# SEISMOLOGY OF MARS.

**SEISMOLOGY OF MARS.** T. V. Gudkova and V. N. Zharkov, Schmidt Institute of Physics of the Earth, Russian Academy of sciences, 123495, Moscow, B.Gruzinskaya, 10, gudkova@ifz.ru

**Introduction:** On the basis of the various interior structure models of Mars we have calculated free oscillation periods and seismic travel times. Our goal is to investigate the difference between the various available models, particularly in their seismic response. The most recent interior structure models are based on geodetic information: the moment of inertia and the Love number $k_2$. The moment of inertia of Mars is known from the measurements of the precession rate of the planet by the Pathfinder mission and, then, by MGS mission. The Love number $k_2$ was obtained from gravity analysis of orbiting spacecrafts: 0.152±0.009 [1] and 0.10-0.13 [2]. The latter value allows the presence of perovskite bearing lower mantle The seismology could answer the crutial question on the value of the radius of the planetary core.

The level of tectonic and geological activity on Mars suggests that it should be seismically more active than the Moon but less active than the Earth. Most theoretical models of the seismic activity on Mars, which are based on the thermoelastic cooling of the lithosphere [3, 4, 5, 6], predict a total of 10-100 quakes per year with seismic moments larger than $10^{22}$ dyne cm. The quakes are related to the cooling of the planet, which accumulates stresses that are then released by quakes. This type of activity is the minimum expected activity on Mars. Taking into account the fact that one can see giant faults on the surface of Mars (within Tharsis region, Tempe Terra, Valles Marineris, Olimpus region), it is not possible apriori to rule out large seismic events.

**Interior structure models:** Among the interior structure models fitting the currently available geophysical and geochemical knowledge [7, 8] we select 7 of them for this study. The models differ by the crust thickness (50-100 km) and the density of the crust (the average density of the crust varies from 3200 to 2700 kg/m$^3$), and the core radius (1580-1770 km).

For the calculations of the free oscillation periods and travel-times we also consider: 1) the model A of [9] (the core radius 1468 km; the density of 110-km thick crust is 2810 kg/m$^3$), this model was used by Knapmeyer et al. [10] for their study; 2) the model by Okal and Anderson [11] (the core radius 1694 km, the density of 50-km thick crust is 2700 kg/m$^3$).

**Free oscillations:** The periods of fundamental modes of spheroidal and torsional oscillations with the degree $l$ =2-6 are quite sensitive to the core parameters. The period values increase practically linearly with the increase of the planetary

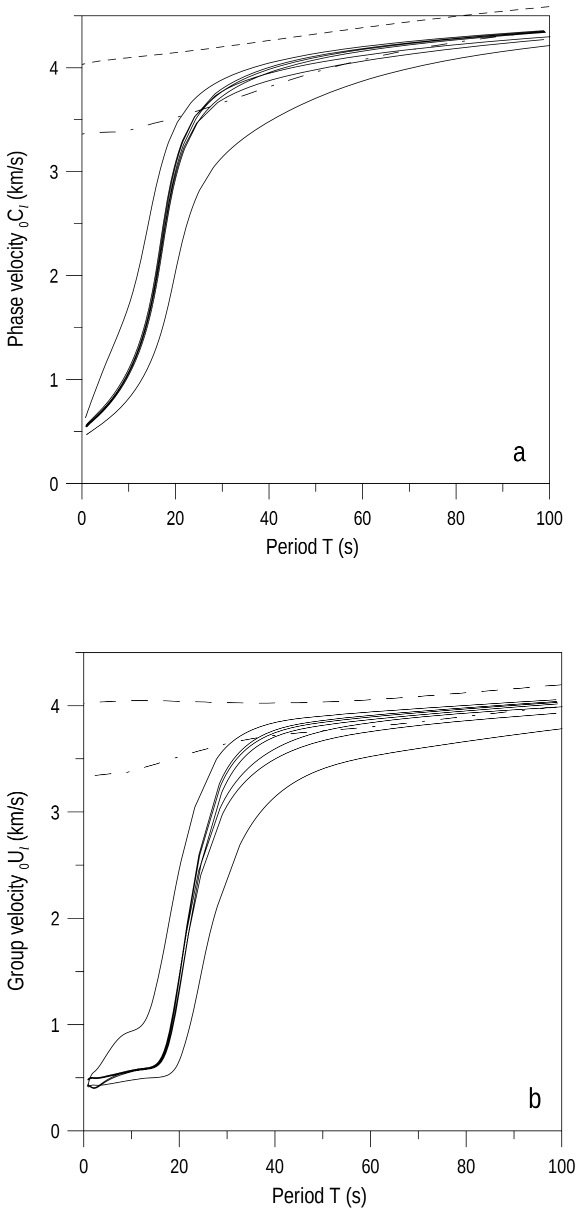


Fig. 1. Phase velocities $_0C_l$ (a) and group velocities $_0U_l$ (b) for the fundamental mode of Love waves as a function of period T for different interior structure models (solid lines – models of [7,8], dashed line – model A of [9], dot-dashed line – model of [11].

core radius. A change of the core radius by 1% provides a change of the period by 1.5%. Along with calculating the spectrum of free oscillations we have calculated the dispersion curves for phase and group velocities. It is seen from fig. 1, that dispersion curves for models with different crust thickness and density differ in the range of periods up to 40 sec. The behavior of the dispersion curves for interior structure models [7,8] differ substantially from those curves for the models of [9] and [11], which have a rather constant phase velocity, itself resulting in a smooth group velocity. The dispersion curves can be used to solve problem of determining the structure of the crust and the upper mantle.

If there is a registration of free oscillations, it is important to know down to what depth the normal modes could sound the planetary interiors. The torsional modes with $\lambda \geq 3$ (if a marsquake with $M_0=10^{25}$ dyne cm occurs), with $\lambda \geq 6$ ($M_0=10^{24}$ dyne cm), and with $\lambda \geq 12$ ($M_0=10^{23}$ dyne cm) could be detected by currently available instruments. The torsional modes with $\lambda \geq 3$, 6 and 12 can sound the Martian interiors down to 1600, 1100 and 700 km, respectively [12]. The displacement amplitude for the overtones is smaller than that for the fundamental modes. The spheroidal modes with only $\lambda \geq 17$ ($M_0=10^{25}$ dyne cm) could sound the outer layers of Mars down to 700-800 km [13]. For a marsquake with a higher seismic moment ($10^{26}$ dyne cm) the spheroidal modes with $\lambda \geq 6$ could be detected (sounding the outer layers down to 2000 km. These results are in agreement with the results obtained by Lognonné et al. [14], who concluded that normal mode detection would be clearly successful for a $10^{25}$ dyne cm seismic moment marsquake and $10^{-9} ms^{-2}Hz^{-1/2}$ noise level and the seismic moment may be reduced to $10^{24}$ dyne cm for a noise level of $10^{-10} ms^{-2}Hz^{-1/2}$ .

**Travel-time calculations**: Travel times P, PKP, PcP, S, SKS, ScS waves for the considered models were calculated using the code developed by Knapmeyer [15]. The source was located on the surface and at the depth of 300 km. Figure 3 shows the difference in travel-time curves as function of epicentral distance between a trial model M7_3 [7, 8] and .the model A of [9]. We see that the difference are up to 40 s for P and PcP , and up to 100 s for S and ScS arrivels. PcP and ScS, phases reflected from the core, could provide a strong constraint on the core's radius. For diagnostic purposes, the core phases PKP and SKS are the most promising phases in Martian seismology. The difference between models are about 300-350 s.

**Conclusion:** In this abstract we examine what kind of future seismic measurements could yield answers to questions concerning the interiors of Mars. We would like once more to emphasize the importance of the information on normal mode frequencies, in order to determine the very deep structure of Mars, as the seismic information from only one seismic instrument will be able.

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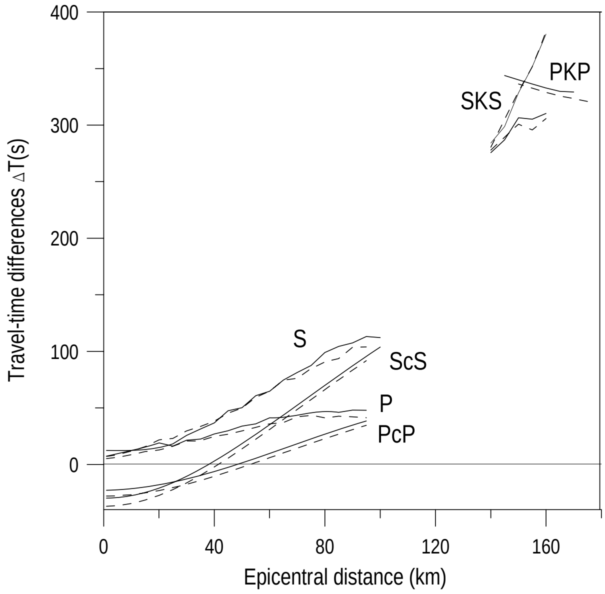


Fig. 2. Travel times P, PKP, PcP, S, SKS, ScS waves difference between a trial model M7_3 [7, 8] and the model A of [9] for the source on the surface (solid line) and at the depth of 300 km (dashed line)..

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