Stereoscopic visualization study of turbulence and vortex-tangle dynamics in He II

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Over the past fiscal year, both our experimental and numerical research have yielded significant outcomes. Most notably, we achieved a breakthrough by successfully imaging quantized vortex rings as they propagate in superfluid helium (He II) [1]. With the obtained data, a grant challenge in modeling quantized vortex dynamics is solved.

The motion of quantized vortices is responsible for many intriguing phenomena in diverse quantum-fluid systems. Having a reliable theoretical model to predict the vortex motion should promise a broad significance spanning multiple physical science disciplines. A grand challenge in developing such a model is to evaluate the frictional force caused by thermal quasiparticles in the quantum fluids scattering off the vortex cores. Various models have been proposed over decades of research, but it remains unclear which model describes the physical reality due to the lack of experimental data for comparison. In our experiment, we managed to produce an unprecedented imaging of quantized vortex rings propagating in He II. By examining how the vortex rings spontaneously shrink and accelerate, we have generated decisive data to identify the model that best reproduces observations. This study eliminates ambiguities about the dissipative force acting on vortices, which could have implications for research in various quantum-fluid systems that also involve similar forces, such as superfluid neutron stars and gravity-mapped holographic superfluids.

[1] Y. Tang, W. Guo, H. Kobayashi, S. Yui, M. Tsubota, and T. Kanai, "Imaging quantized vortex rings in superfluid helium to evaluate quantum dissipation", Nature Communications, **14**, 2941 (2023).

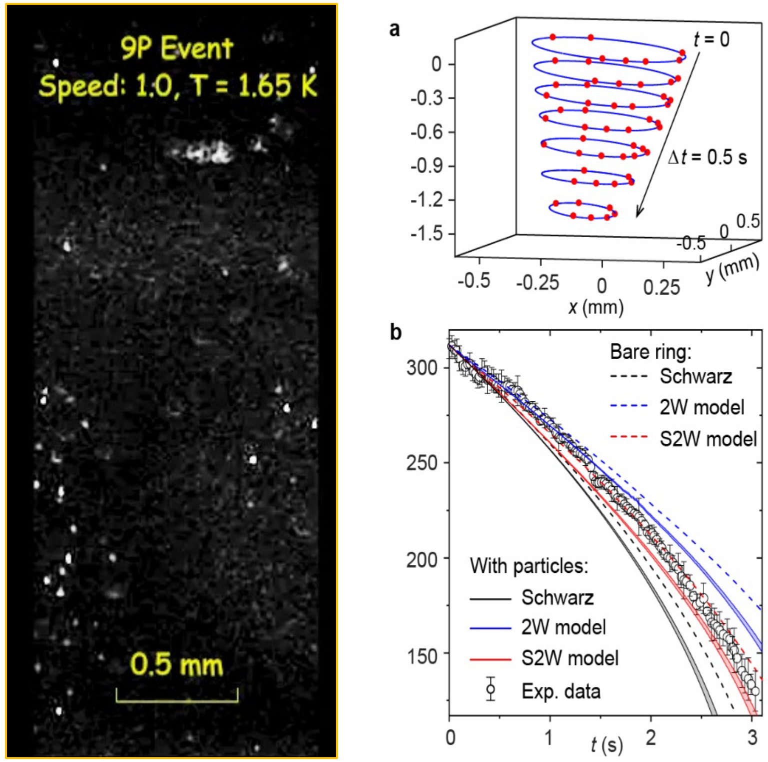

Figure 1: Left: a video showing the propagation of a quantized vortex ring in He II; Right: the obtain vortex-ring radius versus time data compared with the prediction of various theoretical models.

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The broader impacts from our research in the current fiscal year includes:

1) Our research program has engaged both graduate students and part-time undergraduate interns. These students have gained valuable experiences in fluid dynamics, cryogenics, laser technologies, etc.

2) Our research work has got media coverage. See for instance the news story from FSU:

- https://news.fsu.edu/news/science-technology/2023/07/17/famu-fsu-researchers-confirm-theory-for-superfluid-helium/

3) The PI's proposal to organize the 2024 International Conference on Quantum Fluids and Solids in Florida, USA has received the green light from the conference steering committee. Hosting this premier event in the QFS arena will amplify the influence of our QFS research. With a steadfast commitment to diversity, equity, and inclusion (DEI), the PI has successfully procured conference grants from both the NSF and the Moore Foundation. These funds are dedicated to eliminating financial and other barriers that could potentially restrict the involvement of underrepresented minorities and other participants.

4) Our group members continue to contribute in educational programs, such as the Maglab’s annual open house (see Fig. 2).

Figure 2: Pictures showing “frozen flower” and “rocket car” demonstrations conducted by the PI’s group using cryogenic fluids at the Maglab’s annual open house educational event.