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First-principle-based and tractable flux-driven turbulent tokamak transport modelling

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An accurate and predictive model for turbulent transport fluxes driven by microinstabilities is a vital component of predictive tokamak plasma simulation. However, tokamak scenario prediction over energy confinement timescales is not currently feasible by direct numerical simulation with nonlinear gyrokinetic codes. The quasilinear approximation allows significant computational speedup, 6 orders of magnitude quicker than nonlinear models. The justification of the quasilinear approximation for transport driving spatial scales is a consequence of the underlying structure of tokamak microturbulence, and is validated by comparison to nonlinear simulations. Recently, significant progress has been made in the development of the quasilinear gyrokinetic transport model QuaLiKiz [1,2]. Coupling to the tokamak integrated modelling suite JINTRAC [3], allows flux-driven core transport modelling for heat, particle, and momentum channels, with JET discharge timescales simulated in under 100CPUh. This talk will summarize the justification of the quasilinear approximation [4], sketch the basis of the QuaLiKiz transport model and its validity in comparison to nonlinear simulations, and illustrate validation of the model against experimental measurements at JET and ASDEX-Upgrade through flux-driven integrated modelling simulations. This capability enables the interpretation and optimisation of present-day experiments, and extrapolation to future machine performance. Finally, we present an approach to further accelerate first-principle-based transport models towards realtime calculation capability. This is based on machine learning methods, where a large database of QuaLiKiz runs are trained by feed forward neural networks to reproduce the model predictions. The neural network transport model provides a further 6 orders of magnitude speedup, 1 trillion times faster than nonlinear simulations. Extensions of an existing proof-of-principle [5] are shown. By coupling to the RAPTOR [6] control-oriented fast tokamak simulator, realtime-capable transport predictions are possible. This opens up a plethora of possibilities and innovation in realtime controller design and validation, scenario preparation, and discharge optimization.

References

[1] J. Citrin et al., 2017, Plasma Phys. Control. Fusion **59** 124005 ; [2] C. Bourdelle et al., 2016, Plasma Phys. Control. Fusion **58** 014036 ; [3] M. Romanelli et al., 2014, Plasma Fusion Res. **9** 3403023 ; [4] J. Citrin et al., 2012, Phys. Plasmas **19** 062305 ; [5] J. Citrin et al., 2015, Nucl. Fusion **55** 092001 ; [6] F. Felici and O. Sauter 2012, Plasma Phys. Control. Fusion, **54** 025002