Understanding solar atmosphere by ALMA observations

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ALMA started solar observations with Bands 3 and 6 from Cycle 4. Millimeter waves at 100 GHz (band 3) and 240 GHz (band6) are radiated by free-free emission in the chromosphere, and brightness temperatures are directly related with electron temperatures by the Planck function. Before ALMA, observations of the chromosphere are mainly performed by absorption lines from UV to near IR. These lines are formed under non-local thermodynamically equilibrium, and it is difficult to interpret brightness temperatures directly with electron temperatures. Thus, ALMA opens a new window for temperature diagnostics in the solar atmosphere.

Although intensities in millimeter wave in a quiet sun are directly related with electron temperatures, where these emissions come from is not well understood. Numerical and observational comparisons between millimeter waves and UV lines are performed in the past. However, temperature structures in the solar atmosphere are complex and full of varieties. We cannot simply estimate the formation region of millimeter waves from the case studies. In order to understand temperature structures in solar atmosphere by ALMA, it is crucial not only to compare between multiwavelength observations but also to understand radiative processes of millimeter waves and chromospheric lines in multiple regions in the solar atmosphere.

We analyze ALMA data of a plage region observed in Cycle 4. We compare the ALMA data with vector magnetic field in the photosphere by Hinode/SP, transition-region images and spectra by IRIS, and chromospheric and coronal images by SDO/AIA. As a result, velocities of a moving feature in a stripe structure in ALMA data correspond to sound speeds in the chromosphere, and it is reasonable to interpret that millimeter waves are emitted from the mid-chromosphere. However, we do not find the same structures between millimeter waves and chromospheric images. In this presentation, we review the preceding studies on the formation region of millimeter waves in the solar atmosphere, introduce the plage observation, compare with numerical simulation of radiative transfer of millimeter wave and chromospheric lines, and discuss what ALMA is looking in the solar atmosphere.

Keywords: Sun, radiative processes, chromosphere

