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The CCD Cassegrain Spectrograph at the Shane Reflector

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Important Numbers

Scale at Cassegrain Focus	3″.9/mm
Maximum slit opening	2 × 2 arcmin
Slit setting	5 units = 1 pixel

CCD Characteristics	TI $(800)^2$	TI $(500)^2$
Pixel size	15μ	15μ
e^-/DN	2.5	2.5
Readout noise	$\leq 7e^-$	$\leq 10e^-$

Scale on CCD	grism mode	grating mode
arcsec/pixel	0″.71	0″.66
1″ on sky	1.4 pixels	1.5 pixels*
2 pixel slit	1″.42 on sky	1″.32 on sky*
3 pixel slit	2″.13 on sky	1″.98 on sky*

* ignores anamorphic magnification of gratings (0.83-0.97)

Spinrad night sky filter bandpass ~ 6100 - 7600.

X-Y Stage

1. Increasing X on X-Y stage moves center of spectrum toward blue. Scale is 1.5 units per pixel.

2. Increasing Y on X-Y stage moves center of slit to higher column numbers (in normal mode of spectrum along colums). Scale is 1.5 units per pixel.

3. In direct mode, increasing (X,Y) moves the window to higher (rows, columns) at 1.5 units per pixel.

GRISMS

Grism	grooves/mm	λ Blaze	Spectral range	Å/pixel	X-stage
1	300	5700Å	6400	8.0	$-\frac{\lambda_c}{535} + 15.75$
2	600	6500	1880	2.65	$-\frac{\lambda_c}{177} + 42.53$
3*	300	8925	5840	~ 7.3	unknown
4	600	4840	2880	~ 3.6	$-\frac{\lambda_c}{230} + 27.62$
5	300	7800	6160	~ 7.7	$-\frac{\lambda_c}{494} + 20.93$
6	420	5600	4400	~ 5.5	$-\frac{\lambda_c}{335} + 22.18$

* System response is ~ 0 from 9000Å to 1μ.

GRATINGS

Grating	grooves/mm	λ Blaze (Å)	Spectral range	Å/pixel (First Order)	tilt
1	600	5000	1600	2.0	$2.44\ \lambda_c + 8000$
2	600	7500	1600	2.0	$2.44\ \lambda_c + 8000$
3	830.8	8460	1150	1.4	$3.46\ \lambda_c + 8030$
4	1200	5000	800	1.0	$5.09\ \lambda_c + 7150$
5	300	4230	3100	3.9	$1.2\ \lambda_c + 8150$
6	300	7500	3150	4.0	$1.2\ \lambda_c + 8150$
7*	600	3000	1600	2.0	$2.44\ \lambda_c + 8000$

* More efficient than No. 1 for wavelengths shorter than about 3600Å.

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Illustrations

I. INTRODUCTION AND OVERVIEW

The CCD Spectrograph at the Cassegrain focus of the 3-m telescope may be used in two different ways. In the grism mode, the dispersing elements are transmission gratings cemented to prisms ("grisms"). The throughput is quite high (15-25% for telescope plus spectrograph plus detector), but absorption in the lens camera cuts off the ultraviolet at about $\lambda 3850$. In the UV Schmidt mode, reflective optics are used, except for the quartz corrector of the Schmidt camera, so response is good down to the atmospheric cutoff, but efficiency is lower in the visual regions.

For grism operation (see Figure 1) the system is a straight-through design with the following light path: after passing through the slit and the three filter wheels, the light passes through a collimator lens about midway down the spectrograph. Traveling almost an equal distance again, the collimated beam encounters the remotely-controlled shutter located just above the grism tray. After passing through a grism (or open space for the direct mode) the spectrum is focused onto the CCD by a specially coated, high quality Nikkor lens. Between the lens and the CCD is a manually-operated dark slide, and the CCD dewar is mounted on a precision X-Y stage to allow choice of position of the spectrum on the CCD.

In the UV mode, the light path is quite different (Figure 2). The grism optics are removed, and a collimator mirror is installed at the bottom of the spectrograph. The light first passes through the slit/decker assembly and filter wheels (which are the same in both grism and grating configurations), then goes to the collimator which tilts the beam and sends it back up to the grating tray where it is dispersed, or simply reflected if a flat mirror has been installed for direct imaging. The light then passes through a Schmidt camera which images onto the CCD.

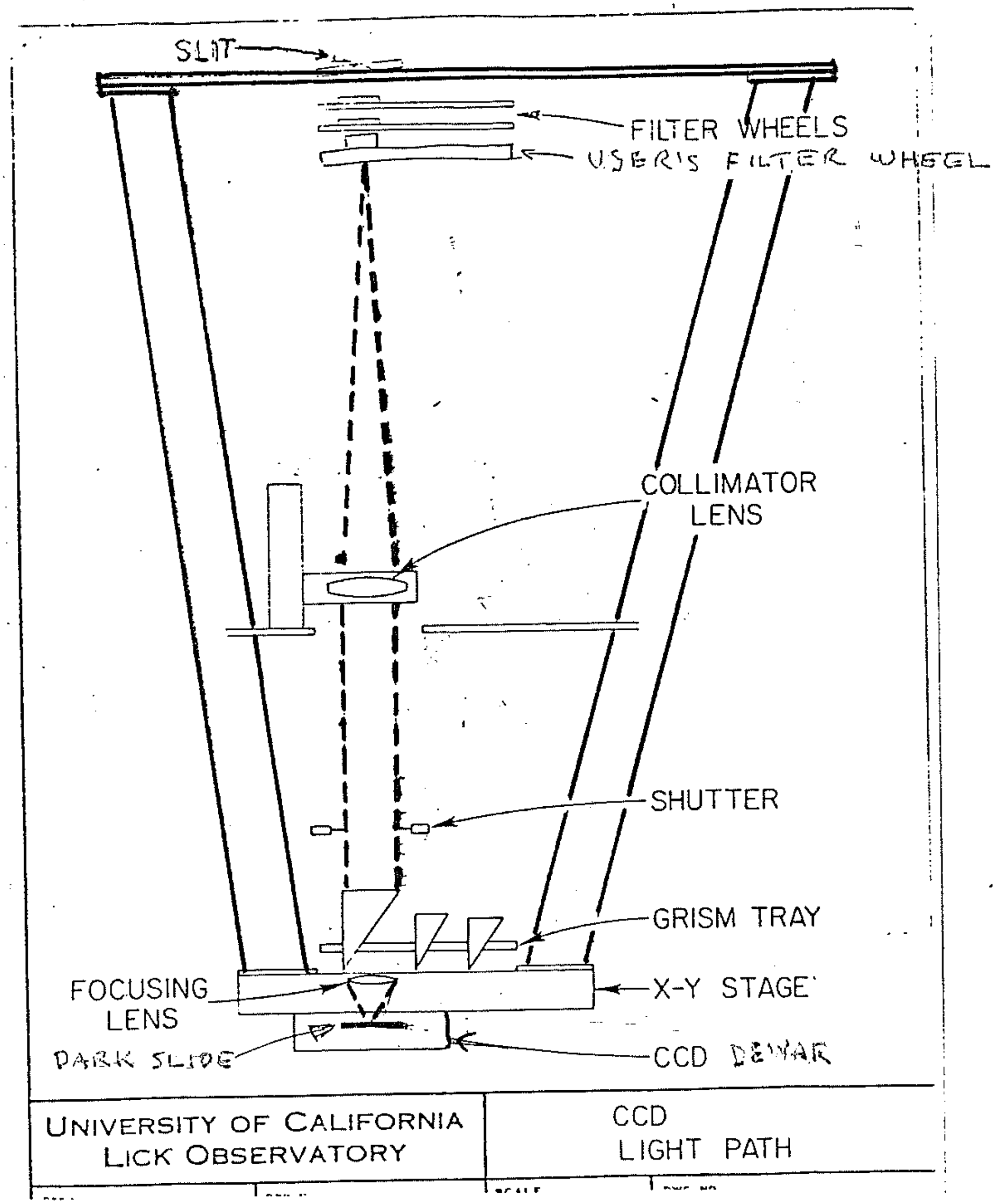

Figure 1 Grism operation

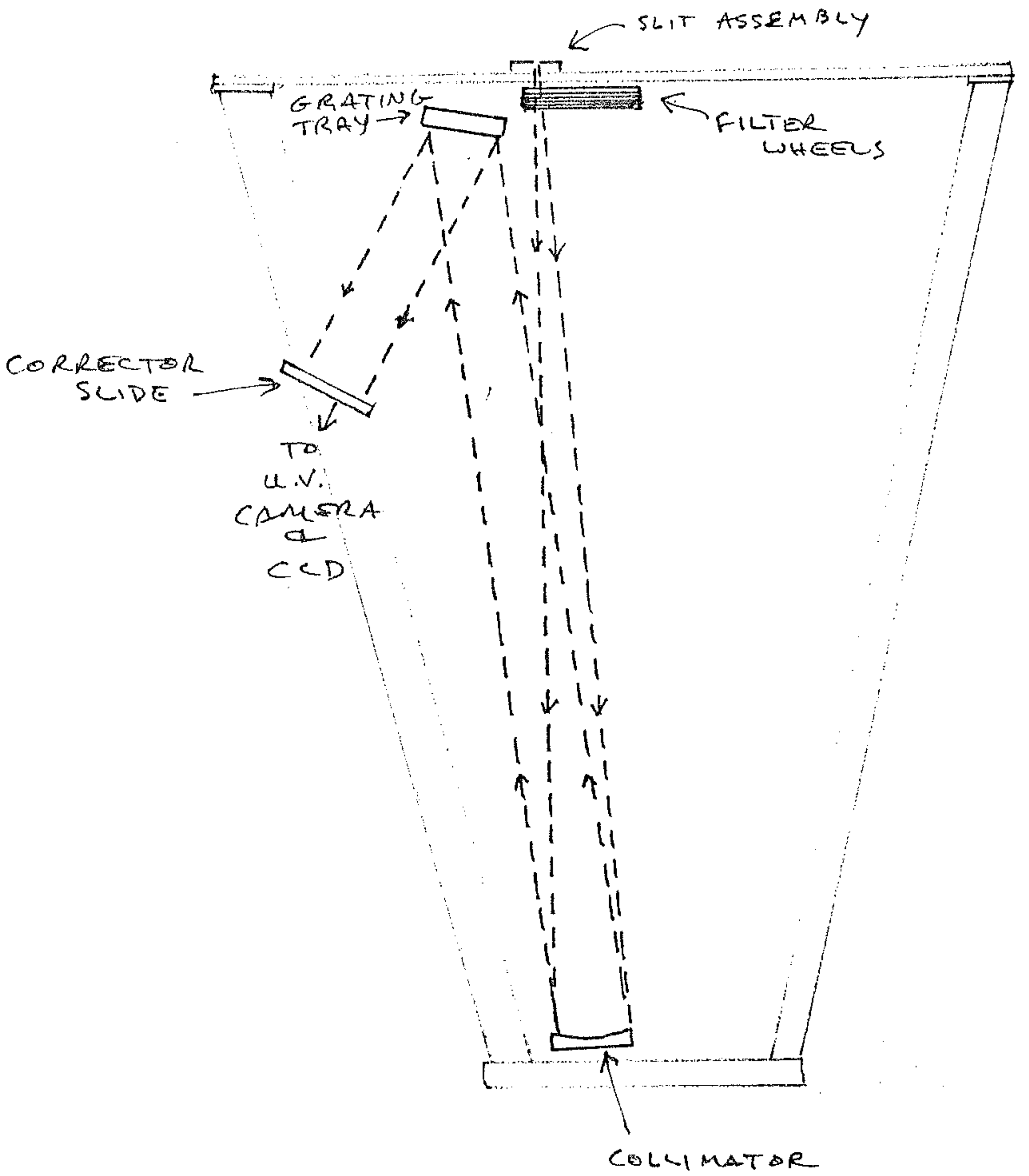

Fig 2: LIGHT PATH FOR U.V. SCHMIDT PLUS CCD

Two Schmidt correctors are present and can be remotely switched; the "blue" corrector is well-connected for 3000-6000Å and the "red" from 3900-11000Å. The CCD is protected by a manual dark slide, and is mounted at the odd angle on the side of the spectrograph which is determined by the emergent beam from the camera.

A major advantage in both modes is the ease with which one may switch between direct imaging and spectroscopy. This, in combination with a good telescope offset program, is often crucial for centering the slit on very faint objects.

The spectrograph is controlled remotely from the readout room. At present, the only functions that cannot be controlled remotely are to open/close the manual dark slide and (in the grism mode) to move the X-Y stage. Usually it is not necessary to change these during the night, so the result is that the observer usually does not need to go onto the dome floor at all during the night, but makes all necessary changes remotely.

Data taking and preliminary analysis is done from two terminals in the control room. The data-taking process is a menu-driven system, and is described in *CCD Data-Taking at Lick Observatory* by Richard Stover. Most observers find it to be an extraordinarily user-friendly system.

An ISI workstation is used for preliminary data analysis using Lick Observatory's locally developed language, VISTA. It is a command-driven system and features excellent help documentation, but it will be very useful if you acquire some prior familiarity with what is available by looking over the VISTA manual written by Richard Stover and Donald Terndrup. Use of the workstation is described in *The New Lick Data-Taking System* by Richard Stover.

Hardware is shared by the data taking and data analysis (VISTA) systems.

Built by Integrated Solutions, Inc. (ISI), the VME-bus UNIX machine includes two 68020 CPU's, 16 Mbytes of memory, a 360-megabyte hard disk, and a nine-track tape drive, a high resolution monochrome graphics monitor with mouse, an 8-plane color image display with a trackball, and a video printer. Again, use of this equipment is covered in *The New Lick Data-Taking System.*

IMPORTANT

> We wish to stress here an important and not-to-be-forgotten responsibility of the observer. The CCD response is enhanced and made more uniform by flooding it with UV light during a complicated cooling procedure. Once this flood is performed, the beneficial effects remain as long as the CCD is kept cold. To keep the CCD cold is the observer's responsibility. You may delegate the task, but it remains your responsibility if the task is not carried out, and it will cause hard feelings among those who will have to rush it to Santa Cruz for a reflood. So please be very careful to always keep the dewar cold.

II. COMPONENTS ON THE TELESCOPE

Before we get to the specifics, here is a very important thing to bear in mind. The mobile lift platform ("cherry picker") we have been using for access to the spectrograph is sufficiently tall to strike the spectrograph. It has always been an area of concern, but now when the CCD is mounted right at the bottom of the spectrograph for the grism mode, it is an even greater worry. Any contact between the cherry picker and the CCD stage could leave us without our best detector for many months. For this reason, some stairs on wheels are provided, and they should be used whenever possible. In practice, that means you should only need the cherry picker for access to the calibration lamp switches, the grating carrier (UV mode), and possibly the filter wheel, as described below. Please be very, very cautious with the cherry picker!

The order of discussion below will generally follow the light path through the system.

A. TUB.

The *T*elescope *U*tilization *B*in (TUB) is that portion of the telescope below the primary mirror cell. It acts as a carrier for the Cassegrain instrumentation, including the TV acquisition and guidance system, the diagonal mirror system, comparison lamp sources and the spectrograph itself. The entire TUB assembly may be rotated from the control room. Its function remains identical in both the lens/grism and UV Schmidt modes.

1. Diagonal Mirror. There are four switch-selectable positions of the diagonal mirror carrier. In position 1, the carrier is completely out of the beam, so all of the light is passed down to the detector, but none is available for guiding. Position 2 puts a full surface flat mirror in the beam, which diverts all the light to the TV for field acquisition; no light reaches the detector. A white card on the back of the mirror in position 2 directs light from the quartz and/or line lamps onto the slit for setting up or wavelength calibration. In position 3, a portion of the diagonal mirror that has a hole in it is positioned so that light from the object passes through the hole to the detector, and the surrounding mirror is available for offset guiding. Finally in position 4, the mirror is entirely out of the way, but a periscope is in position to view the slit. The slit jaws are tilted slightly, and light reflected from them is directed to the periscope, which directs the light to the TV for guiding.

2. TV. An integrating CCD camera system is used for object acquisition and guiding. It is mounted on an x-y stage for offset guiding.

3. Line and Continuum Lamps.There are a variety of lamps available in the TUB. A switch panel on the TUB allows the user to choose various combinations of line lamps to be selected by either of two switches in the readout room. Each is controlled by a 3-position toggle: up for "relay 1," center for off, and down for "relay 2." Relay 1 is controlled by a pushbutton in the control room arbitrarily marked "He HgA" and relay 2 is controlled by a button marked "Ne." In fact, of course, you can put whatever combination of lamps you want on either relay. Here is a list of the lamps in left to right order on the TUB switch panel:

1. Helium
2. Mercury-Cadmium
3. Mercury-Argon
4. (unusable)
5. Neon
6. Helium-Argon
7. Argon

Sample spectra are presented at the end of the manual.

Please keep the lamps turned off when not in use, because they tend to have short lives and are expensive. This applies particularly to the cadmium lamp, which has a life of only a few hours and costs > $200 each.

The cadmium lamp requires about two minutes warmup time in order to get hot enough for any significant Cd emission. The others are usually ready right away, but if they get old the characteristics may change. Line strength ratios vary with age and temperature, so if what you see varies moderately from what you have seen in the past or from the sample spectra in the Appendix, it is probably not a cause for worry.

There is also a quartz lamp in the TUB which is contolled from the readout room. It is quite bright, and will require ND filters to prevent saturating the CCD. It illuminates the slit in a *very* different way from a celestial source, so it is not useful for flat fields, for example, but you may want to use it simply as a source of light.

4. Tub Rotation. The entire TUB can be rotated remotely from the control room. The reason for doing this is usually to put the slit at some preferred position angle. All the TUB contents and the spectrograph go with the TUB, so nothing changes except the relationship of the sky to the TUB contents; thus, sky orientations on the TV and on the CCD rotate. This is discussed further in Section III.8 below.

The TUB is usually stowed at position angle 90°, which puts the slit east-west. The position angle is read most easily from the telescope status display – ask the night assistant to show you where to look. It is not possible to rotate through PA = 20° from either side. Any position angle can be reached, but it may require going around the long way. In many cases, using the supplementary angle will save time.

B. SPECTROGRAPH

The spectrograph is fixed to and rotates with the TUB. Nearly all components of the spectrograph can be set by remote control using either the spectrograph controller in the data room or the computer. The spectrograph controller provides a display which indicates the positions of the components and a guide to what the positions actually mean in terms of filters, slit widths, etc.

Flexure at the CCD is measured by rotating the tub at large zenith distances and various azimuths. The flexure in the grism mode is less than 0.8 pixel at 60° zenith distance through a full rotation of the spectrograph. In the UV mode it has yet to be measured.

The description of the spectrograph which follows is divided into two sections, one for the grism mode and one for the UV mode. They are partially redundant, but the advantage is each section is complete and self-contained.

1. Grism mode

a. Slit. The slit opens bilaterally, and may be set remotely at 0.2″ increments. It is about 2′ long, and when fully open it is a bit over 2′ wide. The slit jaws are reflective and may be used to guide on.

b. Decker. The decker overlies the slit. It is a long reflective piece of material which allows the observer to select a variety of options. Many of the positions are two channel options intended for use with the ITS. They are not used with the CCD, since ordinarily it is preferable to record information from the whole length of the slit. A single channel step wedge portion of the decker allows choices of 1, 2, 15, 30, and 60″ slit lengths or an unobstructed slit of 2′ length. A blocker is available which may be used to block the light from obects which may saturate the CCD before fainter outlying regions are satisfactorily detected. Blocker sizes of 2, 4, 6 and 8″ are provided. It is often useful to position the blocker just off of the slit and to use it as a pointer for positioning objects of interest at the center of the slit length. Finally, the decker may be removed entirely so the entire 2 ′ × 2 ′ area of the fully opened slit is unobstructed for direct CCD frames. Decker parameters may change with time in response to observer‘s needs (e.g., different sizes may be available), so always check the spectrograph control box for the latest configurations.

c. Filters. There are three stacked filter wheels known as the upper, lower, and user wheels. One position of each wheel is always empty. The position of each wheel is selected with the spectrograph controller. Here is what is usually in the upper and lower wheels.

Upper: 2.5 mag ND, 7.5 mag ND, $CuSo_4$, 5.0 mag ND, "Spinrad" Night Sky, beam splitter for polarimeter.

Lower: GG495, GG385, 1.25 mag ND, GG455, 6.25 mag ND, 0G570, "BG 14"

Notice that the BG-14 in the lower wheel is actually a stack of filters for CCD flat fielding.

The user's filter wheel is available for observer's own filters (or ones from our growing filter library, kindly made available by various astronomers within the system). The wheel accepts filters up to 2" square and 8mm deep mounted in special holders available on the mountain. Someone will definitely need to show you how to mount the filter holders in the wheel. You may have four filters mounted in the wheel at once. Please remove your filters at the end of your run.

d. Collimator lens. The collimator is focused remotely from the control room. Its diameter is 82.5 mm, focal length 711 mm.

e. Shutter. The shutter is controlled automatically by the computer. It is operated by a Uniblitz power supply mounted on the TUB. Occasionally it is useful to operate the shutter manually by a toggle on the power supply (for example, to be sure it is opening or not sticking) but the manual control *must* be left in the "closed" position for control by the computer. The minimum exposure time is 1 sec. Timing error is a few msec.

f. Grism tray. Two varieties of grism tray are available. The normal tray holds any three grisms. The other one holds the eschism with its cross-dispersing grism (see Section V.B) plus one other grism. Either tray may be repositioned remotely, including being moved completely out of the beam for direct imaging.

Access to the grism tray is easiest at grism select 000, and is via an aluminum door which is on the south side of the spectrograph, for normal TUB position angle. To change grisms, close the manual dark slide, then open the door by releasing two latches on the bottom. The grism trays are locked in by a small brass post that swivels 90° in either direction to release. Then push up carefully on the handle of the grism tray in order to pop it out of its slot, and withdraw the tray. Be very careful not to let the grisms touch anything. In particular, do not let the brass locking latch gouge into the bottoms of the grisms.

In order to change grisms, please work in a well-lighted room (e.g., the control room). Be sure the table is clear of any small items like screws that might damage the grisms. It is the bottoms of the grisms that are grooved and vulnerable. Please do not touch the two bright metal screws at the top and bottom center that lock the grisms into their holders at a particular angle; they have been carefully set. To remove a grism, unscrew only the two black metal screws in the upper right and lower left corners of the metal frames, and lift the grism out carefully.

Fit the new grism in place. Be sure the prism's angled surface is oriented correctly, or the spectrum will be reversed. The thick part of the prism should be towards the tray handle. If you only remove one grism at a time then you can use the ones still in the slide to get the sense of the prism right. Be sure the grisms are properly seated in their cut-outs in the tray, then tighten the corner screws.

Reinstall the tray carefully, guiding it over the locking post and sliding it into its recess in the tray holder. Slide it in until the far end goes under the brass hold-down tab, then press down on the near-end corners to ensure a proper seat. Rotate the locking post into position and close the access door.

See Section V.A. for a description of the grisms available.

g. Camera Lens. The camera lens is a specially coated 58 mm f/1.2 Nikkor lens. The coating is supposed to give good transmission to 1.4 μ, but in fact its transmission is very poor between about 0.9 and 1.0 μ. Response farther to the red than 1 μ has not been adequately explored. At the blue end, the glass is opaque to wavelengths shorter than λ3850. The focal plane is fairly flat from about λ4000-λ7000, but requires compromise elsewhere.

h. X-Y Stage Assembly. The stage carries the chip in its dewar, the LN (used generically to mean liquid nitrogen or liquid air) reservoir, and some of the readout electronics. (See Figure 3, next page)

(1) Manual dark slide. The dark slide is an integral part of the stage assembly. It is usually left open when actively using the CCD, and closed during the daytime, or when the spectrograph is open in order to change grisms. It is a red anodized piece of metal that is hard to reach behind the LN reservoir. There is *no* remote indication as to whether it is in or out. The first reminder of it is often a CCD image that is unexpectedly dark. Do not forget to close the dark slide at the end of the night. It is natural to think of it when you refill the dewar.

(2) X-Y stage. The standard set-up for the dewar has the spectrum along columns of the CCD. A movement of the stage in the X direction, parallel to the dispersion, is used to adjust the central wavelength (λ_c) and/or to position the

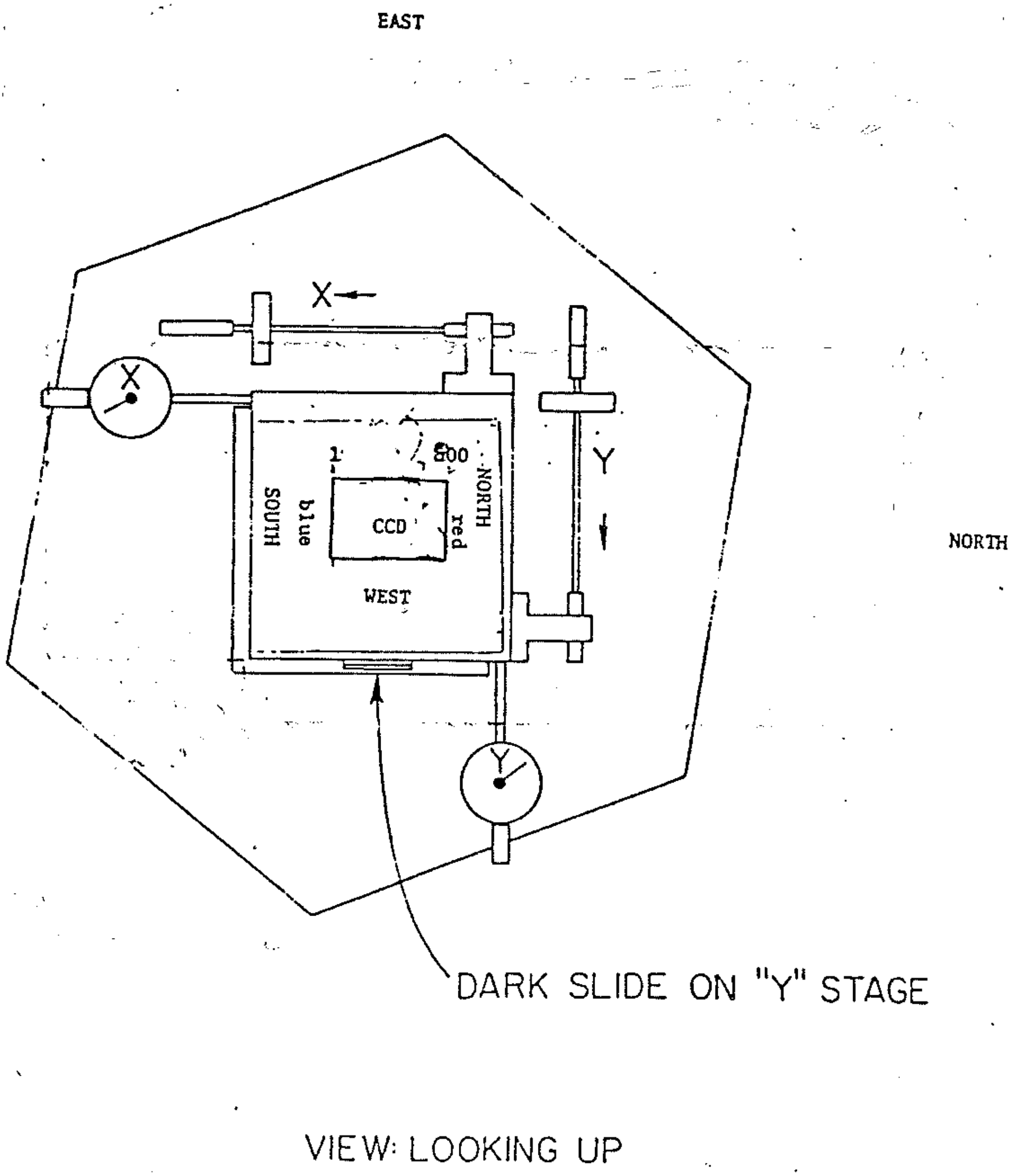

Figure 3 X-Y Stage for Grism Spectrograph

direct window at a particular place on the chip. Notice that these are not independent settings. Putting the direct window at a particular place on the chip in the X-direction determines λ_c for all grisms, or setting λ_c for one grism determines λ_c for the others, as well as the position of the direct window. Think of the direct window and the spectra as being fixed with respect to the spectrograph and each other and the CCD as being moved past them – since that is the way it works. So you set the one that is most important, then either take what you get with the others, or start making compromises. Increasing the X-setting results in a decrease of central wavelength and an increase of the pixel number of the center of a direct image.

A move in the Y direction is perpendicular to the dispersion. Most users agree on which part of a given chip is cosmetically best for the spectrum, so the Y settings are rarely changed. Increasing Y moves the center of the slit to higher column numbers.

To set in either X or Y, unlock the appropriate two clamps on opposite sides of the stage a quarter turn, then move the stage with the appropriate screw (see Figure 2). The position is read out as **a.bbb**, where **a** comes from the very small dial in the micrometer and **bbb** is read from the large dial. The scale is 1 mm per full turn of the big dial. There may well be backlash in the screw, but there should be none in the spring loaded micrometer, so you do not need to worry about it. Be sure to relock the stage *firmly* with two clamps for each direction.

Finally, there is a limited adjustment in rotation, but users may not change it.

(3) Ion pump. An ion pump is used to help control any outgassing or minor leakage. It should be on at all times. In case of a power failure it must be reset.

Ask maintenance or a night assistant to do this.

(4) Cooling. The hold time of the dewar is very good. All that is required is to refill the LN reservoir every 12 hours or so. It is good to do it, say, after supper and again at the end of the night. Above all, do not forget!

2. UV Mode

a) Shutter. The shutter for the UV mode is located above the slit. Since one often needs to see the slit between exposures in order to position the object to be observed, an unusual shutter sequence has been devised. Between exposures the shutter is open, but an automated computer controlled dark slide below the slit is closed. When an exposure is initiated, the shutter is closed (briefly obscuring the view of the slit on the TV), the behind-the-slit dark slide is opened, and then the shutter is opened and the exposure is begun. At the end of the exposure the sequence is reversed. This shutter-dark slide-shutter sequence takes a few seconds at each end of the exposure, but be assured that the exposure times are correct.

b) Slit. The slit opens bilaterally, and may be set remotely at $0.2''$ increments. It is about $2'$ long, and when fully open it is a bit over $2'$ wide. The slit jaws are reflective and may be used to guide on.

c) Decker. The decker overlies the slit. It is a long reflective piece of material which allows the observer to select a variety of options. Many of the positions are two channel options intended for use with the ITS. They are not used with the CCD, since ordinarily it is preferable to record information from the whole length of the slit. A single channel step wedge portion of the decker allows choices of 1, 2, 15, 30, and $60''$ slit lengths or an unobstructed slit of $2'$ length. A blocker is available which may be used to block the light from obects which may saturate the CCD before fainter outlying regions are satisfactorily detected. Blocker sizes of 2, 4, 6 and 8″ are provided. It is often useful to position the blocker just off of the slit and to use it as a pointer for positioning objects of interest at the center of the slit length. Finally, the decker may be removed entirely so the entire 2 ′ × 2 ′ area of the fully opened slit is unobstructed for direct CCD frames. Decker parameters may change with time in response to observer's needs (e.g., different sizes may be available), so always check the spectrograph control box for the latest configurations.

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e) Collimator mirror. The collimator mirror is an off-axis paraboloid which directs the beam back up and off to the side a bit to the grating tray. The spectrograph is focussed by moving the collimator remotely from the control room.

f) Grating Tray. Before you go up to the spectrograph, set the grating tilt to 01500 and grating select to 500 in order to be able to get at the gratings. The gratings are stored in the prime focus prep room on the mezzanine level – you'll need someone to show you where they are the first time. The replacement cost per grating is thousands of dollars, so handle them with extreme care. Handling the gratings is normally the direct responsibility of the scheduled observer. If you're not comfortable with it, please ask for help. The dome personnel would rather do it for you than to see a grating damaged. Never leave a grating lying around. They should go directly from the grating file into the spectrograph or vice versa. As soon as you're done, return the grating file to the prime focus prep room.

Access to the grating tray is via a long black door at the top of the south side of the spectrograph. You'll need to use the cherry picker in order to get high enough (be careful, and while you're up there check the line lamp setup [Section II.A.3]). Two small red thumbscrews (not captive) secure the door, which is hinged at the bottom. If you set the tilt and grating select as suggested in the preceding paragraph, you'll find that you can read the labels on the gratings. Even if you don't plan to change gratings from those used by the prior observer, we suggest you verify for yourself what gratings are in the tray. A label inside the door will remind you of the unexpected fact that the grating accessed by grating select 000 is the rightmost one in the carrier, and grating select 999 gets you the leftmost one.

To change a grating, turn the metallic latch 90° counterclockwise, withdraw the grating very carefully (they're heavier than you might expect), and immediately put it in an empty slot in the grating file. Of course, <u>never</u> touch the grating surface with anything. Slide the new grating into the carrier – you may have to wiggle it around a bit to get it lined up so it will slide in. <u>Do not</u> force it in order to make it go in. When it's lined up properly it will slide in easily. Lock it in by turning the latch firmly clockwise.

Finally, double check to be sure you have the desired gratings (and flat mirror if you'll be doing direct imaging) in the correct slots. There is a little flexure in the grating tray, so if you'll be taking directs in order to center faint objects, the 000 position is preferred for the flat mirror.

This is a good time to open the manual dark slide.

g) <u>Corrector slide.</u> Two correctors are incorporated into the spectrograph. They are positioned remotely from the control room. The blue corrector is preferred for $\lambda \leq 6000$Å, the red for wavelengths from 3900-11000Å.

h) <u>Manual dark slide.</u> The manual dark slide is normally left open unless you'll be away from the telescope for an extended period. The slide is not easy to see since it's black, but it's just at the top of the CCD dewar and electronics package, and it pulls out as far as you can move it to the right (4-5").

i) <u>Ion Pump.</u> The ion pump helps to control any outgassing or minor leakage. It should be on at all times. In case of a power failure it must be reset. Ask maintenance or a night assistant to do this.

j) <u>Cooling.</u> Although the hold time of the dewar is very good, it sits at a funny angle on the spectrograph so that even at the zenith its probably only 2/3 full, and as soon as you move the telescope in any direction, the situation gets worse. If no adjustment is made, it is possible to move the telescope so as to dump out essentially all the coolant. We try to correct for this by rotating the tub, depending on which quadrant of the sky you're observing in, so as to keep the dewar relatively upright. A flowchart to help with this is posted in the readout room at the telescope. The night assistant (NA) will try to help you stay aware of the preferred position angle of the tub; conversely, if you're moving to another part of the sky, you can help by pointing this out to the NA . There is an alarm in case the coolant gets so low that the chip starts to warm up, but if that happens your data may be affected, so you really want to keep ahead on the coolant situation. If the alarm goes off, you must interrupt your observation immediately and add coolant. You can minimize the likelihood of an interrupted observation by using the preferred position angles, by refilling the dewar periodically between observations – more often if you've been observing at larger zenith distances, and by trying to observe as high in the sky as possible.

If you need a particular position angle for your observations, it may require some extra thought and planning to determine a position in the sky compatible with the angle required. It is possible that some desirable position angles may not be possible. In any case, be cautious and thoughtful about the problem.

Installation of a newly designed dewar may alleviate this problem soon.

C. CCD Controller

The controller is mounted on a rack attached to the TUB, and contains most of the readout and temperature control electronics for the CCD. It will be properly set up by the dome crew. The only thing the observer need be concerned with is the temperature readout in the upper right corner of the controller panel. It reads the temperature near the chip in degrees Celsius. It should be stable to within ± 0.1 degree (the last digit is tenths of a degree). If it starts to rise, check the LN; if it starts to fall, the heater is failing to control the temperature properly and you should get help immediately. Since the response of the chip is temperature sensitive, it is quite important that it remain constant.

D. Top-end Flat Field Lamps

The primary (that is, first choice) flat field lamps are mounted on the top of the secondary mirror housing. There are two lamps, switch selectable from the control room. The blue lamp is usually the lamp of choice for dispersed flat fielding, and is usually used with a stack of filters (called BG-14 because that is what one of them is) in order to get a more even continuum distribution. The red lamp is much dimmer and more sky colored, and is used for direct (non-dispersed) flat fielding.

Flats are taken on the inside surface of the dome. Irregularities on the dome can be ignored because they are so far out of focus. Do not forget that the mirror cover must be open, and the diagonal mirror must be in some position other than 2 in order for light from the secondary flat field sources to reach the chip. *Use position 3 for direct flats (and direct observations) in order to avoid possible occultation of the field by the periscope in position 4.* Do not use the internal quartz lamp for flat fields because it illuminates the chip in very strange ways.

III. CONTROL ROOM

A. Monitors and Terminals

For a more in-depth discussion, please see Richard Stover's *The New Lick Data-Taking System.* Here we tell you just enough to turn on and log in at the terminals.

The ISI Workstation turns on with a switch on the rear of the monitor.

Normally it comes on with a big ISI logo and a login prompt in the lower left corner. If you don't see that, try turning up the brightness, which is a roller adjustment on the right rear of the large square front section. (Ignore the "offline" and "keyboard locked" lites on the keyboard, which often seem to be on but lying.) Log in with "user." The logo will disappear and you will see a number of icons displayed on the screen. Use the mouse to position the cursor over the "Vista" logo and press and hold the center mouse button (the mouse looks like it has nine buttons in groups of three, but if you investigate you will see each "group of three" is really one button, so there are in fact only three buttons total). Pressing and holding the center mouse button will generate a short menu. Use the mouse to select "run" and let up the button. A Vista window will appear, so you are now logged on and running Vista.

Vista runs pretty much as before, with a few exceptions. First, we now run the full "downtown" Vista, so if you're efficient (and like Vista) you can do a complete reduction on the spot. Second, the terminals are no longer locked out during readout. The two CPU's make it possible for the CCD control functions and the terminals to operate independently. Third, the graphics operate differently. See Stover's manual for details. One remark which may help past users is that the cursor may be displayed on an image from either terminal, as before, but row, column and pixel numbers are displayed on the terminals rather than on the image display device. Finally, the "plot" command works only on data buffers, so it is no longer possible to plot directly from the disk.

The brand of the data-taking terminal has been changing every few days at the time of writing. So, turn it on (somehow!), hit "return" and get a login prompt. After various messages, you'll receive a "ucscloc.user:" prompt. Enter "d" for data-taking, and after some more messages the data-taking menu will appeaer.

B. Tapes and Tape Drives

Data can be taken on the hard disk, or on 9-track tape, or both. Most users elect for both. After your tape is loaded and write enabled, see the options under Z2 from the data-taking terminal to initialize your tape. It is important to know that the tape must be reinitialized every time the data taking program is reloaded. You can bring your own tapes, or buy them on the mountain (not for cash – they will be recharged to you). See the electronics people or night assistants to buy tapes. Please remove your tape from the tape drive at the end of each night.

C. Log Sheets

The tape headers are quite complete, but a log on paper is useful for recalling images during the night as well as just keeping track of what has happened. Log sheets are usually available from the telescope technicians (also referred to as night assistants or NAs) or help yourself from the bottom right-hand drawer of the NA's desk. See the Appendices for a sample.

D. Guide and Acquisition Television

The camera is a very sensitive CCD device. On a dark night with full integration and good seeing, you can see objects as faint as 22nd magnitude. The field of view is about 2 arcmins diagonally.

The camera is relatively invulnerable to damage – the only prohibition is don't look at the sun. It will not harm the camera even at max gain to turn on the room lights or comparison lamps, for example.

The NAs will operate the camera for you or you may do it yourself. There are only five controls. The gain and integration are self-explanatory. Most people like to use the gain alone up to max before using any integration. The binning feature allows rows and columns of the CCD chip to be combined as they are read out. This has the effect of making the CCD map onto a smaller area of the TV screen. Only with 2 x 2 binning can you see the entire chip area on the TV. With a 1 x 1 (or unbinned) display, about 2/3 of the chip fills the TV screen at twice the scale of 2 x 2 binning. The display switch allows you to map the center or your choice of the four quadrants onto the TV when binning 1 x 1. Finally, the offset control affects the zero point and dynamic range of the display. Usually it's not necessary to adjust it, but in high contrast situations you may be able to improve the picture.

E. Guiding Aids: Crosses, Reticle, Grease Pencils, The Finger, and the Autoguider

The finger does not mean pointing at the desired object. It refers to the blocker on the decker. By positioning the blocker (or "finger") just off the slit, it serves as a pointer to aid in putting and keeping an object at a fixed position along the length of the slit. This is desirable since the flux calibration will presumably be done at the same position. In theory, flattening will mean it does not matter, and for extended or multiple objects you have to hope it is true; but the smart money still says keep everything the same if you can. Also the fewer the rows/columns summed for the final spectrum, the lower the readout noise in the result.

There are various other ways to mark the TV screen for reference purposes. A cross generator provides three crosses (+) which can be positioned anywhere on the screen. They are pretty stable, but they slowly creep over a period of time.

Another option is to use grease pencils to mark the screen. Two colors are usually readily available. Grease pencil marks are guaranteed not to creep across the TV screen, but there may be flexure in the camera mounting and/or the periscope, so the image may move even if the grease pencil marks are stable.

There is a reticle which may be projected onto a pellicle and thereby mixed into the TV image. The pellicle is highly stable with respect to the slit when mirror positions 2 or 3 are used, but the periscope is not rigid and can cause some wandering of the apparent slit image seen through it relative to the reticle.

Finally, there is an autoguider, which is what you will probably really use. It produces a reticle of its own on the TV, which the NA will position over a guide star. The reticle is divided into four quadrants, and the autoguider senses what fraction of the light from the guide star is in each quadrant, and then guides so as to maintain that balance. The autoguider is very good but not infallible, so you should watch it from time to time especially if there are clouds about. Fall asleep at your own risk. Ask the NA to explain the autoguider history display to you. It is a useful check on autoguider performance. Also, you should know that you can use the guide paddle to recenter the guide star image on the autoguider reticle at any time. The autoguider will sense the paddle input, and automatically reinitialize on the new position. Because autoguiding with an integrating detector is not always straightforward, the autoguider may have to be tweaked for some situations to improve performance.

The most worry-free situation is if your object is bright enough to see directly on the slit. If you can guide directly on that portion of the light that does not make it through the slit jaws, then at least you are assured that the rest is going into the slit. In many cases, the object of interest is too faint for that, in which case you will be interested in:

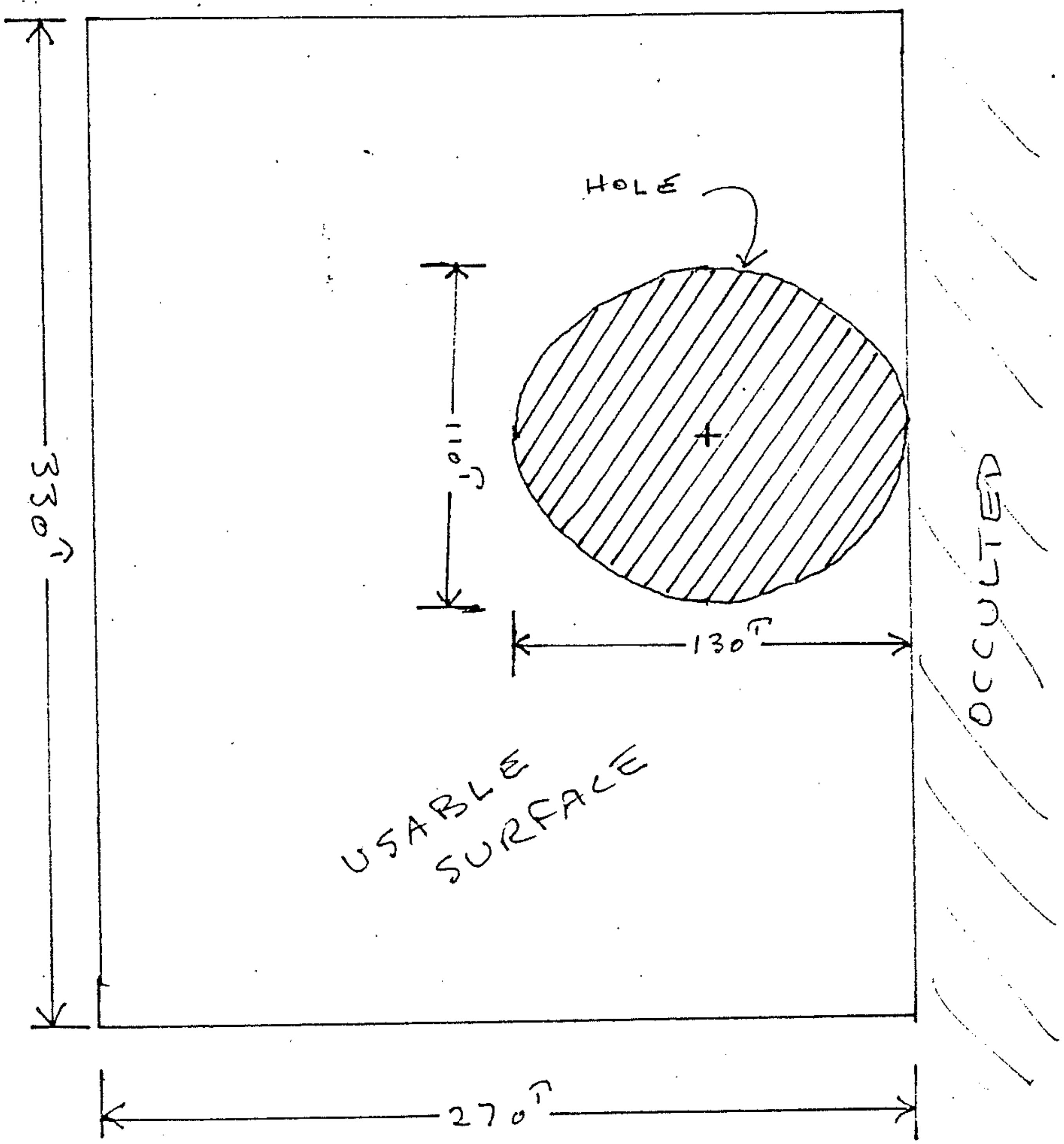
F. Offset Guiding

The simplest case is where there's enough light from the object to guide on the slit. Often, however, the object is bright enough to visually center it on the slit, but there is not enough light left over to guide on. If you are lucky, you may be able to guide on some other object that happens to be visible on the slit jaws. Or, more commonly, there will be no such object and you will have to offset guide. In the latter case, advise the NA and he will find you a guide star. You might be able to help if you can advise the NA where a likely candidate star is. The useful area of the offset guiding mirror (position 3) is approximately as shown on the next page.

G. Centering on Very Faint Objects

If the object is too faint to visually center it on the slit, then a major advantage of this spectrograph design becomes apparent. In almost any case one might imagine, you can dead reckon the object to within an arcminute or so of the slit center. Then, take a direct CCD image while offset guiding to prevent drift, identify your object (down to 23rd mag is not unusual), and use the CCD telescope offset routine to move the telescope so as to center the image in the slit for a spectroscopic observation. Use the cursor routine from the data-taking terminal to mark the positions, then the Z-5 submenu to move the telescope so as to move the object from one marked position to the other. It works, and it is really nice. Here are two important hints: 1) be sure to turn off the autoguider during moves, and 2) all of the experienced observers take another direct image to be sure the telescope moved as desired.

The CCD can be mounted at the telescope so the spectrum is either along rows or along columns, though it is almost always preferred along columns. The system does not sense which way the dewar is mounted, so there is provision in the software



Mirror Position 3 Showing Usable Offset
Guiding Area

for the user to specify, on submenu Z3. Usually the chip is mounted in the same way for successive observers, but if the CCD offset program moves the telescope at right angles to what you expected, try resetting the CCD orientation parameter under Z3.

H. Manual Guiding

Yes, it is still possible! The standard Lick guide paddle provides a joystick and has three switches. The "enable/disenable" switch should be left on enable, so the computer can move the telescope for offsets, for example. The "set/normal" switch allows fast (set) or slow (normal = guide) speeds. Finally, the "norm/rev" switch allows you to reverse the sense of the joystick for the R. A. direction, so you can set it to your liking.

The paddle provides aural feedback, which is a surprisingly useful feature. Each click represents one step of the stepping motors, and corresponds to about $0\farcs05$ ($\cos\delta$) in R. A., and about $0\farcs07$ in Dec. Occasionally these might be useful for making small precise corrections in setting, but usually it is easier to use one of the offset programs. Generally, the aural feedback feature is useful in a less precise way, like if a bunch of clicks went twice as far as you wanted, then half a bunch the other way should be just right.

I. Field Size and Orientation

The long slit capability of the CCD has proven to very useful on extended objects, as well as on multiple colinear objects. For these observations, one nearly always wants to rotate the instrument tub to some predetermined (or in some cases, determined on the spot from the TV or CCD direct frames) position angle. It's useful to know which directions are which, for various position angles, in order to plan setups and verify that they are correct.

First, a word on scale and orientation on the TV, as a function of diagonal mirror position. If the instrument tub is in "normal" position angle = 90°, then in mirror position 2, one sees a field about 2 arcmin across on the TV, with north at the top and east to the left. When offset guiding in position 3, this is of course the same. In position 4, the field size is roughly one arcmin, and there's an east-west flip of the image because of an extra reflection, so north is at the top and west is to the left.

How about the CCD's? It would be nice if they had the same orientations as the TV, but they don't. For normal TUB position (PA = 90°), the orientations are: TI$(500)^2$, north right and east at the top; TI$(800)^2$, north down and east right. It could be worse; at least these correspond to simple rotations of most charts. For different position angles, the *relative* positions of the TV, slit, and CCD are unchanged. The effect of going to a *higher* position angle (that is, in the usual sense of north through east) is to rotate images on both the TV and CCD *clockwise.*

Again for PA = 90°, the slit as you look at it on the TV lies left (west) and right (east). About 60% of the total slit length is seen on the TV at a given TV position; the TV camera may be moved on its stage to view different locations along the slit length.

J. Spectrograph Controller

1. Function selector, digiswitches and codes. In the center is a rotary selector with which you choose the spectrograph item you wish to change. This piece of equipment predates cheap microprocessors, so to change the settings of a spectrograph component, you choose the correct numerical code from lists on the front of the unit, set the code in with a set of five thumbwheels, set the selector switch to the item to be changed, and push the enable button. When the move is complete, a repetitive beep

will remind you to press the stop button. Codes may be 2 to 5 numbers in length, but they are always entered *left-justified* into the thumbwheels. A digital readout for each item tells how that item is positioned. A peculiarity is that the upper and lower filters have only two digit readouts, yet the codes are three digits long. Enter all three digits into the thumbwheels anyway; the last digit will be lost in the readout, but is used to actually position the filter. Once you have started a motion, do not move the selector switch until the motion is complete.

2. Limits. There is a red limit light on the panel. If it should light, then look to see which device is at an extreme position and move it away from the limit. It is important to do this right away, because if *two* devices reach opposite limits, then the controller goes catatonic, and it will be necessary to reposition at least one of them manually.

3. Slit. The slit opens bilaterally from 000 (fully closed) to 999 (fully open). A change of 005 represents one 15 μ pixel, or 0.7 arcsec. When fully open, it is about $2'$ wide.

4. Decker. See the code sheets on the face of the spectrograph controller for specific codes. With the CCD, one usually observes in long slit mode, which at least samples the sky pretty well, or with luck, allows one to obtain multiple spectra or spatial information in a single exposure. See Section II.B.1.b or II.B.2.b for a few additional remarks on the decker.

5. Filters. See Section II.B.1.c or II.B.2.c for the filters installed at the time of writing, and the code sheet on the controller for specific codes. Be sure to dial in all three code digits, even though only the first two are echoed in the display.

6. Corrector plates. There are two correctors in the spectrograph. They are

not in the light path for the grism mode, and for that it does not matter in which position the corrector plate selector is left. For the UV spectrograph, use the blue corrector for observations below 6000Å, and the red corrector longward of 3900Å. A toggle switch at the bottom of the spectrograph control panel may be used to select manual or computer control of the corrector plates. If under manual control, just punch the button to change correctors. Under computer control, from the VT-100 type "blue" for the blue corrector and (illogically) "redcorr" for the red corrector.

7. Grating Select. This function selects the disperser to be used. The grating tray has three positions, coded 000, 500 and 999 (one may contain a flat mirror for direct imaging).

As was mentioned, the normal grism trays hold three grisms of your choice. They are selected by "grating select" codes 345, 670, 999, which correspond to the grism farthest from the handle of the tray, in the middle, and next to the handle, respectively. In addition, code 000 removes the tray from the beam for direct imaging.

The echism tray holds one normal grism at position 345, and the cross-dispersed echism at position 830.

8. Collimator. The spectrograph is focused by moving the collimator up and down. (Of course, it is a physically different collimator for the UV or grism mode.) It takes a change of about 50 units in order to produce a noticeable difference in the spectrum. Some observers just take a sequence of spectra at different collimator positions (usually with a smallish slit; 007 [about a pixel and a half] seems popular for the slit size) and look at them. Others like to count pixels in two or three lines across the spectrum (perhaps down to FWHM). A third approach is to plot individual lines with an offset between different successive foci. There does not appear to be a best

technique, but do not forget to consider both ends of the spectrum, unless you really only care about the middle. TI chips are not flat, which can cause additional focus problems.

9. Grating tilt. See the info sheets at the beginning of the manual or Section V for grating tilt equations. When in grism mode, the best position in which to leave the grating tray is 38000, since it is most clear of the beam there. The grisms, of course, do not tilt.

There is one aspect of the grating tilt which is so bizzare that we reprint part of the following memo to describe it:

> Cass Spectrograph – Grating Tilt Description – EL 360
>
> October 2, 1975
>
> The behavior of the Grating Tilt readout can be somewhat mystifying unless the mechanism is explained. For example, if one wishes to change position from 21,500 to 20,400, the readout will change in the following peculiar way:
>
> 21500, 21499—21002, 21001, 21000, 21999(!), 21998—21003, 21002, 20002(!), 20003, —20399, 20400.
>
> The reason for this is that the number is derived from two sources. An incremental digital encoder generates the least significnat 3 digits, and an analog to digital encoder generates the 2 most significant digits from the voltage on a gear coupled 40 turn potentiometer. These two upper digits are recorded only at the time the low 3 digits read 002. Thus when numbers are decreasing, it is nec-

essary to reach the bottom of a 1000 count segment before learning for sure which thousand it is. When numbers are increasing, there is no anomalous behavior.

Moral: Let the grating tilt procedure continue uninterrupted until it reaches its destination.

10. Remote Dark Slide. Remember: the remote controlled dark slide is just below the slit and is to be distinguished from the manual dark slide located near the CCD. When in grism mode, it is usually most convenient to leave the remote spectrograph dark slide out at all times. This dark slide does work, but it is very easy to forget to open it again. The manual dark slide protects the CCD better, and the shutter acts as a dark slide between exposures, so the remote spectrograph dark slide is usually not required.

When in UV mode, the remote controlled dark slide is part of the shutter system, described in Section II.B.2.a, and must be under computer control. Computer or manual control of the dark slide is selected by a toggle switch at the bottom of the panel.

11. Computer control. Under Z5 of the Data Taking program menu, you will find options to set all of the above by computer. During setup, it is often easiest to do it manually, but once you have worked out what settings you are going to use, the computer is usually best. The wonderful thing about the computer is that it does not get tired at 3:00 A.M. and forget things.

There are a couple of useful hints to make regarding use of the program. First, there are two lists given, the "request" list and the "actual" setup list. The actual list of course reflects how things are now, and the request list is how you would like things to be. When you change any parameters by computer, only the request list is changed, until you command "set spectrograph." All other commands operate only on the request list. This means, for example, that you can modify the request list and save the modified setup on the disk without actually changing the spectrograph. Similarly you can recall a setup from the disk, and check it or change it, without changing the setup being used.

It is very important to fix in your mind that this arrangement means that *two* separate steps are required to change spectrograph settings in the middle of the night. First, you "recall a setup" to make the request list show the setup you want; then "set spectrograph" to make the spectrograph settings according to the request list. More than one very tired astronomer has recalled a setup and then forgotten the second step. The unfortunate result is to make an observation with the wrong setup. There is also an "express" change of spectrograph setup invoked by typing "K" on the Data Taking program menu and entering the setup number you want.

K. Lamp Controls

Below the spectrograph controller is a panel which controls TUB components and flat field lamps. For the user, the important functions are lamp and diagonal mirror, tub rotation control, TV filters, X-Y stage for the reticle, and rheostat for the reticle. A number of controls are not used at present.

The lamps are controlled by a set of six switches in the center of the panel. The upper right switch turns on whichever of the two flat-field lamps at the top end that has been selected by the upper left switch. The upper left switch selects either red (for direct flats) or blue (for spectroscopic flats). The upper right switch just turns them on and off. The upper center switch is not presently used.

The lower three switches control the TUB lamps. The left switch actuates "relay 1" line lamps (see Sec. II.A.c above) and the center switch operates "relay 2" lamps. They are labelled "He Hg Ar" and "Neon" respectively, but remember that you can put any line lamp or combination of line lamps on either switch. Both switches may be operated at once to produce a combined spectrum. The lower right switch activates the (very bright) TUB quartz lamp.

You may notice that the TUB lamps do not illuminate the slit uniformly. This is true of all of the TUB lamps, line and continuum. Be assured that whatever it is that causes this nonuniformity, the secondary flat field lamps are not affected.

Please remember to keep the line lamps turned off when not in use, especially the cadmium.

L. Diagonal Mirror

The diagonal mirror is controlled by a switch just below the lamp switches. See Section II.A.1 for a description of the various mirror positions. Remember to use position 2 for TUB lamps, 3 for direct flats to avoid any possible occultation of the direct field by the periscope, and either 3 or 4 for dispersed flats.

M. Reticle and TV Stage Controls

The reticle X-Y stage and the TV stage may be moved independently or in slave mode by a joystick. Three speeds are available, × 1, × 10, and × 100. The reticle stage has some very nice digital readouts. For the normal position angle of the TUB (90°), to move the reticle in X is to move E-W, and Y is N-S. In mirror position 2 or 3 (but not 4) one unit in the stage readout is 0.1 arcsec. Be sure to turn off power to the stage after a motion is complete to avoid heat generation in the TUB.

N. Telescope Technicians and Night Assistants

All TTs can operate the telescope and all NAs are TTs, but on a given night one TT will be assigned as the "night assistant." The NA's primary duties are to 1) protect the telescope, and 2) help you get as much astronomy done as possible. NOTICE the order of those duties. The NA does have the authority to terminate observing at any time in order to protect the telescope or equipment. Usually this means closing the dome in case of high humidity, or ash fallout from a nearby forest fire, or high winds. Please read the Director's memo of 30 March 1983 reproduced in the Appendix, which outlines some of the mutual responsibilities of the TTs and observers.

In general the NAs are extremely cooperative and helpful. Ask for what you want, and they will try hard to provide it.

One occasional source of friction is the TV (that is, the Johnny Carson-type TV). Some observers like to watch it, while others are driven up the wall by it. If it is interfering with your work, ask for it to be turned down, or that headphones be used, or that it be turned off. Generally the NAs will be sensitive to your needs, so it probably won't be a problem.

The present schedule also provides a TT for the first half of the night. The TT's primary duty is to provide expert technical repairs as needed, and then to carry out other tasks, usually maintenance and fabrication. However, they can help out with NA functions if the real NA is momentarily unavailable.

IV. CCD's

At present we are using the TI 800 × 800 ($[12 \text{ mm}]^2$) chip exclusively. The $(500)^2$ remains available, but the $(800)^2$ advantages of larger format (= better wavelength coverage) and superior uniformity of response have resulted in a clear choice by Cass observers.

The $(800)^2$ TI chips are not perfect, however. They typically have blocked columns. By running the spectrum down columns rather than along rows, very bad spots may be avoided. Lower level problems still remain, however. There can be partially blocked columns that give a nonlinear response at low (sky) light levels. These may be dealt with (discarded) by reduction software. At the other extreme, light levels above 22K DNs may result in $\gtrsim$1% nonlinearities in chip response. This is usually easily avoided by controlling exposure times. Since we plan to improve the quality of CCDs when better ones become available, ask about the ideosyncrosies of the one in use.

The 15 bit A-D converter produces one DN (digital number) for every 2.5 electrons captured. Readout noise is $\lesssim 7e^-$.

The saturation level is about 31K DNs. When the chip is badly saturated, it takes a while for the excess charge to disappear. The best policy is not to saturate it, but to take a conservative exposure first in order to scale subsequent exposure times. (Remember the 22K DN limit for linearity.) If you do badly overexpose the chip, recovery is logarithmic with time. If you want to check for latent images, try a longer dark frame and use a small bit select for the display. By far the most common occasion to overexpose is to forget a filter during flat fielding.

All of the TI chips have 0.015-mm square pixels, so the resolutions provided by the grisms are the same for both chips, for a given grism.

The LN dewar for either chip must be refilled faithfully twice per day and more often at night in the UV mode. This is the responsibility of the observer, and must not be forgotten. If you forget to refill the dewar and it warms up, the beneficial effects of the UV flood procedure will be lost, resulting in decreased efficiency and increased nonuniformity of response. The CCD must be returned to Santa Cruz for a new flood (if you are lucky and it is a working day and if the people who know this black art are available). The possible penalties are 1) hard feelings, and 2) lost observing time.

It is possible that the $(500)^2$ TI may be used if some catastrophe befalls the $(800)^2$, so here are a few brief remarks on it. The best part of the chip is the top 100 rows. (Be sure to update "CCD orientation" under Z3 of the Data Taking System). If you set the Y stage setting to 5.77, the center of the slit will be about row 27, which avoids a defect known as "the tooth," the top of which is about row 45. The readout noise is $\sim$ 10 electrons, and there are $\sim$ 2.5 detected electrons per DN. Saturation and linearity considerations are the same as for the $(800)^2$ chip. The stage equations are not quite the same as for the $(800)^2$. Use the equations as given in the table in the next section, but with the following additive constants in place of those given in the table: grism 1 (16.96), 2 (43.74), 3 (not used), 4 (28.82), 5 (22.14), 6 (23.38).

V. DISPERSERS

A. Grisms

Grism	Grooves (mm)	Blaze (Å)	Å (pixel)[a]	Wavelength Coverage (Å)[b]	Stage Equation[c,d]
1	300	5700Å	8.0	6500	$X = -\frac{\lambda_c}{535} + 15.75$
2	600	6500	2.65	2120	$X = -\frac{\lambda_c}{177} + 42.53$
3[e]	300[e]	8925[e]	~ 7.3	5840	
4	600	4840	~ 3.6	2880	$X = -\frac{\lambda_c}{230}\ 27.62$
5	300	7800	~ 7.7	6160	$X = -\frac{\lambda_c}{494}\ 20.93$
6	420	5600	~ 5.5	4400	$X = -\frac{\lambda_c}{335}\ 22.18$

[a] 0.15 mm pixels. Two pixel slit width minimum recommended.

[b] TI 800 × 800. Multiply by 5/8 for TI 500 × 500.

[c] Gives the X-stage setting for a given central wavelength. Notice that a larger X-setting results in a decrease in λ_c

[d] The additive constant is different for the $(500)^3$ TI chip; see preceding paragraph.

[e] System response is ~ 0 from 9000 to 10,000Å.

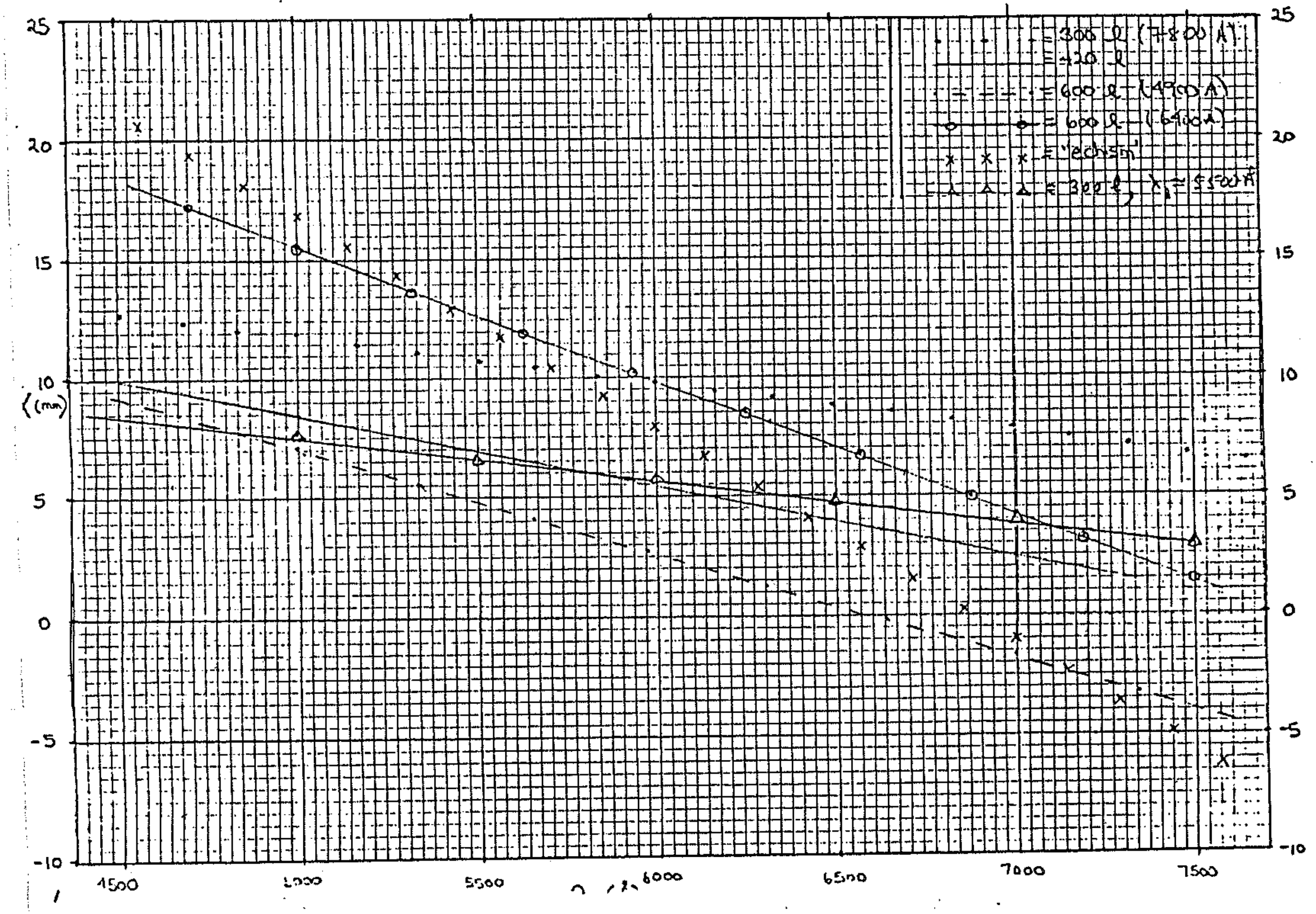
On the next page we present a handy graph, provided by Mike DeRobertis, for finding X as a function of λ_c.

Refer again to Section II.2.g for directions and cautions regarding changing grisms. The grisms will be found either in the grism tray in the spectrograph, or in either of two wooden boxes in the cass prep room.

If you cannot find a 300 or 420 ℓ grism, try the echism tray. It may be mounted as the cross-disperser there (Section V B).

Central wavelengths (λ_c) for "X" offsets

as per. Nov 28 1963.



The 300 line grisms have generally not been used with the TI $(800)^2$ chip, since one can use the 420 line grism and get better wavelength coverage and better resolution than the 300 line plus $(500)^2$ chip provided.

The blaze wavelengths were chosen so that one can cover the available optical spectrum by changing grisms rather than by moving the CCD stage. The advantage is that grisms can be changed remotely, whereas to reset the stage requires setting the telescope near the zenith and going onto the dome floor.

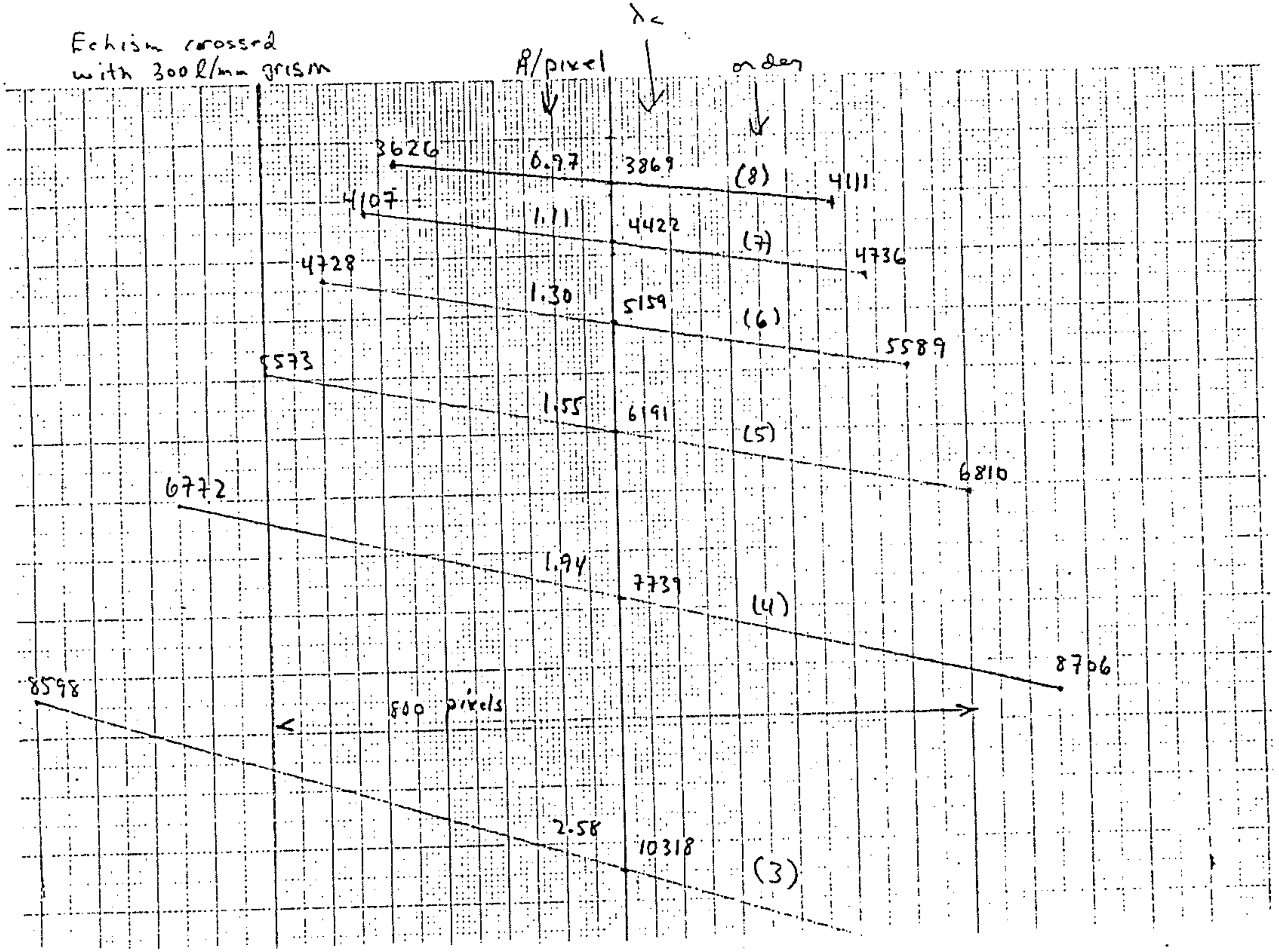
B. ECHISM

The echism is an echelle made out of a grism. It can be cross-dispersed, and the cross-disperser used is usually the 420 ℓ grism. The primary disperser is the tallest of the grisms, and is called the echism because it is an echelle grism.

A disadvantage of the echism is that it is a thick piece of glass. Its efficiency is estimated to be less than 50%, as compared to $\sim 80\%$ for the 600 line grisms. The advantages are good resolution and wavelength coverage. At 6200 Å, one gets 1.55 Å/pixel (fifth order), with better resolution at higher orders and worse at lower orders. This is summarized on the chart on the following page. Notice that in orders less than fifth, the ends of the orders exceed the size of the $(800)^2$ chip, so there begin to be gaps in the spectrum.

When loading the echism tray, first mount the cross-disperser. The correct sense for the cross-disperser is so that, with the tray handle to your left, the thick part of the grism is toward you. The writing on the grism holder will then be perpendicular to the long dimension of the tray, running from bottom to top. If you get it in backwards, the bluer orders will be at the bottom of the chip, but everything else will be OK.

Echism crossed
with 300 l/mm grism



The echism grism goes on top of the cross-disperser, on four posts. The thick side of the prism goes towards the handle. If you mount this backwards, red will be at the left in each order.

The echism tray also allows one normal grism to be mounted in the normal way. The "grating select" code on the spectrograph controller for the normal grism is 345. The code for the echism is 830.

The spectra from the echism are at an angle to the rows and columns of the chip (since the cross-dispersion is proportional to wavelength), and since the entire chip is used, portions of the spectrum will cross some bad columns. In this case, you may choose to use the spectra along rows, so the interference from bad columns may be minimized, or you may be able to arrange the CCD position so that the bad columns do not affect any areas of interest to you. Allow some extra setup time on the first afternoon to find the best setup.

Besides making positioning of the chip more difficult, the fact that the spectra are "slanty" means the normal spectrum extraction routine "mash" does not work. However, a similar version called "emash" is available from VISTA.

The very long $2'$ slit allows some orders to overlap considerably. You can prevent overlap by use of a shorter (15 or $30''$) decker at the cost of giving up some information along the slit. For stellar objects in reasonable seeing the choice may not be too hard, but if you plan to observe extended objects it may be more difficut. The amount of overlap varies with wavelength, so again plan some extra time to make this judgment when setting up.

A different approach to use of the echism grism is to use filters to isolate a particular order. This has been done, for example, using the Spinrad night sky filter to isolate the fifth order, containing Hα. The resulting throughput is not so good as with the 600 line red grism, but the tradeoff in improved resolution may be worth it for some observations.

C. GRATINGS

Note: The gratings exhibit some anamorphic magnification. The table below gives typical slit magnifications for the gratings. Example: a slit magnification of 0.9 would imply a scale on the CCD of 0″.73/pixel in the dispersion direction, while of course the scale perpendicular to the dispersion remains 0″.66/pixel. The scale is 0″.66/pixel in both coordinates when the flat mirror is used for direct imaging. Because these numbers are based on calculations using best estimates of focal lengths, they may be in error by a few percent from the actual values.

GRATINGS

Grating	ℓ/mm	λ(blaze) Littrow	Slit mag.	Å/pixel* (1st Order)	Spectral range* (Approx.)
1	600	5000 A	0.92	2.0	1600
2	600	7500	0.88	2.0	1600
3	830.8	8460	0.83	1.4	1150
4	1200	5000	0.84	1.0	800
5	300	4230	0.97	3.9	3100
6	300	7500	0.94	4.0	3150
7**	600	3000	0.94	2.0	1600

$*$ Calculated, not measured.

** This grating is more efficient than No. 1 for wavelengths shorter than about 3600Å.

Approximate central wavelengths may be derived from the following:

(ℓ/mm)	grating tilt
300	$1.2\ \lambda_c + 8150$
600	$2.44\ \lambda_c + 8000$
830	$3.46\ \lambda_c + 8030$
1200	$5.09\ \lambda_c + 7150$

VI. SETTING UP AND OBSERVING

This is not exactly a checklist, but rather an orderly discussion of what needs to be done in the usual case, with hints here and there.

Bring 1/2" magnetic tapes, or you can get them on the mountain from the Telescope Technicians (TTs) and be recharged for them.

Logsheets are in the bottom right-hand drawer of the NA's desk.

In all likelihood your predecessor will have refilled the dewar at the end of the night just past, but you probably don't really know that, so the most conservative thing to do is refill it right away. Don't forget to do it again, approximately every dusk and dawn thereafter during your run (more often at night with the UV).

Next, check to see if the dispersers you want are loaded into the spectrograph. There is a grease pencil list on the spectrograph controller of what is probably in the disperser tray, but the only way to really be sure is to look in the tray itself.

Set up the wavelength calibration lamps on the TUB as desired. Need to change any user filters? Now is a good time.

Open the manual dark slide.

Turn on the data-taking terminal and the ISI Workstation. Log in with "user" on the data-taking terminal, and "user" on the ISI. When the Data Taking System

(DTS) returns a "next command" prompt, answer "d" (for data taking). On the ISI, open a Vista window with the middle mouse button.

You will probably want to update the observer's name in the DTS header; use Z3.

Turn on the image display monitor.

Load your tape, and initialize it with one of the routines under Z2.

As soon as you conveniently can, do a short integration to be certain everything is OK. The most complete check is to read the whole chip and write it to disk and tape. If you do it with the manual dark slide open and the dome lights on, the light leaks in the spectrograph will illuminate the chip enough to give you something to look at. If it is a fresh tape, after the test you can reinitialize it to get rid of the unwanted frame; if you already have data on your tape, you may want to use a scratch tape for the test. The point, of course, is to find any problems as early as possible in the day, in order to allow enough time for fixes. Be sure the shutter opens and closes, that the chip reads successfully to disk and tape, and that the TV display looks reasonable.

For the rest of the setup, you will probably not want to record to tape until you are at the point of taking wavelength calibration spectra. If you do not record to disk or tape, the last image will be stored in the scratch area so you can still plot, redisplay, etc.

Set up a spectroscopic window. This is best done by illuminating the slit with the blue secondary flat field lamp, mirror cover open, diagonal position 3 or 4, a ND filter (if using low dispersion), and reading out the full 800^2. In particular for the gratings, the dispersed illuminated areas may not be precisely coaligned. You may wish to use one setup which reads out only the subset of overlap, or one setup with an all inclusive window (trim out the junk later), or you can define different windows for each. If you're in the grism mode, refer to Section V.A., and determine the X-stage setting for your most important setup. Set the X stage (2 locks). Take a look at a line lamp (diagonal mirror position 2) to see if you are getting the coverage you expect. If that is fine, take a look at the other grisms to be sure you will get what you want with them as well. Compromises may have to be made. Of course you *can* reset the X stage during the night, but that is usually not a very efficient procedure because of the extra flat-fielding required.

Choose order separating filters as necessary for each setup to be used.

Determine where the direct window is. In the grism mode, its location is a function of the X stage setting. In the grating mode, use grating tilt ~ 23050. Find the window by setting up for direct (slit and decker wide open, no disperser) but use either the full chip or the spectroscopic window in order to find where the direct window is along that strip of the chip. Measure the edges with the cursor. Choose an appropriate selection number, and set up the direct window. Try it to be sure it works as expected.

If you will be using the direct mode to find and center faint objects, you will need to know the row and column of the center of the slit. Close the slit to spectroscopic size and, with illumination from any source, take a direct (undispersed) frame. Use the cursor to measure the center, and record it for later use.

Go back to spectroscopic mode and focus on a line lamp with a small (1-1/2 pixel) slit. The optimum foci for the different dispersers are not precisely the same. For the grisms, smaller collimator focus numbers improve the red at the expense of the blue, whereas for the gratings the opposite is true. It takes a focus change of 50 units or more to produce a noticeable difference.

During focusing, the chip readout time becomes a significant time loss. This is one of the rare instances when on-chip binning of the data is useful. By binning the data perpendicular to the dispersion, the resolution is preserved but the readout time is reduced by a corresponding fraction. Don't forget to "unbin" before you start taking real data.

Perhaps a better alternative is to use the "fast readout" mode (selection F on the Data Taking terminal). This mode reads out the chip about 4 times faster, but at the expense of greatly increased readout noise. During setup the readout noise is generally irrelevant, but before taking any recorded observations, be sure to switch back to slow mode.

There are a variety of ways to estimate the focus. Be sure to examine the focus along the entire range of interest, though, since it will not be the same everywhere. The two basic variations are to make a plot with ITV, or to make a plot with the plot command. The plot command allows convenient summing for better signal-to-noise. Either way you can blow up a portion of the spectrum for more detailed examination if desired, by using the zoom feature from ITV, or specifying starting and ending pixels with the plot command. The plot command has the possible advantage of permitting overplots, using the "noerase" keyword. With a bit of experience, though, you can probably do just as well by looking at the whole spectrum and making a subjective judgment about when it is best. When you are looking at it, it seems to be useful to mentally divide the spectrum into left, middle, and right segments, since they may not all change at the same rate. If you want to be a bit more quantitative, the ISI

Workstation will allow choosing representative lines (beware of blends) and counting the numbers of pixels at FWHM, for example. It may be useful to make hardcopies of your plots for comparison.

It is useful to record the spectrograph setups you have arrived at. Most users now do it with the computer (DTS, Z5). Ten setups may be recorded and recalled later for automatic setup.

Start a log, and take wavelength calibration spectra. Do it with the dome lights off, mirror position 2, dispersed setups, and record to disk and tape.

Take your direct flat fields: red secondary lamp, mirror cover open, diagonal mirror position 3, direct setups (probably with the Spinrad filter).

Wait until after the sun has set before doing your dispersed flats, in order to avoid any solar spectral features in the flat fields. Use the blue secondary lamp, mirror cover open, mirror position 4, dispersed setups. For the lower resolution grisms (420 line or less), you will need the "BG 14" filter to reduce the red end flux enough to get a decent number of counts at the blue end. The filter may not be necessary for the 600 line grisms, since the bandpass is less. In general, you may need a few separate exposures to get a sufficient total of counts in the more weakly exposed pixels, while not getting too many counts elsewhere.

Make a strong association between refilling the dewar, and coming into the dome in the evening and leaving in the morning, so you will not forget.

Weather permitting, you might like to have the dome opened during the late afternoon. Usually the night assistant will consult with you about this, but since it is ordinary practice they may do it even if they do not see you. Therefore, please close the manual dark slide when you have completed your setups, and remember to open it again before the first telescope setting.

At the beginning of the night, the night assistant will choose a bright focus star with good coordinates from *Apparent Places*, and set to it first. You can focus the telescope if you wish, or the NA can do it for you. The NA will put the focus star on the center of the slit and reset the telescope readouts, then will mark the location on the TV in mirror position 2 which corresponds to the center of the slit.

You can give the object coordinates to the NA one by one, or as a complete list, whichever you prefer. The NA will run the coordinates (any epoch) through a computer program which will correct for precession, nutation, aberration, refraction, the cost of living index, and (most of all) flexure. Usually the telescope points well, but it would be wise to come with well-prepared charts to avoid errors.

If the last thing you did was a spectroscopic flat, be sure the BG-14 filter is removed before doing an object.

Before each exposure, be sure the spectrograph setup and selection is appropriate. Set the integration time and object name. Try to anticipate the need for an offset guide star so the NA can be setting that up while you are setting up the spectrograph.

The autoguider is used about 95% of the time, so there is not usually much to do during an exposure.

At the end of the night, do line and flat calibrations as required. Some observers only take one set of line calibrations for an entire run, since changes are small and San Jose provides a comparison spectrum on every exposure to monitor the small changes. Close the manual dark slide and top off the dewar. Remove your data tape, log out, and turn off the terminals and data display monitor.

APPENDICES

Checklist for Setting Up

1. Refill dewar
2. Select and install dispersers
3. Set up line lamps on TUB
4. Mount user filters as necessary
5. Open manual dark slide
6. Be sure magnetic tapes and logsheets are on hand
7. Log in on both terminals
8. Turn on the image display monitor
9. Update the DTS header
10. Load and initialize a tape
11. Take a test frame
12. Set spectroscopic window
13. Determine your central wavelengths and set grating tilts (UV) or X-stage (grisms).
14. Choose order separators
15. Set direct window
16. Find row and column of slit center (for offset program)
17. Focus spectrograph
18. Save setups
19. Take calibration spectra and flat fields

Checklist for Closing

1. Take calibration spectra and flat fields.
2. Be sure all line and flatfield lamps are off.
3. Close manual dark slide.
4. Refill dewar.
5. Remove data tape from tape drive and turn off drive.
6. Log out and turn off both terminals.
7. Turn off display monitor.
8. Turn off hard copy unit.
9. Fill out User's Logbook.
10. Take a last look around to be sure everything you're responsible for is off.
11. Ask yourself: Did you *really* fill the dewar?

CCD Spectrograph: UV Schmidt / Lens–Grism

page ____ of____

Observer(s): ____________ Assistant(s): ____________ Slit/Decker Size: ____________ Tape No. ________

Date: ____________ Clouds/Clarity: ____________ Stage: X= ______ Y= ______ CCD: ________

File No.	Object	Exp	H.A.	PST	S″	Gr	λ_C/tilt	Coll Focus	Upper Filter		Lower Filter		User Filter		Tub PA	Remarks
									Set	ID	Set	ID	Set	ID		

UNIVERSITY OF CALIFORNIA
SANTA CRUZ 95064

March 30, 1983

Shane (3-m) Telescope Technicians
Shane (3-m) Telescope Observers

Re: Policies with Respect to Observations, etc.

Dear Technicians and Observers:

It is a good idea to restate from time-to-time, some of the policies governing the relationship between TT's and observers. As we are all aware, members of the staff change, new astronomers come aboard, people forget things, certain misunderstandings develop with time among persons having the best of intentions. So we touch on several matters here; this set of remarks is not meant to be exhaustive, and will be updated from time-to-time.

1) When should a TT be available to begin work? This depends on the nature of the observing, the season of the year, etc. For example, a coude observer may well want to start observations on a clear night in the winter as early as 4:30 or 5 PM. Tc provide an avenue for communication between the observer and technician on this matter we are setting aside a small area of the Readout Room bulletin board for the purpose. On arrival at Mt. Hamilton observers will please enter, in the space provided, the tim they wish the technician to appear so that observations may be initiated. If the astronomer does not provide this information, the technician will proceed on the basis of current practice.

2) Leaving the Readout Room at night. Technicians will please not leave the readout room at any time without first checking with the observer. This is crucial fo prime focus operations; it is also obviously inconvenient and wasteful of telescope time if a coude observer must come upstairs to hunt for a TT. Permission to leave to check the weather or dome, use the toilet, etc., etc., will normally be given by the observer unless he/she is at some crucial point in the work, e.g., about to conclude an exposure and set on another star, etc.

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The normal practice is to have one telescope technician (TT) work for the entire observing night. On nights when it is not possible to open because of observing conditions, the TT should be available to assist the astronomer if he or she needs some assistance in tests, calibrations, or whatever. Otherwise the TT can go about normal tasks, but the TT should keep the astronomer informed of his or her whereabouts. At some time during the night the TT may have worked a full shift. The TT will inform the astronomer when this will occur, and at that time the astronomer can release the TT if the remainder of the night looks hopeless. The TT can then go home, saving the Observatory some money.

4) Humidity limits. This is a vexing problem. We are presently studying ways of improving these measurements so that the amount of "down-time" can be minimized. TT's will probably be asked to participate in some experiments involving new procedures, and their cooperation will be appreciated. However, until new procedures are adopted, the 93% rule will be maintained.

5) Dome opening. Astronomers have different views on the advisability of openin the dome in the afternoon or early evening. Consequently, on arrival at the 3.0-m dome, astronomers are asked to enter this information also in the space provided on th readout room bulletin board. Of course, the TT is expected to use discretion and keep the dome closed if there is imminent danger of rain, snow, etc., regardless of the time posted.

6) <u>Readout Room doors and other doors</u>. As you know, we are trying to keep warm air from flowing into the dome area. Consequently, I would be grateful if observers and TT's would keep the two sets of doors between the readout room and the dome floor closed tightly at all times when passage is not required. Also, before observing begins, TT's should also see that all other doors into the dome area are also closed tightly (not "locked," of course); the automatic "closers" do not work well on some of these.

7) <u>Disagreements</u>. Rules regarding normal operations involving, e.g., accessibility of certain parts of the sky, humidity limits, wind speed limits, etc., are set by the Director and his advisors; these are known to the TT's, and astronomers are asked to cooperate with the TT's in seeing that these rules are observed. However, in case of disagreement between TT and observer on some matter not covered in the ordinary regulations, TT's should acceed to the astronomer's request, unless in so doing the TT judges that failure of the telescope or dome is imminent, or a life-threatening situation will develop. In such cases, the Superintendent (or his designee in his absence) will be called out and will have final immediate authority.

Nonemergency disagreements will normally be adjudicated in the daytime by the Superintendent, who has "on-the-spot" authority in such matters. However, general matters of policy in these areas will be decided by the Director, in consultation with the Assistant Director, the Mountain Superintendent, and others as the Director deems appropriate.

Sincerely yours,

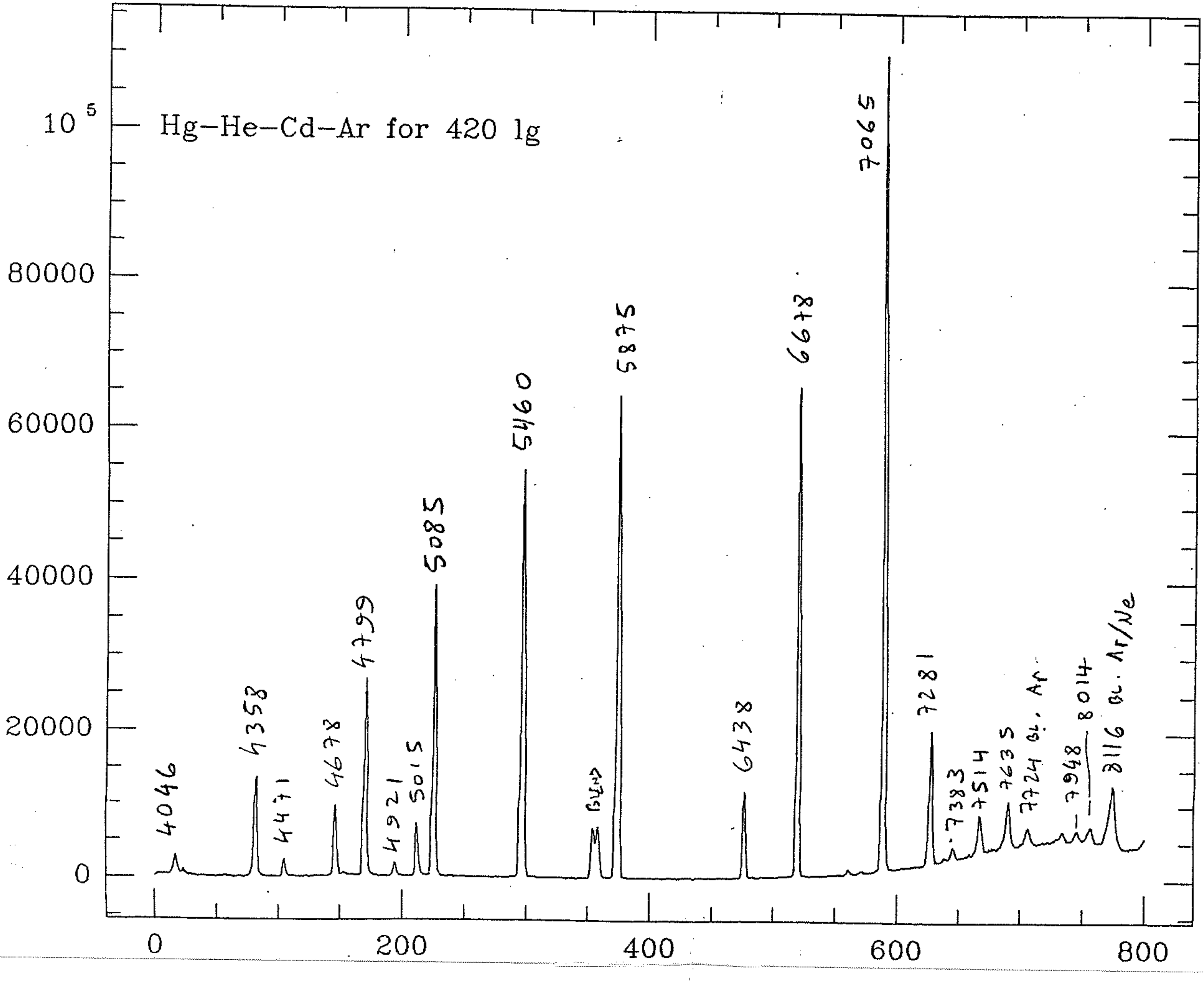
Robert Kraft

Robert P. Kraft
Director

Ron Laub /gp

Ron Laub
Superintendent

RPK:RL:gp
cc: J. Miller
J. Calmes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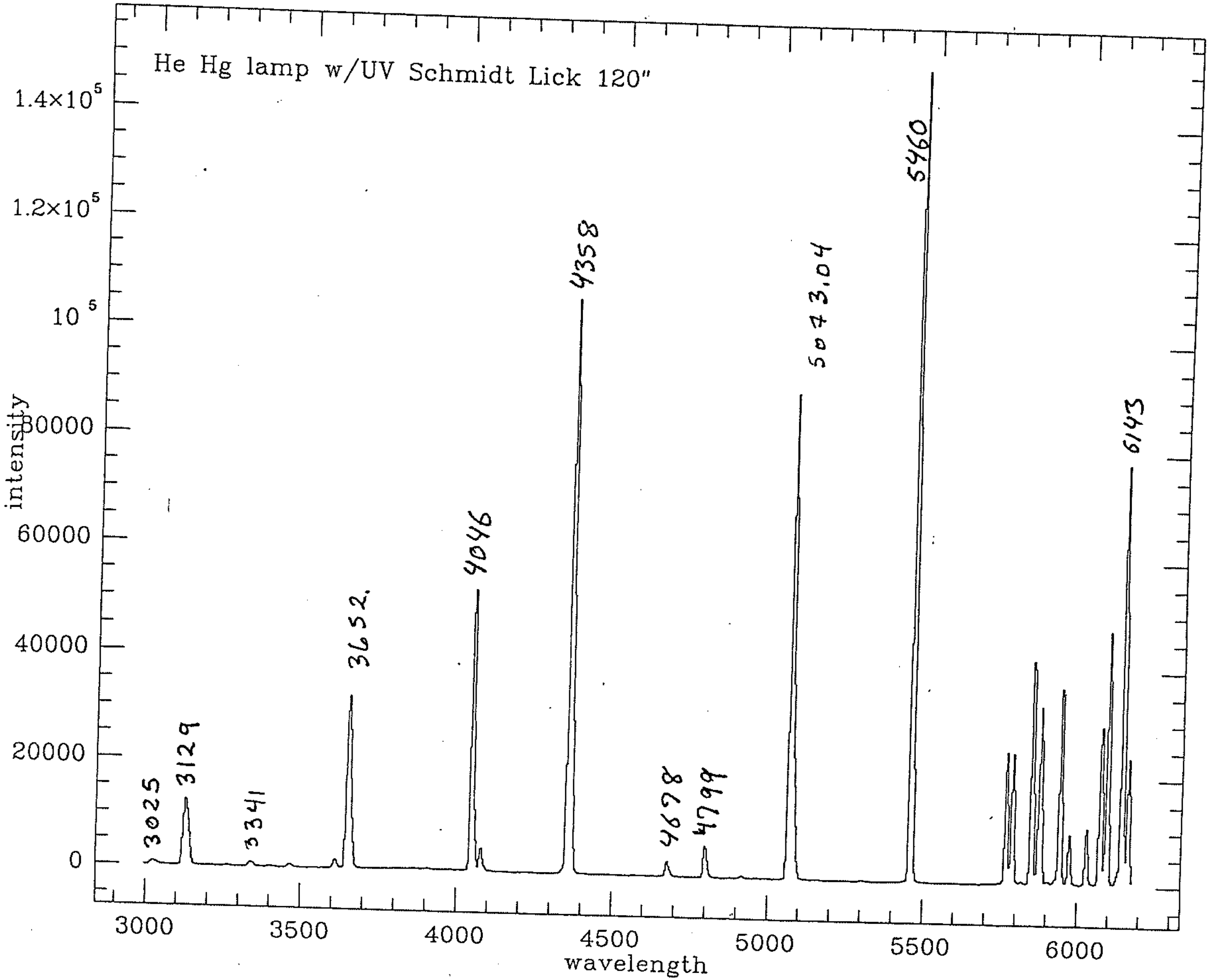
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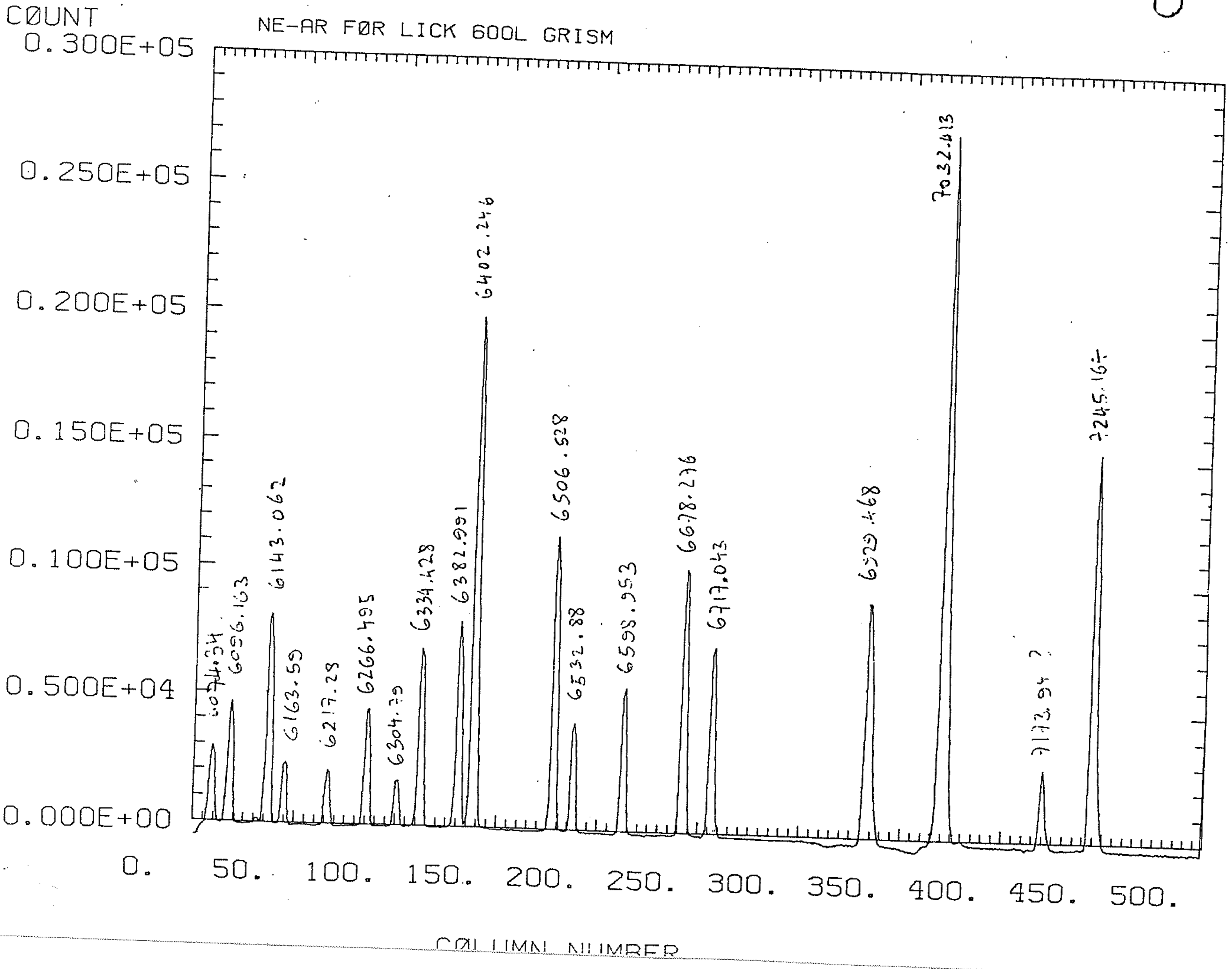

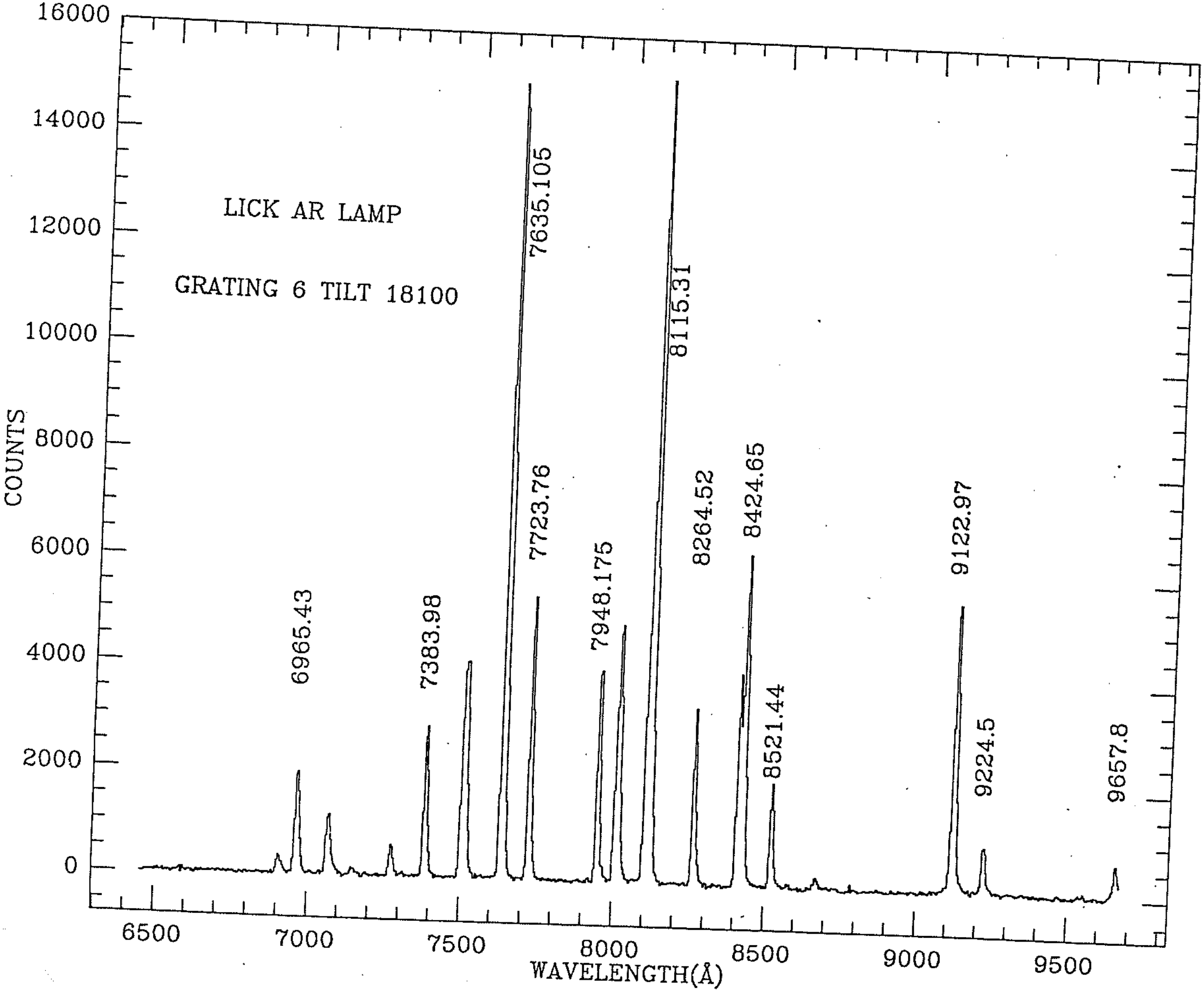
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