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# The western drift of poles of principal equatorial axes of inertia of the Earth and Mars

J.M. Ferrandiz J.M. (1), Yu.V. Barkin (1, 2)

(1) University of Alicante, Alicante, Spain/jm.ferrandiz@ua.es
(2) Sternberg Astronomical Institute, Moscow, Russia/ barkin@inbox.ru/Fax:+07-095-9328841

**Resume.** It is shown, that principal equatorial axes of ellipsoid of inertia of the Earth rotate with angular velocity $\dot{\lambda}_0 = -(7"2 \pm 1"3)$ 1/cy in the western direction in the Greenwich terrestrial system of coordinates of the given epoch. The similar western rotation has been established for principal equatorial axes of inertia of Mars with angular velocity about $\approx 18"$ 1/cy. Both phenomena are caused by assumed directed secular redistributions of planetary masses.

**1 Introduction.** The geometry of masses of a planet (the Earth, Mars etc.) changes from time owing to tidal and non-tidal deformations, forced redistributions of air and oceanic masses and others reasons. It means, that position of the centre of mass of such planet and orientation of its principal central axes of inertia varies in time. The motion of poles of the principal axes of inertia of the Earth owing to its tidal deformations (luni-solar and rotary) has been in details investigated earlier [1], [2]. Rather significant displacements of poles of equatorial axes of inertia mainly in a plane of equator have been revealed. By virtue of features of tidal deformations of the Earth displacements of poles of axes of inertia have periodic character. In the given work attempt to estimate possible secular changes in position of these poles for the first time is undertaken. The basis of the study makes the discovery of the directed redistribution of fluid masses of the Earth from a southern hemisphere in northern, characterized by geocentric axis OP directed to a geographical point 70ºN, 104º E [3]. On a basis of simple point model of the directed redistribution of masses in the specified work velocities of secular changes of coefficients of the second, third and fourth harmonics of a geopotential, including tesseral harmonics, in first have been estimated. In particular values of velocities of secular changes:

$$\dot{C}_{22} = (-0.11 \pm 0.02) \cdot 10^{-11} \text{ 1/yr},$$

$$\dot{S}_{22} = (-0.06 \pm 0.01) \cdot 10^{-11} \text{ 1/yr}$$

have been obtained. These characteristics determine position of poles of principal equatorial axes of inertia of the Earth on its surfaces and their secular displacements. There are arguments to believe, that the similar directed redistribution of fluid masses exists on Mars, on what in particular specify observed appreciable tendencies of secular changes of coefficients of the second and third zonal harmonics of its gravitational potential [4]. In the given work the secular western trends of displacements of poles of principal equatorial axes of inertia for considered planets have been determined.

**2 Orientation of the principal equatorial axes of inertia.** Let $Oxyz$ and $Ox_py_pz_p$ are two central Cartesian systems of coordinates. Axes of system of coordinates $Ox_py_pz_p$ are orientated on the principal axes of inertia of a planet. We shall concentrate attention to displacement of poles of principal equatorial axes of inertia, believing, that axes $Oz$ and $Oz_p$ coincide with a polar axis of inertia of the Earth. The principal equatorial axis $Ox_p$ appropriate to the least moment of inertia of a planet $A_p$, is revolved in a coordinate plane $Oxy$ on some angle $\lambda$. Other two principal axes $Oy_p$ and $Oz_p$ also correspond to a middle $B_p$ and greatest $C_p$ of the principal moments of inertia ( $C_p > B_p > A_p$ ). We shall designate through $C_{nk}$, $S_{nk}$ and $C_{nk}^p$, $S_{nk}^p$ Stoks constants of the planet gravitational field calculated in the basic planetary system of coordinates $Oxyz$ and in the principal axes of inertia $Ox_py_pz_p$. At the made assumptions of a choice of systems of coordinates between these constants are obtained simple relations:

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$$C_{nk} = C^p_{nk}\cos(k\lambda) - S^p_{nk}\sin(k\lambda),$$
$$S_{nk} = C^p_{nk}\sin(k\lambda) + S^p_{nk}\cos(k\lambda) \qquad (1)$$
$$C^p_{nk} = C_{nk}\cos(k\lambda) + S_{nk}\sin(k\lambda),$$
$$S^p_{nk} = -C_{nk}\sin(k\lambda) + S_{nk}\cos(k\lambda). \qquad (2)$$

The value of an angle $\lambda$ can be determined unequivocally from conditions $S^p_{22} = 0$, $C^p_{22} > 0$. From equality (2), we obtain: $\tan(2\lambda) = S_{22}/C_{22}$.

**The Earth.** For the Earth it is obtained, that the pole of the principal equatorial axis of inertia $Ox_p$ in present epoch has a longitude $\lambda = \lambda_0 = -14^0 7404\,\mathrm{E}$ (Fig. 1). Accordingly the pole of other equatorial axis $Oy_p$ corresponding to the middle principal moment of inertia, is characterized by a longitude $75^0 2596\,E$. **Mars.** We shall accept for coefficients of potential of Mars $C_{22}$ and $S_{22}$ values: $C_{22} = -54.632194 \cdot 10^{-6}$ and $S_{22} = 31.587092 \cdot 10^{-6}$ [5]. In result it is obtained, that the pole of the principal equatorial axis of inertia $Ox_p$ of Mars has a longitude $\lambda = \lambda_0 = 105^0 0178\,W$. Accordingly the pole of other equatorial axis corresponds to middle principal moment of inertia and it is position is characterized by a longitude $15^0 0178\,W$ (Fig. 2).

**3 The western drift of poles of principal equatorial axes of inertia of the Earth and Mars.** We shall consider a planet as a body with changeable geometry of masses. Then all coefficients (1), (2) and an angle $\lambda$ will be functions of time and on a basis (1), (2) it is uneasy to obtain similar relations between derivatives on time from the specified parameters. In particular for derivative of angle $\lambda$ we obtain following expression:

$$\dot{\lambda} = \left(C_{22}\dot{S}_{22} - S_{22}\dot{C}_{22}\right) \Big/ \left[2\left(C^2_{22} + S^2_{22}\right)\right].$$

Under this formula and for values of the appropriate coefficients of a geopotential $C_{22}$, $S_{22}$ and abovementioned velocities of their secular variations, we obtain angular velocity of rotation of the principal equatorial axes of inertia for the Earth in present epoch: $\dot{\lambda} = -(7"2 \pm 1"3)\,1/\mathrm{cy}$.

For coefficients of potential of Mars $C_{22}$ and $S_{22}$ we adopt abovementioned values, and for their secular variations we shall take advantage of values obtained on the basis of point model of redistribution of fluid masses of changing Mars [4]: $\dot{C}_{22} = -7.3 \cdot 10^{-11}\,1/\mathrm{cy}$, $\dot{S}_{22} = 2.1 \cdot 10^{-11}\,1/\mathrm{cy}$. In result it is obtained the approached value of velocity of possible western drift of poles of the principal equatorial axes of inertia of Mars: $\dot{\lambda} \approx -17"9\,1/\mathrm{cy}$.

On Fig. 1 positions of the centers of lithosphere plates (epicenters of the centers of mass) near to inclined equator of lithosphere [6] are marked: AF - the African plate; AR - the Arabian plate; EC - East-Chinese; PH – Philippine plate; MA - Marianne plate; PA - the Pacific plate; ES - Easter; NA - Nasca; SA - the Southern America plate. On equator the positions of poles of equatorial axes of inertia $X_p$ and $Y_p$, appropriate to the smallest ($A_p$) and middle ($B_p$) from the principal moments of inertia of the Earth are specified.

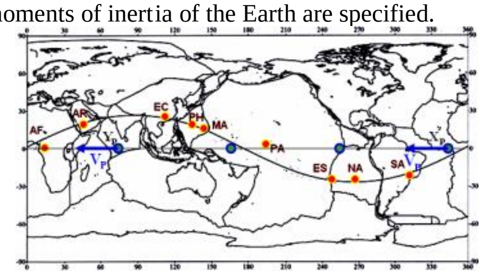


Fig. 1. Western drifts of the poles of equatorial axes of inertia of the Earth with velocity $\mathbf{V_P = -(7"2 \pm 1"3)\,1/cy}$.

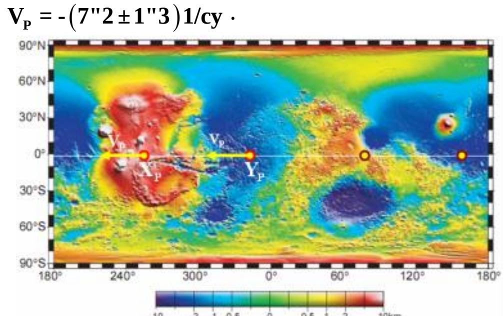


Fig. 2. Possible western drift with velocity $\mathbf{V_P \approx -17"9\,1/cy}$ and positions of poles of equatorial axes of inertia of Mars: $X_p$ (for minimal from principal moment of inertia $A_p$) and $Y_p$ (for middle from principal moments of inertia of Mars

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$B_p$) mentioned on the topography map with the first harmonic of shape removed [7].

## References

[1] Vondrak J. (1984) Bull. Astron. Inst. Czechosl. Vol. 35, N2, pp. 92 – 104.

[2] Barkin Yu.V. and Ferrandiz J.M. (2000) Astron. and Astrophys. Trans., Vol. 18, Issue 4 (2000), pp. 605-620.

[3] Barkin Yu.V. (2001) Proc. of Int. Conf. «AstroKazan-2001». Astronomy and geodesy in new millennium (24-29 September 2001), Kazan State University: Publisher «DAS», pp. 73-79.

[4] Barkin Yu.V. (2009) EGU General Assembly (Vienna, Austria, 19-24 April 2009). Geophysical Research Abstracts, Vol. 11, 2009, abstract # EGU2009-1618.

[5] Konopliv A.S., Yoder C.F., Standish E.M., Yuan D.-N. and Sjogren W.L. (2006) Icarus, V. 182, pp. 23-50.

[6] Barkin Yu.V. (1994) Int. Conf. "Planetary Problems of the Earth's Studies" (Kazan, Tatrstan, 15-18 November, 1994). Thesis of Reports. Kazan. p. 1.

[7] Smith, D.E., M.T. Zuber et al. (1999) Science, *284*, 1495-1503.