Transport Barriers: Theory and Simulation

M. Yagi
e-mail: yagi@riam.kyushu-u.ac.jp
RIAM, Kyushu University, Kasuga, Fukuoka, Japan

The internal transport barrier (ITB) is one of the most promising methods for improving confinement in tokamaks. For the advanced operation scenario in ITER, it is necessary to understand the dynamics of ITB so as to sustain it for long durations using profile control.

The roles played in ITB formation by the negative magnetic shear, gap around minimum-q position, ExB flow shear, and zonal flow generation have been discussed previously [1]. However, a complete picture of ITB formation that can explain all features observed in experiments is not yet clear. Unexplained features include the relation between the ITB foot location and the low-order rational surface, or the effect of the magnetic shear profile on the shape of the ITB profile, giving rise to box or parabolic shapes [2]. These observations imply that the ITB dynamics depend on not only the magnetic shear, but also the safety factor (resonance channel) itself.

In this overview, the dynamics of the ITB will be discussed putting emphasis on nonlinear, nonlocal (multi-scale), statistical point of view. It was shown that the nonlocal interactions are important to the dynamics of ITB and are beyond the scope of the local model [3]. In addition, the theoretical understanding of ITB in recent years will be reviewed briefly.

This work is partially supported by the grant in aid for scientific research B (19360415) and S (21224014).

References

[1] Hahm T. S. 2002 *Plasma Phys. Control. Fusion* **44** A87
[2] Connor J. W. *et al* 2004 *Nucl. Fusion* **44** R1
[3] Tokunaga S., Yagi M., Itoh S.-I. and Itoh K. 2009 *Nucl. Fusion* **49** 075023

Destabilization mechanism of edge-localized MHD mode by a toroidal rotation in tokamaks

N. Aiba[1], M. Furukawa[2], M. Hirota[1], S. Tokuda[1]

E-mail contact of main author: aiba.nobuyuki@jaea.go.jp

[1] *Japan Atomic Energy Agency, Naka, Ibaraki 311-0193, Japan,*

[2] *Graduate School of Frontier Science, University of Tokyo, Kashiwa, Chiba 277-8561, Japan*

From the viewpoint of the heat load on the divertor, Type-I edge localized mode (ELM) needs to be suppressed or the amplitude of this ELM needs to be reduced. In JT-60U, some experimental results showed that the ELM frequency depends on the toroidal rotation, and the rapid rotation in the counter direction of the plasma current changes from Type-I ELM to Grassy ELM [1], whose frequency is high and the amplitude is small. Since both Type-I and Grassy ELMs are considered as ideal magnetohydrodynamic (MHD) modes destabilizing near the plasma surface, theoretical and numerical analyses are important for understanding the toroidal rotation effects on the edge localized MHD mode to understand this dependence of the ELM frequency on a toroidal rotation. Previous works about the toroidal rotation effect on the edge MHD stability have illustrated that the toroidal rotation with shear can destabilize low/intermediate-*n* (<50) modes [2], but the destabilizing mechanism of the low/intermediate-*n* mode is not still clarified. To understand the stability property related to ELM suppression/mitigation, it is important to clarify this destabilizing mechanism.

In this paper, we investigate numerically the destabilizing effect of a toroidal rotation on the edge localized MHD mode with the MINERVA code [2], which solves the Frieman-Rotenberg equation. Particularly, we pay attention to the effects of the toroidal rotation shear and the centrifuged force on not only equilibrium but also change of equation of motion.

[1] N. Oyama et al., Plasma Phys. Control. Fusion **49**, 249 (2007).

[2] N. Aiba et al., Nucl. Fusion **49**, 065015 (2009).

Rotation dynamics with & without Internal Transport Barriers

G. Dif-Pradalier, P. H. Diamond
Center for Astrophysics and Space Sciences, UCSD, La Jolla, CA 92093, USA
C. S. Chang, S. Ku
Courant Institute of Mathematical Sciences, New York University, NY 10012, USA
Y. Sarazin, A. Strugarek, V. Grandgirard, X. Garbet, Ph. Ghendrih
Association Euratom-CEA, CEA/IRFM, Cadarache, France

Emphasising on the statistical, open-system aspect of a tokamak, *full–f* flux-driven capability in gyrokinetic computations allows to address the central question of the mean profile dynamics while self-consistently evolving the electric field, the mean profiles and the flows. In such systems, collisions take on a prominent role for an accurate computation of both the electric field and the poloidal flows. The dynamics of these latter flows has lately triggered much interest, especially since experimental evidence of a deviation from their neoclassical prediction has increasingly been documented in the presence of an Internal Transport Barrier (ITB) [1], at the Low to High transition [2] or throughout the H–mode [3]. From the perspective of modeling, turbulence-generated rotation is a prime candidate to drive the system away from its neoclassical expectation. In this spirit, recent evidence of a turbulent generation of poloidal momentum has been observed [4], consistently with earlier theories [5]. Though its impact in L–mode-like plasmas is moderate, it may not remain so in the presence of an ITB.

The proposed presentation aims at investigating the dynamics of the flows (poloidal and toroidal) in the presence (or absence) of an ITB through a scan in the incoming heat power applied to the plasma. Doing so, it incidentally also addresses the question of a power threshold for a self-consistent ITB formation in gyrokinetic modeling. The study is performed using both the XGC-1 and GYSELA codes with Enhanced Reverse Shear (ERS)-like parameters.

References

[1] K. Crombé *et al.*, *Phys. Rev. Lett.*, **95**:155003, 2005.
[2] K. Burrell *et al.*, *Phys. Plasmas*, **1**:1536, 1994.
[3] R.M. McDermott *et al.*, *Phys. Plasmas*, **16**:056103, 2009.
[4] G. Dif-Pradalier *et al.*, *submitted to Phys. Rev. Lett.*
[5] P. H. Diamond *et al.*, *Phys. Rev. Lett.*, **72**(16):2565, 1994.

Generic Suppression Mechanism of Micro-turbulence by Vortical Flows

J. Q. Dong[1,2], Z. X. Wang[3], J. Q. Li[3,2] , and Y.Kishimoto[3]

E-mail address of the presenting author: jiaqi@swip.ac.cn

1, Southwestern Institute of Physics, P. O. Box 432, Chengdu 610041, China
2, Institute For Fusion Theory And Simulation, Zhejiang University, Hangzhou 310027, China
3, Graduate School of Energy Science, Kyoto University, Gokasyo, Uji, Kyoto 611-0011, Japan

Large spatial scale vortex flows (VFs), varying in both poloidal and radial directions to provide two-dimensional (2D) flow-shear effects, are observed in tokamak plasmas extensively. Such flows are inevitable due to the inherent poloidal asymmetry features of the equilibrium field anisotropy. Additionally, many mechanisms associated with fluid or plasma instabilities, such as the Kelvin-Helmholtz (KH) and/or tearing mode, can intrinsically generate large-scale vortices. However, transport processes affected by such VFs in regulating micro-turbulence can not be understood based on the previous theory of the 1D flow-shear effect. Therefore, the special roles of VFs have been investigated recently. Nevertheless, the underlying physics of micro-turbulence suppression by VFs with the 2D flow shear is not clear yet. Identification of the relevant mechanism is fundamental to improving the understanding of turbulent transport as well as gaining insight into phenomena of multi-scale interactions.

The interaction between two-dimensional vortex flows and micro-turbulence is studied numerically using gyrofluid simulations. It is shown that, qualitatively different from usual mean flows, vortex flows can dramatically suppress micro-turbulence even with weak flow shear. A generic suppression mechanism is identified as the multiplied effects of both radial and poloidal mode couplings, which induce the formation of a new global mode. Furthermore, an oscillatory zonal flow is found to form through interaction between the vortex flows and micro-turbulence.

Nonlocal theory of excitation of GAMs by drift waves in tokamak edge plasmas*

P. N. Guzdar[a], R. G. Kleva[a], N. Chakrabarti[b], V. Naulin[c], J. J. Rasmussen[c],
P. K. Kaw[d] and R. Singh[d]

[a]IREAP, University of Maryland, MD, USA
[b]Saha Institute of Nuclear Physics, Kolkata, India
[c]Association EURATOM-Risø DTU, DK-4000 Roskilde
[d]IPR, Gandhinagar, India
e-mail:guzdar@umd.edu

The geodesic acoustic modes (GAMs) have been observed in many toroidal plasmas as well as in many numerical simulations. Thus investigating the source of excitation of these modes has been a very active area of research. Earlier, it was shown that these modes can be excited nonlinearly by three-wave resonant mode coupling to electron drift waves preferentially in the edge region of tokamaks[1]. Recently[2], a nonlocal theory of excitation of these modes in inhomogeneous plasmas typical of the edge region of tokamaks has been developed. The continuum GAM modes with coupling to the drift waves can generate discrete "global" unstable eigenmodes localized in the edge "pedestal" region of the plasma. These global eigenmodes have a two space scale character. There are multiple, unstable, overlapping eigenmodes that can co-exist in the region of the edge pedestal. Inclusion of finite β effects[3] of the drift waves shows that the excitation of GAMs by the three-wave parametric coupling is stabilized by the Maxwell-stress component of the nonlinear coupling. We will present comparison of our theoretical/numerical model with observations of the GAMs spatial structure in various tokamak devices.

[1] N. Chakrabarti et al. Phys. Plasmas **14**, 052308 (2007).
[2] P. N. Guzdar et. al Phys. Plasmas **16**, 052514 (2009).
[3] N. Chakrabarti et al. Phys. Plasmas **15**, 112310 (2008).

* Work partially supported by the US DOE and by the Danish Natural Science Research Council (FNU-272-06-0367).

Extension of theory based models for anomalous transport to near separatrix region using the FACETS code

A. Hakim[a], A.Y. Pankin[b], S. Kruger[a], S. Vadlamani[a], J. Cary[a], M. Miah[a],
T.D. Rognlien[c], S. Shasharina[a], and FACETS team

ammar@txcorp.com
[a] Tech-X, Boulder, CO, USA
[b] Lehigh University, Physics Department, Bethlehem, PA, USA
[c] LLNL, Livermore, CA, USA

The FACETS code, an integrated modeling code used to compute plasma profiles self-consistently for the whole discharge region in tokamaks, is being developed as a part of the SciDAC project for core-edge simulations. The plasma core region in these core-edge coupled simulations is described in 1D approximation. A choice of transport models that describe anomalous and neoclassical transport in the core region is available in the FACETS code through the FMCFM interface. In near separatrix and SOL regions, anomalous transport becomes two dimensional and UEDGE code is used to compute the transport fluxes. The core and edge regions are coupled concurrently through the framework. The coupled FACETS core-edge simulation allows extrapolation of theory-based models from plasma core into the edge domain that is described with UEDGE. In this study, a combination of transport models that covers the whole discharge domain is investigated using the FACETS code in realistic tokamak geometry. In order to reconstruct the anomalous fluxes at the plasma edge, a resistive ballooning contribution that is a part of Multi-Model Model is used together with anomalous transport driven by ITG/TEM and ETG instabilities computed with GLF23. In addition to the anomalous fluxes, the FACETS code is used to compute neoclassical fluxes self-consistently from a neoclassical model available in the FMCFM interface. The effect of paleoclassical transport [1] on the dynamics of electron thermal profiles in the edge region is also investigated..

[1] J. D. Callen, Nucl. Fusion 45, 1120 (2005).

Transport simulation on transport barriers associated with radial electric field and rotations

M. Honda[1)], T. Takizuka[1)], A. Fukuyama[2)]
[1)] Japan Atomic Energy Agency, Naka, Ibaraki 311-0193, Japan
[2)] Graduate School of Engineering, Kyoto University, Kyoto, Kyoto 606-8501, Japan
E-mail contact of main author: honda.mitsuru@jaea.go.jp

Transport barriers in tokamaks are of significant importance to achieve high beta plasmas. In ITER the edge transport barrier (ETB) is required to obtain a desired performance and the internal transport barrier (ITB) will also be necessary to maintain a steady-state plasma. It has been observed in experiments that the notch structure of the radial electric field E_r and the toroidal rotation emerge associated with the formation of ETBs and ITBs [1], and theoretically E×B flow shear and zonal flow are well accepted to play a role in it [2]. In this paper, from the aspect of transport simulations the relation among the transport barrier, E_r and the plasma rotations is studied by using a 1-D two-fluid transport code, TASK/TX [3]. The code can deal with the dynamics of E_r and the rotations consistently, unlike conventional diffusive transport codes. Simulations with a theory-based turbulent transport model have obtained a clear ITB with notched E_r and toroidal rotation profiles in case that we give the same profile of a perpendicular viscosity as that of the thermal diffusivity. On the other hand, the notch structure of the toroidal rotation profile cannot be observed when we fix the given viscosity profile, although the temperature profiles form the ITBs. This indicates that the structure of the rotation profile may be regulated by the viscosity rather than the force balance. The dynamics of the transport barriers with an emphasis on the role of E×B shear flow and the rotations will be explored in comparison with simulations by a conventional transport code.

This work is supported in part by the grant in aid for scientific research B and Start-up.

References

[1] Ida K *et al* 1990 *Phys. Rev. Lett.* **65** 1364; Shirai H *et al* 2000 *Plasma Phys. Control. Fusion* **42** A109
[2] Hahm T S 2002 *Plasma Phys. Control. Fusion* **44** A87
[3] Honda M and Fukuyama A 2008 *J. Comput. Phys.* **227** 2808

"Tail-wagging-dog" dynamics of ITG-turbulent H-mode-profile plasma in a full-f gyrokinetic simulation*

S. Ku[1], C.S. Chang[1], P.H. Diamond[2] and the CPES team
sku@cims.nyu.edu
[1]Courant Institute of Mathematical Sciences, New York University
[2]University of California at San Diego

H-mode experiments ubiquitously show that the core energy confinement is promptly enhanced with the edge confinement enhancement, which is usually triggered and maintained by strong core heating and the good edge conditioning in diverted magnetic field geometry. In order to understand this important "tail-wagging-dog" phenomenon at first-principles level, a multiscale turbulence-neoclassical gyrokinetic simulation of an integrated core-edge plasma in a realistic diverted geometry is a necessity, but has been a formidable task. Taking advantage of the rapid development in the high performance computing, we have succeeded in such a full-function gyrokinetic particle simulation of the electrostatic turbulence in realistic diverted tokamak geometry for the first time. New physics understanding of the nonlocal core-edge ITG turbulence coupling under a strong core-heating condition has been obtained in an H-mode-like plasma profile. Two strong electrostatic turbulence sources have been identified: A heating-driven source exists in the central core (which generates a fast-rotating local electrostatic turbulence), and, an Ion Temperature Gradient (ITG) driven source exists in the ion-temperature pedestal top. The edge ITG turbulence spreads radially inward and combines with the local turbulence in the core to generate bursty turbulence energy and radial transport. The inward-propagating turbulence shows a collision with the central rotating-turbulence. The system eventually self-organizes to a quasi-steady state, raising the core temperature gradient to a nonlinear super-critical level. In the final quasi-steady state, the globally self-organized ion heat conductivity increases toward the pedestal top, but decreases rapidly in the pedestal slope due to the separatrix effect. A strong heat flux provides the fuel to support the ion temperature pedestal in the edge and to maintain the "tail-wagging-dog" nonlocal turbulence self-organization phenomenon. ExB shearing dynamics is found to be an important part of this process. Experimental validation collaboration will be discussed for the insights already obtained and for the next step simulations to be performed.

*Work supported by US DOE Office of Fusion Energy Science and Office of Advanced Scientific Computing Research.

Gyrokinetic simulation of equilibrium shear flow and its effects on ITG turbulence in a tokamak geometry

KWON Jae-Min and KIM J. Y.

jmkwon74@nfri.re.kr
National Fusion Research Institute, Daejon, Korea

Highly sheared equilibrium plasma flows generated by steep temperature and density profiles in tokamak plasmas are now widely accepted as main suppression mechanism of small scale fluctuations like ion temperature gradient (ITG) modes in high performance tokamak operations. However, for the simulation of ITG turbulence with self-consistent equilibrium shear flow, it is necessary to resolve slow collisional and fast turbulent timescales simultaneously. Although the long transport timescale study of plasma turbulences including full neoclassical physics is an ultimate goal of kinetic simulations, it is still one of the most challenging problems even for the most powerful supercomputers in present days. In this work, we propose a simulation scheme based on δf gyrokinetic PIC code, which can bypass the difficulties in resolving the two distant time scales and provide a way to understand the essential physics of the equilibrium shear flow stabilization of micro-turbulences. We start from a given set of equilibrium profiles and follow the neoclassically self-consistent time evolution in a long enough time to achieve the neoclassical kinetic equilibrium using a moderate number of simulation particles. Then the simulation particles representing the achieved neoclassical equilibrium are copied and the total particle number is increased to a number which is large enough to resolve fine scale ITG turbulences. After the continuation of relatively short term neoclassical simulation, which is to remove the phase space granulites, nonlinear ITG turbulence is performed including a wave spectrum of high toroidal and poloidal mode numbers. Using this simulation scheme, we study the equilibrium shear flow effects on ITG turbulence for profiles with various gradient length scales. In particular, simulation results for high ∇T_i comparable to internal transport barrier will be presented.

Where is the edge in toroidal plasmas ?

Leonid E. Zakharov
Princeton University, PPPL, PO Box 451 Pronceton NJ 08543

It is believed that by definition the plasma edge is the separatrix which separates the confinement zone from the convection dominated plasma periphery. Another belief is that the H-mode has a miraculous ”edge transport barrier” providing a steep temperature pedestal in front of the last closed magnetic surface.

The DIII-D experiments with Resonant Magnetic Perturbations undermine both of these beliefs. Instead, the interpretation of these experiments suggests that the top of the edge electron temperature pedestal, rather than the separatrix, represents the end of the electron confinement zone, i.e. the edge for the electron temperature. On the other hand, the edge for the ion temperature and plasma density seems to be situated at the separatrix (or behind it).

GAM shearing feedback loop in transport bifurcation and turbulence spreading.

K. Miki[1)], P.H. Diamond[1)], Z. Lin[2)]
[1)]Center for Astrophysics and Space Science, UCSD, La Jolla, CA 92093, USA
[2)]Department of Physics and Astronomy, University of California, Irvine, CA 92697, USA

There are many experimental results indicating some link between turbulent fluctuations and geodesic acoustic modes (GAMs). In experiments on edge turbulence in DIII-D involving injection of neutral beam power, torque and consequent plasma toroidal rotation, the poloidal turbulence velocity spectrum exhibits a transition from a GAM to lower-frequency zonal flow as rotation varies from co-current to balanced, which facilitates the L-H transition[1]. Here the GAM is possibly a player in the L-H transition dynamics because it is easily excited in high-q region, i.e. especially in the edge region. Thus it is useful to build a model for describing the transition including GAM shearing, so as to estimate turbulent transport in the edge region, with high-q.

To theoretically discuss the impact of the GAM on turbulence, two synergistic processes are elucidated; zonal flow modulation and the effect of secular wave group propagation on spreading. Using wavekinetic modulational analysis, the response of turbulence to the GAM is calculated. Unlike zero-frequency zonal flows, the finite GAM group speed gives a resonance between the drift wave group and the GAM strain field, which allows secularity. Finite real frequency and radial group velocity are intrinsic to the GAM, so non-local phenomena at the edge region are likely. To understand the effect of the GAM on turbulence dynamics, a predator-prey model incorporating the turbulence and the GAMs is constructed and analyzed for stability. Three possible states are identified, namely on an L-mode-like, an H-mode-like, and a limit-cycle state which reproduces a regime where the GAM shearing regulates the turbulence level. The system is attracted to the state with the minimum turbulence level for the given control parameters. The analysis shows the possible transition from the limit-cycle state to the stationary H-mode-like state occurs by a change in the contribution of the group propagation of the GAMs, followed by changing the stationary level of turbulence. Thus, GAM propagation damping appears as an important element in the transition dynamics.

This material is based upon work supported by the Department of Energy under Award Numbers DE-FG02-04ER54738 and DE-FC02-08ER54959.

References

[1] G. McKee *et al.*, in *22nd IAEA Fusion Energy Conf.* (Geneva Switzerland) (2008), IAEA-CN-165/EX10-1.

A Simple *Non-Perturbative* Model of Turbulence Spreading in the Presence of Dissipation and Zonal Flows

L.T. Neko, P.H. Diamond, M. Malkov and A. Ulvestad
phd@mamacass.ucsd.edu
University of California, San Diego, La Jolla, CA 92093-0424 USA

We present the results of analysis of a simple model of turbulence spreading, coupled to zonal flows, fluctuation dissipation and flow damping by drag. The model consists of coupled equations for the:

a.) zonal pseudomomentum of drift wave packets.

b.) zonal flow.

c.) the radial wave number of the drift wave packet.

The equations are eikonal but *fully non-perturbative*. They do *not* assume weak nonlinearity, quasilinear modulation, etc., etc. Moreover the model explicitly conserves the total of the wave pseudomomentum and the flow momentum, up to growth and dissipation, and so manifestly satisfies the Charney-Drazin theorem[1].

The model is studied assuming a region of localized pumping or growth, and packet propagation into an adjacent domain of flow and fluctuation damping. This allows us to formulate the spreading problem as one which compares depth of penetration into a dissipative zone given some fixed pumping over a certain range. Radial wave packet propagation is thus the mechanism for turbulence spreading. Results indicate that pulse-like solutions exist, but are determined *entirely* by dissipation processes. The governing equation loosely resembles Burgers equation. Indeed, the pulse speed is set by *both* the flow and fluctuation damping. In the absence of damping, radial propagation is *weak*. This is a consequence of zonal momentum conservation and the strong effect of shearing on the packet group velocity. The non-perturbative secular evolution of k-radial severely restricts propagation, in contrast to what is predicted by perturbative models.

Analysis is ongoing and further results will be presented. This material is based upon work supported by the Department of Energy under Award Numbers DE-FG02-04ER54738, DE-FC02-08ER54959 and DE-FC02-08ER54983.

[1] P.H. Diamond, *et al.*, *P.P.C.F.* 50, 124018 (2008)

Self-consistent turbulence-based transport simulations in the tokamak edge region*

T.D. Rognlien, M.V. Umansky, R.H. Cohen, and X.Q. Xu
E-mail: trognlien@llnl.gov

Lawrence Livermore National Laboratory
P.O. Box 808, Livermore, CA 94551 USA

The understanding of plasma turbulence, transport, and profiles in the edge region of a tokamak requires a model where turbulence and profile evolution are self-consistently coupled. The characteristics of such a system may differ in the L-mode and H-mode regimes and play a role in the transition between the two. An algorithm is presented in Ref. 1 for coupling a fast timescale turbulence model and a much slower timescale transport model, which represents a class of Relaxed-Iteration Coupling (RIC) schemes. This type of method is applied to the edge plasma problem in Ref. 2 to couple the BOUT turbulence and UEDGE transport codes. One key issue for such a method applied to edge turbulence relates to the fact that here the transport events can be large, intermittent, and have spatial scales comparable to equilibrium gradients. Thus, the long-time averages of the resulting transport fluxes coupled to the transport code may not faithfully represent the actual transport/profile-modifications from large events. This issue is addressed here by comparing BOUT/UEDGE simulations using the RIC algorithm to more time-consuming direct simulations where BOUT evolves the edge plasma profiles at each step of the turbulence simulation during the course of a long transport timescale run. The results yield a quantitative measure of conditions (intermittency frequency and amplitude) when the RIC scheme can be applied to edge transport and provides a more detailed understanding how the resulting profiles from the two methods differ. The analysis is applied to both L-mode and H-mode cases.

*Prepared by LLNL under USDOE contract DE-AC52-07NA27344.

1. A.I. Shestakov, R.H. Cohen, J.A. Crotinger, L.L. LoDestro, A. Tarditi, and X.Q. Xu, J. Comp. Phys. **185** (2003) 399.
2. T.D. Rognlien, M.V. Umansky, X.Q. Xu, R.H. Cohen, and L.L. LoDestro, J. Nucl. Maters. **337-339** (2005) 327.

Extending TGLF Transport Modeling Towards the Edge*

G.M. Staebler, J.E. Kinsey and R.E. Waltz

e-mail: staebler@fusion.gat.com

General Atomics, PO Box 85608, San Diego, California 92186-5608, USA

The trapped gyro-Landau fluid (TGLF) transport model was designed to be valid in the near separatrix region of tokamaks and spherical tori. The TGLF model uses a higher moment system of equations than its predecessor GLF23 to compute more accurate linear driftwave eigenmodes. General numerical equilibrium magnetic geometry and an improved electron-ion collision model have recently been added to TGLF. The saturation rule for the quasi-linear flux calculations has also been improved obtaining a better fit to non-linear gyrokinetic simulations with three fit parameter rather than the four needed for the previous saturation rule. Most importantly, momentum transport has been added. Both the parallel and ExB velocity shear and the coriolis drift are now included in the eigenmode calculation so that the linear wavefunction and viscous stress matrix can be computed quasi-linearly. The ExB velocity shear is included using a generalization of the successful quench rule that includes a model for the radial wavenumber induced by the ExB velocity shear. With these improvements, the TGLF model is ready to push out to the edge of the closed flux surface region. The change in plasma conditions from the core to the near separatrix region is extreme. The magnetic shear and change in flux surface shape with radius are much stronger than in the core. The gradient lengths for temperature and density approach the poloidal gyroradius scale, where both neoclassical and gyrokinetic theory ordering assumptions break down. The plasma is rapidly transitioning from nearly collisionless to strongly collisional over a small region. The ExB velocity is strongly sheared suppressing all but the high wavenumber electron driftwaves (ETG). The first TGLF results of linear stability calculations and particle, energy and momentum transport simulations of H-mode and L-mode near edge regions of the DIII-D tokamak will be reported.

---

*This work was supported by the US Department of Energy under DE-FG03-95ER54698.

GENE simulations for an ASDEX Upgrade edge transport barrier

D. Told[1], F. Jenko[1], P. Xanthopoulos[2], L.D. Horton[1], E.Wolfrum[1]
and the ASDEX Upgrade Team
dtold@ipp.mpg.de
1) Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching, Germany
2) Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald, Wendelsteinstr. 1,
D-17491 Greifswald, Germany

In the present study, the gyrokinetic turbulence code GENE is employed to investigate the long and short wavelength turbulence in the pedestal of an ASDEX Upgrade H-mode plasma. The simulations are carried out with fully gyrokinetic ions and electrons, using numerical ASDEX Upgrade MHD equilibria and experimentally determined temperature and density profiles. Passing and trapped particles are taken into account as well as collisions and finite-beta effects, while the simulations do not yet consider nonlocal effects. Linear simulations in the long-wavelength regime show that in the pedestal the plasma is very close to the ITG-Ballooning transition. In the short-wavelength regime on the other hand, an ETG instability is found to be the most unstable mode, generating electron heat transport levels similar to those inferred from transport modeling studies. Since the aforementioned instabilities occur over a broad wavenumber range, nonlinear simulations spanning both ranges simultaneously are presently not possible. Separate simulations for long and short wavelengths are therefore performed. In order to study the interplay of transport and ExB shearing effects, the diffusivities calculated by the GENE code can serve as input for the full-f PIC code XGC0, which calculates edge plasma profiles taking into account neutral physics and ExB shearing effects. These profiles can then serve as input for GENE again. Preliminary results of such a study will be shown.

TEMPEST kinetic full-f simulations of the steady-state pedestal profiles in a single-null tokamak geometry*

X. Q. Xu,

Lawrence Livermore National Laboratory, Livermore, CA 94550 USA

We present edge gyrokinetic simulations of tokamak plasmas using the fully nonlinear (full-f) continuum code TEMPEST$^{1-4}$. Either static and kinetic electron model is used. TEMPEST simulations were carried out for plasma transport and flow dynamics in a single-null tokamak geometry, including the pedestal region that can extend across the separatrix into the scrape-off layer (SOL) and private flux region. . The core radial boundary particle distribution is a fixed Maxwellian $F_{M\alpha}$ with $N_{0\alpha}$, $T_{0\alpha}$ and $U_{\|0\alpha}$, and the exterior radial boundary particle distribution is a Neumann boundary condition with $\partial F_\alpha(\psi, \theta, E, \mu)/\partial\psi|_w$ = 0 during a simulation, where α represents the particle species. Given boundary conditions and initial profiles, the interior plasma in the simulations should evolve into a steady state. A series of TEMPEST simulations are conducted to investigate the transition of midplane pedestal heat flux and flow from the neoclassical to the turbulent limit and the transition of divertor heat flux and flow from kinetic to fluid regime via a density-scan and an anomalous transport scan. TEMPEST simulations demonstrate that turbulent transport plays a similar role as a collisional decorrelation of particle orbits and the large turbulent transport leads to Maxwellianization of particle distribution. We also show the transition of parallel heat flux and flow at the entrance of divertor plates from fluid to kinetic regime, leading to a modified relationship of flux-limited heat flux. Even for an absorbing divertor plate boundary condition, a non-half-Maxwellian is found due to the substantial collision for slow particles.

References

[1] X. Q. Xu, Z. Xiong, M. R. Dorr, J. A. Hittinger, *et al.*, *Nucl. Fusion* **47**, 809 (2007).

[2] X. Q. Xu, *Phys. Rev. E.* **78**, 016406 (2008).

[3] X. Q. Xu, Z. Xiong, Z. Gao, W. M. Nevins, G. R. McKee, *Phys. Rev. Lett.* **100**, 215001 (2008).

[4] X. Q. Xu, *et al.*, *Nucl. Fusion* **49**, 065023 (2009).

---

*Work performed for U.S. DOE by LLNL under Contract DE-AC52-07NA27344