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Experiments on Rogue Waves in Superfluid ^{4}He

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We describe an experimental and theoretical study of nonlinear wave interactions in superfluid helium and report the observation of rogue waves.

Rogue waves (or freak waves, or killer waves, or extreme waves) have long been recognized by sailors as a menace to shipping and are believed to have been responsible for the unexplained losses of vessels of all sizes, including e.g. 22 super-carriers between 1968 and 1994 [1, 2]. Rogue waves on the ocean are rare, and are much higher (and steeper) than all the other waves around them. They seem to appear from nowhere and subsequently to disappear without trace [3]. Following the famous "New Year wave" measured by instruments on the Draupner North Sea oil rig at the beginning of 1995, the existence of oceanic rogue waves is no longer in doubt. There have been several suggestions about possible mechanisms for the creation of rogue waves. These include the combined effects of wind and currents, and the focusing effects associated with the profile of the ocean floor and nearby shorelines. Where rogue waves appear in deep water far from any shore, which they sometimes do, it seems likely that they must evolve through nonlinear interactions within the "noisy background" of smaller wind-blown waves [4]. Rogue waves have been modeled theoretically, especially by exploiting the special properties of the nonlinear Schrödinger equation. They have been sought experimentally and/or studied in large wave tanks [5], optical systems [6, 7], and superfluid ^{4}He [8].

Our experimental system consists of high intensity second sound (temperature-entropy) waves within a resonant cavity filled with superfluid ^{4}He at 2.1 K. Under steady state conditions, with a constant oscillatory driving force at the resonant frequency, the second sound waves are turbulent and fluxes of energy flow towards both high and low frequencies. It is found that rogue waves appear under the nonequilibrium conditions that prevail shortly after the drive has been switched on, prior to establishment of the steady state. The experiments will be described, relevant results will be presented and discussed theoretically in terms of nonlinear wave interactions, and possible connections to rogue waves on the ocean will be considered.

It will also be pointed out that, quite generally, and even without considering detailed interaction mechanisms, rogue waves can be considered as classical large fluctuations [9, 10, 11]. Thus they may be expected to possess deterministic features in the sense of developing and decaying along optimal paths, despite the inherently random, fluctuational, mechanisms that generate them.

We conclude that second sound in superfluid ^{4}He constitutes a convenient laboratory scale experimental system for studies of rogue waves. Our experimental observations and numerical simulation show that it is the nonlinear wave interaction that are responsible for generation of the direct and inverse energy cascades in the turbulent wave system. Rogue waves are created in profusion during the transient process towards the state where the inverse cascade exists in steady state. We suggest that the underlying mechanism for the development of the rogue waves in superfluid helium, i.e. the decay instability of large-amplitude waves, is analogous to that responsible for the generation of rogue waves on the ocean surface.

References

[1] C. Kharif, E. Pelinovsky, Eur. J. Mech. B/Fluids **22**, 603 (2003)

[2] E.N. Pelinovsky, A. Slunyaev, A. Slunyaev, *Rogue Waves in the Ocean* (Springer-Verlag, Berlin, 2008)

[3] N. Akhmediev, A. Ankiewicz, M. Taki, Phys. Lett. A **373**, 675 (2009)

[4] A.I. Dyachenko, V.E. Zakharov, JETP Lett. **81**, 255 (2005)

[5] M. Onorato, T. Waseda, A. Toffoli, L. Cavaleri, O. Gramstad, P.A.E.M. Janssen, T. Kinoshita, J. Monbaliu, N. Mori, A.R. Osborne et al., Phys. Rev. Lett. **102**(11), 114502 (2009)

[6] D.R. Solli, C. Ropers, P. Koonath, B. Jalali, Nature **450**(06402), 1054 (2007)

[7] A. Montina, U. Bortolozzo, S. Residori, F.T. Arecchi, Phys. Rev. Lett. **103**, 173901 (2009)

[8] A.N. Ganshin, V.B. Efimov, G.V. Kolmakov, L.P. Mezhov-Deglin, P.V.E. McClintock, Phys. Rev. Lett. **101**(6), 065303 (2008)

[9] L. Onsager, S. Machlup, Phys. Rev. **91**(6), 1505 (1953)

[10] M.I. Dykman, P.V.E. McClintock, V.N. Smelyanskiy, N.D. Stein, N.G. Stocks, Phys. Rev. Let. **68**(18), 2718 (1992)

[11] D.G. Luchinsky, P.V.E. McClintock, Nature **389**(6650), 463 (1997)