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THE STABILITY THE AMPLITUDES AND PHASES OF THE CHANDLER'S, ANNUAL AND SEMI-ANNUAL TERM IN THE POLAR MOTION

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Summary. Using the unsmoothed ILS coordinates of the instantaneous pole (Yumi and Yokoyama, 1980) the stability of the amplitudes and phases of the main harmonic terms in the polar motion are investigated. It has been established that the amplitudes and the phases were not subject to systematic fluctuations. As for the amplitude A and the phase P of the Chandler nutation, it seems that the amplitude forms a periodic function of time enclosing as the most prominent the components with 53.0 and 34.5 year periods, while the phases kept stable over longer time intervals, apart from jump-like change from 1925 to 1940.

N. Pejović, STABILNOST AMPLITUDA I FAZA ČENDLEROVOG, GODIŠNJEG I POLUGODIŠNJEG ČLANA U KRETANJU POLA — Koristeći neizravnate ILS koordinate trenutnog pola (Yumi and Yokoyama, 1980) ispitana je stabilnost amplituda i faza glavnih harmonijskih članova u kretanju pola. Ustanovljeno je da amplitude i faze godišnjeg i polugodišnjeg člana nemaju sistematske fluktuacije. Što se tiče amplitude A i faze P Chandler-ove nutacije, verovatno je da amplituda predstavlja složenu periodičnu funkciju vremena sa najizrazitijim komponentama od 53.0 i 34.5 godina, a da faza ostaje stabilna u dužim vremenskim intervalima, sa mogućom skokovitom promenom kao u periodu 1925—1940.

INTRODUCTION

Following the organising of the ILS in 1899 until the present day the observational data of exceptional scientific value has been collected. Many known researchers have studied this data and all of them confirmed, as is well known, the existence of the circular free nutation component, revealed by Chandler, as well as the existence of the annual elliptical nutation termed the forced nutation. Geophysical causes of exciting of free nutation of the Earth's rotation axis are still unknown (Lambeck, 1980). The variability of its period phase is a matter of controversy for a whole century. In the opinion of some authors, including Chandler himself, there exist two or even more free nutations with close periods to each other or, one single with a variable period (Chandler, Kimura, Melchior, Sekiguchi, Gaposchkin, Carter, Vondrak). There is also another group of authors

(Newcomb, Ooe, Okubo) prooving that there exists one single free nutation having a stable period.

From our previous investigations (Pejović, 1983) we inferred that there exist in the spectra of the polar coordinates two close peaks with periods of 1.171 and 1.197 years, which lends to the free nutations hypothesis. By this hypothesis Melchior (1957) explained the variability of the Chandler period and amplitude. This variability in Melchior's view is due the interference of two free nutations, one of which providing from the Earth's core and the other one from the Earth's elliptic crust. According to Vondrak (1984) the rapid change of the phase in the period 1925—1940 is a consequence of the change of Chandler period.

In the present paper our attention will be directed towards analysing the variation of the amplitude and the phase of the Chandler's, annual and semi-annual terms in the polar motion.

VARIATION OF THE ANNUAL AND THE SEMI-ANNUAL TERMS

For the present analysis the data over six-year subintervals have been treated. According to the assumption that the amplitudes and the phases of the annual and the semi-annual terms are more stable then those of the Chandler term, which was confirmed by the results á posteriori, the amplitude A_a and the phase P_a of the annual term as well as the amplitude A_h and phase P_h of the semi-annual term were calculated and eliminated from both coordinates, using the method of least squares (MLS). Our purpose was to observe the Chandler variation of the polar coordinates as a function of time (Fig. 1). The results A_a, A_h, P_a andP_h are given in Table I. In columns 2 and 6 are listed in seconds of arc the amplitudes of the annual term in X and Y coordinate, and in the columns 4 and 8 those of the semi-annual term. In the columns 3 and 7 and 5 and 9 are presented the phases of these terms in arc degrees.

TABLE I

Period	X coordinate				Y coordinate			
	A_a	F_a	A_h	F_h	A_a	F_a	A_h	F_h
1899.8—1905.8	.080	335.4	.008	282.8	.065	260.7	.001	92.1
1905.8—1911.8	.108	329.0	.008	286.0	.093	253.3	.005	263.2
1911.8—1917.8	.081	343.5	.005	128.1	.086	265.0	.010	158.7
1917.8—1923.8	.090	332.6	.005	191.7	.077	234.9	.005	98.9
1923.8—1929.8	.058	360.3	.006	120.3	.045	278.8	.018	121.4
1929.8—1935.8	.113	348.8	.006	338.3	.091	267.5	.006	349.4
1935.8—1941.8	.107	341.1	.007	300.4	.097	256.4	.003	288.7
1941.8—1947.8	.114	340.3	.005	264.5	.088	260.8	.007	184.4
1947.8—1953.8	.114	329.5	.009	321.5	.100	238.1	.008	247.1
1953.8—1959.8	.085	330.2	.010	301.5	.059	244.2	.006	89.6
1959.8—1965.8	.103	336.4	.002	302.1	.069	238.3	.010	120.7
1965.8—1971.8	.099	337.4	.006	326.1	.067	254.4	.006	163.6
1971.8—1977.8	.078	360.1	.002	306.9	.078	282.7	.016	107.9

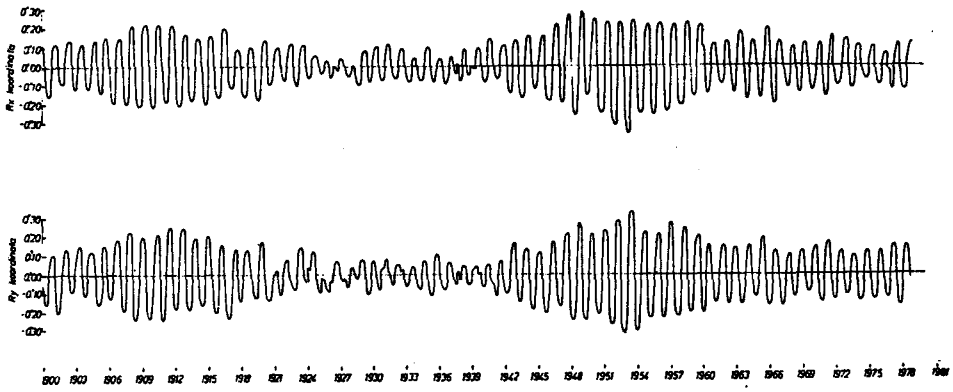

Fig. 1.

From the data of the Table I we computed the mean values of the amplitudes A_a and A_h ($\bar{A}_a$, $\bar{A}_h$), the mean values of the phases P_a and P_h ($\bar{P}_a$, $\bar{P}_h$) and the standard deviations of these variables. The phases are referred to JD = 2414 948. The obtained results are presented in the Table II.

TABLE II

Coord.	Annual term		Semi-annual term	
	$\bar{A}_a \pm \sigma_{\bar{A}_a}$	$\bar{P}_a \pm \sigma_{\bar{P}_a}$	$\bar{A}_h \pm \sigma_{\bar{A}_h}$	$\bar{P}_h \pm \sigma_{\bar{P}_h}$
X	0".0948 ± 0".0050	340° ± 3°	0".0060 ± 0".0007	266° ± 21°
Y	0.0778 ± 0.0046	256 ± 4	0.0077 ± 0.0014	176 ± 25

Practically the same results we have obtained earlier by the method of Fourier transforms (Pejović, 1983).

In order to examine whether the variations of the amplitude and the phase of the annual term were bearing a systematic or accidental feature we used Abbe's criterion (Djurović, 1979).

Let G and G_0 be statistics specified by the relations

$$G = \frac{\frac{1}{2N-1}\sum_{i=1}^{N-1}(A_{i+1}-A_i)^2}{\frac{1}{N-1}\sum_{i=1}^{N-1}(A_i-\bar{A})^2}$$

$$G_0 = 1 + \frac{u_q}{\sqrt{N+0.5(1+u_q^2)}}$$

where $u_q = -1.645$ is the quantil of the order 0.05 (u_q is a quantil of the order q provided the probality of the accidentally variable $x > u_q$ is q) of the Gaussian distribution of the probability. The quoted equation is used for calculating the statistics G_0 if $N > 20$, whereas for $N \leqslant 20$, in our case $N = 13$ and for $q = 0.05$ it assumes the value $G(13) = 0.578$ (Djurović, 1979).

The G values relatives to the amplitude and the phase of the annual term in the X and Y coordinates are given in Table III.

The G values in Table III are greater than $G(13) = 0.578$. Thus the $A_i - \bar{A}$ differences might be considered as the accidental errors.

According to Abbe's criterion the variations of the amplitude and phase of the semi-annual term (with respect to the mean values) are also accidental.

TABLE III

Calcul. statist.	X coord. A_a	X coord. F_a	Y coord. A_a	Y coord. F_a
G	0.973	0.722	0.960	0.872

CHANDLER TERM VARIATIONS

The amplitude and the phase of the Chandler term (the adopted period 1.20 years) were computed by MLS for 15 months subintervals by moving their beginings for one year (the zero point is at 1899.8 and the overlapping of the successive subintervals is three months). The amplitudes are plotted in Figure 2 and the phases in Figure 3. The phases are relatives to JD = 2414 948.

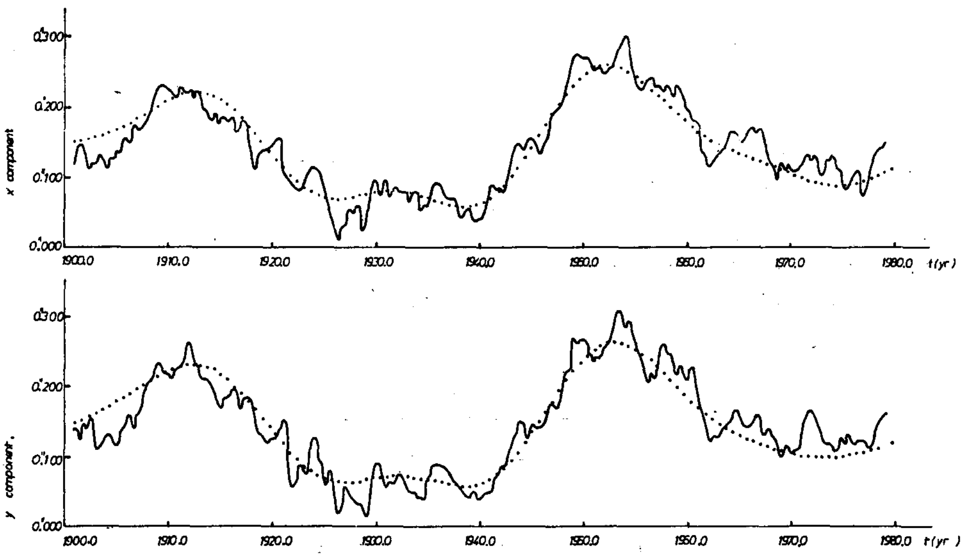

Fig. 2. Periode variation of Chandler's amplitude

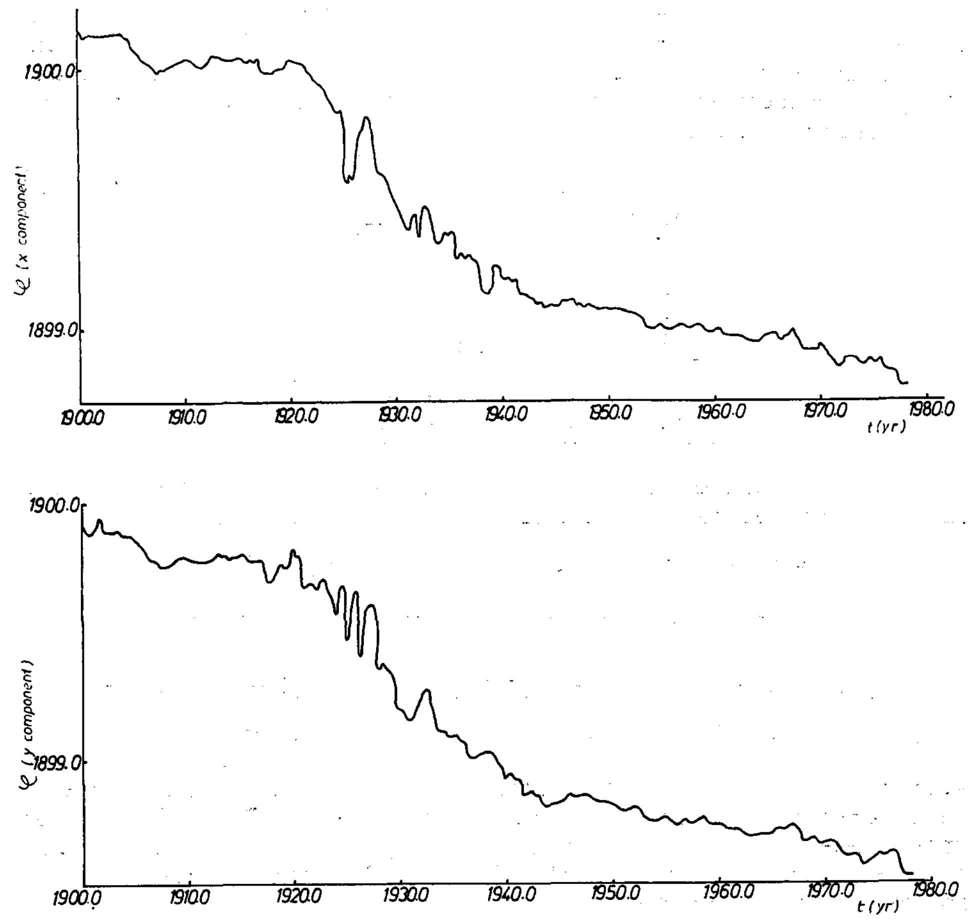

Fig. 3

The results in Figures 2 and 3 are close to those of Guinot (1972, 1973) and Dickman (1981). One gets the impression from Figure 2 that the Chandler amplitude has a periodic variation while the phase, outside of the period 1925—1940, has a relatively good stability. The 180° change of the phase in the period 1925—1940 is a unique and as yet unexplained phenomenon.

Shouxion, Yingmin and Shuhe (1982) have concluded that the phase of the Chandler nutation is periodically variable. This conclusion could not be confirmed from our analysis.

In order to determine the periods of the assumed harmonic variations of the Chandler amplitude we computed by MLS the amplitude m and the phase ν of the sinusoide $A(t) = m \sin(\omega t + \nu)$, varying the trial period

P within a 15 to 80 years range, with the increment $\Delta P = 0.5$ year. In Figure 4 is presented the amplitude m in function of P. Two prominent maxima are evident in Figure 4, corresponding to the periods of 53.0 and 34.5 years, respectively. The amplitudes and the periods of these two and two weaker maxima, are given in Table IV.

TABLE IV

Period (year)	Amplitudes X coord.	Y coord.
53.0	0".0598	0".0632
34.5	0.0417	0.0438
23.0	0.0188	0.0234
17.5	0.0206	0.0168
The standard deviation is ±0".005		

The Chandler amplitude as a function of time is synthetized as a sum of mentioned four periodic functions (in X and Y separately):

$$A_x(t) = C_0 + C_1 \cos\omega_1 t + C_2 \sin\omega_1 t + C_3 \cos\omega_2 t + C_4 \sin\omega_2 t + \\ + C_5 \cos\omega_3 t + C_6 \sin\omega_3 t + C_7 \cos\omega_4 t + C_8 \sin\omega_4 t \tag{1}$$

$$Ay(t) = D_0 + D_1 \cos\omega_1 t + D_2 \sin\omega_1 t + D_3 \cos\omega_2 t + D_4 \sin\omega_2 t + \\ + D_5 \cos\omega_3 t + D_6 \sin\omega_3 t + D_7 \cos\omega_4 t + D_8 \sin\omega_4 t$$

Adopting for their periods, amplitudes and phases the values of the Table IV we obtained the functions $A_x(t)$ and $A_y(t)$ presented in Figure 2 by dotted lines. These functions (equation 1), including four harmonic components of largest amplitudes (at 53.0, 34.5, 23.0 and 17.5 years), represent a good approximations of Chandler amplitude variation.

Let A_R (Fig. 5) represent the differences between the observed and computed amplitudes $A - A_x(t)$ or $A - A_y(t)$. Since the shape of A_R curves makes one suspect the presence therein of smaller periodical terms, by the Fourier transforms we have computed the spectrum of A_R. The trial period was varied from 2 months up to 15 years, with the increment of 1 month. The periods and the amplitudes of several best pronounced terms are listed in Table V.

TABLE V

Period (year)	Amplitudes X cord.	Y cord.
11.3	0".011	0".008
8.2	0.007	0.004
7.1	0.010	0.009
6.0	0.008	0.010
The standard deviation is ±0".001		

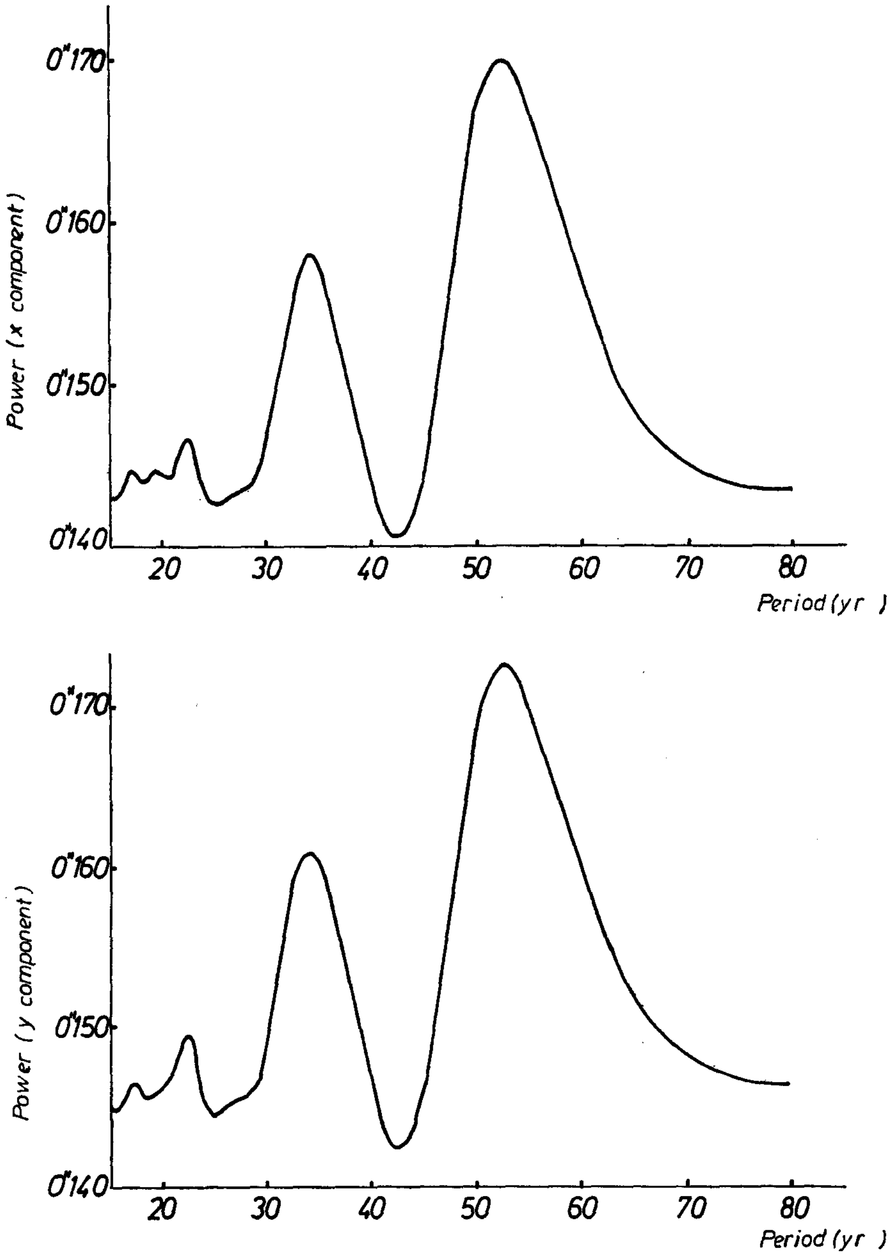

Fig. 4. Spektrum of Chandler's amplitude

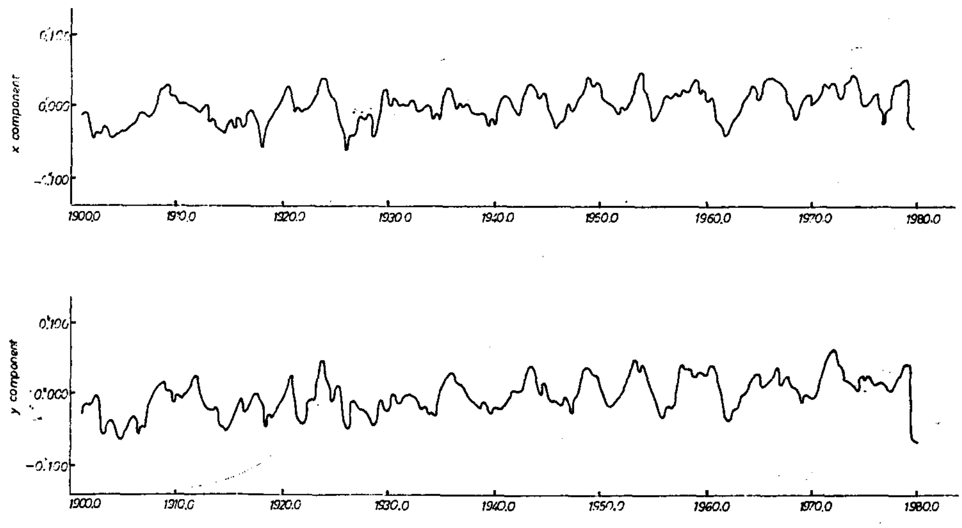

Fig 5

According to the some authors there exists in the universal times UT1 and UT2 a periodic variation with the characteristic period of 60 years (Kalinin and Kiselev, 1980; Kiselev, 1982; Emetz and Korsun, 1978; Stajić, 1983) and an amplitude of few seconds! Should this prove true one should check whether the 53-years variation in X and Y is due to the same cause. A variation of 35 years period has also assumed in UT1 system (Morison, 1979; Stajić, 1983) which in its turn incites one to ponder over their common exciter.

Weak variations of 23 and 11-years have the periods of the known solar activity cycles. They anticipated in the universal time systems (Djurović and Stajić, 1985; Vondrak, 1977). The term of 17.5-year corresponds approximately to the nutation cycle.

The 6- and 8-year variations (Table V) are likewise noted in UT1 or UT2 (Lambeck and Cazenave, 1983; Djurović, 1979; Djurović and Stajić, 1984; Djurović, 1981). Despite the fact that the mentioned periodic or quasiperiodic variations of the polar coordinates and angular velocity of the Earth's rotation (e. g. variations of 60, 35, 22, 11, 18 and 6 years periods), have been assumed conclusive evidence of their existence is still missing. The present paper and the similar papers of other authors may only help us discerning those spectral regions which deserve paying greater attention to.

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