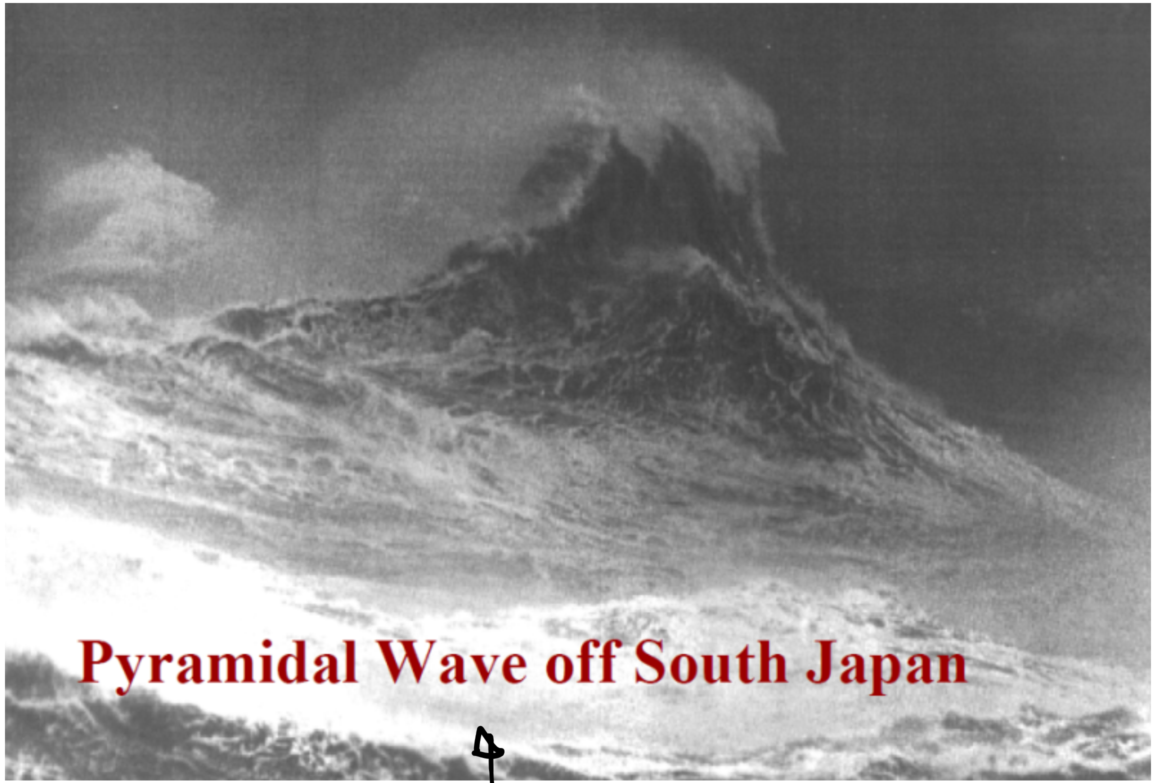
EXTREME WAVE EVENTS

Extreme wave events, also referred to as freak or rogue waves, are mostly known as oceanic phenomena responsible for a large number of maritime disasters. These waves, which have height and steepness much greater than expected from the sea average state, have recently become a topic of intense research.

In contrast to tsunamis and storms associated with typhoons that can be predicted hours (sometimes days) in advance, the particular danger of oceanic rogue waves is that they suddendly apper from nowhere only seconds before they hit a ship, then they disappear.

Rogue wave



Les photos impressionnantes du lac Érié en Amérique du Nord

Le Figaro 31/12/2015

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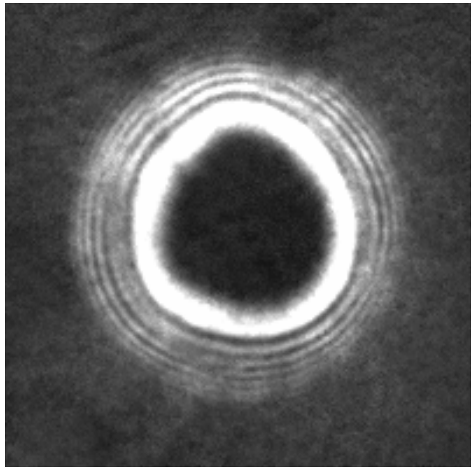
Rogue waves have been studied in the last two decades in water waves, but rogue waves appear also in the atmoshere, in BEC, in plasmas, in capillary, and in optics.

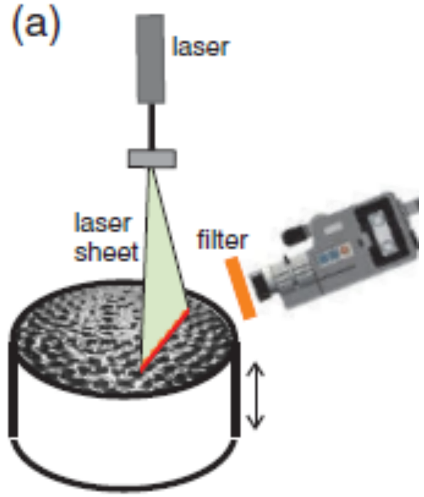
The common features and differences among rogue wave dynamics in their different contexts are subject of intense discusson.

Oceanography

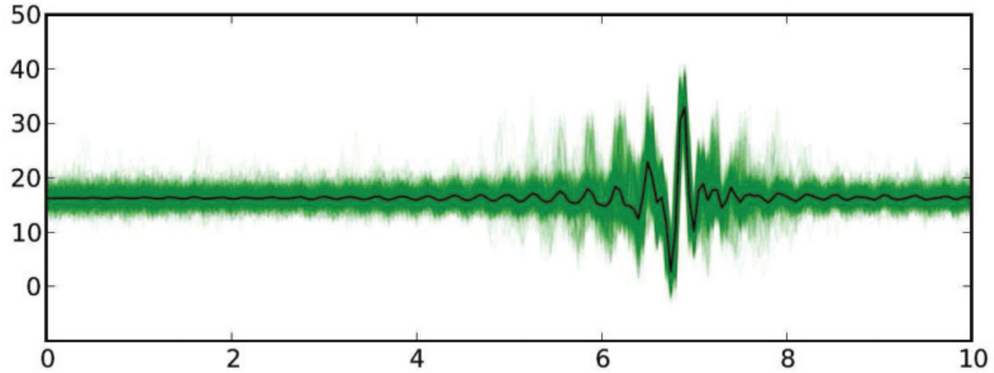
Bose-Einstein Condenstates



Capillary waves



Optics



M. Onorato et al., Phys. Rep. 528, 47 (2013).
N. Akmediev, B. Kibler, F. Baronio et al, J. Opt. 18, 063001 (2016).

We consider Rogue Waves in optics.

A formal mathematical description of a rogue wave is provided by the Peregrine Soliton, which is a solution of the NLSE

This soliton was discovered by Peregrine in 1983.

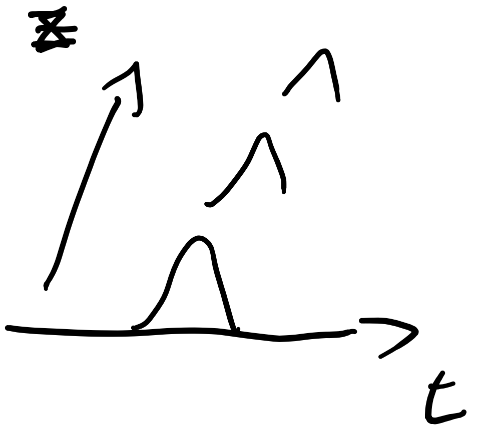
solitons are localized waves arising from nonlinear and dispersive interaction, and are central objects of nonlinear science.
The well-know envelope solitons of the NLSE have been studied in many different systems including optical fiber, cold atoms and plasmas.
In addition to bright and dark envelope solitons, shaping invariant solitons, the NLSE admits

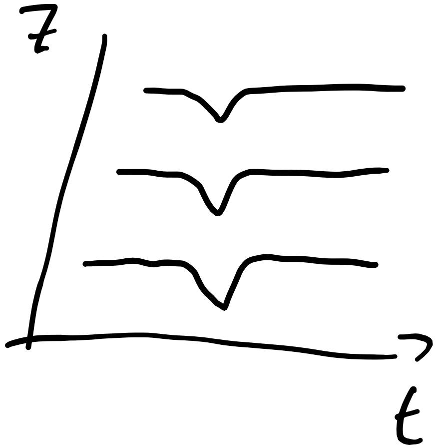
other classes of localized solutions, and there has been significant interest in spatio-temporal breather solutions that undergo periodic energy exchange with finite background.

In a sense, these solutions have been overlooked in the past decades. This is surprising because the theory of NLSE breather evolution also describes the phenomenon of modulation instability, which is a process extensively studied in optics and hydrodynamics.

Experiments in optics have strongly motivated by telecommunications goals to generate high-contrast pedestal-free pulses, and the opportunity to characterize solitons on a finite background have been overlooked up to the year 2010

Bright and dark shaping invariant solitons have been studied from the 1990s.





We consider the NLSE, in anomalous regime

$$i\frac{\partial F}{\partial z} + \frac{1}{2}\frac{\partial^2 F}{\partial t^2} + |F|^2 F = 0 \qquad \beta_2 = -1 \quad \gamma = 1$$

Akhmediev breathers:

$$F(z,t) = \left[\frac{(1-4a)\cosh(bz) + \sqrt{2a}\cos(\Omega t) + i b \sinh(bz)}{\sqrt{2a}\cos(\Omega t) - \cosh(bz)}\right] \cdot \exp(iz)$$

Ω is the modulation frequency, $a = \frac{1}{2}\left(1 - \frac{\Omega^2}{4}\right)$ where $0 < a < \frac{1}{2}$ determines the frequencies that experience gain and $b = [8a(1-2a)]^{1/2}$ determines the instability growth.

→ STUDY NUMERICALLY THE ANALYTICAL SOLUTIONS

→ STUDY NUMERICALLY THE PROPAGATION

The limiting solution is obtained for $\Omega \to 0$ and $a \to 1/2$, and correspond to the Peregrine soliton, which can be expressed as

$$F(z,t) = \left[1 - \frac{4(1+2iz)}{1+4t^2+4z^2}\right] e^{iz}$$

This is a rational solution of the NLSE

→ STUDY THE PROPERTIES OF PEREGRINE SOLITON

→ STUDY NUMERICALLY ITS DYNAMICS

PEREGRINE SOLITONS AND AKHMEDIEV BREATHERS HAVE BEEN DEMONSTRATED EXPERIMENTALLY IN OPTICS IN 2011.

PEREGRINE SOLITONS ARE USED TODAY TO DESCRIBE EXTREME EVENTS IN OPTICS,

WATER WAVES, PLASMAS, ACOUSTICTS.., ETC,
ALL PHYSICAL CONTEXTS DESCRIBED BY
THE NLSE.