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ALMA Measurement of the Brightness Temperature of Ceres and Search for HCN

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Abstract

We obtained spatially resolved mapping of Ceres over its full rotation with ALMA 12 m array in Band 6 in three epochs in 2015 and 2017. In addition, we collected ACA Band 6 data in one of the 2017 epochs for a full rotation of Ceres to measure the disk-integrated lightcurve and to search for HCN. The disk-averaged brightness temperature of Ceres was measured to be 173±2 K in the 2017 epochs, but about 135±5 K in the 2015 epoch. The lightcurve shows a peak-to-peak range of about 4%. Thermal modeling indicates that the loss tangent of Ceres at 265 GHz might be much higher than those measured for lunar-like materials and Comet 67P/Churyumov-Gerasimenko, and its thermal inertia is likely > 30 tiu. No HCN emission is detected, with an upper limit production rate of $Q_{HCN} < 2\times10^{24}$ s^{-1}.

1. Introduction

Recent observations of Ceres by NASA's Dawn spacecraft suggested that the evolution and current status of this dwarf planet are significantly affected by water (liquid or ice, and hydrates) on its surface and crust [1]. Therefore, it is key to understand the thermal environment on and beneath the surface of Ceres in order to determine the existence, current and past state of surface and near surface water. In order to determine the thermal properties we imaged Ceres with ALMA in three epochs in October to November 2015, September and October 2017 with spatial resolutions of 50 – 100 km/beam. The ACA observations were conducted in October 2017 with a spectral configuration that covers the HCN (J=3-2) emission line at 265.89 GHz with a velocity resolution of 0.3 km/s. The primary goal of the 12 m observations was to map out the thermal inertia and layering on the surface of Ceres, in order to identify thermal anomalies that could either be the reservoir of water ice or host water ice in the subsurface. In this paper, we report the disk-integrated thermal flux and the modeling, as well as the results of HCN search.

2. Data reduction and calibration

The interferometer data are first calibrated with the standard calibration process, and then the spatially resolved images of Ceres at an average frequency of 265 GHz continuum were assembled in 5 to 10 min temporal cadence. The flux calibration is performed with the standard calibration procedure with the same reference quasar for all Cycles 4 and 5 data, but a different quasar had to be used for Cycle 3 data. The total flux of Ceres is measured by integrating over the disk of Ceres. The ACA lightcurve was generated by averaging the correlation data over everything at each sample at a temporal resolution of 30 s. The ACA spectral data were reduced by averaging all data points for each spectral channel, and binned into a resolution of 0.56 km/s, which is close to the expected thermal velocity on the expected surface temperature of Ceres.

3. Preliminary results

We produced high-fidelity lightcurves from the 12 m data of September 2017 and the ACA data of October 2017 (Fig. 1). The peak-to-peak amplitude is about 4%, consistent with previous observations at similar frequency [2, 3]. The nearly oblate shape and the low Bond albedo of Ceres of 3.7% [4, 5] suggest that the lightcurve variation is caused by the variations in the thermal properties possibly related to surface features.

We adopted the thermophysical model coupled with the radiative transfer model to model our disk-averaged brightness temperature. The contribution of subsurface emission is primarily determined by the loss tangent of the surface material on Ceres, which is largely unknown. Therefore, we assumed a range of loss tangent values from 0.0001 to 1, and a refractive index of 1.5 to calculate the disk-averaged brightness temperature at 265 GHz for thermal inertias from 10 to 100 tiu. The choice of refractive index does not significantly affect our results. Fig 2. shows that, for the measured brightness temperature of 173 K, the loss tangent of Ceres has to be > 0.1, which is much higher than the typical values measured for lunar like material [6, 7] and for comet 67P [8], which ranges between 0.004 and 0.04. High electrical loss might be related to relatively high electrical conductivity or resonant media, possibly associated with salt, water ice, and/or hydration on Ceres. Based on these models, the thermal inertia of Ceres is likely between 30 tiu and 200 tiu.

The spectrum of Ceres shows no evidence of HCN emission. The 3-σ noise level of the binned spectrum is 0.05 Jy. Assuming a rotational temperature of 23 K and a Haser model distribution, the upper production rate of HCN is estimated to be $Q_{HCN} < 2\times10^{24}$ s^{-1}. If assuming a comet-like HCN/H_2O ratio [9, 10], then the water production rate upper limit is 2×10^{25} s^{-1}, although this number is highly uncertain because the HCN/H_2O ratio for Ceres is completely unconstrained.

4. Summary and Conclusions

We measured the brightness temperature, the lightcurve of Ceres at 265 GHz with ALMA 12 m array data, and searched for HCN with ALMA ACA data using the J=3-2 emission line. The 4% lightcurve amplitude suggests slight variations in the surface and subsurface thermal properties. Thermal modeling suggests a high loss tangent possible, and a thermal inertia >30 tiu for Ceres. HCN search returns a negative result with an upper limit production rate constrained to about 2×10^{24} s^{-1}.

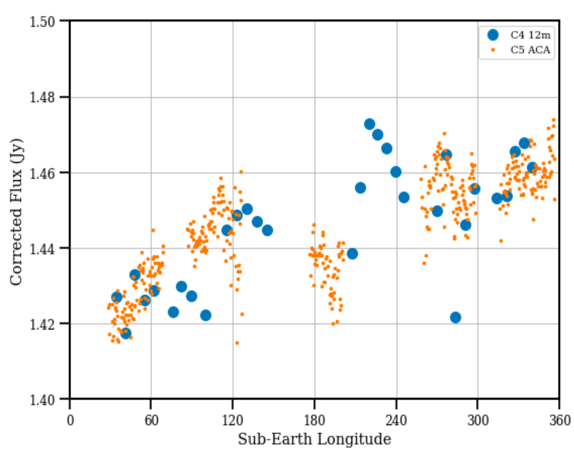

Fig. 1. The lightcurve of Ceres at 1.13 mm wavelength obtained in September 2017 from the 12-m array and in October 2017 from the ACA, both corrected to a common observer distance. The good agreement of the two lightcurves independently obtained from two epochs and two arrays suggests that the features in the lightcurves are most likely real.

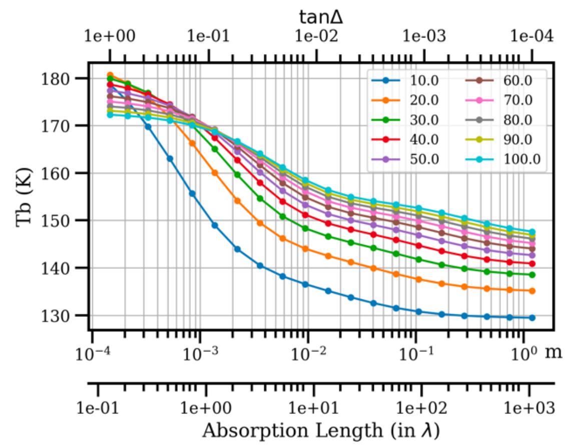

Fig. 2. The modeled disk-averaged brightness temperature of Ceres at the frequency of our observations, with respect to loss tangent for various thermal inertias. The top x-axis is loss tangent, the two bottom x-axes are electric absorption length in m (upper) and in unit of wavelength (lower). The lower the loss tangent is, the longer the absorption length is and the deeper temperature the observations probe, resulting in lower observed brightness temperature.

Acknowledgements

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References

[1] Sizemore, H. G., et al., 2019, doi: 10.1029/2018JE005699.
[2] Moullet, A., et al., 2010, AA 516, L10.
[3] Altenhoff, W.J., et al., 1996, AA 309, 953.
[4] Russell, C.T., et al., 2016, Science 353, 1008.
[5] Li, J.-Y., et al., 2019, Icarus 322, 144.
[6] Garry, B.L. & Keihm, S.J., 1978, 9th LPSC, 2885.
[7] Keihm, S.J. & Langseth, M.G., 1975, Icarus 24, 211.
[8] Schloerb, F., et al., 2015, AA 583, A29.
[9] Biver, N., et al., 2012, EMP 90, 323.
[10] Crovisier, J. et al., 2009, EMP 105, 267.