DWC Profiles: Matt Reeves, PhD student in the Dodd-Walls Centre

Matt Reeves studies turbulence. He is a PhD student at Otago University working under the supervision of Dodd-Walls Associate Investigator Ashton Bradley. "That really caught my attention," says Matt. During his Masters and PhD he has contributed at an international level to the understanding of this complex phenomena.

> "As a younger student he remembers listening to Ashton explaining how they knew the Great Red Spot in Jupiter's atmosphere was a turbulent storm which had been raging for four hundred years."

Research: Finding Order in Turbulence

Turbulence is something we are all familiar with. We observe it in river water flowing around rocks and in cigarette smoke when it suddenly spreads out and curls. Any systems in engineering or industry involving moving gases or liquids are affected by turbulence. But despite it being such a common and significant phenomenon, it still confounds physicists. This is because it involves things happening on vastly different scales all at once.

Matt is shedding light on this age-old problem by running computer experiments looking at turbulence in superfluids. Superfluids are a completely new state of matter formed by cooling atoms down to just above absolute zero (that's - 273°C). At this temperature the atoms stop jiggling around and become "quantum entangled". Superfluids behave more like a single entity than like a collection of separate particles and they have no viscosity, the stickiness which is caused by internal resistance between the atoms or molecules.

One of Matt's big achievements has been to develop a quantum equivalent to the Reynolds number for superfluids. The Reynolds number is the one concrete thing that physicists have worked out to explain turbulence. It is a single number that predicts when the flow will switch from smooth to turbulent. For an ordinary fluid you work it out by dividing the speed and the length of the obstacle by the viscosity of the fluid. To Matt's surprise the superfluids obey a similar rule to ordinary fluids. He has worked out a way to define an equivalent to the Reynolds number for superfluids, which goes a long way to understanding this completely new territory.

Matt is technically a theoretical physicist but he works more like an experimentalist. He programmes the known laws of physics into the computer, defines the parameters, then presses go. The computer simulates billions of complex interactions then spits out a video of the resulting motion.

One video shows a superfluid flowing around a laser beam, which acts just like a rock in a stream. Tiny pairs of whirlpools stream out behind the laser in a perfect line. This is called a vortex street (see image 1). Image 2 shows the same pattern of vortices forming in the atmosphere downwind of an island off the coast of Chile. Image 3 shows the superfluid bursting into turbulent swirls when Matt speeds up the flow.

“When you observe these universal patterns in such different systems you begin to feel you are getting to the heart of the problem,” says Matt. “That’s what attracted me to turbulence right from the start.”

The calculations involved in Matt’s experiments are so intense, it can take weeks of continuous time on a supercomputer to process a single simulation. It is testament to the success of Matt’s research that the university has invested in powerful new graphics processors to enable him to take the next steps forward.

Generally in physics the theory comes first then experiments follow. But in this field of superfluid dynamics, the experiments, both on computers and in the lab, are leading the way. Theorists are following, attempting to make sense of their results.

“It’s just like exploring a new land,” says Matt, “only it’s not a physical one. The rabbit hole goes as deep as you want to follow it. It never gets boring.”

Research Impact:

Matt’s research has extremely wide-ranging value. By helping to understand turbulence at its most basic level, it could improve our ability to create accurate climate models, understand the formation of galaxies and the design of vehicles, planes and industrial processes.

Since Matt published the superfluid Reynolds number, experimentalists have used it to explain the transition from regular to turbulent flow in superfluid helium. Superfluid helium is the most efficient coolant for maintaining the ultra-low temperatures needed for superconducting magnets. These are used in MRI machines in hospitals, in the Large Hadron Collider at CERN and in astronomical detectors. The new understanding of turbulence is likely to improve the cooling capability of superfluid helium in all these applications.

Student Life in the Dodd Walls Centre

Matt's Master's research and academic record was so good that he could have gone to any university for his PhD but he chose to stay at Otago.

"HERE YOU CAN DO GOOD SOLID RESEARCH AND BE LOOKED AFTER BY THE DEPARTMENT. IT'S A REALLY FRIENDLY COMMUNITY. I ALMOST FELT OBLIGED TO APPLY FOR OVERSEAS SCHOLARSHIPS BUT I JUST LIKED OTAGO. I HAD A REALLY GOOD RELATIONSHIP WITH MY SUPERVISOR, THE RESEARCH WAS GOING WELL AND THERE WAS STILL MORE TO DO."

The Dodd Walls Centre arranges meetings to connect students and members from around the country. Matt attended KOALA, an international optics conference held in Auckland in 2015. It was organised by DWC students specifically for students.

"Sometimes it's nice to stop thinking about your own problem and listen to other people's," Matt says. "I was particularly impressed by the students' presentations at KOALA. Maybe it's because we are more aware of what other people don't know, but I actually understood most of them. That doesn't happen at most conferences."

Matt also attended an optics summer school for students at Otago University which brought experts from all around the world, including Nobel Laureate Bill Phillips, to speak and work with students. This was made possible by funding from the Dodd-Walls Centre.