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Excitation of nonlinear breather in magnetized plasmas

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Breather is a nonlinear amplification of wave energy localized in time and/or space. When the amplification exceeds the factor of 2, breather is called a rogue/freak wave. Once excited, breathers introduce dynamic behavior in the system. A typical example of such a nonlinear breather in natural systems is associated with freak/rogue waves in ocean. Ocean rogue waves, once considered to be a myth, can lead to abrupt increase of the sea surface level by a factor of 2 or larger. Given its impact, several studies are ongoing, and its existence is also confirmed in water tank experiments. Since then, breathers/rogue waves are reported from several systems, including ocean, optics, complex plasmas.

A common element associated with the breather excitation is the nonlinear evolution of dispersive waves. Table I summarizes the representative dispersive waves. Among others, drift wave in magnetized plasmas is no exception of such dispersive waves. This naturally raises a concern for the excitation of breathers in fusion plasmas. The excitation of breathers in fusion plasmas is an important issue, since breathers lead to transient increase of the fluctuation amplitude; for example, divertor heat load may be transiently amplified by a few factors. This is not desirable from engineering perspective.

In this work, we discuss the excitation of nonlinear breathers in magnetized plasmas. To demonstrate its excitation, we present a theory to describe breather arising from drift waves (drift breather, in short), and then this theory is applied to experimental data to identify the existence of breathers. Theoretically, the nonlinear evolution of drift wave envelop is formulated in terms of nonlinear Schrodinger equation. Exact solutions are obtained to describe nonlinear spatial-temporal structures. Then this wave form is used to extract breather excitation in linear magnetized plasma experiment, PANTA. The excitation of breathers is confirmed both in amplitude and phase. Consequences on transport will be discussed.

Reference: [1] Y. Kosuga, S. Inagaki, Y. Kawachi, submitted to Phys. Rev. Research (2022)

Dispersive waves	Surface wave $\omega^2 = gk$	Light $\omega = \frac{ck}{n_{ref}}$	Langmuir wave $\omega^2 = \omega_{pe}^2(1+3k^2\lambda_D^2)$	Drift wave $\omega = \frac{\omega_{*e}}{1+\rho_s^2 k_\perp^2}$
Nonlinearity	Surface elevation	Medium response $n_{ref} \propto \sqrt{\epsilon(E)}$	Ponderomotive force Ion acoustic coupling	Reynolds stress Large scale flows pumped
Feedback	Modulation of sea surface	NL refraction self-focusing	Refraction by modulated density field	Shearing by flows

Table I: Dispersive waves in various systems

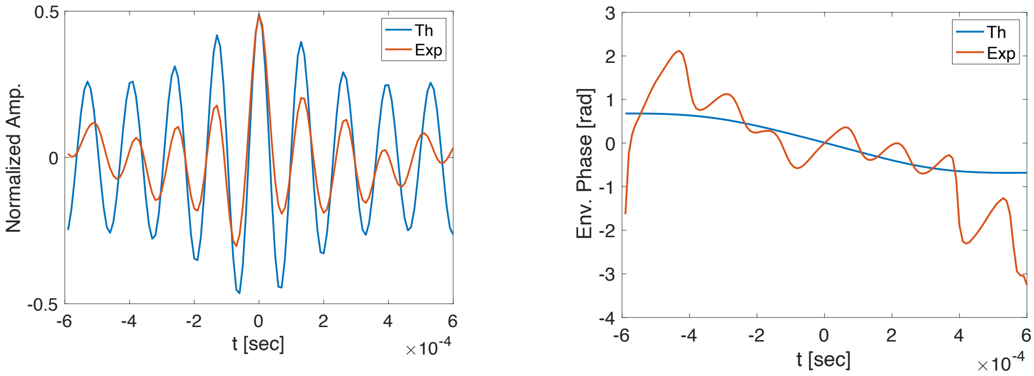

Figure 1: Comparison of theoretical wave form and experimental data (ion saturation current) for (a) amplitude and (b) phase