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Model simulations of ionizations at the planetary atmosphere induced by energetic particles from a central star

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We are performing monitoring observations of millimeter-waveband spectral lines of carbon monoxide (CO) in the middle atmospheres of Mars and Venus with a 10-m telescope, Solar Planetary Atmosphere Research Telescope (SPART), to understand how the activities of central stars influence the middle and lower atmospheres of terrestrial planets in the solar system and of exoplanets.

For understanding the electron production rate at different altitudes of the planetary middle atmosphere induced by incident energetic particles from planets, we developed an analytical model, using which ionization losses are numerically calculated on the basis of the Bethe-Bloch formula. The ionization of carbon dioxide induced by the energetic particles is considered to increase the production rate of CO. With a basic model under conditions of relatively great solar proton events with incident-proton energies of less than 1 GeV, it was found that the ionization rate reaches its maximum at an altitude of 80-90 km in the Venusian atmosphere and at the ground in the Martian atmosphere. In addition, we also developed a Monte-Carlo simulation model using the Particle and Heavy Ion Transport code System (PHITS). With this model, highly accurate calculation can be achieved by implementing the latest nuclear-reaction database and algorithms for the transport processes including several particles such as electrons, positrons, pions, neutrons, muons, kaons, and photons, in addition to protons, neutrons, and photons. We found that the results of this Monte-Carlo model are in good agreement with those of the above analytical model. The calculated results also suggest that the effect of neutrons produced on the ionization processes is greater than that of protons produced at a low altitude in Venus (<80-km altitude).

In this conference, we will present the results of these models.

Keywords: terrestrial planet, planetary atmosphere, flare and CME, high-energy particle, heterodyne spectroscopy, radio telescope