

The SQUIID User's Manual

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1. Introduction

The NOAO SQUIID Infrared Camera (Simultaneous Quad Infrared Imaging Device) produces simultaneous images of the same field in the J, H, K, and narrowband L filters, using individual 512X512 quadrants of ALADDIN InSb arrays and is designed for use at the f/15 Cassegrain foci of the KPNO 2.1-m and 4-m telescopes. The observations are generally background (photon statistics) limited. The designated array for each channel is selected for characteristics (read noise, settling time, and dark signal) appropriate to background limited operation under actual observing conditions for its single filter. SQUIID, which serves as its own acquisition camera, is a good match to "point and shoot" observing at the 2.1-m without a telescope operator. The filters are fixed in place and dark slide and window covers are the only moving parts. SQUIID employs closed cycle refrigeration instead of liquid cryogenes and in its prior configuration operated flawlessly for periods as long as 40 days, providing an unparalleled degree of system stability. Typical observing programs include:

- taking a few (2-5) exposures on the same target with small offsets (to counter ghosts and bad pixels and improve spatial sampling of the images);
- taking many exposures of the same target with a dither pattern of offsets (to build up long exposures);
- spatial mosaics of dithered pairs of images covering larger regions with limited overlap between images (to build up large images).

Each detector is a Raytheon Vision Systems (nee SBRC) ALADDIN 1024X1024 indium antimonide (InSb) hybrid focal plane array with 27 micron pixels (90% geometric and 100% optical fill factors) produced

under contract to the ALADDIN Consortium. The ALADDIN Consortium, consisting of NOAO/KPNO and the US Naval Observatory, Flagstaff, under the engineering guidance of Al Fowler, has designed, developed, characterized and optimized the performance of the ALADDIN array for the wider community. Since each SQIID channel illuminates a single 512X512 quadrant, devices need only one otherwise excellent operable quadrant to be acceptable. The optics for each channel are independently optimized with a relatively narrow bandpass (apart from the entrance window, which is shared in common), permitting high efficiency AR coatings to deliver high instrumental throughput. The four separate channels are co-focused and co-aligned with a minimum overlap region of roughly 500X500 pixels common to all channels and are physically edge-masked to stop stray light from entering (or leaving) the readout. The detectors are of sufficiently high quality and uniformity that the dark/sky subtracted raw data are useful in assessing data quality in near real-time.

Detector area, stability, uniformity, quantum efficiency, low read noise and dark signal combine to make SQIID the system of choice for any observation which requires multi-color (JHK) imaging over large areas of the sky, quick look at transient targets, and for deep observations of selected regions. IR observations of necessity consist of sequences of frames with interspersed telescope motions. Each set includes a subset of small telescope motions (dithering) to dodge bad pixels and provide better image sampling and may require equal time spent off target (especially when observing extended sources and/or crowded fields). Typically the minimum time spent on taking a complete set of frames at a given field (within detector FOV) can be on the order of 10 minutes or more. With a single channel imager, the same set of pointings needs to be repeated for each filter. Since variations in observing conditions - seeing, airmass, sky transparency, and atmospheric background - ultimately limit the cohesiveness of a data set, multi-color observations are necessarily limited in depth and/or areal extent by the mechanics of taking the observations and the systematic effects of combining them into a single coherent data set. The advantage of SQIID is self-evident. During the time necessary to take the observations at the most time consuming wavelength, one in effect gets the other channels for free under the same observing conditions. Systematic effects are limited and determinate. This is why SQIID competes favorably with larger format arrays for multi-color applications. In addition, wide field L band imaging is possible (albeit with restricted bandpass) with sufficient sensitivity to detect and accurately locate red sources in the field. This feature is particularly important for detecting and identifying for further study sources with IR excess, highly reddened sources, and intrinsically cold sources near the galactic plane where the star formation process is still active.

Details of the prior SQIID system are discussed by Ellis et al. 1992 ("The Simultaneous Quad-color Infrared Imaging Device (SQIID): A Leap Forward in Infrared Cameras for Astronomy" by T. Ellis, R. Drake, A. M. Fowler, I. Gatley, J. Heim, R. Luce, K. M. Merrill, R. Probst, & N. Buchholz, 1992, in *Proc. SPIE*, **1765**, pp. 94-106.) and the ALADDIN detectors are discussed by Fowler et al. 1996 ("ALADDIN, The 1024x1024 InSb Array: Design, Description, and Results", by A. M. Fowler, Ian Gatley, P. McIntyre, F. J. Vrba, & A. Hoffman, 1996, in *Proc. SPIE*, **2816**, pp 150-160).

2. Instrument Description

Optical Description

The SQIID optical system, which is matched to f/15, has a demagnification of 4. The pupil masks are fixed (i.e., not selectable), but a reasonable compromise for the 2.1-m and the 4-m telescopes has been implemented (n.b., by design, the KPNO IR secondaries handle the central obscuration without requiring a separate cold stop within the pupil mask.) According to Charles Harmer (who has the current design available), the worst case blur circle for SQIID is about 75 microns with 90% encircled energy. The optical layout of SQIID is shown in Fig. 1. The f/15 telescope focal plane is located inside the entrance window near the top of the instrument. A series of dichroics and flat mirrors separates the incoming beam into four separate wavelength channels, each with its own camera (Lyot stop, filter, optics) and focal plane array.

Dichroic #1 passes L and reflects JHK. Dichroic #2 passes H and reflects JK. Dichroic #3 passes J and reflects K. The telescope exit pupil is imaged at the Lyot stops that are sized to the exit pupil image diameter to serve as an optical cold stop. Standard astronomical passband filters located at the Lyot stops restrict the range in wavelength passed to the array.

The system of dichroics is matched to natural atmospheric windows, adequately spaced in wavelength so that their in-band transmission and out-band reflectivity is very high. Since each camera is designed for optimum performance over a limited wavelength range, the AR coatings provide unusually high transmission. The opportunity for optimizing each channel for operation over a restricted wavelength compensates for transmission losses within the dichroic system and has yielded high throughput in all channels, comparable to that of a single camera system.

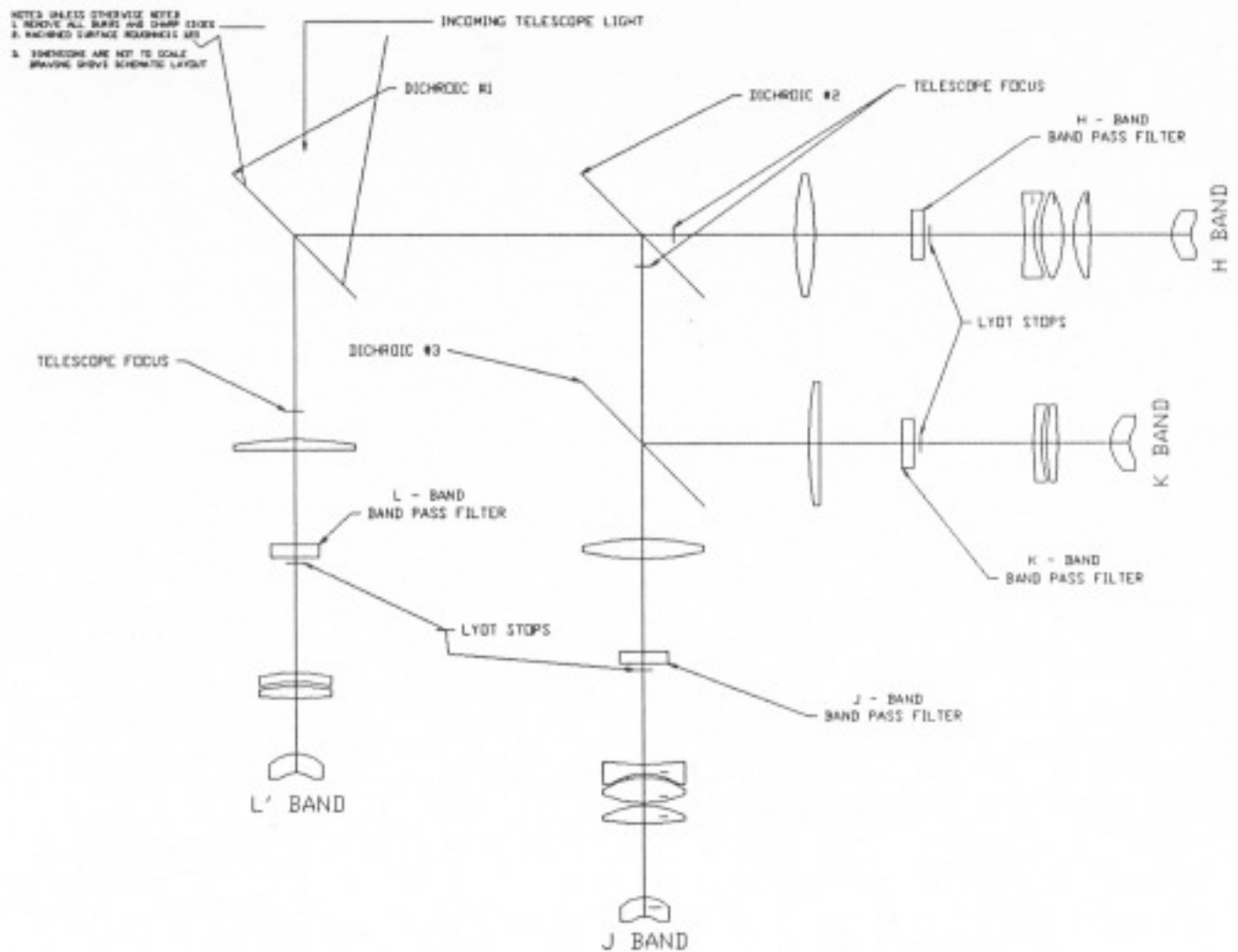


Figure 1. SQIID Optical Schematic

Fig. 1 - Optical layout of SQIID. The elements are identified in the text.

SQIID, which was built in an era where 58X62 was standard and initially deployed (1990-1995) with 256X256 Platinum Silicide arrays, was designed to smoothly accommodate larger devices. The optics was designed to illuminate a 512X512 array of 25 micron pixels. Since the ALADDIN array has 27 micron

pixels, some vignetting is inevitable. In addition, upon seeing the full FOV for the first time, we discovered some unintended vignetting in RA within the instrument that would require a substantial effort to rework. The pixel scale and the unvignetted spatial coverage at the two telescopes are summarized in Table 1.

Table 1. Pixel Scale and FOV

Telescope	f/ratio	arcsec/pixel	# pixels	RA X DEC field (arcsec)
2.1-m	15	0.69	440 X 460	304 X 317
4-m	15	0.39	440 X 460	172 X 179

Filters

Each channel of SQIID has its own fixed filter. *We are unable to accommodate other filters tailored to specific programs.* The deployed filter complement as of February 2002 is summarized in Table 2. **Note: Prior to February 2002, the K channel contained a Barr K filter.**

Table 2. SQIID Filters

Channel	vendor ID	midpoint (microns)	FWHM bandpass (microns)	HP short (microns)	HP long (microns)
J	Barr J	1.267	0.271	1.131	1.402
H	Barr H	1.672	0.274	1.535	1.809
K pre 02/2002	Barr K	2.224	0.394	2.027	2.421
K post 02/2002	OCLI Ks	2.225	0.35	1.95	2.30
L	Barr PAH	3.299	0.074	3.262	3.336

J filter data are estimated from the manufacturer's warm tracing by applying 1.63% shortward shift. Other data are from manufacturer's 77K tracings. Dichroic transparency has not been applied.

The geometric distortion is comfortably small within the unvignetted area, so that the data from the different channels can be brought to a common basis using a superposition of linear transforms (position shift, rotation and magnification) and a modest amount of pincushion/barrel distortion. (Note: J has pincushion distortion and HK have nearly identical barrel distortion.) The geometric distortion appears to be radially symmetric and is well represented by the addition of a cubic term. This simplifies the data reduction enormously, as spatial registration at any channel can be directly translated into registration at all channels.

Since the individual channels of SQIID illumine a single quadrant of a four quadrant array (which is has to be physically mounted within a small volume so as to not interfere with its neighbors) and the best quadrant of each device is selected, the relative orientation on the sky on the array is channel specific. From the point of view of the array, which is read from the outside corner (see Fig. 13, rows are oriented along the horizontal and columns along the vertical), the sky is "natively" seen oriented as follows:

J	H	K	L
W	N	S	E
S N	W E	E W	N S
E	S	N	W

Initially, SQIID data were displayed and saved oriented as shown. **As of September 2000, the saver task correctly handles the orientation issue during the saver process. Images saved to disk (and automatically displayed) are properly oriented with North up and East to the left.**

Mechanical Description

Located at the telescope focal plane are the imager cryostat, the mechanical interface, and the associated warm electronics in two boxes mounted to the instrument. Fig. 2 shows a side view of the instrument and identifies the important parts. SQIID communicates with a remotely located instrument computer and ultimately with the user in a remote observing room (Fig. 3). Even though the f/15 focal plane at the 4-m is well back from the "nominal" focal plane of the telescope, a re-imaging lens in each guide probe assembly permits them to be used for guiding and precision offsetting.

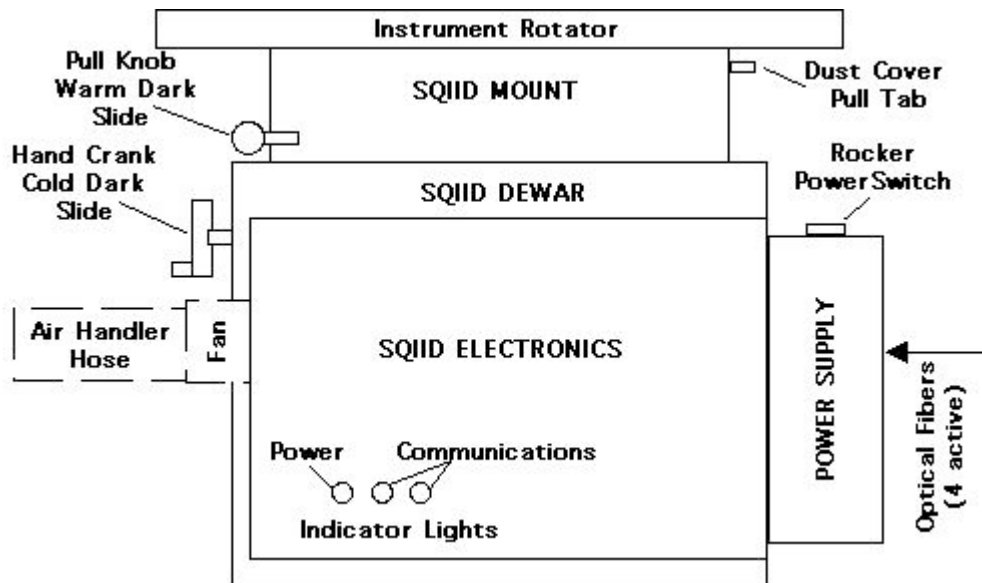


Fig. 2 - Side View of SQIID

SQIID's temperature is maintained by a pair of Closed Cycle Cryogenic Coolers that employ pressurized helium gas as a refrigerant. Most of the internal parts, including the dichroics, optics, and filters, are cooled below 70 K with the first stage of the Closed Cycle Cryogenic Coolers. Each array is operated at ~30 K by a thermal strap to the second stage of the Closed Cycle Cryogenic Coolers plus a closed loop heater circuit.

Refer to Fig. 2 to identify the external features of the instrument. SQIID will be cabled upon installation, and **should not be uncabled for any reason without contacting KPNO staff first**. The only necessary user contacts with the focal plane instrument are the instrument power switch located on the electronics box and the mechanisms for inserting the internal and external dark slides.

3. Command, Communication, and Control

SQIID operates through a distributed computer network that has slowly evolved to meet changing needs of computer support. Historically SQIID was operated by the user from a SUN workstation in the telescope control room through the WILDFIRE system, a transputer based system that communicates over optical fibers. WILDFIRE supports fast co-adding in place, movie mode, and data transfer directly to the SUN.

Since WILDFIRE is tied to Sbus based hardware and a SunOS host system there is little room for growth in the core machine. The system was hard pressed by the upgrade from four 256X256 arrays to four 512X512 arrays during the SQIID upgrade. Movie mode was dropped owing to I/O delays associated with this upgrade.

The current configuration has SQIID remotely operated from a Linux-based Workstation (physically located in the control room) that connects to the SQIID host Sun Workstation (now completely in the computer room) through a VNC server.

The WILDFIRE system uses transputers and transputer links to control and acquire data from SQIID. A transputer is a single-chip microcomputer with its own local memory and communication links, which can operate either by itself or in conjunction with other elements linked to form computing arrays and networks. The WILDFIRE system consists of three main hardware components:

- The SQIID instrument control unit inside the DCU (Digital Control Unit) box contains two transputers that provide housekeeping data and control and generate the sequences that operate each array.
- The DSP unit (a VME based Digital Signal Processor system located inside the black Heurikon box in the computer room) contains eight transputers that provide the math processing needed to do coadding as the data are taken and buffer space for finished data before it is transferred to the SUN computer.
- The B016 unit (a programmable dual-port memory and interface board located inside the black Heurikon box in the computer room) interfaces the transputers and the SUN and handles the formatting of data before it is saved to disk.

Communications between SQIID and the DSP take place over transputer links implemented on an optical fiber cable. The B016 interconnects the transputer DSP to the SUN SparcStation computer via a VME to SBUS converter within the Heurikon box.

The WILDFIRE user interface on the SUN is implemented within the TCL (tool command language) environment. On startup, one can configure the image save to produce either FITS images or IRAF images (via IMFORT routines) so that they can be manipulated and archived to tape within IRAF. The image data are generated in IEEE 32-bit floating point format. It is important to note that these images are NOT PROTECTED in any way and can be overwritten if the full path names of existing and new images are the same. (Currently the saver task attempts to manage conflicting filenames by appending ".nnn" to the incoming conflicting filename.) The data may be written to Exabyte or DAT tapes on local tape drives or sent via 'ftp' to one's home institution. Depending on the amount of header information, a single FITS file of a 512 X 512 image is about 1.057MB and a single 4 color exposure is 4 images (4.2MB).

Under the present version of WILDFIRE data acquisition:

- At the 4-m, SQIID is accessed from the Linux workstation *tan* which is connected via VNC to the SQIID host Sun computer *khaki*.
- At the 2.1-m, SQIID is accessed from the Linux workstation *sapphire* which is connected via VNC to Sun computer *lapis* which handles the SQIID host Sun computer *royal* remotely.

It is interesting to note that the current arrangement allows SQIID operations to be viewed remotely. However, since hosting multiple VNC connections places an undue burden on the Sun systems, this is not recommended for continuous useage.

A separate Linux based system serves as the telescope control, with a terminal at the LTO station; a hardwire link between the TCS and instrument control computers is used to send TCS commands to the

telescope (singly, or within TCL scripts) and to retrieve telescope information for the image header. A schematic depiction of this arrangement is shown in Fig. 3.

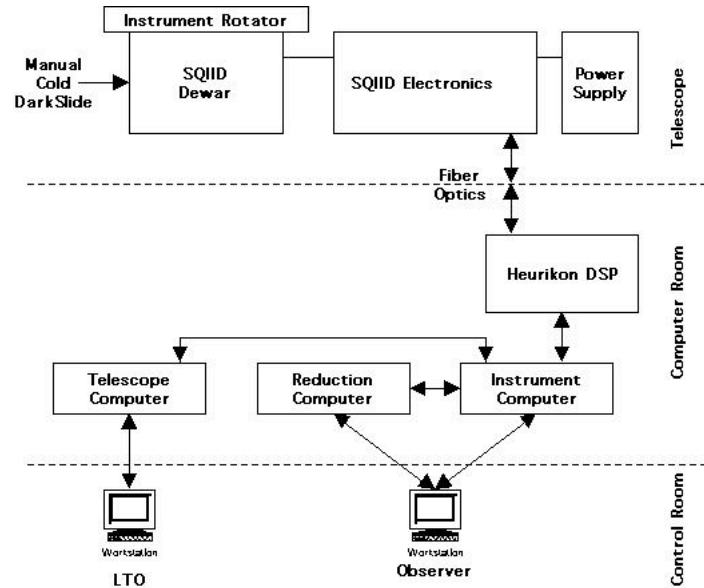


Fig. 3 - Schematic configuration of electronics and computers used with SQUIID/WILDFIRE

Important Note: The disks within the primary workstations *khaki* and *lapis* are designated `/data1`. At the 2.1-m, WILDFIRE is run on the secondary workstation *royal*, whose partition is `/data2`. The disks are cross-mounted so that access to both is possible from either machine. However, such cross-access (e.g., `/data1` from *royal*) is significantly slower than accessing the disk resident in the workstation. Therefore, it is *imperative* that the partition used for storing data taken by WILDFIRE be `/data2` on the 2.1-m telescope! While it is possible to designate `/data1` as the WILDFIRE data partition, operation will be much slower and subject to crashes, so don't do it. At the 4-m, one may designate either `/data1` or `/data2` as the data partition.

WARNING: Do not let the designated data disk fill up. You will lose data! The filenames may appear, but they will have zero length. (The WILDFIRE housekeeping screen reports available space.) See [Appendix VI](#).

4. The InSb Detector Array

The four detectors in SQUIID are ALADDIN 1024X1024 hybrid focal plane InSb arrays produced by Raytheon Vision Systems (nee Santa Barbara Research Center). They consist of a photovoltaic InSb detector array mated to a silicon direct readout multiplexer via indium bumps. The readout is a p-channel MOSFET device. The ALADDIN array was cooperatively designed and developed at RIO/SBRC with the ALADDIN Consortium, consisting of NOAO and the US Naval Observatory, Flagstaff.

The device is presently operated in a non-destructive readout mode providing double correlated sampling. A representation of the voltage on a single pixel during an integration and readout is shown in Fig. 4. An address cycle consists of a "reset" to the canonical detector bias voltage, a non-destructive "read", followed by a second "read". During the reset operation, the voltage on each pixel is set to the value V_R . When the reset switch is opened, the voltage left on the sense node will differ slightly from V_R , due to charge

spillback from the reset gate and from "kTC" noise. After a time 'fdly', the voltage on the pixel is sampled nondestructively (i.e., without resetting), yielding V_1 . After a second time interval, defined as the integration time, the voltage is again sampled, yielding V_2 . The "signal" is the difference between the two reads. Note that this technique, known as "double correlated sampling" eliminates the effect of the transient following the reset operation. The intervals indicated (not to scale) at the bottom of Fig. 4 represent the time required to carry out each operation on the entire array; thus, on an absolute frame, the time at which a given pixel is reset and read depends on its location in the array.

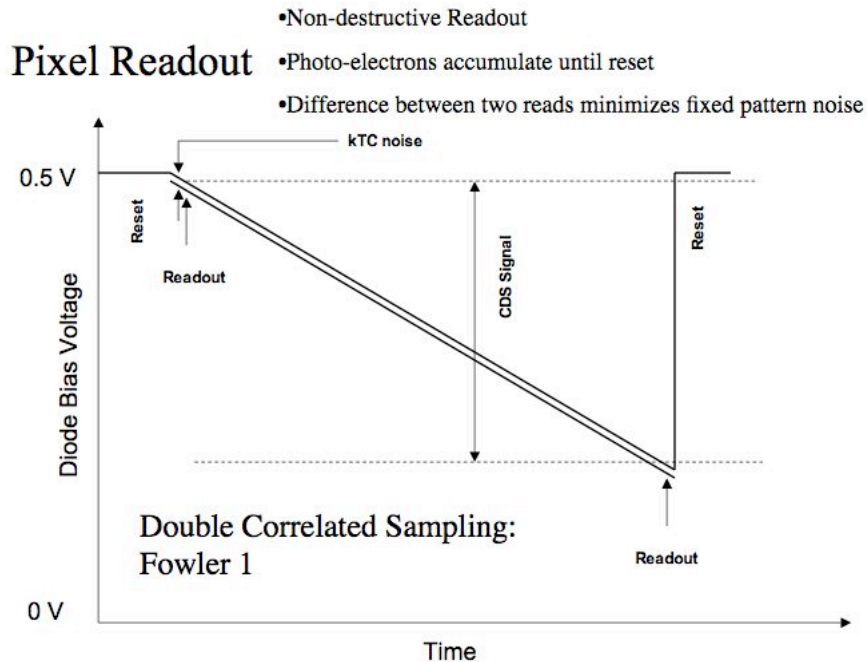


Fig. 4 - Schematic representation of the voltage on a single pixel as a function of time. The intervals labeled "reset" and "readout" suggest the time when these events occur and are not to scale.

The operating microcode for ALADDIN arrays includes a provision for "multiple correlated sampling" (frequently referred to as Fowler sampling in deference to its discovery, Al Fowler of NOAO) in which the "reads" consist of a series of N nondestructive reads coadded to yield the values V_1 and V_2 . This greatly reduces (by approximately $N^{0.5}$) the array read noise on long, low-background integrations. *Since SQIID observations are generally background limited (specifically, they are not detector limited), we only use "Fowler 1" which corresponds to double correlated sampling.* At the shortest integrations (within the SQIID environment) selecting "coadds ≥ 2 " also improves S/N (by approximately $N^{0.5}$).

Table 3 summarizes the device characteristics and measured performance levels (according to standard lab protocol) of the ALADDIN arrays assigned to SQIID. SQIID was designed for background limited performance at low to moderate backgrounds. The ALADDIN array has 27 X 27 micron pixels with 90% geometric fill factor (100% optical fill factor) and a 1024 X 1024 format comprised of 4 electrically independent quadrants. The ALADDIN2/ALADDIN3 readout designation corresponds to improvements in the readout design. **Note: Table 3 reflects the array assignments within SQIID as of February 2002. The prior configuration was SCA49484_Q3 at H channel, SCA41375_Q3 at K channel and SCA414107_Q3 at L channel. The bias values listed are effective as of January 2005.**

Table 3. SQUIID Arrays

Characteristic	J	H	K	L	Comments
SBRC Identification (Quadrant)	SCA 45986 (Q3)	SCA 46888 (Q4)	SCA 414375 (Q2)	SCA 415412 (Q3)	ALADDIN InSb
Readout type	ALADDIN2	ALADDIN2	ALADDIN3	ALADDIN3	version
Response uniformity	+/-5%	+/-5%	+/-5%	+/-5%	within FOV
Quantum efficiency	95%	95%	95%	85%	in band
Bias	600	600	700	800	mv
Full well	>200000	>160000	>200000	>300000	electrons
lab read noise	40	45	35	35	electrons rms
lab dark signal @ 300mv bias	0.3	0.4	0.6	0.1	electrons/sec
Conversion gain	10	10	11	11	electrons/ADU
Cosmetics	isolated regions	isolated pixels	reduced QE region	isolated pixels	primary defects

It is useful to note that "dark current" is a function of applied bias and because both "dark current" and read noise are temperature dependent in opposite senses (below 40K "dark current" decreases with decreasing temperature to a minimum near 30K and read noise increases with decreasing temperature from a minimum near 40K) they cannot both be minimized. Hence the array operating temperature is generally selected to provide an application (background) specific compromise. Further information on the array design and operation may be found in Fowler et al., *Proc. SPIE*, **2268**,340-345 (1994), and in Fowler et al., *Proc. SPIE*, **2816**,150-160 (1996). The multiple correlated sampling technique used for read noise reduction is described in Fowler and Gatley, *Ap. J. (Letters)*, **353**, L33 (1990).

Telescope performance is covered in Section 5. The relatively high dark signals listed in Table 4 - which do not compromise performance - are indicative of compromises in the instrument design (not intended for low backgrounds), the need to operate at high bias, and the freedom to deploy specific arrays that might be unsuited to more demanding applications.

5. Observing Run Preparation

The limiting performance of SQUIID depends on a number of factors.

System Responsivity

Typical observed fluxes for a 10.0 magnitude star at the 2.1-m telescope are listed in Table 4. By direct measurement the fluxes are a factor of 3.21 higher at the 4-m telescope and the sky background per pixel is essential the same. The conversion gain is a detector-specific 10-11 electrons/ADU. **Note: the biases listed are not necessarily the current bias values.**

Table 4. SQUIID Performance on 2.1-m

channel	J	H	K	L	comments
10 mag star within aperture	3.25e4	2.90e4	1.78e4	?	ADU/sec
Sky brightness level	98	421	387	???	ADU/sec/pixel
Sky brightness origin	OH airglow, scattered light	OH airglow, scattered light	OH airglow, thermal emission	thermal emission	Note: components vary in intensity
Conversion gain	10	10	11	11	electrons/ADU
Bias	600	600	700	800	mv
Full well	>200000	>200000	>200000	>250000	electrons
in situ read noise	40	40	35	35	electrons rms
in situ dark signal	21	32	197	26	electrons/sec
Minimum integration time	0.84	0.84	0.84	0.11	seconds

The estimated limiting magnitude for $S/N = 3$ in 60 sec integration time for a point-source (pt: mag) and a diffuse-source (diff: mag/square_arcsec) under average conditions (temperature = 50F; 3mm PWV; midrange OH background) sans sky subtraction is summarized in Table 5. For the purposes of this calculation, a 10 pixel collecting area on the sky is assumed. In practice, observing limits are dependent on the mode of sky subtraction employed. When mapping an extended region, the number of frames available for producing sky frames significantly exceeds the depth at a given position, virtually eliminating the sky subtraction "penalty". However, *for the case where sky frames are exposed for an aggregate time comparable to that of the source frames, sensitivity is reduced by $0.376 * \text{mag}$ ($2.5 * (\log(\sqrt{2}))$) from the values listed in Table 5* . Such is often the case for deep integrations of individual fields.

Table 5. SQUIID limiting magnitude for $S/N = 3$ in 60 sec

Channel	2.1-m pt	2.1-m diff	4-m pt	4-m diff
J	19.8	20.2	21.1	21.3
H	18.9	19.7	20.2	20.4
K	18.3	19.2	19.6	19.8
PAH	12.3	13.1	13.5	13.7

Sky Background

There are two predominant sources of sky background, which are essentially independent, both physically and spectrally. The transition between the two occurs at approximately 2.3 microns. Short of this wavelength, the sky background is dominated by emission lines from OH in the upper atmosphere (typically 90 km altitude). The strength of these lines can vary over the course of the night with a timescale on the order of an hour; in addition, upper level winds generate inhomogeneities and overall [motion of the airglow](#). As a result, the intensity of the background emission can vary unpredictably during the night. Beyond 2.3 microns, thermal emission from the telescope optics and sky is the predominant background. This roughly follows a blackbody at ~300K temperature and increases very rapidly with increasing wavelength. To further complicate matters, atmospheric lines (primarily H₂O, HDO, CH₄, and N₂O), which show up as absorption features in spectra, appear as emission features in the sky background, so that the loss of signal and the increase in background are temperature and wavelength dependent. For imaging one generally ignores the finer points and treats the longer wavelength filters like their shorter wavelength brethren when processing data.

One must be prepared for the simple fact that IR observations are subject to a wider range of sensitivity variations linked to changing environmental conditions (OH airglow and temperature) than the optical, where phase of the moon and sky transparency predominate. Table 6 estimates the relative sensitivity for SQIID for three levels of OH airglow.

Table 6. Estimated SQIID performance variation with OH airglow

Airglow	J	H	K	L	Comments
low	+0.25	+0.25	+0.08	+0.00	magnitudes improvement
medium	+0.00	+0.00	+0.00	+0.00	magnitudes improvement
high	-0.24	-0.20	-0.10	+0.00	magnitudes improvement

Estimates of the relative background and sensitivity variation for SQIID for three different ambient temperatures and 4 values of Precipitable Water Vapor are summarized in Table 7 and Table 8 respectively. At KPNO, 1mm PWV is a winter rarity and 9mm PWV is a Monsoon Season staple. It is useful to remember that the thermal background comes from both the atmosphere (which varies with airmass) and the telescope (which does not vary with airmass) in comparable quantities. Although observations at JHK are onscale under all conditions, at high temperature the L channel can saturate and become unusable. The primary symptom of saturation is an East/West gradient in the L background at the shortest integration times. If one desperately needs to perform L channel observations under higher temperature conditions, insertion of the cold internal polarizer element (it is the third choice in the open/dark/polarizer position controlled by the hand crank on the instrument) drops the background (and the signal!) by a factor of two, with edge vignetting (because it is too small to service the full FOV). Although one can obtain useful data at JHKL within the central field with the polarizer in place, the vignetting near the edge (which is variable, since we do not put a close tolerance on the indication when the polarizer is in position) is problematic. It is also worth remembering that for polarized sources your signal loss will be larger.

Table 7. Estimated SQIID performance variation: ambient temperature

Ambient Temperature	J	H	K	L	comments
30 F	+0.00	+0.00	+0.21 (0.7)	+0.35 (0.5)	magnitudes improvement (background relative to 50F)
50 F	+0.00	+0.00	+0.00 (1.0)	+0.00 (1.0)	magnitudes improvement (background relative to 50F)
70 F	+0.00	+0.00	-0.30 (1.7)	-0.31 (1.8)	magnitudes improvement (background relative to 50F)

Table 8. Estimated SQIID performance variation: Precipitable Water Vapor

PWV	J	H	K	L	comments
9mm	+0.00	+0.00	-0.02 (1.02)	-0.19 (1.12)	magnitudes improvement (background relative to 6mm)
6mm	+0.00	+0.00	+0.00 (1.00)	+0.00 (1.00)	magnitudes improvement (background relative to 6mm)
3mm	+0.00	+0.00	+0.03 (0.98)	+0.26 (0.84)	magnitudes improvement (background relative to 6mm)
1mm	+0.00	+0.00	+0.06 (0.95)	+0.54 (0.67)	magnitudes improvement (background relative to 6mm)

System Overheads

To optimize observing efficiency, it is important to keep the two distinctly different system overheads in mind, related to:

- Data pipeline flow (~40 sec, roughly fixed)
- Mode of array operation (mode dependent)

It takes time to move the data from the instrument through the distributed hardware out into storage on the Sun Workstation. During this time, critical resources are involved which do not lend themselves to overlap/reuse, so that the start of a new integration must be held off until the pipeline is clear. For an externally realized integration, it currently takes 40 seconds following the last readout to safely deliver the results. Since the actual disk write time is but a fraction of this total, little time is to be gained, for example, by electing to not save undesired channels to disk.

The preferred method for improving observing efficiency involves internal co-addition, since co-addition of JHK frames entails an overhead of only 10 millisecond. *By co-adding integrations to produce the equivalent of a 1 to 3 minute integration, the effect of data pipeline flow overhead is minimized.*

The mode of array operation also has a significant impact on observing efficiency. In particular, it is important to understand the role of minimum JHK integration time in the JHK observing efficiency. SQIID currently employs global reset and double correlated sampling to produce an image: each image is the difference between two reads of the array and the minimum integration time is roughly the time to read the array once. *Consequently, at the shortest integration times (approaching the minimum integration time of order 1 sec) the observing efficiency declines to 50% and for integration times of order 10 seconds, the JHK observing efficiency approaches 90%.*

It is equally important to understand the relationship between JHK integration time and L integration time that affects L observing efficiency. During the course of an integration, SQUID simultaneously resets the JHK arrays, then simultaneously performs a non-destructive read (equivalent to a CCD bias frame) on the JHK arrays, waits roughly an integration time then reads out the JHK arrays again. Between JHK reads, the L band array is read out (in pairs and differenced) as often as will fit between the JHK read pair and the results co-added. Since there is some dead time before running L and since the minimum integration time is roughly the readout time, the maximum time spent integrating at L within a JHKL cycle is less than half the JHK integration time. One could use a different technique to read L (e.g., row reset) to improve efficiency, but we have yet to produce the complex code required to read L differently than JHK and will most likely produce a code employing row reset for all channels. The situation is summarized in Table 9 for the case of the shortest L time:

Table 9. L channel observing efficiency

L time per coadd (sec)	JHK time (sec)	L coadds	total L time (sec)	% time (L/JHK)
0.11	1.00	1	0.11	11.0%
0.11	2.00	6	0.66	33.0%
0.11	3.00	10	1.10	36.6%
0.11	5.00	19	2.09	41.8%
0.11	10.00	42	4.62	46.2%
0.11	15.00	65	7.15	47.7%

Channel Specific Characteristics

Channel specific characteristics, such as scans of the filters, geometric distortion, and representative bad pixel masks can be found at [Supplement 1: Channel Specific Characteristics](#).

Other Preparations

Object Coordinates for any epoch can be entered into the telescope computer for use during the run. Although this task could be done by the telescope operator during the course of the night, lengthy observing lists are best entered by electronic submission (see below). These may include objects, standards, offset and guide stars, etc. Acquisition of optically faint or invisible objects might require initial acquisition and coordinate updating on a nearby bright star, so advance selection of these offset stars can save considerable time while observing. SQUID does not use a guider.

Conscientious observers may send coordinate lists via email (two weeks or more before the run) to coords@noao.edu. Files should be ASCII text, no longer than 2000 lines. Start the file with your name, a cache name, telescope, and dates of the observing run. Coordinates will be checked for format, loaded into the appropriate telescope computer, and acknowledgement will be sent. Each object should be one line of text. The format is object name, RA (starting column 16 or greater, delimited by first blank after col 15; hours, minutes, seconds), DEC (degrees, minutes, seconds), and epoch. Each field should be separated by one or more spaces (NO TABS); the delimiter in the RA and DEC fields may be spaces or colons. Example:

- alpha nuti 12:34:56.7 -89:59:59.9 1734.4

Further details may be found in the June 1992 *NOAO Newsletter* or the new Observers Handbook.

Standards are a subject of continuing discussion, and probably will remain so for some time. For the purposes of determining and removing the effects of telluric absorption and throughput in the instrument, it is desirable to observe a calibration star as near as possible to the object in both space and time. Owing to its high sensitivity and relative coarse pixel scale, SQIID must be calibrated using standard stars fainter than JHK=9mag. Recent compendia of faint standards are extremely useful in this regard:

- *A New System of Faint Near-Infrared Standard Stars* by S.E. Persson, D. C. Murphy, W. Krzeminski, M. Roth, and M. J. Rieke in *Astron. J.*, 116:2475-2488 (1998).
- *Northern JHK Standard Stars for Array Detectors* by L. K. Hunt, F. Mannucci, L. Testi, S. Migliorini, R. M. Stanga, C. Baffa, C., F. Lisi, and L. Vanzì in *Astron. J.*, 115:2594-2603 (1998).
- *JHK standards for large telescopes: the UKIRT Fundamental and Extended lists* by Timothy G. Hawarden, S. K. Leggett, Michael B. Letawsky, David R. Ballantyne, and Mark M. Casali in *mon. Not. R. Astron. Soc.*, 325:563-574 (2001).

Visitors should arrive on the mountain at least by early afternoon of the first night. This will allow time to become familiar with the instrument, create and test observing parameter sets, and enter object coordinates into a cache. First-time users of SQIID may wish to arrive a day early and spend some time in the evening looking over the shoulder of the previous observer, with his/her prior permission.

6. The IR Instrument Control System -- WILDFIRE

Note: This contains a SQUIID-specific synopsis of the WILDFIRE manual written by Nick Buchholz.

Interim notes for operation at the 2.1-m telescope

As of December 2006, the SQUIID operating environment at the 2.1-m telescope has changed with the incorporation of a Linux-based workstation as the console for operations in the control room:

- The two monitors, along with keyboard/mouse, that used to belong to *lapis* now connect to *sapphire*, a Red Hat 9 Linux machine. The monitors are in Xinerama mode which produces a display w\that seamlessly spans the two monitors. Login and password are as before (i.e., user "2meter", etc). Both *lapis* and *royal* reside with their monitors and keyboards in the computer room.
- Access to *lapis* is via VNC. Clicking on the "VNC" icon on the menu bar at the bottom of the left hand sapphire screen opens the X:1 desktop on lapis, without a need to enter a password. After lapis reboots, and after an obsinit, this desktop automatically opens the Instrument Control Window. Please note that people can access this desktop from ANY machine on NOAO network (e.g., if an observer has a laptop connected to the 2.1 meter hub). They just need to do: % vncviewer lapis:1 and enter the 2meter password. Since this will slow the VNC linkage, viewing from other machines should not be abused with extended usage during observations.
- Important: currently, after an obsinit it takes about 2 minutes for the VNC to restart - so be patient.
- If it becomes necessary to reboot *royal*, go to the *royal* console in the computer room and use the [L1 A] or [STOP A] keys and then enter boot.
- Do not try and run a web browser on lapis. Although Netscape has been removed from the menu, it can still be run it a command line. Use sapphire for web browsing and other fun stuff (we have tested the printer and it works). Lapis should only be used for acquiring images.
- People can now use the xcdroast icon to burn DVD-Rs and CD-Rs. Bob is gonna send you some instructions. Meanwhile, here is the documentation and FAQ on the web: <http://www.xcdroast.org/#manual>
- If just the VNC needs to be restarted, log on to lapis as user 2meter and do: % restart-vnc and after 2 minutes a new one should be ready.

Initializing the Environment with OBSINIT

The optical CCD (ICE) and infrared (WILDFIRE) environments are both operated from the same account on the 2.1-m (*2meter*) and 4-m (*4meter*) telescopes. The all-important `obsinit` command performs a number of functions relevant to this operating procedure.

- Switching from ICE to WILDFIRE environment on the first night of an IR observing run.
- Efficiently and gracefully cleaning the disk of data from previous observers.
- Storing the current observer name and proposal number for archiving.

First Night of SQUIID Block

On the first night of an IR block, the ICE environment will still be active (the presence of the "CCD Acquisition" and "CCD Reduction" windows will verify this). It will be necessary to run `obsinit` to change to the WILDFIRE environment, as well as for the other reasons above; since the hardware may be in an unknown state, it is also recommended to run through a complete hardware initialization on the first night of an IR block as part of the obsinit process. This will involve rebooting the observer's SUN workstation with the DSP (in the computer room) powered on and the SQUIID instrument power off.

The "First Night" procedure is detailed within [Appendix IX. Installation Issues](#). Since this procedure differs both in complexity and detail from the situation normally confronting the observer, we will not recount it here.

New Observer

The following assumes that the change from ICE to Wildfire has already occurred and that Wildfire is already running properly.

On subsequent SQIID runs, `obsinit` is run only to enter the new observer and proposal ID information. It is NOT necessary to power down SQIID or reboot the computer. After typing `exit` in the Instrument Control window and logging out of all IRAF processes and running `obsinit`, simply exit OpenWindows from the desktop menu and log back in when the login window appears.

At the 2.1meter telescope, `PROPID` and `OBSERVER` can be modified without running `obsinit`. One can either run the `newobserver` command within the Wildfire Instrument Window or one can change the appropriate environmental variables within the `“.cshrc2”` file used by Royal on `/data1/2meter/`.

Note: The SQIID instrument power supply is located on the instrument itself. The (rocker) switch is on the right (South) side (near the top by the power cord) of the electronics box mounted on SQIID.

- If Wildfire is running (“%” prompt active in Instrument Control window), enter “exit” in the Instrument Control window.
- Verify that the DSP power is ON (Black Huericon box in computer room).
- Verify that the power to SQIID is OFF (power supply on SQIID itself).
- Quit the "CCD Reduction" and “Xintool/SAOimage” windows.
- Logout of any other IRAF processes.
- Enter the command `obsinit` in a Shelltool or Xgterm window. One will be led through an interactive process:
 - name(s): (enter observer names)
 - Proposal ID: (check the schedule or Preparation Form)
 - Operation (fire/ice): (enter `fire`)
 - Delete old data from disk and initialize (y/n): [this can take a while, but to assure proper initialization you should choose `y`]
 - Replace `wfpar` and `tclSamples` (y/n): (n will leave any changes)

After a few seconds, OpenWindows will automatically load and present the login window shown below:

Welcome to Kitt Peak (^\\ to exit)

Login:

Password:

Login as *[telescope]* (where telescope is "2meter" or "4meter" as appropriate) with the current password posted on the workstation terminal. The WILDFIRE system will then load automatically, resulting in a

terminal screen layout approximately like Fig. 5 below; the dashed window labeled Instrument Status will appear in the approximate position shown only after the instrument microcode has been loaded.

Normal WILDFIRE Startup

The Windows

Once the environment has been set to WILDFIRE by `obsinit`, it will remain in that state, even if it is necessary to reboot the instrument computer for any reason. There should be no reason to execute `obsinit` more than once during a run. If a reboot is required, the login procedure in the window displayed above will automatically bring up the WILDFIRE windows.

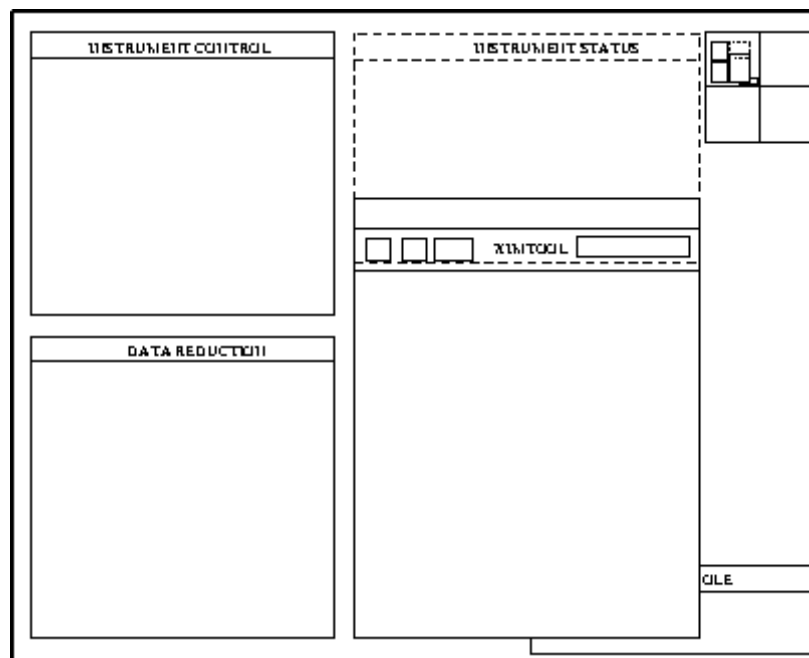


Fig. 5 -Windows layout after initiation of WILDFIRE

A brief description of the windows follows:

- 1. Instrument Control -- This is the window for entering all commands controlling the instrument or telescope. It will initially have a "[instrument computer]" prompt, and a "%" prompt when the instrument microcode is running.
- 2. IRAF XGTERM -- This window is used for IRAF commands for analysis of data or for shell commands such as creating directories, moving, or archiving data.
- 3. Instrument Status -- Once the instrument microcode has been loaded, this window will appear. Instrument, voltage, detector status commands in the Instrument Control window will output here. The existence of this window is a diagnostic of WILDFIRE, as a system crash will often close it.
- 4. Display -- This is an XIMTOOL window which may be accessed either through the Instrument Control window, where images may be automatically displayed as they are taken, or through the IRAF XTERM window via the IRAF *display* task. Those who are desperately attached to the SAOimage display may use it in place of XIMTOOL by killing the XIMTOOL process in the Console window (enter `ps -ax` in the Console window to get a listing of the process numbers,

- then `kill -9 [process #]`), and then entering `saoimage &` to bring up the SAOimage window.
- 5. Console -- This is generally used only for diagnostic or emergency purposes, such as killing a hung process or the entire WILDFIRE when it hangs up.

Bringing up WILDFIRE

There are three basic steps in the complete startup of WILDFIRE: hardware initialization; starting WILDFIRE; instrument initialization. The procedure below will go through all three steps, as would be necessary on the first night the instrument is on the telescope.

Hardware Initialization

This procedure establishes the link between the DSP box and the computer, by rebooting the observer's SUN workstation with the SQUIID power off. The *obsinit* procedure for the first night of an SQUIID block (described above) includes these steps.

HISTORIC NOTE: *The startup script for WILDFIRE was simplified significantly in 1999. The microcode will be loaded automatically and the bias for SQUIID set to the default values. The dialog during a typical WILDFIRE/SQUIID initialization is recorded in [Appendix IX](#).*

Starting WILDFIRE

HISTORIC NOTE: *The startup script for WILDFIRE has been simplified significantly in 1999. The microcode will be loaded automatically and the bias for SQUIID set to the default values. The dialog during a typical WILDFIRE/SQUIID initialization is recorded in [Appendix IX](#).*

At this point, the windows should be present as in Fig. 5. Go to the Instrument Control Window and enter:

```
startwf
```

This will lead you through an interactive startup procedure. READ THE QUESTIONS CAREFULLY; simply entering [cr] will return the default, which may not be appropriate. For the full startup, the replies are:

- Has the WFire DSP box power been off for any reason since the last time you ran startwf or restart (if unsure try 'n')? [n] y
- Was the computer rebooted with the instrument power off? [n] y (a short initialization process follows)
- Has the instrument power been off since the last time you ran startwf or restart? [n] y
- Is the instrument power on now? [n] (you will be prompted to turn on the instrument power) [cr]
- Which instrument are you using (enter PHOENIX, IRIM, CRSP, SQUIID, etc.) ? SQUIID (the instrument name may now be in either capital or lowercase letters!)
- Do you want windows? [y] [cr]
- Do you want to save in IRAF format ? [n] (default is FITS). [cr]

At this point, the transputer nodes will bootstrap, and four .tld files will load. Eventually (when the startup script automatically executes "setup sqiid") you will see messages regarding the downloading of the microcode, setting of 4 values of VddC11 (-1.3), VddC12 (-3.5), VggC11 (-4.9), VggC12 (-2.8), and Vset (-1.8). When this is completed, the final message will appear:

- Do you want to activate the array? (y or [n]) **y**

You will see messages reporting 4 biases being set, followed by:

- The arrays are now activated

If you want to use a different parameter file than the default "sqiid" parameter file that was executed by the startup script, you can enter "puse parameter_filename" at this time.

SQIID is now ready for operation.

Problems?

If difficulties are encountered in startup, entering *trouble* in any of the windows (except the Instrument Control) will open a troubleshooting diagnostic, listing symptoms and possible solutions. However, most problems occur during the initial installation, and are often hardware related. The most common problems are listed below:

Note: Detailed instructions for recovering WILDFIRE operation are contained in [Appendix III](#).

red LED(s) in DCU	Bad fiber connection. With the instrument power on, the green LED in the DCU should be on, and the two red LEDs off. If either or both red LEDs is lit, there is a fiber problem which must be repaired. A similar set of LEDs in the DSP box can diagnose fiber problems at that end.
halt after "Configuring C004"	Bad fiber optic connection (see above). Even if red LEDs are off, one or more fibers may have poor throughput, which must be measured. Power supplies may be connected improperly. Check that the analog connector goes to "CCD Power" and not "PS-10 Power" on the telescope.
halt after "bootstrapping node 100"	Bad fiber optic connection (see above). C004 may not be configured and a full startup may be necessary (DSP cycle, reboot, startwf).
"error #16 (cannot open link)"	System stuck in funny state. Full startup may be required. If that does not help, check for proper power connection and fiber throughput.
"cannot read telescope status"	Link to TCP computer is down. This is usually solved by rebooting the TCP computer. WILDFIRE will still work, but cannot move telescope or retrieve telescope status information for header.

In addition, comments, suggestions, and descriptions of persistent problems should be emailed to wfire@lemming, which has been set up as an equivalent to *service* for WILDFIRE instrumentation.

Parameter Sets

"parameter sets" are used to control the attributes of data acquisition. A listing of the parameters is given below. Because the data are saved directly as IRAF images, note that parameters include not only observation-specific items such as integration time, but archiving items such as the IRAF filename and the header and pixel directories.

Observing Parameters	
title	IRAF header title
coadds *	number of coadded integrations per image
lnrs	number of low noise reads (1 for SQIID)
pics	number of pictures per observation
integration_time *	integration time (seconds)
filename	IRAF filename
header_dir	image header directory
pixel_dir	pixel file directory
mode	process mode [stare, sep, hphot]
nextpic	picture index
ucode	microcode
display	channels to display (j, h, k, or l for SQIID)
ra	RA of object #
dec	DEC of object #
epoch	epoch of object #
offset	observation offset
imag_typ	type of observation [object,dark,flat..]
airmass	airmass of object #
comment	comment
im_list	filename of image list
save	channels to be saved to disk ([j h k l] or subset for SQIID)
archive	channels to be archived ([j h k l] or subset for SQIID)

*** WARNING: Use 'set-time' to set coadds and integration time rather than responding to the individual 'coadds' and 'integration_time' queries from 'ask'.**

In general, the parameters fall into three categories:

- those which one may wish to modify for an observation (integration time, title, ...)
- those which one might want to change on an infrequent basis (comment, header directory, ...)
- those which are never changed (mode, display) or are automatically entered into the header through the link to the TCS computer (marked with # above).

The command `ped` will open an editing session on the current parameter set, listing each parameter in turn and prompting for new entry ([`cr`] returns the present value). At the beginning of a run, one should execute `ped` and set up those parameters falling into categories 2 and 3 above. NOTE: One cannot specify a non-existent header or pixel directory in `ped`; it is necessary to go to the IRAF XTERM window and create those directories first! Since it is cumbersome to go through the entire parameter list for each observation, there is a command `eask`, which runs through the entire parameter list, permitting the observer **to specify which parameters should be queried at the beginning of each observation**. Entering "1a" for a parameter selects it for the "observation menu"; entering "1" excludes it. NOTE: The "up arrow" key may be used to back up through the `ped` list if one wishes to change a previously entered parameter.

When this is complete, save the parameter set with the command `psave [filename]`. This will save both the edited parameter set and the menu selected by `eask` in the file '[filename].par'. Should the system crash, this information may be retrieved by the command `puse [filename]`. Should major changes be made to the parameter file, such as change of header or pixel directory (say on another night of the run), it is a good idea to `psave` the updated file so it, and not the previous version, will be recovered by `puse`.

Observing Words

The basic observation is initiated by the command `observe`. The system will print on the screen, one at time, those parameters selected by `eask`, and the current value [], prompting for entry of a new value or [cr], which will enter the current value. The command `go` will begin an observation, but will use the current values for the parameters (except the picture index, which will be automatically incremented). The command `movie` will begin a loop consisting of an observation (using the current parameters!) and a display; this may be terminated with `end` at any time. The observation in progress will be completed and displayed. **Movie observations are stored on disk!** This is unfortunately necessary to prevent orphaned pixel files from filling up the disk. A recommended procedure is to include the 'filename' parameter in the `ask` menu and change to a dummy filename at the beginning of a movie. When returning to data taking, one may reset the filename to that used for the data. If one wishes to retain continuity in the index number, it is also necessary to reset 'nextpic' to the value before the movie observations. Keep good logs!!

The `ask` command will cycle through the selected parameters, prompting for changes, just as with `obs`, but will NOT begin an observation. This command is useful for checking parameters, and is **essential** before executing `movie`, which will use the parameters for the previous observation, even if it were 600s in length. The combination of `ask` and `go` is a perhaps preferable alternative to `observe`.

One may abort an observation (such as an unintentional 600s movie) by entering `abort` in the Instrument Control window; the system should respond by acknowledging the abort and the observation should terminate gracefully in a few seconds. **This can sometimes turn off the display and save operations**, so it is advisable to re-enter `save j h k l` (or whichever subset you have been using) and `display k` (or whichever channel you have been using after an abort).

TCL Scripts and IRAF Tasks

The user interface is written in the Tool Command Language (tcl), which is well-suited to the construction of scripts for data taking. Scripts are a powerful tool for executing a sequence of tcl commands, including telescope motions, instrument motor commands, and observations, as a single executable program. Even for those who are not veteran programmers (most of us), simple scripts are fairly easy to construct. Scripts are highly recommended for spatial sampling (dithering) and linearity calibrations. The best recipe for starting out is to copy an existing script to a new file and then edit that file as desired. The first line of the script file contains the base name of the script file ("proc "), and must be edited to reflect the new name of a script created in this manner. Before the initial use of a script (or after a system restart), it must be identified as an executable in the Instrument Control window, using the full path name of the file; e.g.,

```
source /data2/2meter/tclSamples/[scriptname].tcl
```

To execute the script, enter the base name [`scriptname`] as a command in the Instrument Control window. A sample script is given in [Appendix IV](#).

Scripts may be found in directory "tclSamples" under the "[telescope]" directory, as in the path above, and also in /usr/wfire/tcl. This latter path is the system response to query `pwd` in the Instrument Control window. When creating a custom script, please copy a system script into an observer directory and then rename and modify it, to avoid confusion.

Scripts copied into the user home script directory (/data2/2meter/wfire at the 2.1-m and /data2/4meter/wfire at the 4-m) and sourced can be marked for automatic inclusion in subsequent invocations of "startwf" by entering "mkIndx".

For the more sophisticated (or daring) observer, a TCL manual is available. WILDFIRE presently uses TCL version 6.7 and properly written code should run with no special limitations. Please note we will not debug or otherwise support user code, nor will user supplied TCL routines be saved within WILDFIRE from one observing run to the next.

The following WILDFIRE default scripts are useful for various observing programs, and as templates for user-constructed modification. They are initiated by entering the script name as a command, and going through a series of interactive queries to set internal parameters. Alternatively, several have command line versions for faster use. **These are default scripts which do not require sourcing.**

- `do_standard` : takes 5 observations in a fixed spatial pattern using the current parameter set for integration time, filename, etc. First observation is at the current position, next four are in a square centered on the first position; routine then repositions the telescope to the starting position and quits. You are prompted for the side of the square in arcseconds. Verify that your objects do not systematically land on bad pixels; if they do, change the initial point or offset value. Note: script updates the telescope information in the image header on the first image (using "tcp_on") and then turns header updates of telescope information off (using "tcp_off") for the rest of the sequence. After the last image is taken, telescope header updating is restored (using "tcp_on").
- `do_standard_on` : same as `do_standard`, but updates telescope information in the image header for each image in the sequence.
- `do_field` : observe an M x N (RA x Dec) spatial grid of positions, with fixed separation E-W and N-S, using the current parameter set. Returns to starting point when completed. The grid is *centered* on the starting position. Prompts for the number of grid positions E-W, the number N-S, and the grid separation in arcsec. Observations begin at NE corner, proceeding W and S a row at a time. The command line version is

```
do_fld [ewnum] [nsnum] [gridsep]
```

- `do_dither` : observe an M x N (RA x Dec) spatial grid of dithered pairs, with fixed separation EW and NS, using the current parameter set. Two frames slightly offset (dithered) EW are taken at each grid location. Grid is centered on the starting position, and returns here when done. Prompts for the number of grid positions E-W, number N-S, grid separation in arcsec, and E-W dither in arcsec. Observations begin at NE corner and proceed W and S a row at a time. The command line version is

```
do_dthr [ewnum] [nsnum] [gridsep] [dither]
```

- `do_pair` : take a pair of spatially offset images and return to the first position. This is particularly useful to confirm the location of a faint object, which can be determined by subtracting the two frames. Prompts for the offset vector in arcsec, and *must* receive two values: RA first, then Dec, separated by a space. Use "+" to specify E and N, "-" for W and S. The command line version is

```
pair [ewsep] [nssep]
```

- `do_9raster` : observe a 3 x 3 spatial grid of source and dithered offset sky data pairs, in the sequence source-sky-sky-source. The sky position is dithered between each sky frame so that objects in the sky field are not position locked relative to the source frames. The data are taken in an order which minimizes telescope motions. Note: script updates the telescope information in the image header on the first image (using "tcp_on") and then turns header updates of telescope

information off (using "tcp_off") for the rest of the sequence. After the last image is taken, telescope header updating is restored (using "tcp_on"). Prompts for grid separation, sky dither vector (small motion: *must* have two values) and sky offset vector (large motion: also two values), all in arcsec. The vectors are ordered (RA, Dec) with "+" for E and N, "-" for W and S. The command line version is

```
do_9rstr [gridsep] [ewdither] [nsdither] [ewsky] [nssky]
```

- `do_9raster_on` : same as `do_9raster`, but updates telescope information in the image header for each image in the sequence. The command line version is

```
do_9rstr_on [gridsep] [ewdither] [nsdither] [ewsky] [nssky]
```

Refer to the Appendices for listings of WILDFIRE and SQIID commands ([Appendix II](#)) and troubleshooting procedures ([Appendix III](#)).

tmove

Michael Merrill's provisional IRAF script *tmove* may be used for centering stars on the array, using an image displayed in the ximtool window. Because this is not yet a standard IRAF task, it will probably have to be manually installed for an observing run.

- If the file "tmove.cl" is not found in the [telescope] or [tclSamples] directory, [download](#) it.
- The script is defaulted for SQIID at the 2.1-m. If you are at the 4-m, it will be necessary to edit the telescope string parameter in the file "tmove.cl".
- In the data directory, identify the task to IRAF by entering the full path name of the file; e.g.,

```
task tmove    =    /data1/4meter/tmove.cl
```

- To execute, enter `tmove`. You will be prompted to put the cursor on the star in the ximtool display. Entering `c` will compute the offset to the center (256:256) of the array; entering `[spacebar]` will prompt you to move the cursor to the target position and enter another `[spacebar]`. In either case, the computed offsets will be displayed in the IRAF window
- The displayed offset command "toffset..." may be pasted directly into the Instrument Control window.

idisp

Michael Merrill's provisional IRAF script *idisp* may be used to display sky-subtracted images in the ximtool window. Because this is not yet a standard IRAF task, it will probably have to be manually installed for an observing run.

- The script is defaulted for SQIID at the 2.1-m. The parameters are as follows:

```
first_image = "test010j.fits" First image in sequentially
                                numbered images
sky_image = "-1"                Name or sequential number of sky frame
(frame = 2)                    Display frame #
(number_id = "000")            image number template results image? 000
(listid = "/tmp/list")         name of wildfire system image list?
(dolast = no)                  Repeat for most recent image
(dostats = yes)                Perform imstats?
(statsec = "[100:400,100:400]") Image section for calculating
```

	statistics
(lthreshold = INDEF)	Lower threshold for exclusion in statistics
(hthreshold = INDEF)	Upper threshold for exclusion in statistics
(imsave = no)	Save difference of each pair?
(saveid = "dpr_")	String prepended to object name
(zscale = yes)	automatic zscale on each frame?
(ztrans = "linear")	intensity transform: log linear none
(z1 = 0.)	minimum intensity
(z2 = 1000.)	maximum intensity

- To execute, enter `idisp`. You will be prompted to put the name of the image you want sky-subtracted and the identity of the sky image. The sky image can either be the name of another image, the special entry "prev" which indicates the previous image, or an ordinal number offset (+ or -) from the image in the first entry.
- Image statistics for the two frames and their difference will be also be displayed.
- If you set "dolast=yes" (either using the IRAF `epar` or appending "dolast+" to the command line), `idisp` will display the sky-subtracted result from the most recent image using the filename and channel parts of the first entry.
- If you want to save subtracted image (e.g., so you can use `imexam` on it), set `imsave=yes` (either using the IRAF `epar` or appending `imsave+` to the command line).
- The "z" parameters are the same as those in the "display" task.

7. Observing Practices

The installation of the instrument and cables will be handled before the beginning of the run by the mountain technical staff and are not of concern to the user. The [SQIID Reference Manual](#) provides coverage of the details of installation and setup for those who are interested. SQIID remains on the telescope (with power on, under normal circumstances) for the entire observing run.

Getting Started

After SQIID is installed on the telescope, go through the WILDFIRE startup procedure outlined previously. Once the system is operational and the detector activated, check the detector and temperature status with `status s` and compare with the nominal values below:

status s

	SQIID Base Status Display				18:11:29
	H detector	K detector	J detector	L detector	
Integ time (secs) =	0.855	0.855	0.855	0.185	
CoAdds =	1	1	1	1x1	
Lnrs =	1	1	1	1	
Number of Pics =	1				
Detector Temp =	29.81K	30.68K	29.81K	30.68K	
Det Heat Pwr (mw) =	129.39	56.15	146.48	75.68	
Observation Settings Mode	=	stare	stare	stare	stare
File name = "test%03d%s"	Index = 95			Space Available	
Header Dir = "/data2/2meter"				3046308kb	
Pixel Dir = "/data2/2meter/pixels"				3046308kb	

Housekeeping information is reported via status screens. Additional status screens for SQIID are:

status t

SQIID Temperature Display				
	H detector	K detector	J detector	L detector
Detector Temp	= 29.81K	30.68K	29.81K	30.68K
Det Heat Pwr (mw)	= 136.72	61.03	153.81	78.12
Bench 0 (North)	= 40.69K	Bench 1 (South)	= 39.61K	
Wheel	= 46.29K	Sieve Plate	= 18.15K	
Cold Hd A 1st St	= 32.17K	Cold Hd B 1st St	= 32.34K	
Cold Hd A 2nd St	= 11.53K	Cold Hd B 2nd St	= 13.47K	

status v

SQIID PRCD Voltage Status Display				
	H detector	K detector	J detector	L detector
VSet	= -1.783	-1.790	-1.779	-1.803
ISet	= 0.266	0.297	0.257	0.322
VDet	= -2.897	-2.815	-2.926	-2.701
VDesUR	= -5.579	-5.589	-5.583	-5.587
BOK	= -2.896	-2.815	-2.925	-2.698
VddUC	= -3.475	-3.497	-3.488	-3.489
VddOut	= -0.986	-0.992	-0.989	-0.991
VddCl1	= -1.315	-1.319	-1.303	-1.303
VddCl2	= -3.545	-3.560	-3.517	-3.514
VggCl1	= -4.867	-4.886	-4.861	-4.908
VggCl2	= -2.773	-2.786	-2.769	-2.791
Vp	= -0.489	-0.494	-0.494	-0.493
VnRow	= -6.207	-6.186	-6.179	-6.177
VnCol	= -3.988	-3.993	-3.987	-3.987
VDesLr	= -0.494	-0.489	-0.497	-0.494
VRowOn	= -5.985	-5.983	-5.985	-6.002
VRowOff	= -0.685	-0.694	-0.695	-0.688
VRstOn	= -5.971	-5.989	-5.973	-5.970
VRstOff	= -2.991	-2.991	-2.989	-2.991

status 3

SQIID Power supply Voltage Display				
Gnd Ref H/K Box	= -0.097	Gnd Ref J/L Box	= -0.105	
Vcc1 H/K Box	= 4.740	Vcc1 J/L Box	= 4.699	
Vcc2 H/K Box	= 4.750	Vcc2 J/L Box	= 4.706	
PRCD Card				
	H detector	K detector	J detector	L detector
+5v Sup	= 4.951	4.951	4.945	4.944
+15v Sup	= 14.866	14.906	14.893	14.922
-15v Sup	= -15.100	-15.198	-15.078	-15.250
+7v VRef	= 6.914	6.921	6.911	6.906
-7v VRef	= -6.909	-6.914	-6.897	-6.897
PA Cards				
	H detector	K detector	J detector	L detector
+5v Sup	= 4.952	4.950	4.944	4.947
+15v Sup	= 14.968	14.923	14.960	14.804

-15v Sup	=	-15.188	-15.062	-15.295	-15.131
+5v VRef	=	5.002	5.001	4.992	4.992
-5v VRef	=	-4.986	-4.986	-4.980	-4.978
		H detector	K detector	J detector	L detector
Voff1	=	0.675	0.675	0.669	0.669
Voff2	=	0.678	0.677	0.668	0.672

Techniques

Focus

SQIID acts as its own acquisition camera. Open up and acquire a star in SQIID. Stars with K magnitude fainter than 6 are OK for initial acquisition, but stars fainter than K = 9 are necessary to avoid saturation for final focus adjustments. [Note: When SQIID is first installed, it is best to start with unambiguous stars to verify initial telescope pointing. Stars brighter than K = 3 are best for this purpose.] Use individual "go" exposures (because of the 40 second delay movie can be confusing), to get the star within the central region of the array. Choose a wavelength channel for determining focus (preferably K which suffers least from seeing) and stick with it through the run to avoid confusion. The four SQIID channels are near parfocal, but differences in sensitivity to seeing and slight differences in image quality away from focus can be confusing if you switch back and forth. Once the star is found, move the telescope until it is centered. and focus the telescope, resetting display limits and integration time as necessary, until a tight image is obtained. For optimizing focus, it is best to obtain single images, using `observe` or `go`, and analyze the image quality with the IRAF task `imexam` using the 'r' command. Remember that it may be necessary to relocate the beam when moving to a new object.

An example of excellent focus (K channel, 1.0 sec) can be seen in Figure 6. Note that the star appears to be positioned at the center of a pixel. Since the geometric quality of the optics on the order of 80% flux within two pixels radius and the profile fitting algorithms stall near 1.5 pixels, this is as good as it gets. FWHM of 1.8-2.0 is more typical. (The rightmost three values at the bottom of the profile image are the FWM from different profile fitting algorithms.) Naturally, longer exposures will have somewhat broader profiles.

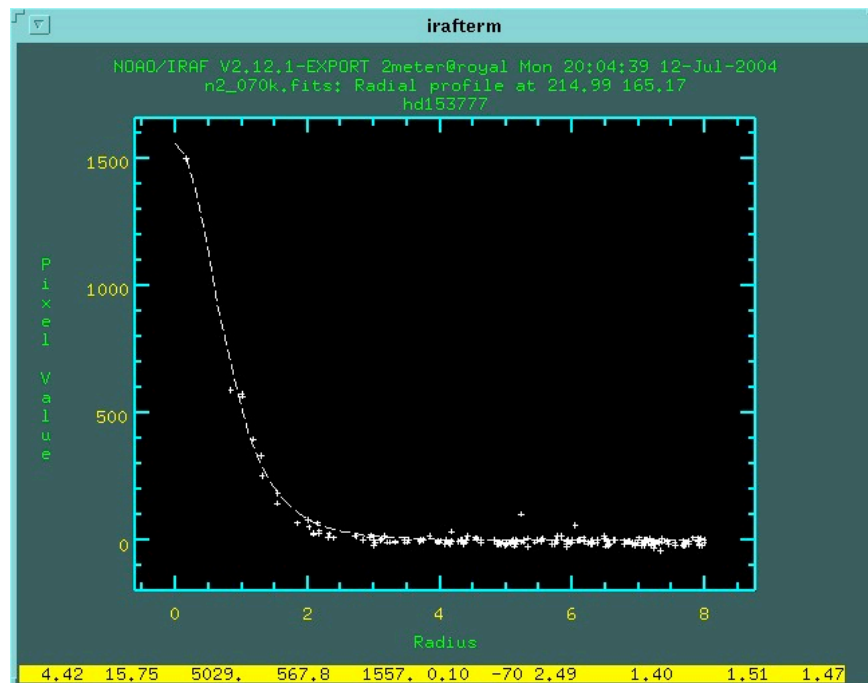


Fig. 6 - Radial image profile for excellent short exposure focus: 1 sec at K

Stars that are too bright will tend to be either flat topped or possibly even contain a central void as seen in Figure 7.

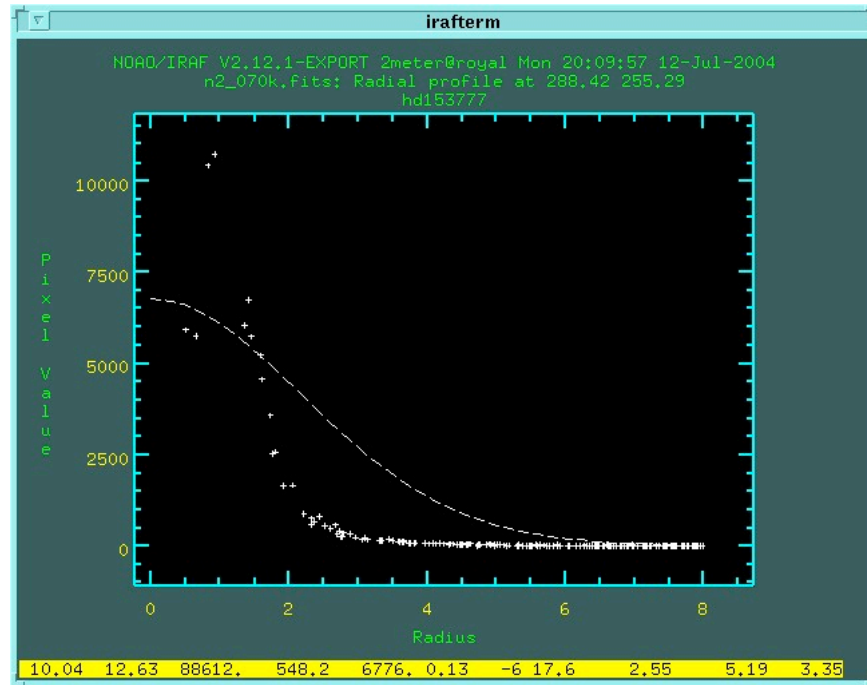


Fig. 7 - Radial image profile of a star that is too bright

NOTE: It is likely that the single pixel events (that occur at the roughly once per second) are in response to alpha particles from the anti-reflection coating of the last lens surface. We have since discovered that thorium fluoride is the coating of choice for producing durable wide bandpass coatings. The magnitude of these single pixel events is typically 3000-5000 ADU with of order 5% leakage into the four nearest neighbors. Figure 8 is the radial profile for a typical single pixel event.

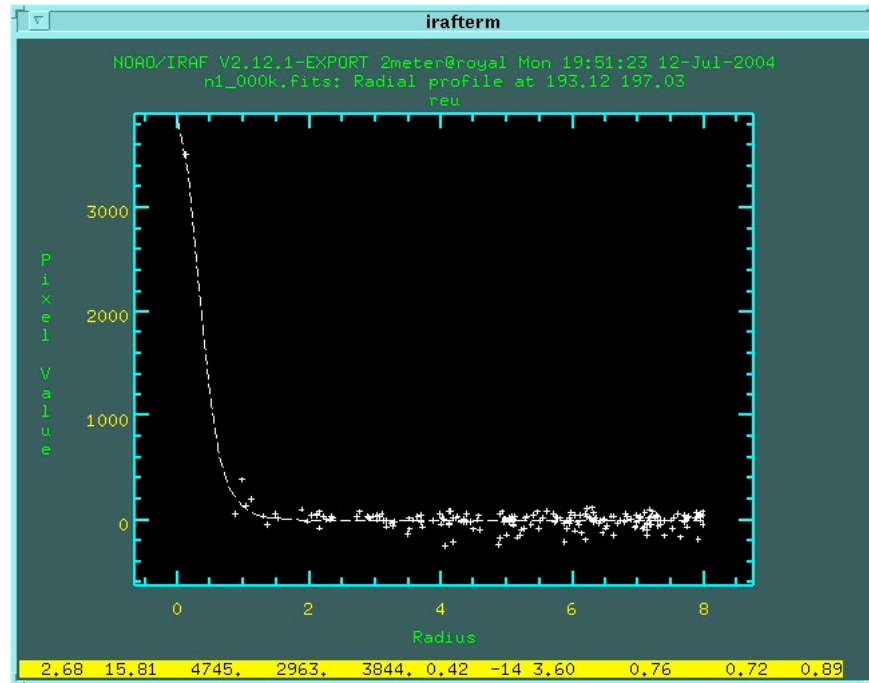


Fig. 8 - Radial image profile of a single pixel event

At the 2.1m telescope focus is a simple function of temperature. Best focus as a function of temperature shifts as $\Delta F / \Delta T = 0.025$ per degree K with a focus at 5.10 for 8K. After the temperature of the telescope structure stabilizes (it varies rapidly for roughly an hour after opening), the relationship provides an accurate estimate for best focus, which generally shifts towards smaller values as the night progresses. Pick a temperature (such as the secondary or the front surface of the primary) and monitor that temperature to adjust focus. It appears that best focus was a tolerance of at least ± 0.01 focus units. It is useful to note that there appears to be no backlash in the IR secondary. At the 4m telescope, nominal focus is -7300 with an as yet undetermined temperature dependence.

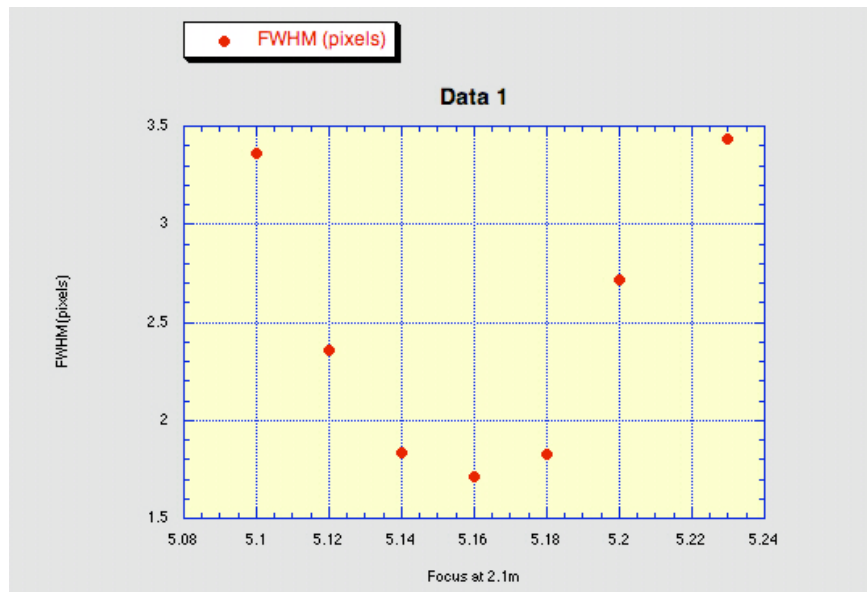


Fig. 9 - Focus at the 2.1m telescope

Performance Checks

SQIID will be installed and checked out at the start of each observing run by a competent and cheerful support scientist. Users may confirm continued proper operation during their run with software interrogation and by comparing dark and flatfield frames against "standard" frames.

Detector status and temperature information is displayed with the word `status` s; it is also automatically updated at the beginning of an observation. Standard values for the default SQIID configuration are displayed above. The [cryogen temperature readouts](#) are displayed as temperature based on a generic relationship between voltage at constant current and temperature.

The heater power may vary somewhat around the typical value given. However, a significant and persistent departure from this value may indicate the dewar is losing its vacuum (going "soft") or that the Closed Cycle Cooler System is losing efficiency. If this is suspected, **contact the instrument support scientist**.

Finally, sky- or dark-subtracted frames may occasionally show a dark (or light) circular artifact about 30 pixels wide. This "Phobos effect" (see Fig. 10) results from a region of lower signal in one of the frames, and can appear as a positive or negative image anywhere on the array. This occurs very infrequently, and is apparently a crystal relaxation phenomenon in response to the array being warmed after having been too cold (below 25K). This can happen over a span of a few hours when the SQIID electronics have just been powered on after they have been off for an extended period. (The array heater power is controlled by the same power supply as the electronics.)

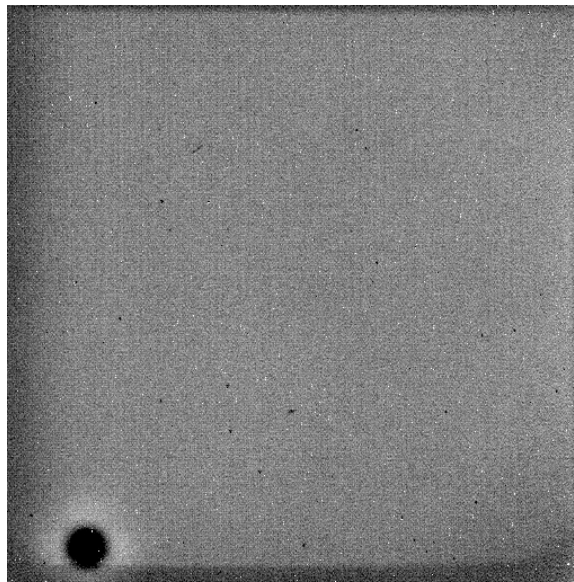


Fig. 10 - "Phobos effect" (dark circular patch at lower right)

8. Calibration

Responsivity Calibration

Atmospheric extinction must be calibrated by observations of either a standard star as close as possible to the same zenith distance used for the object or a series of stars that span the range in zenith distance for the observation. Typical extinction for SQUID is summarized in Table 9.

Table 9. Estimated SQUID Extinction in mag/airmass

J	H	K	PAH
0.15	+0.06	+0.08	TBD

Flatfield exposures are necessary to calibrate the pixel-to-pixel gain variations in the array and the effects of the illumination of the array by the internal optics. The system response is stable and is very flat across the arrays, with a slight intrinsic column to column modulation of \pm a few percent (owing to relative array orientations, columns may have either NS or EW orientations in the saved and displayed images). Consequently, the flatfield for each channel should be stable at the percent level under normal illumination and global flatfields can be constructed which are viable for extended periods of time. Since direct illumination of the array is possible (remember that the secondary mirror is undersized), observations near bright sources, such as the moon, which have atypical illumination, should not be used to determine global flatfields. Observations during twilight will also have illumination atypical of nighttime observations.

Because sky flats provide the same array illumination as real observations, they are preferable in principle to dome flats using the White Spot. It is, nonetheless, a good idea to obtain dome flats as a backup. If one is observing in a sufficiently sparse star field, one may use the same set of observations for the object, sky, and flatfield. Because the sky flats will include the array dark current, it is necessary to obtain separate "dark" observations for subtraction from the sky observations. Unfortunately, what constitutes a "dark" frame for creating flats is ill-determined due to the "memory" effect which accumulates in time. For example, a series of observations in the dark filter immediately following sky (or dome) flat observations will show a monotonic decrease in mean value as the "memory" of the relatively bright preceding observations decays over 5 to 10 integration times. By the same token, a series of dome flats following dark or low-background observations will show a monotonic increase in mean value as the "memory" of the higher flux observations accumulates. One possible approach is to take a larger number of dome flat or dark observations and reject those early in the series, when the change in value from one frame to the next is the greatest.

Should one decide to obtain "dome flats", it is recommended that one take exposures when the dome is dark, to minimize the ambient radiation at J and H. At the 2.1-m and 4-m telescopes, the dome screen is illuminated by lamps mounted on the telescope top ring. (The 4-m telescope is positioned by mountain technical staff.) Darkening the dome may require waiting until visitor hours end at 1600 hr. The lamp controls at these telescopes are on the LTO console. One should obtain a relatively large number (7 or more) of flatfield images for post-processing within IRAF, where floating point arithmetic and sigma-clipping or median combining are possible (the latter to eliminate noise artifacts which may appear in a single observation). Since the illumination level differs markedly at J, H, K and PAH, one should anticipate taking data at several settings of the lamps. Within the K and PAH bands, one will be dominated by the thermal emission from the dome screen, and at the PAH band, the lamps are not necessary. Dark current and residual illumination subtraction require obtaining an identical series of observations with the flatfield lights off (for J,H,K) or the dark slide in the beam (PAH). After subtraction of the "off" or "dark" frame, normalization (using, for example the IRAF 'response' task) and median combining of these observations should eliminate noise spikes or systematic features in the spectra. To stay within the relatively linear

portion of the array response, it is preferable to turn down the lamp intensity and use exposure times relatively long in comparison to the readout time of 0.84s (e.g., 3 - 5 s). Keeping the flux at a modest signal level (< 5000 ADU) may also help in this regard; with a read noise ~ 35 e, one is completely background limited by signals > 500 ADU.

The time-dependent **dark** signal is generally small compared to the sky background for all four arrays. However, higher-order spatial features, such as the gradient on one side of the H channel, are significantly brighter and cannot be neglected when constructing flatfields. "Dark" images contain both static and time variable components with diverse causes that obviate simple scaling of dark frames to alternate integration times. Consequently darks corresponding to the integration times for data that will be used for defining flatfield and linearity issues should be taken. A sequence of 9 exposures should be sufficient. Since the dark current is so low, you will be able to see transient events, such as those due to cosmic rays that can be removed by median filtering. Darks should be taken in the afternoon and/or in the morning. Closing the cold internal darkslide (hand crank on the side of the instrument) is both necessary and sufficient for taking darks. The time dependence of the median dark current within [100:400,100:400] is shown in Figure 11. Note that the H channel exhibits an apparently negative dark current at short integration times.

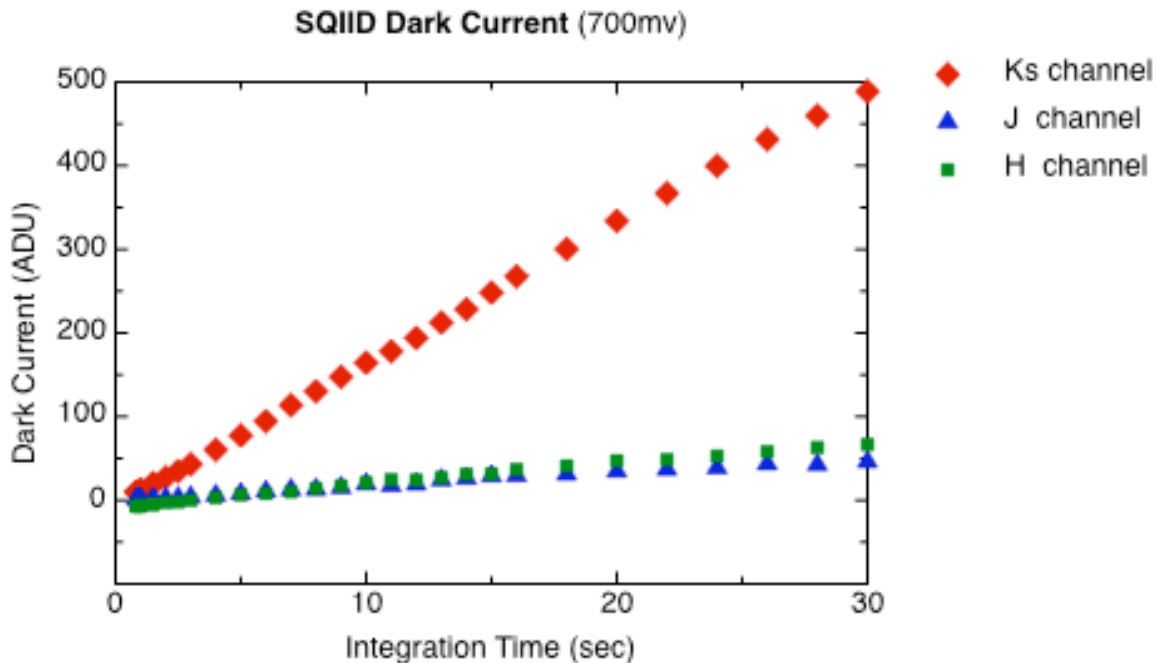


Fig. 11 - SQIID dark current for H (green), K (red), and J (blue) Channels at 700mv bias. Conversion gain is approximately 11 electrons per ADU.

Sky Subtraction

While the detectors are stable, the sky is not necessarily so. Under good conditions, sky flux varies only with airmass and at a given position the sky can be stable over an hour or more. Naturally sky flux increases when you get near the moon. When airglow is high and variable, the sky at H can vary by a factor of two over the course of an hour, while the sky at J varies by 40%. Consequently it is prudent to monitor the sky (use *imstat* inside IRAF) to be sure that you have sufficient data to perform sky subtraction on your targets.

CAUTION: One cannot expect to simply co-add observations of faint surface brightness sources and allow the off-source portion of the observations within the detector FOV to determine the presumably constant level of the sky. At some level, defects in the flatfield (pupil ghosts, object

ghosts, or whatever) dominate the accuracy of the results. This deficiency is typically overcome by subtracting off-source observations of the sky, then flatfielding the differences. This improves the accuracy of the detected signal by at least an order of magnitude.

In the IR (even at JHK) observations of all but the brightest stars (9 mag) are background limited so that typical diffuse targets (such as galaxies) are seen at very low contrast in individual frames. As noted above, the sky background is constantly changing (slowly with airmass and on slow to moderately rapid timescales with sky emission) so that the contrast varies as a function of time. Since observations are ultimately limited by inadequacies in the flatfield, one cannot simply co-add such observations and obtain a meaningful result; median filtering such data merely selects the middle frame. (For example, as the contrast varies the illumination pattern on the array also varies since the relative mix of radiation seen through the telescope optics and that seen directly past the secondary changes.)

One must devote a comparable amount of time off-source, intermixed throughout the on-source observations, to provide sky frames; subtracting sky frames on a pixel by pixel basis reduces the contrast problem and allows one to successfully co-add data taken over a long interval of time. When the targets are much smaller than the array, one can accomplish this sky subtraction by moving the target around the array and in effect taking the sky and source data at the same time.

GHOSTING - Each channel has its ghost, whose position is opposite the optic axis from its parent bright star. Only saturated stars are bright enough to clearly show their ghost, which is out-of-focus, covering about 25% of the chip. The out-of-focus ghosts that lie opposite the optic axis from the primary have the following characteristics:

J	H	K	
90	108	56	pixels diameter
5.5	6.3	5.5	difference in integrated flux in magnitudes

In addition, the J channel has an in-focus ghost located 36.5 pixels east of its parent and 5.4 magnitudes fainter.

Linearity

When a pixel is reset, the voltage difference (bias) between the pixel and detector substrate creates a depletion region that acts as a potential well for the collection of (mostly) photo-generated carriers. Electrically, one may consider this potential well as a capacitor. As charge accumulates in the pixel, the depletion region fills in, increasing its capacitance and that of the entire pixel node. Changes the gain of the system, resulting in a sub-linear voltage-charge relationship, which quickly rolls off (saturates) when the pixel voltage reaches that of the detector substrate (zero bias). Technically, a pixel will continue to accumulate charge even into forward bias, but its response by that time will be significantly nonlinear. As a direct consequence, pixel response departs from linearity in a predictable fashion for accumulated signals above a device-specific level. Since the total capacitance (which determines system gain) is the sum of the distributed (non-varying) capacitance of the system and the (variable) capacitance at each detector node, the degree of non-linearity is a function of the ratio of nodal to total capacitance. Since key pixel parameters such as quantum efficiency are very uniform, the linearity appears to be a global property of the array rather than pixel specific.

Increasing the bias on a pixel will not only increase the depth of the potential well, but by decreasing the capacitance of the depletion region in relation to parallel components of the node capacitance, will result in a more linear voltage-charge relation. As a result, a bias increase from 0.6 to 0.8 volts will effectively double the charge capacity of the pixel. This comes, however, at a significant cost in dark current, which increases dramatically with bias. Therefore, we recommend a bias of 0.6v for JH, 0.7 for K, and 0.9v for

high-background (L band) observations, where the increased dark current is not important. These are the default bias values for SQIID.

In the following discussion, observed (output) values have not been corrected for the unseen charge collected during delay between biasing the detectors (reset) and the first (non-destructive) read of the bias. A second (non-destructive) read is taken an integration time later. Only the difference between reads is output. In detail, the global reset mode used to operate SQIID resets all the pixels at the same time and then performs a non-destructive read of the array. The first pixel is read out shortly after the global reset and the last pixel is read out 0.61 sec after the global reset. The charge accumulated at the time of the position dependent first read is "lost", since its value does not get reflected in the difference. Hence, the reported signal is always less than the total signal on the array at the time of the second read. At short integration times and high rates of photon arrival (bright stars and/or high background), this unreported charge can lead to a significant underestimate of the signal outside the scope of the usual linearity correction. The unseen charge can be accurately estimated (apart from noise issues) on the basis of the timing, but since the amount of unseen charge is position dependent, one is better off not "going there"! Ideally, the data fit are always within the regime where this correction for unseen charge was small. This is not the case, for example, when doing 0.84 sec integrations on standards!

One normally expresses the departure from linearity in terms of the relative error (**input-observed**) or the normalized relative error (**input-observed**)/**observed** for each array and fits these data to an appropriate mathematical model. For SQIID, the model fitted function for the relative error is:

$$ym[x] = a(1) * x^{**2} + a(2) * x^{**3}$$

where $ym = \text{relative error} = (\text{input} - \text{observed})$
 $x = \text{observed (adu)}$

The fit is valid for values < Xmax. For values beyond Xmax, the array is rapidly approaching saturation. The fitted parameters for each channel are summarized in Table 10 and the fitted linearity is plotted in Figure 12. A new array was installed in the H channel in February 2002.

Table 10. Fitted Linearity Coefficients

Valid from	Jun 2000	Jan 2005	Jan 2005	Mar 2002	Jun 2000	Jun 2000
Channel(bias)	Ks (700mv)	H (700mv)	J (700mv)	H (600mv)	J (600mv)	H (600mv)
a(1)	6.4864e-7	-1.3456e-8	1.2626e-6	8.4783e-7	1.2164e-6	4.5326e-6
a(2)	4.4790e-10	6.1010e-10	2.9498e-10	6.8416e-10	4.7829e-10	4.8759e-10
Xmax(ADU)	16000	16000	16000	16000	16000	14000
Data date	Apr 2003	Apr 2003	Apr 2003	Apr 2003	Apr 2003	Apr 2001

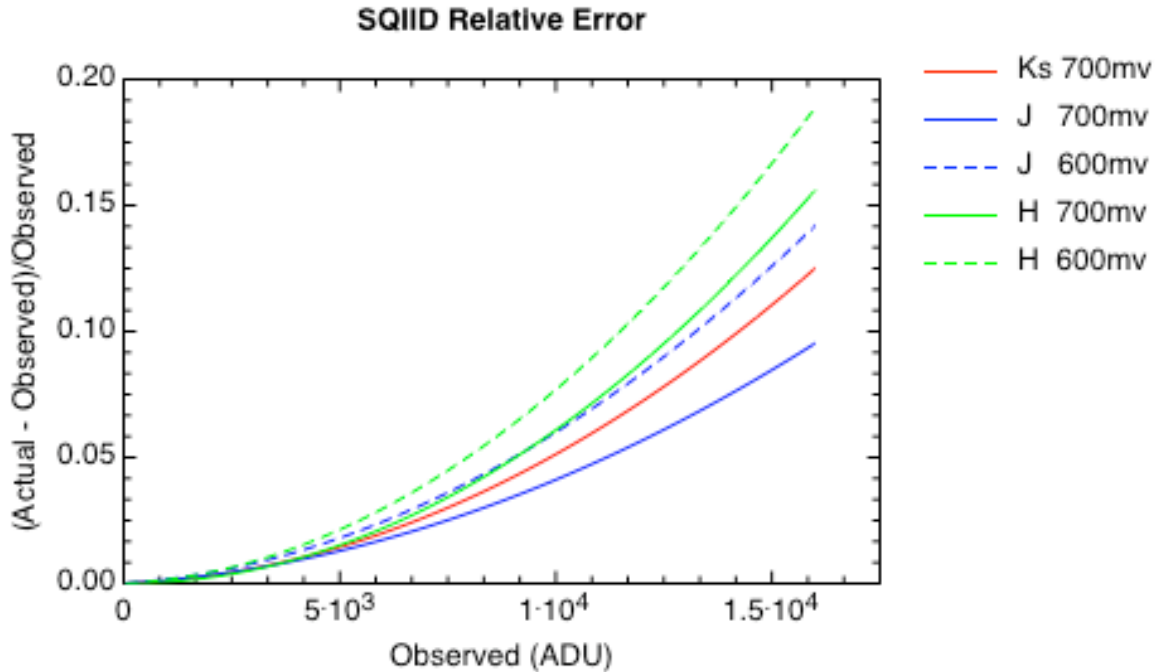


Fig. 12 - Linearity Correction for SQIID. Relative error for H (green), K (red), and J (blue) Channels for 600mv and 700mv bias. Conversion gain is approximately 11 electrons per ADU. Prior to 2005, the JH bias was 600mv. **As of January 2005, the JHK bias is 700mv.**

Saturation

Eventually, a pixel will accumulate sufficient charge to forward bias it to the point where no more is collected, resulting in a condition known as saturation. The reset-read-read address cycle used in double correlated sampling (Fig. 4) results in a characteristic, but unusual, saturation behavior. For a given integration time, the effect of increased flux is a steeper slope of the voltage-time curve. As the flux increases, the voltage V_2 will eventually saturate, while the voltage V_1 will continue to increase because of the time interval between the reset and the first read; the difference signal will thus decrease with increasing flux. Finally, the detector will saturate in the short interval between the reset and first read, resulting in identical values for V_1 and V_2 , or a difference value of zero. Thus, the double-correlated signal relation with flux is initially nearly linear, then increasingly nonlinear, and eventually decreasing to an ultimate value of zero as one saturates. The A/D channels (2 for J,H,K and 8 for L) will saturate at slightly different levels, resulting in an evident odd-even column pattern. These effects are evident in a [Saturation Image](#) of the L band, in which the flux increases rapidly from the bottom to the top of the array.

Pixel Masks

Representative pixel masks for the J, H, K channels of SQIID are contained in [Supplement 1: Channel Specific Characteristics](#). These masks include the combined effects of intrinsically bad pixels and instrumental vignetting.

9. Appendices

Appendix I: Telescope Checklist

Computer Room Setup

- Computer, Heurikon DSP power on (normally left on)

Observing Platform / Cassegrain Cage Setup

The telescope and dome are operated by the Telescope Operator (nights) or the Technical Assistant (days). Arrange schedules with them in advance for positioning for dome flats, and opening the telescope and dome at the start of the night. The observer should:

- Verify that the Instrument power supply is on (normally on). Switch is on the right (South) side (near the top by the power cord) of the electronics box mounted on SQIID. (If the sides of the rocker show red, the switch is on.)
- Check that the upper SQIID guider dark slide (fiberglass slide with aluminum pull tab at top of telescope interface ("guider") on the South) is out. This is normally removed at the start of a run but it may have been reinserted for added protection in response to high humidity/rain.
- Check that the lower SQIID guider dark slide is out. The "stick shift" on the west of the SQIID guider should be fully out. Pull it out firmly to engage the detent.
- Check that the internal SQIID aperture wheel is open (except when actually obtaining darks). Status is indicated by the lights at the hand crank on the North side of SQIID. Turn on the indicator lights and follow the directions posted there. Turn off the indicator lights when you are finished. The 3 positions (dark:red, polarizer:yellow, open:green) are equally spaced roughly 30-31 turns apart. The hand crank can be used to move in either direction and the dark and open stations are larger than the FOV.



Fig. 13 Cold Dark Slide hand crank and indicator

Control Room Setup

Inside the control room there are a number of tasks to attend to:

- **[2.1-m only]** Turn on chopping secondary rack units, bottom to top, five in all. Push MOTOR ON, SERVO ON buttons on drive modules (power must be on, even though one is not chopping). Be sure to set both the X and the Y axis source selectors to EXT ANALOG position and dial in OFFSETs for best collimated images as noted on the rack. The secondary should be left ON all the time. For additional information, please refer to the on-line 2.1-m Chopping Secondary User's Manual.
- Prepare object list for entry into XOBJECT cache by LTO; alternatively, have LTO check at earliest opportunity that coordinates sent by email are properly loaded.
- **[First SQIID night only]** Execute `obsinit` to switch from ICE to WILDFIRE environment; this should be done by support person.
- If it is not already running, bring up WILDFIRE on the instrument terminal and activate detector.
- Instrument power is controlled by the switch on the instrument located on the SQIID electronics box near the power cord.
- Create parameter set(s) as needed for observing with `ped` and `eask` and save with `psave`.
- Create and `source` any custom observing scripts required.
- Check that `status` `s` gives proper values.

SQIID is now ready to take data.

Calibration Data

Although sky flats are generally adequate for reducing SQIID observations, dome flats may be useful. Dome flatfields may be done either in the afternoon before observing or in the morning. Remember that you will need dark frames taken the same way (integration time and number of coadds) as your sky/dome exposures to properly produce your sky flats. Since the temperature and operating conditions for SQIID are highly stable by design, one should not have to repeat flatfields once they have been verified. In any case, it may be desirable to take some short and long (30s) dark frames before the first night of observing to verify performance.

- Telescope focus set to nominal value for SQIID (approximately -5.20 at 2.1-m; -7300 at 4-m)
- Dome flats:
 - Dome and telescope positioned by TA/LTO to center of flatfield target
 - Dome lights off; door to visitor gallery closed
 - Turn on flatfield lamps; intensity controlled by buttons at LTO console

While all channels are exposed simultaneously, one may find different lamp settings are required to be properly onscale at each channel. Flatfield series should be obtained for each bandpass (J, H, K) used for observing, as each wavelength channel is serviced by its own array. Two settings, one for J/H and one for K should suffice. The high background at L band obviates dome flats - use sky L band flats instead Use an illumination level sufficient to give approximately 5000 ADU in 2 s integration time. Higher signals in shorter integration times may exacerbate nonlinearity effects. Read noise is sufficiently low that 200 ADU signal will be background limited. Obtain 5 - 10 flats in each band desired for later median averaging. Turn flatfield lights off and obtain an equal number of non-illuminated bias images at each setting.

- Compare flatfield and dark current data with standard frames as check on array performance
- Look at IRAF/FITS longheader to verify that telescope coordinate information is being acquired

Final Setup at Start of Night

Telescope Operator will do final dome and telescope checks and acquire stars, offset, etc. SQUIID acts as its own acquisition camera.

- Acquire ephemeris star ($K \sim 9 - 10$)
- Ensure telescope focus is near nominal value (5.20 at 2.1-m; -7500 at 4-m)
- Acquire, center, and focus infrared image, resetting zs and integration time if necessary
- When satisfied, zero telescope pointing

Observing Miscellany

Telescope motions are generally commanded from LTO terminal, although they can also be entered from the observer's terminal. For programs demanding frequent motions, agree on a mutually compatible protocol with the LTO. In the event of multiple observers, only one should serve as the communication link to the LTO.

- `movie` may be used to fine-tune position before beginning an observation
- **[2.1-m]** The dome lower shutter must be raised to reach large airmasses (zenith distance $< 62^\circ$). This takes about five minutes. Zenith distances $< 30^\circ$ are inaccessible with the lower shutter up
- The catwalk is off limits to observers, unless accompanied by the LTO. Check the weather from the ground floor level

Control Room Shutdown

- LTO will position and close up telescope and dome
- **[2.1-m]** Leave chopping secondary rack powered up, except last night of block run
- Save image data to tape, either by:
 - `wfits` IRAF/FITS images to Exabyte or DAT
 - `tar` FITS images to Exabyte or DAT
 - `wfits` IRAF images to FITS files on disk and `tar` them to tape.
 - `ftp` files to home computer
- Enter work requests into `service` program through the LTO
- Verify operational hours for LTO to enter into electronic observing log

Observing Platform / Cassegrain Cage Shutdown

- Leave the Instrument power supply alone (normally on).
- Close the lower SQUIID guider dark slide. The "stick shift" on the west of the SQUIID telescope interface should be fully in.
- Set the internal SQUIID aperture wheel to dark. Status is indicated by the lights at the hand crank on the North side of SQUIID. Turn on the indicator lights and follow the directions posted. Turn off the indicator lights when you are finished.

Computer Room Shutdown

- Rewind and remove tape
 - Leave computer, instrument, and Heurikon DSP power ON at all times
-

Appendix II: WILDFIRE Command List for SQUIID

SQUIID image names follow the naming convention:

"filename"//"ch_id"//"XXX"//"image_extension" (e.g., n1_001j.fits)

where "filename" is an observer controlled parameter, "ch_id" is the appropriate designator from the set "j h k l", the number "XXX" is sequentially numbered (being automatically incremented for each exposure until a new value is declared, either at a new object or new night) and "image_extension" is either ".fits" or ".imh" (depending on the saver setting declared at startup). If you correctly set 'oldirafname = yes' when reading the data from tape, the image names will be restored to their original names and match the log sheets.

A list of available commands within the WILDFIRE instrument control window is:

SYSTEM LEVEL	
<i>! commands</i>	execute the commands in csh or run csh
<i>? command</i>	give help on a command
<i>ed name</i>	call up an editor on a proc
<i>help name</i>	display help for one of these topics
<i>man name</i>	display a man page for a given topic
<i>progress 0</i>	minimize diagnostic output during integrations (**node...)
<i>source program</i>	temporarily include tcl program within recognized system; need to source again after powerup or go (full path name required)

DETECTOR	
<i>activate</i>	activate the detector
<i>deactivate</i>	deactivate the detector
<i>setup squid</i>	set up the default SQUIID voltages and prompt for activation. Alternative parameter named parameter files can also be invoked via <i>setup filename</i>

?ucode	list array microcode currently in use (also in image header)
dl <i>microcode_name</i>	download specific array microcode

WILDFIRE

startwf	initiate bootstrapping and downloading of the WILDFIRE system
exit	deactivate the array and exit the WILDFIRE controller
trouble	open troubleshooting session (do NOT enter in Instrument Control window)
hung	attempts to complete link protocol; used as part of the restart procedure when WILDFIRE is hung (INSTRUMENT CONTROL window unresponsive and data collection stalled); must be entered in Console window

HOUSEKEEPING

newobserver	enter observer name and proposal ID for image header
status [lslvltlf]	display a status screen; (general status lsl; voltageslvtl; temperaturesltl; filters lfl)
longheaders [onloff]	will disable/enable house keeping data in the header
tcp_on	enable link to TCP for telescope status info and offsetting
tcp_off	disable link to TCP for telescope status info and offsetting

PARAMETER FILES

Note: a parameter has two attributes, its value and flags indicating whether the parameter and its value should be displayed and/or queried when the *ask* or *observe* tasks are run.

lpar	list the names of the available parameter files
------	---

plist	list all the current parameters
psave <i>filename</i>	save the current parameter set (values and ask/display flags) to the named parameter file
puse <i>filename</i>	load the named parameter file
ped	edit the current parameter file selected by <i>puse</i> asking all questions regardless of query status
ask	prompt for the <i>eask</i> selected subset of parameters within the current parameter set
eask	iterate through all the known parameters, allowing the user to specify which parameters are queried and which are displayed. After each question an "l" signifies display only; "a" signifies query; "la" will list the current value (which may be selected by [cr]) or accept a new entry

ACCESSING INDIVIDUAL PARAMETERS

Note: many SQIID parameters have 4 values (one per channel) which are entered on the same line separated by whitespace. The last argument in a series is adopted for the rest of the arguments: "1" yields "1 1 1 1", "1 2" yields "1 2 2 2"; "1 2 3" yields "1 2 3 3". When no argument is given, task prompts with current value.

?coadds	returns the number of coadds for next image
pics [n]	sets the number of pictures to be taken at each <i>observe/go</i>
set-time [f f2 n]	prompts and sets the JHKL coadds and integration time (in seconds to millisecond level) sets JHK time to f sec, L time to f2 sec, and JHK coadds to n (task computes L coadds). This is the preferred method to set integration time and/or coadds.
setIntegration [f f2 n]	sets JHK time to f sec, L time to f2 sec, and JHK coadds to n (task computes L coadds)
nextpic [n]	sets the picture index appended to filename to [n]
header_dir	sets path for FITS image or IRAF image headers

pixel_dir	sets path for IRAF image pixel files (unused for FITS images)
mode	sets operational mode for array readout (<i>stare/sep</i>); <i>sep</i> is for observing
title	sets title field for IRAF/FITS image header
comment	sets comment line within IRAF/FITS image header
offset	relative telescope (RA,DEC) position parameter updated by TCL commanded motions
resetoffset	reset the position "offset" values in the IRAF/FITS image header to "0,0"
filename <i>filename</i>	sets the IRAF/FITS image "filename". The path is not included in "filename"; if no argument given, will prompt with current value. For SQUID, a "%d" or "%03d" should be inserted where the picture number should be placed. If no field is given, "%03d" will be appended. The format will be: "filename"//"nextpic"//"ch_id"//"image_extension" (Note: when filenames conflict, the saver task attempts to create a unique name by appending .nnn to conflicting filename.)

OBSERVING	
ask	prompting for pre-selected observing parameters
go	initiate an observation using the previously set parameters
observe	perform one observation using current parameter set, prompting for key parameters
abort	abort an observation (enter in Instrument Control window); follow with <i>save</i>
save [ch_id ...]	include all the channels you wish to save, eg., "j h k"; be sure to re-issue after an <i>abort</i>
display [ch_id ...]	display channel <i>n</i> after each coadded integration
east [n]	move telescope <i>n</i> arcseconds east

west [n]	move telescope n arcseconds west
north [n]	move telescope n arcseconds north
south [n]	move telescope n arcseconds south
toffset [e] [n]	move telescope e arcsecs east and n arcsecs north: + for north/east; - for south/west
zs [z1] [z2]	set zscale values [z1] and [z2] for the image display
zs 0 0	enables autoscaling for the image display
tcp_on	enable link to TCP for telescope status info and offsetting
tcp_off	disable link to TCP for telescope status info and offsetting
movie	begin observe/display loop. NOTE: parameters (filename, running number, integration time, coadds, etc.) will be those of previous observation or 'ask' routine unless specifically reset!!!! Movie frames are saved to disk and should be deleted periodically. It helps to use a filename like "junk" when using movie. Terminate movie with <code>end</code> [CR] in Instrument Control window. <i>Pay careful attention to the nextpic numbers, as movie increments nextpic for only the selected channel and after movie terminates, nextpic for the channels will no longer match.</i>

Appendix III: Troubleshooting

As with all Kitt Peak instrumentation, nothing is ever supposed to *malfunction*. On the rare occasions when something seems to go wrong, either by pilot error, exquisite software gotchas, or hardware failures, recovery can in many cases be fairly simple. In particular, hang-ups in the instrumentation software can usually be corrected without resorting to rebooting the computer, which should be considered a last resort.

The following tables cover situations that may arise with the Instrument Computer or SQUIID itself. Some situations are not covered in this manual, since the recommended recovery could involve procedures that are potentially harmful if done incorrectly. In these cases, the user is requested to call for technical assistance from the Observatory staff.

Instrument Hardware

no signal	Internal cold dark slide closed. Check <code>status</code> s for proper temperatures, voltages. Check that green LED in analog electronics box is lit. If the detector has been accidentally deactivated, program will not sense this; <code>observe</code> will work, but return pixel values near zero in image.
minimal signal at J/H; large signal at K	Telescope mirror covers, dust slide (top, South), and/or external dark slide (pull knob at NorthEast) closed. Check <code>status</code> s for proper temperatures, voltages.
apparent vignetting	External darkslide may be partially in place or internal aperture wheel may not be set to <i>open</i> position. Vignetting by external darkslide or dust cover will elevate K background. If the internal polarization analyzer is in position, the image will be vignetted on all sides with half the signal. Vignetting also results in higher backgrounds in the K and L channels.
bootstrap failure	If the <code>startwf</code> procedure fails during the "bootstrapping node ..." process, a likely culprit is a bad (or incorrect, if the failure occurs on the initial setup) fiber optic connection. Check the three status LEDs visible through sight holes on the SQUIID electronics. The left LED should be green if there is power to the instrument; the middle and right LEDs should be off. If either the middle (channel 1) or right (channel 2) LED is red, there is a fiber continuity problem in that channel. There is a duplicate set of LEDs in the Heurikon DSP box in the computer room (reporting on the other two fibers); it is necessary to remove the front cover to view them. A bad fiber channel will require the substitution of one of the spare fibers. Call for assistance.

WILDFIRE RESTART PROCEDURES

The following procedures are intended as a guide for restoring the WILDFIRE system following various levels of system failure. Re-booting the computer and cycling power to the instrument or DSP in the Heurikon box in the computer room are not normal WILDFIRE operations and should not be done without proper consultation, or unless the specific conditions below are valid. These procedures are listed roughly in order of increasing severity, so unless a specific condition has occurred (e.g., DSP power cycling), try the less dramatic procedures first.

An extensive troubleshooting library may be consulted by entering `trouble` in any active window (except the Instrument Control window). The resulting interactive session can be used to diagnose and correct problems.

FAST RESTART:

If WILDFIRE has been exited normally and the system is intact (neither instrument power nor Heurikon DSP power has been interrupted), one can simply type the following within the Instrument Control window to restore operation:

```
g sqiid
```

The startup script will run automatically to the point where the question about array activation is presented.

INSTRUMENT STATUS WINDOW HAS VANISHED:

If the Instrument Status window has vanished, first check to see if it has simply been closed. Type `fireproc` (or `!fireproc` if necessary) from an active window and look for the "hkserv" process. If the "fireproc" task is unavailable, type:

```
ps ax | egrep 'PID|hkserv' | egrep -v grep
```

- in the Console window at the 4-m
- in a Unix (xgterm) window logged into royal at the 2.1-m (if necessary, use the menu to start one)

If the process is present, the window has been closed, and it will be necessary to locate and open it. If the icon is not visible, it may be hiding behind one of the open windows. In OpenWindows, one can check the "windows" item in the menu for the status of all operating windows; if the Instrument Status window is present, open it and continue observing.

If the Instrument Status window has died, perform the SIMPLE RESTART procedure below.

SIMPLE RESTART:

If WILDFIRE has crashed (Instrument Status window has vanished and could not be found by above procedures), and/or the "[hostcomputer]" prompt has returned to the Instrument Control window, the following steps within the Instrument Control window should restore operation:

- If the "%" prompt is present, first enter `exit` to cleanly exit the processes and get the "[hostcomputer]" prompt
- At the "[hostcomputer]" prompt, enter: `g sqiid`, answering 'y' to question about windows (note CAPS)
- Enter `puse [parameter_file]` to restore the parameter file active before the crash
- Verify "pixel_dir", "header_dir", and "nextpic" with `plist` or `ped` to make sure data will still be going to the desired location and will not overwrite existing data.
- Verify "settime".
- Reload any scripts with the `source` command
- Continue observing

[NOTE: If the power to the instrument and/or the Heurikon DSP box in the computer room has been interrupted or the computer has been rebooted, this procedure may not be sufficient. See below for more specific procedures]

STALLED SYSTEM RESTART:

If WILDFIRE is hung (Instrument Control window unresponsive - won't respond with a system prompt after issuing a "CR" - and data collection stalled):

- Enter ^C ^C in the Instrument Control window
- Enter hung several times:
 - at the 4-meter in a Unix (xgterm) window logged into *khaki* (rlogin khaki).
 - at the 2.1-meter in a Unix (xgterm) window logged into *royal* (rlogin royal).

until either the WILDFIRE "%" prompt or the UNIX "[hostcomputer]" prompt returns in the Instrument Control window

- If you see the "%" prompt first, type `exit` in the Instrument Control window; the "[hostcomputer]" prompt will return
- When you see the "[hostcomputer]" prompt in the Instrument Control window, proceed with the SIMPLE RESTART procedure above

TOTALLY STALLED SYSTEM QUICK RESTART:

If the STALLED SYSTEM procedure fails to return the UNIX prompt, or an examination of the operating processes by entering `ps ax` in the Console window reveals a process which cannot be halted via the `kill -9 [process number]` command, it will be necessary to reboot the instrument computer. In detail, type `fireproc` (or `!fireproc` if necessary) from an active window and look for the "hkserv" process. If the "fireproc" task is unavailable, type:

```
ps ax | egrep 'PID|wfire' | egrep -v grep
```

- in the Console window at the 4-m
- in a Unix (xgterm) window logged into royal at the 2.1-m (if necessary, use the menu to start one)

Look for a "control" process in state "D".

- Reboot the instrument computer
 - At the 2.1m, type "freboot" on Royal's console (VT220 or whichever terminal is currently attached to royal) in the computer room downstairs
 - At the 4-m, use the [L1 A] or [Stop A] keys, then enter `boot`. After sytem has returned, login as "[telescope]" on the instrument computer with thecurrent password
- In the control room, go to the Instrument Control window and type:

```
g sqiid
```

The startup script will run automatically to the point where the question about array activation is presented - answer 'y' to question about detector activation

- Enter `puse [parameter_file]` to restore the parameter file active before the crash
- Verify "pixel_dir", "header_dir", and "nextpic" with `plist` or `ped` to make sure data will still be going to the desired location and will not overwrite existing data.
- Verify "settime".
- Reload any scripts with the `source` command
- Continue observing

TOTALLY STALLED SYSTEM RESTART:

If the STALLED SYSTEM procedure fails to return the UNIX prompt, or an examination of the operating processes by entering `ps ax` in the Console window reveals a process which cannot be halted via the `kill -9 [process number]` command, it will be necessary to reboot the instrument computer. In detail, type `fireproc` (or `!fireproc` if necessary) from an active window and look for the "hkserv" process. If the "fireproc" task is unavailable, type:

```
ps ax | egrep 'PID|wfire' | egrep -v grep
```

- in the Console window at the 4-m
- in a Unix (xterm) window logged into royal at the 2.1-m (if necessary, use the menu to start one)

Look for a "control" process in state "D". If you find such a process, then:

- Turn the instrument power OFF before rebooting, using the switch on the instrument
- Reboot the instrument computer :
 - At the 2.1m, on the *royal* console in the computer room downstairs) use the [L1 A] or [Stop A] keys, then enter `boot`. After system has returned, login as "[telescope]" on the instrument computer with the current password.
 - At the 4-m, on the *khaki* console (in the computer room downstairs) use the [L1 A] or [Stop A] keys, then enter `boot`. After system has returned, login as "[telescope]" on the instrument computer with the current password.
- In the control room, go to the Instrument Control window and continue with the RESTART procedure below.

RESTART AFTER INSTRUMENT POWER INTERRUPTION:

If the power to the instrument was interrupted but the black Heurikon DSP box in the computer room remained powered up and the computer was not rebooted:

- In the Instrument Control window, enter `startwtf`, following the interactive startup procedure, turning the instrument power ON when requested using the switch on the instrument
- Enter `setup sqiid`, answering 'y' to question about detector activation (Note: you may use your previously saved - via `psave` - parameter filename in place of "sqiid")
- Enter `puse [parameter_file]` to restore the parameter file active before the crash
- Verify "pixel_dir", "header_dir", and "nextpic" with `plist` or `ped` to make sure data will still be going to the desired location and will not overwrite existing data.
- Verify "settime".
- Reload any scripts with the `source` command
- Continue observing

RESTART AFTER HEURIKON DSP BOX POWER INTERRUPTION:

If the black Heurikon DSP box in the computer room has been powered down, then it is necessary to do the following.

NOTE: The order of these steps is important. If the dsp box is powered down, rebooting the instrument computer is necessary. Make sure no one else is using the instrument computer at the time. If only the power to the instrument has been interrupted, perform the procedure above. Whenever the instrument computer is rebooted, the instrument power must be off and the heurikon dsp power on!

- Verify that the Heurikon DSP box is powered up
- Turn OFF power to the instrument using the switch on the instrument
- Turn the DSP power OFF for 30 sec, then ON
- Reboot the instrument computer:
 - At the 2.1m, on the *royal* console in the computer room downstairs) use the [L1 A] or [Stop A] keys, then enter `boot`. After system has returned, login as "[telescope]" on the instrument computer with the current password.
 - At the 4-m, on the *khaki* console (in the computer room downstairs) use the [L1 A] or [Stop A] keys, then enter `boot`. After system has returned, login as "[telescope]" on the instrument computer with the current password.
- Go to the Instrument Control window and enter `startwf`. Follow the interactive procedure.
- Turn ON the instrument power when requested by `startwf`
- In the Instrument Control window, enter `setup sqiid`, answering 'y' to question about detector activation (Note: you may use your previously saved - via `psave` - parameter filename in place of "sqiid")
- Enter `puse [parameter_file]` to restore the parameter file active before the crash
- Verify "pixel_dir", "header_dir", and "nextpic" with `plist` or `ped` to make sure data will still be going to the desired location and will not overwrite existing data.
- Verify "settime".
- Reload any scripts with the `source` command
- Continue observing

WILDFIRE PROCESSES:

By way of information, these are the WILDFIRE specific processes running on royal at the 2.1-m under normal operations:

```

230 p1 IW    0:00 /bin/csh /usr/wfire/bin/startwf-lapis
242 p1 IW    0:00 /bin/sh /usr/wfire/bin/startwf
290 p1 R     7:25 /usr/wfire/bin/SQIID/control
249 p2 IWN   0:00 /bin/csh/usr/iraf/extern/ice/startup/config/fire/start.red
304 p3 IW    0:00 /bin/csh /usr/wfire/bin/sun_daemons SQIID -fits
311 p3 R    26:08 ./saver -fits
312 p3 S     0:07 ./hkserve ../config/SQIID DISPLAY=lapis:0.0 EXINIT=set optim

```

Appendix IV: Data Reduction Guide

INTRODUCTION

Given the large variety of observing programs being carried out SQIID, no single approach to data reduction is universally applicable. This section reviews the promising approaches to data reduction for several specific observing scenarios: observations of a bright stellar source, a faint stellar source, and an extended object.

IR imagery with the InSb array presents several problems not encountered in visual imagery with an optical CCD. These include high background with strong variable emission lines and regions of bad pixels. Fortunately, the frontside illuminated InSb arrays do not suffer from fringing so that to overcome the bad pixels, we recommend taking a large number (>5) of observations of a given object, spatially offset between exposures, and deriving the median of the individual observations. True dark frames are generally not necessary in the course of normal observing, since sky subtraction removes the dark current as well, and flatfield exposures (except for L) are best done by cycling the illumination lamps on and off. Most importantly, the strong and variable background requires that sky subtraction be handled in a two step

process. First order sky subtraction is achieved by subtracting a sky frame. The very high level of IR sky brightness precludes the "traditional" CCD approach of flatfielding and background reduction on a single object frame, since even a 1% uncertainty in the flatfield would produce effects large in comparison to the object signal. The first order sky subtraction will typically remove 95 - 99% of the sky, thus greatly reducing the effects of flatfield uncertainties in the second order background removal.

The majority of experience with SQUIID has been in the J, H, and K bands, where the background consists of OH and O₂ lines superposed on the spectrum. Beyond 2.3 microns, the background consists of a smooth continuum due to the emission from the telescope as well as emission lines in telluric features. Thus, transitions that produce telluric **absorption** lines in astronomical spectra will produce **emission** lines in the sky background. Although this scenario is more challenging, the same routines of sky subtraction and off-object residual background subtraction work well, as long as one operates in the linear (< 10000 ADU) region of the detector.

TRIMMING AND LINEARIZATION

FLATS, DARKS, & SKY FRAMES

Proper data reduction requires accurate solutions for the small additive effects of internal illumination and charge generation (DARK frames), the large additive effects of sky illumination (SKY frames) and the multiplicative effects of position dependent pixel sensitivity (FLATFIELD frames).

The creation of DARK, FLAT, and SKY calibration frames are the first step in the data reduction process. The DARK frames are simple to obtain and process but the FLAT and SKY frames are more difficult to create and are crucial to the quality of the final images. Compared to optical band CCD observations, infrared observations are extremely background limited. Furthermore, the background in the near-infrared is variable at many temporal and spatial scales.

System SKY frames are established from observations with the same integration time and near in time and place to the source frames. This is done by interspersing frames of off-source (ideally) blank sky fields in the sequence of source observations. Many of these sky frames, each at different position, are then median filtered to remove celestial sources to generate a SKY frame, which is measure of the temporally stable illumination on the array, including dark current and fixed pattern noise.

System FLATFIELD frames are established using the sky as a uniform external illumination source. The background in the IR results in sky levels with S/N of better than 100 in a single 3 minute exposure. By taking the median of a reasonable number of blank fields (or target fields without large objects) obtained at different times during the night and at different locations on the sky, a satisfactory measure of the system flatfield can be derived.

Generally, DARK frames (taken with the internal cold dark slide in place) are stable over a night (at about 1 electron/sec) and are probably stable over an entire observing run. Changes in dark current can accompany changes in the ALADDIN array temperature. Since the SQUIID dark current has both a base level and a time-dependent component, a dark frame must be created for each exposure time (that you intend to use to determine flatfields or for dark subtraction) during the observing run (it is assumed here that the observer has obtained such dark exposures).

BRIGHT STAR

One may define a bright star as one that can be observed in frame times of less than 10 s; in this case, the greatest limitations to S/N are systematic effects rather than background limited statistics. To overcome these, set coadds to 3 - 5 (to build up signal to noise on each frame) and take 5 - 7 observations of the star, displacing it between observations. The `do_standard` script is ideal for this operation. Since the observations span a short time, the sky will not vary significantly, and one can generate a sky frame from a median of the individual observations. Subtracting this median sky from the individual observations removes the dark and first order sky. Each image is then divided by the flat.

SQIID Package

SQIID produces simultaneous images of the same field in the J, H, K, and narrowband L passbands, using individual 512X512 quadrants of ALADDIN InSb arrays. The observations are generally background (photon statistics) limited. Typical observing programs include:

- taking a few (2-5) exposures on the same target with small offsets (to counter ghosts and bad pixels and improve spatial sampling of the images)
- taking many exposures of the same target with a dither pattern of offsets (to build up long exposures);
- spatial mosaics of dithered pairs of images covering larger regions with limited overlap between images (to build up large images).

These three kinds of observations are distinguished because they require somewhat different data reduction strategies. This document describes a set of IRAF programs (created by Michael Merrill at NOAO) designed to facilitate the reduction of SQIID datasets. These programs reside in the IRAF package "upsqiid". They have a number of imperfections in the user interface (especially a large number of irrelevant parameters) and currently do not have help files. *NB: The SQIID package is not an officially released and supported IRAF package; all queries should be directed to Michael Merrill at NOAO (merrill@noao.edu; 520-318-8319)*

We will define a "dataset" to be the set of direct observations of a given field. These may be dithered observations of a single target or a mosaic of a larger region. In the extreme case, the dataset may contain only a single exposure (and only steps A and B listed below would be required). The basic path for the reduction of SQIID dataset can be described as follows:

- Create DARK, FLAT, and SKY frames for each channel.
- Process each individual source frame to remove instrumental dark current, sky background, and pixel to pixel sensitivity variations.
- Combine all images of a given target into a "database".
- Interactively define the relative spatial offsets between each image in the database for one of the channels.
- Combine the images in the database into a single image suitable for analysis, using bad-pixel masks to exclude bad pixels.

Users are cautioned that IR image datasets often present a greater data reduction challenge than optical CCD images both due to the superior performance of optical CCD detectors (lower dark current, readout noise, and pixel to pixel sensitivity variations) and especially due to the extreme background limited nature of most IR observations. The results at each step in the process should be carefully examined and problems understood before proceeding. Many problems can be solved by the exclusion of bad images from the datasets.

The upsqiid IRAF package is contained within a tar file called "upsqiid.tar" at the SQIID web site

- <http://www.noao.edu/kpno/sqiid/>
- <http://www.noao.edu/kpno/sqiid/upsqiid.tar>

Restore the package using "tar upsqiid.tar" within your IRAF login directory and follow the "README" directions for installing the package within your system. Since the package consists entirely of IRAF *cl* procedures, no recompiling is needed. Assuming you copy the package somewhere in a directory called "upsqiid", you would put the following definitions in your "loginuser.cl" file:

```
task    upsqiid = "your_pathname/upsqiid/upsqiid.cl"
```

You also need to edit the file upsqiid.cl in the "upsqiid" package to point to your path instead of my path:

```
set      upsqdir = "your_pathname/upsqiid/"
```

One loads the "upsqiid" package by typing `upsqiid` in the IRAF xgterm window where the *cl* is running. At KPNO the "DATA REDUCTION" window would qualify. Alternatively, you can bring up a new "xgterm" from the menu.

At the KPNO 2.1m one has the option of performing data analysis on *lapis* (either directly or remotely on *royal*) or *azure*, since the /data1 and /data2 disks are accessible from all three machines. Since *royal* is busy with data aquisition, *lapis* or *azure* are preferred. When running locally on *lapis*, one also needs to bring up a local ximtool window from the menu. If the "upsqiid" package is unavailable, type the following in your (lapis/azure) IRAF window:

```
task upsqiid = "/data2/ir2meter/merrill/upsqiid/upsqiid.cl"
upsqiid
```

Appendix V: TCL Scripts

Scripts are a powerful tool for executing a sequence of tcl commands, including telescope motions, instrument motor commands, and observations, as a single executable program. Many of the wildfire commands are simply protected scripts within the wfire/tcl directory. Observers may generate their own scripts in the "public" directory /data2/[telescope]/tclSamples. One approach is to browse through the existing scripts to find one that performs a function similar to that desired, copy it to a new file, and edit it as required. **It is important to note that the first line contains the base name of the script, and must be edited to reflect the new name of a script created in this manner.**

Scripts copied into the user home script directory (/data2/2meter/wfire at the 2.1-m and /data2/4meter/wfire at the 4-m) and sourced can be marked for automatic inclusion in subsequent invocations of "startwf" by entering "mkIndx".

Below is a typical script, "dotransit", used with SQUIID. This will take 5 observations - one at the center and four corners of a box. This script employs a string array (setup by the "set step" lines) to hold the commands, which are run within the "while" loop. After each step, the loop recognizes a CR as a signal to abort the script, leaving the telescope pointed wherever it was. Since the "reset_offset" command zeroed the north and east position variables, these variables accurately report the current position relative to that at the start of the script. The script "dotransit" modifies the "do_standard" script to keep the header information current. (To save time, the "do_standard" script, which takes five images, normally shuts off the TCP info (RA, DEC, airmass, ZD) after the first position and turns it back on at the end.)

```
proc dotransit {} {
#*****
# (do_standard - take 5 images, starting at the initial position, then scanning
#               the corners of the enscribed square. The telescope is returned
#               to the initial position when done. Prompts for the side of the
#               square in arcseconds.)
#               based on do_standard without turning off tcp
#*****

global north east
if ![ yorn "Is the telescope set to the center of the field? " ] then {
    error "telescope not set"
}

# make sure the coordinates are centered
reset_offset
# turn tcp header information on
tcp_on

# get size of grid
puts stdout "What is the separation between pictures in arc seconds? "
set size [readline]
puts stdout "Side of enscribed square = $size arc seconds"

# observe (0, 0)
set step(1) { puts stdout "Taking Center field" ; go }
set step(2) { puts stdout "Taking SE field"; toffset [expr "$size/2"] [expr "-$size/2"] ; go }
set step(3) { puts stdout "Taking NE field"; toffset 0 [expr $size] ; go }
set step(4) { puts stdout "Taking NW field"; toffset [expr "-$size"] 0 ; go }
set step(5) { puts stdout "Taking SW field"; toffset 0 [expr "-$size"] ; go }
set step(6) { puts stdout "Returning to starting field"; toffset [expr
"$size/2"] [expr "$size/2"] }

puts stdout "Hit return to abort Grid."
```

```

set i 1
while { $i <= 6 } {
    eval $step($i)
    if [select] then {
        break;    }
    incr i }
# turn tcp header information on
tcp_on

puts stdout "TRANSIT GRID COMPLETE "
}

```

The script "box5.tcl" does something similar to the "dotransit.tcl" and the "do_standard.tcl" scripts, but organizes things for easier expansion. One could fill a "set set() {}" structure" with the position increments you want to visit. It is recommended that you build a series of such scripts rather than set up one that executes a massive generalized observing program in one fell swoop. Note that the "ask" command is used to query the observation parameters (only once) before the observations start and provision is made for a graceful exit before committing to the observation.

```

proc box5 {} {
#*****
# box5.tcl does something similar to the dotransit.tcl/do_standard.tcl
# scripts, but organizes things for easier expansion.
#*****

    puts stdout "Starting object sequence"
    global north east # zero offset parameters
    set north 0
    set east 0
#    set_offset
# make sure the coordinates are centered
    reset_offset
# turn tcp header information on
    tcp_on
# run through standard 5 position grid, one observation (picture) taken
# at each position. The sequence starts centered, but takes no data and
# ends with data at center.
    set step(1) { east 30.0 ; south 30.0}
    set step(2) {          north 60.0}
    set step(3) { west 60.0          }
    set step(4) {          south 60.0}
    set step(5) { east 30.0 ; north 30.0}
# run through ask sequence
    ask
# allow for graceful exit
    if ![ yorn "Do you want to continue  "] then {
        error "Safe exit"
    }
# issue exit procedure reminder
    puts stdout "Hit return to abort Grid."
    set i 1
    while { $i <= 5 } {
        eval $step($i)
        go
        if [select] then {
            error "error in sequence"
        }
        incr i
    }
# issue beep at end
    puts stdout "Sequence completed"
    beep 10
}

```

Appendix VI: Cautions and Caveats

A number of operational issues are worthy of note:

- **WARNING: Do not let the designated data disk fill up. You will lose data!** When the data acquisition disk is full, zero length images are written to disk and the data are lost. Although the housing window dutifully reports the available space after each exposure, there is currently no additional visual or audible alert that the disk has filled. Although the storage preferred location for data acquisition */data2* is large (4 GB) each exposure quad of 512X512 floating point images is 4MB. To avoid filling the disk it is recommended that you move the images from previous nights over to a larger disk, such as */data1* before beginning the next nights observing.
- When restarting the WILDFIRE System, the default *squid* parameter set may not load the preferred microcode (*squid4d_2233_03*). After the "setup squid" task has completed, one can check the microcode using "?ucode" and download the proper code with "dl squid4d_2233_03".

Appendix VII: Changes to SQUIID

During February 2002, the final planned upgrades to SQUIID were installed. The relative spatial orientation and offset amongst the channels has changed and channel characteristics will need to be re-determined. The changes are summarized as follows:

- New masks, designed to redirect the images on the mask away from the array, were placed in front of the arrays.
 - Within the K channel, the Barr K filter was exchanged for a OCLI Ks/K' filter of the type used in FLAMINGOS and TIFKAM/MOSAIC. Despite the 12% decrease in bandpass, the improvement in transmission and the lower thermal background of the Ks filter should improve limiting performance by about 0.2 magnitudes.
 - The K channel array was rotated 180 degrees to remove the diagonal crack from the FOV. It was judged that the small region of reduced QE (about 10% lower) near the NW edge of the field in Q2 was preferable to the diagonal crack in Q3. The crack in Q3 was difficult to remove by dithering.
 - Following the official closure of the highly successful ALADDIN Consortium (involving NOAO, USNO Flagstaff, and Raytheon Vision Systems), the ownership of specific arrays was determined. As a consequence the H and L channel arrays in SQUIID were exchanged for more appropriate devices. The new H channel array has better cosmetics (no cracks) and the new L channel array has higher well capacity than their predecessors.
 - A new Lyot stop, with central obscuration intended to reduce the background, was installed in the L channel.
-

Appendix VIII: Representative WILDFIRE Interchange

Starting WILDFIRE

The following session is representative of starting up a WILDFIRE session with SQUID. Actions on the part of the observer are set apart in bold type inside square brackets: "**->[Enter "commands here"]<-**", where one types the enters the quoted text at the keyboard followed by a carriage return. Informational asides are set apart in bold ("**[Note:]**"). WILDFIRE presents choices as bracketed values [n], where the default value, selected by answering with a "return", is the value inside the brackets. The proper answer to yes and no questions is "y" or "n" (not "yes", "no", etc.) Generally, the boolean values are defaulted to the most likely value.

->[In the Instrument Control window type "startwf"]<-

```
lapis% startwf
royal being added to access control list
[1] 18486
2meter@lapis% stty: TCGETS: Operation not supported on socket
[1] 27884
[2] 27885
```

[Note: at this point control passes to WILDFIRE. At the 2meter, a new Instrument Control window running remotely on royal overlays the Instrument Control window on lapis.]

WELCOME TO THE WILDFIRE INSTRUMENT CONTROL SYSTEM.

This procedure walks you through a startup of the instrument control program.

All yes/no questions should be answered with a "y" or an "n".
Instrument names can be typed in upper or lower case.

Should this procedure abort or hang during the start up, please use another window to run the "trouble" routine. This will allow you to search a TROUBLESHOOTING file to try determine why the startup failed.

Please mail trouble reports or suggestions for improvements to wfire@lemming

Press "return" to Continue

->[Press "return"]<-

If the power to the WFire DSP box in the computer rack was interrupted, a hardware setup procedure must be run before it can be used. This procedure must be run if the power to the DSP box went off for ANY reason.

Has the WFire DSP box power been off for any reason since the last time you ran startwf or restart (if unsure try 'n')? [n]

->[Press "return"]<-

The Instrument hardware must be setup to allow correct data transfers between the instrument and the DSP Box. This setup MUST only be done once each time the instrument is turned on.

Has the instrument power been off since the last time you ran startwf or restart? [n]

->[Press "return"]<-

The Instrument hardware must be setup to allow correct data transfers between the instrument and the DSP Box. This setup MUST only be done once each time the instrument is turned on.

Has the instrument power been off since the last time you ran startwf or restart? [n]

->[Press "return"]<-

Which instrument are you using (enter PHOENIX, IRIM, CRSP, SQUIID, etc.) ? SQUIID

->[Enter "SQUIID"]<-

Do you want windows? [y] (type 'n' if not using X windows).

->[Press "return"]<-

Do you want to save in IRAF format ? [n] (default is FITS).

->[Press "return"]<-

FITS=-fits

[Note: at this point WILDFIRE bootstraps the system.]

sldnet-noio

SQUIID LD-NET (Network Loader), Version 89.1 [Link I/O Driver: 'SCIO']
Copyright (c) 1986-1989 by Logical Systems

Loading first phase of bootstrap to root node 1
Finished loading first phase, awaiting first acknowledge
Loading second phase of bootstrap to root node 1
Bootstrap loaded, awaiting acknowledge
Successfully bootstrapped root node 1

[Note: If there are problems either establishing or linking with the root node, the system hangs or exists here. Hangups during "Bootstrapping node 100" are due to poor fiber communications or failed memory in the SQUIID electronics. Overheating or lack of power are the most common cause of such "failures".]

Bootstrapping the remainder of the network:

Bootstrapping node 100
Bootstrapping node 101
Bootstrapping node 102
Bootstrapping node 103
Bootstrapping node 203
Bootstrapping node 202
Bootstrapping node 201
Bootstrapping node 200
Bootstrapping node 2
Bootstrapping node 10
Network successfully bootstrapped

```

Downloading program: ../tld/SQIID/b011.tld
Downloading program: ../tld/SQIID/inst.tld
Downloading program: ../tld/SQIID/seq.tld
Downloading program: ../tld/SQIID/dspw.tld
Program downloading completed

```

WILDFIRE SQIID SYSTEM CONTROL

LAST BUILT: Fri May 21 14:47:16 MST 1999

entering wfininit

[1] 28110

[2] 28111

NOTE: All parameters should be given in j h k l order.

j h and k integration time, lnr's & coadds must be identical.

Be sure to set itvoffset before using sqtv or sqiid.

Get_picture message received from Saver

number digital averages for { j h k l } set to 4 4 4 1.

Be sure to rerun settime to correct the sequence timing

Min time for j = 0.61

Min time for h = 0.61

Min time for k = 0.61

Min time for l = 0.061

L Integration Time = 0.321, L coadds = 1

JHK Integration Time = 0.321, JHK coadds = 1

Initialization Complete

[Note: at this point WILDFIRE accesses and loads the sqiid parameter file. If the system stops here, ->[Enter "setup sqiid"]<-]

% setup sqiid

Min time for j = 0.61

Min time for h = 0.61

Min time for k = 0.61

Min time for l = 0.061

L Integration Time = 0.321, L coadds = 1

JHK Integration Time = 0.321, JHK coadds = 1 seq

Stopped.

here

	0	128	256	384	512	640	768	896	1024	1152
1280	1408	1536	1664	1792	1920	2048	2176	2304		
2432	2560									

Min time for j = 0.61

Min time for h = 0.61

Min time for k = 0.61

Min time for l = 0.061

running

Please wait while voltages are set ...

setting VddCl1

Array 0, VddCl1 0 set to -1.306

Array 1, VddCl1 0 set to -1.319

Array 2, VddCl1 0 set to -1.323

Array 3, VddCl1 0 set to -1.300

setting VddCl2

Array 0, VddCl2 0 set to -3.518

Array 1, VddCl2 0 set to -3.551

Array 2, VddCl2 0 set to -3.576

Array 3, VddCl2 0 set to -3.513

setting VggCl1

Array 0, VggCl1 0 set to -4.881

Array 1, VggCl1 0 set to -4.870

Array 2, VggCl1 0 set to -4.892

Array 3, VggCl1 0 set to -4.921

setting VggCl2

Array 0, VggCl2 0 set to -2.785


```

Array 1, VggCl2 0 set to -2.797
Array 2, VggCl2 0 set to -2.786
Array 3, VggCl2 0 set to -2.791
setting VSet
Array 0, VSet 0 set to -1.784
Array 1, VSet 0 set to -1.790
Array 2, VSet 0 set to -1.810
Array 3, VSet 0 set to -1.816
Do you want to activate the array? (y or [n]) y

```

->[Enter "y"]<-

[Note: "n" is the safe value. However, one must type "y" to get the arrays properly activated. The detector biases may vary from those indicated]

```

Array 1, Detector Bias 0 set to 0.575
Array 2, Detector Bias 0 set to 0.681
Array 0, Detector Bias 0 set to 0.571
Array 3, Detector Bias 0 set to 0.589
The arrays are now activated

```

Parameter files

WILDFIRE operates through parameter files. The default default parameter set is "sqiid". If you are restarting the system and have saved your own parameter file "my_set", activate it by typing

->[Enter "puse my_set"]<-.

Examine parameter list by typing

->[Enter "plist"]<-.

```

% plist
Title
Number of coadds          1 1 1 1
Number of lnrs            1 1 1 1
Number of pictures        1
Integration time (seconds) 0.321 0.321 0.321 0.321
Filename template         a%03d%s
Header Directory          /data2/2meter
Pixel Directory           /data2/2meter/pixels
Process mode              stare stare stare stare
Picture index             0 0 0 0
Microcode                 sqiid4d_2231_01
Channels to display
RA of object              0:00:00
DEC of object              0:00:00
EPOCH of object           1950
Observation offset        0
Image type                 object
Current airmass            1
Comment                   none
Image name list file       /tmp/list
Header Var 1
Header Var 2
Header Var 3              Header Var 4
Channels to save           j h k l
Channels to archive        j h k l

```

One edits the "ask" sequence - the questions task "ask" will ask you by

->[Enter "eask"]<-.

In this exchange "l" corresponds to list and "la" corresponds to list and ask during the "ask" sequence. Representative choices are given below.

```
% eask
List/Ask params(title):    [1]  la
List/Ask params(coadds):   [1]
List/Ask params(lnrs):     [1]
List/Ask params(pics):     [1]
List/Ask params(integration_sec):  [1a]
List/Ask params(filename):  [1a]
List/Ask params(header_dir):  [1a]
List/Ask params(pixel_dir):  [1a]  1
List/Ask params(mode):      [1]
List/Ask params(pic_num):    [1a]
List/Ask params(ucode):      [1]
List/Ask params(display):    [1]
List/Ask params(ra):         [1]
List/Ask params(dec):        [1]
List/Ask params(epoch):      [1]
List/Ask params(offset):     [1]
List/Ask params(type):       [1]
List/Ask params(airmass):     [1]
List/Ask params(comment):     [1]
List/Ask params(im_list):     [1]
List/Ask params(var1):        [1]
List/Ask params(var2):        [1]
List/Ask params(var3):        [1]
List/Ask params(var4):        [1]
List/Ask params(save):        [1]
List/Ask params(archive):     [1]
```

Changes to ask and the parameter file are preserved using

->[Enter "psave my_set"]<-

```
% psave
WARNING: Overwriting existing file ~/wfpar/SQIID/squid.par
OK to proceed ? (y or [n]) y
Saving to ~/wfpar/SQIID/squid.par.
```

Setting detector bias

The following interchange sets the bias on the K channel.

->[Enter "setbias 2 0.7"]<-

```
% setbias 2 0.7 % Array 2, Detector Bias 0 set to 0.681
```

The sequence noted below sets all the biases:

```
->[ Enter "setbias j .6"
      Enter "setbias h .6"
      Enter "setbias k .7"
      Enter "setbias l .9" ]<-
```

Appendix IX: Installation Issues

Initializing the Environment with OBSINIT

The optical CCD (ICE) and infrared (WILDFIRE) environments are both operated from the same account on the 2.1-m (*2meter*) and 4-m (*4meter*) telescopes. The all-important `obsinit` command performs a number of functions relevant to this operating procedure.

- Switching from ICE to WILDFIRE environment on the first night of an IR observing run.
- Efficiently and gracefully cleaning the disk of data from previous observers.
- Storing the current observer name and proposal number for archiving.

First Night of SQUIID Block

On the first night of an IR block, the ICE environment will still be active (the presence of the "CCD Acquisition" and "CCD Reduction" windows will verify this). It will be necessary to run `obsinit` to change to the WILDFIRE environment; since the hardware may be in an unknown state, it is also recommended to run through a complete hardware initialization on the first night of an IR block as part of the `obsinit` process. This will involve rebooting the observer's SUN workstation with the DSP (in the computer room) powered on and the SQUIID instrument power off.

The SQUIID instrument power supply is located on the instrument itself. The (rocker) switch is on the right (South) side (near the top by the power cord) of the electronics box mounted on SQUIID.

- Verify that the DSP power is ON (Black Huericon box in computer room).
- Verify that the power to SQUIID is OFF (power supply on SQUIID itself).
- Quit the "CCD Acquisition", "CCD Reduction" and "Ximtool/SAOimage" windows.
- Logout of any other IRAF processes.
- Enter the command `obsinit` in a Shelltool or Xgterm window. One will be led through an interactive process:
 - name(s): (enter observers here)
 - Proposal ID: (check the schedule or Preparation Form)
 - Operation (fire/ice): (enter `fire`)
 - Delete old data from disk and initialize (y/n): [this can take a while, but to assure proper initialization you should choose `y`]
 - Replace wfpar and tclSamples (y/n): (n will leave any changes)

Once this is complete, it is necessary to reboot the instrument computer with the instrument power off.

- At the 2.1-m, type "freboot" at the login prompt on Royal's console (VT220 or whichever terminal is currently attached to royal) in the computer room downstairs
- At the 4-m, use the [L1 A] or [Stop A] keys, then enter `boot`

After rebooting, the UNIX login prompt "[hostcomputer] login:" will appear; **IGNORE THIS**. After a few seconds, OpenWindows will automatically load and present the login window shown below:

```

Welcome to Kitt Peak (^ \ to exit)

Login:
Password:

```

Login as *[telescope]* (where telescope is "2meter" or "4meter" as appropriate) with the current password posted on the workstation terminal. The WILDFIRE system will then load automatically, resulting in a terminal screen layout approximately like Fig. 5 below; the dashed window labeled Instrument Status will appear in the approximate position shown only after the instrument microcode has been loaded.

Normal WILDFIRE Startup

The Windows

Once the environment has been set to WILDFIRE by `obsinit`, it will remain in that state, even if it is necessary to reboot the instrument computer for any reason. There should be no reason to execute `obsinit` more than once during a run. If a reboot is required, the login procedure in the window displayed above will automatically bring up the WILDFIRE windows.

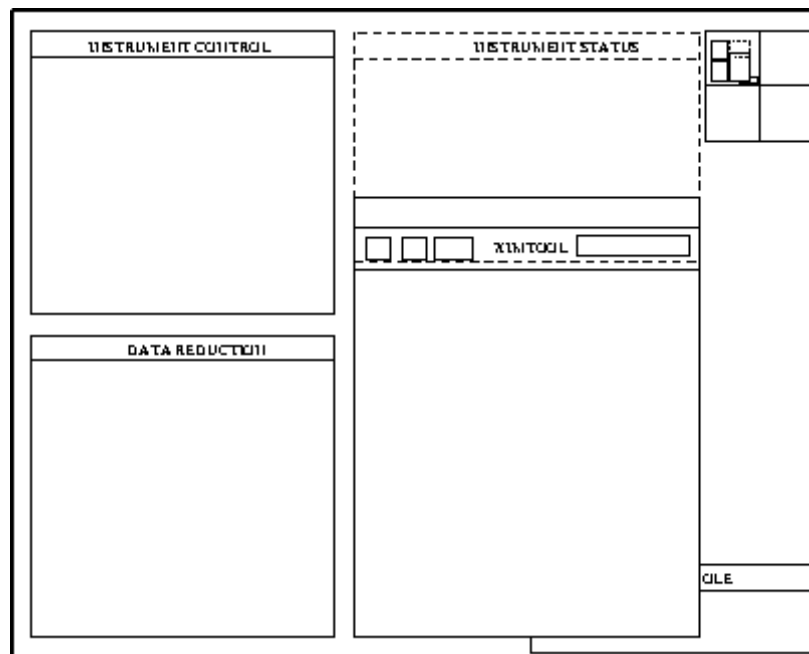


Fig. 5 -Windows layout after initiation of WILDFIRE

A brief description of the windows follows:

- 1. Instrument Control -- This is the window for entering all commands controlling the instrument or telescope. It will initially have a "[instrument computer]" prompt, and a "%" prompt when the instrument microcode is running.
- 2. IRAF XGTERM -- This window is used for IRAF commands for analysis of data or for shell commands such as creating directories, moving, or archiving data.
- 3. Instrument Status -- Once the instrument microcode has been loaded, this window will appear. Instrument, voltage, detector status commands in the Instrument Control window will output here. The existence of this window is a diagnostic of WILDFIRE, as a system crash will often close it.
- 4. Display -- This is an XIMTOOL window which may be accessed either through the Instrument Control window, where images may be automatically displayed as they are taken, or through the IRAF XTERM window via the IRAF *display* task. Those who are desperately attached to the SAOimage display may use it in place of XIMTOOL by killing the XIMTOOL process in the Console window (enter `ps -ax` in the Console window to get a listing of the process numbers, then `kill -9 [process #]`), and then entering `saoimage &` to bring up the SAOimage window.
- 5. Console -- This is generally used only for diagnostic or emergency purposes, such as killing a hung process or the entire WILDFIRE when it hangs up.

Bringing up WILDFIRE

There are three basic steps in the complete startup of WILDFIRE: hardware initialization; starting WILDFIRE; instrument initialization. The procedure below will go through all three steps, as would be necessary on the first night the instrument is on the telescope.

Hardware Initialization

This procedure establishes the link between the DSP box and the computer, by rebooting the observer's SUN workstation with the SQIID power off. The *obsinit* procedure for the first night of an SQIID block (described above) includes these steps.

Starting WILDFIRE the first night

NOTE: When starting SQIID the first night we have found that it is important to thoroughly exercise the Wildfire distributed memory by bringing up IRIM, then PHOENIX, and finally SQIID. The following sequence walks you through this task.

At this point, the windows should be present as in Fig. 5. Go to the Instrument Control Window and enter:

```
startwf
```

This will lead you through an interactive startup procedure. READ THE QUESTIONS CAREFULLY; simply entering [cr] will return the default, which may not be appropriate. For the full startup, the replies are:

- Has the WFire DSP box power been off for any reason since the last time you ran startwf or restart (if unsure try 'n')? [n] y
- Was the computer rebooted with the instrument power off? [n] y (a short initialization process follows)
- Has the instrument power been off since the last time you ran startwf or restart? [n] y

- Is the instrument power on now? [n] (You will be prompted to turn on the instrument power) [cr]
- Which instrument are you using (enter PHOENIX, IRIM, CRSP, SQUIID, etc.) ? IRIM (The instrument name may now be in either capital or lowercase letters!)
- Do you want windows? [y] [cr]
- Do you want to save in IRAF format ? [n] (default is FITS). [cr]

At this point, the transputer nodes will bootstrap, and .tld files will load. Eventually (when the startup script automatically executes "setup irim") you will see messages regarding the downloading of the microcode, setting assorted voltages. When this is completed, the final message will appear:

- Do you want to activate the array? (y or [n]) n

You will see messages about assorted voltage failures and servo errors (since the IRIM task looks for DACs and for motors that SQUIID does not have), but the housekeeping window and the saver task should successfully start.

Go to the Instrument Control Window and exercise the system by typing "status s", "status v", and "status t", then exit the system by typing:

`exit`

Continue by typing:

`g phoenix`

Answer the questions:

- Do you want windows? [y] [cr]
- Do you want to save in IRAF format ? [n] (default is FITS). [cr]

At this point, the transputer nodes will bootstrap, and ".tld" files will load. Eventually (when the startup script automatically executes "setup phoenix") you will see messages regarding the downloading of the microcode, setting assorted voltages. When this is completed, the final message will appear:

- Do you want to activate the array? (y or [n]) n

You will see messages about assorted voltage failures and servo errors (since the PHOENIX task looks for DACs and for motors that SQUIID does not have), but the housekeeping window and the saver task should successfully start.

Go to the Instrument Control Window and exercise the system by typing "status s", "status v", and "status t", then exit the system by typing:

`exit`

Continue by typing:

`g sqiidd`

Answer the questions:

- Do you want windows? [y] [cr]
- Do you want to save in IRAF format ? [n] (default is FITS). [cr]

At this point, the transputer nodes will bootstrap, and four ".tld" files will load. Eventually (when the startup script automatically executes "setup sqiid") you will see messages regarding the downloading of the microcode, setting of 4 values of VddC11 (-1.3), VddC12 (-3.5), VggC11 (-4.9), VggC12 (-2.8), and Vset (-1.8). When this is completed, the final message will appear:

- Do you want to activate the array? (y or [n]) y

You will see messages reporting 4 biases being set, followed by:

- The arrays are now activated

The housekeeping window and the saver task should successfully start.

If you want to use a different parameter file than the default "sqiid" parameter file that was executed by the startup script, you can enter "puse parameter_filename" at this time.

SQIID is now ready for operation.

Checking system noise

One tests the system noise by taking 10 dark exposures with short (1 sec) integration time. These data are combined with the IRAF *imcombine* task to determine the rms per pixel. The IRAF *phist* task can be used to examine the results (nbins=200, z1=0, z2=25). A typical result is shown in Figure 12. Peak values significantly higher than the 3.5-4.0 shown are indicative of excess noise. Either the array temperatures have not yet stabilized (detector heater power is not on unless the instrument power is on) or there is a problem with the electrical ground. SQUIID should not be run with instrument power connected through an isolation transformer.

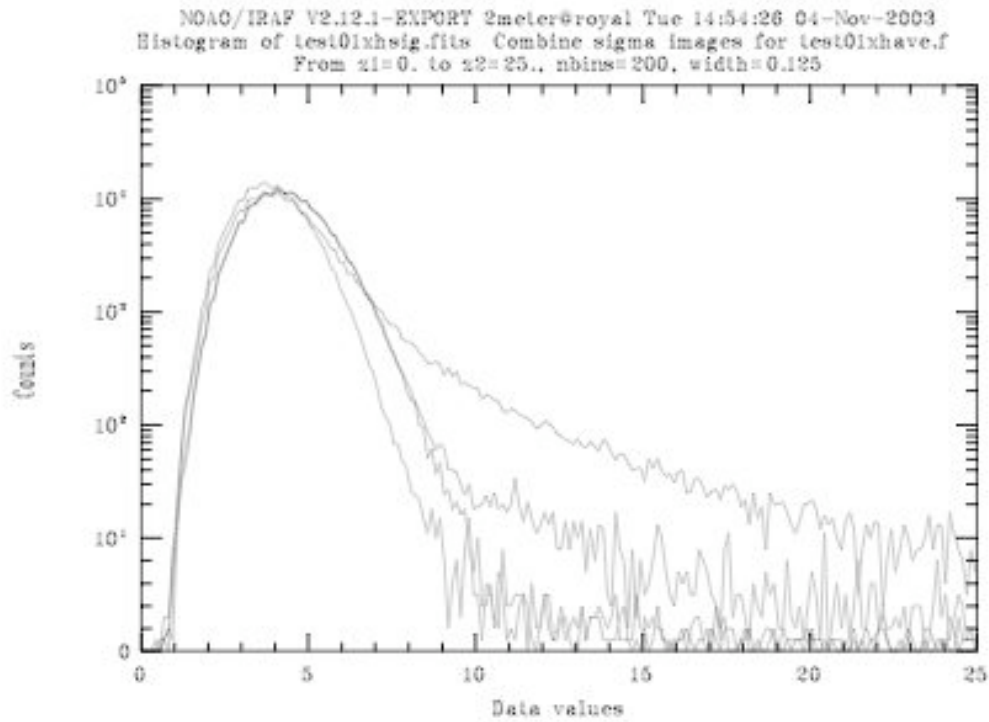


Fig. 12 - Typical detector noise for SQUIID. The K channel has the long tail.

Appendix X: ToO Observations

Target of Opportunity Observations

The typical Target of Opportunity (ToO) observation for SQUIID entails deep observations of a transient target, such as a Gamma Ray Burst. A special script has been that moves the telescope a pseudo-random distance between exposures. Hopefully the tcl code has been copied to the wfire subdirectory (located within /data2/2meter/wfire at the 2.1-meter and within /data1/4meter/wfire at the 4-meter) for easy access. Since these scripts are not part of the static WILDFIRE dictionary, they must be sourced from within the Instrument Control window by sourcing a file called setup_grb.tcl:

```
source /data2/2meter/wfire/setup_grb.tcl
```

This file executes the following commands:

```
source /data2/2meter/wfire/randith2d.tcl
source /data2/2meter/wfire/jrand.tcl
source /data2/2meter/wfire/getdelay.tcl
source /data2/2meter/wfire/randseed.tcl
set iseed 17427
setIntegration 15.0 0.11 10          (15*10+40 = 190 seconds)
pics 1
tcp_on
```

Command usage is:

```
randith2 N_pictures min_offset_x min_offset_y max_offset_x max_offset_y
```

A typical choice would be:

```
randith2 15 4 4 10 10
```

This would generate 15 images and take 2250 seconds total integration time and probably burn about 50 minutes of wall clock.

If the special scripts noted above are unavailable, one should do the following:

- Use `set-time` to set JHK integration time to 15 sec and coadds to 10.
- Run one of pattern scripts such as:
 - `do_9spiral` with a separation of 8 to 10 arcsec. Run this twice.
 - `do_standard_on` with a separation of 8 to 10 arcsec. Run this thrice.
 - `do_field_on` with a separation of 8 to 10 arcsec and a 4 by 4 grid.

The integration time of 15 sec is conservative, intended to keep things on scale. If your own observations suggest that a longer time, such as 20 to 25 seconds keeps counts below 8-10000 adu in H and K, then by all means use what's been working. Adjust the coadds to get a frame-time near 150 sec and the total number of frames to get a total integration time of 2200 to 2400 seconds.

Under normal circumstances these data can be used to generate a sky and a flat so that only a set of darks with the same integration time as the data need to be taken. If other flatfield data are available, it should also be provided to the ToO team as backup.

Appendix XI: FYI

ALADDIN Array Architecture

The ALADDIN readout protocol is illustrated in Fig. 13. The array has 4 physically contingent and electrically independent quadrants that are read out simultaneously column by column along a row starting from the outermost edge and ending at the array center. Given the reset- read - (wait for integration time) – read technique employed, it follows that the accumulated charge grows from the outermost corner to the center of the array. A SQUID channel illuminates a single quadrant.

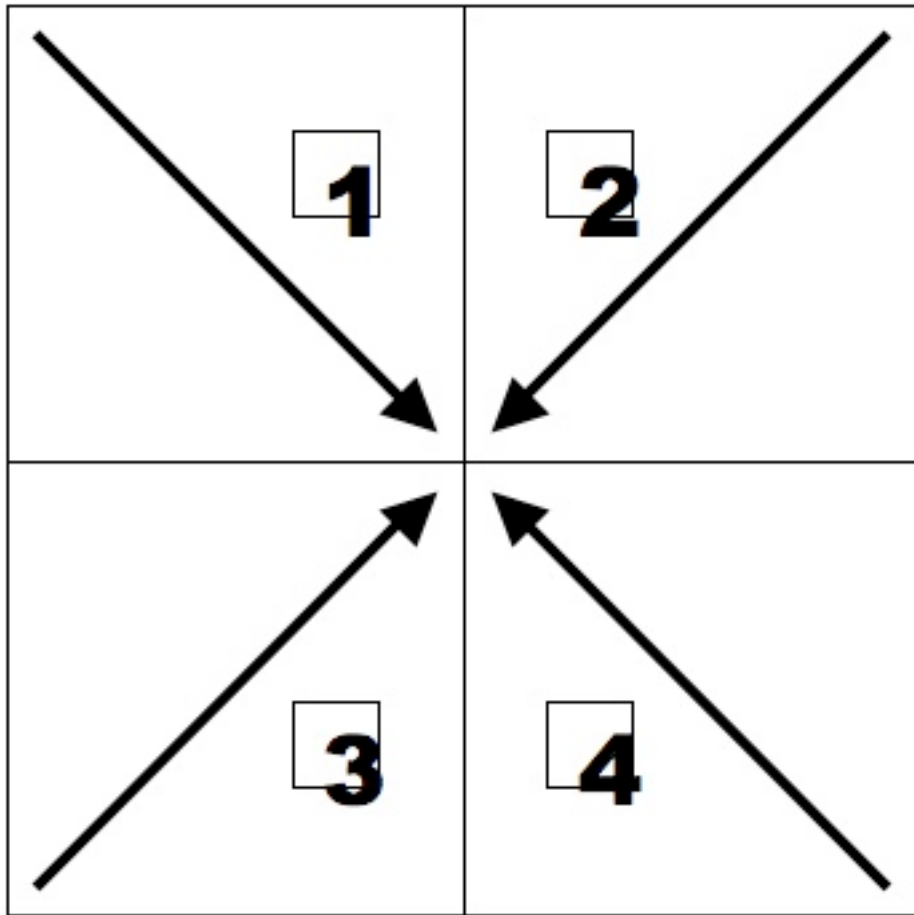


Fig. 13 – ALADDIN Readout Protocol. The arrows are indicative of the address architecture: within each quadrant, pixel addressing moves along rows and columns towards the center of the device.