CORRECTIONS TO THE LUNISOLAR PRECESSION AND THE MOTION OF THE EQUINOX FROM PROPER MOTIONS OF CEPHEIDS

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Abstract. Corrections to Newcomb's lunisolar precession and to motion of the equinox are evaluated from proper motions of 77 Cepheids, employing recently determined values of their distances. Results are diverse, depending on the weighting method. If the effect of the cosmic dispersion is neglected and ω_0 is imposed to be 25 km/s/kpc, then $\Delta p_1 = 1''1 \pm 0''2$ and $\Delta\lambda' + \Delta e = 1''0 \pm 0''1$ per century in the FK4 system.

1. Procedure

Corrections to Newcomb's lunisolar precession and to the motion of the equinox together with the galactic rotation velocity are evaluated from proper motions of Cepheids. The same procedure as that of Weaver and Morgan (1956) is applied. Basic equations are:

$$\begin{aligned}
&- \omega_0 \cos b \cos\phi + \kappa\, \Delta n \cos\delta\,(\cot\varepsilon + \sin\alpha\tan\delta) - \kappa\,(\Delta\lambda' + \Delta e)\cos\delta \\
&\quad = \kappa\,(15\mu_\alpha\cos\delta) - \frac{U_0}{r}\sin\alpha + \frac{V_0}{r}\cos\alpha \\
&\quad - R_0\,\Delta\omega(R)\left(\frac{\cos l}{r\cos b} - \frac{1}{R_0}\right)\cos b\cos\phi - R_0\,\Delta\omega(R)\sin l\,\frac{\sin b}{r}\sin\phi
\end{aligned} \tag{1}$$

$$\begin{aligned}
&- \omega_0 \cos b \sin\phi + \kappa\,\Delta n\cos\alpha \\
&\quad = \kappa\mu_\delta - \frac{U_0}{r}\cos\alpha\sin\delta - \frac{V_0}{r}\sin\alpha\sin\delta + \frac{W_0}{r}\cos\delta \\
&\quad - R_0\,\Delta\omega(R)\left(\frac{\cos l}{r\cos b} - \frac{1}{R_0}\right)\cos b\sin\phi + R_0\,\Delta\omega(R)\sin l\,\frac{\sin b}{r}\cos\phi\,.
\end{aligned} \tag{2}$$

Symbols have their customary meanings: ω, angular velocity of the galactic rotation; $\Delta p_1 = \Delta n/\sin\varepsilon$; correction to the lunisolar precession; $\Delta\lambda'$, correction to the planetary precession; Δe, correction to motion of the equinox; U_0, V_0, W_0, the solar motion components; ϕ, parallactic angle; R, distance from the galactic centre; r, distance from the Sun. Suffix 0 refers to the position of the Sun and $\Delta\omega = \omega - \omega_0$. R_0 is taken as 10 kpc.

In the right-hand side of each equation above, U_0, V_0, W_0 and $R_0\,\Delta\omega(R)$ are obtained

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from distances and radial velocities of Cepheids. Then, ω_0 and Δn are obtained from (2) and are substituted into (1) to evaluate $(\Delta\lambda' + \Delta e)$.

In the formation of normal equations two kinds of weights are assigned to the individual proper motions, i.e.

$$w_1 = \frac{w_r}{\sigma_{\mu_i}^2 + \left(\frac{\sigma_t}{\kappa r}\right)^2}$$

and

$$w_2 = \frac{w_r}{\sigma_{\mu_i}^2}.$$

Here, w_r is taken as 2 or 1 according to the reliability of the distance determination. For σ_{μ_i} the probable error of the proper motion for each star is employed. As for the effect of the cosmic dispersion, σ_t is taken as 10 km/s tentatively.

TABLE I

System	$R_0\Delta\omega(R)$	All available radial velocities		Radial velocities of cepheids in $-2 < R - R_0 < +2.5$ kpc		Weaver and Morgan (1956)
	Weight	With cosmic dispersion	Without cosmic dispersion	With cosmic dispersion	Without cosmic dispersion	
				km/s/kpc		
	ω_0	17.3	26.2	19.3	28.6	23.2
	p.e.	± 3.8	± 2.7	± 3.8	± 2.7	± 3.4
				per century		
N30	Δp_1	0″.66	1″.13	0″.71	1″.18	0″.76
	p.e.	± 0.28	± 0.21	± 0.28	± 0.22	± 0.26
				per century		
	$\Delta\lambda' + \Delta e$	± 0″.63	± 0″.93	± 0″.65	± 0″.96	± 0″.78
	p.e.	± 0.10	± 0.07	± 0.10	± 0.07	± 0.07
				km/s/kpc		
	ω_0	18.9	29.0	20.8	31.4	
	p.e.	± 3.6	± 2.6	± 3.6	± 2.6	
				per century		
FK4	Δp_1	0″.55	1″.33	0″.60	1″.38	
	p.e.	± 0.27	± 0.21	± 0.27	± 0.21	
				per century		
	$\Delta\lambda' + \Delta e$	0″.75	1″.05	0″.78	1″.04	
	p.e.	± 0.08	± 0.07	± 0.08	± 0.07	

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2. Data

Distance and radial velocity data are mostly taken from the catalogue of Fernie and Hube (1968) with a few additions from the table of Kraft and Schmidt (1963). Crampton and Fernie's (1969) values of the solar motion are directly adopted. The relation between $R_0 \Delta\omega$ and R is empirically determined from (i) all available radial velocities of 133 Cepheids and (ii) radial velocities of 125 Cepheids which lie in the range $-2 < R - R_0 < +2.5$ kpc, since the Cepheids whose proper motion data are available are distributed in this range.

Proper motion data of 77 Cepheids are taken from Weaver and Morgan's (1956) material on the N30 system. For reducing these values to the FK4 system, systematic differences by Brosche *et al.* (1964) are applied for each star.

3. Result

The solutions of the least squares method are given in Table I. Since most of the

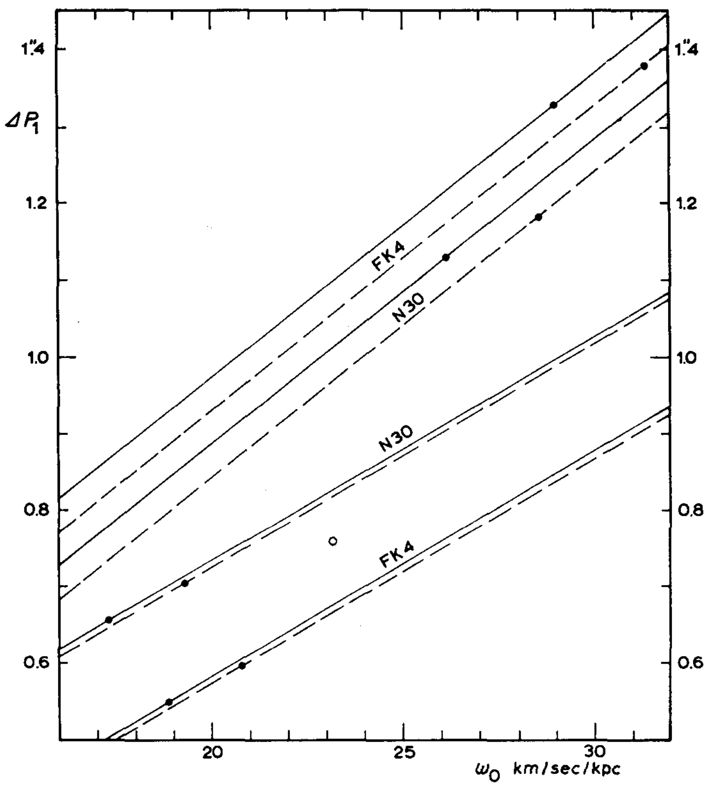

Fig. 1. Δp_1 against ω_0. Upper 2 sets: weight without cosmic dispersion. Lower 2 sets: weight with cosmic dispersion. $R_0 \Delta\omega$ from radial velocities of: ——— all available Cepheids; -------- nearby Cepheids; ● least squares solutions; ○ Weaver and Morgan (1956).

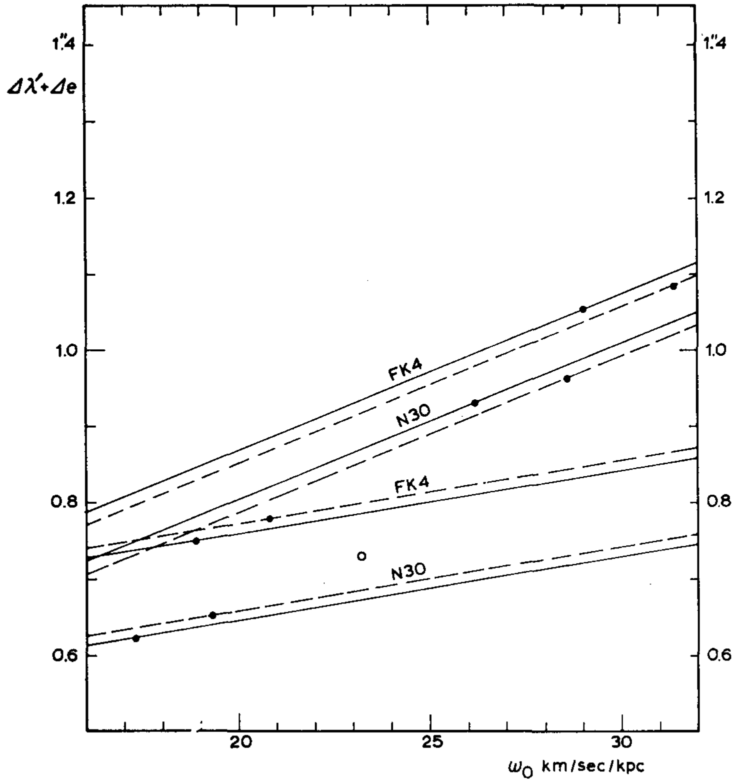

Fig. 2. $\Delta\lambda' + \Delta e$ against ω_0. Upper 2 sets: weight without cosmic dispersion. Lower 2 sets: weight with cosmic dispersion. $R_0 \Delta\omega$ from radial velocities of: ——— all available Cepheids; -------- nearby Cepheids; ● least squares solutions; ○ Weaver and Morgan (1956).

values of ω_0 seem to be rather unlikely, Δn and $(\Delta\lambda' + \Delta e)$ are evaluated by assigning various values of ω_0. The results are shown in Figures 1 and 2. Their probable errors are almost the same as those of the least squares solutions in Table I, respectively. In Figures 1 and 2, dots show the least squares solutions and circles the values by Weaver and Morgan (1956).

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