Reconstruction of magnetic flux tubes and magnetic field lines from observational and simulated data

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Summary

We consider different methods of tracing of magnetic flux tubes from observational solar data and simulated examples and discuss to what extent the obtained structures are applicable for calculation of some topological invariants.

1 Magnetic flux tubes in solar data

Topology of magnetic flux tubes plays an important role in MHD processes. A set of invariants, developed in [1], acts as a natural limiter for enhancing and relaxation of magnetic field. Remarkably, these invariants remain an intuitive topological meaning in terms of individual flux tubes, which can be also extended on infinite number of tubes after an appropriate adaptation [2]. From a theoretical point of view, presentation of magnetic field as a set of flux tubes allows to introduce topological invariants that describe higher helicity moments and advanced parameters of knottedness. On the other hand, practical implementation of these concepts require detailed information about magnetic field. Typically we are very limited in observation of magnetic fields of astrophysical objects and can operate only with its small parts. Complex extrapolation methods give us information in 3D volume, but we are basically unable to come out the bounding box. However, finite resolution of data and discretization of signal are the main problems for applying theoretical formulas. We consider different approaches to the problem of tracing of magnetic flux tubes in observational and simulated data and discuss which of them are the most suitable for MHD problems.

2 Algorithmic ways of flux tubes tracing

Classical approaches to the flux tubes tracing usually reconstruct individual magnetic field lines and consider them as thin flux tubes. However, it does not provide a flux balance at the footpoints of flux tubes. A natural idea is to set a number of field lines proportional to the strength of magnetic field, but it trace a central line of the tube rather than its 3D shape. We introduce a method, that considers flux tubes as clusters composed from individual magnetic field lines. The procedure of clustering of many field lines can be adjusted in a such way that provides both minimal flux disbalance and lateral diameter of tubes. The method also gives an optimal number of clusters. We demonstrate that the algorithm works reasonably well in both observational and simulated data and enables topological characterisation of individual flux tubes and its mutual knottedness.

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References

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