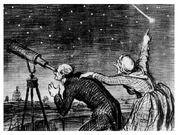
Ay 122:
Practical Observing Skills
(Visible/IR)



(Many slides today c/o M. Bolte)

So, You Want Some Data?

- First, have a clear idea what are the questions you want answered, and what kind of data are needed
  - Do you need collaborators? Form/join a team?
- Do the adequate data already exist?
  - In archives (surveys, space missions, etc.)
  - Someone else got them, and might want to share
- If not, where can you get the data?
  - Which observatories, where you can get time?
  - When are the proposal deadlines?
- What is it that you can do (much) better than what was already done?

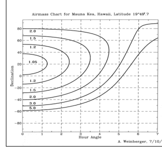
Writing Proposals

- First and foremost: **Scientific Justification!**
  - Give context
  - Clearly state what unanswered questions are to be addressed
  - Clearly state what you will do new or better
- Look competent and smart, be confident
  - Do S/N and exposure time calculations
  - Justify the choice of filters/spectral resolution, sample size etc.
- Get to be on the TAC, or have some friends on it!
- Try, try again …

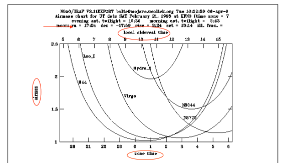
Observing

- **Rule #1 -- keep collecting photons!**
  - Have a good backup program ready, in case of imperfect conditions
- Know your S/N targets; don't overspend the precious observing time
- Plan the night out carefully ahead of time:
  - Which target at which LST/HA, how long, …
  - Make the finding charts and compute offsets if needed
- Useful tools:
  - Instrument website
  - Calendar tools
  - Airmass charts
  - Parallactic angle chart for spectroscopy
  - Weather websites

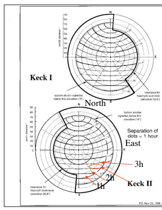
Hour Angles and Airmass



- The *local sidereal time* (LST) gives the RA that is passing through the meridian. RA = 12h is overhead at midnight on March 21, and advances 2 hours per month.
- The *hour angle* (HA) is the time before or after a particular RA is at the meridian. HA=LST-RA
- *Airmass* is a combination of the HA and the difference between the telescope latitude and the pointing declination. Airmass ~ sec(zenith angle)



- IRAF Airchart in the mtools packages is very handy.
- Typically observe with airmass <2
- Atmospheric dispersion can be a problem for airmass >1.5

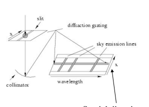


There are often other limits that govern where you can point in the sky.

Decisions before observing

- Sometimes, the gain in e-/DN for the system
- On-chip binning?
  - Smaller files (not important)
  - Faster readout time (can be important)
  - Less readout noise per area detector (can be important)
- For direct imaging in broadband filters, readnoise is very rarely an issue. You want to have the FWHM of point sources to be at least 2.5 pixels to properly sample the PSF. If you are oversampled, that doesn't usually have any dire consequences. The readout time can be a deciding factor.

Binning for spectra



•Sometimes, RN is a significant component of the noise. Having fewer pixels under the spectrum reduces the noise in a resolution element.

•Binning in *Spectral* direction can reduce resolution

•Binning in the spatial direction can compromise fitting the sky lines

Observing Checklist: Afternoon

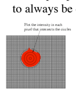
- Bias frames - should be boring! WWW site for instrument should have an example to compare to.
  - Move filterwheels, gratings, telescope, dome during readout to see if it will be safe to do so during the night
- Dome Flats
  - Is the shutter opening?
  - Shutter timing observations
- For spectra, check the grating tilts for proper wavelength range
- Things are working- take flats, arcs, biases, darks
- Get quick-look reduction procedures in place

At Night

- Efficiency is everything!
  - Have the shutter open
  - Know your S/N goals
  - Have targets queued up
  - Check focus
  - Have the shutter open
- Be looking at your data in near real time including flat-fielding and bias subtraction

Telescope Focus

- Whether you focus yourself or the telescope operator does it for you, you need to always be checking *radial profiles*.



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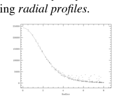
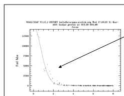
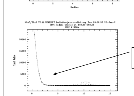


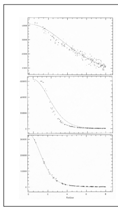


Poor focus (scatter is lack of roundness and probably astigmatism)

- Using the ``r'' command in IRAF's *imexam*, you can produce radial profiles for any object in a frame. :.snap eps in the graphics window will output an .eps file.



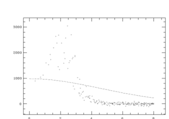
Excellent focus. Very round (and dangerously sharp) image



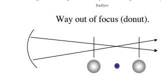
Galaxy

Saturated star

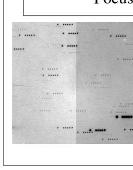
Well focussed star



Way out of focus (donut).



Focus frames



1. Set focus, start exposure.
2. Pause exposure, move telescope, change focus
3. Repeat
4. Make a double telescope move on the last focus value, then read out

Splitting Exposures

- How long to expose? Once in the sky-limited regime, the S/N only depends on the total exposure time. There is only the CCD readout time penalty to be paid by splitting long exposures into multiple shorter exposure.
- Why do shorter exposures?
  - Cosmic ray rejection
  - Increase dynamic range
  - ``in-field dithering'' along slit or on the sky can help with flat fielding
  - Reduce risk

Preliminary Processing

- There are two types of instrumental signature to remove:
  - Additive:
    - Bias Level
    - Bias Structure
    - Dark Counts
    - ``charge skimming''

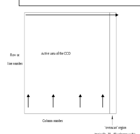
    Constant # of counts added independent of the brightness of the source(s).
  - Multiplicative:
    - Q.E. variations on all scales

    Constant *fractional* effect

Bias Correction

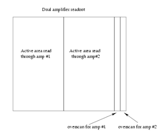
- Bias level and any y (along columns) gradient is taken out via *overscan* subtraction.
- Bias structure is taken out by subtracting a *zero-level* frame.
- In IRAF *ccdproc* takes care of both.

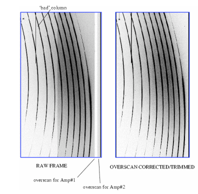
Overscan



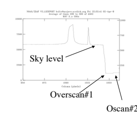
After reading out the CCD `real' pixels, you can continue to read out virtual pixels and record the bias level and read noise of the amplifiers. These virtual pixels are called the overscan region

Two amplifier overscan





Overscan subtraction



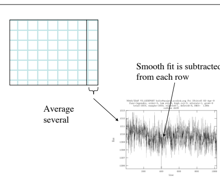
- First you need to identify the relevant columns.
- In IRAF use the format:

  [x1,x2:y1,y2]

In IRAF, plots like this are made using *implot*

Colbias

- The overscan subtraction is accomplished by fitting a smooth function to the average of several columns in the overscan region.
- The value of the fitted curve is subtracted from each row. This accounts for a mean bias level and any gradient in along columns.



Flat Fielding

- There are pixel-to-pixel QE variations and lower spatial frequency QE variations in all electronic detectors. The goal of flat-fielding is to multiply every pixel by the correct normalizing factor to eliminate these QE differences.
- Ideally, illuminate the detector with a source that is as flat on the sky as the background and collect at least a million e- per pixel. Then could flat-field to $\frac{\sqrt{10^6}}{10^6} = 0.001$ =0.1%.

Flat Fielding

- If you could illuminate the CCD uniformly, then normalize the mean to 1, this image could be divided into every frame.
- For direct imaging, usually use a combination of:
  - Dome Flats
  - Twilight Flats
  - Dark Sky Flats

Dome Flats

- Put some quartz (hot, continuum source) lamps on the telescope and illuminate a white screen or spot on the dome.
- These often don't work very well for two reasons:
  - The lamps are always too cool (red)
  - The dome is not even close to infinity and usually illuminates the primary differently than the sky
- But, you can collect a lot of photons during the day

Twilight Flats

- These often work pretty well
- The Sun is pretty hot, the scattering surface illuminates the telescope just like the dark night sky
- Doesn't use dark time

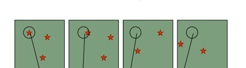
Dark-sky Flats

- These tend to work very well. They match the sky perfectly
- They sometimes require useful dark time
- They sometimes contain fringes

Stars and Galaxies

- For twilight and dark sky flats you have a problem in that they contain stars and galaxies. The usual trick is to move the telescope between exposures and then do a non-registered stack of the frames in each filter.
- Median or better yet *minmax* rejection (for example, in the frame combining can effectively eliminate all the stars and galaxies in the combined flat.

Minmax rejection



Pixel value: 1000 200 180 180

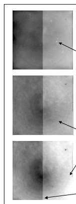
Average with minmax rejection, reject 2 highest value averaging lowest two will give the sky value. NOTE! Must normalize frames to common mean or mode before combining! Sometimes it is necessary to pre-clean the frames before combining.

Combining Frames

- In IRAF, *imcombine* is the task to combine frames.
  - combine=average
  - reject=minmax
  - scale=mode
  - nlow=0
  - nhigh=2

Flat fielding tricks

- Combine domes (high counts, bad illumination) with dark sky flats (low counts, excellent illumination).
  1. Spatially smooth (or fit low-order surface to) both combined dome and combined dark sky. > sDome, sDark
  2. Remove dome low-spatial-frequency pattern: Dome/sDome
  3. sDark is the sky flat with the low-f pattern already removed.
  4. Best of both worlds is (Dome/sDome) x sDark



I-band

PFCam flat fields

Dust on filter

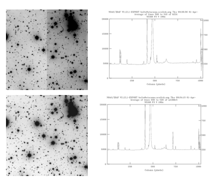
V-band

Note differences with color. This means that objects with different spectra will be flat-fielded slightly incorrectly.

Rings due to non uniform thinning

U-band

Two amplifer readout



Flat-field tests

1. Take cuts through your flat-fielded frames and make sure the sky is flat (check corners). IRAF *implot*
2. In blank areas, make sure the pixel-to-pixel variations are consistent with shot noise from the sky level. IRAF *imexam* and the `m' key.

After the Run:

- Make sure you have the data (+ at least 1 extra copy) safely backed up; probably on a DVD
- Figure out what data reduction package(s) to use
  - IRAF is very common and freely available, but can be awkward and "blackboxy"
  - IDL is also very popular
  - Many special purpose packages (e.g., DAOPhot, MAKEE, SEXtractor, …)
- Do you need to learn some new expertise, or find a collaborator who does?
- Reduce, analyse, and publish in a timely fashion!

Now Let's Look at Some of Those Observing Tools …

Start with

http://www.astro.caltech.edu/~george/links_observing.html