OPTI/ASTR 428/528: Adaptive Optics and Imaging through Random Media
Effective Spring 2015

Course Description:

This course provides an overview of adaptive optics fundamentals. The course consists of lectures and team projects. For each of the three team projects during the semester, astronomy and optics students will work together to design an instrument, using material presented during the lectures. Each team projects will result in an oral presentation.

Pre-requisites:

None

Number of Units/ component:

3 units, lecture

Locations and Times:

TBD

Instructor Information:

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Expected Learning Outcomes: (Required to submit 3 learning outcomes)

- Students will understand the fundamentals of light propagation in random media, including Earth's atmosphere.
- Students will understand Wavefront sensing techniques, their strengths and limitations.
- Students will be able to design adaptive optics systems

Required Texts:

No Required Text. Students will be directed to readings for background material.

Topics and/or general calendar:

Part I: Propagation and imaging through random media

1. Wave propagation through random media from an intuitive and phenomenological perspective.
2. Atmospheric aberrations and scattering.
3. Scattering other contexts: Vision, biomedical, microscopy, radar, radio astronomy, acoustics, ultrasound, etc.
4. A statistical analysis of an imaging system with phase aberrations in the pupil plane. Motivation for various statistical moments and metrics. What happens if the aberrations are not in the pupil plane. PSF translation invariance.
5. The phase structure function and seeing. Scattering regimes. Difference between seeing and scintillation.
6. Turbulence theory and the optical implications.
7. The paraxial approximation and the Parabolic Wave Equation.
8. Numerical evaluation of the parabolic wave equation. Important scales.
9. Imaging through a thin turbulent layer at different distances. Scattering disk size, isoplanatic patch, etc.
10. Correcting for a distant turbulent layer with a phase screen in the pupil plane.
11. Propagation through extended turbulence. The importance of geometry and turbulence profile.
12. Split-step modeling of propagation through extended turbulence.
13. Split-step in the limit: the Feynman Path Integral. Constructing field moments.
14. Turbulence profiles and multi-conjugate correction.
15. Other WPRM problems: beam wander, image warping, scintillation, pulse propagation.

Part II: Adaptive Optics

16. Introduction to Adaptive Optics. The building blocks of an AO system.
17. Statistical imaging metrics: mean PSF, MTF, structure functions, Fried length, Strehl ratios, isoplanatic patch, coherence times.
18. A generic AO system. Basic requirements and implications.
19. Deformable mirrors and other wavefront-altering devices.
20. Wavefront sensors (cover multiple types, focus on Shack-Hartmann as main example).
21. Reconstructors and feedback servos.
22. Building an AO simulation.
23. Tuning and tricks.
24. A natural guide star (NGS) AO system.

25. Laser guide star (LGS) system. Sodium LGS and Rayleigh LGS. Range gating. Tomography.
26. Alternative optimization metrics: field of view, ground-layer AO, stable photometry, etc.
27. Multi-Conjugate AO. Tomographic WFS approaches and issues.
28. AO from different perspectives: horizontal, downward-looking, space-based, etc.
29. Enhancing the AO servo: tracking and prediction. Non-common-path errors. Woofer-tweeter architectures. Outer servo loops vs sequential loops. Extreme AO.
30. Retinal imaging with an AO fundus camera.
31. An Adaptive Optics Scanning Laser Ophthalmoscope (AOSLO).
32. Adaptive Optics Microscopy.
33. Related problems: Radio astronomy through the ionosphere; non-redundant masks; numerical AO for ultrasound, etc., laser communication, beam propagation.

Part III: Advanced Topic: Adaptive Optics for Exoplanets

34. Exoplanet science instroduction, observational challenges
35. Advanced wavefront sensing techniques
36. Controlling non-common-path aberrations, PSF calibration, speckle statistics.
37. High contrast imaging with coronagraphs

Number of Exams and Papers:

One exam (50%)- 1 hour oral exam.

Graduate students will be asked to solve problems using course material

Undergraduate students will be expected to describe their contributions to team projects in detail.

Three team projects/oral presentations (50%)

Course Policies:

Grading Policy

Team Projects (3)	50 %
Final Oral 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 (http://deanofstudents.arizona.edu/policies-and-codes/code-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.

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.