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REVISED ELEMENTS. III. UZ PERSEI, V LYNCIS, X OCTANTIS, T MUSCAE, SZ ARAE, and GY AQUILAE

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Abstract

The long period variables UZ Per, V Lyn, X Oct, T Mus, SZ Ara, and GY Aql, considered for the HIPPARCOS observing program, have been studied using the Harvard College Observatory photographic plate collection. Previously published elements have been revised.

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This paper is the third in a series of four which examine the behavior of large-amplitude long period variables considered for observation by the HIPPARCOS astrometric satellite. Data for the stars in this survey were collected from Harvard College Observatory photographic plates, as there were no visual observations for them in the files of the AAVSO. These data were then used to update the elements published in the fourth edition of the **General Catalogue of Variable Stars** (Kholopov et al. 1985) to assist in scheduling their observation by the satellite.

With the exception of SZ Ara, which is a Mira, the stars discussed here are semiregular variables. Their periods have been revised for the most part by a date-compensated discrete Fourier transform (DCDFT) period search, a FORTRAN program kindly supplied to the AAVSO by the director of the Maria Mitchell Observatory, Dr. E. P. Belserene. Data acquisition and reduction are discussed in more detail in Lysaght (1989a; 1989b).

The results of this study are listed in Table I, along with other pertinent information regarding the stars. Finder charts and photographic sequences obtained with the iris photometer at Harvard College Observatory (Lysaght 1989b) are shown in Figures (1a) - (1f).

1. UZ Persei

UZ Per, a semiregular sub-type b, was discovered by L. Ceraski (W. Ceraski 1911). The star has superimposed long and short cycles: Payne-Gaposchkin (1952) found the period of the long cycle to be 927 days and that of the short cycle to be 91 days.

DCDFT analysis of the long cycle produced the following revised elements:

$$JD_{(max)} = JD\ 2443463 + 908\ E. \qquad (1)$$

The mean range of the long cycle is magnitude 10.2 - 11.8 pg.

The amplitude of the short cycle is approximately one magnitude, and its period was found to vary:

$$P_2 = 65 \text{ days} \qquad JD\ 2426000 - 30000 \qquad (2a)$$
$$107 \qquad 42000 - \text{present} \qquad (2b)$$

There were not enough data to analyse the short cycle in the interval from JD 2430000 to 42000.

The 212 data points (October 1930 - March 1988) used in the above calculations are shown in Figure 2.

2. V Lyncis

V Lyn was discovered by Cannon (Pickering 1908). Beyer (1948) found it to belong to the UU Herculis class of b-type semiregular variables. Periods of 87 and 55 days alternately replace one another, and there is an irregular variation in the mean brightness with a period on the order of 300 to 800 days.

The 241 observations from the Harvard photographic plates spanned the interval from January 1928 to May 1988; these data were too widely spaced for analysis of the two alternating periods. They are shown in Figure 3. The DCDFT period search found a weak period near 88 days, but there was no indication of the shorter period.

Figure 4 shows 743 published visual observations (Beyer 1931; 1948) which better describe this star's unusual behavior.

3. X Octantis

X Oct is an a-type semiregular discovered by Leavitt (Pickering 1916). The following elements were calculated by Dwyer (Payne 1928):

$$JD_{(max)} = JD\ 2411340 + 205\ E. \quad (3)$$

Its period was later found to be variable (Payne-Gaposchkin 1945):

Elements	Interval (Julian Date)	
$JD_{(max)}$ = JD 2415170 + 208.40 E	2415100 - 17100	(4a)
17425 + 201.24 E	17100 - 20700	(4b)
23780 + 207.95 E	22000 - 24000	(4c)
24370 + 200.18 E	24000 - 25600	(4d)
28885 + 206.80 E	25600 -	(4e)

The elements have been further revised by DCDFT analysis:

$JD_{(max)}$ = JD 2428695 + 207.8 E	2425600 - 29000	(4f)
32320 + 202.7 E	29000 - 33000	(4g)
41067 + 201.4 E	40000 - 44000	(4h)
45674 + 197.2 E	44000 - 46000	(4i)
47063 + 199.8 E	46000 - present	(4j)

The shape of the lightcurve is irregular, displaying non-periodic variations in the depths of its minima and an occasional secondary maximum. The 199 observations (January 1929 - January 1988) used in the calculation of the above elements are shown in Figure 5.

4. T Muscae

T Mus is a semiregular sub-type b which was discovered by Wells (Pickering 1904). Gaposchkin (1946) found two superimposed cycles: a short cycle with a period of 93 $\pm$14 days and a long cycle with a period of 1021 days.

The DCDFT period search found only a weak period around 1000 days, so the set of 288 observations (February 1929 - September 1988) was broken down into shorter time intervals and searched. Its period has the following values over the given time intervals:

P_1 = 1099 days	JD 2425000 - 29000	(5a)
984	29000 - 34000	(5b)
1082	43000 - present	(5c)

The mean range of the long cycle was found to be magnitude 10.0 - 11.3 pg.

There were not enough data to analyze the short cycle rigorously, but its period varies about a mean value of approximately 90 days, and its range is less than a magnitude. Figure 6 shows the observations from the Harvard photographic plates.

5. SZ Arae

SZ Ara is a Mira discovered by Cannon (1921). The following elements were found by Swope (1936):

$$JD_{(max)} = JD\ 2427640 + 220.5\ E. \qquad (6)$$

O-C values calculated from equation (6) and the maxima of the 246 photographic observations (May 1931 - August 1988) are plotted in Figure 7. A least-squares analysis (Maria Mitchell Observatory FORTRAN program) produced a parabola with a confidence level of 99.44%. This confidence level is the probability that the curvature of the parabola is not due to random fluctuations in the data (Pringle 1975). The third term calculated from this parabola is 0.0129 day ($\pm$0.0043) E^2. The revised elements are:

$$JD_{(max)} = JD\ 2433837 + \underset{\pm 0.14}{221.38}\ E + \underset{\pm 0.0043}{0.0129}\ E^2. \qquad (7)$$

The third term implies a rate of change in the period of 0.043 days per year and is confirmed by the data. The mean curve is shown in Figure 8. Phases were calculated taking the third term into account, as defined by:

$$\text{phase} = \frac{-P_1 + (P_1{}^2 - 4P_2(JD_0 - JD))^{1/2}}{2P_2} - E \qquad (8)$$

where,

JD_0 = 2433837
P_1 = 221.38
P_2 = 0.0129

and,
JD = date of observation.

6. GY Aquilae

GY Aql is a semiregular variable discovered by Reinmuth (1930). A period of 202 days was calculated by Kukarkin et al. (1948). This value was revised to 216.14 days by Gaposchkin (1952b) and later to 204 days by Kukarkin et al. (1969).

The star's light curve varies considerably in shape and amplitude from cycle to cycle (Figure 9). Figure 10 shows the periodogram of the 441 observations (May 1928 - October 1987) with peaks at 231 and 456 days. The periodograms of the residuals of these periods are plotted in Figures 11a and 11b. The noise level is approximately equal in both figures, indicating that neither period is favored over the other (see Fullerton 1986). The recent data support the period of 456 days. The revised elements are:

$$JD_{(max)} = JD\ 2447084 + 456{:}\ E. \qquad (9)$$

Figure 9 shows a large number of gaps in the Harvard photographic plate data; more data are needed to confirm the revised period.

Data are especially needed for the stars in this paper because of their irregular behavior. Members are again encouraged to observe these stars before and during the HIPPARCOS mission in order to obtain better-defined light curves, as all of these stars were found to be bright enough for the satellite's observing program. Anyone wishing to assist the AAVSO in this collaboration may obtain charts appropriate for visual observing from AAVSO Headquarters (Grenon et al. 1989; Sturch 1989; Scovil 1989).

I would like to thank Dr. Janet A. Mattei for her guidance; Dr. Martha L. Hazen, curator of the Harvard College Observatory Photographic Plate Collection, for her assistance with the plates; Dr. Emilia P. Belserene of the Maria Mitchell Observatory for providing computer programs; and the staff at AAVSO Headquarters for their support. I gratefully acknowledge NASA grant NAGW-1493 to the AAVSO, which funded this project; and the Fund for Astrophysical Research, which provided the computer facility.

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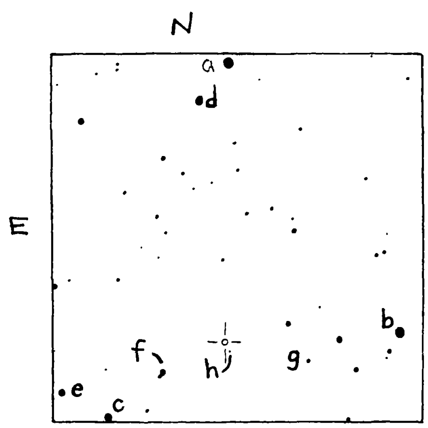
TABLE I

Summary Table for UZ Per, V Lyn, X Oct, T Mus, SZ Ara, and GY Aql

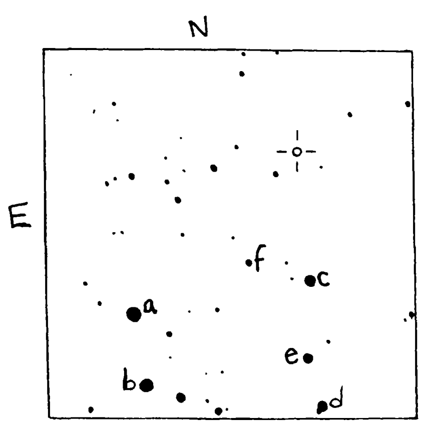
Star	Position (1950) R.A.	Dec.	Type	Spec.	Revised Period	Revised ptg Max.	Min.	No. Obs.	Remarks
UZ Per	$03^h17^m01^s$	$+31^{\circ}50'.5$	SRb	M5II-III	908	<10.2>	<11.8>	212	1
V Lyn	06 25 05	+61 34.6	SRb	M5III-IV	87	10.2	12.0	241	2
X Oct	10 28 01	-84 05.5	SRa	M3e-M6IIIe	199.8	8.6	13.9	199	3
T Mus	13 17 18	-74 10.2	SRb	C	1082	<10.0>	<11.3>	288	4
SZ Ara	17 06 32	-61 53.6	M	Ce	221.38	<11.65>	<14.02>	246	5
GY Aql	19 47 25	-07 44.5	SR	M6III:e-M8	456:	11.0	(13.9	441	

Comments:
1. Secondary period is variable: see equations (2a) and (2b).
2. UU Her type (Beyer 1948): period alternates between 87 and 55 days.
3. Period is variable: see equations (4a) - (4k). Listed period is valid for JD 2446000-present.
4. Period is variable: see equations (5a) - (5c). Listed period is valid for JD 2443000-present. $<P_2> \sim 90$ days
5. Period is variable: see equation (7).



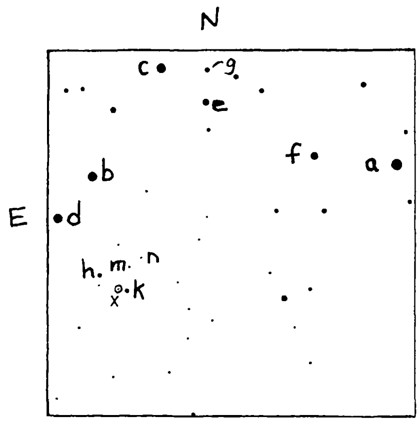
a = $8^m.1$ pg
b = 8.9
c = 10.5
d = 11.3
e = 12.0
f = 12.9
g = 14.0
h = 14.7

Figure 1a. UZ Per. From an AAVSO (d) chart. Each side is 45'.



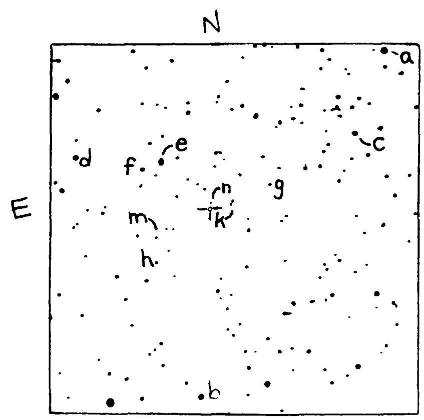
a = $8^m.9$ pg
b = 9.9
c = 10.9
d = 11.1
e = 11.4
f = 12.2

Figure 1b. V Lyn. From an AAVSO (d) chart. Each side is 30'.



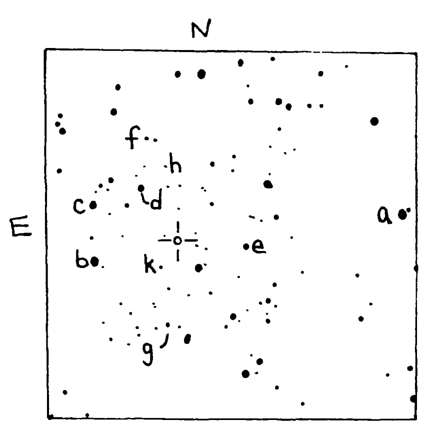
	pg	V
a =	$7^{m}.6$ pg	
b =	9.1	$8^{m}.8$ v
c =	9.4	9.1
d =	9.6	9.1
e =	10.0	9.5
f =	10.4	8.5
g =	11.5	11.1
h =	12.1	11.0
k =	12.4	11.8
m =	13.1	
n =	14.7	

Figure 1c. X Oct. From Bateson (1986). Each side is 45′. Photoelectric (V) magnitudes are from Grenon **et al.** (1989).



a =	$9^{m}.1$ pg
b =	9.7
c =	9.9
d =	10.4
e =	10.7
f =	11.0
g =	11.7
h =	12.1
k =	12.4
m =	12.8
n =	13.1

Figure 1d. T Mus. From Papadopoulos (1980). Each side is 50′.



a =	$10^{m}.0$ pg
b =	10.5
c =	11.0
d =	11.9
e =	12.1
f =	12.4
g =	12.8
h =	13.4
k =	14.0

Figure 1e. SZ Ara. From an AAVSO (d) chart. Each side is 25′.

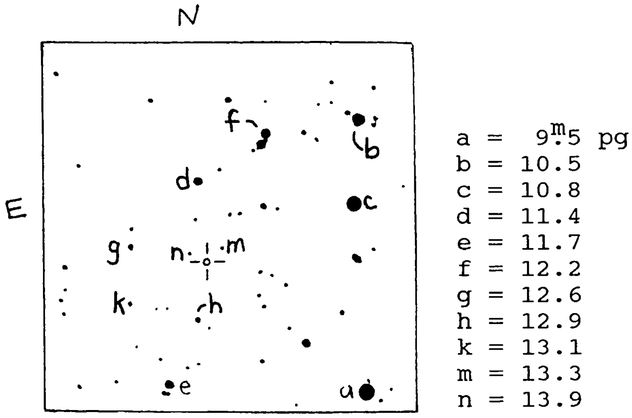


Figure 1f. GY Aql. From an AAVSO (d) chart. Each side is 25′.

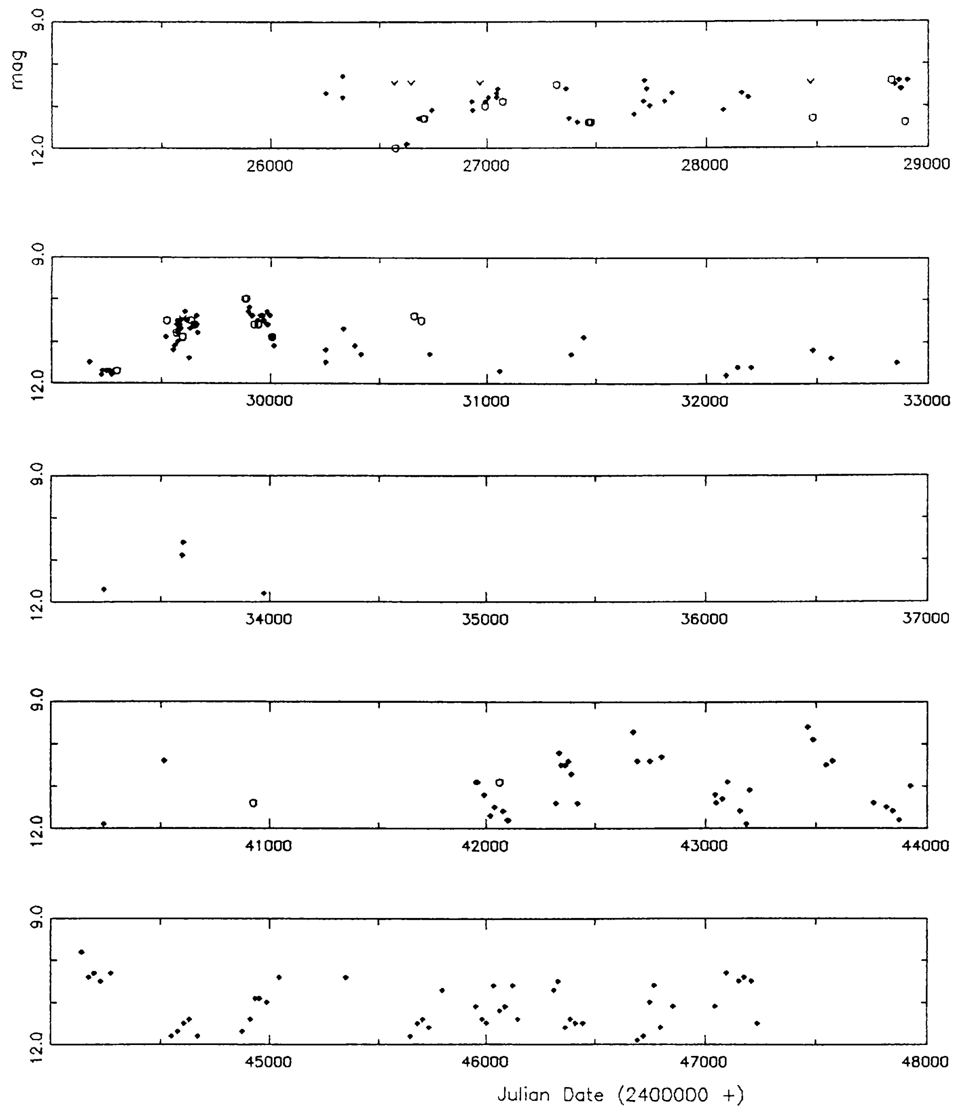


Figure 2. UZ Persei: Photographic data obtained from Harvard College Observatory patrol series plates.

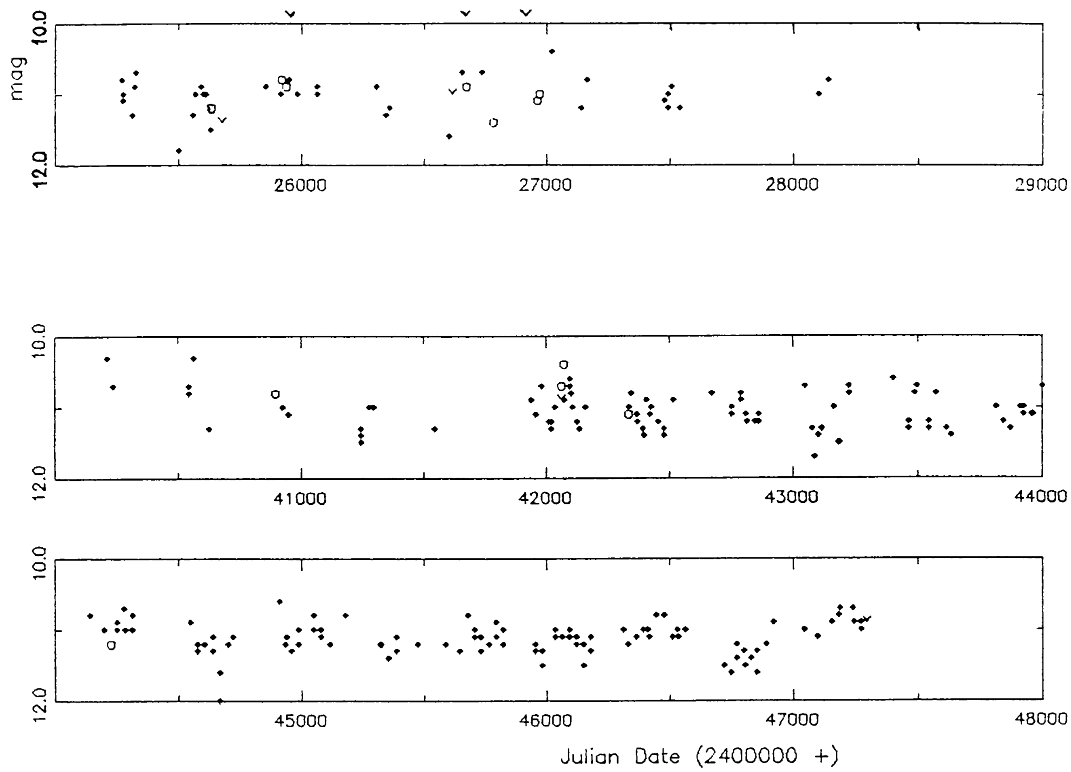


Figure 3. V Lyncis: Harvard photographic data.

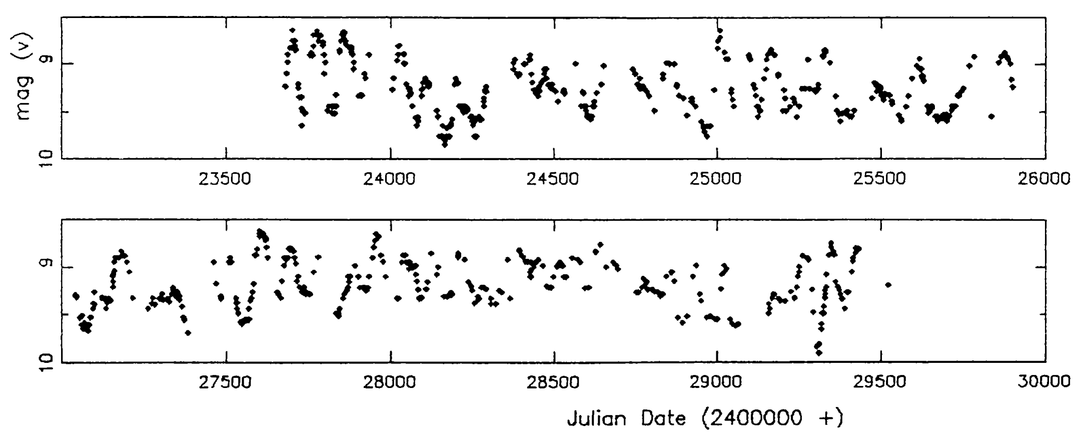


Figure 4. V Lyncis: Visual data from Beyer (1931) and (1948).

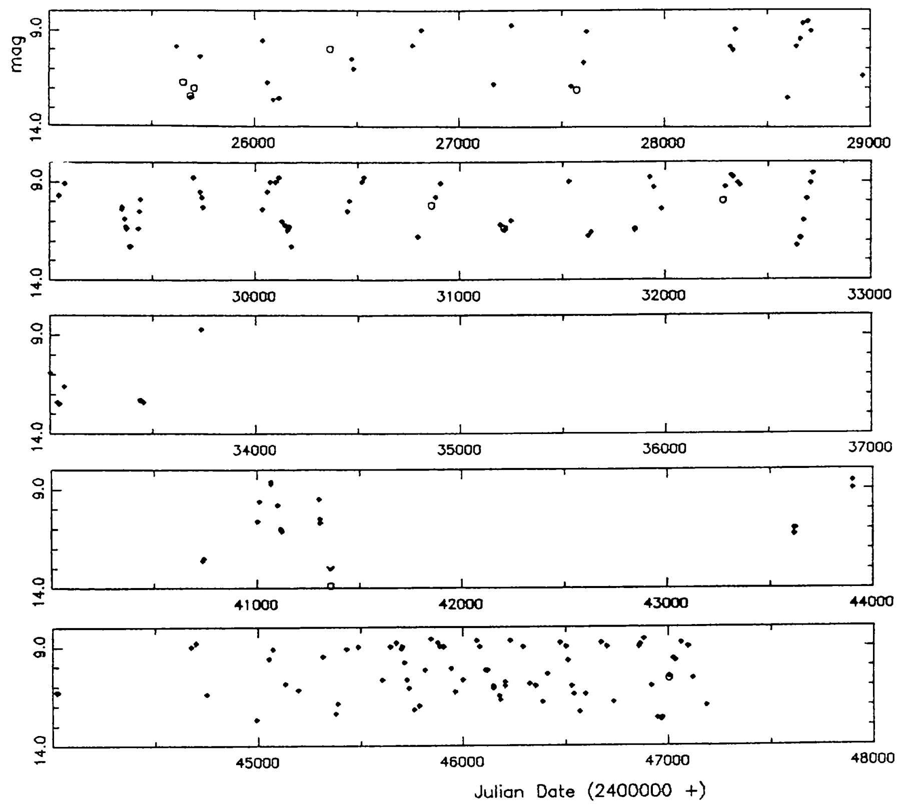


Figure 5. X Octantis: Harvard photographic data.

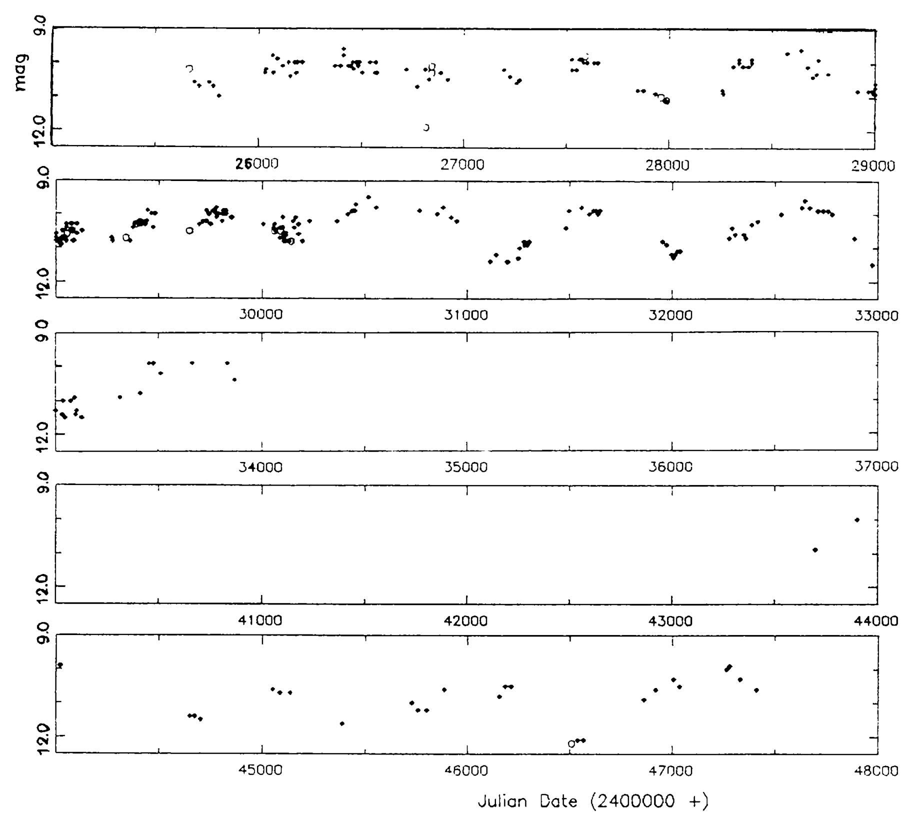


Figure 6. T Muscae: Harvard photgraphic data.

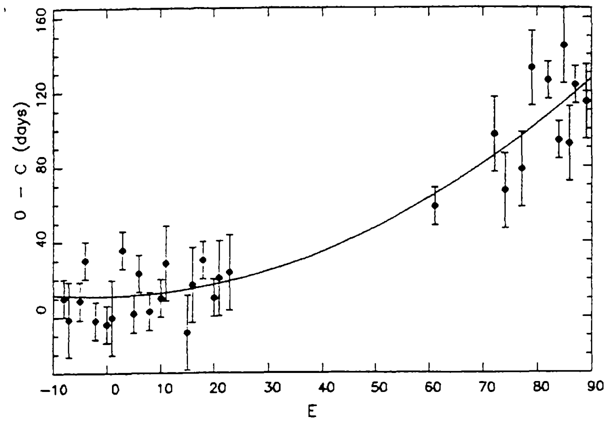


Figure 7. SZ Arae: O - C curve. Points were calculated with C defined by equation (5).

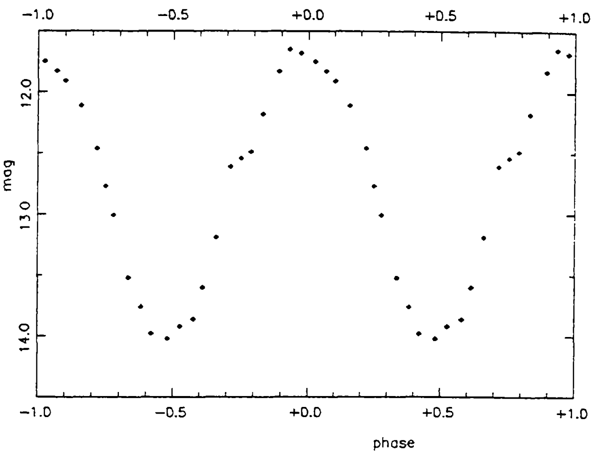


Figure 8. SZ Arae: Photographic mean light curve. Phase is defined by equation (8).

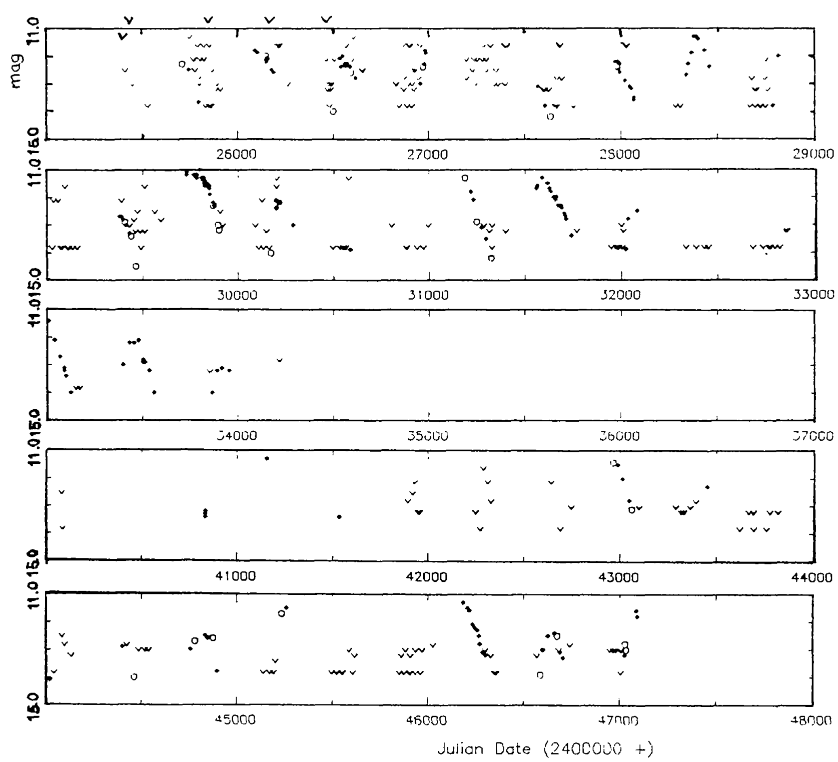


Figure 9. GY Aquilae: Harvard photographic data.

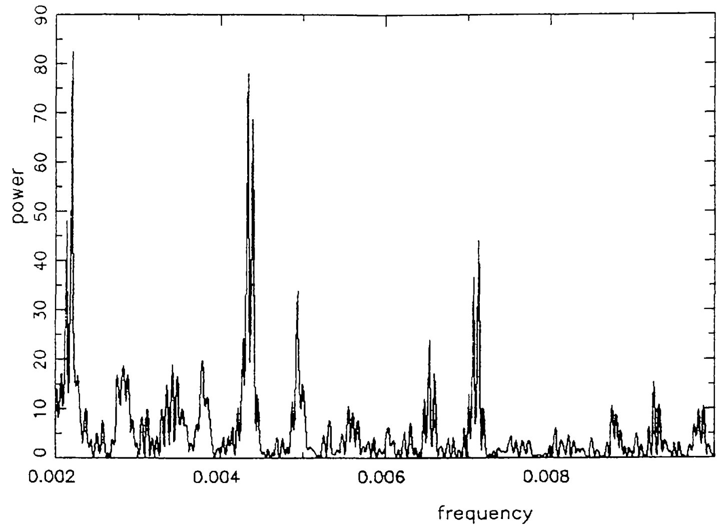


Figure 10. GY Aquilae: Periodogram. Power is defined by Scargle (1982). Peaks occur at 231 days (f = 0.0043 d^{-1}) and 456 days (f = 0.0022 d^{-1}).

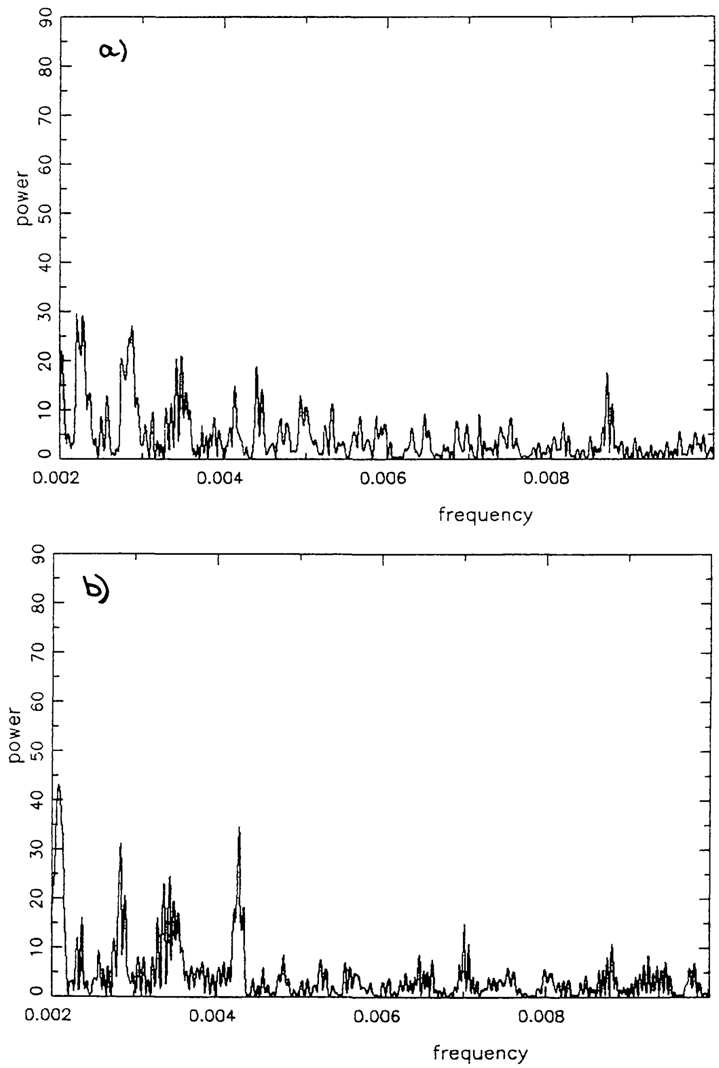


Figure 11. GY Aquilae: Periodograms of the residuals of (a) the 231-day period and (b) the 456-day period.