Double Arc Instability in the solar corona

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Abstract

Solar explosive phenomenon such as solar flare or coronal mass ejection impact the electromagnetic environment around the Earth. On the solar explosive phenomena, twisted flux rope was sometimes observed to be ejected. It suggests that the stability of flux rope is related to the occurrence of solar explosive phenomenon. To elucidate the stability, we modeled flux rope as current loop and analyzed its stability based on the theoretical framework developed by previous studies. Torus Instability (TI) was proposed by Kliem & Toeroek (2006) to explain the mechanism of solar eruption. Based on the results, they suggested that the stability is determined by "decay index", which is an index of attenuation of external magnetic field from torus axis. Although TI is often used as the criteria of explosive phenomenon recently, how the loop becomes unstable is still unclear. Although various scenarios have been suggested, the tether-cutting reconnection scenario suggested by Moore et al. (2001) is widely accepted. However, although the tether-cutting reconnection forms a double arc loop before eruption, the stability of double arc loop has not been analyzed yet.

Thus, the objectives of this study is to analyze the stability of double arc loop theoretically. We model a double arc loop as two circular tori connected each other. The equations of equilibrium state and the ideal MHD constraint, which is the conservation of magnetic flux below the double arc, are derived, and we solve them numerically. As the result of analysis, we found that double arc current loop can be destabilized for any type of external field, and the critical height of the instability is much lower than that of TI. We also found that the decay index is not relevant to the double arc instability (DAI). On the other hand, by calculating the criteria for DAI under force-free field, we found that necessary condition for DAI is that twist of magnetic field line is larger than one half. In addition, we demonstrate that the dynamics of DAI can reproduce the observational feature that fast eruption occurs after slow-rise phase. These results show that solar explosive phenomenon can occur as a result of destabilization of double-arc loop which is formed by tether-cutting reconnection before flux rope become torus shape. Thus, it suggests that the onset of solar explosive phenomena may be determined by the DAI.