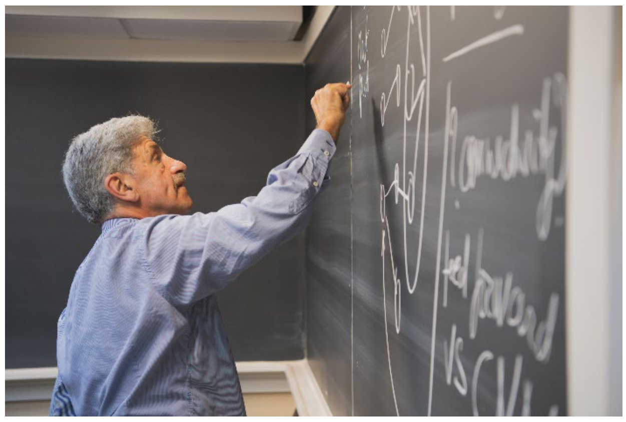
PHYSICAL MATH SEMINAR

Stability and Bifurcations in Free Boundary PDE Models of Cell Motility.



Leonid Berlyand

Penn State University

ABSTRACT:

We begin with a brief overview of the rapidly developing research area of active matter, a.k.a. active materials. These materials are intrinsically out of equilibrium, resulting in novel physical properties whose modeling requires the development of new mathematical tools. We present a free boundary PDE model of the cytoskeleton of a moving cell. The key mathematical features of our model are the nonlocal boundary conditions, nonlinear diffusion, and the Keller-Segel cross-diffusion term. We present an overview of three recent works on that model. We begin from the 2D model with linear diffusion, in which we derive an explicit formula for the stability-determining eigenvalue for the linearized non-self-adjoint operator. Next, we present a recent result on the nonlinear stability of stationary and traveling wave solutions in a 1D model. Here, we focus on the non-self-adjointness of the linearized problem, which plays a key role in the spectral stability analysis. Finally, we consider a 2D model with nonlinear diffusion and prove that this nonlinearity results in the change of the bifurcation from supercritical to subcritical, leading to two drastically different scenarios of the onset of the cell motion. Here, we derive an explicit formula that governs the change of the bifurcation type in terms of measurable physical parameters and therefore can be used for both qualitative and quantitative biological predictions. Finally, we discuss how our results lead to an open question of bistability. This work resulted in two published papers with A. Safsten and V. Rybalko (Phys. Rev . E, 2022, Transactions of AMS, 2023), as well as recent papers with A. Safsten and L. Truskinovsky (ARMA, 2025) and with O. Krupchytski and T. Laux (Nonlinear Science, 2025, accepted subject to revision).

BIO:

Leonid Berlyand is a Professor of Mathematics and a member of the Materials Research Institute and the Huck Institute of Life Sciences at Penn State University. His research is at the interface between mathematics and other disciplines: physics, life sciences, and computer science. In 2021 he received Humboldt Research Award. Leonid is a founding co-director of PSU Center for Mathematics of Living and Mimetic Matter and PSU Center for Interdisciplinary Mathematics. He received his Ph.D. degree from Kharkiv State University (Ukraine) and co-authored three books and over 100 research papers.

TUESDAY, NOVEMBER 4, 2025

2:30 PM – 3:30 PM

Building 2, Room 449

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