NUTATION AND NEARLY DIURNAL LATITUDE VARIATIONS FROM THE DATA OF BRIGHT ZENITH STAR OBSERVATIONS IN POLTAVA FROM 1950 TO 1977

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1. OBSERVATIONAL DATA

The observations of bright zenith stars (α Persei and η Ursae Maj) have been carried out in Poltava since 1939. These observations have been used for determining the corrections to semiannual and fortnightly nutation terms and for studying the nearly diurnal free polar motion (Popov, 1968; Popov and Yatskiv, 1977). Recently the reduction of the new series of bright zenith star observations has been finished in Poltava (see Table 1). Therefore it was interesting to carry out a new analysis of these observations for the purpose of studying the nutation and of searching for the nearly diurnal free polar motion.

Table 1. Observations of bright zenith stars in Poltava

Time Series	Interval of Observations in months	Instrument
I	March, 1950 - October, 1968 223 months	Zenith-telescope of Zeiss
II	November, 1968 - February, 1977 100 months	Zenith-telescope ZTL-180

We have used the monthly mean values of the differences of the latitude obtained for two stars

$$\Delta\phi_t = \phi_{\alpha,t} - \phi_{\eta,t} \quad . \qquad (1)$$

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The weights of $\Delta\phi_t$ are given by formula

$$P_t = n_\alpha n_\eta/(n_\alpha + n_\eta) \quad ,$$

where n_α and n_η are the numbers of observations of α Persei and η Ursae Maj respectively. As the difference of right ascension of these stars is about 11^h the diurnal and nearly diurnal latitude variations manifest themselves with a nearly double amplitude in differences of $\Delta\phi_t$ (amplifying factor $k = 1.96$).

2. METHOD OF ANALYSIS

Maximum entropy spectral analysis (MESA) (introduced by Burg, 1970) was used to study periodic variations of $\Delta\phi_t$. The maximum entropy estimate of the power spectrum is given by

$$G(T) = \frac{2\Delta t G_{m+1}}{\left|1 + \sum_{\ell=1}^{m} h_{m\ell} \exp(-i2\pi\ell\Delta t/T)\right|^2} \quad , \qquad (2)$$

where $h_{m\ell}$ are prediction error filter coefficients; Δt is the data sampling interval; G_{m+1} is the mean output power of the (m+1)-long prediction error filter; G_{m+1} and $h_{m\ell}$ are obtained by a recursive method for solving the prediction error equation system (see, for example, Smylie et al., 1973). In practice we choose several values of m to be able to judge the stability of a spectrum.

Since the MESA is a power estimator it contains no phase information and a relation between G(T) and amplitude, A, is not simple. Therefore in order to determine the estimates of amplitudes A_j and phases β_j we have used the least-squares solution of equation (3)

$$\Delta\phi_t = A_o + \sum_j A_j \sin(2\pi/T_j \, t\Delta t + \beta_j) \quad , \qquad (3)$$

where T_j are the periods found by means of MESA,

$$\Delta t = 366,\ 2422/12. \qquad t = 1,2,\ldots,n \quad .$$

In our analysis the phase β_j refers to the mean epoch of bright zenith star observations in March 1, 1950.

3. NUMERICAL RESULTS

From our previous study of bright star observations we know that there are significant variations of the differences of latitudes with the periods 122, 183, 366 and 6798 in sidereal days (Popov and Yatskiv, 1977). We have found estimates of A_j and β_j for these periodicities, which are given in Table 2. Subtracting these well-known variations from the initial data set we have the residuals $\widetilde{\Delta\phi}_t$. The entire 223-month series have been divided into 3 overlapping 100-month intervals (Ia,Ib,Ic). The ME power spectra of Ia, Ib, Ic and II time series are given in Figures 1 and 2 for different frequency regions. Figure 3 shows the ME power spectrum of the entire 223-month series. On the basis of the MESA we have chosen the following significant periods: 96, 117, 127, 144, 176, 190, 243, 256, 265, 321, 390, 455, 539, 582 and 707 s.d. The results of the least-squares solution for some of these periods are given in Table 3. The amplitudes of other periodic variations have proved to be smaller than 0".02.

Table 2. Least-squares solution

Period in s.d.	Time Series	Amplitude	Phase
122	I	0".017 ± 0".008	120° ± 28°
	II	0".015 ± 0".011	165 ± 42
183	I	0".044 ± 0".008	265 ± 11
	II	0".040 ± 0".014	223 ± 20
366	I	0".051 ± 0".009	101 ± 10
	II	0".090 ± 0".016	64 ± 10
6798	I	0".014 ± 0".008	321 ± 33
	II*	--	--

*For this time series the 18.6-yr variation has not been determined.

Table 3. Least-squares solution

Period in s.d.	Time Series	Amplitude	Phase
117	I	0".026 ± 0".008	-24° ± 17°
	II	14 ± 15	+125 ± 57
190	I	28 ± 8	+39 ± 17
	II	28 ± 15	+167 ± 30
390	I	39 ± 8	+35 ± 11
	II	40 ± 15	+125 ± 22
455	I	24 ± 9	-35 ± 20
	II	7 ± 17	+15 ± 136
707	I	16 ± 8	+191 ± 28
	II	28 ± 21	+80 ± 45

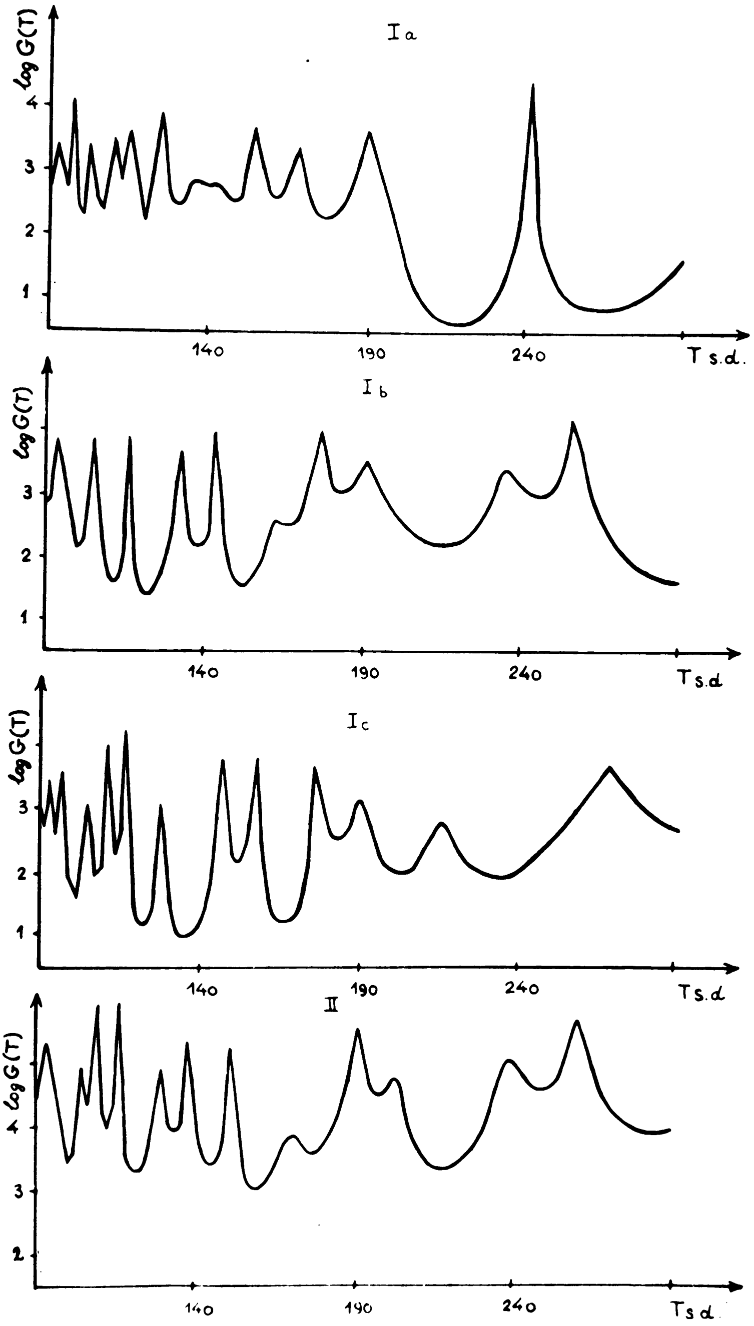

Figure 1. ME spectrum of $\Delta\widetilde{\phi}_t$ time series. Abscissa is periods in sidereal days. Ordinate is logarithm of spectral estimate.

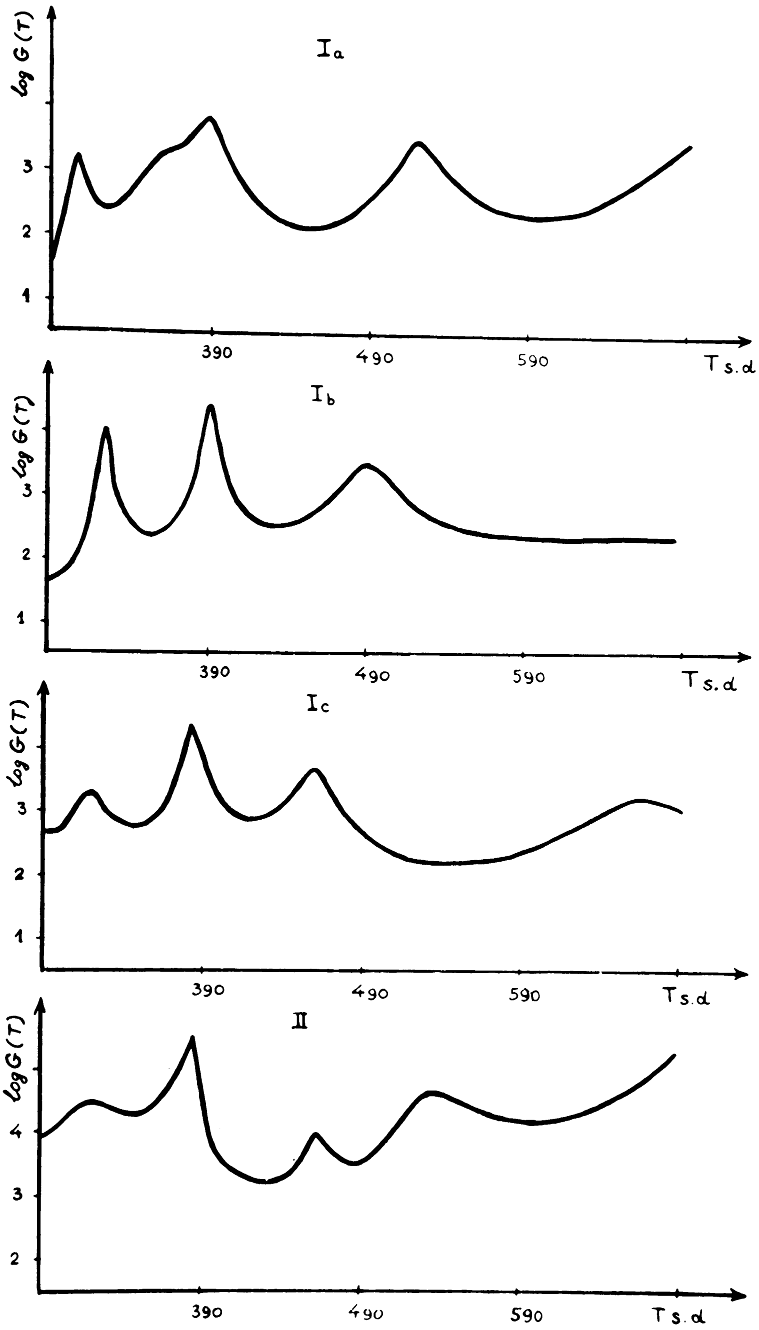

Figure 2. ME spectrum of $\widetilde{\Delta\phi}_t$ time series. Abscissa and ordinate are the same as Figure 1.

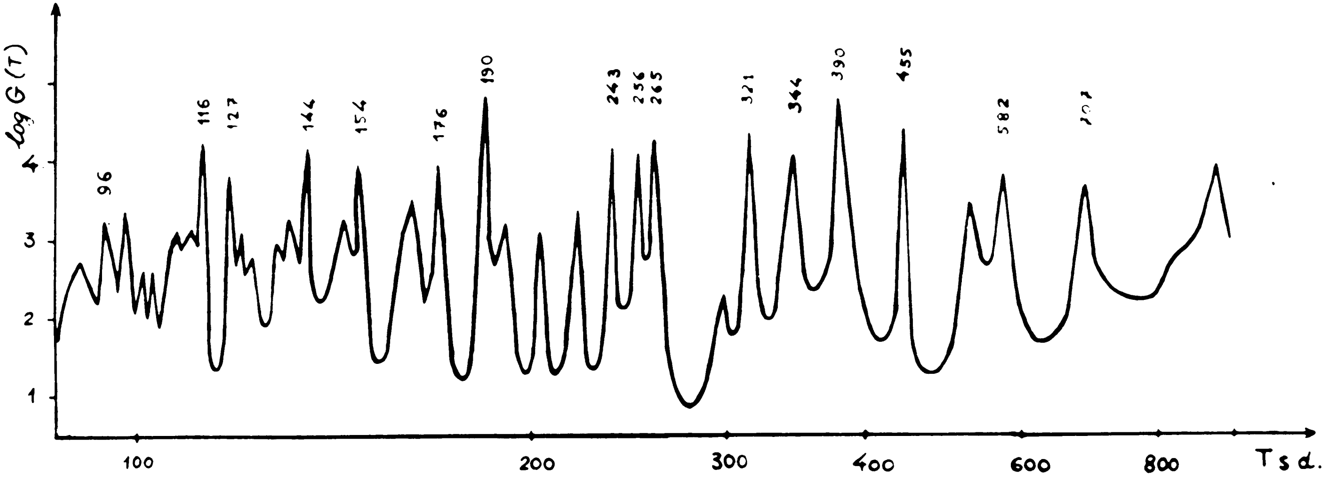

Figure 3. ME spectrum of the $\widetilde{\Delta\phi}_t$-I time series. The figures under the peaks designate the values of periods.

4. DISCUSSION

a) 18.6-yr Nutation

With observations only of two stars it is impossible to find corrections to this adopted coefficient of nutation in both obliquity and longitude. Supposing that the absolute values of these corrections are equal and taking into account an amplifying factor $k = 1.96$ we find the correction of nutational constant from the data given in Table 2

$$\Delta N = -0''.007 \pm 0''.003 \quad .$$

b) Semi-Annual Solar Nutation

With the same supposition as in the case a) we find the correction of an adopted coefficient of semi-annual nutation in obliquity

$$\Delta a = +0''.022 \pm 0''.004 \quad .$$

This correction is in agreement with the determinations by Popov (1968) and Yokoyama (1973).

c) Annual Solar Nutation

As one can see from Table 2 the diurnal latitude variations in Poltava are significantly different for different instruments. This suggests a meteorological and instrumental origin of the diurnal latitude variations. Therefore we are not able to derive the value of the annual nutation from these observations.

d) Nearly Diurnal Free Polar Motion

If the nearly diurnal free polar motion exists, it will manifest itself as a harmonic variation of the latitude differences $\Delta\phi_t$ with an aliasing period of about 460 s.d. Generally speaking, this aliasing period could correspond to a number of nearly diurnal, semidiurnal and other periods due to the fact that harmonic oscillations with frequencies $(\Delta t)^{-1} \pm f$, where $(\Delta t)^{-1}$ is sampling frequency, all look alike in digital records with sampling interval Δt. We restrict ourselves to the nearly diurnal periods τ, one of which is shorter, and the other longer, than a day. The values of τ_j and some of the aliasing periods, T_j, which correspond to those mentioned in previous sections, are given in Table 4. T_{2j} is the aliasing period for the case of customary latitude observations.

Yatskiv et al. (1975) indicated the existence of both the direct and retrograde components of nearly diurnal polar motion with periods 186, 206, 247, 193 and 210 m.d. respectively. These components cannot be distinguished using the latitude data of a single station. It may be

Table 4. Aliasing and nearly diurnal periods, in days

T_j s.d.	τ_j s.d.	T_{2j} m.d.
390	0.99744 1.00256	189 5650
455	0.99780 1.00220	203 1892
707	0.99859 1.00142	242 759

the reason for the observed periods of 390, 455 and 707 s.d. in bright zenith star observations in Poltava.

e) Period of 190 s.d.

This period seems to be real and can correspond to nearly diurnal periods (1 ± 0.00526) s.d. and to aliasing periods $T_2 = 396$ and 125 m.d. respectively. The period $T_2 = 396$ m.d. has been found earlier by Taradij (1968) in the latitude variations of the ILS-stations. It is interesting to note that the existence of this periodic variation hampers deriving the 18.6-yr. nutation from the ILS-observations provided if the duration of observations is less than 36 years.

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