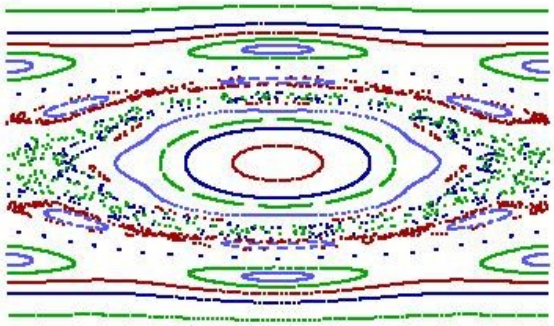
Relativistic chaos in laser-matter interactions

Background

The dynamics of charged particles interacting with electromagnetic fields can often become ***chaotic****, i.e. unpredictable in practice. Diagnosing chaotic dynamics is a fundamental issue in classical mechanics but is also very important for practical applications. For example, chaotic particle motion can play an important role in novel* ***laser-plasma accelerators*** *which use pulses from the most intense laser systems available, in order to accelerate particles in a plasma to speeds close to the speed of light. Understanding chaotic motion of* ***relativistic*** *particles is one of the steps that need to be taken in order to construct usable laser-plasma accelerators.*

Problem description

Many ways to quantify chaos have been formulated for a variety of physical systems. For example, Lyapunov exponents characterize the rate of divergence of slightly different initial conditions in a chaotic system. Although Lyapunov exponents are independent of the choice of coordinates in phase space, the situation is more subtle when one considers general time-dependent transformations, for example the Lorentz transformations of the theory of special relativity.



Thesis description

The master student will be introduced to the field of chaotic dynamics by a literature survey and hands on exercises. They will understand how signatures of chaos, such as Lyapunov exponents, transform under Lorentz transformations. They will then write simple computer programs that will allow them to study chaotic trajectories of relativistic electrons in intense laser fields. They will contact thought-experiments in order to understand possible signatures of chaos in such systems and their expectations will be tested by computer simulations that they will perform. Finally, a proposal for possible experimental verification of their findings will be formulated.

Literature

Edward Ott*, Chaos in Dynamical Systems,* Cambridge University Press (2002)

A. E. Motter*, Relativistic Chaos is Coordinate Invariant,* Phys. Rev. Lett. **91***,* 231101 (2003)

Z.-M. Sheng*, Stochastic Heating and Acceleration of Electrons in Colliding Laser Fields in Plasma,* Phys. Rev. Lett. **88**, 055004 (2002)

Supervisor

Evangelos Siminos, Department of Physics, siminos@chalmers.se