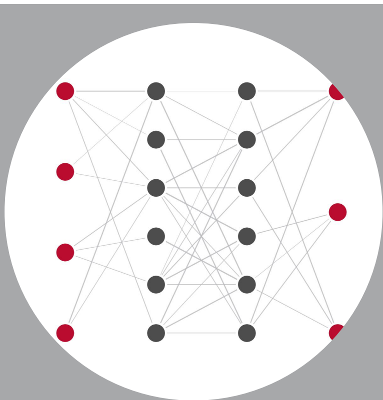

# Advanced Seminar: Computation and AI

PHYS 480/500

## Instructor Info


Prof. Francis-Yan Cyr-Racine
PAIS 3214
fycr@unm.edu

Prof. Huaiyu Duan
PAIS 3212
duan@unm.edu

Prof. Keith Lidke
PAIS 2218
klidke@unm.edu


## Course Info

Prereq: PHYS 2415 (Computational Physics) is strongly recommended for undergraduate students. Familiarity with Python and/or Julia will be helpful throughout the Seminar.

Fri

14:00pm-14:50pm

PAIS 2540

Course materials on UNM Canvas

## Why Computation and AI?

Artificial intelligence is rapidly reshaping how physics and astronomy research gets done – from classifying galaxy morphologies and pulling gravitational-wave signals out of noise, to accelerating simulations, guiding materials discovery, and helping physicists write and debug the code that ties it all together. Whether or not AI ends up being part of your own learning or research, understanding what these tools can (and cannot) do, how they work under the hood, and how to use them responsibly is becoming as fundamental a skill as programming itself. This seminar offers a broad, hands-on tour of the modern computation and AI landscape, taught by three physics faculty who each use these tools in their own research.

## Overview

This one-credit-hour seminar meets weekly and is aimed at Physics & Astronomy undergraduate majors (PHYS 480) and graduate students (PHYS 500). Rather than a deep dive into any single topic, the course is a guided tour of the computational and AI landscape relevant to modern physics and astronomy research: setting up a productive computing environment, understanding the basics of machine learning, getting hands-on with PyTorch and image classification, learning how AI fits into a real research workflow, and looking under the hood of large language models and agentic AI systems built with JAX. We will also discuss responsible research practices around AI and data handling throughout the semester. Time permitting, we will invite outside experts for guest talks, and the last few seminars will be reserved for you to present the AI-based artifact you build over the course of the semester.

## About the Instructors

This seminar is co-taught by three UNM Physics & Astronomy faculty who each bring a different flavor of computation and AI to the table.

- Prof. Francis-Yan Cyr-Racine – theoretical cosmologist/astrophysicist (dark matter, early Universe) who has increasingly relied on differentiable programming (JAX) and LLMs in his research.
- Prof. Huaiyu Duan – works in astrophysics and nuclear/particle physics, directs UNM's Center for Fundamental Physics, and relies on large-scale numerical simulations; brings that perspective to our PyTorch/image classification unit.
- Prof. Keith Lidke – works in atomic, molecular, and optical physics and biophysics, developing optical microscopy and computational methods to visualize single molecules in living cells; brings that perspective to our unit on AI in the research workflow.

## Material

### Required Text

None. Slides, tutorials, and code notebooks for each week will be posted on the course site.

## Grading Scheme

This seminar is graded on a Credit/No Credit (CR/NC) basis. To receive credit, you must satisfy all of the following:

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| Required | Attendance and active participation in weekly seminar sessions (minimum 11 of 15) |
| Required | Completion of weekly hands-on exercises and coding notebooks |
| Required | A final AI-based artifact relevant to physics/astronomy research |
| Required | A short oral presentation of the final artifact to the seminar |

# FAQs

**I don't have a strong programming background. Can I still take this seminar?**

Your coding skills should be at the level that is expected by the end of PHYS 2415 Computational Physics. But what matters most is your curiosity and a willingness to experiment.

**Is this seminar going to teach me how to become a machine learning engineer?**

Not exactly. Our goal is to give you a broad, practical map of the AI landscape and hands-on experience with some of its core tools, so you can confidently use AI in your own physics or astronomy research.

**Do I need to already know machine learning or deep learning?**

No prior ML/DL background is assumed. We will introduce the key concepts from scratch before diving into PyTorch, JAX, and large language models.

**Since this is an AI seminar, can I use AI tools like ChatGPT or Copilot for my final project?**

Yes, and we encourage it! See the Policy on the Use of AI Tools below for what we expect in terms of understanding and disclosure.

## Class Format

Each week we meet for a single 50-minute session combining a short lecture, live-coding demonstrations, and hands-on exercises with the tool introduced that week (PyTorch, JAX, or otherwise). Bring a laptop and follow along with the code. During the last few weeks of the semester, sessions are reserved for guest talks and for your final project presentations.

## Student Learning Outcomes

Upon successful completion of this course,...

- Students will be able to navigate a modern scientific computing environment (command line, VS Code, Python environments, version control).
- Students will understand the basic concepts of machine learning, including the distinction between supervised and unsupervised learning.
- Students will be able to build, train, and evaluate a neural network in PyTorch, including a basic image classifier.
- Students will understand how physics-informed neural networks incorporate physical laws into machine learning models.
- Students will understand how AI fits into a real research workflow, including data handling and reproducibility practices.
- Students will understand, at a conceptual level, how large language models and transformer architectures work.
- Students will be able to design and use simple agentic AI workflows.
- Students will be able to use AI tools responsibly and transparently in their own research and coursework.
- Students will design, build, and present an AI-based artifact applied to a physics- or astronomy-relevant problem.

## Course Goals

- Students will gain a practical, working map of the modern AI tooling landscape (PyTorch, JAX, LLMs, agentic frameworks).
- Students will use appropriate computational tools to build and evaluate an AI-based artifact.
- Students will practice responsible and transparent research practices around data and AI use.
- Students will demonstrate effective communication of technical AI-based work through an oral presentation.

## Weekly Hands-On Exercises

Most weeks include a short hands-on coding exercise (e.g., a PyTorch notebook or a small JAX script) that builds directly on that week's material. These exercises build your practical skills and count toward the participation requirement for credit; they are not individually graded for correctness, but completion is checked. Exercises and supporting files are posted on the course site.

## Final AI-Based Artifact

To receive credit for this seminar, each student will design, build, and present an AI-based artifact of their choosing over the course of the semester – for example, a trained model applied to a physics or astronomy dataset, a small agentic workflow, a physics-informed neural network, or another project developed in consultation with the instructors. During the last two weeks of the semester, you will give a short ($\sim$10 min) presentation of your artifact to the rest of the class.

## Credit-hour statement

This is a one credit-hour course. Class meets for one 50-minute session of direct instruction per week for fifteen weeks during the Fall 2026 semester. Please plan for a minimum of two hours of out-of-class work (reading, tutorials, and work on your final AI-based artifact) each week.

## Policy on the Use of AI Tools

Since one of the goals of this seminar is fluency with modern AI tools, you are strongly encouraged to use AI systems (e.g., ChatGPT, Claude, Gemini, GitHub Copilot) throughout the semester, including for weekly exercises and your final artifact.

*Expectations for Use:* Regardless of how much AI assistance you use, you must be able to explain, in your own words, how your artifact works and why you made the design choices you made. During your final presentation, be prepared to answer questions about the underlying algorithms, code, and design decisions – not just about what the AI produced for you.

*Requirement for Disclosure:* For your final artifact, include a short methods note describing which AI tools you used, how you used them, and what you learned or verified as a result. This kind of transparent, documented use of AI as a research tool is itself an example of the responsible research practices this seminar aims to teach.

*Not Permitted:* Submitting an artifact you cannot explain, or that was produced without your meaningful intellectual engagement, will not satisfy the credit requirement for this course, even if properly disclosed.

## Course Material Access

This seminar does not require any paid textbook or course materials. If you are automatically enrolled in the Complete option through the My Shelf link in Canvas (a UNM-wide bookstore program billed at a flat rate per semester across all your Albuquerque campus courses), you may opt out of coverage for this specific course there if you wish, since no materials will be assigned. See the information here for details on the Complete, Select, and Opt-out options.

## Undergraduate vs Graduate students

Students registered for graduate credit (PHYS 500) are expected to demonstrate greater technical depth in their final AI-based artifact and presentation – for example, through a more sophisticated model, a more rigorous evaluation, or a more substantial connection to their own research area.

## Academic Integrity

Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, up to and including dismissal, against any student who is found guilty of academic dishonesty or otherwise fails to meet the standards. Any student judged to have engaged in academic dishonesty in course work may receive a reduced or failing grade for the work in question and/or for the course. Academic dishonesty includes, but is not limited to, dishonesty in quizzes, tests, or assignments; claiming credit for work not done or done by others (including AI; see AI policy above); hindering the academic work of other students; misrepresenting academic or professional qualifications within or without the University; and nondisclosure or misrepresentation in filling out applications or other University records.

## Respectful behavior and absences

We are committed to building with you a positive classroom environment in which everyone can learn. We reserve the right to intervene and enforce standards of respectful behavior when classroom conduct is inconsistent with University expectations. Interventions and enforcement may include but are not limited to required meetings to discuss classroom expectations, written notification of expectations, and/or removal from a class meeting. Removal from a class meeting will result in an unexcused absence. Three or more unexcused absences may result in permanent removal and a drop from the course. The University of New Mexico ensures freedom of academic inquiry, free expression and open debate, and a respectful campus through adherence to the following policies.

## Accommodations

UNM is committed to providing equitable access to learning opportunities for students with documented disabilities. As your instructor, it is my objective to facilitate an inclusive classroom setting, in which students have full access and opportunity to participate. To engage in a confidential conversation about the process for requesting reasonable accommodations for this class and/or program, please contact the Accessibility Resource Center at arcsrvs@unm.edu or by phone at 505-277-3506.

## UAP 2720 and 2740

Our classroom and our university should foster mutual respect, kindness, and support. If you have concerns about discrimination, harassment, or violence, please seek support and reports incidents. Find confidential services at the LoboRESPECT Advocacy Center, the Women's Ressource Center, and the LGBTQ Ressource Center. UNM prohibits discrimination on the basis of sex (including gender, sex stereotyping, gender expression, and gender identity). All instructors are "responsible employees" who must communicate reports of sexual harassment, sexual misconduct and sexual violence to Compliance, Ethics, and Equal Opportunity. For more information, please see UAP 2720 and UAP 2740.

## Tentative Class Schedule

### MODULE 1: Foundations – Computing & the AI Landscape

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| Week 1 | The AI Landscape in Physics Research and Education | All instructors |
| Week 2 | Inside Large Language Models: transformers and attention. Customization and Skills. | Prof. Cyr-Racine |
| Week 3 | AI-assisted coding | Prof. Duan |
| Week 4 | Differentiable programming for physics | Prof. Cyr-Racine |
| Week 5 | Intro to Agentic AI | Prof. Lidke |
| Week 6 | Agentic AI: Making the AI work for you | Prof. Lidke |

### MODULE 2: Machine Learning for Research

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| Week 7 | Machine Learning Fundamentals: supervised vs. unsupervised learning, what a neural network is | Prof. Cyr-Racine |
| Week 8 | Fall Break (No Seminar) | |
| Week 9 | Introduction to PyTorch I: tensors and autograd | Prof. Duan |
| Week 10 | Introduction to PyTorch II: building and training neural networks | Prof. Duan |
| Week 11 | Image Classification with Convolutional Neural Networks | Prof. Duan |

### MODULE 3: Developing your own AI Research Workflow

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| Week 12 | Agentic AI: building autonomous AI workflows | Prof. Lidke |
| Week 13 | Guest Speaker Session: AI in Physics Research | Invited guest(s) |

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| Week 14 | Guest Speaker Session: AI in Physics Research | Invited guest(s) |
| Week 15 | Student Project Presentations I | All instructors |
| Week 16 | Student Project Presentations II<br>Final AI-based artifacts due | All instructors<br>Last day of class |