Helical self-organization in 3D MHD modelling of fusion plasmas: plasma flow effects and Alfvén waves detection

M. Veranda[1], D. Bonfiglio[1], S. Cappello[1], L. Chacòn[2], D. F. Escande[3], A. Kryzhanovskyy[1], M. Zuin[1]
[1] *Consorzio RFX (CNR, ENEA, INFN, Università degli Studi di Padova, Acciaierie Venete SpA), Padova, Italy*
[2] *Los Alamos National Laboratory, Los Alamos, New Mexico, USA*
[3] *Aix-Marseille Univ, CNRS, PIIM, UMR 7345, Marseille, France*

Self-organized helical states are a ubiquitous feature in astrophysical and magnetic confinement current carrying plasmas. In the reversed-field pinch toroidal plasmas quasi-helical states are observed both in high current experiments [1] and in nonlinear magnetofluid numerical simulations [2]. In the tokamak helical self-organization is an essential part of the dynamics in advanced regimes [3]. In this work we show two main advancements in our 3D nonlinear visco-resistive magnetohydrodynamic (MHD) studies. First, we study the effect of a macroscopic plasma rotation on helical states, to model both reversed-field pinches and tokamaks: in particular, we analyze the interaction between an external momentum source and/or seed magnetic perturbations (MPs), both static and rotating. We find the expected interplay between plasma rotation and applied MPs in tokamaks [4] confirming MPs screening over a threshold in normalized plasma rotation. We then focus on the reversed-field pinch case: starting from previous works [5,6,7], where it is shown that a mean flow arises from and interacts with nonlinearly coupled kink/tearing modes, and then introducing a momentum source, we analyse the impact of mean plasma flow on self-organized helical regimes. Our modelling indicates that an external momentum source of sufficiently high intensity can prevent the formation of a helical state, while a moderate one is compatible with a slight enhancement of the intensity of the helical state. We present a novel study in the realistic cases [2] of experimental-like helical states stimulated by MPs: the presence of a plasma flow, previously not considered, introduces quantitative changes to their properties. As a final novelty, we here also show (for the first time) that the typical intermittency with reconnection events displayed in the RFP helical self-organization process is accompanied by the excitation of both compressional and shear Alfvén waves, in reasonable agreement with experimental measurement [8].

References:

1 R. Lorenzini, E. Martines, P. Piovesan, et al, Nature Physics **5**, 570 (2009)
2 M. Veranda, D. Bonfiglio, S. Cappello, et al., NF **57**, 116029 (2017)
3 P. Piovesan, D. Bonfiglio, M. Cianciosa, et al., NF **57**, 076014 (2013)
4 R. Fitzpatrick, NF **33**, 1049 (1993)
5 S. Cappello, M. Viterbo, 26th EPS Conference, Maastricht (1999)
6 K. Kusano, T. Tamano, T. Sato, NF **31**, 1923 (1991)
7 F. Ebrahimi, V.V. Mirnov, S.C. Prager et al., PoP **15**, 055701 (2008)
8 S. Spagnolo, M. Zuin et al., NF **51** 083038 (2011)