Simulations of dust charging and wake formation in magnetized plasmas

W. J. Miloch[1]

[1] *Department of Physics, University of Oslo, Box 1048 Blindern, N-0316 Oslo, Norway*

Dust grains in plasmas acquire electric charge and interact with each other via screened Coulomb (Yukawa) potentials. External magnetic field can influence the charging of dust grains and plasma in their vicinity. This can have implications for the structuring and dynamics of complex (dusty) plasmas. This work presents results from numerical particle-in-cell (PIC) simulations of charging of a single dust grain in magnetized plasmas. Different strengths of magnetic field are considered for both stationary and flowing plasma conditions. Structural properties of the wake, and the wake effects on the interaction between the dust grains are addressed. It is demonstrated that the wake size and the potential structures in the wake, and hence the electric fields, can be significantly affected by the magnetic field.

1. Introduction

Dust grains immersed in plasma are charged by plasma and other currents. Studies of potential and plasma density distributions on and around charged grains in flowing plasmas are essential for the understanding of dynamics of complex (dusty) plasmas [1]. Plasma flows will break the symmetry of charging and lead to formation of wake. This can influence interactions between grains and align them in the direction of the flow [1, 2].

Another reason for the symmetry breaking in dust charging is the magnetic field that restricts the dynamics of plasma. It has been demonstrated in experiments that magnetic field can significantly modify the nonreciprocal dust interactions [3]. The dynamics of systems comprising many grains can significantly differ from the unmagnetized case [4]. However, charging in either weakly or strongly magnetized plasmas is still not well understood.

To understand interactions between many grains in magnetized plasmas, it is crucial to understand the charging of a single grain and wake formation. This work presents first results from particle-in-cell (PIC) simulations of dust charging in magnetized plasmas. The study is carried out with the DiP3D code [2].

2. Results

In the present simulations, the plasma parameters are typical for laboratory dusty plasma experiments, the flow is supersonic, and the magnetic field is considered as a variable parameter. The wake size and strength can be significantly affected by the magnetic field, see Figure 1. Strong magnetic fields diminish ion focusing, and the corresponding potential maxima in the wake become smaller. On the other hand the potential oscillations in the wake get more pronounced, with strong negative minima downstream from the grain. For the considered magnetic fields, the charge on the grains is only little affected and is similar to the unmagnetized case. The changes in the potential distribution and the topology of the wake due to external magnetic fields can have important effects on the interactions between grains and charging of downstream grains.

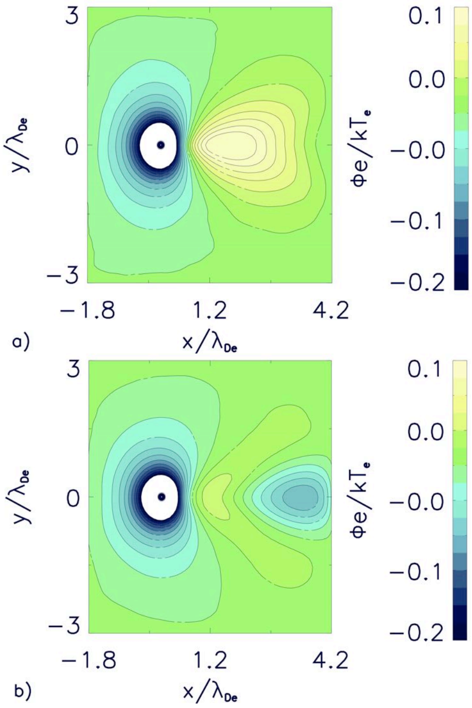

Figure 1: *Potential distribution behind dust grains in supersonic plasma flows (1.2 Mach) for the electron to ion temperature ratio* $T_e/T_i=100$ *and magnetic field aligned with the flow of* $B=5$ Gs *(a), and* $B=100$ Gs *(b). The flow is in the positive x-direction. In both cases the potential on the grain is* $\Phi \approx -1.1 e/kTe$. *In the figure only shallow potential variations are shown.*

3. References

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