Random motion is present in a plethora of systems in nature. A prime example is Brownian motion, named so after Robert Brown [1], who first discovered it in 1827, while studying the motion of pollen grains in water under a microscope. The explanation of the erratic, inconsistent motion of the particles was given in 1905 by Albert Einstein [2], who attributed it to collisions of the pollen particles with water molecules, thus providing evidence of the existence of atoms and molecules. Brownian motion can be modeled by a simple random walk and is a microscopic explanation of the macroscopically observed diffusion in a medium.

While Brownian motion is arguably the most celebrated and understood random walk, there have been other, more complicated randomly moving and/or diffusing systems. One such interesting example is the so-called run-and-tumble behaviour, which can be observed e.g. in collections of Escherichia coli bacteria. These bacteria propel themselves in a straight line by rotating their flagella in the same direction and turn by moving at least one flagellum in a different direction to the others, thus picking a new, random direction (Fig. 1a).

We propose to simulate the run-and-tumble behaviour, possibly along with other complicated random walks, with synthetic self-propelled particles, known as Quincke rollers [3], particles which roll towards a randomly picked direction due to a torque perpendicular to the direction of an inducing electric field. Modifying the duration of the application of the electric field, we can simulate the behaviour of the bacteria and their randomly changing direction of motion (Fig. 1b). The main focus of the project will be to study the relation between the particles’ velocity and their density, as it has been theorised that the two should be directly related [4].

During the initial stage of the internship, the candidate will undergo training in both the experimental procedure (preparation and measurements) and the post-processing of the obtained data. Subsequently, they will use their newly obtained skills in order to test the density-velocity relation hypothesis and summarise the results into a report/thesis.

The candidate should be motivated and willing to work in a collaborative environment. They are not required to have a background in experimental physics or data analysis, even though it would be a big plus.

Figure 1: a) Run-and-tumble in E. Coli: Scheme of E. Coli showing typical run-and-tumble behaviour. A tumble is made when the bacterium stops suddenly and changes direction randomly, b) Run-and-tumble in artificially engineered systems: i) First run-like event of particles depicted by a superposition of 3 snapshots from an experiment of spherical particles moving due to the Quincke electro-rotation phenomenon and observed using bright-field imaging (time interval between snapshots = 166.6 ms). Three particles are chosen at random and their trajectories are marked with bold green, orange and red arrows respectively. ii) The external electric field is switched off for roughly 0.2 s. After switching it back on (tumble-like event), Quincke rotation of the particles renders them to ‘run’ in a randomly chosen direction once again. The updated trajectories are once again marked with bold arrows and the angle $\theta$ measures the change in directions of motion between the two runs.