# ON THE NONGRAVITATIONAL EFFECTS IN THE COMET ENCKE MOTION

Yu.V. Batrakov and Yu.A. Chernetenko
Institute for Theoretical Astronomy
Naberezhnaya Kutuzova, 10
191187 Leningrad
USSR

ABSTRACT. A factor depending on geomagnetic index was introduced in the B. Marsden's formula for the nongravitational force. The orbit of the comet Encke covering seven apparitions (1895-1914) obtained with this modified formula shows better residuals than that obtained with the non-modified one.

For some comets (P/Encke, P/Giacobini-Zinner and others) the nongravitational forces are subjected to irregular changes. Whipple and Sekanina (1979) have explained such changes by the precession of the spin axis of the oblate comet nucleus. However, some other causes for such changes cannot be excluded.

Backlund (1910) was the first to suggest the possibility of a connection between the changes of the mean motion of P/Encke and the solar activity. In Figure 1 Wolf numbers $W$ (Loginov, 1976) and the mean daily motion changes $\Delta n$ obtained by Dubjago's method (Dubjago, 1956) are plotted. The discontinuity of the graph of $\Delta n$ is explained by the absence of observations at the comet's return in 1944. The values of $\Delta n$ and their errors are given in Table I. The greatest value of $\Delta n$ corresponds to 1898, if the two observations which were made at this apparition can be relied upon.

The comparison of the $W$ and $\Delta n$ graphs shows that the greatest $\Delta n$ correspond to the fallings or to the minima of the solar 11-year cycle. It is known that at the fallings of $W$ the high speed recurrent solar wind streams are developed and become numerous. It is natural to suppose that these streams can influence the comet motion due to changes of the outflow of matter from the comet's nucleus. This supposition comes to mind when one observes the correlation of the outbursts of the brightness of some comets and the high speed solar wind streams (Andrienko et



*A. Carusi and G. B. Valsecchi (eds.), Dynamics of Comets: Their Origin and Evolution, 381–385.*

TABLE I

The changes of the mean daily motion of P/Encke

| Year | $\Delta n$ (1°10⁻⁶/day) | Year | $\Delta n$ (1°10⁻⁶/day) |
|---|---|---|---|
| 1891 | +16.9 ± 0.2 | 1931 | +10.5 ± 0.2 |
| 1895 | +14.6 ± 0.2 | 1934 | + 6.7 ± 0.2 |
| 1898 | +17.3 ± 0.3 | 1937 | + 7.3 ± 1.5 |
| 1901 | +11.9 ± 0.3 | 1951 | + 5.3 ± 0.1 |
| 1904 | +12.2 ± 0.2 | 1954 | + 5.5 ± 0.1 |
| 1908 | +12.3 ± 0.2 | 1957 | + 3.7 ± 0.1 |
| 1911 | +12.8 ± 0.4 | 1961 | + 3.1 ± 0.1 |
| 1914 | +10.5 ± 0.4 | 1964 | + 4.3 ± 0.2 |
| 1918 | +10.7 ± 0.2 | 1967 | + 3.0 ± 0.2 |
| 1921 | +10.6 ± 0.1 | 1970 | + 2.6 ± 0.1 |
| 1924 | + 9.1 ± 0.1 | 1973 | + 3.1 ± 0.1 |
| 1928 | + 8.2 ± 0.1 | 1977 | + 2.5 ± 0.1 |

al.,1981). The high speed streams influence the terrestrial magnetic field. So, it is natural to take one of the geomagnetic indexes as the measure of the intensity of the corpuscular stream as well as the measure of the change of the nongravitational forces which can be caused by this stream. As such a measure we have taken the daily values of the $aa$ index given by Sutorik and Cruickshank (1977) and obtained from the $A_p$ index. We use only those values of the $aa$ index which correspond to the corpuscular recurrent streams picked by these authors.

For the transverse component of the nongravitational acceleration we took the expression

$$F_2 = (A_2 + A_2'\tau)(1 + \chi aa) g(r), \qquad (1)$$

where $\tau$ is the time in years from the initial epoch 1900.0, $g(r)$ is the variation of the nongravitational acceleration with heliocentric distance $r$ ( Marsden et al., 1973). $aa$ is the geomagnetic index, the values of which range from 0 to 5. It deserves mentioning that geomagnetic indexes must be taken for the time moments at which the corpuscular streams reach the comet. Let $t+\Delta t$ be the time moment at which the corpuscular stream touches the Earth and some geomagnetic disturbance is registered by observer and, in the same way, $t$ be the time moment when the stream touches the comet. For $\Delta t$ we have the following formula (Dobrovol'skij, 1964)

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$$\Delta t = \frac{\Delta\lambda}{\bar{\omega}} + \frac{\Delta r}{V}, \qquad (2)$$

where $\Delta\lambda$ is the difference of the heliographic longitudes of the comet and of the Earth, $\Delta r$ is the difference of the heliocentric distances of the comet and of the Earth, $\bar{\omega}$ is the angular rotation rate of the Sun, $V$ is the speed of the corpuscular stream. We used the values $\bar{\omega}$ =13°4/day, $V$ =700km/s. For the radial and normal components of the nongravitational acceleration we took the usual form

$$F_1 = A_1\, g(r)\,, \qquad (3)$$
$$F_3 = A_3\, g(r)\,,$$

because the attempts to determine the secular coefficients $A_1'$, $A_3'$ and parameters in $F_1$ and $F_3$ analogous to $\chi$ have failed.

The seven apparitions of P/Encke (1895-1914) were linked taking into account the $aa$ geomagnetic index (orbit (A)) and without this index (orbit (B)). The orbits were obtained by the Everhart's numerical integration method (Everhart, 1974) with the 1 day step. This step was chousen because the $aa$ index values were given at 1 day intervals. In all 109 observations of the comet were used for the orbit computation. The results for the nongravitational parameters $A_1$, $A_2$, $A_3$, $A_2'$, $\chi$ are summarised in Table II and the orbital elements are:

Epoch 1901 Sept. 13.0 E.T.

| Orbit (A) | | Orbit (B) | |
|---|---|---|---|
| $T$ = 1901 Sept. 15.9618 E.T. | | $T$ = 1901 Sept. 15.9614 E.T | |
| $\omega$ = 183°9886 | 1950.0 | $\omega$ = 183°9855 | 1950.0 |
| $\Omega$ = 335.4932 | | $\Omega$ = 335.4955 | |
| $i$ = 12.8993 | | $i$ = 12.8987 | |
| $e$ = 0.846 047 | | $e$ = 0.846 046 | |
| $q$ = 0.341 612 a.u. | | $q$ = 0.341 620 a.u. | |

The mean residual for the orbit (A) is smaller than that one for the orbit (B). In this sense the orbit (A) is better than the orbit (B). The comparison of $\sigma_{(A)}$ and $\sigma_{(B)}$ according to the Fisher's criterium showed the real significance of the $\chi$ parameter in the case. However the orbit (A) is not completely satisfactory, because there are small systematic trends in the 1895 and 1904 residuals and the maximum 1898 residual amounts to 12". Besides, the mean residual for 1918 observations not included into the orbit determination for the orbit (A) is greater than that for the orbit (B). Further investigations are certainly

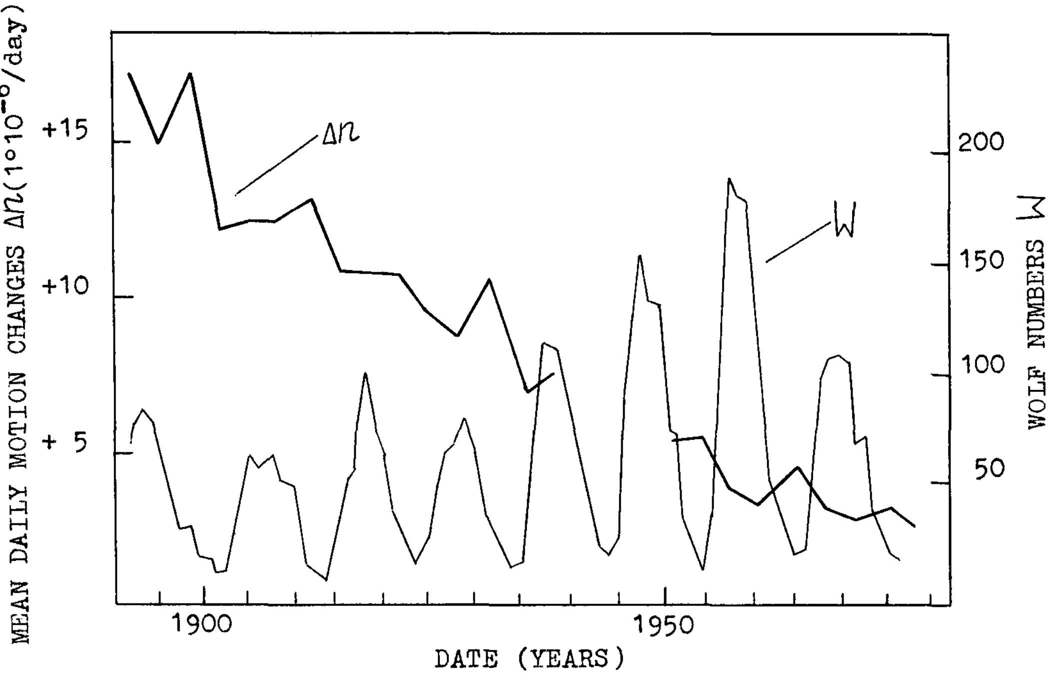


Figure 1. Mean daily motion changes $\Delta n$ and Wolf numbers W during 1891 - 1977.

needed. If the parameter $\chi$ makes a real effect it means that the interaction of the high speed solar wind stream with the comet results in the rapid change of the nongravitational forces up to 2-4 times of their nominal value.

TABLE II

Nongravitational parameters for P/Encke

| Orbit | Mean residual 1895-1914 | $A_1 10^8$ | $A_2 10^8$ | $A_3 10^8$ | $A_2' 10^{11}$ | $\chi$ | Mean residual 1891 | 1918 |
|---|---|---|---|---|---|---|---|---|
| (A) | 3".7 | -0.23 ± 2 | -0.01846 ± 13 | -0.01 ± 12 | +0.197 ± 14 | +2.5 ± 2 | 16" | 9" |
| (B) | 4.5 | -0.28 ± 2 | -0.01922 ± 8 | +0.37 ± 13 | +0.219 ± 14 | - | 28 | 7 |

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The results presented in Table II allow us to draw the conclusion that the inclusion of the geomagnetic index into Marsden's nongravitational force formula makes a non-negligible reduction of the residuals of P/Encke.

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