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The Role of Plasma Instabilities in Sheath Physics

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Abstract - Sheaths are an essential aspect of most plasma-based technologies because they determine how a plasma interacts with its surroundings. This talk will review a few recent advances in our understanding of how sheaths work [1]. Because sheath and presheath regions are often small compared to collisional relaxation scales in low temperature plasmas, the associated electric fields can cause a highly non-equilibrium state in which different species flow at dramatically different rates. Such differential flows provide an energy source that, when strong enough, can seed the excitation of electrostatic instabilities. These waves have been shown to grow to large enough amplitude that they feedback and influence the overall transport rates. Such behavior arises in a number of contexts. Ion-acoustic instabilities in the ion presheath have been observed to influence the ion velocity distribution function via wave-particle scattering. A similar instability, seeded directly by the electric field, has been found to cause the time-dependent Tonks-Langmuir problem to be unstable. Ion-ion two-stream instabilities have been observed in the presheath of plasmas with ionic mixtures, and lead to an instability-enhanced friction force that influences the ion flow speeds. Flow-driven instabilities have also been found to play a prominent role in electron sheaths, where an electron presheath generates electron-ion two-stream instabilities that influence electron transport. Since these instabilities lead to observable changes in plasma transport, they must be considered in order to accurately model plasma-boundary interactions in a number of application areas.

[1] S.D. Baalrud, B. Scheiner, B.T. Yee, M.M. Hopkins, and E. Barnat, Plasma Sources Science and Technology 29, 053001 (2020)

Short Bio

Scott Baalrud is an Associate Professor of Physics at the University of Iowa. He attended the University of Wisconsin-Madison, receiving B.S. degrees in Nuclear Engineering and Mathematics (2006), followed by a Ph.D. in Engineering Physics (2010). After graduation, he furthered his training as a DOE Fusion Energy Sciences Postdoctoral Fellow at the University of

New Hampshire and as a Feynman Fellow at Los Alamos National Laboratory before joining the University of Iowa as an Assistant Professor in 2013. His research concerns the theoretical foundations of plasma physics, with a focus on kinetic theory. It connects with several applications, including strongly coupled plasmas, sheaths, warm dense matter and magnetic reconnection. His research and teaching accomplishments have been acknowledged by the Thomas H. Stix Award (2020), Hershkowitz Early Career Award (2018), as well as the University of Iowa's Distinguished Mentor Award (2016) and Early Career Scholar of the Year Award (2017). He is actively engaged in the APS Division of Plasma Physics, having served as a co-chair of the APS-DPP community planning process, as member at large of the executive committee, as topical group chair of the program committee, as chair of the Dawson prize committee, and as a member of the fellowship selection committee.