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Michigan Institute for Plasma Science and Engineering



Wednesday
February 3, 2027
3:10 pm
Room 1311 EECS

Prof. Minna Palmroth

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Beyond Global MHD: Ion-Kinetic Modeling of the Entire Magnetosphere with Vlasiator

Global magnetospheric modeling has traditionally relied on magnetohydrodynamics, while kinetic plasma physics is treated locally or within embedded kinetic regions. Vlasiator removes this separation, modeling the entire near-Earth plasma environment while retaining ion kinetics throughout the simulation domain. Vlasiator solves the Vlasov equation for the ion distribution function self-consistently with electromagnetic fields; electrons are treated as a charge-neutralizing fluid. It is the world's first and only global magnetospheric hybrid-Vlasov simulation capability.

This talk will discuss Vlasiator development strategies, and the type of science that is possible when ion kinetics is retained on global scales. Examples include the formation of the foreshock, wave transmission through the bow shock, magnetosheath dynamics, magnetic reconnection, and magnetotail plasma eruptions. A central question is how local kinetic instabilities and ion-scale processes couple to the dynamics of the global system. Vlasiator was initiated at time when the computers needed to run it did not yet exist. Over nearly two decades, we developed the numerical methods, software architecture, and research program alongside generations of European supercomputers, ultimately enabling production-scale six-dimensional phase-space simulations of the entire magnetosphere.

The talk concludes by discussing why space physics matters more than ever as near-Earth space becomes both critical infrastructure and a rapidly growing economic domain. Sustainable use of space requires understanding of the plasma environment.

About the Speaker: Minna Palmroth is an Academy Professor and Professor of Computational Space Physics at the University of Helsinki and Director of the Finnish Centre of Excellence in Space Resilience. She conceived and founded the Vlasiator program in 2008 and has built it, through competitively funded research programs, into the world's only global magnetospheric hybrid-Vlasov simulation capability. She leads a research group of approximately 30 scientists and students and has pioneered the use of Europe's largest supercomputers for global ion-kinetic modeling of near-Earth space. Palmroth has received two European Research Council grants and has led two consecutive Finnish Centres of Excellence. Her research connects fundamental space plasma physics with high-performance computing, space weather, sustainable use of space, space technology, and space resilience. Earlier, she served as Research Professor and Head of Earth Observation at the Finnish Meteorological Institute, where she initiated Finland's 24/7 operational space-weather service. She is an elected member of four Academies, including the Academia Europaea.