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Analysis of the Secular Variations of Longitudes of the Sun, Mercury and Venus from Optical Observations

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Abstract. About 240 000 optical observations of the Sun, Mercury and Venus, accumulated during the era of classical astrometry from Bradley up to our days, are incorporated to analyse the secular variation of the longitudes of innermost planets. A significant discrepancy between modern ephemerides and optical observations is discovered. The possible sources of discrepancy are discussed. The tidal acceleration of the Moon has been revised to conform the lunar theory with the ephemerides of the planets. The offset and residual rotation of Hipparcos-based system with respect to the dynamical equinox is determined. Interpretation of this rotation is given.

1. Observations and method of analysis

A mass of 244960 observations of the Sun, Mercury and Venus accumulated during historical period of astronomy from 1750 to 2000 have been incorporated.

In the transformation procedure a set of corrections were formed by direct comparison of standard star catalogue with ICRS-based catalogue rotated from J2000 to the respective epoch by use of modern precession constant and Hipparcos based proper motions. The systematic differences are interpolated onto observed positions of planets and applied. Other corrections account for differences in modern and historical astronomical constants. The N70E catalogue (Kolesnik 1997) rigidly rotated onto Hipparcos frame was used as a reference catalogue. Observations were compared with DE405 ephemeris. The series (ET−UT) by Stephenson & Morrison (1984) were applied before 1955. After 1955 ET is equal to TDT or TT and directly related to atomic time TAI.

The conditional equations for the Sun are the same as applied by Newcomb. For Mercury and Venus these are the same as given in Kolesnik (1995). The secular variation of corrections to the longitudes were determined separately from right ascension and declination residuals. In the conditional equations for right ascensions the equinox correction is omitted assuming that it will be absorbed in solution by corrections to the longitude of the Earth. Corrections to the longitudes were derived in relatively short bins, and evaluation of secular variations of longitudes was based on a set of stepwise individual solutions in bins. Corrections to the mean longitude of the Earth ΔL_0 were determined from right ascension and declination residuals of all objects, corrections to the mean

longitudes of Mercury and Venus ΔL result from residuals in right ascension only.

2. Results

In the 20th century longitude corrections derived from the Sun and both planets have quadratic trends nearly proportional to the respective mean motions. Their 2nd order approximations are presented in Table 1.

Table 1. 2nd order approximations of the trends in secular variations of the longitudes of the Earth ΔL_0, and Mercury and Venus ΔL in the 20th century. Index indicates from which kind of observations (right ascensions or declinations) longitude corrections are derived. $T = (t - 1960)/100$.

	T^0	T^1	T^2
Sun $(\Delta L_0)_\alpha$	$-0''.05 \pm 0''.01$	$-0''.28 \pm 0''.01$	$1''.42 \pm 0''.04$
Sun $(\Delta L_0)_\delta$	$-0''.28 \pm 0''.01$	$+0''.02 \pm 0''.02$	$1''.51 \pm 0''.10$
Mercury $(\Delta L)_\alpha$	$-0''.80 \pm 0''.03$	$-0''.89 \pm 0''.10$	$4''.51 \pm 0''.41$
Venus $(\Delta L)_\delta$	$-0''.20 \pm 0''.01$	$-0''.30 \pm 0''.03$	$2''.78 \pm 0''.15$

Since

$$\Delta E = (\Delta L_0)_\delta - (\Delta L_0)_\alpha \quad \text{and} \quad \Delta \dot{E} = (\Delta \dot{L}_0)_\delta - (\Delta \dot{L}_0)_\alpha \tag{1}$$

then at the epoch J2000.0

$$\Delta E = -0''.10 \pm 0''.01 \quad \text{and} \quad \Delta \dot{E} = +0''.30 \pm 0''.03/\text{cy}. \tag{2}$$

The most peculiar feature of trends in the 19th and 18th centuries is a sharp ramification of corrections ΔL_0 inferred from right ascension and declination residuals. This cannot be explained only by the transition to moving-wire micrometer which causes maximum $0''.5$ discontinuity. Large systematic errors of observations in declination are suspected. The negative deviations of corrections to the mean longitudes of planets in the early epoch are nearly proportional to the respective mean motions.

3. Interpretation of the secular trends in longitude corrections

The dependence of the trends on mean motions give evidence that some acceleration factor affects results of comparison. As the possible sources of quadratic trends two hypotheses are discussed: 1) an additional acceleration not accounted for in equations of motion, 2) inadequate model of the actually adopted differences between the Ephemeris and Universal time.

1) The Scale Expanding Cosmos theory by Masreliez (2000) predicts accelerations of the planets in the Solar system according to relation $\dot{n}/n = 3/H$ (H is the Hubble constant). For Mercury, Venus and the Earth these are $5''.7$, $2''.3$, $1''.4$, i.e. of the same order as the actually detected quadratic terms presented

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in Table 1. Estimation of the analog of Jones–Clemence empirical correction to account for tidal acceleration necessary to conform ET−UT differences with the hypothesis of additional acceleration of the Sun and planets has resulted in the following expressions: $-3''.18 - 51''.96\tau + 9''.07\tau^2$ from declinations, and $-8''.41 - 39''.17\tau + 5''.72\tau^2$ from right ascensions. This leads to the model of the Earth's rotation which implies the absence of the tidal deceleration of the Earth resulting in radical confrontation with the theoretical models of Earth–Moon tidal interaction.

2) Revision of the Jones–Clemence empirical correction to Brown's purely gravitational theory from observations in the interval 1750–2000 has given an expression $\Delta L_t = (-9''.56 - 27''.32\tau - 8''.42\tau^2)$ resulting from observations of Mercury and Venus in right ascension, meantime as declination observations yield values of the tidal acceleration of the Moon close to the presently adopted.

4. Interpretation of the equinox drift

Residual rotation of proper motion systems of principal compiled catalogues of the 19th and 20th centuries was investigated by their direct comparison with Hipparcos motions. The results are given in Table 2.

Table 2. Estimation of the residual rotation Δe and correction to adopted precession constant (Δp_1) of historical compiled catalogues from their direct comparison with Hipparcos proper motions in the equatorial zone. All estimates are in arcsec/cy.

	N2	NFK	PGC	FK3
Δe	-0.17 ± 0.53	-0.07 ± 0.43	1.33 ± 0.41	0.87 ± 0.22
$(\Delta p_1)_\alpha$	-0.79 ± 0.59	-0.24 ± 0.47	1.36 ± 0.45	0.79 ± 0.24
$(\Delta p_1)_\delta$	$+1.13 \pm 0.17$	$+1.11 \pm 0.16$	1.11 ± 0.16	1.33 ± 0.07
	FK4	N30	FK5	N70E
Δe	1.10 ± 0.16	1.33 ± 0.18	-0.28 ± 0.12	-0.21 ± 0.11
$(\Delta p_1)_\alpha$	1.11 ± 0.18	1.40 ± 0.20	-0.20 ± 0.14	-0.12 ± 0.12
$(\Delta p_1)_\delta$	1.17 ± 0.05	1.06 ± 0.06	-0.03 ± 0.05	-0.03 ± 0.05

The direct comparison with Hipparcos of the catalogues constructed before the FK5 indicate $(\Delta p_1)_\delta$ correction to Newcomb's precession close to Fricke's correction $1''.11$/cy. As for the FK5 and N70E they give nearly zero values. This result is in evident conflict with an independent determination of the precession constant from LLR and VLBI (Charlot et al. 1995). If LLR and VLBI results are to be believed, a conclusion follows: in the global sense Hipparcos system is not absolutely independent from the input catalogue (which is FK5-based). Otherwise LLR and VLBI determinations are to be revised. As a result the systems of Hipparcos and N70E (after rigid rotation) should not be considered as rotation free, the systematic difference $\Delta\delta_\alpha$ in proper motions due to the IAU 1976 precession constant which is by $0''.3$/cy larger its actual value can affect results of secular variation of the longitude of the Sun and produce the linear

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trend absolutely equivalent to the value $0''.3$/cy just obtained. If we accept this interpretation, the linear trend should be considered rather as correction to Fricke's precession $\Delta p_1 = -0''.30$/cy than the drift of the origin of right ascensions with respect to dynamical equinox.

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