The features and possible cause of the low-frequency marsquake S1022a

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1.Introduction

The Mars Lander "InSight" landed in 2018. In early 2019, the first seismic data were recorded, and approximately 1,300 marsquakes were detected until the mission ended in December 2022 (Lognonné et al. 2023).

Each marsquake event detected by the InSight Marsquake Service (MQS) is labeled with the martian day (Sol) on which it occurred, and assigned to four classes based on data quality: Quality A, B, C, and D from highest to lowest. For Quality A events, distinct arrivals of P and S waves are identified, and polarization of P wave is sufficiently clear to estimate the back azimuth. MQS (2023) classified fourteen events with Mw between 3 and 5 as Quality A.

By investigating the waveform data of the P and S waves from the Quality A events, we found that the event labeled "S1022a" is characterized by monochromatic signals at a specific low frequency. In this presentation, we will show the characteristics of the marsquake S1022a and discuss its cause.

2.The features of the low frequency marsquake S1022a

According to MQS, S1022a occurred at the distance of 31°(1800 km) from the InSight lander. The back azimuth and Mw were estimated to be 63°and 3.6, respectively. The background seismic noise increases during the day and decreases at night (Giardini et al. 2020). S1022a occurred during the relatively noisy time in the early evening.

The spectrum of P wave from S1022a has a significant peak around 0.2 Hz, decreasing rapidly around 0.4 to 0.5 Hz and being low at higher frequencies. This feature is also observed in the three components of S wave. The motion of P wave around 0.2 Hz is linearly polarized, and the polarization direction agrees with the back azimuth estimated by MQS. The horizontal motion of S wave around 0.2 Hz is roughly perpendicular to the back azimuth direction.

The spectra of the other Quality A events do not have significant peaks at specific frequencies below 1 Hz. Giardini et al. (2020) showed that some of the spectra match the Brune source models (Brune 1970) with the attenuation effect due to t*. We observed that some low-frequency events of Quality B have dominant energy at specific frequencies below 1 Hz, but the peak frequencies are higher than 0.2 Hz.

Although before and after S1022a, there are time periods with high noises, we confirmed that the characteristics of the noise spectra are not similar to S1022a.

3.The cause for the features of S1022a

Since the features observed for S1022a are not seen for the other Quality A events, it is unlikely that the features are attributed to underground structures near the seismometer. Therefore, if an underground structure is the cause, it should be located away from the seismometer. Moreover, it should cause a peak frequency of 0.2 Hz for both P and S waves.

On the other hand, if the source is the cause, its source model should explain a peak frequency of 0.2 Hz along with low amplitudes at high frequencies (>0.5 Hz).

Kedar et al. (2021) explored volcanic tremor models of Julian (1994) to explain the two Quality B events that have a spectral peak at 0.35 and 0.6 Hz, respectively. Martire et al. (2020) argued that near-surface infrasound can explain one of the two events.

Compared with the two events in Kedar et al. (2021), S1022a has larger Mw, clearer arrivals of P and S waves, a shorter duration of signals, and a lower peak frequency.
Martire et al. (2020) showed the characteristics of ground motions due to infrasound. The characteristics do not agree with the observation of S1022a.
Searching Julian's (1994) models with a sharp spectral peak at 0.2 Hz, we examined whether S1022a can be volcanic tremor. When the models have a sharp peak at 0.2 Hz, they also have multiple peaks at frequencies higher than 0.2 Hz. The appearance of multiple peaks, however, does not match the spectrum of S1022a. Source models other than Julian’s (1994) may be necessary for S1022a.

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