Validation of estimated interplanetary flux rope axial direction using internal plasma motions: benchmark test

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Interplanetary flux rope (IFR) is a structure with helical magnetic field lines wrapping around a central axis to form a flux rope structure. Accurate estimation of this structure is important for improving the space weather forecasting and understanding the evolution of IFR. Local structures of IFRs have been investigated by many model fittings and reconstruction method. However, the outputs of these model fittings and reconstruction method are often different. The chirality and magnetic flux of corresponding flux rope at the Sun are often compared with those of IFR to check the validity of estimation of IFR properties, but it is questionable whether this consistency check guarantees the validity of IFR axis direction which is one of the important properties of IFR. In this study, we propose a method that validates IFR axial direction based on plasma motion. It is known that the radius of IFRs often expand or sometimes contract during the passage of IFR through a spacecraft and if the expansion or contraction exist, the direction of plasma motion in IFR may be perpendicular to IFR axis in the frame comoving with the IFR. This suggests that plasma velocity in IFR reflects the axial direction of IFR. We test the method for a well-investigated IFR event on May 21-22, 2007. The magnetic field structure of this event has already been investigated by Liu et al. (2008) using multi-spacecraft measurements at STEREO-B, ACE, Wind, and STEREO-A and other researches (e.g. Kilpua et al. 2009) which report similar axial directions to that of Liu et al. (2008). Herein, We consider that the axial direction determined by them is correct since Liu et al. (2008) found that output from reconstruction at STEREO-B agrees fairly well with the observations at ACE and Wind. We fit the cylindrical and toroidal IFR models (Marubashi et al. 2007) to this event and then apply our validation method proposed in this study to the outputs from the fittings. We checked whether the outputs with the correct axial direction are judged to be valid and vice versa. We find that the fitting result with correct axial direction is judged valid. However, our validation method also judged some fitting results with wrong axial direction to be valid. We need to improve our validation method to make it work well.

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