1 Writing Proposals

You need to get good at this. The two most important sections of a proposal are the introduction and the technical justification. In the introduction you clearly state what the question is that you plan to answer and tell the TAC why anyone else wants to have the answer. In the technical justification you need to convince the TAC that you know what you are doing and that the proposed observations will be sufficient to get the job done. Make S/N calculations and determine exposure times, know what S/N you need, show that you have the reduction pipeline figured out ahead of time. Make sure you address all the obvious questions like what spectral resolution you need and which grating/slit combination(s) give you the resolution/wavelength coverage you want. Do you need order blocking filters? If you have examples of the data you are proposing to take, show them to demonstrate competence.

2 Observing

2.1 Planning a run

There are some questions you will have to have answers to when you arrive at a telescope. For direct imaging, you will have to have sent in a filter list, for taking spectra you will have chosen one or more diffraction gratings. For either case, you may have a choice of the "gain" setting for the CCD (the number of photo-electrons per ADU). You may also have to make a decision about binning the CCD.

You will want to have a list of all the calibration data you could possibly need: biases, darks, flat-fields, and arc spectra. The flat-fields in particular are crucial for almost all data. Take no chances that you will come up short with calibration exposures – it is usually too late after the run to go back and get more.

You also want to plan out your observations blocked out in 15 or 20 minute increments. With your exposure time estimates and knowledge of the instrument overheads (CCD readout, time to move various things in cameras and spectrographs) it is possible to plan out the a night pretty well. At the Lick or Keck WWW sites (http://www.ucolick.org/ npm/calendar.html) there are observing calendars with the times of sunset, sunrise, moonset and moonrise, astronomical twilights and the RA of the zenith at a few points during the night. When the Sun is 6° below the horizon this is called civil twilight and the sky is still pretty bright. When the Sun is 12° below the horizon this is "nautical" twilight and 18° twilight is "astronomical" twilight. You can start to get serious about observing at nautical twilight.
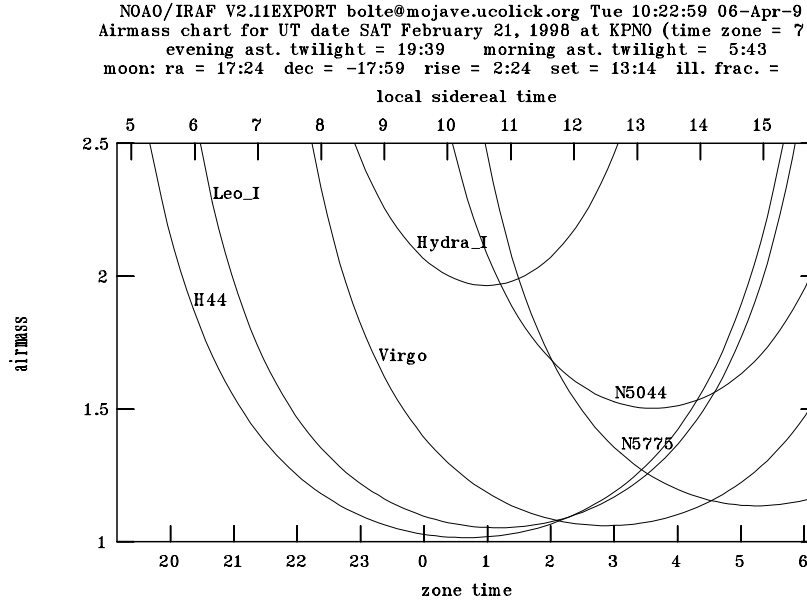
KECK OBSERVATORY CALENDAR FOR 1999

DATE(HST) 1999	SUN SET	TWILIGHT ENDS 12	TWILIGHT ENDS 18	MOON RISE	MOON SET	DAWN BEGINS 18	DAWN BEGINS 12	SUN RISE	SIDEREAL TIMES TWI	SIDEREAL TIMES MID	SIDEREAL TIMES DAWN
SAT MAY 01	18 55	19 35	20 03	19 48	07 43	04 35	05 03	05 42	09 52	14 18	19 21
SUN MAY 02	18 56	19 35	20 03	20 38		04 34	05 02	05 42	09 56	14 22	19 24
MON MAY 03	18 56	19 36	20 04	21 27		04 34	05 01	05 41	10 01	14 26	19 27
TUE MAY 04	18 56	19 36	20 04	22 17		04 33	05 01	05 41	10 05	14 29	19 31
WED MAY 05	18 57	19 37	20 05	23 05		04 32	05 00	05 40	10 10	14 33	19 34
THU MAY 06	18 57	19 37	20 05	23 53		04 31	04 59	05 40	10 14	14 37	19 37

2.2 Aircharts

The *local sidereal time* (LST) is the same as the right ascension (RA) on the sky that is crossing the local meridian (the north-south line that goes directly overhead at your position). Sidereal time is in the reference frame of the stars rather than the Sun. Since we advance a little less than one degree per day in our orbit around the Sun, the Earth needs to rotate more than $360°$ from noon to noon. So the *solar day* is a little longer than a sidereal day.

The *hour angle* of a particular object is how far it is from the local meridian and is equal to LST-RA for the object. The *airmass* is a measure of the column of atmosphere in the direction of an object and is approximately equal to sec(ZA) where ZA is the zenith angle. This is a function of the hour angle and the difference between the latitude of the observertory and the declination of the object. It is usually uncomfortable for telescopes to be pointed more than 4 hours either side of the meridian in hour angle or to airmasses greater than 2.

There is a very handy IRAF tool that calculates the airmass of an position in the sky throughout the any night at any astronomical site. I get vaguely oriented by remembering that objects with RA= 0^h go overhead at local midnight on September 21, and the sky moves overhead by 2^h per month. So, on October 21, objects with 2^h RA will go overhead at midnight. At 8pm (4 hours before midnight), 22^h will be overhead and you could imagine pointing the telescope to an object with RA= 19^h (3 hours west) to observe for an hour before it was lost to the western horizon. At 4am, 6^h will be overhead and you could imagine picking up objects with RA= 9^h over in the East and following it till dawn.

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         NOAO/IRAF V2.11EXPORT bolte@mojave.ucolick.org Tue 10:22:59 06-Apr-9
         Airmass chart for UT date SAT February 21, 1998 at KPNO (time zone = 7
                evening ast. twilight = 19:39    morning ast. twilight =  5:43
          moon: ra = 17:24  dec = -17:59  rise = 2:24  set = 13:14  ill. frac. =
```

An example output of airchart. You need to know the timezone, declination and latitude of the observatory.

2.3   Things to do at the telescope

Usually the telescope is turned over to you sometime during the day of your first night on the schedule. For any type of observing you want to make sure the basics are in place:

1. Take a few bias frames – 0 second exposure time with the shutter closed. You should see very little structure (certainly no banding). If possible, ask to have the telescope moved during a bias-frame readout to satisfy yourself that you can be moving to targets at night during CCD readout. Do the same tests with motor moves in the spectrograph or camera (for example, start a bias and then move the filter wheel).

2. Take a few dome flats in any broad-band filter. You should see something different than what was in the bias frames. If you do, then in the very least shutter is opening. You can use pairs of bias frames and flat-field frames to calculate the readnoise and gain of the CCD (this is done individually for multiple-amplifier readout). There is an IRAF task called **findgain** that does this for you. The basic formulae assume Poisson statistics and determine the readnoise/gain combination that will allow the correct scaling of the noise comparing the zero-signal bias frames with the non-zero-signal flats.

   Δflat = flat1 − flat2

   Δbias = bias1 − bias2

$$\text{gain} = \frac{(\overline{\text{flat1}} + \overline{\text{flat2}}) - (\overline{\text{bias1}} + \overline{\text{bias2}})}{\sigma(\Delta\text{flat})^2 - \sigma(\Delta\text{bias})^2}$$

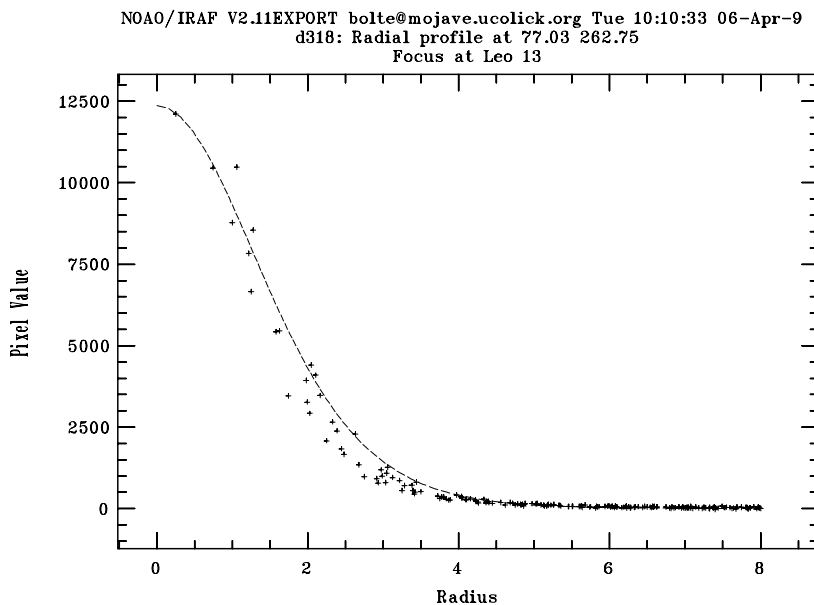$$\text{readnoise} = \frac{\text{gain} \times \sigma(\Delta\text{bias})}{\sqrt{2}}$$

3. For spectroscopic data, verify that the correct gratings and slits or slit masks are in place. Using the arclamps, make sure you have the grating tilt set to give you the wavelength coverage you want. Decide on the proper binning of the CCD.

4. Once you are happy that the CCD is reading out and the various components are in place. Take biases (not so important), flats of all sorts (domes for direct data, quartz lamps for spectroscopic data), arclamp spectra and a few darks of different lengths to make sure (for CCDs) that the dark current is negligible.
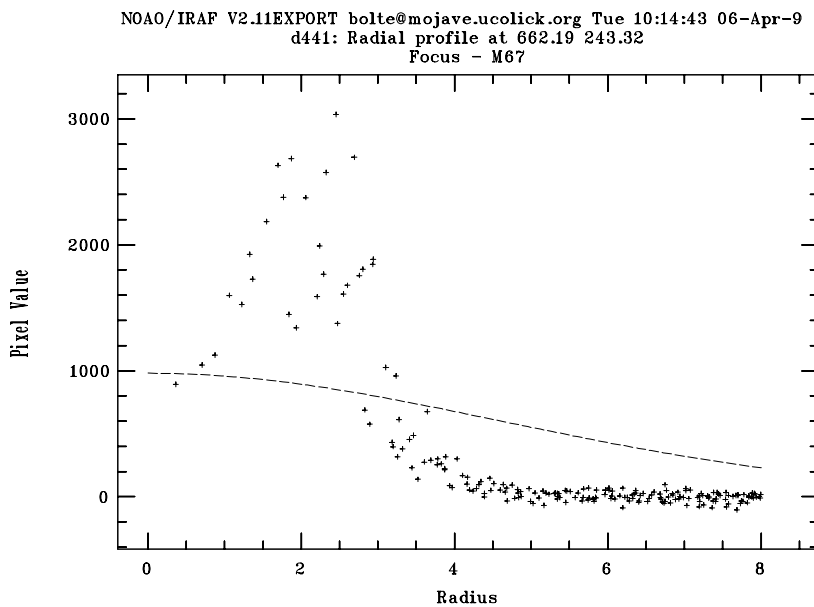
2.4   At night

Other than being very efficient, there is not that much to do. Particularly for direct imaging, you want to monitor the telescope focus (the *camera* focus is separate and usually there are previously-derived best-focus values for different filters and slits). In addition to adding more sky in your measuring apertures than necessary, being out of focus introduces a funny PSF and, particularly for "fast" (f/1.8 or faster) cameras, the PSF gradients over the field can grow considerably.
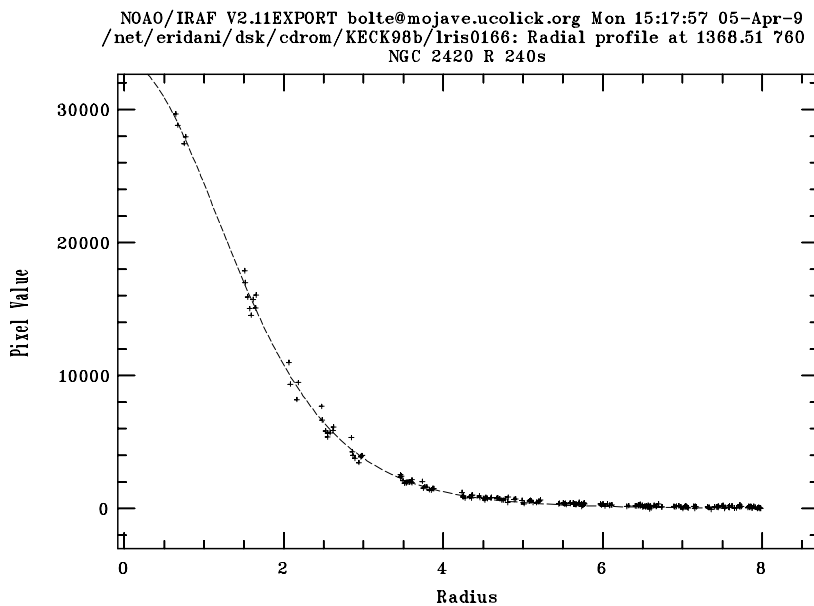
An example of a pretty-well focused image of a star. **imexam** and the "r"-key option will produce this plot.

NOAO/IRAF V2.11EXPORT bolte@mojave.ucolick.org Tue 10:10:33 06-Apr-9
d318: Radial profile at 77.03 262.75
Focus at Leo 13

An example of a not-well focussed image of a star. **imexam** and the "r"-key option will produce this plot.

NOAO/IRAF V2.11EXPORT bolte@mojave.ucolick.org Tue 10:14:43 06-Apr-9
d441: Radial profile at 662.19 243.32
Focus - M67

An example of a very-out-of-focus image of a star. **imexam** and the "r"-key option will produce this plot.

2.5   Attitude is Everything

You want to feel a certain sense of urgency whenever the shutter is not open. Catching photons is the name of the game here. For example, suppose you are trying to verify a field. Take an exposure and while you are turning your chart sideways and holding it backwards to the light to see if you can figure out where you are, have the shutter open! If you happen to be at the right spot, you will be a few minutes or more ahead of the game. As a second example, after verifying that the telescope can slew and motors can move in the spectrograph during CCD readout without increasing the readout noise, use that readout time to move to the next target or change filters or gratings.