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Study of fast resistive magnetic reconnection in the upper atmosphere of Venus

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Although Venus has no intrinsic magnetic field, magnetic field exists in the upper atmosphere through the interaction of the solar wind. In the dayside ionosphere of Venus, small magnetic rope-like structures called 'flux ropes'were often observed when solar wind dynamic pressure was low. Pioneer Venus Orbiter (PVO) observed flux ropes on more than 40% of the orbits passing through the dayside lower ionosphere, and founds its occurrence rate maximizes at altitude170km [Elphic et al., 1983].

So far some models to generate flux ropes have been proposed (K-H instability [Wolff et al., 1980], nonlinearity associated with the Hall effect [Kleeorin et al., 1994]), but the generation mechanism is not yet understood. In this study, we propose a new model to generate flux ropes based on recently proposed fast resistive magnetic reconnection [Loureiro et al., 2007]. This fast resistive reconnection occurs in a very long Sweet-Parker (SP) current sheet. The growth rate in the linear stage is proportional to the one-quarter power of the Lundquist number, and the current sheet is unstable under the condition that the Lundquist number is more than 10 to the power of 4. According to MHD simulation results [Samtaney et al., 2009], a chain of plasmoids is formed after reconnection at many points in the current sheet. Such a chain structure is similar to flux ropes. In the dayside ionosphere of Venus, a very long current sheet can form, where the fast resistive magnetic reconnection occur. Therefore, we considered a model to generate flux ropes through the formation of a very long current sheet and subsequent fast resistive reconnection in the dayside ionosphere of Venus, and then examined its applicability. The outline of the generation model we propose in this study is as follows: First, the interplanetary magnetic field (IMF) carried by the solar wind penetrates into the dayside lower ionosphere when solar wind dynamic pressure is high. Then, the field reversal structure resulting from an IMF turning penetrates there, and a very long SP current sheet is created. Finally, flux ropes are generated through the fast resistive reconnection in the current sheet.

In order to examine the applicability of our model, we estimated the altitude profiles of the Lundquist number, the growth rate of the fast resistive reconnection, and the SP current sheets thickness by using the result of a hybrid simulation in the upper atmosphere of Venus [Terada et al., 2002]. From the profiles, we chose the altitudes corresponding to specific Lundquist numbers, and we consider that the fast resistive reconnection can occur if the following conditions are satisfied at the chosen altitudes. First one is that the fast resistive reconnection can grow sufficiently. Second one is that the SP current sheet thickness is larger than the observed flux rope radius [Elphic et al., 1983]. Consequently, we found that our model is applicable between near 170 km altitude (Lundquist number is 10 to the power of 5 at this altitude) and near 230 km altitude (Lundquist number is 10 to the power of 6 at this altitude). We will show the result of MHD simulation performed with the parameters at these applicable altitudes.

Keywords: reconnection, ionosphere, Venus