IDENTIFYING A COMPOSITION-RELATED TB ANOMLAY IN COPERNICUS CRATER USING CE-2 MRM DATA

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ABSTRACT

In this study, two special thermal behaviors are discovered and identified with the brightness temperature (TB) derived from Chang'e-2 MRM data. First, there exists a 37-GHz TB at noon, which is not related to the topography. Second, there exists a low 3.0-GHz TB anomaly. After comparison the distribution pattern and the correlation coefficients between the rock abundance, or FeO and TiO_2 abundances, we ascribe the special thermal behaviors to be a composition-related TB anomaly, which likely reflects the heterogeneity of the lunar crust in vertical direction.

Index Terms - Copernicus crater, MRM data, brightness temperature, cold thermal behavior

1. INTRODUCTION

Copernicus crater (9°N, 20°E), 93 km in diameter, is one of the most important Copernican impact craters on the moon (Fig.1a). Its age and thousands of kilometers long sputtering blanket have always been the important contents of the current lunar scientific research [1].

Based on the LROC WAC mosaics data, Dhingra et al. believed that this region is optically and, hence, compositionally heterogeneous [2]. Based on near infrared spectroscopy, Dhingra et al. believed that the northern and central peaks of Copernicus Crater had different olivine-bearing lithologic origins, which were mainly related to stratigraphy [3]. In particular, Li et al. and Milliken et al. suggested that Copernicus crater exhibits high water content that may reflect the retention of volatiles from hydrous impactors according to the Moon Mineralogy Mapper data [4,5]. Using microwave radiometer (MRM) data from Chang'e(CE)-2 mission, Chan et al. and Hu et al. provided the existence of the rock and its influence on the thermal behaviors in microwave domain [6,7]. Meng et al. found that the 37 GHz brightness temperature (TB) derived from the CE-2 MRM data is abnormal, which is not related to the topographic-related solar illumination but likely related to the composition-related ejecta (Fig.1b) [8]. But they did not further discuss the abnormal TB performances.

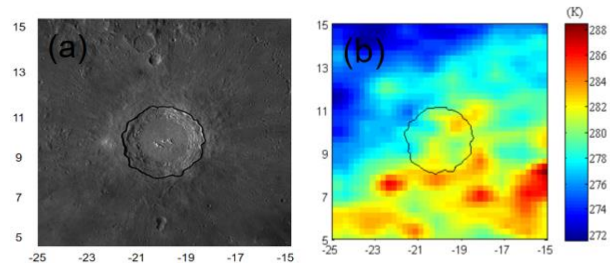

Fig 1. The Copernicus crater. (a) Geographical map, (b) Daytime TB map at 37 GHz [8].

Therefore, the intention of this paper is to systematically analyze the TB anomaly in Copernicus crater using multi-source data.

2. DATA PROCESSING

The study area is from 5°N to 15°N latitude and 15°W to 25°W longitude, including Copernicus crater and part of the ejecta blanket. To further understand the abnormal TB performances, the MRM data, UV-VIS data and Diviner thermal infrared are employed in this study. The rims of the craters are drawn and overlaid on the following figures.

2.1 MRM Data

In this study, the 1849 data were selected according to the range of the study area. For the observation time of these data is not identical, the hour angle is introduced to ascribe the MRM data points into the 24-hr time lunation intervals, which can weaken eliminate the influence of the solar illumination conditions on the TB map. Then, a seventh-degree polynomial fitting scheme linear polynomial interpolation method was used to fit the observed TB data to the simulated data. Finally, the 24-hr TB maps at 3.0, 7.8, 19.35, and 37 GHz were generated with a spatial resolution of the 0.25°×0.25°, only the TB maps at 37GHz are shown here (Fig.2).

Also, the four-channel TB maps at 12:00 to 13:00 and 0:00 to 1:00 are generated to systematically study the thermal behaviors of the surface anomaly in Copernicus crater at noon and at night (Figs. 3 and 4).

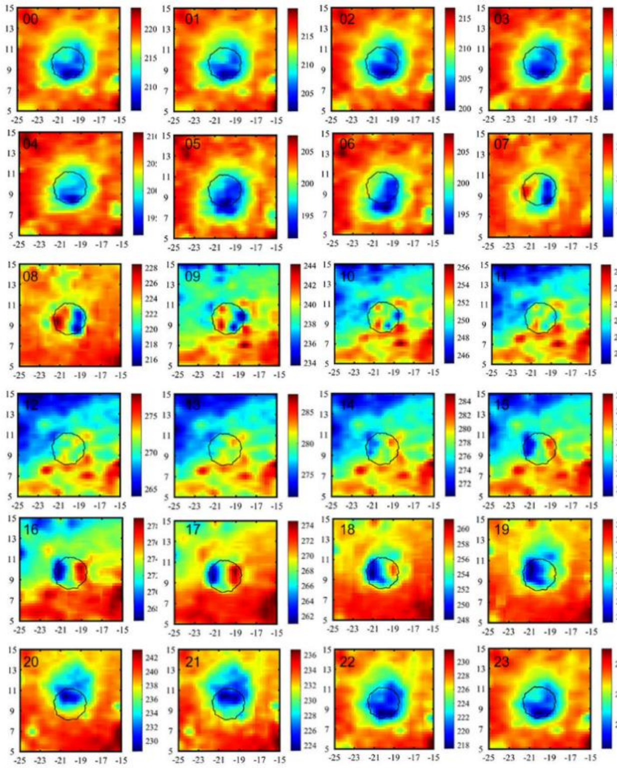

Fig. 2 24-hr TB map of study area at 37GHz, the black line is the range of Copernicus crater.

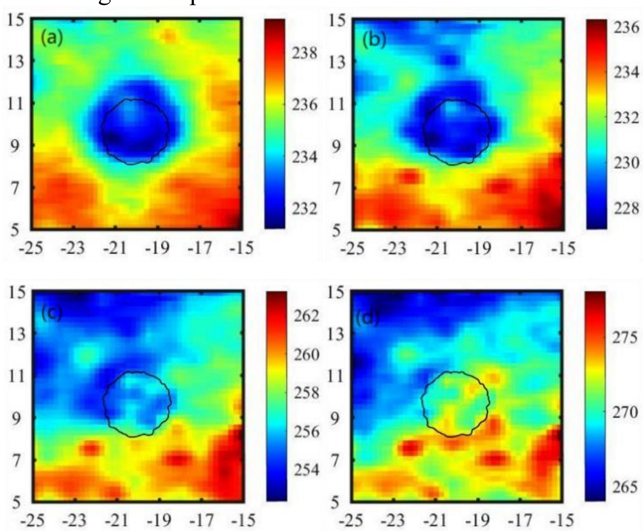

Fig. 3 Daytime TB maps of study area at (a)3.0GHz, (b)7.8GHz, (c)19.35GHz, (d)37GHz, the black line is the range of Copernicus crater.

2.2 Other datasets

FeO and TiO_2 abundance (FA and TA) is an important parameter changing the absorption feature of the lunar regolith, which are retrieved using the Clementine ultraviolet-visible data with the method developed by Lucey et al. [9] Fig.5 shows that FA and TA are rather low in the crater floor and the northern part of Copernicus crater.

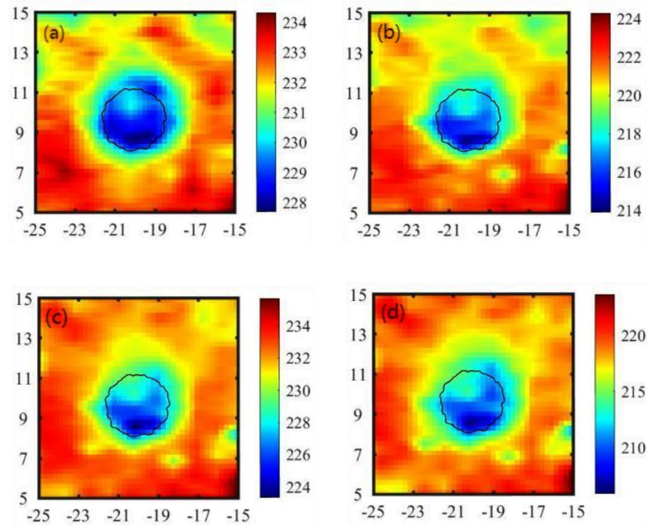

Fig. 4 Nighttime TB maps of study area at (a)3.0GHz, (b)7.8GHz, (c)19.35GHz, (d)37GHz, the black line is the range of Copernicus crater.

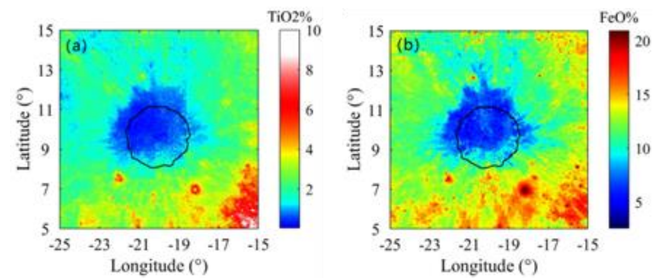

Fig.5 Distribution of TA (a) and FA (b) in study area, the black line is the range of Copernicus crater.

The LRO Diviner data were used to estimate the rock abundance (RA) at the Copernicus crater with the method developed by Bandfield et al. (Fig.6) [10]. The RA can change the porosity and dielectric constant of the lunar regolith, which affect the microwave thermal emission of the Moon surface.

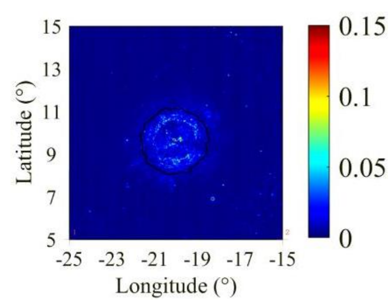

Fig.6 Rock abundance map of Copernicus crater

3. RESULTS AND DISCUSSIONS

3.1 TB at noon

Fig.3 indicates that the TB of Copernicus crater at noon. Here, two phenomena should be mentioned.

First, the TB in and around Copernicus crater is clearly lower than its vicinity at 3.0 and 7.8 GHz. Here, within the crater, the TB in the northern slope orienting to the solar illumination is a bit higher than that in the slope opposite the solar illumination. This is rational according to the TB simulation when considering the orientation of the slopes.

However, the TB just outside the crater is also lower than the nearby regions, including the south outer slope with enhanced solar illumination. This is the first abnormal TB behavior in Copernicus crater.

Second, the correlation between the TB behavior and the crater is weakened at 19.35 GHz, and the TB no longer reflects the crater at 37 GHz. At 37 GHz, where the TB gradually decreases from the southeast part of the study area to the northwest part. Also, the TB values are almost homogeneous along the northeast direction.

Interestingly, Ran et al. postulated the TB of Copernicus crater with CE-1 MRM data, which indicates a similar phenomenon at 37 GHz [11]. This means that such TB behavior actually exists in Copernicus crater.

This is the second abnormal TB behaviors in Copernicus crater.

3.2. TB at night

Fig.4 is the TB of Copernicus crater at night. Here, the TB indicates a homogeneous change with the frequency. Within the crater, the TB is much lower than its vicinity. The lowest TB occurs in the southern slope and the relatively highest TB occurs in the northern slope. this TB behaviors are similar as those in Copernicus crater, indicating that the influence of the surface heating at daytime is fairly strong on the TB values of the crater materials.

Here, one phenomenon should be paid attention. The TB in and around Copernicus crater is still lower than its vicinity. This is the third abnormal TB behavior in Copernicus crater.

3.3. Daily variation

Fig.2 shows a well description of the special TB behaviors of Copernicus crater in a lunation. Here, the TB is higher in the slope orientating to the solar illumination than that in the slope opposite to the solar illumination, which is in the west slope in the morning and in the east slope in the afternoon.

However, the aforementioned second TB anomaly occurs from 11:00 to 13:00. Moreover, even if the northern slope is orientating to the solar illumination in this time, not any abnormally high TB occurs in this slope. Therefore, the second TB anomaly can be identified in this study.

Meanwhile, the TB in and around Copernicus crater is lower than the nearby regions no matter at noon and night, identifying the existence of the first and third TB anomalies.

3.4 Cause of the abnormal noon TB at 37 GHz

Until now, no literatures have been reported about the abnormal TB at 37 GHz in Copernicus crater. It is hard to pursue the cause of the phenomenon.

Hu et al. and Meng et al. suggested that the TB is highly influenced by the compositions of the regolith and the local rock abundance [7,8]. Then, the FA, TA and RA maps as shown in Figs. 5 and 6 are used to evaluate the abnormal 37-GHz TB.

However, Figs. 5 and 6 can not support the abnormal TB at noon. At least in surface distribution, there is no correlation between the FA, TA, RA and TB.

Interestingly, a special phenomenon should be mentioned. The distribution of the 3.0 GHz TB is highly correlated to that of the TA and FA. Here, the low TA and FA values are located in and surrounding Copernicus crater, including the south outer slope of the crater. Correspondingly, the TB shows a similar distribution pattern as mentioned in the first phenomenon. The statistics in Table 1 show a fairly high coefficient between the FA, TA and TB, which are up to 0.93 at noon. Thus, the special TB behaviors are likely brought by the composition including FA and TA.

However, though the low FA and TA can support the relatively low TB at daytime, but they can not support the low TB at night. Thus, a new hypothesis can be concluded: an undetected composition brings the low TB at noon and night, which also produces the abnormal 37 GHz TB at noon. This hypothesis is supported by the distribution pattern of the three datasets and the high correlation coefficients at 3.0 and 7.8 GHz. That is, the undetected composition was excavated during the impact event and shows a similar distribution as FA and TA in and around Copernicus crater.

TAB.1 Correlation coefficients between FA, TA, RA, and TB at the four channels (GHz)

Time	Noon				Midnight			
Channel	3.0	7.8	19.35	37.0	3.0	7.8	19.35	37.0
FA	0.93	0.92	0.51	-0.17	0.93	0.95	0.92	0.87
TA	0.87	0.95	0.73	0.03	0.82	0.86	0.80	0.78
RA	-0.78	-0.75	-0.23	0.34	-0.85	-0.87	-0.86	-0.80

4. CONCLUSIONS

In this study, the day and night TB maps derived with CE-2 MRM data are used to evaluate the abnormal TB performances in Copernicus crater. The main results are as follows.

First, the abnormal TB performances are identified, including the abnormal low TB in the solar-orientating slopes and the abnormal 37 GHz TB at noon.

Second, the comparison between the distribution patterns and the statistics between TA, FA, RA and TB hints that the abnormal TB in Copernicus crater is likely brought by the composition, and the composition is not detected until now.

This composition likely hints the inhomogeneity of the lunar crust in vertical direction, and more work deserves to be done to further study the nature and origin of the composition.

5. ACKNOWLEDGMENTS

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