HNA Spectrograph Operations Manual

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May 24, 1999

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Preface

The HNA Spectrograph[1] is a cryogenic spectrograph designed for use in the near-infrared, and operating on the Palomar 200-inch Telescope. Its modular nature allows one to choose from two[2] infrared cameras. The slit in the HNA spectrograph is 38″ long, with a continuously adjustable width from fully closed to $\sim 10''$. Two resolution modes are available, as well as an imaging mode, with a maximum field size of $\sim 10'' \times 38''$. The low resolution spectral mode delivers a resolution of $R \approx 1000$, while the high resolution mode has $R \approx 4000$, both for a slit width of $\sim 0.7''$. The spectral coverage in these modes are ∼16,000 km s^{-1} and ∼4,500 km s^{-1}, respectively. Any wavelength may be selected for observation in the low resolution mode, but high resolution mode may be used only where existing filters permit order sorting. The HNA has proven thus far to be a robust, predictable instrument. Coupled with the high quality instrumentation comprising the Cassegrain IR setup, the HNA is a sound and versatile instrument well suited to scientific research.

The HNA spectrograph was built by James Larkin and Rob Knop, with assistance from Sean Lin and Keith Matthews. I owe a lot to Rob and James for providing me with an instrument with which to build a large collection of high-quality spectra of ULIRGs for inclusion in my thesis. Without doubt I have been the major beneficiary of their work, and have used their spectrograph more than both of them combined. The HNA also provided a proof-of-concept, and a design launching point for the Palomar Integral Field Spectrograph (PIFS). For this, also, I am endebted to James and Rob.

This manual is adapted from the PIFS manual. Due to the similar nature of the two spectrographs, and the fact that this manual covers the entire observing environment, the two manuals are much the same. An attempt has been made to remove all text specific to the PIFS, and to adjust observing strategies, etc. accordingly.[3] But I apologize if any information non-applicable to the HNA remains.

This document is accessible at `http://www.its.caltech.edu/~tmurphy/pifs/pifs.html` in PostScript form.

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[1] Which, unfortunately Has No Acronym. Also affectionately known as D81.

[2] As of this writing, D80 and D78 are available for use with the HNA.

[3] I actually did more than a global replace of PIFS with HNA, though doing so would have *almost* sufficed.

Chapter 1

Before the Run

1.1 Scientific Objective

The most important first step of any successful observing run is to have a clear understanding of the scientific goal of the observation. This knowledge lies at the base of every decision that must be made during an observing session. How important is continuum shape to you? How important is spatial information? How important are velocity gradients? Are you after line fluxes, line ratios, continuum features, or velocity profiles? How much will exact positioning of the target within the slit affect your science? Do you care if cross-slit spatial information is convolved with the spectral information? The overall goals of the research will guide the manner in which the observations are carried out.

Therefore the best preparation consists of both knowing what you want to see, and knowing what it is you *expect* to see. Are the lines strong enough? What velocity range is expected? Will the object fit into the field? How long of an integration will be necessary to get an adequate signal-to-noise ratio?

1.2 Choice of Infrared Camera

Currently two infrared cameras, called D80 and D78, are available for use with the HNA. D80 is the preferred camera for its selection of order-sorting filters, particularly CVFs. D80 contains a 256×256 HgCdTe array, operating from 1–2.5μm, with a pixel scale of $0.167''$ per pixel. D78 uses a 256×256 InSb array, with an accessible wavelength range of 1–5μm and a pixel scale of $0.125''$ per pixel. The physically smaller detector in D78 will not accommodate the entire HNA slit length, only passing the central 75% of the slit. Another drawback of D78 is slightly reduced spectral coverage due to the smaller array. The only reason one would elect to use D78 in lieu of D80 is if the range from 2.5–5μm is of interest.

One additional bit of relevant information is that the cameras are not interchangeable with zero effort. This is due to the fact that matching the optical output of the HNA to the input of the cameras requires adjusting the gimbal holding the camera. While not terribly hard to do, this does take some effort. Most importantly, D78 has seldom been operated on the HNA[1], so there may be unrecognized problems with this regime.

1.3 Object Preparation

Prior to arriving at the telescope, one should have the following information about the various objects to be observed:

- good object coordinates (~1 arcsecond accuracy)
- a list of guide stars
- atmospheric transmission and OH lines
- wavelengths to be observed
- preferred position angles
- optional finder chart

For general observation preparations, see Section 1.4.

1.3.1 Object Coordinates

Object coordinates can be expressed in any equinox, but due to the limited field of the HNA, one desires coordinates good to 1–2″. Pointing just a few arcseconds off in the narrow dimension of the field will miss the object, perhaps with no clue of its direction—especially for compact objects in good seeing. For faint objects where blind offsets from a brighter star are required, the coordinate offsets from the reference object ought to be good to at least 0.5″, in order to assure proper placement within the slit.

1.3.2 Guide Stars

The offset guider for the Cassegrain IR setup is capable of moving out to a radius of 190–200″. Any visible star with $V < 14$ within this range may be used for guiding. However, if the star is closer than about 40″ to the object, it is likely that the offset guide head will vignette or totally obscure the HNA field of view. Therefore the useful range is about 40–190″. It is also worth noting that if the guide star is directly north, south, east, or west from the object, light from the star may be partially occulted by one of four vanes located in the telescope baffle tube.

The magnitude limit of the guider varies with the conditions, as can be expected. On the best of nights, with 0.5″ seeing, and photometric skies, stars

[1] Only once, in fact. But this was successful.

down to $V = 15.5$ are useful for guiding. However, crummy nights impose limits more like $V = 11$–12.

A recommended source for generating guide star lists is the Hubble Guide Star Catalog (GSC), which is often encountered as a two-CD set. Gerry Neugebauer wrote a nice routine called `guide` to search the GSC and dig up all stars within a specified radius of a point on the sky. The output gives the star magnitude, radial offset, offsets east and north, and position angle from the object. This is a handy format for both selecting the guide star, and entering the information into the guider controller. The input file used by `guide` requires the following fields separated by spaces (*not* tabs): object name, R.A. (in hh mm ss.ss), and dec. (in dd mm ss.s). One warning: if the object name contains a "+" or a "−", a positive or negative declination will be assumed accordingly. The program looks for any plus or minus sign in the input line to signal the sign of the declination. So be careful. If I'm still at CIT, I'll be happy to run the program for you, given an input list. I'll go out on a limb and say that any member of the IR group will be helpful in providing guide stars given a formatted input list.

The GSC stars are not complete down to the limiting magnitude of the guider, so under good conditions it is likely that a suitable star is within range of the guide head even though nothing shows up on the GSC output. See Section 1.3.5 for how to cope with this situation.

1.3.3 Atmospheric Transmission and OH Lines

Though the HNA itself will operate anywhere between 0.5μm–5μm, and the usable cameras span the 1–2.5μm and 1–5μm ranges (see Section 1.2), the atmosphere is not so flexible. Various absorptions, mainly due to CO_2 and H_2O limit the useful wavelengths to discrete bands. Information on atmospheric transmission as a function of wavelength can be found at: `http://www.jach.hawaii.edu/UKIRT/astronomy/`. The online data is for Mauna Kea, and should be raised to a factor of $\sim$1.6 for Palomar. A glimpse of what this transmission looks like can be seen in Figures 2.2 and 2.3. One definitely wants to take the atmosphere into consideration when planning object observations.

A second consideration is the atmospheric airglow spectrum of OH. These lines are relatively abundant throughout the J, H, and the first half of the K bands, and are useful for wavelength calibration (see Section 1.4.3). For the most part, these lines are a minor hindrance to the observation. They are resolved out quite well in both the high and low resolution modes, and hardly interfere with observations of moderately bright objects. However, if observing faint objects, one may want to verify that the expected emission line feature lies between OH lines. Otherwise the line emission may be swamped in the high background of the OH line. See Oliva & Origlia, A&A **254**, 466 for wavelengths and relative strengths. Also see the `http://www.jach.hawaii.edu/UKIRT/astronomy/` web page for online graphs and line lists.

1.3.4 Wavelengths and Position Angles

I highly recommend arriving at the telescope with wavelength and position angle information prepared for each object on your list. The HNA is tunable to any wavelength between 1–5μm in the low resolution mode, so the only limitation comes from the atmosphere. In the high resolution mode, observable wavelengths are restricted by the filter selection available for order sorting. See the table list in Section 5.2 for available wavelengths in high resolution mode.

If there are multiple objects to be observed around the same wavelengths, I recommend standardizing wavelengths, minimizing the number of dome-flats necessary for calibration. After all, two observations with spectra displaced only by a few pixels is somewhat wasteful. In addition to the number of dome-flats required, another disadvantage of close-but-not-equal wavelength tunings is that should one forget lamp spectra or some other calibration (i.e. G-star observation) for one object, the calibration from the similar wavelength observation cannot be used as a backup. In general, if $\Delta\lambda/\lambda < 0.01$ for the low resolution mode (0.002 for high resolution), it is pretty safe to standardize to a single wavelength.

In terms of position angle, it is wise to know beforehand which position angle (or angles) will be used for each object. The entire infrared Cassegrain setup can be rotated to any angle between $0°$ and $360°$ at the command of the night assistant.

1.3.5 Finder Charts

Finder charts are very helpful for verifying the positions of both object and guide stars (or reference stars as aids to pointing). In addition, finder charts may enable one to locate guide stars in the absence of suitable candidates in the list generated by the method discussed in Section 1.3.2. If the guide star list is produced from the Hubble GSC, then unless the seeing is good and conditions are photometric it is unlikely that "unlisted" stars picked off the finder chart will be sufficiently bright for guiding. But don't completely write it off until you've tried.

I generally make finder charts using the "Advanced" interface to the SkyView Virtual Observatory at `http://skyview.gsfc.nasa.gov/skyview.html`. Here, I create a field that is $500''$ on a side ($0.138889°$) using the Digitized Sky Survey as a grayscale image. Saving this as `fits`, I then use IDL to normalize the image (subtract median and divide by sky noise level) and display from -5σ to $+15\sigma$. Then I put crosshairs on the image and draw a circle of radius $200''$—the maximum offset guider range. Plotting the 300×300 pixel image on paper at 5.875 inches on a side seems to work well for producing a scale of 0.3mm per arcsecond. If interested in the IDL code used to generate these finders, see Appendix A.

1.4 Other Observing Preparations

There are other useful items to have at the telescope for the purpose of observing. These mostly deal with calibration. They include:

- a list of bright Gv stars
- a list of standard stars
- a list (or plot) of the noble gas infrared emission lines
- log sheets

1.4.1 G-stars

G-stars are used primarily to calibrate the spectral throughput of the atmosphere, but are also used to generate flat-fields for spectral observations. Main sequence G-stars (and late F-stars) have only minor absorption lines, making them a good choice for spectral calibration, as their spectral shape is very well approximated by a blackbody. I have prepared a list of F8–G9 stars, of luminosity class V, with apparent magnitudes ranging from 3.5-6.5. This makes for about 270 stars, spread throughout the entire sky. Appendix B has this entire list.

Because the atmospheric transmission function varies with airmass, it is desirable to match the airmass of the calibrator star with that of the observed object. Matching the airmass within 5% results in a faithful atmospheric profile, but in a pinch a 10% match is probably acceptable. To minimize potential complications from instrument flexure, it is most desirable to find a calibrator star in the same part of the sky as the object was during observation. So for instance, the ideal G-star for a one-hour long observation would be positioned at the same declination, and approximately 30–40 minutes to the east in right ascension. Sometimes it is necessary to observe more than one G-star in order to accommodate the full range of airmass encountered during the object observation. For this reason, it is often best to obtain the G-star calibration after the observation, so that the observation's airmass range is known. Keep in mind that careful G-star calibration will have the most significant impact on precise continuum shape. If this is not at all important, a less careful G-star calibration will suffice.

To aid in finding G-stars at the appropriate airmass and sky positions, I have made a handy little analog computer. This is nothing more than a plot of all the G-star positions on the sky, and an overlay with lines of constant airmass drawn on. By setting the meridian axis of the overlay at the right ascension corresponding to the LST at the anticipated time of G-star observation, one immediately sees the airmasses of all the stars contained in the list. In general, there will be several stars of appropriate airmass. The one with a position closest to the observed object is the best choice. The analog computer may be obtained in PostScript form from `http://www.its.caltech.edu/~tmurphy/pifs/pifs.html`.

1.4.2 Standard Stars

Standard stars are used to tie the spectral observations to a photometric reference. For this purpose, I have taken to using the HST standards, the photometry of which was provided by S. E. Persson. These stars have near-infrared magnitudes in the 10–12 range. See Appendix C for a list of standard stars.

1.4.3 Gas Lamp Spectral Lines

The HNA uses two types of sources for spectral calibration. The first is the atmospheric airglow spectrum of OH. These lines are relatively abundant throughout the J, H, and the first half of the K bands, and come for free with the observation. See Oliva & Origlia, A&A **254**, 466 for a good treatment of the use of OH airglow lines as a means of spectral calibration. When the OH lines are not present, as happens at the long-wavelength end of the K band, or if their density is not sufficient, as may be the case for the narrow wavelength coverage offered by the high-resolution mode, gas lamp spectra are used to supplement (or supplant) the OH spectrum for wavelength calibration. Four different lamps are available for the HNA: neon, argon, krypton, and xenon.

In order to know which of these lamps are appropriate for the wavelength range of interest, it is good to have a plot of the spectrum for each lamp. In this way, one can choose which lamps to use, and may avoid wasted time on null spectra.

1.4.4 Log Sheets

I can't say enough for the value of log sheets. Log sheets help guide the observation, and act as a reminder of the current instrument state. The status of the grating and flip mirror is not displayed on the observer's terminal, making the log sheet the primary source for this information. The form I use, which was passed down to me, has the following fields: frame number, object name, integration time, slit width, grating setting, filter, flip mirror status, tertiary mirror status, Universal Time, airmass, and a roomy comment field. Appendix D has a LaTeX file that generates one of these lovely log sheets. The HNA logsheet may also be acquired from: `http:/www.its.caltech.edu/~tmurphy/pifs/pifs.html`.

Chapter 2

A Brief Orientation

The intent of this chapter is to provide a brief overview of what observing with the HNA is all about. In addition to such an orientation, things such as the orientation of the field and grating characteristics will be covered here.

2.1 Basic Information

The HNA is a standard near-infrared longslit spectrograph with a continuously variable slit, two spectral modes, and a field imaging mode. Though designed to have capabilities beyond 2.5μm, the primary design considerations favor use of the HgCdTe 1–2.5μm camera.

The instrument itself is simple to use. User controls enable selection of wavelength center, spectral resolution mode (low or high), slit width, and selection between imaging and spectral modes. The HNA-specific commands can be found in Section 5.2. Other commands for controlling the camera, moving the telescope, displaying images, and configuring the $f/70$ tip-tilt guider are treated in Chapter 5.

The more difficult aspect of using the HNA instrument has to do more with observing strategy, and having a mental picture of the current state of the instrumental setup. Getting used to telescope control, using the guider to maximal advantage, and obtaining G-star calibration will be the most taxing activities for the newcomer. The observer's cookbook in Chapter 7 is a good resource for learning how to conduct an observing session.

The status of the HNA optics is not reflected anywhere in a direct manner. Therefore it is good to keep track of where the grating is, where the flip mirror is, the current slit width, where the tertiary mirror is, etc. The motor positions are recorded in the header, so this information is not lost, but nonetheless not easily accessed by the observer. It is my belief that a familiarization with the instrument layout, as presented in Section 3.1 will help develop this mental picture of where things are.

2.2 Facts and Figures

This section simply provides a random assortment of pertinent information about the HNA instrument, and the observing environment in general.

- The HNA field of view is 0–10″ × 38″, continuously variable between these extremes. The field of view can be rotated to any position angle on the sky.

- The HNA low resolution grating delivers $R \approx 1000$ spectra for a $\sim 0.7''$ slit, with ∼16,000 km s^{-1} of coverage in velocity space, or roughly 55 resolution elements. Velocity centroids for bright lines may be accurate to ∼20 km s^{-1}. This mode is typically enabled with the `clowres`, or `lowres` command.

- The HNA high resolution grating delivers $R \approx 4000$ spectra for a $\sim 0.7''$ slit, with ∼4,500 km s^{-1} of coverage in velocity space. This mode is typically accessed with the `hires` command.

- When using D80, the pixel scale is 0.167″ per pixel, with an unvignetted field of 234×216 pixels (234×60 in imaging mode).

- The HNA has an imaging mode that enables quick assessment of what is in the field. This imaging mode is accessed via the "flip mirror in" command, `fmi`.

- Flexure of the HNA is minimal, with measured focal plane shifts on the order of one pixel for large motions of the telescope. Most observations will be unaffected by flexure. However, this may be a factor in the mismatched fringing of dome flats (see Section 7.3).

- The total HNA system throughput, including D80 is ∼25%, from the top of the atmosphere to total electron counts.

- The calculated sensitivity of the HNA estimates the ability to detect 5×10^{-16} erg s^{-1} cm^{-2} at 3σ in 30 minutes for a spatially and spectrally unresolved line emission source under 1 arcsecond seeing. With the most optimistic seeing conditions (0.5–0.7″), one should be able to see a $K = 18$ continuum source (0.04 mJy) in something like one hour of on-source integration.

- The HNA cryogen hold time (25 liters of LN_2) is approximately two days, sitting still.

- The array characteristics of D80, with MPARM2 set to 16 are: 17 electron read noise, 8 electrons per dN. Saturation for D80 is at about 20,000dN, provided CSCALE is appropriately set.

- Minimum exposure time is 0.375 seconds, and the minimum with 16 reads is 6.0 seconds.

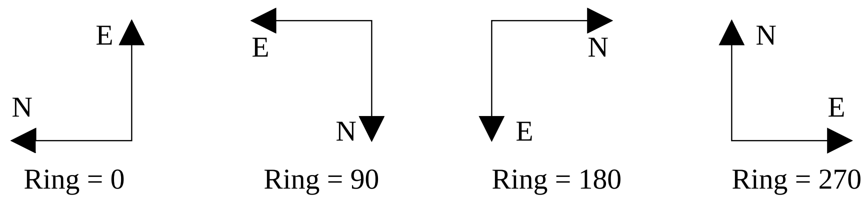

Figure 2.1: Orientation of the HNA field for the four cardinal ring angles. Note that left always corresponds to the ring angle. Also note that there is an overall reflection, such that when North is up, East is to the right instead of the familiar left.

- The chopping $f/70$ secondary is undersized to permit chopping without losing light from the secondary. The net effect is an effective primary mirror area of 15.5 m^2.
- The offset guider is a fiber bundle with a hexagonal shape, measuring $15''$ across the flats (as opposed to a corner-to-corner measurement).
- The offset guider can access guide stars as far out as $200''$, and as close in as 30–$40''$ without vignetting. Guide stars on crummy nights need to be brighter than V =11–13, but can be as faint as $V \sim 16$ on the best of nights.
- The center-field camera has a circular field measuring $70''$ across. The field is oriented with north up and east to the left for a ring angle of 90°.
- The telescope focus should be somewhere in the range of 63-65mm.

2.3 Field Orientation

The orientation of the HNA field of view has one reflection relative to the conventional orientation (i.e., that of the sky). The orientation of the rectangular field (or slit), seen as horizontal on the image display, is shown for the four cardinal ring angles in Figure 2.1. The way to remember this is: the left end of the slit points along the Cassegrain ring angle (position angle), and there is a net reflection in the up-down direction. Compared to the center-field camera, left on the display is left on the center-field, but the up-down direction is flipped. Thus the center-field camera has the conventional orientation when the ring angle is 90°.

The images that accompany Chapter 7 will likely be of great help in orienting the HNA newcomer to the appearance of the data as it is acquired at the telescope. In particular, Section 7.5.4.8 offers an example of the kind of data one may expect from the HNA.

2.4 Grating Characteristics

The HNA uses two replication gratings for the two resolution modes. The low resolution grating is reasonably well matched to the atmospheric windows, with 2nd order in K, 3rd order in H, and 4th order in J. The high resolution grating has many orders spanning the near-infrared windows, essentially randomly placed with respect to atmospheric features.

2.4.1 Low Resolution Grating

The low resolution grating has a blaze angle of 34°, with 240 grooves per mm. This puts the first order blaze peak at 4.65μm, with higher order peaks at 2.33μm, 1.55μm, and 1.16μm. Figure 2.2 shows the general characteristics of this grating, including the blaze function, wavelength coverage, input grating angle, and effective spectral resolution, all as a function of wavelength.

Obvious from Figure 2.2 is that the blaze peaks are moderately well matched to the atmospheric windows, with poorest performance at the long-wavelength ends of the J and H bands. In the lower portion of the uppermost panel in Figure 2.2 is an indication of the simultaneous wavelength coverage as a function of wavelength. The scale for this function is the wavelength scale itself, such that the coverage at 2μm, for instance, is about 0.15μm, and about 0.08μm at 1μm. The input angle, discussed more in Section 5.2 is computed using a value for $\alpha - \beta$ of 5.2°, as is appropriate for the HNA geometry. The lower panel in Figure 2.2 shows that effective spectral resolutions can vary from $\sim$ 850 to $\sim$ 1400 across the J, H, and K bands, for a slit width of 0.7″.

There are roughly 55 spectral resolution elements presented on the array, so one may compute the wavelength or velocity coverage at any point as $\Delta\lambda = 55\lambda/R$, or $\Delta v = 55c/R$. Caution must be taken about pushing these numbers to their limits. Don't plan to put important features at the edge of the range!

To cover the K band, one must use 4 grating settings in the low-resolution mode. Suggested settings are: 2.04μm, 2.15μm, 2.25μm, and 2.35μm.

2.4.2 High Resolution Grating

The high resolution grating has a blaze angle of 69°, with 52.67 grooves per mm. This puts the first order blaze peak at 35.4μm, with many high order peaks spanning the near-infrared bands. Figure 2.3 shows the general characteristics of this grating, including the blaze function, wavelength coverage, input grating angle, and effective spectral resolution, all as a function of wavelength.

As is seen in Figure 2.3, many grating orders span any given near-infrared window. It is for this reason that not all wavelengths are available for observation with the high resolution grating, as order sorting cannot be accomplished with broad-band filters. The 1.3% CVF (`cvf1`) provides continuous accessibility from 2.0–2.5μm, but observations in other bands require the existence of narrow-band interference filters. There are a limited number of such filters, centered at the rest wavelengths of strong near-infrared lines. The list of applicable wavelength

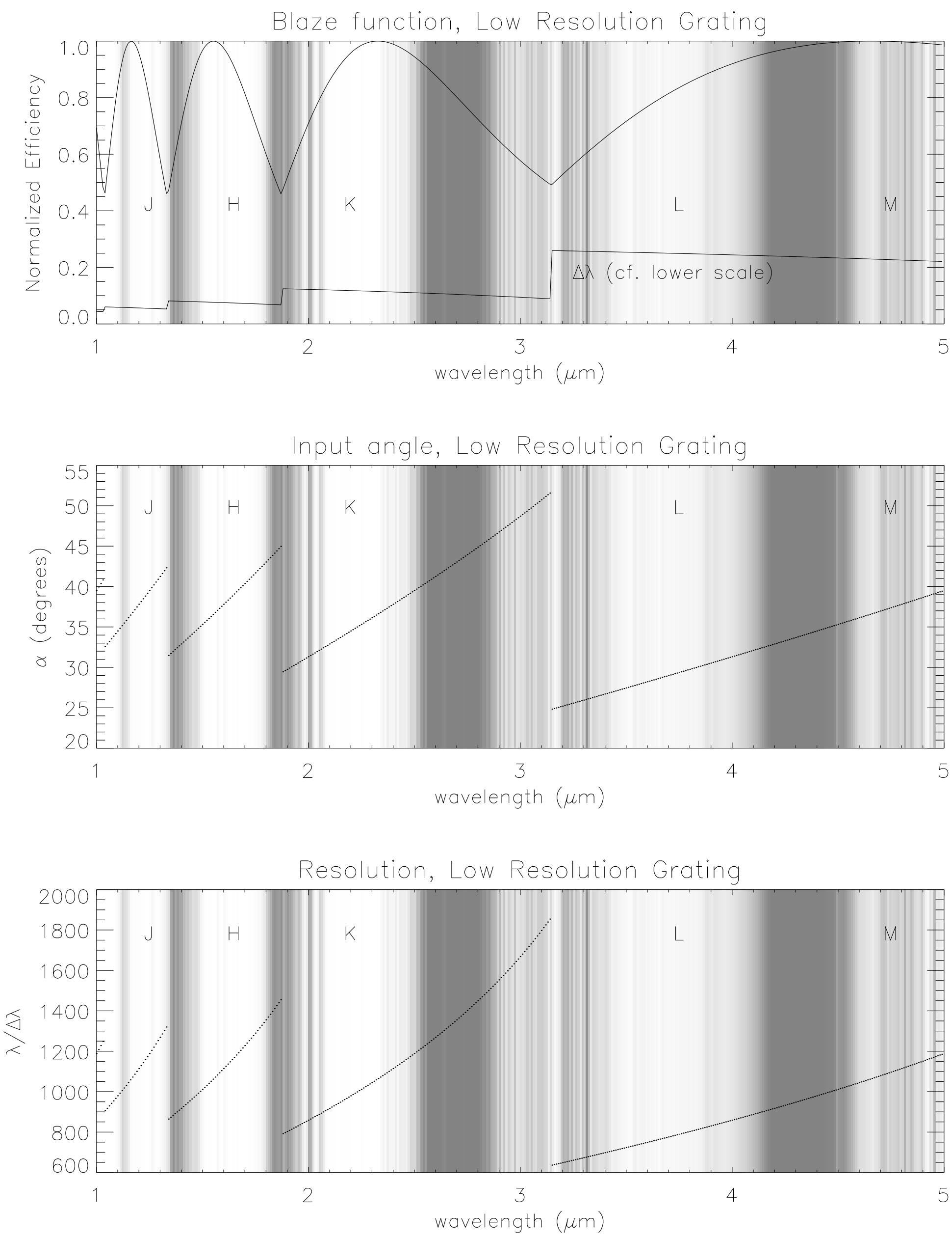

Figure 2.2: Low resolution grating characteristics as a function of wavelength. The grayscale represents atmospheric transmission, with dark bands signifying high opacity. The $\Delta\lambda$ plot in the uppermost panel represents wavelength coverage as a function of wavelength, the scale for which is represented by the lower wavelength scale. The coverage at 2μm, for instance, is about 0.15μm.

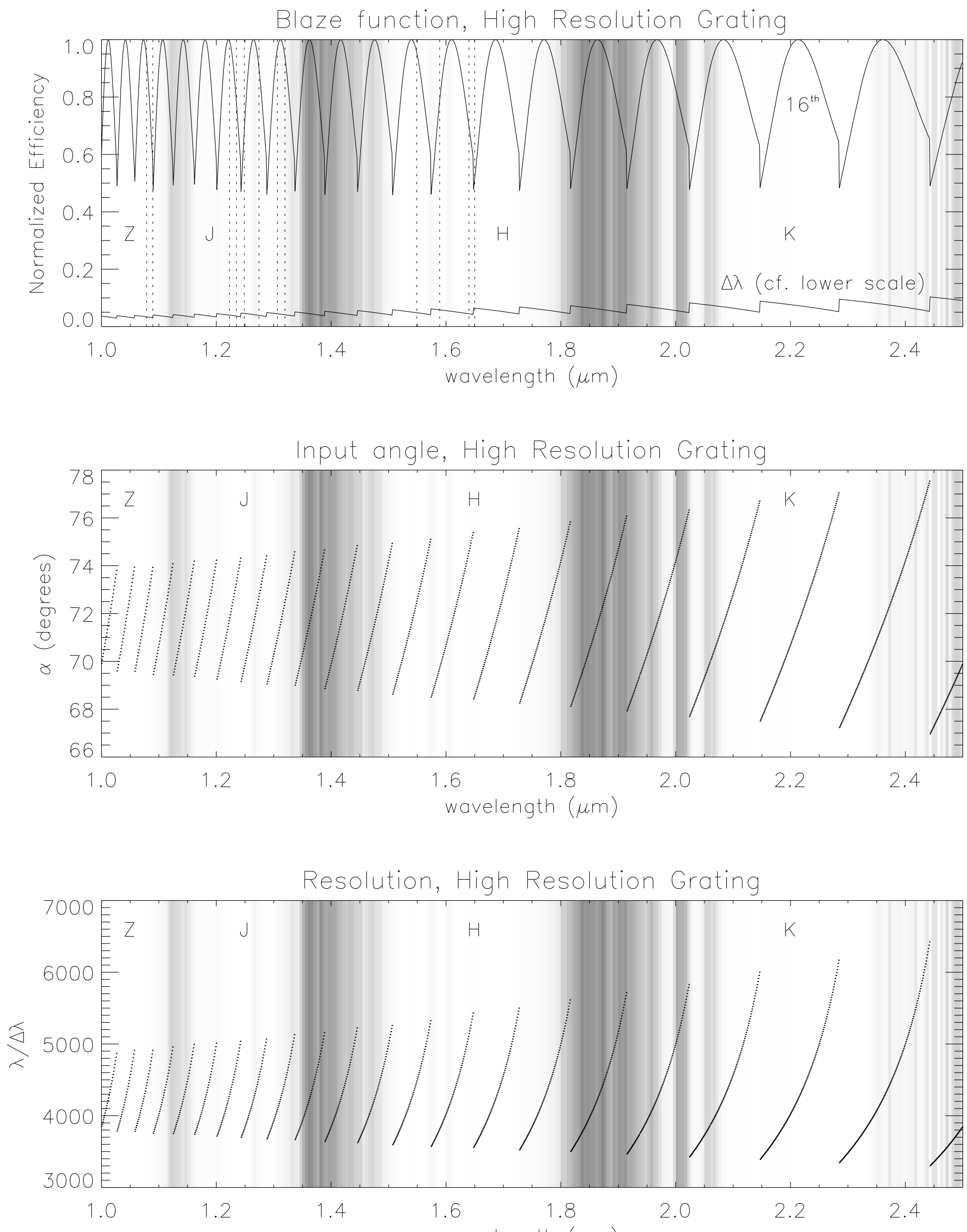

Figure 2.3: High resolution grating characteristics as a function of wavelength. The grayscale represents atmospheric transmission, with dark bands signifying high opacity. The $\Delta\lambda$ plot in the uppermost panel represents wavelength coverage as a function of wavelength, the scale for which is represented by the lower wavelength scale. The coverage at 2.2μm, for instance, is about 0.04μm. The 16th order blaze peak is marked for reference. Narrow-band filter locations are indicated by dotted pairs of lines.

ranges can be found on page 37. Operation near the edges of these bandpasses may result in the spectrum being truncated on the array.

Chapter 3

The HNA Instrument

The HNA Spectrograph is a simple device to use. The user has control of the slit width, the wavelength tuning (and choice of grating), and can choose between spectroscopic mode and imaging mode. That's it. It's hard to mess that up. The following sections describe in a little more detail the control the user has over the instrument, from the instrument's point of view.

3.1 The Optical Layout

No good instrument manual can go without a figure of the instrument layout. A diagram of the HNA is therefore presented in Figure 3.1.

3.1.1 The Optical Path

The optical path through the HNA goes as follows. The $f/70$ cone of light comes down from the secondary mirror, flying past the offset guider (which is not shown here, but exists near the top-plane of the drawing), then hits the small tertiary mirror (also not shown), sitting in the warm environment of the "coffin". The still-converging beam enters the HNA dewar through a rectangular CaF_2 window, with a 93° fold at the top of the dewar. From this point until exiting the dewar, all optical surfaces are at $\sim 77°K$. The beam comes to a focus at the adjustable slit, then expands again on the way to the collimator mirror, at the bottom of the dewar. This spherical mirror stops the beam divergence, sending cylinders of light converging onto the grating. The grating is able to rotate through a large angle, and has two different grating surfaces that can access the beam. This is what provides the two resolution modes. The grating is shown rotated to both modes simultaneously in Figure 3.1. Not shown here, but existing just below the grating carriage, is a flip-in mirror. This mirror can be moved into the beam in front of the grating, interrupting spectral service to bring instead an imaging service. Leaving the grating, the cylinders of light have acquired a variety of angles in the plane of the page corresponding to various

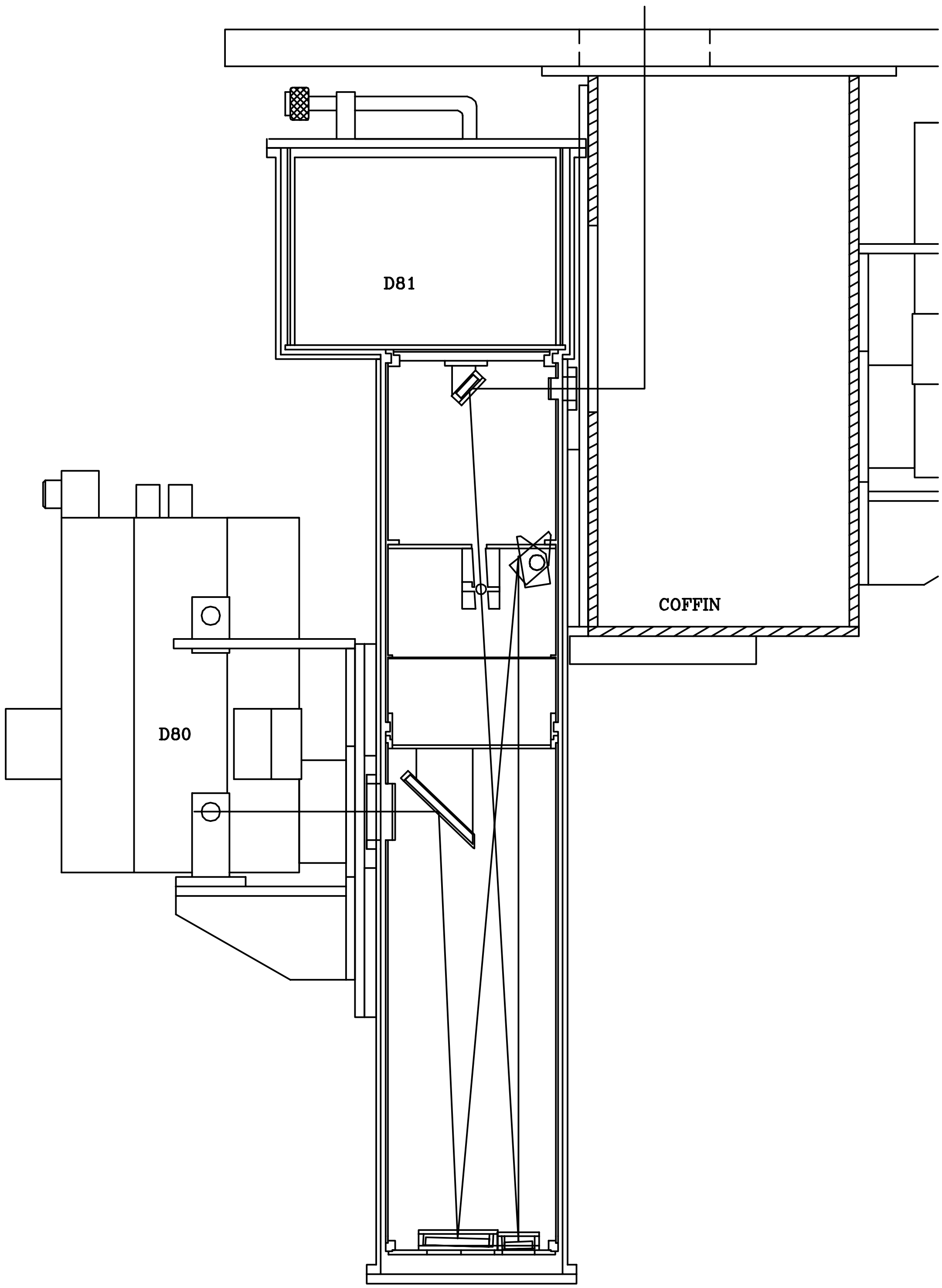

Figure 3.1: The HNA layout. It's the only electronic version I could find. Labels are scarce, so see text for description.

wavelengths. These cylinders are collected at the bottom of the HNA dewar by a spherical mirror sharing the same focal length as that of the collimator mirror. The effect is to produce a converging $f/70$ beam which folds off of the large diagonal mirror and out through a CaF_2 window, coming to focus within the infrared camera. Therefore the infrared camera, designed to image the $f/70$ field of the 200-inch, is being fed a seemingly identical $f/70$ beam that has been slit and dispersed. The mirrors in the HNA are all Fused Silica substrates with gold coating.

Within the camera are mirrors, filters and lenses, in addition to its own CaF_2 entrance window. The total efficiency of the camera, from window to electron counts is about 47%, while for HNA, the window-to-window throughput is in the neighborhood of 60%.

A point worth mentioning is that the two-dewar approach used here has a few disadvantages. The main disadvantage doesn't rear its head until the thermal infrared regime is reached, out past 2.2μm. It doesn't become formidable until somewhere past the K band, where few dare tread. If observations past 2.5μm are desired, the warm window interface will present a serious barrier, perhaps limiting the type of science that can be done to very bright objects. A less serious disadvantage of this approach is the 8% transmission loss of each window.

3.2 Observer Controls

The observer is able to move various elements within the spectrograph, the camera, the coffin, and the IR baseplate. These motions are accomplished via stepper motors through a computer interface. The available motions pertain to the offset guider (2 motors), the tertiary mirror (1 motor), the slit jaws in the HNA (1 motor), the HNA grating (1 motor), the HNA flip-in mirror (1 motor), the camera slit and slit mask (unused for the HNA—2 motors), the camera filter wheels (2 motors), and the Noble gas calibration lamps (1 motor).

3.2.1 Offset Guider

The offset guider is moved via two motors (#15, #16)[1], moving the guide head in θ and r, respectively. As mentioned in Section 1.3.2, the offset guider has a range out to a radius of 190–200″. The `og` and `og/r` commands will be used to move the guide head.

3.2.2 Tertiary Mirror

The tertiary mirror moves on a slide, propelled by a screw turned by motor #8. In practice, one only needs to move the tertiary mirror either *in* or *out*. The

[1]For this and other paragraphs in this section, keep in mind that it is almost never necessary to know which motor does what, as direct motor commands are generally not needed. Macros to perform the sensible motor motions are described in Chapter 5. This information is presented here for the sake of completeness.

"in" position is used for observing through the HNA, and the "out" position is used to clear the tertiary mirror from the center field camera's view. When the mirror is moved out of the way, a cover moves in front of the mirror. This protects the mirror from dust and dewar condensation. Thus when not using the spectrograph, *please* remember to move the tertiary mirror *out* to its protected position. The commands `mspect` and `/o` are used to move the mirror in and out, respectively.

3.2.3 HNA Grating

The grating within the HNA can be moved through about 75°, in order to tune wavelength and select the low- or high-resolution modes. Motor #9 controls the grating. The existing macros are simply called `clowres`, `lowres` and `hires`. For the real gear-head, grating angles (α in the grating equation) can be controlled directly via `grating` and `echelle`. The `lowres` and `hires` commands are really just front-ends to these two macros. See Section 5.2 for details.

3.2.4 HNA Flip-in Mirror

The flip-in mirror (or just flip mirror), is moved by motor #6.. Being two-state in nature, only two commands are needed: `fmi` and `fmo`, for flip mirror in, and flip mirror out.

3.2.5 Calibration Lamps

The calibration lamps, which shine light into the coffin from above the HNA entrance window, are powered from a single power supply. A motor-driven rotary switch (motor #7) sends the high voltage feed from the power supply to the individual arc lamps. The switch only connects one lamp at a time, such that multiple lamp suites must be done sequentially.

3.2.6 Camera Motions

For most intents and purposes, the slits and slit mask in the camera do not need to be moved, and will therefore not be discussed here. What will be moved without doubt are the filter wheels inside the camera. There are two filter wheels in each of the two IR cameras. Each has 5–10 holes for filters, plus a semi-circular hole for a CVF (Circularly Variable Filter). D80 has two CVFs, one covering the K band at 1.3% bandpass, and the other going from 1.5–3μm with a 5% bandpass. There are broadband filters for Z, J, H, K_s, and K. There is also a smattering of narrow-band fixed-λ filters. In addition to filters, there exists in the D80 filter wheel a Si lens that images the pupil (secondary mirror). This lens makes alignment of the camera in its gimbal quite easy. Macros are used to access the various filters, which are covered in Section 5.3.

3.2.7 Other Mechanical Motions

Besides the controls described above, there are a few other motions of importance that are not motorized. But these motions are for alignment purposes and should not be attempted by anyone not already familiar with the process. Some of these motions are relevant to the interchange of D80 and D78. These cameras are held in a gimbal mount attached to the HNA dewar. The gimbal mount provides the camera with four degrees of freedom, namely two translational motions and two rotational motions. The translational motions can be exercised to optimize the position of the focal plane[2]. The rotational motions allow the camera to be "tipped-up", aligning the cold-stop in the camera to the pupil image of the secondary mirror. The tipping will be different for each of the cameras[3]. Each camera has a pupil-imaging lens that greatly facilitates the tipping process.

[2] This position is currently optimized for D80.

[3] The current values for D80 (as read on the micrometers) are: tip: 0.345, rotation: 0.290.

Chapter 4

Starting Up

This chapter describes the process of starting up from scratch, as well as how to restart in the event of a crash of some form. Some of the computer commands mentioned in this chapter are explained in greater detail in Chapter 5.

4.1 Booting Up

After the spectrograph and camera are in place at the Cassegrain focus, with all the cables attached and microVAX in the cage up and running, the system is ready to start. Log into SAM at the observer station:

```
Username: IRCASS3                              (if using D80)
Password:           (look at terminal border for current password)
$ SET PROC/PRIV=OPER
$ RMIRELLA
```

The last command runs the Mirella program, which is the primary camera control environment. From here on, a `M>` prompt represents the Mirella environment, and a `$` prompt indicates the VAX prompt. As Mirella starts, you will need to enter a few tidbits of information:

```
Choose target camera: D78 or D80 > d80
Valid array sizes are (64,64) (128,128) (256,256)
Enter array size: x,y > 256,256
USE OLD MOTOR SETTINGS FILE? (Y/N)   Y
USE OLD OFFSET GUIDER SETTINGS FILE? (Y/N)   Y
RESTORE MACROS TO MEMORY FROM SAVE FILE? (Y/N)   N
```

You will then be asked to enter the observers, or accept the current list. The IRA tradition is to input initials here.

```
M> ready                     (sets a target task for the camera)
Starting target network task...
```

```
M> gosby                              (go standby—awaiting commands)
M> spawn                                            (start a VAX shell)
$ copy appl:[ircass3.userdir]d81.m userdir:
$ copy appl:[ircass3.userdir]d81ze.p1m userdir:
```

Hint: use the up arrow to edit the first command, saving typing.

```
$ eoj                                                     (end-of-job)
M> load d81.m         (load the macros, or words really, for HNA)
M> rmacf camst                     (read macro file for camera start)
M> // camst   (run the camera start macros, homing motors, etc.)
M> damac                                       (delete all macros)
M> rmacf d81ze                        (read macro file for HNA start)
M> // d81ze                       (run the HNA motor homing macros)
M> damac                                       (delete all macros)
M> rmacf cam          (read the macro file for camera commands)
M> 0. 0. og/o                         (set the guider origin to (0,0))
M> agon                                  (turn the auto-guider on)
M> 0.6 d(set differential refraction term for K band; use 0.4 for J)
```

Now everything is ready to roll. If the process doesn't go smoothly, I suggest trying again. If things seem to hang up for several minutes when running the motor-homing macros, then something is probably wrong with the motor controller or associated connections. Go into the Cassegrain cage and check that all motor cables are properly seated. If failure persists, there is a motor controller reset switch tie-wrapped to the inside of the rack containing the motor controller. It is a little pushbutton device. It is rare that such action is necessary, but it has been known to happen.

4.2 Checking Camera Status

After booting up, verify that the camera is in the correct mode. This is done by looking at the top of the Mirella screen at the various numbers characterizing the camera status. An example for D80 appears below.

MODE	10308	F70P	0.0	PICT	1	F70DISP	1
MPARM1	0	OGAUTO	0	FRAMES	1	SING_POS	1
MPARM2	16	DELAY	0.0	PIXRATE	16.5	F70N	1
AMPGAIN	25	DETBIAS		TINT	120.0	EXP_TIME	126.75
CYCLE	1	COADDCYC	1	DETGATE		CSCALE	16
NEXTFILE	1	OBJECT	IR0831	FILTER	CVF2	NOD-E	100.0
LASTFILE		IMAGETYP	OBJ	WAVELEN	2.360	NOD-N	0.0

Many of the numbers in the lower display will change with observing mode, as will numbers referring to exposure time, etc.

4.3 Verifying Operation

Upon starting up, the first thing to do is verify that everything is working properly and there are no apparent problems. First and foremost, see that the camera is delivering images.

```
M> /77k
M> 10. tint
M> goi dcp
M> goi wait odiff
```

This series takes a pair of 10 second dark frames, first displaying the raw dark, then a difference between two. The raw dark should look mostly flat, with a few blotches and hot corners. The difference should look pretty flat. Section 7.2 shows examples of what the dark frames should look like.

Next, check that light is making its way into the camera. This can be done by simply looking at the warm tertiary mirror cover using the K band filter.

```
M> /k
M> oslit                                  (open slit all the way)
M> 10. tint                             (if not already set to this)
M> fmi    (flips the mirror in front of the grating for a slit image)
M> goi dcp
```

Don't worry too much about the commands and their meanings at this point. This will all be covered in Chapter 5. The current display should show the thermal emission of the tertiary mirror cover in the form of a thick horizontal bar near the top half of the array.

Now it would be good to check the spectral mode and make sure all is working there. To do this, send the tertiary mirror out (should already be there), close the slit to a smaller width, and turn on a lamp:

```
M> /o
M> 0.7 slit            (nominally 0.7 arcseconds, or ~4 pixels)
M> neon
M> 10. tint
M> 2.36 clowres                                  (or use hires)
M> goi dcp
M> lampoff
```

You should be staring at a sequence of neon emission lines, with the appearance shown in Figure 4.1. Try other lamps as well, but just remember to issue the `lampoff` command when you are done.

You may notice that part of the array is vignetted, at the sides and bottom. This vignetting is due to the fact that D80 is a copy of D78, which was designed for a 256×256 array of 30μm pixels. But D80 has an array using 40μm pixels, so it's a bit oversized. If reducing data from D80, you will come to appreciate

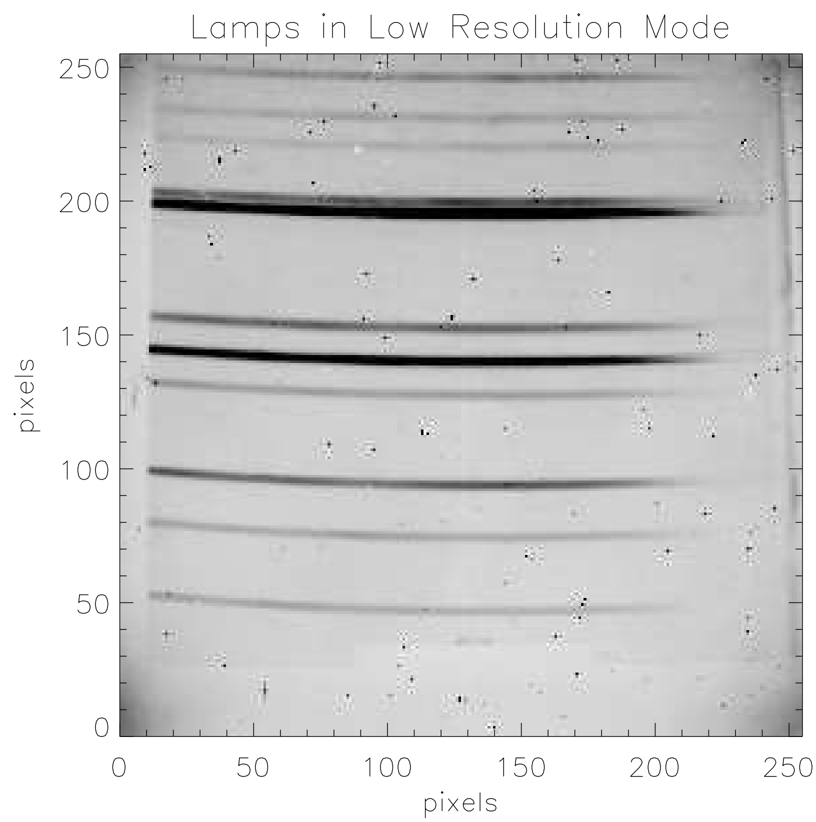

Figure 4.1: Neon lamp spectrum with the low resolution grating set to 2.36μm. The lines trail off at right because the diffuser/mirror-cover does not extend all the way to the edge of the tertiary mirror, so the slit illumination drops to nearly zero there.

this vignetted region as a tool for adjusting floating quadrant levels. With the vignetting as it is, the center y-value of the usable space is at pixel 148, not 128.

If you feel that seeing is believing, then it may be worth turning on the lamps in sequence, then walking out to the cage, and peering into the coffin (from the side opposite the spectrograph, if an imaging camera is not in place there) to see that each tube is glowing. The neon tube will be the brighteset of the lamps in the visible regime. Remember to turn the lamps off with `lampoff` when done.

With the imaging and spectral modes checked out, all systems are go for the night sky. There are, however, slit-mapping duties, darks, and dome flats that can be taken during daytime hours. See Sections 7.1, 7.2, and7.3 for more on this.

4.4 Restarting After a Crash

Sometimes things just go wrong. It may not be your fault, but it probably is. Most of the time there is no need to panic. By panic, I mean start over from scratch. If the problem is software, there is no need to re-home the motors, for instance. If the problem is hardware, then maybe this step will be necessary after all.

4.4.1 Software Restart

Should the software become confused, it may be desirable to restart the Mirella program. To do this, first type:

```
M> bye
```

to exit Mirella. It may be the case that you were dumped out already, in which case you will see the `$` (VAX) prompt. Occasionally I've encountered an anomalous problem with Mirella kicking me out in the process of entering an object name. It's a bizarre bug, and is certainly not your fault. I have developed a superstition that it only happens when shortening the `object` command to `obj`. This theory may be completely insane, however.

In any case, once out of Mirella, restart the program:

```
$ RMIRELLA
```

Now answer the usual questions again:

```
Choose target camera: D78 or D80 > d80
Valid array sizes are (64,64) (128,128) (256,256)
Enter array size: x,y > 256,256
USE OLD MOTOR SETTINGS FILE? (Y/N)   Y
USE OLD OFFSET GUIDER SETTINGS FILE? (Y/N)   Y
RESTORE MACROS TO MEMORY FROM SAVE FILE? (Y/N)   N
```

At this point, just hit return to keep the same observer list (or change list if desired).

```
M> ready            (sets a target task for the camera)
M> gosby            (go standby—awaiting commands)
M> load d81.m       (load the macros, or words really, for the HNA)
M> rmacf cam        (read the macro file for camera commands)
M> 0. 0. og/o       (set the guider origin to (0,0))
M> agon             (turn the auto-guider on)
M> 0.6 d(set differential refraction term for K band; use 0.4 for J)
```

Now the system is ready to go again.

4.4.2 Hardware Restart

In the event that the motors become confused, or you become confused about the motors, or the motor controller goes belly-up, you may need to re-home the motors. First, exit Mirella:

```
M> bye
```

Then go through the following startup procedure:

```
$ RMIRELLA
Choose target camera: D78 or D80 > d80
Valid array sizes are (64,64) (128,128) (256,256)
Enter array size: x,y > 256,256
USE OLD MOTOR SETTINGS FILE? (Y/N)   Y
USE OLD OFFSET GUIDER SETTINGS FILE? (Y/N)   Y
RESTORE MACROS TO MEMORY FROM SAVE FILE? (Y/N)   N
```

At this point, just hit return to keep the same observer list (or change list if desired).

```
M> ready            (sets a target task for the camera)
M> gosby            (go standby—awaiting commands)
M> load d81.m       (load the macros, or words really, for the HNA)
M> rmacf camst      (read macro file for camera start)
M> // camst   (run the camera start macros, homing motors, etc.)
M> damac            (delete all macros)
M> rmacf d81ze      (read macro file for HNA start)
M> // d81ze         (run the HNA motor homing macros)
M> damac            (delete all macros)
M> rmacf cam        (read the macro file for camera commands)
M> 0. 0. og/o       (set the guider origin to (0,0))
M> agon             (turn the auto-guider on)
M> 0.6 d(set differential refraction term for K band; use 0.4 for J)
```

Now everything is ready to roll. If the process doesn't go smoothly, I suggest trying again. If things seem to hang up for several minutes when running the motor-homing macros, then something is probably wrong with the motor controller or associated connections. Go into the Cassegrain cage and check that all motor cables are properly seated. If failure persists, there is a motor controller reset switch tie-wrapped to the inside of the rack containing the motor controller. It is a little pushbutton device. It is rare that such action is necessary, but it has been known to happen.

Chapter 5

Commands

The Mirella commands you will be using can be divided into four groups:

- HNA commands
- camera commands
- telescope control commands
- display commands & other miscellany

In addition, if using the $f/70$ tip-tilt guider, there are commands for the guider. The guider commands are entered on the MINC terminal usually to the left of the VAX terminal.

5.1 A Word About FORTH

The Mirella program is written in FORTH, which is a stack-thinking language, much like good old RPN on HP calculators. The Mirella command structure inherits this stack mentality, and as such, most of the commands take arguments previously placed into the stack. Thus arguments precede commands on the command line, e.g., `10. tint`; `2.2 clowres`.

Now before assuming all is understood, be aware that there are *two* stacks: an *integer* stack and a *float* stack. These are not the same stack. The input sequence: `1.0 3 5.2 80 command` puts two arguments into the float stack (the first and third), and two entries into the integer stack (the second and fourth). If `command` takes two floats, then it first grabs the value `5.2` off the stack, followed by the value `1.0`.

Also worth mentioning is that any number of commands may be placed on the command line, with spaces between. Examples might look like:

```
M> 10. tint 16 mparm2 1 frames 16 cscale
M> goi dcp -10. 0. 90. mvpix goi wait odiff
```

Most of the forth commands presented in the following sections are technically not macros, but FORTH "words". There is limited room ("dictionary space") for words, though there is usually enough room left over for a few user words, which is the subject of Section 5.6.

5.2 HNA Commands

The following words (commands) are located in the `d81.m` file, loaded during the startup process.

`fmi` — Flip mirror in front of the grating. Used for imaging mode.

`fmo` — Flip mirror out of the way, exposing grating to beam. Used for spectral mode.

`mspect` — Moves the tertiary mirror into the HNA spectrograph position.

`/o` — Moves the tertiary clear out of the way, allowing the center field camera an unobstructed view. Also puts cover in front of mirror for protection, and provides diffuse surface for scattering calibration lamp-light.

`oslit` — Open slit to its maximum width, approximately $10''$.

x `slit` — Set slit to roughly x arcseconds wide, where x is a *floating-point* number. The mapping of x to actual arcseconds varies slightly from run-to-run. See Section 7.1 for suggestions on how to accurately set the slit width.

`cslit` — Close the slit to its completely shut-off position.

λ `clowres` — The `c` stands for CVF. Rotates low-resolution grating to center λ μm on the array, where λ is a *floating-point* number. This routine also sets the CVF to the appropriate wavelength and performs a `fmo` command, removing the flip mirror from the beam. Use this command for the wavelength range of 1.5–2.5μm.

λ `lowres` — Rotates low-resolution grating to center λ μm on the array, where λ is a *floating-point* number. This routine also selects the appropriate broad-band order-sorting filter and performs a `fmo` command, removing the flip mirror from the beam. Use this command for the wavelength ranges of 1–1.5μm and 2.5–5.0μm.

λ `hires` — Rotates high-resolution grating to center λ μm on the array, where λ is a *floating-point* number. This routine also selects the appropriate order-sorting filter, if available, and performs a `fmo` command, removing the flip mirror from the beam. An error will be reported if the chosen wavelength cannot be accommodated. Below is a list of applicable wavelength ranges, for D80:

Filter	Wavelength Range
`1.084mu`	1.07858–1.08942μm
`1.229mu`	1.222855–1.235145μm
`1.255mu`	1.248725–1.261275μm
`1.268mu`	1.26166–1.27434μm
`1.313mu`	1.306435–1.319565μm
`1.569mu`	1.549–1.589μm
`1.644mu`	1.64–1.65μm
`cvf1`	2.00-2.40μm

neon Turns off all lamps, then turns on the neon tube.

argon Turns off all lamps, then turns on the argon tube.

krypton Turns off all lamps, then turns on the krypton tube.

xenon Turns off all lamps, then turns on the xenon tube.

lampoff Turns off all lamps.

α **grating** Takes the *floating-point* argument, α, and moves the face of the low-resolution grating in such a way that the input light strikes the grating at angle, α, in degrees. This is a low-level command that is actually the back-end to `clowres` and `lowres`.

α **echelle** Takes the *floating-point* argument, α, and moves the face of the high-resolution grating in such a way that the input light strikes the grating at angle, α, in degrees. This is a low-level command that is actually the back-end to `hires`.

The last two commands will probably never be used, but I realize that their inclusion here is pointless without the following information about the two grating surfaces. The low-resolution surface has a blaze angle of 34°, with 240 grooves/mm. The high-resolution face has a blaze angle of 69°, with 52.67 grooves/mm. The average value of $\alpha - \beta$ is about 5.2°, using the standard convention in the grating equation:

$$\sin\alpha + \sin\beta = \frac{m\lambda}{a}$$

with α as the input angle, β as the exit angle, m as the order, and a as the groove spacing, This should enable one to calculate desired grating angles for certain wavelengths. At present, the `lowres` and `hires` commands do not support grating tunings beyond 2.4μm. Working in this long-wavelength regime will necessitate using the lower level `grating` and `echelle` routines, or using a higher order setting then manually selecting the appropriate filter.

5.3 Camera Commands

The following words (commands) are read in when the `rmacf cam` command is entered upon startup. Refer to the standard IR camera user manual for more detailed descriptions and additional commands.

t `tint` — Integration time for each frame. Can take *float* or *integer* arguments for t. The integration time can range upwards from 0.375 seconds, but see the discussion of `mparm2` below.

i `mparm2` — Number of non-destructive reads at beginning and end of integration. For integration times less than 6.0 seconds, use a value of $i = 1$ for MPARM2. For longer integrations, use $i = 16$ for MPARM2. The value, i, should be an *integer*.

i `frames` — Set this to co-add i frames (an *integer*) into a single data file. This command also issues a i `cscale` command.

i `cscale` — Should set i equal to (the number of frames)$\times$(the number of reads), or to (FRAMES)$\times$(MPARM2). All this does is sets the display to a consistent scale, such that saturation is always at the same display value (20,000 for D80). Note that the `frames` command automatically sets CSCALE to the same thing. This is okay if MPARM2 is 1, but is wrong otherwise. The stored data is independent of the value of CSCALE.

`goi` — Go immediately. This command sends a request to the camera to take the specified number of frames of the specified integration time. In other words, this command is the "take a picture" command. The `go` command does essentially the same thing, but prompts for object name, etc.

`snapi` — Similar to `goi`, but this command also grabs a sky image after the object image. For the sky image, a telescope move command is issued, the image type changes to "SKY", and an equal-length exposure is taken of the sky, after which the telescope returns to the original position, with the image type field restored to its original value. The sky position is determined by the NOD-E and NOD-N values (see Section 5.4). Like `go`, there is also a plain `snap` command that first prompts the user for information.

`/77k` — Moves the 77° blocker in front of the array.

`/z` — Moves the Z band filter into place.

`/j` — Moves the J band filter into place.

`/h` — Moves the H band filter into place.

`/ks` — Moves the K_s band filter into place.

`/k` Moves the K band filter into place.

λ `cvf1` Moves the narrow (1.3%) bandpass CVF into place, centered at wavelength λ μm, which is a *floating-point* value. This filter (in D80) runs from 2.0–2.5μm.

λ `cvf2` Moves the medium (5%) bandpass CVF into place, centered at wavelength λ μm, which is a *floating-point* value. This filter (in D80) runs from 1.5–3.0μm, and is the primary order-sorting filter used throughout this wavelength range for both the high-resolution and low-resolution spectral modes.

`/lens` Places the filter-wheel lens in front of the array, allowing one to image the pupil (secondary mirror) for the purpose of assessing the camera alignment within the gimbal.

`lo` Open secondary lid, so that light around the edge of the secondary comes from beyond the telescope. This action reduces thermal background, as the warm lid is replaced by cold sky. The `/ks` and `/k` filter commands automatically open the lid, unless it has been locked with `ll`. A sustained beep sounds when the lid is in motion.

`lc` Closes secondary lid, so that light around the edge of the secondary comes from the dome-temperature lid itself. This action reduces non-thermal background, and should be implemented shortward of 2μm. The `/77k`, `/z`, `/j`, and `/h` filter commands automatically close the lid, unless it has been locked with `ll`. A sustained beep sounds when the lid is in motion.

`ll` Locks the secondary lid so no action is taken when the `lo` or `lc` commands are issued, which also holds for filter changes.

`lu` Unlocks the secondary lid, such that the `lo`, `lc`, and filter commands will affect a motion of the lid. This is the normal lock state of the lid.

5.4 Telescope Commands

The following commands pertain to moving the telescope and the guider, or both at once. Except where noted, these commands are read in with the **`rmacf cam`** command as entered upon startup. Refer to the standard IR camera user manual for more detailed descriptions and additional commands.

$\Delta\alpha$ $\Delta\delta$ `mt` Move telescope $\Delta\alpha$ arcseconds East, and $\Delta\delta$ arcseconds North. $\Delta\alpha$ and $\Delta\delta$ are *floating-point* numbers, and negative signs affect motions West and South, respectively.

$\Delta\alpha$ $\Delta\delta$ **mtg** Same as the `mt` command, but move the guide head in the opposite direction by the same amount thus leaving the guider looking at the same spot on the sky. In other words, keep the guide star. Obviously this command only makes sense for small moves within reach of the guide head.

$\Delta\alpha$ **e** Move telescope $\Delta\alpha$ arcseconds East, where $\Delta\alpha$ is a *floating-point* number.

$\Delta\alpha$ **w** Move telescope $\Delta\alpha$ arcseconds West, where $\Delta\alpha$ is a *floating-point* number.

$\Delta\delta$ **n** Move telescope $\Delta\delta$ arcseconds North, where $\Delta\delta$ is a *floating-point* number.

$\Delta\delta$ **s** Move telescope $\Delta\delta$ arcseconds South, where $\Delta\delta$ is a *floating-point* number.

x y θ **mvpix** This command comes from `d81.m`, and moves the object around on the field of view, keeping the guide star in the guider. This is opposite the philosophy of moving the telescope. In essence, this is simply an `mtg` command with a coordinate transformation. All arguments are *floating-point* values, with x representing the number of $0.167''$ pixels to move to the right, and y representing the number of $0.167''$ pixels to move in the up direction. The third value, θ, is the Cassegrain Ring Angle, in degrees. For instance, the command: `10. -6. 75. mvpix` moves the *object* 10 pixels to the right and 6 pixels down if the ring angle is currently 75°. Do not be alarmed by the message on the screen that the guider is locked off, no action. This simply means that during the move, the guider is turned off.

gsky This is really just the latter part of a `snapi` command, from `d81.m`. It changes the image type to "SKY", moves to the designated nod position, takes an exposure, then returns both the telescope and the image type to their original fields. Useful for G-stars after a `goi` command, or for a quick sky-grab.

$\Delta\alpha$ **node** Set the nod to $\Delta\alpha$ arcseconds East. $\Delta\alpha$ is a *floating-point* value. This nod is used by `snap` and `gsky` to determine the sky offset.

$\Delta\delta$ **nodn** Set the nod to $\Delta\delta$ arcseconds North. $\Delta\delta$ is a *floating-point* value. This nod is used by `snap` and `gsky` to determine the sky offset.

$\Delta\alpha$ $\Delta\delta$ **nod** Set the nod to $\Delta\alpha$ arcseconds East and $\Delta\delta$ arcseconds North. Both $\Delta\alpha$ and $\Delta\delta$ are *floating-point* numbers. This nod is used by `snap` and `gsky` to determine the sky offset.

$\Delta\alpha$ $\Delta\delta$ `og/o` Set the offset guide head origin to $\Delta\alpha$ arcseconds East and $\Delta\delta$ arcseconds North. $\Delta\alpha$ and $\Delta\delta$ are both *floating-point* values. Should only have to set once per run, and usually then it's set by: `0. 0. og/o`.

$\Delta\alpha$ $\Delta\delta$ `og/r` Send the offset guide head to $\Delta\alpha$ arcseconds East and $\Delta\delta$ arcseconds North of the guider origin. $\Delta\alpha$ and $\Delta\delta$ are both *floating-point* values, and are recorded in the header variables OGX and OGY, respectively. The `/r` stands for rectangular coordinates.

`og` This updates the guide head position, and is used to verify that the guider is where it thinks it should be. Most commonly, this is used if the Cassegrain ring angle has changed after the last `og` command was issued.

`agon` This turns the auto-guider on, such that Mirella has control of the MINC computer. It is necessary that the auto-guider is on for many operations to work correctly.

`agoff` Not surprisingly, this turns the auto-guider off.

5.5 Display Commands and Other Miscellany

The following commands are read in with the `rmacf cam` command as entered upon startup. Refer to the standard IR camera user manual for more detailed descriptions and additional commands.

`wait` Wait for current exposure to finish before processing the next command.

`lastfile` Returns *integer* corresponding to frame number of last *complete* exposure. This is often used to feed `pdiff`, as in `lastfile 102 pdiff`.

i `nextfile` Sets the frame number in which to place the next exposure. If you set this to overwrite previously taken frames, the old frames must first be deleted.

i `dp` Display Picture with frame number *i*, an *integer*.

`dcp` Wait, then Display Current Picture. If no exposure is in progress, this displays the last picture, like the `dlp` command listed below. This command is essentially a `wait lastfile dp` command.

`dlp` Display Last Picture, as referenced by LASTFILE.

`odiff` Subtract (LASTFILE-1) from LASTFILE and display. The command means "object difference", and is used when the sky frame is taken *before* the object frame. No `wait` is built in, so `goi wait odiff` is frequently seen.

`sdiff` — Subtract LASTFILE from (LASTFILE−1) and display. The command means "sky difference", and is used when the sky frame is taken after the object frame. No `wait` is built in. The `snap` command does have a wait, so `snapi sdiff` is a frequently used command.

i j `pdiff` — Subtract frame *j* from frame *i* and display. Both *i* and *j* are *integers*.

i j `lindisp` — Change the display stretch to a linear ramp from value *i* at the low end to value *j* at the high end. Both *i* and *j* are *integers*.

`cu` — Enter cursor mode. This offers a means to explore the currently displayed image, allowing multiple cursors to move across the display as both markers and probes. Cursors #0 and #1 display their x and y positions, as well as their data value at the bottom of the display screen. Cursors #0–3 have distinct shapes, going plus, diamond, box, x-shape, respectively. Cursors are moved around using the numeric keypad on the right side of the keyboard. The eight keys surrounding the "5" key move the cursor in eight corresponding directions. The `cu` command enters its own environment with the following commands:

- `+` — Increment to next cursor.
- `-` — Decrement to previous cursor.
- `x` — Print cursor position and data value on terminal.
- `f` — Speed up cursor (FAST) one notch.
- `s` — Slow down cursor (SLOW) one notch.
- `c` — Change cursor color (`0`=black, `1`=white, `2`=blink)
- `q` — Quit cursor mode, returning `M>` prompt.

`box` — Statistics in a box. Enters cursor mode and provides two cursors (usually pop up at screen center) to move around, ultimately defining opposite corners of a box. The cursors are toggled in the usual way, with the (`+`/`-`) keys, and otherwise manipulated in the same ways as normal cursors in cursor mode. When the box is defined, quitting cursor mode (with `q`) draws the box on the display, and prints statistics information to the terminal.

i `photometric` — Specify the photometric conditions (for inclusion in the header). The *integer*, *i*, can be `1` (photometric), `0` (not photometric), or `-1` (unknown).

`poff` — Turn off requests for photometric status updates.

`object` — Prompts for object name.

`typ` Prompts for image type (out of a list, e.g., Dark, Flat, Object, Sky, etc.).

`abort` Abort the exposure currently being taken. Do not write to file, and reset NEXTFILE to the aborted frame number.

`^C` CONTROL-C interrupts the current action, sending a prompt saying that you are impatient, and asking if you want to return to the interpreter (do you want a prompt back?). Unless the CTRL-C was a mistake, you'll want to answer yes (`Y`). You'll then get a prompt, and will most likely `abort` the exposure, if that's why you hit CTRL-C in the first place. It is also useful for getting a prompt back after a `goi dcp` command, or the like. In this case, the exposure will continue unless aborted, but the `dcp` is prevented. The virtue of this is that you get a prompt back in case there is something you want to do.

`spawn` This temporarily leaves Mirella, providing a VAX prompt. This is often used to delete files, edit word files, or check file headers. When finished with the task, type `eoj` at the `$` prompt to return to Mirella.

`/end_night` This command should be performed whenever there is about to be a significant downtime. It pulls the tertiary out (`/o`), protecting it from junk, puts the 77°K filter in (`/77k`), protecting the array, and closes the secondary lid (`lc`). It doesn't have to be the end of the night for this command to be sensible.

`bye` Exits Mirella, leaving a VAX prompt.

5.6 User-Defined Commands

Sometimes frequently repeated command sequences are most efficiently placed into a user-defined FORTH word (command). Any name can be assigned to a word, though if the chosen name is already associated with a previously defined word, Mirella will complain that the word is not unique, and the old function will be replaced by the new function—sort-of. The caveat is that any other word that uses the doubly-defined word still uses the definition that was in place at the time of its own definition. There is a `forget` command to un-define a word, but *every* word defined *after* the erased word will also be erased. So use `forget` only if familiar with its operation, and *use with caution* even then.

That said, the best way to explain word definition is by example. In the following examples, the `]` symbol is the prompt Mirella uses during word definition. Any number of carriage returns are acceptable, being treated much like spaces. The definition is started with a colon command, and terminated with a semi-colon.

```
M> : dolamp
] /o 10. tint
] neon goi dcp argon goi dcp        (dcp has wait built in)
] krypton goi dcp xenon goi dcp
] lampoff goi wait sdiff mspect
];
M>
```

This example defines the word **dolamp**, which, when executed, will move the tertiary mirror out of the way, set the integration time to 10 seconds, then take five exposures, four with the different lamps on and one with lamps off. The lamp-on raw images are displayed as they are obtained, as is the final difference. When all is done, the tertiary mirror is moved back in place[1]. The next examples abbreviate the process of switching back and forth between long and short exposure regimes.

```
M> : short
] 1 mparm2 10 frames 0.375 tint
];
M> : long
] 10. tint 16 mparm2 1 frames 16 cscale
];
M>
```

The **short** command sets up the shortest possible exposure, 0.375 seconds. Ten frames are used to better average atmospheric fluctuations. The **long** command leaves this regime for the more normal long exposure setup. In the **short** example, note that the **tint** command comes last. This is to prevent Mirella from complaining that the integration time chosen is too short for the current value of MPARM2. It would still do the right thing if the **tint** command came first, but would issue a warning. In the **long** example, the **tint** command could go anywhere, as all exposure times greater than 0.375 seconds are valid with MPARM2 set to 1. Note also that the **short** command does not include a **cscale** command. Recall that **frames** automatically changes CSCALE to the same value. So in this case all is well. It is for this reason that **cscale** comes *after* **frames** in the **long** example.

5.7 $f/70$ Tip-Tilt Guider Commands

If using the $f/70$ tip-tilt guider controller (the MINC) rather than the Palomar facility guider, the guiding workload is higher, but with potentially sharper images/spectra. This section is by no means complete, and may be the only

[1] Ordinarily, I would not include the tertiary commands. I prefer to do this manually because if two `dolamp` commands were executed in a row (i.e. for two grating settings), the mirror would move back and forth unnecessarily, wasting time and effort.

documentation ever attempted for this system. Bear in mind that this subject has some nebulous regions in my head. Only Keith[2] knows this system cold.

Not discussed in this chapter is the operation of the Quantex DS-12, which is a key element in the guider system. The operation of the Quantex is briefly discussed in Section 6.1.

5.7.1 Basic Setup and Operation

If you know nothing else about the guider, at least know the `GO` command. This activates guiding. How is guiding stopped? By hitting <RETURN>. The `GO` command has three bits to toggle. `GO 7` runs the guider with all three options on: (1) Basic guiding (called auto-guiding), (2) Tip-tilt guiding, and (4) the graphical stripchart. Simply multiply the numbers in parentheses above by 1 (on) or 0 (off) and add for functionality. Thus `GO 5` runs the guider without tip-tilt.

Aside from the `GO` command, there are a number of parameters to set. This is not done in stack-style, but in a more conventional `command` *argument* syntax. Entering the command with no argument returns the current value, with no change made. This is a convenient way[3] of checking the current parameter values.

Be aware that this system was created without concern for robustness or user-friendliness. Therefore if the wrong thing is typed, "The whole world may blow up and you'll be left with nothing"[4].

5.7.2 The Commands

`GO` i — i is a bitmask, with 1=guiding, 2=tip-tilt, and 4=stripchart. See explanation at the beginning of this section if confused. To stop guiding, hit <RETURN>.
Examples:

`GO 1`	Guide without stripchart and without tip-tilt.
`GO 5`	Guide with stripchart, but without tip-tilt.
`GO 7`	Guide with tip-tilt and stripchart

`GO` — If no number is provided, the last used value is assumed.

`HEAD` [θ] — Angle of guide head. Must match actual angle of guide head within 10° for proper guiding. To get correct value, type og in Mirella to find out.

---

[2] I refer to the illustrious (wacky?) Keith Matthews, or KYM. He built the $f/70$ tip-tilt secondary, and wrote the control software. He knows it.

[3] Heck. It's the only way!

[4] A quote from Keith Matthews.

F70A [θ] Angle of the current secondary chop direction. Should match the actual angle within 10° for proper guiding. Look at numeric LED display near bottom of $f/70$ rack for appropriate angle. Remember to change this parameter if the secondary is moved.

BOX [n] Set guide box to n pixels across. Usually $n = 4$ is good, though bad seeing calls for a bigger box ($n = 5$) and good seeing will benefit from a smaller box ($n = 3$). I have seen conditions good enough to use a 2-pixel box, but that's very rare. BE AWARE that the smaller the box, the faster the computation, therefore the faster the guiding feedback. The rate-controllers below (or "gains") are therefore affected by the box size, and are not invariant in their feedback rate.

TVLL [x] TV Low Level control. Default is 0.1. Keith Likes 0.05–0.07. This sets the sky background level above which to look for the guide star.

AGG [i] Auto-Guiding Gain. This sets how fast the system issues telescope move commands in response to excursions from the box center. High number is fast, low number is slow. Good conditions are suited by a value for i (an *integer*) of 5–10. If the star is faint, lower this number to the 1–4 range. Keep in mind that box size also affects the response time (see `BOX` entry).

F70G [i] The $f/70$ Gain. This sets how fast the secondary tries to track image wander in response to excursions. For faint stars or poor seeing, use a low value for i (an *integer*), from 1–4. For decent conditions with a reasonable guide star, set this to 5–10. For the best of conditions (i.e. 9^{th} magnitude guide star, $0.5''$ seeing) this value may go up to 15 or so. Keep in mind that box size also affects the response time (see `BOX` entry). When changing `F70G`, also adjust `F70D` accordingly.

F70D [i] The $f/70$ Damping. For low values of `F70G` (< 5), this parameter doesn't do much. For these cases, use a value of $i = 0$. For higher values of `F70G`, use a value for i that is maybe 70% of the `F70G` value. Or set i to be smaller than `F70G` by about 3–4. Only Keith will get it right.

5.7.3 Normal Operation

Normally, when going to a new guide star, do the following things in roughly the suggested order. Remember that to check values of parameters, simply type in the parameter name with no argument.

- Retrieve `HEAD` angle for guide head (from Mirella og command) and set.
- Check that `F70A` is properly set. Only changes when secondary chop angle is adjusted.

- Verify (visually on guider TV) that box size is reasonable for the current seeing.
- Check the values of `AGG`, `F70G`, and `F70D` for reasonable settings.

Now type `GO`, or some variant thereof, to start guiding.

Be aware that if issuing a large `mtg` command, the guide star's position angle relative to the new field may significantly differ from the old position angle. This means that the `HEAD` angle has changed. Be sure to check the head angle after large moves, and reset if necessary.

When moving the telescope with `mvpix` or `mtg`, a message will appear on the screen that the autoguider is locked off, with no action taken. This message simply means that during the move, the guider is turned off. Operation will return to normal once the move is complete. The stripchart will verify that the guider resumes guiding.

5.7.4 That Wacky Stripchart

The graphical stripchart displayed on the guide computer screen is actually a helpful tool. To first order it signals whether or not guiding is going on. If points are being added to the right, and the dots are scrolling by, the guider is doing its thing (at least it thinks it is).

The shape of the strip chart can indicate at a glance the stability of the atmospheric conditions. A level stripchart chugging along indicates a stable sky—quite possibly photometric. There are two points plotted for each time step. The top point is the total flux inside the box, with some weighting unbeknownst to me. The lower point is the sum of the flux in the central four pixels. So under photometric conditions with variable seeing, the spacing between these two points will reflect the seeing fluctuations. Under less than ideal conditions, or with a faint guide star, the chart may be all over the place to the point that distinguishing two separate stripcharts is impossible.

5.7.5 Abnormal Operation

If the guide star is pushed out of the box, or appears to orbit the box, the angle information is wrong (by $\sim 180°$ in the first case, and $\sim 90°$ in the second case). Check the `HEAD` and `F70A` values.

If you accidentally hit the BREAK key, as I have done plenty of times, the familiar `$` prompt will disappear, and a scary `@` prompt appears. Hit `P`, then <RETURN> to get back to the `$` prompt (of course!).

If the system goes totally haywire, go over to the MINC computer (far left), and follow the instructions taped to the top of the box. The few times I've had to do this, it has worked well.

Chapter 6

Other Hardware

Chapter 5 focused on computer operations, which encompasses the majority of observing tasks. There are, however, some pieces of hardware that need to be manipulated during the course of observation. The devices covered here are (roughly right-to-left from computer):

- The guider TV's Quantex DS-12 image processor
- The function generator
- The secondary angle control
- The crosshair machine
- The center field TV's Quantex DS-12 image processor

6.1 The Guider Quantex

The guider Quantex sits just below the guider TV, and above the oscilloscope on top of the $f/70$ tip-tilt rack. The most important control on the guider Quantex is the gain knob at lower left. Adjust this to bring the star up to a reasonable brightness level (all the way up for faint stars). The optimal gain level will have the star's central pixel saturating (rolling the color map over for this pixel, turning it dark[1]) a small fraction of the time. Remember to turn the gain all the way down before a telescope move (and hit <RETURN> on the guider computer to cease guiding). The guider Quantex should have the following nominal settings:

Mode:	Average (1 frame count for bright objects)
Source:	Memory
Gain:	Manual

[1]Known to us as "brown-capping".

Video Gain: 4×

Bit Level: 6 bits

White Level: roughly 9 o'clock position

Black Level: roughly 12 o'clock position

The white- and black-levels can be tweaked to suit.

For faint stars, one can `average` 2 or more frames, but adjust the guider `AGG` to a lower value accordingly. If the star is still not bright enough, try the `integrate` mode. If you resort to this, turn `F70G` and `F70D` to zero (or use `GO 5`), as tip-tilt corrections in this regime are meaningless.

Just a note: the guider is extremely good at picking up faint stars. It can guide on stars that are barely visible to the eye on the screen. Motion of the strip chart will indicate when guiding is taking place.

When the sky is bright (i.e. twilight, moonlit, etc.), the sky background will be visible in the guider monitor. The offset guider is a hexagonal fiber bundle, whose shape will become apparent under these conditions. The size of the hexagon is 15″ across the flats (not corner-to-corner).

6.2 The Function Generator

The function generator is a beige box below the oscilloscope, which is just below the guider Quantex. The output of this generator is sent to the chopping secondary, forcing the secondary to wobble in the manner dictated by the function generator. In normal operations, the generator function knob is set to DC, but can be set to sine, triangle, or square waveforms.

The angle on the sky that the secondary moves is determined by the secondary angle control, discussed in Section 6.3.

The amplitude and frequency of the chop are controlled via the function generator. The secondary is a physical block of material, and has limits about how fast and how far it can be moved. Don't over-do it. There are no safety mechanisms, and anyone is perfectly capable of breaking the darned thing with careless turns of knobs. So know what you're doing when adjusting the function generator.

There is a knob at lower right with a ten-turn potentiometer and a turn counter (100 units per turn). This knob controls amplitude. There is also a pull-out-to-flip switch located just to the left of the amplitude knob labeled 20dB. Pulling this switch up increases the amplitude by an order of magnitude. Be careful when doing this that the ten-turn pot reads less than about 200. If without the 20dB increase activated there is still not enough throw for your purposes, turn the amplitude *all the way down* before throwing the switch. This will keep the secondary attached to the telescope. Once flipped, you may increase the amplitude to the desired amount.

A word about the 20dB switch. Even after turning the function generator back to DC, some residual noise will cause a sub-arcsecond wiggle in the secondary, which could slightly elongate point source images. To take care of this, simply get into the habit of turning off the 20dB switch whenever turning off the chopper (switching back to DC). If the amplitude was already set to a reasonable value before flipping the 20dB switch off, don't bother turning amplitude down before flipping the switch back on, as suggested above. In this case you already know that the chop amplitude with the 20dB switch on is not going to hurt anything.

As for frequency, there's hardly ever a reason to adjust this. 50 Hz is a reasonable value, but don't go too much higher than this.

6.3 The Secondary Angle Control

Below the function generator in the $f/70$ guider rack is a simple box with a 4-digit LED display in the center, and a double-pole switch underneath. The 4-digit number reads the position angle from North of the secondary chop direction. The range is $-90 <$`F70A`< 90. The use of `F70A` here is no coincidence. This is the same angle that the guider computer needs in order to know how the secondary is oriented (see Section 5.7).

To change the secondary angle, simply pull the switch to one side (guess which way) and hold it there while the numbers change. Let go of the switch when approximately one degree away from the target angle and wait a second for it to stop. Bumps of the switch can produce the small changes necessary for tuning.

If the angle is equal to the Cassegrain ring angle (modulo 180) then the chop direction will be along the HNA slit direction.

Tie a mental string around your finger to remind yourself to change `F70A` on the guide computer before guiding again (assuming you're using the tip-tilt system). Better yet, change it now.

6.4 The Crosshair Machine

This beautiful piece of work sits below the center field camera monitor. There is a 6-position switch labeled 1-2-3-4-1&2-3&4, a toggle for white/black, and eight locking potentiometers.

The crosshair generator displays one of four crosshairs on the center field display, or certain combinations of two at a time. The crosshair number is selected with the 6-position switch, and made white or black with a toggle switch. The crosshair positions are manipulated with the locking pots. The top row of four controls the x-position of cursors 1–4 (left to right), and the bottom row of pots controls the y-positions. Use these to mark the central position, the position of the guide head for G-star sweeps, or whatever makes sense. The locking pots operate by sliding the tab to one side (thus unlocking), dialing the knob, then sliding the tab back into the lock position.

To locate the appropriate central position, move the guider to the origin and guide on it. Then move the guider out of the way and place the crosshair on the star position. This ties the guider origin (also the center of the HNA field) to the crosshair. This sequence will look like:

Place a star in the center of the field.
`M> 0. 0. og/r`
`minc$ HEAD` θ (get θ from `og` output)
`minc$ GO`
`minc$ <RETURN>` (once guider has locked on)
`M> 50. 50. og/r` (move guider out of the way)
Now adjust crosshair to star position.

6.5 The Center Field Display

The center field camera display is controlled with a Quantex image processor, just like the guider camera. Therefore I won't repeat the basics of operation or default settings, as these are virtually identical to the guider Quantex setting. Refer to Section 6.1 for the general operations and settings. The only difference is that you'll probably be better off with a bit level setting of 7 bits for increased dynamic range. I'll also repeat the request to turn the gain all the way down before a telescope move. This will save the Xybion camera from getting zapped by the moon or some other bright source during the move.

The center field F.O.V. is 70″ across, and is very useful for the following:

- Initial pointing, centering up on SAO star
- Focusing on star
- Finding guide star
- Verifying position of tertiary mirror
- Verifying chop angle

One other caution here regards the calibration lamps. If the gain is not down when the lamps are turned on, the camera will be overloaded with light. Turn the gain down before doing calibration lamps.

The field orientation is in the conventional sense when the ring angle is 90°. In general, the left side of the display points towards the position angle equal to the ring angle. In comparison to the HNA field, the left-right direction is identical, while the vertical direction is flipped. Flipping the arrows in Figure 2.1 about the horizontal yields the center field orientation.

Chapter 7

Observing Cookbook

This chapter is divided into 8 sections covering different operations, roughly in order of complexity. Examples offered are for typical scenarios, and will vary depending on the observation. Explanations abound, so it should be easy to understand what is happening. In all the examples, a `M>` prompt represents a Mirella prompt, a `$` represents a VAX prompt, and a `minc$` represents the prompt on the guide computer (if using the $f/70$ tip-tilt system). Refer to Chapter 5 for a full description of the commands encountered in this chapter.

The following observing operations are covered in this chapter:

- Mapping the Slit
- Dark frames
- Dome Flats
- Imaging Sky Flats
- Typical object observation
- Obtaining a PSF
- Standard Star
- G-star for atmospheric calibration & flat field

7.1 Mapping the Slit

Each time the motors are homed (i.e. the beginning of the run), the slit mechanism has a slightly different calibration, for whatever reason. As a result, the command `1.0 slit` may produce a slit that is anywhere from 0.8 to 1.2 arcseconds across, though the target is exactly $1.0''$. In order to understand the exact width of the slit, as well as its location on the array, I typically map out the slit before the run. This is a good activity for the first day, after instrument operation is verified (Section 4.3). Though I have graduated to using an IDL procedure to perform the analysis, I present here the tried and true way, as I practiced it for years. Come on, it's fun.

7.1.1 Taking the Data

Find a piece of graph paper to make your life simple. Grab another person to make it go even faster. The method involves taking a thermal image in the K-band (just of the dome environment) through the narrow slit, then measuring its width and position on the array.

A typical command sequence goes like this:

`M> mspect`	(move tertiary into place)
`M> oslit`	(start from open position)
`M> /k`	(use K filter for thermal response)
`M> fmi`	(flip mirror in for image, not spectrum)
`M> 10. tint`	(may adjust later)
`M> 1.2 slit`	(best to start wide)
`M> goi dcp`	(take exposure and display)
`M> cu`	(enter cursor mode for measurement)
...much measuring and plotting...	
`q`	(exit cursor mode)
adjust `tint` for convenient signal level, if desired	
`M> 1.0 slit`	
`M> goi dcp`	
`M> cu`	
etc.	

I usually shoot for a peak signal level of ~10,000dN, which makes for convenient plotting. But the style of graph paper may decide the most convenient scaling. Adjust `tint` accordingly, but be aware that going below 6 seconds requires different camera settings, as discussed on page 44, and in Section 5.3. Another way to lower the level is to use the **`/ks`** (K_s) filter for less thermal flux.

I always try to approach the narrow slit from the open direction. This is what is done in practice during observation. While not much hysteresis has been observed, it's just the right thing to do, dad-gummit.

It is convenient to place cursor #0 at $x = 60$ and cursor #1 at $x = 180$, as these are near the nominal left and right slit positions. See section 5.5 for information on cursor mode. I have found that the quickest way to accomplish the task is to have one person plot while the other handles the cursor and camera duties. Be sure to mark the y-value of the starting cursor position so that one may determine the slit center location.

7.1.2 Slit Width Map

In the end one has information on the FWHM of the slit (at two x-locations) for a variety of slit widths, as well as central y-value at left and right. A plot of slit width versus input parameter reveals the linear relation between input parameter and actual width. Ideally, the intercept would be at the origin, and `1.0 slit` would produce a 6-pixel wide slit. In practice, neither of these are true, and even the slope has been seen to vary from run-to-run, though for what reason I cannot begin to imagine.[1]

In principle, two readings are all that is needed. After all, the relation has at least always proven to be linear.[2] But three or four widths allow a more accurate width assessment. Once the relation is known, the decided slit width can be easily related to the slit parameter that must be typed in. Because the entered value does not correspond to the real width in a one-to-one fashion, I term the input value "Slit Parameter", and record it as such on the log sheets.

7.1.3 Slit Position

The other matter regarding the slit center is important for exact placement of targets in the slit. One thing that is immediately obvious upon performing the measurement is that the right side of the slit is lower than the left side of the slit. The slope is very nearly one pixel over 120 pixels. *REMEMBER THIS!* The slit center may be at $y = 171$ on the left, and at $y = 170$ on the left.

Now enter cursor mode, select cursor #2 (box), and place it on the nominal left-hand slit position, around $x = 60$. Periodically hit **`x`** as you move the cursor to get updates on its coordinate position. The cursor moves in half pixel steps, offset by 0.25 pixels from the integral values. Thus the left position may end up being (60.25,171.25). Put cursor #3 on the right slit position in the same manner, around $x = 180$. These two reference points will serve as your guide in positioning objects squarely on the slit. The two cursors are displayed in their appropriate positions in Figures 7.3 and 7.4.

7.1.4 Cleaning Up

When the slit mapping is complete, move the tertiary mirror out of the way and put the camera and secondary lid in safe mode with the following two commands:

`M> /o`	(move tertiary out)
`M> /77k`	(close lid and put in cold plug)

7.2 Dark Frames

Often times, it is good to take dark frames at the beginning of the run, in the daytime, after everything is set up but there is time before dinner. I usually take a whole suite of darks, many different integration times, and usually 5 exposures per integration time (enough to perform a meaningful median). Since this is usually the first data I care to keep, I reset the **`nextfile`** to 1 to start anew. I try to get darks for every exposure time I'm likely to use.

[1] After all, it's gears and mechanics. I'm quite surprised to see slope variations.

[2] At least we have that!

```
M> 1 nextfile              (do this only if starting out fresh)
M> spawn
$ del *.hdr.*              (CAUTION! will wipe out everything!)
$ del *.img.*              (CAUTION! will wipe out everything!)
$ eoj
```

The preceding chunk should be used only if starting fresh with no useful data taken as yet.

```
M> /77k                    (puts in 77 Kelvin blocker)
M> object                  (will prompt me for object name)
   dark
M> typ                     (will prompt me for image type)
   d                       (will select Dark out of list)
M> 10. tint
M> goi dcp goi dcp goi dcp goi dcp goi wait odiff
```

This command takes five darks in a row, displaying each as it goes, and displaying a difference of the last two when done. This serves as a signal to when all is done, since the difference looks different from the raw dark. You can tell from across the room when it's done. See Figure 7.1 for the appearance of a raw dark frame. Figure 7.2 shows a subtracted dark frame, which is read-noise dominated. Sometimes the four quadrants subtract differently, which is no cause for alarm. This can easily be remedied in software. The vignetted edge of the array is your friend here.

```
M> 20. tint
M> goi dcp goi dcp goi dcp goi dcp goi wait odiff
M> 30. tint
M> goi dcp goi dcp goi dcp goi dcp goi wait odiff
M> 60. tint
M> goi dcp goi dcp goi dcp goi dcp goi wait odiff
M> 120. tint
M> goi dcp goi dcp goi dcp goi dcp goi wait odiff
M> 300. tint
M> goi dcp goi dcp goi dcp goi dcp goi wait odiff
```

This last sequence takes 30 minutes, and is a good dinner-time project. Leave it running while enjoying the yummy vittles at the Monastery.

If there are other exposure times you expect to use, you probably want to get a few darks at these integration times as well.

7.3 Dome Flats

Dome flats are used in the spectral flat-fielding process, but not directly. The G-stars are used for the real flat-fields, but the dome flats help tie the G-star

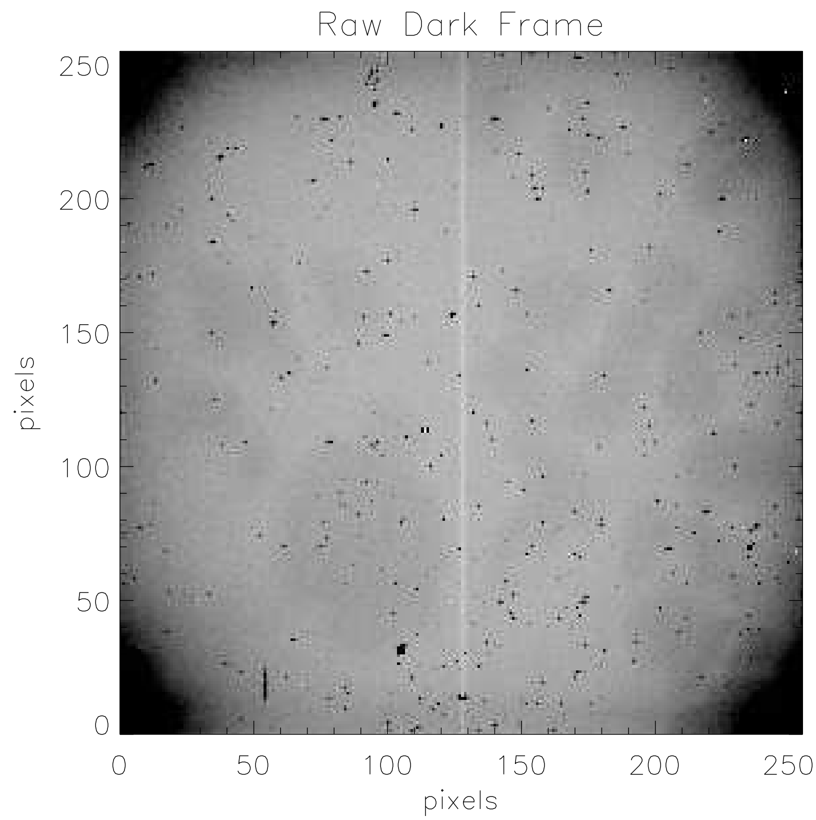

Figure 7.1: A raw 20 second dark frame with D80.

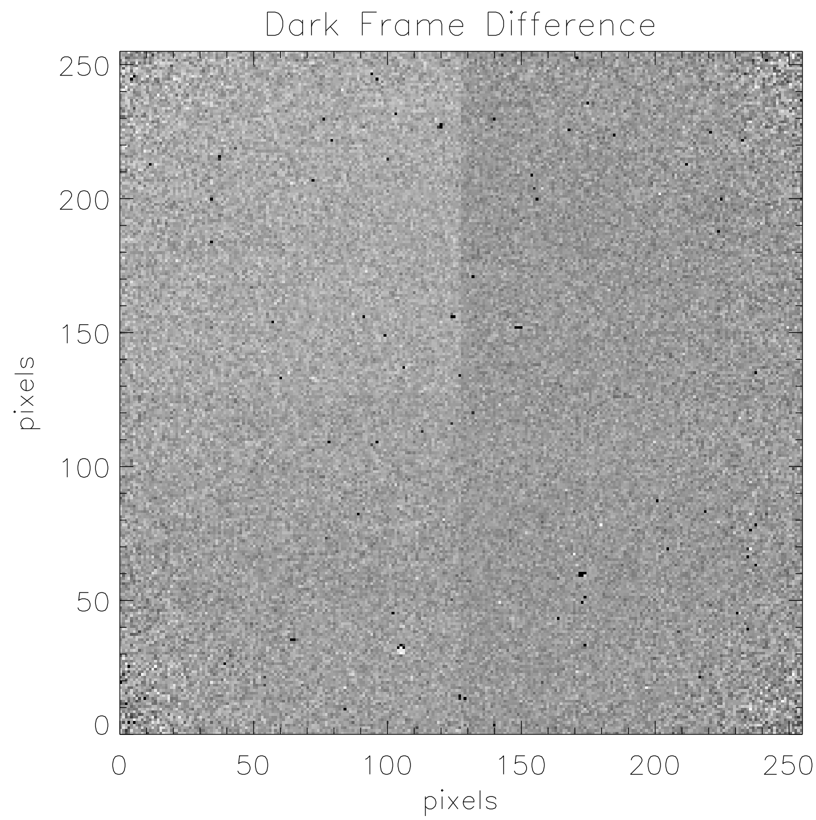

Figure 7.2: Differenced 20 second dark frames from D80.

flats down, and ensure they are flat. Any non-uniformity in slit illumination while obtaining the G-star flat may be calibrated out via the dome flat, which at least has a uniformly illuminated slit.

The chief reason for using G-star flats as opposed to dome flats is the fringing problem. The HgCdTe array in D80 has a sapphire coating on it that acts as a Fabry-Perot device. It is never noticed in broad-band imaging, as the fringes are averaged over. But the fringes show up in spectral frames. It is found that the fringing isn't rock-solid repeatable. It may be flexure, but whatever the reason, the best cure seems to be to get the flat-field as close in time and telescope orientation as possible to the object observation. Thus the G-star flats. Because it is hard to ensure uniform illumination of the slit with G-star photons, the dome flats provide this uniform reference.

Dome flats are performed with the dome "hi-lamps" turned on and off. The Hi-lamp switch is at the telescope control panel, at the bottom of the diagonal panel. It is a three-position switch: up is hi-lamp on, down is low-lamp on, and center is both off.

The dome flats (and other flats) should also be done with the secondary lid closed. I won't go into details about the lid here, but having the lid closed ensures that light will not be coming through around the secondary mirror.

I find that dome flats are most efficiently done near the end of the run, because until then it may not be known which grating settings need calibration.

One last note: It may be desirable to obtain lamp spectra at each grating setting along with the dome flat to wavelength-calibrate the dome flat. In practice, I have never used such calibration, assuming it to be similar enough to the observation calibration. Because of the minor role of dome flats (given G-flats), this step is really unnecessary. If spectral shape calibration is important, however, you may want lamp spectra with every G-star flat you take.

7.3.1 Getting Set Up

First open the primary mirror cover. If you've never done this, find help.

`M> mspect`	(put tertiary into place)
`M> lc ll`	(close secondary lid and lock it)
`M> 60. tint`	
`M> object`	(prompts for object name)
`dome_flat`	
`M> typ`	(prompts for image type)
`f`	(chooses Flat from list)
`M> 9001 nextfile`	(sets flats apart from other data)

7.3.2 Taking Dome Spectra

`M> 2.121 clowres`	(set grating, filter, flip-mirror)
`M> 0.7 slit`	(use same slit width as observation)
Turn Hi-lamp on (manually)	

```
M> goi dcp
```
After exposure, turn Hi-lamp off
```
M> goi
M> wait sdiff 2.143 clowres
```
(type while exposure is going `wait` command holds action until end)

This action is a way to streamline the process, preparing the next grating setting immediately after the exposure is done. These commands can, of course be separated onto their own lines, which you may want to do at first. The above method is a little more efficient. Now to continue:

Turn Hi-lamp on
```
M> goi dcp
```
After exposure, turn Hi-lamp off
```
M> goi
M> wait sdiff 2.033 clowres
```
(set up for next calibration)

After exposure, turn Hi-lamp on
```
M> goi dcp
M> goi
M> wait sdiff 2.35 hires
```

OH NO! forgot to turn off hi-lamp, and exposure is underway. Now there is no prompt available (due to the `wait` command). Here's what you do:

`^C` (Ctrl-C interrupts and asks if you are serious)
```
You are very impatient. Blah Blah Blah.
Do you want to return to the interpreter (Y/N)?   Y
```

Answer yes, and you'll get the prompt back. All commands following the `wait` command will not be executed as a result of the interrupt. Now you want to quickly abort the exposure:

`M> abort` (stops exposure, sets `nextfile` back)

Now turn off hi-lamp
```
M> goi
M> wait sdiff 2.35 hires
```

Continue going on in this manner until all the desired wavelength settings have "on-off" dome pairs. Once finished, perform the configuration clean-up described in the next section.

7.3.3 Cleaning Up

First, close the primary mirror before you forget.

`M>` *n* `nextfile` (set file counter back to the next empty frame)
`M> lu` (restores lid to unlocked status)
`M> /o` (moves tertiary mirror out into protected position)
`M> /77k` (puts blocker in front of array)

The log sheet should indicate the appropriate value for n to feed to `nextfile`.

7.4 Imaging Sky Flats

Imaging flats can be helpful things to have. Try to get at least something during the run. For the K band flats, the sun practically has to be up for the sky to be brighter then the thermal environment of the dome. I find that night assistants would rather arrive early enough to get sky flats at the beginning of the night than sit around waiting for the sky to get bright at the end of a long night. If you start within 10 minutes after sunset, you'll probably be fine.

The tricky thing about sky flats is that the sky is bright and rapidly changing. Short integrations are called for.

Keep the secondary lid closed for the sky flats. This will better approximate the illumination pattern of the night sky under operating conditions.

7.4.1 Setting Up for Flats

Once the dome is open and mirror cover open, it's show time:

`M> lc ll`	(close and lock secondary lid)
`M> 1 mparm2 5 frames 1.0 tint`	
`M> fmi`	(flip mirror in)
`M> oslit`	(open slit all the way)
`M> mspect`	(tertiary mirror in)
`M> object`	(prompts for object name)
`   sky_flat`	
`M> typ`	(prompts for image type)
`   f`	(chooses Flat from list)

7.4.2 Doing K and K_s Flats

Once the setup from Section 7.4.1 is done, perform the following steps.

`M> /k`	(do K first, for sky brightness reasons)
`M> goi dcp goi dcp goi dcp`	(3 makes for good combine)
`M> cu`	(enter cursor mode, and check signal level)

If the signal level reads more than about 15,000, there may be saturation problems. Saturation is at 20,000[3]. Try cutting the integration time to 0.500 or 0.375 if saturation is a problem. Saturated sky flats will do you no good.

Leave cursors #0 and #1 in the exposed field.	
`q`	(to quit cursor mode)
`M> /ks`	
`M> goi dcp goi dcp goi dcp`	(another series for K_s)

Check that level is good (5,000–10,000 is optimum). If the two cursors are already in the field, you can read off values from each image as it is displayed. Adjust the integration time if necessary.

[3] The saturation value of 20,000 is for D80, with CSCALE set correctly

Now close the mirror cover for the "off" images.
`M> goi dcp goi dcp goi dcp` (off series for K_s)
Note the level of the "off" signal and compare to "on" value.
Set `tint` to the value used for the K flats.
`M> /k`
`M> goi dcp goi dcp goi dcp` (off series for K)
Again, check levels and compare to "on" values.

If the levels of the "on" integrations (mirror cover open) are lower than the "off" exposures (mirror cover closed), then the sky wasn't bright enough thermally in comparison to the mirror cover. Try again the next night (or morning). Unless going on to do J and H flats, perform the clean-up activities in Section 7.4.4.

7.4.3 Doing J and H Flats

Imaging flats for J and H are easier in the sense that the mirror cover is never brighter than the sky, especially during twilight. But it may be necessary to wait 10 minutes or so for the sky to get dark enough to image without saturating. First, be sure that the steps in Section 7.4.1 have been done.

Open primary mirror cover
`M> /h`
`M> 0.375 tint` (as short as it gets)
`M> goi dcp goi dcp goi dcp` (3 makes for good combine)
`M> cu` (enter cursor mode, and check signal level)

If the signal level reads more than about 15,000, there may be saturation problems. Saturation is at 20,000[4]. If saturation is a problem, wait a few minutes for the sky to darken (evening twilight). If the counts are low, increase the tint accordingly. A good target level is 5,000–10,000 dN.

Leave cursors #0 and #1 in the exposed field.
`q` (to quit cursor mode)
`M> /j`
`M> goi dcp goi dcp goi dcp` (another series for J)

Check that level is good (5,000–10,000 is optimum). If the two cursors are already in the field, you can read off values from each image as it is displayed. Adjust the integration time if necessary.

Now close the mirror cover for the "off" images.
`M> goi dcp goi dcp goi dcp` (off series for J)
Note the level of the "off" signal and compare to "on" value.
Set `tint` to the value used for the H flats.
`M> /h`
`M> goi dcp goi dcp goi dcp` (off series for H)
Again, check levels and compare to "on" values.

[4] The saturation value of 20,000 is for D80, with CSCALE set correctly

Once done with flats, clean up the configuration as suggested in Section 7.4.4.

7.4.4 Cleaning Up

After finishing with the flats, here are a few items that will put the camera back into an orderly state:

```
M> 1 frames                         (be sure to remember this!)
M> 10. tint                         (a reasonable default value)
M> 16 mparm2 16 cscale
M> lu lc                            (Unlock and close secondary lid)
M> /77k                             (put in blocker)
M> /o                               (move tertiary out to protected position)
```

The last three command lines can be accomplished more expediently with the `/end_night` command.

7.5 Typical Object Observation

This is what you're at the telescope for—not for dome flats and dark frames. Calibration techniques are covered in subsequent sections. Several mock observations are spelled out below, with an attempt to cover most likely scenarios. What follows is at least a fair portrayal of my typical observing sessions. Because I have never used the high-resolution grating, and because few others have, the examples in this chapter will consist exclusively of low resolution data. The technique will be so similar for the high resolution setting that not much is lost in this approach.

7.5.1 Getting There

Much of the time, the object to be observed is faint, and will not show up prominently in the center field camera. If this is the case, it helps tremendously to first point at a nearby SAO star. If your object is bright, this step may be skipped.

Provide the object coordinates and desired ring angle to the night assistant. For faint objects, ask to go to a nearby SAO star first. The star can be used both to fine-tune the pointing, and to check and adjust telescope focus.

While the telescope moves, it is a good time to enter guide star information. See Section 7.5.2 for more on this.

At the SAO star, center up on the crosshair (use the correct crosshair; see Section 6.4), and ask the night assistant to "TX", or issue a "temporary X" command. Focus if necessary, writing down the new value when done.

Now make the short hop over to the object.

7.5.2 Start Guiding

Enter the guide star information into Mirella. If our guide star has offsets from the object of 63.7″ West and 120.2″ North, then enter:

```
M> -63.7 120.2 og/r                (put in guide star offsets)
```

This moves the guider into position, and prints guide head information to the terminal screen. Get the **HEAD** angle from this information and put it into the MINC guider computer. Also enter the secondary angle into **F70A**.

```
minc$ HEAD 332
minc$ F70A 5
```

After the telescope move is complete, if the Cassegrain ring angle has changed, update the guider with:

```
M> og                              (update guider position)
```

It's not a bad idea to do this anyway, as it ensures that the guider is where you told it to be. Turn up the gain on the guider Quantex and behold your guide star.

Adjust gains and other guider parameters (Section 5.7), then start guiding:

```
minc$ GO                           (or some variant thereof)
```

7.5.2.1 No Guide Star

If the guide star does not appear, first do an `og` command, and check the output to verify that the input coordinates are what you intended.

Next try finding the guide star in the center field camera, by "sending" the star over, centering up, then "sending it back".

```
M> /o                              (if the tertiary mirror is in)
M> -63.7 120.2 mt (move telescope to alleged guide star position)
```

Now turn up the gain on the center field camera, and look for the star. Sometimes it helps to already be looking at the TV when the telescope motion is executed, by virtue of the fact that sometimes the motion makes it easier to see. If the star is visible, center it on the crosshair. If not, check coordinates, etc. or pick another guide star if available. In any case, you'll want to send the telescope back to the starting position.

```
M> 63.7 -120.2 mt   (up arrow to last mt and negate arguments)
```

If the guide star was centered in the center field (and the crosshairs are a fair representation of the guider origin—see Section 6.4), then it should now appear in the guider camera. Of course it may be too faint, in which case refer to the next section.

7.5.2.2 Faint Guide Star

In the case of a faint guide star, the first thing to realize is that if you can see it on the screen, the guider can guide on it. Turn the Quantex gain all the way up. If more is needed, try messing with averaging or integrating on the Quantex (see Section 6.1).

If the guide star is very faint, but visible, turn off tip-tilt (either with gains or with `GO 5`—see Section 5.7) and adjust `AGG` to a low value.

7.5.3 Find and Center Object

7.5.3.1 Take the First Image

If the guide star offsets are correct, and the guider is guiding on the star, then the object should be visible within the HNA open-slit field. So let's find out.

`M> object`	(prompts for object name)
`   IR0423`	
`M> typ`	(prompts for image type)
`   obj`	(selects Object from list)
`M> mspect`[5]	(put tertiary in)
`M> fmi`	(flip mirror in for imaging)
`M> oslit`	(open slit all the way)
`M> /ks`	(choose K_s for imaging)
`M> 10. tint`	
`M> goi dcp`	(take and display first image)
`M> -60. 0.` θ`. mvpix`	(move *object* 60 pixels to left)
`M> goi wait odiff`	(take next exposure and subtract first)

The last sequence obtains a "sky" frame with the object only slightly displaced, so that the difference should show both positive and negative representations of the object. The `mvpix` command is used to move the object 60 pixels to the left. In the case where the object starts out centered, the second frame should show the object near the nominal left-position of the slit. Figure 7.3 shows the appearance of the slit image for the command sequence illustrated above. The display convention for Mirella is black=positive flux, white=negative flux. If the object is reasonably bright, the black and white images will be visible in the difference.

7.5.3.2 Positioning the Object

Most objects observed will be small enough to fit comfortably in only half the slit length ($\sim 20''$). In this case, the object may be dithered from one side of the slit to the other, such that "sky" frames still contain the object somewhere along the slit. This makes for very efficient observing, as all the integration time

[5] You are bound to forget this step at least once during the run. If you can't seem to find *anything* in the sky, check this mirror. Let the log sheet guide you.

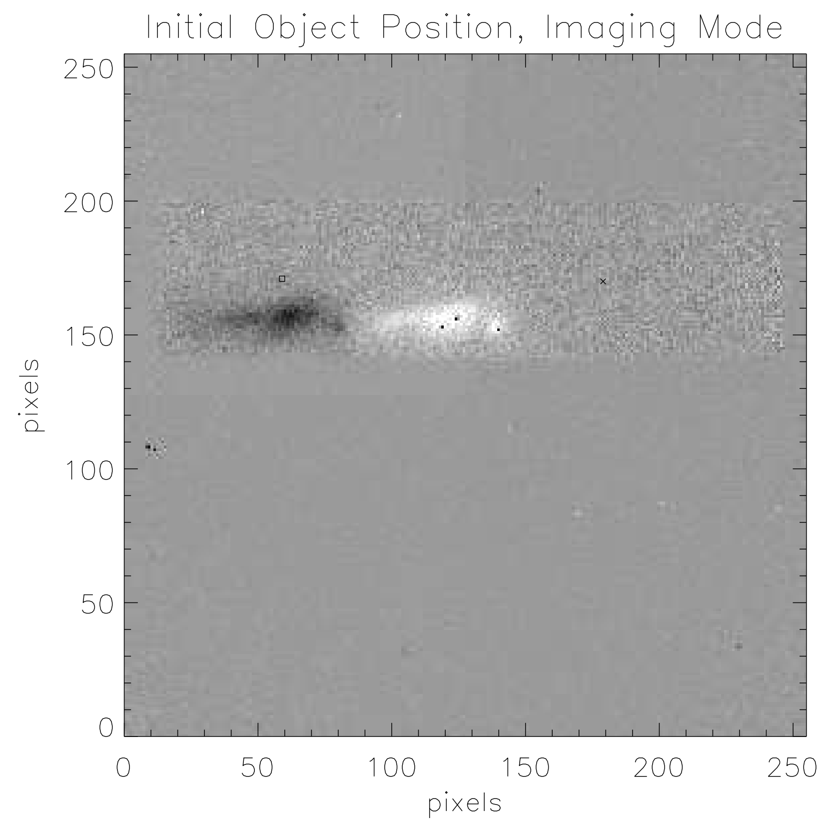

Figure 7.3: A sky-subtracted open-slit image revealing the initial and adjusted positions of the object within the HNA field. The object started out low-center, and was then moved to the left. The box and cross (i.e. cursors #2 & #3) mark the location of the slit center.

is on-source. Typically, 90% of the time in this mode of observation is spent collecting photons. The other fraction of time is spent reading the array, and moving the telescope around. I highly recommend using this approach. For this, I usually set up cursor positions at about $x = 60$ and $x = 180$ to mark the nominal left and right slit positions. See Section 7.1.3 for more on this.

Only if your object is reasonably bright beyond about $20''$ is it necessary to obtain separate sky integrations. This strategy, however, will require separate sky integrations for sky subtraction, doubling the observing time and introducing the effects of fluctuating sky (i.e. OH line) levels. In these cases, the object is best positioned near the center of the slit. Beware, though, of the sometimes-visible disjoint at $x = 127$–128. Perhaps a good target central position is $x = 115$.

Regarding the two scenarios of sky acquisition discussed above, I will almost exclusively focus on the compact object scenario, wherein sky observations are made with the source still in the slit. Section 7.5.4.6 offers suggestions for how the separate sky technique may be implemented.

Picking up with the initial image pair, first determine how many pixels the object is away from its desired position (i.e. left slit cursor). The recommended way of determining this exactly is to enter cursor mode, place cursor #0 or cursor #1 (whichever is closest) onto the part of your object you want centered on the slit. Type `x` to get the exact cursor position, then hit `+` until reaching the cursor used to mark the slit position (usually cursor #2 for left position), then hit `x` again to get this position. Exit cursor mode with a `q`. Some quick mental math will give you the Δx and Δy offsets. For the example shown in Figure 7.3, the appropriate motion is about 6 pixels to the left, and 14 pixels up. Remember the object remained in the left-hand position after the most recent integration.

`M> -6. 14. 5. mvpix` (6 pixels left, 14 up for 5° ring)
`M> goi wait odiff` (using previous integration for sky)
Verify that the object now looks well placed
`M> 120. -1. 5. mvpix` (move to right side of slit)
`M> goi wait odiff` (Get "slit-position" pair)

Don't be alarmed by the appearance of a message that the guider is locked off, and no action is taken when issuing an **`mvpix`** command. This simply means that the guider is shut off during the move. As long as the stripchart resumes operation, guiding is functioning normally. Verify that the images of the object fall where you want them with respect to the cursors marking the slit position. Figure 7.4 shows the centered "slit-position" image,

Once satisfied with the position, type `og` and *write down* the OGX and OGY coordinates of the offset guider. These appear on the screen as `Guider X =` OGX and `Guider Y =` OGY entries. This information becomes be invaluable if you loose track of your motions.

The slit position image of Figure 7.4 is important to have so that one knows exactly what portion of the object, relative to the two-dimensional spatial extent, is in the slit. Also of use is the photometric calibration one gets by imposing artificial apertures on the image, allowing one to estimate the total fraction of light from the source entering the slit.

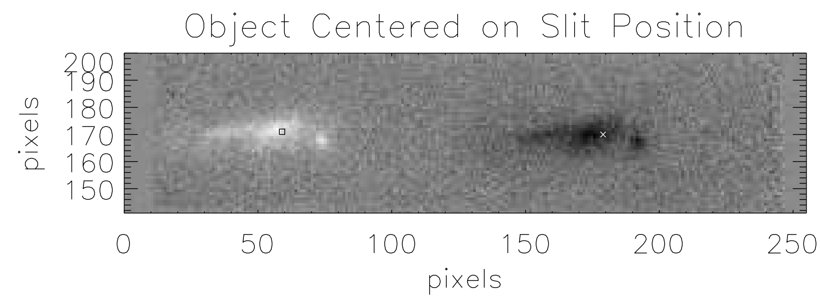

Figure 7.4: "Slit-position image" of centered object. The box and x-shaped cursors (#2 and #3) mark the position of the slit

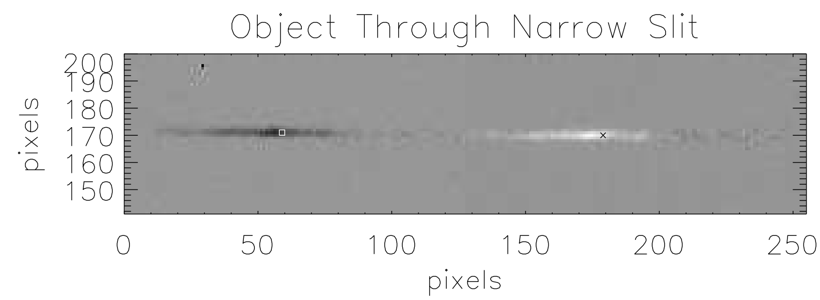

Figure 7.5: Image through the narrow slit, incidentally called the "slit image". This image aids in photometric calibration of the spectra to come.

To improve the photometric calibration capability further, an image through the narrow slit is of great value. This is a simple and quick procedure, given that most of the setup is already in place.

```
M> 0.7 slit                  (put slit to desired width)
M> goi dcp
M> -120. 1. 5. mvpix            (back to left position)
M> goi wait odiff
```

Now two eyes stare at you through the slit, one black and one white, seen for example in Figure 7.5. This image, called the "slit image", provides a direct measure of the light coming through the narrow slit, and may be compared with the total object flux as seen in the previous "slit-position image" of Figure 7.4.

7.5.3.3 Faint Objects

Faint objects may not be visible in a 10 second exposure. Try longer exposures, but be careful not to saturate. Look at the 10 second raw image (**dlp** or **dp** commands) and use cursor mode to measure data values on the slit. This will guide your decision regarding how long it will take to saturate. If CSCALE is set correctly (see Section 5.3), then saturation is at 20,000 dN, so aiming for 10,000 dN is not a bad idea.

If longer integration is not revealing the object, and if this object has an emission line feature, it may be possible to see using the narrow bandpass (1.3%) CVF, which operates from 2.0–2.5μm. Even the 5% CVF, running from 1.5–3.0μm may help.

`M> 90. tint`
`M> 2.345 cvf1` (1.3% CVF tuned to 2.345μm)
`M> goi dcp`
Check level of slit to verify no saturation
`M> gsky sdiff` (performs second half of a snap and displays)

Integration times can be much longer with the narrow CVF (`cvf1`), perhaps up to 300 seconds.

The other approach is to use a blind offset from a reference star. This method involves setting up the reference star on the nominal slit position, much like is done above for a visible object. Once on the slit, a precise move will leave the object in the same position, ready for taking spectra. Assuming that the reference star is close enough that the same guide star is accessible, here's what you do:

`M> 10. -15. mtg` (reference star 10″ East, 15″ South)
Check the `HEAD` angle reported, and adjust on MINC if more than 15° off.
`M> 10. tint` (longer if necessary)
`M> /ks` (or other filter)
`M> snapi sdiff`
If you see the star, center it:
`M> 13. -3. 90. mvpix` (for example)
`M> goi wait odiff` (verify position)
`M> -10. 15. mtg` (offset to object)

Now if the reference star offsets are worth their salt, the science target should be centered on the slit. If the reference star never was visible, check coordinates, equinox, etc.

7.5.4 Spectra

Satisfied with the object position, it is time to take some spectra. In this example, we will get a set of low-resolution data around 2.023μm, and another low-resolution set around 1.26μm. Let's say the Cassegrain ring angle is set to 5°.

7.5.4.1 Dither Patterns

Dithering along the slit from the left side of the array to the right allows one to spend all integration time pointing at the object. This is definitely the recommended approach if the object size is small enough to allow such a method. In addition to the gross motions across the slit, a small dither pattern in the x-direction is advantageous from the perspective that bad pixels have less of an effect on the final product if the pixel pattern is moved around with respect to the object.

I typically employ the following scheme. The possibility for confusion is greatly diminished if the same scheme is invariably followed. I usually start the observation by placing the object on the left slit position. One exposure at the left position, together with an image at the right position, constitute the "slit-position image". Then the slit is closed down to its working width, and an exposure at the right position, followed by one at the left position give the "slit image". If this procedure is followed, the object is again back at the left position, and ready for spectra.

The rule I follow now for dithering is: always go right by 120.0 pixels. When going back to the left, go only −115.0 pixels, until the sixth move, which is −130.0 pixels, thus arriving back at the nominal position. In this way, the object slowly creeps right, and is reset after every sixth spectrum.

Always remember to throw in the slope of the slit in the dither pattern. The sign is a place where many have gone wrong, but it is enough to simply remember that the x and y moves always have *opposite* sign.

One last note is that the `HEAD` angle will slightly change as the object is dithered across the slit. The sole purpose of the `HEAD` angle (as with `F70A`) is to tell the guider which way to kick the telescope (or secondary) if the star wanders this way or that. The angle does not, therefore need to be highly accurate. Anything within 10° is probably just fine.

7.5.4.2 Integration Time

I almost always use a 300 second integration time for spectra. Sometimes I'll go to 450 seconds. While I can't rigorously justify my choice, I think it offers a reasonable balance between factors such as: read noise, cosmic rays, atmospheric transparency variation timescale, seeing variation timescale, and OH skyline variation timescale. All but read noise argue for shorter times. In the K band, especially beyond 2.2μm, a 300 second integration time definitely is in the background-limited regime. I'll more often opt for 450 seconds in the H or J bands. Remember that variability is a greater concern when there is a lengthy sky integration sandwiched between adjacent object integrations. Of course if the conditions are completely stable, many of these factors wane in importance—so integrate for however long you want.

7.5.4.3 Slit Width

The slit width should be chosen based on science goals, such as spectral resolution, importance of spatial isolation in the cross-slit direction, and the degree to which convolution of spatial and spectral information is detrimental (in determining velocity centroids, for example). But the seeing also plays a role in the choice. I very frequently use a width of 4 pixels, or $0.67''$. If in doubt, this is not a bad value to go with.

7.5.4.4 A Sample Series

`M> object`	(prompts for object name)
`   IR0423`	
`M> typ`	(prompts for image type)
`   obj`	(selects Object type from list)
`M> 0.7 slit`	(if not done already)
`M> 300. tint`	
`M> 2.023 clowres`	(sets grating, filter (5% CVF), flip mirror)
`M> goi dcp`	

Now you're off and running. If you want to regain a prompt, hit CTRL-C and answer yes to the insulting question. If you do interrupt, `dcp` will not be executed. Otherwise, the raw spectrum will be displayed as soon as available, looking like the image seen in Figure 7.6. In what follows, it is extremely helpful to record all motions (or offsets) so that a reconstruction of events can be made later. I usually put this in small print on the left edge of the "Comments" column in the log sheet. Now get a complementary "sky" spectrum:

`M> 120. -1. 5. mvpix`	(move to right position → record this)
`M> goi wait odiff`	(grab second of pair and display difference)

Figure 7.7 displays the much improved sky-subtracted spectrum, showing the Paα line blazing through, with dramatic spatial extent. Note the fine velocity information seen here as well.

`M> -115. 1. 5. mvpix`	(left-ish position → record move)
`M> goi wait odiff`	(expose and subtract previous frame)
`M> 120. -1. 5. mvpix`	(right-ish position → record move)
`M> goi wait odiff`	
`M> -115. 1. 5. mvpix`	(left-ish position → record move)
`M> goi`	
`M>`	(no `wait` or `dcp` → got prompt back)
`M> wait odiff 120. -1. 5. mvpix`	(display and move in one)
`M> goi`	
`M> wait odiff -130. 1. 5. mvpix`	(display and move back)

This sequence took 6 object frames, or 3 pairs, taking about 35 minutes with overhead. The object is back in its original position and ready for another round

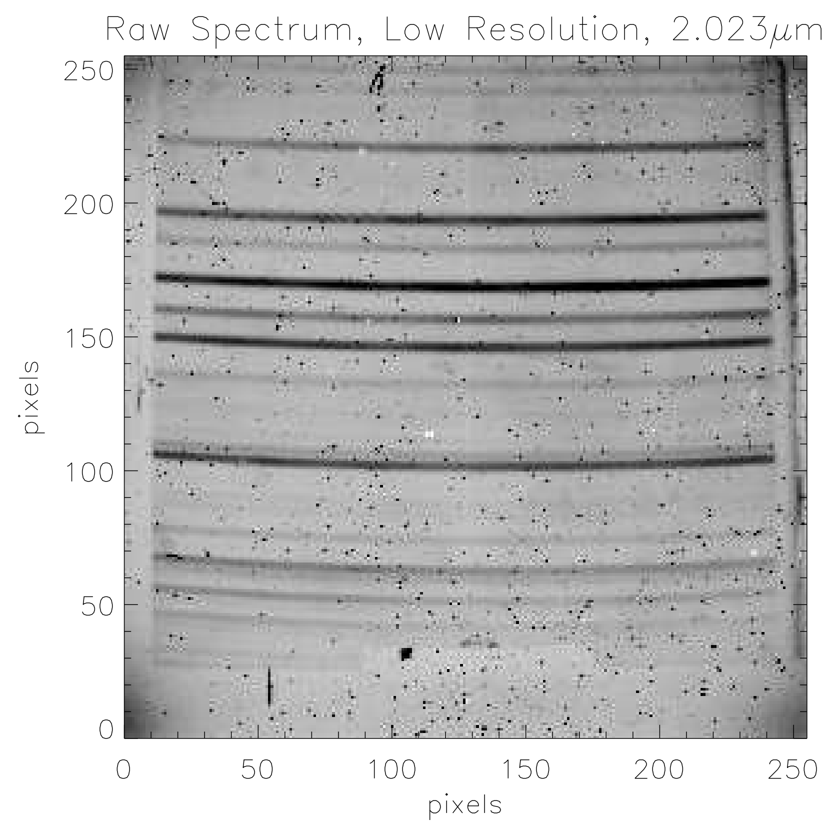

Figure 7.6: A raw spectrum. The spectrum is dominated by OH skyline emission. Note the curvature of the lines. The curvature is about 4 times more dramatic in the high-resolution spectra. Also seen are cosmic ray hits scattered across the array. Often times the object spectrum is not visible in the raw frame.

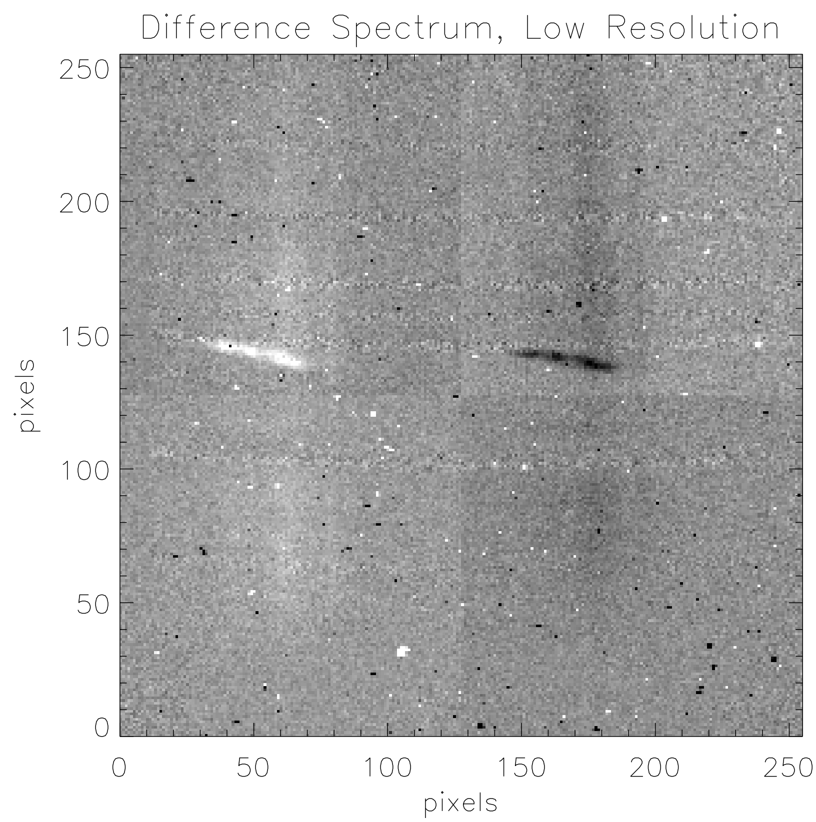

Figure 7.7: The sky-subtracted spectrum shows clearly the continuum of the nucleus, and the spatially extended Paα line is also prominently seen. Note the interesting velocity information present in the Paα emission as well. Residuals from the OH lines can be seen here. Often, these will have a net positive or negative value, as a result of skyline intensity fluctuations.

at a different wavelength. Check the OGX and OGY values (type `og` to get) and verify that you're back at the starting values recorded earlier.

Before changing the grating, we'll get lamps. Though not necessary in this case given the propensity of OH lines, it will illustrate the technique. It is also advisable at this time to obtain a measure of the PSF (see Section 7.6 for how to do this).

```
M> /o          (take mirror out, using mirror cover as lamp diffuser)
M> 10. tint
M> neon                          (neon lamp on, watch Quantex gain)
M> goi dcp
M> argon goi dcp krypton goi dcp xenon goi dcp
M> lampoff                           (remember to turn lamps off)
M> goi wait sdiff
M> mspect                                          (don't forget!)
```

That's it for lamps. Though some of these lamps may not have lines in the current wavelength range, the above demonstration acquired spectra of all four.

Now let's do the next sequence of spectra. This time, the observation will be with the low-resolution grating at 1.26μm. Because the 5% CVF does not access that wavelength range, the `lowres` command will be used instead of the `clowres` command. Comments will be much more sparse for the next sequence.

```
M> 450. tint
M> 1.26 lowres
M> 0.7 slit                                 (if not done already)
M> goi
M> dcp 120. -1. 5. mvpix
M> goi
M> wait odiff -115. 1. 5. mvpix
M> goi
M> wait odiff 120. -1. 5. mvpix
M> goi
M> wait odiff -115. 1. 5. mvpix
M> goi
M> wait odiff 120. -1. 5. mvpix
M> goi wait odiff
M> -130. 1. 5. mvpix            (back to left ("home") position)
M> /o
M> 10. tint
Make sure Quantex gain is down.
M> neon goi dcp argon goi dcp      (not really nec. in J band)
M> krypton goi dcp xenon goi dcp
M> goi wait sdiff
M> mspect                                          (don't forget!)
```

With that observation done, you may want to get a PSF now. See Section 7.6 for how.

7.5.4.5 All Done?

If you're done with this object, you'll need to obtain a G-star calibration. See Section 7.8. It may also be a good time to grab a photometric standard, as described in Section 7.7.

If done for the night, don't forget to type `/end_night` to protect various hardware.

7.5.4.6 For Larger Sources

If the source is too big to be comfortably dithered across the slit, separate sky observations are necessary. This, of course, reduces observing efficiency and provides less control over varying OH airglow intensities. But if ya gotta do it, here are some suggestions.

The best way to specify a sky location is via the nod location. This location is set via the `node` or `nodn` commands, or more generally, the `nod` command (Section 5.4). The `snapi`, command, much like the `goi` command, takes a pair of exposures. The first is a guided exposure at the current location, and the second is an unguided exposure at the pre-specified nod position. A `wait` is built into the end of the command, so `snapi sdiff` is an oft seen construction. The disadvantage of the `snapi` command is that the user is locked out of control until the entire sequence is over. Displaying intermediate products is not possible without interrupting the sequence. I have therefore included the `gsky` procedure[6] to make this easier. The `gsky` procedure simply executes the last half of the `snap`. Therefore `snapi sdiff` may be effectively replaced with `goi gsky sdiff`. But the commands may be split up, or intermediate results displayed by `goi dcp gsky sdiff`.

Dither patterns may still be used around the central position in the slit. The following offers an example of how these observations might go:

`M> mspect`	
`M> 2.121 hires`	(let's do high resolution, for spice)
`M> 450. tint`	
`M> 0.7 tint`	
`M> -100. node`	(set nod position 100″ west)
`M> goi`	(get first exposure)
`M> dcp gsky sdiff`	(display, get sky, then display difference)
`M> 5. 0.` θ`. mvpix`	(for dither)
`M> goi wait odiff`	(use previous sky for display)
`M> gsky sdiff`	
`M> -10. 0.` θ`. mvpix`	
etc.	

[6] The `gsky` command was made for the PIFS, and *may* not be in the `d81.m` file. If it is not defined, look at the `d83.m` file for its definition.

7.5.4.7 Additional Notes

Lamps are typically needed beyond about 2.2μm, where the OH lines give out. Lamps are always a good idea for high-resolution spectra, because even if there are OH lines in the raw spectrum, not all those lines are reliable wavelength calibrators on account of being blends of two nearby lines. Lamps provide backup calibration, and are quick and easy to do. Just remember to move the tertiary mirror back in after the lamp spectrum.

The science integration times are often very long, and quite often there are things you want to do while integrating—such as display previous images, or change the stretch of the display (see `lindisp` in Section 5.5). Therefore it is nice to have a prompt available for these tasks. For this reason, I prefer a plain `goi` command to a `goi dcp` or `goi wait odiff`, or the like. When there are only 30–60 seconds left in the integration, I'll type the display and move command, such as `wait odiff -60. 0. 90. mvpix`, then hit return. The `wait` command keeps the `odiff` and `mvpix` commands from being processed until the exposure is finished. If you wait until the exposure is finished before typing the display and move commands, photons are hitting the floor while you type. Sure, it's only a 5–10% effect, but I for one like to leave the telescope thinking I wasted no time and got as much data as I could have in the available time.

7.5.4.8 The Final Product

To illustrate the kind of data that the HNA delivers in low resolution mode, the example galaxy used throughout this cookbook section is shown in its reduced form. Figure 7.7, which represents a single object-sky pair, is fraught with cosmic rays, and lacks the signal to really see the structure of the Paα emission line gas as compared to that of the continuum. Figure 7.8, however, has been cleaned, straightened, and represents 30 minutes of on-source integration time. Wavelength increases upwards, and clear spatial extent and velocity structure of the Paα emission are seen in the two-dimensional spectrum.

7.6 Obtaining the PSF

A PSF image is the best way to get a measure for the local current seeing condition. I try to get a new measure every 30–45 minutes. In addition to seeing variability, telescope focus changes as a function of temperature. PSF images therefore facilitate the assessment and adjustment of focus.

7.6.1 Setting Up for PSF image

I'm assuming here that the camera and spectrograph are set up in the spectral configuration. If set up in imaging mode, much of the following will already be configured.

`M> 10. tint`	(at least 10 sec. to avg. short time variations)

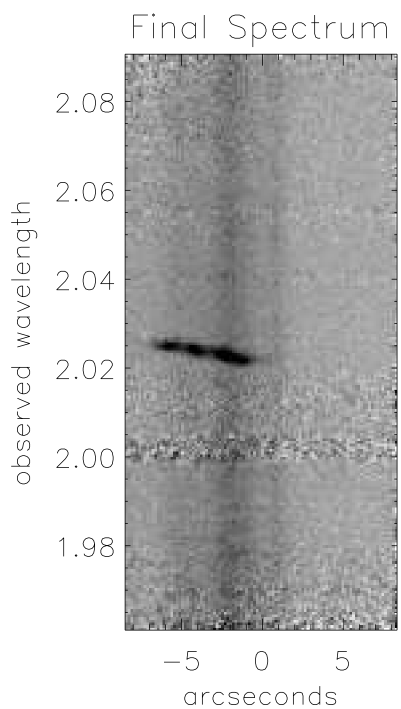

Figure 7.8: Two-dimensional spectrum of the ultraluminous infrared galaxy IRAS 0423+14, showing the difference between spatial distributions of Paα emission line gas and continuum light. Also seen is some interesting velocity structure. The continuum lump at right doesn't show any line emission. Boy do I need an integral field spectrograph…

```
M> fmi
M> oslit
M> /ks          (or filter best covering current wavelength tuning)
```

7.6.2 Guided PSF Image

The most desirable scenario is to have a PSF star within 200″ of the current guide star such that the same guide star can be used, and an `mtg` command is all that is needed to get to the PSF star. Look at the list of guide stars, and see if there are any other stars near the guide star. A good first indication is position angle to the guide star (from the main object). This information is one of the items in Gerry's `guide` program output (see Section 1.3.2). Potential guide stars with similar position angles are almost sure to be accessible. If nothing turns up in the list, look at the finder chart that you have hopefully made (Section 1.3.5) for a star within 200″ of the guide star. If the scale of the plot is some convenient fraction (e.g., 0.3 mm/arcsecond), then obtaining offsets (from the main object) is a simple task.

If both methods fail to turn up a PSF within range of the current guide star, there are two options available: either switch to a different guide star within reach of another star, or move the telescope to the current position of the guide star and take an unguided image of the thing.

7.6.2.1 Using Current Guide Star

This is the best of situations, requiring the minimum effort and having the best chance of not getting off track.

Before moving anywhere, type the `og` command, and write down the OGX and OGY coordinates of the offset guider in the current (home) position. Should you loose track of moves, this info will help guide you back home. This information is reported on the screen as `Guider X =` OGX, for example.

For this example, we pretend that the guide star OGX and OGY (offsets from home) are (42.7, 145.2), and the PSF star has offsets of (−23.1,125.4). One note: comparing the guide star offsets with the list values may indicate a coordinate offset that, if applied to all stars on the list will give improved pointing accuracy.

Stop the guider (hit <RETURN> on the MINC), then type in the move command.

```
M> -23.1 125.4 mtg
Note the HEAD angle reported on the screen
minc$ HEAD 73                                  (73° for this example)
minc$ GO                                (once guide star is visible)
M> goi dcp                       (PSF should be near left slit position)
M> 120. 0. θ. mvpix                               (move to right side)
minc$ <RETURN>                                      (to stop guiding)
M> -120. 0. θ. mvpix      (can up-arrow then edit previous mvpix)
M> 23.1 -125.4 mtg          (can up-arrow then edit previous mtg)
```

```
Check reported guider position with home position (OGX,OGY)
minc$ HEAD 16                     (set back to original HEAD angle)
M> 300. tint
```

If additional moves were made in the process of finding the PSF star, be sure to reverse each of those motions. In the end, verify guider position with that recorded prior to the moves.

7.6.2.2 Switching Guide Stars

This is the second-choice scenario, but is sometimes necessary. It is similar to the previous example, but with a few extra bits at beginning and end.

Before moving anywhere, type the `og` command, and write down the OGX and OGY coordinates of the offset guider in the current (home) position. Should you loose track of moves, this info will help guide you back home. This information is reported on the screen as `Guider X =` OGX, for example.

For this example, we pretend that the guide star OGX and OGY (offsets from home) are (165.2,-16.9), and the PSF star has offsets of (220.6,40.7). Note that the PSF star is too far out to be used as a guide star for the object, but is within reach of the chosen guide star—on the other side of it. This often happens.

Stop the guider (hit <RETURN> on the MINC), then type in the move command.

```
M> 165.2 -16.9 og/r                    (move guider to new star)
Adjust gain on guider Quantex.
minc$ HEAD 96
minc$ GO                               (once guide star is visible)
M> goi dcp                   (PSF should be near left slit position)
M> 120. 0. θ. mvpix                              (move to right side)
minc$ <RETURN>                                     (to stop guiding)
M> -120. 0. θ. mvpix   (can up-arrow then edit previous mvpix)
minc$ <RETURN>        (now with star locked in, shut off for move)
M> 220.6 40.7 mtg
minc$ HEAD 224
minc$ GO                               (once guide star is visible)
minc$ <RETURN>                                     (to stop guiding)
M> -220.6 -40.7 mtg                              (reverse ALL moves)
M> 42.7 145.2 og/r              (move guider back to original star)
Adjust gain on guider Quantex.
minc$ HEAD 16
minc$ GO                               (once guide star is visible)
M> 43.2 144.8 og/r            (revise position as per OGX, OGY
                           recorded previously for home position)
Check that guider update did not loose guide star.
M> 300. tint
```

Again, reverse any and all motions performed in search of the PSF. This will ensure that you get back to your home position with minimum fuss. The importance of recording the home position's OGX and OGY values cannot be stressed enough. This saves the effort of re-finding the object and re-centering it. Once guiding at the same-old OGX and OGY, you can be assured that the object is right where you left it.

7.6.3 Unguided PSF Image

In the unfortunate situation that no PSF stars are available from nearby guide stars, You'll have to go-it unguided. Though the integrations are short and tracking errors are non-existent, you are more vulnerable to wind shake and image wander. These are really only concerns if using the tip-tilt guider. Otherwise the main spectroscopic observations are subject to the same influences. The bottom line is that you want the PSF measure to be as representative as possible of the science observation PSF. Thus try as much as possible to use the same guiding method for both.

And yet again, before moving anywhere, type the `og` command, and write down the OGX and OGY coordinates of the offset guider in the current (home) position. Should you loose track of moves, this info will help guide you back home. This information is reported on the screen as `Guider X =` OGX, for example.

Probably the lowest brain-power approach is to offset the telescope to the guide star. At least you know this star exists, and that it is indeed a star (not just some unidentified entry in the guide star list—which can cause problems occasionally).

Stop the guider, then type in the move command:

`minc$ <RETURN>`	(stop guider before move)
`M> 43.2 144.8 mt`	(use the actual recorded OGX, OGY offsets)
`M> goi dcp`	(PSF should be near left slit position)
`M> 120. 0.` θ`. mvpix`	(move to right side)
`minc$ <RETURN>`	(to stop guiding)
`M> -120. 0.` θ`. mvpix`	(can up-arrow then edit previous `mvpix`)
`M> -43.2 -144.8 mt`	(reverse ALL moves)
`minc$ GO`	(resume guiding)
`M> 300. tint`	

In this case, the guider was never moved (except for the excursion to the right side of the field), so no adjustment is necessary. Once guiding again, the object is assured to be right where you left it.

7.6.4 Using PSF to Focus

The center field camera is parfocal with the infrared array, so in general focusing via the center field camera is perfectly adequate for getting the array focused.

However, in conditions of great seeing, there may be advantage in focusing via the array images. Another scenario that often arises is the recently acquired PSF image shows some obvious shortcoming. In this case, since everything is already set up for PSF imaging, it often makes sense to focus in this mode. This section offers hints pertaining to efficiently performing a focus in this manner.

Firstly, focus adjustments should always be made in the same direction, as there is some backlash in the mechanical device. I usually come up from the bottom (out?), such that the focus number increases. Increments of 0.1 mm seem to be sufficient in practice. Typical values may lie around 64–65 mm.

Though there is no convenient method to assess the PSF shape and size on SAM, the roundness is easily eye-balled, and focus can be adjusted to give the best apparent shape. If running the SPARC auto-`ftp` process, these images can be evaluated on the image processing platform of your choice. See Appendix E for more on this.

There isn't too much new to say about imaging here, since this should be relatively familiar by now. But I have a few suggestions for making the process efficient.

Let's say the next frame number is 101. A pair of images, one with the object on "side A" of the array, and the next with the object on "side B", will result in the object being left on "side B", with frame number 101 available to act as a sky frame. The following one-liner command will take each new data-point in the focus run:

```
M> goi wait lastfile 101 pdiff 0 3000 lindisp
```

The values for `lindisp` may need adjustment, but you get the idea. A simple up-arrow after each new focus setting recalls this command for immediate re-execution. Makes it fast.

Don't forget to write down each focus setting (i.e. very small in the comment field of the log sheet).

If this concludes the nights activities, remember to enter the `/end_night` command, placing various pieces of hardware into their protected positions.

7.7 Standard Stars

For photometric calibration, it is necessary to obtain an image (or several) of a photometric standard star in each filter band being used. Preferably, several standard stars will be imaged through the course of the night. For standard selection, see Section 1.4.2 or Appendix C.

The images of the standard stars allow one to tie down the flux in the continuum images of the science objects, then assign the continuum flux density to the continuum in the spectrum, adjusted for the estimated amount of light coming through the slit. This is where the "slit-position image" and "slit image" (Figures 7.4 and 7.5) come in handy.

I won't assume anything here about the current configuration, so some of the below steps may not be necessary. We'll start out after the telescope move is complete.

```
M> /o                                    (get tertiary out of the way)
Locate star in center field and center on crosshair
M> mspect
M> object
   std_9155
M> typ
   cal
M> 10. tint
M> 16 mparm2 1 frames 16 cscale                   (if necessary)
M> fmi
M> oslit
M> /ks                                             (or other filter)
M> goi dcp                          (probably visible near field center)
M> -60. 0. θ. mvpix      (move to left side, modify offsets if nec.)
M> goi wait odiff
M> 120. 0. θ. mvpix                              (move to right side)
M> goi wait odiff
```

Multiple exposures at each filter may be desirable for statistical purposes.

```
M> /k
M> goi dcp
M> -120. 0. θ. mvpix                                   (back to left)
M> goi wait odiff
And so on...
```

If this is the last thing for the night, remember to execute the `/end_night` command, which places the hardware into a protected state.

7.8 G-star Calibration

Perhaps the most difficult procedure encountered while observing with the HNA is the G-star calibration spectrum. This is hard because the G-star is also used as a spectral flat-field in addition to its primary use as a calibrator for the atmospheric throughput function. For more about this, refer to Section 1.4.1 and Section 7.3.

The first step in this process is G-star selection, which I usually do 10–15 minutes before dropping off of the science object. Look at the current LST, and add the amount of time yet to spend on the object, adding any time for a PSF measurement. Add some time for getting set up on the G-star, about 10 minutes (5 if you're an expert). Figure out which airmass (or airmasses) you will want calibration for, trying to stay within 5% for careful calibration. Anticipate motion of G-stars, and how fast their airmass will change. Sometimes it's better to wait an extra few minutes than to waste time on a missed airmass.

If using the analog computer (iso-airmass overlay on plot of positions, see page 11), set the meridian of the airmass overlay to the projected LST and find the closest star to the present telescope position with the correct airmass. The number next to the star (on my plot) is the star's HR number. The telescope operator doesn't have this catalog, so look on the G-star list for the corresponding SAO number, which the operator can zip right to.

7.8.1 Preparation

While the telescope is slewing, do the following preparation:

```
M> object
   HR5853
M> typ
   cal
M> 1 mparm2 10 frames 0.375 tint            (10 fast frames)
M> 2.023 clowres              (substitute with appropriate λ)
M> fmi           (first we'll image to center chopped star on slit)
M> oslit
M> /o                                (experts may skip this step)
```

First, we'll be imaging the star to get it properly positioned within the slit, and the short integration is due to the fact that the star is very bright. See the discussion on pages 38 and 44 if you need refreshing over how to set up for short integrations. Ten frames are used to eliminate atmospheric freezing—the multiple frames allow a better estimate of the star's average position. By executing the `clowres` command, the 5% CVF is put in as a filter, helping cut out more light, and the grating set to the appropriate wavelength for calibration. Of course the flip-mirror has to be flipped in *after* the `clowres` command, as `clowres` has a `fmo` built in.

If the airmass allows, it is best to calibrate the last used grating setting first. This way, the `lowres` (or `hires`) command does not actually move the grating, and maximum reproducibility is achieved. If the grating has to move, then so be it.

7.8.2 General Procedure

Before doing anything else, get the chopper a-chopin'.

- Set the chop angle to equal the Cassegrain ring angle plus 0.5°, keeping in mind that the secondary range is $-90 < \phi < 90$ (Section 6.3). For instance, for ring of 49°, set the chop angle to 49.5°. For a ring angle of 115°, use a chop angle of -64.5°. This 0.5° offset is due to the sloped slit (1 pixel in 120).

- Do yourself a favor. Enter the new secondary angle into the MINC computer (as `F70A`) *now*, before you forget.
- With the 20dB switch in the down position, select the triangle wave.
- Slowly turn up gain on center field camera Quantex and verify star in field.
- Unless chop amplitude has been set already, turn pot down to about 140, and flip the 20dB switch on. Otherwise, simply flip the switch up to 20dB to get previous amplitude. Verify that chop angle is correct (horizontal on TV).
- Use paddle to move chopped star onto horizontal crosshair, centered on the vertical crosshair. If the tertiary mirror is still in the way, it is sufficient to position the left end of the chopped star such that it peaks out (about one-half inch) from behind the secondary, and at (or just below) the horizontal crosshair.
- If the star is double, it may be necessary to resolve the ambiguity of which one is the G or late-F star. In some cases, it may be necessary to change the ring angle by about 90° to split the two. But as this changes the flexure-state, it is not recommended unless near the zenith.
- Once paddle moves are finished, ask the night assistant to "Z", zeroing the telescope offsets on the telescope status display (this will help immensely in centering the star).

The rest of the procedure is summarized below, and explained in great detail farther down.

- Put the tertiary mirror in.
- If the chop amplitude has not been previously determined, check that the enpoints of the chopped star are visible on either side of the tertiary mirror. Adjust chop amplitude if necessary. Usually, a setting of about 140 on the potentiometer, with the 20dB switch in the up position produces the correct chop amplitude.
- Take an image to find out where the star currently is, relative to the slit. The setup for the imaging mode is spelled out above.
- Adjust vertical placement of star to lie on the center of the slit. I recommend using the paddle for the move, and referencing the telescope offset readouts for positional information. Take another exposure to verify positioning.
- Repeat above step until satisfied that the star is well placed on the slit. It is important to get it right, as suitable fringing correction depends on proper centering.

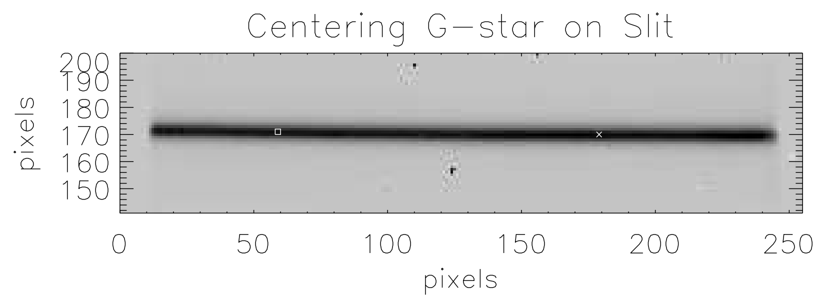

Figure 7.9: Chopped G-star, vertically positioned so-as to lie on the slit. The box and x-shaped cursors mark the slit position. Note the slight downward angle of the slit is matched by the star. This is the reason for the 0.5° offset used when adjusting the secondary angle control.

- Perform the **`snap`**, or alternatively, the **`goi`** and **`gsky`** routines to get object/sky pair.
- Repeat the last step for each wavelength to be calibrated.

Sounds like a complicated sequence, and in some ways it is. But a few nights of this and you'll certainly have the hang of it.

7.8.3 Putting it into Action

Having completed the tasks in the top list, here's the lower list in greater detail:

`M> mspect` (if not already in)
Verify chop amplitude in center field display
`M> goi dcp` (See how well the star is centered on the slit)
Adjust star position with paddle
`M> goi dcp` (now centered?)
Repeat until happily centered

Figure 7.9 shows the appearance of a centered star on the slit, ready for a spectrum.

I used to use **`mvpix`** to push the star onto the slit, but became frustrated with this technique, as I always found myself fighting telescope backlash. After all, no guide star is being used, and motion commands are not held to be true. I started using the paddle and readout approach because at least the encoders tell you how much the telescope has really moved.[7] Unfortunately, this method requires mental calculation of which way is up on the array. Hint: if the ring angle is

[7] I have since started guiding on the end of the chopped star, using raw motor commands to set the guider at the correct position. This is definitely an advanced method, but eliminates the messing around, and even the need to verify positioning via imaging. The PIFS manual offers more guidance on using this approach.

90°, moving north will move the star up on the array. Refer to Figure 2.1 to help ascertain the direction of "up" for the current ring angle. A hybrid method is also possible, and may offer the best compromise. Use **mvpix** to affect the motion, and monitor the telescope offset readouts to verify position.

Now we are ready to take a spectrum. The grating and CVF are already in place. The slit needs to be closed down, the flip mirror taken out, and the camera timing changed back to multiple reads and longer integration.

```
M> 120. tint                          (usually delivers adequate signal)
M> 16 mparm2 1 frames 16 cscale       (back to 16 reads)
M> 0.7 slit
M> fmo
M> snapi sdiff                        (or use goi dcp gsky sdiff)
```

Figure 7.10 shows the appearance of the G-star spectrum for a grating setting of 2.023μm, in which one can see the absorption of the atmosphere between 2.00 and 2.02μm (towards center of array), and one also gets a look at the fringing, which is why we bother getting spectral flats in this bizarre manner.

Look for a signal level of $> 1,000$ dN in the bright parts of the array. The target of 1,000 dN is somewhat arbitrary, and is based on wanting a 1% noise level in the flat. The D80 array has about 10 e^- per dN, so that 1,000 dN is 10,000 e^-, the noise of which is 1%. If the signal is weak (less than 500 dN), it may be advisable to obtain a second snap exposure.

If you suspect the star may have wandered off the slit (low signal can be a hint), go back into imaging mode to verify the star position. A couple of minutes checking is better than 5 wasted minutes on an off-center star. Not only is signal an issue, but the spatial gradient across the slit will induce a perceived spectral shift. The result is a fringe pattern out of phase with the object fringe pattern. Residuals will torment you.

Now get lamps, if necessary. You know the drill:

```
M> /o
M> 10. tint
M> neon                               (watch Quantex gain)
M> goi dcp argon goi dcp krypton goi dcp
M> xenon goi dcp lampoff goi wait sdiff
M> mspect
```

Be sure to remember to get the tertiary back in before spending 5 minutes on the next calibration spectrum.

The star should still be squarely in the slit (check telescope offsets as a precaution), and is ready for another round. The next round is simple:

```
M> 120. tint
M> 1.26 clowres
M> goi dcp gsky sdiff
```

You can keep doing this until the cows come home, but watch the airmass and make sure it is not getting away from the target value.

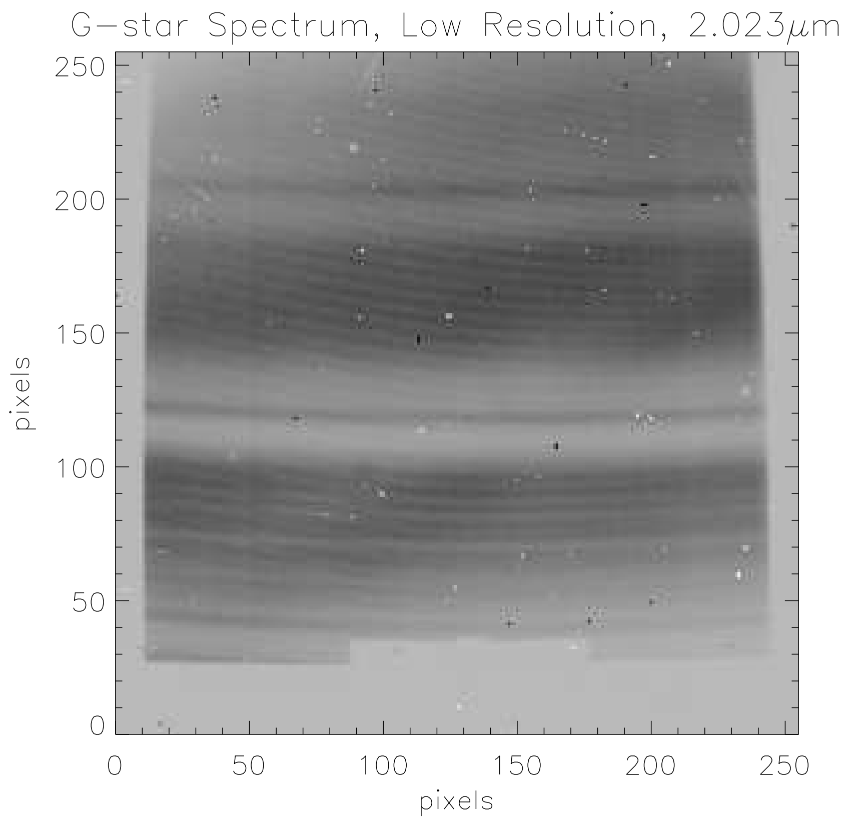

Figure 7.10: G-star spectrum, after sky subtraction. The entire slit has been illuminated by the chopped star, making this a flat-field in addition to being an atmospheric calibrator. The atmospheric absorption seen here towards the center of the array runs from 2.00–2.02μm. The fringing on the array is also seen here.

7.8.4 Moving On

7.8.4.1 To Another G-star

If going to another G-star (for a different airmass, perhaps), you can leave the chopper going during the move. Turn down the Quantex gains before the move, as usual. You'll have to go through the entire centering procedure again at the new G-star, so take it from the top of Section 7.8. This is one reason I prefer the more advanced technique of guiding on the end of the chopped star. No re-centering is necessary—just start guiding again. The PIFS manual has more on this approach.

7.8.4.2 Not Another G-star

No, that's not a complaint from the back seat, though perhaps it should be. If going to another object, first turn the Quantex gains down, then turn off the chopper (set to DC, then throw 20dB switch down). Remember to update the MINC with the new value of `F70A`.

7.8.4.3 To the Monastery

If this concludes your fun-filled night of observing, remember to enter the `/end_night` command before leaving. This command moves out the tertiary mirror, placing the protective cover over it, puts the cold plug in front of the array, and closes the secondary lid.

7.9 Now What?

Well, that does it for the cookbook. I'm hungry.

Chapter 8

Saving the Precious Data

The data taken with the HNA resides on SAM, the VAX on the Mezzanine level. This is the computer that Mirella is running on, and the computer whose terminal you've been typing on all this time. The data is stored in WFPC format. But astronomers really want FITS files. What follows is a guide to retrieving the data, converting it to FITS, and putting it onto a tape or CD.

If the files are already in place on a SPARC station, as they would be if running the auto-ftp process (see Appendix E), most of these steps can be skipped, and the tape written directly.

8.1 Hooking up the Machines

The sequence that follows is written for the rhea SPARC station, but will be valid for any SPARC station running in the data room.

The first step is to physically connect rhea to SAM, which is done on the wall panel to the right of where the telescope operator sits. Find the BNC jack labeled SAM (ports 1 & 2), and find the one labeled rhea (or replacement). There is very likely a short cable running from the rhea jack to one labeled "repeater", which is the internet connection. Otherwise, if rhea is set up near the observer, the BNC may simply go straight from rhea to the repeater jack. SAM's jack is likely terminated with a 50Ω terminator. Remove the terminator, and take the "repeater" end of rhea's cable, attaching it to SAM (ie, port 2). Though unnecessary, place the terminator on the repeater jack for safe-keeping. Now rhea is off the internet, and SAM is directly connected to rhea.

8.2 Transferring the Data

What follows may look strange, but `ftp` will only work right in one direction: from SAM to rhea. From the rhea terminal:

```
rhea> telnet sam
```

```
  Username: IRCASS3
  Password:                               (use current password)
$ ftp rhea
  (some prompt): user visitor (actually type these two words)
ftp> cd /scr/visitor/tmurphy/night1             (for example)
ftp> type binary
ftp> mput w*.hdr             (or subset of data if incremental)
ftp> mput w*.img             (or subset of data if incremental)
ftp> quit
$ logout
```

Now disconnect SAM from rhea, and replace cables and terminators where you found them. This step is unnecessary if rhea is currently set up to auto-ftp new files (as in Appendix E).

It is not a bad idea to do this transfer after every night of successful data-taking. In such a case, modify the `mput` commands above to reflect the partial selection.

8.3 Converting to FITS

With the data now on the SPARC disk, make a list of the files, which will be edited and then executed as a shell script.

```
rhea> ls *.hdr > fitslist
```

Now edit the list with your favorite editor such that each entry reads:

```
wfpc2fit w00001
wfpc2fit w00002
etc.
```

If using `vi`, this can be quickly done with the following sequence:

```
:1,$s/\.hdr//
:1,$s/w/wfpc2fit w/
:wq
```

With `emacs`, first move the cursor to the very first character in the file, and do the following commands, where a `M-` command is interpreted as an <ALT>-command, and a `C-` is interpreted as a <CONTROL>- command:

```
M-x replace-string
Replace string: w
Replace string w with: wfpc2fit w
Now move cursor back to beginning of first line
M-x replace-string
Replace string: .hdr
Replace string .hdr with:                    (just hit return)
C-x C-s C-x C-c                                (save and exit)
```

This sequence (in `vi` or `emacs`) will properly format the file for shell execution.

Now execute this file in one of the two following ways:

```
rhea> csh < fitsfile
—OR—
rhea> chmod +x fitsfile
rhea> fitsfile
```

Perform this process in each of your data directories, if you have more than one. If skeptical about this `wfpc2fit` program, first do an `ls -l` command to check that the file size is about right (roughly the sum of a `.hdr` file and a `.img` file). Still not convinced? Run `saoimage` and look at the files directly. Seeing is truly believing, but hopefully one or two will convince you that all is fine, and you won't be compelled to visually inspect each file.

If you have trouble with `wfpc2fit`, or can't find it, try another SPARC station. But it should be on all of them, and have execute permissions for all users. If all else fails, issue the following command: `find -name wfpc2fit.c -print` and compile the program in your own directory using a `gcc wfpc2fit.c -o wfpc2fit` sequence.

8.4 Writing to Tape

With the various fits files in their various directories (or single directory as the case may be), insert a tape into the drive and follow the pattern shown below[1].

```
rhea> cd /scr/visitor/tmurphy/night1
rhea> tar -cv *.fit
rhea> ../night2
rhea> tar -cv *.fit
rhea> ../flats
rhea> tar -cv *.fit
```

It is also possible to write your data files onto a CD. There is an instruction manual at Palomar on how to do this.

8.5 Delete the Files

Once assured that your data is safely backed up on tape, be courteous and delete the leftover files. Even if paranoid, you can delete the `.hdr` and `.img` files on the SPARC.

Wait until the end of the run to delete files on SAM. Once all the data is safe on the tape or CD, exit Mirella and delete files:

[1] I know this is not new to anyone, but what can I say—I've already gone overboard and I can't seem to stop myself.

```
M> /end_night                (stows hardware)
M> bye
$ del *.hdr.*                (this wipes out all your data)
$ del *.img.*                (this wipes out all your data)
```

And that's it. Go home.

Appendix A

Finder Charts

The following is an IDL routine meant to create a grayscale finder in PostScript form for a 300×300 pixel SkyVeiw-generated fits file (**infile**) that is 500″ on a side. The second argument, **outroot**, is the root filename to use for output. Two files are generated: a normalized fits file (zero median and sky noise of 1.000), and a "**.plt**" file, which is to be executed at the IDL prompt via an "at" (@) command.

```
pro finder,infile,outroot

if strpos(infile,'fits') eq -1 then infile = infile+'.fits'

im = readfits(infile,h)
med = median(im)
sig = noise(im)

im = (im - med)/sig

fitsfile = outroot+'.fit'
writefits,outroot+'.fit',im,h

outfile = outroot+'.plt'
openw, 1,outfile

printf,1,"; skyview image is "+infile
printf,1,"old_dev = !D.NAME"
printf,1,"set_plot, 'PS'"
printf,1,"device, filename='",outroot+'.ps',"'"
printf,1,"device, bits_per_pixel=8,scale_factor=1.0"
printf,1,"fullx = 8.49"
printf,1,"fully = 10.99"
printf,1,"device, /inches, xoffset=0.0,yoffset=0.0,xsize=fullx,ysize=fully"
printf,1,"deg = string(176B)"
printf,1,"mm = string(180B)"
printf,1,"ss = string(168B)"
printf,1
printf,1,"im = readfits('",fitsfile,"',h)"
printf,1,"imtitle = 'XX:XX:XX.XX, +XX'+deg+'XX'+mm+'XX'+ss+' (1950.0)'"
printf,1,"size = [1.375,3.375,7.25,9.25]"
```

```
printf,1,"psize = size/[fullx,fully,fullx,fully]"
printf,1,"dx = psize[2] - psize[0]  &  dy = psize[3] - psize[1]"
printf,1,"imtmp = bytscl(im,min=-15,max=5)"
printf,1,"tvscl, -imtmp,psize[0],psize[1],xsize=dx,ysize=dy,/normal"
printf,1,"x = (-findgen((size(im))[1])+(size(im))[1]/2.0)*500.0/(size(im))[1]"
printf,1,"y = ( findgen((size(im))[2])-(size(im))[2]/2.0)*500.0/(size(im))[2]"
printf,1,"contour,im,x,y,xstyle=1,ystyle=1,position=psize,$"
printf,1,'  xtitle="!4Da!N!3 (arcseconds)",ytitle="!4Dd!N!3 (arcseconds)",$'
printf,1,"  xrange=[x[(size(x))[1]-1],x[0]],title=imtitle,c_color=[254],$"
printf,1,"  /nodata,/noerase"
printf,1
printf,1,"theta = findgen(361)*3.14149/180.0"
printf,1,"xcirc = 200.0*cos(theta) & ycirc = 200.0*sin(theta)"
printf,1,"plots,xcirc,ycirc"
printf,1,"plots,[[00.0,200.0],[00.0,40.0]]"
printf,1,"plots,[[0.0,-200.0],[0.0,-40.0]]"
printf,1,"plots,[[-200.0,0.0],[-40.0,0.0]]"
printf,1,"plots,[[200.0,00.0],[40.0,00.0]]"
printf,1,"plots,[[00.0,40.0],[00.0,20.0]],color=!d.table_size-1"
printf,1,"plots,[[0.0,-40.0],[0.0,-20.0]],color=!d.table_size-1"
printf,1,"plots,[[-40.0,0.0],[-20.0,0.0]],color=!d.table_size-1"
printf,1,"plots,[[40.0,00.0],[20.0,00.0]],color=!d.table_size-1"
printf,1
printf,1,"device,/close"
printf,1,"set_plot,old_dev"

close, 1

end
```

The above routine calls a procedure known as `noise.pro`, which is a crafty little routine that calculates the Gaussian-like noise background in an image, ignoring positive or negative features in the image (assumes some level of sparseness). This is my own routine, so don't trust it for everything. But for most of what I do, this is a real nice thing to have.

```
function noise,im

; function to find the std dev of a block of pixels

; sort the array

imsort = im(sort(im))

; find the number of pixels

npix = (size(imsort))[1]

; pick the integer that is closest to 2/3 of the number of pixels
; this is an integer

num = 2*npix/3 + 1

; find the noise as a the minimum difference between
; the averages of two pairs of points approximately 2/3 of the
; entire array length apart
```

```
noise =  $min(imsort(num-1:npix-1)+imsort(num-2:npix-2)-imsort(0:npix-num)-imsort(1:npix-num+1))/2.0

; now correct the noise for the fact that it´s not exactly over 2/3 of the
; elements

noise = noise / (1.9348+(float(num-2)/float(npix) - 0.66667)/.249891)

; now correct for the finite number of pixels

if npix gt 100 then $
        noise = noise/(1.0-0.6141*exp(-0.5471*alog(npix))) $
        else $
        noise = noise/(1.0-0.2223*exp(-0.3294*alog(npix)))

return, noise

end
```

Appendix B

Atmospheric Calibrator Stars

The following is a list of F8–G9 main sequence stars, generated on SIMBAD. The stars cover the entire sky, and all have $3.5 < V < 6.5$. Every star has an SAO number, but not all have an HR designation. These are instead given letters as a means of labeling the analog computer plot (see Section 1.4.1).

HR	SAO	RA (2000.0)	Dec (2000.0)	M_V	Spectral Type
9088	91669	00 02 07.0	+27 05 45	5.75	G5Vb
9107	53622	00 04 50.5	+34 39 31	6.10	G2V
5	21085	00 06 14.2	+58 26 11	5.93	G5V
A	166137	00 14 20.2	-27 31 46	6.46	G5V
B	147208	00 17 57.4	-13 27 20	6.50	G2V
72	128690	00 18 40.4	-08 03 04	6.46	G0V
77	248163	00 20 04.2	-64 52 29	4.20	F9V
88	147237	00 22 50.3	-12 12 37	6.38	G3V
108	166296	00 28 21.5	-20 20 00	6.44	G3V
142	128839	00 35 13.4	-03 35 33	5.20	F8V
176	232143	00 40 19.8	-59 27 39	5.88	G1V
173	166475	00 40 30.5	-23 47 59	6.14	G3/G5V
203	147432	00 45 28.7	-12 52 41	6.15	G2V
209	215232	00 45 44.6	-47 33 11	5.80	G1V
225	92099	00 48 58.6	+16 56 36	5.07	F8V
219	21732	00 48 59.1	+57 49 24	3.45	G0V
244	11444	00 53 04.6	+61 07 18	4.82	F8V
321	22024	01 08 16.4	+54 55 13	5.12	G5Vb
340	36984	01 10 19.3	+42 04 55	5.70	F8V
370	215428	01 15 07.9	-45 32 03	4.96	F8V
458	37362	01 36 48.3	+41 24 28	4.09	F8V
512	258271	01 37 52.4	-82 58 36	5.87	G2V
483	37434	01 41 43.4	+42 36 56	4.90	G1.5V
506	232501	01 42 28.3	-53 44 22	5.52	F9V
509	147986	01 44 10.0	-15 56 58	3.50	G8V
523	54994	01 48 42.1	+32 41 10	5.79	F8V
535	193326	01 49 48.8	-38 24 26	6.37	F8V

650	129752	02 12 46.2	-02 23 34	5.68	F8V
660	55420	02 16 58.5	+34 13 40	4.90	G0.5V
683	167697	02 18 59.2	-25 57 07	6.34	G5V
695	167736	02 22 31.8	-23 48 56	5.19	G2V
706	215892	02 24 32.8	-40 50 31	6.18	G2V
720	75391	02 28 48.7	+29 55 51	5.89	G0V
741	92998	02 32 54.2	+15 02 03	6.00	F8V
761	55711	02 37 06.1	+32 53 28	6.20	F8V
788	55793	02 42 14.9	+40 11 47	4.90	F9V
810	232864	02 42 31.6	-50 48 12	5.40	G0V
937	38597	03 08 57.5	+49 36 53	4.05	G0V
962	130355	03 12 45.7	-01 11 43	5.06	F8V
1006	248770	03 17 36.5	-62 35 04	5.54	G2.5V
1010	248774	03 18 03.2	-62 30 56	5.24	G1V
996	111120	03 19 20.7	+03 22 08	4.83	G5Vvar
1008	216263	03 19 41.7	-43 04 48	4.27	G8V
1024	130457	03 23 17.7	-07 47 28	6.20	G2V
1099	111291	03 36 47.3	+00 35 24	5.71	G9V
1232	130860	03 58 52.5	-05 28 03	5.83	G9V
1262	76438	04 05 19.6	+22 00 38	5.90	G5V
1294	248945	04 07 20.0	-64 13 37	6.37	G3V
1405	233506	04 24 12.8	-57 04 14	6.28	G4V
1489	57377	04 41 49.2	+38 16 53	5.99	G0V
1532	149888	04 47 35.8	-16 56 13	5.50	G3V
1538	149901	04 48 32.4	-16 19 48	5.75	F8V
1536	131504	04 48 35.3	-05 40 14	5.77	F8V
1608	150060	04 59 50.3	-10 15 41	5.38	G4V
1651	217153	05 03 53.8	-41 44 50	6.31	F8V
C	150156	05 07 09.9	-19 23 45	6.44	G2V
1665	150159	05 07 24.4	-12 29 22	5.97	G2V
1656	94332	05 07 25.1	+18 38 41	5.01	G4V
1747	150326	05 18 49.1	-18 07 51	5.96	G0V
1780	94526	05 24 24.5	+17 23 01	5.00	F8V
1828	25241	05 32 33.1	+57 13 27	6.40	F8V
1912	234026	05 33 43.9	-54 54 09	6.42	F8V
2022	258421	05 37 04.0	-80 29 01	5.67	G1V
1980	170756	05 44 28.4	-20 07 37	6.34	F8/G0V
1988	113119	05 46 35.1	+01 10 12	5.95	G4V
2007	132554	05 48 34.7	-04 05 29	5.97	G4V
2047	77705	05 54 23.5	+20 16 38	4.41	G0V
2141	58739	06 06 08.9	+35 23 30	6.12	G0V
2261	256274	06 10 13.0	-74 45 00	5.09	G6V
2208	95394	06 13 12.2	+10 37 53	6.44	G2V
2225	171428	06 13 45.3	-23 51 49	6.39	G5V
2274	234418	06 16 18.9	-59 12 33	6.43	G0V
2254	171502	06 17 03.1	-22 42 42	6.04	F8/G0V
2251	113683	06 17 16.8	+05 05 53	5.71	F9V
2313	133229	06 25 15.6	-00 56 34	5.90	F8V
2400	234551	06 31 17.7	-51 49 39	5.60	F8V
2431	196987	06 35 54.2	-36 05 15	6.35	G0V
2468	249604	06 38 00.7	-61 32 03	6.18	G1.5V
2493	172264	06 44 51.9	-27 20 44	6.43	G2V
D	78717	06 46 10.4	+23 22 14	6.4	G8V
2401	5946	06 46 15.9	+79 34 24	5.45	F8V
2483	41330	06 46 44.3	+43 34 31	5.27	G0V
2569	78866	06 55 18.7	+25 22 31	5.70	G0V
2643	79009	07 03 29.8	+29 20 55	5.93	G4V

2667	218421	07 03 57.7	-43 36 48	5.54	G3V
2692	79131	07 10 07.3	+21 15 13	6.43	G9V
2711	79170	07 12 48.9	+27 13 34	6.44	F8V
2721	41644	07 15 49.9	+47 14 33	5.60	G0V
2779	115269	07 19 47.5	+07 08 38	5.90	F8V
2866	134742	07 29 25.4	-07 33 11	5.90	F8V
2918	115693	07 36 35.0	+05 51 42	5.90	G0V
E	235442	07 43 21.8	-52 09 58	6.5	G0V
3018	198404	07 45 36.0	-34 11 46	5.37	G0V
3064	153500	07 51 46.5	-13 53 36	5.16	G2V
3138	250035	07 57 43.4	-60 18 17	5.60	G0V
3119	26634	08 02 35.9	+57 16 28	6.49	F8V
3191	79995	08 10 27.4	+25 30 44	5.73	G7V
F	97645	08 12 12.4	+17 38 59	5.05	F8V
3210	97646	08 12 12.9	+17 38 57	6.20	G5V
3271	135783	08 20 12.9	-00 54 29	6.20	F9V
3309	42369	08 27 36.8	+45 39 28	6.30	G5V
3368	236032	08 29 36.4	-55 11 26	6.36	G0V
3404	199402	08 35 12.2	-39 58 15	6.47	G1V
3395	116929	08 35 51.4	+06 37 19	6.00	F8V
3430	176226	08 39 08.8	-22 40 04	5.05	G3/G5V
3391	14609	08 39 11.9	+65 01 11	5.60	G1.5Vb
3510	98168	08 51 01.8	+15 20 59	6.38	G1V
3522	80478	08 52 37.6	+28 20 03	5.95	G8V
3538	136389	08 54 19.3	-05 26 05	6.00	G2V
3625	61288	09 08 51.8	+33 53 02	5.90	F9V
3648	14819	09 14 20.6	+61 25 25	5.20	F9V
3677	200152	09 14 57.1	-37 36 08	5.86	G0V
3750	136872	09 27 47.5	-06 04 12	5.40	G2V
3754	117717	09 28 27.2	+09 03 25	5.41	F9V
3862	177866	09 42 15.8	-23 55 09	4.94	G0V
3901	137185	09 51 22.0	-06 10 57	6.42	F8V
3916	178130	09 52 59.0	-27 20 01	6.30	G1V
3992	201109	10 09 33.5	-35 51 25	6.13	F8V
4013	201186	10 13 26.2	-33 01 57	6.35	G1V
4012	81250	10 14 30.2	+21 10 08	6.02	F9V
4027	81259	10 16 28.3	+28 41 01	6.49	G0V
4039	81270	10 17 16.0	+23 06 27	5.80	F8Vbw
4051	27606	10 20 15.2	+53 46 43	6.40	F9V
4085	118278	10 24 12.9	+02 22 06	6.32	G9V
4098	43351	10 28 03.4	+48 47 49	6.44	F9V
4112	27670	10 30 38.6	+55 58 52	4.80	F8V
4168	62178	10 39 08.5	+37 54 39	5.85	F9V
4277	43557	10 59 29.3	+40 25 46	5.10	G1V
4285	43564	11 00 21.1	+42 54 48	6.00	F9V
4298	201998	11 00 41.0	-31 50 27	6.07	F8V
4345	62451	11 12 33.2	+35 48 57	6.41	G0V
4375	62484	11 18 12.6	+31 32 15	4.41	G0V
4437	99648	11 31 46.0	+14 22 02	6.20	G0V
4443	179967	11 32 16.1	-29 15 55	5.77	F8V
4444	179968	11 32 16.4	-29 15 47	5.68	F8V
4439	15542	11 32 20.8	+61 05 01	5.48	F8V
4486	43841	11 38 47.6	+45 06 30	6.44	G0V
4489	180065	11 39 00.2	-24 43 03	6.42	G6/G8V
4496	62655	11 41 03.0	+34 12 25	5.32	G8V
4498	180098	11 41 09.5	-29 11 57	6.44	G0V
4523	223020	11 46 37.7	-40 30 21	4.89	G5V

4525	202811	11 47 16.7	-30 17 00	6.48	G5V
4540	119076	11 50 39.2	+01 46 07	3.61	F9V
4550	62738	11 52 41.8	+37 47 58	6.45	G8Vp
G	157003	11 56 56.0	-13 45 09	6.5	G1/G2V
4688	82244	12 19 30.3	+28 09 31	6.33	F8Vs
4708	119360	12 22 32.5	+05 18 22	6.40	F8V
4734	223443	12 26 51.3	-48 54 43	6.26	G4V
4758	157326	12 30 05.6	-13 23 33	6.35	G1/G2V
4767	28413	12 30 49.9	+53 04 26	6.20	F9V
4785	44230	12 33 47.6	+41 21 12	4.26	G0V
4788	223527	12 34 42.7	-44 40 13	5.77	G1V
4845	63177	12 45 00.9	+39 16 37	6.00	G0V
4864	82511	12 48 48.2	+24 50 30	6.31	G7V
4903	223753	12 54 59.4	-44 08 56	5.89	G1V
4979	204227	13 12 04.7	-37 48 13	4.85	G3V
4980	240653	13 12 55.8	-59 48 54	6.21	G0V
5011	119847	13 16 47.6	+09 25 18	5.22	G0Vs
5019	157844	13 18 28.0	-18 17 47	4.74	G5V
5070	16071	13 26 02.7	+63 15 29	6.50	G6V
5072	100582	13 28 26.5	+13 47 12	5.00	G4V
5213	16186	13 49 45.0	+61 29 26	5.96	G3V
5209	182026	13 51 22.4	-24 23 11	6.45	G5V
5258	139666	13 59 49.3	-03 32 56	6.40	F8V
5268	205123	14 03 01.5	-31 41 06	6.18	F8V
5273	100832	14 03 32.0	+10 47 28	6.27	G8V
H	224702	14 07 41.5	-49 52 08	6.5	G3V
5322	139806	14 14 22.2	-05 56 56	6.36	F9V
5325	224798	14 15 38.0	-44 59 55	6.31	F9V
5346	83259	14 16 33.2	+20 07 23	6.25	F8V
5384	120424	14 23 14.5	+01 14 54	6.30	G1V
5423	45075	14 29 36.0	+41 47 56	6.40	G5V
5472	83458	14 40 21.8	+21 58 31	6.05	G0V
5504	182858	14 46 11.0	-21 10 28	6.40	G2V
5534	83553	14 50 15.2	+23 54 41	5.85	G1V
5596	2459	14 50 15.8	+82 30 54	5.64	F9V
5544	101250	14 51 22.7	+19 06 09	4.55	G8V
5542	206035	14 52 34.3	-30 34 35	6.29	G1V
5550	101273	14 53 23.3	+15 42 16	6.41	F9V
5566	225328	14 58 08.7	-48 51 29	6.35	G4V
5583	140256	14 58 53.9	-04 59 16	6.09	F8V
5618	45357	15 03 49.3	+47 39 14	4.76	G0Vnvar
5630	64503	15 06 35.3	+36 27 19	6.34	F8V
5639	101403	15 08 53.5	+13 14 03	6.10	G6V:
5632	253043	15 10 45.9	-61 25 20	6.30	G2V
5657	183275	15 13 30.1	-25 18 30	6.45	G5V
5699	225697	15 21 56.2	-48 18 49	5.65	G4V
5698	225703	15 22 08.9	-47 55 33	5.00	F8V
I	64673	15 23 11.7	+30 17 26	5.02	G2V
5734	64687	15 24 31.4	+37 20 47	6.50	G1V
5853	121152	15 44 01.8	+02 31 02	5.88	G2.5V
5868	121186	15 46 27.3	+07 21 15	4.43	G0V
5864	206976	15 47 30.7	-37 54 48	6.01	G6V
5914	45772	15 52 38.5	+42 26 34	4.62	F8Ve...
5911	101792	15 53 12.5	+13 12 16	6.10	G0V
5996	159706	16 07 04.2	-14 04 16	6.32	G5V
J	207479	16 14 12.2	-31 39 36	6.4	G1V
6094	207622	16 24 00.9	-39 11 35	5.40	G5V

6098	253554	16 28 26.1	-70 05 09	4.91	F9V
K	30055	16 42 27.0	+49 56 16	6.47	F8V
6360	17324	17 02 15.6	+64 36 00	6.10	G5V
6439	141611	17 19 59.3	-05 54 53	6.32	G9V
6441	160474	17 20 34.7	-19 19 52	6.50	G1V
6458	65963	17 20 38.9	+32 28 56	5.40	G0V
6469	46664	17 21 43.5	+39 58 31	5.51	F9Vn...
6598	17572	17 36 40.1	+69 34 25	6.42	F9V
6637	8891	17 41 57.5	+72 09 39	5.78	G0V
6669	47009	17 51 14.0	+40 04 20	6.40	F8V:
6697	85575	17 57 14.3	+23 59 42	6.30	G2V
6748	209710	18 06 23.2	-36 01 11	5.95	G5V
6761	254157	18 10 26.6	-62 00 19	5.49	G0V
6847	47343	18 15 32.8	+45 12 39	6.29	G2V
6836	186593	18 17 23.1	-28 17 13	6.40	G0V
6828	254209	18 19 39.8	-63 52 58	6.18	F9V
L	228983	18 24 32.9	-49 39 03	6.47	G1/G2V
6907	186838	18 27 49.4	-29 49 01	5.91	F9V
6981	103886	18 35 53.1	+16 58 33	6.21	G2V+...
6998	187086	18 38 53.5	-21 02 59	5.86	G5V
6994	257625	18 47 49.5	-77 52 11	6.40	F8V
7079	86451	18 48 16.2	+23 30 52	6.20	F8V
7162	67612	18 57 00.8	+32 54 13	5.22	F9V
7172	104308	18 59 05.6	+13 37 27	5.23	F8V
7161	254446	19 03 29.7	-68 45 19	5.88	F8V
7260	104511	19 07 57.0	+16 51 27	6.07	G5V
7291	187883	19 15 32.7	-24 10 40	6.25	F8V
7345	68144	19 19 39.1	+37 19 59	6.31	G8V
7330	211206	19 21 29.4	-34 58 57	6.48	G5V
7368	68239	19 23 33.6	+33 13 11	6.37	G8V
7477	48673	19 37 56.4	+49 16 57	6.47	G6V
7503	31898	19 41 49.6	+50 31 38	5.96	G1.5Vb
7504	31899	19 41 52.6	+50 31 11	6.20	G3V
7522	31923	19 43 13.6	+58 01 02	6.20	G0V
7560	105338	19 51 00.7	+10 25 03	5.10	F8V
7569	105348	19 52 04.5	+11 37 59	6.10	G0V
7597	188722	19 55 49.5	-26 18 02	4.70	G5V:
7637	163168	19 59 48.2	-09 57 10	5.88	F8V
7672	105635	20 04 07.5	+17 04 33	5.80	G1V
7644	254721	20 05 25.4	-67 18 42	6.07	G3V
7674	246444	20 07 34.8	-55 01 00	6.26	F8V
M	246453	20 08 09.5	-52 34 39	6.4	G3V
7783	18796	20 17 27.2	+66 50 59	5.93	G3V
7766	246546	20 21 42.7	-49 59 46	6.28	G0V
7793	106042	20 22 52.0	+14 33 05	6.10	F8V
7855	163686	20 34 11.4	-13 43 20	6.13	G0V
7875	254846	20 40 00.4	-60 32 28	5.12	F8V
7898	189549	20 40 09.8	-23 46 49	6.37	G8/K0V
7914	106373	20 40 44.6	+19 55 52	6.45	G5V
7994	163953	20 53 05.4	-11 34 27	6.38	G1V
8041	145022	21 00 33.6	-04 43 42	6.21	G1V
8077	126535	21 05 26.9	+05 57 36	5.90	F8V
8061	257890	21 09 17.2	-73 10 07	5.68	F9V
8170	50739	21 21 01.4	+40 20 54	6.40	F8V
8283	164580	21 41 33.2	-14 02 36	5.18	G2V
8310	89939	21 44 07.3	+28 44 46	6.08	G2V
8314	107364	21 44 30.6	+14 46 26	6.00	G0V

8323	230846	21 48 14.8	-47 17 59	5.58	G0V
N	90260	22 08 18.9	+24 09 29	6.5	G2V
8455	107706	22 10 18.6	+19 37 04	6.18	G0V
8472	34151	22 11 47.1	+56 50 15	5.20	F8V
8477	231045	22 14 36.0	-41 22 15	6.26	G5V
8501	247400	22 18 13.0	-53 37 07	5.33	G3V
8526	258036	22 25 50.3	-75 00 57	6.11	G3V
8545	165078	22 26 33.5	-16 44 33	6.35	G3V
8631	108094	22 40 51.6	+14 32 50	5.71	G4V
8635	231257	22 42 36.7	-47 12 23	6.02	G0V
8700	231343	22 53 36.7	-48 35 50	6.03	G0V
8737	127870	22 58 33.7	+09 21 32	6.43	G2V+...
8829	255435	23 14 03.1	-62 41 39	6.12	G8V
8883	191840	23 21 15.5	-26 59 12	5.64	G4V
8931	146752	23 31 30.8	-04 05 05	6.49	F8V
8935	258154	23 33 19.2	-77 23 08	5.81	G2V

Appendix C

Photometric Standard Stars

The standards used for HNA observations are the so-called "HST faint standards" that Eric Persson and company put together. The full sky list with photometric uncertainties can be found in AJ, **116**, 2475, November 1998. Uncertainties are generally better than 0.01 magnitudes.

n	HST	RA (J2000)	DEC	J	H	K	Ks
9101	P525-E	00:24:28.3	07:49:02	11.622	11.298	11.223	11.223
9104	S754-C	01:03:15.8	-04:20:44	11.045	10.750	10.693	10.695
9105	P530-D	02:33:32.1	06:25:38	11.309	10.975	10.897	10.910
9107	P247-U	03:32:03.0	37:20:40	11.934	11.610	11.492	11.503
9108	P533-D	03:41:02.4	06:56:13	11.737	11.431	11.337	11.336
9116	S840-F	05:42:32.1	00:09:04	11.426	11.148	11.077	11.058
9118	S842-E	06:22:43.7	-00:36:30	11.723	11.357	11.264	11.261
9122	P161-D	07:00:52.0	48:29:24	11.680	11.408	11.356	11.352
9126	P309-U	07:30:34.5	29:51:12	11.876	11.522	...	11.450
9131	P035-R	08:25:43.8	73:01:18	10.819	10.546	10.499	10.515
9133	S495-E	08:27:12.5	-25:08:01	11.521	11.048	10.965	10.960
9134	P545-C	08:29:25.1	05:56:08	11.881	11.624	11.575	11.596
9135	S705-D	08:36:12.5	-10:13:39	12.362	12.098	...	12.040
9138	S852-C	09:41:35.8	00:33:12	11.354	11.041	10.981	10.982
9139	P091-D	09:42:58.7	59:03:43	11.683	11.338	11.276	11.282
9141	S708-D	09:48:56.4	-10:30:32	11.081	10.775	10.715	10.718
9142	P212-C	10:06:29.0	41:01:26	11.993	11.729	11.686	11.697
9143	P550-C	10:33:51.8	04:49:05	12.344	12.121	12.067	12.081
9145	P064-D	12:13:12.0	64:28:56	11.958	11.711	11.664	11.675
9148	P266-C	12:14:25.4	35:35:55	11.642	11.378	11.324	11.343
9149	S860-D	12:21:39.3	-00:07:13	12.213	11.917	11.861	11.865
9150	S791-C	13:17:29.6	-05:32:37	11.661	11.310	11.250	11.267
9152	P133-C	13:58:40.2	52:06:24	11.149	10.878	10.831	10.839
9153	P499-E	14:07:33.9	12:23:51	11.947	11.605	11.560	11.540
9155	S867-V	14:40:58.0	-00:27:47	12.045	11.701	11.622	11.633

9156	P041-C	14:51:57.9	71:43:13	10.873	10.588	10.523	10.530
9158	P272-D	14:58:33.1	37:08:33	11.640	11.277	11.210	11.223
9160	S870-T	15:39:03.5	00:14:54	10.914	10.701	10.649	10.659
9162	P177-D	15:59:13.6	47:36:40	12.258	11.924	11.857	11.868
9164	P565-C	16:26:42.7	05:52:20	12.180	11.895	11.842	11.844
9166	P330-E	16:31:33.6	30:08:48	11.816	11.479	11.419	11.429
9169	P138-C	17:13:44.5	54:33:21	11.355	11.118	11.075	11.080
9170	S875-C	17:27:22.2	-00:19:25	11.132	10.835	10.739	10.744
9177	P182-E	18:39:33.7	49:05:38	12.104	11.764	11.688	11.696
9178	S808-C	19:01:55.4	-04:29:12	10.966	10.658	10.566	10.575
9182	S813-D	20:41:05.1	-05:03:43	11.479	11.142	11.082	11.085
9183	P576-F	20:52:47.3	06:40:05	12.247	11.940	11.873	11.880
9185	S889-E	22:02:05.7	-01:06:02	12.021	11.662	11.586	11.585
9186	S893-D	23:18:10.0	00:32:56	11.403	11.120	11.045	11.055
9187	S677-D	23:23:34.4	-15:21:07	11.857	11.596	11.538	11.542
9188	P290-D	23:30:33.4	38:18:57	11.634	11.337	11.257	11.262

Appendix D

LaTeX Log Sheet

Log sheets can be produced by via the LaTeX program below, or obtained as PostScript from the PIFS website: `http://www.its.caltech.edu/~tmurphy/pifs/pifs.html`. The following is a LaTeX document which will produce a log sheet for the PIFS. Note the line reading: [repeat 24 times...]. Replace this with the line: `& & & & & & & & & & \\ \hline` repeated 24 times.

```
\documentclass [12pt]{article}
\usepackage{portland}
\usepackage{array}
\setlength{\evensidemargin}{-0.5in}
\setlength{\oddsidemargin}{-0.5in}
\setlength{\textwidth}{7.75in}
\setlength{\topmargin}{0.1in}
\setlength{\headheight}{0in}
\setlength{\headsep}{0in}
\setlength{\textheight}{10in}
\begin{document}
\begin{landscape}
\renewcommand{\baselinestretch}{1.18}
\begin{center}
\Large
HNA Spectrometer Log Sheet \hfill Page\underline{\hspace{0.35in}}of\underline{\hspace{0.35in}} \\
\medskip
\normalsize
Observers\underline{\hspace{3.5in}} \hfill Night
 Assistant\underline{\hspace{1in}} \hfill UT Date\underline{\hspace{1in}} \\

\medskip
\setlength{\tabcolsep}{0pt}
\begin{tabular}{|m{0.5in}|m{1.25in}|m{0.625in}|m{0.75in}|m{0.75in}|
      m{0.875in}|m{0.5in}|m{0.625in}|m{0.5in}|m{0.625in}|m{3in}|}
\hline
\centering Frame & \centering Object & \centering TINT &
\centering Slit Param. & \centering Grating & \centering Filter & %
\centering Flip Mirror & \centering Tertiary Mirror & %
\centering UT & \centering Airmass & %
\hspace{0.1in}Comments \\
\hline
```

```
& & & & & & & & & & \\ \hline
[repeat 24 times...]
\end{tabular}
\medskip
{\large Remarks:} \hfill {\tiny TWM 01/16/99}\\
\end{center}

\end{landscape}
\end{document}
```

Appendix E

Automatic Transfer to SPARC

An automated ftp process was developed for the purpose of reconstructing PIFS images on the fly, and as a means of providing a more capable platform with which to look at data. For this latter reason, the automatic transfer is relavent to HNA data as well. Eiichi Egami wrote a series of shell scripts for the SPARC that automatically transfers new data from SAM to the SPARC as it becomes available. This Appendix briefly documents these routines.

The scripts can be found in /home/user/egami/sam_to_sparc/ on rhea, and are called cpfile, ftpls, and ftpimget. Copy these files, plus the blank file hdr_blank into the working directory on the SPARC station.

It is best to have the SPARC situated on the table to the right of the main observing station. Connection to SAM should be done following the example in Section 8.1, which takes the SPARC station off the internet.[1]

The main script, cpfile, has at its beginning a set of instructions that you should read and follow. Those instructions are summarized here:

- Copy the files cpfile, ftpls, ftpimget, and hdr_blank into the current working directory from /home/user/egami/sam_to_sparc/.

- Make sure that wfpc2fit is in the path by typing which wfpc2fit.

- Set the variables datadir, samuser, and sampass in *all three* files: cpfile, ftpls, and ftpimget. The datadir and samuser variables will not need to be changed unless using D78, or some other non-standard arrangement is being used.

- Type cpfile to run the script.

[1]Sometimes it is necessary to exit the desktop, the re-enter, which requires temporarily reconnecting the internet connection while everything starts up.

- A <CONTROL>-C command in the appropriate window will terminate the process.

The `cpfile` process may be run all night long, but it can also be run intermittently. Every time `cpfile` starts, all the files not listed in `hdr_list.old` will be slurped over.

If `wfpc2fit` was not found, see the suggestions on page 91. If there are problems with the SPARC after disconnecting from the internet, such as IDL hanging up, quit all processes (or kill them) such as IDL, `cpfile`, etc., and exit the desktop. Re-connect the SPARC to the internet repeater (terminate SAM when doing so) and then re-enter the desktop, start IDL, then disconnect the internet and go back to the dedicated SAM connection.

I have found it convenient to make a new working directory for each night, and copy over the `hdr_blank`, `hdr_list.new`, `hdr_list.old`, `hdr.list`, and `hdr.diff` files from the previous night's working directory, then restart `cpfile`. This separates data into the various nights, which makes it easy to write tar files to tape with night-separated data. Another, easier way to do this is to name files according to night number. For instance night one would begin with `w01001.fit`, night two with `w02001.fit`, etc.

Using HNA IDL Utilities

After starting IDL, add the following directories to the path such that the following routines, plus supporting routines will be visible.

```
IDL> !path = '/home/user/tmurphy/idl/util:' + !path
IDL> !path = '/home/user/tmurphy/idl/hna:' + !path
```

Within these directories are programs for reducing HNA data, though instruction is definitely needed before they would be of use.

There is a package now visible to you called `imtool`, that is a nice display of IDL images. You can pull up files using the pull-down menu on the utility. If you want to view an IDL array named `image`, type `prep,image` at the IDL prompt, then select "View Array" under the file pull-down menu. Functionality is much like SAOimage, but with added features such as statistics in a box, and PSF fitting. The color stretch can be adjusted in the SAO fashion, by dragging the mouse around with the left button down. Not all the bugs are worked out, so if you drag the mouse outside the box, things may freeze up on you. If things go squirrelly, type `retall` at the IDL prompt, and things should return to normal.

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