

Introduction. Since the outer layers of Mars are very heterogeneous, as in the case of the Moon [1], it is difficult to construct a spherically symmetric model of its interior structure (a model of a zeroth approximation), by using only a few seismometers for recording seismic body waves. First of all, they will allow to obtain the structure of the crust at the sites of their location. That is why, in this paper the excitation of free oscillations of the planet will be considered.

The estimate of oscillations amplitude. 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. Phillips and Grimm [2] and Solomon et al. [3] considered that only the thermoelastic cooling of the lithosphere could generate marsquakes. They found that more than 10 events of seismic moment greater than 10^{23} dyne cm, and more than 250 events of magnitude greater than 10^{21} dyne cm, may be expected per year. A few (2-3) per year should have a moment greater than 10^{24} dyne cm. A 10^{25} dyne cm quake is the upper bound of the estimate of the activity on Mars [2]. Their estimates of seismicity are consistent with conclusions by Golombek et al. [4]. Golombek et al. have determined the seismicity on Mars based on all shear faulting visible at its surface. They have concluded that Mars is seismically active today.

To judge whether the free oscillation method can be used to study the Martian interiors, it is necessary to estimate the amplitudes for different types of free oscillations during marsquakes and to determine how these amplitudes depend on focal depth and excitation processes based on the available estimates of the Martian seismic activity and the sensitivity of current instruments. Currently available broadband seismometers can measure accelerations [5]

$$a_{N,E} = -\omega^2 u_{N,E} \approx 10^{-8} \text{ cm s}^{-2}. \quad (1)$$

Thus, the problem is to find the modes that satisfy condition of Eq.(1) and to assess their diagnostic capabilities.

We have calculated the amplitudes of torsional and spheroidal oscillations for sources at different depths (0-300 km) and with different focal mechanisms for a trial model of Mars. The displacement components u_N , u_E and u_R are proportional to the seismic moment M_0 of the source. That is why, to estimate the values of the displacements for different seismic moments, they are calculated for a unit seismic moment. We have considered two possible locations of a marsquake: in Olympus region (135°W, 18°N) and in Valles Marineris (80°W, 5°S) and located a seismometer at "Gusev" crater (14.64°S, 175.06°E).

Figure shows the amplitudes of horizontal displacements u_N and u_E for the fundamental tones of torsional oscillations for two different focal mechanisms. We see from Figure that the displacements of the torsional fundamental modes with $\ell \leq 20$ lie in the range of 10^{-27} - 10^{-31} cm for a unit seismic moment. For a marsquake with $M_0=10^{23}, 10^{24}, 10^{25}$ dyne cm, the amplitudes of oscillations lying above the corresponding curves are about $\geq 10^{-8}$, t.e. they satisfy Eq.(1). And, consequently, the torsional modes with $\ell \geq 3$ (if a marsquake with $M_0=10^{25}$ dyne cm occurs), with $\ell \geq 6$ ($M_0=10^{24}$ dyne cm), and with $\ell \geq 12$ ($M_0=10^{23}$ dyne cm) could be detected by currently available instruments. The torsional modes with $\ell \geq 3, 6$ and 12 can sound the Martian interiors down to 1600, 1100 and 700 km, respectively [6].

The displacement amplitude for the overtones is smaller than that for the fundamental modes. Only a marsquake with $M_0=10^{25}$ dyne cm can excite overtones of torsional oscillations with $n=10-$

20 and $\ell=2$, the amplitudes of which satisfy the condition of Eq.(1).

The noise level on Mars can reach significant values [7], and in this case torsional modes will not be observed for seismic moments described above. Torsional modes will be observed if a real seismic event has a larger moment or a seismometer is placed by a penetrator deeper into the ground in order to eliminate wind effects.

A marsquake with a seismic moment 10^{25} dyne cm is required for the spheroidal oscillations to be detected. In this case, the spheroidal modes with only $\ell \geq 17$ could be detected by currently available instruments. The spheroidal modes with $\ell \geq 17$ can sound the outer layers of Mars down to 700-800 km [8]. For a marsquake with a higher seismic moment (10^{26} dyne cm) the spheroidal modes with $\ell \geq 6$ could be detected. The spheroidal modes with $\ell \geq 6$ can sound the outer layers of Mars down to 2000 km [8]. Only a marsquake with $M_0=10^{26}$ dyne cm can excite overtones of spheroidal oscillations with $n=5-25$ and $\ell=2$.

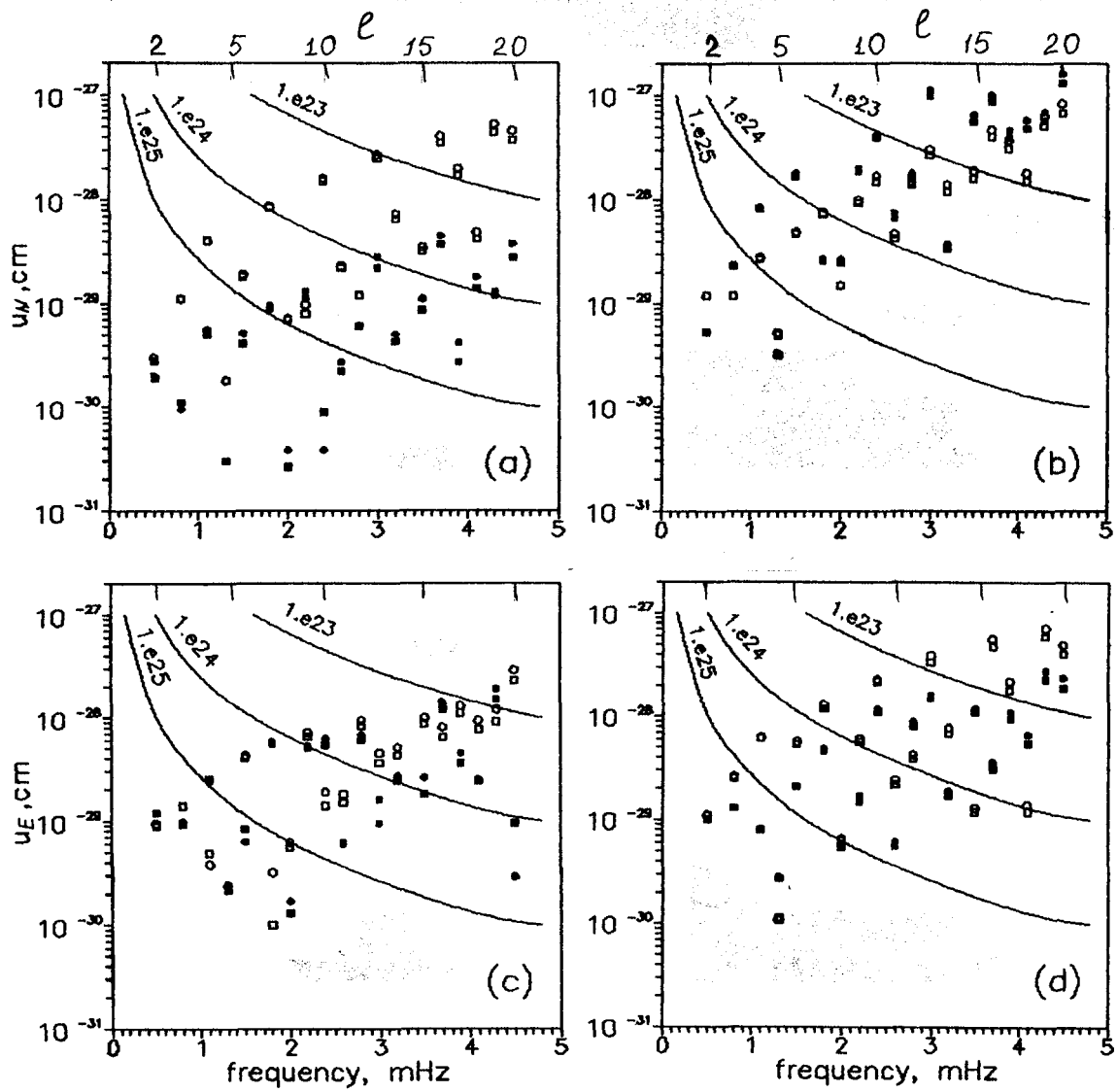
These results are in agreement with the results obtained in [5], where the authors concluded that normal mode detection would be clearly successful for a 10^{25} dyne cm seismic moment marsquake and $10^{-9} \text{ ms}^{-2} \text{ Hz}^{-1/2}$ noise level and the moment may be reduced to 10^{24} dyne cm for a noise level of $10^{-10} \text{ ms}^{-2} \text{ Hz}^{-1/2}$.

Conclusion. In the future the Netlander mission will have a geodesy and seismic payload and it is of great importance for studying Martian interior. The paper is related to the excitation of normal modes and the possibilities of detecting such modes by future Mars missions.

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. A good installation of a broadband seismometer is mandatory to provide this information. It is found down to what depth the normal modes can sound the planetary interiors. A marsquake with a seismic moment of 10^{25} dyne cm is required for spheroidal oscillations (with $\ell \geq 17$) to be detected. These spheroidal modes are capable sounding the outer layers of Mars down to a depth of 700-800 km. These results are in agreement with the results obtained by Lognonné et al. (1996), who concluded that normal mode detection would be clearly successful for a 10^{25} dyne cm seismic moment marsquake and $10^{-9} \text{ ms}^{-2} \text{ Hz}^{-1/2}$ noise level.

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Amplitude of displacements u_N (a, b) and u_E (c, d) for the modes of torsional oscillations with $l = 2-20$ and $n=0$ versus frequency $f=1/T$ and degree of oscillation l for two focal mechanisms. M_0 is equal to 1. The focal mechanisms are $45^\circ, 45^\circ, 45^\circ$ (a, c) and $90^\circ, 90^\circ, 90^\circ$ (b, d) for the dip, strike and slip angles. The seismometer coordinates are $15^\circ\text{S}, 185^\circ\text{W}$. The epicenter coordinates are $18^\circ\text{N}, 135^\circ\text{W}$ (Olympus), the epicentral distance is 59.3° (open circles - a focal depth of 0.3 km and open squares - a focal depth of 300 km) and $5^\circ\text{S}, 80^\circ\text{W}$ (Valles Marineris), the epicentral distance is 103.1° (filled circles - a focal depth of 0.3 km and filled squares - a focal depth of 300 km).