ASTRO 500
University of Wisconsin-Madison
Professor Matthew Bershady

COURSE OUTLINE / FALL 2022

[] = # of lectures: lecture #'s
{} = reading assignments (chapters)
M = McLean
W = Walker
S = Schroeder
K = Kitchin
G = Gray

1. Course Overview [3 lectures: 1-3] {M 1.1-12, 2.1-2.3, 4, 9.6; W 1, 2, Ap.B; S 17}

Properties of light and light collection
Foregrounds and backgrounds
Large telescopes - overview

Flux, magnitudes, surface-brightness
Magnitude systems and zeropoints

Statistics of distributions (mean, mode, median, & higher moments)
Noise: distribution shape, sources
Errors: random vs systematic; precision vs accuracy;
error propogation; logarithmic derivatives

2. Digital detectors - CCDs and IR Arrays [2 lectures: 4-5]
{M 1.3-1.9, 5.1, 5.5, 7-9, 11; W 8; handout}

How they work and why they are needed

Properties: QE, gain, read-noise, non-linearity, CTE,
dark-current, diffusion, fill-factor
Photon propagation technique

S/N calculation and regimes

3. Telescopes and Optics [4 lectures: 6-9] {M 3, 6.1-6.3; W 2, 3; S 2, 4, 6-9}

Simple optics
Optical telescope designs

Pupils and the field lens
Lens design
Optical aberrations

WIYN
SALT

4. Imaging & Observing [2 lectures: 10,11] {M 4.1, 5.1, 7, 9, 11.6-11.7}

Direct imaging
Shutters

SALTICAM, RSS, ODI

Drift-scanning
Filters & characterization

Observing
- Coordinates, catalogues, resources, proposals
- Before observing (targets, airmass, exposures)
- Instrument setup (configuration, focus, calibration)
- At night (focus, conditions)

Image processing
Overscan correction
Bias correction
Dark current correction
Field-flattening
Frame-combination
S/N optimization

Imaging analysis: Detection & Photometry
Quick look: imexamine
Source detection
Sky estimation
Centering
Aperture photometry
Curve of growth
Photometric calibration
Stellar vs extended source methods
Stellar photometry: profile-fitting / DAOphot
Surface photometry:
- Extended-source photometry: challenges
- Isophotes
- Profile decomposition and the Sersic fcn.
- Star-galaxy decomposition
- Moments, eta, and total magnitudes
- Source Extractor

MIDTERM-1

5.-6. Spectroscopy I-II: Grating-dispersed spectrographs & analysis
[9 lectures: 12-20]
{M 4.2, 5.2, 6; W 5; S 12, 13, 15; K 4; G 3, 12; handout}

Basic design and concepts
o Demagnification
o Anamorphism
o Spectral resolution
Grating: types, properties, efficiencies

Dichroics and double spectrographs
Throughput issues

Fibers and fiber-fed spectrographs

Grating-dispersed spectrograph types:
o Spectrometers
o Long-slit spectrographs
o Multi-object spectrographs (slits vs fibers)
o Echelle spectrographs

Specific examples in detail:
o WIYN/Bench
o SALT/RSS

Notes about observing:
o spectroscopic observing considerations
o S/N for spectroscopic observations
Atmospheric dispersion
Quick-look: splot
Basic processing (bias, flats)
Wavelength calibration
Sky subtraction
Flux calibration
Echelle format

Line-strengths and equivalent widths
Velocimetry and cross-correlation

7. Spectroscopy-III: Interferometry [1 lecture: 21] {M 5.4; W 5; S 13; K 4; G 2, 12; handout}

Fabry-Perot spectroscopy
o imaging
o spectral (WHAM)

Fourier-Transform spectroscopy
Spatial-Heterodyne spectroscopy

8. 3D Spectroscopy: Challenges & Current instruments [3 lectures: 22-24] {handout}

Fundamental considerations for sampling the data cube
Figures of merit
The detector limit-I: three into two dimensions
The detector limit-II: read-noise

Approaches and examples of available instruments
o Grating-dispersed spectrographs
o Interferometers

Existing instruments, sorted by parameter sampling
o Summary of sampled parameter space

Examples of data and science product:
o Extra-galactic science at high-spectral resolution and low surface-brightness.

Future 3D instruments [1 lecture: 30] {M 14; handout}

Ground-based instruments on 10m telescopes
Ground-based instruments on 30-100m telescopes:
o AO-driven designs
o Specific examples of TMT and ELT instrumentation
Space-based instruments: JWST
o Foregrounds revisted
o Planned instruments
Unexplored options: some examples

MIDTERM-2