Quasi-Recurrence: a new novel feature observed in 3D-Magnetohydrodynamic plasmas

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Among different MHD models, the resistive one is well known to support irreversible conversion of magnetic energy into fluid kinetic energy through the process of magnetic reconnection. The exact reverse mechanism is also possible in MHD i.e generation of magnetic energy from kinetic energy via Dynamo action. Notwithstanding these two processes, it is observed very recently that there exist processes in the form of coherent nonlinear oscillations which facilitate back and forth conversion of energy from kinetic mode to magnetic mode via numerical simulation [1] for 3D Arnold–Beltrami–Childress [ABC] flow [Figure: 1(a)]. These oscillations are identified as dispersion-less nonlinear Alfven wave known for long a time [2]. In principle all periodic and quasi-periodic motion can be considered as an example of Recurrent Dynamics. Very recently [3] the complete recurrence of velocity and magnetic field for 3D Taylor-Green [TG] flow and complete non-recurrence of the same for 3D Arnold–Beltrami–Childress [ABC] flow in MHD simulations of magnetized plasma were reported for the first time.

Here we report existence of non-linear Alfven wave phenomena for a newly identified [4] initial condition namely EPI Two Dimensional [EPI-2D] flow. We discover a "partial recurrence" wherein magnetic field fails to recur whereas the velocity field does. This is unlike any other flow reported in the past. A possible explanation for the recurrence phenomenon is addressed by Rayleigh Quotient [Q(t)] [5]. The Rayleigh Quotient [Q(t)] can be thought of the active number of degrees of freedom available in the system. For 3D Arnold–Beltrami–Childress [ABC] flow Q(t) is known to be unbound and same quantity is known to be fully bounded for 3D Taylor-Green [TG] flow [3] [Figure: 1(b)]. Remarkably, for EPI-2D flow Q(t) is found to stay between unbound 3D Arnold–Beltrami–Childress [ABC] flow and fully bounded 3D Taylor-Green [TG] flow [6]. Several more interesting observations obtained will be presented.

References:

1. R. Mukherjee, R. Ganesh, and A. Sen, "Coherent nonlinear oscillations in magnetohydrodynamic plasma", Physics of Plasmas 26, 042121 (2019) https://doi.org/10.1063/1.5083001.

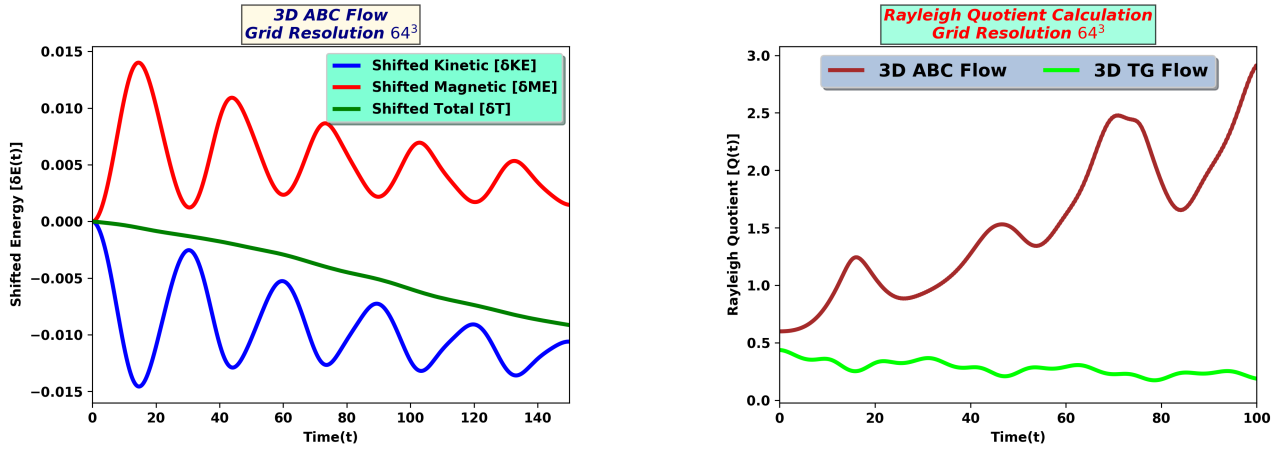
2. H. Alfvén, (1963). Cosmical electrodynamics.

3. R. Mukherjee, R. Ganesh, and A. Sen, "Recurrence in three dimensional magnetohydrodynamic plasma", Physics of Plasmas 26, 022101 (2019) https://doi.org/10.1063/1.5083052.

4. Z. Yoshida, and P. J. Morrison, "Epi-two-dimensional fluid flow: a new topological paradigm for dimensionality." Physical Review Letters 119.24 (2017): 244501.

5. A. Thyagaraja, "Recurrent motions in certain continuum dynamical systems", The Physics of Fluids 22, 2093-2096 (1979) https://doi.org/10.1063/1.862519.

6. Shishir Biswas, Rajaraman Ganesh, Rupak Mukherjee and Abhijit Sen, "Dynamics of a novel quasi-recurrent flow in 3D MHD plasmas", Manuscript Under Preparation (2021).



(a) (b)

Figure 1: Time evolution of (a) shifted kinetic energy for 3D ABC flow. (b) Rayleigh Quotient for 3D ABC flow and 3D TG flow.