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Year 2 (2020-21) MSci Mathematics.

UROP (Summer 2021): undertaken in the Dept of Mathematics

UROP title: Exploring the interplay between phase separation and collective motion in active matter

Since joining Imperial, I have known that I have wanted to become a professor and I actively seek out anything that can help me in achieving that goal. In conversation with my personal tutor, we came to the conclusion that a UROP would be perfect for me, helping me develop skills that would be invaluable in finishing my degree and also giving me a taste of research. It was in fact my personal tutor, Dr Thibault Bertrand, that I approached to do the UROP as he is someone I have looked to as a role model since I have met him and loved the idea of being able to work alongside him. Note that I performed this project as part of a group of three undergraduate researchers.

My UROP project found its roots in the field of Active Matter, in particular studying the interplay between phase separation and collective motion in systems of interacting self-propelled aspherical particles. To prepare for this, we first spent time looking through many papers and discussing with Dr Bertrand the mathematics behind this UROP. In particular, it was the first time the entire group had encountered Stochastic Differential Equations, as well as ways to numerically approximate these using methods such as the stochastic Runge-Kutta method.

The theory was just the beginning however, as it became immediately clear that this project was going to stretch my coding ability beyond anything I had done before. The main part of this project consisted of us implementing active Brownian particles simulations, initially with spherical particles but later with ellipsoidal particles. Through these numerical simulations, we studied the influence of important parameters like the aspect ratio of the particles (measuring how elongated the particles are) or packing fraction of the system (measuring how jammed the particles are) on the emergence of macroscopic collective properties like phase separation or collective motion. To do so, we measured the change in nematic order (a measure of particle alignment) and polar order (a measure of particle directionality) of these systems; this allowed us to study both structural and dynamical properties of these systems. We were extremely happy to see our code returning results that supported our initial suspicions, for example that increasing the aspect ratio of particles (i.e. making them more needle-like) increases these order parameters over time as the particles meet and align along their major axis (i.e. favours alignment and collective motion).

I am happy to say that in finishing this UROP, my coding is the strongest it has ever been; I am now able to debug more efficiently, I have learnt about Python packages I was not even aware of and I even had a first encounter with MATLAB. The confidence I have gained in both the computational side and theoretical side of this project has for sure influenced me in my study decisions, as I now know for certain that I will pursue modules in and around these respective areas for the remainder of my degree.

The pandemic was obviously not ideal for everyone, but particularly in a research environment initial challenges presented themselves. Due to social distancing, we were unable to meet as a group in person and work through this project. As a result, this UROP was conducted remotely. It was nonetheless not all negative as I personally found that this strengthened my ability to work as part of a group, knowing that we had to overcome this distance issue. Working efficiently as a group under these circumstances meant that all of us needed to make a conscious effort in regularly setting up

meetings (something which is quite natural when the UROP is done on campus) and so reinforced our determination and commitment to the project. While we met on a regular basis as a group; we also had more structured weekly meetings (i.e. Zoom calls) where we were all able to communicate effectively. These occurred twice a week. The first of these meetings was dedicated to discussing the progress of our UROP working group with our supervisor; the second one took place with the entire research group of our supervisor (including MSc students, PhD students and postdocs). At these group meetings, everyone was able to compare and discuss research results or interesting research papers related to their projects. In fact, in the final week the group put on a presentation of about 30 minutes discussing everything we had covered during our UROP project and the results we had obtained. This definitely helped my presentation skills, and we were very happy to have results to share with the group.

Overall, I am overjoyed that I was able to be a part of such an amazing experience, one I am sure that will stay with me for a long time.