“Soliton gas in shallow water. 1D and 2D experiments”

E. Barthélemy, T. Leduque, H. Michallet, N. Mordant

March 2, 2023

We present the results of soliton gas experiments for both 1D and 2D configuration. A soliton gas is an ensemble of shallow water solitons of Korteweg-De Vries (KdV) type random in amplitude and phases. In this context solitons are said to behave as particles since their collisions during the propagation in the gas are elastic.

1D soliton gases are generated in the LEGI 35 m long wave flume equipped with a piston wave-maker. The water elevation is highly resolved in space and time by utilizing a set of 8 synchronized cameras over 14 m stretch of flume. Experimental soliton gases differ from theoretical ones on different aspects: finite length flume and therefore wave reflection with bi-directionnal propagation, slow energy dissipation due to friction wave and interactions with the wave-maker. We will discuss the methods to analyze these gases, specifically the Periodic Scattering Technique (PST), but also give the statistical properties of such gases (Redor et al., 2019; 2020; 2021).

2D soliton gas were investigated during the experimental campaign in the ARTELIA LHF shallow water wave tank in Pont de Claix (Isère) (30 m x 27 m, 35 cm deep). Wave are generated by a set of 60 pistons located on one side of the flume in order to allow oblique wave generation. Individual oblique solitons, ensemble of random obliques solitons and random JONSWAP type of waves were generated. Surface elevation is measured using a stereoscopic reconstruction using 2 cameras (space and time resolved) as well as with a set of 30 localized wave gauges.

A possible theoretical framework of such 2D configuration is that of Kadomtsev-Petviashvili (KP) equation (Kadomtsev and Petviashvili, 1970). Individual KP solitons are infinite line solitons which profile are similar to KdV solitons. However the experimental generation of such solitons faces several practical concerns. The wave tank limited size imposes wave interaction with side walls. This results in very specific structures (Mach stems) along the walls. The wave maker is also limited in length. Waves crests are of finite length producing nonlinear diffraction at each edge of the line soliton. We will present the statistical properties of shallow water wave turbulence with varying wave forcing parameters resulting in either weak turbulence of dispersive waves or solitonic regimes.

References

B. B. Kadomtsev and V. I. Petviashvili. On the stability of solitary waves in weakly dispersing media. In *Doklady Akademii Nauk*, volume 192, pages 753–756. Russian Academy of Sciences, 1970.

I. Redor, Barthélemy E., H. Michallet, M. Onorato, and N. Mordant. Experimental evidence of a hydrodynamic soliton gas. *Physical Review Letters*, 122:214502, 2019.

I. Redor, Barthélemy E., N. Mordant, and H. Michallet. Analysis of soliton gas with large-scale video-based wave measurements. *Experiments in Fluids*, pages 61–216, 2020.

Ivan Redor, Hervé Michallet, Nicolas Mordant, and Eric Barthélemy. Experimental study of integrable turbulence in shallow water. *Physical Review Fluids*, 6(12):124801, 2021.