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Spectrum of free oscillations of the Moon

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Abstract

Despite the recent reanalyses of limited Apollo-era seismic data by two research teams [1, 2] with searching of wave phases, reflected from core, there remain questions about seismic velocity variations in the planetary interior and structure of the planetary core. The measurements of the periods of free oscillations, if they are excited, could provide additional constraints for interior structure models. We investigate the possibility of studying the Moon' interiors with free oscillations method.

1. Introduction

Since the Moon's outer shells are very inhomogeneous, a global, spherically symmetric model of its interior structure is difficult to construct by using only seismic body-wave data. Since the planet has finite dimensions and is bounded by a free surface, the study of the free oscillations is based on the theory of vibration of an elastic sphere. The planet reacts to a quake (or an impact) by vibrating as a whole, vibrations being the sum of an infinite number of modes that correspond to a set of frequencies. The free oscillations are divided into two types: torsional oscillations, whose displacement vector is perpendicular to the radius of a sphere - ${}_nT_l$; and spheroidal oscillations, whose displacement vector has components in both the radial and azimuthal direction – ${}_nS_l$ The fundamental modes sound to those depth in the interiors where their displacements ≥ 0.3 [3]. The important feature of free oscillations is that they concentrate towards the surface with increasing the degree l . Therefore different regions of interiors are sounded by different frequency intervals. Interpretation of data on free oscillations does not require knowledge of the time or location of the source; thus, data from a single station are sufficient.

2. Interior structure models

The models fit both geodetic (lunar mass, polar moment of inertia, and Love numbers) and seismological (body wave arrivals measured by Apollo network) data.

MW model [1]: Apollo lunar seismograms were reanalyzed using array processing methods to search for the presence of reflected and converted seismic energy from the core. The results suggest the presence of a solid inner (240 km) and fluid outer (330 km, 8 g/cm^3) core, overlain by a partially molten boundary layer (about 150 km thick).

MG model [2]: The Very Preliminary Reference Moon model was constructed and the core radius was estimated by detecting core reflected S wave arrivals from waveform stacking methods. The core radius is 380±40 km and the average core mass density is 5.2±1.0 g/cm^3.

3. Spectrum of free oscillations

The effect of the inner core rigidity on the structure of oscillations is shown in Figure 1. The model MW has the 'core oscillation' - FC. As the rigidity of the inner core increases, its period (42.96 min at μ=0) decreases up to 6.94 min at μ=4.23x10^{11} dyne/cm^2, and its amplitude covers the mantle. At μ=0.5x10^{11} dyne/cm^2 it looks like a regular oscillation R with a period of about 16 min. Besides the regular oscillation and its overtones O1,O2, and so on , there are 'inner core' oscillations, with the energy localised in the core. The curves are not crossed, they change a slope and a type of oscillation.

As the lunar core is rather small, the period difference of oscillations for the regular oscillation and the first overtone, for the models with inner core and without it, is very small, about 0.1 and 0.7%, respectively. It increases with the overtone number, and reachs 5-10% for the second and third overtones (Figure 2). The rigidity of the inner core influences mostly the periods of core oscillations, but their amplutudes are very small at the surface.

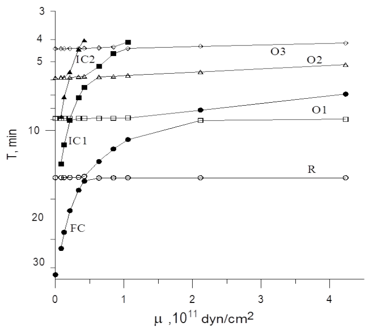

Figure 1. Spheroidal oscillations, l=2. Period T (in min) as a function of shear modulus of the inner core (for the model in [1] $\mu = 4.23 \times 10^{11}$ dyn/cm^2) . R – relular, FC – basic core and IC – inner core oscillations; O – overtones of regular oscillations.

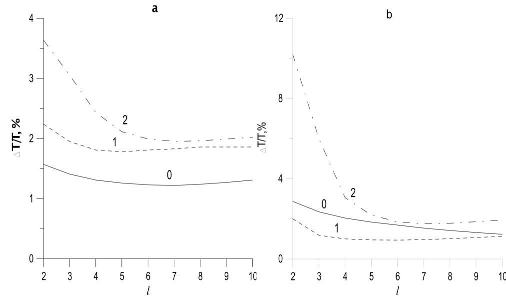

Figure 2. Relative period difference ΔT/T(%) as a function of the oscillation number for fundamental mode (solid line) and two first overtones (dashed and dot-dashed lines) of torsional (a) and spheroidal oscillations (b) for models from [1] and [2].

4. Conclusion

Free oscillations, if they are excited, are indeed particularly attractive to probe beneath the surface of the Moon into its deep interiors. The spectrum of torsional modes $_nT_l$ would allow noticeable progress to be made in constructing a global model of the Moon's interior structure (up to about 500 - 700 km depth), as it was shown in [4], that the torsional modes with l > 5-7 can be recorded with current instruments. The seismic events on the Moon detected so far are too weak to excite free oscillations that could be recorded [4, 5]. The accuracy of seismometers has been improved [6], and the application of new methods for processing seismic data let us hope to identify harmonics with smaller amplitudes in the future.

Acknowledgements

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References

[1] Weber, R.C., Lin, P., Garnero, E.J., Williams, Q., Lognonné, Seismic detection of the lunar core, Science, Vol. 331, pp.309-395, 2011.

[2] Garsia, R.F., Gagnepain-Beyneix, J.G., Chevrot, S., Lognonné, Very preliminary reference Moon Model PEPI, Vol. 188, pp. 96-113, 2011.

[3] Zharkov V.N. Physics of the Earth and planetary interiors, 1986.

[4] Gudkova, T., Zharkov, V.N. On excitation of free oscillations of the Moon, Astronomy Letters, Vol. 10, pp. 658-670, 2001.

[5] Gudkova T., Lognoné, P., Gagnepain-Beyneix J. Large impacts detected by the Apollo seismometers: impactor mass and source cutoff frequency estimations Icarus, Vol. 211, pp. 1049-1065, 2011.

[6] Lognoné, P., Johnson, C. 2007, Planetary Seismology, in: Schubert, G., (Ed.), Treatise on Geophysics, Vol. 10, Elsevier, pp.69-122.