Near-Infrared Photometry at the Gornergrat Infrared Telescope

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Introduction

This manual is designed not to be an exhaustive reference, but rather to provide a "recipe book" for performing near–infrared (NIR) photometric measurements at the Infrared Telescope at Gornergrat (TIRGO). To this end, brief descriptions of the use of the wobbling secondary and television acquisition systems are given, followed by the characteristics of the Arcetri InSb photometer. Observational procedures are then outlined. For further information, Salinari (1982) and Saraceno *et al.* (1982) give detailed descriptions of the telescope and wobbling secondary system, respectively. The charge amplifier system of the photometer is described in Hartill *et al.* (1986). Details of the TIRGO standard star network are given in Hunt *et al.* (1987).

For convenience, a list of the TIRGO calibration stars is provided in Appendix A. Note that a few of the secondary standard magnitudes given in Appendix A differ with respect to Hunt *et al.* (BS 4392, BS 6707, and BS 7504). We will provide a complete updated version of the secondary standard star magnitudes with the completion of the proposal approved for Winter 1991 for the refinement of the TIRGO photometric calibration.

Wobbling secondary and telescope beam switching

To accurately subtract the NIR sky background, it is necessary to alternate source with sky measurements at frequencies > 2 Hz. Beam switching the telescope effectively eliminates both spatial and temporal linear variations in sky + telescope emission (see Appendix B). These operations are accomplished at the TIRGO through the use of a wobbling secondary system and an automatic beam switching algorithm incorporated in the data acquisition program.

The direction of the secondary modulation is adjusted through a toggle switch on the telescope control panel; the position is reflected in a numerical readout on the telescope status screen. Numerically, an EW direction is roughly 1120 with beam B to the left of beam A on the TV acquisition video; NW corresponds to about 2390 with beam A below beam B on the TV. These numbers are not exactly reproducible and, if required, should be checked for accuracy. The above mentioned numerical fiducials correspond to about 14.1 cts/degree. It is therefore possible to set the secondary chopping direction according to the desired position angle, taking into account the orientation of the TV acquisition video.

The amplitude of the secondary modulation ("throw") is set by means of a potentiometer on the rack above the telescope control panel. 100 potentiometer units correspond to roughly 19.3 arcsec. This number can be checked by measuring on the TV a given displacement in mm and converting it to arcsec.

In the thermal bands (L and M), it is possible (and may be necessary) to minimize offset (difference in sky background between the two reference positions) by adjusting the center position of the secondary. This is effected by adjusting (on the same rack as the amplitude potentiometer) a similar potentiometer that indicates the nominal secondary centering (usually 500 along the telescope optical axis). This should be done while in "FREE RUN" with the telescope pointed to an empty sky field.

Beam switching is defined by an option in the data acquisition program after the direction and amplitude (and centering) of the chopping secondary are set. When this is done, a measurement always starts with a positive beam on the source ("A"); after a given time interval (also set in the acquisition program), the program automatically moves the telescope to the alternate beam ("B"). A complete beam switching cycle consists of four beams, ABBA. In theory the centroid of the two beams should lie on the optical axis of the telescope, but in practice it is common to center positive beam A on the axis. This should not be a problem in the NIR as the unaberrated field is sufficiently large.

Television system

Two television cameras are available: one with a large field of view (FOV) ($\sim 1°$) is mounted on the telescope structure and the other (total FOV $\sim$ 12 arcmin) is mounted on the instrument cube. The second TV is equipped with two magnifications (f/10 and f/20) and is the one preferentially used for data acquisition. The FOV of the TV monitor is roughly 3×4 arcmin with the f/10 magnification and the magnitude limit for point sources (with no moon) is $\sim$ 16 mag.

The CRT tubes of both TV cameras are powered up by switches on the TV control panel to the right of the telescope console. Shutters and filters should be checked and placed in the desired position. It is *very important* that the shutters on both TV cameras be closed if the dome is not dark. The TV screen can monitor either the image of the camera mounted on the telescope or that mounted on the instrument cube; this is controlled by a toggle switch on the TV control panel.

Before observing (see preliminaries), the focal plane position of the TV mounted on the cube should be reset and brought to the nominal position of the detector. This position should be given on the telescope control panel.

When the dichroic is in place, the position of the star on the TV screen is displaced relative to that when the dichroic is not inserted in the optical path. The direction (either horizontal or vertical) of the displacement depends on the face being used. This should be remembered when centering sources by eye.

The TV system is also provided with an Arlunya image intensifier capable of enhancing images up to a factor of 10 (depending on the sky background, presence of moon, etc.). The control panel for the Arlunya is above the telescope console and can be adjusted to optimize the identification of faint sources. In addition, the Arlunya can be used to draw boxes of any size on the monitor screen (control box to the right of the TV control panel). This avoids parallax errors when centering sources in small diaphragms.

Arcetri InSb photometer

The detector is a single element chip maintained at solid nitrogen temperature. This temperature is indicated by the PT100 readout installed to the left of the console; solid nitrogen temperatures correspond roughly to 10 – 13 Ω of the PT100. This temperature should be frequently checked whenever problems are suspected, or after refilling the internal chamber.

Nominal values for filters and diaphragms are given in Tables 1 and 2, respectively. The measured filter transmission curves are given in Figure 1.

Table 3 gives approximate magnitude limits obtained with the current detector (mounted in January 1990). Of course, these depend on sky conditions and should be considered only a rough guide. Since sky magnitudes depend on lunar phase and proximity as well as air mass, the values in Table 3 are approximate. (They are representative of grey time and intermediate air mass.)

Table 1
InSb Filters

Name	Symbol	λ [μm]	$\Delta\lambda$ [μm][a]	Max. ϕ [arcsec]
J	J0	1.25	0.28	28
H	H0	1.65	0.34	28
K	K0	2.24	0.38	28
L′	L0	3.83	0.63	28
M	M0	4.74	0.62	20
H(large)	HG	1.65	0.33	42
CO	CO	2.35	0.10	28
CVF1	–		1.40 - 2.55	14
CVF2	–		2.50 - 4.50	14
CVF3	–		4.4 - 5.6	14

[a] 50% transmission.

Table 2
InSb Diaphragms

Name	Diameter	
	[Arcsec]	[mm]
D1	7	1.0
E1	10	1.5
D2	14	2.0
E2	17	2.5
D3	21	3.0
E3	24	3.5
D4	28	4.0

Figure 1

Table 3
Limiting Magnitudes

Band	Limit[a]	Sky Magnitude [mag arcsec^{-2}]
J	15.4	13–14
H	15.25	13.5
K	14.4	12.5
L	8.5	3
M	5.5	0

[a] 1 σ in 1 sec at low gain.

As noted in Hunt (1986), the detector functions differently in observing conditions (AC), than in the laboratory (DC). This difference results in an inability to observe with the same calibration bright objects (K $<$ 3) and faint ones. Because of the difference in detector sensitivity, the corrections given in Hunt (1986) are not applicable to data acquired after January 1990. Therefore, if only bright objects are observed, it is advisable to use only bright calibrations stars; conversely, if program objects are faint, only faint calibration stars should be used. Caution should be exercised when comparing photometrically bright objects and faint objects. This problem has been addressed, although the solution has not yet been implemented.

Observational Procedures

Before beginning science observations, it is important to perform the preliminary operations outlined below. To minimize dome seeing, it is best to open the dome and turn on the ventilator fans an hour or two before beginning observations. If the fans will not be used, then the trap door isolating the dome from the building should be closed. It is assumed that the telescope pointing has been set and that the dome has been enabled and the mirror covers opened. The photometer should be ON (*i.e.*, switches on the electronics box in the dome), and the various panels (modulating secondary, TV acquisition system/image intensifier, etc.) should be powered up. It is assumed that the latest beam profiles have been checked for symmetry.

Preliminaries

Reset the TV acquisition video, then position at nominal values for the InSb detector. The nominal position should be given on the telescope control panel for the photometer.

Reset filter and diaphragm wheel. This is advisable to ensure the acquisition computer is apprised of the position of the filter and diaphragm encoders.

Set filter and diaphragm. Preliminaries are usually done in H or K to maximize the instrumental count rate. Initially, it is advisable to use a 28 arcsec diaphragm (D4) as it will facilitate finding the position on the screen corresponding to the location of the detector.

Set dichroic to appropriate face for photometer. The setting should be indicated above the dichroic indicators (telescope control panel).

Point to a bright star. It is usually advisable to point to a star near the zenith initially. At the beginning of the night, a pointing initialization is usually performed (LAD) so as to correct for any temporal (or other) error accrued relative to the previous observations.

Set the amplitude of the modulating secondary. This amplitude need not be that required for the science observations; in fact, for focusing and aperture definition, it is probably better to use small throws (at least a diaphragm diameter).

Define the aperture to be used for science observations. This is typically done using the FREE RUN option of the data acquisition program which gives a sort of analog display (digitized) on one of the terminals. When the source is centered in beam A, counts should be positive; if counts are negative (and large), the source is probably centered in beam B. Dimensions of the diaphragms should be checked both for symmetry (equal diameters in NS and EW), and for correspondence with the nominal dimensions. If multi–aperture photometry is to be performed, then each diaphragm to be used should be defined and checked as above. In addition, the diaphragms should be concentric; if not, then each diaphragm requires a new center position.

Focus the telescope. There are many different methods to focus a telescope; the technique usually adopted at the TIRGO involves minimizing the dimension of a point source, as measured by the width of the rise in a beam profile. This procedure can be performed either in FREE RUN or by using the strip chart recorder and passing a star (typically in declination to avoid correcting for $\cos\delta$) in guide across the diaphragm. When using FREE RUN, the width of the seeing disk is measured by counting the number of points needed to go from minimum to a stable maximum. These are then converted to arcsec by measuring the time difference between each point (a function of the integration time and chopping frequency) and multiplying the time corresponding to the number of points from minimum to maximum by the number of arcsec per unit time (guide speed). This then is the full width of the seeing disk at zero intensity. Typical focused secondary positions corresponding to about 6°C in the dome are 1540 (read off the telescope status panel). When temperatures are warmer, the numbers decrease (about 20 cts per degree). Absolute numbers change every time the instrument is remounted so these should only be used as a relative guideline. Typical seeing at TIRGO is around 3 arcsec (in K).

Define telescope beam switch. This is performed by an option in the data acquisition program. Before doing this, the amplitude and direction of the wobbling secondary should be set to the program values. The procedure involves centering (by eye and by looking at the "analog" (digitized) output) a star first in beam A, then in beam B. During this operation, it may be helpful to disable the pointing corrections (TRK OFF). For large beam throws, it is helpful to define the telescope beam switch on a faint star so as to best match the actual observing conditions. Otherwise, the beam switch (defined on a bright star) probably will not be precise for program objects (if they are faint) because the static and dynamic secondary positions differ slightly and the difference varies with chopper frequency (which is slower for fainter sources). Slight discrepancies from the defined beam switch can be adjusted for by lightly tampering with the modulating amplitude potentiometer. Note that the parameters of the chopper throw (amplitude and direction) are not read by the acquisition program, so if desired, they should be introduced explicitly.

Update parameters for pointing corrections. Since accurate pointing depends on the temperature and pressure (refraction index) and the central secondary position, it is wise to introduce these parameters explicitly into the file read by the pointing algorithm. (Presently, this is accomplished in the CAT program.)

Check for automatic dome control. Sometimes the positioning algorithm for the dome puts the dome in a position that is 180° away from the correct one. This should be checked if there seem to be problems. When this occurs, it is helpful to perform a pointing reset (LAD) on a star to the south and east while the dome is stationary. (This problem should be resolved with the new pointing control system.) Note that a LAD should never be performed while the dome is in motion.

Program observations

After setting up the telescope and ascertaining focus, instrument function, etc., standard star and science observations can begin. After pointing the object:

Set filter and diaphragm.

Perform the automatic scaling that sets the instrument parameters. This is done using an option in the data acquisition program; by sampling source + sky and sky flux, the scaling algorithm sets up the gain, integration time, chopping frequency, and temporal parameters of the instrument.

Set desired S/N, duration of a single beam, and minimum and maximum number of ABBA cycles. It is advisable to perform at least two ABBA cycles even on bright sources as the first integrations can be systematically different from the others.

Start observation. Once the measurement is started, it is important to check for large offsets that retain the same sign in all filter bands. These could indicate unwanted objects in the reference beam.

Suggestions for extended source observations

We advocate the use of offset pointing to ensure accurate telescope positioning at the nominal position of the object to be observed. This is effected by selecting either a SAO or an HR star as close as possible to the nominal coordinates of the program object, pointing the telescope to the star, then fixing the coordinates by performing a "LAD" with the star perfectly centered (with dichroic in). In these conditions, the pointing accuracy of the telescope is better than 2 – 3 arcsec rms.

The program object can then be pointed with a reasonable probability that the dominant pointing error is the error in the coordinates, and not telescope pointing error. It may be possible to center by eye on the optical center (using the lowest magnification of the TV), although guiding will be difficult if integrations are long and there is no guide star in the field. If necessary, a guide star should be found by moving the television camera while keeping the telescope fixed at the nominal position.

Having positioned the guide star on the screen, the program object, if the signal is sufficiently intense, can be centered by maximizing the NIR signal. For galaxies, H or K are the best bands to use as the sky counts are such that the integration times are shorter. The NIR signal is maximized using FREE RUN and watching the counts as a function of position of the guide star when the telescope is displaced from the nominal coordinates. Alternatively, the strip–chart recorder can be used but by connecting the "InSb OUT" cable to the input and disabling the chopping (detaching the cable from the input signal). Note that the "analog out" output on the detector is the correct one for this option.

If the object is too faint for this method to be effective, the data acquisition mode can be used to maximize the signal. In the menu where the measurement is begun, the minimum and maximum number of ABBA cycles should be set to 1. It is typically necessary to perform at least five measurements positioned at the nominal coordinates, and equidistant on each of the four sides; each measure lasts from 30 – 60 sec according to the duration of each beam. The procedure should be iterated until the center measurement exceeds that of the surrounding regions.

Note that after restoring the television camera to its nominal position, it is advisable to recheck the diaphragm definition (in case of slippage).

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Appendix A: TIRGO Primary Standards

Appendix A, cont.: TIRGO Secondary Standards

Appendix B: Elimination of linear variations in the background

To be defined.

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