

# Initial observations verify existence of slow plasma wave in expanded quadrapole domestic dynamics experiment.

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A unique new plasma wave has been discovered in the recently upgraded Cates quadrapole domestic dynamics experiment. This plasma wave, which we denote Henry Philip Cates, has a slower phase velocity than the previously observed, coexisting fast plasma wave, denoted Nathaniel James Cates [Cates *et al.*, *Phys. Plasmas* **6**, 1475 (March 1999)]. The new wave was measured to have an equivalent initial mass of 4.06 kg (8 lbs., 15 oz.) and an initial characteristic wavelength of 54.6 cm (21.5 in). The growth rate of this new wave is predicted to be large and on the order of previously observed growth rates. © 2002 American Institute of Physics. [DOI: 10.1063/1.1500394]

## I. INTRODUCTION

The Cates quadrapole upgrade was designed in order to find a stable equilibrium with coexisting, distinct waves. In this paper we report the initial observation of a stable dual wave system. While the pre-existing fast wave, may be perturbed by the initial introduction of a second wave into the system, the two waves are predicted to equilibrate into a stable state where sufficient coupling and information transfer can take place.

The launching of the second wave in our two wave system was marked by a sudden onset after an extended incubation period. We are expecting rapid gains in both mass and volume as the slow wave becomes self propagating; the growth rate may indeed be exponential as is characteristic of previously observed wave growth.

We have observed a complex feedback system involving audible frequencies signaling the need for an increase in consumable fuel or reduction of waste material. These audible bursts could also signal immediate loss of energy or an unfavorable interaction with the preexisting fast wave. It is expected that the initial large volume of waste product will eventually be limited to designated waste disposal areas.

There has been reported short term loss in the overall free energy available to the system, but this perturbation should be stabilized as the steady state solution leads to enhanced family dynamics.

## II. WAVE KINETIC EQUATION AND GENERALIZED WAVE ACTION INVARIANT

The wave kinetic equation is an effective tool to describe the modulations of high frequency turbulence in the presence of slowly varying processes. Initially

introduced to describe the interaction of Langmuir (fast) and ion-sound (slow) waves,<sup>22</sup> the wave kinetic equation was recently effectively used in the problem of interaction of drift wave turbulence with large scale structures, in particular, in the problem of the generation of large scale flows.<sup>7,16,18,23</sup> It has been noted that for drift wave type fluctuations in the presence of the mean flow the wave action may be different from the standard definition of the wave action as the ratio of the wave energy to the wave momentum. It has been shown that the exact form of the conserved wave-action-like quantity (generalized wave action) depends on the form of the coupling matrix describing the interaction of small scale fluctuation and the mean flow.<sup>17,18</sup> This property has long been noted in the theory of waves in fluids<sup>24,25</sup> and can be traced to a certain ambiguity in the definition of the wave momentum.<sup>25</sup> The ambiguity is related to the contribution of the mean flow to the total momentum in the medium. We have developed a formal approach that allows one to calculate a generalized wave action invariant for a given form of the wave-mean-flow interaction coefficient.<sup>17,18</sup> we apply this method for the electromagnetic short-wavelength Alfvén-wave fluctuations to derive the proper form of the wave action invariant and use it to calculate the zonal flow growth rate.

Evolution of the wave packets is described by wave kinetic equation in the standard form

$$\frac{\partial N_k}{\partial t} + \frac{\partial \omega}{\partial k} \cdot \frac{\partial N_k}{\partial \bar{x}} - \frac{\partial \omega}{\partial \bar{x}} \cdot \frac{\partial N_k}{\partial k} = 2\Gamma_k N_k - \Delta \omega N_k^2 / N_0,$$

where  $\Gamma_k$  is the linear instability growth rate, and the term  $\Delta \omega N_k^2 / N_0$  describes the nonlinear damping due to “nonadiabatic” wave interactions. In what follows, we consider deviations from the saturated state.

The wave action quanta density  $N$  is modulated by the large scale perturbations due to the variations of the eigenfrequency in the presence of the mean plasma flow. After linearizing one gets

$$(\omega + \omega_{*e})(\omega - \omega_{*e} - 2\omega_E) = k_{\parallel}^2 v_e^2 k_{\perp}^2 d^2,$$

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