Image: *A zoomed-in region of a map of the distribution of matter made from lensing of the CMB using ACT data, shown against the distribution of emission from dusty star forming galaxies. From*

PHYS 5533
Topics in data-oriented cosmology

Fall 2023 with [Prof. Mathew Madhavacheril](#)

Tuesdays and Thursdays 1:45-3:14pm
Location **DRL 2C8** (33rd and Walnut St.)

Office hours: Tuesdays and Fridays 3:15-4:15pm, DRL 4N39
[How to get to my office](#)

SYLLABUS

The goal of this course is to provide a survey of current research topics in observational cosmology, with a focus on data analysis from large cosmological observatories. By the end of this course, you will have an understanding of how we explore cosmological questions with the cosmic microwave background (CMB), galaxy clusters and galaxy clustering. The course will consist of a hybrid of lectures, hands-on lab sessions, student presentations and projects. The projects will involve analysis of public data and include a proposal and a report.

Prerequisites: Introductory cosmology (at the level of Ryden; some basic familiarity with General Relativity, FLRW metric and the Einstein equations at least at the conceptual level), intermediate Python

Attendance: We will have classes in-person. In-person attendance is critical: while some of the classes involve lectures, many will be dedicated to interactive labs, discussions and student-led activities.

Accommodations

> **It's important to me that everyone who wants to participate has the [resources](#) to be fully included in this course. Please let me know if you need special accommodations in the curriculum, instruction or assessments of this course to enable you to participate fully. I will make every effort to maintain the confidentiality of the information you share with me.**
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> Penn provides reasonable accommodations to students with disabilities who have self-identified and been approved by [Student Disabilities Services](#) (SDS). If you have not yet contacted SDS and would like to request accommodations or have questions, you can make an appointment by calling SDS at 215-573-9235. The office is located in the [Weingarten Learning Resources Center](#) at Stouffer Commons: 3702 Spruce Street, Suite 300. All services are confidential.

Topics

- **Review** (you are assumed to have seen this before)
    - the expanding universe and distance measures
    - thermal history of the universe, BBN and recombination
    - behavior of matter perturbations and the origin of CMB anisotropies
- **Statistical description and information content of various observables**
  Some or all of:
    - Matter fluctuations
    - CMB temperature and polarization anisotropies
    - Gravitational lensing
    - Baryon acoustic oscillations
    - Redshift space distortions
    - Projected observables, angular clustering and the Limber approximation
    - Galaxy clusters and Sunyaev-Zeldovich effects
    - The halo mass function and the halo model
- **Statistical methods and algorithms**
  Some or all of:
    - Astronomical coordinate systems, WCS and maps of the sky
    - Fisher matrices, linear models and Bayesian inference
    - Harmonic analysis and power spectrum estimation
    - CMB lensing reconstruction

Material

Recommended, but not required:
1. A Course in Cosmology, Huterer
2. Cosmological Physics, Peacock
3. Modern Cosmology, Dodelson and Schmidt

Evaluation

A letter grade will be assigned based on the following:

1. **30% Project:** The project can be chosen from a list that we discuss during class. Topics outside the list may also be used, but must be approved by the instructor and involve analysis of public data. A project proposal (NSF-style) due mid-semester, a Github repository for associated code and a final report will be included in the evaluation.
2. **20% Final presentation:** a 10-15 minute talk in the form of a research seminar on the topic of the final project. These presentations will be held during class time, with the last set of presentations held on December 7, 2023.
3. **50% Lab submissions and class participation:** these will be graded continuously throughout the course, with code and reports being the primary content that is evaluated.

COVID Precautions

In order to keep everyone as safe as we can, please respect the following [precautions](#):
- **Get vaccinated**. This is required by Penn for all students, faculty, and staff, with few exceptions.
- **If you feel sick or were exposed to COVID, get a test**: The University offers on-campus Covid testing to all students on demand and at no cost regardless of vaccination status. To schedule a voluntary Covid test, please go to [this website](#) and click on the "Schedule a Test" link. The SAS Dean's office strongly encourages all students to take advantage of this free service at any time, especially if you are feeling ill or believe that you have been exposed to someone who has Covid. Alternatively, take a home rapid test.
- **If you test positive for COVID, please do not come to class or office hours**. Specifically, please participate remotely for [5 days after a positive COVID test.](#) Let me know you'll miss class by filing a [Course Absence Report](#) through [Penn InTouch](#), keep up with the material online, and follow up with me to make up assignments as needed. **Your grade in this class will not be penalized for precautions to protect each other from COVID.**

- **You can rest assured that I will follow similar precautions if I feel sick or were exposed to COVID or test positive for COVID. It is likely that the class will be held remotely on Zoom if this happens.**
- **You are invited to [wear a mask](#) in class if you:**
  - want to for any reason
  - are immunocompromised and personally at high risk
  - are in frequent close contact with someone who is high risk
  - tested positive for COVID-19 more than 5 but less than 10 days ago (if less than 5 days, please participate remotely)
  - have been exposed to someone with COVID-19
  - have recently traveled to an area with substantial or high spread of the virus

Please respect the choices of your classmates. If you feel targeted or uncomfortable in class, speak with me.

Academic Integrity

Participants are expected to abide by the [Penn Code of Academic Integrity](#) in letter *and* spirit. Scientific research is a collaborative endeavor that depends on proper acknowledgment of each person's contributions to a project: this holds in this course as it does in general.

Fostering an inclusive atmosphere in scientific discussions is an integral part of academic and professional ethics. Participants are expected to abide by the [Penn Code of Student Conduct](#) during course activities, and to use the following guidelines as a standard of behavior[1]:

Expected Behavior
- Be considerate, respectful, and collaborative.
- Critique ideas rather than individuals.
- Avoid personal attacks directed toward other participants.
- Be mindful of your surroundings and of your fellow participants.
- Respect the rules and policies of our online classroom in [Canvas](#), Slack, and [Zoom](#).

Unacceptable Behavior
- Harassment, intimidation or discrimination in any form will not be tolerated.
- Physical, verbal, or online abuse of any participant will not be tolerated.
- Examples of unacceptable behavior include, but are not limited to: verbal or online comments related to gender, gender identity and expression, sexual orientation, disability, physical appearance, body size, race, religion, national origin, as well as inappropriate use of nudity and/or sexual images, and threatening or stalking any participant.

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[1] Adapted from the [Ecological Society of America meeting code of conduct](#).

- Recording or photographing another individual without their explicit permission is not allowed.

Consequences
- Anyone requested to stop unacceptable behavior is expected to comply immediately.
- The course instructor may take any action deemed necessary and appropriate, including immediate removal from a class session or the course, or referral to university disciplinary procedures.

Reporting Unacceptable Behavior
- If you are the subject of unacceptable behavior or have witnessed any such behavior, please immediately notify the instructor.
- Anyone experiencing or witnessing behavior that constitutes an immediate or serious threat to public safety should contact campus security at 215.573.3333.

Any member of the Penn community can call the Penn HELP line[2] at any time
to be connected with staff trained for mental health referrals:
215-898-HELP(4357)

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[2] https://www.publicsafety.upenn.edu/safety-initiatives/help-line-215-898-help/