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Skewed coherent electrostatic structures: their electric field and particle distributions

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Skewed coherent electrostatic structures have been reported in a wide variety of space plasmas by both WIND and CLUSTER. Phenomena falling under this rubric include non monotonic double layers, isolated electrostatic structures, unsymmetrical electron and ion holes and, lately, tripolar spikes. At variance with the properties of the well known electrostatic solitary waves, the peculiarity of these structures lies in the distinctive lack of symmetry (or skew) in the spatial distribution of their electric potential. The collision-less kinetic approach to such structures, so successfully used for electrostatic solitary waves, presents a number of challenges, which precisely originate from the mentioned skew of the potential waveform. Some of these challenges are tackled in our present contribution.

We first work out a differential equation for the potential waveform starting from its morphological properties, without making any prior reference to the velocity distributions of the particles which sustain the coherent structure. In the approximation of small potential amplitudes, this equation may be solved by quadrature up to the fourth order. In particular, even the second order solutions, which we give in terms of elementary functions, are able to reproduce the observed potential waveforms of skewed coherent electrostatic structures in remarkable agreement with observations. We show that the potential waveforms associated with unsymmetrical electron and ion holes and with both monotonic and non monotonic double layers are in fact special cases of the more general potential waveform associated with a tripolar spike.

The general tripolar electric potential thus found is then introduced into Poisson's equation, which accounts for both electron and ion charges.We prove that the electron and ion distributions which solve this equation, subject to appropriate boundary conditions, are elliptic functions of energy and that they are singular. Finally, we show that their singularities may be regularised and that the particle distributions may be retrieved as appropriate boundary values of sectionally analytic functions of complex energy.