Primitive results from passive microwave exploration in Chinese Chang'e lunar mission. Xiongyao Li[1], Shijie Wang[1], Hong Tang[,2],and Yongchun Zheng[3], [1]State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, lixiongyao@vip.skleg.cn; [2]Graduate University of the Chinese Academy of Sciences, Beijing 100049; [3]National Astronomical Observatories, Chinese Academy of Sciences, Beijing 10012.

Introduction: In Chinese Chang'e lunar mission, the microwave radiometer (MRM) was firstly loaded to surveying the thermal emission properties of surface materials on lunar orbit. The CE-1 lunar satellite was launch in Oct 24th, 2007 and had exploring the Moon for more than one year. The MRM surveying the Moon in 3.0GHz, 7.8GHz, 19.35GHz, and 37GHz channels, and it had got abundance of data which covered the whole moon 8 times.

Data analysis: In CE-1 lunar mission, the brightness temperature was surveyed near lunar noon at daytime. At that time, the solar irradiance is strongest, and it is an inflexion for lunar surface temperature. So, a static thermal equilibrium could be assumed at that time. In the static thermal equilibrium, the lunar surface temperature could be worked out easily with specific solar irradiance and incidence angle. Comparing to the maximum temperature at Apollo 15 and 17, it coincides well with the simulation. Hence, the assumption of a static thermal equilibrium at lunar noon is used to estimate the lunar surface temperature in this study. By analyzing the CE-1 brightness temperature, it shows an increasing trend with the lunar surface temperature as a whole (Fig.1).

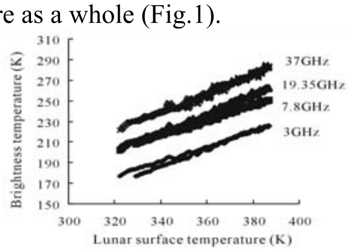

Fig.1. CE-1 brightness temperature change with lunar surface temperature in low latitude (60S~60N), data are got from MRM 2C scientific data (track No.381) in CE-1 lunar mission.

In lunar exploration of CE-1 microwave radiometer, besides the lunar surface temperature, topography, physical characters, thickness and structure of lunar surface might have a remarkable effect on the brightness temperature. To eliminate these effects, Apollo landing sites (Table 1) were discussed.

Table 1 Characters of Apollo landing site

Site	Coordinate	ε'[a]	ε''[a]	Thickness
Apollo 11	0.7ºN,24.3ºE	2.53	0.043	4.4[b]
Apollo 12	3.2ºS,23.4ºW	2.28	0.033	3.7[b]
Apollo 14	3.7ºS,17.5ºW	2.97	0.025	8.5[c]
Apollo 15	26.1ºN,3.7ºE	3.23	0.030	4.4[b]
Apollo 16	9.0ºS,15.5ºE	2.55	0.009	12.2[c]
Apollo 17	20.2ºN,30.8ºE	2.82	0.040	4.0[c]

a, Heiken et al., 1991; b, Cooper et al., 1974; c, Nakamura et al., 1975.

At these Apollo sites, the CE-1 lunar satellite flyby about 4 times in lunar day with the microwave radiometer work well in about one year. And the locations corresponding to those brightness temperatures analyzed in this study are projected in the Apollo sites, respectively (Fig.2).

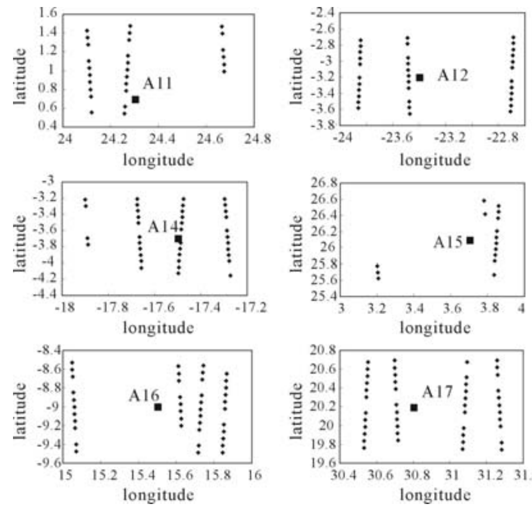

Fig.2. Distribution of CE-1 data points around the Apollo sites. Rectangles are the Apollo sites listed in table 1, and rhombuses are location of CE-1 data.

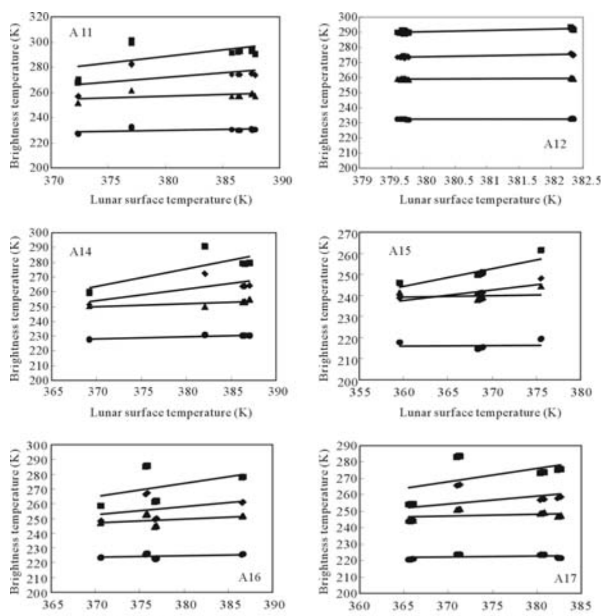

Fig.3. CE-1 brightness temperature changes with lunar surface temperature at Apollo sites. Rectangle, rhombus, triangle, and circle stand for the brightness temperature at 37GHz, 19.35GHz, 7.8GHz, and 3GHz, respectively.

Fig.3 shows the brightness temperature change with the lunar surface temperature at these Apollo sites. As a whole, the CE-1 brightness temperature increase with the lunar surface temperature and the gradient increase with the frequency. These are consistent with the results of theoretical analysis. It indicates that the brightness temperature is sensitive to the lunar surface temperature at high frequency. The change of lunar surface temperature might be shown better at 37GHz and 19.35GHz than 7.8GHz and 3GHz.

With the parameters in table 1, the temperature response factor at Apollo landing sites have been calculated. And it is compared to the results of CE-1 data analysis (Table 2). The theoretical temperature response factors are close to those of CE-1 data analysis at high frequency, except Apollo 16. From table 1, we could find that the ε" is very small at Apollo 16. Such a small ε" might not stand for the dielectric properties of the whole region. And it leads to the underestimation of temperature response factor at Apollo 16 landing site. The difference between β_{theo} and β_{data} decrease with the frequency increasing. It might indicate that the brightness temperature change less in low frequency than the theoretical estimation. The reason is that the thermal emission by the lunar subsurface play an important role to the brightness temperature at low frequency, and the simplification of thermal radiation transfer in theoretical analysis might enhance the contribution of thermal emission in lunar subsurface. By comparing the Apollo 14 and 16 to the other Apollo sites, the lunar soil thickness has little effect to the brightness temperature and temperature response factor.

Conclusion: By the analysis of theory and CE-1 data, it could be confirmed that the brightness temperture increases with the increase of lunar surface temperature. Comparing to all the four frequencies of CE-1 microwave radiometer, the brightness temperature is most sensitive to lunar surface temperature at 37GHz. And the brightness temperature is weakly affected by lunar surface temperature at 3GHz. The lunar surface temperature increase 1K might lead to the brightness temperature increase more than 0.8K at 37GHz, and increase about 0.1K at 3GHz. With the sensitivity of 0.5K, the CE-1 microwave radiometer could detect the lunar surface temperature change at 3GHz only when the change is larger than 5K. So, to study the lunar surface temperature, the brightness temperature at 37GHz might be the best choice. The temperature response factor trends to a constant when the lunar soil thickness is large enough. At the high frequency, the brightness temperature contains little information of subsurface. In this case, the temperature factor approximately equals to the emissivity of lunar surface. So, besides the lunar temperature, the brightness temperature might be used to interpret the information of emissivity.

References: [1] Cooper, M.R., Kovach, R.L., and Watkins, J.S. (1974), Rev. *Geophys. Space Phys.*, 12, 291~308. [2] Heiken, G., D. Vaniman, B. M. French (1991), *Cambridge University Press*, Cambridge, UK. [3] Nakamura, Y., J. Dorman, F. Duennebier, D. Lammlein, and G. Lathan (1975), *Moon*, 13, 3 ~15.

Table 2 Comparisons of temperature response factor at Apollo landing site

	3 GHz		7.8GHz		19.35GHz		37GHz	
	β_{theo}	β_{data}	β_{theo}	β_{data}	β_{theo}	β_{data}	β_{theo}	β_{data}
A11	0.309	0.117	0.566	0.248	0.776	0.577	0.858	0.908
A12	0.265	0.125	0.512	0.186	0.745	0.612	0.846	0.916
A14	0.183	0.134	0.385	0.262	0.63	0.556	0.765	0.886
A15	0.204	0.0023	0.417	0.067	0.656	0.496	0.777	0.843
A16	0.079	0.122	0.188	0.245	0.383	0.552	0.562	0.887
A17	0.277	0.0485	0.524	0.107	0.743	0.48	0.834	0.805