The Lunar Surface Gravimeter as a Lunar Seismograph

Conference or Workshop Item

The Lunar Surface Gravimeter as a Lunar Seismograph. T. Kawamura[1] , Y. Saito[1], S. Tanaka[2], S. Ono[1], K. Horai[2], A. Hagermann[3], [1]The University of Tokyo(Hongo, Bunkyo-ku Tokyo 113-0033 e-mail: kawamura@planeta.sci.isas.jaxa.jp), [2]Institute of Space and Astronautical Science(Yoshinodai, Sagamihara, Kanagawa, 229-8510 e-mail: tanaka@planeta.sci.isas.jaxa.jp),[3]Open University(e-mail: a.hagermann@open.ac.uk)

Introduction: The primary objective for the Lunar Surface Gravimeter (LSG) on Apollo 17 was to search for gravitational waves, but it failed in detecting them [1]. When the instrument was deployed on the Moon, the sensor beam could not be balanced in the proper equilibrium position. Consequently, the LSG was not able to function as originally designed. Lauderdale and Eichelman (1974) [1] concluded that "no provision has been made to supply data from the experiment to the National Space Science Data Center." However, it was reported in Giganti et al. (1977) [2] that though they had not detected gravitational waves, after a series of reconfigurations the beam was recentered and the LSG gathered useful data. Besides the observation of gravitational waves, the LSG was also designed to observe seismic signals and tidal deformations [3]. According to Giganti et al. (1977) [2] LSG's sensitivity covered the frequency range from 1~16Hz (Fig.1). There are several types of moonquakes reported, deep moonquakes, meteorite impacts, and high frequency teleseismic (HFT). Each of the moonquakes is known to have a resonant frequency around 1Hz and in addition, HFT has a predominant frequency around 10 Hz [4]. Therefore it is likely that the LSG was detecting the seismic events on the Moon. However, the LSG data have not been analyzed from a seismological point of view.

We have been working on the re-analysis of a data set called the Work Tape. The Work Tape contains all the Apollo Lunar Surface Experiments Package observation data from 1976 3/1 to 1977 9/30. Saito et al. (2007) [5] succeeded in showing a new possibility of deriving the lunar heat flow from unanalyzed data on the Work Tape. The Work Tape also contained the LSG data. We successfully archived the data and examined the LSG data and checked whether it detected seismic signals or not.

Detection of the Seismic Signals: Seismic events during the Apollo missions are listed in Nakamura et al. (2004) [6]. To confirm whether the LSG was detecting the seismic signals, we took the LSG data of the event time recorded in the catalog from the data set and checked if we can see envelopes of seismic signals. We also constructed spectrograms from the data and examined whether signals were spectrally consistent with the signature of moonquakes.

Most of the LSG data had a low S/N ratio. Some large HFT (high-frequency teleseismic) events and meteorite impacts were strong enough that we could identify seismic signals in the noise but seismic signals of small events such as deep moonquakes were hardly distinguishable. On the other hand, the spectrogram showed a prominent peak around 1Hz for each event time reported (Fig.2a). For HFTs, a double peaked feature of about 1Hz and 10Hz was seen. This suggests that signals detected by the LSG were seismic signals. By filtering just the signals of about 1Hz and 10Hz, seismic signals are emphasized compared to noise signals (Fig.2b). Using a band-pass filter enables us to improve the accuracy of seismic analyses with LSG data.

Scientific contribution expected from the LSG data: Apollo Stations 12,14,15,16 were located on the near side of the Moon. This observation network is known as a triangle network representing an equilateral triangle of 1100km. In particular the distance between Station 12 and Station 14 was about 181km which is relatively close together in the global observation network. Since the number of seismic stations and their observable area is limited, more than 3500 seismic events were detected with two or less stations and unclassified [6]. By using the LSG data, these unclassified moonquakes may be identified.

By adding the data set of Apollo Station 17, baseline of the network will be extended to 2200km at most and observation of a wider range will be possible. The expansion of the observable area may provides us with new information of the lunar core. One interesting target is deep moonquakes. Deep moonquakes are the most common among the lunar seismic events and they are known to occur periodically at particular hypocenters. Some hypocenters are already defined and there are hypocenters on the far side. Nakamura (1983) [7] reported that seismic signals from the far side may travel through the central core. An expanded observation network enables us to detect more of these kinds of signals and evidence of a lunar core may be detected by analyzing them.

Future work: In this study, we confirmed that the LSG was observing seismic signals. The LSG may provide useful information on the lunar interior. We have already worked on HFTs [8] and now dealing with deep moonquakes. We are expecting to obtain new information of the lunar interior from further analysis.

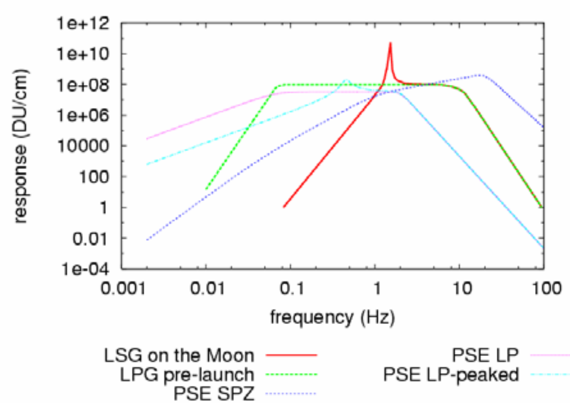

Fig.1 The response curve of LSG copied from Giganti et al. (1977) Green line indicates the response before launch and red line indicates response on the moon. Sensitivities of the Passive Seismic Experiments (PSE) of other Apollo missions are superposed for comparison. The blue, pink, and light blue line indicate short period mode, long period, and peaked long period mode of the PSE respectively. The figure shows that the LSG has comparable response with seismographs of other Apollo missions around 1Hz to 10Hz. Since moonquakes have resonant frequency of about 1Hz and 10Hz, it is likely that the LSG was detecting seismic signals.

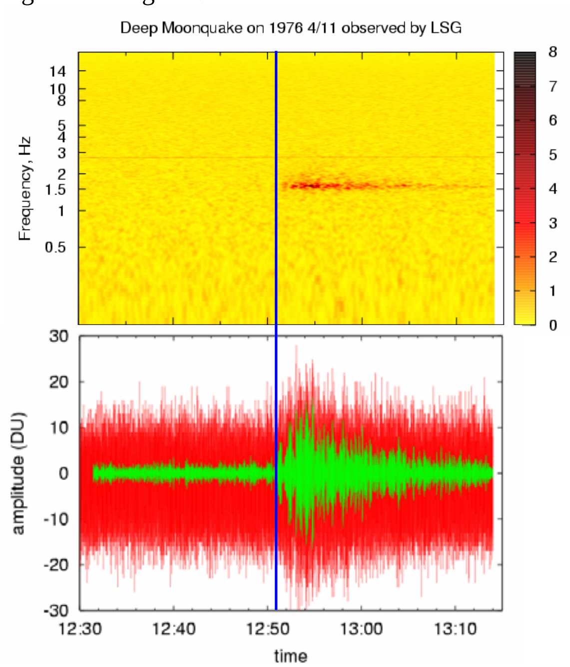

Fig.2 Upper panel (a) is a spectrogram of a deep moonquake on 1976 4/11 observed by the LSG. Time resolution of the figure is 60seconds. Lower panel (b) shows the seismic signal of the same moonquake. The red line indicates the raw signal and the green line indicates the signal after noise reduction. Signals with a frequency from 1.4 Hz to 1.8 Hz were filtered. Nakamura et al. (2004) reported that a deep moonquake occurred at 12:51.Both figures show that the LSG is detecting the seismic signal and the data is consistent with the catalog compiled from the data of other seismic stations.

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