The IRIM User's Manual

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1. Introduction

The KPNO Infrared Imager (IRIM) is a general-purpose instrument for moderately wide-field imaging in the 1 - 2.5 micron region using a 256 X 256 HgCdTe NICMOS3 array. It is used primarily for broadband work in the J, H, K and K' filters, but it can also be used with narrowband filters for special applications.

2. Instrument Description

IRIM is an uplooking cryostat which interfaces to the f/15 foci of the 2.1-m and 4-m telescopes. The telescope focal plane is warm, about 5 cm above the entrance window. The dewar carries analog and digital electronics boxes and communicates through optical fibers with the instrument computer. Apart from an "on" button for the dewar electronics, there are no external user adjustments. Cooling is by LN_2 with a dual reservoir system. The large outer tank cools the radiation shields, optics, and other innards, while the inner tank cools the detector mount assembly. Cryogen refill can be done with the instrument in place on the telescope. Hold time is typically 12 hours, but a refill halfway through a long winter night is advised for caution's sake.

Optical Diagram

An optical diagram of IRIM is shown below.

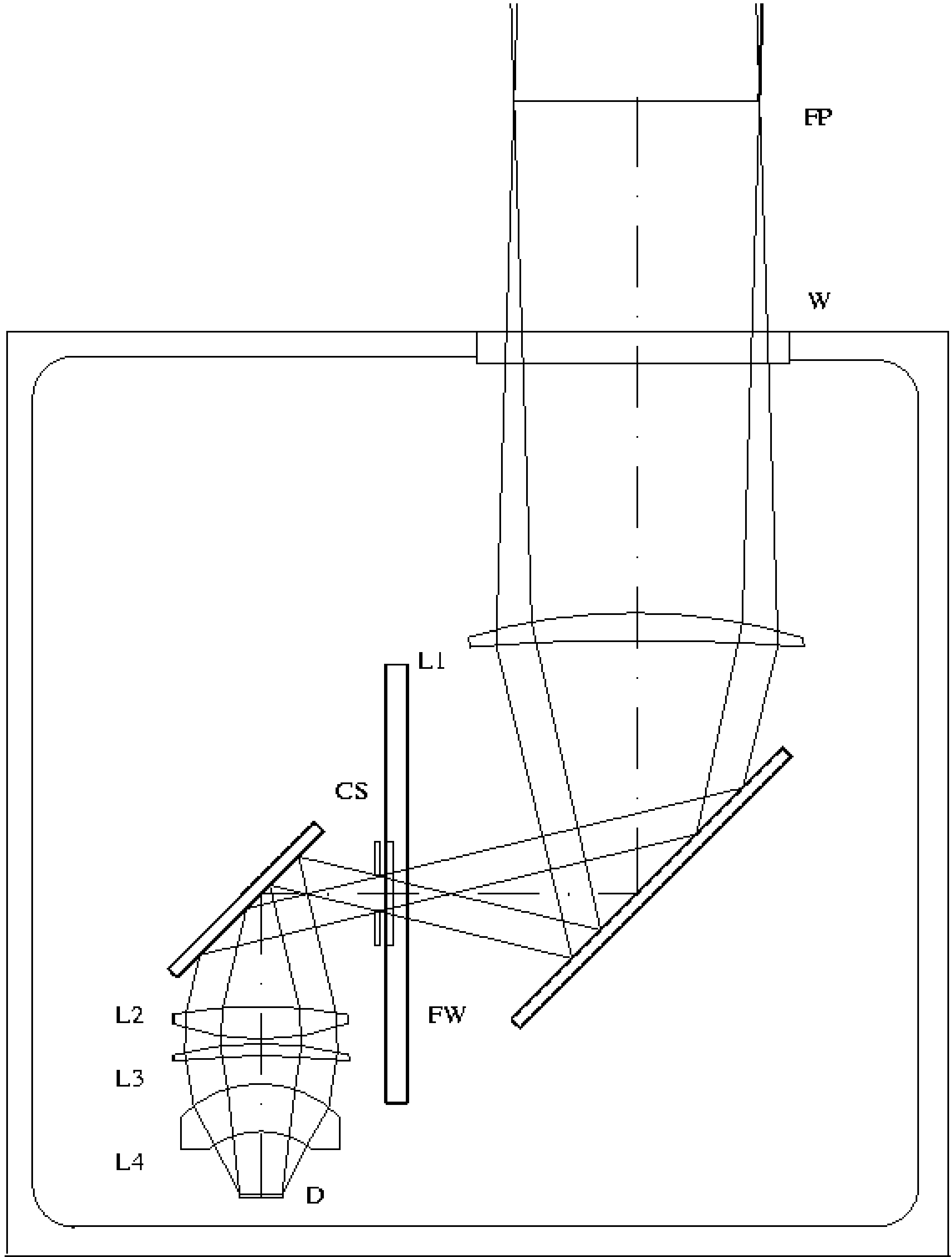

Fig. 1 Optical Layout of IRIM

The internal optics are a refractive, collimator-camera design with a cold pupil stop of fixed size. The telescope focal plane (FP) lies approximately 75 mm above the CaF_2 window (W). The collimator (L1) images the telescope pupil onto the cold stop (CS). The 8-position filter wheel (FW) is located very close to the cold stop and carries 7 filters and a cold dark slide. The camera (L2, L3, L4) then reimages the focal plane onto the array (D). The overall optical reduction of 4:1 was designed to give field of view, particularly at the 4-m telescope, at the expense of optimal spatial sampling of the image.

Field and Filters

Table 1. Resolution and field size

Telescope	arcsec / pixel	field of view
2.1-m	1.09	280x280 arcsec
4-m	0.60	154x154 arcsec

Measurements at the 4-m show a wavelength dependence of scale: 0.608 arcsec/pix at J, 0.605 at H, 0.603 at K and narrowband filters. Proportional changes should occur at the 2.1m, but they have not been determined accurately.

Table 2. Filter List

Position	Name	cuton	cutoff	Comments
1	DARK	...	...	Cold dark slide
2	2.12	2.110	2.128	1% Bandpass S(1) H_2
3	1.281	1.275	1.287	1% Bandpass Pa beta
4	2.16	2.150	2.172	1% Bandpass Br gamma
5	J	1.095	1.38	Barr lot 0492
6	H	1.51	1.79	Barr lot 0492
7	K'	1.99	2.32	Barr lot 1292
8	K	2.03	2.42	Barr lot 1090

Notes on filters:

- The narrowband filters are matched in bandpass and wedged to decrease fringing from night sky lines.
- Narrowband filters may be changed on occasion to accommodate specific observing runs. The broadband filters will not, in general, be switched out.
- The broadband filters are chosen to match those in SQIID and COB.
- Filter tracings

3. Command, Communication, and Control

IRIM is operated by the user from the SUN workstation in the telescope control room, through the WILDFIRE system, a transputer based system which communicates over optical fibers. WILDFIRE supports fast co-adding in place, movie mode, and data transfer directly to the SUN.

The WILDFIRE system uses transputers and transputer links to control and acquire data from IRIM. 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 IRIM instrument control unit inside the DCU (Digital Control Unit) box contains two transputers which provide housekeeping data and control and generate the sequences which operate each array. The motor controller module is also inside the DCU, eliminating the need for a separate motor controller box. All motor, data, and power cables are connected to the DCU.
- The DSP unit (a VME based Digital Signal Processor system located inside the black Heurikon box in the computer room) contains eight transputers which 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 IRIM 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. The data appear as IRAF images, produced (in IEEE 32-bit floating point format) via IMFORT routines so that they can be manipulated and archived to tape inside IRAF. 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. The data may be written to Exabyte or DAT 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 256 X 256 image is about 270KB.

At each of the telescopes where IRIM is used are two SUN workstations for data acquisition and reduction. Under the present version of WILDFIRE, the workstations khaki (4-m) and royal (2.1-m) are used for data acquisition. The other workstations [pecan and lapis at the two telescopes] have common access to the data disk, so additional observers can reduce and analyze the data independently. A third SUN 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. 2.

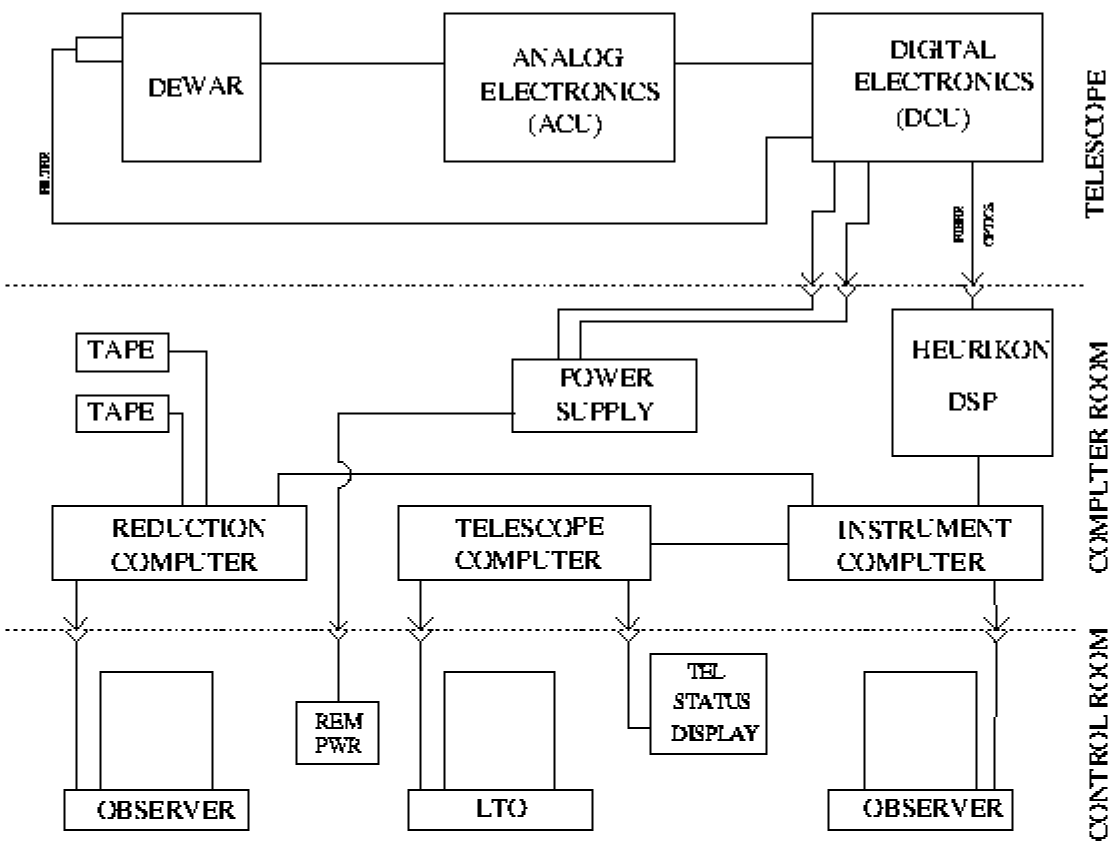

Fig. 2 Schematic configuration of electronics and computers used with IRIM/WILDFIRE

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-accessing (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.

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4. The HgCdTe Detector Array

The detector array is a 256 X 256 HgCdTe array developed by Rockwell International and designated as a NICMOS 3 device. It reads out in quadrants and is operated in a double correlated sampling (read, reset, read) mode with capability for multiple nondestructive reads.

The array has a rather nonflat response, with \(+- 25% variations in response and about three full high-low cycles across the field.

The number of "bad" pixels is somewhat a matter of definition:

- There are about 250 nonresponsive (open or shorted) pixels scattered uniformly across the array, typically singly or in 2 X 2 clumps.
- There are about 250 pixels with noisy dark current; i.e., a standard deviation calculated from a series of darks is > 2 sigma above the mean for the whole array.
- There are about 900 pixels with response outside the range mean +- 25% or equivalently mean +- 2 sigma.
- There are about 1000 pixels with noisy response; i.e., a standard deviation calculated from a series of flatfield exposures which is > 2 sigma above the mean for the whole array.

Clearly some pixels fall in more than one category, and a useful definition of "bad pixels" will depend on the program. For most IRIM programs, the combination of categories (3) and (4) is useful. A bad pixel map can be constructed interactively using IRAF tools and applied during the reductions. A table of the detector characteristics appears on the following page.

Table 3. Detector characteristics at 77 K

Detector bias	1000 mV
System gain	10.46 electrons/ADU
Read noise	35 electrons RMS

Dark current	Approximately 2 electrons/s; does **not** scale simply with time
Full well capacity	4 X 10^5 electrons @ 1000 mV bias
Minimum integration time	382 ms X number of low-noise reads
Linearity	100% at low signal declining to 94% at 3 X 10^5 electrons
Response uniformity	+-25% p-p at low spatial frequency
Unresponsive pixels	About 250, scattered across array
Cosmetics	Bad pixels tend to clump in twos and fours

Linearity and Dark Current

Both InSb and HgCdTe detectors utilize a hybrid architecture in which each pixel has an associated unit cell which controls the biasing and readout of that pixel. Thus, each pixel is essentially independent of the others, and effects seen in CCDs, such as charge bleeding or trailing from saturated pixels, are not present. However, this independence also means that such properties as linearity and dark current can vary from pixel to pixel, and it is necessary to calibrate these effects for optimum scientific performance. When a pixel is reset, the voltage difference (bias) between the pixel and detector substrate creates a depletion region which acts as a potential well for the collection of (mostly) photogenerated 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. Coupled with the steadily decreasing bias on the pixel, this yields a sublinear 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.

Unlike the InSb detector, whose response is only weakly temperature-dependent, the NICMOS detector shows a significant temperature dependence of quantum efficiency and, possibly, related properties such as linearity and dark current. The IRIM detector is cooled with LN_2, at an approximate temperature of 75 K on Kitt Peak, but it is not absolutely controlled with a servo temperature controller. The actual detector temperature may thus depend on the ambient dome temperature and atmospheric pressure. Empirically, we have not seen significant differences in several linearity curves we have generated in the past, suggesting that such effects are small. Cautious observers may wish to take the time to generate a linearity relation during their run.

As the linearity relation indicates, while one may loosely define a full well of about 400,000 electrons, the response has already fallen by 6% at 350,000 electrons. The read noise and dark current of the array are quite low, as tabulated above. However, the dark current has a rather complex character and *cannot be simply scaled with time*. Necessary dark frames (e.g., for construction of flatfields or dark+bias subtraction of linearity sequences) must be taken separately at each integration time desired. In addition, it is strongly suggested that linearity sequences contain repeated "check" observations at one integration time (e.g., 1 sec) to verify the stability of the source. The array quantum efficiency improves by a factor of two from 60 K to 77 K, so we presently operate the device at the ~ 75 K temperature of LN_2 at Kitt Peak, and all tabulated values are referred to this temperature. There is a "charge retention" or "memory" effect whereby a small portion of incident signal from a given exposure survives many subsequent reset cycles, declining slowly. On stars the integrated value of the "memory" image is about 0.1% of the incident flux. A second aspect of this phenomenon is that the signal seen in a dark integration depends on how long the array has been exposed to sky.

Sky Background

There are two predominant sources of infrared sky background, which are essentially independent, both physically and spectrally. At short wavelengths, the sky 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 a night; in addition, upper level winds create inhomogeniety and motion of the airglow. As a result, the intensity of the background can vary unpredictably during the night. At longer wavelengths, thermal emission from the telescope optics and optically thick telluric lines predominates. The transition between these two regimes occurs at approximately 2.3 microns, so the background with filters other than K' or K is primarily OH airglow. The K' background is partially thermal, so one may expect it to vary with the ambient temperature. Typical levels are given in Table 4.

Signal Levels

Table 4 also gives the integrated flux for stars observed on the 2.1-m telescope, averaged over high and low response regions on the array. These have been converted to the flux for a 10.0 mag star in 1 sec integration time. The areal ratio of the 4-m and 2.1-m telescopes is approximately 2.9, so the anticipated signal levels would scale appropriately.

Table 4. Typical Sky and Signal Levels on 2.1-m at f/15

Filter	Sky Brightness (ADU/s-pixel)	Signal from 10.0 mag Star(ADU/s)
J	120	31000
H	600	26000
K'	720	16200
K	950	16300
2.12	35	750
2.16	50	840

The "natural color" of the system is J-K ~ 0.6, H-K ~ 0.3.

Operational Modes

The device is presently operated in a 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. 3. An address cycle consists of a "reset" to the canonical detector bias voltage, a "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 the figure 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.

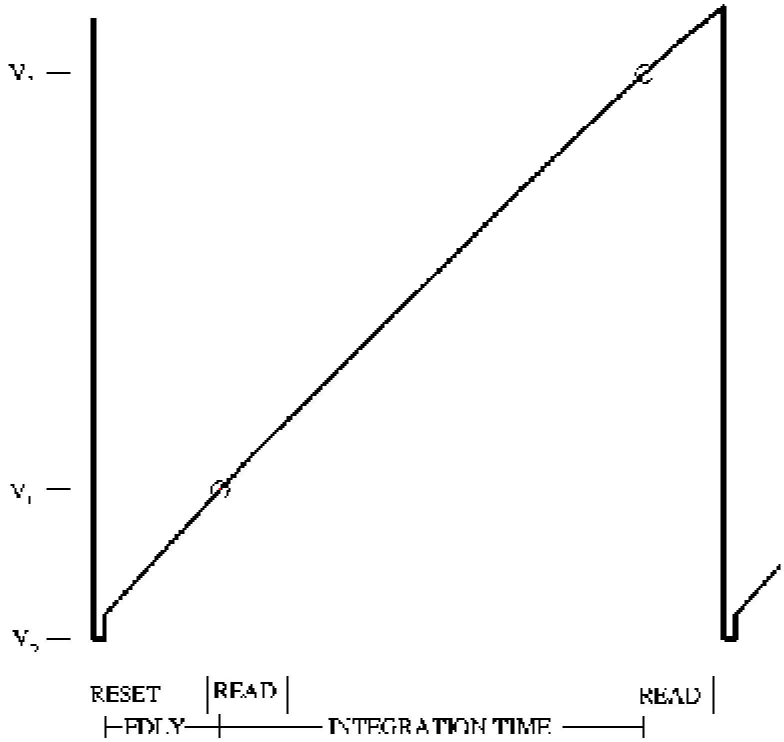

Fig. 3 Schematic representation of the voltage on a single pixel as a function of time. The intervals labeled "reset" and "read" represent the time over which these operations occur on the entire array, and are not to scale.

The readout cycle of the array (reset, read, integrate, read) presently includes the delay time 'fdly' between the reset and first read, at the start of an integration, to allow the array to thermally stabilize following selfheating induced by the rapid reset. The default value of this time is 1.0 sec for integration times longer than 1.382 sec, and there should be no need to adjust this parameter.

In the usual mode of operation of the array, known as "stare" mode in the WILDFIRE software, the image stored on disk is the differential signal, read 2 - read 1. Note that the pixels begin accumulating flux immediately after reset, and the charge accumulated during the delay time is NOT accounted for in the differential signal (see Fig. 3). This can cause difficulties in trying to derive linearity corrections or flatfields from very high flux inputs such as with dome flats. In effect, one has already climbed well up the linearity curve before the first read under these circumstances. The same is true when observing very bright standard stars. In practice, keeping the brightest pixels on standard stars and the average sky level on background limited observations at approximately the same value makes a linearity correction a second order effect. One may then apply a correction derived from a similar flux input level. This empirical approach is usually quite adequate.

A second mode is provided for those who need or prefer a more painstaking approach. Known as "sep", this mode records the first read and the second read consecutively on disk as separate pictures. One may then apply a linearity correction to each read separately before calculating the difference signal. This will properly account for the flux accumulated during the delay time, so may be the preferred mode for improved precision when some sources are unavoidably high in flux.

A third mode, "hphot", records three pictures on disk for every array cycle: first read, second read, and difference. Having the difference signal immediately available for display and inspection is often convenient, although at the cost of the increased consumption of disk space.

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5. Observing Run Preparation

Preparations

Object Coordinates for any epoch can be entered into the telescope computer for use during the run. This is often done by the telescope operator during the course of the night, but lengthy observing lists are best entered ahead of time by the observer (ask for help on this) or, preferably, by electronic submission (see below). These may include objects, standards, offset and guide stars, etc. Because of the large field of view, precise offsetting to an object is not critical. However, detection of very faint objects requires accurate long-term tracking combined with precision spatial modulation (dithering) to determine the sky level, a task for which the open-loop tracking of the telescope is usually inadequate. Use of the telescope guide probes for precision offsetting with reference to an off-axis guide star is highly recommended for registration of the many individual frames which such a limiting observation will require.

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.

Photometric Performance and Flatfielding:

A series of experiments determined that exposing to about the same ADU level for each, a 10.5 and 14.0 K mag star scaled correctly to within 0.03 mag without linearity correction. Observing the same star at different locations around the chip and at different integration times gave rms scatter of a few hundredths of a magnitude after flatfielding, considered to be within the errors given the rather uncertain weather in which observations were made. Flatfield response using the sky is constant in a given filter over at least a factor of three in signal level. Flats in the J, H, and K' filters are very similar overall but show 5% differences when divided. Comparing dome flats to sky flats shows them equivalent to 1% at J and H but quite different at K', evidenced by a pronounced centro-symmetric pattern in the division. There is no quantitative information for the narrowband filters.

One may use the NOAO Exposure Time Calculator to estimate the performance of IRIM for observing programs. However, it is very important to understand the assumptions and limitations of this tool, and we strongly suggest reading the background material on Signal-to-Noise Calculations.

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6. The IR Instrument Control System -- WILDFIRE

This is an IRIM-specific synopsis of the WILDFIRE manual written by Nick Buchholz. Observers interested in a more in-depth analysis of WILDFIRE are referred to that manual.

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 IRIM 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 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 IRIM instrument power off.

- Verify that the DSP power is ON.
- Verify that the power to IRIM is OFF
- Quit both the "CCD Acquisition" and "CCD Reduction" 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):
    - 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 if you 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 `L1 A` or `Stop A`; again, the instrument power must be off. 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] 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. 4 below; the dashed window labeled Instrument Status will appear in the approximate position shown only after the instrument microcode has been loaded.

New Observer

On succeeding IRIM runs, `obsinit` is run only to enter the new observer and proposal ID information. It is NOT necessary to power down IRIM or reboot the computer. After 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.

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.

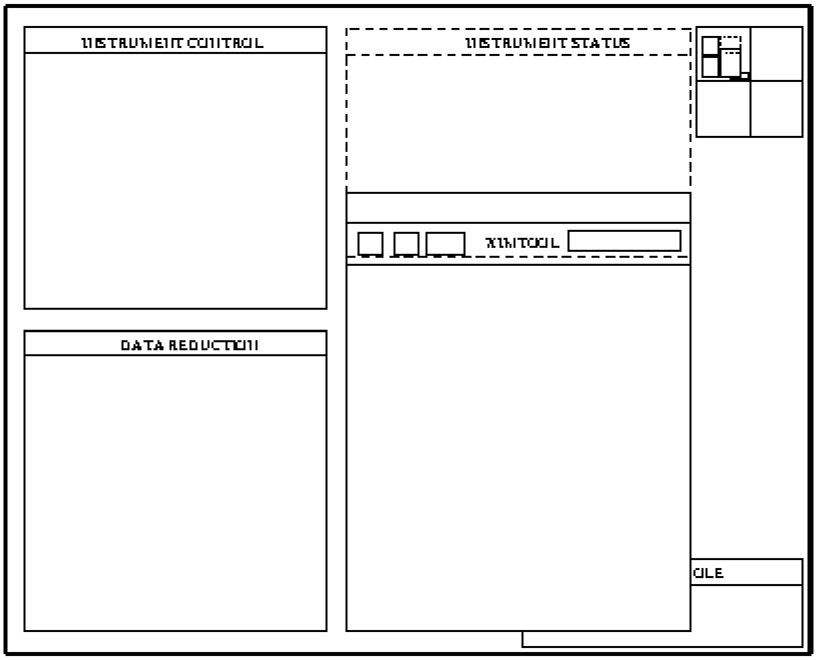


Fig. 4 Windows layout after initiation of WILDFIRE

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 IRIM power off.
The *obsinit* procedure for the first night of an IRIM block (described above) includes these steps.

Starting WILDFIRE

NOTE: *The startup script for WILDFIRE has been simplified significantly in 1999. The microcode will be loaded automatically and the bias for IRIM set to the default value of 1.0. It will still be necessary to push the Blue Button to activate the array. In addition, the syntax for operating the mechanisms has been unified*. Refer to the Command Reference Sheet for details.

At this point, the windows should be present as in Fig. 4. 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 DSP box been off since last startwf? y
- Was the computer rebooted with the instrument power off? y (a short initialization process follows)
- Has the instrument power been off since last startwf? y
- Is the instrument power on now? n (you will be prompted to turn on the instrument power) [cr]
- Do you want windows? y

- What instrument is being used? IRIM (the instrument name may now be in either capital or lowercase letters!)

At this point, the transputer nodes will bootstrap, and four .tld files will load. Shortly thereafter, this downloading procedure will complete with a "%" prompt.

You will see messages regarding the downloading of the microcode, setting of Vdoff0 (2.30), and Vdoff1 (2.30), followed by a message that the array will be activated with the default bias of 1.0. When this is complete, the final message will appear:

- Push the button, Max!

At this point, go to the instrument and push the blue ACTIVATE button on the right side of the ACU box. Ensure that the green LED, visible through the hole on the ACU cover, has come on. The instrument 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:

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
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 [only one for IRIM]
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 archive	channels to be saved to disk [only one for IRIM] channels to be archived [only one for IRIM]

In general, the parameters fall into three categories: 1). those which one may wish to modify for an observation (integration time, title...); 2). those which one might want to change on an infrequent basis (comment, header directory...); 3). 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 `la` for a parameter selects it for the "observation menu"; entering `l` 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 at time, those parameters selected by `eask`, and the current value [], prompting for entry of a new value or , 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 observation should terminate gracefully in a few seconds. **This can sometimes turn off the display and save operations**, so it is advisable to enter `save only` and `display only` after an `abort`.

Scripts

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, then edit that file as desired. The first line of the script file contains the basename 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  /data2/4meter/tclSamples/[scriptname].tcl
```

To execute the script, enter the basename `[scriptname]` as a command in the Instrument Control window. A sample script is given in Appendix III.

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.

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.
- `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. Prompts for grid separation, sky offset vector (*must* have two values) and dither vector (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_9raster [gridsep] [ewdither] [nsdither] [ewsky] [nssky]
```

Refer to the Appendices for listings of WILDFIRE and IRIM commands (Appendix I) and troubleshooting procedures (Appendix II).

Tmove

Mike 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.

```
# TMOVE: 23AUG95 KMM
# TMOVE: 12DEC95 KMM
# TMOVE: 16FEB95 KMM
# TMOVE: 23MAR94 KMM
# TMOVE: 23JUN94 KMM
# TMOVE: 04JUN99 RRJ
# TMOVE: 04JUN99 RRJ; MODIFIED FOR N-S TIFKAM ORIENTATION OPTION
```

```
procedure tmove ()

#  Edit instrument and telescope string below for your configuration.
#  Default orientation for TIFKAM is E-W slit.  If slit is N-S, then
#  set 'rotate = yes' in line 76

#  You may wish to edit the "center" coordinates for the particular
#  detector configuration for use with the 'c' key

#  Install edited file in data directory and identify as an IRAF task
#  with 'task tmove=tmove.cl'.  Enter 'tmove' to execute

string instrument  {"IRIM",
                    prompt="IR instrument
(SQIID|PHX|IRIM|CRSP|TIFKAM|none)?",
                        enum="SQIID|PHX|IRIM|CRSP|TIFKAM|none"}
string telescope   {"2.1m", prompt="KPNO telescope (1.3m|2.1m|4m|none)?",
                        enum="1.3m|2.1m|4m|none"}
bool   verbose     {yes,  prompt="Verbose reporting"}

imcur   *starco

begin

   int    stat, nin, nout, slen, wcs, rid, prior
   real   xin, yin, xref, yref, xshift, yshift, dist, adist, foo
   real   xscale, yscale, xcenter, ycenter
   bool   xinvert, yinvert, rotate
   string uniq,sjunk,sname,key
   struct command = ""

# Get offset between master reference and reference frames

   if (instrument == "SQIID") {
      xcenter = 128.; ycenter = 128.
      xinvert = no; yinvert = yes; rotate=no
      if (telescope == "2.1m") {
         xscale = 0.76; yscale = 0.76 # K channel
      } else if (telescope == "4m") {
         xscale = 0.43; yscale = 0.43
      }
   } else if (instrument == "PHX") {
      xcenter = 128.; ycenter = 512.; rotate=no
      if (telescope == "2.1m") {
         xscale = 0.25; yscale = 0.25 # Viewer Scale
         xinvert = yes; yinvert = no
      } else if (telescope == "4m") {
         xscale = 0.125 ; yscale = 0.125
         xinvert = no; yinvert = yes
      }
   } else if (instrument == "IRIM") {
      xcenter = 128.; ycenter = 128.; rotate=no
      if (telescope == "2.1m") {
         xinvert = no ; yinvert = yes
         xscale = 1.09; yscale = 1.09
      } else if (telescope == "4m") {
         xinvert = no ; yinvert = yes
```

```
         xscale = 0.60; yscale = 0.60
      }
   } else if (instrument == "CRSP") {
      xcenter = 85.; ycenter = 128.; rotate=no
      if (telescope == "2.1m") {
         xinvert = no ; yinvert = yes
         xscale = 0.61; yscale = 0.61
      } else if (telescope == "4m") {
         xinvert = no ; yinvert = yes
         xscale = 0.36; yscale = 0.36
      }

   } else if (instrument == "TIFKAM") {
      xcenter = 200.; ycenter = 502.7; rotate=no
# Set rotate=yes if slit is N-S and uncomment lines 160, 161
      if (telescope == "2.1m") {
         xscale = 0.34 ; yscale = 0.34
         xinvert = yes; yinvert = yes
      } else if (telescope == "4m") {
         xscale = 0.18 ; yscale = 0.18
         xinvert = no; yinvert = yes
      }
   } else if (instrument == "none") {
         xinvert = no ; yinvert = no ; rotate=no
   }

   if (!xinvert && !yinvert)
      print ("NORTH at top and EAST at left in frame XY system")
   else if ( !xinvert && yinvert)
      print ("NORTH at bottom and EAST at left in frame XY system")
   else if ( xinvert && !yinvert)
      print ("NORTH at top and EAST at right in frame XY system")
   else if (xinvert && yinvert)
      print ("NORTH at bottom and EAST at right in frame XY system")

   print ("Use image cursor to indicate current position...")
   print ("Allowed keystrokes: |c(to center)|spacebar(here)|q(skip)|")
   while (fscan(starco,xin,yin,wcs,command) != EOF) {
      if (substr(command,1,1) == "\\")
         key = substr(command,2,4)
      else
         key = substr(command,1,1)

      if (key == "c") {
         xref = xcenter; yref = ycenter
         print ("")
         print ("==> Offset position: ",xin,yin," to frame center:
",xref,yref)
         break
      } else if (key == "040") {                      # 040 == spacebar
         print ("Current position is = ",xin,yin)
         print ("Indicate where you want to be..")
         while (fscan(starco,xref,yref,wcs,command) != EOF) {
            if (substr(command,1,1) == "\\")
               key = substr(command,2,4)
            else
               key = substr(command,1,1)
```

```
            if (key == "c") {
               xref = xcenter; yref = ycenter
               print ("Desired position is frame center = ",xref,yref)
               break
            } else if (key == "040") {        # 040 == spacebar
               print ("Desired position is = ",xref,yref)
               break
            } else if (key == "q") {
               print ("Safe exit!")
               goto err
            } else {
               print("Unknown key: ",key," allowed = |c|f|spacebar|q|")
               beep
            }
            break
         }
         print ("")
         print ("==> Offset position: ",xin,yin," to: ",xref,yref)
         break
      } else if (key == "q") {
         print ("Safe exit!")
         goto err
      } else {
         print("Unknown key: ",key," allowed = |f|spacebar|q|")
         beep
      }
   }

# Eastward motion of telescope is defined as positive
   xshift = 0.1*real(nint(10.0*(xscale * (xref - xin))))
# Northward motion of telescope is defined as positive
   yshift = -0.1*real(nint(10.0*(yscale * (yref - yin))))

   print(xinvert,yinvert, rotate)
   if (xinvert)
      xshift = -1.0 * xshift
   if (yinvert)
      yshift = -1.0 * yshift
#  if (rotate)
#     foo = yshift; yshift = -1.0 * xshift; xshift = foo

   dist = sqrt(xshift ** 2 + yshift ** 2)
   adist = 0.01*real(nint(100.0*dist))
   dist  = adist/((xscale+yscale)/2.)
   print ("Separation = ",dist," pixels : ", adist," arcsec")

   if (xshift >= 0)
      print (xshift, " east")
   else
      print (-1.0*xshift, " west")

   if (yshift >= 0)
      print (yshift, " north")
   else
      print (-1.0*yshift, " south")
```

```
   print ("Within the instrument control window type: toffset
",xshift,yshift)

   err:

   xref = 0.0

   end
```

- The script is defaulted for IRIM 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 (128:128) 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 may be pasted directly into the Instrument Control window

---

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. IRIM remains on the telescope for the entire observing run and the LN_2 cryogen flasks are filled twice per day by the observing technicians.

Cable Harness -- Three cables run from the telescope junction box to the IRIM DCU. Two of these are power for the analog and digital electronics, the other a fiber optic cable containing six individual fibers. Four of these, marked TRANS1, RCVR1, TRANS2, RCVR2 provide communication to the DSP in the computer room, and are connected to the appropriate connectors on the DCU. The other two are spares for use in the event of a failure. **Caution:** The fiber optics are delicate and should not be subjected to force or bending of short (< 7 cm) radius; they should be secured to the instrument to relieve any strain on the connectors.

Dewar Cables -- There are two cables from the DCU box to the rest of the instrument:

- ACU Power: A single cable from the DCU to the ACU provides analog power.
- Filter: This is a Y-cable from the DCU to the filter drive motor and encoder.

In addition, four ribbon cables carry commands and data from the DCU to the ACU. These should always be left in place.

Getting Started

After IRIM 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:

Nicmos Irim Status Display	
VDet = 0.982	VDDsr = 5.006
VOff = 4.796	
VDM-LL = 0.991	VDM-HL = 5.006
Vsout-LL = 0.991	VSout-HL = 4.825
Vclk = 4.991	
Data Offset 0 = 2.305	Data Offset 1 = 2.310

Verify that the filter wheel is functional by moving to a number of filters using the command `fwl to [filtername]`. The successful completion of a motion should return a verifying message. The command `fwl ?pos` should return the current filter position.

Dark Current and Noise

After the detector is stabilized at operation temperature, one may check the dark current and read noise with a series of dark bias observations. With the filter wheel at the "dark" position (`fwl to dark`), take a large number (10 - 50) of observations at the minimum integration time of 0.38 s. Using the IRAF 'imcomb' task (mode=average, sigclip), calculate the average and sigma images. Examine the statistics of the average and sigma images with 'imstat', using a [50:200,50:200] subarray to avoid the bad regions at the edge of the array. If IRIM is operating properly, one should obtain approximately:

Mean Image : mean ~ 4.5 ADU

Sigma Image: mean ~ 3.2 ADU

If the value of the mean image is much greater than 5 ADU, there is additional dark current, most likely a result of the system not being completely cooled down. A sigma image value much greater than 3 ADU (30 e-) suggests high read noise and a call for help is in order.

Twist & Shout

This one-time exercise aligns the optical axes of the telescope and instrument, by the adjustment of a gimbal mount within the rotator. The alignment is determined by use of the "Christmas Tree" lights, which mount at the periphery of the secondary mirror at the N,E,S,W directions. Using a narrowband filter, one checks the brightness of the image for opposite lights and adjusts the tilt in that direction until the illumination is equal; this process is then repeated for the other coordinate. The primary covers should be open just enough to view the secondary. This will be done during the first night of setup and should not need repeating during a blocked run.

Techniques

Focus

IRIM is not fully achromatized, and there will be focus differences between filters. At the beginning of a run, one should determine these offsets empirically for all filters one intends to use. To focus the telescope in a given filter, use a star which gives 5000-10000 ADU peak signal in a few seconds' integration. Initial focus is easily done by observing using `movie` (continuous integration and display), changing the telescope focus and noting the character of the image vs focus readout. For fine adjustment, take a series of frames covering several focus steps across what appears to be the best value. Use the IRAF 'imexam' task to judge the best setting. **It is dangerous to query the display with 'imexam' while running in movie mode**. If IRAF and instrument tasks access the display window simultaneously, WILDFIRE will crash.

A recent determination of the focus settings at the 2.1-m and 4-m telescopes in the J, H, K, and K' filters yielded the following focus readout offsets relative to J (using the absolute value of the readout in both cases):

Filter	Focus Readout	
	2.1-m	4-m
J	0.00	0.00
H	-0.03	-100

K, K'	-0.06	-150

Although this table should provide a rough guide for the focus offsets, we still recommend that they be determined empirically during an observing run.

Changing temperature of the telescope structure will also require refocus. A recent determination of focus vs temperature at the 4-m is tabulated here, courtesy of S. Courteau and J. Holtzman.

External Temperature (°C)	Focus Value
2.1	5586
8.1	5787
12.2	5970
13.1	5998
17.7	6158

Keep in mind that the zero point of this relation will change from run to run as IRIM is remounted on the telescope, although the slope of ~37 units/ °C should be the same.

Observing

Because of the high brightness of the infrared sky, often greater than that of the objects under study, and the complex dark current, the technique of subtracting a bias (dark) frame and dividing by a flatfield works poorly in the infrared. Some technique of subtracting the sky prior to flatfielding is necessary. In practice, this is accomplished by several observations of the object field, separated by small motions of the telescope, so that the stars in the field are imaged onto different sets of pixels in each of the images (this is sometimes referred to as "dithering"). If the spatial object density of the field is relatively low, then combining the images using a median algorithm will result in an average from which the astronomical sources have been removed; i.e., a sky frame. This may be done using the IRAF 'imcombine' task. If the sky amplitude varies from frame to frame, it may be necessary to scale the frames by the mean to obtain a good median average. The resultant sky frame may then be subtracted from each of the raw images to yield sky-subtracted images which then may be flatfielded and reduced. Note that the detector dark current is also removed in this process. Creating the sky frame from a number of raw images also reduces the increase in statistical noise resulting from arithmetic operations on the images.

If the object field is extremely crowded (e.g., a globular cluster) or contains an extended source, it is necessary to move the telescope a significantly larger distance ("wobbling" or "jogging") to a suitably sparsely populated "sky" field. However, succeeding observations within both the object and sky fields should still be "dithered" so that one may obtain an average sky frame using the median averaging technique and to avoid imaging the same parts of the object field onto defective pixels. As noted below, there are some instances in which this method introduces other problems.

There are a number of resident scripts which will automatically carry out these types of observations. In addition, existing scripts may be copied and customized by the observer to carry out more complex or exotic observations.

Flatfielding

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 slowly decays. 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.

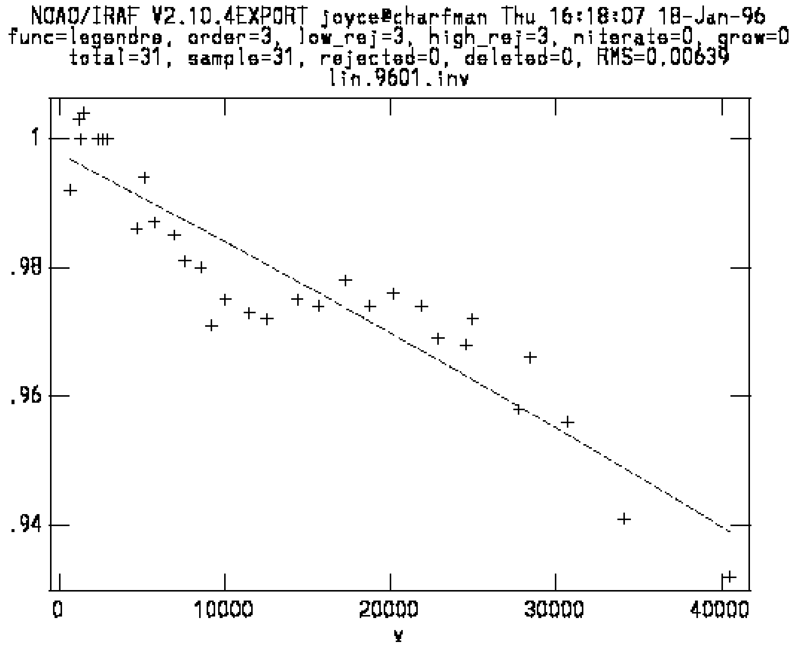
Photometric Standards

The best near-infrared standards are those defined by Elias et al (1982, AJ, 87, 1029), but these stars are all too bright to observe with IRIM (i.e., they saturate the detector array in the minimum available exposure time). There are several sets of fainter standards, including those measured by Carter & Meadows, the UKIRT Faint Standards, and a set of stars being measured to support NICMOS. The Carter & Meadows measurements appear to be excellent quality, but the stars are relatively bright (e.g. K = 9-10 mag) and may also not be observable with IRIM. The UKIRT standards are probably fine for measurements requiring no better than 5% accuracy or so.

We suggest that the list of standards prepared for NICMOS be used when the most accurate photometry is desired. Both the UKIRT faint standards and NICMOS standards should be in starfile caches at the 2.1-m and 4-m telescopes.

Linearity Corrections

As mentioned previously, linearity corrections are crucial, particularly for broadband photometry, where the sky background signal will be large. Whether one is operating in the "stare" or "sep" modes (in the latter case, both array readouts are preserved and linearity relations are derived for each separately), the basic technique is to observe a source of constant illumination (e.g., the white spot) and use the integration time to obtain a range of signal levels. A flux in the 1000 - 2000 ADU/s range permits one to sample both relatively small and large signals in a reasonable time. It is necessary to intersperse control frames of a single integration time (e.g., 1 sec) throughout this process as a check on the stability of the source. In addition, it is necessary to obtain dark frames of the same integration time as the linearity frames for subtraction of any dark current or other fixed artifacts. After dark subtraction, the pixel statistics in one or more subregions of the image can be normalized by the integration time to yield a linearity relation. Although the linearity curve becomes nonlinear at high signals, experience indicates that a linear (e.g., second-order polynomial) fit is sufficient for signals < 30000 ADU. The derived linearity curve must be inverted to determine the coefficients for the IRAF task 'irlincor'. For the "canonical" linearity curve, in which a linear decrease of about 1.5%/10000 ADU is observed, the 'irlincor' coefficients would be A=1.00, B=0.050, C=0.0.



General Suggestions

- Use sky flats whenever possible, but obtain dome flats as a backup
- Maintain the same integrated flux in ADUs on standards and program fields to minimize the effects of detector nonlinearity.
- The "memory" effect may be troublesome in fields with large variations in source brightness; e.g., star clusters. For a target with a bright central source, dithering may actually make things worse if the retained image contaminates fainter portions of the field.
- Guiding is provided at both telescopes with the facility off axis guiders. Programs requiring frequent telescope moves but not precise registration will proceed more efficiently without guiding. At the 4-m, the guide probes are often used to dither in a repetitive pattern which allows image registration without requiring that a high S/N source be present in the individual data frames.

IRIM will perform very well with well constructed protocols based on an understanding of these device characteristics. For example, IRIM has been used extensively for deep background limited K' band detections of cosmological sources. Repetitively dithered integrations, using the 4-m guider for precise offsetting in a multiposition pattern and two hours' total duration, detect sources to K'~ 22 and allow precise photometry to K' ~ 20 (R. Elston, private communication).

HST/NICMOS Faint Standards

This page contains information on standard stars currently being used at CTIO with our facility imagers. The photometry data are from the lists compiled for the new faint HST/NICMOS standards on the Las Campanas (LCO) system. An additional set of RED stars has been observed on the LCO system. We are grateful to Eric Persson, and his collaborators David Murphy, Wojciech Krzeminski, Miguel Roth, and Marcia Rieke for making these data available for the CTIO www pages.

n	HST	RA(J2000)	Dec(J2000)	J	+/-	H	+/-	K	+/-	Ks	+/-
9101	P525-E	00:24:28.3	07:49:02	11.622	0.005	11.298	0.005	11.223	0.008	11.223	0.005
9103	S294-D	00:33:15.2	-39:24:10	10.932	0.006	10.657	0.004	10.596	0.005	10.594	0.004
9104	S754-C	01:03:15.8	-04:20:44	11.045	0.005	10.750	0.005	10.693	0.010	10.695	0.005
9105	P530-D	02:33:32.1	06:25:38	11.309	0.010	10.975	0.006	10.897	0.006	10.910	0.005
9106	S301-D	03:26:53.9	-39:50:38	12.153	0.007	11.842	0.005	11.772	0.010	11.788	0.006
9107	P247-U	03:32:03.0	37:20:40	11.934	0.005	11.610	0.004	11.492	0.011	11.503	0.005
9108	P533-D	03:41:02.4	06:56:13	11.737	0.009	11.431	0.006	11.337	0.008	11.336	0.005
9109	S055-D	04:18:18.9	-69:27:35	11.552	0.002	11.326	0.002	11.255	0.027	11.269	0.002
9111	S361-D	04:49:54.6	-35:11:17	11.246	0.006	11.031	0.006	10.992	0.033	10.980	0.006
9113	S252-D	05:10:25.6	-44:52:46	11.059	0.005	10.766	0.005	10.708	0.034	10.713	0.005
9115	S363-D	05:36:44.8	-34:46:39	12.069	0.007	11.874	0.005	11.826	0.007	11.831	0.005
9116	S840-F	05:42:32.1	00:09:04	11.426	0.009	11.148	0.009	11.077	0.014	11.058	0.008
9118	S842-E	06:22:43.7	-00:36:30	11.723	0.011	11.357	0.009	11.264	0.016	11.261	0.010
9119	S121-E	06:29:29.4	-59:39:31	12.114	0.006	11.838	0.005	11.765	0.009	11.781	0.005
9121	S255-S	06:42:36.5	-45:09:12	11.719	0.004	11.434	0.004	...	...	11.372	0.004
9122	P161-D	07:00:52.0	48:29:24	11.680	0.006	11.408	0.006	11.356	0.013	11.352	0.006

9123	S427-D	06:59:45.6	-30:13:44	10.833	0.007	10.499	0.007	10.431	0.015	10.442	0.009
9125	S005-D	07:19:38.6	-84:35:06	10.885	0.007	10.598	0.006	10.514	0.013	10.522	0.008
9126	P309-U	07:30:34.5	29:51:12	11.876	0.013	11.522	0.014	...	...	11.450	0.022
9129	S209-D	08:01:15.4	-50:19:33	10.914	0.007	10.585	0.006	10.487	0.021	10.496	0.009
9131	P035-R	08:25:43.8	73:01:18	10.819	0.008	10.546	0.007	10.499	0.010	10.515	0.008
9132	S312-T	08:25:36.1	-39:05:59	11.949	0.006	11.669	0.005	11.608	0.004	11.609	0.004
9133	S495-E	08:27:12.5	-25:08:01	11.521	0.007	11.048	0.008	10.965	0.016	10.960	0.010
9134	P545-C	08:29:25.1	05:56:08	11.881	0.007	11.624	0.005	11.575	0.005	11.596	0.006
9135	S705-D	08:36:12.5	-10:13:39	12.362	0.010	12.098	0.011	...	...	12.040	0.014
9136	S165-E	08:54:21.7	-54:48:08	12.489	0.008	12.214	0.008	12.138	0.018	12.142	0.011
9137	S372-S	09:15:50.5	-36:32:34	11.153	0.007	10.891	0.007	10.830	0.019	10.836	0.010
9138	S852-C	09:41:35.8	00:33:12	11.354	0.006	11.041	0.006	10.981	0.015	10.982	0.008
9139	P091-D	09:42:58.7	59:03:43	11.683	0.008	11.338	0.007	11.276	0.011	11.282	0.010
9140	S262-E	09:45:42.8	-45:49:40	11.409	0.011	11.085	0.008	...	...	11.022	0.012
9141	S708-D	09:48:56.4	-10:30:32	11.081	0.008	10.775	0.008	10.715	0.035	10.718	0.010
9142	P212-C	10:06:29.0	41:01:26	11.993	0.006	11.729	0.005	11.686	0.009	11.697	0.007
9143	P550-C	10:33:51.8	04:49:05	12.344	0.007	12.121	0.005	12.067	0.006	12.081	0.005
9144	S264-D	10:47:24.1	-44:34:05	11.642	0.009	11.335	0.008	11.263	0.018	11.280	0.010
9145	P064-D	12:13:12.0	64:28:56	11.958	0.009	11.711	0.008	11.664	0.011	11.675	0.009
9146	S217-D	12:01:45.2	-50:03:10	11.323	0.007	11.002	0.005	10.931	0.003	10.936	0.004
9147	S064-F	12:03:30.2	-69:04:56	12.111	0.007	11.803	0.007	11.722	0.013	11.724	0.007
9148	P266-C	12:14:25.4	35:35:55	11.642	0.009	11.378	0.008	11.324	0.011	11.343	0.008
9149	S860-D	12:21:39.3	-00:07:13	12.213	0.007	11.917	0.006	11.861	0.005	11.865	0.005

9150	S791-C	13:17:29.6	-05:32:37	11.661	0.008	11.310	0.007	11.250	0.014	11.267	0.008
9152	P133-C	13:58:40.2	52:06:24	11.149	0.009	10.878	0.007	10.831	0.011	10.839	0.010
9153	P499-E	14:07:33.9	12:23:51	11.947	0.008	11.605	0.008	11.560	0.013	11.540	0.008
9154	S008-D	14:23:45.5	-84:09:58	11.232	0.007	10.990	0.007	10.904	0.009	10.915	0.008
9155	S867-V	14:40:58.0	-00:27:47	12.045	0.008	11.701	0.005	11.622	0.005	11.633	0.005
9156	P041-C	14:51:57.9	71:43:13	10.873	0.008	10.588	0.006	10.523	0.009	10.530	0.007
9157	S273-E	14:56:51.9	-44:49:14	11.341	0.007	10.924	0.005	10.851	0.004	10.849	0.004
9158	P272-D	14:58:33.1	37:08:33	11.640	0.008	11.277	0.006	11.210	0.008	11.223	0.007
9160	S870-T	15:39:03.5	00:14:54	10.914	0.008	10.701	0.008	10.649	0.010	10.659	0.009
9162	P177-D	15:59:13.6	47:36:40	12.258	0.012	11.924	0.008	11.857	0.013	11.868	0.012
9164	P565-C	16:26:42.7	05:52:20	12.180	0.007	11.895	0.006	11.842	0.007	11.844	0.006
9166	P330-E	16:31:33.6	30:08:48	11.816	0.007	11.479	0.005	11.419	0.007	11.429	0.006
9169	P138-C	17:13:44.5	54:33:21	11.355	0.007	11.118	0.005	11.075	0.008	11.080	0.007
9170	S875-C	17:27:22.2	-00:19:25	11.132	0.005	10.835	0.005	10.739	0.006	10.744	0.005
9172	S279-F	17:48:22.6	-45:25:45	12.477	0.009	12.118	0.006	12.026	0.006	12.031	0.006
9173	S024-D	18:18:46.2	-80:06:58	11.039	0.007	10.778	0.007	10.693	0.009	10.711	0.008
9175	S071-D	18:28:08.9	-69:26:03	12.252	0.006	11.916	0.007	11.834	0.011	11.839	0.007
9177	P182-E	18:39:33.7	49:05:38	12.104	0.005	11.764	0.004	11.688	0.006	11.696	0.005
9178	S808-C	19:01:55.4	-04:29:12	10.966	0.007	10.658	0.008	10.566	0.014	10.575	0.008
9181	S234-E	20:31:20.4	-49:38:58	12.464	0.011	12.127	0.008	12.095	0.007	12.070	0.007
9182	S813-D	20:41:05.1	-05:03:43	11.479	0.005	11.142	0.005	11.082	0.010	11.085	0.005
9183	P576-F	20:52:47.3	06:40:05	12.247	0.004	11.940	0.004	11.873	0.007	11.880	0.005
9185	S889-E	22:02:05.7	-01:06:02	12.021	0.005	11.662	0.004	11.586	0.012	11.585	0.005

9186	S893-D	23:18:10.0	00:32:56	11.403	0.009	11.120	0.006	11.045	0.006	11.055	0.006
9187	S677-D	23:23:34.4	-15:21:07	11.857	0.003	11.596	0.003	11.538	0.009	11.542	0.003
9188	P290-D	23:30:33.4	38:18:57	11.634	0.005	11.337	0.004	11.257	0.008	11.262	0.006

In addition, we are assembling finding charts for all the standards listed in these tables. These will be useful at the telsecope.

please mail questions or comments to: Bob Blum (rblum@noao.edu). rev 31 July 1998.

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