OPTI/ASTR 416/516 Modern Astronomical Optics

Course Description:
This course provides an overview of astronomical optical systems. The perspective is primarily centered around astronomical and optical concepts related to exoplanet detection and characterization, currently a very active area of astronomical research. By focusing on a particularly challenging observational problem of modern astronomy, the course will teach design and analysis of high precision optical systems and measurement techniques for astronomy, including spectroscopy, photometry, optical metrology and interferometry, and adaptive optics. Design and fabrication of both ground-based and space-based astronomical observatories and instruments will be discussed.

The course consists of lectures and team projects. For each of the team projects during the semester, astronomy and optics students will work together to design a mission/telescope/instrument for astronomy using material presented during the lectures. Each team project will culminate in an oral presentation to the class by the team members.

Prerequisites:
None required.

Location and Times:
Times: Tuesday, Thursday 9:30 – 10:45
Place (physical): Optical Sciences (Meinel) 432
Place (virtual): https://arizona.zoom.us/j/86113225437
D2L site: https://d2l.arizona.edu/d2l/home/1390536

Instructors
Prof. Josh Eisner
Steward Observatory N414
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Will cover first half of course. Lectures will be given in-person, and simultaneously on zoom.
Office hours: by appointment

Prof. Olivier Guyon
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Will cover second half of course. Lectures will be given on zoom.
Office hours: by appointment

Expected Learning Outcomes:
Students will understand:
- The astronomical instrument design process from requirements to implementation.
- The fundamental challenges in detecting and characterizing faint sources and how they may be addressed.

- How a toolkit of basic optical techniques may be employed to address scientific questions in astronomy.
- The essential elements of accurate astrometry, photometry, and spectroscopy (where did the light come from, how much of it was there, and what color was it?) and the sources of uncertainty in these quantities.
- Develop expertise in oral presentation and communication of scientific and technical concepts.

Required Texts:
No required text.

Optional Texts for Additional Reading:

Astronomical Optics
http://ezproxy.library.arizona.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=209294

Exoplanets
http://ebookcentral.proquest.com/lib/uaz/detail.action?docID=3411728

Topic List

Course introduction: fundamentals of astronomical imaging systems
This part of the course introduces fundamental concepts of astronomy and optics which will be explored in more detail during the rest of the course. Connect astronomical science drivers to telescope and instrument requirements. Introduction to units used in astronomy and how they relate to radiometric quantities.
- Introduction to course
- Fundamentals of astronomical imaging systems: diffraction limit, photon noise

Fundamentals of telescope design
- First-order design: plate scale, field of view, pixel size, diffraction limit
- Telescope types: refractive, reflective
- Wide field of view designs and aberration correction
- Space and ground: cryogenic telescopes, design choices, challenges
- Measuring large optics
- Fabrication challenges and solutions: large optics fabrication, integrating optics and telescope structure

Optical systems for space-based scientific remote sensing
- Fundamentals of space-based imaging systems
- System engineering
- Project management

Spectrographs for astronomy

- Fundamentals of spectroscopy: science goals, prisms, gratings, spectral resolution, detector sampling, wavelength coverage
- Types of spectrograph: slit, multi-object, integral field unit (IFU)

Interferometry

- What does an interferometer measure?
- First-order design: angular resolution, wavelength
- Applications to stellar diameter measurement, exozodiacal dust detection, exoplanet detection, image synthesis
- Beam combination in interferometers
- Phase correction: delay lines and adaptive optics
- Interferometry in a single aperture: aperture masking, speckle interferometry

Adaptive optics

- Introduction to adaptive optics systems
- Atmospheric turbulence and its effect on image quality
- Wavefront sensing for adaptive optics
- Wavefront correction
- Laser guide stars
- Wide field of view correction: ground-layer, multi-conjugate and multi-object adaptive optics designs
- System design, control strategies

High contrast imaging, nulling interferometry and coronagraphy

- High contrast imaging science: exoplanets and disks
- Coronagraphs
- High contrast imaging systems
- Extreme adaptive optics systems

Team Projects

There will be three team projects, related to photometry, astrometry/interferometry, direct imaging/wavefront control. For each team project, teams of 3-4 people will design an optical system (full system, telescope, or instrument for a telescope). The result of this work will be presented to the class, and a short report compiled. The duration of each team project, from assignment to final report due date, is approximately 4 weeks.

Exams and Papers:

Final oral exam (50%)
Three team projects with oral presentations to the class (25%)
Homework assignments (25%)

Course Policies:

Grading Policy

Team Projects (3 assignments)	25%
Homework (5 assignments)	25%
Final Exam	50%
Total	100%

The grade will be determined according to the cumulative percentage earned such that 90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, below 60% = E.

Academic Integrity

According to the Arizona Code of Academic Integrity, "Integrity is expected of every student in all academic work. The guiding principle of academic integrity is that a student's submitted work must be the student's own." Unless otherwise noted by the instructor, work for all assignments in this course must be conducted independently by each student. Co-authored work of any kind is unacceptable. Misappropriation of exams before or after they are given will be considered academics misconduct. Misconduct of any kind will be prosecuted and may result in any or all of the following:

- Reduction of grade
- Failing grade
- Referral to the Dean of Students for consideration of additional penalty, i.e. notation on a student's transcript re. academic integrity violation, etc.

http://deanofstudents.arizona.edu/policies-and-codes/code-academic-integrity

Attendance Policy

It is important to attend all classes, as what is discussed in class is pertinent to adequate performance on assignments and exams. If you must be absent, it is your responsibility to obtain and review the information you missed. This is especially important in this course where a substantial amount of course material will emerge through class discussion.

"All holidays or special events observed by organized religions will be honored for those students who show affiliation with that particular religion. Absences pre-approved by the UA Dean of Students (or Dean's designee) will be honored."

Classroom Behavior

The Arizona Board of Regents' Student Code of Conduct, ABOR Policy 5-308, prohibits threats of physical harm to any member of the University community, including to one's self. See: http://policy.web.arizona.edu/threatening-behavior-students

Students with Disabilities

If a student is registered with the Disability Resource Center, he/she must submit appropriate documentation to the instructor if he/she is requesting reasonable accommodations. http://drc.arizona.edu/instructor/syllabus-statement.shtml

The information contained in this syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor.