

**Title:** Particle flows around an intruder

**Abstract:** Particle flows injected as a beam and scattered by an intruder are numerically studied. We find a crossover of the drag force from Epstein's law to Newton's law depending on the ratio of the speed to the thermal speed. These asymptotic laws can be reproduced by a simple analysis of a collision model between the intruder and the particle flows. The crossover from Epstein's law to Stokes' law is also found for the low speed regime as a time evolution of the drag force caused by beam particles. We also show the existence of weak turbulent-like behavior of the particle flows behind the intruder with the aid of the second invariant of the velocity gradient tensor and the relative mean square displacement for the high speed regime.