# APPLIED MATHEMATICS SEMINAR

## Beyond Integrability: Computational Adventures in Complex Nonlinear Dynamical Systems


**ABSTRACT:**

Complex nonlinear systems are ubiquitous in nature and human-designed environments. The overarching goal of our research is to combine advanced computational methods with fundamental theoretical analysis to study systems that are not readily amenable to integrable-systems techniques. Applications include superfluidity and superconductivity in ultracold atomic physics (e.g., Bose-Einstein condensation), extreme and rare events (e.g., tsunamis and rogue waves), and collapse phenomena in nonlinear optics (e.g., light propagation through a medium without diffraction). To investigate these systems, we have developed computational techniques for bifurcation analysis that reveal the structure of their parameter spaces, together with continuation methods--including pseudo-arclength continuation and the Deflated Continuation Method (DCM) -- for efficiently tracking solution branches and connecting mathematical predictions with physical observations. Ultimately, these approaches can contribute to technological advances such as the discovery of new materials and the development of precision measurement devices (e.g., interferometers), as well as to the prediction and characterization of extreme phenomena through features of the underlying eigenvalue spectra. In this talk, we will present a broad range of results obtained using these computational techniques. By adapting DCM to the Nonlinear Schrödinger (NLS) equation, we uncover previously unknown, inconspicuous solution branches, including weakly nonlinear unstable states that are potential targets for experimental verification. Using pseudo-arclength continuation, we also show the existence of a novel Kuznetsov-Ma breather -- a time-periodic solution -- of the discrete, non-integrable NLS equation, with potential relevance to periodic extreme and rare events in optical systems. In addition, combining perturbation methods with pseudo-arclength continuation enables us to elucidate collapsing waveforms associated with the one-dimensional focusing NLS and Korteweg-de Vries equations. We further demonstrate how exploiting symmetries of the underlying PDEs, and their connections to conservation laws, can improve the robustness of fixed-point iterations. Looking ahead, our research will focus on developing an ecosystem of computational tools for the numerical investigation of complex nonlinear systems, with the ultimate goal of disseminating an open-source FreeFEM library for bifurcation and stability analysis.


## SPEAKER:


**Dr. Stathis Charalampidis**

**San Diego State University**


**Biography:**

Dr. Stathis Charalampidis is an Assistant Professor in the Department of Mathematics and Statistics at San Diego State University and a member of the Computational Science Research Center. Prior to joining SDSU in 2024, he was an Assistant Professor in the Mathematics Department at Cal Poly San Luis Obispo from 2019 to 2024. He earned his PhD in Applied Mathematics from Aristotle University of Thessaloniki, Greece, and pursued postdoctoral studies at the University of Massachusetts Amherst, where he was later appointed Lecturer and Chief Undergraduate Advisor for Mathematics majors. His research interests revolve around computational studies of complex nonlinear dynamical systems arising in mathematical physics, condensed matter physics, nonlinear optics, materials science, and fluid mechanics. He has also held a CNRS Visiting Professorship at the Laboratoire de Mathématiques Raphaël Salem at the University of Rouen Normandy, France, and currently serves as an Editor for Chaos, Solitons & Fractals. His research has been supported by the National Science Foundation, the Department of Energy, and the Department of Defense through the Army Research Laboratory, with projects focusing on collapse phenomena and rogue waves, high-temperature plasma research, and quantum simulation of multi-component droplets. He is actively involved in mentoring undergraduate and graduate researchers and is particularly proud of involving students in peer-reviewed research. He is passionate about teaching and has taught courses ranging from calculus and differential equations to numerical analysis, computational differential equations, and scientific computing, including Domain Decomposition Methods. As a first-generation college graduate, he values accessible public higher education and is committed to supporting students from diverse backgrounds while serving as an ambassador for Computational and Applied Mathematics. In his spare time, he enjoys hiking, traveling, playing the guitar, and working on electronics, particularly repairing tube and solid-state audio amplifiers—an interest that originally inspired him to study physics.

**September 24, 2026**
**3:00 - 4:20pm**
**SSB 120**

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