Non-linear Langmuir wave study in a small-scale laboratory plasma, a model for solar wind

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A small-scale laboratory experiment has been realized for the investigation of Langmuir waves excitation in a weakly ionized plasma. A beam-plasma instability is induced through the acceleration of a supra-thermal electron population (electron beam) in a background cold plasma. A system of closely spaced antennas and a multichannel high-frequency data acquisition system allows the characterization of the dispersion relation even in small (of the order of the mm) wavelength regimes.
We show that the experimental results, complemented by dedicated Vlasov–Poisson kinetic simulations, well reproduce the onset and nonlinear evolution of beam-driven Langmuir waves with close similarities with in-situ observations in the solar wind by the Parker Solar Probe diagnostics.
Above a threshold electron beam energy, Langmuir wavepackets develop with a clear non-linear behavior, which also characterizes spacecraft electrostatic waveforms. The experimental dispersion relations align with theoretical Bohm–Gross prediction.
Due to the low ionization fraction, the dynamics of the plasma under investigation is dominated by electron-neutral collisions, whose characteristic frequency is orders of magnitude lower than those associated to Langmuir waves. This allows to consider the plasma in the laboratory a relevant model for the collisionless condition of the solar wind.

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