Shear Alfvén waves in Chaotic Magnetic Fields

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Energetic particles inside fusion plasmas have speeds comparable to the Alfvén velocity, making them able to excite shear Alfvén waves.

Because these waves travel along the magnetic field lines, coordinates aligned to the magnetic field offer significant simplification of the dynamics. The construction of these straight field line coordinates then becomes a key first step to studying shear Alfvén waves. By treating the magnetic field line evolution as a Hamiltonian system, these coordinates become equivalent to action-angle coordinates. This is limited to cases where the Hamiltonian is integrable, equivalent to the magnetic field existing on closed nested flux surfaces.

When the magnetic field is perturbed, the nested flux surfaces can be destroyed, preventing action angle coordinates from being constructed.

Resonant Magnetic Perturbation (RMP) coils are a common example in real experiments that destroy the nested flux surfaces. Recently, RMP coils have been shown to modify the growth rate of Toroidal Alfvén Eigenmodes [1]. Understanding this process requires studying shear Alfvén waves inside non-integrable regions.

Provided the perturbations are not too large, the system still contains some structure [2]. Exploiting this, the invariant action surfaces of unperturbed, integrable systems is generalised to quadratic-flux-minimising (QFM) surfaces [3, 4], shown in Figure 1. From these surfaces, a pseudo magnetic field is created, and approximate straight field line coordinates can be constructed.

Employing this methodology, we study shear Alfvén waves inside regions of chaotic magnetic fields. We show that chaotic regions still exhibit significant shear Alfvén activity, with many similarities to equivalent non-chaotic regions. This provides an important first step towards understanding the modification of the shear Alfvén spectrum due to chaotic magnetic fields.
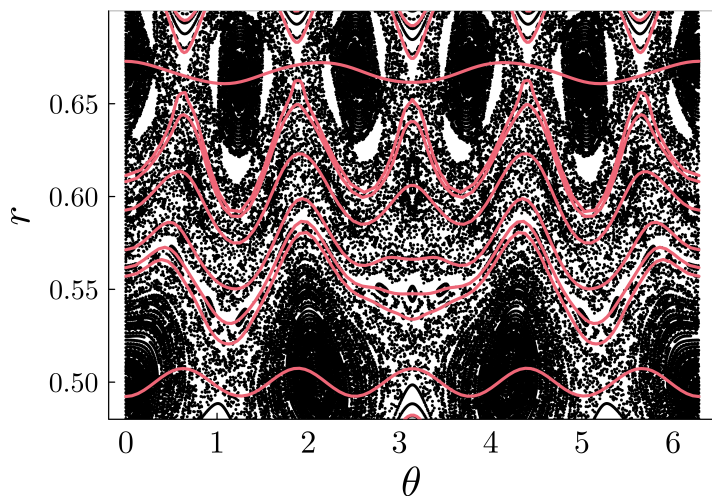
References

[1] J. Gonzalez-Martin et al., Physical Review Letters 2023, 130, 035101

[2] J. D. Meiss, Reviews of Modern Physics 1992, 64, 795–848.

[3] R. L. Dewar et al., Physics Letters A 1994, 194, 49–56.

[4] S. R. Hudson, Y. Suzuki, Physics of Plasmas 2014, 21, 102505.

Figure 1. QFM surfaces (red) in chaotic region of Poincaré plot.