EPSC Abstracts,
Vol. 4, EPSC2009-42, 2009
European Planetary Science Congress,

Seismic properties of Martian interior structure models

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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 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 [1, 2, 3, 4], predict a total of 10-100 quakes per year with seismic moments larger than 10^{22} dyne cm. 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 to rule out large seismic events.

Interior structure models

Among the interior structure models fitting the currently available geophysical and geochemical knowledge [5, 6] 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 R_c (1580-1770 km). We also consider: 1) the model A of [7] (R_c=1468 km; the density of 110-km thick crust is 2810 kg/m^3), this model was used in [8] for the study of seismic phase amplitude decay and event detection rates; 2) the model by Okal and Anderson [9] (R_c=1694 km, the density of 50-km thick crust is 2700 kg/m^3).

Free oscillations

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 behaviour of the dispersion curves for interior structure models of [5,6] differs substantially from the behaviour of the curves for the models of [7, 9], 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 $\ell \geq 3$ (if a marsquake with $M_0=10^{25}$ dyne cm occurs), with $\ell \geq 6$ ($M_0=10^{24}$), and with $\ell \geq 12$ ($M_0=10^{23}$) could be detected. The torsional modes with $\ell \geq 3$, 6 and 12 can sound the Martian interiors down to 1600, 1100 and 700 km, respectively [10]. The spheroidal modes with only $\ell \geq 17$ ($M_0=10^{25}$) could sound the outer layers of Mars down to 700-800 km [11]. For a marsquake with a higher seismic moment (10^{26}) the spheroidal modes with $\ell \geq 6$ could be detected (sounding the outer layers down to 2000 km). These results are in agreement with the results obtained by Lognonné et al. [12].

Travel-time calculations

Travel times P, PKP, PcP, S, SKS, ScS waves for the considered models were calculated using the code developed in [13]. The source was located on the surface and at the depth of 300 km. Figure 2 shows the difference in travel-time curves as function of epicentral distance between a trial model M7_3 [5, 6] and the model A of [7]. We see that the difference is 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

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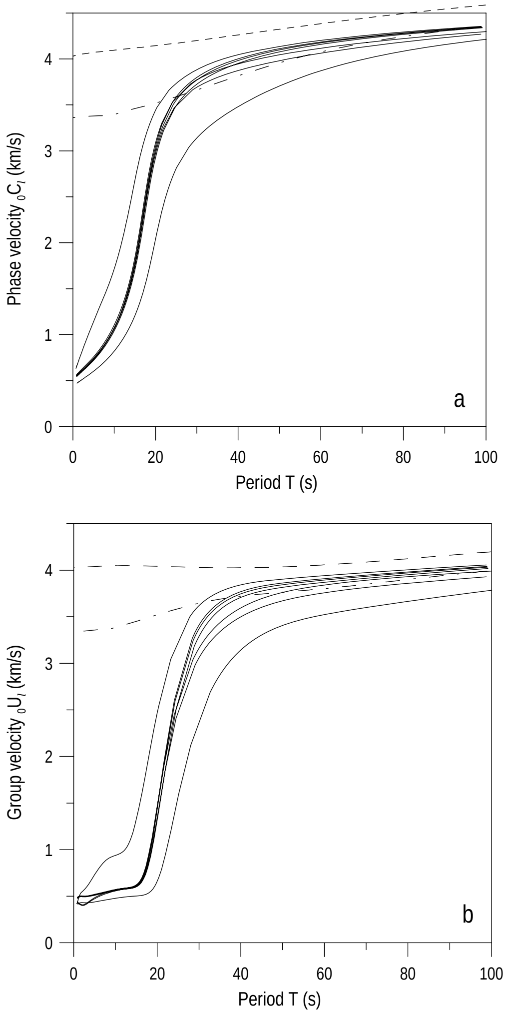

Figure 1: Phase velocities ${}_0C_l$ (a) and group velocities ${}_0U_l$ (b) for the fundamental mode of Love waves as a function of period T for different interior structure models (solid lines – models of [5,6], dashed line – model A of [7], dot-dashed line – model of [9].

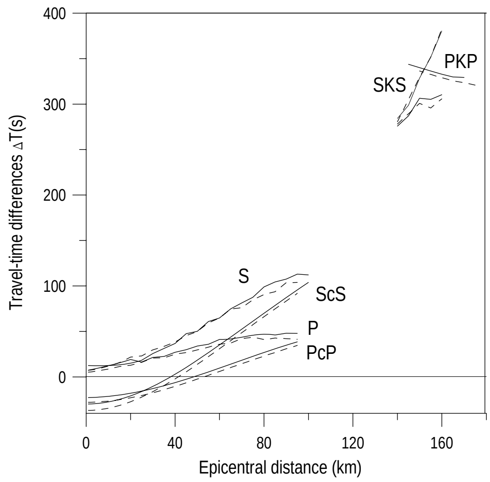

Figure 2: Travel times P, PKP, PcP, S, SKS, ScS waves difference between a trial model M7_3 [5, 6] and the model A of [7] for the source on the surface (solid line) and at the depth of 300 km (dashed line).

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.

Acknowledgments. The study was supported by the Russian Foundation for Basic Research (project no. 07-05-00178 and project no. 09-02-00128).

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