EPSC Abstracts
Vol. 6, EPSC-DPS2011-1840, 2011
EPSC-DPS Joint Meeting 2011

Rotation and physical libration of Phobos

A. Gusev
Kazan Federal University, Kazan, Russia. (Alexander.Gusev@mail.ru / Fax: +7- 843-2924448)

Abstract

One of the most interesting characteristics of a Phobos are a physical librations. The Phobos has the big amplitude physical librations among known synchronously rotating a moons of planets of Solar system. In the report will be presented the review of Phobos physical librations. We give the basic parameters of the Phobos's rotation and some scientific problems to be solved with the help of the scientific instruments installed on the spacecraft "Phobos-Grunt". Measurement of the Phobos's libration parameters will allow to study features of rotation of this insignificant body for definition of its internal structure and of its dissipation evolution in future.

1. Introduction

Phobos has the wrong form which can be approximately approximated an ellipsoid which sizes for a Phobos make 13,00 x 11,39 x 9,07 km, the major axis of an ellipsoid of the moon is directed to Mars, and it are rotated synchronously round Mars. A moon orbit practically circular with radius-vector 9.375 km. The orbital plane of the moon is close to an equatorial plane of Mars and is inclined under an angle of 24^0 to an ecliptic plane. A cycle time of a Phobos round of Mars is 7 h. 39 min. Phobos is located well inside the corotation radius of 5.9 Martian radii, and Deimos is just outside this radius. The tides raised on Mars thus cause Phobos to be spiraling toward Mars and Deimos to be spiraling away.

2. Status of Phobos librations

Yoder (1982) has calculated the dissipation in the Phobos accounting for both the tidal dissipation caused by the eccentric orbit and that caused by the forced libration of the very asymmetric satellite. This libration has an amplitude of 3.9° (Duxbury & Callahan 1981, Yoder 1982) and causes twice the tidal dissipation in Phobos that would occur if Phobos were nearly axially symmetric in the same eccentric orbit. Both the dissipation in Phobos and that in Mars from tides raised by Phobos damp the eccentricity. Even though Phobos is in a synchronous orbit around Mars, a free libration can be observed due to the varying angular speeds along an elliptical orbit. Phobos pronounced non-spherical body interacts with the gravitational field of Mars causing a large forced libration, a superimposed sinusoidal oscillation. Principal cause of it is that fact, that period of a free libration of this moon (~10 hour.) it is close to period of orbit rotation (~7,7 hour.). On exact measurements of amplitude of a libration it is possible to determine a Phobos moment of inertia that is important for mass distribution researches (interior structure) of Phobos. The free libration period could be better constrained by an estimate of dynamical ellipticity from a more accurate determination of the shape of Phobos along with an accurate measure of its physical libration amplitude.

3. Physical libration of Phobos.

On average Phobos shows always the same face to Mars, with its axis of greatest inertia X directed towards the planet. Because the smallest moments of inertia of Phobos A and B are not equal, the moon is subjected to a restoring torque so that Phobos can theoretically freely oscillate around the direction of Mars (free physical libration in longitude). Really, because the orbit of Phobos around Mars is eccentric, the axis of greatest inertia of Phobos is forced to oscillate around the equilibrium position (forced physical libration in longitude). There are two latitudinal normal modes: Chandler-like free wobble and a free nutation of its spin axis relative to its mean position (Borderies & Yoder ,1990). Probably the free modes are small in amplitude to be detected by ranging to a lander. However, for the Moon these free modes have enough great values of amplitudes (3″ x 8″). For Phobos the forced librations in longitude may reach 100 to 300 m in rotational displacement and will be easily detectable with a 10 m ranging system of "Phobos-Grunt" mission. For describing of longitudinal physical libration of

Phobos the parameter dynamical ellipticities $\alpha = (C-B)/A$; $\beta = (C-A)/B$; $\gamma = (B-A)/C$, where A<B<C are three normalized principal moments of inertia (MOI), is very important. The predicted amplitude of physical libration (APL) is $\tau = 2e/[1-(1/3\gamma)]$ (Peale,1977), where e is the orbit eccentricity (0.015 for Phobos). Given the shape and the uniform density, MOI can be computed by direct integration. However, a simpler and more enlightening alternative is to use the gravitational coefficients: $B-A = 2\sqrt{5}\, C_{22}/\sqrt{3}$ and $C = (T-2\sqrt{5}\, C_{20})/3$, where $T = A+B+C$, in the principal axes. A numerical integration yields T = 1.258 (compared with 1.2 for a uniform spheres, which is the lower bound for a homogeneous body). Given the values of C_{20} and C_{22} it has been found A = 0.355, B = 0.414, C = 0.489 (compared with 0.4 for a uniform sphere). Substituting of MOI into γ, it has been estimated γ = 0.12 and APL $\tau = 0.97^0$ (Chao & Rubincam, 1989), within the rather large standard deviation of the observed value 0.78 ± 0.4^0 (Duxbury,1989). It must be pointed out that τ is rather sensitive to the density distribution. A more accurate observation of a longitudinal and latitudinal physical librations amplitudes will provide useful constrains on the Phobos density profile.

Semi-numerical series for Phobos physical libration (Chapront-Touze, 1990) was computed by using three recent sets of Phobos inertial parameters. The importance of second order for arguments whose frequencies to the free libration frequencies is emphazed. The largest periodic terms induced by Phobos' figure, by Deimos and by Mars' nutation amount respectively to about 800, 50, 30 meters, in rectangular coordinates. They are below the present level of accuracy of observations but must be taken into account in a precise theory in view of future space mission.

The last dynamical model of Phobos librations (Jacobson, 2010, AJ) included the figure acceleration due to a librating of Phobos; it determined the amplitude of the forced libration. Jacobson also took into account the secular acceleration of Phobos due to the tide that it raises on Mars and estimated the Martian tidal quality factor *Q*. In modeling the acceleration induced by the Phobos's figure, Jacobson assume that Phobos is in synchronous rotation with its pole normal to its orbit plane and its prime meridian librating about the sub-Mars direction (i.e., a libration in longitude); the libration in latitude is ignored. JPL planetary ephemeris DE421 (Folkner et al. 2008) provides the positions and *GM*s of the Sun, Moon, and planets. The Love number, gravity field, and orientation of Mars are from Konopliv et al. (2006). The Phobos quadrupole field gravitational harmonics (J_2 and C_{22}) in the figure acceleration are from Borderies &Yoder (1990)

For comparison purposes, Jacobson (2010) includes the libration amplitude observed optically from *Viking 1* images by Duxbury & Callahan (1989) and the amplitude and periapsis rate from the analytical work of Borderies & Yoder (1990). Numerically integrated orbits take into account the effects of the Phobos quadrupole field, Phobos longitude libration, and the tide raised on Mars by Phobos. The author obtained estimates of the amplitude of the Phobos-forced libration angle and of the Martian tidal quality factor. The amplitude of physical librations (APL) is 1.03 ± 0.22^0. For comparisons, by Chao & Rubincam (1989) for the APL gave 0.97^0; by Duxbury & Callahan (1989) the APL has 0.81 ± 0.5^0 and for Borderies & Yoder (1990) the APL is 1.19^0.

Subsequent studies of the residuals of the control points of Phobos by Willner et al, (2010) indicates: 1) moments of inertia along the principal axes are A = 0.3615, B = 0.4265, C = 0.5024 and the amplitude of 1.2° for the force libration. The observed amplitude differs slightly from the amplitude of 0.8 +/- 0.3° observed and computed by (Duxbury,1991), but is in well agreement with the amplitude of 1.2° derived from a topographic model (Borderies & Yoder,1990) .

4. Conclusion and Perspectives.

Essential improvements in our knowledge of Phobos orbit, shape, rotation, librations, and interior geochemical composion are expected, when a high-precision images and tracking data from spacecraft, captured in Phobos orbit, become possible (Phobos – Grunt project, 2011y). The importance of high-precision orbit determination for investigations in radio-science and planetary research, for example, such as physical librations, is well-known (Gusev, 2008). The interest in high-precision ILR to Mars is motivated by: i) studies of Martian interior – via the range's sensitivity to Mars precession, nutations, polar motion; ii) planetary science – via improvement of basic dynamical model parameters for the solar system; iii) tests of relativistic gravitation (Turyshev, 2010).