Systematic dissection of the guiding center phase space based on orbital spectrum analysis

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The Guiding Center (GC) description of plasma particles motion plays a crucial role in the study of particle, energy and momentum transport in fusion plasmas. For an axisymmetric toroidal magnetic field configuration, the particles' motion is integrable and can be fully described in terms of the three Constants Of the Motion (COM), uniquely labelling each orbit. In addition to their topological character as trapped, co-passing or counter-passing and their shapes (thin/fat banana, potato and stagnated orbits), GC orbits are characterized by a set of frequencies, namely bounce/transit, orbit-averaged toroidal precession and gyration frequency. These frequencies crucially determine the particle transport due to resonances with characteristic frequencies of various non-axisymmetric perturbations such as MHD instability or plasma wave modes. Due to its resonance character, strong transport takes place in localized regions of the GC phase space.

In a recent work [1], the full Orbital Spectrum of the GC motion has been obtained analytically for a large aspect ratio equilibrium magnetic field, demonstrating a remarkable agreement to numerical calculations. In this work, the analytical results are utilized to construct the full skeleton of the resonance structure in the space of the COM, known as Arnold web, along which significant particle energy and momentum transport takes place under the presence of non-axisymmetric perturbations. Moreover, we pinpoint the location and the extent of various resonances in the GC phase space [2] and systematically dissect the phase space with appropriate Poincare surfaces of section to confirm our analytical predictions and further study single and collective particle dynamics.

References

[1] Y. Antonenas, G. Anastassiou and Y. Kominis, *J. Plasma Phys.* 87, 855870101 (2021)

[2] P.A. Zestanakis, Y. Kominis, G. Anastassiou, and K. Hizanidis, *Phys. Plasmas* 23, 032507 (2016)