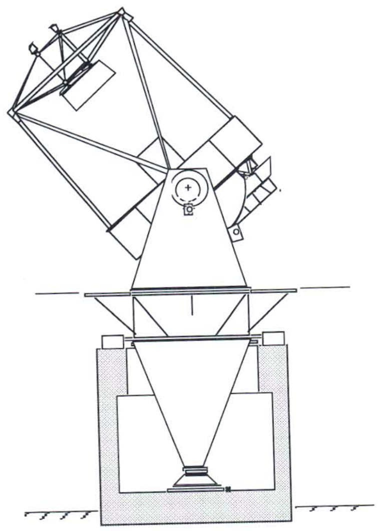
WISCONSIN
INDIANA
YALE
NOAO



3.5 METER TELESCOPE

WIYN Operations Readiness Review: MOS/Hydra Report

WODC 02-41-01

Operational Readiness Review – Hydra/WIYN

S. Barden

February 1, 1996

1 Introduction

The requirements and goals for the MOS instrument, Hydra, are addressed in this document. Issues relating to the focal plane through light passing through the fibers will be covered. The Bench Spectrograph is described in a separate report.

2 Requirements and Performance

The following description is from WODC 00-01-05:

> Description: Robot for positioning fiber optics in the focal plane of the MOS port. HYDRA will mount directly to the instrument rotator and place its focal plane at the appropriate position as specified. The fibers will pipe light to a spectrograph off the telescope. Means will be provided for acquiring the field and for sensing guide errors, field rotation, and focus errors. An alignment camera with the ability to simultaneously view the superimposed images of the fiber and program object will provide a check of fiber positioning.

As Built Instrument:

Hydra mounts to the MOS rotator along with a spacer assembly which houses Cu-Ar and Th-Ar calibration lamps.

The focal surface of the instrument was matched to that derived from the best estimate of the as-built optical design (see Science and Technical Requirements Review).

The fiber optics feed down the telescope cone, through the azimuth bearing and into the spectrograph laboratory where they are interfaced to a Bench Spectrograph (See Review for the Bench Spectrograph).

Field acquisition is achieved through use of the ICCD camera that rides on the robotic gripper. The camera sees an image of the sky superimposed on a view of the focal plate. LEDs on the gripper provide illumination of the focal plate and fiber buttons. LEDs on the spectrograph can provide back illumination of the fiber optics for direct viewing of the fiber apertures.

Guider error sensing is achieved by sampling the image of the twelve Field Orientation Probes (FOPS). Each probe samples a 3 arc-second diameter view with 7 segments. A minimum of 3 probes are required to be placed on stars ($V<15$) in the target field for minimal Alt-Az and Rotational guiding. Guide rates of about .5 to 1 Hz are sufficient for good Alt-Az guiding. This guider also corrects for field rotation errors and is used to achieve best rotational alignment when first acquiring the target field. Rotational guiding is carried out at a rate of about .1 to .2 Hz. Some fine tuning of the algorithms could improve guiding performance, but current performance appears to be adequate.

A secondary guider is available via the TV on the robotic gripper. Field rotation is not correctable with this guider. Use of the gripper guider is restricted to the observation of single stars down a fiber positioned at field center.

Telescope focus is achieved by an automated routine which uses the signal from the FOPS as an estimator of the image quality. Single or multiply centered FOPS can be used to achieve a good focus. The current routine appears to do an adequate job.

The camera on the robotic gripper allows the simultaneous viewing of the sky and fibers.

Item	Specification	As-Built
Positioner		
(*)Usable field diameter:	385 mm	381 mm
Field Curvature Compensation:	TBD	Vacuum-warpable Plate
Area lost to steps:	<TBD	0%
(*)Mechanical Positioning Accuracy	<20μm	50μm global 23μm repeatable (Y axis: 10μm, X axis: 20μm)
(*)Min. Fiber-Fiber Spacing	3.5 mm	3.875 mm
(*)Mean setup time per fiber:	<9 sec.	13 sec
Max. Number of Fibers	200	288
Number of Science Fibers	180 min.	98 Red + 96 Blue = 194
Number of Guide Fibers (FOPs)	N/A	12
(*)Size	1.5m x 1.5m x 0.9m D	1.7m x 1.6m x 1.1m D
(*)Weight	227 kg.	523 kg.
(*)Power	TBD	10 Amps max @ 110VAC
Temperature Range	TBD	0–60 C (encoders)
Humidity	TBD	up to 98% rh non-condensing

Usable Field Diameter:

Limit is set to minimize edge effects of the warpable plate.

Positioning:

The mechanical positioning spec is nearly met in repeatability, but not in global positioning. Numerous contributors to residual positioning error are currently suspected:

- Gripper hysteresis
- Inadequate Z-stage preload
- Fiber Pivot hysteresis
- X-stage servo oscillations

- Random dirt
- Non-orthogonal button magnetic surface

The gripper hysteresis was measured to be 0.013 inches and was found to arise from a loose preload nut and misaligned bores which hold the gripper fingers. Rework of the gripper has reduced the hysteresis to a level of only 0.0005 inches, a factor of 20 reduction. Recent positioning measurements suggest that this has improved positioning repeatability by 30%.

The Z-stage bearing was also found to have a loose preload which resulted in a 0.001 inch wobble. Preloading is now set to eliminate the wobble.

The Fiber pivots can introduce tilts in the fiber buttons of more than 5 degrees. This not only misaligns the fibers with the telescope exit pupil, but also can result in a positioning error of greater than 3 arc-seconds! A fix involves constraining the hypodermic tube so that it has a restoring force for it's position along the length of the pivot slot.

A temporary fix for the pivots uses masking tape to restrict the motion of the tube along the pivot slot. Unfortunately, when a fiber is picked up from the park position, significant torsion is induced by this restricted motion which causes several fibers to shift in the gripper so that they are positioned at a position different than if they were originally picked up from some other location on the focal plate. One red fiber shows a 2 arc-second error. This problem should be fixed with the final fix to the pivot flaw.

The X-stage displays some servo oscillation which may be causing the X direction of the positioning error to be a factor of two higher than that seen for the Y-axis. The Y-axis displays positioning repeatability of about 0.10 arc-seconds rms, well below the goal for positioning. The X-axis is currently delivering 0.2" rms repeatability. The servo oscillation is probably the dominant source, but some contribution may arise from measurement error due to the measurement technique. We are awaiting resources to explore servo parameters to see if we can minimize this effect.

Random dirt will also tilt a fiber when it is positioned onto the focal plate. Routine cleaning (every few months) should minimize this source.

Non-orthogonal magnetic surfaces on the button will mean that the button experiences a tilt when it is released from the gripper. It appears that this may account for the fact that several fibers do not show good repeatability. The magnitude of this error is probably on the order of .3 arc-seconds and affects maybe 10 to 20% of the fibers. There is no easy solution for this other than more careful fabrication of the button assemblies for future fiber cables.

All of these factors add up to global positioning errors which exceed the desired goal of 0.2 arc-seconds. The above causes are those that have either been reduced, are known to still contribute to the error, or are highly suspected of introducing some of the error. As we clean up these sources, there is still a possibility that we will discover other underlying contributors which may require further attention. Continued effort is needed until we meet a reasonable level of improvement in the global fiber positioning. This will require some downtime of the instrument and will need some modest amount of engineering resources for fix implementations.

A plan for improving fiber positioning is currently under negotiation. We will likely explore the X-stage servo oscillation during the March T&E block with the goal of quantifying the effect and attempting to minimize the amplitude. The pivot block problem will be analyzed over the next few weeks. Once a design has been tested and approved, we will need to restrict Hydra from use for probably a 5 to 10 day block in order to implement and evaluate the fix. This is not likely to happen until at least the April T&E block.

Minimum Fiber to Fiber Spacing:

Instead of 3.5 mm as the closest approach between positioned fibers, we need a buffer space which increases that tolerance up to 3.875 mm. This is comparable to that used at the 4 meter.

Mean Setup Time per Fiber:

We attempted to minimize the mean setup time but failed to succeed. Fiber positioning overhead is dominated by I/O traffic and somewhat due to the relatively slow accelerations on the servo motors. These overheads are a consequence of the technology in Hydra's motors and controllers. The motors have insufficient torque to reliably run at a higher acceleration which could potentially save a couple of seconds per fiber move. The significant I/O activity is required to send commands and receive status reports from the motor controllers during a fiber move. We estimate that nearly 7 seconds of time is attributed to I/O overhead. Until a modern, programmable controller is implemented, we can not improve upon the I/O overhead.

Improvement in mean setup time can be realized by an upgrade of the motors and controllers to modern technology. Our efforts in development of the Hydra/CTIO instrument are taking into account the possible retrofit of Hydra/WIYN with such an upgrade, assuming that WIYN decides to pursue this as a future instrument improvement project.

Size:

The dimensions of the instrument do not cause any operational problem.

Weight:

The mass of the instrument includes the spacer assembly weight of 91 kg. These masses are estimates, not actual measurements. The instrument mass does not cause any operational problems.

Power:

10 Amps max at 110VAC is the peak power requirement while Hydra is configuring a field. The rms power during a field configuration is about 300 Watts which reduces to about 30 Watts when the instrument is idled for an observation.

Item	Specification	As-Built
Fiber Placement Camera		
Type	Intensified CCD	As specified
Input photocathode	S25 with extended blue response	As specified
(*)Brightness operating range	V=8–21	Not measured
Active imaging diameter	18 mm	As specified
Controls	Power and Gain	As specified
Output	RS170 standard video format	As specified

Brightness Range:

We have not formally measured the limiting sensitivity of this camera.

Item	Specification	As-Built
(*)Field Alignment/Guide Camera		
Type	Intensified Lens coupled CCD	Intensified CCD
Input photocathode	S25	S25 with extended blue response
(*)Brightness operating range	V=11–17	V=9–15
Active imaging diameter	16 mm	18 mm
Controls	Power and Gain	As specified
Output	RS170 standard video format	As specified

Field Alignment Camera:

The ICCD type of camera was selected over the ILS type due to superior performance of the ICCD sensitivity.

Brightness Range:

It is our experience that the sensitivity of this camera requires that guide stars be no fainter than V=15th for optimal guider and focus performance.

Item	Specification	As-Built
Fiber Cable #1 ("blue")		
Fiber Type	Polymicro FVP	As specified
(*)Active and Spare Fibers	100	96 (no spares)
Min. number of active fibers	90	96
(*)Fiber Diameter	300μm	310μm
Length	<25 m	25 m
Transmission	TBD	See figure

Active and Spares:

There were only 97 usable fibers in the blue cable when it was removed from service at the 4-meter. During installation of some fiber loop supports, the single spare fiber was broken, lowering the number to 96 usable fibers.

Fiber Diameter:

310 microns was the diameter of the fiber in use at the 4-meter.

Item	Specification	As-Built
Fiber Cable #2 ("red")		
(*)Fiber Type	Polymicro FBP	FIP
(*)Active and Spare Fibers	100	98 active 2 spares
Min. number of active fibers	90	98
Fiber Diameter	200μm	200μm
Length	<25 m	25 m
Transmission	TBD	See figure

Fiber Type:

FIP is the current identifier for what Polymicro used to call FBP.

Active and Spare Fibers:

Two of the active fibers are actually in spare positions and can be used for scientific observation. Two additional spares are also incorporated which do not currently feed into the fiber slit.

Item	Specification	As-Built
Specification of Foci		
(*)Linear Field	385 mm	381 mm
Wavelength Range	3300Åto 1.5μm	covered in Bench Spectrograph
(*)Field Radius of Curv.	5.51 meter	5.6752 meter
(*)Broadband foc. tol.	delta lam/lam 0.5 for 0.1 arcsec enlarg.	unknown

Linear Field:

This is the same as the specification called "Usable field diameter" discussed previously.

Field Radius of Curvature:

The as-built number is that derived from the best estimate of the as-built optical design.

Broadband Focus Tolerance:

We don't currently have the means to measure this quantity.

3 Misc. Items

The following two items were mentioned in a discussion of remaining Hydra deliverables and are currently unfinished.

Transition Bug in Hydra Software:

The bug which introduced the loss in assignment of an occassional fiber remains. A potential fix has just been developed and awaits testing and verification before being implemented. If valid, this fix will be installed during the March T&E block.

Image Quality Estimator:

Low priority for implementation. Unknown completion date.

Instrument Reliability:

The design changes in the fiber maintenance for Hydra/WIYN from that used at the 4 meter has resulted in a significant improvement in fiber movement reliability. Excluding T&E activity, we have only encountered 1 button move failure in 8700 moves during November and December, 1995. This failure rate of .013% compares to a failure rate of about 0.5% typically experienced at the 4 meter.

Though undocumented, the number of phone calls to assist in instrument troubleshooting at WIYN is also significantly lower than when Hydra was at the 4 meter.

HYDRA-WIYN Spares inventory

LOCATION: Inside upper HYDRA Electronics Rack chassis in Pier

1) spare gripper control card (86-pin custom hand-wired) is the normally unused right side card on front of upper control rack

LOCATION: Hydra/MOS 2nd floor cabinet

2) "Black box" motor control / motor spares

CompuMotor "KS230/240" Servo Drive, (configurable for either X1/X2/Y motors)
CompuMotor "372" single-axis indexer, (configurable for X1/X2/Y axis)
CompuMotor "AX57-51" controller, (drive/indexer for Z axis)

CompuMotor "KS240" Servo Motor (spares X1/X2/Y stages)
CompuMotor AX57-51 NEMA23 Stepper Motor (Z motor)
Airpax #K92121, 1 is prewired, (spares Gripper motor)

Calibration screen DC motor, Micro-MO #3557K012C

3) STD Bus hardware

4 spare STD cards are located in cabinet: VL188-1B CPU, LPM7614 IO, custom WW and LPM7904 motor driver cards, 1 for each system card

Spare VL188-1B CPU EPROM dated 10-31-94, checksum = 43E7, file "hydra.hex".

4) Miscellaneous electrical hardware:

spare AC line fuses (0.5 to 15A) for Power supplies and Racks
spare RS232 linedrivers/modems (RAD SRM5A/5D-M/F)
spare slotted opto (TIL138) for gripper homing
spare, pre-wired Gripper LED ring (3 LED's w/ connectors)
spare electronic components for gripper control cards
(plus a few other assorted "widgets)

5) Miscellaneous mechanical hardware:

spare Cal lamps
spare gripper leadscrew drive belts
spare Helical motor coupling (X1/X2/Y motor connection to screw)
(plus a few other assorted "widgets)

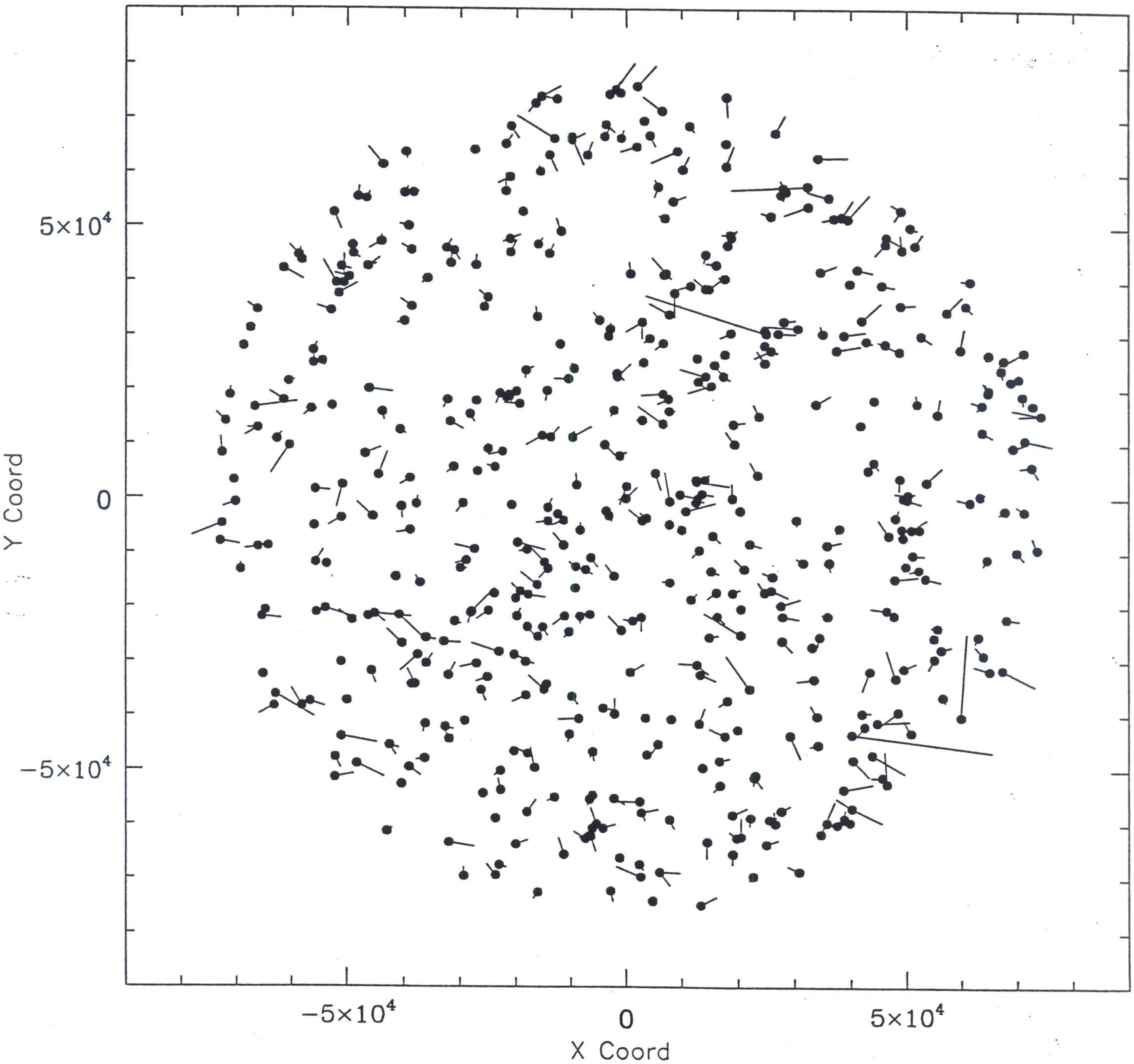
LOCATION: Downtown FO Lab (in box under West table)

6) DRC 24" travel Linear Encoder #LT-4A-0620-CC-03, spares X or Y axis

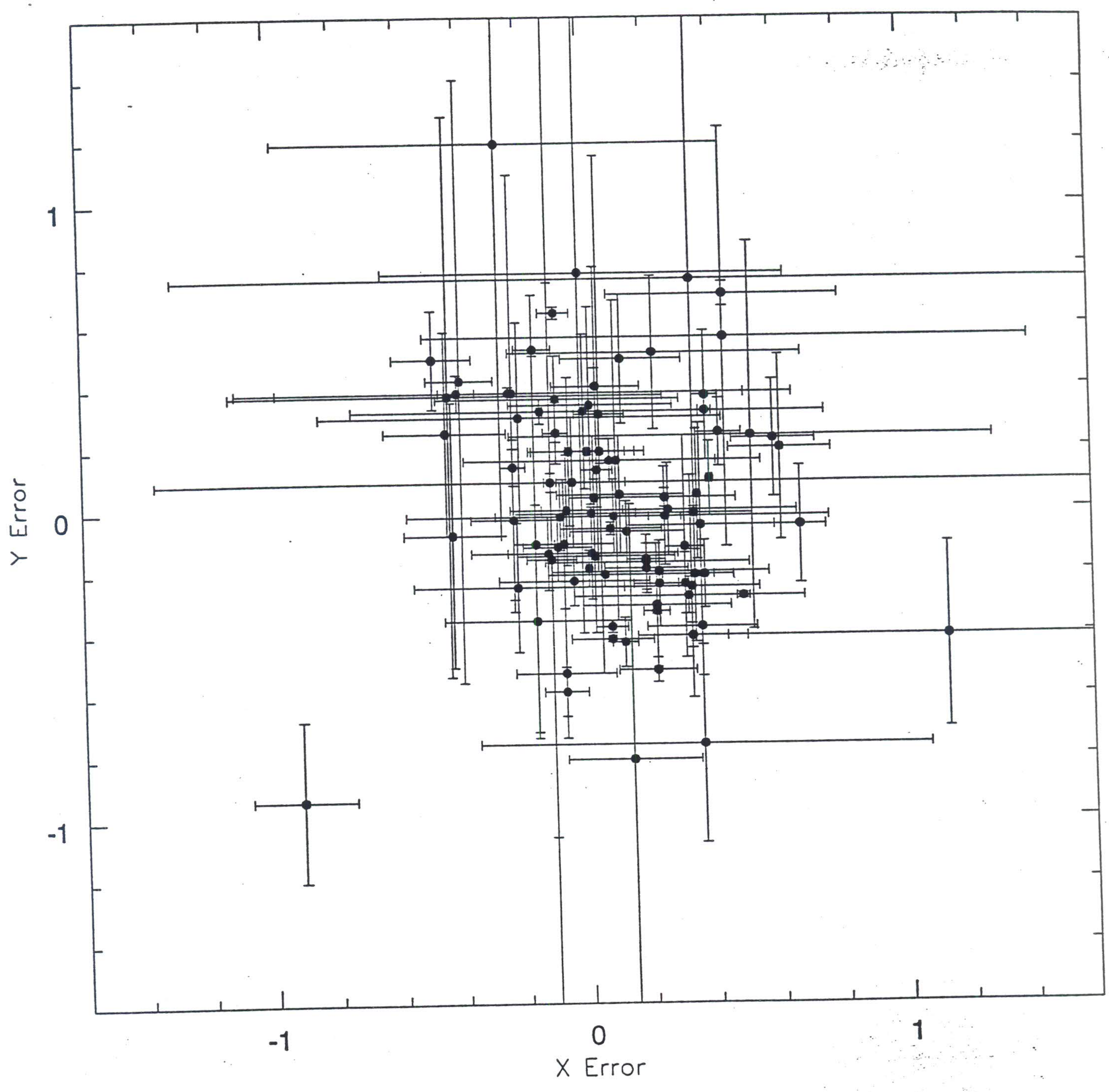
Andy Rudeen 31 jan 96

all of Sam's fields.

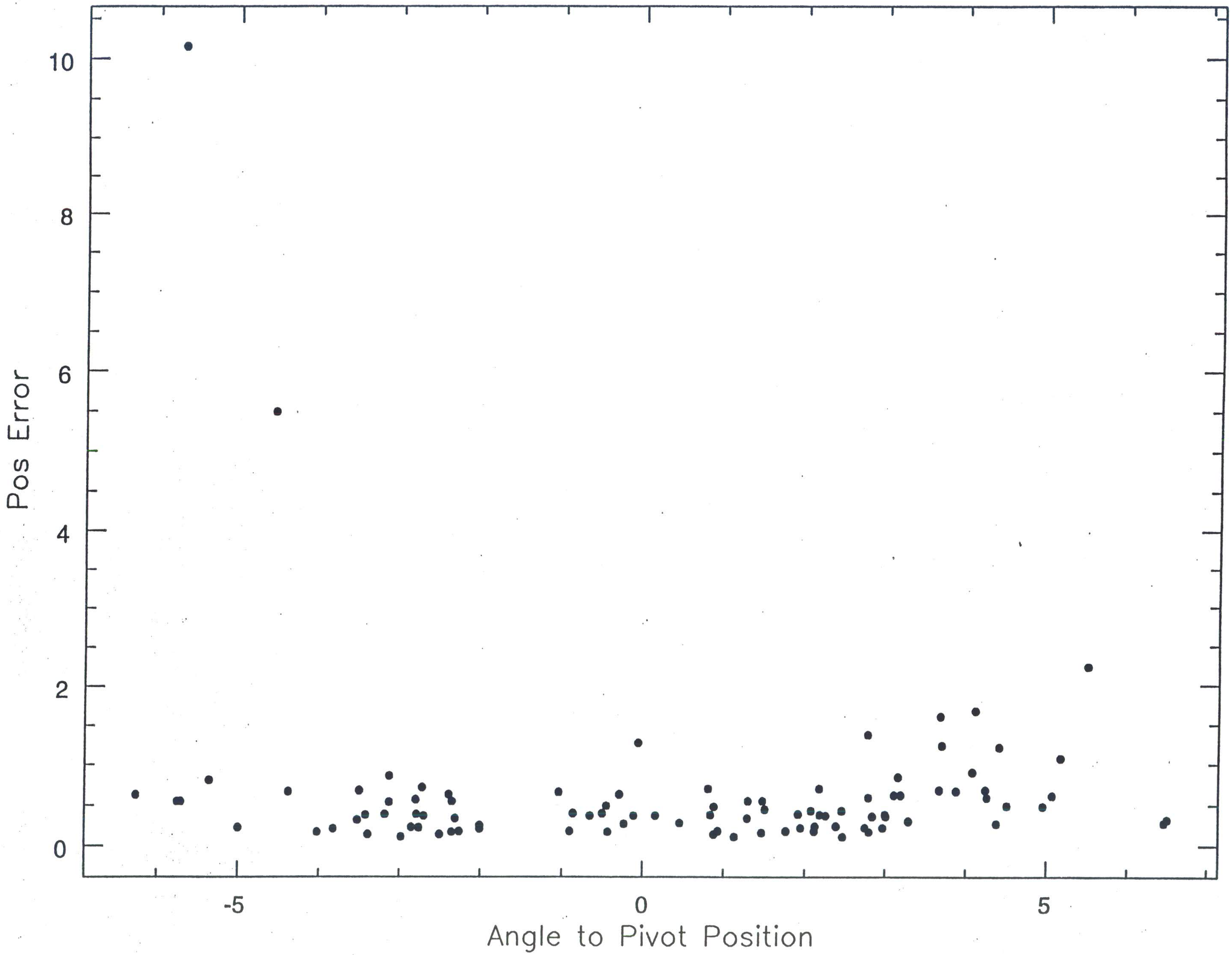
[illegible].dat.out.mod



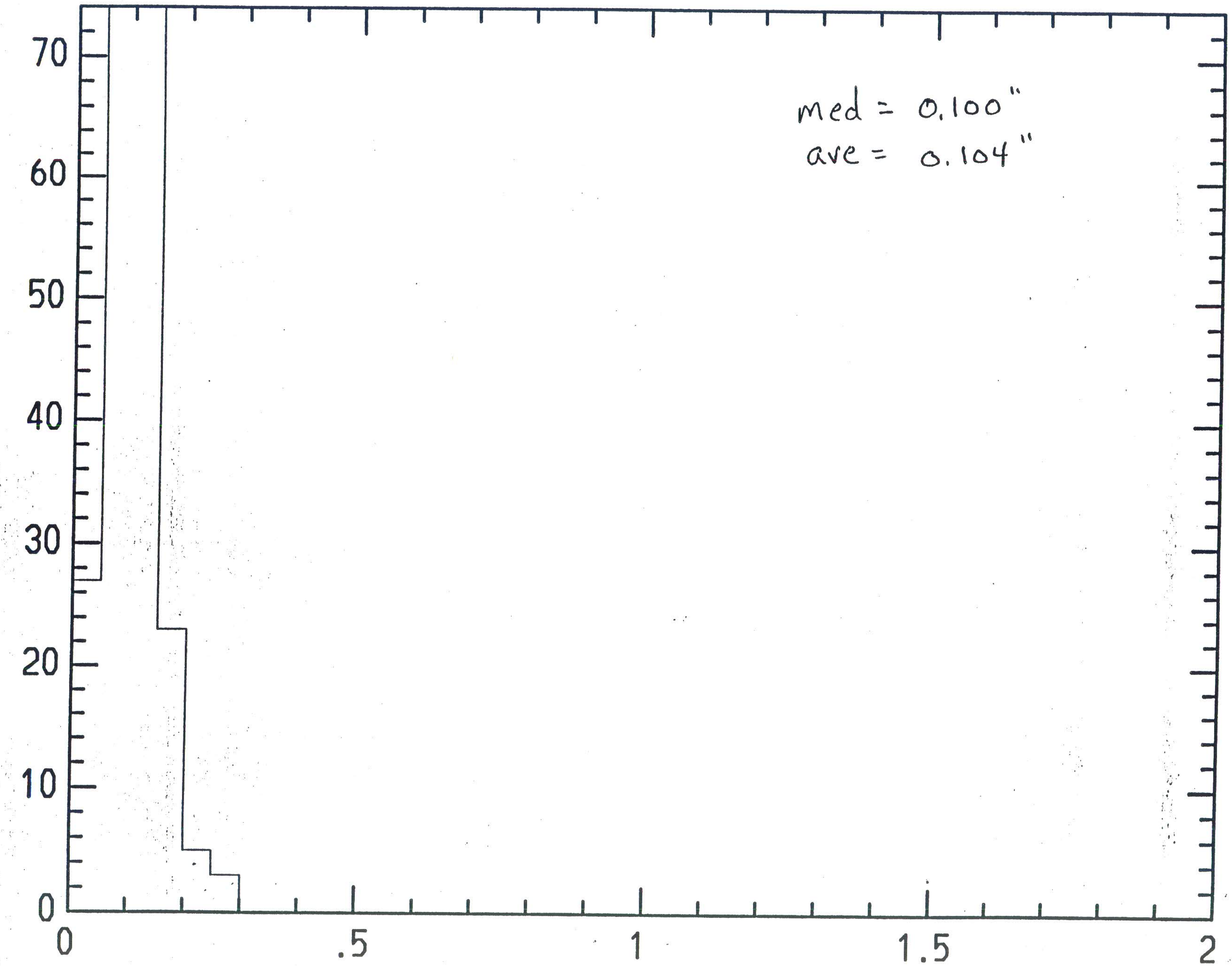
January, Average Results

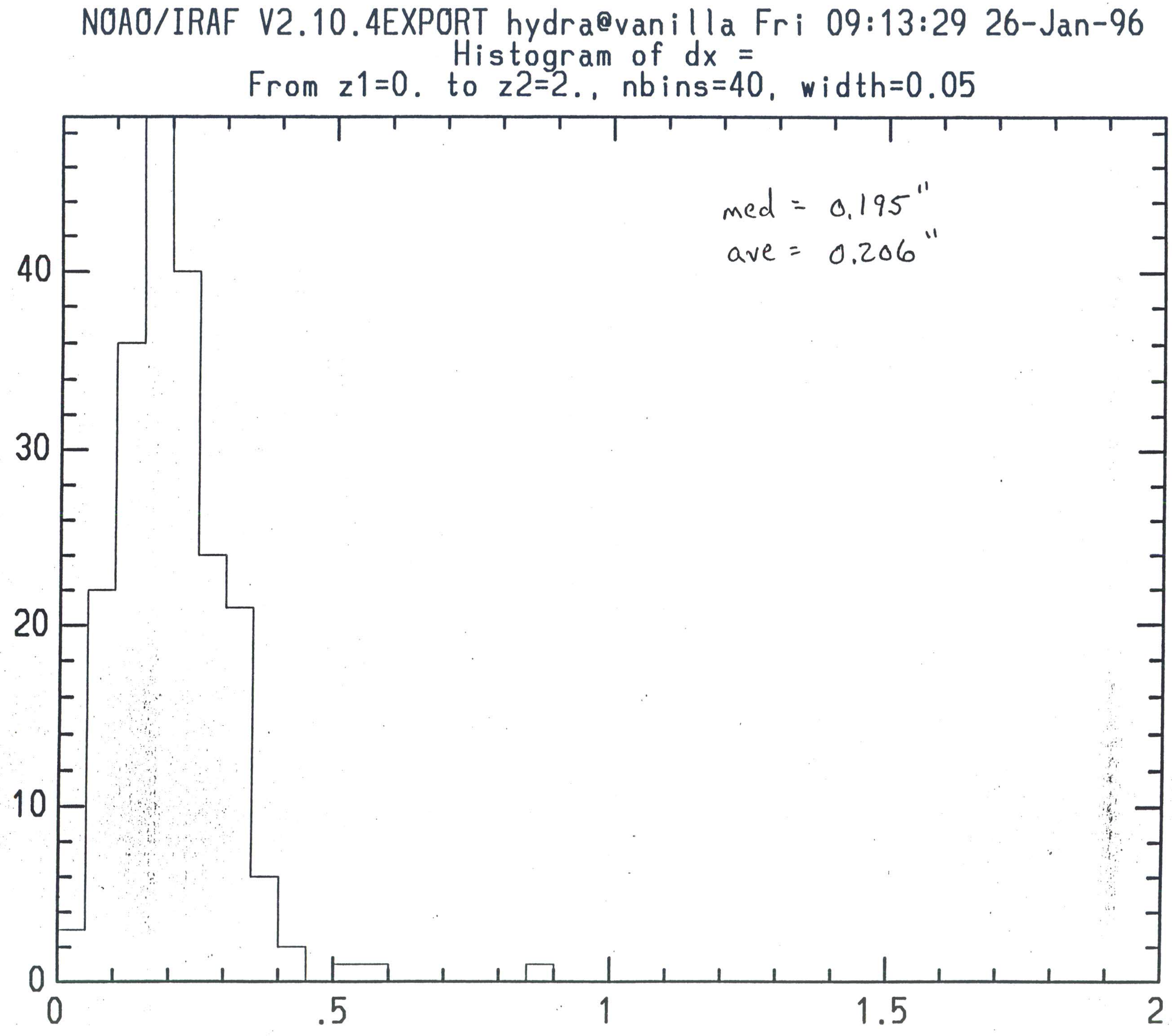


hxperf2a

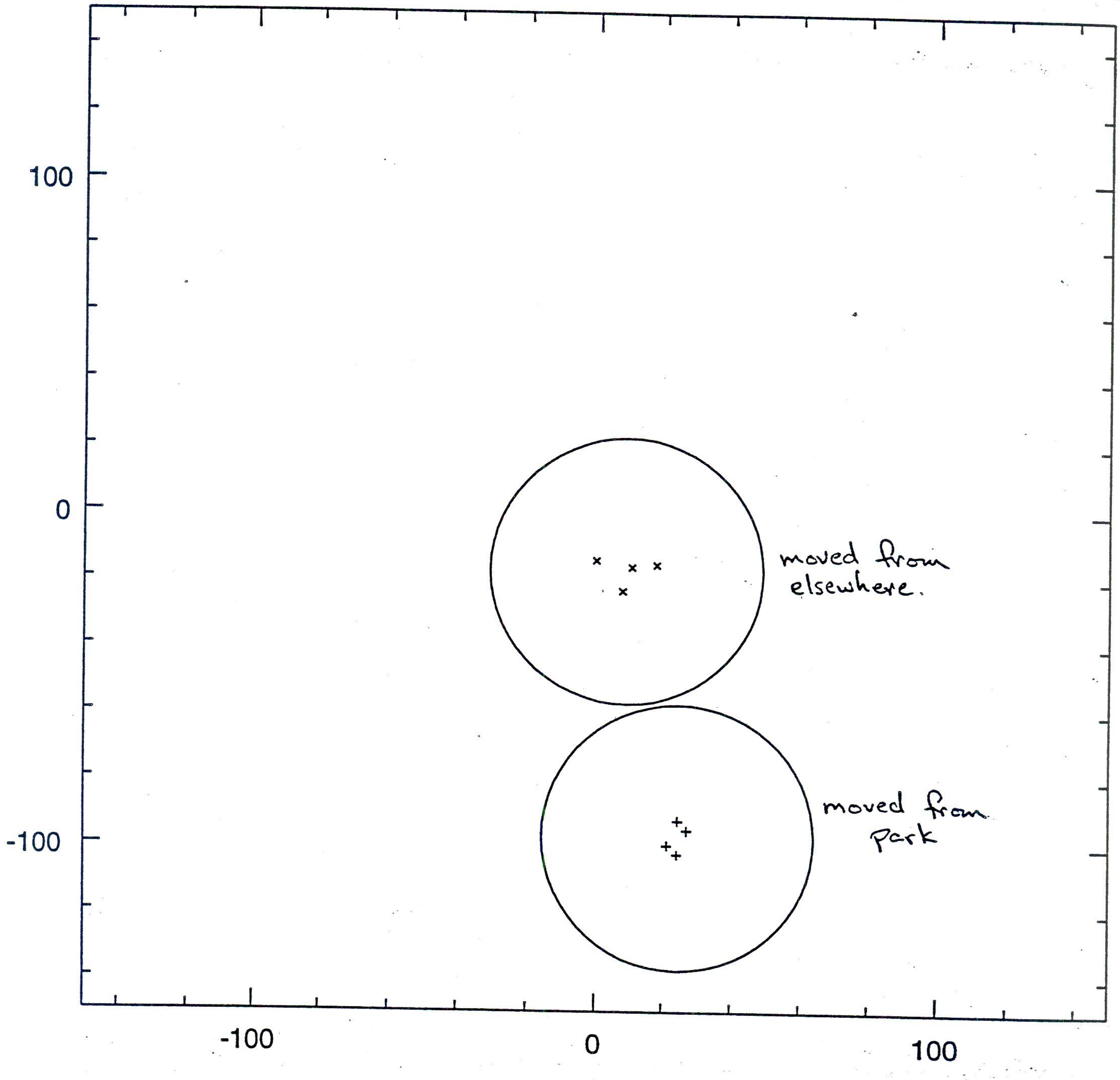


NOAO/IRAF V2.10.4EXPORT hydra@vanilla Fri 09:13:37 26-Jan-96
Histogram of dy =
From z1=0. to z2=2., nbins=40, width=0.05



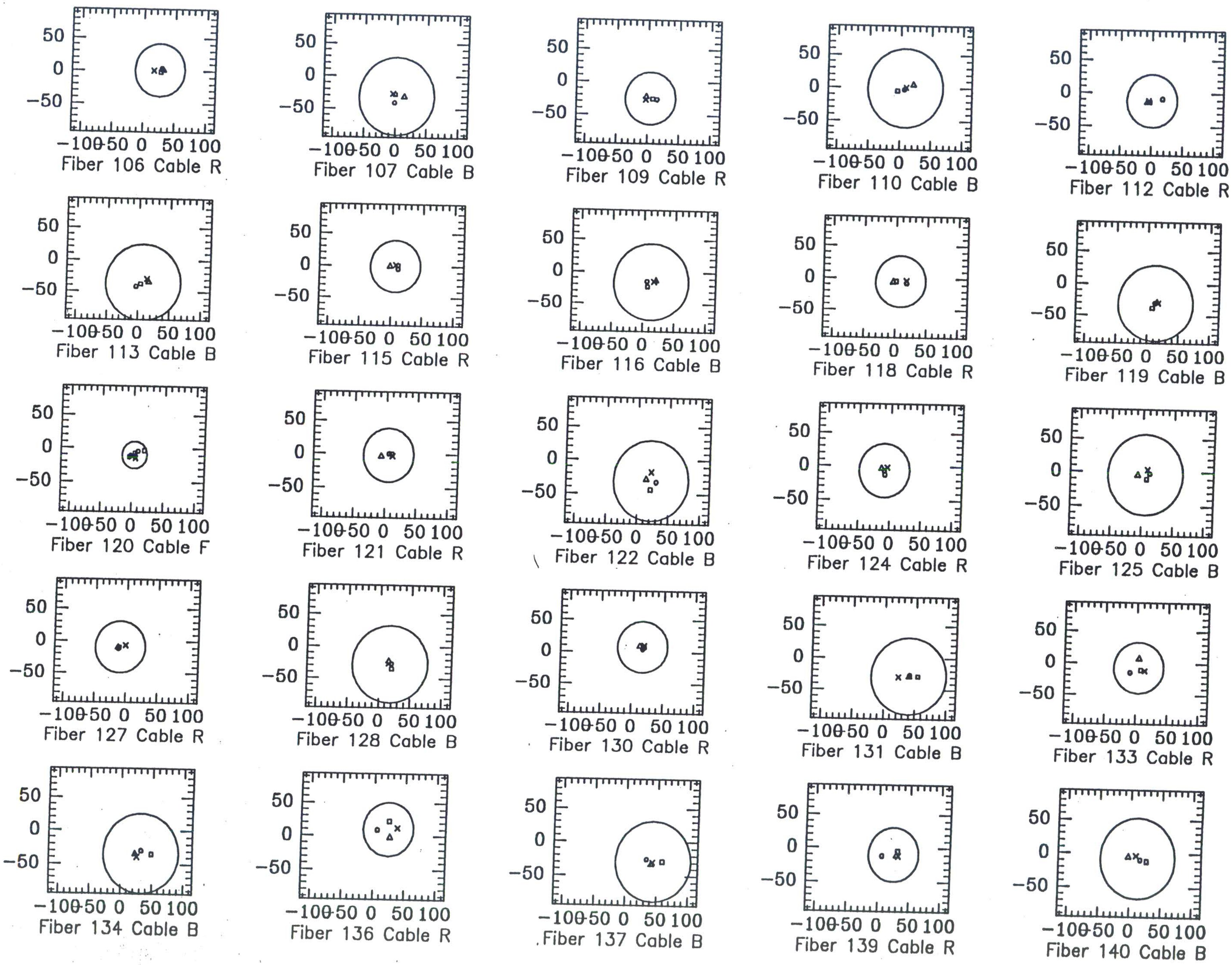


NOAO/IRAF arcon@vanilla Fri Jan 26 09:13:33 1996

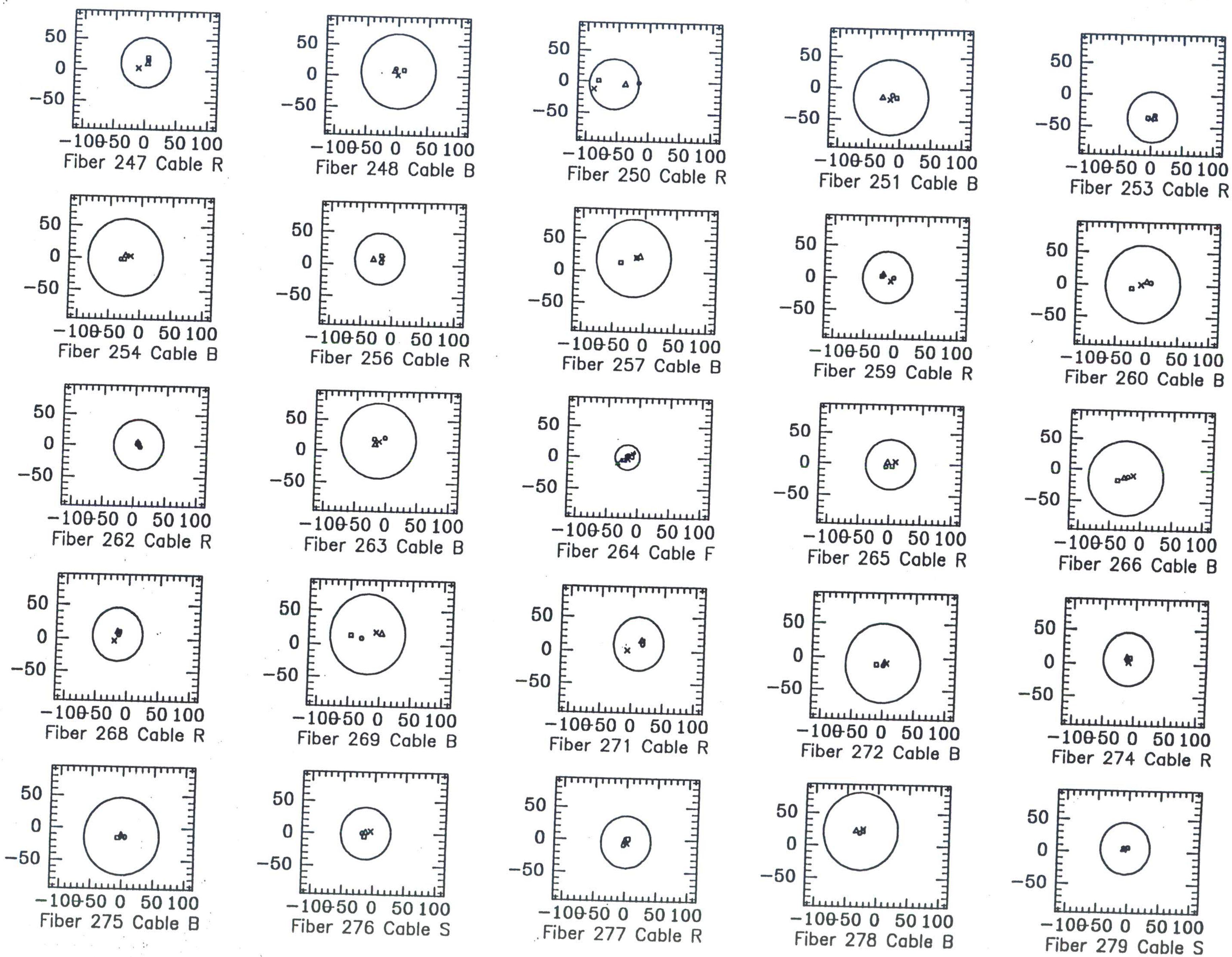


100
0
-100
-100
0
100
moved from elsewhere.
moved from Park

VS11


Fiber 106 Cable R
Fiber 107 Cable B
Fiber 109 Cable R
Fiber 110 Cable B
Fiber 112 Cable R
Fiber 113 Cable B
Fiber 115 Cable R
Fiber 116 Cable B
Fiber 118 Cable R
Fiber 119 Cable B
Fiber 120 Cable F
Fiber 121 Cable R
Fiber 122 Cable B
Fiber 124 Cable R
Fiber 125 Cable B
Fiber 127 Cable R
Fiber 128 Cable B
Fiber 130 Cable R
Fiber 131 Cable B
Fiber 133 Cable R
Fiber 134 Cable B
Fiber 136 Cable R
Fiber 137 Cable B
Fiber 139 Cable R
Fiber 140 Cable B

V5.1


Fiber 247 Cable R
Fiber 248 Cable B
Fiber 250 Cable R
Fiber 251 Cable B
Fiber 253 Cable R
Fiber 254 Cable B
Fiber 256 Cable R
Fiber 257 Cable B
Fiber 259 Cable R
Fiber 260 Cable B
Fiber 262 Cable R
Fiber 263 Cable B
Fiber 264 Cable F
Fiber 265 Cable R
Fiber 266 Cable B
Fiber 268 Cable R
Fiber 269 Cable B
Fiber 271 Cable R
Fiber 272 Cable B
Fiber 274 Cable R
Fiber 275 Cable B
Fiber 276 Cable S
Fiber 277 Cable R
Fiber 278 Cable B
Fiber 279 Cable S

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.

6.1 FIBER SPECTRAL TRANSMISSION

Figure 7 shows the transmission characteristics of the fiber optics. Both red and blue fiber

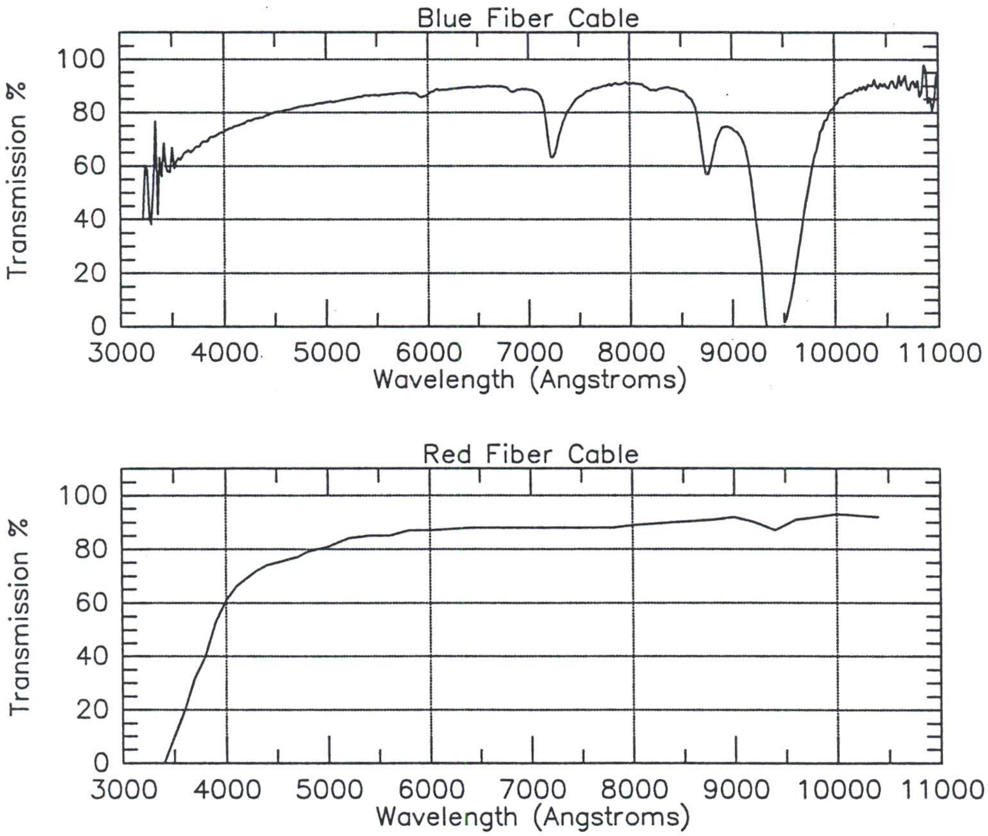


Figure 7: Fiber transmission curves.

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.