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THE CHANDLER NUTATION FOR THE PERIOD 1949–1985

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SUMMARY: The values of the amplitude, the period and the phase of the Chandler nutation are computed by using the homogenized series of Belgrade latitudes for the period 1949-1985. The observations were realised by the Talcott method at ASKANIA zenith – telescope (D=11 cm, F=128.7 cm).

The amplitude of the nutation varies with a period of about 38 years; its minimum was around 1971 and the maximum – around 1952. This result is in good agreement with the results of some other authors (Markowitz, 1960; Rykhlova, 1969; McCarthy, 1972; Vicente and Currie, 1976; Wilson and Vicente, 1980; Guinot, 1972, 1982; Nastula et al., 1993; Vondrák, 1985, etc.).

The period of the Chandler nutation is also variable. Thus, the results of Carter (1981), Vondrák (1985), Pejović (1985) and some other authors are confirmed.

1. INTRODUCTION

Different series of classical astrometry data are analysed with the aim to examine the stability in time of the amplitude and the period (or the phase) of Chandler nutation. Besides the 80–year long series of ILS coordinates, the combined series of ILS and pôle coordinates computed from the observations of individual observatories as, for example, Washington, Greenwich, Pulkovo, Kiev, etc. enabled the studies of Chandler nutation to be extended far away in the past. So, for example, the series analysed in Rykhlova (1969) and Nastula et al. (1993) span over the intervals of 119 and 140 years, respectively. In all mentioned series the quasi–periodic instability of the Chandler nutation amplitude whose period lies in the range 30–40 years is detected. In the recent study of Vondrák and Ron (1995), based on the latitudes reduced to HIPPARCOS system of star positions, this result is also confirmed. Having in mind that the HIPPARCOS coordinates are free of known systematic errors and local distortions of classical astrometry coordinates and proper motions, the latter result is particularly interessting.

Despite the above results the observational evidence of the 30–40–yr Chandler nutation amplitude variation is not widely accepted as a real one.This situation could be explained by the lack of the physical explanation of the phenomenon.

Since the homogenized series of Belgrade latitudes provides an opportunity for the studies of long–period variations of latitudes, the present work is focused on examining the Chandler nutation period and amplitude stability and so to give a contribution for a better description of their behavior with time.

The Belgrade latitudes data (in the list of Bureau International de l' Heure (BIH) series denoted by BLZ) for the period 1949 – 1985 are obtained by two observation programs: the old one (Djurković, Ševarlić, Brkić, 1951), until the end of 1960, and the new one (Ševarlić and Teleki, 1960), from the beginning of 1960 and onwards.

All latitudes are reduced to the FK5 reference frame (Damljanović, Pejović, 1995) and apparent star positions are computed following the procedure known as MERIT standards (Melbourne et al., 1983). For this purpose the PPM Star Catalogue (Röser and Bastian, 1991) is used.

The latitudes are analysed for some systematic instrumental, personal, refraction and star position errors. Those of them which are confidently determined are removed from the data (Damljanović, 1994, 1995).

To obtain the equidistant data, the raw latitudes were averaged and after that they were interpolated by the cubic spline method. The "normal points" (the average values of 49–58 Talcott pair latitudes) have approximately equal weights. The interpolated latitudes are computed by the lag of 0.1 yr: their total number being $N = 369$.

2. THE AMPLITUDE, THE PERIOD AND THE PHASE OF THE CHANDLER NUTATION

The Chandler nutation is slightly elliptical or near circular (see, for example, Guinot, 1982). According to Vondrák (1985) and Vondrák and Ron (1995), its amplitude varies from $0''.07$ to $0''.28$. Assuming the phase constant, the mentioned authors have found the period of free nutation to be also variable, ranging from 387 days (or 1.06 yr) to 442 days (or 1.21 yr).

The amplitude and phase of Chandler nutation in the present work refere to the Belgrade meridian $\lambda_{BLZ} = 20^o.5E$. This fact has to be kept in mind when one compares the BLZ rezults with the results based on ILS, IPMS, BIH and IERS data.

In the present work the Fourier transforms – DFT of interpolated latitudes are first computed for the whole observation period. As usually, the secular latitude variation was previousely determined (by the least–squares method – LSQ) and removed from the data.

The amplitude periodogram of interpolated latitudes is presented in Fig. 1. The numerical values for the periods, the amplitudes and the phases (for the epoch $1949.^y1$) of three known oscillations are given in Table 1.

The amplitudes are corrected for the white noise contribution.

The standard deviation of residuals (see Fig. 5.), obtained after the removing of the secular term and three mentioned oscillations is $\sigma_0 = 0''.066$. This value was used to compute the amplitude and the phase standard deviations:

$$\sigma_A = \sigma_0\sqrt{\frac{4-\pi}{N}} = 0''.003,$$

$$\sigma_F \approx 57.^\circ296\frac{\sigma_0}{A}\sqrt{\frac{2}{N}}.$$

The values of σ_F of the Chandler, the annual and the semiannual terms are: $1.^\circ6$, $4.^\circ0$, $18.^\circ1$ respectively.

The mentioned white noise correction to amplitude is

$$\Delta A = \sigma_0\sqrt{\frac{\pi}{N}} = 0''.006.$$

The value $A_a = 0''.063$ is less than the value of A_a from the international data for the same period because of the presence of strong Z–term whose seasonal component has an amplitude $A_Z = 0''.041$ and a phase $F_Z = 41.^\circ3$ (epoch: $1949.^y1$).

When the results from the Table 1. are used for the removing of annual and semiannual oscillations the residuals presented in Fig. 2. are obtained. These residuals are used to obtain the "instantaneous" amplitude and the phase of Chandler nutation by the LSQ method.

Besides the DFT method, the mean period of Chandler nutation for the time span 1949-1985 was recomputed by the LSQ method. For this purpose P_C is varied to obtain the minimum of standard deviation ($\sigma = 0''.0836$) of residuals. Thus the value $P_C = 1.185$ yr was obtained. Evidently, this result, as theoretically expected, is very close to the DFT value of P_C.

With constant $P_C = 1.185$ yr the amplitude and the phase (for the epoch $1900.^y0$) of Chandler nutation were recomputed for the independent 1.2 yr subintervals. In this way the results presented in the Table 2. were obtained.

At the bottom of Table 2. the phases relative to the epoch $1949.^y1$ are also given. They may be compared with DFT results.

Evidently, the phases computed by two mentioned methods are close to each other.

In Table 2. are also given the amplitudes and the phases (for the epochs $1949.^y1$ and $1900.^y0$) computed by using $P_C = 1.^y19$. The aim of this computation was to compare our results with those based on international data. For example, with P_C=1.19 yr

Table 1. The period (P), the amplitude (A) and the phase (F, epoch: $1949.^y1$) of the Chandler (c), the annual (a) and the semiannual (sa) terms

P_c	A_c	F_c	P_a	A_a	F_a	P_{sa}	A_{sa}	F_{sa}
$1.^y19$	$0''.170$	$73.^\circ4$	$1.^y01$	$0''.063$	$205.^\circ7$	$0.^y49$	$0''.009$	$168.^\circ1$

Table 2. The values of the amplitude (A_C) and phase (F_C) of the Chandler wobble obtained by LSQ

year (1900+)	No	$A_c('')$	$F_c(°)$ (epoch: $1900.^y0$)
49.7	1	.2365	212.9
50.9	2	.1799	189.8
52.1	3	.3373	209.9
53.3	4	.2202	232.0
54.5	5	.3068	209.5
55.7	6	.2334	208.6
56.9	7	.2100	221.1
58.1	8	.2129	205.8
59.3	9	.2259	224.0
60.5	10	.1958	222.2
61.7	11	.1751	219.5
62.9	12	.1291	206.0
64.1	13	.1960	230.1
65.3	14	.1574	225.0
66.5	15	.1602	233.1
67.7	16	.1507	257.1
68.9	17	.1066	234.6
70.1	18	.1320	248.4
71.3	19	.1071	226.4
72.5	20	.1468	248.2
73.7	21	.1618	239.5
74.9	22	.1601	224.6
76.1	23	.1196	232.0
77.3	24	.1539	229.9
78.5	25	.1686	224.7
79.7	26	.1655	222.2
80.9	27	.1870	202.3
82.1	28	.1598	197.8
83.3	29	.2312	209.0
84.5	30	.2171	213.1
mean		.1848 ±.0096	222.0 ±2.8
period: 1949–1985 ($P_C = 1.^y185$)		.1802	218.6 (epoch: $1900.^y0$)
period: 1949–1985 ($P_C = 1.^y185$)		.1802	62.1 (epoch: $1949.^y1$)
period: 1949–1985 ($P_C = 1.^y19$)		.1749	134.3 (epoch: $1900.^y0$)
period: 1949–1985 ($P_C = 1.^y19$)		.1749	40.5 (epoch: $1949.^y1$)

the mean phase of Chandler nutation from BLZ data at the epoch $1900.^y0$ is $F_c = 134.^o3$. Taking into account the Belgrade longitude, this result is in good agreement with the results of Vondrák (1985, 1988).

The series of independent values of the amplitude and phase (for $P_C = 1.^y185$) are shown in Fig. 3. and Fig. 4. respectively.

The sinusoidal approximation of the amplitude (dotted line in Fig. 3.) is obtained by LSQ varying the period of sinusoid from 35.0 up to 40.0 years with a lag of 0.5 year. The minimum of standard deviation $SD = 0\overset{''}{.}0324$ of residuals (which are shown in Fig. 6.) corresponds to the period $P_{aC} = 38.^y0$ and the amplitude $A_{aC} = 0\overset{''}{.}0597$.

From the results presented in Fig. 4. it seems probable that the Chandler nutation phase in the period of 1964–1978 is systematically above the values outside this period. The corresponding periods are: 447 days (in the interval 1964–1978) and 423 days (outside this interval).

The results obtained from Belgrade data are in relatively good agreement with the results obtained from international data series (Guinot, 1972; Gaposchkin, 1972; Guinot, 1982; Markowitz, 1982; Vondrák, 1985; Vondrák and Ron, 1995). Accordingly the 30 − 40 yr variation of the Chandler nutation amplitude is confirmed. In addition, the phase variation is also shown.

3. CONCLUSION

In the homogenized series of Belgrade latitudes the decade variation of Chandler nutation amplitude is detected. The period of variation is $P_{aC} =$ 38 years, the amplitude is $A_{aC} = 0\overset{''}{.}0597$.

For the period of Chandler nutation two values are found: $P_C = 447$ days, for the period 1964–1978 and $P_C = 423$ days, outside this period.

Assuming P_C constant ($P_C = 1.185$ yr), the corresponding values of the phase are: $F_C = 235.^o7$ (1964–1978) and $F_C = 212.^o8$.

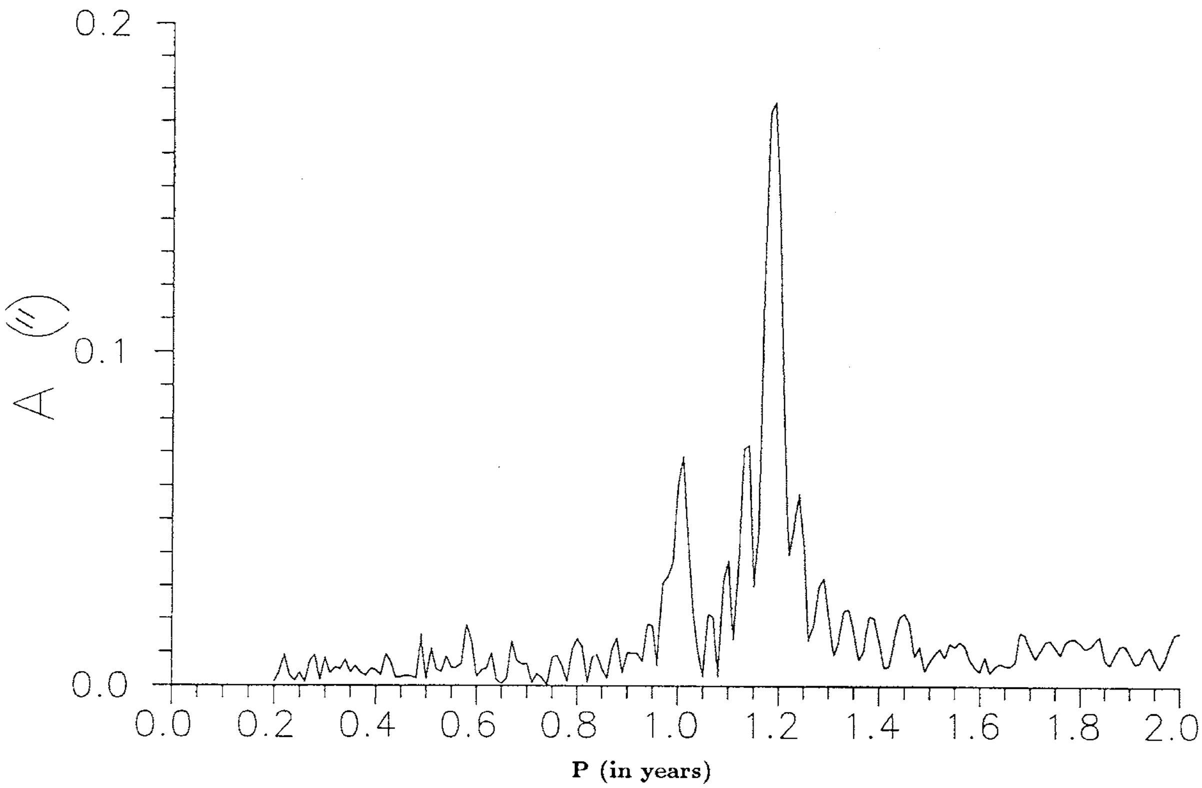

Fig. 1. *Amplitude periodogram of unsmoothed BLZ data.*

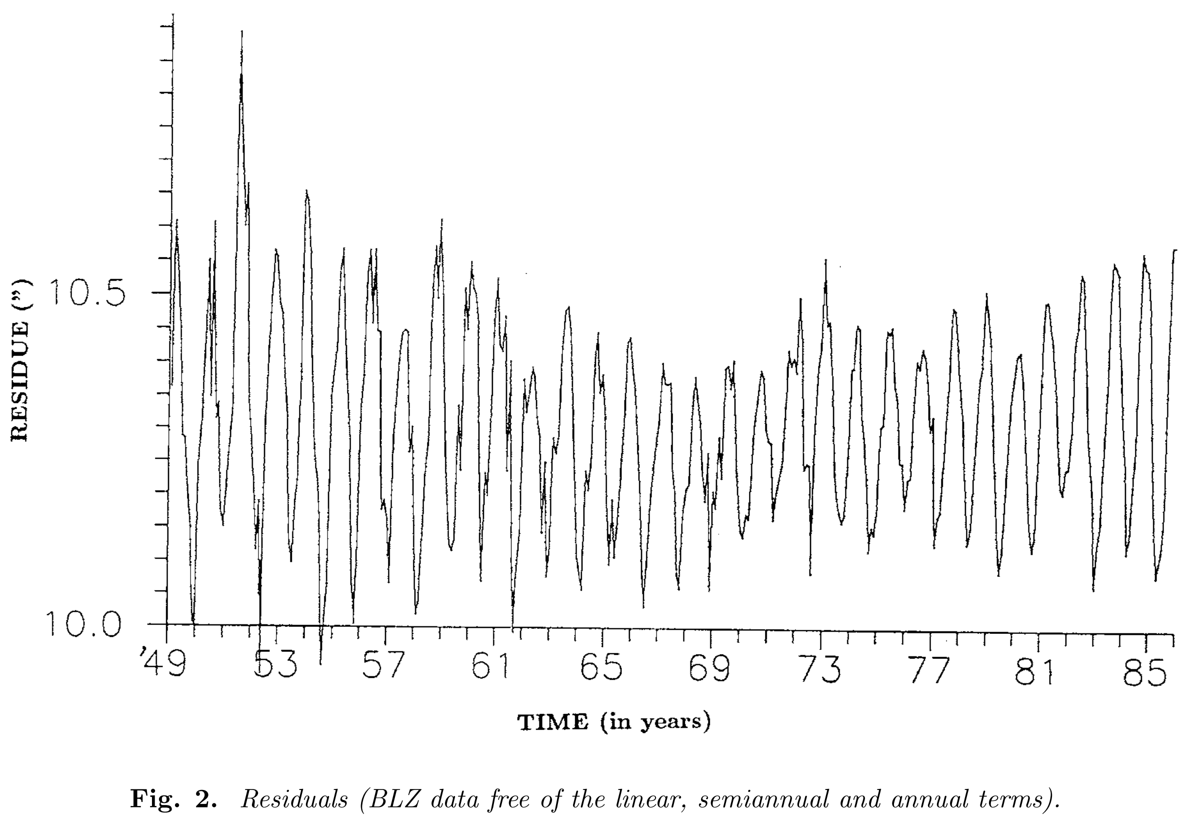

Fig. 2. *Residuals (BLZ data free of the linear, semiannual and annual terms).*

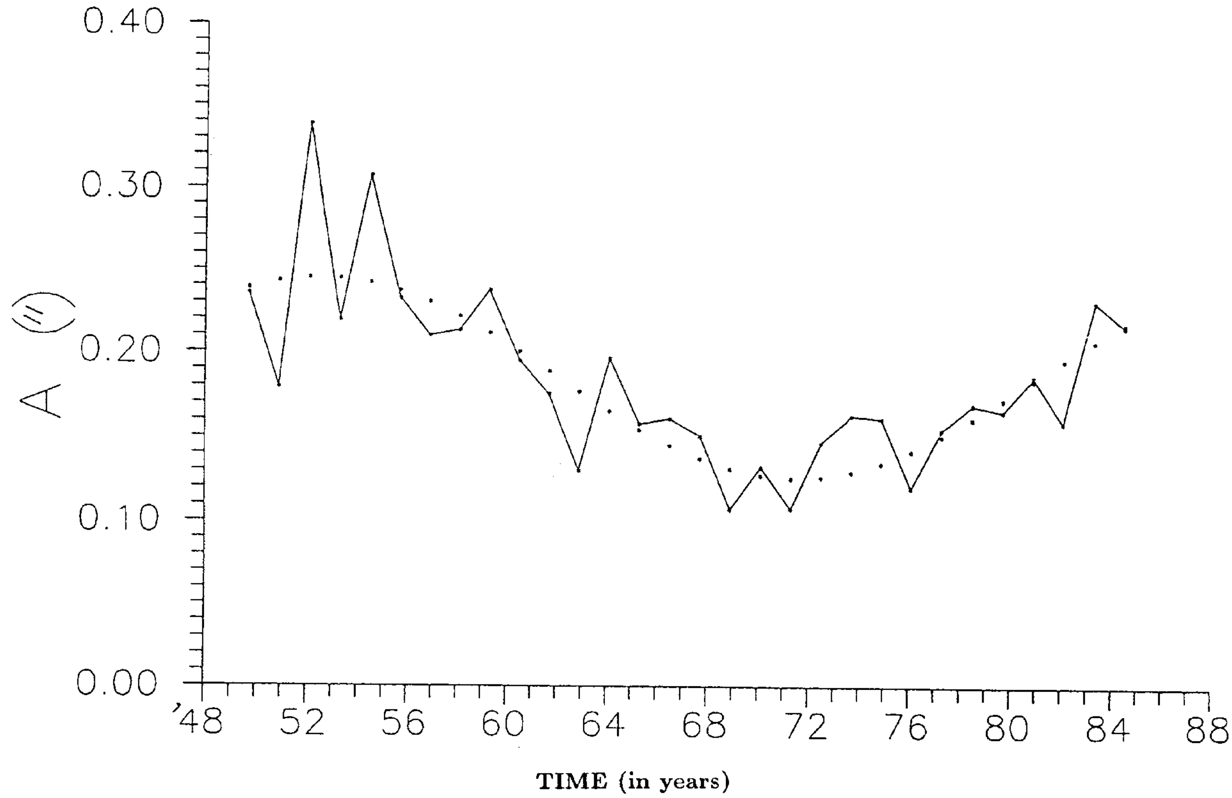

Fig. 3. *The independent values of the Chandler nutation amplitude.*

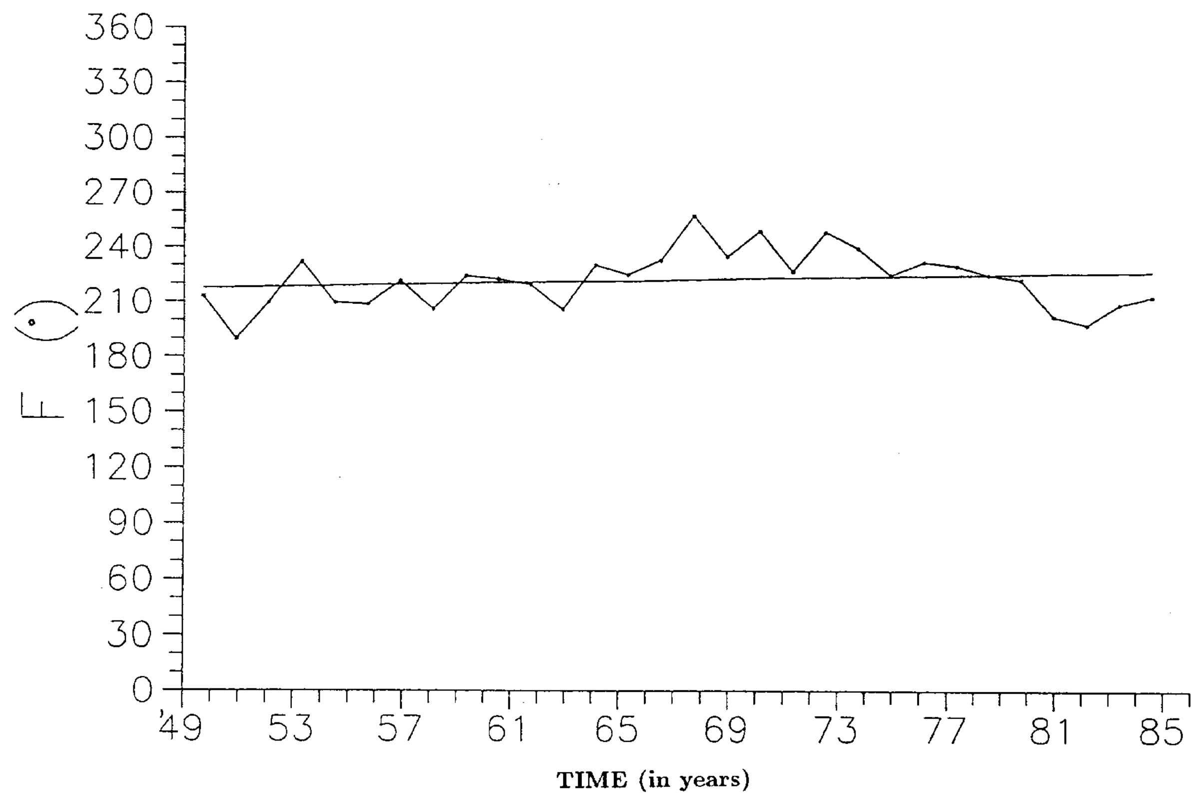

Fig. 4. *The independent values of the Chandler nutation phase.*

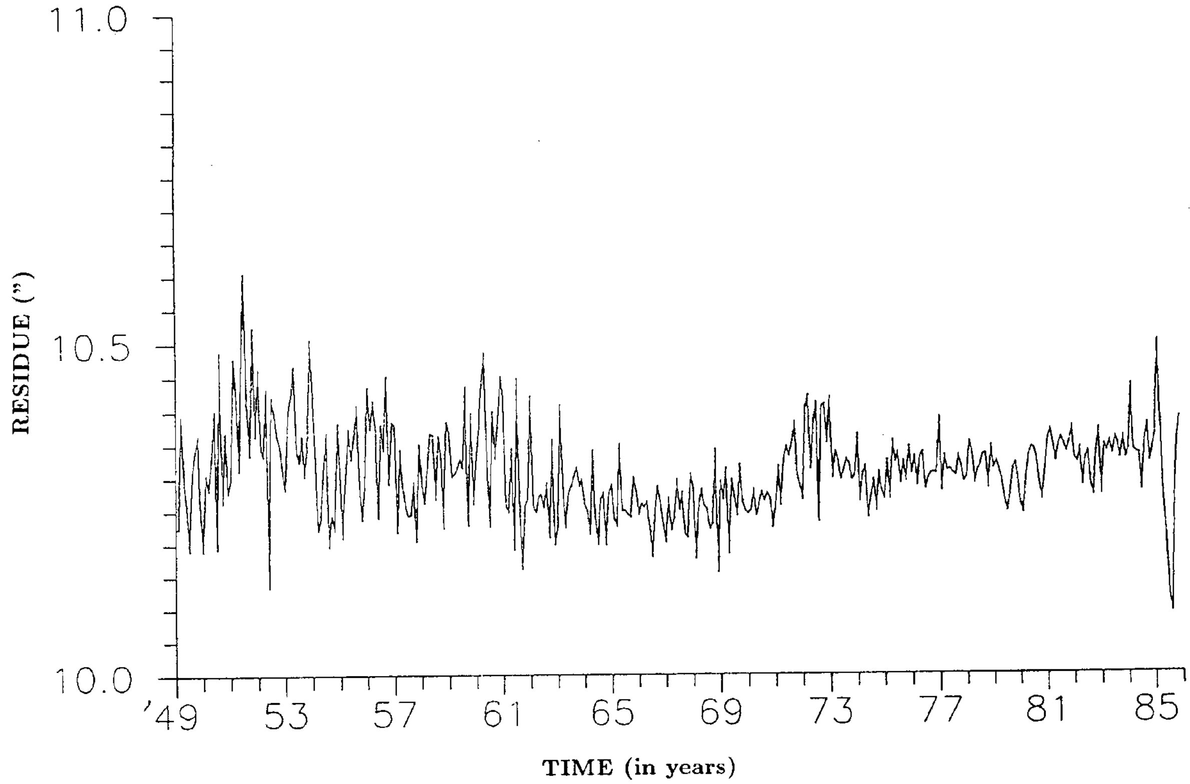

Fig. 5. *Residuals (BLZ data free of the linear, semiannual, annual and Chandler terms).*

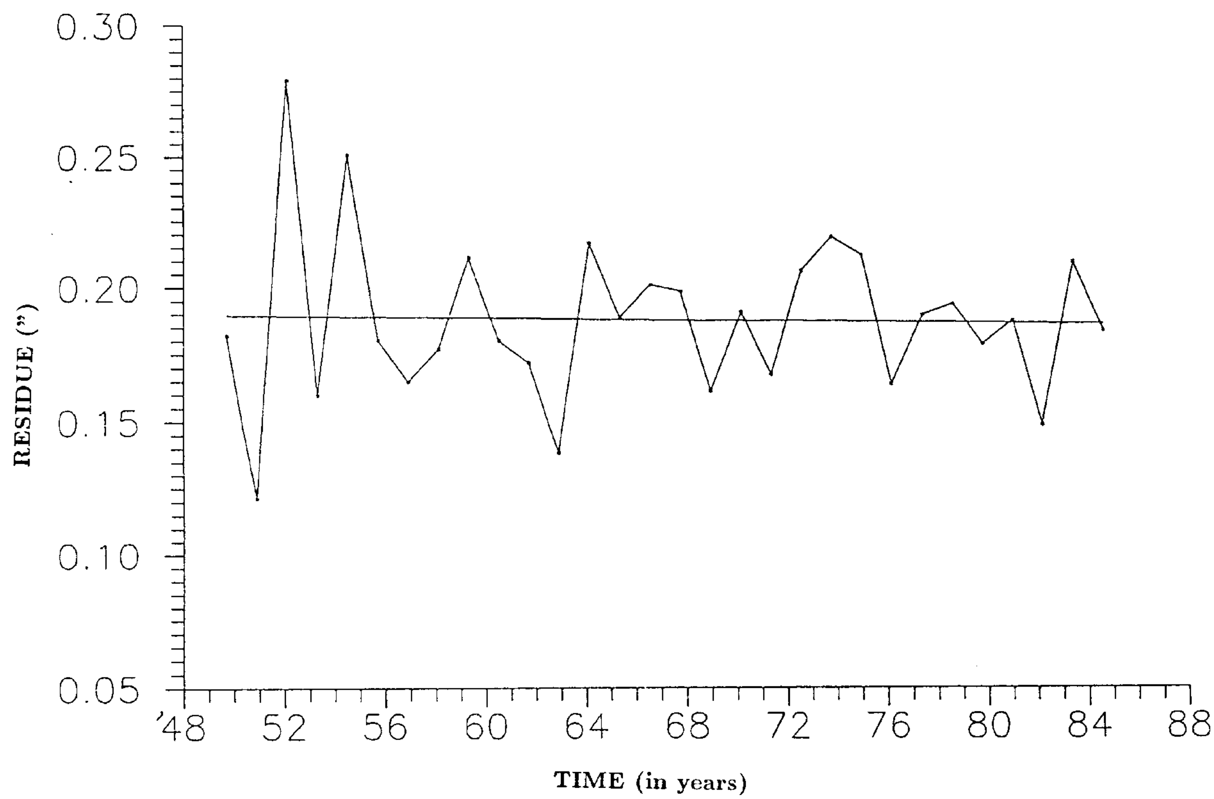

Fig. 6. *Residuals of the Chandler nutation amplitude.*

Table 3. The parameters (A_{aC}, P_{aC}, F_{aC} for the epoch $1900.^y0$) of the harmonic term which was present in the changes of the amplitude of the Chandler nutation, the values of coefficients (C(1), C(2), C(3), with their standard deviations) obtained by LSQ and the standard deviation (SD)

P_{aC}	C(1)	A_{aC}	F_{aC}	C(2)	C(3)	SD
$38.^y0$	$0\overset{''}{.}1878 \pm 0\overset{''}{.}0059$	$0\overset{''}{.}0597$	$137.^\circ7$	$0\overset{''}{.}0402 \pm 0\overset{''}{.}0086$	$-0\overset{''}{.}0442 \pm 0\overset{''}{.}0082$	$\pm 0\overset{''}{.}0324$

REFERENCES

Carter, W. E.: 1981, *J. Geophys. Res.*, **86**, 1653.

Djurković, P., Ševarlić, B., Brkić, Z.: 1951, *Publ. Obs. Astron. Belgrade,* **4**.

Damljanović, G.: 1994, *Bull. Astron. Belgrade*, **150**, 29.

Damljanović, G.: 1995, *Bull. Astron. Belgrade*, **152**, 71.

Damljanović, G., Pejović, N.: 1995, *Proc. of the Journées 1995, Système de référence spatio-temporels,* eds. N. Capitaine, B. Kolaczek, S. Debarbat, Warsaw, 131.

Guinot, B.: 1972, *Astron. Astrophys.,* **19**, 207.

Gaposchkin, E. M.: 1972, *Proc. of the IAU Symp. No. 48, Rotation of the Earth,* eds. Melchior P. and Yumi S., Reidel, Dordrecht, 19.

Guinot, B.: 1982, it Geophys. J. R. Astr. Soc., **71**, 295.

McCarthy, D. D.: 1972, *Proc. of the IAU Symp. No. 48, Rotation of the Earth,* Melchior P. and Yumi S. (eds.), Reidel, Dordrecht, 86.

Markowitz, W.: 1960, In *Methods and Techniques in Geophysics,* ed. Runcorn, S.K., Interscience, New York, 325.

Markowitz, W.: 1982, Polar motion for 1825–1981 and 1727–31 analysed by new methods, *Report to IAU Commissions 19 and 31,* Patras.

Melbourne, W. et al.: 1983, Project Merit Standards, USNO Circular, No. **167**.

Nastula, J. et al.: 1993, *Manuscripta Geodaetica 18,* 131.

Pejović, N.: 1985, *Publ. Dept. Astr. Beograd,* **13**, 31.

Rykhlova, L. V.: 1969, *Soviet Astr. A J*, **13**, 544.

Roeser, S., Bastian, U.: 1991, *Positions and Proper Motions (PPM) Star Catalogue,* Astron. Rechen-Institut, Heidelberg.

Ševarlić, B., Teleki, G.: 1960, *Bull. Obs. Astron. Belgrade,* **24**, No. 3/4, 19.

Vicente, R. O., Currie, R. G.: 1976, *Geophys. J. R. astr. Soc.,* **46**, 67.

Vondrák, J.: 1985, *Annales Geophys.,* **3**, 3, 351.

Vondrák, J.: 1988, *Proc. IAU Symp. 128 The Earth's Rotation and Reference Frames for Geodesy,* Babcock, A., Wilkins, G. (eds.), 359.

Vondrák, J., Ron, C.: 1995, *Proc. of the Journées 1995, Système de référence spatio–temporels,* eds. N. Capitaine, B. Kolaczek, S. Debarbat, Warsaw, 95.

Wilson, C. R., Vicente, R. O.: 1980, *Geophys. J. R. Astr. Soc.*, **62**, 605.

ЧЕНДЛЕРОВА НУТАЦИЈА У ПЕРИОДУ 1949 – 1985

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Оригинални научни рад

Рачунате су вредности амплитуде, периоде и фазе Чендлерове нутације из хомогене серије ширина Београда за период 1949 - 1985. Посматрања су рађена Талкотовом методом на зенит – телескопу ASKANIA (D=11 cm; F=128.7 cm).

Добијене вредности амплитуде Чендлерове нутације варирају са периодом око 38 година; минимум је био око 1971 а максимум око 1952. Овај резултат је у доброј сагласности са резултатима других аутора (Markowitz, 1960; Rykhlova, 1969; McCarthy, 1972; Vicente and Currie, 1976; Wilson and Vicente, 1980; Guinot, 1972, 1982; Nastula et al., 1993; Vondrák, 1985, итд.).

Период Чендлерове нутације је такође променљив. Дакле, потврђени су резултати које су предочили Carter (1981), Vondrák (1985), Пејовић (1985) и други аутори.