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Non-linear analyses for phase coupling between density and magnetic fluctuations on H-mode plasma in LHD

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Magnetically confined plasma devices, either tokamaks or stellarators, can benefit from better performance when L-H transitions occur [1]. However, some magneto-hydrodynamic fluctuations that are excited in the H-mode plasma cause profile saturation and prohibit further confinement improvements. A thorough understanding of the profile saturation mechanism and the correlation between MHD fluctuations and particle transport through experimental research is critical.

In our previous linear analyses with density and magnetic fluctuations, we discovered some interesting discharges where even though the base harmonics have high cross-coherence, the coherence for higher harmonics is low [2]. This result suggests that density and magnetic fluctuations in H-mode plasma do not necessarily behave the same, which is contradicted to conventional MHD theories that particles move alongside magnetic surfaces so that each harmonic of magnetic fluctuations excite its density fluctuation respectively. Based on this discovery, we came up with a hypothesis that density fluctuations may have different non-linear evolution mechanisms compared to magnetic fluctuations.

To examine our working hypothesis, bicoherence and biphase of density and magnetic fluctuations were calculated, as shown in Figure 1. In this analysis, bicoherence and biphase between the base and second harmonics are focused upon in each fluctuation. Nonzero (~0.2) bicoherence values at the 1-1-2 matching condition were obtained for both fluctuation quantities, which indicates that the second harmonics are excited by the base harmonics through nonlinear coupling processes. The similar bicoherence value implies that the two fluctuations have similar characteristics for the first-and-second harmonic coupling strength and consistency of the relative phase difference in either density or magnetic fluctuations. A similar biphase value was obtained for both density and magnetic fluctuations, suggesting that both fluctuation components share a similar nonlinear evolution process from base to second harmonics, without specifically distinguishing the exact mechanism of the nonlinear process. According to the fact that the density and magnetic fluctuations showed nearly the same values of bicoherence and biphase, our hypothesis was rejected.

References
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[2] W. Hu, et al., Plasma and Fusion Res. 16 2402031-2402031 (2021).

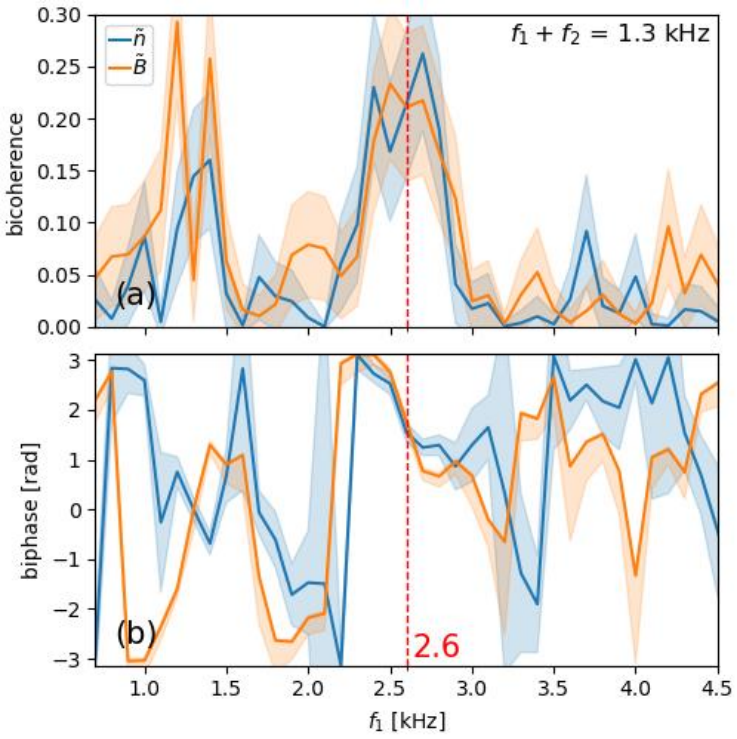

Figure 1. Sliced bicoherence and biphase of H-mode density fluctuation $\tilde{n}$ and magnetic fluctuation $\tilde{B}$ signals. The shadow represents corresponding error bar at each frequency. Both the values of bicoherence and biphase are approximately equivalent.