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New results in solitons: Realization of Peregrines and a dense soliton gas

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Solitons are a hallmark feature of nonlinear dynamics. By balancing dispersion with interactions, solitons acquire a persistent nature that makes them observable in many important nonlinear systems. A variety of solitons have been considered in physical realizations including BECs, water tanks, optical fibers, plasmas, magnetic materials and more, making their study a central part of nonlinear science in general.

Due to the rich atomic physics toolbox with which quantum gases can be manipulated, BECs are a prime testbed for the study of these nonlinear features and their dynamics. Here, we present two recent advances of the field obtained in our experiments at WSU: the realization of a Peregrine soliton, and the observation of a dense soliton gas.

The Peregrine is a dynamic solution of the nonlinear Schroedinger equation. It localizes in space and time: it emerges out of a background, forms a large, pronounced peak, and vanishes again. This makes the Peregrine a possible candidate for explanations of rogue waves. This solution was first found theoretically, and later confirmed experimentally using optical fibers and large water wave tanks. Here we present the first realization of a Peregrine in a dilute-gas BEC. Compared to water tank and optical experiments, our system has very different time and length scales and affords a very rich tool set for the controlled, reproducible creation and detailed investigation of these features. This work opens up a new path towards experimental studies of spatio-temporal solitons.

In a second, separate line of research, we have used a phase winding technique to realize a dense soliton gas. In this system,
a large number of solitons is strongly confined so that the solitons are in a constant state of collisions. The dynamics of such systems are the topic of strong research efforts in nonlinear dynamics and applied mathematics. Our observation of this system in BECs complements existing experiments in water tanks and optics, and opens up a new playground for the investigation of its underlying dynamics.

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Primary author: ENGELS, Peter (Washington State University)

Co-authors: MOSSMAN, Sean (University of San Diego); ROMERO-ROS, Alejandro (University of Hamburg); KATSIMIGA, Lia (University of Massachusetts, Amherst); MISTAKIDIS, Simos (ITAMP); BIONDINI, Gino (University at Buffalo); SCHMELCHER, Peter (University of Hamburg); KEVREKIDIS, Panayotis (University of Massachusetts, Amherst)

Presenter: ENGELS, Peter (Washington State University)

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