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Brightness Temperature Distribution of the Moon

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Abstract

The thermal radio emission from the Moon provides important information on the properties of the lunar regolith. With model fitting, it is possible to estimate the geometrical and physical properties of the lunar regolith based on multiband images of the brightness temperature distribution of the lunar surface. The microwave radiometers mounted on both ChangE-1 and ChangE-2 has obtained the brightness temperature distribution at frequencies 3.0GHz, 7.8GHz, 17.35GHz and 37GHz. Also, ground-based observations were carried out with several radio telescope arrays at frequencies 610MHz, 1.067GHz, 1.4GHz, 2.3GHz and 8.4GHz. Here we report some preliminary results of the brightness temperature distributions derived from these observations.

1. Introduction

The Moon, which is the nearest celestial body to the Earth, has many valuable resources, among which ^{3}He is probably the most important one. It is a clean fusion material, which may solve the energy crisis for the mankind. Almost all of the ^{3}He contents exist in the lunar regolith layer. Therefore, to estimate the total amount of ^{3}He, it is necessary to find out the thickness and the distribution of the lunar regolith layer. Shkuratov and Bondarenko (2001) studied the thickness and mineral content of the regolith layer based on the radio and optical data. Wu et al. (2005) presented a possible relation between the brightness temperature and the thickness of the regolith layer.

To derive the thickness of the regolith layer, a possible method is to implement multiband imaging of the brightness temperature distributions on the Moon. The lunar microwave at millimeter-band comes from the thin top layer of the regolith, whereas the emission at meter band comes from the deep layer. Theoretically, the brightness temperatures of the moon at different wavebands depend on the physical temperatures, the dielectric constants, and the Fresnel coefficient of the lunar regolith (Poppi et al. 2002, Troitskii et al. 1973). This allows an indirect estimate of the thickness of the lunar regolith layer from multiband observations of the brightness temperature distribution on the Moon.

2. Observations

This study is based on ground-based observations, as well as observations made by ChangE-1 and ChangE-2. The details of these observations are listed in the following table.

Frequency	Telescopes	Resolution
610MHz	GMRT	6.3”
1.067GHz	GMRT	3.6”
1.42GHz	DRAO	1’
1.425GHz	VLA	44.8”
2.3GHz	WSRT/Miyun	7.8”/8.97’
8.4GHz	WSRT/Miyun	2.2”/3.5’
3.0GHz	ChangE-1/2	50km/25km
7.8GHz	ChangE-1/2	35km/17.5km
17.35GHz	ChangE-1/2	35km/17.5km
37GHz	ChangE-1/2	35km/17.5km

3. Results

3.1 GMRT at 610MHz & 1.067GHz

The Giant Metrewave Radio Telescope (GMRT) is composed of thirty telescopes with a diametrical size of 45 m. In data processing at 610MHz and 1.067GHz, GMRT is lack of short distance UV coverage and has low signal noise ratio, so it is difficult to get the clear structure of the full moon.

3.2 VLA and DRAO at 1.42GHz

The Very Large Array (VLA) consists of 27 radio antennas in a Y-shaped configuration on the Plains of San Agustin fifty miles west of Socorro, New Mexico. Each antenna has a diametrical size of 25 meters (82 feet). The Moon was observed by the VLA at 20 cm band with the D configuration and full polarization.

The Dominion Radio Astrophysical Observatory (DRAO) includes three components, a 26-metre fully steerable dish, a seven-antenna synthesis array, and a pair of solar flux monitors. The observation was made with a seven-antenna synthesis array, each of which is 9 meters in diameter.

We have obtained some good brightness temperature distributions of the entire moon surface, with high resolution of 1’ and 44.8” respectively.

3.3 Miyun and GMRT at 2.3GHz and 8.4GHz

The observations were made by the Miyun 50m telescope in China and WSRT in Holland.

The Westerbork Synthesis Radio Telescope (WSRT) is an open user facility available for all scientists across the world. WSRT consists of 14 antennas. As a one dimensional array, the observations should be made when the Moon in the position with high declination. The selected areas of interest are the three Apollo landing sites on the lunar surface, i.e. the Oceanus Procellarum (Apollo 12 landing site), the Descartes Highlands (Apollo 16 landing site), and the Hadley-Apennine region near the Apennine Mountains (Apollo 15 landing site). These Apollo landing sites are chosen because they represent three distinct types of the lunar terrain with different regolith depth and different brightness temperatures.

The Miyun 50m observations provide high quality mapping of the Moon at 8.4GHz with low resolution, revealing the rough structures of the brightness temperature distribution. Observations were also made at 2.3GHz, but with significantly lower quality due to strong contamination by the local mobile phone signals..

3.4 ChangE-1&2 at 3GHz, 7.8GHz, 17.35GHz and 37GHz

The microwave radiometer is an important payload of both the Chang’E-1 and Chang’E-2 lunar orbiters. The microwave radiometer is capable of scanning the Moon at 4 distinct frequencies. At each frequency, it has two antennas, with one pointing to the clean night sky for background calibration and the other one pointing to the Moon for brightness temperature observation.

The altitudes of the orbiters are 200km for Chang’E-1 and 100km for Chang’E-2 respectively. Accordingly, the spatial resolution ranges from 50km to 25km at 3GHz, and from 35km to 17.5km at the other three frequencies. The main difficulty in data processing lies in calibration of the instrument. Some parameters used for data processing were derived from the calibration experiments in ground laboratory, where the laboratory environment is similar to that in space. We have got good maps at day time as well as night for both sides of the moon.

4. Summary and Conclusions

We have obtained the multi-frequency brightness temperature distributions of the moon with both ground-based and space-born observations. In general, the temperature is higher at the dayside as compared to the nightside. The measured brightness temperature also presents some meridional variations with lower temperatures in the polar regions. The brightness temperature distributions obtained at different frequencies will be used to investigate the geometrical and physical properties of the lunar regolith.

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