THE FIRST MICROWAVE IMAGE OF THE COMPLETE MOON FROM CHANG'E-1 LUNAR ORBITER. Yong-Chun Zheng[1,*] K. L. Chan[2] K. T. Tsang[2] F. Zhang[1] Y. L. Zou[1] and Z. Y. Ouyang[1] [1]National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China. Email: zyc@nao.cas.cn. [2]Centre for Space Science Research, Hong Kong University of Science and Technology.

Introduction: China's first scientific mission to explore planetary bodies beyond Earth, Chang'E-1 (CE-1) Lunar Orbiter, have made successful achievements in the global image of the Moon, the acceleration of scattered solar wind protons close to the lunar polar terminator by the eight science instruments on board the spacecraft.

Here we present the first global microwave image of the Moon from CE-1's microwave radiometer (MRM). This new results is uncomparable by any ground-based observation in spatial resolution and temperature sensitivity, and could be unsurpassed in the near future.

Instrument and TB data sets: The CE-1 MRM was calibrated onboard periodically to assure its reliability and accuracy, using a two-point calibration method[1]. A matching calibrating heat source of known temperature onboard provided the high temperature reference point, and the cold/deep space cosmic microwave background served as the low temperature reference point.

As shown in the schematic view of the CE-1 MRM (Fig. 1), the four antennas at the left-side were designed to point to the cold/deep space which acted as the low temperature (2.7 K) calibrating source. The downward antennas were designed to point to the lunar surface for taking measurements. The sizes of the antenna dishes are proportional to the wavelengths of the four microwave channels.

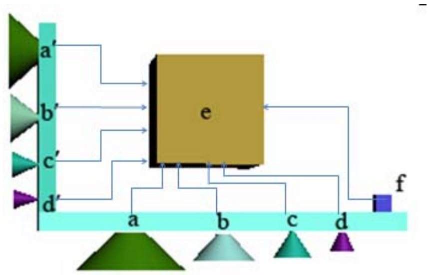

Figure 1 Artistic view of the MRM on-board CE-1. a'-d': Cold calibration antenna. a-d: Observation antenna. e, microwave receiver. f, hot match-load. MRM has two calibration modes and one observation mode, and switches between the calibration modes and observation mode periodically.

As CE-1 had a circular polar orbit of 200 km above the lunar surface, MRM observation can achieve complete coverage with a nadir view. The spatial resolution is orders of magnitude better than any ground-based microwave observation. The sensitivity (0.5 K) and dynamical range (20-500 K) of observable TB is unsurpassed (Table 1)[2]. Due to the long lifespan of CE-1 (494-days), the MRM obtained TB data that covered the Moon globally eight times, from lunar day to night. The global, diurnal coverage of the TB data would provide extremely valuable information for studying the physical properties of lunar regolith and thermal environment of the lunar surface.

Table 1: Major technical parameters of CE-1 MRM

Frequencies	3.0, 7.8, 19.35 and 37 GHz
Integration time	200(±15%) ms
Temperature Sensivity	≤0.5 K
Linearity	≥0.99
Footprint	56km for 3.0GHz and 30km for other three channels

Microwave Image of the Complete Moon: The TB at any point on the lunar surface was measured by CE-1's MRM at different lunar local times, with different solar incident angle and azimuthal angle. These are the dominant factors that determine the spatial and diurnal variation of the TB data.

Due to the systematic decrease of TB values towards the two poles, diurnal variation of TB is modeled in a number of latitudinal bands each has a width of 20°. TB data within a narrow latitude extend (±0.1°) at the center of a band is used to build the diurnal model for the band. After comparing a number of possibilities, we decided on a degree-seven polynomial fitting scheme to describe the general variation of TB versus local time in each latitudinal band. This is an improvement over the numerical scheme established in a previous work[2,3].

With this numerical model fit, the TB at any location during any lunar local time can be projected from the CE-1 TB data within the accuracy of our model fit. In order to reveal the topographic information and other geological features hidden in the TB data, microwave maps are constructed using data rescaled to the same local time so that the resulting images are free from distortion due to local time effects. The final "normalized" microwave TB image were created with the GIS softwares (Fig. 2~3), resulting in qualities much better than those of previous studies[2,3]. These microwave images of the Moon, which look familiar at first sight (especially the 37GHz daytime image), is very different from what we are used to see in the UV-VIS-IR images.

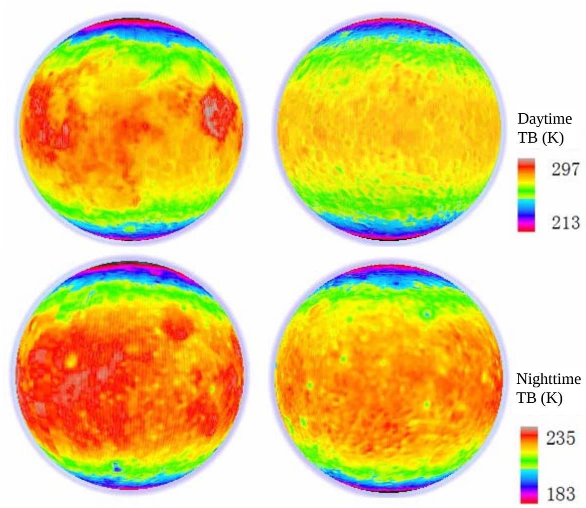

Fig.2 37GHz TB image of the Moon
Left: nearside; right: farside

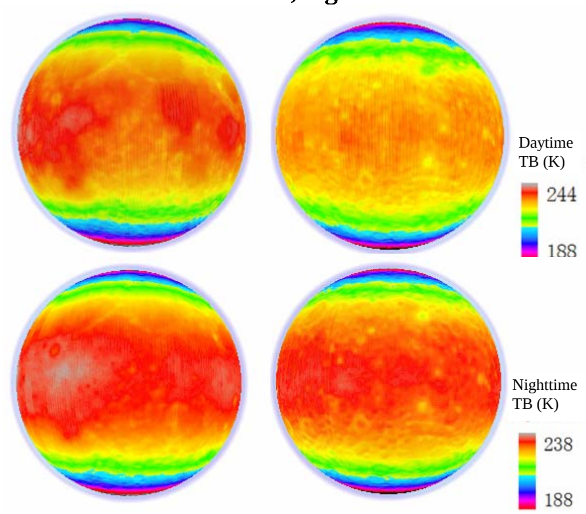

Fig.3 3.0GHz TB image of the Moon
Left: nearside; right: farside

From Figure 4, we can found NW of Crater Wapowski, West of Crater Kocher, and West of Crater de Gerlache are the three relatively temperate areas. These sites have good thermal environment to be selected as the location for future lunar base.

Discussion: For the longer wavelength, only passive microwave observation can sense emission from below the surface (several centimeters to some meters). Orbital passive microwave observation at different frequency could be used to retrieve the global heat flow and average regolith depth of the Moon. The information could help to study the thermal evolution of the Moon and helium-3 resource amount estimation.

LRO's temperature instrument, Diviner, has found a place in the floor of the moon's Hermite Crater as the coldest temperature (26K) measured anywhere in the solar system (Press release of Diviner). However, CE-1 MRM has measured the coldest brightness temperature, at 37GHz and midnight of the North pole, 67K. The higher temperature in microwave bands might be contrbuted in part to the heatflow of the Moon.

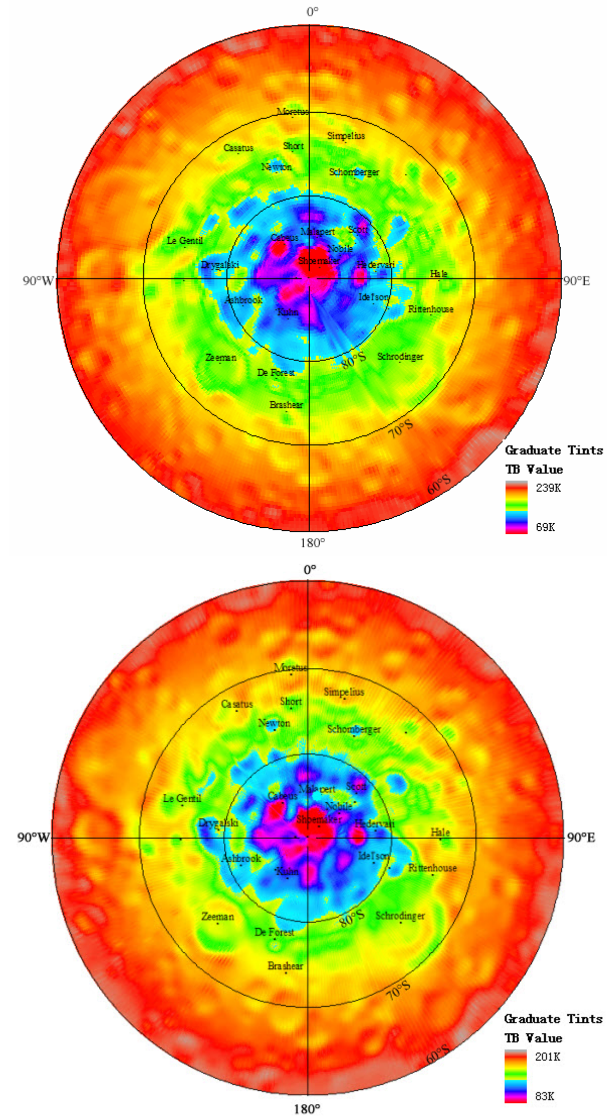

Fig.4 37GHz TB of southpole of the Moon
Up: daytime; down: nighttime

A sister probe of CE-1, CE-2 had been launched in Oct. 1, 2010. MRM aboard CE-2 has been measuring TB of the Moon at 100 km orbital altitude since that time. TB measurements of the Moon was continued from 2007's CE-1 to nowdays' CE-2. This long time span of TB measurements is very beneficial to find new results about the thermal environments of the Moon.

References: [1] Zhang H.Y. Zhang X.H. and Yang J. (2008) Adv Space Res., 42, 350-357. [2] Wang Z. et al., (2010) Science China (D), 53 (9), 1392-1406. [3] Zheng Y.C., et al. (2010) European Planetary Science Congress, EPSC2010-2224.