PHY688: Gravitational lensing, Spring 2025

Instructor: Prof. Simon Birrer, ESS 457-A, simon.birrer@stonybrook.edu

Class description

Gravitational lensing, the bending of light due to the space-time distortions predicted by General Relativity, is a unique phenomena to test the laws of Gravity, and has become a powerful cosmological probe. Gravitational lensing is the prime method to study the properties of dark matter on scales of galaxies and galaxy clusters; it can provide the statistically most representative census of exoplanet populations; and it can measure the composition and evolution history of the Universe.

The success story of lensing as an astrophysical tool is closely tied to technological advances, such as high-resolution imaging capabilities (e.g. the Hubble Space Telescope and the James Webb Space Telescope, adaptive optics on large ground-based telescopes, radio interferometry), large telescopes and wide-field cameras, time-resolved photometry in crowded fields, as well as advanced statistical techniques. For a number of current and future large-scale astronomical surveys such as the Vera Rubin Observatory, the Euclid and Roman satellites, lensing is (one of) the main method(s) to constrain cosmology, i.e. to determine the properties of dark energy and dark matter.

This class will cover the lensing formalism, and discuss lensing applications and techniques. It will include a brief introduction of Bayesian statistics and Monte Carlo Markov Chains (MCMC), and several opportunities to work with actual data to reproduce research at the frontier of current gravitational lensing science.

The content will be a mix of lectures, homework assignments, and projects at the forefront of science, including the use of recent science observations, and paper discussions.

Prerequisites (or equivalents for graduate students)

None, though familiarity with basic astrophysical and cosmological concepts will be helpful. AST 203 (Astronomy): Students must be familiar with a broad range of astronomy topics.
AST 347 (Cosmology): Students must be familiar with basic concepts in cosmology, such as the background metric.
PHY 277 (Computation for Physics and Astronomy): Students must be familiar with Linux and bash, and have basic programming experience in the language of Python. Example code will be provided in Python.

Course Website / Syllabus

All course materials will be available on the class webpage:

`https://github.com/sibirrer/strong_lensing_lectures.wiki.git`

Technical requirements

Students are expected to use their own computing machine to run analysis scripts in Python or through a cloud service (such as Google Colab). Students with Windows computers are encouraged to create a Linux partition on their system before the start of classes.

Communication tools

Lectures, tutorials, and office hours will take place in person. Asynchronous communication with the instructor will be organized on slack.

Class hours

Mondays 3:30pm - 4:50pm, ESS 450
Wednesdays 3:30pm - 4:50pm, ESS 450

Office Hours

Birrer: Thursdays 4-5pm, ESS 457-A
Additional appointments may be arranged by e-mail or slack.

Textbook

There is no required textbook. Suggested text is:

- Introduction to Gravitational Lensing (with Python exampels); by M. Meneghetti (Springer Nature 2021)
- Schneider, Kochanek, Wambsganss: Gravitational Lensing: Strong, Weak and Micro. Proceedings of the Saas Fee lectures on Gravitational Lensing. The main chapters are also available on the web: strong, weak and micro.

Course Grade

The final grade will be based on the following weighting:

- Homeworks: 20%
- Presentations and class discussions: 20%
- Modeling project: 15%
- Coding project: 15%
- Final project and report: 20%
- Final presentation: 10%

Computed this way, the overall course grade will range from 0–100.

Attendance

Attendance is mandatory, unless a student is feeling sick or is in isolation / quarantine. In this case, the student MUST inform the instructor ahead of time, so that attendance / recording through zoom can be arranged. Unexcused absences result in 1 grade point penalty on the final grade.

Disability Support Services

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information go to the following website: `https://ehs.stonybrook.edu//programs/fire-safety/emergency-evacuation/evacuation-guide-disabilities` and search Fire Safety and Evacuation and Disabilities.

Academic Integrity Statement

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at:

`http://www.stonybrook.edu/commcms/academic_integrity/index.html`

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

Religious Observances

See the policy statement regarding religious holidays at

`https://www.stonybrook.edu/commcms/provost/faculty/handbook/employment/religious_holidays_policy`

Students are expected to notify the course professors by email of their intention to take time out for religious observance. This should be done as soon as possible but definitely before the end of the 'add/drop' period. At that time they can discuss with the instructor(s) how they will be able to make up the work covered.