NASSP OT1 Course: Outcomes

Observational Astronomy 1: Optical & Infrared Astronomy

– 2012 –

The outcomes are listed for the specific major topic areas:

- **Observing basics, coordinates and time**

The students should be able to demonstrate a conceptual understanding of astronomical coordinate systems, spherical trigonometry and time systems. They should understand the various factors that affect the measured position of a star, including precession, parallax, proper motion, aberration of starlight, and refractive effects of the Earth's atmosphere, and their relative importance.

- **Telescopes and optics**

Knowledge about basic optical principles, including aberration theory and telescope design, is one outcome of this course. Students should gain a basic conceptual understanding of how to describe aberrations and understand why Seidel and Zernike polynomials are used to describe them. Students should be able to describe the major components of a telescope, including the mirror support system, alternative types of mounts and enclosures, and they should appreciate factors which can affect image quality. An understanding of modern methods for fabricating mirrors and the various ways for supporting mirrors, particularly using active optics systems, should be gained. There should also be a good understanding of the effects of the Earth's atmosphere, and specifically the principle of Kolmogorov turbulence theory and how its effects image quality. The definitions of the Point Spread Function (PSF) and the Optical and Modulation Transfer Functions (OTF & MTF) should be known, and how they are modified by wave-front perturbations. Similarly, the principle of the Shack-Hartmann wave-front sensor and its use should be able to be described. Student should also understand how adaptive optics (AO) works and describe how and why it is implemented. The meaning and functional dependence of some of the atmospheric parameters (Fried's seeing parameter; isoplanatic patch; Greenwood frequency) should be known, and the definition of Strehl ratio and its effect on OTF/MTF curves. Students should appreciate how modern telescope design has evolved and be familiar with examples of the latest large telescopes, particularly SALT and how its design differs from conventional telescopes.

- **Detectors**

Students should have an understanding of how the detection of light has advanced and what influence it has had on observational astronomy. An understanding of the principles and importance of astrophotography should be gained. The discovery of the photoelectric effect and the consequent development of photon counting detectors should be understood, as well as the observational principles and practice.

Knowledge of the principles of semi-conductors should be gained, and particularly how they are important for detecting light. The students should be able describe the basic principles of a p-n junction and how this is relevant in the development of Charge Coupled Devices (CCDs). The concepts of depletion regions, charge carriers, electron-hole pairs, should all be understood in the context of CCDs.

An understanding of how CCDs are read out should be gained by clocking electrode voltages should be gained, particularly the principle of the three-phase CCD. Some of the issues affected efficiency of light detection in CCDs should also be understood, as well as the various methods employed to improve this, like thinning, back illuminating and employing high resistivity silicon in deep depletion devices. Students should be able to describe the various practical issues involved in reducing CCD observations, including listing the various causes and effects of cosmetic defects that can arise and how they are dealt with. An understanding of the signal-to-noise equation should be gained, and how it is modified for different observing regimes. Finally, the importance of frame transfer and electron multiplication CCDs for time resolved observations should be understood, and knowledge of how they operate.

- **Photometry**

The students should understand how stellar magnitudes are defined and measured and how corrections are applied for atmospheric extinction. Definitions of colours and bolometric corrections should be understood, as well as knowledge of the various photometric systems and what they are capable of measuring. There should be an understanding of the processes involved in undertaking photometric observations and how such data is reduced and transformed to a standard photometric system.

The principles of differential photometry should be understood and why it is advantageous, particularly for SALT. Analysis of photometric time series using Fourier techniques to search for periodic signals should be understood, including the interpretation of periodograms (power and amplitude spectra) to search for multiple periodicities, harmonics and aliases.

- **Spectroscopy Principles**

The students should know the definition of a black body, its effective temperature and colour temperature, and understand the significance of the Stefan-Boltzmann law. How spectroscopy is done using dispersive techniques with prisms should be known, as well as the impact of objective prism spectroscopy on astronomy. The principles of diffraction and the use of gratings and grisms should be understood and how to define and apply the grating equation. Students should also know the definition of the grating blaze angle and the Littrow condition. The importance of high blaze angle échelle gratings for high dispersion spectroscopy should be understood. Knowledge of how Volume Phase Holographic gratings (VPHGs) work, the principles of Bragg diffraction and the ability of "tuning" such gratings should be gained. The principle of the multiplex VPHG should also be understood.

- **The Virtual Observatory**

Students should understand the potential of the VO and become familiar with various VO tools for collecting, combining and cross-matching data from a wide range of observations and data archives on astronomical sources. They should be able to use VO tools to analyze specific science objectives.

- **Near Infrared Techniques**

Students should be able to explain:

1. Why observing in the IR is more difficult than in the visual;
2. What can be done to make IR observing possible or easier;
3. Why you would want to observe particular types of object at IR wavelengths and what you might get out of such observations.
4. The operational principles and practice of a modern IR array detector.

- **Polarimetry**

The students should understand why light from astronomical sources is often polarized and how that polarization (linear and circular) can be measured and interpreted physically. The definition of the Stokes parameters should be known, and how these are manipulated to derive both linear and circular polarization. They should also know about the operational principles of various polarimeters in use at SAAO, including SALT.

- **Practical Astronomical Data Reduction**

The students will be exposed to the practicalities of data reduction and should understand the following:

1. types of observations, methods and resources available
2. the standard FITS data format

3. issues relating to CCD data reductions and the tools needed for this
4. errors and signal-to-noise (S/N) calculations
5. photometry methods (aperture, curve of growth) and calibrations
6. astrometry and source detection
7. familiarity with using the IRAF data reduction package

- **The Southern African Large Telescope**

The design and operational principles of SALT should be understood, particularly in regard to its advantages and disadvantages compared to other similar sized telescopes. Students should be able to contextualize the choice of scientific instrumentation on SALT and have a basic understanding of the designs and operational modes of the first generation instruments. They should also know how observations are taken and the overall data flow path, including data processing steps.