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Detection of Small Orbital Debris by Signatures of Charged Debris-Plasma Interaction

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Collision of a spacecraft with a mm scale orbital debris could be mission ending. There are millions of small (mm - cm) scale orbital debris, which are hard to optically detect and track. We discuss the possibility of exploiting the signature of a speeding charged debris interaction with the space plasma for detection of small debris that is difficult otherwise. Generation mechanism for solitons due to such interaction in warm isothermal ionospheric plasma with the background magnetic field oriented at an arbitrary angle to the debris trajectory is analyzed. It is found that the fluctuations in the floating potential, which the debris acquires due to charging, can be amplified into growing ion acoustic waves by streaming ions on the debris. Normally, the ion acoustic fluctuations are ion Landau damped in the ionosphere because their phase speed matches the acoustic speed for equal ion and electron temperatures. However, in the debris frame the plasma streams with an inhomogeneous velocity profile. The velocity shear in the streaming ions can overcome Landau damping by effectively increasing the wave phase speed by a factor proportional to the product of the shear and the wave normal angle, causing dislocation of the Landau resonance. Consequently, the ion acoustic fluctuations can grow to sufficiently large amplitudes even in an isothermal plasma and trigger nonlinear effects resulting in KdV solitons, which have larger footprint than the debris itself, and hence easier to detect. For debris motion at an angle to the magnetic field unique signatures are generated by the combination of coherent and incoherent processes in both along and across the magnetic field directions that may be exploited for distinguishing the debris-generated signatures from those due to natural causes for positive identification of the orbital debris.