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Breathing Laboratory Plasmas

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Fluids and plasmas are typical examples of non-equilibrium media. An interesting feature of such non-equilibrium systems is that they exhibit dynamic, sometimes abrupt, response. Examples include, but not limited to, flares, rapid release of heat via Edge Localized Modes (ELMs), blobby transport, etc. These phenomena play key roles in the success of fusion energy production, and thus it is a critical issue to understand the origin of these dynamical phenomena.

In this talk, we elucidate a dynamic feature of turbulent plasmas caused by the excitation of nonlinear breathers. Here, a breather is a nonlinear wave that exhibits transient increase of fluctuation amplitude. As shown in Table I, breathers are found to be excited in various systems such as ocean[1], optical fibers, and plasmas[2]. We show that there are comment elements across these different problems. Namely, dispersive waves are excited in each system, and the nonlinear evolution of these waves can result in exciting breathers, which shows transient increase of wave amplitude, as depicted in Fig. 1.

Due to commonality of the problem, it may be not surprising to find a comment model can be developed for ocean surface waves and drift waves in magnetized plasmas. Indeed, we show that nonlinear Schrodinger equation can be derived for the nonlinear evolution of the wave envelope. Based on the model, we can calculate theoretical nonlinear wave form as an exact solution of NLS. In addition to the transient increase of the wave amplitude, we show that the excitation of breathers is characterized by the evolution of the phase of the envelope. These features are used to extract the excitation of breathers in the data obtained from magnetized plasma experiment, PANTA.

As shown in Fig. 2, the excitation of breathers can lead to the transient increase of the particle flux. Since this feature may play a key role in regulating particle balance in fusion plasmas, we developed a model for the excitation of breathers in the presence of multiple ion species[3]. Results show that it becomes easier to excite breathers in plasmas with heavy impurities. We discuss that impurities may introduce self-regulating dynamical behaviors of plasmas.

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References

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

Table I: Comparison of nonlinear dynamics of dispersive waves in various systems

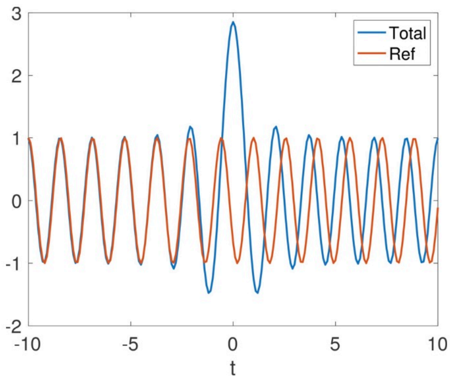

Fig. 1: Typical wave form of nonlinear breathers

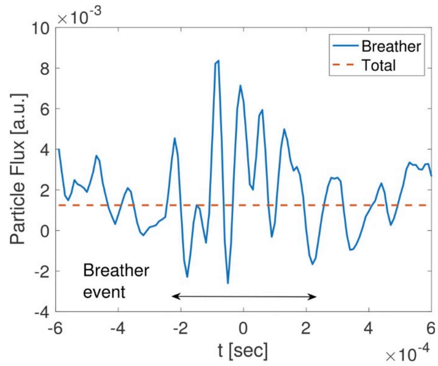

Fig. 2: Transient increase of particle flux associated with breather excitation