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An MHD simulation study of magnetic reconnection in the dayside Venusian ionosphere

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Venus and Mars have no significant global intrinsic magnetic field. However, it is considered that magnetic reconnection can occur in their ionospheres and magnetotails through the direct interaction with the solar wind. The occurrence frequency distribution of magnetic reconnection at the 400km altitude of Mars has been obtained from magnetic field and electron observations by Mars Global Surveyor [Halekas et al., 2009], but the occurrence frequency at other altitudes is yet to be obtained because of the limitation of its trajectory. In addition, the role of magnetic reconnection in determining the structure and dynamics of the ionospheres of unmagnetized planets has been unclear because there is no observation that constrains the relation among them. Not only observational studies but also theoretical studies have been needed for further understanding magnetic reconnection around unmagnetized planets, and we have studied magnetic reconnection caused by the rotation of interplanetary magnetic field (IMF) in their dayside ionospheres, using a two-dimensional multi-species magnetohydrodynamic (MHD) simulation.

We would infer that magnetic reconnection has a possible relation to some unexplained phenomena observed around the ionospheres of Mars and Venus, considering the dependences of their occurrence rate and spatial distribution on the rotation of IMF. One example is the ejection of plasma 'clouds' from their ionospheres [Brace et al., 1981; Crider et al., 2004]. The occurrence rate of this phenomenon is relatively high when the direction of IMF changes [Ong et al., 1991], and plasma 'clouds' can be ejected by magnetic reconnection caused by the IMF rotation. Another example is the existence of small magnetic rope-like structures called 'flux ropes' [Russell and Elphic, 1979; Cloutier et al.,1999]. When the solar wind dynamic pressure is low, 'flux ropes' are most often observed in the lower ionosphere [Elphic et al., 1983]. So far some models to generate the 'flux ropes' in the ionospheres have been proposed, e.g., Kelvin-Helmholtz instability at the ionopause [Wolff et al., 1980] and nonlinear effects in the lower ionosphere [Kleeorin et al., 1994], and Dreher et al. [1995] suggested that magnetic reconnection due to the IMF rotation generates 'flux ropes' using a numerical simulation.

In this presentation, we will show the time evolution of magnetic reconnection in the dayside Venusian ionosphere and the structure of plasmoids obtained from the two-dimensional multi-species MHD simulation. We will present, in particular, the altitudes where magnetic reconnection effectively develops, the time scale of the development of magnetic reconnection, and the spatial scale of plasmoids generated by the reconnection. Our simulation result shows that multiple magnetic reconnections occur in the current sheet and plasmoids are generated above 240 km altitude, where the Lundquist number is more than 10^6. It has been found that the inflow condition of the current sheet and the growth time of the fast resistive magnetic reconnection [Loureiro et al., 2007] are important factors in determining the altitudes where reconnection effectively develops. Plasma flows into the current sheet from the both side of it above a certain altitude, and reconnection is likely to occur under this inflow condition. However, the intrinsic downward flow in the Venusian lower ionosphere inhibits plasma from flowing into the sheet, which diminishes the reconnection rate below a certain altitude. In addition, we find that the growth time at the lower regions where the fast resistive reconnection does not occur is comparable to or shorter than the time scale of the transportation of magnetic filed. We will examine whether the magnetic reconnection caused by the rotation of IMF generates the ejection of plasma 'clouds' and the 'flux ropes'.

Keywords: Venus, ionosphere, reconnection