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TITLE CAVITON DYNAMICS IN STRONG LANGMUIR TURBULENCE

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Caviton Dynamics in Strong Langmuir Turbulence*

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Recent studies based on long time computer simulations of Langmuir turbulence described by Zakharov's model will be reviewed. These show that for moderate ion sound damping the turbulent energy is dominantly in non-caviton excitations which are localized in space and time. A local caviton will be presented which accounts for the nucleation-collapse-burnout cyclical cavitons as well as their space-time correlations. This model is in agreement with many features of the electron density fluctuation spectra in the ionosphere modified by powerful HF waves as measured by incoherent scatter. Recently such observations have verified a prediction of the theory that Langmuir waves are emitted in the caviton collapse process. These observations and theoretical considerations also strongly imply that cavitons in the heated ionosphere, under certain conditions, evolve to states in which they are ordered in space and time. The sensitivity of the high frequency Langmuir field dynamics to low frequency ion density fluctuations and the related caviton nucleation process will be discussed.

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I. INTRODUCTION

In this lecture I want to summarize the results of a research program which has been used on the "long time" development of strong Langmuir turbulence (SLT) which is driven by intense coherent radiation in long scale length plasmas near critical density. This problem was chosen for its theoretical simplicity and because of its relevance to ionospheric modification experiments using powerful HF radiation. These experiments probably provide the best physical realization of the theoretical ideal, long scale length, quasi stationary plasma.

The strong Langmuir turbulent system which I will try to describe is a fascinating system in which locally coherent, nonlinear "wave" structures or excitations undergo chaotic or turbulent motion. These elementary excitations which we call "cavitons" consist of high frequency Langmuir waves trapped in self-consistently forming density cavities. The low frequency density response which describes the caviton evolves under the influence of the ponderomotive force of the localized Langmuir waves. These excitations have a finite lifetime; they are born by gaining energy from the external fields in a process of "nucleation;" they "collapse" to small dimensions where they die or "burnout" by giving up their electrostatic energy to accelerated electrons. These excitations also interact by the radiation of ion acoustic waves and "free" Langmuir waves. The study of this interaction is in its infancy but we have examples in which the caviton gas apparently undergoes a phase transition to states which are highly ordered in space and time. These phenomena are a significant departure from our concepts of linear wave excitations and weak turbulence or renormalized turbulence theories with their often uncontrolled assumptions such as random phase approximations.

Data from the ionospheric modification experiments has accumulated for about 10 years. In the early days these data seemed consistent with the conventional theory involving linear parametric instabilities and weak turbulence cascades. However, with the passage of time it was realized that these data were manifestly inconsistent with the conventional theory. A more detailed discussion of this is given in reference 1 from which much of the material here is derived.

During the same time period new theoretical insights into SLT were developed centering around the seminal work of V. E. Zakharov.² He developed a very useful