How to find magnetic nulls and reconstruct field topology with MMS data?

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In this study, we apply a new method—the first-order Taylor expansion (FOTE)—to find magnetic nulls and reconstruct magnetic field topology, in order to use it with the data from the forth-coming MMS mission. We compare this method with the previously used Poincare index (PI), and find that they are generally consistent, except that the PI method can only find a null inside the spacecraft (SC) tetrahedron, while the FOTE method can find a null both inside and outside the tetrahedron and also deduce its drift velocity. In addition, the FOTE method can (1) avoid limitations of the PI method such as data resolution, instrument uncertainty (Bz offset), and SC separation; (2) identify 3D null types (A, B, As, and Bs) and determine whether these types can degenerate into 2D (X and O); (3) reconstruct the magnetic field topology. We quantitively test the accuracy of FOTE in positioning magnetic nulls and reconstructing field topology, by using the data from 3D kinetic simulations. The influences of SC separation (0.05~1 d_i) and null-SC distance (0~1 d_i) on the accuracy are both considered. We find that: (1) for an isolated null, the method is accurate when the SC separation is smaller than 1 d_i, and the null-SC distance is smaller than 0.25~0.5 d_i; (2) for a null pair, the accuracy is same as in the isolated-null situation, except at the separator line, where the field is nonlinear. We define a parameter in terms of the eigenvalues of the null to quantify the quality of our method—the smaller this parameter the better the results. Comparing to the previously used one, this parameter is more relevant for null identification. Using the new method, we reconstruct the magnetic field topology around a radial-type null and a spiral-type null, and find that the topologies are well consistent with those predicted in theory. We therefore suggest using this method to find magnetic nulls and reconstruct field topology with four-point measurements, particularly from Cluster and the forth-coming MMS mission. For the MMS mission, this null-finding algorithm can be used to trigger its burst-mode measurements.

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