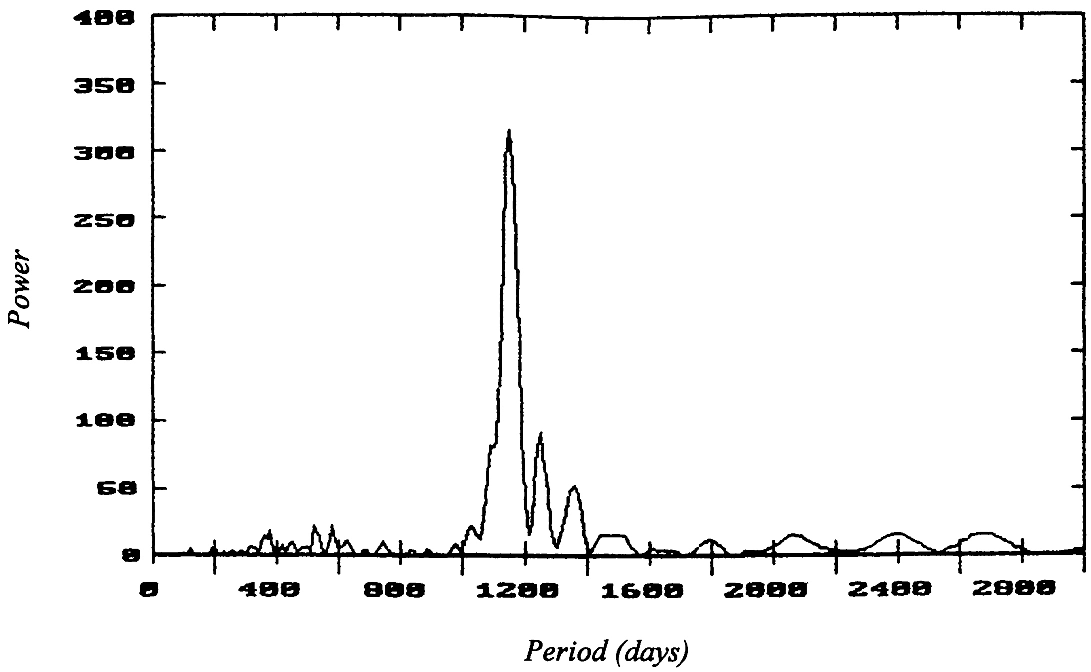

Figure 6. Power spectrum of U Del based on all AAVSO visual data from 1916 to 1997. Once again the 1150-day period is the dominant feature.

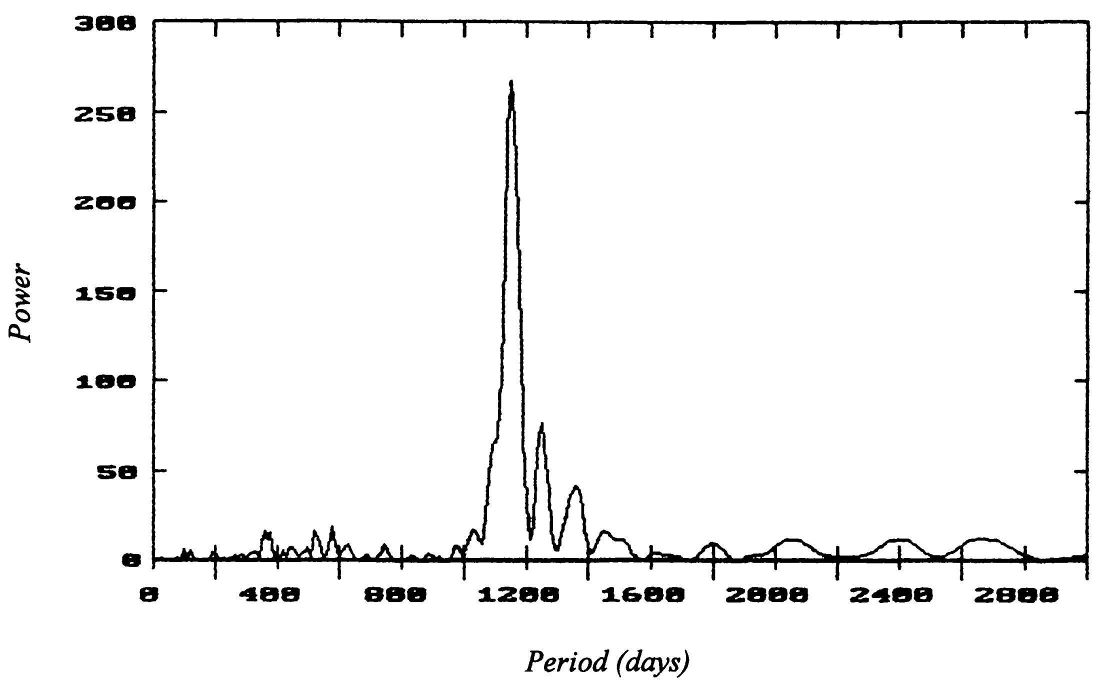

Figure 7. Merging all available data (except photoelectric) produced a power spectrum of U Del almost identical to that shown in Figure 6 above.

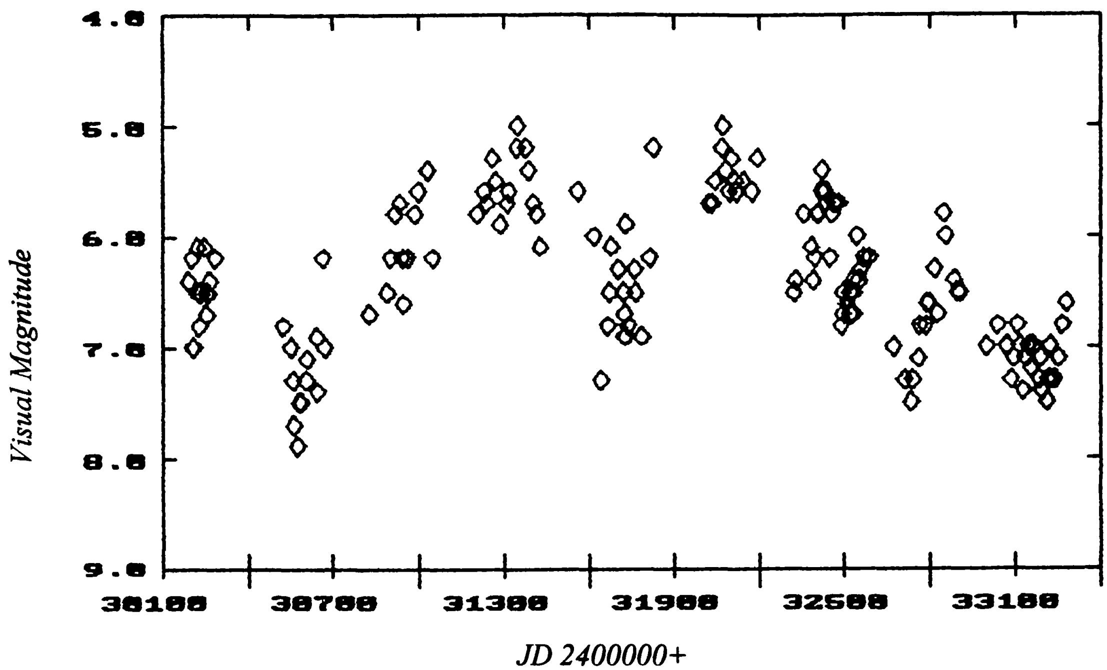

Figure 8. Data set 40+, AAVSO visual observations from 1941 to 1950. The arch-like structure is clearly visible, and there are three well-marked minima separated by >1000 days. Note the greatly increased, 3-magnitude amplitude.

To further confirm the historical presence of the star's long period, two other sets of data were fed to the AAVSO Fourier search program (Foster 1996): (a) all of the visual data from 1916 to 1997 (Figure 6), and (b) the complete set of visual and photographic data for the last century (Figure 7). The similarity among Figures 4, 6, and 7 is immediately apparent, which presumably indicates that for the last hundred years at least, the 1100-day period has been the dominant feature of U Del's variability. Also of interest is the fact that in all three, the peaks are at 1150 days. Whether this is a case of the good data overwhelming the rest is a moot point, but at least it seems to provide confirmation of the fact that this period is a comparatively permanent aspect of the star's behavior. Figure 5 also shows that, whatever the cause, the 3-year arches are more strongly marked after 1968, and are really striking from 1983 on.

Finally, it was thought advisable to give separate attention to the star's exceptional performance during the 1940's (Figure 8). Apart from providing further proof that pulsating stars often change their pattern of variation for a time, it raises the question of whether or not the 1200-day period persisted during these years of unusual activity. Actually, a close look at Figure 8 answers the question. Three clearly marked minima are visible with a separation of over 1000 days, and Fourier analysis gives the greatest power to 1221 days. It is also interesting that during these active years, the arch-like character of the light curve is once again apparent, and one is tempted to suggest that the greatly increased amplitude of over three magnitudes made the feature more readily accessible to the visual observers of the time.

In conclusion, it seems safe to assert that for the past century, the long period has been the dominant feature of U Del's behavior, and that during the 1940's, the change was one of amplitude rather than of periodicity.

4. Acknowledgements

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This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

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