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What we can learn about interiors of Mars with "MISS"

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Abstract

Interior structure models of Mars are based on geochemical knowledge, experimental data on the behavior of material at high pressure and high temperature, and information on gravitational field of the planet. But there are not yet enough data to constrain the velocity and density distributions well. The experiment MISS (Mars Interior Structure by Seismology) can provide some information on subsurface structure and average global structure of the planet.

Goals of the experiment:

1) The first goal of the experiment is determining Mars' seismicity level.

Most theoretical models of the seismic activity on Mars, which are based on the thermoelastic cooling of the lithosphere [1, 2], 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, it is not possible apriori to rule out large seismic events.

An additional and very important seismic sources for a planet with a weak atmosphere as Mars are meteoroid impacts, which strike the surface of Mars at a relatively high rate. The number of impacts are expected to be 2-4 times larger then for the Moon [3,4]. Their impact time and location can be known with orbital imaging. The main characteristics of the seismic source generated by an impact (its amplitude and cutoff frequency) allow us to constrain the mass and velocity of the impactor [5].

2) As soon as impacts are located by these non-seimic methods, impacts become the seismic sources that can be used by a single seismic station on a planet for inverting the interior structure. Both P and S arrival time can be used on a seismometer. If the time is not known, the P-S differential travel-times can be used. Natural impacts on Mars are indeed important seismic sources for constraining the crustal and upper mantle structure.

3) Free oscillations, if they are excited, is the most effective tool for sounding of deep interiors. 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. For torsional oscillations 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. These modes can sound the Martian interiors down to 1600, 1100 and 700 km, respectively. The spheroidal modes with only $\ell \geq 17$ ($M_0=10^{25}$) could sound the outer layers of Mars down to 700-800 km. 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). Stacking multiple quakes with an equivalent cumulative moment could be apllied.

4) The dispersion curves of surface waves can be used to solve problem of determining the structure of the crust and the upper mantle. The data on Rayleigh waves enable one to distinguish between not only the crusts with different composition (MK2M and MK1M, Figure), but also between the models based on different temperature distribution in the crust (MK2M, MK2H and MK2L, Figure).

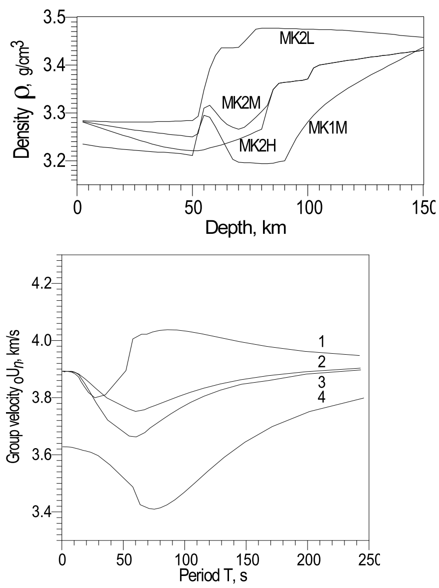
5) Estimates of crustal thickness by receiver function method. This method is a powerful tool for studying the depth to the crust-mantle boundary or to other layering within the crust. It was applyied to get shear velocity with depth for the lunar crust [7].

6) Differential measurements of arrival times of later-arriving phases (PcP, PcS, ScS) in comparison to P could put some restrictions on the seismic velocities in the deep mantle [8]. Synthetic seismogram analysis for interoir structure models can lead to identification of these phases. The difference in travel-time curves for P, PKP, PcP, S, SKS, ScS waves between a trial model M7_3 [9] and the model A of [10] 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 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

Here we have showed the mission possibility to get seismic information on Martian interiors from only one seismic instrument using non-traditional sources of seismic waves and new seismic techniques. Very Broad Band seismometer will record the full range of seismic signals, from the expected quakes induced by the thermoelastic cooling of the lithosphere, to the possible permanent excitation of the normal modes. VBB seismometer is currently part of the core payload for the Martian project InSight [11]. There is a good chance to have two seismometers on the planet.



Profiles of density in the different models of the Martian crust (MK1M, MK2M, MK2H and MK2L) are on the left (the data are from [6]) and group velocities ${}_oU_n$ for a fundamental mode of Rayleigh waves as function of the period of oscillation for these models: 1, MK2L; 2, MK2M; 2, MK2H; 4, MK1M.

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