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Intermediate Shocks: Real or Imaginary?

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One of the most fundamental yet unsettled issues in magnetohydrodynamics (MHD) is the presence (or absence) of the so-called intermediate shock waves. Just as the fast and slow shocks may be considered as the steepened, finite-amplitude versions of their linear wave counterparts, the intermediate shocks may be realized via steepening of finite amplitude intermediate waves, as first demonstrated by high-precision numerical simulations [1-3]. Certainly, the intermediate shocks satisfy the Rankine-Hugoniot conditions, upstream and downstream flows are respectively supersonic and subsonic to the intermediate speed, and the entropy increases across the shock. Nevertheless, the intermediate shocks were considered non-existent in reality, as they do not satisfy the "evolutionary conditions [4, 5]," i.e., infinitesimally small perturbations given to the shock cannot be resolved as a superposition of waves outgoing from the shock due to the lack of degrees of freedom (=number of waves).

On the other hand, it has been proposed that this entire argument can drastically be altered when dissipation is included in the plasma, no matter how small the dissipation may be [6-8]. When dissipative wave modes are included, arbitrary perturbations given to the shock can be expressed as a superposition of outgoing wave modes. Therefore, the intermediate shocks are evolutionary in dissipative MHD, and hence, in a real plasma.

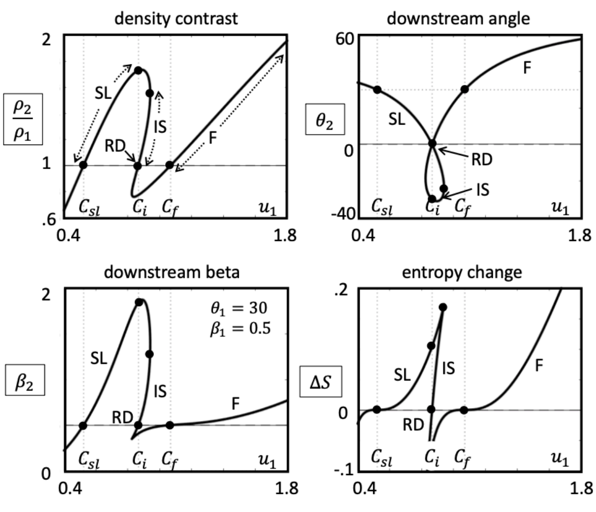

Figure 1: Density contrast, downstream magnetic field angle, downstream beta ratio, and the entropy increase across the shock plotted versus the upstream flow speed. C_f, C_i, and C_{sl} stand for the fast, intermediate, and slow wave speeds. The part denoted IS is the intermediate shock we consider here (among other possible IS's).

In the presentation, we will show that the waves incident to the intermediate shock generate waves in other modes (including the dissipative modes) by a "strong" mode conversion, and the distribution of waves can be uniquely determined across the shock. After making a remark on the uniqueness to the MHD Riemann problem [9,10], we will argue that it is worthwhile trying to detect the intermediate shocks by spacecraft observations [11-13] given the recent development of accurate and fine resolution measurements and data analysis techniques.

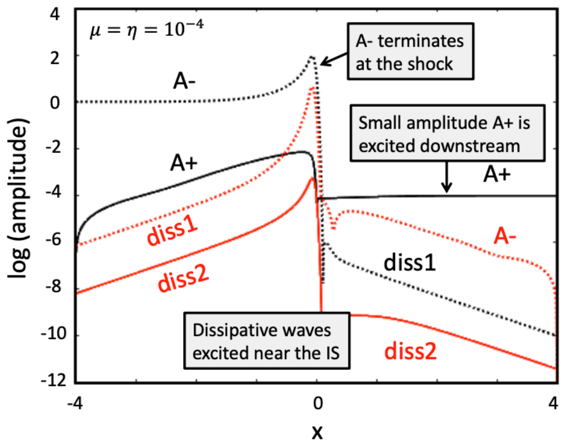

Figure 2: Logarithmic amplitude of various waves near the intermediate shock at x~0. A+/A- denote the Alfven waves with positive/negative phase velocities, and diss1 and diss2 are two dissipate wave modes.

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