MHD TRAVEL TIME IN THE MAGNETOTAIL AND ITS IMPLICATIONS FOR TIMING OF SUBSTORM PROCESSES

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An accurate estimate of the time required for a disturbance in the magnetotail to propagate to the ionosphere is needed in order to establish the time history of phenomena related to substorms. Recent THEMIS observations of the 26 February 2008 substorm have found that the time delay from a substorm onset at X = -20 R_E in the magnetotail to the corresponding auroral intensification in the ionosphere can be as short as 96 sec, calling into question whether or not Alfven waves can propagate fast enough to serve as an agent connecting the two phenomena. Using empirical models of magnetic field and plasma parameters, we have calculated the minimum time for an MHD wave to travel from a substorm onset in the magnetotail to the ionosphere. The shortest time delay can be shown to correspond to propagation along the so-called Tamao travel path, which consists of an earthward-propagating segment in the equatorial plane in which the disturbance is carried by the fast mode and a field-aligned route to the ionosphere in which the disturbance propagates in the Alfven mode. Our results show that the travel time of an MHD wave along the Tamao path is a strong function of the source location and the latitude of the ground observer. For a source at X = -20 R_E, the Tamao travel time can within 90 sec to ground stations connecting to magnetic field lines within 10 R_E but outside the plasmasphere. It is therefore feasible for an impulse generated by a substorm onset at X = -20 R_E to be carried by MHD waves and reach the ionosphere within 100 sec. However, travel delays on paths to the high-latitude ionosphere and the low-latitude ionosphere are longer. The fact that auroral intensification usually starts at low auroral latitudes and propagates poleward is a natural consequence of MHD wave propagation, and the onset location in the magnetotail should not be estimated by mapping along the magnetic field between the first appearance of auroral intensification in the ionosphere and the magnetotail.

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