Study of the formation of a charge separation and electric field at a plasma edge using Eulerian Vlasov codes

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The problem of the formation of a charge separation in a plasma in the presence of a steep density gradient is of major importance in tokamak physics. It strongly affects the physics associated with the high confinement mode (H mode) and the reversed shear equilibria. We study the formation of a charge separation, together with the self-consistent electric field at a plasma edge, using Eulerian Vlasov codes. These codes apply a method of fractional steps associated with cubic spline interpolation to advance the advection term, and have the advantage of a very low noise level, which makes it possible to measure accurately a very small charge separation. The results are obtained by solving the Vlasov equation both in Cartesian and in cylindrical geometry. In the latter case, the presence of centrifugal and Coriolis forces require a 2D-interpolation in velocity space effected by using a tensor product of B-splines instead of applying successively cubic splines. In the limit of very large plasma radius the two different methods yield identical results. The results show the important role played by the ratio of the ion gyro-radius to the Debye length in determining the electric field at the plasma edge. The higher this ratio, the higher the electric field. It is the combined effect of the steep profile at a plasma edge and the finite ion orbits along the gradient which leads to establishing the charge separation at the plasma edge. The electrons, which are frozen to the magnetic field, cannot compensate along the gradient the charge separation caused by the finite ion gyro-radius. Due to the fact that heavy impurities have very large gyro-radii, even a small amount of impurities can contribute significantly to the increase of the charge and the self-consistent electric field at the edge. The electric field calculated at the edge is compared with the values calculated for the ion pressure gradient force and the $\vec{v}\ x\ \vec{B}$ Lorentz force. This comparison shows a very good agreement along the gradient, in the sense that these forces balance exactly the electric force.