University of Maryland
PHYS 715
Nonlinear Dynamics and Chaos
Syllabus
Fall 2024

Course Emphasis

Physics 715 is a graduate level introduction to Nonlinear Dynamics and Chaos. The course will cover nonlinear dynamics, chaos, and a sample of spatially extended systems and turbulence. In addition, we will read and discuss some more important papers in the field. The course work will include a project. Most projects will involve data analysis, simulations, and possible experiments. Projects related to existing research are possible.

Professor

Daniel P. Lathrop
Office: 3319 A.V. Williams. Office Hours: Right after class or by appointment
E-Mail: Is not the best way to contact me. In person at class or just after class is most effective, otherwise by the course Slack.

Location

Lecture meets Tuesday and Thursdays 2-3:15 p.m. in Toll Physics 4221.

Prerequisites

No single course is required, but a working knowledge of linear algebra, differential equations (ODEs and PDEs), and some coding experience (e.g. matlab or python) is assumed.

Recommended books (both can be found through the UMD STEM library):

Edward Ott, "Chaos in Dynamical Systems"
Steven Strogatz, "Nonlinear Dynamics and Chaos"

Important papers

During the semester we will be reviewing a sample of more important papers in the field. These will be distributed electronically as .pdf files for discussion in class.

Grades

The semester grade for the course will be determined in the following way:
PHYS 715

Semester Project	35%
Lecture participation (sign-in)	10%

Homework	35%
Take home exam	20%

Project

Everyone will have an individual project based on interests. The project can be theoretical, numerical, data analytical, or experimental. Project related to existing research are welcome when appropriate.

Exams

The course will include two in-class exams which will be based closely on prior lectures and homework.

Preliminary list of lecture topics (preliminary)

- Fixed points and linear stability analysis
  - 1D maps and flows
  - 2D maps and flows
- Bifurcations
  - 1D maps and flows
  - 2D flows
- Chaos
  - Chaos and the Lorenz attractor and original paper
  - 1-D Map from the Lorenz system
  - Logistic map, tent map, etc.
  - Probability distributions aka invariant measures
  - Symbolic dynamics
  - Topological and metric entropies
  - 2D maps and the Hénon system
  - Lyapunov exponents
  - Fractals
- Analysis of experimental/observational time series
  - Power spectrum
  - Histograms
  - Phase space embeddings
    - Time delay embeddings
  - Poincaré sections (minima as an example)
  - Surrogate data sets
  - Computation of Lyapunov exponents
  - Probability distributions aka invariant measures
  - Symbolic dynamics
  - Topological and metric entropies
- Dynamics in spatially extended systems
  - Waves
  - Wave turbulence
  - Linear stability analysis and pattern formation
  - Bifurcations in fluid systems
  - Turbulence as a general phenomena
- Machine learning techniques

    - Reservoir computing
    - Sparse Identification of Nonlinear Dynamics (SINDy)
- Networks
- Hamiltonian dynamics and transport
- Synchronization