Understanding the Internal Magnetic Field Configurations of ICMEs using 20+ years of Wind Observations

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Abstract Interplanetary Coronal Mass Ejections (ICMEs) often contain well- organized magnetic structures, generally consistent with magnetic flux ropes. In those cases, their 3D magnetic field topology can be reconstructed via idealized magnetic flux rope models. Unfortunately, the various models do not produce consistent results and there are disagreements between reconstructions based on imaging and in-situ data. To understand better the status of the internal magnetic field of ICMEs, we take advantage of the 20+ years of Wind observations of transients at 1 AU to compile a comprehensive database of ICMEs through three solar cycles, from 1995 to 2015. Our catalog is publicly available at wind.gsfc.nasa.gov. We identify and collect the properties of 342 ICMEs and 301 with organized magnetic field signatures. To allow for departures from idealized magnetic configurations, we introduce the term of 'Magnetic Obstacle' (MO) to signify the possibility of more complex or distorted flux rope configurations.

To quantify the asymmetry of the magnetic field strength profile within these events, we introduce the Distortion Parameter (DiP) and calculate the expansion velocity within the magnetic obstacle. We perform a statistical study of these two parameters, to find: (1) Only 34% of the events show symmetric magnetic profiles and small enough expansion velocity to be compatible with the assumption of an idealized cylindrical static flux rope. (2) 40% of the events do not show the expected relationship between expansion and magnetic field compression in the front, 10% show contractions and 30% show magnetic field compression in the back. None of the three categories do conform with the assumptions of currently-used reconstruction models and hence the results are suspect. (3) We derive an empirical law between DiP and expansion velocity that is the first step towards improving reconstructions models with possible applications to Space Weather studies. We also evaluate the forces acting on the ICMEs. We find that only at speeds > 600 km/s or fields above 22 nT, do the kinetic or magnetic energy dominate the ICME evolution. The results of this study should aid in the development of more sophisticated reconstruction and better understanding of the discrepancies between image-based and in-situ reconstructions.