**Syllabus: UHH ASTR 450 (F18): Astronomical Instrumentation**

**Prof. Klaus W. Hodapp**

This course is the final course in the 3-course series on optics and astronomical instrumentation offered at UHH. We will concentrate on detector technology and the design of astronomical instruments. The goal is for the students to develop an understanding of how astronomical technology has historically evolved and how today's most common instruments are being designed, constructed and operated. Students will develop a thorough understanding of the present state of the technology of astronomical instrumentation, so that they have the background to develop plans for new instruments, or to pass judgment on such plans when working on review or funding committees. For those who plan to specialize in instrumentation, the course will give a good foundation to start on this career path, but cannot possibly teach everything there is to know about instrument development.

Due to conference travel (the IAU General Assembly) and Labor Day, this course will start on 9/10. It will be held at the IfA building, in room 131, on Mondays, from 3:00 pm to 5:30 pm. The last class will be 12/3, and the written final exam will be on 12/10.

I am planning on 12 sessions of nominally 2.5 hours with a break.
This course is for three credits. Grades for this seminar will be assigned on the basis of homework assignments (60%) and the final exam (40%). Homework assignments will be typically rather broad and sometimes open-ended questions trying to simulate the type of reports or brief conceptual studies typically required from instrumentalists. Usually, there is not a unique correct answer. Rather, you will be expected to make your own assumptions about some or most of the input parameters, and justify your assumptions, just as you would in real life. I encourage you to communicate and collaborate with your fellow students about the homework assignments. I insist, however, that each of you write your own version of the assignment, even if you collaborated on it. There is a significant benefit in learning to write clear, well organized technical summaries. Simply signing other people's work does not convey this benefit. Completed homework assignments should be emailed to me and be time-stamped by the UH email system before the deadline, which is the start of the next class Monday at 3:00 pm.

The written final exam will consist of a small number of open questions, similar but not identical to homework assignments, and the answers are expected in the form of a few paragraphs of text and/or calculations with comments.

**Course Schedule in Fall 2018**

**ASTR-450-1 (9/10/2018)**
Introduction, schedule, homework policy, grading policy
Discussion of student interest and expectations

Classification of detectors:
Detector Types: coherent – incoherent
photon sensitive – thermal or bolometric
photo-emissive – semiconductor

Radio and Sub-mm Instrumentation:
Heterodyne receivers
Bolometer arrays
Transition-Edge detectors
Kinetic Induction Devices
Interferometry at radio and infrared wavelengths

Noise statistics : Read noise, background noise
Quantitative discussion of the human eye as an astronomical detector system
Evolution of detection systems
(catalogs, sketches, photography, electronic detectors)
Expansion of wavelength coverage over history

**ASTR-450-2 (9/17/2018)**

The silver-halide photographic process

The solid-state physics behind detectors:
The photoelectric effect – photocathodes
Isolators – semiconductors – metals
Electron and hole propagation, mobility, effective mass

PN junctions, diode, photodiodes, Field-effect-transistors
Typical amplifiers, source followers, operational amplifiers,
Negative feedback circuit, trans-impedance amplifier, charge integrating circuits
Detailed discussion of a simple PIN diode photometer

**ASTR-450-3 (9/24/2018)**
CCD:
History
Basic design, 3 phase and 4 phase,
CCD fabrication, signal sampling, noise sources, dual slope integration
binning, drift scan operation
Visit to CCD laboratory

Solid state physics of silicon
Quantum efficiency of CCDs
Improvements of quantum efficiency
Typical design of a data acquisition system
Data reduction procedures, Performance limits
Special CCDs: OTCCD, EMCCD
Detectors for X-rays and gamma-rays

**ASTR-450-4 (10/1/2018)**
IR Detector Arrays:
Basic design (hybrid technology)
Multiplexer designs and their historic evolution
Today's most common design (source follower)
Detector material choices, dark current, wavelengths, operating temperature

Operation:
- Signal sampling, multi-sampling
- Noise sources: white, 1/f
- Reference signals and reference pixels
- Typical design of a data acquisition system
- ASIC operation
- data reduction procedures
- calculation of detector system sensitivities

Photon counting systems
Far-Infrared photoconductors
Optical CMOS imagers

**ASTR-450-5 (10/8/2018)**
Practical work with CCD camera:
flatfield
simulated star photometry
data reduction (IRAF)

**ASTR-450-6 (10/15/2018)**
Instrument Design Overview:
Cameras (optical and IR)
Spectrographs (optical and IR)
Fiber-linked spectrographs
Integral-field spectrographs
Polarimeters with emphasis on the Savart plate polarimeter that we are using for lab work
Solar instrumentation
Vacuum technology
Thermal design of cryogenic instruments,
Cooler Technologies

**ASTR-450-7 (10/22/2018)**
Practical work with a vacuum system,
cooling of a cryogenic instrument
practical data acquisition with an infrared camera.

**ASTR-450-8 (10/29/2018)**
Practical experiments with the Savart plate polarizer,
to determine how to best implement this system on a small telescope like Hokukea.

**ASTR-450-9 (11/5/2018)**
Basic Optical Design (with Zemax demos):
- Lens forms, basic properties
- Optical aberrations
- Achromatic systems
- Example: designing a visual refractor
- Reflective telescope designs
  - Newton
  - Cassegrain
  - Ritchey Chretien
- Studying the optical properties of the Savart plate polarimeter

Practical work: optical testing of telescope mirrors

**ASTR-450-10 (11/19/2018)**
Mechanical Design:
Introduction to technical drafting

Introduction to computer aided design (CAD)
Practical work: design a mount for the polarimeter on Hokukea.

**ASTR-450-11 (11/26/2018)**
Visit to the machine shop, practical work on lathe and milling machines on some of the components of the polarimeter mount.

**ASTR-450-12 (12/3/2018)**
Instrumentation Project Management:

- Funding sources
- Grants vs. Contracts
- Project planning tools
- Cost estimates
- Project review
- IfA Instrumentation Division, Job order system
- Purchasing rules
- Legal issues such as International Traffic in Arms Regulations
- Instrument testing, acceptance testing
- Observatory integration and commissioning
- Maintenance
- Instrument upgrades

Practical experience with project planning tool.

**Final Exam (12/10/2018)**