PHYSICS OF PLASMAS **24**, 081101 (2017)

Preface to Special Issue Containing Invited Papers Presented at Gyrokinetic Particle Simulation: A Symposium in Honor of Wei-li Lee (University of California, Irvine, July 18–22, 2016)

Z. Lin[a)]

Department of Physics and Astronomy, University of California, Irvine, California 92697, USA

(Received 14 August 2017; accepted 14 August 2017; published online 29 August 2017)

[http://dx.doi.org/10.1063/1.5000231]

This special issue includes a collection of invited papers presented at a symposium to honor Wei-li Lee for his pioneering contributions to gyrokinetic particle-in-cell simulations. Since its invention by Wei-li Lee more than 30 years ago, gyrokinetic particle simulation[1,2] has transformed the study of magnetized plasmas with applications to low frequency processes including microturbulence, meso-scale Alfven eigenmodes excited by energetic particles, macroscopic magnetohydrodynamic (MHD) instabilities, and collisional (neoclassical) transport in fusion and space/astrophysical plasmas. It has inspired the development of modern gyrokinetic theory and advanced simulation models such as perturbative simulation method and gyrokinetic continuum simulation. It has also been a key driver for the engagement of plasma physics as a prominent application domain in the exciting growth area of high performance computing—from the present to the next generation supercomputers based on heterogeneous architectures.

Twenty-eight papers were presented at the symposium to discuss the current status and future directions in the gyrokinetic particle simulation, followed by technical discussions on extending the gyrokinetic simulation to new parameter regimes and for applications including the key area of energetic particle dynamics under burning plasma conditions. These papers provide a snapshot of a vibrant and fruitful research area of gyrokinetic simulation that is effectively leveraging the remarkable advances in physics models, numerical methods, and computing power to improve our understanding of instability, turbulence, and transport in magnetized plasmas. Gyrokinetic particle simulation has undoubtedly emerged as a powerful tool for studying nonlinear physics of low frequency kinetic-MHD processes that underlie stability and confinement properties of fusion plasmas. In particular, integrated simulation using the gyrokinetic model is critical to understanding the excitation and evolution of macroscopic electromagnetic instabilities in magnetized plasmas, which often depend on kinetic effects at microscopic scales as well as the nonlinear coupling of multiple physical processes spanning disparate spatial and temporal scales.

Nine papers presented at the meeting were reviewed to the usual high standard of the *Physics of Plasmas* and published in this special topic issue and are highlighted in what follows. A system of nonlinear electromagnetic gyrokinetic Vlasov-Maxwell equations conserving energy and including both shear and compressional magnetic perturbations[3] has been derived by Brizard using variational principle in the parallel-symplectic representation. The gyrokinetic particle simulation model incorporating effects of compressional magnetic perturbations[4] has been formulated by Dong *et al.* using perpendicular force balance equation and verified in simulations of drift-Alfvenic instabilities in tokamaks. A conservative scheme of drift kinetic electrons for gyrokinetic simulations of kinetic-MHD processes in toroidal plasmas[5] has been developed by Bao *et al.* and verified in simulations of kinetic Alfven waves and collisionless tearing modes. This conservative scheme minimizes the electron particle noise and is free from the so-called "cancellation problem," which arises when a large term associated with electron canonical momentum is added to both sides of the Ampere's Law. Numerical techniques to mitigate the "cancellation problem" are reviewed by Mishchenko *et al.*,[6] which highlight control-variate method and mixed-variable pullback scheme developed and verified in electromagnetic gyrokinetic simulations.

Regarding applications, global gyrokinetic particle simulations by Li and Xiao[7] find a radially outward shift of kinetic ballooning modes in the normal magnetic shear tokamak, which is attributed to effects of ion parallel compressibility. A gyrokinetic mechanism, i.e., the difference in gyroradii between electrons and ions, is invoked by Lee and White[8] to explain the generation of an equilibrium electrostatic potential in the presence of spatial inhomogeneity of background plasmas, as observed at the edge of tokamak experiments. Beyond the conventional gyrokinetic simulations, a fully kinetic ion model[9] is formulated by Sturdevant *et al.* and applied to simulations of toroidal ion-temperature-gradient instability, which verify global gyrokinetic particle simulation results. The gyrokinetic model is used by Todo *et al.*[10] to describe the fast ion dynamics in MHD-gyrokinetic hybrid simulations of Alfven eigenmodes in a stellarator. The gyrokinetic model is also used by Wang *et al.*[11] to derive fluid moment closures for Landau damping in non-Maxwellian plasmas in the tokamak edge.

Detailed meeting information is available at the symposium webpage (https://www.physics.uci.edu/Lee-Symposium-2016/index.html). Attendees of the meeting (Fig. 1) include 36 researchers from United States, EU, Canada, China, and Japan. We thank the editors and staff of the *Physics of Plasmas* for publishing this important and timely special issue on gyrokinetic particle simulation in honor of Wei-li Lee.

a)zhihongl@uci.edu

FIG. 1. The group photo shows the attendees of Gyrokinetic particle simulation: A Symposium in Honor of Wei-li Lee, University of California, Irvine, July 18–22, 2016.

[1]W. W. Lee, Phys. Fluids **26**, 556 (1983).
[2]W. W. Lee, J. Comput. Phys. **72**, 243 (1987).
[3]A. J. Brizard, Phys. Plasmas **24**, 081201 (2017).
[4]G. Dong, J. Bao, A. Bhattacharjee, A. Brizard, Z. Lin, and P. Porazik, Phys. Plasmas **24**, 081205 (2017).
[5]J. Bao, D. Liu, and Z. Lin, "A conservative scheme of drift kinetic electrons for gyrokinetic simulation of kinetic-MHD processes in toroidal plasmas," Phys. Plasmas (to be published).
[6]A. Mishchenko, A. O. Bottino, R. Hatzky, E. Sonnendrucker, R. Kleiber, and A. Konies, Phys. Plasmas **24**, 081206 (2017).
[7]Y. Li and Y. Xiao, Phys. Plasmas **24**, 081202 (2017).
[8]W. W. Lee and R. B. White, Phys. Plasmas **24**, 081204 (2017).
[9]B. J. Sturdevant, Y. Chen, and S. E. Parker, Phys. Plasmas **24**, 081207 (2017).
[10]Y. Todo, R. Seki, D. A. Spong, H. Wang, Y. Suzuki, S. Yamamoto, N. Nakajima, and M. Osakabe, Phys. Plasmas **24**, 081203 (2017).
[11]L. B. Wang, X. Q. Xu, and B. Li, "Fluid moment closures for landau damping in non-Maxwellian plasmas," Phys. Plasmas (submitted).