

A critical review on solar cycle variation of interplanetary magnetic flux ropes

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The interplanetary magnetic flux rope (IFR) has been a subject of extensive research activity since its discovery in 1981 as a key structure in the solar wind that provide important information on the solar eruption phenomena and on how the southward magnetic fields are carried from the Sun to the Earth. In this review, we discuss solar-cycle variation of occurrence frequency of IFRs that still remains unsettled, based on our own results. First, we have found more than 500 IFRs in the time period from 1995 to 2009, whereas the survey by Lepping et al. (AnnGeo, 2006) identified 82 IFRs during 1995-2003. The difference mainly comes from the fact that their survey was not successful in identifying IFRs when the spacecraft passed only near the surface of IFRs. Our result indicates that the rate of IFR occurrence to the ICMEs should be much higher than those which were suggested by previous evaluation. Secondly, the following trend is clearly seen: namely, the occurrence rate of IFRs increases rapidly after the 1996 solar minimum, reaches maximum in 1998, and then decreases monotonically toward the next solar minimum. This trend seems in concert with the trend of the magnetic butterfly diagram (Hathaway, <http://solarscience.msfc.nasa.gov/images/magbfly.jpg>). The time of rapid increase of IFR rate coincides with the time when the active regions begin to emerge at mid latitude (Li et al., Solar Phys., 2011). In addition, Marubashi et al. (Solar Phys. 2015) found that 2/3 of IFRs were erupted from neutral lines at the Hale boundaries, using another data base. An important implication is that the IFR occurrence should be closely related with the evolution of large-scale solar magnetic fields. An interesting question arises also: how the Hale boundaries are preferably selected for any instabilities to occur that lead CMEs. In a more general term, interrelationships among the occurrence of IFRs, CMEs, flares, and sunspot cycle seem to be an unsettled problem.

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