NASSP Course Template

Course Title: Observational Techniques 1: Optical and Infrared Astronomy
Course Lecturer: Dr Rudi Kuhn (SAAO/SALT) / Dr. Yusuke Tampo (SAAO)
Course credits: 1
Lecturer contact hours: 24
Tutorial/practical hours: 6

1) Course overview:
The aim of this course, which comprises nominally of 24 lectures plus associated hands-on exercises and projects, is to give a general introduction to optical and infrared observational astronomy, emphasising the instrumentation and techniques used. This includes discussion of basic telescope optics and design, active and adaptive optics, techniques for light detection and the principles and practices employed in photometry and spectroscopy. Illustrated examples are given of the different types of science achieved by various astronomical instruments and techniques. The practicalities of planning and conducting observations, as well as the reduction of astronomical data and data reduction software are also introduced in the course. Ethics surrounding aspects such as telescope time and publications are also covered. Particular emphasis is given to get practical experience on data reduction and analysis through various laboratory sessions.

2) Course breakdown/syllabus:

- *Observing basics*

Astronomical coordinate systems; spherical trigonometry; precession & nutation; parallax; proper motions; stellar aberration; atmospheric diffraction and dispersion; time systems.

- *Telescopes*

Basic optics; aberration theory; telescope parameters and configurations; telescope lenses, mirrors, tubes, mounts, domes and enclosures; mirror coatings; active and adaptive optics (A-O); optical nature of the Earth's atmosphere, science with AO; modern large telescopes

- *SALT*

The Southern African Large Telescope (SALT). Telescope design; current instruments; data products; future instruments.

- *Detectors*

The human eye; the magnitude scale; photographic techniques; photoelectric effect; photomultiplier tubes; image tubes; microchannel plates; semi-conductor basics; CCD principles; CCD design and operation; noise sources and signal to noise equation; cosmetic defects; practicalities of CCD data reductions; demonstration of CCD operation.

- *Photometry*

Absolute and bolometric magnitudes; colour index; blackbodies; filters and photometric systems; spectral energy distributions; two-colour diagrams; dust extinction and reddening; line blanketing; colour-magnitude (C-M) diagrams; atmospheric extinction, absorption and emission; reducing photometric data; differential photometry;

- *Spectroscopy*

Early history; dispersion and prisms; objective prism spectroscopy; diffraction gratings, the grating equation and grating parameters; échelle gratings; grisms; volume phase holographic gratings (VPHGs); spectrometer design, collimators and cameras; spectrograph examples including the SALT RSS; slit effects; CCD gain and digitization; signal to noise calculations; sky background.

- *Infrared astronomy*

History; sources of IR emission; IR detectors; IR observatories and instruments

- *Virtual Observatory*

Multi-wavelength astronomy; Hanny and the Voorwerp; online data libraries; the virtual observatory; VO standards and protocols; VO data services and tools

- *Computing*

Linux and the command line; bash scripting; ds9; fitsview; command line text editors; plotting tools; fitting tools; managing data; SQL and databases.

- *Applying for telescope time*

Overview of how to apply for telescope time. How to write and plan good proposals. Time allocation committees. Ethics surrounding publications and telescope time. Conflicts of interest. Plagiarism.

- *Photometric Data Reductions*

Photometric reduction methods and calibrations; astrometry and source detection; the AstroImageJ data reduction package. Practical exercises in reducing real data. Fitting transit models to the extracted lightcurves to get planetary parameters.

- *Spectroscopic Data Reductions*

Spectroscopic reduction overview; data reduction methods; Wavelength and flux calibrations; the IRAF data reduction package. Practical exercises in reducing real data.

- *Machine Learning in Astronomy*

What is machine learning; when to use machine learning; Supervised learning; Unsupervised learning; Reinforcement learning; labelled and unlabelled data; features and targets; evaluating machine learning algorithms; common problems in machine learning; machine learning algorithms; machine learning in astronomy.

3) Resources:

Lecture slides will be provided that draw upon a variety of resources including textbooks and online material. There is no prescribed textbook, but useful textbooks may include Foundations of Astronomy (Seeds & Backman), An Introduction to Modern Astrophysics (Carroll & Ostlie) and Introductory Astronomy & Astrophysics (Zelik & Gregory)

4) Breakdown of practicals/tutorials:

The lab sessions will cover photometric and spectroscopic data reduction. Real data from international facilities will be provided for students to process and analyse.

5) Additional skills to be developed during the course:

How to write a good telescope time proposal; Manipulation of text data; basic usage of the AstroImageJ package for reduction of astronomical data; displaying and manipulating FITS data.

6) Assessment

The course will be assessed by 3 assignments each counting 15% of the final grade, a photometric data reduction practical counting 10%, a spectroscopic data reduction practical counting 10% of the final grade and a final exam making up the last 35% of the final course marks.