WIYN HYDRA AND BENCH SPECTROGRAPH USERS MANUAL - v5

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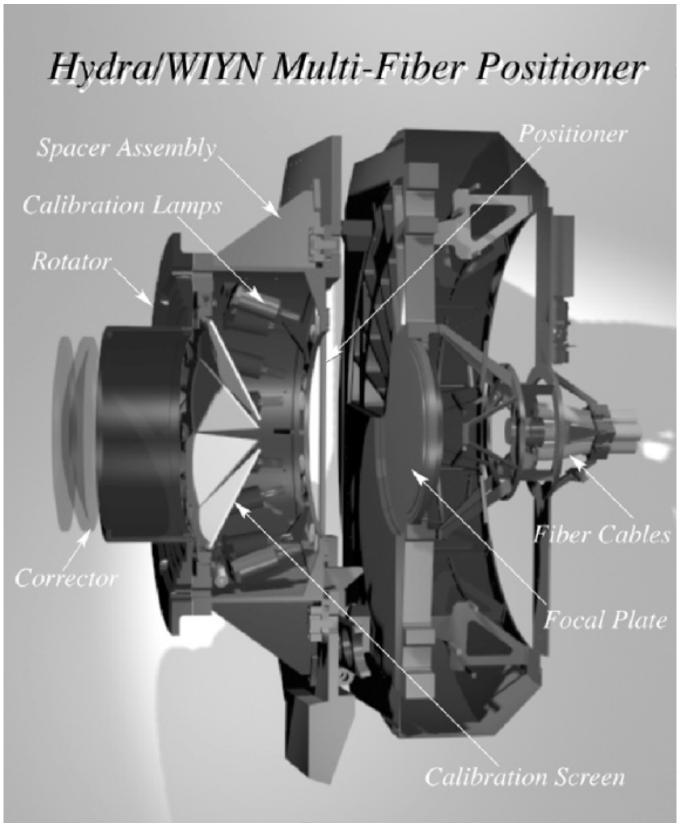
July 12, 2006



Abstract

Hydra is a fiber positioner on the WIYN 3.5 meter telescope for multi-object spectroscopy of up to 93 objects over a 1 degree field. An optimized, bench mounted spectrograph provides low, moderate, or high dispersion spectra.

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Part I

STAFF CONTACTS AND INTRODUCTION

1 STAFF CONTACTS

The following staff are available for questions related to Hydra observing:

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2 INTRODUCTION

Hydra derived its name from the resemblance of the fiber cable to the fresh water polyp of the genus Hydra. The complexity of the instrument, however, may make inexperienced users feel that the name was selected for the following definition:

> Hydra *n.* A multifarious source of destruction that cannot be eradicated by a single attempt.[1]

We certainly hope that this is not the case. As Hercules required planning and perseverance in conquering the mythical monster Hydra, so should users of the Hydra instrument likewise take the time and effort to carefully plan their strategy and be well prepared for the observing process. In that manner, Hydra shall not be a foe, but rather a friend, capable of providing a wealth of valuable astronomical data.

3 ACKNOWLEDGMENTS

A complex instrument like Hydra does not come into being from the efforts of only a few people. Some of the key folks among the many who have contributed are: Lee Groves, author of the fiber positioner software; Phil Massey, author of the assignment code and assignment manual; Gary Muller, mechanical engineer for Hydra; Andy Rudeen, electrical engineer for Hydra; David Vaughnn, engineer for the Bench Spectrograph; Shelby Gott, programmer for the Bench Spectrograph; Jim Irvine, primary instrument maker; Ron McLean and Dave

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[1] The American Heritage Dictionary of the English Language

Rosin, mechanical designers for Hydra and the spectrograph; Jorge Simmons, optical designer for the Bench Spectrograph and camera; Dianna Kennedy, programmer for the CCD detector; Jeff Lewis, author of the Hydra guider; and Caty Pilachowski, author of the bench setup program. The WIYN plate scale was measured and evaluated by Phil Massey and Xinjian Guo (Yale University) from plates taken with the Lockheed camera.

In v4 of this manual, the Linux package for the Hydra Simulator, bench setup program, and fiber assignment program was developed by Behzad Abareshi.

In 2005 the instrument was given a major overhaul with Pat Knezek as the project scientist. Essentially all electronics were replaced including the servo motors and controls, and cabling. Most of the mechanical hardware except the fiber assembly and gripper were replaced. The software upgrades included porting the Hydra control program to Linux and adding diagnostic routines. The major participants in this effort included Behzad Abareshi, Charles Corson, Dave Dryden, Rich Gomez, Di Harmer, George Jacoby, Pat Knezek, Phil Massey, Gene McDougall, Gary Muller, Dave Sawyer, and John Stein. Phil Massey also conducted final commissioning tests and provided throughput data.

The Autolog program was written by Ronald Marzke and converted to Tcl by Dave Mills. Dave also overhauled the FOPs Guider software in 2005.

Part II

INSTRUMENT DESCRIPTION AND PERFORMANCE

4 INSTRUMENT DESCRIPTION OVERVIEW

Although the typical user need not be intimately familiar with all of the details of the instrument, it is still very important to have some basic knowledge of Hydra in order to design an optimal observing strategy and program. We give here a basic review of Hydra and its functionality. Those interested in additional information on the instrument design should look at the reference papers listed below.

4.1 REFERENCE PAPERS

Descriptive papers about Hydra and the Bench Spectrograph have been published.

The first three papers address the initial version of Hydra as designed for use on the Mayall 4 meter and cover some of the fundamental aspects of the instrument concept and some instrumental capabilities.

- Barden, S. C. and Rudeen, A. C. (1990), *Kitt Peak National Observatory Fiber Actuator*

Device, in Instrumentation in Astronomy VII, ed. David L. Crawford, SPIE Vol. 1235, p. 729.

- Barden, S. C., Armandroff, T., Massey, P., Groves, L., Rudeen, A. C., Vaughnn, D., and Muller, G. (1992), *Hydra – Kitt Peak Multi-Object Spectroscopic System*, in Fibre Optics in Astronomy II, ed. Peter M. Gray, A.S.P. conference series Vol. 37, p. 185.
- Barden, S. C., Elston, R., Armandroff, T., and Pryor, C. P. (1992), *Observational Performance of Fiber Optics – High Precision Sky Subtraction and Radial Velocities*, in Fibre Optics in Astronomy II, ed. Peter M. Gray, A.S.P. conference series Vol. 37, p. 223.

The next two papers address specific modifications to Hydra for use on the WIYN telescope.

- Barden, S. C., Armandroff, T., Muller, G., Rudeen, A. C., Lewis, J., Groves, L. (1994), *Modifying Hydra for the WIYN Telescope: an Optimum Telescope, Fiber MOS Combination*, in Instrumentation in Astronomy VIII, ed. David L. Crawford and Eric R. Craine, SPIE Vol. 2198, p. 87.
- Barden, S. C. and Armandroff, T. (1995), *Performance of the WIYN Fiber-Fed MOS System: Hydra*, in Fiber Optics in Astronomical Applications, ed. Samuel C. Barden, SPIE Vol. 2476, p. 56.

4.2 THE HYDRA FIBER POSITIONER

Table 1 lists a summary of the Hydra fiber positioner characteristics.

4.2.1 The Fiber Cables

Two science fiber cables are currently available on Hydra, but only one may be selected for a particular configuration. The red cable has nearly constant transmission (Figure 9) from 5000Å to >10,000Å, while the blue cable is essential shortward of 4000Å. Each fiber in the red cable subtends 2 arc-seconds on the sky while each blue fiber subtends 3 arc-seconds. The blue cable may also be desirable for certain applications below 7000Å when the larger diameter fibers are needed.

On the end of each fiber is mounted a small right angle prism with an aluminized hypotenuse. This fiber/prism assembly, in turn, is mounted in a magnetic “button” which holds the fiber in position on the focal plate. Figure 1 shows a schematic view of this button. Note the beam f-ratio is f/6.3 at WIYN.

HYDRA POSITIONER CHARACTERISTICS	
Full Unvignetted Field Size	60 arc-minutes diameter
Minimum Fiber to Fiber Separation	37 arc-seconds
Positioning Accuracy	0.3 arc-seconds (30μm) rms measured
Configuration Time (100 fibers)	20-25 minutes
Total Number of Fiber Slots	288
Number of Guide Fibers (FOPs)	10 (two of the 12 now broken)
Number of Available Science Cables	2
Number of Active Fibers Per Cable	90 Red[2], 83 Blue[2]
Fiber Cable Length	25 meters
Blue Cable Spectral Window[1]	3000Å – 7000Å
Blue Cable Fiber Diameter	3.1 arc-seconds (310μm)
Red Cable Spectral Window[1]	4000Å – 1.8μm
Red Cable Fiber Diameter	2.0 arc-seconds (200μm)

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[1] See Figure 9 on page 16.

[2] The concentricities file has up to date info, or contact staff.

Table 1: Summary of the Hydra Positioner characteristics.

4.2.2 The Focal Plate Assembly

Fibers selected for use are positioned onto a thin, flat steel plate during target configuration. After all fibers are in place, a vacuum is applied on the back side of the plate to warp it against a spherical backstop. This both draws the fibers onto the true focal surface and aligns them axially with the telescope exit pupil.

Unused fibers are left positioned in either stow or park positions, located around the outer circumference of the assembly. These positions are at a depth lower than the surface of the warpable plate so that fibers in use can cross over unused neighbors.

There are 288 total fiber positions evenly spaced around the focal plate numbered from 0 through 287. The red fibers occupy every third position beginning at location 1 and include an additional two fibers at positions 276 and 279. The blue fibers are also located at a spacing of every third position starting at location 2. The Field Orientation Probes which are used for field acquisition and guiding (see Section 4.4), are set at spacing intervals of every 24th with the first occupying position 0. The remaining 82 empty slots are available for future fiber cable implementations.

4.2.3 The Gripper and Stages

To position the fibers, a 3-fingered gripper rides on a 3-axis stage mechanism moving each fiber, one by one, onto the focal plate assembly. The center of the gripper jaw enclosure is optically transparent allowing a gripper camera to "view" the button placement via illumi-

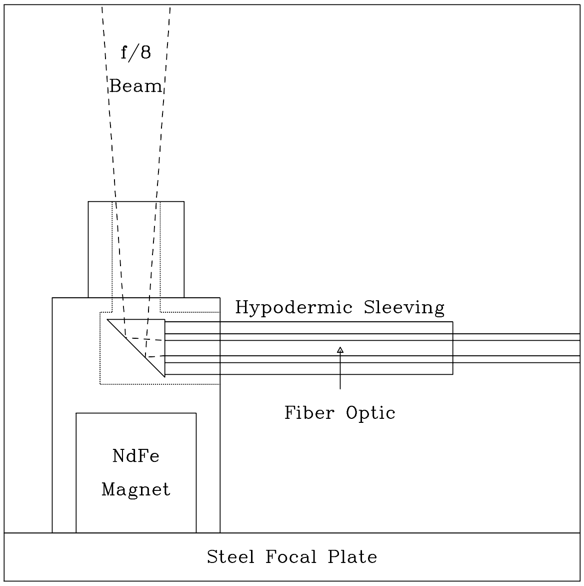


Figure 1: Schematic view of a fiber button on the focal plate.

nation from a bank of LED's on the gripper.

The Z-axis, allowing the gripper to pick up and place, rides on a Y-stage which in turn is mounted to a dual drive X-stage. Both X and Y stages are encoded to 2.5μm steps (0.024 arc-seconds on the sky). Positional error has been measured to be about 0.3" (30μm) rms.

4.3 CALIBRATION SOURCES

Two banks of 8 hollow-cathode tubes (a ThAr and a CuAr set) are located a few inches away from and in a radial pattern around the edge of the focal surface for wavelength calibrations. The lamps illuminate a screen which folds into the beam when in use. Selection of the lamp type is made by swapping a cable connection near the instrument.

Flat field calibrations are made by pointing the telescope at a white spot which is mounted onto the side of the dome. A bank of quartz lamps, mounted on the telescope top ring, illuminates the white spot.

4.4 THE HYDRA GUIDER

Target field acquisition, alignment, focus, and closed loop guiding are controlled by the use of the Field Orientation Probes (FOPS). Twelve such probes are mounted symmetrically about the focal plate. Each probe consists of a 7-fiber coherent array with 1 arc-second fibers.

A TV views the output of all ten probes (2 are now broken) for the provision of guider signals and for the visual inspection of the field alignment and the telescope focus.

Since the guider must perform 3-axis guiding (altitude, azimuth, and field rotation), it is absolutely necessary to have at least 3 probes in use within the target field. However, we strongly recommend more than 3 probes so that astrometry errors will be less critical. See sections 6 and 9.1.3 for details on proper selection of FOPS stars.

Filters are available for use in the FOPS TV (BG-39, RG610, or clear glass) to optimize alignment with respect to the spectral bandpass being observed.

4.5 THE BENCH SPECTROGRAPH

The Bench Spectrograph is a stable, isolated spectrograph optimized for use with optical fibers. It permits relatively easy changes of configuration between high and low dispersion and between various spectral regions. The bench-mounted nature also allows for future additions and modifications. Figure 2 shows the schematic layout of the Bench Spectrograph.

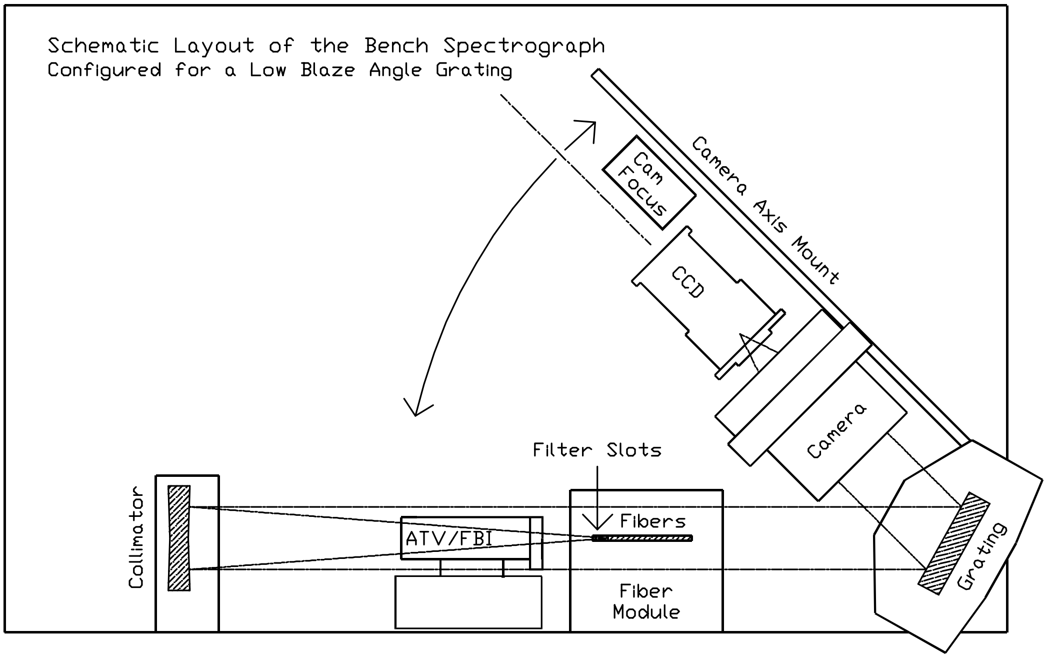


Figure 2: Overhead schematic view of the Bench Spectrograph.

Interchangeable components include the choice of blue or red fiber cables, eight gratings, and two cameras, Adjustable items include a variable collimator-camera angle and grating-detector distance. In practice however, the collimator-camera angle is used almost always at 11° for the echelle grating and bench camera (13° for Simmons camera), and 30° for all other gratings.

4.5.1 Summary of Spectrograph Characteristics

The spectrograph characteristics are summarized in Table 2.

BENCH SPECTROGRAPH CHARACTERISTICS	
Available Gratings	Seven; See Table 4
Cameras	Simmons Camera (f.l. 381 mm, 3000Å – 1.5μm) Bench Camera (f.l. 285 mm, 3800Å – 1.5μm)
Collimator	6 inch f/6.7 Paraboloid
Camera Collimator Angle	Variable between 11° and 45° (see Section 4.5.7)
Detector	2048 Thinned SITe (24μm–pixels) CCD
Typical Resolution Element	2 to 4 pixels
Spectral Coverage	100Å to ~1 octave (see Table 6)

Table 2: Summary of the Bench Spectrograph characteristics.

4.5.2 The Fiber Module

The Fiber Module holds the fiber slit (foot) of either the red or blue Hydra cable, SparsePak or DensePak in alignment with the collimator. Collimation adjustment (fiber focus) is made via translation of this unit. Note that only one cable can be mounted on the Fiber Module at any given time.

4.5.3 Filters

There are four filter slots in each fiber foot. The first slot (A) holds aperture masks and is not currently used; the second slot (B) holds thick (0.35 in) filters (the interference filters for the Echelle grating and the liquid $CuSO_4$); the other two (C and D) hold thinner (0.25 in) filters (the glass filters). Hence, it is possible to use a broad-band glass filter in concert with another glass filter or with an interference filter for maximal blocking.

A list of available filters for order separation is given in Table 3. In that Table, LP stands for longpass, BP for bandpass. "λ-" and "λ+" are the half maxima. Several of the interference filters are noted as "not constructed" but their computed parameters are given for completeness. Transmission curves for the available filters are shown in Figures 3, 4, and 5.

BENCH SPECTROGRAPH FILTERS

No.	Filter	Type		$\lambda-$ (Å)	$\lambda+$ (Å)	Notes
G1	RG–610	Glass	LP	6000		
G2	RG–695	Glass	LP	6970		
G3	GG–375	Glass	LP	3750		
G4	GG–420	Glass	LP	4240		
G5	GG–495	Glass	LP	5020		
G6	BG–38	Glass	BP	3370	6230	red leak $>0.85\mu$m
G7	BG–39	Glass	BP	3420	5970	slight red leak $>0.85\mu$m
G8	KG–3	Glass	BP	3250	6750	
G9	KG–3+GG–495	Glass	BP	4800	6800	
L1	$CuSO_4$	Liquid	BP	3220	5780	currently not available
X1	orders 17&18	Interference	BP	3150	3292	not constructed
X2	order 17	Interference	BP	3238	3383	not constructed
X3	orders 16&17	Interference	BP	3336	3498	not constructed
X4	order 16	Interference	BP	3490	3600	not constructed
X5	orders 15&16	Interference	BP	3554	3721	not constructed
X6	order 15	Interference	BP	3654	3840	for 316@63.4 echelle
X7	orders 14&15	Interference	BP	3784	3976	for 316@63.4 echelle
X7.5	CaII H&K	Interference	BP	3847	4058	for 316@63.4 echelle
X8	order 14	Interference	BP	3906	4131	not constructed
X9	orders 13&14	Interference	BP	4065	4266	for 316@63.4 echelle
X10	order 13	Interference	BP	4212	4424	for 316@63.4 echelle
X11	orders 12&13	Interference	BP	4375	4626	for 316@63.4 echelle
X12	order 12	Interference	BP	4557	4815	for 316@63.4 echelle
X13	orders 11&12	Interference	BP	4733	5059	for 316@63.4 echelle
X14	order 11	Interference	BP	4941	5277	for 316@63.4 echelle
X15	orders 10&11	Interference	BP	5162	5582	not constructed
X16	order 10	Interference	BP	5413	5817	for 316@63.4 echelle
X17	orders 9&10	Interference	BP	5684	6164	for 316@63.4 echelle
X18	order 9	Interference	BP	6005	6493	for 316@63.4 echelle
X19	orders 8&9	Interference	BP	6320	6944	for 316@63.4 echelle
X20	order 8	Interference	BP	6669	7374	not constructed
X21	orders 7&8	Interference	BP	7086	7960	not constructed
X22	order 7	Interference	BP	7609	8440	for 316@63.4 echelle
X23	orders 6&7	Interference	BP	8137	9212	for 316@63.4 echelle
X24	order 6	Interference	BP	8712	9992	not constructed

Table 3: List of Bench Spectrograph filters.

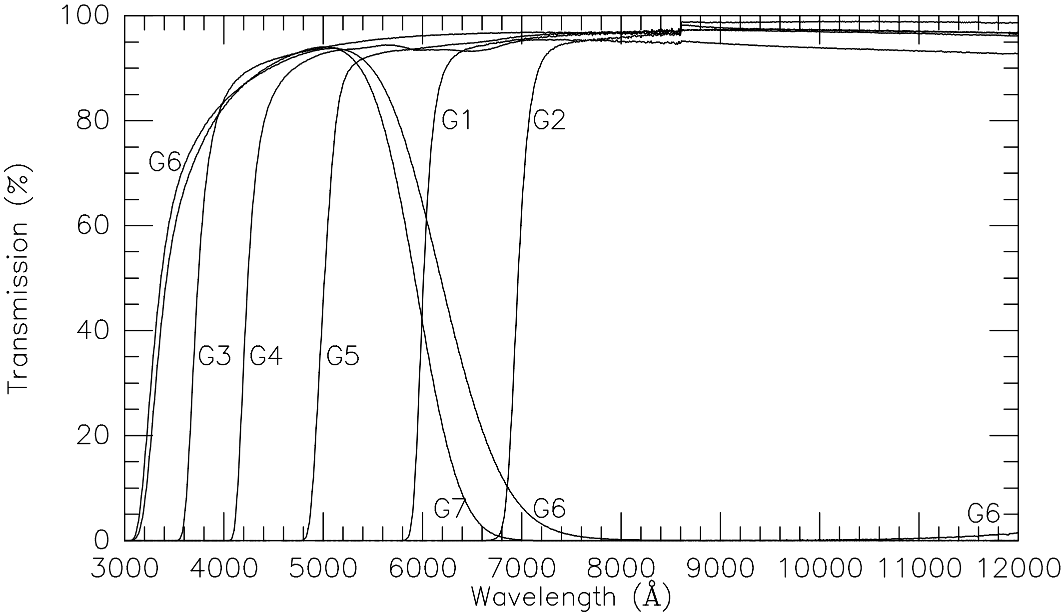


Figure 3: Transmission curves for the G1 - G7 glass filters. Note the red leak in the G6 filter. The glitches at 8600 Å are artifacts from the scanning process.

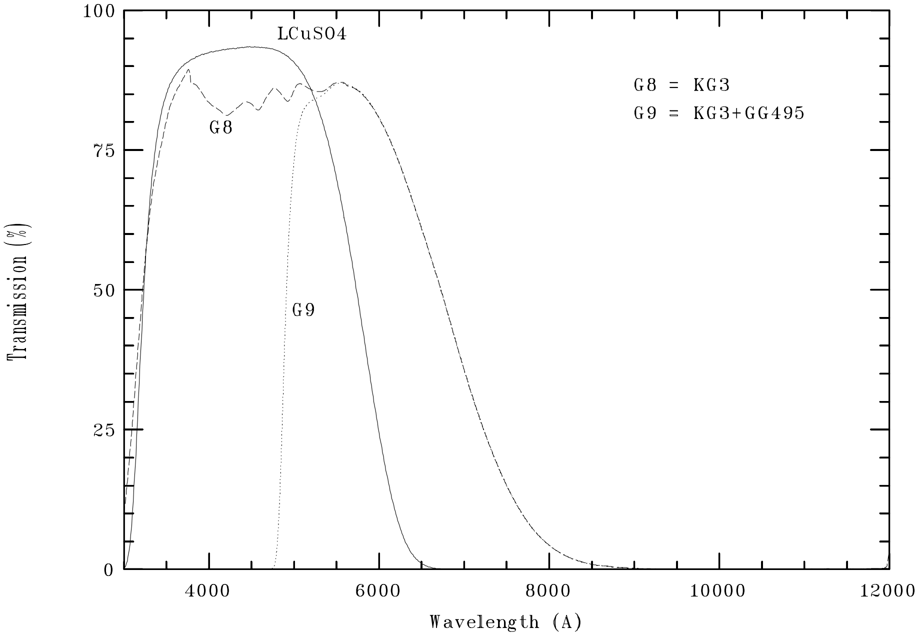


Figure 4: Transmission curves for the G8, G9, and $LCuSO_4$ glass filters.

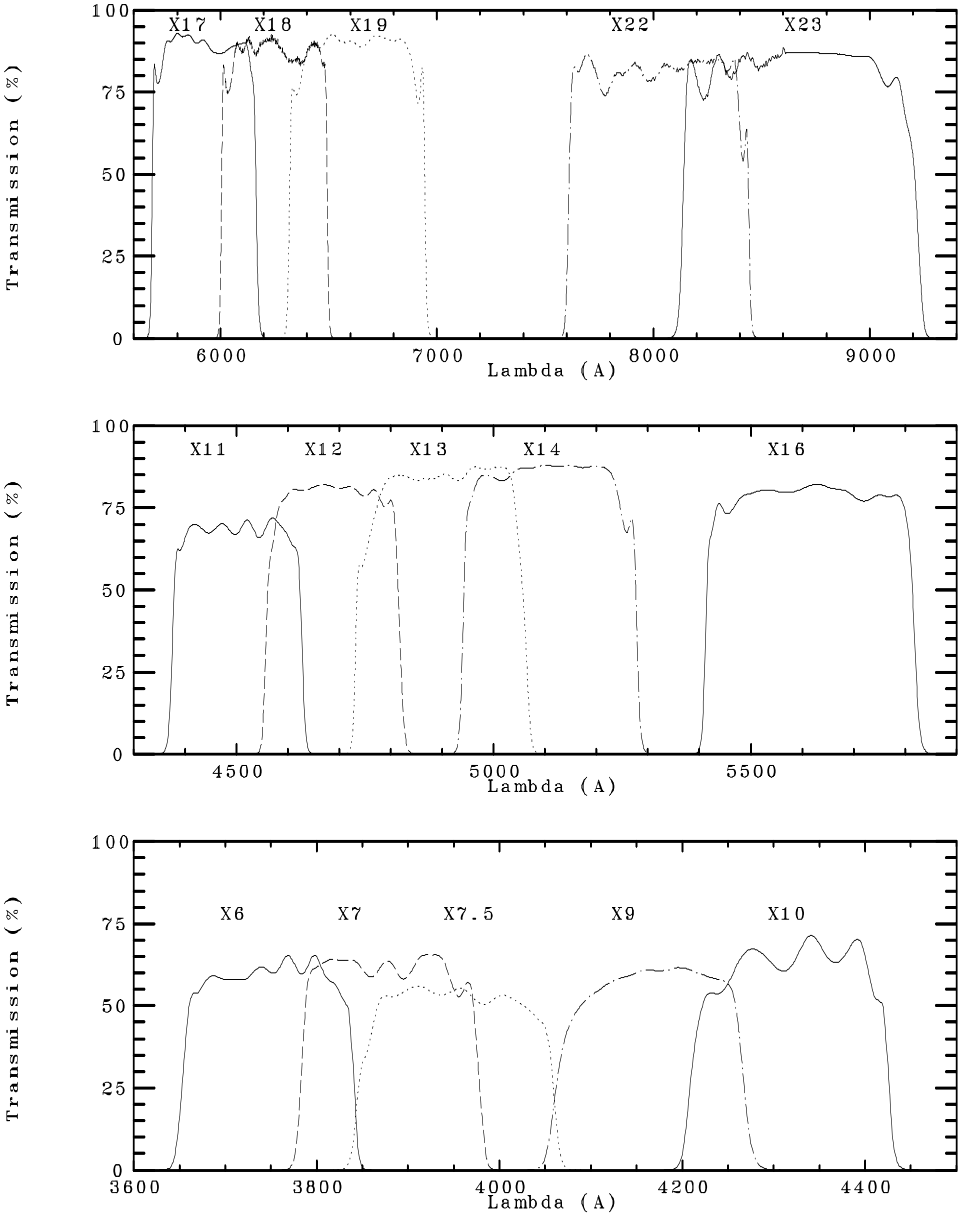


Figure 5: Transmission curves for the interference filters.

4.5.4 The Bench Acquisition TV and Fiber Back Illuminator

A rear slit viewing TV (called the Acquisition TV or ATV) for viewing the fiber ends is located immediately after the last filter slot.

A bank of LED's called the Fiber Back Illuminator (FBI) is attached to the ATV assembly and is used to back light the fibers while viewing them with the Hydra Gripper TV. When not in use, the FBI is turned off and located off-axis from the ATV.

Both the ATV and FBI are removed from the spectrograph beam when not in use. *Caution! Beginning an exposure before the Bench GUI indicates the ATV is completely stowed will result in fogging from a sensor on the ATV.*

4.5.5 The Collimator

The collimator is an aluminum-coated parabolic mirror nominally producing a 152 mm (6 inch) beam (per fiber). Focal ratio degredation in the fibers will however produce somewhat larger beam sizes, resulting in some over-illumination of the grating. A detailed discussion of this and the throughput in general may be found in Bershady, et al. (see Section 5.3).

4.5.6 The Grating Module and Gratings

The Grating Module holds large gratings, such as the 206 by 406 mm echelle (grating 316@63.4), one at a time. Grating angle is remotely adjusted and set by this unit.

The parameters for the available gratings are listed in Table 4.

BENCH SPECTROGRAPH GRATINGS

Grating	l/mm	Blaze Angle	Peak Efficiency	Ruling(mm)	Notes
316@7.0	316	7.0°	70%	259 × 213	Similar to BL181
400@4.2	400	4.2°	70%	262 × 217	First Order Blue
600@10.1	600	10.1°	72%	210 × 216	New Feb. 1999
600@13.9	600	13.9°	70%	256 × 206	Similar to BL420
860@30.9	860	30.9°	65%	262 × 217	Similar to KPC-24
1200@28.7	1200	28.7°	55%	262 × 206	Similar to BL380
316@63.4	316	63.4°	50%	206 × 406	Echelle grating

Table 4: List of Bench Spectrograph gratings.

Efficiency curves for the Bench Spectrograph gratings are displayed in Figures 6 and 7. Note that the curves for gratings 316@7.0, 600@13.9, 860@30.9, and 1200@28.7 are taken from the RC gratings of similar characteristics and for a camera-collimator angle of 45 degrees. The 400@4.2 and 600@10.1 curves were measured from the actual gratings at Milton-Roy's Richardson Grating Laboratory for an angle of 30 degrees.

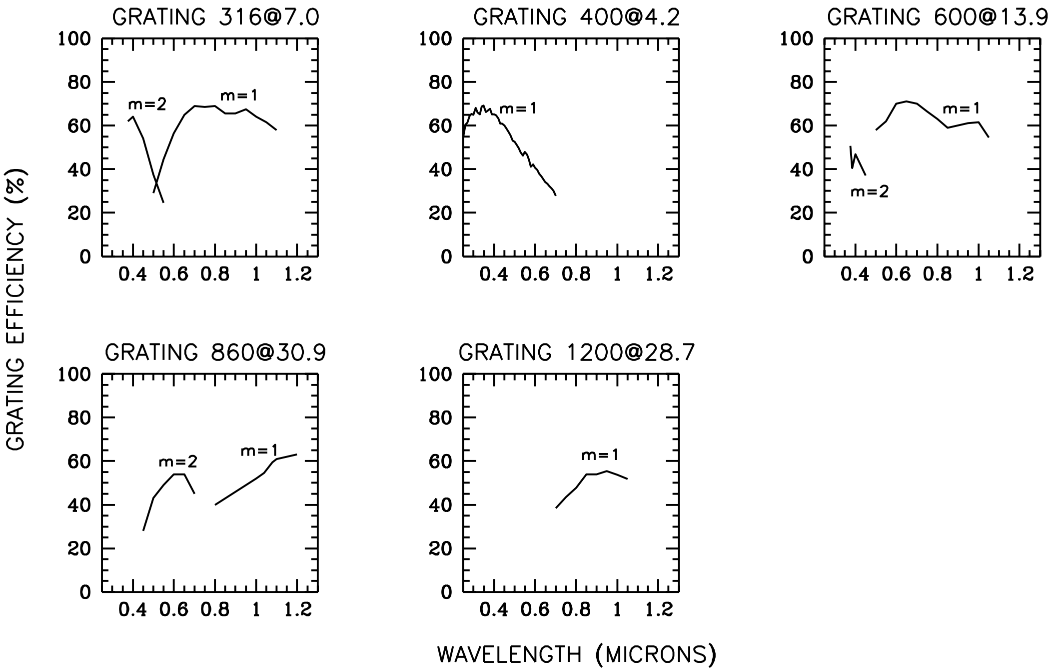


Figure 6: Grating efficiency curves. Curves for the 316@63.4 echelle are not available.

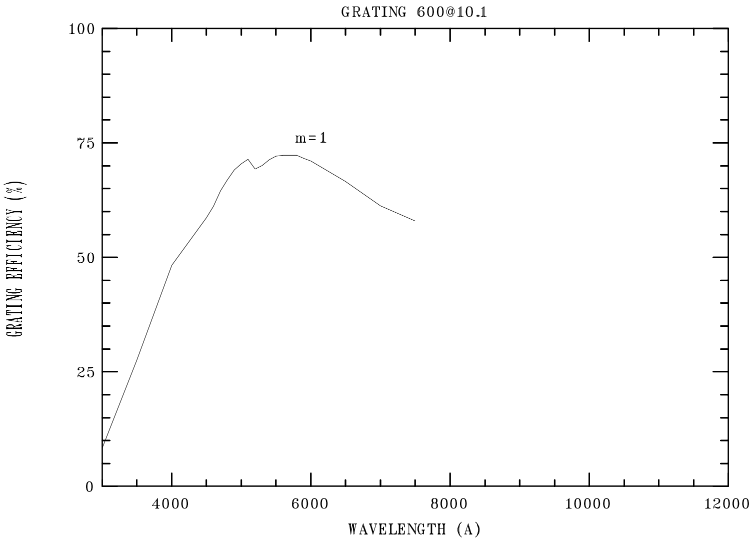


Figure 7: Grating efficiency curve for grating 600@10.1.

4.5.7 The Camera Axis Mount

The camera axis mount extends from under the Grating Module to provide for rotation of the camera about a vertical axis through the center of the front surface of the grating. This allows the camera-collimator angle to be varied between 11 and 45 degrees. The camera-grating distance can also be varied along the camera axis in order to place the camera entrance as close to the grating surface as possible without vignetting the light path from the collimator to the grating.

A camera-collimator angle of 13 degrees is used for the echelle grating (316@63.4) when used with the Simmons camera and 11 degrees when used with the Bench Spectrograph Camera. The low blaze angle gratings normally use an angle of 30 degrees.

4.5.8 The Simmons Camera

The Simmons Camera (formerly from the Mayall RC spectrograph) is of the Cassegrain Mangin-Mirror Maksutov type, employing two corrective meniscus lenses. The focal length is 381 mm.

The throughput of the Simmons Camera is flat at 45%; higher than the Bench Camera blueward of 3800 Å, and lower redward of 3800 Å. The Simmons Camera and blue fiber cable must be used for observations that extend significantly blueward of about 3800 Å.

4.5.9 The Bench Spectrograph Camera

A 285 mm focal length, all-transmission camera, optimized for use between 4500 and 7300 Å with a 24 μm-pixel SITe 2048x2048 CCD, has been fabricated. The throughput rises above that of the Simmons camera redward of 3800 Å and stays above 70% from 4000 Å to 11,000 Å. Achieving optimum focus is highly dependent on using the correct dewar azimuth tilt value which is wavelength and wavelength range dependent. Nominal azimuth tilt values vary typically from +1.3° to -0.4°. The instrument assistant will tune the angle for optimum focus during the initial bench setup. Note the use of the 400@4.2 grating with the Bench camera is not recommended due to the inability to focus over a range of wavelengths that extend well below 4000 Å.

4.5.10 The Detector

The Bench Spectrograph uses the T2KA chip, a thinned SITe 2048x2048 CCD with 24 μm-pixels. The Hydra spectra are aligned along the columns of this CCD.

Figure 8 shows the quantum efficiency curve for the CCD. Table 5 lists the readnoise and recommended gain of the CCD.

4.5.11 The Camera Focus Module

This unit translates the CCD with respect to the camera for final focus.

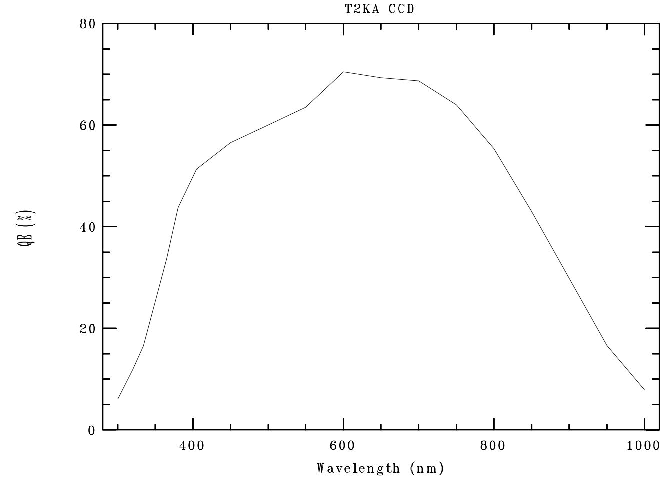


Figure 8: Quantum Efficiency of the T2KA CCD.

T2KA CHARACTERISTICS	
Quality	Value
Readout Noise	4.0e$^-$
Default Gain	2.1 e$^-$/ADU (gain index = 4)

Table 5: Characteristics of the T2KA CCD.

Spectrograph focus is achieved by placing the fibers into collimation with the Fiber Module (see section 4.5.2 on page 7), followed with a focus sequence obtained by moving the CCD with respect to the camera via the Camera Focus Module.

4.5.12 The Simultaneous Comparison Sources

Two fibers (one is currently broken), located at either end of the "slit" assembly, connect to comparison sources located near the Bench Spectrograph. This permits comparison lamp exposures to be made over the course of a target field integration. Such ability to monitor the wavelength zero point may be useful for programs seeking to measure high-precision radial velocities. The comparison source choices are ThAr or CuAr with the added availability of a quartz lamp for the aperture/flat field definition of those two fibers. Neutral Density filters are used to adjust the illumination of the Simultaneous Comparison Sources (SCS).

4.5.13 Sample Bench Spectrograph Capabilities

Table 6 gives some specific sample spectrograph parameters for the available gratings. This table should provide a rough guideline to spectral coverage and resolution for each available grating. The final custom setup should be explored using the program *setup.f* (see Section 8.1 on page 26).

SAMPLE BENCH SPECTROGRAPH CONFIGURATIONS

Grating	Centralλ	Order	λ Coverage		Spectral Resolution		Dispersion	
	(Å)		(Å)		(Å)		(Å/pixel)	
			Simmons	BSC[1]	Red Cable[2]	Blue Cable[3]	Simmons	BSC
316@7.0	7500	1	4000	5400	5.72	8.87	1.97	2.64
316@7.0	3750	2	2000	2700	2.86	4.44	0.99	1.32
400@4.2	5000	1	3200	4250[4]	4.56	7.07	1.56	2.08
600@10.1	5500	1	2140	2850	3.35	4.60	1.05	1.40
600@13.9	7500	1	2150	2900	2.86	4.43	1.05	1.40
600@13.9	3800	2	1075	1450	1.43	2.22	0.53	0.70
860@30.9	10800	1	1500	2000	1.64	2.54	0.71	0.95
860@30.9	6000	2	720	960	0.77	1.19	0.35	0.47
860@30.9	4000	3	480	640	0.52	0.80	0.23	0.31
1200@28.7	7500	1	1050	1400	1.19	1.84	0.51	0.68
1200@28.7	4000	2	520	700	0.58	0.90	0.25	0.34
316@63.4	6563	9	200	270	0.16	0.25	0.10	0.13
316@63.4	3890	14	175	230	0.17	0.27	0.08	0.11

---

[1] Transmission of the Bench Red camera drops below Simmons blueward of 3800Å.

[2] Transmission of the red fibers drops off rapidly blueward of 4000Å.

[3] Transmission of the blue fibers drops off non-uniformly redward of 8500Å.

[4] Not recommended due to difficulty focusing over the wavelength range.

Table 6: Sample Bench Spectrograph configurations.

4.6 INSTRUMENT COMPUTERS

There are three computers and two consoles from which the full operation of Hydra and the Bench Spectrograph take place:

- Oatmeal – An AMD Athlon XP 1800+ PC running Linux Red Hat 7.3 for Hydra positioner operation.
- Almond – An Intel Pentium 4 (2.4 GHz) Pc running Linux Red Hat 7.3, used as the interface to Oatmeal and for Hydra Simulator use.
- Vanilla – A Sun SPARCstation 20 running SunOS 4.1.4, used for operation of the CCD and the Bench Spectrograph.

5 INSTRUMENT PERFORMANCE

Several factors determine the performance level of the instrument. Instrumental factors governing the throughput include the transmission characteristics of the fiber optics, quality of the prism mountings, optical axis alignment of the fiber at the telescope and in the spectrograph, focal ratio degradation within the fibers, grating efficiency, camera throughput and vignetting, presence of central obstructions, detector efficiency, and quality of the coatings on the various optical components within the spectrograph and telescope. Environmental factors that can impact the peak instrumental performance include seeing, image quality and focus, atmospheric transparency, and external stresses on the fiber cable. Additional factors that can vary efficiency between target fields arise from astrometry errors and fiber positioning errors.

5.1 FIBER SPECTRAL TRANSMISSION

Figure 9 shows the transmission characteristics of the fiber optics. Both red and blue fiber

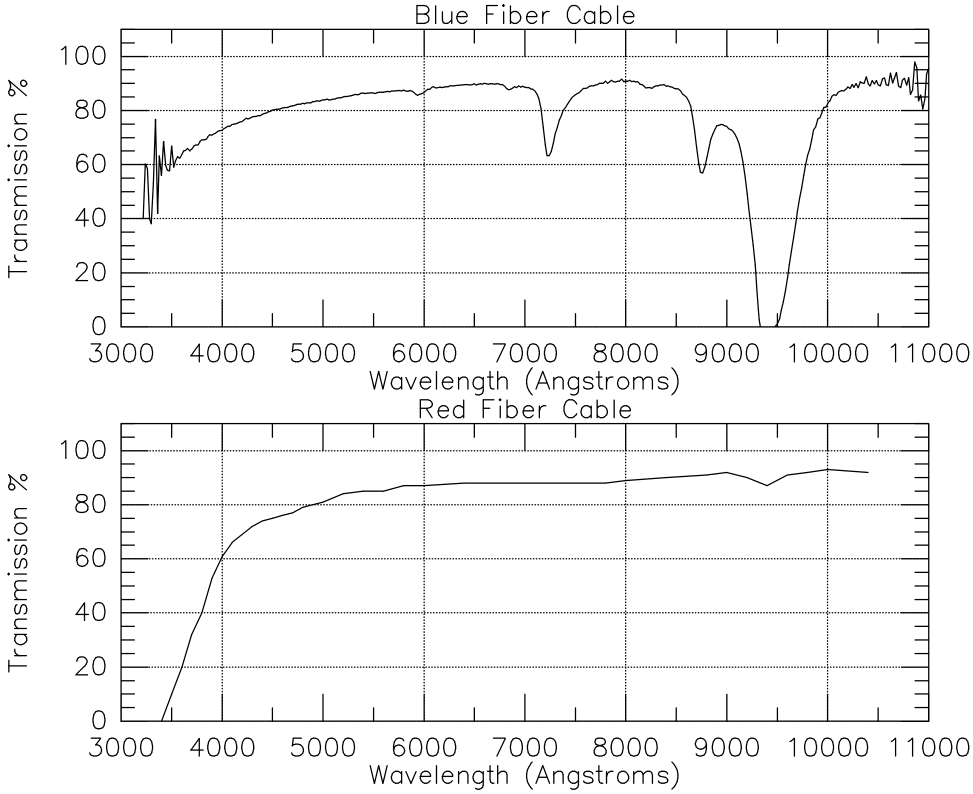


Figure 9: Fiber transmission curves.

cables are 25 meters in length. These curves include end reflection losses, but do not include the additional loss (maybe 5-10%) that may be present from the small prism epoxied onto the fiber end. Focal ratio degradation losses are also not included. The focal ratio of the spectrograph collimators are f/6.7 and should collect >95% of the light contained within the output cone of the fibers. Fiber radiance measurements made in the summer of 1998 show however, only about 57% of the light from the red fibers and about 68% of light from the blue fibers, is incident on the collimator. The same measurements on the DensePak fibers yield about 62%.

5.2 FIBER TO FIBER THROUGHPUT

Fiber to fiber throughput variations do exist. The top half of Figure 10 shows a typical cross section of a flat field obtained for the red fiber cable. A similar cross section is shown in the

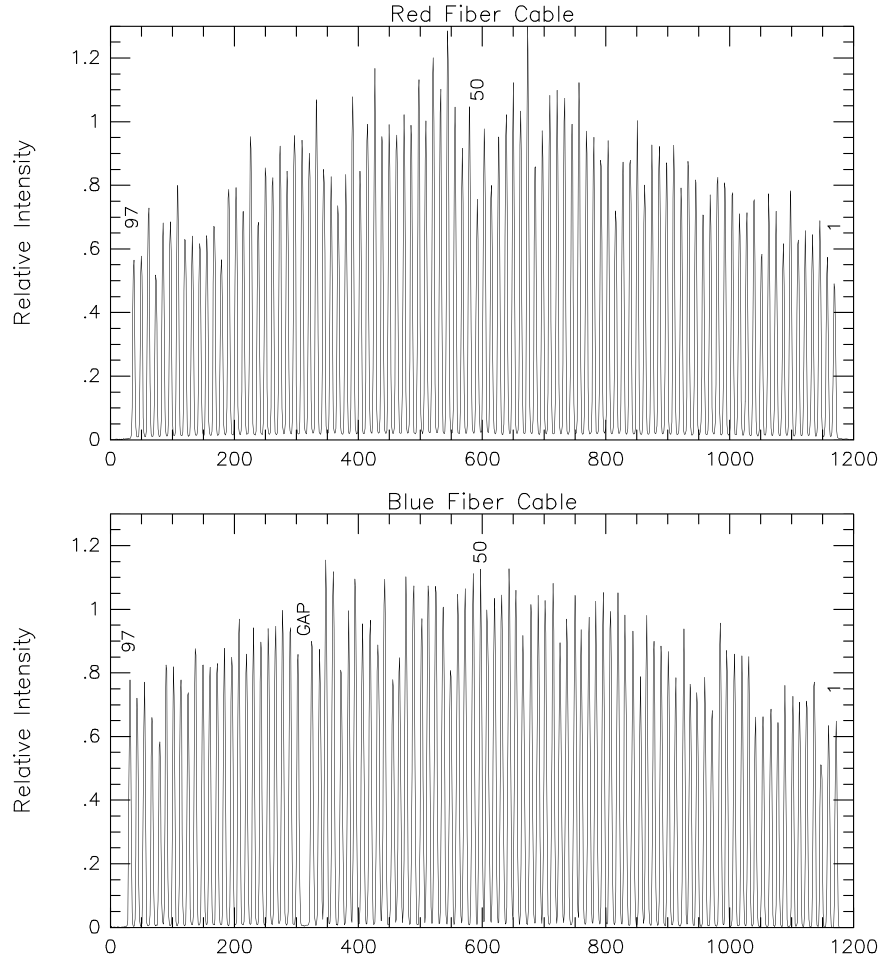


Figure 10: Cross section plot of spatial profiles.

bottom half of Figure 10 for the blue cable. These fiber-to-fiber differences are most likely due to the quality of the prism attached to the input end of the fiber and inherent stresses in each fiber. Spectrograph vignetting across the spatial dimension is apparent in both figures. A few broken fibers are apparent, and the concentricities file has the latest updates on any fibers taken out of service.

5.3 SEEING, POSITIONING, AND ATMOSPHERIC LOSSES

The fiber diameter for the red cable corresponds to 2 arc-seconds on the sky while the blue fibers subtend 3 arc-seconds. Based on the graphs in Bershady et al. (see below) seeing losses should be about 45% and 30% for the blue and red fibers respectively when the seeing FWHM is equal to the diameter of the fiber aperture. If the FWHM of the seeing profile is on the order of one-half of the fiber aperture, the seeing losses will be about 10%. These values of course assume no errors in the astrometry or centering of the fibers on the objects Throughput will degrade rapidly as the seeing increases beyond the size of the fiber.

Note that the WIYN does not have an atmospheric dispersion compensator for the Hydra field. Wide band spectral observations that extend into the blue may be compromised for observations made at airmasses of 1.5 or larger.

The following references provide estimates of fiber losses due to seeing, positional error, and atmospheric dispersion.

Donnelly, R.H., Brodie, J.P., Bixler, J.V., and Hailey, C.J. (1989), *P.A.S.P.***101**:1046.

Brodie, J.P., Lampton, M., and Bowyer, S. (1988), *A.J.***96**:2005.

Bershady, M. A.; Andersen, D. R.; Verheijen, M. A.; Westfall, K. B.; Crawford, S. M.; and Swaters, R. A. (2005), *ApJS***156**:311.

5.4 FIELD VIGNETTING

There should be no vignetting across the full 60 arc-minute field of view. Note, however, that there is some spectrograph vignetting referred to in Figure 10 on page 17.

5.5 MEASURED SYSTEM THROUGHPUT

As can be judged from the previous sections, the instrumental throughput is the product of many factors, some more well known than others. Data taken during the commissioning for the 2005 upgrade (figure 11) show flux levels tightly correlated with magnitude indicating excellent fiber positioning. A plot based on this data showing the flux incident upon the grating is given in Figure 12. This graph has the grating efficiency removed, takes the T2KA CCD QE into account, and includes the blue fiber throughput of 80% at 4400 Å. Estimates of exposure time can be extrapolated from Figure 12 by scaling to a given grating dispersion and blaze efficiency, fiber throughput, filter transmission, and object magnitude.

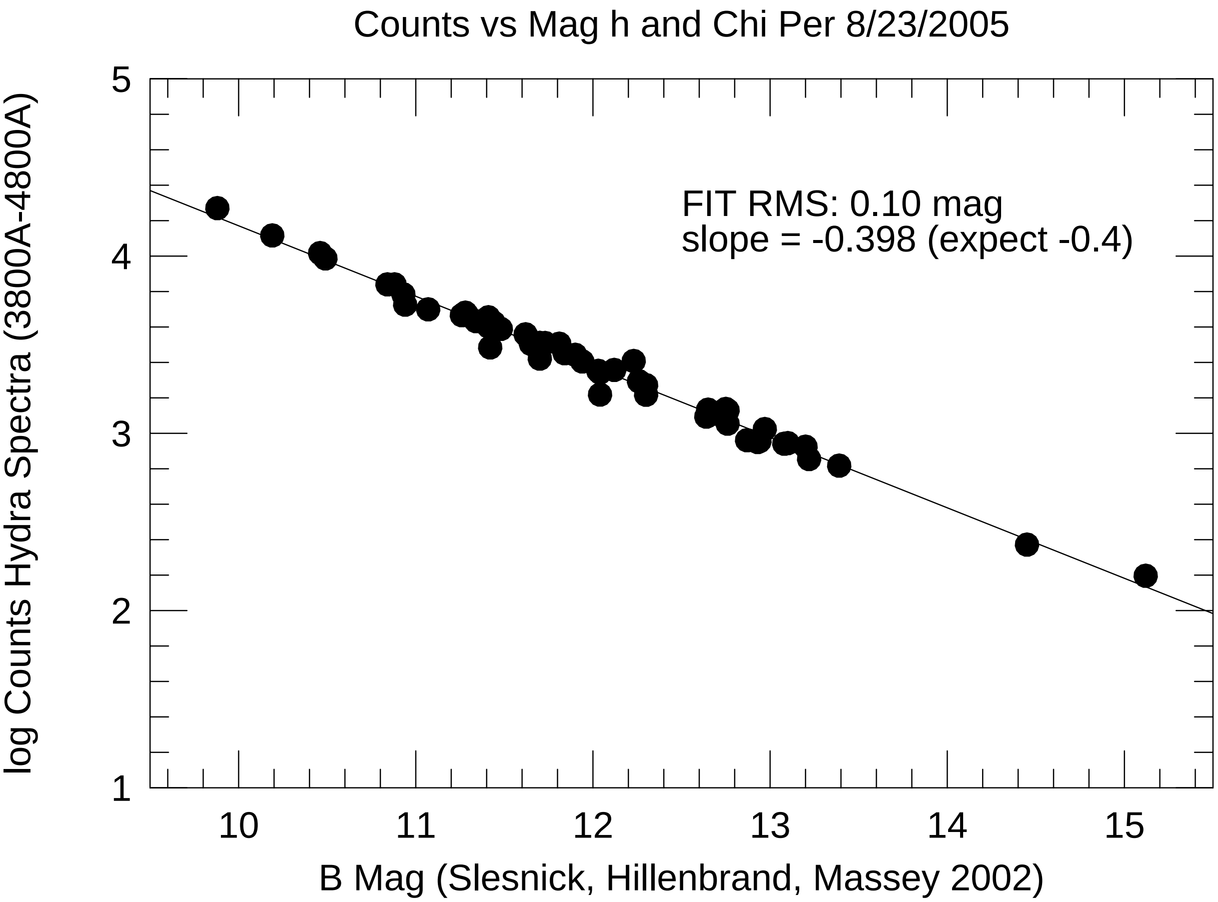


Figure 11: Flux counts with the blue fiber cable. 600@13.9 grating in second order, BG 39 filter, 10 minute exposure.

5.6 FLAT FIELD EXPOSURES

Typical single exposure times on the dome flats, using the high intensity lamps, will range from 10-30 seconds for low dispersion observations to 600-900 seconds for high dispersion observations with the echelle grating.

5.7 WAVELENGTH CALIBRATION EXPOSURES

The typical exposure times for the wavelength calibration lamps can range from 30 to 900 seconds depending on spectral region and choice of lamp (ThAr or CuAr).

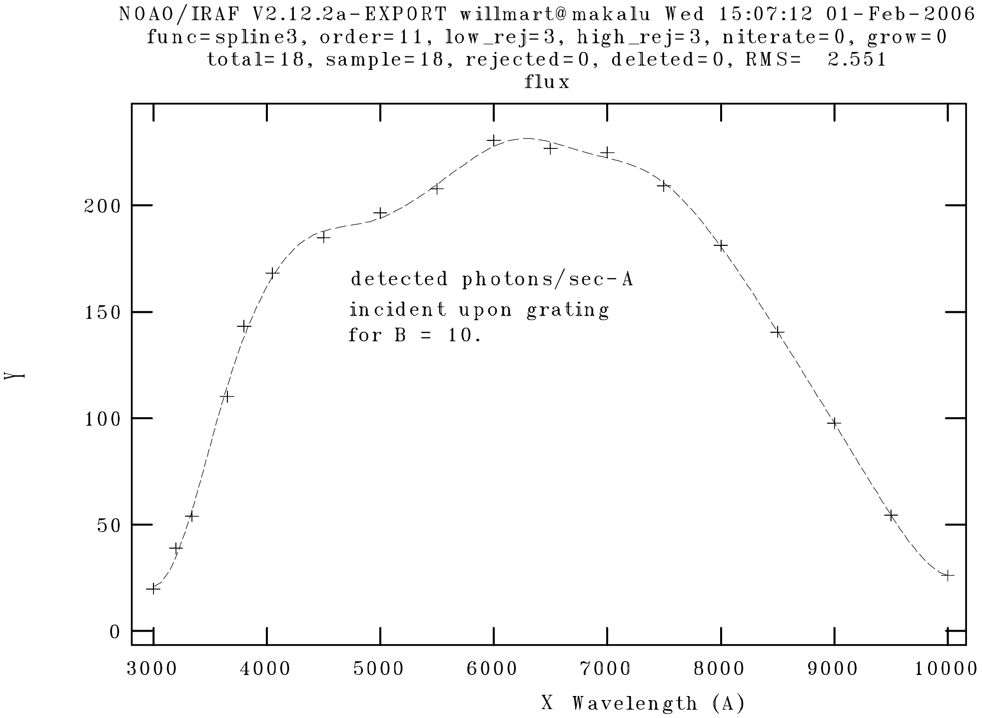


Figure 12: Flux counts incident on the grating for B = 10 with the blue fiber cable. CCD QE included.

5.8 SPECTROGRAPH SCATTERED LIGHT

There may be low level background light with some of the gratings. Figure 13 shows the typical pattern of scattered light for various fibers when using low dispersion gratings.

Measurements of spectra of stars through individual SparsePak fibers (see Bershady, et al., referenced in Section 5.3) have shown that the scattered light with the Bench camera is fit well with a Gaussian core and a power-law tail. This tail starts at about 0.04% and 1.0% at 5125 Å and 8650 Å respectively. Keep in mind that scattered light is additive according to the illumination level of each fiber. With all fibers equally illuminated (as in a flat field), the scattered light contamination may be as large as 5% in some regions. On the target fields, faint objects will suffer from contamination when brighter objects are observed at the same time. To minimize the effects of scattered light contamination on the faint spectra to less than 5%, the brightness range of the targets should not exceed about 4 to 5 magnitudes. A magnitude range of 3 has proven to be ideal under most circumstances.

User verification of the scattered light can be carried out by observing a bright star down one fiber or by taking a strong exposure of the quartz lamp in the Simultaneous Comparison Source.

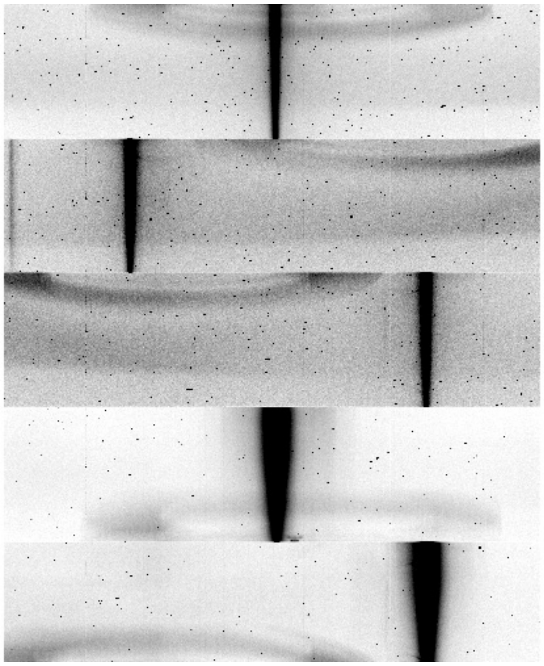


Figure 13: Scattered light patterns for various fibers.

There are fiducial gaps in both fiber cables for the monitoring the background contamination.

The **dohydra** routine in iraf contains the option of fitting the scattered light as part of its process (an equivalent to the iraf **apscatter** routine).

5.9 SAMPLE DATA

Figure 14 shows a sample data frame obtained with Hydra (while at the Mayall) on a cluster of galaxies.[2] The spectra cover from 5500-9500 Å. Roughly 70 galaxy spectra were detected in this 1.3 hour exposure. H-alpha emission can be seen in several of the spectra. An extracted spectrum (sky subtracted) is shown in Figure 15.

---

[2] Data courtesy of Oegerle, Barden, and Hill

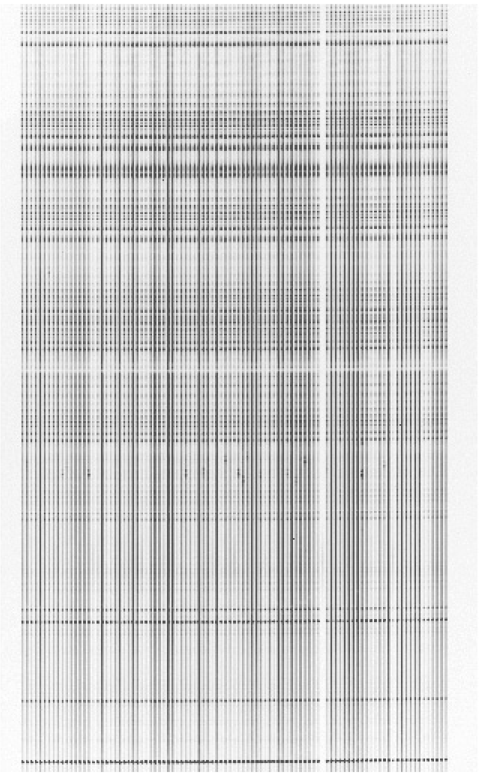


Figure 14: Sample data frame.

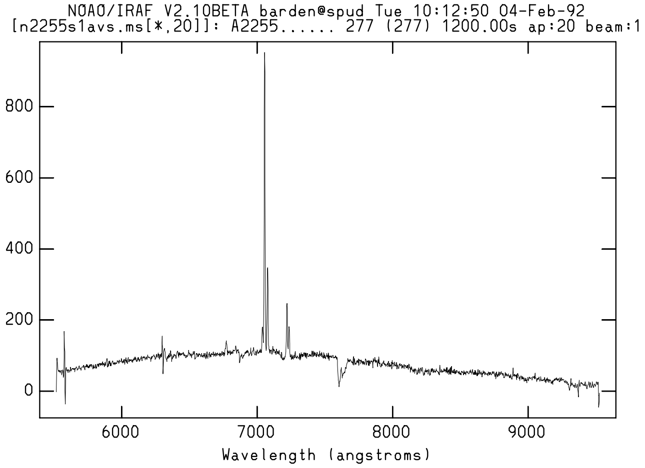


Figure 15: Sample spectrum.

Part III

OBSERVING RUN PREPARATION AND INSTRUMENT OPERATION

6 GENERAL OBSERVING RUN PREPARATIONS

The following guideline should be used in preparation of an observing run which uses Hydra. More details are given in Section 9. **NOTE: Preparation for a Hydra run should ideally start several weeks prior to the telescope time.**

- Obtain good astronomical coordinates for your target objects.

  Good astrometry means relative coordinates to better than 0.5 arc-seconds with all targets in the field derived from the same reference frame.

- While doing the astrometry, measure the positions of several non-program stars ($10<V<14$) for use as field orientation stars.

  The more stars measured, the less impact FOPS assignment will have on the science target assignments.

  At least 3 stars are required, preferably toward the edges of the field, and with good angular separation. We suggest that more than 3 Field Orientation Probes are actually assigned in order to provide redundancy in the correction of astrometric errors and field rotation.

  These stars should also span a relatively small magnitude range ($\leq$2 to 3 mags) so that each star can be seen on the TV at the same gain.

- Measure lots of sky positions if sky subtraction is important.

  Again, the more positions available to the assignment algorithm, the less impact the sky assignments will have on getting fibers to the target objects.

- Obtain copies of the manuals and available software (see below).

- Read the manuals!

- Run the assignment code on your fields.

  The assignment manual gives a description of how the assignments are made. Familiarization with this process prior to completion of the astrometry may allow better selection of sky and field orientation star positions.

- After running some fields through the assignment code, try out the Hydra simulator (current version only available for Linux OS) to view those assignments.
- Iterate on your assignments and produce the final assignment files for the observing run.
- Run the spectrograph setup program to determine the configuration desired.
- Fill out and submit the Observing Run Preparation Form.
- Contact any of the staff contacts for answers to unresolved questions.
- First time users are strongly encouraged to seek advice.
- During your run, make sure that the telescope operator is aware of any daytime tasks that you wish to perform (dome flats, sky observations, etc.). Tell the O.T. to inform the daytime staff of any such tasks so that any assistance is rendered while the daytime staff is available. This is especially important in the current era of reduced support.
- Provide us with useful criticism at the end of the run so that we can attempt to smooth out Hydra's operation.
- Hope for clear weather and have a productive run!

7 MANUALS AND SOFTWARE ACCESS

7.1 AVAILABLE MANUALS

There are 3 manuals required for Hydra use.

- WIYN Hydra and Bench Spectrograph Users Manual (this manual)

  > This manual describes the operation of the fiber positioner and the Bench Spectrograph.

- Hydra: A Program for Assigning Fibers

  > This manual describes the use of the assignment algorithm which determines which fibers are assigned to which target objects.

- An Observer's Guide to Taking CCD Data with ICE

  > This manual describes operation of the CCD.

7.2 AVAILABLE SOFTWARE

The following software is available for use at the observer's home institution as an aid in preparation for the observing run. We only support Linux versions of the sotware at the present time. Older versions of the Assignmemt program (whydra) will not produce output .hydra files compatible with current hardware limits.

- *setup.linux* – Spectrograph Configuration Software

  This program allows the user to model the spectrograph configuration for optimization of the spectral setup.

- *whydra* – Assignment Program

  The user will need this routine in order to properly assign the available fibers onto the target objects. This is the most important program for observing run preparation. The user should obtain this program several weeks prior to the observing run in order to have sufficient time for determining and optimizing the fiber assignments.

- *hydrasim* – Hydra Simulator

  A Hydra simulator is available that allows the user to view the assignments and practice operation of the instrument.

7.3 ACCESS TO MANUALS AND SOFTWARE

You can access current versions of the software and manuals through the ftp facility. Follow the steps listed below.

7.3.1 FTP Access of Hydra Manuals and Software

Copies of the assignment code and manuals are kept on the NOAO anonymous ftp area. To obtain copies of everything, do the following:

- **ftp ftp.noao.edu**
- login as **anonymous**
- give your email address for the password.
- ftp>**cd kpno/hydra**
- **See the README file for a description of the available Linux software versions.**

- **ftp>get README**
- ftp>**binary**
- ftp>**get hydra_tools.0.7.redhat.tgz (or.fedora.tgz)**
- ftp>**get hydrawiynmanual.ps**
- ftp>**get hydraassign.ps**
- ftp>**bye**

This will transfer the files:

- README [Discussion of Linux versions]
- WIYN Hydra and Bench Spectrograph Users Manual [this manual]
- hydrasim [the Hydra simulator program]
- whydra [the assignment program]
- setup.linux [the bench spectrograph configuration program]
- Various test fields and scripts for the Hydra simulator.
- A README file pertaining to the version of Linux acquired.

7.3.2 To Access and Print the ICE CCD Manual

In order to obtain a copy of the ICE (IRAF Control Environment) manual for operating the CCD, see the following URL: http://www.noao.edu/kpno/docs.html.

8 BENCH SPECTROGRAPH USE

8.1 DESIGNING A SPECTROGRAPH CONFIGURATION

As described previously, the camera-collimator angle on the Bench Spectrograph is variable for increased flexibility. Because of this extra free parameter, and because of the large number of gratings usable with the Bench Spectrograph, we provide a computer program, *setup.linux*, to facilitate the calculation of spectrograph parameters. A sample run of the program is shown below. (See also Table 6 on page 15 for some starting points.) It is recommended that new users contact a member of the support staff (Section 1 to verify the appropriatness of their setup to the science application.

8.1.1 Sample Run of Spectrograph Setup Program

Below is an example run of *setup*, using the 860@30.9 grating in the vicinity of the Mg triplet.

```
vanilla% setup


 STARTING WIYN/BENCH SETUP PROGRAM



 enter desired central wavelength in Angs....
5170
 enter camera selection (1=BSC or 2=Simmons)...
2



 the available WIYN gratings are:

  1 = 316@7.0    316 l/mm,  7450A first order
  2 = 400@4.2    400 l/mm,  5000A first order
  3 = 600@13.9   600 l/mm,  7700A first order
  4 = 860@30.9   860 l/mm, 11500A first order
  5 = 1200@28.7 1200 l/mm,  7700A first order
  6 = 316@63.4   316 l/mm,  63.4 degree echelle
  7 = other

 enter the number of the grating....
4



 SET-UP FOR THE WIYN/BENCH SPECTROGRAPH (ON-AXIS)

 COLLIMATOR                      DETECTOR (T2KC)
 diameter (mm):        150.      pixel number, size: 2048.   24.
 focal length (mm):  1023.6      rdnoise, gain:        4.3    1.7
 focal ratio:          6.00      overall size (mm):   49.2

 GRATING (860@30.9  )            CONFIGURATION
 lines per mm        860.00      camera-coll angle:   30.
 blaze angle:         30.90      use angle (alpha):   42.406
```

```
 selected order    2(  2.23)    beta:               12.406

 CAMERA (Simmons )              FIBER DIAM.  (Red Cable )
 focal length (mm):   381.0     in mm:               0.200
 focal ratio:          1.92     in arc-sec           2.00
 mono. beam diam. (mm): 198.

 SPECTRAL PARAMETERS
 lower lambda:        4802.     dispersion (A/mm):   14.903
 central lambda:      5170.     dispersion (A/pix):   0.358
 upper lambda:        5533.     resolving power:       6163.

 DEMAGNIFICATION                SLIT IMAGE (in mm):    0.056
 spectral:             3.55     SLIT IMAGE (in pix):   2.345
 spatial:              2.69     SLIT IMAGE (in ang):    0.84

 ESTIMATED OBSERVING AND PERFORMANCE PARAMETERS
 magnitude:          16.00      summed e-/pix:          260.
 exp. time (sec):      600.     summed adu/pix:         153.
 seeing (arc-sec):      1.0     s/n per summed pix:      14.


 0 = save to wiyn.setup   5 = exposure time
 1 = quit (no save)       6 = fiber diam. (mm)
 2 = wavelength           7 = grating
 3 = magnitude            8 = camera/config
 4 = seeing               9 = detector

  enter 0-9 to change the parameter listed above:
0

 0 = save to wiyn.setup   5 = exposure time
 1 = quit (no save)       6 = fiber diam. (mm)
 2 = wavelength           7 = grating
 3 = magnitude            8 = camera/config
 4 = seeing               9 = detector

  enter 0-9 to change the parameter listed above:
1
vanilla%
```

8.2 BENCH SPECTROGRAPH SOFTWARE CONTROL

The Bench Spectrograph is controlled via a graphical user interface on Vanilla. This GUI is typically started in a separate desk-top space by clicking on **bench GUI** in the background window menu. This starts up the Bench Spectrograph status window (figure 16) from which the Bench Spectrograph Setup window (figure 17) can be started. Besides showing the present spectrograph status, the primary window allows control of the Simultaneous Comparison Sources (SCS) and the stage that carries the fiber viewing TV and fiber back-illuminator (FBI).

The Bench Spectrograph Setup window (BSS) allows control and displays the status of all the important spectrograph parameters. While the correct filters must be manually loaded, they can be inserted or removed with the BSS GUI. Be sure to select the proper filter in the pull-down button next to the filter designation (A,B,C,D) in order for the optimum collimator-fiber focus to be set. The camera focus will be initially set by your instrument support person. Optimal focus values may vary from run to run due to the dewar-camera spacing being slightly different after subsequent camera changes. The grating position may be set using any of the three quantities, Ångstroms, degrees, or encoder value. Unless the setup has been used previously, Ångstroms is usually the best choice. The fiber cable must match that actually deployed by Hydra if the resolution values are to be correct. Finally, typing in the camera-collimator angle, dewar azimuth angle, and grating-camera distance will allow the proper calculation of wavelength and resolution. This may be a two-step process as the grating-camera distance will not be generally known until it is calculated from the other parameters. The dewar azimuth angle for the Bench (red) camera is also set by the instrument person as part of the focus optimizaton.

After the desired values are entered, the Apply button is pushed, and the colors of the numbers indicate the instantaneous status. The key for the color interpretation is given on the upper right region of the GUI.

There is also a **Configuration** button useful for storing configurations if several might be used, or the current setup might be saved for future use.

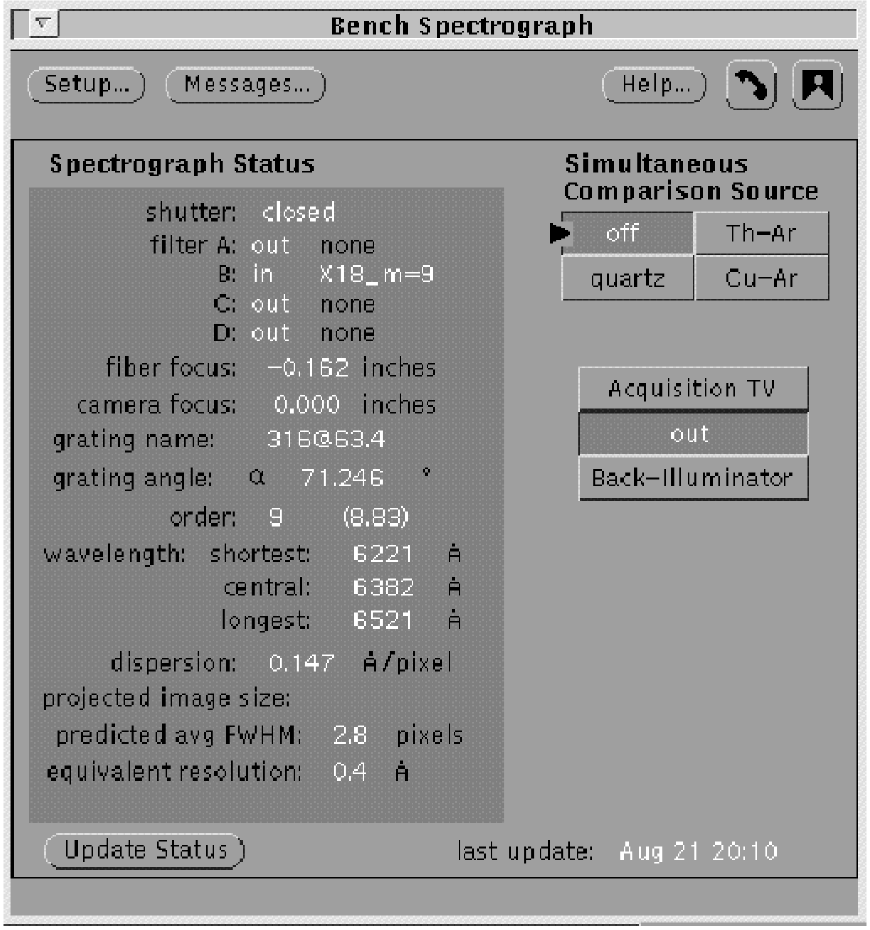
9 HYDRA INSTRUMENT USE

9.1 SUGGESTIONS FOR CREATING THE TARGET FIELDS

The following hints should aid in defining the target fields.

9.1.1 Target Selection

- Minimum fiber-to-fiber placement distance is 37 arc-seconds. Note that button to tube interactions will also govern how close together the fibers can be assigned and that each fiber can only reach to field center and deflect to 4 degrees on either side.



Spectrograph Status

shutter: closed
filter A: out none
B: in X18_m=9
C: out none
D: out none
fiber focus: -0.162 inches
camera focus: 0.000 inches
grating name: 316@63.4
grating angle: α 71.246 °
order: 9 (8.83)
wavelength: shortest: 6221 Å
central: 6382 Å
longest: 6521 Å
dispersion: 0.147 Å/pixel
projected image size:
predicted avg FWHM: 2.8 pixels
equivalent resolution: 0.4 Å

last update: Aug 21 20:10

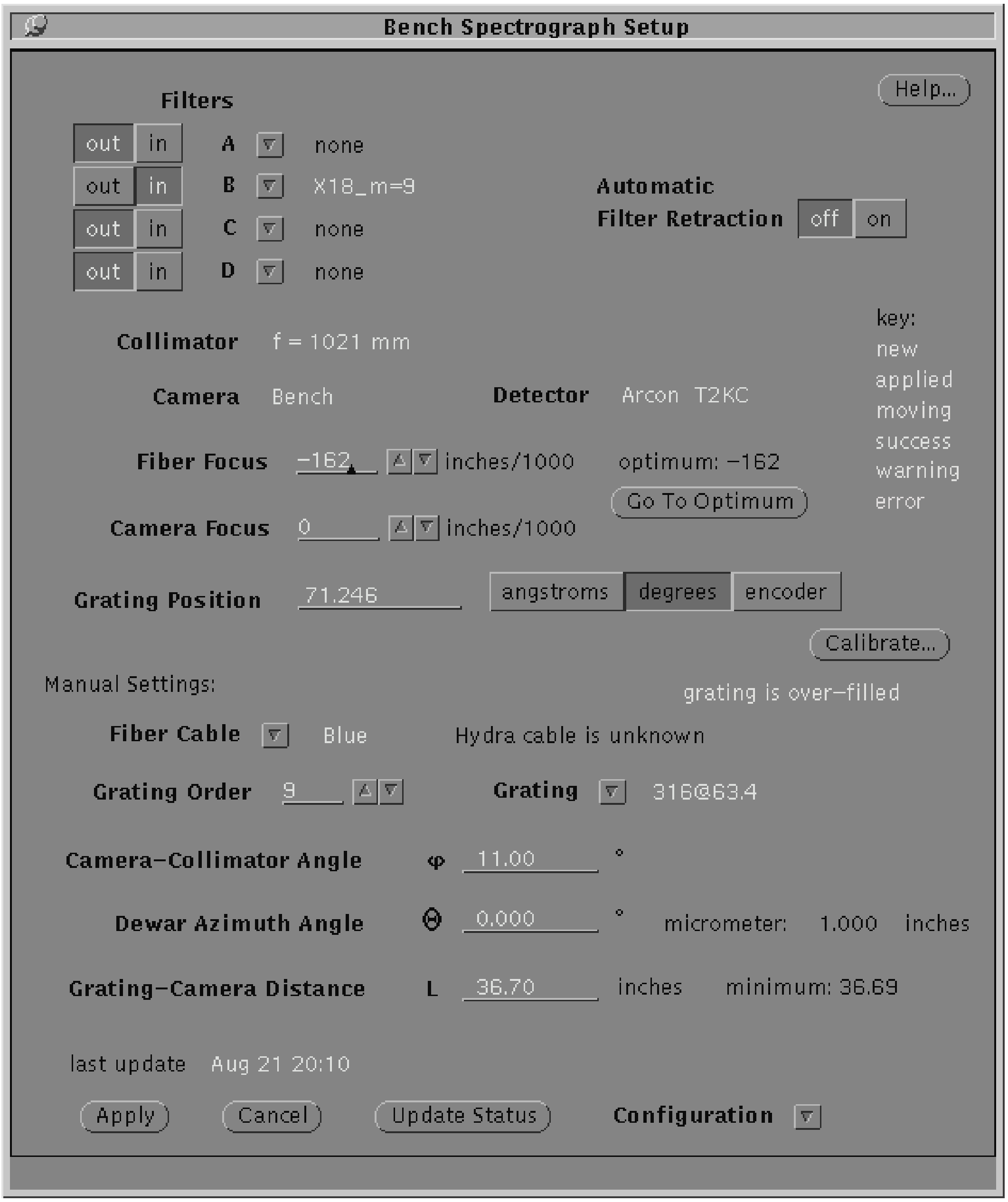
Figure 16: Sample view of the primary Bench Spectrograph GUI window.

- Keep the magnitudes of the targets in a given assignment to within a range of 3 to 4. Scattered light may compromise the spectra of the faint objects if the range is much larger than this.

9.1.2 Sky Positions

- Select many (many more than will get assigned) sky positions so that fibers can get assigned to the desired number of them with minimal impact on the assignment of target objects.

- In cases where sky is important, but not dominating the signal, on the order of a dozen fibers should probably be assigned to observe the sky. It is ideal to measure blank sky positions in all cases, but random sky positions are probably OK in many situations. Try generating lists of a few hundred random coordinates located on the circumference



Bench Spectrograph Setup

Filters

A none

B X18_m=9

C none

D none

Automatic Filter Retraction off on

key:
new
applied
moving
success
warning
error

Collimator f = 1021 mm

Camera Bench

Detector Arcon T2KC

Fiber Focus -162 inches/1000 optimum: -162

Camera Focus 0 inches/1000

Grating Position 71.246 angstroms degrees encoder

grating is over-filled

Manual Settings:

Fiber Cable Blue

Hydra cable is unknown

Grating Order 9

Grating 316@63.4

Camera-Collimator Angle φ 11.00 °

Dewar Azimuth Angle Θ 0.000 ° micrometer: 1.000 inches

Grating-Camera Distance L 36.70 inches minimum: 36.69

last update Aug 21 20:10

Figure 17: Sample view of the Setup Window for the Bench Spectrograph GUI.

of circles of varying radii (5 to 30 arc-minutes) centered on the field. The biggest danger of the random sky positions is the risk that a sky fiber will be placed on or near field stars, particularly in crowded fields.

- For objects that are fainter than the sky, more care is required to hand select blank regions of sky. Again, select many positions. Probably half of the fibers should be dedicated to sky. Designing your field to allow telescope beam switching may be beneficial for the best sky subtraction (unfortunately, we don't have any algorithms for generating beam switching configurations).

9.1.3 Field Orientation Star Selection

- At least 3 Field Orientation Probes (FOPs) must be assigned in order to "lock" the telescope onto the target field. We suggest, however, that more than 3 probes be assigned (with at least 1 near field center and two near opposite edges of the field) to provide redundancy and to serve as a check on astrometric "goodness" and other possible fiber placement errors.

- Since assignment to a field orientation star can impact the assignment of fibers onto neighboring target objects, select several times more potential field orientation stars than are needed and let the assignment routine find the ones that have the smallest impact on neighboring fiber assignments.

- The stars selected for use by the FOPs should fall in the magnitude range 10<V<14. (If there are clouds and/or the seeing is larger than 1 arc-second, stars fainter than 14th may not be visible with the FOPs TV camera.)

- If possible, keep the range in magnitude of your FOPs sample in each field to 2 magnitudes or less so that the intensity of each star falls within the dynamic range of the FOPs TV camera. Including the FOPs star magnitudes in the configuration file may also be useful later when setting up the field at the telescope.

- Make absolutely certain that the stars selected for use by the FOPs have good astrometric solutions and were used (or measured) within the same solution as the target objects (ie. same zero point reference). Be careful of possible proper motion problems (ie. don't use old plates or catalogs). You must account for proper motion effects as our astrometry routines don't compensate for proper motion. Reject any stars with large uncertainties in their coordinates.

REMEMBER THAT THESE STARS ARE BEING USED TO LOCK AND GUIDE THE TELESCOPE ON YOUR TARGET FIELD!

9.2 FIBER CABLE SELECTION

The two science cables available differ in spectral response and in aperture size. Guidelines for selecting the appropriate cable can be derived from the following discussion of each cable's advantage over the other.

9.2.1 Advantages of the Red Cable

The red cable has good spectral transmission redward of 4000 Å out to nearly 2 μm (see Figure 9).

The aperture size of 2 arc-seconds was selected for good sky suppression of the OH emission lines that dominate the sky brightness redward of about 6000 Å. In addition, since atmospheric dispersion is not as significant towards the red end of the optical spectrum, the 2 arc-second diameter should not present a significant loss of light due to this effect.

9.2.2 Advantages of the Blue Cable

The blue cable has good spectral response blueward of 7000 Å down to the atmospheric cutoff (see Figure 9).

A 3 arc-second aperture was selected to provide some compensation for atmospheric dispersion while not significantly impacting on the level of the sky contamination.

9.3 CREATING THE TARGET ASSIGNMENTS

Once you have your astrometry files in hand with sufficient sky and FOPs locations, and have selected which fiber cable to use, you can proceed with the target field assignments.

Please refer to the Assignment Manual (Hydra: A Program for Assigning Fibers) for details on making the target assignments.

9.4 SUBMITTING THE TARGET ASSIGNMENTS

Observers can bring either a CD or DAT tar tape of their configuration files. The tapes will serve as a backup in case there are difficulties in establishing remote connection to your home computer for ftp access to those files.

When you arrive for your observing run, you will then copy your configuration files into the hydra/fields/ directory on Oatmeal. This is where the hydra code will search for those files when you are ready to configure the instrument.

9.5 LOGGING ONTO THE COMPUTERS

The software for configuring and controlling Hydra resides on the Linux machine Oatmeal which is accessed via the Linux machine Almond. The CCD control and data acquisition computer is Vanilla. Terminals for these machines are side-by-side in the WIYN control room.

9.5.1 Logging onto the Console Terminal for Vanilla

The login name (hydra) and password are located on the Vanilla monitor. After the ICE software has loaded, the bench spectrograph control and status GUI can be brought up in another desktop from the background menu. Further details of the ICE software, which runs under IRAF, can be found in the ICE manual.

9.5.2 Logging Onto the Console Terminal for Oatmeal

On Almond, visiting astronomers should login under 'hydra' with a password the same as the mountainwide passwords. Once logged into Almond, start a terminal window and type:

- **ssh hydra@oatmeal** (same password).
- **cd hydra**

9.5.3 Starting up the Instrument Software

It is important to insure that the Hydra rotator is at zero degrees before starting up the instrument control software. Check with your startup person or the telescope operator if in doubt about how to check this important item.

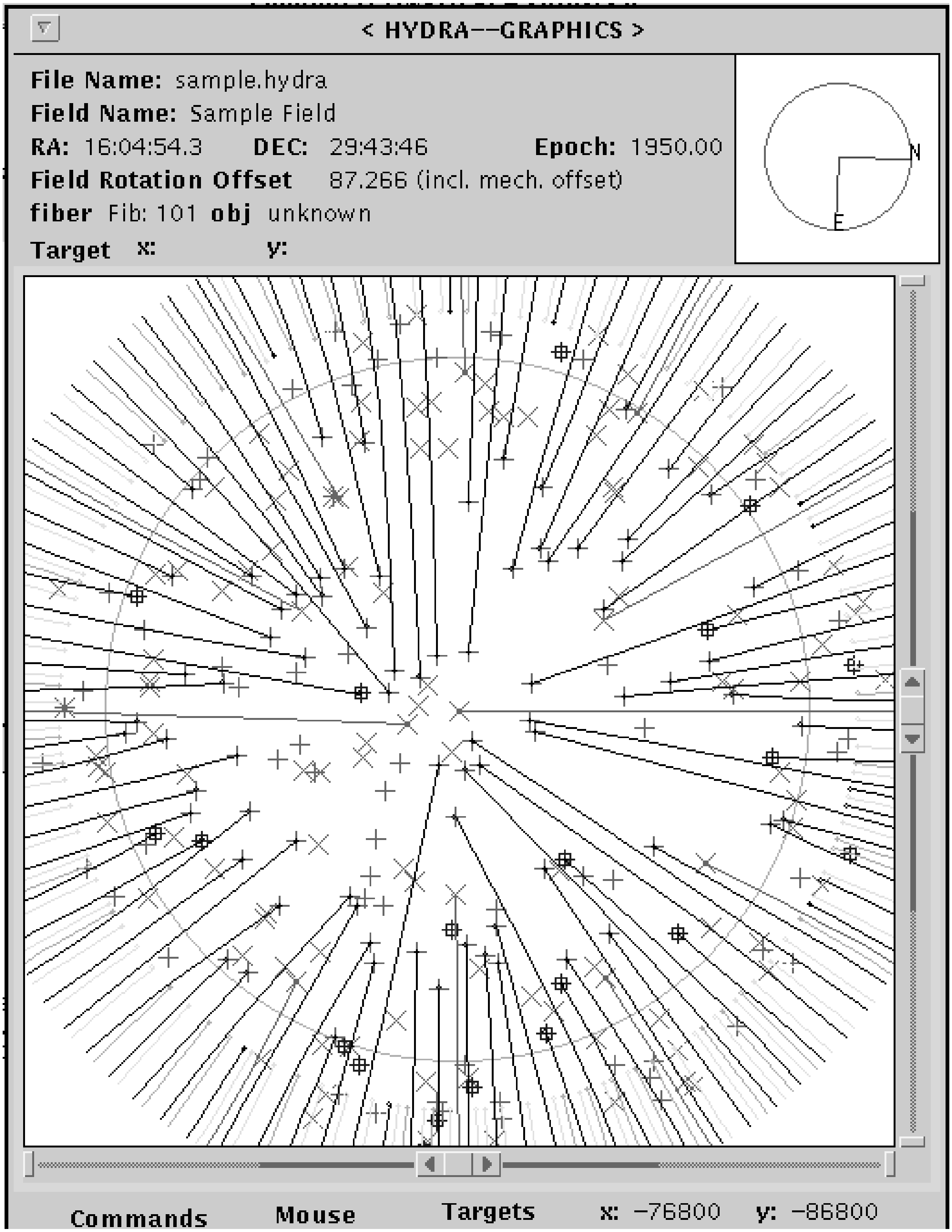
After logging into Oatmeal, type

hydrawiyn

to start up the instrument program. Note that the simulator program is now on the Almond. See Section 9.5.5 for instructions on use.

Three windows will appear.

- The HYDRA-COMMANDS window where you type in the various commands to operate the instrument.
- The HYDRA-GRAPHICS window which displays a plot of the Hydra configuration and provides some rudimentary GUI capability.
- The System Status window which displays the status of the gripper LED's, the comparison lamps, the plate, the calibration screen, the gripper location, and the instrument rotator.



File Name: sample.hydra

Field Name: Sample Field

RA: 16:04:54.3 **DEC:** 29:43:46 **Epoch:** 1950.00

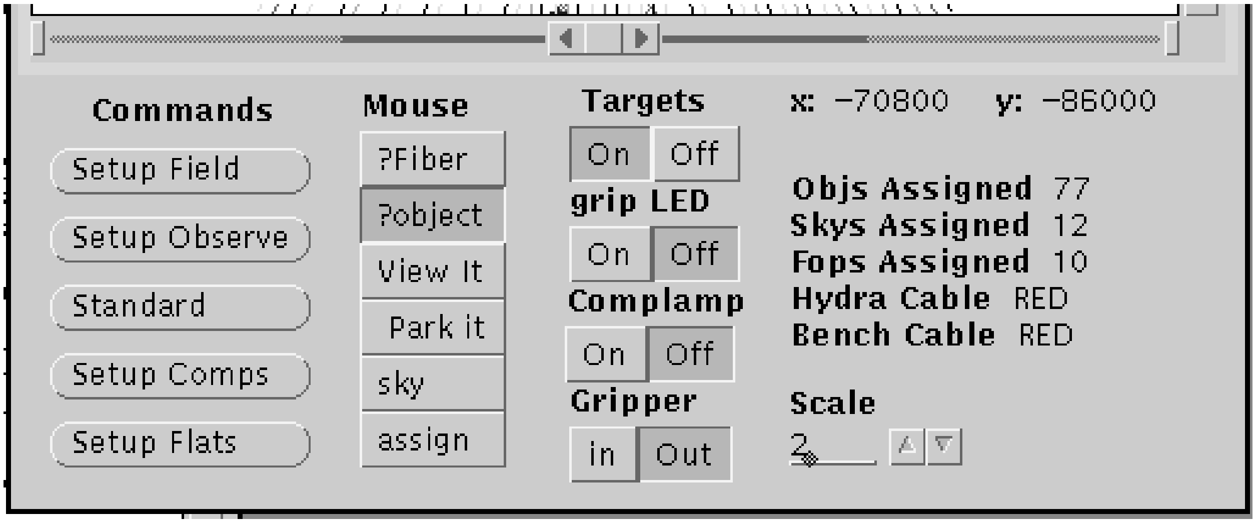
Field Rotation Offset 87.266 (incl. mech. offset)

fiber Fib: 101 **obj** unknown

Target x: y:

x: −76800 y: −86800

Figure 18: Sample view of the Hydra graphics window (top portion).



x: -70800 y: -86000

Objs Assigned 77
Skys Assigned 12
Fops Assigned 10
Hydra Cable RED
Bench Cable RED

Scale 2

Figure 19: View of the GUI buttons located in the lower portion of the Hydra graphics window.

An example of the graphics window is shown in figure 18. The GUI buttons located in the lower portion of the graphics window are shown in figure 19.

Press the **setup field** button to do a field configuration. The **setup observe** button will ready the instrument for observations. The **standard** button executes the **standard** command for observing single stars (see Section 9.11.3) . To take wavelength calibrations, click on the **setup comps** button and use the **setup flats** button when getting ready for dome flats.

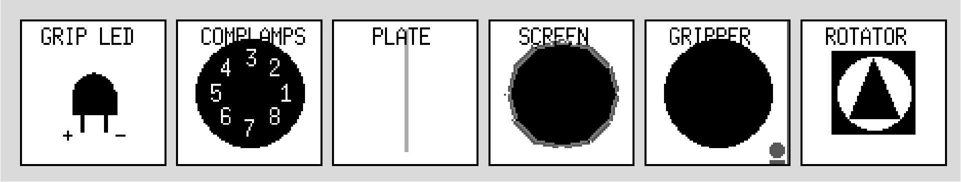
The System Status window will reveal important instrumental status:

- Gripper LED's on or off.
- Comparison lamps on or off and which, if any, is non-functional.
- Focal Plate warped or flat.
- Calibration Screen in or out.
- Gripper location within the field after each move.
- Instrument rotator position (only if rotator has been initialized).

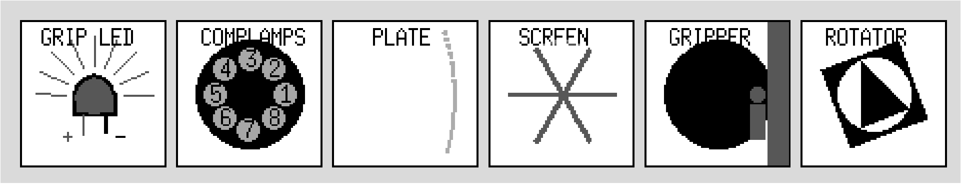
Figure 20 displays examples of the status window.

9.5.4 Initializing the Instrument

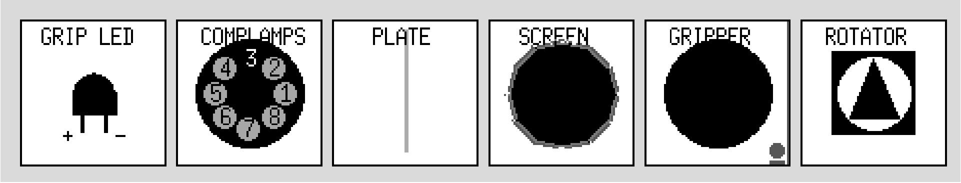
In the COMMANDS window there will be a series of initializations and various messages. The bench cable will be compared with the Hydra cable. These may not initially agree



Gripper LED's are off, comparison lamps are off, the plate is flat, the screen is out, the gripper is in the gripout position, and the rotator is at zero degrees.



Gripper LED's are on, comparison lamps are on, the plate is warped, the screen is in, the gripper is in the field, and the rotator is not at zero degrees.



Here comparison lamp #3 is not functioning.

Figure 20: System Status Display Examples.

depending on whether or not the bench cable has been changed since a field has been configured. The program will list the temperature of the instrument. This value should be checked for validity to an accuracy of about 5-10 degrees F. This is used to compensate for thermal expansion of the stage encoders. After the power has been established, the program will halt until the

```
coldstart
```

command has been executed. This command initializes the motors; finds the home positions for the X, Y, and Z axes; and resets the encoder counters to correspond to the center of the focal plate. It takes approximately one minute for a coldstart to complete. If the gripper camera is turned on along with the gripper LED's, you should be able to see the motion of the X and Y stages as they home.

NOTE: If there are problems, please contact trained personnel (your OT, mountain electronics, or your startup person).

The instrument is now ready to move fibers. If a fiber reconfiguration will not be done shortly, please stow the gripper with the **gripper out** button, or type **gripout** in the commands window.

9.5.5 THE HYDRA SIMULATOR

The Hydra simulator is available on the computor Almond in the console room. After logging in as user hydra, open a terminal window and type

```
cd hydra_simulator

hydrasim
```

If a version of the simulator is already running, the user will be queried whether or not to wipe out the directory and start again. Restarting will delete any configuration files already in the hydra_simulator directory.

9.6 CONFIGURING FIELDS

9.6.1 The Setup Field Command

In order to simplify the instrumental configuration, we have created user commands which step the astronomer through the configuration process.

The first of these configures the fibers. To execute, either type

```
setup field
```

or click on the **setup field** button in the graphics display. You will be prompted to give the full name of the configuration file (.hydra file).

If the file is not designed for the currently selected fiber cable, a warning message will be given and you will have the opportunity to switch to the cable that your field is designed for. NOTE: This only changes a software flag of cable type. You must still verify that the Bench Spectrograph has the appropriate cable installed. (The cable installed on the Bench Spectrograph should be displayed in the HYDRA-GRAPHICS display.)

Next you will be given the opportunity to modify how long you plan to observe the field in this configuration and what the anticipated midpoint sidereal time will be. Both of these values will be used to fine tune the atmospheric refraction component of the astrometry. It is good practice to make a note of these values in case a problem occurs during fiber configuration. Re-running the setup with different values may cause the positioner to adjust the position of every fiber instead of picking up where it had left off.

After this, you have the option to either park all unused fibers or leave unused fibers where they are as long as they don't interfere with fiber placement. Leaving them where they are allows such fibers to be flagged as random sky positions and also decreases the configuration overhead since the positioner doesn't have to spend time moving them.

The program will then check certain aspects of the instrument status (plate flat, comps off, rotator at zero degrees), compute the new astrometry, and proceed to move the fibers.

When all fibers have been positioned, the .iraf file will be generated and fiber information will be passed to the CCD computer for inclusion in the data headers.

NOTE: The instrument is not yet ready to take the observations. You MUST execute the **setup observe** command described in section 9.6.3 when asked to do so by the telescope operator.

9.6.2 Sample of Setup Field Command

```
Fiborg > setup field

 Starting rotator towards Zero

Enter name of  hydra file.
> m35_b1_blue_mar06.hydra

Current file:    m35_b1_blue_mar06.hydra
Field name:      M35
Equinox(IN):     2000.00
Current epoch:   2006.20
Mid-exposure ST: 7.00
Exp. Time (hr):  2.00
Spectrograph WL: 5130.00
```

```
 ATTENTION:  bench is is not configured for this fiber cable!
               ( You might want to change that...)


Obtaining instrument tempertaure from sensor...
T =   1.70 C     *OK*


How long do you plan to observe with this configuration? [hours]
(2.00)> 2.0

Enter the anticipated sidereal time at midpoint.
(  7:00:00.0)>

Park unused fibers [ Yes or No ]?
(Yes)> no
Astrometry Finished...
Making sure comparison sources are off.
Turning on gripper. LEDs
Moving screen in.
Flatting plate.
WAITING: --for rotator to go to zero.
WARNING:  Instrument Rotator has not been initialized.
Please verify rotator position visually...
Is the rotator at zero [ Yes or No ]?
(Yes)>
TRANSITION WARNING:  Optimizer could not obtain system status
generating interaction table.
Transition Finished...
moving button   5 to  73396,   8524
moving button   2 to  31921,   6552
moving button   8 to  73625,  13533
moving button  11 to  55444,  12451
moving button  17 to  70349,  27919
moving button  20 to  18395,   5982
.
.
.
moving button 287 to  74189,   -468
moving button 284 to   3802,   3742
moving button 281 to   7519,   1600
```

```
moving button 278 to   8712,   -837
moving button 266 to   1015,   -533
Writing Aperture Identification file into:
/home/hydra/hydra/fields/m35_b1_blue_mar06.hydra.iraf.1
Compressing and purging archive CurrentLocations file. Please wait.
Warping the focal plane plate.
--please wait...

Fiborg >
```

9.6.3 The Setup Observe Command

After the telescope operator has pointed the telescope to the field center, he or she will ask the observer to type

setup observe

or click on the appropriately labeled button in the graphics display.

Note that this command is only valid after a field has been configured with the **setup field** command.

The program will make sure that the plate is warped, the comp lamps are off, and that the screen is out of the way. It will then ask if you are ready to move the instrument rotator into position (check with operator). After that, the gripper will move to field center for initial field acquisition. You will then be allowed to view fibers or objects with the gripper TV. (Use the menu driven view process as the graphics view control is not interlaced with the setup observe command.)

FOPs stars can now be viewed at the request of the operator as necessary to adjust pointing and the rotator offset angle.

When finished viewing and aligning on the field, the gripper will be stowed and the stage motors disabled to minimize vibration and heat generation during the observations.

The operator will then start up the guider which will center the FOPs stars and optimize the rotational alignment. A focus sequence for the FOPs guider will also usually be done now.

9.6.4 Sample of Setup Observe Command

```
Fiborg > setup observe
Writing Aperture Identification file into:
/home/hydra/hydra/fields/m67_f1_blue_mar06.hydra.iraf.2
Making sure comparison sources are off.
```

```
ATTENTION:  Gripper was disabled--re-enabling...

BRINGING IN GRIPPER.  (please wait).
 Making sure the focal plane plate is warped.
--please wait...
Do you wish to move the rotator into position [ Yes or No ]?
(Yes)>
Positioning the rotator.
Moving to field center.
Insuring LEDs are off.
Making sure screen is out of the way.
Do you wish to view any fibers [ Yes or No ]?
(No)> yes

To view buttons or objects, enter:

        'o id# <return>' for an object
        'f id# <return>' for a  fiber
        's id# <return>' for a  slit position
        '  c   <return>' for the field center
        '  b   <return>' for a benign gripper position
        '  ?   <return>' for this menu

Hitting <return> on an empty line will exit the loop

view> f 120
viewing button #120
This fiber, #120, is Extended
Viewing obj. #86 " 3054 10.3-1.04     "  fiber: 120 Probe F
view> f 240
viewing button #240
This fiber, #240, is Extended
Viewing obj. #88 " 3055 11.5-1.04 1741"  fiber: 240 Probe K
view> c
view> f 240
viewing button #240
This fiber, #240, is Extended
Viewing obj. #88 " 3055 11.5-1.04 1741"  fiber: 240 Probe K
view> f 96
viewing button #96
This fiber, #96, is Extended
```

```
Viewing obj. #56 " 2033 11.6 0.74     "  fiber: 96 Probe E
view> b
Parking...
Done.
WARNING:  X,Y motion is now *disabled*!
Use "gripin" to re-enable.
view>
Making sure Gripper is out of the way.
STOWING GRIPPER.  (please wait).
 Gripper is already parked

YOU ARE NOW READY TO BEGIN OBSERVATIONS!

Fiborg >
```

9.7 WAVELENGTH CALIBRATIONS

Wavelength calibrations are made by moving a screen over the fibers and illuminating the screen with a bank of hollow cathode tubes. Either ThAr or CuAr sources are available. To switch sources, cables located on the fork of the telescope underneath the instrument must be swapped after lamp power is off. On-line atlases of ThAr and CuAr spectra are available at http://www.noao.edu/kpno/specatlas/index.html.

9.7.1 The Setup Comps Command

One can prepare for wavelength calibrations by executing the command

setup comps

which, again, can either be typed or executed by clicking the appropriate button in the graphics display.

The routine will check to see if the TV's are turned off (to save them from exposure to the bright light). After that, the lamps will be turned on and the screen will be moved in. The gripper will again be moved out of the field and deactivated. Note that the **setup comps** command warps the focal plane plate. If that is not desired, execute the command **plate flat** .

Note that the screen is not light-tight and will not completely block light from bright stars in the field or dome lights if the mirror covers are open.

9.7.2 Sample of Setup Comps Command

```
Fiborg > setup comps
Bringing in calibration screen.
Making sure gripper LED are off.
Checking Gripper and FOPS camera(s)
GRIPPER TV IS ON
Please have OT turn down high voltage on camera(s)

Are the cameras off? [ Yes, No, Quit ]?
(No)> y
Turning on comparison lamps.
Making sure gripper is out of the way.
STOWING GRIPPER (please wait).
Making sure the focal plane is warped.
--please wait...

YOU MAY NOW BEGIN TAKING COMPS.

Please use "setup observe " or "complamp off" when finished.
Fiborg >
```

9.8 FLAT FIELD CALIBRATIONS

There is a White Spot on the side of the WIYN dome for taking flat fields. Dome flats are best taken for each configuration of the fibers either just prior to the target observations, or soon afterwards. However, if many fields are anticipated during the night, considerable time savings can be had by taking dome flats before dark in either the red or blue circle configurations. Then perhaps one flat per field might be obtained during the night to discern any differences in the fiber-to-fiber throughputs. Both the fiber-to-fiber throughput differences and CCD pixel-to-pixel sensitivity variations can be corrected for using the white spot flat fields.

9.8.1 The Setup Flats Command

To set the instrument up for taking dome flats, either type the command

setup flats

or click the button in the graphics display.

This routine only makes sure that the instrument is in a state for flat field observation. The operator will have the responsibility of pointing the telescope at the white spot and for turning on the flat field lamps.

We have been using the bright lamps on their highest setting (3200) for all spectrograph configurations except some low dispersion configurations. A test exposure is recommended before starting any sequence of exposures.

9.8.2 Sample of Setup Flats Command

```
Fiborg > setup flats
flats
Making sure gripper LED are off.
Please have OT turn down high voltage on camera(s)
Are the cameras off[i Yes, No, Quit ]?
(No)> y
Making sure comparison sources are off.
Making sure screen is out of the way.
Making sure gripper is out of the way.
STOWING GRIPPER (please wait).
Gripper is already parked.
Making sure the focal plane is warped.
--please wait...
ATTENTION:  Please have OT set to white spot and turn on lamps.

Is telescope in position with lamps on? [ Yes or No ]?
(No)> y
Fiborg >
```

9.9 TELESCOPE FOCUS

The telescope operator will generally do a wavefront optimization and Delivered Image Quality (DIQ) measurement early in the night to check and set the telescope optics. However, this does not establish the proper focus for the Hydra instrument. The telescope focus for Hydra must be done while on the target field or while viewing a star with the FOPs.

Telescope focus is best done while observing stars with the FOPs, most likely after acquiring the first target field. The focus can be achieved either manually by maximizing the signal into the central fiber of a FOPs probe, or by running an autofocus routine (an operator task).

In conditions of very poor seeing (> 2 to 3 arc-seconds), the telescope can be focused with the Hydra Gripper TV on a star about half way between the center and edge of the field. However, do not rely on this as a good focus when the seeing is less than 2 arc-seconds.

9.10 AUTOGUIDING

The FOPs information is automatically transferred to the guider software (in most cases). This is an OT operation and should be fairly straightforward with good communication between the OT and the observer.

A minimum of 3 FOPs must be active in order to guide the three axes of the telescope (azimuth, altitude, and field rotation). Again, we remind you that we suggest more than 3 active FOPs in order to compensate for astrometric and fiber positioning errors. Ideally, the assigned FOPs will be scattered throughout the field and not concentrated in only a portion of the field.

Figure 21 displays the orientation of the FOPs as viewed on the real time TV display. The FOPs are named A through L and are also referred to by their fiber number (location around the focal plate).

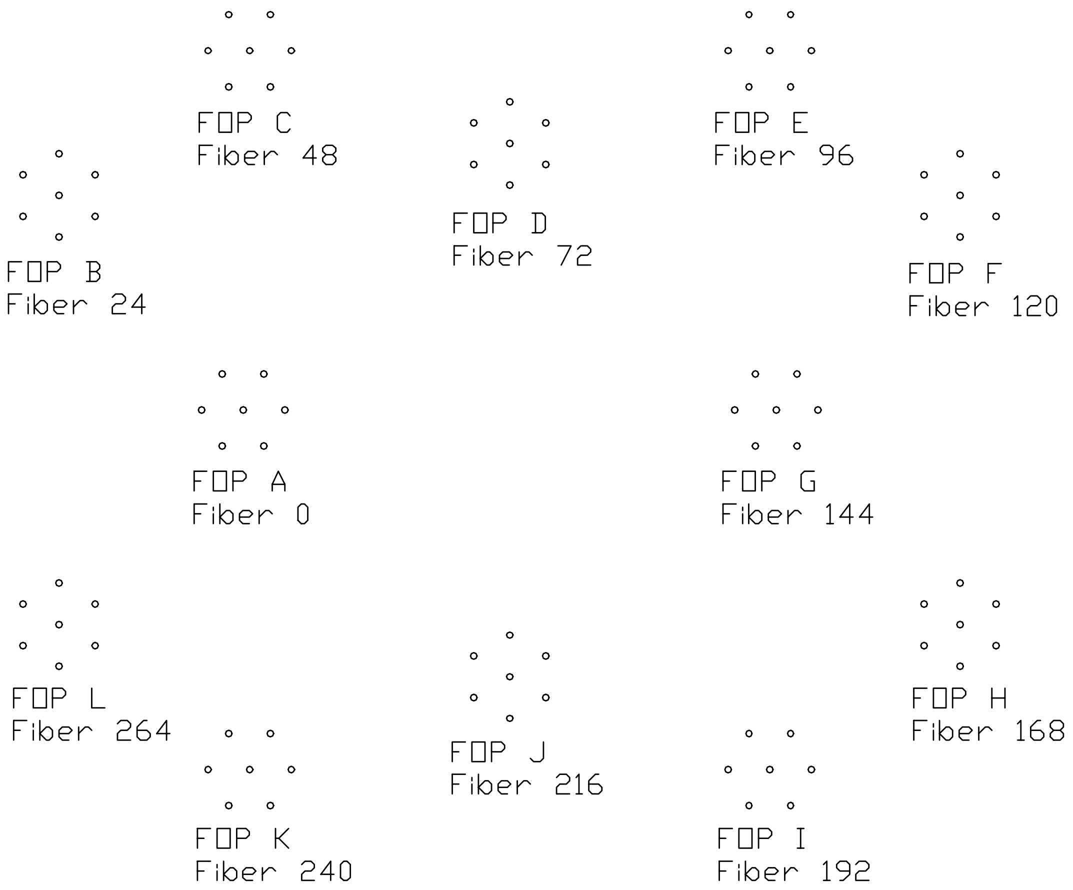


Figure 21: The orientation of the FOPs on the real time video.

The guider display reorients each FOP into the orientation presented in Figure 22. When guiding, a histogram of the signal picked up in each guide fiber is displayed to the left of

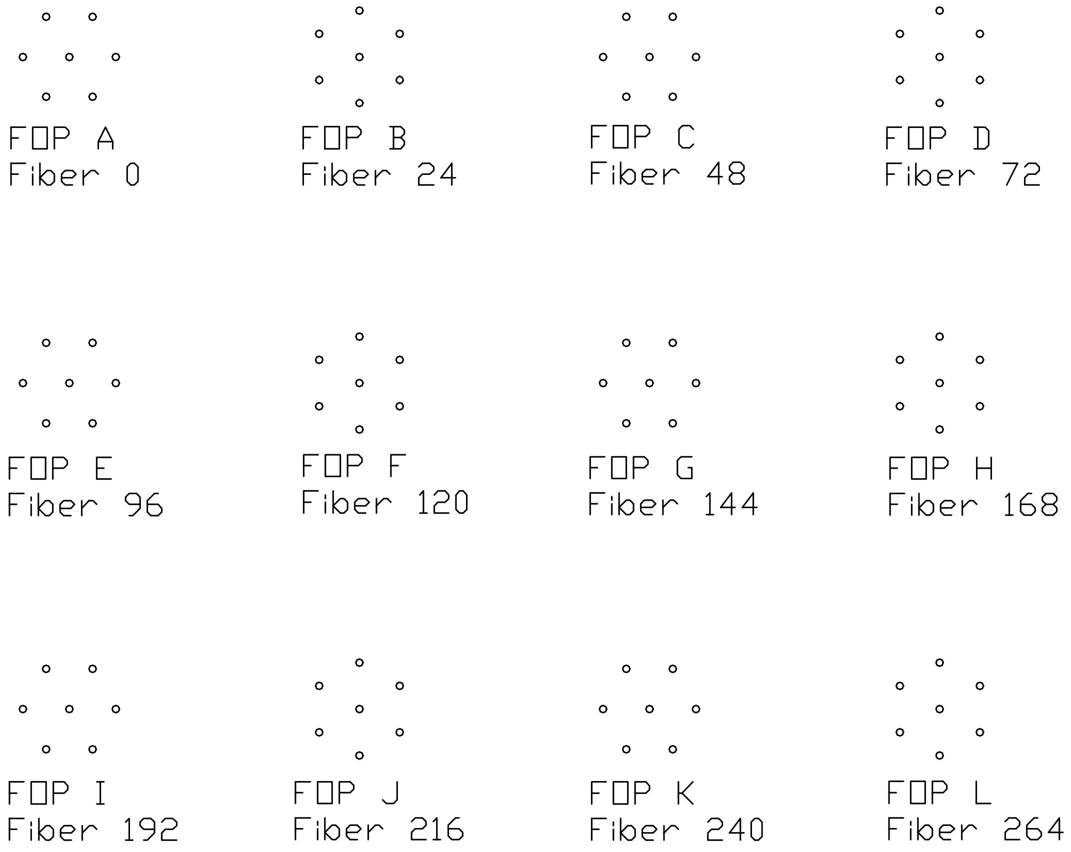


Figure 22: The orientation of the FOPs as viewed on the guider display monitor.

each active FOP. The guide error, determined by the centroid of the signals, is graphed underneath each active FOP. Along the top of the display will be information concerning number of active guide FOPs, guide rates, and the guider error that is being sent to the telescope. A theta error is also displayed when rotational guiding is enabled.

9.11 OBSERVING STANDARD STARS

There are a number of techniques which can be used to obtain spectra of single stars used as standards:

- Move a fiber into the field center and take a short (≤300 sec) unguided exposure.
- Move a fiber into the field center, cruise to find a gripper guide star, and take a guided exposure.
- Use the **standard** command to execute a series of fiber moves to set up the desired fiber and guide star.

- Use the archived set of standard star field configurations, or make similar configurations.

Each of these procedures is described in the sections below, and each has its own advantages and disadvantages. Prospective observers are urged to discuss their needs for standard star observations with their staff contact in advance of their run.

9.11.1 Short Unguided Exposures

This is the quickest method and works well for short exposures (<300 sec.). Pick a fiber that appears to have a clear shot at the center without moving other fibers. Click the cursor arrow on it to identify it. The tables in Appendix D can be used to choose a fiber near the center of the output spectra if desired. With the the rotator at zero degrees, execute the following commands:

plate flat

gripin

move n 0 0 (where n is the fiber number)

plate warp

Now bring in the ATV from the bench GUI to view the output end of the fiber. The telescope operator will set on the star. Move the gripper to a benign position using the command

goxy 50,000 -50,000

The operator will peak up the signal as viewed on the ATV. Finally, while the ATV is moving out, start the **observe** or **object** command, delaying the final return until the ATV is all the way down. *Do not start the exposure until the ATV is completely stowed, or light from a sensor on the ATV will ruin your exposure* . If another exposure is desired, center the gripper (**goxy 0 0**), and let the operator recenter the star as above.

When the standard star exposures are finished, the **setup field** command will be needed to restore the fiber to its field position. Be sure to note the sidereal time and length of exposure used to do the initial configuration, or all of the fibers may be tweaked if different values are used.

9.11.2 Quick Setup Guided Exposures

A fiber is chosen and set up as in the first method. After the telescope position is peaked up with the ATV, cruise with the gripper to find a guide star, being careful to search positions which keep the gripper stage out of the beam. See the next section for details on cruising with the gripper. After a guide star is selected, do a final tweak of the telescope position as seen with the ATV. Then remove the ATV and start the exposure as above. If the object is too faint to be seen with the ATV, the Fiber Back Illuminator (FBI) can be used to mark the fiber position on the monitor as viewed with the gripper TV. The operator must also switch the proper cables at the location "B" video distribution panel to guide with the gripper.

If the same object will be observed again later, the gripper coordinates can be queried with the **where** command.

9.11.3 The Standard Command

The following command can be used to place a star down any user specified fibers (specified by position along the slit).

Note, however, that this command may park some extended fibers in order to get the desired fiber positioned to field center. When you are ready to observe the field, rerun the **setup field** command to reconfigure the displaced fibers making sure that you keep the same values for the sidereal time and duration of the observations; otherwise, all of the fibers may be slightly repositioned instead of just those that were parked.

Type

standard

to execute a procedure for putting a single star down the fiber of the currently selected cable.

You will be prompted for the slit position that you desire. A FOP will then be moved into the field center for centering and focusing the telescope on the star.

You will then search for a guide star with the gripper TV using the arrow keys in the same manner as the **cruise** command (see page 53). Note that preceding the arrow keys with a zero will cause the gripper to move in steps comparable to the TV field of view.

After that is complete, the command will park the FOP and move in the fiber corresponding to the selected slit position for the observation.

The gripper will then return to the guide star location for closed loop guiding during the observation.

9.11.4 Sample of Standard Command

```
Fiborg 4.0.0 >standard


Which slit Position do you wish to use?
( 99)> 96
Slit position #96 will use fiber #157
************************************
WAITING: --for rotator to go to zero.
```

```
Rotator is in Position.

Moving FOPS 0 to center of field.
generating interaction table.
Parking fiber 46, which means:  moving button  46 to  46367,  72785
Parking fiber 264, which means:  moving button 264 to  74738, -43148
Parking fiber 277, which means:  moving button 277 to  83827, -20510
moving button   0 to      0,      0
Warping the focal plane plate.
viewing button #0
This fiber, #0, is Extended
Viewing unassigned  fiber: 0 Probe A
Presetting and enabling the rotator.

 PLEASE HAVE THE O.T. ACQUIRE AND CENTER THE STAR (on Gripper TV).


  Is the star centered? [ Yes or No ]?
(No)> y
************************************
 Now acquire a guide star with the gripper on gripper TV.

 PLEASE HAVE THE O.T. RE-CENTER THE STAR (on FOPS TV).

--and check the focus (on FOPS TV).


  Is the star centered? [ Yes or No ]?
(No)> y
************************************
WAITING: --for rotator to go to zero.
Rotator is in Position.
generating interaction table.
Parking fiber 0, which means:  moving button   0 to  86299,      1
Parking fiber 160, which means:  moving button 160 to -81095, -29517
Parking fiber 168, which means:  moving button 168 to -74737, -43151
moving button 157 to      0,      0
Warping the focal plane plate.
Presetting and enabling the rotator.

 PLEASE HAVE THE O.T. ACQUIRE AND CENTER THE STAR (on Gripper TV).
```

```
  Is the star still centered? [ Yes or No ]?
(Yes)>y


 YOU ARE NOW READY TO BEGIN OBSERVATIONS.

Fiborg 4.0.0 >
```

9.11.5 Standard Star Field Configurations

There are some Hydra configuration files available for observing standard stars by the normal configuration process which places FOPs in the field of the standard for guiding. This minimizes the overhead of searching for guide stars in the **standard** command with the gripper TV, but will also likely move more of the fibers in the current configuration. These files are located in the ~/stdfields directory of the fibwiyn account and are usable from the hydra visitor account (the program looks in this directory as well as in the fields directory for hydra configuration files).

Hydra can be configured for such files following the normal field configuration process (**setup field** and **setup observe**). Just type in the name of the file when prompted as you would your other files.

Type

ls /home/fibwiyn/stdfields

to see the list of files available in that directory.

The current list of standards available in configuration file format are:

BD+284211 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Feige 34 in file *fxb.feige34.hydra* or *fxr.feige34.hydra*

Feige 66 in file *fxb.feige66.hydra* or *fxr.feige66.hydra*

Feige 67 in file *fxb.feige67.hydra* or *fxr.feige67.hydra*

Feige 110 in file *fxb.feige110.hydra* or *fxr.feige110.hydra*

G191B2B in file *fxb.g191b2b.hydra* or *fxr.g191b2b.hydra*

GD 140 in file *fxb.gd140.hydra* or *fxr.gd140.hydra*

Hiltner 600 in file *fxb.hiltner600.hydra* or *fxr.hiltner600.hydra*

HZ 44 in file *fxb.hz44.hydra* or *fxr.hz44.hydra*

PG0823+546 in file *fxb.pg0823p546.hydra* or *fxr.pg0823p546.hydra*

Wolf 1346 in file *fxb.wolf1346.hydra* or *fxr.wolf1346.hydra*

The fx indicator shows that the star is a flux standard. The fxr files are for slit position 50 of the red cable. Observations through slit position 50 of the blue cable are made by configuring the fxb files.

NOTE: We have not yet verified that all these files are astrometrically viable. Please let us know your experiences with these fields if you choose to use any of them. It is also only possible to observe the star through slit position 50 at the current time. Most of these stars are likely bright enough to observe unguided as above.

9.12 USE OF SCRIPT FILES

9.12.1 How to Run a Script File

Script files are available for Hydra configurations and operation. A script file is a list of instrument commands that can be executed by

exec <*filename*>

There are several script files available for operation.

9.12.2 Useful Script Files

Some useful script files are listed here.

bluecircle — Configures the blue fibers into a circle near the field center.

center — Moves the gripper to the plate (field) center.

parkall — Parks all of the fibers.

redcircle — Configures the red fibers into a circle near the field center.

viewblue — Views all of the blue fibers with a wait delay of 2 seconds between views.

viewfops — Views all of the Field Orientation Probes with a wait delay of 2 seconds between views.

viewred — Views all of the red fibers with a wait delay of 2 seconds between views.

9.13 EXITING AND INSTRUMENT SHUT DOWN

We strongly advise that the Hydra instrument be powered down and the program exited at the end of each night and restarted again in the afternoon.

To quit the program, type

```
quit
```

You will be prompted to power off the racks. Answer **yes** if it is the end of the night. During the night, it may be best to leave the racks powered on if the program will again be started later that night. Also, one may need to leave the power on in cases of instrument difficulty.

9.14 INSTRUMENT PROBLEM RECOVERY

Recovery from Instrument Problems should be done by a properly trained person or under the direct supervision of such a person.

9.14.1 Recovery of Lost Fibers

The button sensing of the gripper will halt the positioning routine if there is a dropped fiber or one that it couldn't pick up. In most cases, the errant fiber can easily be recovered through use of the gripper TV camera.

The following steps should be used for simple fiber recovery.

- If the fiber is not visible in the gripper TV, try to view the errant fiber with

  ```
  view <fiber#>
  ```

  or by clicking the **view** button in the graphics window followed by a click on the fiber in trouble in the graphics display.

- **If there is any doubt about the identity of the fiber in question, stop and get help from the operator or other staff who are trained to open up Hydra and restore the button position. Permanent damage to fibers may result from trying to move the wrong button.**

- If you can see that the fiber/button is displaced from the center of the gripper and are certain it is the correct fiber, type

  ```
  cruise
  ```

  to move the gripper over the button with the H, J, K, L, or ←, ↓, ↑, → keys. Typing a 1 through 9 prior to each arrow key will scale the step size by a power of two scaling.

  Hit return when the fiber is centered in the gripper.

- The software now needs to know the corrected location of the lost fiber.

  Type

  thisis

  to update that position.

- Type

  park *<fiber#>*

  to see if the problem is cured by parking the troubled fiber.

- Rerun the setup command (or whatever action was being conducted) and all should proceed well.

If the lost fiber can not easily be found with the viewer, have trained personnel (the Observing Tech) go to the telescope and inspect the hardware. If they had to reset the lost fiber by hand, they will have placed it into its stow position. The software will have to be informed of this action with the following command.

xstowed *<fiber#>*

That fiber should then be parked with

park *<fiber#>*

before normal operation can resume.

9.15 SOME MISCELLANEOUS USEFUL COMMANDS

9.15.1 Determining Location of the Gripper, Fibers, and Objects

The **where** command will give the coordinates of the gripper.

```
Fiborg 4.0.0 >where

gripper is at plate:  x =  89999  y = -89999  z =      0
                 sky:  x =  89834  y = -90165  z =      0
             encoder:  x =  89976  y = -90020
```

The default **whereis** command will give the coordinates of a fiber by its fiber number.

```
Fiborg 4.0.0 >whereis 64
object: #2226 "SKY                " fiber: 64 at slit pos: 30
That object is at -26315 46102
Button #64 is at x = -26394, y = 46074 which is Extended
```

The **whereis** command can also be used to find a fiber by its slit position number with the **s** flag.

```
Fiborg 4.0.0 >whereis s 38
object: #318 "A2255...... 318     " fiber: 118 at slit pos: 38
That object is at -16898 -15674
Button #118 is at x = -16892, y = -15710 which is Extended
```

In addition, the **whereis** command will show the coordinates of an object using the **o** flag plus object number.

```
Fiborg 4.0.0 >whereis o 449
object: #449 "A2255...... 449     " fiber: 138 at slit pos: 51
That object is at -2332 -11582
Button #138 is at x = -2295, y = -11579 which is Extended
```

9.16 THE .IRAF FILE AND CCD HEADER INFORMATION

The .iraf file is used to inform iraf of which spectrum corresponds to which object. The slit position is indicated by the first column of the file. The second is a flag used by IRAF to determine the type of spectrum (-1 for unused, 0 for sky, 1 for object, and 3 for random position). The third column gives the object name and references the user id number for that object (in parentheses). The decision to leave out any currently unused fibers that were used in a previous configuration causes those entries in the file to be labeled as “Random position”. They may either be used as additional skies or ignored during the data reduction process.

Starting with IRAF version 2.11, the .iraf file is no longer needed for the object to spectrum cross-referencing as the pertinent information is now being stored into the CCD headers. The .iraf files will, however, continue to be used as a backup in case the information in the headers becomes corrupt or is missing.

9.16.1 Sample .iraf File

A sample .iraf file is shown here:

```
# Thu Aug 10 21:19:23 1995
# Hydra Filename: f2125red.hydra
```

```
# LST Middle :   19:30:00.0
  1 -1 not assigned
  2  1 10.43 0.467 (244)
  3  1 12.18 0.135 (13)
  4  1 12.28 0.466 (243)
  5  1 11.69 0.479 (253)
.
.
.
 89  1 12.55 0.320 (114)
 90  1 12.35 0.377 (149)
 91 -1 not assigned
 92  1 12.93 0.335 (120)
 93  1 11.17 0.440 (215)
 94  1 12.80 0.392 (165)
 95  1 12.25 0.389 (163)
 96  1 13.26 0.433 (207)
 97  1 11.56 0.389 (161)
 98  1 13.27 0.503 (277)
 99  1 12.41 0.354 (129)
100  1 11.50 0.312 (105)
```

A LIST OF ACRONYMS AND SOME USEFUL TERMS

Acronyms:

- ICE – IRAF Control Environment, controls the T2KA CCD on the Bench Spectrograph.
- ATV – Acquisition TV camera on the Bench Spectrograph which views the fiber slit.
- FBI – Fiber Back Illuminator, a bank of LED's which illuminates the fiber slit for viewing fibers with the gripper camera.
- FOP – Field Orientation Probe, a 7-fiber bundle placed on a bright star for locking the telescope pointing onto the target field. There are ten FOPs currently available (2 of 12 broken).
- ICCD – Intensified CCD camera. Both the gripper camera and the FOPs camera are ICCDs.
- OA – Observing Assistant, either your telescope operator or the daytime mountain support person.
- SCS – Simultaneous Comparison Sources on the Bench Spectrograph.
- SSD – System Status Display. Video display of telescope and instrument status.
- T2KA – CCD used on the Bench Spectrograph.
- WIYN – Wisconsin, Indiana, Yale, NOAO consortium members of the telescope.

Some useful terms:

- fiber # – The number corresponding to the position of a fiber around the circumference of the focal plate.
- object # – The user number of a target (first column) in the .hydra file.
- slit # – The number referring to the position of a fiber along the spectrograph slit. Fiber number 2 will be at the high pixel number end of the array, unless the simultaneous comparison fibers are in use. See Figure 10 for an illustration of fiber positions.

B LIST OF POSITIONER COMMANDS

The following is a list of most commands for operating Hydra. Many of these can also be used in the simulator mode for checking and modifying configurations. The graphical user interface has buttons which execute many of the most important commands; these are indicated at the end of the description. See also figure 19 for the location of the buttons.

HYDRA-COMMAND window commands:

setup commands:

- **setup field** — User level command for configuring a target field (GUI).
- **setup observe** — Readies the preconfigured instrument for observations (GUI).
- **setup comps** — Sets the instrument up for taking comparison lamps (GUI).
- **setup flats** — Sets the instrument up for taking dome flats (GUI).

Calibration lamp and screen commands:

- **screen in** — Moves the calibration screen into place for calibrations.
- **screen out** — Stows the calibration screen out of the way.
- **screen status** — Displays status information about the screen.
- **screen test** — Moves the screen to test its functionality.

miscellaneous commands:

- **assign o f** — Assign object <#> to fiber <#>.
- **coldstart** — Initializes the hardware.
- **gripout** — Moves the gripper out of the way for observations (GUI).
- **gripin** — Moves the gripper back into action (GUI).
- **gripex** — Exercises the gripper by opening and closing a few times without a button.
- **goxy** <*X*> <*Y*> — Moves the stage to the X, Y plate position in encoder values.
- **gox** <*X*> — Moves only the X stage.
- **goy** <*Y*> — Moves only the Y stage.
- **goz** <*Z*> — Moves the Z stage to the given Z coordinate.

- **move** <#> <*X*> <*Y*> — Moves the fiber at position <#> to the coordinates X and Y (restricted to valid ranges and no collisions).
- **park** <#> — Moves fiber <#> to its park position (GUI).
- **save** — Saves the current configuration. May replace a prevous one or create a new file. Asks for file name.
- **status** — Allows a check of the various modes and their status.
- **view** <#> — Moves the gripper over to view the fiber at position <#> (GUI).
- **view o** <#> — Moves the gripper over to the object with number <#>.
- **view s** <#> — Moves the gripper over to the fiber at slit position <#>.
- **where** — Gives the gripper coordinates (GUI).
- **whereis f** <#> — Gives the coordinates of fiber <#>.
- **whereis o** <#> — Gives the coordinates of object <#>.
- **whereis s** <#> — Gives the coordinates of the fiber at slit position <#>.
- **xparked** <#> — Updates the fiber data base to change the stored X and Y values to the position corresponding to the park position of fiber <#>.
- **xstowed** <#> — Updates the fiber data base to change the stored X and Y values of fiber <#> to the position corresponding to the fiber's stow position. Use this command when manually restowing a misplaced fiber.
- **thisis** — Updates the current fiber position. See Section 9.14.1.
- **ThisIs** <#> — Updates the position of fiber <#> outside of the **setup field** command.
- **targets on** to display the target objects when a configuration field is loaded (GUI).
- **targets off** to turn off the plotting of the targets (GUI).

C ASTROMETRY GUIDELINES

Although it is not our intention to tell astronomers how best to measure their target coordinates, we have realized that some guidelines are in order. We include updated excerpts from two articles written by Phil Massey that have appeared in the NOAO newsletter regarding astrometric measurements.

C.1 Astrometry for Hydra, From KPNO, NOAO Newsletters No. 32 (Dec. 1, 1992) and No. 35 (Sep. 1, 1993)

For years we optical spectroscopists have been able to get by just fine with crummy coordinates, due, in part, to the ease of identification of objects on a slit viewing TV, combined with the fact that most telescopes did not point all that well anyway. However, as our telescopes have begun to perform better and better, and as we have continued to observe fainter and fainter objects, most of us have found that our observing efficiency is considerably enhanced if we arrive at the telescope with coordinates good to an arcsec or two. Now, with the advent of multi-fiber spectrometers, we suddenly find ourselves in a different regime, where an error of "an arcsec or two" means that virtually no light will go down a fiber.

Users of Hydra must come prepared with coordinates good to < 0.5 arcsec over the entire 60 arcmin field if they are to have any hope of success, and furthermore the astrometry of their program objects must be on the same "system" as the brighter stars used for tweaking up the telescope alignment (the so-called "FOPs" stars). In good seeing an error of 0.5 arcsec will result in negligible light-losses; an error of 1.0 arcsec, however, results in losing 50-75% of the light with our 2.0 arcsec fibers, depending upon the seeing. Exact details can be extracted from Figures 1 and 2 in the paper by Donnelly et al. (1989, PASP, 101, 1046). The physical positioning of the Hydra fibers is believed to be accurate to of order 30 um (0.3 arcsec).

There are a number of resources available through NOAO that can help Hydra users determine good coordinates. We list these below.

1) Guide Star Catalog. If the objects you plan to observe with Hydra are bright ($V <$ 15-16), stellar, and relatively uncrowded, chances are good that they will be in the Space Telescope Guide Star Catalog (GSC). If you have the approximate positions, then the Fortran routine FINDER can be used to search the GSC, (which we keep on-line on two CD-ROMS). Care must be taken to select coordinates that all come from a single "plate," as it is well known that the positions of GSC stars that occur on multiple plates have coordinates that are typically offset by 1-2 arcsec. Aside from this concern, we have found that the GSC provides coordinates which have excellent internal consistency ($<= 0.2$ arcsec). In addition, since their coordinates were determined from recent (circa 1985) plates, corrections for proper motion are likely negligible.

2) POSS plates and the Grant Machine. In the downtown Kitt Peak plate vault, we have glass copies of the old (circa 1952) POSS. Positions of objects down to a stellar magnitude

of 21 can be readily measured on these using the 2-axis Grant machine and reduced using FINDER/ASTRO routines. However, because the epoch of the plate material is 40 years old, great care must be taken to assure that proper motion for your FOPS stars and/or program objects is either explicitly accounted for, or is demonstrably negligible. Assuming that one is measuring “faint, far away” things, one could use stars from the SAO catalog as the reference system; to use these same stars as FOPS stars, however, you will need to explicitly correct the catalogued positions using the proper motions listed in the SAO catalog when you construct the Hydra coordinate file. Unfortunately, the proper motions listed in the SAO catalog are of variable quality, and care must be taken to select stars whose listed errors in proper motion are small. Alternatively, one can use the GSC as the reference standards, and simply keep only those stars whose residuals are small in the solution; these stars must have low proper motion (epoch 1985 to epoch 1952). Again, care must be taken to select only stars whose coordinates come from a single plate. The usual accuracy achieved is a little bit better than an arcsec.

3) CCD frames and IRAF’s “finder/tfinder” routines. If you have selected your objects from wide-field CCD frames, then you can use this material directly for determining excellent coordinates. To aid in this, Rob Seaman has provided a set of routines in the “nlocal” package “finder.” These routines will allow you to search the Guide Star Catalog for stars that are on your CCD frames, and display your image overlaying the predicted location of the GSC stars it finds. Interactive cursor options allow you to shift and find “astrometric quality” x and y centers for these reference stars on your frame. Good x and y centers for your program objects can be found using any of a variety of routines within IRAF, that range in complexity from positioning a cursor on a star and striking a key to obtaining centers with psf-fitting in “daophot.” Once you have good x and y centers for your reference stars and program objects, the AAT/STARLINK “astrom” routine is then used to find the six-coefficient plate solution, and the coordinates of the program stars are then output directly in a format that is needed for the Hydra assignment program. As long as one restricts oneself to GSC coordinates determined for a single plate, solutions are typically good to <= 0.2 arcsec RMS. (The software is designed to make this easy.) Because the “tfinder” routines are considered a prototype, and because they require access to the GSC CD-ROMS, these routines are not generally exported, although Rob Seaman has successfully transported them elsewhere; first time users should plan on using them in Tucson. Potential Hydra users are reminded that the wide fields covered by 2048 x 2048 CCDs on the KPNO 0.9-m and Burrell Schmidt telescopes are very useful for isolating samples of objects and performing astrometry.

4) Digitized sky survey images. The “Quick V” (1985) Palomar Schmidt survey used in producing the Guide Star Catalog is available on CDROM. These scans contain stars as faint as V = 19 (i.e., several magnitudes fainter than the GSC itself), and come with an accurate “plate solution” as part of the header information. (One should verify the header plate solution by redetermining their own solution.) Routines in STSDAS (usually distributed with IRAF) can then be used to take x and y positions and output accurate celestial coordinates. Measurements on two test fields provided by STScI have yielded good

results. The advantage to using this material is that the astronomer can perform his/her astrometry at home, rather than traveling to NOAO, and since the "Quick V" plate material is of recent vintage, proper motions are usually immaterial.

5) Mix and match. If you have a small-field CCD image for which you need accurate positions, it may be necessary to measure "secondary reference stars" using either (1) or (4), and then use these as the basis for computing the "plate solution" for your frame. This can be done using either "astrom" or "astro", but will doubtless require a good deal of hand editing.

In order to make use of any of the NOAO facilities significantly in advance of an observing run, you should write to the KPNO director.

D FOCAL PLANE FIBER TO SLIT IDENTIFICATIONS

The two tables shown here give the slit positions of fibers as referenced by their position around the focal plate. This information can be useful for instance, in picking a fiber to use for a standard star spectrum when a particular slit position is desired. A "b" after a focal plane position indicates a damaged fiber which has been taken out of service. Other fibers may be currently unuseable since this writing, and the current concentricities file should be used as the definitive set of fibers.

FOCAL PLANE FIBER TO SLIT REFERENCE - BLUE CABLE					
focal plane	slit	focal plane	slit	focal plane	slit
2	53	98	80	194	16
5	47	101	89	197	69
8	51	104	66	200	95
11	82	107	38	203	78
14-b	22	110	45	206	9
17	72	113	85	209	74
20	19	116	62	212	20
23	83	119	43	215	33
26	56	122	23	218	35
29	67	125	15	221	36
32	39	128	26	224	29
35	41	131	77	227	57
38	94	134	24	230	51
41	71	137	30	233	76
44	5	140	60	236	32
47	93	143	99	239-b	86
50	84	146	96	242-b	59
53-b	98	149	31	245	61
56	64	152	81	248	49
59	27	155	7	251	28
62	42	158	54	254	92
65	70	161	52	257-b	8
68-b	65	164	14	260-b	34
71	90	167-b	18	263-b	40
74	50	170	17	266	6
77	11	173	55	269-b	12
80	25	176	73	272	44
83-b	97	179	3	275	10
86	4	182-b	13	278	2
89	63	185-b	48	281	68
92	46	188	88	284	37
95	79	191	87	287	91

Table 7: Focal Plane Fiber to Slit Reference - Blue Cable

FOCAL PLANE FIBER TO SLIT REFERENCE - RED CABLE

focal plane	slit	focal plane	slit	focal plane	slit
1	66	100	16	199	25
4	32	103	12	202	86
7	10	106	18	205	3
10	40	109	51	208	27
13	65	112	57	211	89
16	5	115	97	214	78
19-b	19	118	11	217	69
22	64	121	49	220	23
25	42	124	20	223	79
28	88	127	37	226	93
31	63	130	71	229	15
34	13	133	75	232	74
37	26	136	70	235	44
40	100	139	31	238	84
43	43	142	4	241	21
46	99	145	36	244	94
49	76	148	77	247	17
52	38	151	80	250-b	75
55	52	154	53	253	62
58	67	157	96	256-b	95
61	2	160	8	259-b	22
64	90	163	24	262-b	48
67	59	166	34	265-b	60
70	14	169	54	268	29
73	61	172	33	271-b	55
76	82	175	7	274	72
79	47	178	92	276	58
82	91	181	9	277-b	30
85	45	184	50	279	85
88	28	187	83	280	81
91	41	190	56	283-b	46
94	98	193	87	286	39
97	73	196	6		

Table 8: Focal Plane Fiber to Slit Reference - Red Cable

E THE AUTOMATED CCD LOG

The autolog pulls information from your image headers to create the log. It only logs images written in FITS format.

To start the autolog program:

- Start an xterm or xgterm using the background menu.
- You must start the program from within the directory data is being taken (e.g. /data1/hydra/night1).
- on Vanilla type: /usr/local/gui/bin/autolog. This will bring up the CCD Autolog Control Panel.
- In the "image directory" box, you will need to type in the full path to your working directory of your Data Acquisition window (e.g. /data1/hydra/night1).
- Select which instrument you are using.
- Click on "Start Logging". Images will only be written to the log after this.

The images (.fits images only) are written to the log after the exposure has read out. Every time an image is logged, the log page is written to a postscript file and saved. These files are stored in the same directory as your images and are called autolog_page1.ps, etc. Each page is then printed when it is full. one nice feature of this log is that you can type virtually anywhere within the log; you can edit any field or add comments wherever you like.

Note: Image root names that contain a period will not show up correctly in the log (e.g. n001.0002.fits). To avoid this, make sure your image root names do not contain periods.

Test images and focus sequences will show up in the log with a sequence number of zero.

F A QUICK GUIDE TO REDUCING WIYN HYDRA DATA, 8/31/97

The following guide by Philip Massey gives a sketch of the reduction steps used to reduce some recent Hydra spectra obtained at WIYN. The data set *corresponding to a single fiber configuration* consisted of the following images:

- dome flat exposures: n190027, n190028, n190029
- comparison exposure: n190026
- object frames: n190023, n190024, n190025
- bias frames: n190030-39
- an ".iraf" file generated by the positioner software called H1954-002.1.iraf

Most of the hard work is done by the "dohydra" routine, which will (optimally) extract the spectra and do the necessary wavelength calibration and sky subtraction, but some preliminary processing is necessary:

1. load the noao.imred.ccdred package
2. setinstrument fibers
3. zerocombine n19*.imh output=Zeron19
4. ccdproc n19002*.imh fix- overscan+ trim+ zerocor+ biassec=[1:31,2:2046] trimsec=[34:2078,2:2046] zero=Zeron19
5. flatcombine n190027,n190028,n190029 output=Flatm33fld2 reject=avsigclip scale- rdnoise="NOISE_12" gain="GAIN_12"

Note that the trim section is a little different than the default suggested in the image header. One is now dealing with the following dataset:

- combined dome flat: Flatm33fld2
- single comparison: n190026
- object frames: n190023, n190024, n190025
- the ".iraf" file H1954-002.1.iraf

```
objects = n190023,n190024,n190025  List of object spectra
(apref  =          Flatm33fld2) Aperture reference spectrum
(flat   =          Flatm33fld2) Flat field spectrum
(through=                     ) Throughput file or image (optional)
(arcs1  =              n190026) List of arc spectra
(arcs2  =                     ) List of shift arc spectra
(arcrepl=                     ) Special aperture replacements
(arctabl=                     ) Arc assignment table (optional)
(readnoi=                  4.5) Read out noise sigma (photons)
(gain   =                  1.7) Photon gain (photons/data number)
(datamax=                INDEF) Max data value / cosmic ray threshold
(fibers =                   98) Number of fibers
(width  =                  12.) Width of profiles (pixels)
(minsep =                   8.) Minimum separation between fibers (pixels)
(maxsep =                  15.) Maximum separation between fibers (pixels)
(apidtab=     H1954-002.1.iraf) Aperture identifications
(crval  =                INDEF) Approximate central wavelength
(cdelt  =                INDEF) Approximate dispersion
(objaps =                     ) Object apertures
(skyaps =                     ) Sky apertures
(arcaps =                     ) Arc apertures
(objbeam=                    1) Object beam numbers
(skybeam=                    0) Sky beam numbers
(arcbeam=                     ) Arc beam numbers
(scatter=                   no) Subtract scattered light?
(fitflat=                  yes) Fit and ratio flat field spectrum?
(clean  =                  yes) Detect and replace bad pixels?
(dispcor=                  yes) Dispersion correct spectra?
(savearc=                  yes) Save simultaneous arc apertures?
(skyalig=                   no) Align sky lines?
(skysubt=                  yes) Subtract sky?
(skyedit=                  yes) Edit the sky spectra?
(savesky=                  yes) Save sky spectra?
(splot  =                   no) Plot the final spectrum?
(redo   =                   no) Redo operations if previously done?
(update =                  yes) Update spectra if cal data changes?
(batch  =                   no) Extract objects in batch?
(listonl=                   no) List steps but don't process?
(params =                     ) Algorithm parameters
(mode   =                   ql)
```

Figure 23: Parameters for dohydra.

The parameters for “dohydra” are given in Fig. 23. The only parameters that have been changed from their defaults are the read-noise, gain, and number of fibers—this has been changed to 98 to make the fiber identification easier.

The algorithm parameters are shown in Fig. 24 and 25. The only parameters that have been changed from their default values are the trace parameters and the arc identification line list. Note that although the weights under the extraction method says “none”, variance weighting will indeed be used since “clean” was specified in the “dohydra” parameters.

Upon running dohydra, you will first be presented with the aperture identifications of the 97 fibers. Check to see that there are gaps (no fiber identified) at 58 and 75 for the blue fiber cable (or check your ”.iraf” file for the current “Gap” locations. For the red cable, make sure that the gap corresponds to the (non-existent) fiber number 68. (Fiber 2 will be

```
(line   =               INDEF) Default dispersion line
(nsum   =                  10) Number of dispersion lines to sum or median
(order  =          decreasing) Order of apertures
(extras =                  no) Extract sky, sigma, etc.?

                               -- DEFAULT APERTURE LIMITS --
(lower  =                 -5.) Lower aperture limit relative to center
(upper  =                  5.) Upper aperture limit relative to center

                               -- AUTOMATIC APERTURE RESIZING PARAMETERS --
(ylevel =                0.05) Fraction of peak or intensity for resizing

                               -- TRACE PARAMETERS --
(t_step =                  10) Tracing step
(t_funct=             spline3) Trace fitting function
(t_order=                   3) Trace fitting function order
(t_niter=                   1) Trace rejection iterations
(t_low  =                  3.) Trace lower rejection sigma
(t_high =                  3.) Trace upper rejection sigma

                               -- SCATTERED LIGHT PARAMETERS --
(buffer =                  1.) Buffer distance from apertures
(apscat1=                    ) Fitting parameters across the dispersion
(apscat2=                    ) Fitting parameters along the dispersion

                               -- APERTURE EXTRACTION PARAMETERS --
(weights=                none) Extraction weights (none|variance)
(pfit   =               fit1d) Profile fitting algorithm (fit1d|fit2d)
(lsigma =                  3.) Lower rejection threshold
(usigma =                  3.) Upper rejection threshold
(nsubaps=                   1) Number of subapertures

                               -- FLAT FIELD FUNCTION FITTING PARAMETERS --
(f_inter=                 yes) Fit flat field interactively?
(f_funct=             spline3) Fitting function
(f_order=                  10) Fitting function order
```

Figure 24: The parameter set "params" (continued on the next page).

the first fiber in each case. You may have to play with "i", "o", and "m" to make this all work. But, this is a critical step!) See Figures 26 and 27.

```
                                -- ARC DISPERSION FUNCTION PARAMETERS --
(thresho=                   10.) Minimum line contrast threshold
(coordli=   linelists$cuar.dat) Line list
(match  =                   10.) Line list matching limit in Angstroms
(fwidth =                    4.) Arc line widths in pixels
(cradius=                   10.) Centering radius in pixels
(i_funct=               spline3) Coordinate function
(i_order=                     3) Order of dispersion function
(i_niter=                     2) Rejection iterations
(i_low  =                    3.) Lower rejection sigma
(i_high =                    3.) Upper rejection sigma
(refit  =                   yes) Refit coordinate function when reidentifying?
(addfeat=                    no) Add features when reidentifying?

                                -- AUTOMATIC ARC ASSIGNMENT PARAMETERS --
(select =                interp) Selection method for reference spectra
(sort   =                    jd) Sort key
(group  =                   ljd) Group key
(time   =                    no) Is sort key a time?
(timewra=                   17.) Time wrap point for time sorting

                                -- DISPERSION CORRECTION PARAMETERS --
(lineari=                   yes) Linearize (interpolate) spectra?
(log    =                    no) Logarithmic wavelength scale?
(flux   =                   yes) Conserve flux?

                                -- SKY SUBTRACTION PARAMETERS --
(combine=               average) Type of combine operation
(reject =             avsigclip) Sky rejection option
(scale  =                  none) Sky scaling option
(mode   =                    ql)
```

Figure 25: The rest of the parameter set “params”.

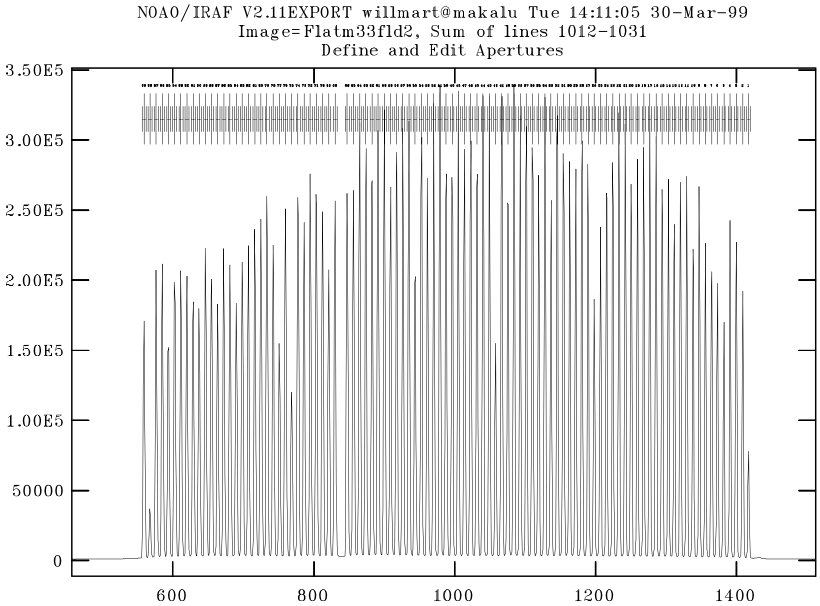


Figure 26: The aperture identifications are shown.

Next, you will be presented with the traces of the flat-field exposures. A typical trace and fit is shown in Figure 28.

You will be presented with the fit of the "average" flat-field extraction; this is shown in Figure 29. This is the normalization step where a function is fit to the average flat spectrum to normalize it to 1.

In the next step the comparison spectrum will be extracted, and you will be given a chance to run the normal "identify" routine on it. Mark ("m") several lines whose wavelength identification you know with certainty. Copies of the CuAr and ThAr atlases are available at the telescope and a new atlas of ThAr is available on the web at http://www.noao.edu/kpno/specatlas/. You can generate a new fit using "f". A typical identification and good fit are shown in Figures 30 and 31.

The program will then extract and wavelength calibrate the individual spectra from the program frames. After this step, you will be presented with a chance to edit (delete) sky spectra before sky subtraction. The most deviant skys, and the ones with the worst cosmic rays, may be deleted using the "d" key, or just left for the "cleaning" algorithm to deal with. Sky spectra (before and after cleaning) are shown in Figures 32 and 33.

After this procedure is repeated for each of the program frames, we find ourselves with three "multislit" spectra n190023.ms, n190024.ms, and n190025.ms.imh. These can now be combined using "scombine" as follows:

```
scombine n1910023.ms,n1910024.ms,n1910025.ms out=m33.ms.imh
```

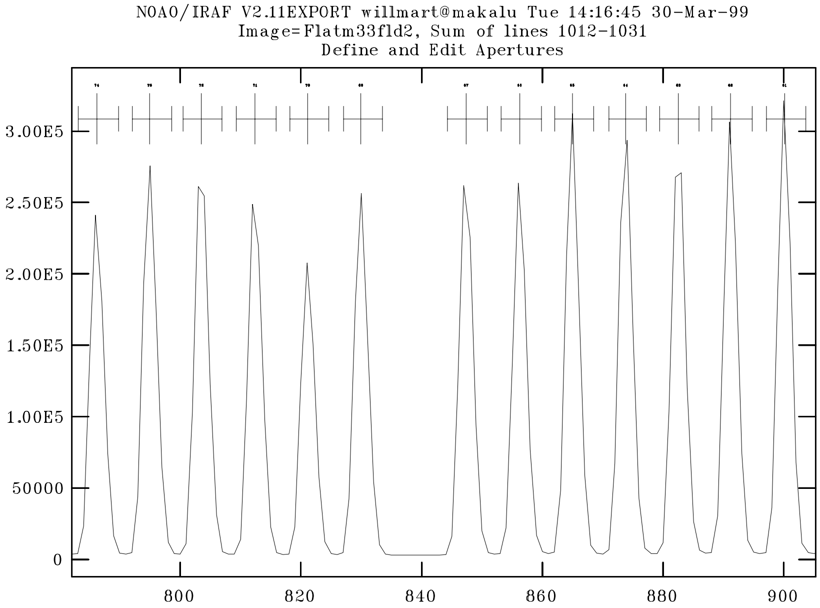


Figure 27: Expanded plot showing gap in Red cable at slit position 68.

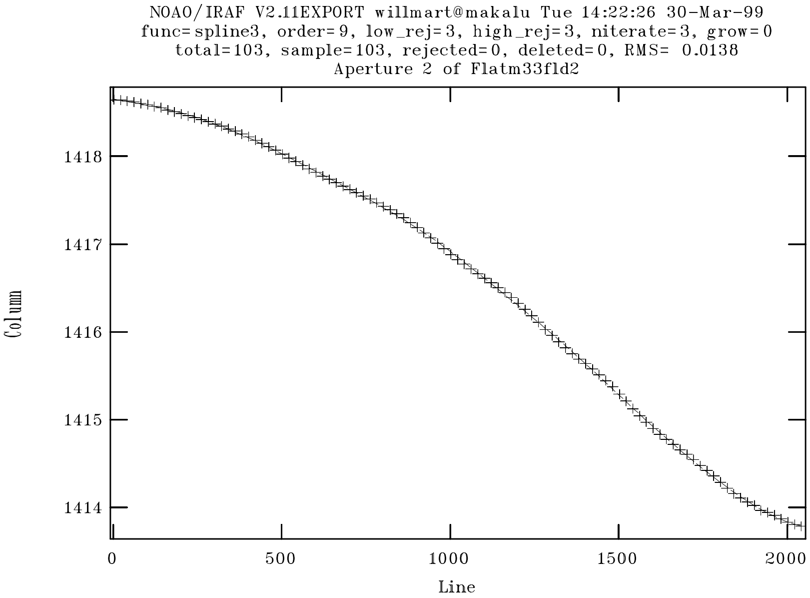


Figure 28: An APTRACE of the flat-field reference.

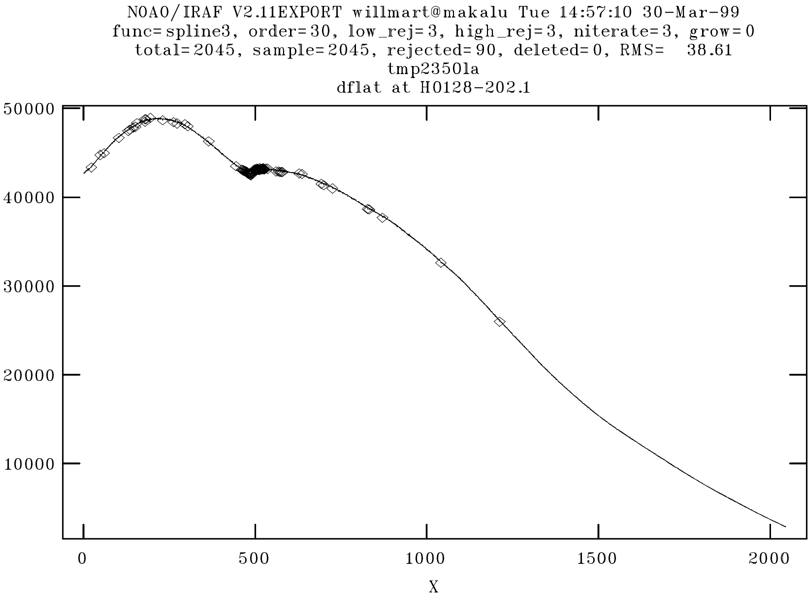


Figure 29: The fit of the averaged extracted flat-field spectrum is shown.

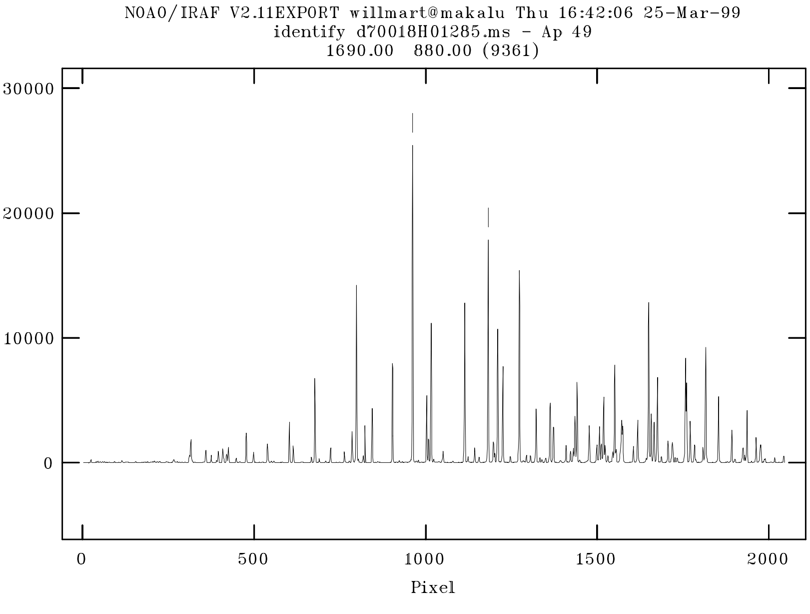


Figure 30: Identifying lines to construct the wavelength solution.

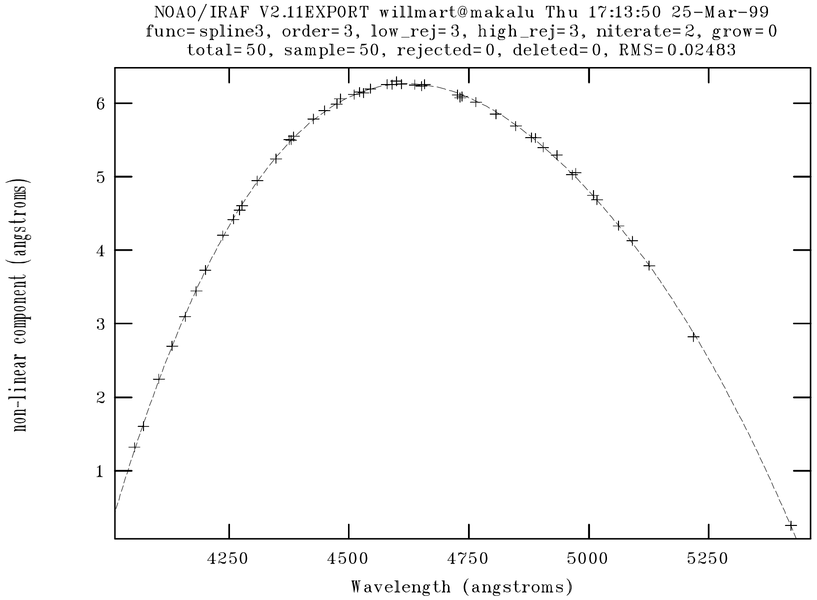


Figure 31: Fitting a function to the identified lines.

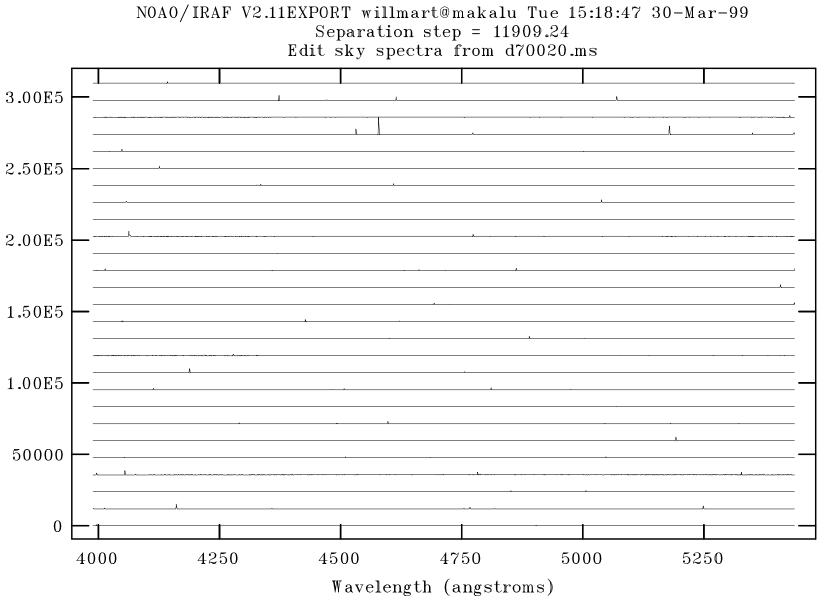


Figure 32: Plot of sky spectra after using “y” key.

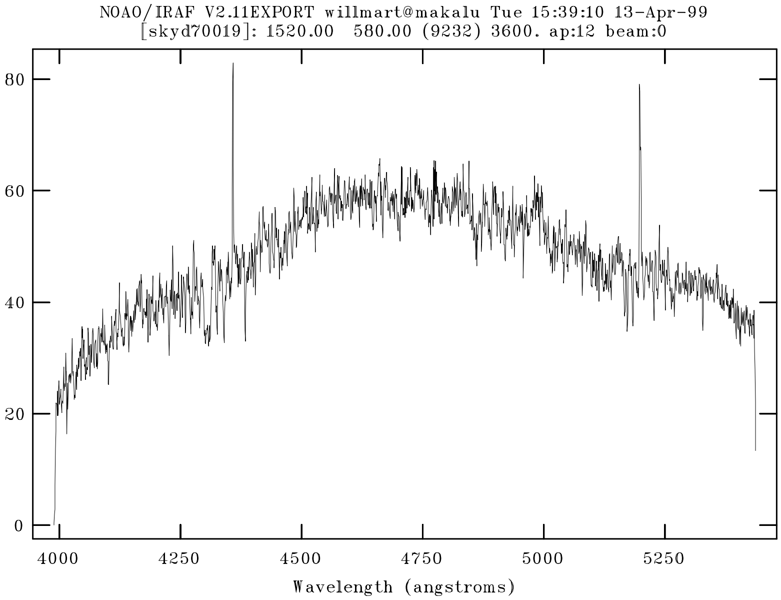


Figure 33: Plot of final sky spectrum after cleaning.