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Erosion, Heating, and Acceleration of Magnetic Cloud as Impacted by Fast Shock

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The impact of an overtaking fast shock on a magnetic cloud (MC) is a pivotal process in CME–CME (CME: coronal mass ejection) interactions and CME–SIR (SIR: stream interaction region) interactions. MC with a strong and rotating magnetic field is usually deemed a crucial part of CMEs. To study the impact of a fast shock on an MC, we perform a 2.5 dimensional numerical magnetohydrodynamic simulation.

Two cases are run in this study: without and with impact by fast shock. In the former case, the MC expands gradually from its initial state and drives a relatively slow magnetic reconnection with the ambient magnetic field. Analyses of forces near the core of the MC as a whole body indicates that the solar gravity is quite small compared to the Lorentz force and the pressure gradient force. In the second run, a fast shock propagates, relative to the background plasma, at a speed twice that of the perpendicular fast magnetosonic speed, catches up with and takes over the MC. Due to the penetration of the fast shock, the MC is highly compressed and heated, with the temperature growth rate enhanced by a factor of about 10 and the velocity increased to about half of the shock speed. The magnetic reconnection with ambient magnetic field is also sped up by a factor of two to four in reconnection rate as a result of the enhanced density of the current sheet, which is squeezed by the forward motion of the shocked MC.

The upstream fast magnetosonic Mach number is about 2 before entering the MC, about 1.4 in the center of the MC, and rises back to about 1.7 after exiting the MC. This manifests that the fast shock does not degrade into a fast wave in the low beta environment of the MC but only weakens in the strength. Furthermore, after overtaking the MC, the shock strength is weaker than the initial state, probably due to the interaction with the MC.

Therefore, the impact of the magnetic cloud by an overtaking fast shock make the geo-effect of the MC more complicated: (1) on one hand, the erosion of the magnetic cloud and the weaken may mitigate the effect of space weather; (2) on the other hand, the heating and acceleration of MC after the impact may aggravate the space weather effect.