LASER INDUCED FLUORESCENCE OBSERVATION OF SELF ORGANIZED ION STRUCTURES INDUCED BY ELECTROSTATIC PERTURBATIONS IN LOW DENSITY ARGON PLASMA

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Since the theoretical work of Moisev and Sagdeev [1] who predicted the existence of ion acoustic solitons and shock waves, intensive theoretical and experimental studies have been pursued and important results have been obtained on the turbulence and instabilities associated with the propagation of a density perturbation.

To experimentally study these kind of phenomenon like propagation, relaxation processes, or instabilities, in weakly collisional (low density) plasma it is necessary to use a diagnostic resolved in time. With repeatable phenomenon, the Laser Induced Fluorescence (LIF) technique [2,3] which provides a means to non-intrusively probe plasmas and to measure the Ion Velocity Distribution Function (IVDF) with unprecedented resolution in velocity and space, can be improved and time resolution added by using a boxcar averager [4] or a multichannel analyzer synchronized with the observed phenomenon [5].

Experiments are performed in a double plasma device [6] with multipolar confinement provided by permanent magnets [7,8]. The LIF diagnostic setup [9,10] uses a ring dye laser pumped by a cw argon laser. To obtain the necessary time resolution, the photomultiplier output is amplified by a wide band amplifier followed by a multichannel scaler (MCS).

At each spatial location where the measurement is performed, a spectral interval of 12 GHz width is scanned by the dye laser and sampled at fifty points which correspond to fifty ion velocities. For each laser frequency, the MCS output corresponding to the summation of several thousands (10,000 in general) of scans (300 temporal channels having a dwell time of 2μs) is stored by a microcomputer.

The ion perturbation results from applying to the source plasma a periodic discharge potential. The structure of the propagating shock is rather complicated since a wide frequency spectrum of waves can be associated with the applied step function. The main unperturbed ion background distribution can be subtracted and the remaining data give the perturbation of the distribution function induced by the propagation of the shock, (Fig. 1a,d). On the positive velocity side of the distribution we observe the formation of a hole, whereas, on the negative velocity side, complex positive ion structures develop. An important observation is that a large range of velocities is always associated with the observed spatially localized propagating perturbation. This implies that the self-consistent electric field must be maintaining the observed structures.

By summing in v the IVDF, the density perturbation is obtained (Figure 1b,e). The spatio-temporal evolution of the perturbation can be most easily studied by using contour plots of the perturbation of the ion velocity distribution function (Fig. 1c,f) . As the shock propagates away from the grid, the overall perturbation appears to propagate at almost a constant speed. Another essential feature of the perturbation is the existence of precursor ions traveling at about twice the ion acoustic speed and that appear as tongues that propagate before the main structure, as seen on the contour plots. This effect becomes more prominent at higher voltage.

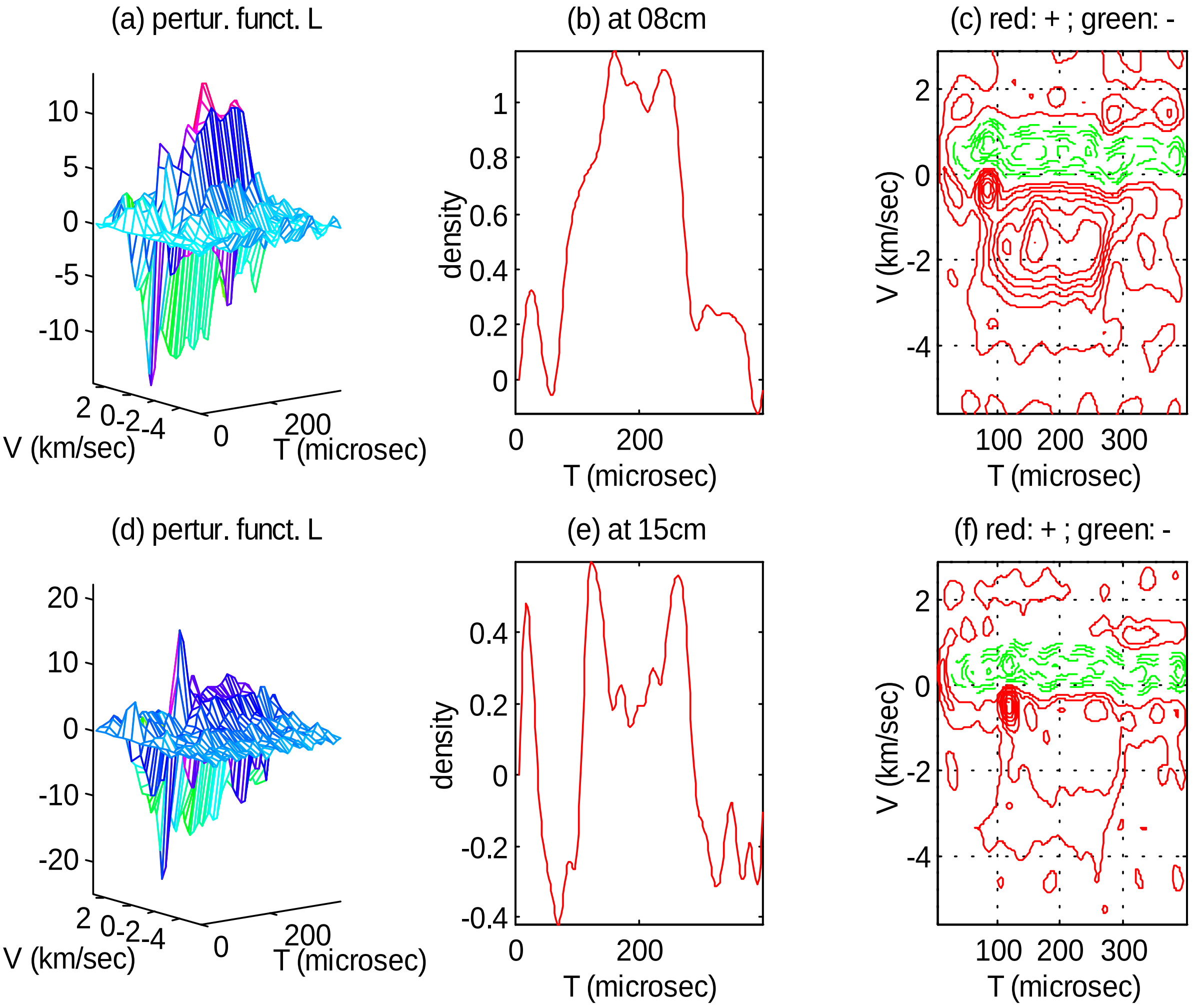

Fig. 1.

In Fig 2, we have adopted a different perspective. The distribution perturbation amplitude contours are cross-plotted in the (v,x) phase space plane for four different times from the beginning of the shock defined as the time of the positive step.

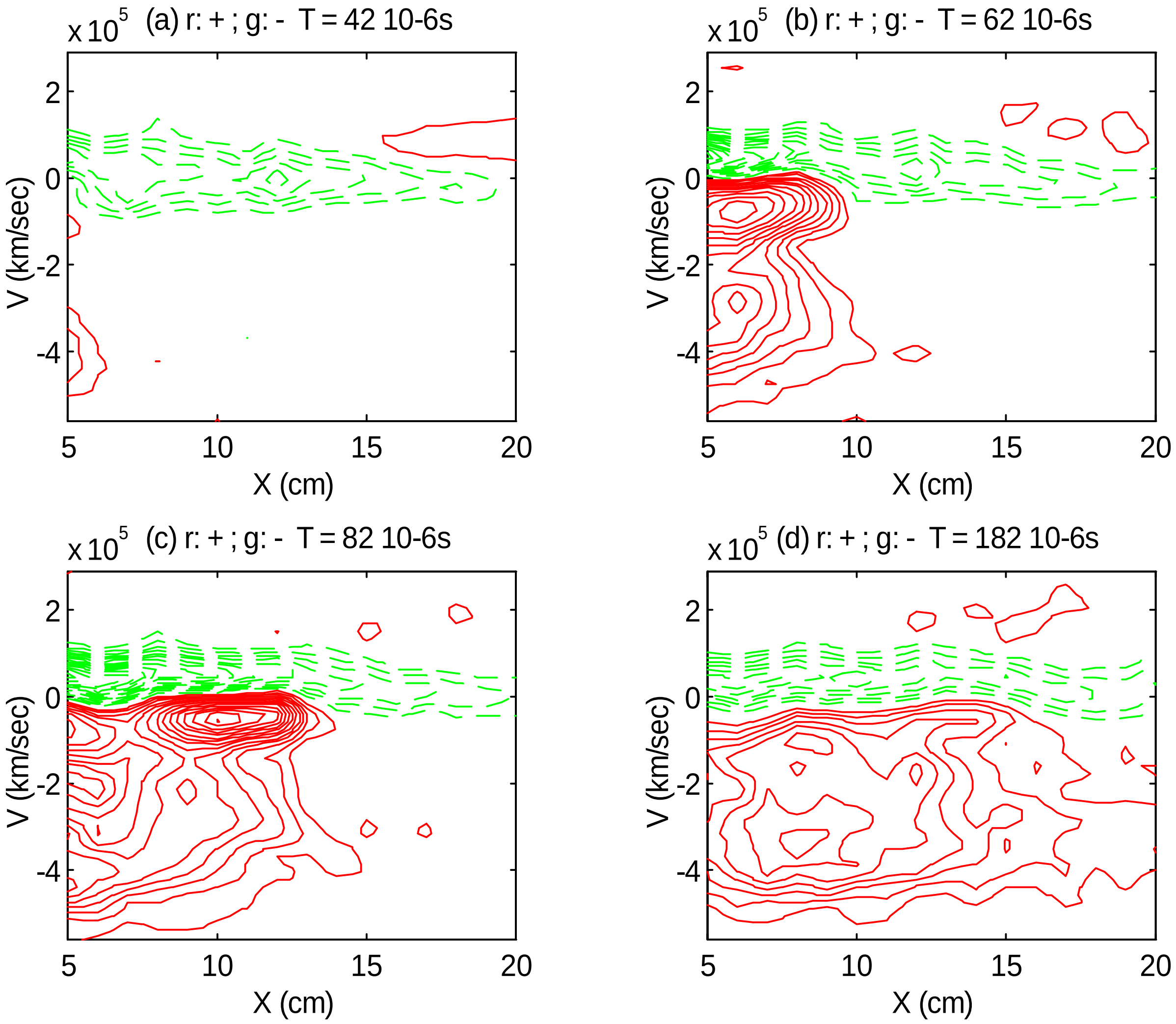

Fig. 2.

Because we have the resolution in velocity space and time, the Vlasov equation can be checked at a particular space point by calculating each of its coefficients (Fig 3-f is a verification of the reconstruction: all what remains is noise).

In conclusion, we have designed a new way to experimentally study ion perturbations propagating in a collision-less plasma by using time resolved laser induced fluorescence. In the special case of a step function perturbation, our study shows in the ion space phase, the existence of very complicated and robust long-lived coherent structures extending over a large number of Debye lengths and propagating with approximately the ion acoustic speed. These structures must result from an intricate balance between collision-less dissipative, dispersive and nonlinear effects. They are certainly not of a solitonic nature since their propagation velocity does not depend on their amplitude. The possibility to determine experimentally the Vlasov equation coefficient offers a powerful tool to check the theoretical assumptions.

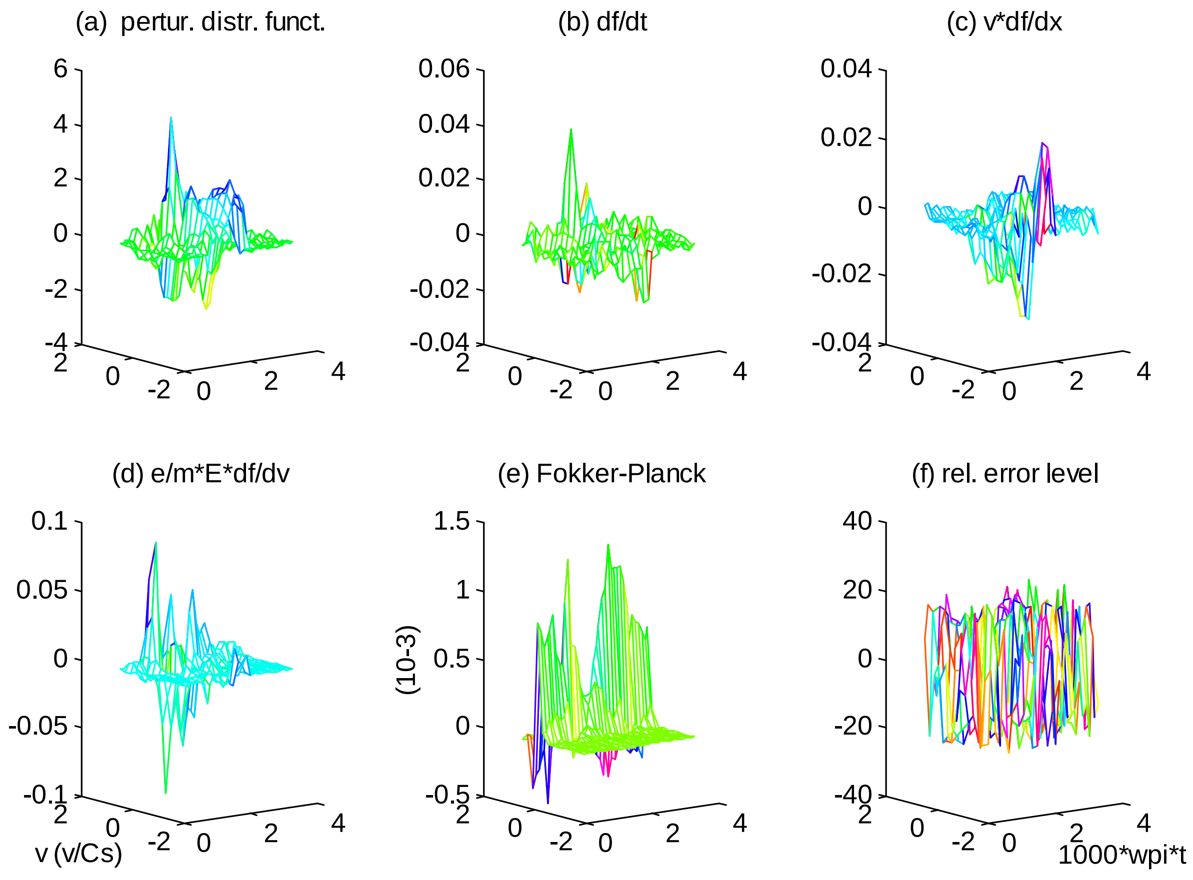

Fig. 3.

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