Experimental study of drift wave–streamer system in linear magnetized plasmas
直線磁化プラズマにおけるドリフト波・ストリーマー系の実験研究

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By using a poloidal multi-channel probe array and a radial mobile probe, a streamer (state of bunching of drift waves) in a linear cylindrical magnetized plasma was identified for the first time. It was revealed that the streamer was produced by nonlinear mode coupling process, that is, the nonlinear phase locking between drift waves and a certain mediator mode. By investigating the radial structures of the streamer and mediator, the streamer had a radially elongated structure, while the mediator had a phase node in the radial direction. These features agreed well with the pair of fast and slow modes derived by a nonlinear Schrödinger equation based on the Hasegawa-Mima model.

1. Introduction

For understanding anomalous transports in magnetized fusion plasmas, study of drift wave turbulence has been an important subject. Theories and simulations have predicted that the nonlinear couplings between the drift waves can generate meso-scale structures, such as zonal flows, zonal magnetic fields, and streamers, which should have a strong influence on the anomalous transports [1]. Recently, experimental approaches are also in progress, and have observed nonlinear couplings between drift wave turbulence and meso-scale structures.

2. Experimental Results

The first experimental identification of a streamer (state of bunching of drift waves) in a linear cylindrical magnetized plasma was achieved [2]. The streamer is a poloidally localized and radially elongated global structure that lives longer than the characteristic turbulence correlation time. By using a 64-channel poloidal probe array [3] and a radial mobile probe, it was revealed that the streamer was produced by nonlinear mode coupling process, that is, the nonlinear phase locking between drift waves and a certain mediator mode, which has the same wave number and frequency with the streamer structure. Figure 1 shows the spatiotemporal of the streamer structure and mediator component measured with the poloidal probe array. The envelopes of the bunching of waves and the mediator have the same structures. By applying two-dimensional (frequency and poloidal wave number) bi-spectral analysis, it was confirmed that the carrier waves of the streamer and the mediator were strongly coupled [3].

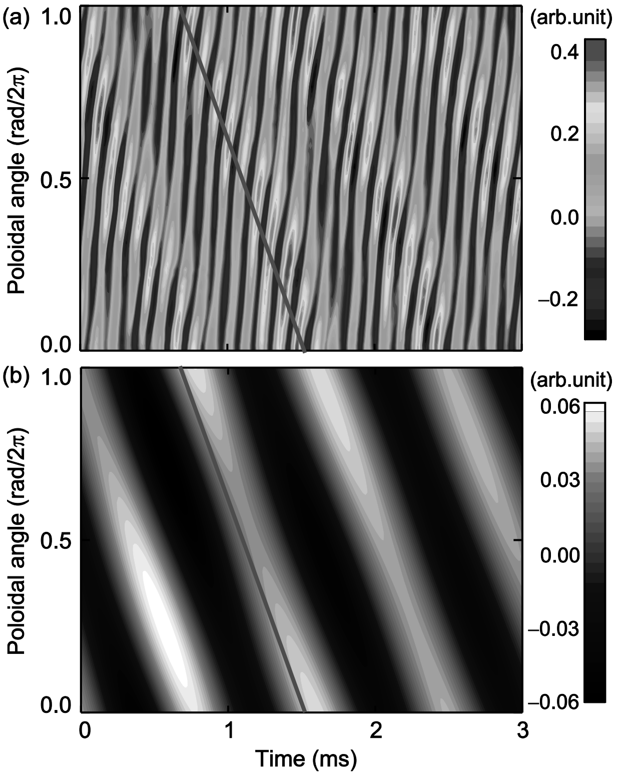

Fig.1. (a) Spatiotemporal behavior of the fluctuation measured with the poloidal probe array. (b) Frequency component under 1.6 kHz extracted from (a).

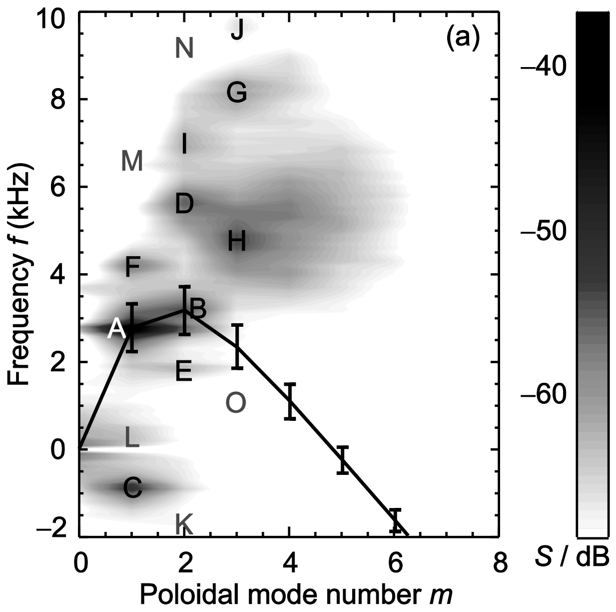

Fig.2. (a) Two-dimensional power spectrum of the fluctuation. A and B are the linear instability modes, C is the mediator for the streamer, and C–O are the quasi-modes.

Furthermore, the radial structures of the streamer and mediator were investigated by calculating the bi-phase between the mediator observed by the poloidal probe array and the carrier wave observed by the radial mobile probe. As a result, the streamer had a radially elongated structure, while the mediator had a phase node in the radial direction. These features agreed well with the pair of fast and slow modes derived by a nonlinear Schrödinger equation based on the Hasegawa-Mima model [4].

The two-dimensional bi-spectral analysis showed another results. By the analysis, the formation of the plasma turbulence was regarded as a result of nonlinear interaction of a small number of parent modes, which were driven by linear instabilities such as drift mode. As is shown in Fig. 2, the two-dimensional power spectrum showed three original parent modes, around ten quasi-modes, and broadband fluctuations. The two-dimensional bi-spectral analysis identified the nonlinear couplings between coherent–coherent, coherent–broadband and broadband–broadband components [5]. To identify the parent modes, amplitude correlation technique was applied. This technique simply deduces the causal relation by only measuring the time lag between two modes. This technique had a problem that the evaluation of amplitude of the mode requires signal in a time window, which can be longer than the time lag. Therefore, the relation between the time window and time lag was investigated in detail and it was showed that this problem would be solved by choosing proper time window [6].

Acknowledgments

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