Contents

1) INTRODUCTION

The Modular Spectrograph for use at the M-D-M Observatory 2.4 m Hiltner Telescope is a second generation cousin of the Modular Spectrograph used on the (nearly identical) duPont 2.5 m Telescope. The original model was designed for use with a Texas Instruments 800 x 800 CCD. The instrument has been redesigned, increasing the camera-collimator angle to take advantage of the larger format *CCD's* used at M-D-M Observatory. This chapter briefly described the spectrograph and its capabilities.

The Modular Spectrograph is shown in Figure 1.1. It consists of three basic modules with their sub-modules as follows:

TOP MODULE

- Biparting Slit
- Aperture Wheel
- Filter Wheel with order separating filters
- Shutter
- Slit Viewing Eyepiece

CENTRAL MODULE

- Collimator
- Filter Holder for imaging
- Transmission Grisms
- 85 mm ("Short") Camera Port
- 200 mm ("Long") Camera Port
- Dewar Mount Tilt Plates

GRATING ROTATOR

- Plane Reflection Gratings
- Immersion Grating
- Plane

The modularity, from which it takes its name, was intended to allow for the upgrading of various parts of the spectrograph to accommodate changing needs and future improvements,

The f/7.5 telescope input is focussed onto the bi-parting slit. The slit is inclined at 10^0 to allow off-axis slit guiding using the standard M.I.S. Guider (Telescope Manual, Chapter 6). This guiding capability is lost if the aperture wheel is used instead of the bi-parting slit. The aperture wheel permits use of multiple slits and useful test masks.

The light then passes through an optional order separating filter and through the shutter. A slit viewing eyepiece allows inspection of images in the slit plane, and focussing using the slit as a knife edge. It completely blocks the light path to the detector when inserted.

Figure 1.1 *(a)*

ASSEMBLY: FRONT ELEVATION

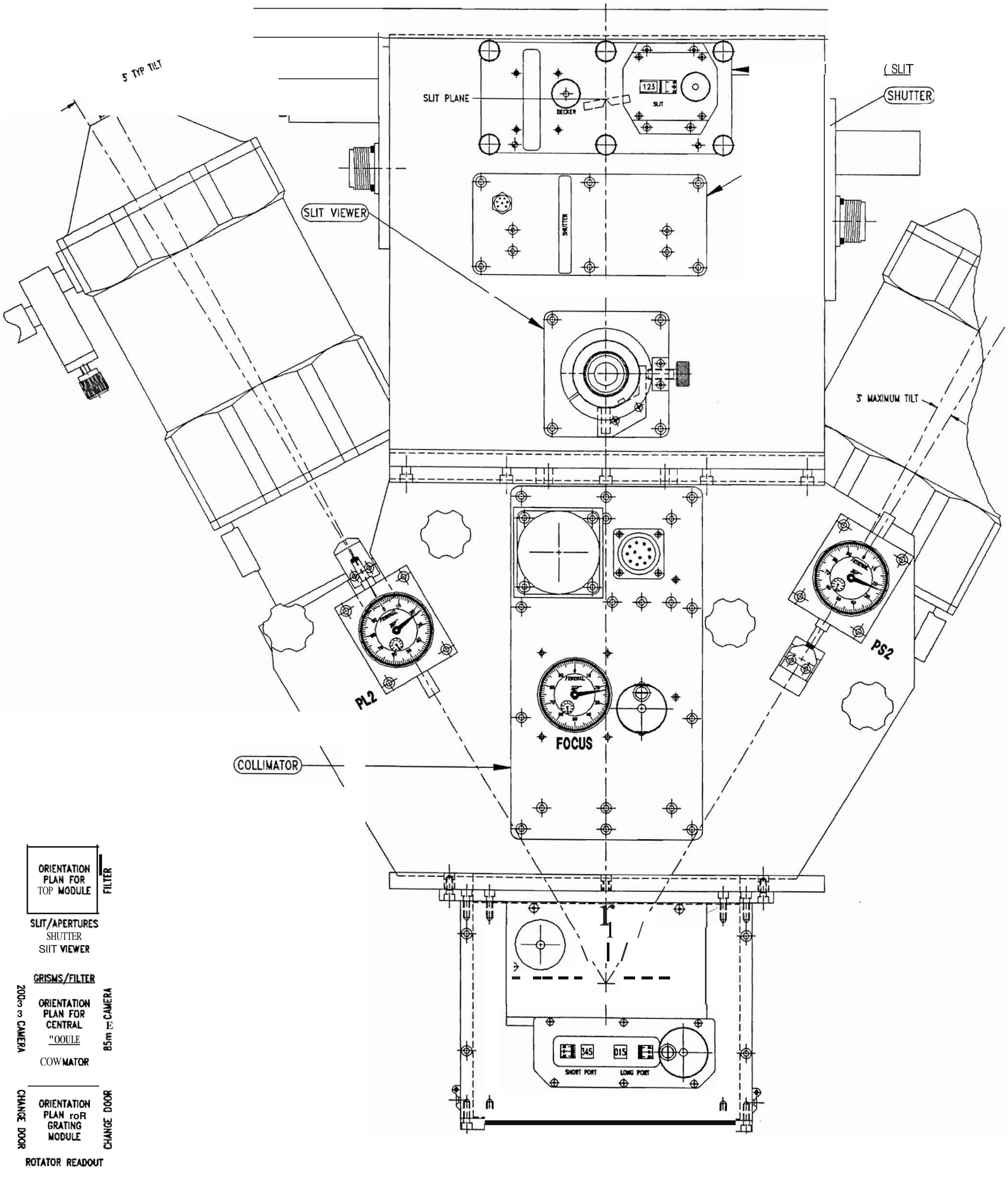
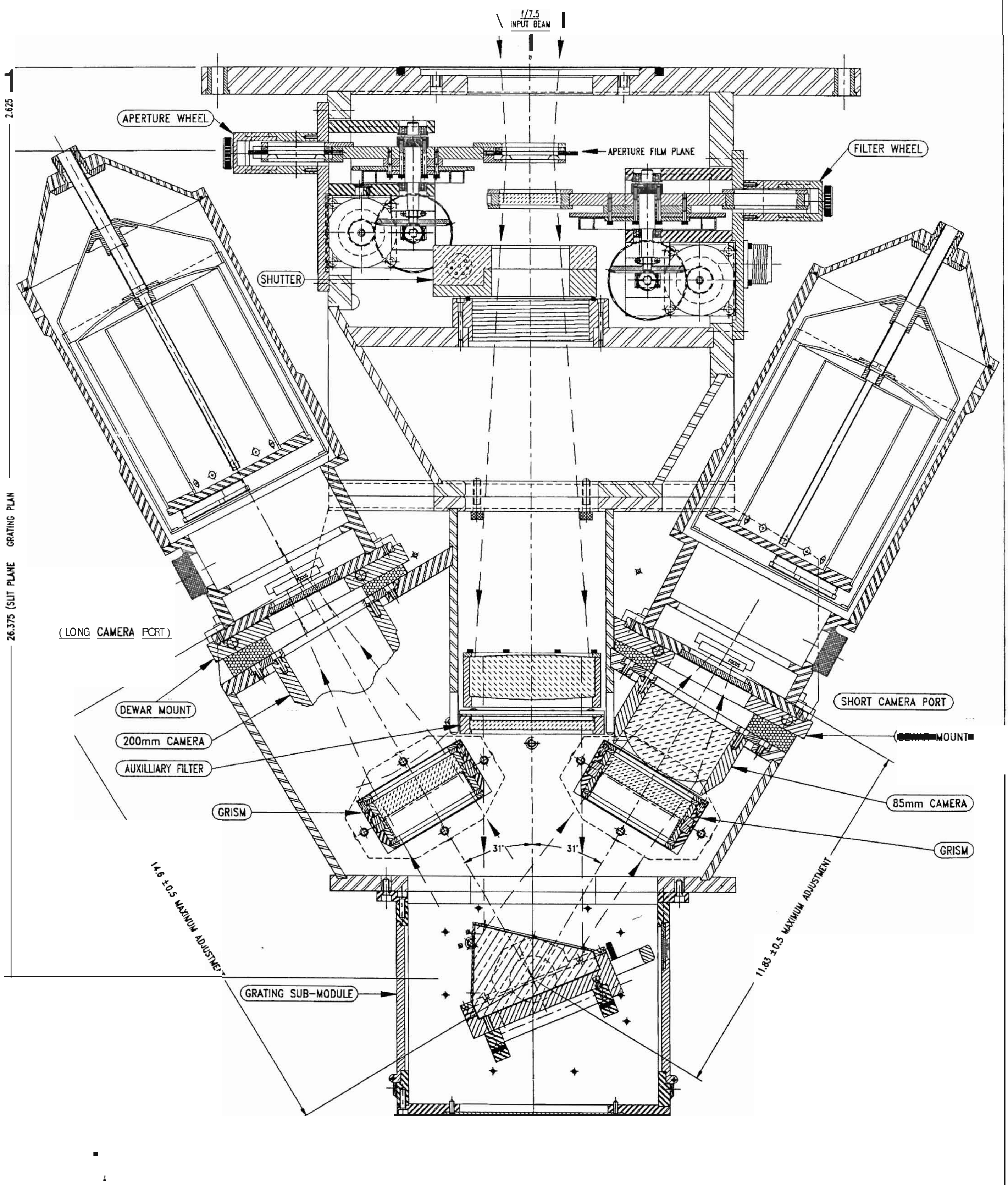


Figure 1.1 *(b)*

ASSEMBLY: FRONT SECTIONAL ELEVATION



ASSEMBLY: SIDE SECTIONAL ELEVATION

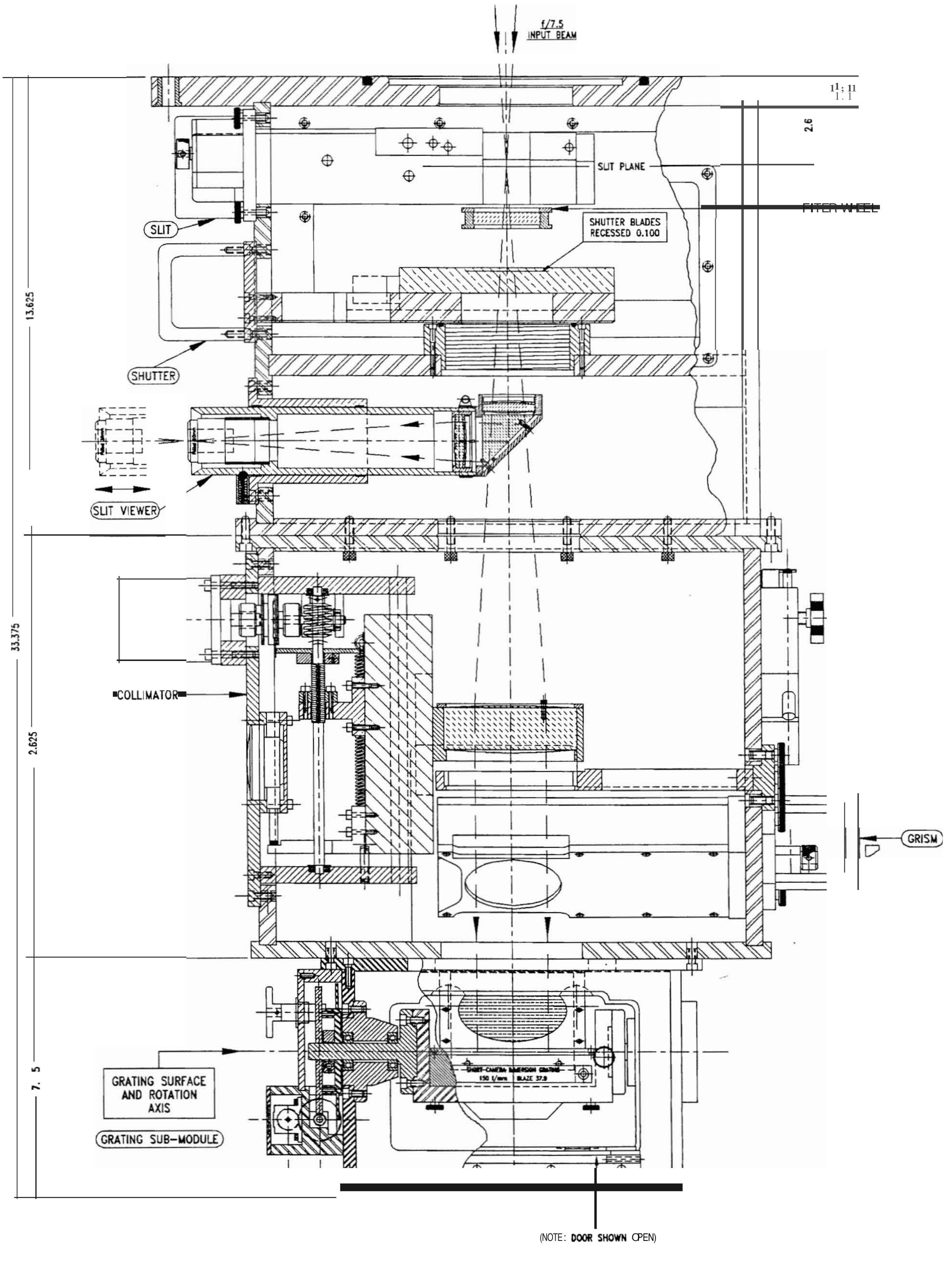
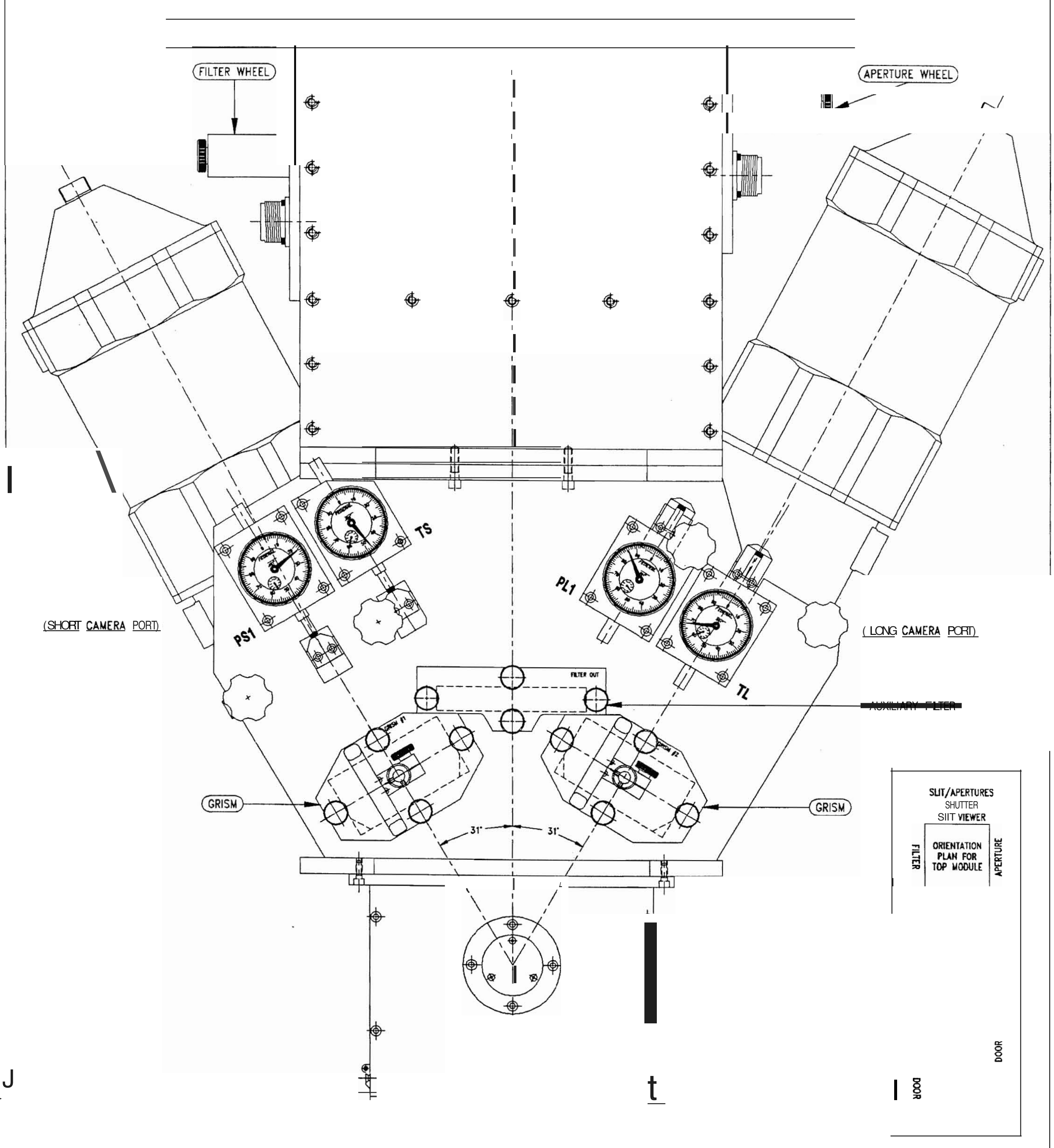


Figure **1.1** *(d)*

ASSEMBLY: REAR ELEVATION



The collimator is a 429 mm f/4.3 UK50-fluorite cemented triplet designed by Jim McCarthy. A second filter holder, intended for employment with direct imaging, sits just below the collimator lens.

The collimated beam then reaches the grating rotator. The rotator can be inclined to allow the beam to reach either of two camera ports, which in the current standard setup hold a Canon 85 mm f/1.2 lens and a Canon 200 mm f/2.8 lens. These give scales of 0.850 and 0.365 arcseconds per pixel, respectively, with 15u pixels.

The collimator has very little chromatic aberration, but the focal lengths of the cameras vary by something on the order of 0.5 percent between 5000 and 10,000 Angstroms. Perhaps one half man-year of effort would be needed to design and oversee the construction of comparable camera lenses incorporating FK52 or FK54 glass, which might be expected to reduce this chromatic aberration by a factor of approximately 5.

The linear part of the chromatic aberration is compensated for by tilt plates on which the CCD dewars are mounted. The tilt plates are cumbersome and exasperating. Grating changes, and some changes in grating angle as well, require adjustment of the tilt plates.

The spectrograph can be used in a multi-order "echelle" mode by inserting a grism cross disperser.

It can also be used a direct camera by mounting a plane mirror in the grating rotator. The grisms can also be used with the plane mirror to obtain low dispersion spectra.

The modular spectrograph is completely "manual" but has the capability for computer control, which will be developed in the future.

Current gratings/grisms are:

Plane reflection gratings:

600 l/mm 5000 A central blaze
831 lfmm 8000 A central blaze
12001/mm 5000 A central blaze

Grisms

200 l/mm 7000 A central blaze
300 lfmm 6500 A central blaze

The remainder of this manual fully describes each sub-module and presents comparison line spectra for each configuration, which will give potential users an insight into its many possibilities.

2) THE SUB-MODULES

2.1) INTRODUCTION

Most components of the spectrograph were designed to make their removal and replacement relatively easy. This allows for more flexible instrument setups and future improvement of individual components. It also invites abuse. Please take special care to keep dust, "oral spray", and fingerprints off transmitting and reflecting surfaces. Please do not attempt to clean the optical surfaces, you are almost certain to do more harm than good.

The observer's cooperation is also asked in putting modules in their storage boxes immediately upon their removal from the instrument. Most modules have storage boxes and an associated cover plate for the access port. The cover plate should be bolted to the spectrograph whenever the module is removed.

2.2) BIPARTING SLIT

The slit is constructed from two pieces of polished stainless steel 2.25 inches long, coated with "protected" aluminum. These jaws are spring loaded, and move simultaneously away from or toward the optical axis of the instrument. The knob on the right of the slit module controls the slit width. The slit jaws are tilted at 10 degrees to perrnit guiding with the slit viewing TV guider (Telescope Manual Chapters 6 & 7).

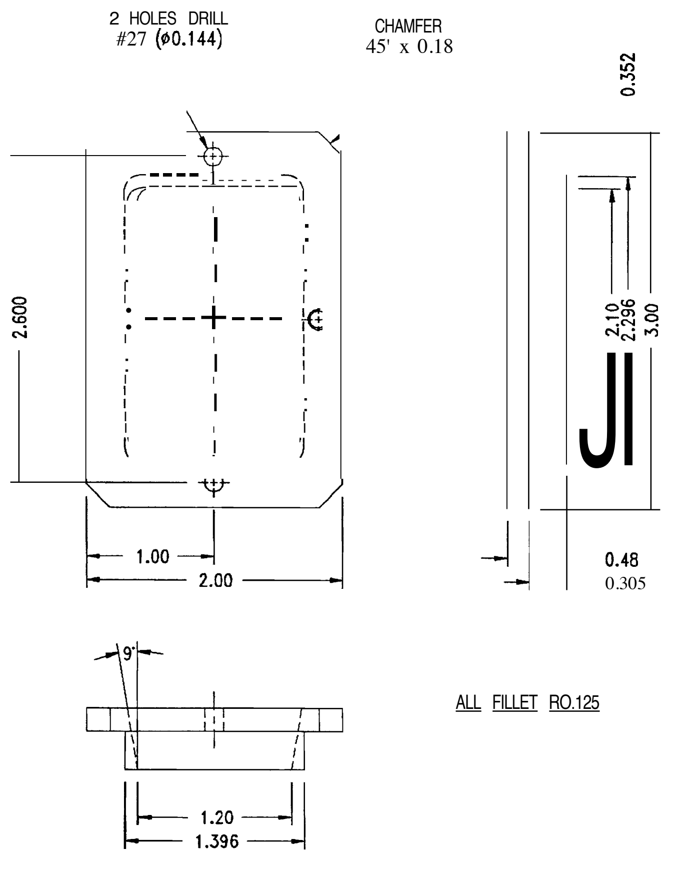
A counter, which approximately reads in arcseconds at f/7.5, gives crude readings of the slit width. A drum immediately to the right of the counter can be read to the nearest hundredth of a turn. Thus if the counter reads 2 and the drum reads .45, the slit width is 2.45 units. Be sure that anyone asked to set the slit width understands how to read it. Do not attempt to force the slit tightly closed, which will ding the slit jaws. When the counter reads zero it is fully closed! To overcome backlash in the gears you should *close* the slit to the desired setting. Each counter unit opens the slit jaws by 0.090714 mm, Thus the conversion from counter units to arc seconds is as follows:

f/7.5	1 counter unit = 1.0432 arc seconds	1 arcsecond = 0.9586 counter units
f/13.5	1 counter unit =0.5806 arc seconds .	larcsecond = 1.7224 counter units

Figure 2.1

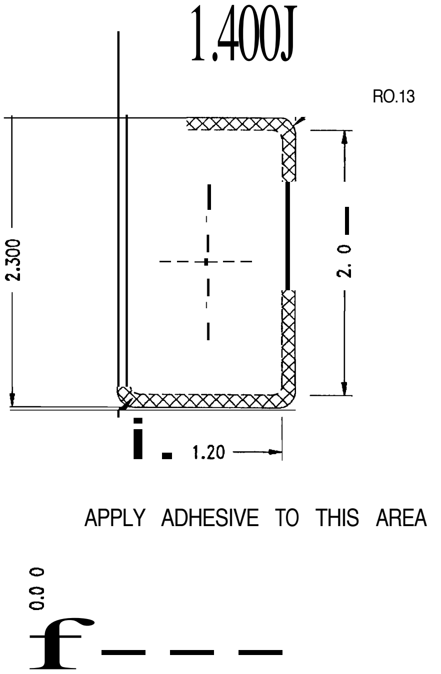
DECKER PLATE

(DECKER MOUNT)



MATERIAL: 6061 ALUMINUM

(DECKER)



MATERIAL: 6061 ALUMINUM

2.2) Decker Plate

A decker rides a few thousandths of an inch above the slit. Decker plates, made from self-adhesive aluminum sheet, can be fabricated as needed and mounted on frames which are easily changed. A decker for is available for use in the echelle mode.

If you want to make your own decker plate from 0.010 sheet aluminum the dimensions are given in Figure 2.1. Considerable care must be exercised when mounting a decker plate for the first time to be certain that the decker clears the slit surface. If not it will destroy the straight edges on the jaws and scratch the surface.

Decker plates made from the self-adhesive aluminum tape are not very flat, causing scattered light. In these cases it is advisable to spray the decker plate with flat black paint.

A knob to the left of the slit module moves the decker in and out. The decker can be viewed using the guider TV.

The slit module must be removed in order to use photographically produced masks in the aperture wheel or for direct imaging.

2.3) APERTURE WHEEL

The aperture wheel was designed for use with photographically produced multislit masks. Aperture masks are also helpful in testing and setting up the spectrograph. The aperture wheel has 4 positions -- 3 for masks and a clear position which allows the biparting slit module to be inserted.

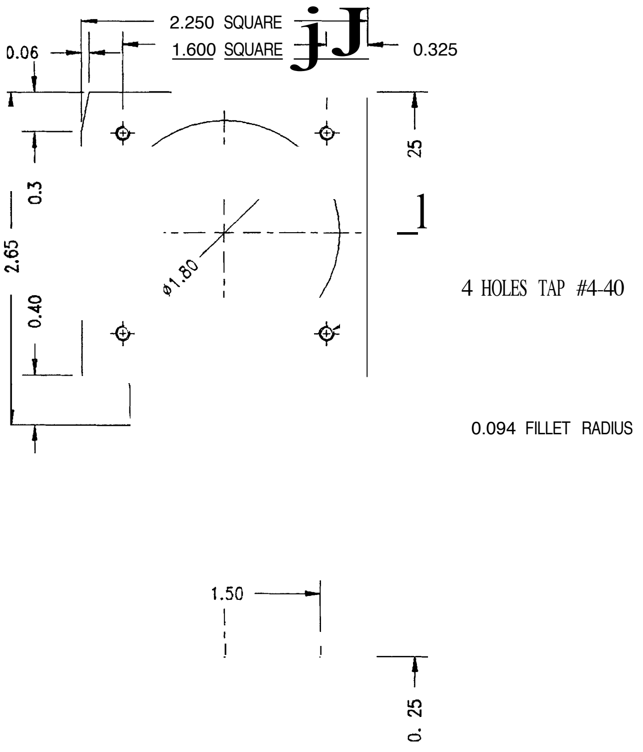
The aperture wheel will eventually be driven by an AC synchronous motor. The wheel is detented, and seats positively from nearby positions. The aperture wheel accepts special holders which have a clear aperture of slightly less than 2 inches. The slots into which these holders slide are equipped with springs to provide positive positioning. A latch captures the holders. Spare holders are available. Observers have access to the aperture wheel through a cover held in place by two knurled knobs. It takes several minutes to replace aperture holders. Several "standard" masks are available or you can make your own (Figure 2.2). The image scale of the telescope is 11.528 arcsecondsjmm at f/7.5 and 6.399 arcseconds/mm at f/13.5.

2.4) FILTER WHEEL

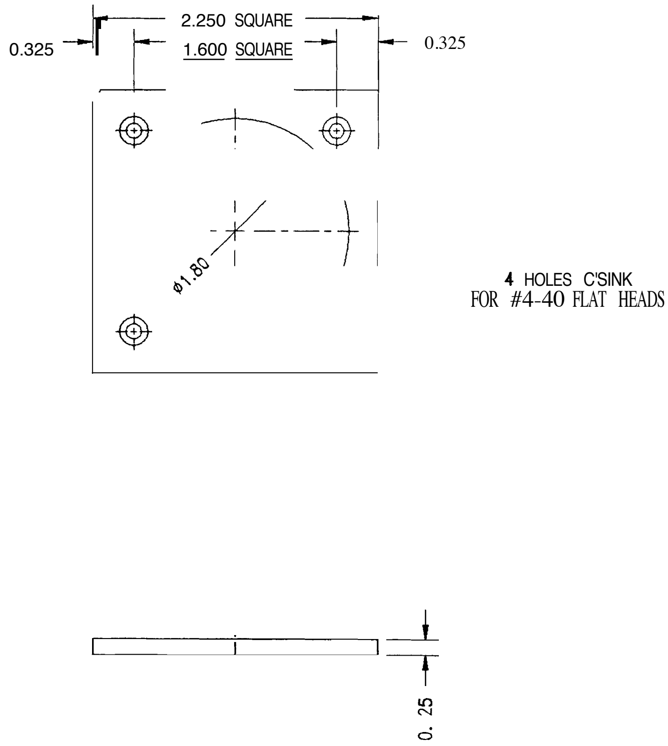
The filter wheel is quite similar in design to the aperture wheel, differing principally in that it has 6 positions. The filter holders accept standard 2 inch <square filters (up to 9 mm thick). Observers have access to the filters through a cover in place with two knurled knobs. Ittakes several minutes to replace filters.

Figure 2.2

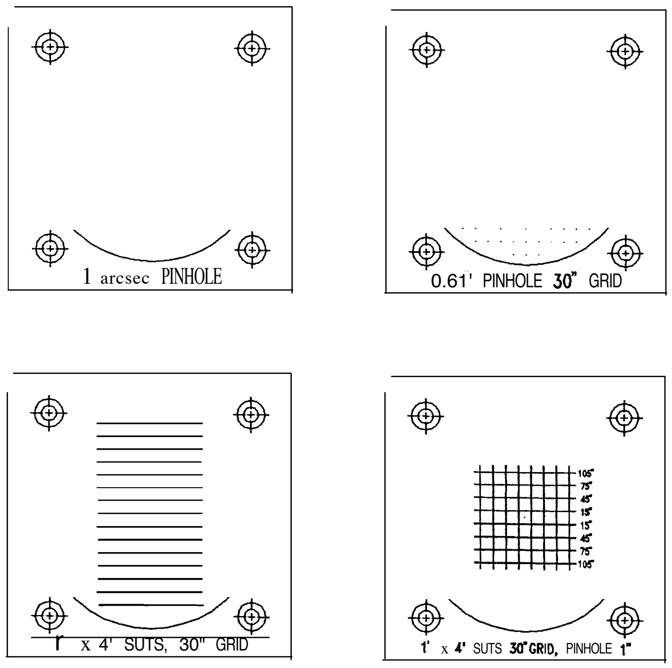
APERTURE WHEEL MASKS



APERTURE FILM JACKET BASE



APERTURE FILM JACKET LID



STANDARD MASKS

The filters are pinched into place by plastic spacers to avoid metal-glass contact. Filter holders should be inserted with the screws face up.

A set of anti-reflection coated order separating filters is mounted in holders and stored in the spectrograph cabinet. It includes GG385, GG455, GG475, GG495 and OG 515. Uncoated OG550 and RG610 filters are also available.

Standard 2 inch square imaging filters can also be mounted if you are using the spectrograph as a direct camera.

Please take great care when inserting and removing the filters. Do not attempt to clean them by touching the surfaces as you may do more harm than good.

2.5) SHUTTER

The shutter is a 2.5 inch diameter Uniblitz Model 262. The moving parts include two long arms and two delicate black leaves which open and close in 25 milliseconds (or so the manufacturers claim). Reports vary on the longevity of these devices. It would seem that they respond well to TLC and poorly to abuse. A spare shutter is available.

The shutter control box is mounted on the telescope instrument rotator. The toggle switch marked N.O. - N.C. is used to manually open and close the shutter. It should normally be left in the N.C. position unless you want to look through the slit-viewing eyepiece.

2.6) SLIT-VIEWING EYEPIECE

An eyepiece allows for viewing objects from behind the slit and for focussing the telescope using the slit as a knife edge. To use the eyepiece unclamp the knurled brass knob and push the sliding tube fully in; reclamp the knob and set the shutter to the N.O. position. The light to your detector is then completely blocked. Do not forget to pull the eyepiece completely out of the beam and clamp it tight when you have done, and reset the shutter to the N.C. position!

To view objects from behind the slit the eyepiece must be focussed on the slit. For knife edge testing the eyepiece must be focussed behind the slit. To change the focus grasp the black eyepiece itself and rotate it. If the slit is in focus turn the eyepiece 10 to 15 turns counter-clockwise for knife-edge testing.

2.9) GRATINGS

The following plane reflection gratings are available with the Modular Spectrograph. All of the gratings have been mounted so that the blaze points away from the grating holder handle, back towards the collimator. The original grating J.D. label and blaze direction can be read through an inspection hole in each grating holder. Please do not remove the gratings from their holders.

(ILT .0(=

1200 - 5000

Plane Reflection gratings

Ruled area 102 x 102 mm
Blank size 110 x 110 x 16 mm
Material BSC2

600 l/rnm

Blaze wavelength	5000 A
Blaze angle	8.63 degrees
Efficiency	80% at 4500 A
	86% at 5000 A
	85% at 5500 A
Resolution	85% of theoretical
Milton Roy Catalog number	35-53-15-260
Date manufactured	7-29-92

830.8lfrnm

Blaze wavelength	8465 A
Blaze angle	20.57 degrees
Efficiency	84% at 8000 A
	82% at 8460 A
	80% at 9000 A
Resolution	>80% of theoretical
Milton Roy Catalog number	35-53-15-460
Date manufactured	2-19-93

1200 l/mm

Blaze wavelength	5000 A
Blaze angle	17.45 degrees
Efficiency	88% at 4900 A
	86% at 5000 A
	85% at 5100 A
Resolution	>90% of theoretical
Milton Roy Catalog number	35-53-15-280
Date manufactured	7-17-92

To place the blaze wavelength on the center of the CCD set the grating rotator angle to 15.5 degrees plus the blaze angle. Spectral plots are shown in Appendix B.

2.10) GRISMS

The spectrograph has ports for 3 inch square grisms immediately in front of the camera lenses. The grisms are mounted in cells which slide into and out of the telescope beam. The sleeve in which the cell slides also serves to protect the grisms. Please pull out the plunger and lock it out before removing a grism from its storage box and putting it into the spectrograph. Likewise please pullout and lock the plunger before removing the grism from the spectrograph and putting it into its storage box.

The cells in which the grisms are mounted can be inserted in any of 8 ways into the sleeve. Each grism holder is marked on its sides. The grism should be inserted in its sleeve with its grooves down (labels correct way upl), Likewise the grooves should face down or away from the observer whenever they are exposed. The grooved side of the grism is the hypotenuse of the and butts against a complementary aluminum wedge. The grism will disperse light in the same direction and in the same sense as a grating if the apex of the grism points toward the collimator. Red rays emerge at the narrow end of the grism and blue at the wide end. When used as the cross disperser in echelle mode the grism must be rotated by 90 degrees.

There is a clip with two stainless steel latches which holds the grism cell in the slide mechanism. Two stainless steel pins, which slide in elongated holes, must be pinched together to remove the clip (and to reinsert it). When the latches are properly seated, the pins are at the extreme ends of their holes, as far from each other as possible. Make certain that both latches are properly seated after inserting the grism by tugging on the clip. The lead time for replacing a grism is approximately 6 months at "bargain prices", 3 months if money is no object.

The grism holders do not vignette the beam along the slit. However they do vignette the beam on either side of the slit and should be removed when doing direct imaging.

The grism holders can collide with the camera lenses when inserted in the spectrograph. Please avoid this by inserting them straight or pointing slightly down. Once again, make sure the grism is pulled back into its protective sleeve during this operation,

200 l/rnm 7000 A (GRISM #1)

Blaze wavelength	6730
Central wavelength	7000 A
Blaze angle	15.0 degrees
Ruled area	102 x 102 mm
Prism angle	16.78 degrees
Material	UBK7
Efficiency	75% at 6500 A
	79% at 7000 A
	79% at 7500 A
Milton Roy Catalog number	35-63-**-630
Date manufactured	12-7-92

300 l/tnm 6500 A (GRISM #2)

Blaze wavelength	5200
Central wavelength	6500 A
Blaze angle	17.45 degrees
Ruled area	102 x 102 mm
Prism angle	23.71 degrees
Material	UBK7
Efficiency	64% at 5200 A
	74% at 5800 A
	71% at 6500 A
Milton Roy Catalog number	35-53-**-770
Date manufactured	12-7-92

2.11) CAMERAS

The spectrograph currently has two cameras, both with 70 mm apertures: a Canon 85 mm f/1.2 lens and a Canon 200 mm *f/2.8* lens. They suffer from severe chromatic aberration (as do most commercial lenses), for which the tilt plates compensate. The *amplitude* of the chromatic aberration for the 85 mm lens, as measured with the MWLCO spectrograph collimator, is given in the table below.

wavelength (A))	3889	4471	4713	5015	5876	6678	7065	7281	7535	8377	8730
collimator (.001")	475	750	855	855	810	700	645	620	590	465	425

The variation in the focal length of the lens is smaller by the square of the ratio of fi(coll)/fl(cam), or roughly a factor of 25. From 5000 to 9000 Angstroms, the focal length of the lens changes by roughly 0.020 inches, or 500 microns. Since the pixel size for the Wilbur (Loral) 2048 x 2048 CCD is 15 microns, a chip which is 500 microns from the focal plane of the lens will give an image of a narrow slit which is approximately 28 pixels wide for an f/1.2 beam.

Alan Stockton of the University of Hawaii (private communication) has carried out similar measurements for a half dozen commercial lenses. Their focus curves are quite similar when the variation in focus is plotted as a fraction of focal length.

The focus curves have a sharp bend in the vicinity of 4861 Angstroms, making it virtually impossible to work simultaneously on both sides of this peak. The tilt plates work reasonably well redward of 4861 Angstroms, and may prove adequate far some wavelength ranges blueward of 4861 Angstroms. The lenses have a large number of elements. It is suspected that they are antireflection coated for use in the "white light" 4000 to 7000 Angstrom range.

The lenses have internal diaphragms, which are opened to full stop. The unused camera port carries a "dummy dewar" to keep the telescope in balance and to stop light leaks.

Both lenses have been mounted in a sleeve which is designed to provide rigid mechanical support at either end, and to lock the focus at infinity, will only fit the lens when it is focussed at infinity).

3) THE TILT PLATES

3.1) INTRODUCTION

This chapter discusses how to mount the dewar(s) to the tilt plates and bring the spectrograph into focus. You will soon discover that it is not possible to bring the whole of the spectrum into sharp focus because the Canon 85 mm and 200 mm lenses used as cameras on the short and long focal length sides of the spectrograph suffer from severe chromatic aberration (as do most commercial lenses). The linear part of this is compensated for by tilting the dewar by an amount that depends on the spectral range covered on the CCD.

3.2) ATIACHING **THE** DEWARS.

The dewar is clamped by two split rings to a tilt plate (Figure 3.1). The short port can only handle dewars with a maximum flange diameter of 6.5 inches *(Wilbur* and *Charlotte),* whilst the long port can also accommodate dewars with an 8.0 inch mounting flange. Once the dewar has been rotated to align the CCD pixels with the spectrograph slit be sure to clamp the split rings down.

3.3) CONTROLLING THE TILT PLATES

The position of the tilt plate is read by three dial indicators (Figures 1.1(a), 1.1(d), 3.1). Two of the indicators lie on an axis passing through the CCD and running parallel to the spectrograph slit. The *average* of these indicators measure the "piston" or focus along the slit, whilst the *difference* between them measures the tilt along the slit..

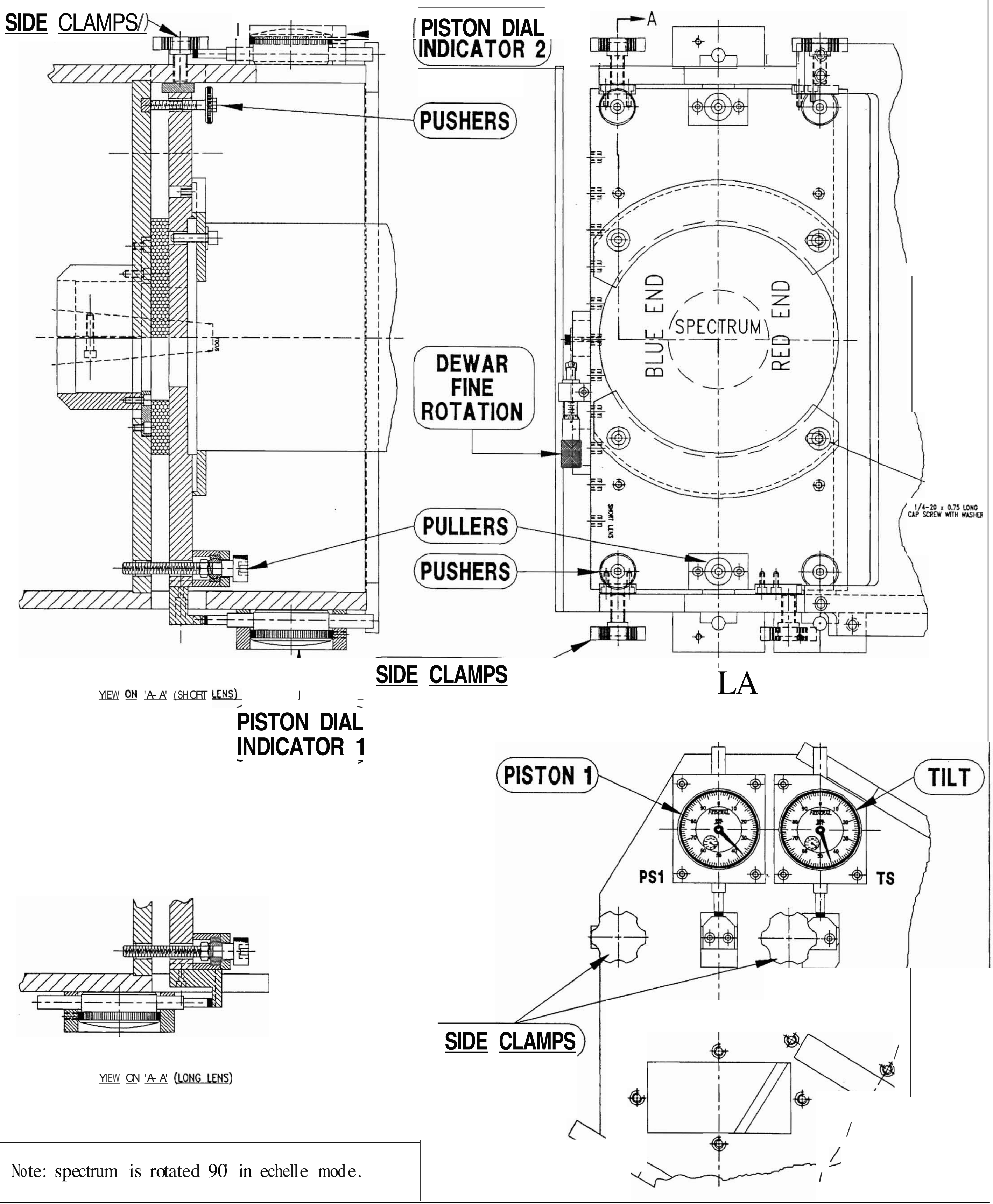
The third indicator, which is situated to the side of the piston indicator above the grism sub-modules, is used to measure the tilt along the dispersion axis. The *difference* between the piston and tilt dial indicators measures the tilt along the dispersion (except when a grism is mounted to cross disperse in a direction along the slit). When there is no tilt (such as for direct imaging) the two indicators should read the same.

The tilt plates are adjusted by a push-pull screw system. Two brass screws 'pivot on spherical bearings which lie on an axis passing through the plane of the CCD and running parallel to the spectrograph slit. These "pullers" lower the plate toward the camera when screwed "in." Each brass "puller" is straddled by a pair of stainless "pushers" with red thumbscrews. The tilt plate has four large black rosette clamps which enter through the side walls and hold everything rigid.

The. brass "pullers" govern the readings of the piston dial indicators.. The red thumbscrew "pushers" govern the tilt along the dispersion axis.

You will need to use a 3/16 hexagonal wrench to adjust the "pullers." If you are pulling the plate down it will be necessary to back off on the red thumbscrews,

DEWAR TILT PLATES



Note: spectrum is rotated 90 in echelle mode.

3.4) HOW TO FOCUS THE SPECTROGRAPH

There is something of an art as well as science to bringing the instrument into focus. It typically takes about 30 minutes to get optimal focus, assuming you have been supplied with starting values for the dial indicators.

We require you to record in the log (Appendix A) the final settings for all your tilts. These are quite difficult to do from scratch but are quite repeatable.

Use the following menu to get the spectrograph focussed:

- Set the collimator so the slit is at its focus (0.568 with no order-separating filter). If the beam is not collimated gratings with large blaze angles will give astigmatic images.

- Unclamp the four side-acting black rosette clamps.

- Rotate the dewar to align the slit with the pixels

- Adjust the "piston" of the tilt plate until some portion of the spectrum is reasonably sharp. Do this by adjusting the brass pullers and the red pushers. changing both pushers by *0.005/f* will make a noticeable change in the focus; final adjustments will be +/-0.002".

- Check that the slit is equally in focus at either end of each spectral line. If not, adjust one of the pistons up or down. Once you are satisfied note the *difference* between the two piston dial indicators. The smallest unit on the dial indicators is 0.001 inch. Because the pixels are of the same order and the beam very fast, this is barely adequate for the piston adjustment. However since the separations between the dials are many times the size of the CCD, motions on the order of 0.025 inch are needed to produce appreciable variations across the chip. (See also section 4.1.1).

- Adjust the "tilt" of the tilt plate to try and get the blue and red ends of the spectrum simultaneously in focus. You can determine which way to tilt the plate by using the collimator:
    - Increase the collimator by 0.050 inches (crude focussing) or 0.020 inches (fine tuning) and take a diagnostic exposure.
    - Return the collimator to its original setting (0.568).
    - Raise that end of the CCD dewar for which the focus improves with increased collimator reading. Note that the tilt dial is at the red end of the spectrum.

- Repeat the last three adjustments to give as good a focus as possible over tile surface of the CCD. Make a spectral plot and observe the line intensities and widths to get the best focus over the most important spectral lines. Since the variation of focal length with wavelength is not linear and since the focal plane of the collimator is curved, it may prove impossible to obtain a uniform focus over the entire chip.

- Make final adjustments to the focus with the collimator lens, Note that large deviations (more than 0.010 inch) from the nominal collimator position will produce astigmatic images.

- Be sure to clamp the tilt plate with the four black rosette knobs located near the dial indicators.

- Record your settings in the copy of the Modular Spectrograph User's Manual kept in the 2.4 m Observing Room.

4) NOTES ON DIFFERENT CONFIGURATIONS

4.1) DIRECTIM:AGING

An aluminized flat mirror is mounted in one of the grating holders, for use in direct imaging. The grating rotator should be set to one half the camera collimator angle (15.5 degrees) so that an image of the center of the aperture wheel is centered on the CCD.

Ideally the aperture wheel should always be at the focus of the collimator, and this will depend on the filter used. In practice one should choose a filter in the middle of the range of collimator settings, set the collimator so that the aperture wheel is at its focus, and focus the telescope using that filter, Collimator positions for the other filters can then be determined.

When the control electronics for collimator are finished it will be possible to automatically change the collimator for each filter.

The grism housings vignette the beam. Completely remove both grism sub-modules and place them in their storage boxes whilst using the spectrograph as a direct camera. Blank cover plates are used to seal the grism ports.

4.1.1) Curved Focal Plane

The collimator has a curved focal plane. If focussed at the center of the field, the spectrograph optics will be several arcseconds out of focus 20 mm (230 arcseconds) off axis. Users interested in obtaining a good focus over a large field will fmd it necessary to compromise between the best possible focus at the center of the field and acceptable focus at the periphery. One of the aperture holders contains a grid of dots roughly 0.67 arcseconds in diameter for daytime testing.

4.2) LONG SLIT

The spectrograph optics are designed to give an unvignetted field diameter of nearly 50 mm in the telescope focal plane, but since the collimator has a curved plane the focus will vary along the slit. The observer must strike compromise between best focus at the center of the slit and an acceptable focus some distance from the center. "Splitting the difference" between best focus at the center and best focus at a radius of 20 mm gives collimator images only slightly worse than 1 arcsecond everywhere. The worst spot size varies inversely as the square of the length of slit used.

In some instances, the user may want to center an object at one end of the long slit. Displacements of more than 60 arcseconds move the object outside the field of the slit viewing TV. Use the upward-looking guider probe if no other object is available off the slit jaws.

4.3) STANDARD CONFIGURATION (REFLECTION GRATINGS)

Use the grating rotator to displace the central wavelength of the spectrum. Increasing the grating rotator angle moves the central wavelength to the red. Remember that the grating efficiency falls off as one moves away from the blaze wavelength. To center the blaze wavelength on the CCD set the grating rotator to 15.5°+ blaze angle.

4.4) IMMERSION GRATINGS

Take great care when inserting and removing the immersion gratings (plane reflection grating with a prism cemented to its face) from the grating rotator. Angle the grating rotator downwards to obtain the necessary clearance.

The immersion gratings are primarily meant for use in the echelle mode. The short port immersion grating is ruled at 150 lines/rum with a blaze angle of 36.8 degrees. To center the central blaze of 5000A set the grating rotator to 58 degrees.

4.5) LOW DISPERSION TRANSMISSION GRATINGS

Install the plane mirror in the grating rotator and set the rotator to 15.5°. The apex of the grism must point back towards the collimator. If you are only getting one line, it is rotated by +/- 90°, and if you are getting very little light it is in backwards. See section 2.10 for instructions on rotating the grisms. To insert the grism into the light beam unclad the knurled red thumbscrew and push the plunger all the way in. Reclamp the red thumbscrew.

4.6) ECHELLE

It is possible to use the spectrograph in a multiorder "echelle" mode using a grism as a cross disperse in conjunction with a reflection grating in the grating rotator.

While echelle mode offers more resolution elements than single order spectroscopy, the observer pays a price both in system throughput and in the increased difficulty in taking and reducing echelle data. The cost in throughput is ahnost a factor of two.

The cross dispersing grisms have rather low dispersions -- 5-10 Angstroms/pixel on the short focal length side and 2-4 Angstroms/pixel on the long side. The tilt plates are twice as long as they are wide, and cannot by themselves produce the tilts needed when a cross dispersing prism is used. To obtain the correct tilt insert the wedged disk between the dewar and the tilt plate. The disk has a scribed line for alignment purposes. When looking at the tilt plate the thickest part of the wedge should be to the right. You will need to use longer 1/4-20 cap screws to hold the dewar clamp rings in place. Fine focussing along the spectrum is achieved with the two pistons. Focussing in each order is achieved with the tilt piston.

To stop the orders from overlapping a "V" shaped decker is placed in front of the slit.

When the CCD is aligned with the spectrograph slit, the different orders are tilted different amounts with respect to the rows and columns of the ceDe The tangent of the angle is given by n*d(grism)/d(grating) where n is the order and the d's are the groove widths.

One difficulty in echelle mode is each grism gives only one central wavelength. It may happen, particularly on the long focal length side, that the orders of interest lie off the chip. The long term solution to this problem is the purchase of additional grisms centered on the desired wavelength (at a cost of perhaps $1250 each with lead times of 3-5 months).

A short term solution is to displace the star along the length of the slit. For example, moving a star 60 arcseconds along the slit shifts the central wavelength 700 Angstroms when the 200 *l/mm* grism is used on the long focal length side. Deckers must be fabricated or improvised specially for this purpose. A piece of self-adhesive aluminum tape, cut with a knife and sprayed flat black, has been found to work effectively.

For displacements of greater than 60 arcseconds the center of the decker will be outside the field of the slit viewing TV.

4.7) MULTISLIT

The aperture wheel is designed to hold multislit masks for multiple object spectroscopy. Since the aperture masks lie parallel to the telescope focal plane, the slit viewing TV cannot be used either for setting up or for guiding in this mode.

The suggested modus operandi for multislit observing is to work with a in the grating rotator and use a grism as the cross dispersing element. The field can be acquired and the mask aligned with the field using the spectrograph in direct mode. The grism can then be slid into place for spectroscopy. The offset guider must be used to guide. The highest resolution obtainable with a grism on the short focal length side is 6 Angstroms/pixel for 15μ pixels.

The chromatic aberration of the lenses introduces an additional complication in multislit observing. The tilt plates can be tilted so that a spectrum for an object in the center of the field is in focus, but objects displaced along the dispersion direction will be out of focus. by an amount proportional to that displacement. If the tilt plate is set up to compensate for chromatic aberration during spectroscopy, images to one side or the other of the field will be out of focus in the direct imaging necessary to acquire objects.

5) COMMON BLUNDERS, THEIR SYMPTOMS AND REMEDIES

5.1) GRATING IN BACKWARDS

Symptom: *too little light.*

The blaze of the grating must always point back to the collimator. The gratings have been installed in their cells so that the blaze points away from the cell handle. Therefore you must insert the grating through the access door underneath the camera port you are NOT using. If you want to swap ports you must take the grating out of the rotator (but not its cell) and re-insert it through the opposite door.

Each grating has an I.D. label on its underside which shows the direction of the blaze.

5.2) rn.r PLATE LOOSE

Symptom: *large shifts in comparison lines, night sky lines, or spectrum position between exposures.*

Ensure that the four red tilt thumbscrews and the four black rosette clamping knobs on the side walls of the spectrograph are all tight.

5.3) GRATING LOOSE

Symptom: *large shifts in comparison lines, night sky lines, or spectrum position between exposures.*

Ensure that all four black rosette clamping knobs under the grating rotator are tight (section 2.8).

5.4) DEWAR LOOSE

Symptom: *large shifts in comparison lines, night sky lines, or spectrum position between exposures.*

Check that the four 0.75 x 1/4-20 cap screws are tight on the dewar mount split rings. If you used 1.00 x 1/4-20 cap screws they will not tighten up; use washers for packing if required.

5.5) SLIT VIEWING EYEPIECE BLOCKING BEAM

Symptom: *no light on all or part of the slit.*

Pull the slit-viewing eyepiece all the way out of the beam and clamp it tight with the knurled brass knob.

5.6) CANNOT FIND SLIT ON TV GUIDER

Symptom: *no image on the guider TV*

Check that the MIS slit viewing optics are the guider probe is at the finder mirror is and that the DTI is set correctly (camera selector, gain, direct/digital). See Chapter 6 of the telescope manual for more details.

5.7) NO STAR WHEN ATIEMPTING KNIFE EDGE

Symptom: *cannot see slit and/or star*

The shutter lies between the slit-viewing eyepiece and the slit. It carl be opened by toggling the *NO/NC* toggle switch on the shutter controller. Be sure to toggle this switch again to close the shutter and then flush the CCD. If you can see the slit but not the star, check the MIS mirrors.

5.8) FAULTY EXPOSURE TIMES

Symptom: *photon counts inconsistent with exposure times.*

You probably forgot to flip the *NO/NC* toggle switch on the shutter controller having done a knife edge test. If it is set incorrectly the shutter will be open when it should be closed, and closed when it should be open. Flush the CCD after correcting the problem.

5.9) DIRECT IMAGING HAS VIGNETIED FIELD

Symptom: *non-uniform illumination of the CCD.*

Remove the grism module(s) if still installed, and check the position of the upward looking optics in the MIS.

5.10) UNABLE TO IMAGE SPECTRAL CALIBRATION LINES

Symptom: *no calibration lines visible on CCD.*

Check that:

- o M.I.S. finder mirror is in the beam
- o spectral lamp is ON
- o slit-viewing eyepiece is out
- o shutter controller *NO/NC* toggle is in correct state
- o exposure time

6) ANTISOCIAL BEHAVIOR

The modularity of the spectrograph allows for considerable flexibility, but leaves the instrument open to all manner of abuse. The following practices are considered antisocial behavior, likely to create problems for downstream users.

Failure to protect gratings at all times.

The gratings are upward-looking and will almost certainly collect dust. Please put them inunediately into the storage box whenever you change gratings. The gratings will be removed, inspected and stored by the staff at the end of your observing run.

Touching (or "spraying") ruled surfaces

Please exercise extreme caution. Keep the grisms face down when rotating them in their slides. Try not to "spray" ruled surfaces by talking when they are face up in front of you. Set the grating rotator to give maximum clearance before removing the grating cell.

Attempting to "clean" any optical surface.

Please leave this to the staff. They will inspect the gratings before and after each observer. The optics will be sent for professional cleaning when necessary.

Changing the zero-point of the dial indicators,

Do not rotate the dial indicator faces. This will invalidate all previously recorded settings and means everyone must start from scratch. Very antisocial!

Failure to record tilt settings for setups in this manual.

These are hard to .detennine and are quite repeatable. Please save the next user the difficulty of starting from scratch by recording your settings in Appendix A.

PREVIOUS SETTINGS OF MODULAR SPECTROGRAPH

Please record the settings here to aid with future setups. Thank you.

DATE	PORT (LONG OR SHORT)	GRATING ROTATOR: OPTICS	GRATING ROTATOR: ANGLE	FOCUS (COLLIMATOR)	DEWAR TILT PLATE: P1	DEWAR TILT PLATE: P2	DEWAR TILT PLATE: TILT	GRISM	FILTER	CCD	NOTES (ECHELLE, IMAGING?)
CHECKED THORSTEN 6/97	L	600 mm⁻¹	(corrup) 26.90	(0.588) 5.88	0.425	0.425	0.152	X	X	(Echelle)	4000-7500 Å (vignetted) 1.9 pix FWHM w/ ~1" slit.
11/13/97	L	831	38.00	.568	.421	.421	.150		OG550	Wilbur	1.6 pix FWHM w/ ~0.5" slit
3/11/98	L	1200	41.1	.568	.458	.460	.201			Wilbur	5990 - 7290 Å 1.4 pix FWHM w/ 0.5" slit
3/29/99	L	600 l/mm	26.0	.568	.464	.464	.264			TEMPLETON	
01/13/00	L	1200 l/mm	36.95	.568	.470	.470	.220			TEMPLETON	5881 RED END 4976 BLUE
05/12/00	L	831	37.00	0.568	.423	.423	.159	-	-	Wilbur	1.8 pix FWHM at 0.5" slit.
Rob 11/19/01	L	831	036.85	0.572	.414	.415	.119	-	5.5	TEMPLETON	
3/11/01	L	831	38.00	0.545	.410	.412	.120		OG515	Echelle	
Set by Bob read by Gerardo 4/23/04	S	831	"35.62"	0.896	.197	.257	.225	X	OG515	Echelle	5150 - 10500 Å
3/02/09	L	831	36.80	0.620	.435	.435	.142	x	x	Wilbur	2.3 pix w/ slit at 0.5" 4.5 w/ slit at 1.0"
3/17/11	L	600	25.86	0.630	0.462	0.462	0.175	x	x	Templeton	≲1.7 pix : 4640-6700. w/ 1" slit. IMPROVED PLATE
6/4/12	L	831	36.85	0.545	0.374	0.371	0.100		OG550	Nellie	
8/13	L	1200	34.39	0.545	0.420	0.420	0.178				

GOOD 05/19/11

* CHECKED BY BOB

PREVIOUS SETTINGS OF MODULAR SPECTROGRAPH

Please record the settings here to aid with future setups. Thank you.

DATE	PORT (LONG OR SHORT)	GRATING ROTATOR: OPTICS	GRATING ROTATOR: ANGLE	FOCUS (COLLIMATOR)	DEWAR TILT PLATE: P1	DEWAR TILT PLATE: P2	DEWAR TILT PLATE: TILT	GRISM	FILTER	CCD	NOTES (ECHELLE, IMAGING?)
4/22/94	LONG	831 l/mm	36°.55	0.580	0.440	0.440	0.149	-	OG 515	Charlotte	IR Ca Triplet Long slit
4/25/94	LONG	600 l/mm	25.96	0.tso	0.489	0.489	0.200	-	NONE	Chalotte	Hβ to Hα - wro:!
5/9/94	LONG	1200 l/mm	35.85	0.580	0.480	0.480	c,184	-	NONE	W.lb	4800-6200 Å Mg Triplet 3.. FWHM t: 0-:
6/22/94	Long	831 l/mm	36.80	0.595	0.425		0.142	—	OG515	Wilbur	CaII triplet M^2
9/06/94	shorT	831 l/mm	31.77	0.690	0.670	0.670	0.720	-	475nm	chAR	
1/16/95	Long	600 l/mm	27.15	0.495	0.480	0.480	0.184	-	NONE	WILBUR	4358 on edge - 2.7 pix FWHM other lines ~2.2 pix FWHM λ = 5570, λred edge = 687
4/15/95	long	~~600~~ 831/mm	"37.79" (off...)	0.500	0.441	0.441	0.149	-	OG.	WILBUR	λλ7300-9150. ~2.0Å FWHM. GRATING TILT INDICATOR OFF BY 1.49.
6/14/95	short	1200 l/mm	34.02	0.950				-	None	charlotte	Wide slit chopping.
9/20/95	short	1200 l/mm	34.02	0.950	0.6705	0.uns	0.721	-	None	charlotte	
1/1 6/95	long	831 l/mm						—	OG515	Wilbur	
11/15/95	long	1200 l/mm	35.89	0.590	osto	0.480	0.220	—	None	Charlotte	Gebhardt Mgb
11/19/95	Short	1200 l/mm	31.02	0.950	0.670	0.668	0.700		None	Charlotte	5000-6500 Å
1/30/97	long	ieco lt:	35.89	0.568	0.482	0.482	o.uv	-	None	Charlotte	Gebhardt Mgb
3/19/97	long	831	38.35	0.568	.440	.440	.rs»		OG515	Charlotte	Gebhardt

* These work, - Ke

APPENDIX A: LOG OF PREVIOUS SPECTROGRAPH SETTINGS

APPENDIX B: OBSERVING LOG SHEETS

A standard observing fonn is available for your convenience. You are not obliged to use it. To print your own copy type logsheet on chichon and follow the instructions on the screen.

Modular Spectrograph form

- Page Number: The box to the right of *M-D-M-Observatory* is for your page number.
- Grating Rotator: Options are refection grating, immersion grating, or plane mirror.
- Grism Port: For echelle cross dispersion or low resolution uncrossed.
- Camera Port: Short (85 mm) or long (200 mm).
- Piston 1, Piston 2: Piston 1 is located next to the tilt dial.
- Tilt: Located next to piston 1.
- Collimator: Focus value of collimator.
- *V.T.:* Determine whether given for beginning, middle or end of exposure.
- Autoguider:
  - PROBE rX, Y): read from MIS window.
  - TVBOX (X, Y, V): read from FIND/GUIDE MONITOR and the CAMERA SELECTOR gain.
- CCD center:
  - Finder (X, Y): read from FIND/GUIDE MONITOR when star centered on slit.
  - Guider (X, Y): read from FIND/GUIDE MONITOR when cursor at slit center.
- Filter:
  - Order separating filter.

MICHIGAN - DARTMOUTH - M.I.T. OBSERVATORY

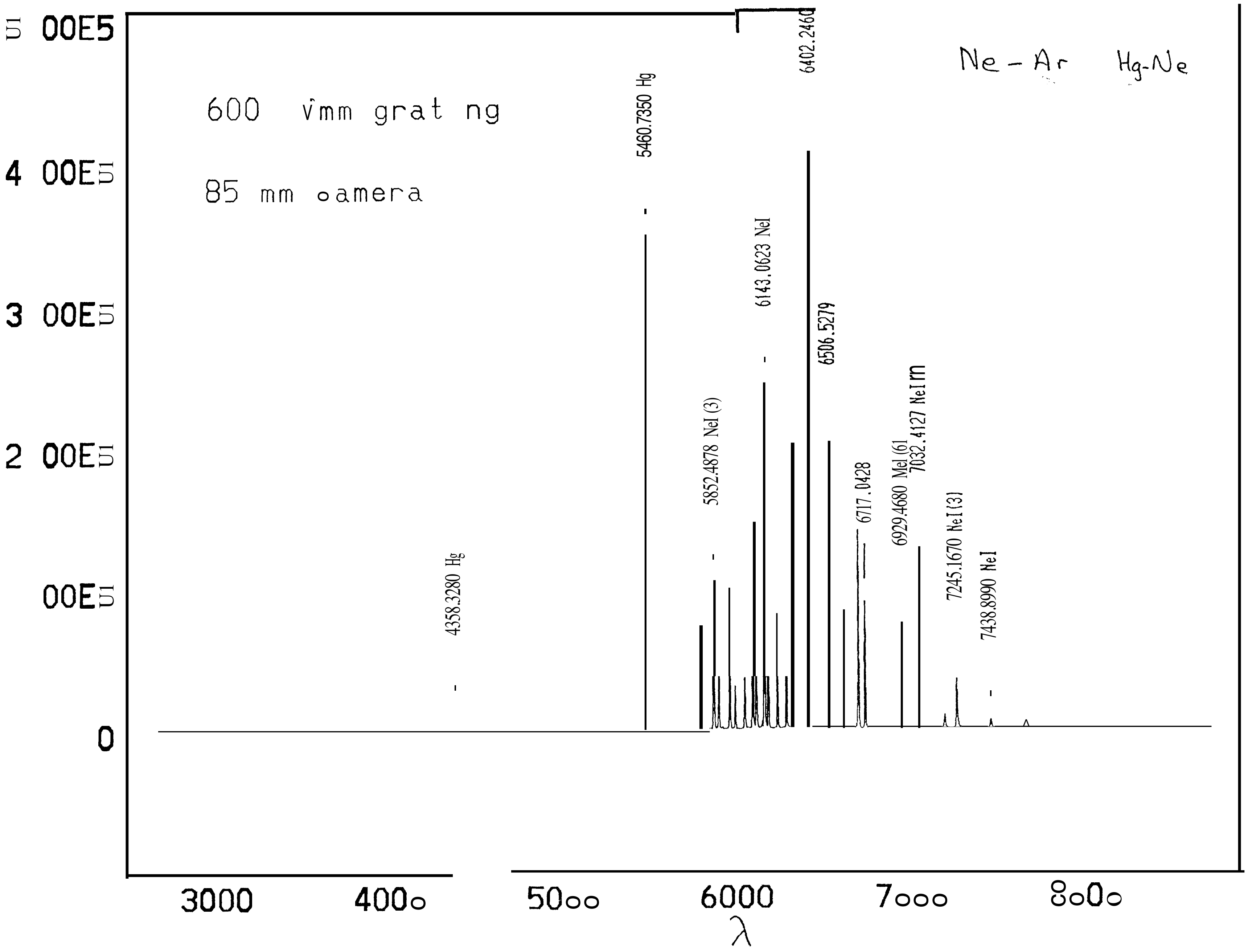
2.4m HILTNER TELESCOPE	f/7.5	GRATING ROTATOR: ______	PISTON 1: ______	DATE: / /
OBSERVER(S): ______	f/13.5	GRISM PORT: ______	PISTON 2: ______	CCD: ______
		CAMERA PORT: ______	TILT: ______	
			COLLIMATOR:	

FILE PREFIX D rnr NUMBER	OBJECT	COORDINATES R.A. hh mm ss.s	EPOCH	DEC. ° ′ ″	U.T. hh mm ss	EXPOSURE	SEC (Z)	ROTATOR ANGLE	SEEING	FILTER		AUTOGUIDER PROBE X y	AUTOGUIDER TVBOX X Y V	CCD CENTER: Finder (,) Guider (,) NOTES

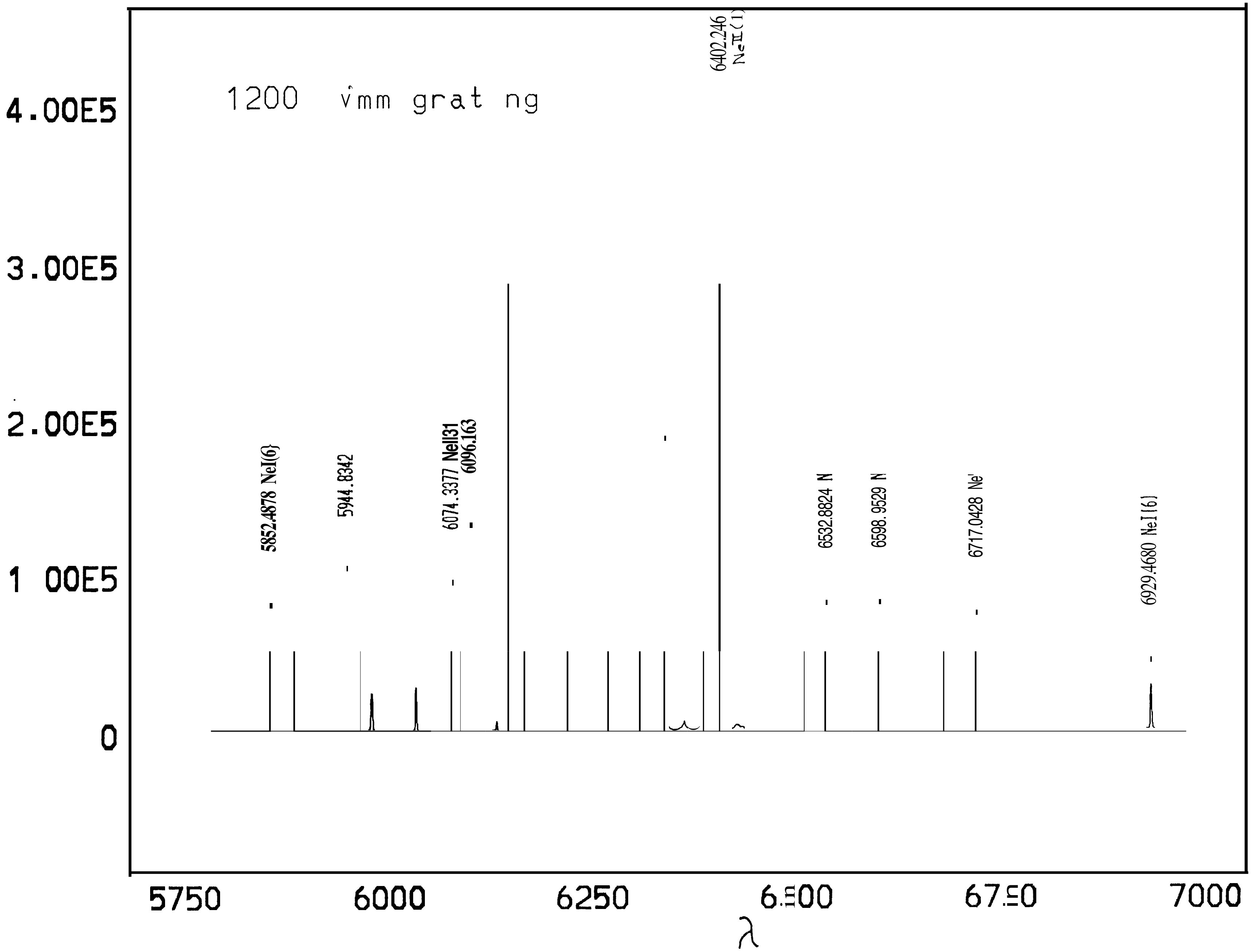
\mdm\admin\monuals\hflt\dwg\appncl.d.dwg (MODULAR SPECTROGRAPH) REVISED AUG 17. 1993

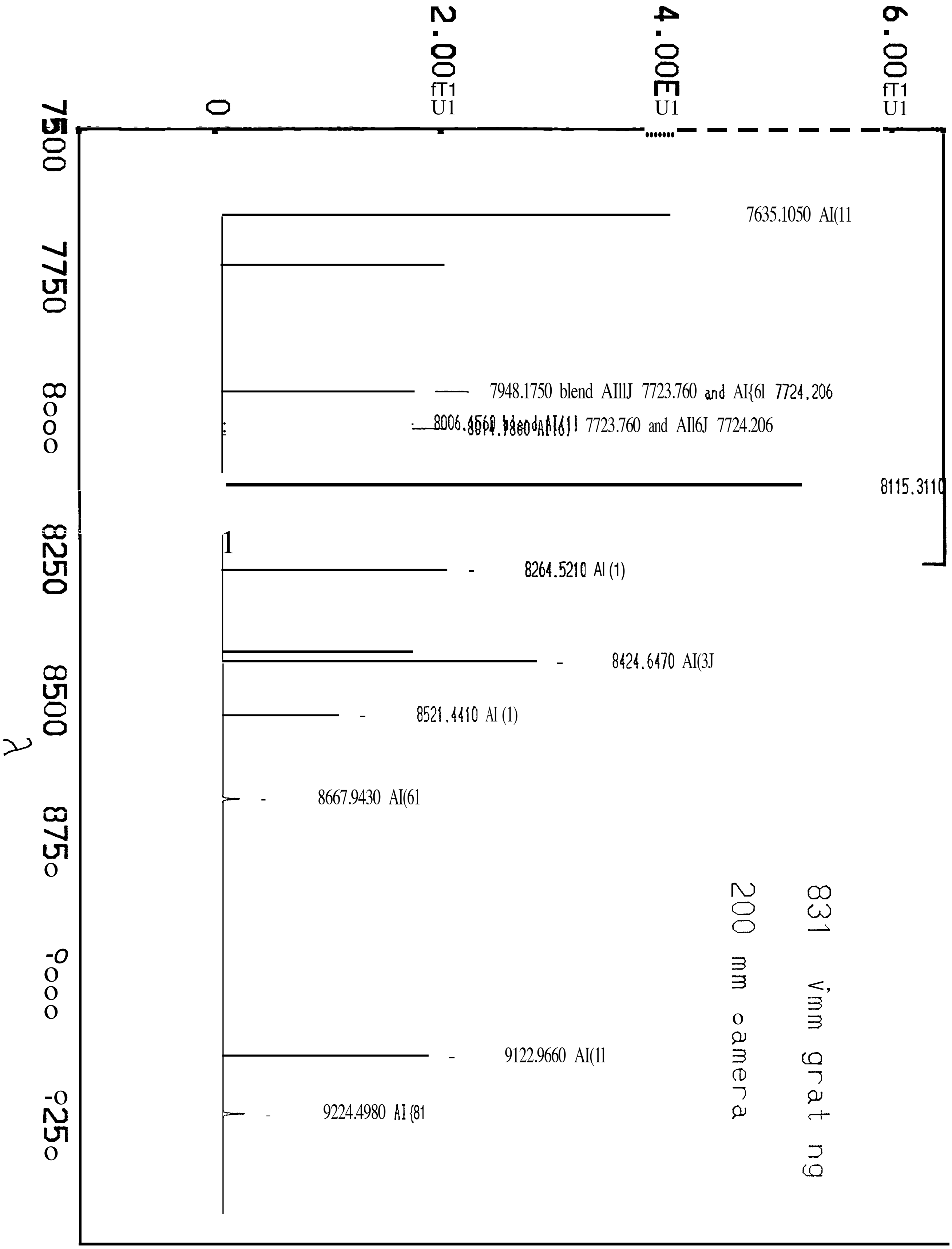
APPENDIX C: SPECTRAL ATLAS FOR PREVIOUS SETTINGS

This section contains calibration spectra for previous settings of the modular spectrograph. Further plots will be added as different gratings and settings are obtained. This will aid observers in selecting the correct configuration for their observing requirements.



00E5
4 00E
3 00E
2 00E
00E
0
600 vmm grat ng
85 mm oamera
Ne - Ar Hg-Ne
4358.3280 Hg
5460.7350 Hg
5852.4878 NeI (3)
6143.0623 NeI
6402.2460
6506.5279
6717.0428
6929.4680 NeI (6)
7032.4127 NeI
7245.1670 NeI (3)
7438.8990 NeI
3000
4000
5000
6000
7000
8000
λ


1200 l/mm grating
4.00E5
3.00E5
2.00E5
1 00E5
0
5852.4878 NeI(6)
5944.8342
6074.3377 NeI31
6096.163
6402.246 NeI(1)
6532.8824 N
6598.9529 N
6717.0428 Ne
6929.4680 NeI(6)
5750
6000
6250
6500
6750
7000
λ



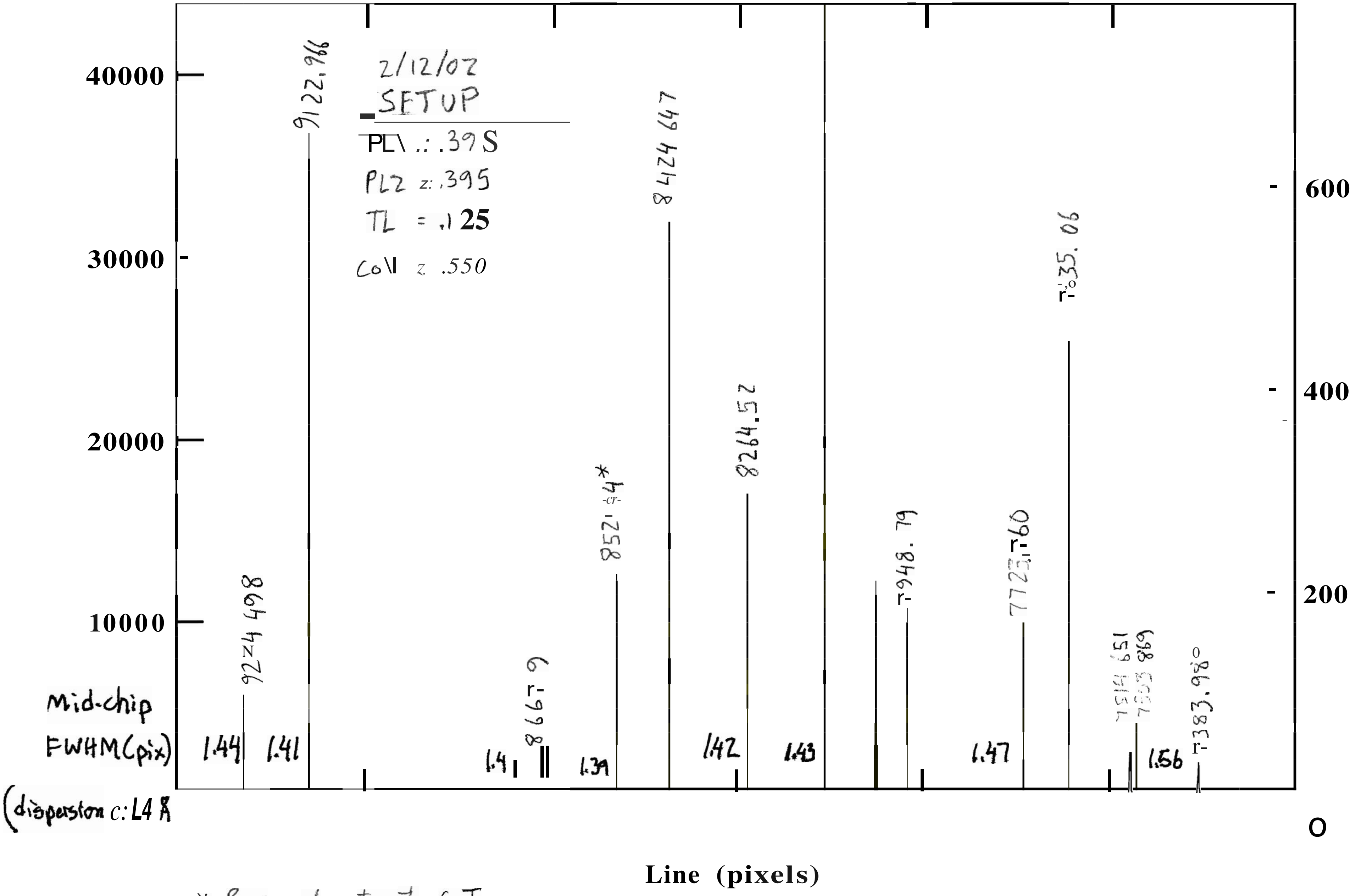
0
2.00
4.00E
6.00
7500
7750
8000
8250
8500
8750
9000
9250
λ
7635.1050 AI(11
7948.1750 blend AIllJ 7723.760 and AI{6l 7724.206
7723.760 and AII6J 7724.206
8115.3110
8264.5210 AI (1)
8424.6470 AI(3J
8521.4410 AI (1)
8667.9430 AI(61
9122.9660 AI(11
9224.4980 AI{81
831 l/mm grating
200 mm camera

Mod Spec + Echelle

NOAO/ IRAF\ V2.11.3EXPORT visitor@chichon Wed 16:28:14 13-Feb-2002

Column 370 of ccd.068

Ar sec exposure

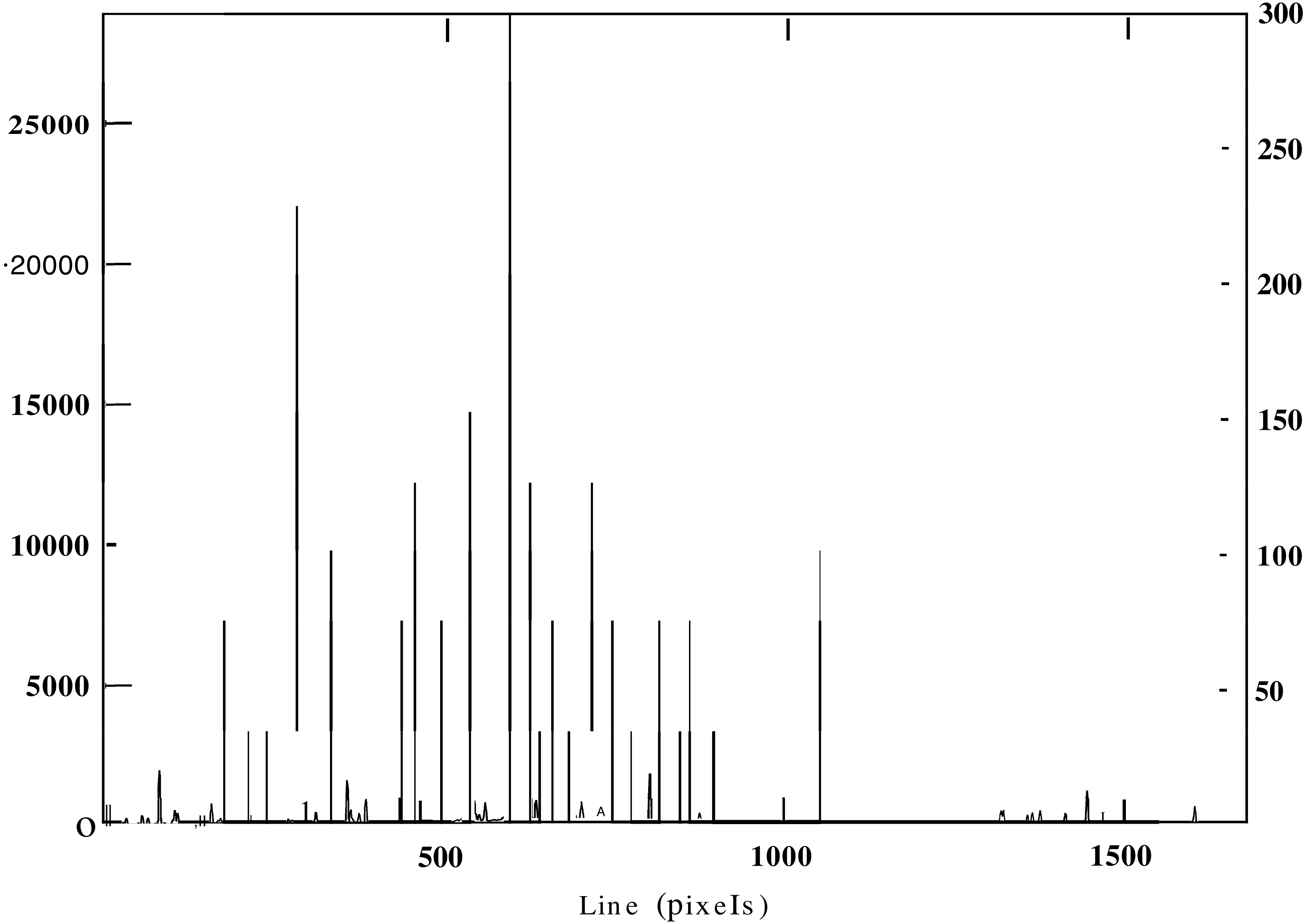


* Region of interest - CaT.

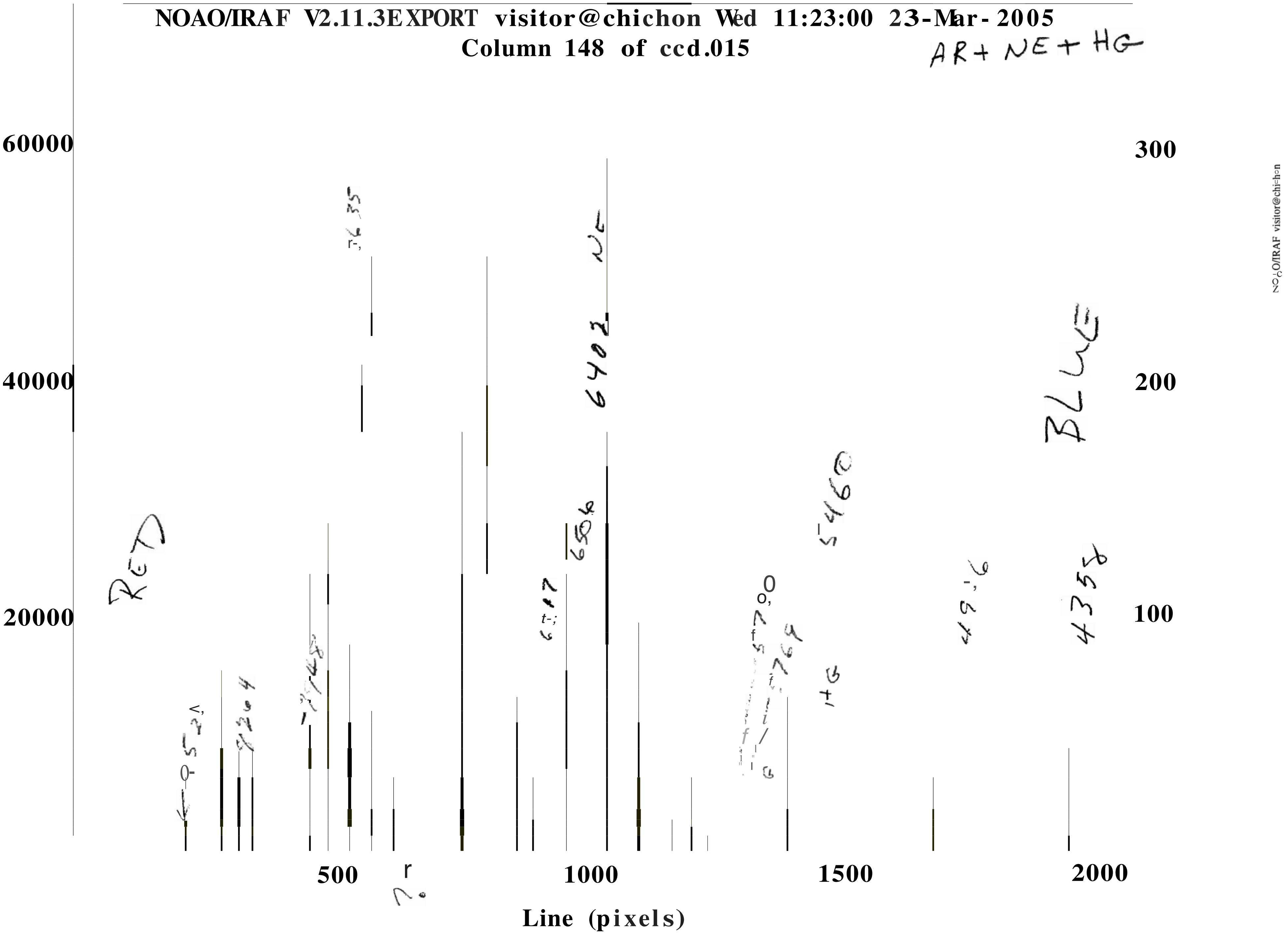
NOAO/IRAF V2.12.2a-EXPORT jules@mimas Tue 19:51:14 30-Nov-2010

Column 150 of ccd.111

HgNeXe



NOAO/IRAF jules@mimas Tue Nov 30 19:51:24 2010


NOAO/IRAF V2.11.3EXPORT visitor@chichon Wed 11:23:00 23-Mar-2005
Column 148 of ccd.015
AR+NE+HG
60000
40000
20000
300
200
100
500
1000
1500
2000
Line (pixels)
RED
BLUE
6402
NE
5460
4358
HG
NOAO/IRAF visitor@chichon

"Warning" grating tilt indicator reads wrong.
On the long port you must add **~1.**5 *degrees to your calculated angle.*
On the short port you must subtract **~.**77 *degrees from your calculated angle.*
Example Long Port: calculated angle =34.5 *then add* 1.5 *to give* 36 *degress.*
Example Short Port: calculated angle =26.27 *then subtract* .77 *to give* 25.5 *degrees.*

Slit indicator: is way out of whack (6/97). ~~Small~~ ~~dial does~~ ~~not~~ Odometer-type counter does not turn over when small dial goes through zero, and position is WAY OFF which mimics TERRIBLE focus at otherwise reasonable slit positions. In this note I indicate odometer posn thusly: $\boxed{01}$ and dial reading as (e.g.) .12 -- remember, it's not really two parts of a ~~a~~ coherent num

$\boxed{99}$ .50 ← APPROXIMATELY CLOSED

$\boxed{99}$ .00

$\boxed{100}$ .50 ← APPROX. i'l

$\boxed{00}$ .00

$\boxed{01}$ .50

(closure extrapolated to avoid damaging jaws.)

These determined by flatfield lamp exposure.

6/24/97

(FWHM is consiste

77.75
28.5(

"*Warning* rr *grating tilt indicator reads wrong.*
On the long port you must add **~1.**5 *degrees to your calculated angle.*
On the short port you must subtract **~.77** *degrees from your calculated angle.*
Example Long Port: calculated angle = 34.5 *then add 1.5 to give* 36 *degress.*
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$\boxed{99}$ .50 ← APPROXIMATELY CLOSED

$\boxed{99}$ .00

$\boxed{100}$ .50 ← APPROX. i'

$\boxed{100}$ .00

$\boxed{01}$ .50

(closure extrapolated to avoid damaging jaws.)

These determined by flatfield lamp exposure 1.
6/24/97

(FWHM is consiste

?
28.r(

7) RESPONSIBLE INDIVIDUALS

The spectrograph was designed and built under the general supervision of Paul Schechter. All questions, complaints and suggestions should be directed to him.

The mechanical design of the Las Campanas version was carried out by Phil Friswold. The drawings for the M-D-M modular spectrograph were produced using AUTOCAD@ and extensively re-worked by Peter Mack,

The majority of the machining was done by Fritz Bausch at Michigan. Additional machining was done by Peter Mack at M-D-M.

The collimator was designed by James McCarthy and fabricated by Harold Johnson Optical Laboratories Inc. The grisms were also fabricated by Harold Johnson, and all the gratings and ruled surfaces were manufactured by Milton Roy Grating Laboratories.

Valuable suggestions reflected in the design of the spectrograph came from Alan Dressler, Eric Persson, and especially Steve Shectman.

Funds for the M-D-M modular spectrograph came from an NSF grant (A.S.T. 89-22101) awarded to D. Richstone, P. Schecter and P. Mack.

This manual is maintained at M-D-M Observatory by Peter Mack, from whom further copies can be requested.

M-D-M Observatory
HC-04, P.O. Box 7520
Tucson
AZ 85735-9734

Tel: (602) 322 3360
Fax: (602) 322 3364