EUROfusion

Objectives and Milestones of MET Project

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Objectives of MET 2019-20

From MET Webpage https://www.afs.enea.it/zonca/METproject/

Energetic particle (EP) transport in fusion devices is a multi-spatiotemporal-scale process due to the crucially important role played by EPs as mediators of cross scale couplings. This makes predictive analyses based on first principle computations very challenging and calls for reduced descriptions, which preserve the necessary physics ingredients. The present project proposes to adopt a multi-level approach, introducing controlled assumptions and increasing simplifications, eventually resulting into a hierarchy of reduced transport models. It is articulated in three main areas: (i) the formulation of the reduced description of EP transport in fusion devices; (ii) the implementation of a numerical framework for solving transport equations coupled with the dynamic evolution of the fluctuation spectrum; (iii) the comparison of the reduced model description with numerical simulation results from comprehensive nonlinear gyrokinetic and hybrid codes in a number of reference/paradigm problems adopted as benchmark cases. The final goal and deliverable of the present project proposal is demonstrating the validity and range of applicability of the developed EP transport models.

MET Research Plan

- Research Plan of MET Project is articulated in four main work packages
  - **WP1 - Theoretical framework and phase space transport equations**
  - **WP2 - Numerical implementation of PSZS transport equations and transport analysis**
  - **WP3 - Comparison of reduced model description with numerical simulation results**
  - **WP4 - Energetic ion transport induced by tearing modes**
- Scientific Deliverables and achievements in 2019 have been discussed in presentation on Monday (03/23)

WP1 - Theoretical framework and phase space transport equations/1

- Key persons: M. Falessi, Ph. Lauber, Z. Lu, A. Mishchenko, F. Zonca

- Milestones:

  WP1-M1 - Derivation of phase space transport equations in 2D tokamak equilibria, including sources and collisions, and taking into account the multi-level approximation approach (Dec. 2019).
  WP1-M2 - Derivation of nonlinear evolution equations for Alfvénic fluctuations in 2D tokamak equilibria taking into account the multi-level approximation approach (Dec. 2019).
  WP1-M3 - Derivation of phase space transport equations in 3D equilibria, extending WP1-M1 (Dec. 2020).
  WP1-M4 - Derivation of nonlinear evolution equations for Alfvénic fluctuations in 3D equilibria, extending WP1-M2 (Dec. 2020).

WP1 - Theoretical framework and phase space transport equations/2

- Key persons: M. Falessi, Ph. Lauber, Z. Lu, A. Mishchenko, F. Zonca
- Deliverables:

  WP1-D1 - Explicit expressions of EP fluxes in phase space as input to transport code (2019).

WP1 - Theoretical framework and phase space transport equations/Discussion Items

- Key persons: M. Falessi, Ph. Lauber, Z. Lu, A. Mishchenko, F. Zonca
- Discussion items:
  - Phase space transport equations in conservation form; zonal state
  - NL envelope equations: book chapter with L. Chen (simplified approach possible; implementation in LIGKA?)
  - Theoretical aspects of generalization of phase space transport & envelope equations in 3D

WP2 - Numerical implementation of PSZS transport equations and transport analysis/1

- Key persons: N. Carlevaro, M. Falessi, Ph. Lauber, Z. Lu, A. Milovanov, A. Mishchenko, G. Montani, F. Zonca

- Milestones:

  WP2.1-M1 - Numerical implementation of general form of phase space transport equations (Dec. 2019).

  WP2.2-M1 - Practical basic understanding of conditions permitting non-diffusive scenarios of velocity space transport for beam plasma systems (Dec. 2019).

  WP2.1-M2 - Numerical implementation of phase space transport equations, taking into account the multi-level approximation approach (Dec. 2020).

  WP2.1-M3 - Implementation of general geometry in the AWECS code for computation of parallel mode structures (Dec. 2020).

WP2 - Numerical implementation of PSZS transport equations and transport analysis/2

- Key persons: N. Carlevaro, M. Falessi, Ph. Lauber, Z. Lu, A. Milovanov, A. Mishchenko, G. Montani, F. Zonca

- Deliverables:

  WP2.1-D1 - Verified transport module with explicit expression of EP fluxes and assuming fluctuating fields and particle distributions from numerical simulation (2019).

  WP2.1-D2 - Verified transport module with explicit expression of EP fluxes taking into account the multi-level approximation approach (2020).

  WP2.1-D3 - Numerical computation of the "matrix coefficients" involved in the non-linear envelope equations using AWECS output (2020).

  WP2.2-D1 - Construction of an effective transport model of velocity space transport beyond the classic bump-on-tail paradigm (2020).

WP2 - Numerical implementation of PSZS transport equations and transport analysis/Disc.

- Key persons: N. Carlevaro, M. Falessi, Ph. Lauber, Z. Lu, A. Milovanov, A. Mishchenko, G. Montani, F. Zonca

- Discussion items:
  - AWECS is not suitable for short term implementation
  - Choice for parallel mode structure calculation (and NL matrix elements in envelope equation) has shifted to FALCON+DAEPS
  - Simplified (averaged) NL envelope equations for implementation in ITER/IMAS workflow (LIGKA?)
  - Reduced model based on BoT paradigm

WP3 - Comparison of reduced model description with numerical simulation results/1

- **Key persons:** A. Biancalani, M. Borchardt, A. Bottino, S. Briguglio, G. Fogaccia, V. Fusco, A. Könies, Ph. Lauber, Z. Lu, A. Mishchenko, X. Wang
- **Milestones:**

  WP3-M1 - Finishing selection of reference cases and relevant plasma scenarios for code benchmarking and testing of reduced EP transport models; finishing linear stability analysis by all codes involved (Dec. 2019)

WP3 - Comparison of reduced model description with numerical simulation results/2

- Key persons: A. Biancalani, M. Borchardt, A. Bottino, S. Briguglio, G. Fogaccia, V. Fusco, A. Könies, Ph. Lauber, Z. Lu, A. Mishchenko, X. Wang

- Deliverables:

  WP3-D1 - Well documented reference cases for various scenarios; data base providing linear stability properties for all participating codes (2019).

  WP3-D2 - Demonstration of applicability of the developed transport models to the selected scenarios (2020).

  WP3-D3 - Analysis of the reference scenarios using the developed models, demonstrating their validity and range of applicability (2020).

WP3 - Comparison of reduced model description with numerical simulation results/Discussion

- Key persons: A. Biancalani, M. Borchardt, A. Bottino, S. Briguglio, G. Fogaccia, V. Fusco, A. Könies, Ph. Lauber, Z. Lu, A. Mishchenko, X. Wang
- Discussion items:
  - Implementation of PSZS transport eqs. demonstrated by HMGC => extensions
  - Comparisons of GK transport vs reduced descriptions (V&V)
  - AUG reference case particularly promising (core ion 'anomalous' heating
  - Others? (e.g. JET?)

WP4 - Energetic ion transport induced by tearing modes/1

- Key persons: D. Zarzoso, M. Faganello, R. Dumont and X. Garbet

- Milestones:

  WP4-M1 - Derivation of a nonlinear reduced fluid model of the tearing mode excitation (Dec. 2019).

  WP4-M2 - Non-linear simulations of tearing mode with energetic ions (Dec. 2020).

  WP4-M3 - Comparison between self-consistent GKW simulations and reduced EP transport model (Dec. 2020).

WP4 - Energetic ion transport induced by tearing modes/2

- Key persons: D. Zarzoso, M. Faganello, R. Dumont and X. Garbet

- Deliverables:

  WP4-D1 - Linear stability analysis of tearing modes with energetic ions (2019).

  WP4-D2 - Upgrade of the test-particle tracking module to include non-axisymmetric modes (2020).

  WP4-D3 - Assess the impact of energetic ions on the stabilization/destabilization of the tearing mode and the induced energetic ion transport (2020).

WP4 - Energetic ion transport induced by tearing modes/Discussion items

- Key persons: D. Zarzoso, M. Faganello, R. Dumont and X. Garbet
- Discussion items:
  - Assess the impact of energetic ions on the stabilization/destabilization of the tearing mode and the induced energetic ion transport (2020).

Conclusions and outlook

- Closing discussion session