Magnetohydrodynamic shocks revisited: magnetically constraining the upstream solar wind condition

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Magnetohydrodynamic (MHD) shocks are commonly found in various space and astrophysical systems. One often encounters the problem that only the magnetic field data are available when studying interplanetary shocks and planetary bow shocks in the solar system, and not the plasma data due to instrumental and/or telemetry limitations. We aim to reveal the mathematical structure of the MHD Rankine-Hugoniot relation under the condition that magnetic field changes across the shock are known, which can be devised into a diagnosis tool to constrain the shock parameters. The perturbative solution is already known for the Rankine-Hugoniot equation. The solution is combined with the condition of de Hoffmann-Teller frame for the vanishing convective electric field, and we obtain a two-dimensional matrix equation for the density jump and the Alfven Mach number. The lesson is that the shock parameters (density jump and Alfven Mach number) are analytically obtained by inverting the MHD Rankine-Hugoniot equation under the condition that the plasma beta is either a-priori set or known. Further numerical studies indicate that the presented shock jump estimation works particularly well for quasi-perpendicular shocks. Moreover, a test case with the Earth bow shock crossing data supports our theoretical development. The presented method opens the door to determine or constrain the shock parameters even if the data are limited to magnetic field only.