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Millimetric observation of the solar chromosphere and space weather using the Nobeyama 45m radio telescope

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The atmospheric structure of the solar chromosphere is basic information to understand the heating mechanisms of the solar atmosphere and various solar phenomena. Hence, the investigation of the chromosphere is also important for the space weather. The main emission mechanism of the Sun in millimeter and submillimeter wavelength range is a thermal free-free emission from the chromosphere. This emission is formed under local thermodynamic equilibrium (LTE) conditions. The opacity of the thermal free-free emission is determined by the electron temperature and density. In addition, the Rayleigh-Jeans law can be applied in this wavelength range. Hence, the observed brightness temperature at several frequency bands can be converted into the thermal electron temperature of the radio source region. However, large millimeter and submillimeter telescopes usually cannot observe the Sun because they are not designed to observe such a high-brightness body. Hence, there have been only a few high-resolution solar observations at this wavelength range. In this paper, we report on the first single-dish observation of the chromosphere at 85 and 115 GHz with sufficient spatial resolution for resolving the sunspot umbra using the Nobeyama 45 m telescope. We used radio attenuation material, i.e. a solar filter, to prevent the saturation of the receivers. We found that the brightness temperature distribution at millimeter range strongly corresponds to the ultraviolet (UV) continuum emission at 1700 Å, at both active and quiet regions. The upper limit of the brightness temperature of the sunspot umbra is almost the same as that of the quiet region. However, the plage region exhibits a higher brightness temperature than the quiet Sun. The 45 m telescope has broad side-lobes, and the sunspot region is surrounded by a brighter plage region. Hence, the actual brightness temperature of the umbra region should be lower than the observational result. This result is inconsistent with the preexisting chromospheric models, which predict that the sunspot umbra should be brighter than the quiet region at millimeter range. This result suggests that an actual height of the transition region can be lower than that of the pre-existing models.

Keywords: Sun, Radio radiation, millimeter, Chromosphere, space weather