Modern Astronomical Optics – spring 2013

Instructors:

- ***Olivier Guyon** (UofA, Subaru Telescope, Jet Propulsion Laboratory)*
- *James Breckinridge (Caltech)*
- *Phil Hinz (UofA)*
- *Jim Burge (UofA)*
- *Hubert Martin (UofA)*

COURSE WEBSITE:

www.naoj.org/staff/guyon

→ Astronomical Optics 2013

Lectures from previous years (2011 & 2012) are available online:

- *2011: Astronomical Optics*
- *2012: Astronomical Optics – Exoplanets*

Contact :

email: oliv.guyon@naoj.org
phone: (818) 293 8826
UofA office: Steward Observatory, 4th floor

1. Course introduction, Fundamentals of astronomical imaging systems [Guyon, Breckinridge]

This part of the course serves as an introduction to the course, and introduces fundamental concepts of astronomy and optics which will be explored in more details during the rest of the course. Connect astronomy to telescope and instrument requirements. Introduction of units used for astronomy and how they relate to radiometric quantities.

Introduction to course
Fundamentals of astronomical imaging systems: diffraction limit, photon noise [Guyon/Breckinridge]

2. Optical systems for space-based scientific remote sensing [Breckinridge]

Fundamentals of space-based imaging systems
System engineering
Project management

3. Fundamentals of Telescope design [Guyon, Breckinridge, Burge, Martin]

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)

4. Spectrographs for Astronomy [Guyon, Hinz]

Fundamentals of spectroscopy: science goals, prisms, gratings, spectral resolution, detector sampling, wavelength coverage
Types of spectrographs: slit, multi-object, Integral Field Units (IFUs)

5. Interferometry [Guyon, Hinz]

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 in interferometers: delay lines and adaptive optics
Interferometry on a single aperture: aperture masking, speckle interferometry

6. Adaptive Optics [Guyon, Hinz]

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-objects adaptive optics
System design, control strategies

7. High Contrast Imaging (nulling interferometry & coronagraphy) [Guyon, Hinz]

High contrast imaging science: exoplanets and disks
Coronagraphs
High contrast imaging systems

Why Astronomical Optics ?

Astronomy relies heavily on observation of light emitted by distant objects with limited ability to perform experiments.

Proper physical understanding of astrophysical objects requires:
- sensitivity (distant objects are faint)
- angular resolution (distant = small apparent size)

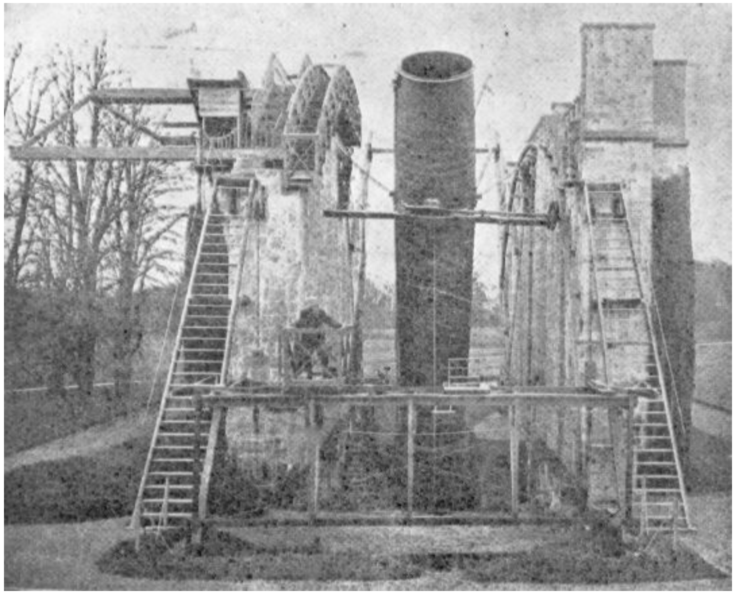
Astronomical instruments measure:
- flux (stellar pulsations, exoplanet transits)
- position (astrometry → masses)
- spectra (temperature, light emission process, chemical composition, velocimetry)
- polarization (magnetic fields, optical scattering of light)

Proxima Centauri – closest star, but still 4.2 lyr away


Galaxy cluster 4 billion light year away
(Hubble Space Telescope)

Astronomical Optics & technology

Astronomy relies on optics, and is largely driven by (and driving) technology advances in optics, with ripple effects in other fields



Lord Rosse's 1.8m telescope Completed in 1845, in the Irish countryside

The largest optical imaging systems are built for astronomy, but telescopes are also used for Earth sciences & defense

Advances in interferometry and adaptive optics are partially driven by astronomy, but are also used for medical imaging, defense, telecommunications etc...

Astronomical Optics

Solving astronomy problems requires new and more capable telescopes and instruments. In most fields in astronomy, advances in astronomical optics are (badly) required.

Very Large Telescope, Chile

Examples:

Characterizing exoplanets and finding life on other worlds is currently largely an astronomical optics challenge (need for large telescope + coronagraph + special adaptive optics)

Understanding origin and evolution of universe requires large telescopes, able to image distant (=old) galaxies

Astronomical Optics

Astronomy offers some of the most challenging (and fun) optical problems. Major advances in astronomy are often done by those who improve/solve optical challenges (ex: Galileo's improvement of the telescope).

Sharp understanding of optics enables astronomers to do ground-breaking new astronomical research:

- develop, build and use new optical concepts for astronomy

- understand how modern complex astronomical optical systems work to extract information

Astronomical Optics – course goals

Provide physical understanding of optics for astronomy, enable astronomy and optics students to understand what optics can do for astronomy. This course will provide an overview of current astronomical optics techniques, limits and capabilities. This knowledge is essential for astronomers:

- how can I solve my astronomy problem ?
- what type of instrument will allow me to measure xxxx ?
- can I build a telescope + instrument that can do xxxx ?

Optics students will find in this course many exiting optics challenges, some of them solved, others not (yet !).

Course will have **team projects**, where astronomy and optics students will work together to solve problems and **think hard about how to build telescopes/instruments for astronomy**.

The goal of the project is not to do a detailed optical design, but to get the overall physics right, and identify suitable approaches to solve problems.

Astronomical Optics – beyond lectures

Team projects (50% of grade)

At the end of a series of lectures, you will chose a project related to the course content (pick suggested project or come up with your own). You will have two weeks to work on it as a team, and then give a ~30mn presentation to instructor(s) and other students. Final report = slides from the presentation, usually modified to address issues raised during presentation.

Some advices:

- Don't wait until the last minute to start working on it. Ask me questions if you don't feel this is going well.
- Clearly identify roles in team (optical design, instrument scientist, etc...)
- Try to convince your audience that you should be trusted (funded) to do the project
- Have fun and play the game ! Don't be shy about asking though questions to other teams

Final oral exam (50% of grade)

“Think on your feet” about quick problems. You will be encouraged to use course concepts to figure out problems.

You may be asked questions about your work in the team projects.