FCN–period dependence on dynamic characteristics of a lunar core

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Two modes in a polar oscillation are obtained when a free rotation of the two–layer Moon was studied:

$$\frac{1}{P_{CW}} = 2\Omega\frac{A}{A_m}\sqrt{\alpha\beta} \sim \frac{1}{74yr}$$
$$\frac{1}{P_{FCN}} = -\Omega\frac{A}{2A_m}\left(\frac{C_c - A_c}{A_c} + (\frac{C_c - B_c}{B_c}\right)\sqrt{\alpha\beta} \sim \frac{1}{144yr}$$

The numerical values of the periods were obtained on the assumption, that $R_c = 220$ km and that the dynamic figure of the core is similar to the dynamic figure of the mantle.

Assuming the uniform density distribution for the core $\rho_c = 7\frac{g}{cm^3}$ and mantle $\rho_m = 3.3\frac{g}{cm^3}$, the modelling of the FCN-period in dependence on the core radius and on its dynamical figure has been carried out.

Changes of the model structure will be reflected mainly in different values of $\frac{A}{A_m}$ and of dynamical flattenings α, β, γ. Taking into account the slow rotation of the Moon and the smallness of its core, we do not consider the deformation of the liquid core by the rotation and propose that dynamical figure of the core is like to the figure of the mantle, i.e. of the total Moon. We have calculated the variation of the FCN period as a function of the core radius $\frac{1}{P_{FCN}} \sim R^5_{core}$ (in a first order relative to dynamical flattening of the core). The FCN period is slightly changed from 52785 days for $R = 220$ km to 52243 days for $R = 600$ km, i.e. the FCN-period is decreased by 542 days as the radius is increased by 2.7 times. Such great value of the FCN period for the Moon (about the 144 years) in comparison with the Earth (435 days — Defraigne et al., 1994) and with the Mars (231–283 days — Van Hoolst, 2000) is explained by the slow lunar rotation ($\Omega_{lunar} = \frac{1rev}{28days}$, where $\Omega_{Earth} = \frac{1rev}{day}$, $\Omega_{Mars} \sim \frac{1rev}{day}$) and by the smallness of the lunar core ellipticity. The relative small decreasing of the FCN (1%) in dependence on the core radius can be attributed mainly to the small relative core of the Moon, and hence core mass. Its mass is 1.4%–3.5% of the Moon's mass (Konopliv, 1998). This results to the value of $\frac{A}{A_m}$ almost equal to unity ($\frac{A}{A_m} = 1.000065$). For the Earth $\frac{A}{A_m} = 1.12$ and for the Mars $\frac{A}{A_m} = 1.03$ (Van Hoolst, 2000).

Geometrical figure of the core was modelled by the formulas:

$$\alpha_1 = \frac{C-A}{A} = \frac{\beta(1+\gamma)}{1-\gamma\beta} \sim \frac{a-c}{R_c} \quad \alpha_2 = \frac{C-B}{B} = \frac{\beta-\gamma}{1+\gamma} \sim \frac{b-c}{R_c}$$

The calculation shows that the FCN-period is significantly decreased and ranges up to the observed values (90 years) for the certain geometrical parameters of the core. But this geometry corresponds to the non–physical values of the dynamical flattening γ and β: in this case the core will have the form of the highly extended or highly flattened ellipsoid. Because of this, the most probable value of the FCN–period falls in the range 130–160 years. Therewith, the ellipticity increases when the core radius increases too. The analysis carried out shows, that the geometry of the core is determined by the values: $(a-c) \sim 200-300$ m, $(b-c) \sim 150-250$ m. For comparison, the LLR data give $(a-c) = 140$ m (Dickey et al, 1994). With these magnitudes the dynamical figure of the core most closely resembles to that of the mantle.

These theoretical simulations may be tested only by the practical measurements of the lunar core. The scientific objectives of a Moon-orbiting mission SELENE (Selenological and Engineering Explorer) (Kawano et al, 2001) are to study the origin and evolution of the Moon, in–situ measurement of the lunar environment, mapping of lunar topography and surface composition, measurement of the gravity and magnetic fields. The mission can obtain the improved value of the lunar moment of inertia with 0.1% accuracy, that can put a constraint on the density of the lunar core with 15% uncertainty provided that the mean crustal density with 3% accuracy and the radii of the crust–mantle and the core–mantle boundaries will be known. This complex of the measurements will allow to determine the lunar core parameters more reliable.

References

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