Can uneven bathymetry freeze water-wave breathers?

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Theoretical problem:

Akhmediev Breathers (AB) and dnoidal-type envelopes are solutions of the nonlinear Schrödinger equation (NLSE). The first represents the nonlinear stage of the modulation instability and is subject to Fermi-Pasta-Ulam recurrence, the second is a steady-state periodic solution. We show how to transform AB at its peak focusing distance to a dnoidal dynamics by an abrupt change of NLSE parameters

Physical implementation:

Surface gravity waves in intermediate waters (depth = *h*, dispersive and nonlinear coefficients depend on *h*)

$$i\frac{\partial U}{\partial \xi} + \underbrace{\beta\frac{\partial^2 U}{\partial \tau^2}}_{\text{Dispersion}} - \underbrace{\gamma U|U|^2}_{\text{Nonlinearity}} = -\underbrace{i\mu_0\frac{\partial (kh)}{\partial \xi}U}_{\text{Shoaling}} - \underbrace{i\nu U}_{\text{Loss}}$$

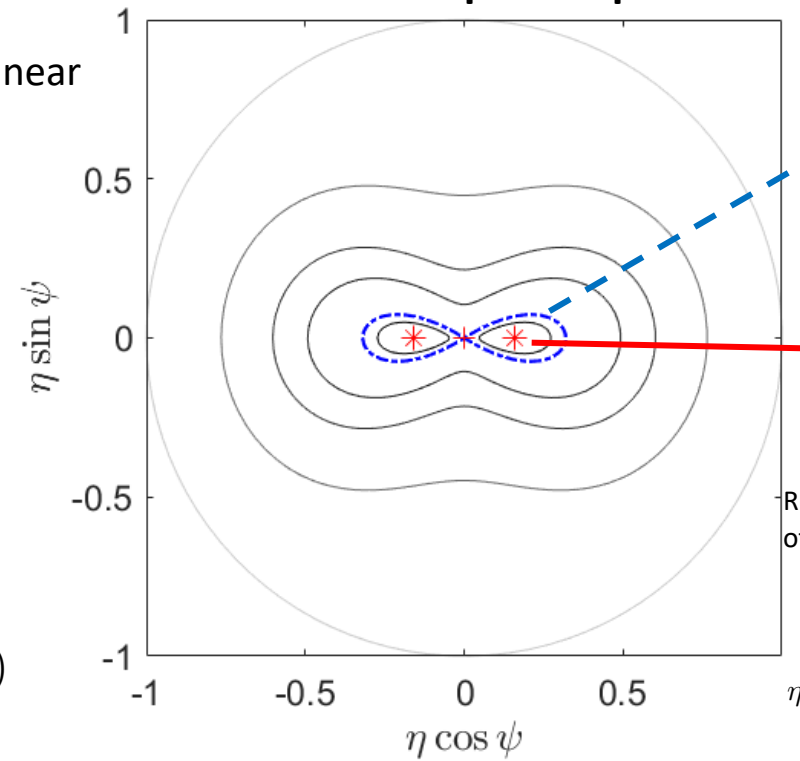
Using a shoaling-corrected complex amplitude:

$$V \equiv U \exp\left[\int_0^{\xi} \mu(y)\,\mathrm{d}y + \nu\xi\right]$$

one obtains a varying parameters NLSE:

$$i\frac{\partial V}{\partial \xi} + \beta\frac{\partial^2 V}{\partial \tau^2} - \tilde{\gamma}\,V|V|^2 = 0\,, \quad \tilde{\gamma}(\xi) = \gamma(\xi)\frac{c_g(\xi=0)}{c_g(\xi)}\exp(-2\nu\xi)$$

Three-wave phase space



Relative phase and amplitude of sidebands:

$$\psi \equiv \frac{\phi_1 + \phi_{-1}}{2} - \phi_0$$

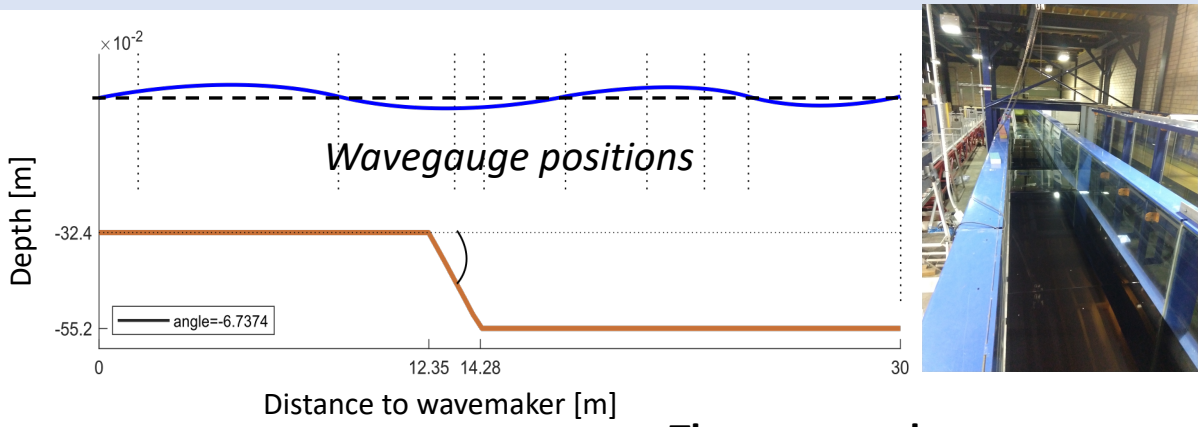
$$\eta \equiv \frac{|V_1|^2 + |V_{-1}|^2}{|V_0|^2 + |V_1|^2 + |V_{-1}|^2}$$

Experimental setup:

30 m long flume at the University of Sydney

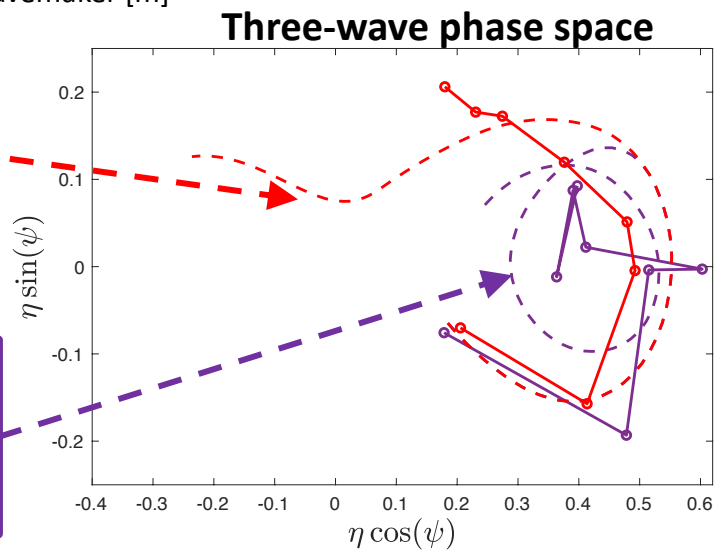
Carrier frequency: f_0 = 1.53 Hz

Initial steepness: ϵ = 0.14



Without step: trajectory outside the separatrix

With step: trajectory inside the separatrix



References:

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