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Magnetic Flux Ropes in Space Plasmas

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Magnetic flux ropes are a type of space plasma structures, exhibiting a set of observational signatures based on in-situ spacecraft measurements. In the solar wind, they are found to possess a wide range of scale sizes [1,2] (see also *fluxrope.info*), ranging from a few thousand kilometers to a few tens of an AU.

The large-scale flux ropes, i.e., magnetic clouds (MCs), are typically embedded within interplanetary coronal mass ejections (ICMEs), originating from the Sun. The modeling of their magnetic field configurations, based on in-situ spacecraft measurements, can be carried out through a χ^2 minimization process, yielding an approximate characterization of the local topology described by an analytic solution for the structure traversed by the spacecraft. One important factor affecting such a procedure, though, is a proper estimation of the uncertainties associated with the time-series data being fitted. Such uncertainties are associated with the relatively small-scale (micro-scale) fluctuations superposed on the large-scale (macro-scale) structures of interest. Therefore, one proper way to provide such estimates is to calculate a root-mean-square value for the data point over, e.g., a 1-hour interval by using the underlying higher-resolution data [3.4].

An approach was developed recently by using an analytic model with quasi-3D spatial dependence and applied to a number of MC events [3-6]. Besides a proper treatment of the uncertainties for the optimal fitting procedure, it was demonstrated that this approach is also directly applicable for multi-point in-situ spacecraft measurements across the same structure by combining the χ^2 minimization processes for two or more datasets along separate paths. Figure 1 below illustrates such a case study[6], showcasing a more general “twisted ribbon” type magnetic field line configuration, where the field-line bundle winds along one direction, markedly lacking a straight central field line. The model solution simultaneously fits two sets of spacecraft data along two distinct paths.

Additional event studies will be shown to demonstrate the merit of this approach and its impact on the interpretation of the flux rope formation process on the Sun. The connections of these results based on in-situ measurements, limited in spatial extent, to the remote-sensing observations [5,7] and global MHD simulations, will be discussed.

Lastly, the flux rope structures near Earth, manifested as flux transfer events (FTEs) at the Earth’s magnetopause, will be examined [8]. An attempt to relate the flux rope formation processes across different space plasma regimes will be made to gain insight into the fundamental physical process of magnetic reconnection.

References

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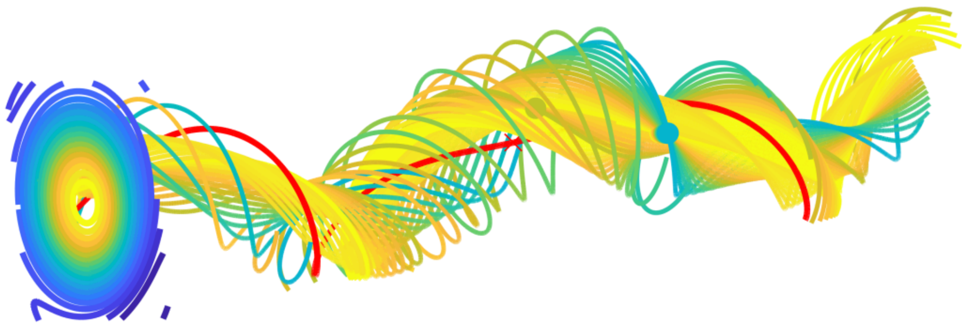

Figure 1. In a view toward the Sun (North is upward), selected magnetic field lines, originating from a unipolar cross-section area, are extending in the approximate East-West (horizontal) direction and color-coded by the axial field strength. The red line highlights the field line with the maximum strength. The two large dots near the middle and to the West denote two separate spacecraft paths across this structure.