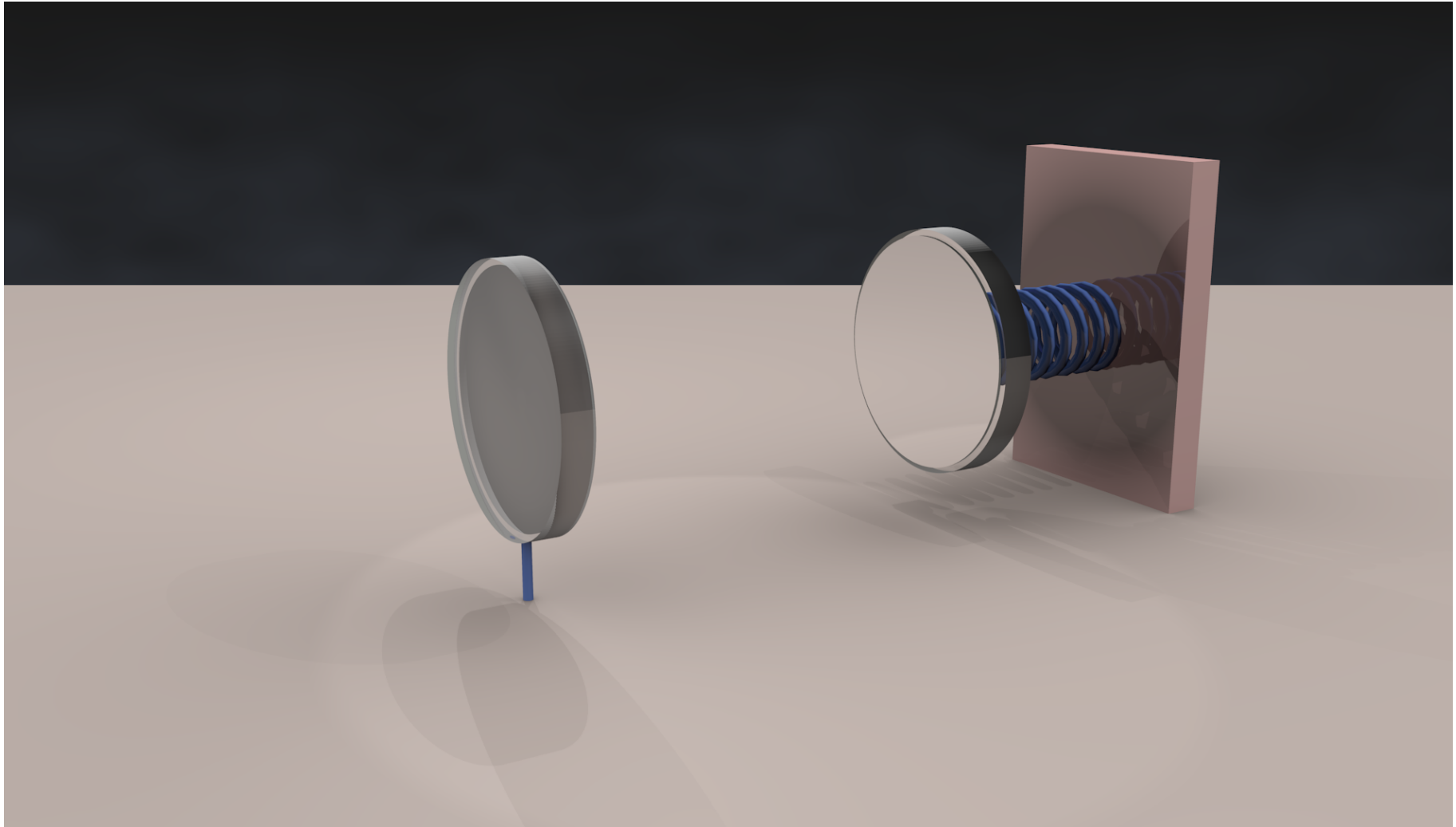


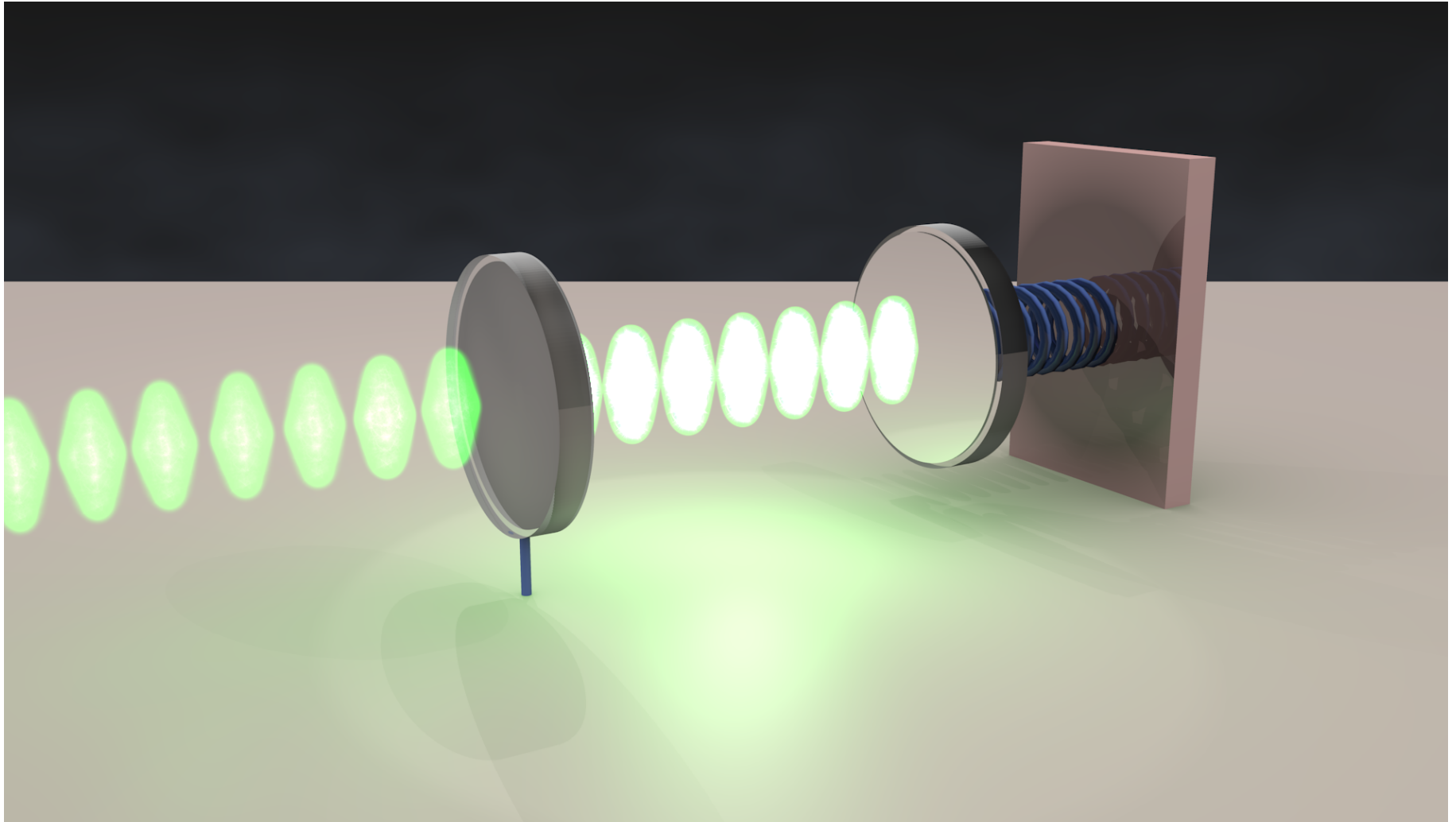
Real time observation of vortex dynamics in superfluid helium films

Christopher Baker, Yauhen Sachkou, Glen Harris, David McAuslan, Xin He, Matthew Davis, Matthew Reeves, Oliver Stockdale, Ashton Bradley, Xiaoquan Yu, Stefan Forstner, and Warwick Bowen

*Centre for Engineered Quantum Systems, School of Mathematics and Physics,
University of Queensland, Brisbane, Australia.*

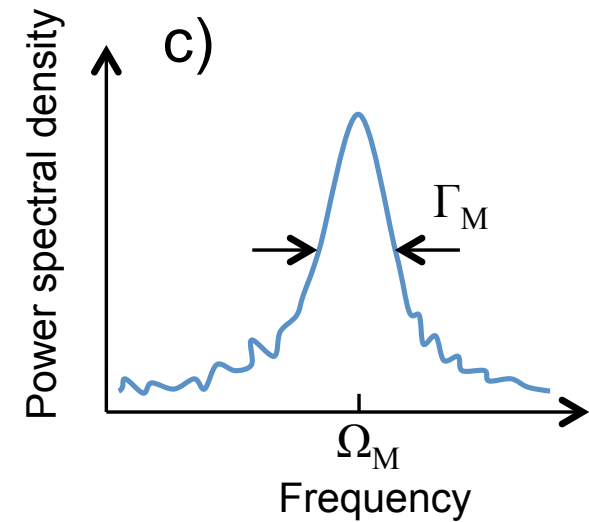
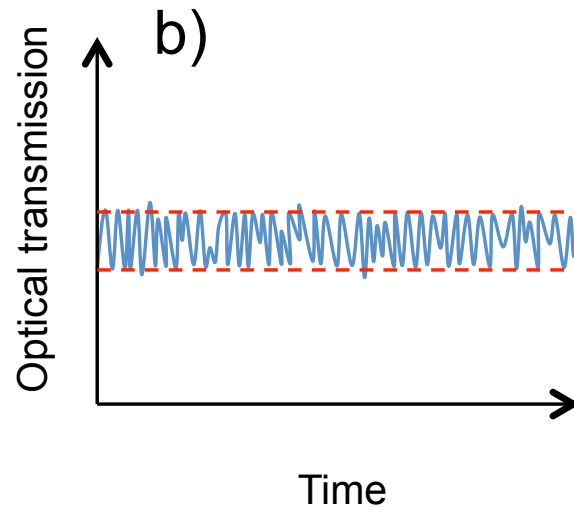
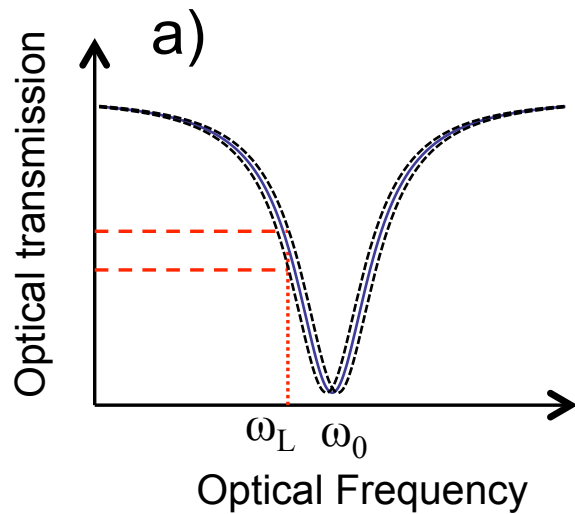
QFS conference August 8th 2019, Edmonton





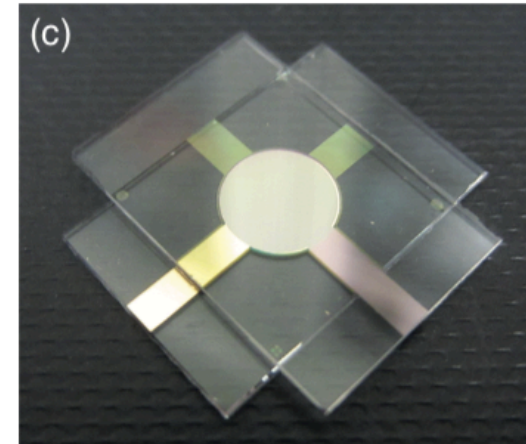
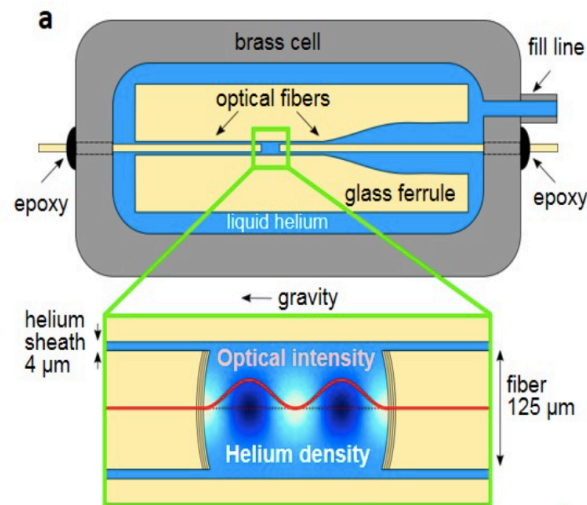
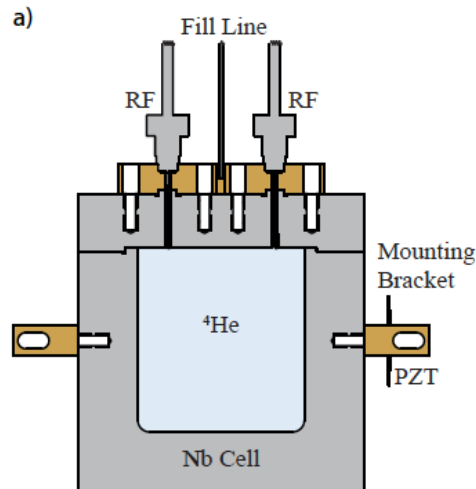


High sensitivity displacement readout





Superfluid optomechanics



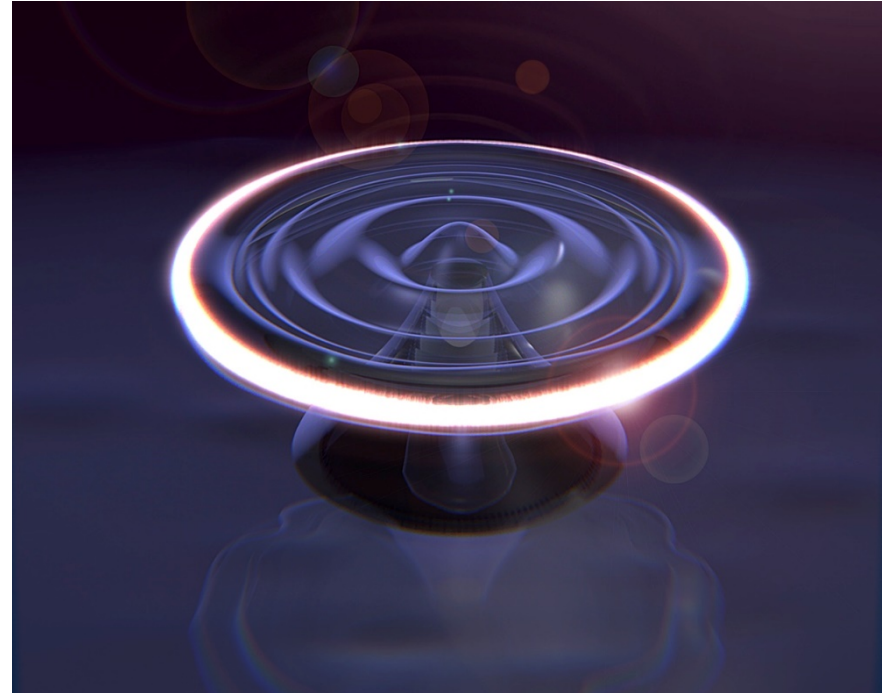
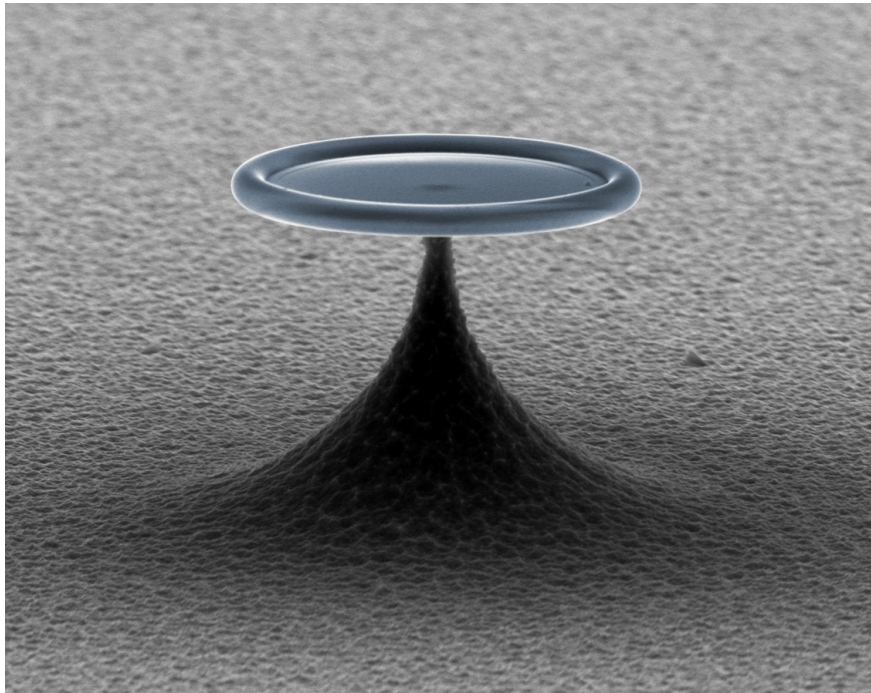
De Lorenzo, L.A., and K. C. Schwab. "Superfluid optomechanics: coupling of a superfluid to a superconducting condensate." *New Journal of Physics* 16,11, 113020 (2014)

A.D. Kashkanova, A.B. Shkarin, C.D. Brown, N.E. Flowers-Jacobs, L. Childress, S.W. Hoch, L. Hohmann, K. Ott, J. Reichel, J.G.E. Harris, *Nature Physics* 13, 74-79 (2017).

Ultra-Low Dissipation Superfluid Micromechanical Resonator, **F. Souris, X. Rojas, P.H. Kim** and J.P Davis, *Phys. Rev. Applied* 7, 044008 (2017).



Superfluid optomechanics

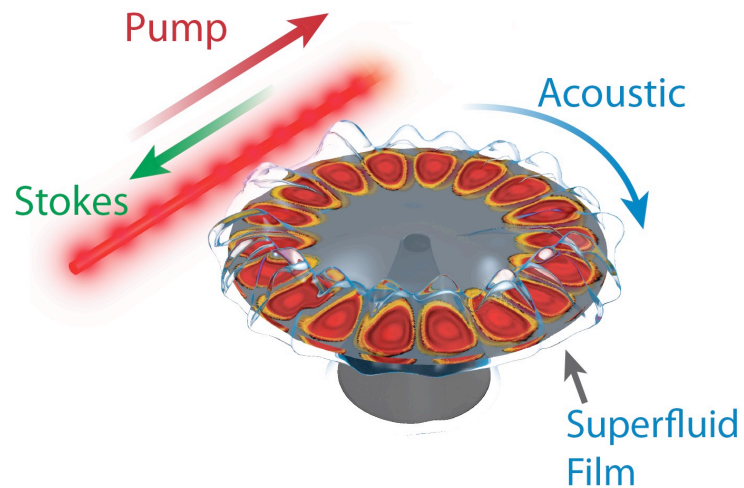


Nature Physics volume **12**, pages 788–793, 2016
Physical Review X, **6**:021012, 2016
New Journal of Physics, **18**(12):123025, 2016

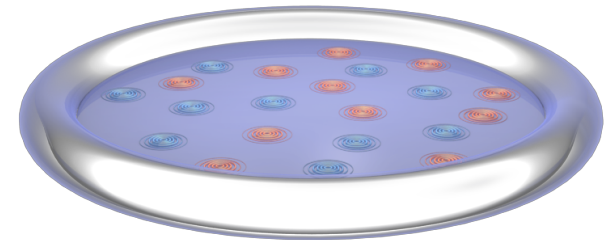


Applications

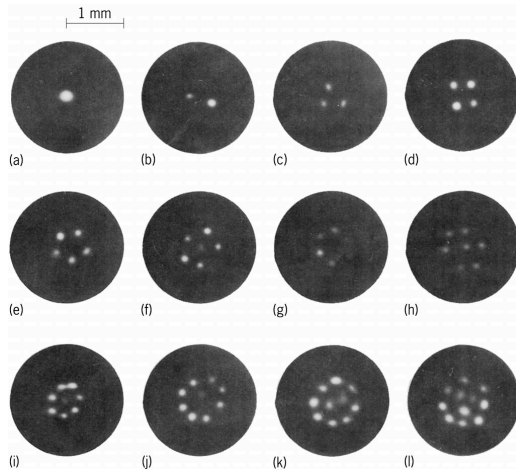
Strong optical coupling with
Brillouin lasing
(next talk by Yasmine Sfindla)



Real-time observation of vortex
dynamics in a strongly
interacting superfluid film



Vortex imaging in superfluid helium



E. J. Yarmchuk, M. J. V. Gordon, and R. E. Packard, Observation of stationary vortex arrays in rotating superfluid helium, *Phys. Rev. Lett.*, **43**:214, 1979

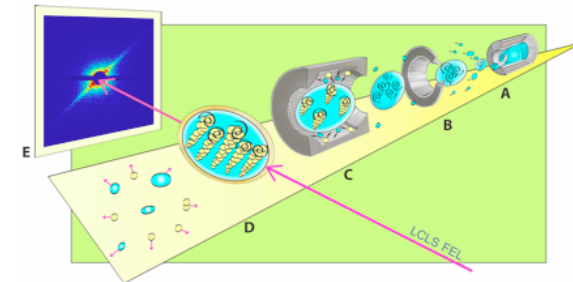
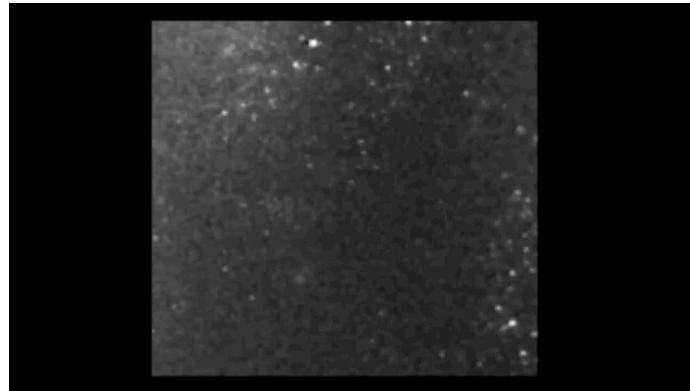
PNAS

Direct observation of Kelvin waves excited by quantized vortex reconnection

Enrico Fonda^{a,b,c}, David P. Meichle^{a,d}, Nicholas T. Ouellette^{a,e}, Sahand Hormoz^f, and Daniel P. Lathrop^{a,d,1}

^aInstitute for Research in Electronics and Applied Physics and ^bDepartment of Physics, University of Maryland, College Park, MD 20742; ^cDipartimento di Matematica e Geoscienze, Università degli Studi di Trieste, 34127 Trieste, Italy; ^dDepartment of Physics, New York University, New York, NY 10003; ^eDepartment of Mechanical Engineering and Materials Science, Yale University, New Haven, CT 06520; and ^fKavli Institute for Theoretical Physics, Kohn Hall, University of California, Santa Barbara, CA 93106

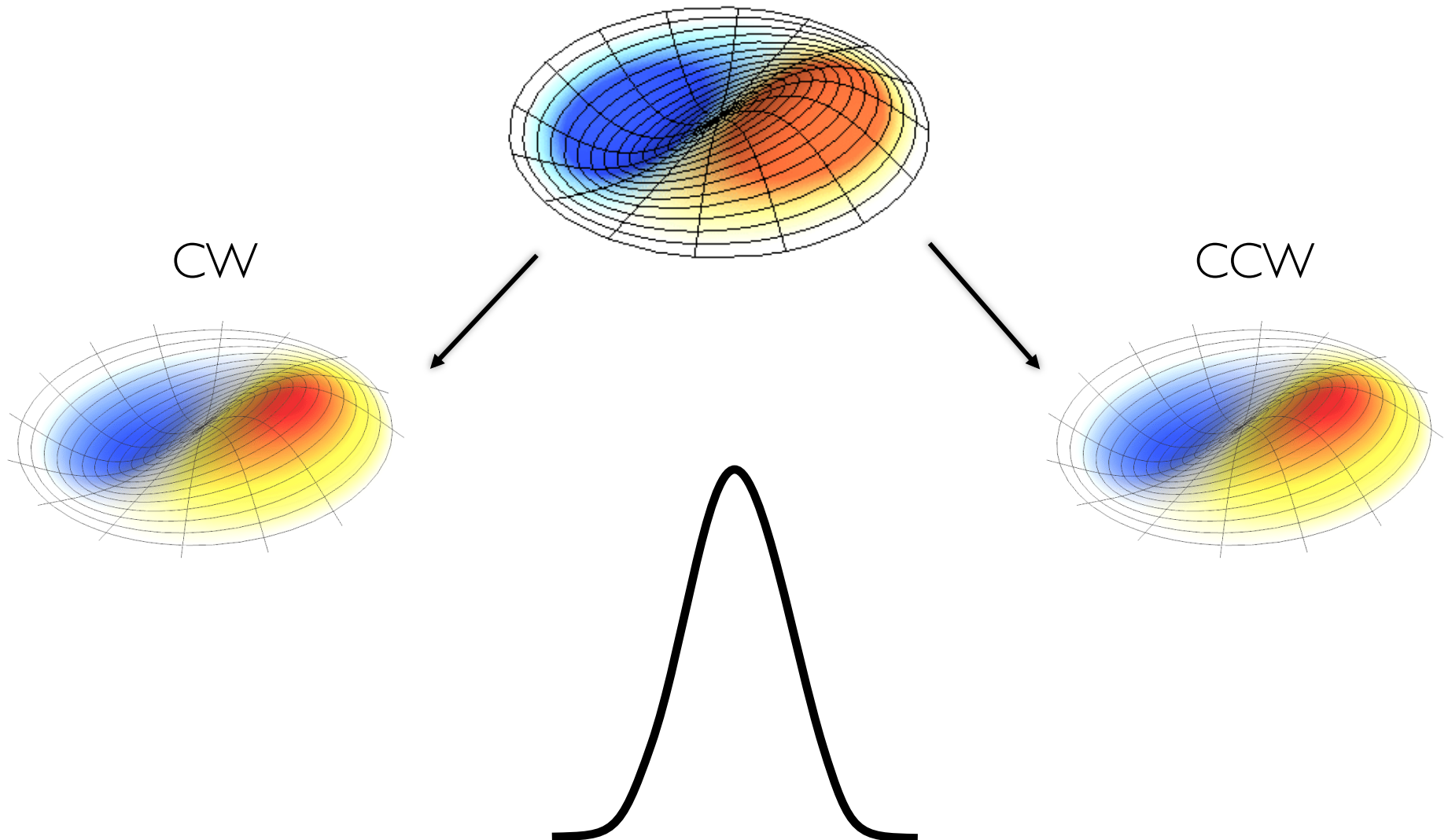
Edited by Katesh R. Sreenivasan, New York University, New York, NY, and approved September 24, 2013 (received for review July 8, 2013)



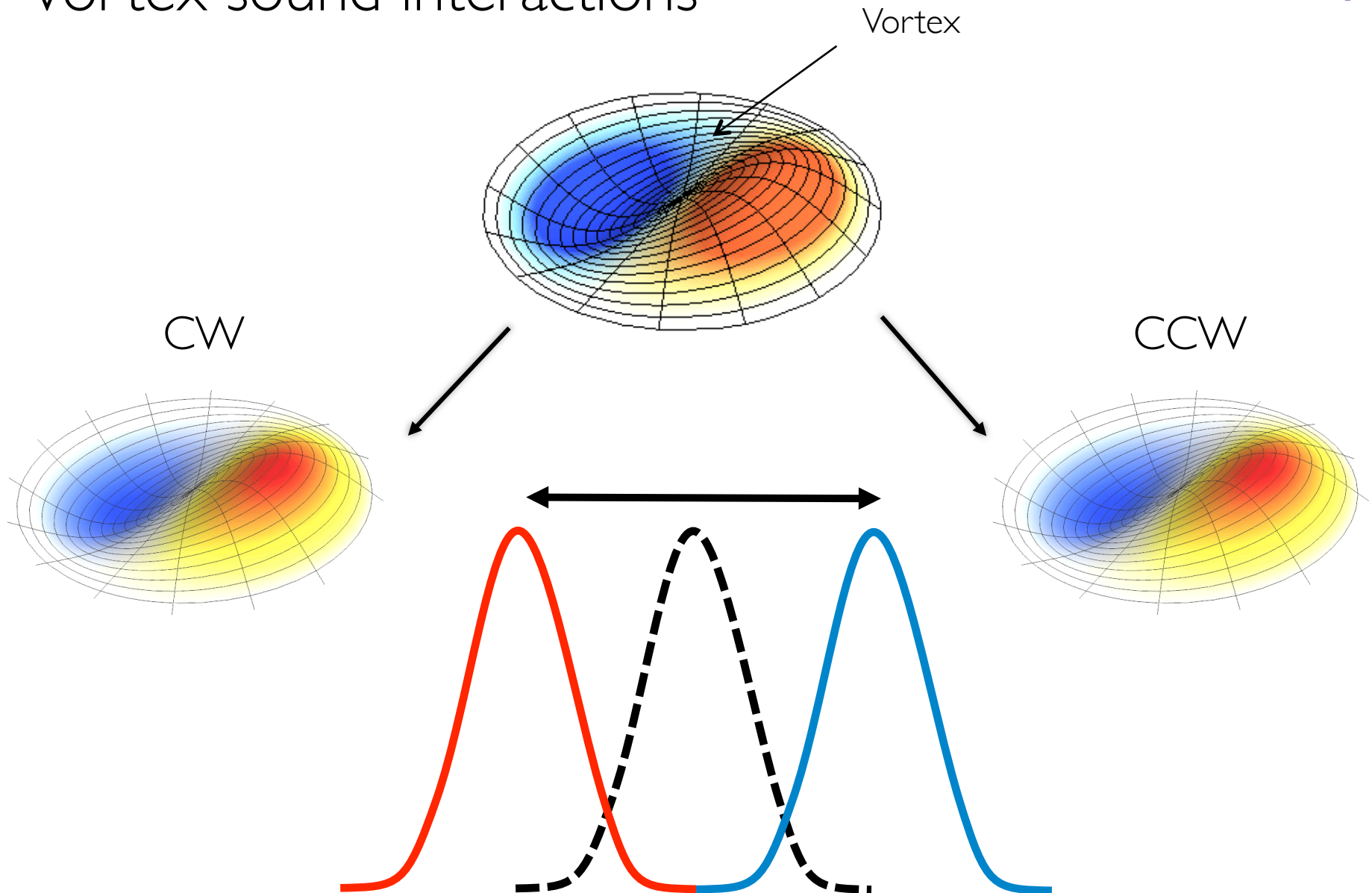
Gomez, L. F., ..., Vilesov, A. F. Shapes and vorticities of superfluid helium nanodroplets. *Science* **345**, 906-9 (2014).

➤ Vortex dynamics not yet observed in thin films

Vortex sound interactions



Vortex sound interactions





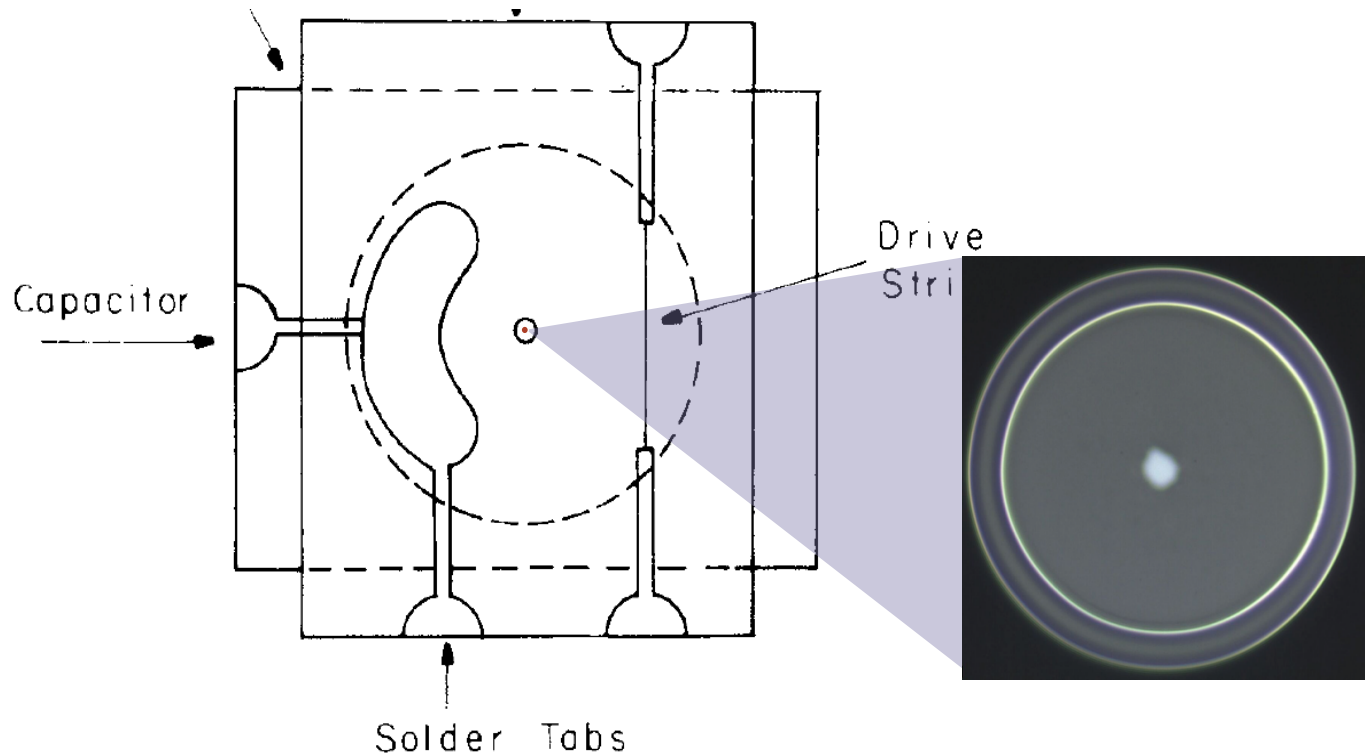
Observation of the persistent-current splitting of a third-sound resonator

F. M. Ellis and Hai Luo

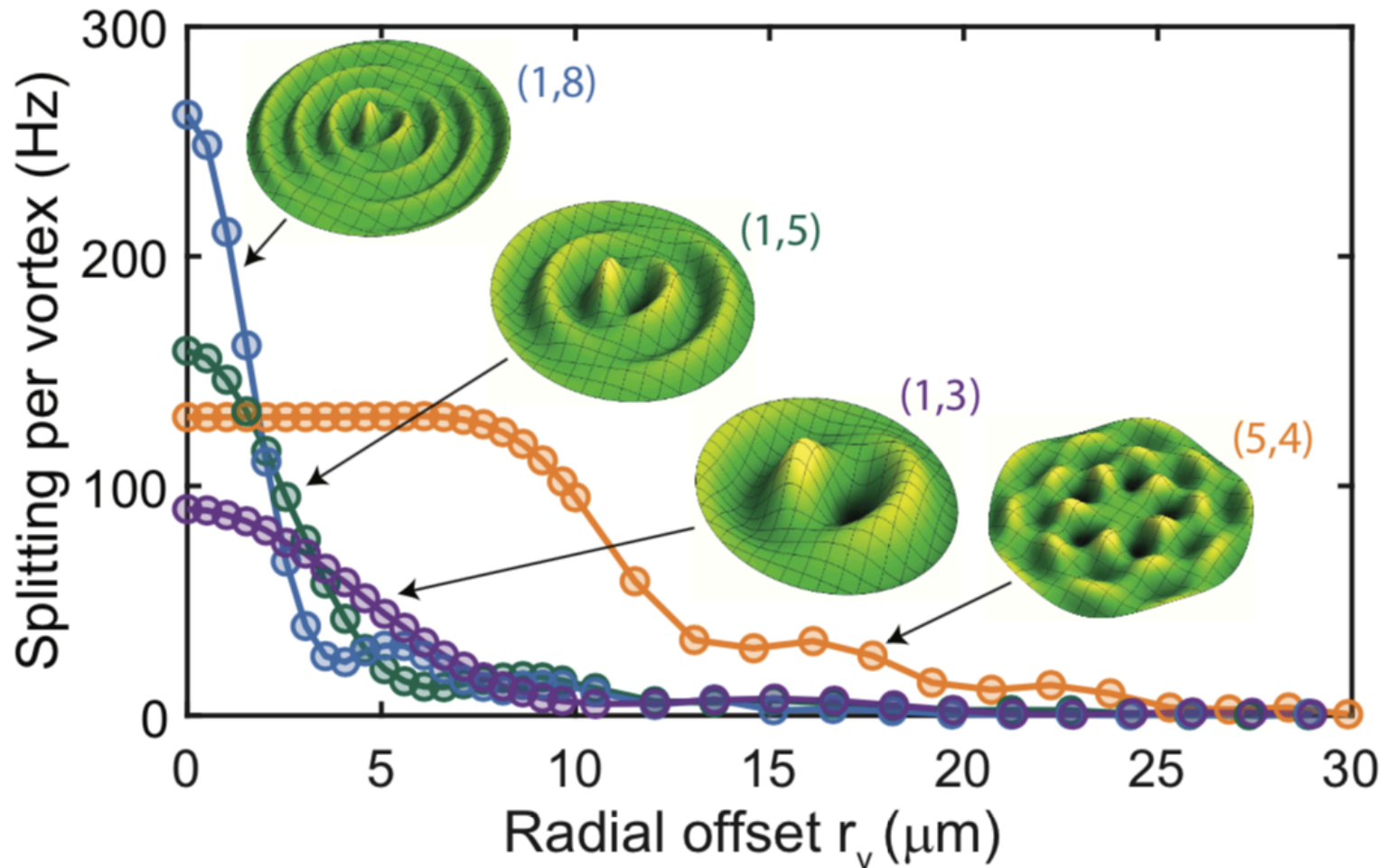
Department of Physics, Wesleyan University, Middletown, Connecticut 06457

(Received 15 June 1988)

The splitting of third-sound modes in a circular resonator due to the presence of a moderate-velocity persistent current has been observed. The absence of splittings in previous resonators is explained in terms of the dynamics of a two-level system. Single quanta of circulation should be observable in a smaller resonator.

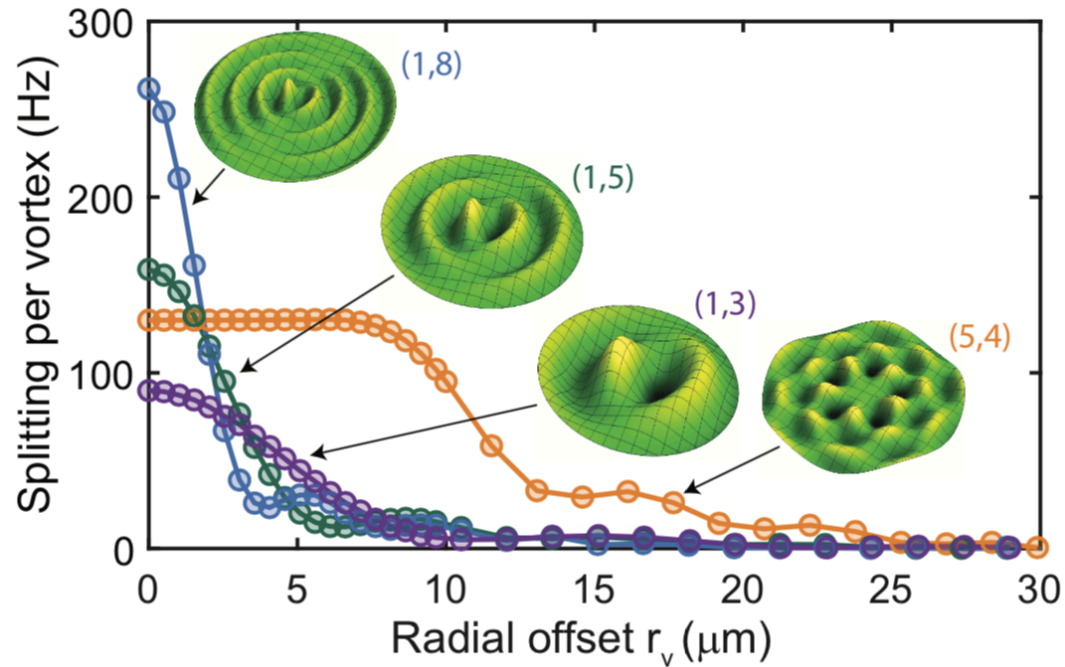


Vortex sound interactions

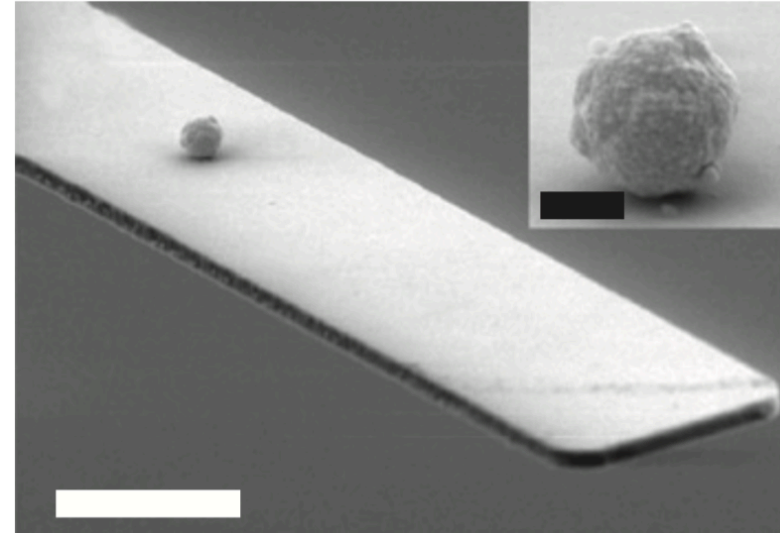


Stefan Forstner, Yauhen Sachkou, Matt Woolley, Glen I. Harris, Xin He, Warwick P. Bowen, and Christopher G. Baker: "Modelling of vorticity, sound and their interaction in two-dimensional superfluids." *New J. Phys.* **21** 053029, 2019

Vortex sound interactions



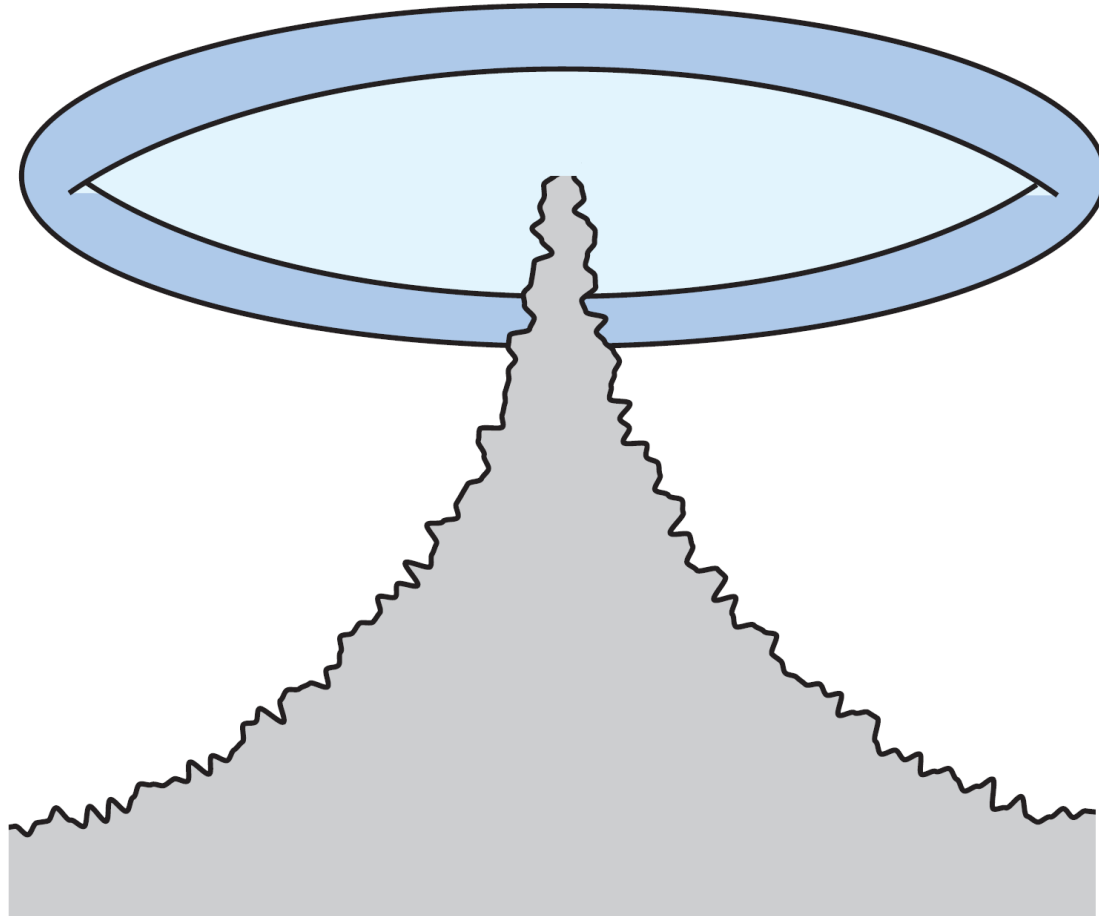
Stefan Forstner et al: *arXiv:1901.05167* (2019).



M. S. Hanay et al., *Nat. Nanotech.* 10, 339-344 (2015).



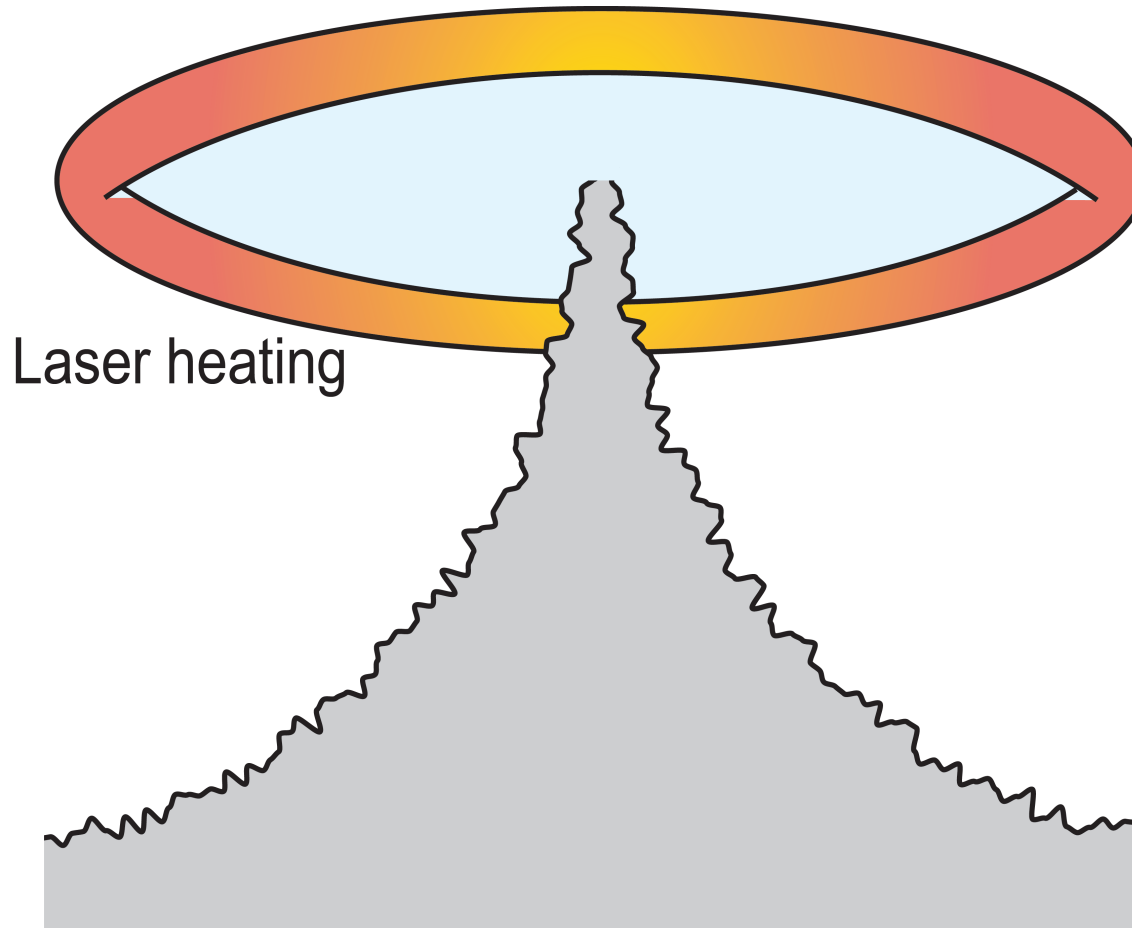
Vortex generation



Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)



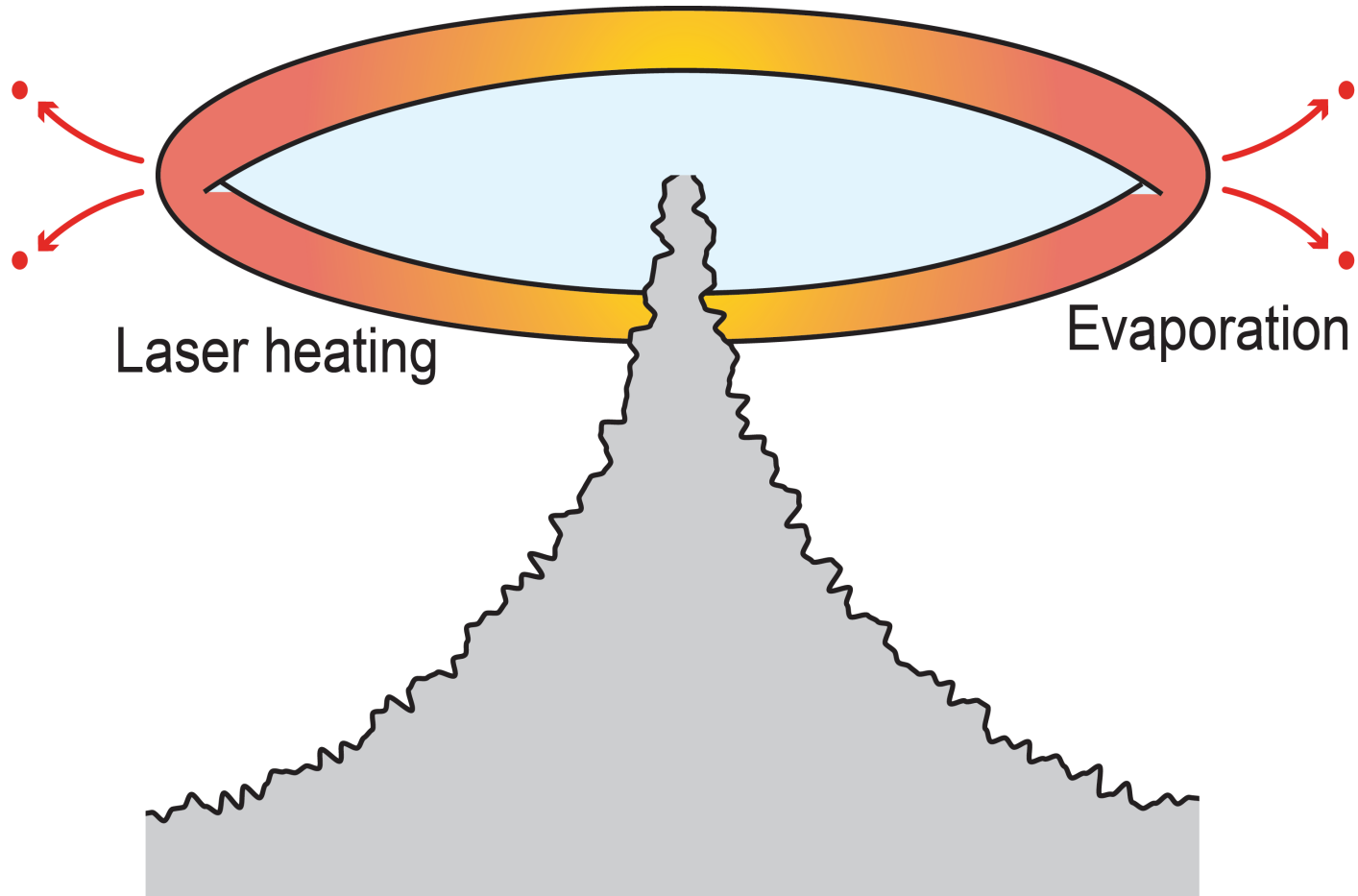
Vortex generation



Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)

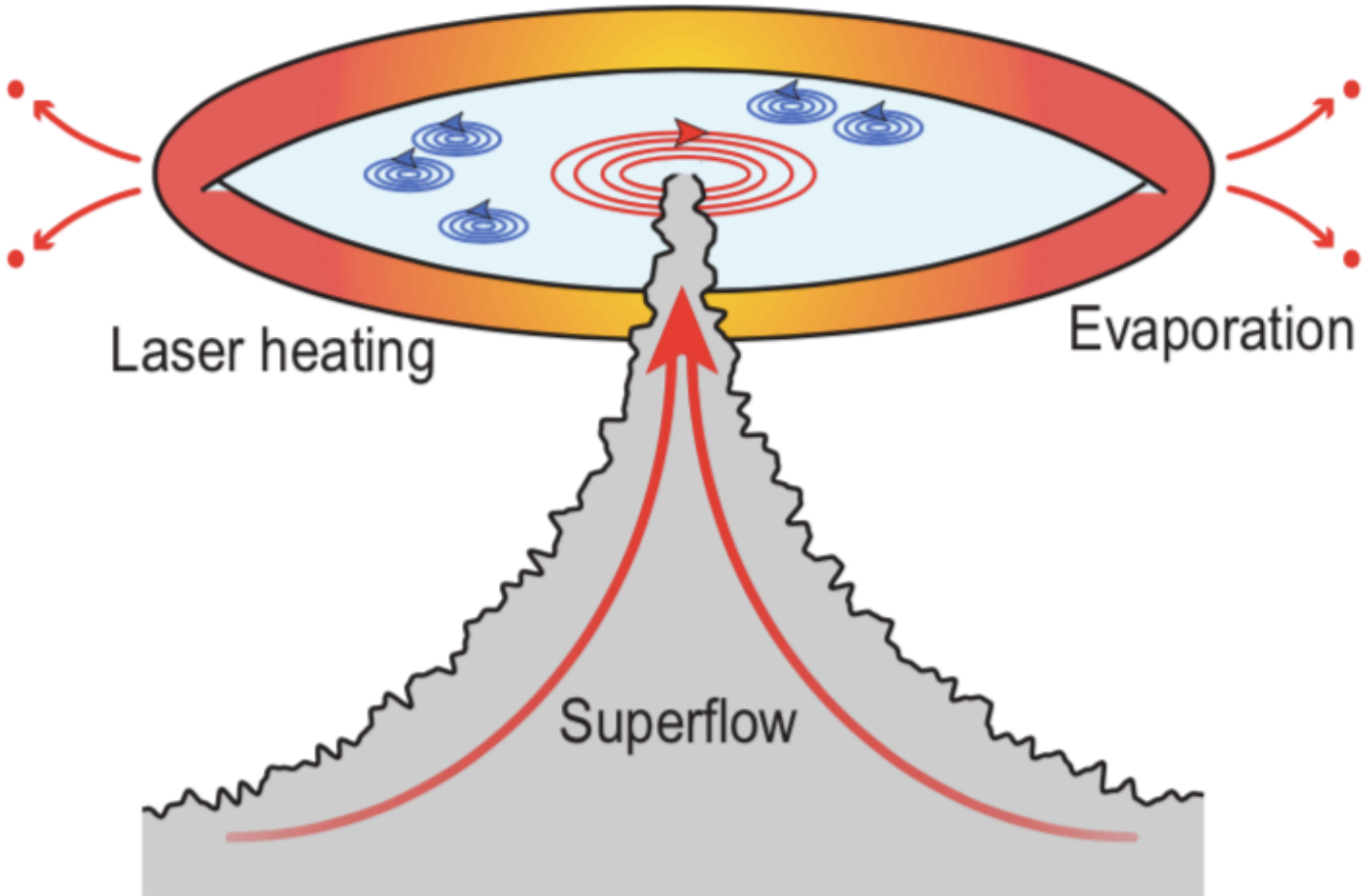


Vortex generation



Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)

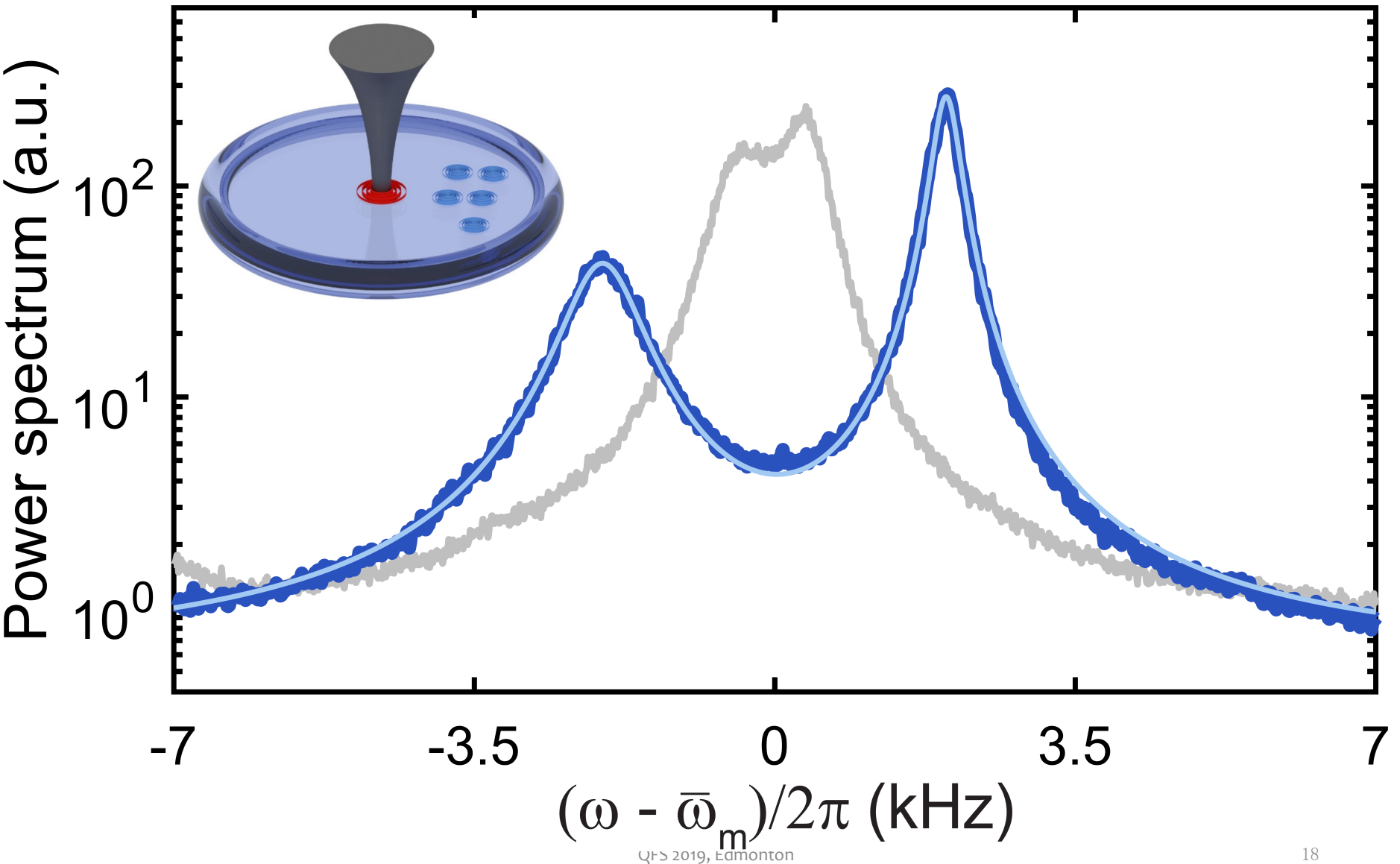
Vortex generation



Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)

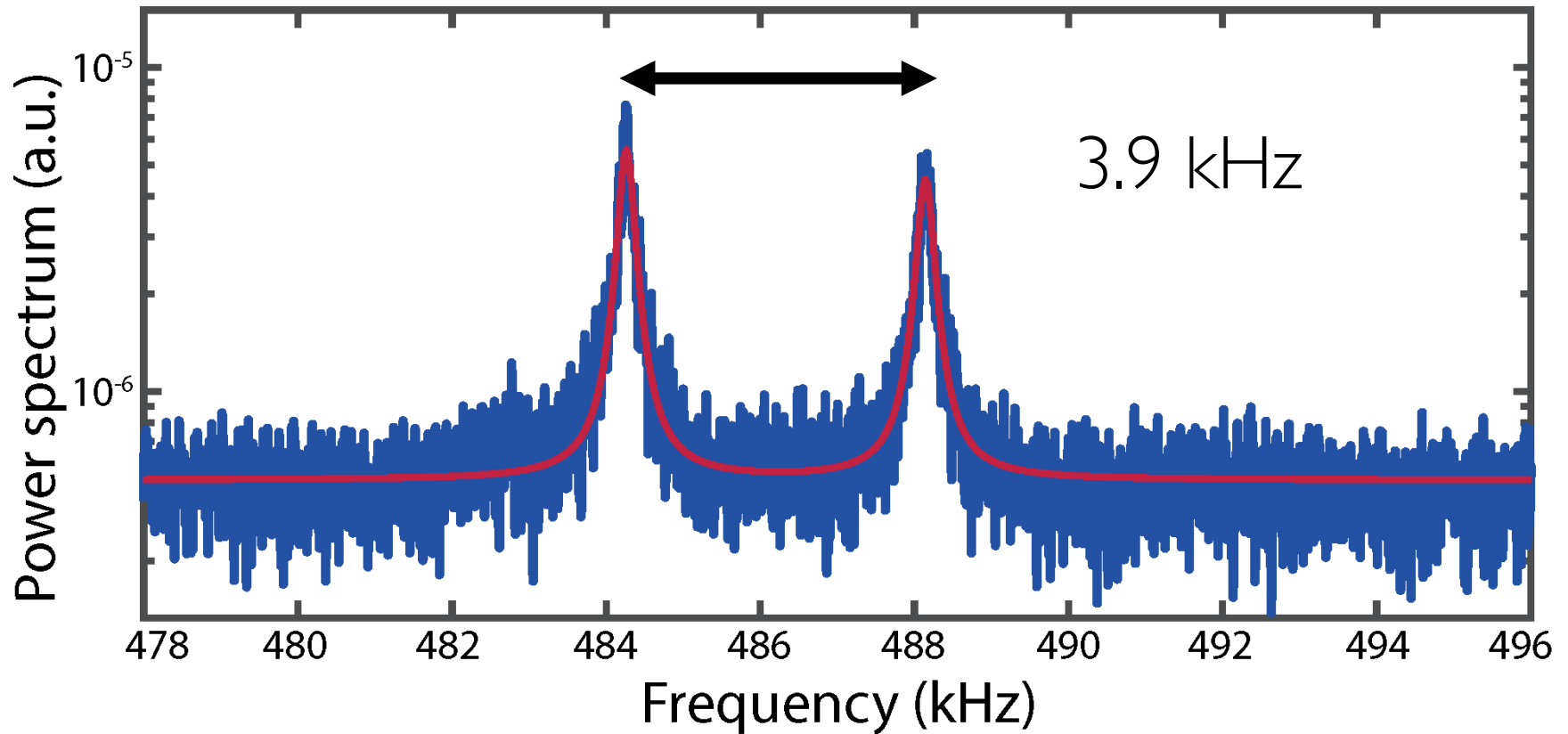


Vortex generation



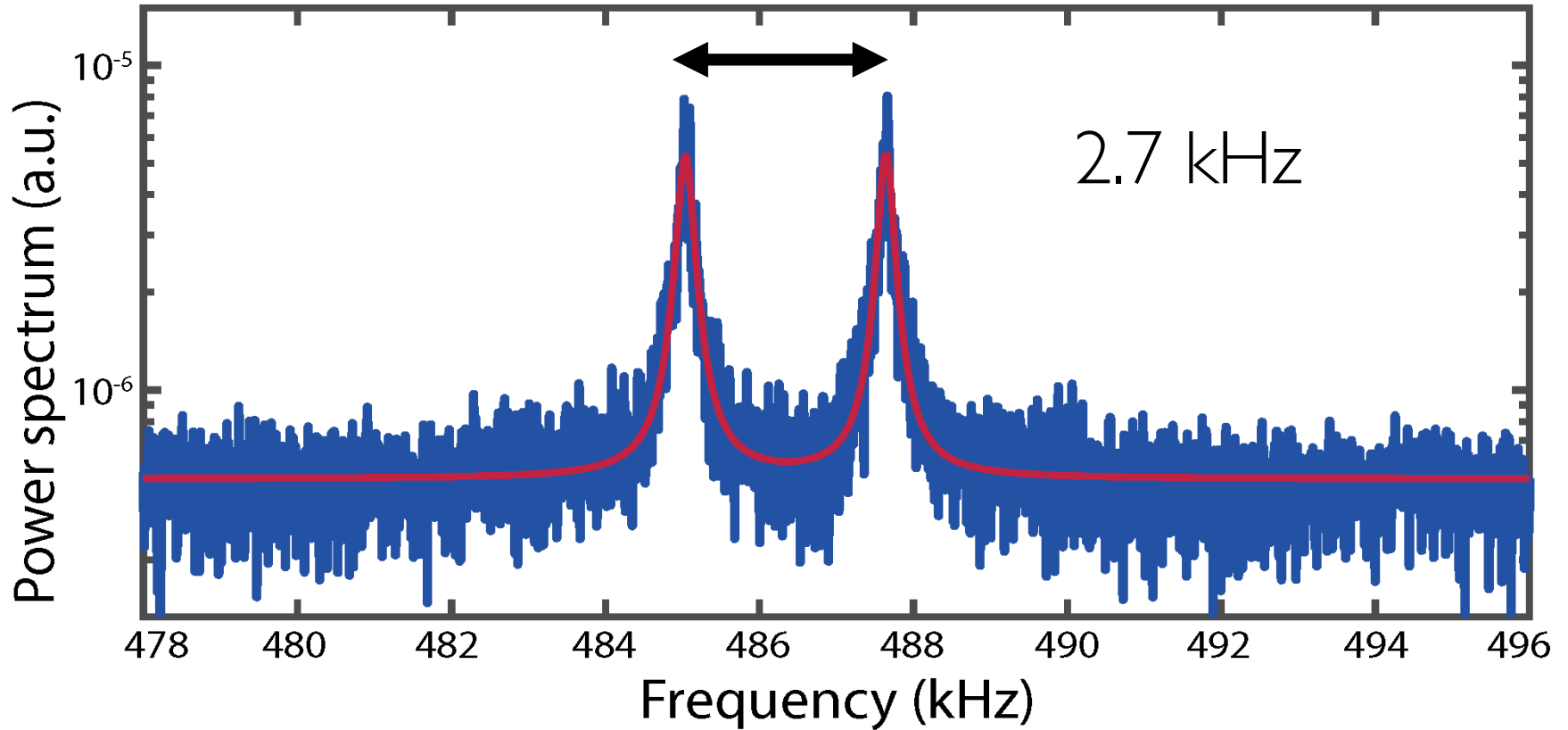


Splitting decay



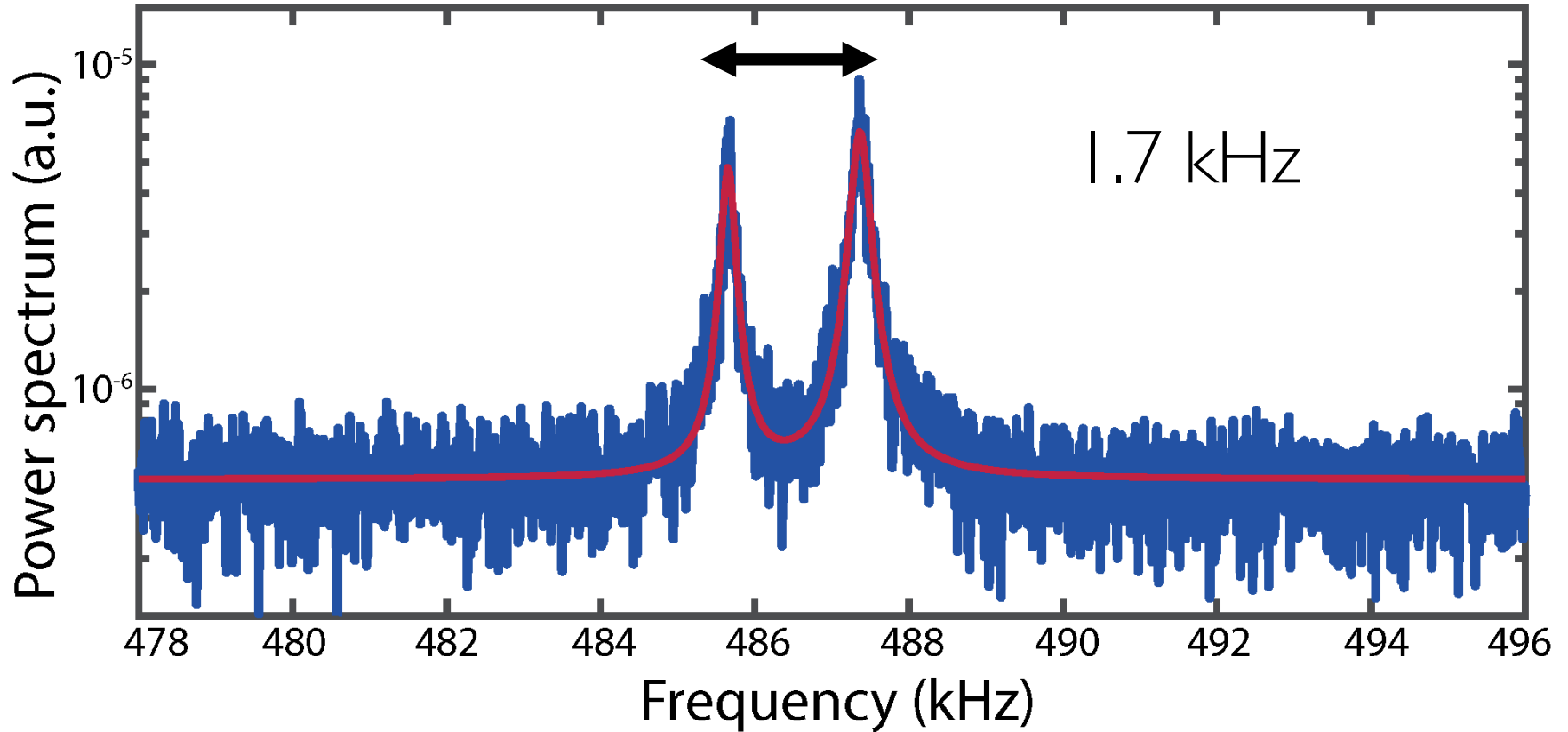


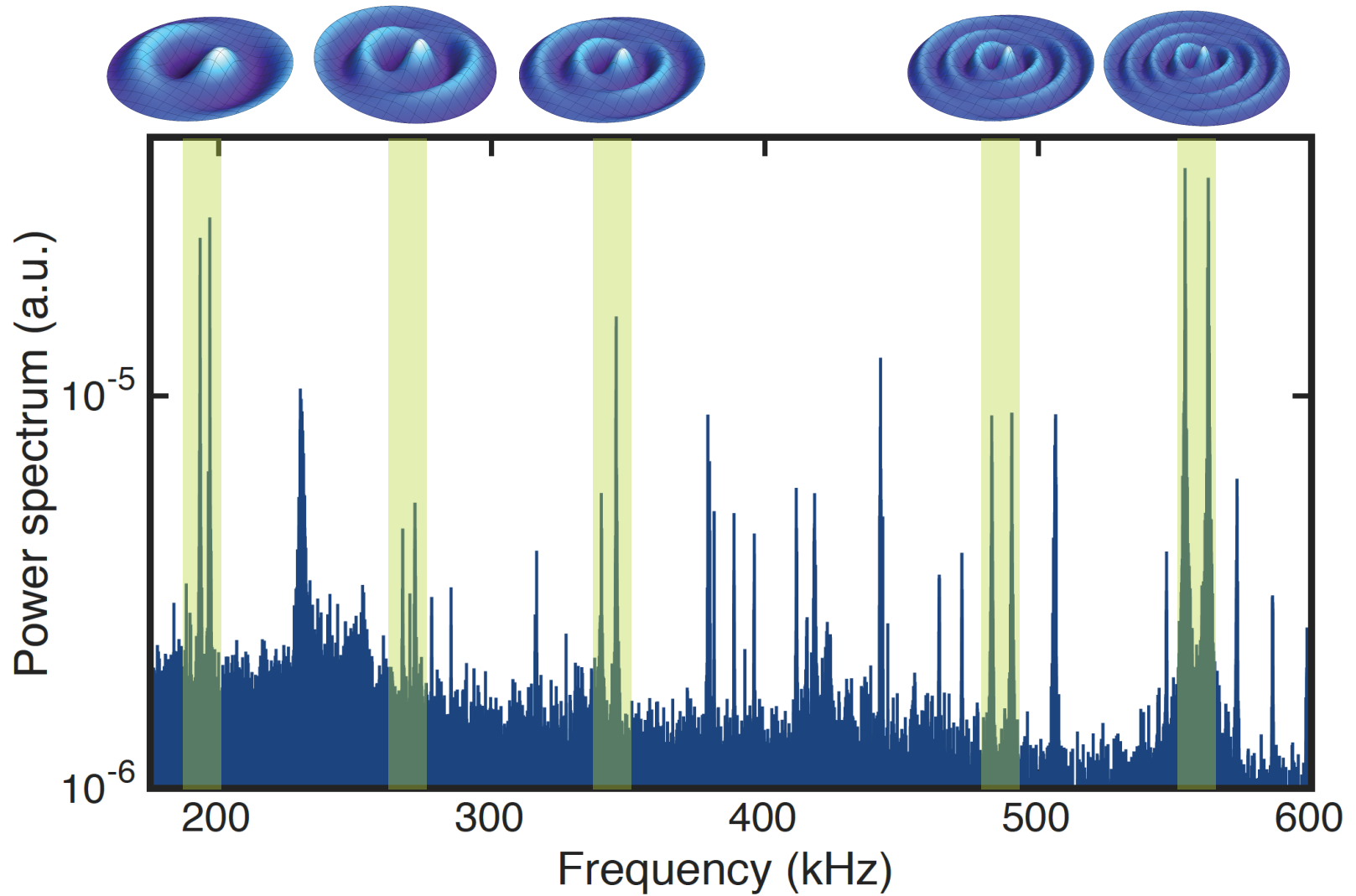
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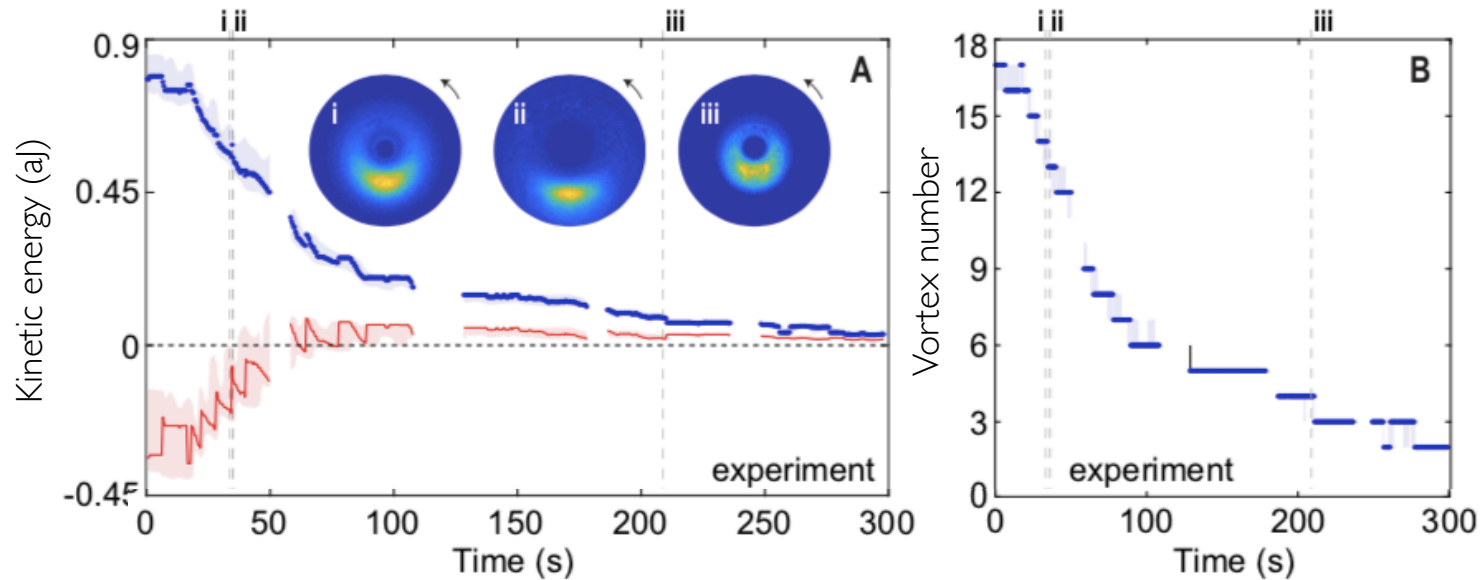
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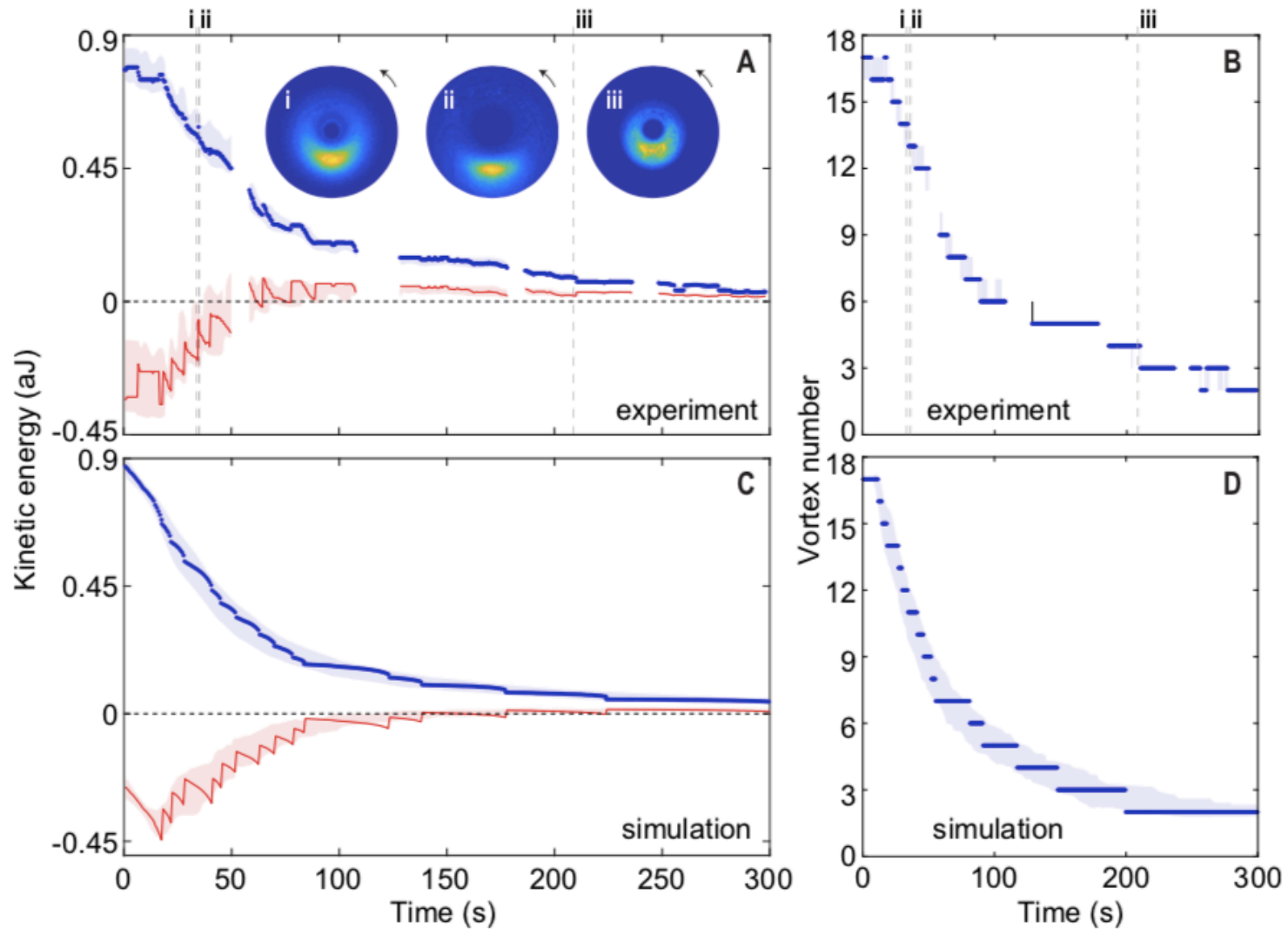
Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)

Non-equilibrium vortex dynamics



Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)

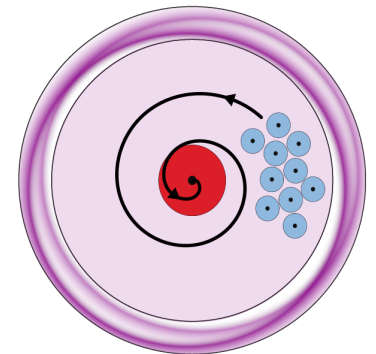
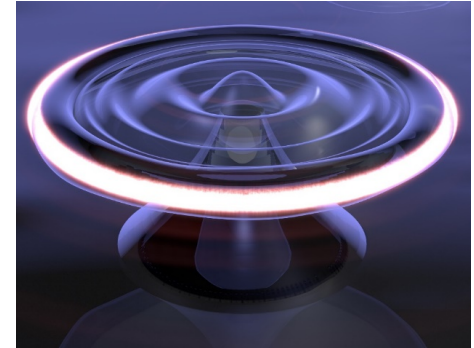
Non-equilibrium vortex dynamics

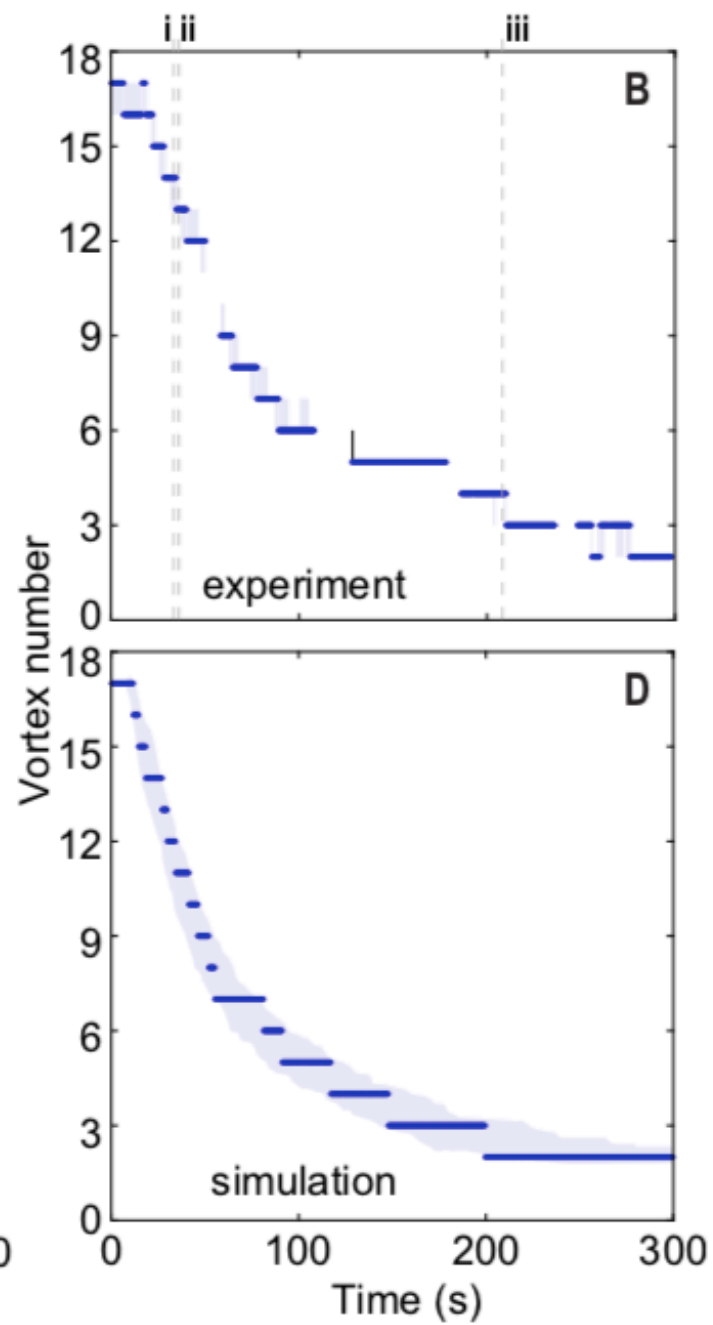
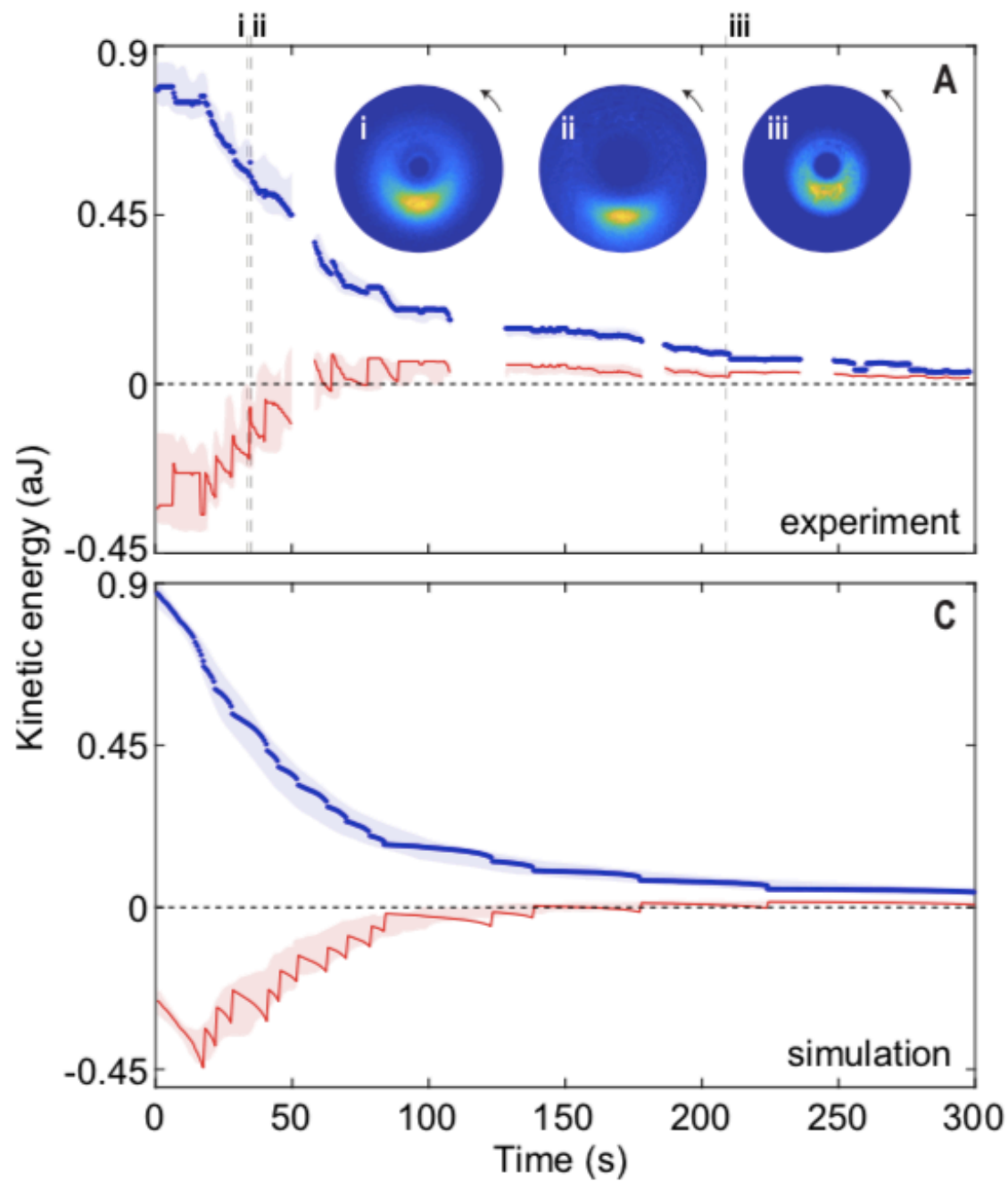


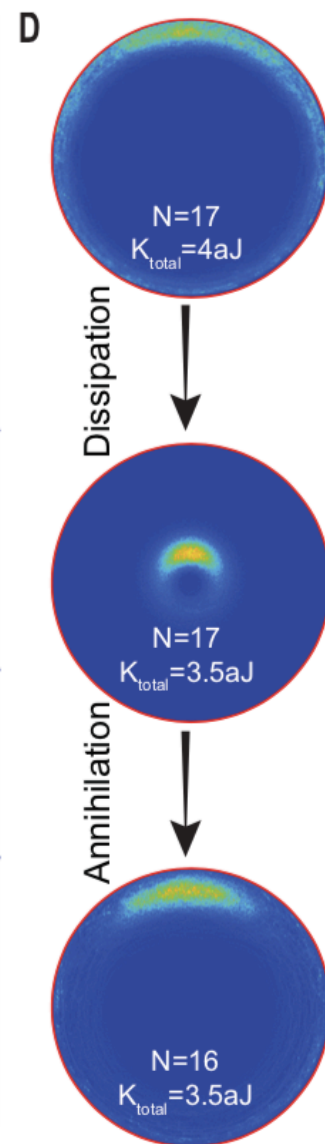
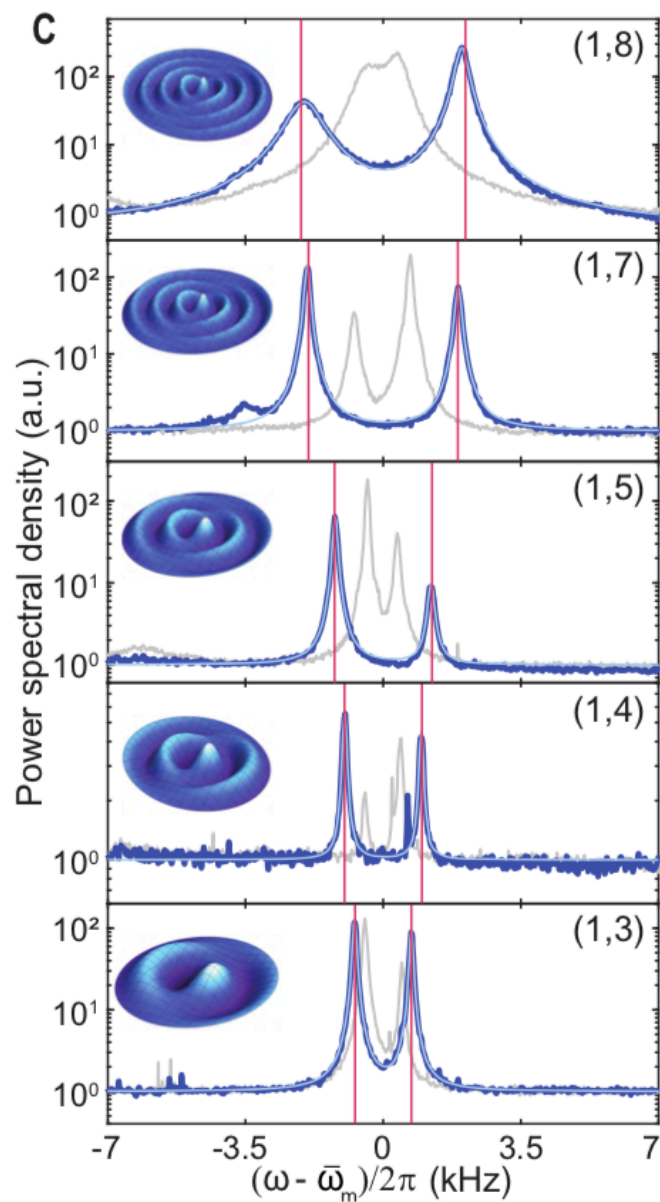
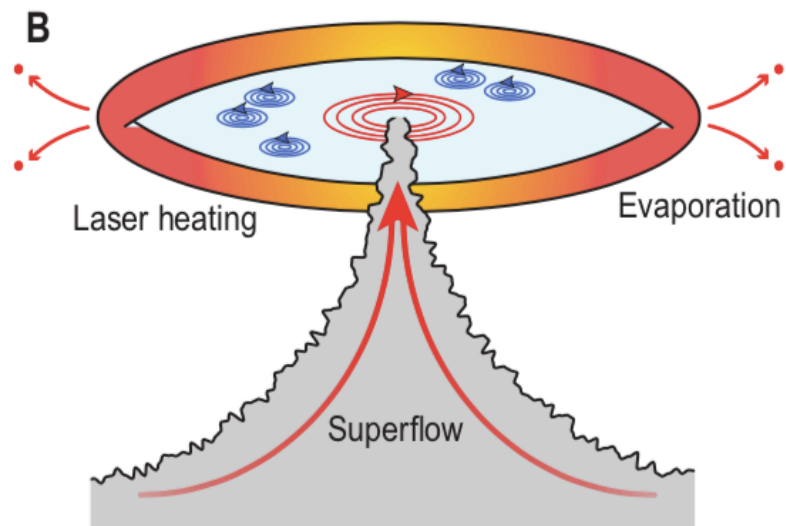
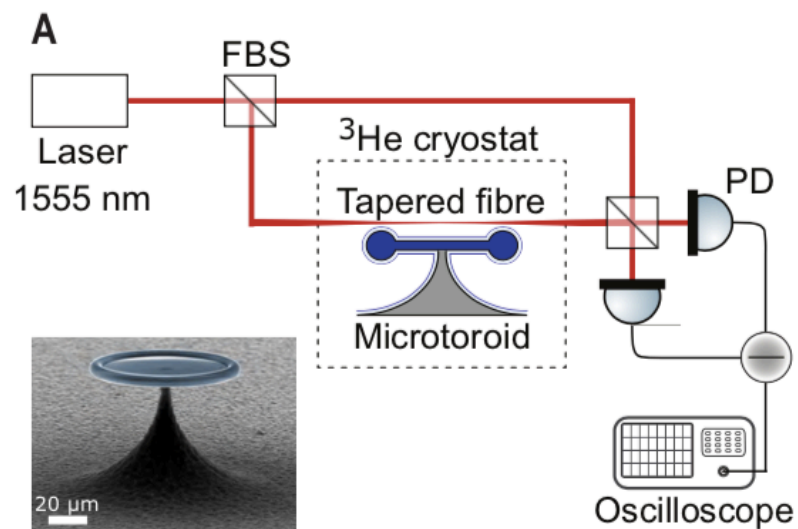
Sachkou, Y. P., Baker, C. G., Harris, G. I., Stockdale, O. R., Forstner, S., Reeves, M. T., ... & Bowen, W. P. "Coherent vortex dynamics in a strongly-interacting superfluid on a silicon chip." *arXiv:1902.04409* (2019)

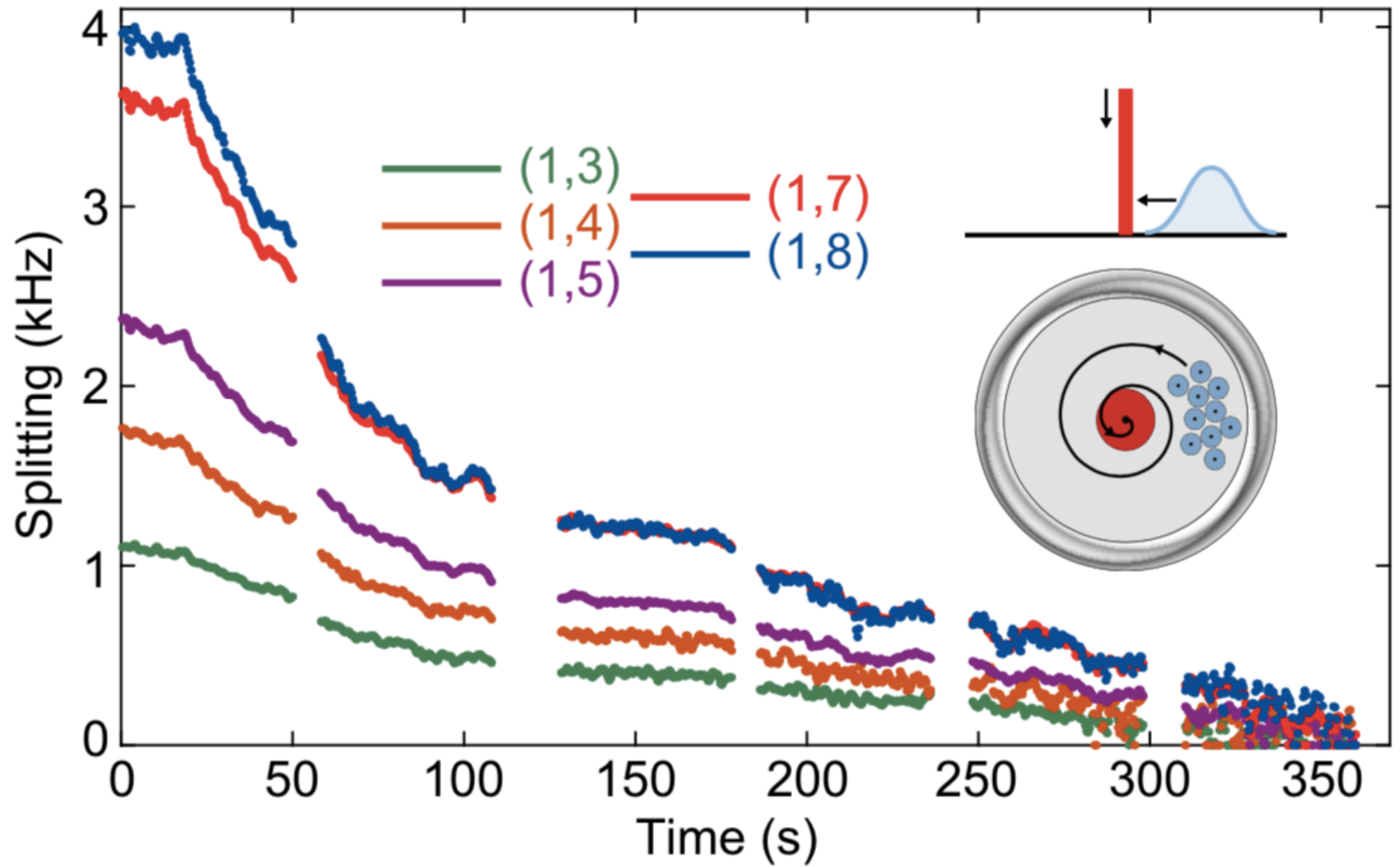
Summary

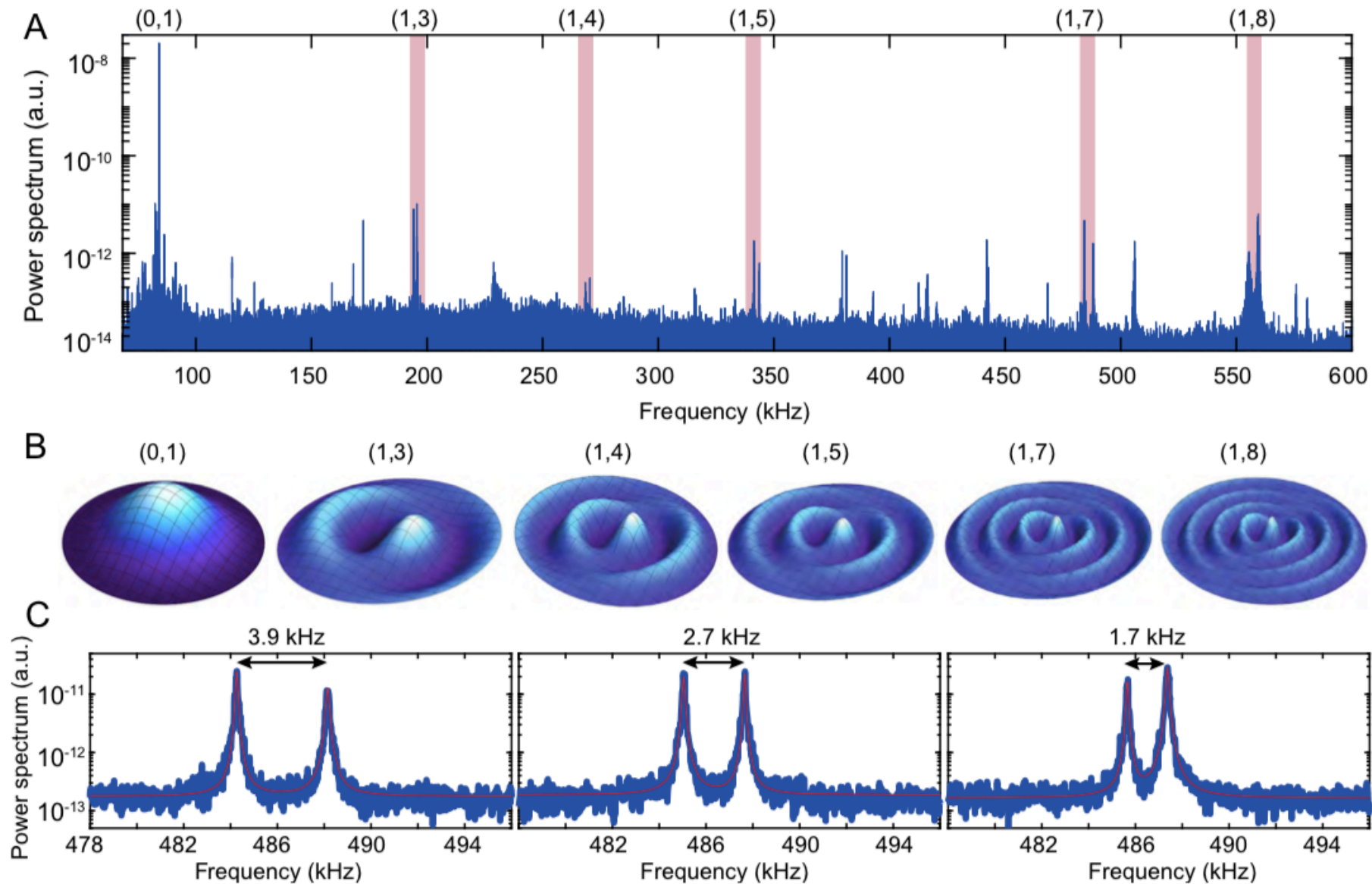
- Dynamics of strongly interacting superfluids is essential but difficult to study
- New technique allowing to study non-equilibrium vortex dynamics of a strongly interacting superfluid film
- First single-shot vortex tracking and observation of evaporative heating in a strongly interacting superfluid film



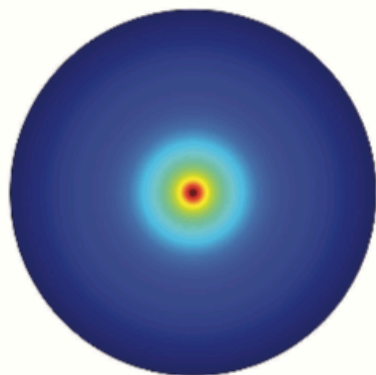




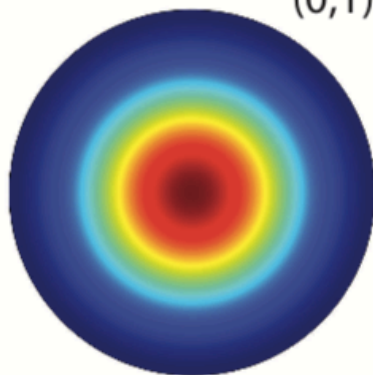




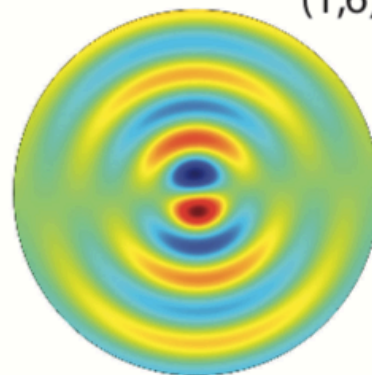
Disk



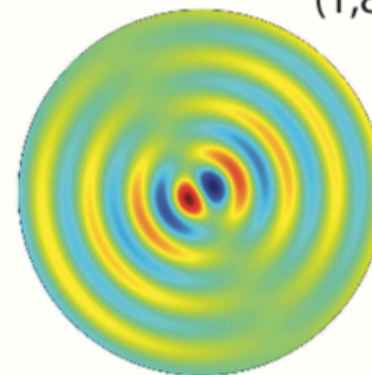
$(0,1)$



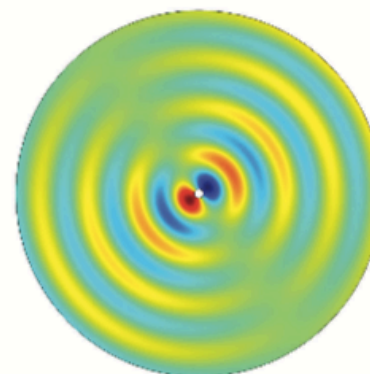
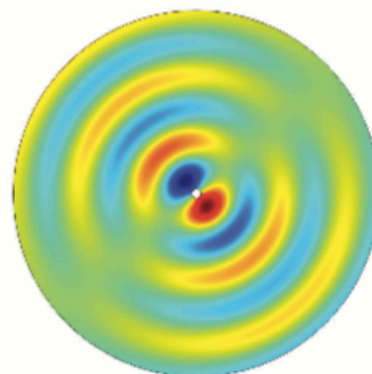
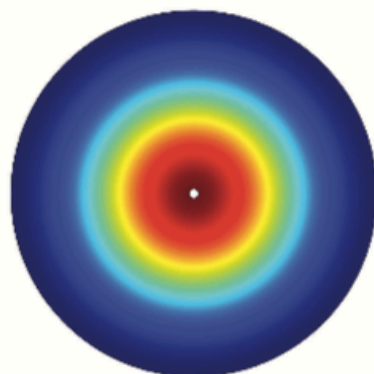
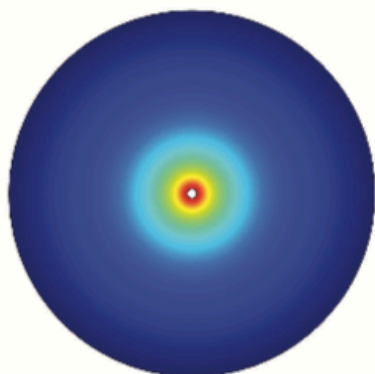
$(1,6)$

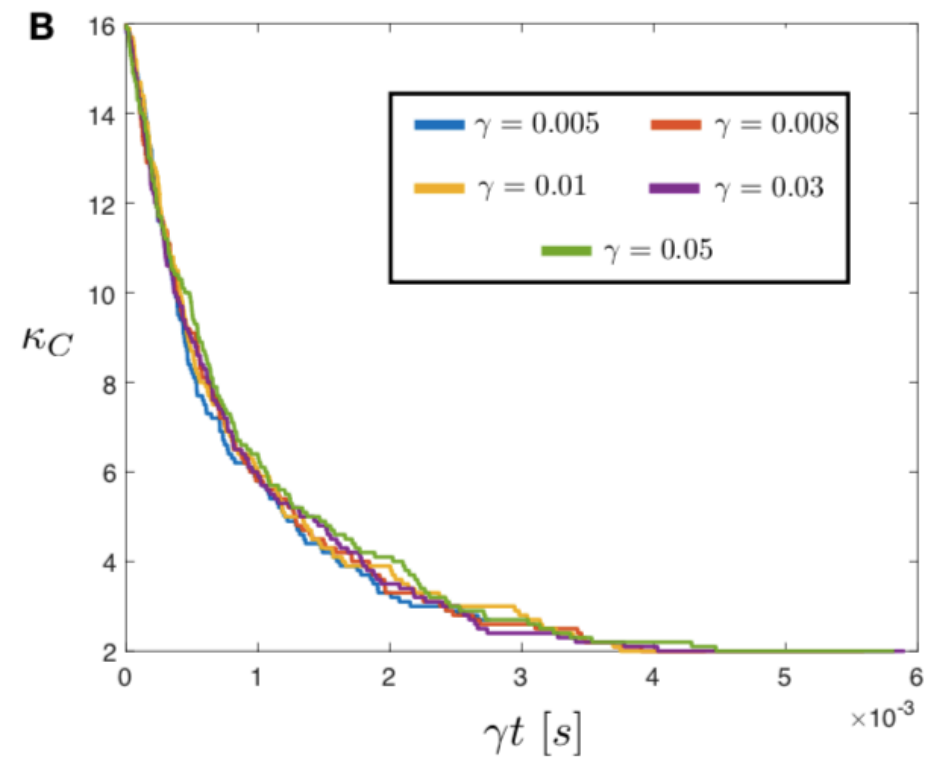
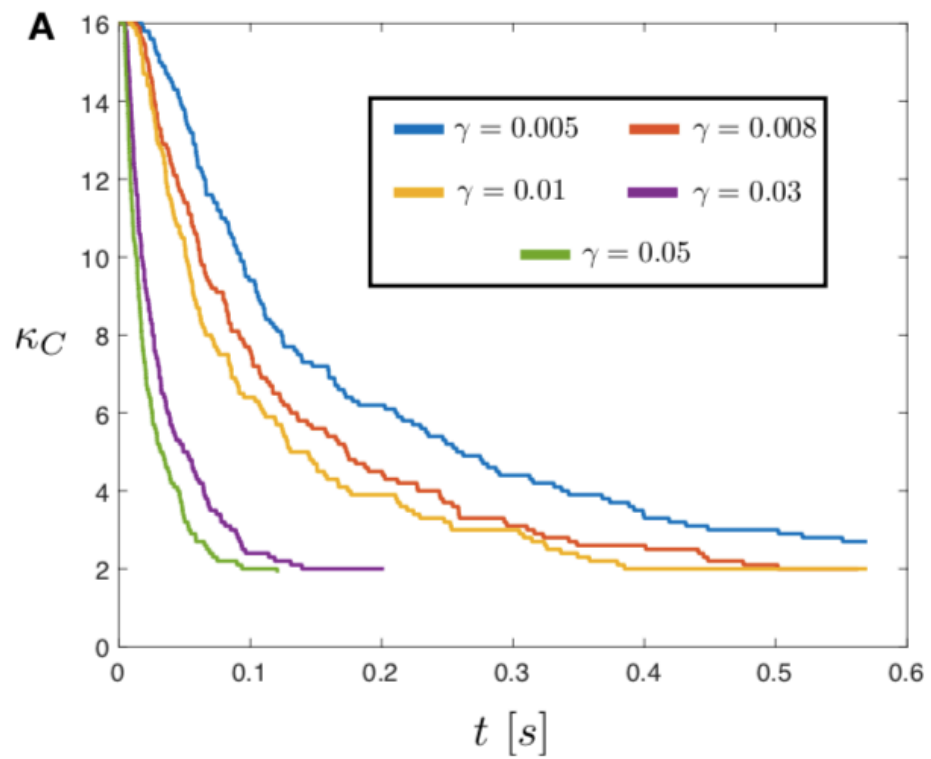


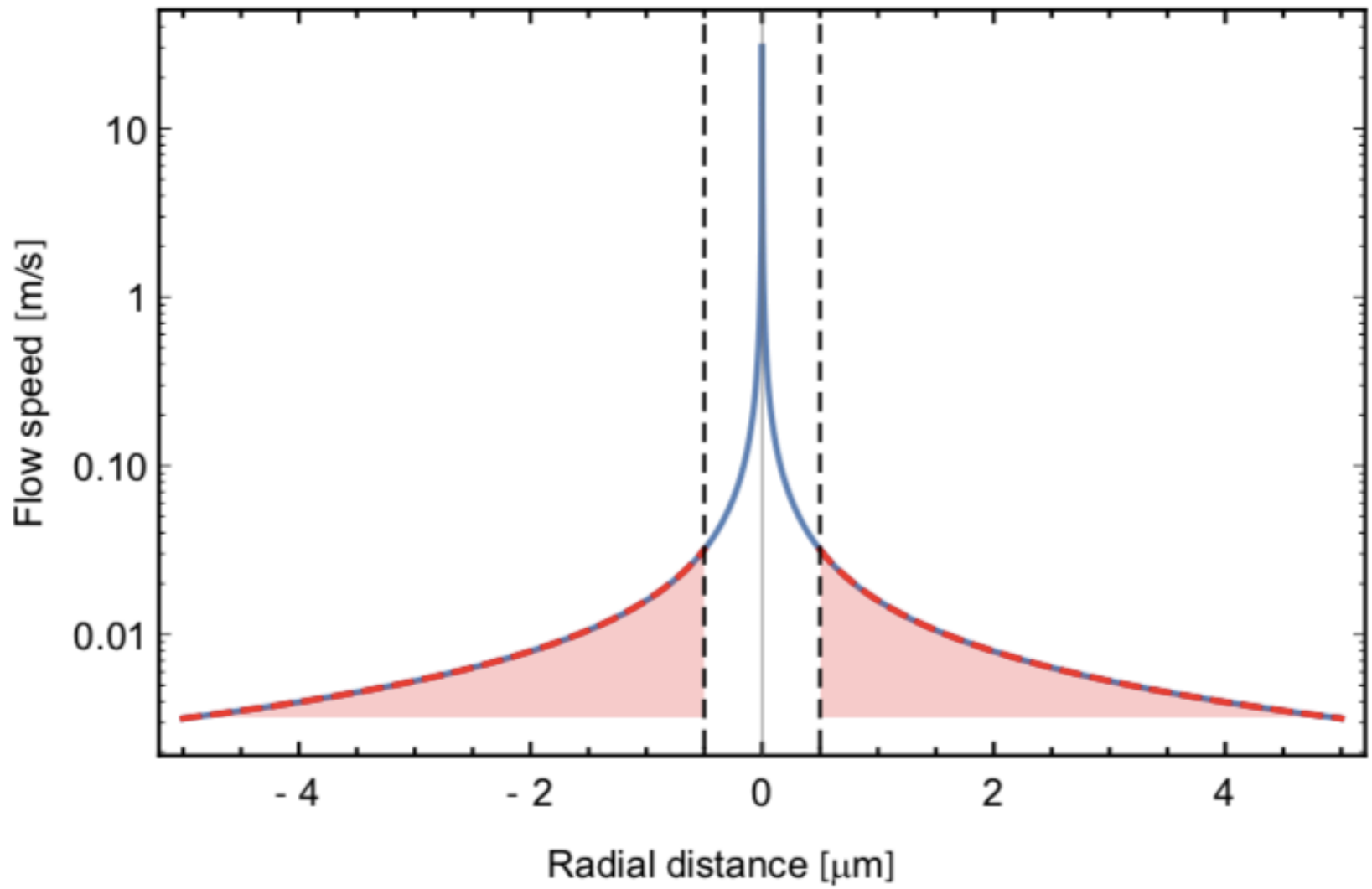
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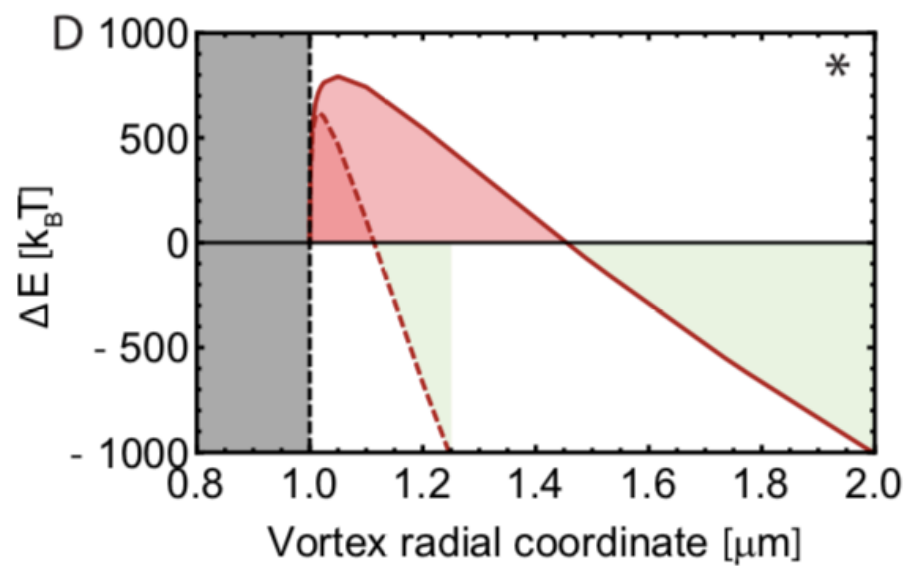
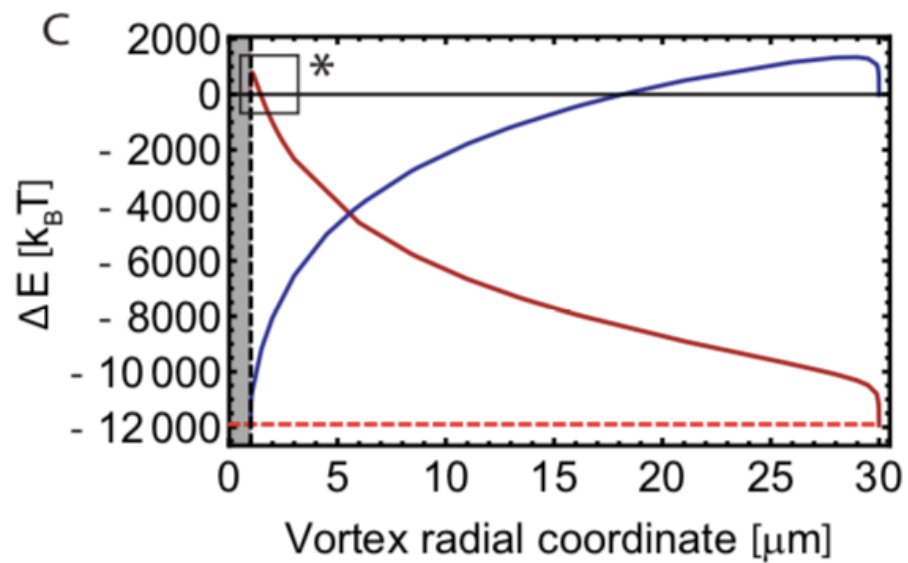
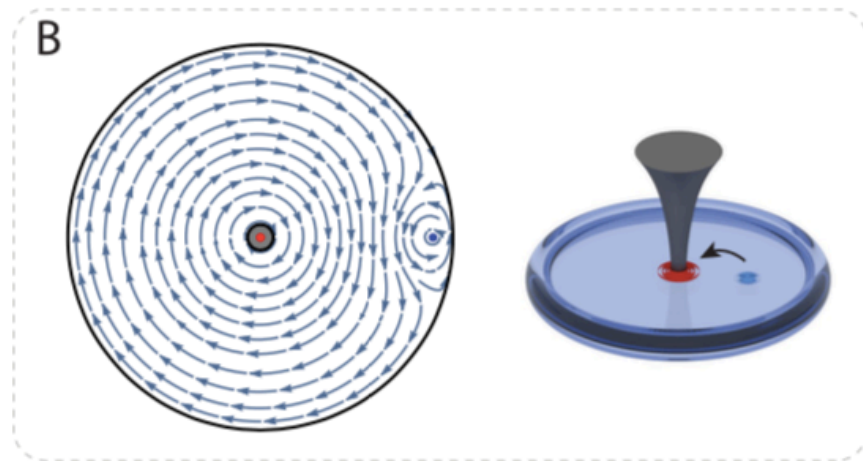
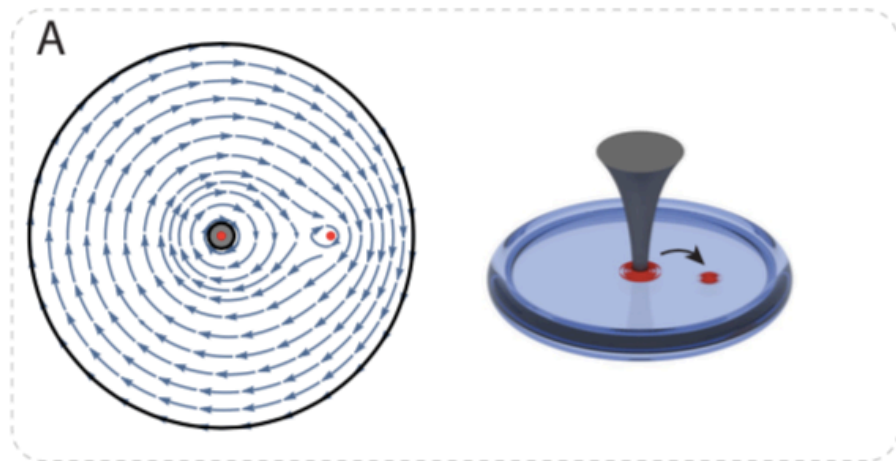


Annulus









Testing various vortex decay scenarios

