ASTR 535

Observational Techniques

Fall 2023

Observing principles and tools

Topics 9/12

- Questions
- Exposure time calculator
- New module : observing concepts and tools
  - APO observing trip schedule : Fri-Sun 10/20B, 10/21B, 10/22A
    - 4th quarter NMSU programs
  - Time systems
  - Coordinate systems
  - Observability

Coordinate systems and time

- Time
  - Solar and sidereal time
- Coordinates
  - right ascension / declination
  - hour angle / declination
  - az / alt
  - airmass

What time is it?

- Local legal time?
- Universal time (UT)?
- Sidereal time?

- If you were observing right now, what would be the optimal right ascension?

Observability

- What do you need to know to determine if/when an object will be observable?
- How long will it be observable?

$$HA = LST - RA$$

- How high will it get?

at HA=0, zenith distance = |Dec – latitude}

- Airmass : how is airmass related to zenith distance?

$$X \sim \sec(Z)$$

Observability tools

- From John Thorstensen, Dartmouth:
  - skycalendar / skycalc : C programs, text output
  - JSkyCalc : Java, graphical output
    - Installation and demo : seasonal observability, nightly almanac, hourly circumstances, airmass graphs, object lists
- astroplan : astropy-affiliated package
  - Various tools, graphical output
  - Note: interface implemented in pyvista
- Airmass.org

Observability

See Canvas assignment

Topics 9/14

- Questions
- Summing and averaging measurements
- Observation planning
- TMO observing : Mon/Tues/Wed evenings next week?
- Exposure time calculator
- Telescope use and planning
- Digital images and image display

Summing and averaging

- Weighted averaging of different measurements
- Expected scatter vs observed scatter

Observation planning

- Sidereal time and right ascension
  - (mean) Sun is always on the meridian at noon (modulo daylight savings)
  - Sidereal clock runs just a tiny bit faster than solar clock, so in a given day, one hour of solar time is almost the same as one hour of sidereal time
  - On vernal equinox, Sun is at RA=0hr, by definition. So 0hr crosses meridian at noon, hence 1h crosses at 13:00, 2h at 14:00, …. 12h at midnight
  - The 4 minutes per day difference between sidereal and solar adds up: after 15 days it amounts to 1 hour, after 30 days, 2 hrs, etc.
  - So each month after the vernal equinox, the RA of the Sun increases by 2 hours: so on April 21, Sun is at RA=2h (and 14h crosses meridian at midnight),on May 21, Sun is at RA=4h (and 16h crosses meridian at midnight), etc. etc….

Image display

- See Canvas assignment

9/18 (Monday night)

- TMO demo/training

9/21

- Questions
- Next week
- TMO observing
- Working with digital images
  - File formats
  - Calculating expected noise
  - Basic data reduction
- TMO data inspection

TMO observing planning

The initial TMO observing project will be:

- Determine the instrumental zeropoints for TMO for the 5 Sloan filters (SU, SG, SR, SI, SZ)
- Estimate the combined throughput of telescope, optics, and detector for each filter

TMO project observing resources

- For photometric zeropoints, want stars with known magnitudes
  - If we wanted to get more subtle, would include stars with a range of colors to see if there are color-dependent zeropoints, i.e. transformation terms
- Traditionally, e.g., UBVRI used fields with relatively bright (V~-10-12) standard stars, e.g. Landolt fields http://articles.adsabs.harvard.edu//full/1992AJ....104..340L/0000340.000.html
  - Note Selected Areas
- For SDSS, the actual photometric system is defined by the SDSS observations themselves
  - These are saturated for bright stars!
  - A u'g'r'i'z' system was set up which is close, but not identical to SDSS. These used the same Landolt fields, Smith et al 2002, see table 7. It will suffice for our use!
  - For finding charts, see Landolt paper
    - Smaller fields: http://james.as.arizona.edu/~psmith/61inch/ATLAS/tableA.html
  - Choose fields based on LST at observation time
  - What do you expect for exposure times?
- For throughput, want spectrophotometric standard, e.g. from http://www.eso.org/sci/observing/tools/standards/spectra.html

TMO observing

- See astronomy.nmsu.edu/tmo-wiki, esp TMO Users guide HowTo
- Get a VNC client to connect to desktop
- Alternatively/additionally, go to http://tmo.nmsu.edu for web based control

TMO observing resources

- General observing procedure:
  - Connect to TMO desktop by VNC to tmo.nmsu.edu or to web interface (tmo.nmsu.edu)
  - Open dome
  - Focus
  - Slew to star(s)
  - Take exposures
  - Take calibration frames: darks (match exposure times) and twilight flats
- Data will be automatically synced to astronomy.nmsu.edu
  - In the morning, link in /home/tmo/YYYYMMDD (also accessible via web http://astronomy.nmsu.edu/tmo/YYYYMMDD (note day number is UT date)
  - More quickly, in /home/tmo/Observations/YYYY-MM-DD if taken directly with MaximDL (but note day number is local date)

TMO analysis

- Looking at images
- Image analysis
  - Image size measurements
  - Basic photometry

pyvista

- Demo
  - imred module
    - Reducer object
    - log()
    - rd()
  - tv module
    - TV object
    - tv()
    - imexam()
  - Stars
    - mark()
    - photom()

pyvista

- Documentation
- Installation
  - Create conda environment
  - pip install astro-pyvista
- Running
  - ipython –pylab
  - Jupyter notebook : %matplotlib qt

Topics 9/26

- TMO status and observing
- Exposure time calculator
- Next module: effects of the Earth's atmosphere
- Midterm : week of October 10
- Looking at TMO data
  - Basic image reading, e..g., pyvista imred.Reducer(), rd() and reduce() methods
  - Basic image display, e.g.,, pyvista TV tool, tv() method
  - Measuring image sizes, e.g. imexam() method of TV tool
  - Basic stellar photometry, e.g. stars.mark(), stars.photom()
  - Determining gain from flats
  - Determining readout noise from biases

Image inspection

- While you may be using pyvista, important to recognize the (relatively simple!) things that are being done
- Instantiating a Reducer : sets up parameters for a detector
- reduce() : without other arguments, calculates mean overscan level and subtracts it from image. Calculates expected uncertainty in array
- TV.imexam() : fits a 2D gaussian to points around cursor
- Stars.photom() : simple aperture photometry

Measuring gain and readout noise

- Basic idea: uncertainty (noise) in counts depends on the gain, so measure the noise and determine gain, under the assumption of Poisson statistics (so measure at high level, where readout noise is negligible)
- How to measure noise: use flat field, but can't just look at variation in a region, because there might be real sensitivity variations
  - Take the difference between two flats
  - Calculate standard deviation in region of ~constant intensity

    $G = 2 <C> / \sigma^2$
- For readout noise, look at bias frames (C=0) and measure noise in counts in a similar way, convert to noise in electrons using gain

Exercises

- See Image Inspection II in Canvas

Topic 9/28

- TMO Status
- Questions
- Effects of the Earth’s atmosphere
- Atmospheric (and other “background”) emission

- Sky model calculator
- Exposure time calculator
- Image inspection II
    - Light transfer curve

- Canvas : sky emission and exposure time calculator
- Canvas : image inspection II