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Two-dimensional Coulomb gas at negative temperature

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Lars Onsager is perhaps best known as the recipient of 1968 Nobel Prize in chemistry and by his tour de force solution to the two-dimensional Ising model. However, his remarkable insight predicting the quantisation of vorticity in superfluid helium and the statistical mechanics description of two-dimensional turbulence have received much less attention. In this talk, I will briefly review certain aspects of the problem of two-dimensional turbulence with a particular emphasis on Onsager's statistical hydrodynamics model. I will then apply this model to turbulent superfluid Bose—Einstein condensates in which the quantised vortices have a long-range effective interaction and can be mapped to a two-dimensional Coulomb gas of positive and negative charged particles. By observing the dynamics of such vortex charges in numerical simulations we have found them to spontaneously arrange to large scale vortex clusters, coined Onsager vortices, that correspond to absolute negative Boltzmann temperatures [1]. I will discuss the microscopic mechanism leading to the emergence of such novel states of matter. Finally, I will outline the recent progress in Australia and elsewhere toward experimentally observing such states [2] with the prospect of realising Onsager's prediction of super vortices in two-dimensional fluid turbulence.

[1] "Emergence of Order from Turbulence in an Isolated Planar Superfluid",
Tapio Simula, Matthew J. Davis, and Kristian Helmerson,
Physical Review Letters **113**, 165302 (2014).

[2] "Vortex Gyroscope Imaging of Planar Superfluids", A. T. Powis, S. J. Sammut, and T. P. Simula, Physical Review Letters **113**, 165303 (2014).

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