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Multi-scales physics of magnetic reconnection in hot plasmas

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Magnetic reconnection consists in a modification of magnetic field topology leading to the formation of island-shaped magnetic structures. Magnetic reconnection is ubiquitous in magnetized plasmas. It is found in space plasmas (with the well-known example of sunspots of the solar flares[1]) as well as in fusion plasmas on earth[2].
The idea of the non-conservation of magnetic connectivity during the movement of a plasma emerged over the years[3]. Since then, many works based on theoretical and/or numerical models have given estimates of the growth rate of reconnected structures in disagreement with experimental observations (in space plasma in particular). In fusion plasmas, it is commonly accepted that the collisionality is too low to explain the existence of magnetic reconnection phenomena at large-scales[4] and at small-scales[5].
Thus, magnetic reconnection still raises many open questions. The work presented here falls within the context of hot fusion plasmas and aims to improve the fundamental knowledge about "the life of a magnetic island".
In the literature, studies mainly focus on how a reconnected structure (magnetic island) can grow, the phenomenon at the origin of magnetic reconnection being not distinguished from the phenomenon of growth. This leads generally to the disagreement between theory and experiences. However, there is no fundamental reason that the non-ideal mechanism at the origin of the reconnection is also the one that will allow the island to grow.
Here, in the light of the many works of the last 70 years, a new paradigm for understanding and studying the magnetic reconnection in fusion plasmas is proposed. The life of a magnetic island (whatever its scale) follows 3 phases : the origin, the growth and the saturation. The possible physical mechanisms at play in these 3 phases will be investigated from ionic Larmor radius scale to the large MHD scale. First, for the island origin, typical time scales in link with magnetic reconnection will be computed for 3 tokamaks of different sizes (TCV, WEST and JET) in order to check if magnetic reconnection is such an unexplained phenomenon in fusion plasmas. Second, for the island drive, the richness of possible mechanisms leading to "rapid" magnetic island growth will be presented from small[6] to large scales[7]. Third, comes the island saturation step. Results on the prediction of a large island size at saturation and its impact on transport will be presented.

References

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