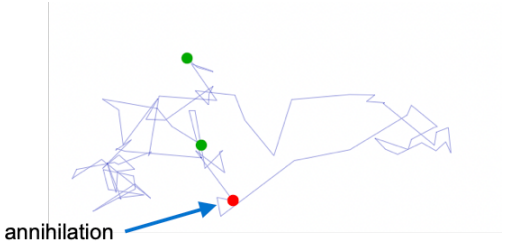
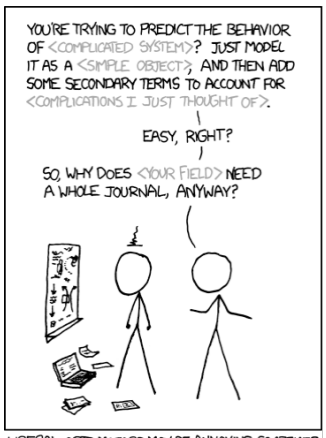
Master project: Numerical simulations of reaction-diffusion systems

Background: Reaction-diffusion models are frequently used in statistical physics to model the dynamics of chemical reactions. The basic building blocks of these models are point-like particles of one or more reactant species that undergo Brownian motion (possibly restricted to move on a line or in a plane). If enough of these particles are in proximity, they will react according to some chemical reaction prescription. Such a reaction can describe, for example, two or more particles that annihilate or fuse together, a fission processes where a reactant splits off into several others, or a process where the reactant changes from one species to another. Because of the simple setup, reaction-diffusion models are used to describe a wide variety of systems, starting with work over one hundred years ago on the coagulation kinetics of gold colloids in a suspension [here, gold colloids cluster together over time to form bigger clusters, which changes the colour of the suspension from red to violet]. They are also often used to describe predator-prey dynamics (where one species eats another and multiplies), the spreading of diseases (where an infectious species infects others), pattern formation (where distinct reactants separate into domains of various shapes), or in condensed-matter physics to describe the annihilation of domain walls or the recombination of excitons in semi-conductors. In all these examples, the dynamics does not depend on the precise microscopic details of the system but is captured accurately by a reaction-diffusion model, which only contains effective parameters (such as a diffusion constant of the reactants or a chemical reaction rate). This independence of the dynamics on the microscopic details is called universality and a main reason why we study these theories: by studying a particular reaction-diffusion model, we describe not only a specific experiment but a whole "universality class" of systems in statistical physics.





https://xkcd.com/793/

Project proposal: The focus of this project is the numerical simulation of reaction-diffusion systems that describe particle annihilation. You will learn how reaction-diffusion systems can be modelled on a computer and perform simulations to extract the universal late-time scaling of the particle number. The project is meant to answer what happens if particles move by another mechanism than diffusion and to describe the influence of various geometries on the dynamics.

A basic knowledge of statistical physics is essential for this project. This project is heavily numerical, where the choice of programming language and platform is left to you. Some experience in high-performance computing is an advantage but can be acquired during the project. Office space in the physics department is available.

Supervisor:
Johannes Hofmann, johannes.hofmann@physics.gu.se, Department of Physics, Gothenburg University.