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Self-consistent Fluid-kinetic Implementation of Flux Expansion in a 1D Hybrid Fluid-kinetic Code

Understanding plasma behaviour in the scrape-off layer (SOL) is critical for predicting particle and energy exhaust in magnetically confined fusion devices. A key feature in the SOL is magnetic flux expansion, which reduces peak heat loads on divertor targets by spreading exhaust across a larger surface area. This phenomenon is typically modelled using fluid codes, which incorporate flux expansion geometrically through area factors in the governing equations [1,2]. However, fluid models often rely on well-behaved time and length scales, such as those in the Braginskii closure, which break down in the plasma edge [3]. In particular, detached conditions and transient events like edge-localised modes (ELMs) can lead to strongly non-equilibrium behaviour, requiring kinetic treatment to accurately capture the non-local and non-equilibrium physics [4,5,6].
The work to be presented in this poster consists of a novel finite volume discretisation for a kinetic model that includes magnetic flux expansion, suitable for implementation in a reduced one-dimensional Vlasov-Fokker-Planck (VFP) code. Unlike in 2D or 3D kinetic models –where expansion and mirroring arise naturally from the coordinate geometry –such effects must be explicitly reconstructed in 1D through the formulation of the governing terms and their spatial discretisation. The kinetic equation is decomposed using Legendre polynomials in the pitch-angle coordinate in velocity space, and the resulting terms are volume-integrated over an expanding grid cell. To ensure consistency with flux-expanding fluid models, the Legendre-decomposed advection and mirror force terms are constructed in such a way as to preserve the expected discretised equations for the fluid moments in the appropriate limit. This introduces specific constraints on the decomposed terms. Implementation of this discretisation within ReMKiT1D, a 1D framework for SOL modelling, will be discussed, along with an outline of the planned steps for further development [7].

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