6th Asia-Pacific Conference on Plasma Physics, Oct 9-14, 2022, Remote e-conference

Induction dynamo using Yoshida-Morrison flow: Generation of large scale magnetic energy

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Large scale magnetic field generation in cosmos and astrophysical bodies is an important problem in astrophysical plasmas. A possible mechanism behind this large scale energy growth is explained via dynamo action [1]. There are various dynamo models, for example, mean field dynamo, fluctuation dynamo, α-dynamo, kinematic dynamo, induction dynamo, self-consistent dynamo and so on. Among these various models, in an induction dynamo, a chaotic plasma flow stretches and folds back the weak ambient magnetic field lines giving rise to an exponential growth of magnetic field, in the limit of low plasma resistivity [2]. For most of the work considered in the past, chaotic, helical Arnold–Beltrami–Childress [ABC] flow has been used for studying dynamo action specially for induction model [2, 3]. It is also known that the exponential growth of magnetic energy is associated with generation of signature "cigar" [2, 3] [Fig. 1(a)] or "ribbon" [2] [Fig. 1(b)] like iso-surface for ABC flow. These special magnetic structures signify strong localization of energy possibly due to magnetic reconnection. In all these past work, fluid helicity $[\int_V \vec{u}.(\vec{\nabla} \times \vec{u})dV]$ has been considered as an important element, for explaining induction dynamo action. However, a systematic study of correlation between injected fluid helicity and induction dynamo action has not yet been brought out.

In this present work we have analyzed induction dynamo model using a flow recently proposed by Yoshida and Morrison (YM) [4]. The point of interest for this flow is that, it is possible to inject fluid helicity $[\int_V \vec{u}.(\vec{\nabla} \times \vec{u})dV]$ in the system, by systematically varying certain physically meaningful parameter. We identify that the production of faster and faster dynamo action is possible via fluid helicity $[\int_V \vec{u}.(\vec{\nabla} \times \vec{u})dV]$ injection using a YM flow as prototype [5]. We provide a new possible route that connects non-dynamo to dynamo regime via fluid helicity injection [5]. The study of magnetic field iso-surface is seen to exhibit untwisted ribbon like structures, when there is no helicity injection, where as, helicity injection is shown to introduce twisting in the iso-surfaces that generates dynamo. We demonstrate as to, how an untwisted ribbon like non-dynamo iso-surface gets converted into cigar like fast dynamo iso-surface [5] with injection of fluid helicty. We have performed the above said studies using an in-house developed, multi-node, multi-card, GPU based 3D MagnetoHydroDynamic solver (GMHD3D) [6]. Several related interesting observations obtained with YM flows as starting point, will also be presented.

References:

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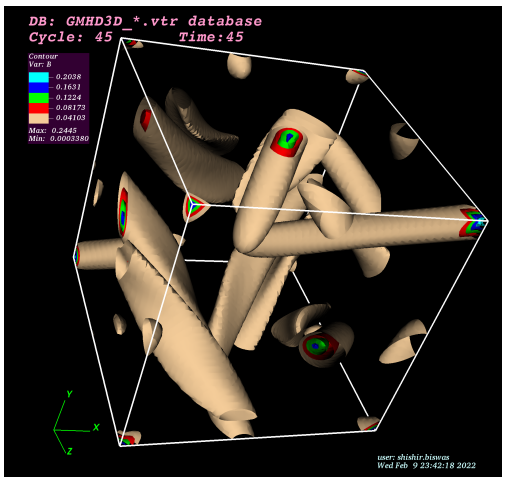
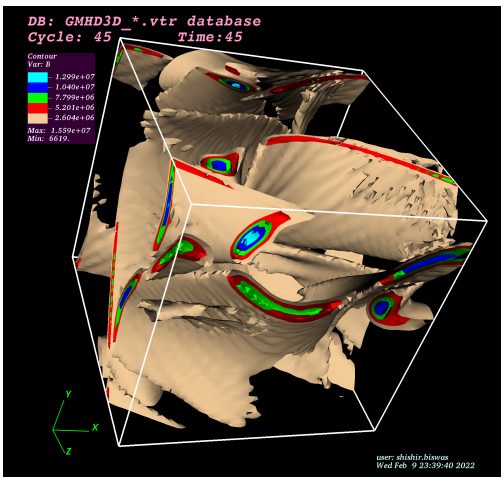


(a)



(b)

Figure 1: Typical structure of magnetic energy iso-surfaces, (a) cigar-like (b) ribbon-like, for induction dynamo model.