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Characterizing Plasmas Produced by Hypervelocity Impacts in Space[1]

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Satellites experience hypervelocity impacts from meteoroids, dust, and orbital debris. A micro projectile striking a satellite at hypervelocity speeds can vaporize and ionize material forming craters and a plasma that expands rapidly into the surrounding vacuum. Various instruments on several spacecraft have measured electromagnetic signals correlated with dust impacts. Understanding the behavior of impact-produced plasmas is not only of academic interest but vital to spacecraft missions since it can damage key sensors and components. The technology available for ground-based experiments can only probe a limited range of projectile mass and velocity. Theoretically and computationally, the problem covers orders of magnitude in spatial and temporal scales as well as multi-disciplinary physics (e.g. solid mechanics, high-energy density physics, phase change and ionization, the transition between highly collisional to collisionless state, and spacecraft engineering). We discuss the behavior of plasmas produced by hypervelocity impacts. Experiments using a Van de Graaff accelerator have demonstrated that hypervelocity dust impacts can produce electromagnetic radiation that propagates away from the impact point. We simulate the process by combining an MHD/hydrocode for the impact and a particle-in-cell code for plasma expansion. The simulations are used to examine physical mechanisms that could produce the electromagnetic signals measured both on the ground and by instruments in space. We discuss a proposed in-situ experiment for characterizing plasmas generated by hypervelocity impacts. Understanding the effects of dust impacts and associated plasmas is necessary for mitigation of electrical interference and diagnosis of spacecraft malfunction.

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