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Influence of solar energetic particles on unmagnetized celestial bodies
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High energy particles associated with solar flares (solar energetic particle; SEP) significantly influence the atmosphere and the surface of non-magnetized planetary bodies. In this presentation, we will show recent observations conducted in the vicinity of Mars and Venus demonstrating the importance of the SEPs on those bodies. In addition, we will also discuss the expected SEP effects on non-atmospheric bodies, such as the Moon.

Without the shielding by the magnetosphere, unmagnetized bodies are directly exposed to the SEPs. As a result, the response of the planetary bodies to the SEPs would be expected to be immediate and harsh. During the famous Halloween event in 2003, Mars Global Surveyor observed a compression of the Martian plasma environment and resulting enhancement of the magnetic field in the ionosphere caused by SEPs and CMEs (Crider et al., 2005). Signatures of the entry of the solar wind protons into the low altitude in the dayside and the enhancement of cyclotron waves associated with proton and oxygen ions in the nightside were found (Espley et al., 2005). These imply the increase of the atmosphere erosion, mainly oxygen ions, into space. During other moderate SEP events, Morgan et al. [2006] reported evidence for an additional ionospheric layer using active radar experience on board Mars Express, indicating the extrordinaly ionization of the atmosphere by the SEPs.

On December 5, 2006, one of the largest flares erupted from the east limb of the Sun. This was a geo-effective flare, but it influenced a wide area of the inner solar system including Mars (about 160? west of the Earth) and Venus (about 160? east of the Earth). Plasma sensor packages, ASPERA-3 and -4 on board Mars Express and Venus Express respectively, detected signatures of the SEPs as a high background count rate of the sensors. The high background condition lasted for a few days, and a higher (about 10 times more than usual) flux of outflowing oxygen ions was detected directly in the plasmatail for the first time. The increasing outflow of oxygen ions occurred before the arrival of the associated CMEs (Futaana et al., 2008). These observations indicate that the SEPs do influence the upper atmosphere to increase the escape of oxygen ions eventually, and thus, the high energy particle environment is one of the significant keys to investigate the atmospheric evolution of the solar system bodies in geological time scales.

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