Reanalysis of Some CLUSTER Bow-Shock Crossings With an Optimized Timing Method

Gérard M. Chanteur
Université Pierre et Marie Curie (CNRS), LPP - Couloir 24/34 - 4ème et 5ème étage - B.C.90, PARIS CEDEX 05, France
(gerard.chanteur@lpp.polytechnique.fr)

When a shock is moving through a cluster of spacecraft, the normal \( N \) to the shock and the velocity of the shock along \( N \) can be determined from the crossing times of the different spacecraft assuming that the shock is planar and moves without deformation or rotation during the time interval of the encounter. For a cluster of four spacecraft there are six pairs of spacecraft, each one giving raise to a scalar equation relating the vector position \( R \) from the first to the second spacecraft, the normal vector \( N \) and the time lag \( D_t \) : \( R \cdot N = V D_t \). This over-determined system of six equations is solved by computing the pseudo inverse of the matrix \( M \) acting on the normal vector on the lhs of the equation. Thus the system is modified by attributing a priori a positive weight to each equation (\( w_j, j=1 \) to 6) the sum being constrained to 1. Then a statistical ensemble of 6-uplets (\( w_j, j=1 \) to 6) is built ; for each element of this ensemble we compute the condition number of matrix \( M \) and we look for the 6-uplet giving the lowest condition number. This procedure warrants the best accuracy of the pseudo-inverse of \( M \) and hence the best estimate of the normal vector \( N \). Adding random perturbations to \( M \) and to the time lags allows to estimate the uncertainties on \( N \) and \( V \) through simulations. This optimized timing method is applied to reanalyze some crossings of the terrestrial bow-shock by CLUSTER and the results are compared to the results obtained by the standard method using the reciprocal vectors defined in the ISSI report SR-008 « Multi-Spacecraft Analysis Methods Revisited » published in 2008. A similar method has been applied to the determination of wave vectors of chorus elements observed by MMS in the inner magnosphere.