Instrumental work while at SAAO

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This is about my instrumental/technical activities after joining SAAO in October 1975. Though my main interest was infrared equipment, inevitably I got involved in other areas. It is only fair to say that most of the projects that I describe here also involved the technical staffs in the instrument workshop and electronics divisions.

The SAAO was dependent for a long time on outside sources for most of its instrumentation. Examples were the Peoples' Photometer (R Bingham, RGO), the Electronographic camera (McMullan, RGO), the St Andrews photometer and St Andrews Scanner (IG Van Breda, St Andrews), the Unit Spectrograph (RGO), the UCT Photometer (Nather, U of Texas) and the RCA CCD camera (University College, London).

Designs

Most of the detailed mechanical drawings for devices that I required I made on graph paper. They probably ran into thousands. I usually did the final assembly. Much of my work involved infrared detectors working at low temperatures: 1K to 77K. Data on the properties of materials at these temperatures were sometimes hard to find, such as thermal conductivities, expansion coefficients and refractive indicies. Many items required tiny infrared-transmitting lenses of materials such as sapphire, CaF_2 , BaF_2, Al_2O_3, KBr and LiF. Some of these were deliquescent and had to be kept dry or under vacuum. They also tended to be easily thermally shocked and needed to be mounted in such a way that they were not strained but were kept in a defined position.

I wrote many computer programmes, usually in C, for controlling instruments. However, I often asked Luis Balona and John Menzies for advice. I also wrote at times in Data General Nova and IBM PC assembly languages. Scientific programmes I usually wrote in Fortran. Luis wrote the first on-line photometer data reduction programme "Manfred" and Patricia Whitelock wrote later versions as well as the software for the filter-wheel spectrometer and 3-channel Dewar.

The Mk I infrared photometer I built in the UK before coming to South Africa but the later equipment described here was made at SAAO. Many parts were imported from many different places, so it was necessary to keep stocks of specialized small things such as screws in BA, metric and USA sizes. I also needed special low-conductivity shafts (Kel-f), wires, cables, connectors, electronic parts, vacuum seals, zeolite sorption material, paints, glues and lubricants for cryogenic applications. Detectors and filters, besides the optical parts, had to be stored in vacuum dessicators because of moisture issues. Some items took months to acquire, so that careful planning was necessary to ensure that they were delivered in time.

I did a fair amount of electronic construction myself, especially of in-Dewar pre-amplifiers and other electronics associated with the detector cryostats. For this I kept a supply of special FET transistors and thin-film resistors with values up to a few times10^{11} Ω. The latter had to be checked to ensure that they obeyed Ohm's law at low temperatures. A particular problem with the feeble low-frequency signals that I had to deal with was the avoidance of ground loops, necessitating strict adherence to single-point grounding. For this reason, the detector cryostats had to be electrically isolated, as did the mechanisms for controlling the filters and apertures.

My laboratory work came to an end in December 2005 when my last contract at SAAO expired, though I continued astronomical observations for several further years afterwards.

Updating the 74-inch Telescope

The Radcliffe Observatory had closed down in 1974 and the CSIR (SA) had bought the 74-inch telescope and the turret that housed it. Woolley insisted that the telescope should be moved "as is" to Sutherland to avoid what he feared might become interminable delays if the technical staff were given free range to update it. There were a few hitches in the move but it was finally ready to use in January 1976 and I was the first person to observe with it. I was soon after put in charge of the telescope and immediately started to address some of its worst problems (*MNASSA*, **37,** 4, 1978).

The original slow motion drive in declination suffered from so much lost motion through sliding joints, a screw drive and backlash that the guide speed could not be used at all. The set speed was also affected to some extent. I arranged to have the slow motion drive screw replaced by a ball screw and the guide and set motors replaced by a single stepper. This greatly improved the response but the declination axis turned out to be so stiff that there was wind-up and the correspondence between number of steps made and actual movement was not sufficiently precise to be able to use step counting for the automatic "nodding" required for infrared purposes [Nodding was a movement of 12 to 60 arcsec in declination that had to occur every 20 seconds, similar to "beam switching" in radio astronomy].

To achieve automatic nodding I ultimately (1985) installed an incremental encoder mounted on Bendix flex pivots and with its shaft running on a stainless steel band fixed to the large declination circle to give a precise sub-arcsec indication of the actual movement (*MNASSA*, 44, 45–47, 1985).

I was also concerned about the reflectivity of the mirrors of the telescope that were not being measured systematically. When it was installed at Sutherland, the SAAO staff concerned with aluminizing found that the surfaces showed a bluish bloom. I resuscitated an old reflectometer that could measure the reflectance at 45 degrees incidence in an undefined band, probably towards the red end of visible. Some "standard" high reflectance mirrors were provided by R Bingham of RGO. A lengthy series of experiments by Eric Banner and JD Laing with sheet glass mirrors suspended in the aluminizing tank revealed that too much aluminium was being deposited each time.

The Cassegrain focus motor was an old pump motor that had been substituted in Pretoria for a failed original and was replaced with a more appropriate one. The original DC declination coarse motion motor failed and was replaced with a modified two-speed AC washing machine motor that gave better control. A small modification had to be made to the motor because the original “spin” speed was uni-directional though fortunately the “tumble” speed worked in both directions. The action of the declination quick motion cone clutch that had at some stage replaced the original Grubb Parsons clutch was very touchy. It was orientated in such a way that it would barely stay in adjustment in all telescope positions. I replaced it by an electric dog clutch, possible since the shaft would not be turning when the clutch was engaged. These modifications required a re-design of the declination counterweights to facilitate access.

The elaborate and troublesome Grubb Parsons guiding, setting and tracking split-field servomotor drive and its vacuum tube electronics of 1960s vintage were replaced by a stepping motor system designed by the electronics department.

RA slewing for many years had been by means of a large steering wheel that even in Pretoria had replaced the original very coarse motor and clutch system. A variable speed motor, new reduction gearing and a dog clutch were installed according to my designs.

The original controls that consisted of an assortment of switchgear were replaced with a streamlined system that could be operated from either side of the North pier.

In about 1977, 19-bit absolute encoders were installed on the axes (they had to be hollow to allow the coudé beam to pass through); I was fortunate enough to find a suitable model by Sequential Information Systems. The mountings of these were quite elaborate as they required accurate centring and alignment perpendicular to the rotation axes, including much awkward work inside the “cube”. Alaistair Walker wrote the DG Nova minicomputer software that read them and included a pointing model. Though we tried at first to use a rational model including terms allowing for misalignment of the axes and flexure, this was unsuccessful and an interpolated numerical table was eventually adopted.

Finally, the dome position was encoded absolutely – this was easy to do because it is driven by two 16-toothed pinions engaging on a rack of 1912 or 239 x 8 teeth. As 239 is a prime number, we could not buy a suitable gear. However, I got the workshop to make one by cutting out the centre of a 240-tooth worm gear and reassembling it on a new hub with one tooth cut out. Luis Balona devised an algorithm that controlled the azimuth of the turret with its non-symmetrical telescope inside! This had to be a bang-bang system allowing for coasting as the dome drive motors were single-speed 3-phase.

The dome was built without a warm room as had happened earlier with all the other telescopes at Sutherland. I designed the first warm room on the east side of the dome and the telescope pointing computer was installed here as well as whatever equipment was needed for the measuring instruments. The present warm room was built when the Boksenberg scanner arrived later and was extended over the years.

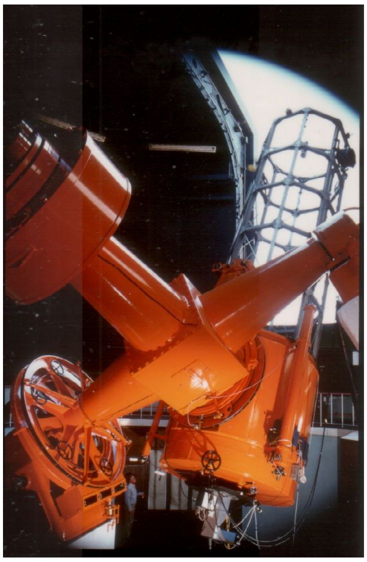
During a trip in December 1975 to observe at the AAO, I visited Mt Stromlo Observatory in Canberra and saw there an automated observing platform that they had replaced with a larger one. In 1976 I arranged to buy the old one for use at the 74-inch in Sutherland. It greatly improved access to the Cassegrain focus that had heretofore been by rather dangerous ladders and a movable tower.

Much of this work was reported in my article in *MNASSA* **37**, 4, 1978.

Television acquisition

Most big telescopes by then had integrating TV finders using SEC vidicons and we with great difficulty (from anti-apartheid sanctions) were eventually able to get one (Quantex), ca March 1978. The problem was that such cameras were classified as "munitions" in spite of their extremely delicate nature. This somehow survived until the era of CCD cameras and, just as the tube failed, a thermoelectrically cooled frame-transfer CCD camera that I had designed was ready for use, connected to one of the Transputer (Merlin) controllers.

Painting the Telescope



The 74-inch telescope was painted a dull grey after the move to Sutherland (it was originally a dull green!). When the need arose to repaint, I chose an orange colour that had been very successful on an old refrigerator at home. This had the advantage of being very visible in the light of a red torch.

Fig 1: The 74-inch after painting orange. It is shown here with the f/50 secondary and the Mk III infrared photometer with the blue Quantex TV acquisition camera (Photo: RM Catchpole).

Updating the MkI/MkIII infrared photometer

The construction of the MkI and II photometers was carried out while I was employed by the Royal Greenwich Observatory and has been described elsewhere (RGO.pdf – see my home page).

To make infrared observing easier, the filter and aperture controls on the back of the MkI instrument were automated during the 1970s so that they could be controlled from the front of the photometer. As mentioned, because of the low-level signals, great care had to be taken to insulate the mechanisms from the photometer so as to avoid ground loops.

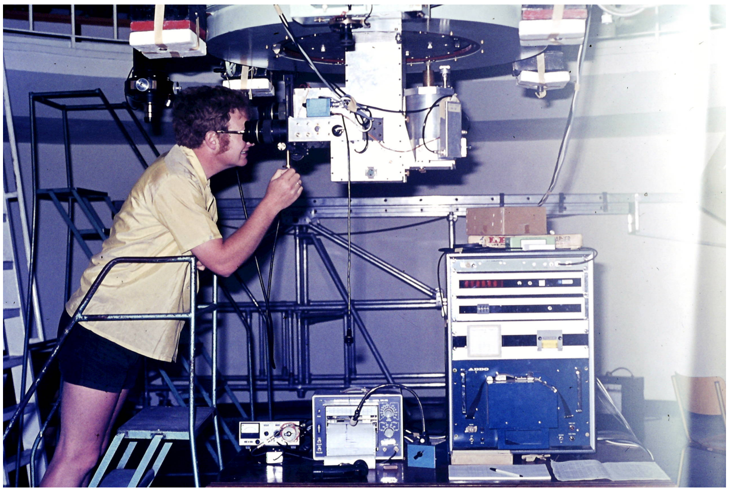


Fig 2: The Mk I IRP on the 40-inch telescope in the 1970s. On the table are the Lock-in amplifier, the Chart recorder and the data machine with printer and paper tape punch. At this time the filter and aperture had to be controlled from the back of the photometer.

The original data acquisition system was scrapped and all the interfaces were placed in one electronics box that was interfaced to a Nova computer in 1979, for which, as mentioned, L Balona wrote the first software, called MANFRED. This then permitted on-line reductions and better quality control of the data. The Quantex TV was attached to the photometer when on the 74-inch to ease the acquisition of faint objects. To do this, the rotating chopper was replaced by a stepwise oscillating one that had a dichroic mirror through which visible light could pass while the infrared was reflected to the cryostat. I designed a focal reducer using a Fresnel field lens, as suggested by R Bingham (RGO; see *MNASSA* **38**, 38, 1979). A problem with this design was that the grooves of the lens scattered too much moonlight when attempting lunar occultations.

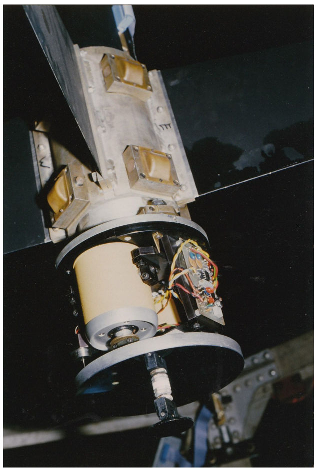


Fig 3: F/50 chopping secondary for 74-inch telescope.

In about 1980 I designed a F50 chopping secondary for better performance at the longer wavelengths. With this system, the telescope was made exceptionally “clean”, in the sense that the only warm elements within the telescope exit pupil were the spiders that supported the secondary mirrors. This used two Ling vibrators in push-pull mode to vibrate a gold-coated f/50 mirror of 7.2 inches diameter made in record time (for them) by Grubb-Parsons. Positional feedback from a linear transducer was used to control the drive circuitry to produce a stepwise action. A small flat mirror in the centre reflected empty sky off the primary. In order to collimate the secondary, the primary had to be correctly collimated in advance (The method I used for collimating when the regular f/18 secondary was in use was to place a mask with a central hole over the mirror and send a laser beam on-axis from the bottom of the telescope, adjusting the secondary tilt until the beam returned on itself. The primary tilt was then adjusted to make it appear central in the secondary when viewed from the nominal Cassegrain focal point). A new focusing mechanism and mount with spiders had to be designed and built for the f/50 system (Ellis/Sommeregger). See: D.T. Ellis, I.S. Glass, E.F. Sommeregger and J.D. Wilson, "A chopping secondary for the 74-inch" (*MNASSA*, **41**, 81–84, 1982).

The Mark I photometer was unsuited for use with f/50 because of the resulting limited field of view, the focal plane scale being then about 2.2 arcsec/mm. In 1985, when the chopping secondary was put into service, the Mk I cryostat was converted to work at f/50 with a new field lens and appropriately scaled apertures. A new photometer was built soon after, viz the Mk III. A sliding piece of glass with an elliptical gold-coated central spot was used to reflect the infrared beam into the cryostat. The graticule was carefully ruled in 6-arcsec squares using an old Repsold plate measuring machine with a sharp knife to scratch a Perspex base (originally converted by Luis Balona for ruling masks for a radial-velocity scanner). The off-centre part of the chopped image could be seen on the TV and used to guide the telescope. Centring of the object to be observed was done by shifting the gold spot out of the way and stopping the chopping secondary. A Fresnel lens directly below the graticule was used as the field lens of the focal reducer, necessary to obtain an adequate field for finding. A stop was necessary to eliminate sky light from outside the secondary of the telescope.

All controls were automated and it then became possible to operate the instrument from the warm room (See *MNASSA* **44**, 45, 1985).

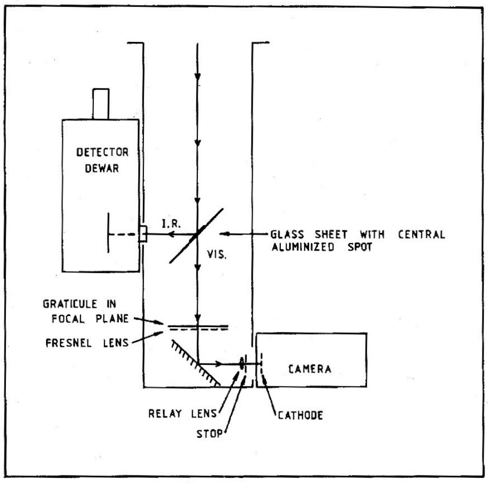


Fig 4: MkIII Infrared photometer, designed for f/50.

In August 1976 I learned from Kitt Peak infrared group and others that the best performance from the InSb detectors of the time was got by flashing them when cold with a bright light through the J filter. The photometers were accordingly modified to allow for this. The result was to increase the resistance of the detectors by factors of 100 or more, so decreasing the Johnson noise current. No satisfactory explanation of why this worked so well was available.

Because the background in the L band was very high, a switchable cold feedback resistor had to be introduced to avoid electronic saturation. This was controlled automatically from the filter-wheel encoder system. It also required automatic shifting of the Lock-in amplifier phase as the self-capacity of the very high resistance JHK feedback resistor shifted the signal phase by about 90°.

In addition, it was found desirable to operate the InSb detectors made by SBRC at about 63K, which meant that the liquid nitrogen cryogen had to be pumped to achieve a low pressure that caused the nitrogen to become a slurry. To do this required delicately controllable pumping systems with micrometer valves.

Filter-wheel spectrometer

In 1982 I built a circular variable filter spectrometer that covered 1-4 microns with 1% resolution. The parts were made to my design by a small outside company. An unexpected problem was that the solid nitrogen coolant lost thermal contact with the copper optical platform inside the Dewar. It was solved by cutting the inner Dewar can open and soldering a copper spiral to the base to increase the contact area of the solid nitrogen. The stainless steel inner can was then re-welded (a specialized task) by the NAC in Faure. This spectrometer was mostly used by PA Whitelock, who also wrote the software. See *MNASSA* **41**, 78, 1982.

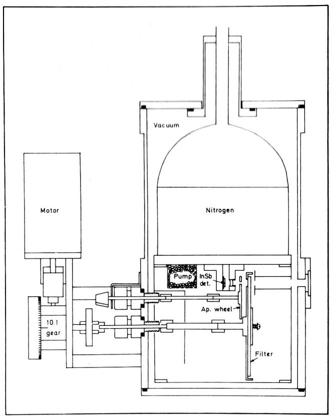


Fig 5: The filter-wheel spectrometer. This worked as a 400-band photometer and relied on a circular variable filter made by OCLI.

3-channel Dewar

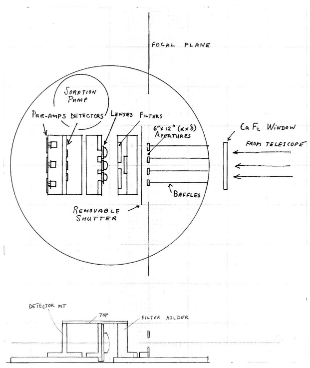


Fig 6: 3-channel JHK scanning cryostat layout. Originally the outer two detectors were at right angles to the incoming beams and fed by mirrors so as to avoid cutting the filters. However, it was found more practical to put them side by side and cut the filters, which was done without accident using a string saw at the UCT Geology Department.

Also in 1982 I built a 3-channel Dewar for area scanning. It was part of a joint project in which it was agreed that PA Whitelock would write the acquisition software and RM Catchpole the data reduction software (which turned out to be the hardest part). This used three aperture/filter/detector sets side by side, with associated electronics. In use, the telescope was started from a known position and automatically stopped as a scan began. This was used over three years, mostly for the Galactic Centre mapping referred to elsewhere. The detectors were used in DC mode without chopping and this sometimes led to drifting of the baseline as the atmospheric emission changed. Occasionally it was necessary to repeat scans because of these drifts.

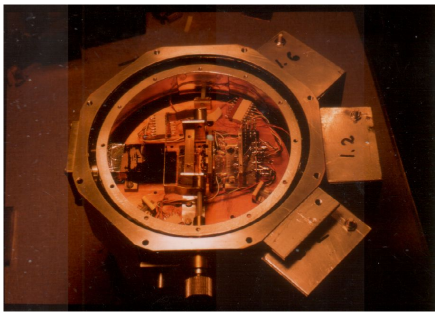


Fig 7: The 3-channel scanning cryostat. Sensitising ("flashing") the detectors was done with infrared LEDs placed nearby.

Ebert-Fastie Spectrometer

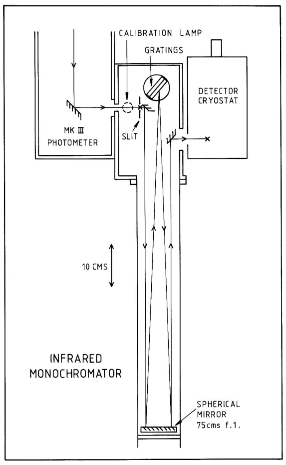


Fig 8: Ebert-Fastie J band spectrometer

In 1987 I built a high-resolution Ebert-Fastie spectrometer/scanner for the J band with a Ford photodiode detector and an integrating preamp. It worked at f/50 and was parfocal with and attached to the MkIII photometer body. It was used for observations of SN1987A. See *MNRAS*, **234**, 5p, 1988.

Modifications to the other telescopes

I proposed an encoder system for the 30-inch telescope that was at first connected to a simple 8-bit computer-on-a-board system that was designed and programmed as an MSc project by a UCT EE student (name forgotten, sorry!). This involved a 48000/rev incremental encoder on the RA axis and a special gear system on the Dec axis with a smaller incremental encoder.

A nodding encoder was afterwards run off the declination circle as on the 74-inch.

I was the first person to use the 40-inch at Sutherland, towards the end of 1972. After finishing their installation work, the technicians promptly disappeared back to Cape Town. When I went up to start observing, the telescope would not respond. By a freak of good luck, I found that a wire had come loose on one of the transformers in the Grubb Parsons drive. I made a temporary repair that lasted until the drive was replaced many years later.

The 40-inch installation at Sutherland had been planned by people who thought only in terms of photography, so there was a large darkroom but only two electrical outlets on the observing floor. I arranged for a small warm room to be built and many more plugs to be installed.

At my suggestion, the 40-inch also later on received a direct encoder on the RA axis and one geared 3:1 on the Dec. Unfortunately, the original Grubb Parsons 3:1 gearing that this arrangement made use of was of inadequate quality and led to erratic results that required a lot of effort to track down. It had been part of the telescope's Selsyn position-indicating system and eventually it was found much better to couple the encoder directly to the declination axis, inside the counterweight. I was partly involved in this.

Transputer Array Controllers

Through my frequent collaborations with Ian van Breda, then at RGO, I learned of a neat Transputer-based array controller system that he had been developing with NR Waltham and GM Newton. Unfortunately, this effort had been stopped by order of Alex Boksenberg when he became director of RGO in spite of its considerable promise. The development group was nevertheless keen to see their system put to use and were happy to collaborate with us. We arranged to purchase Transputer and clocking (later also A/D) boards from them and a major effort was put in by the SAAO electronics group, especially G Woodhouse and DB Carter, to design the other necessary boards such as A/D converters, filter and aperture controllers, power supplies, fibre-optic transceivers and to programme the units in Occam and assembler language. The control computers, by then PCs, were programmed in C.

Many practical problems had to be overcome, such as interleaving parts of the programme to save on dead time. The projects mentioned here are those in which I played a part but there were several others, mainly involving visible-region CCDs.

These Transputer controllers were ultimately used by quite a number of SAAO CCD cameras and array-based infrared detectors.

Acquisition TV

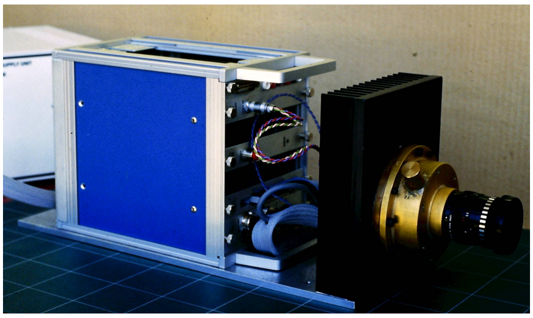


Fig 9: CCD Acquisition Camera. The brass vacuum chamber on the black heatsink contains a 4-stage thermoelectric cooler and the EE frame-transfer CCD. The blue part is the Transputer controller and behind it is the power supply.

As mentioned above, one of the first applications was to design an acquisition TV system based on an EEV frame-transfer chip and a 4-stage thermoelectric cooler. The latter had to be mounted using a low-melting point solder under careful thermostatic control. I based the cryostat on a published design from Lick Observatory and made its front end similar in size to that of the Quantex system for easy replacement. The image display was on a PC-AT with a colour screen. The standard IBM pixel painting routines were impossibly slow but I managed to disassemble them to find out how they worked to make the display very much faster. (Assembler-level technical information on the Tseng VGA display boards had not been available to us.) The problem was that the standard pixel-painting routine went through a large number of checks and board identification procedures each time it was called. This acquisition camera was used at first on the 74-inch and later copied for the 40-inch. Its programme was later improved by others to allow for autoguiding, image size measurement, seeing monitoring, cursors etc. The advent of Gnu C made efficient video programming much simpler.

Infrared Camera No 1 (IRCAM).

As array detectors began to become available for the infrared it was extremely frustrating that we could not import the best ones from the USA due to their strict export laws at the time. ESO suffered from the same problem but they developed a 32 x 32 pixel array camera (Used by me and others in our imaging of the "Quintuplet" – see elsewhere) using a rather unsatisfactory type of HgCdTe chip developed by Phillips Research Laboratory in Redhill, UK. This chip did not use the usual bump bonding technique to connect the HgCdTe and silicon layers together pixel by pixel but instead used a type of through-hole plating. The centre of each pixel had a hole and the pixels themselves were round. There was quite a lot of dead space between pixels and these factors made quantitative photometry of images virtually impossible. However, the worst problem was the non-uniform thresholds of the FET transistors in the silicon layer, so that no satisfactory compromise could be reached between dark current and sensitivity over all the 64 x 64 pixels. In 1990 in a spirit of hope I nevertheless designed a 1.2μm to 3.8μm camera based on a similar chip having 64 x 64 pixels and the necessary boards were constructed by the Electronics group.

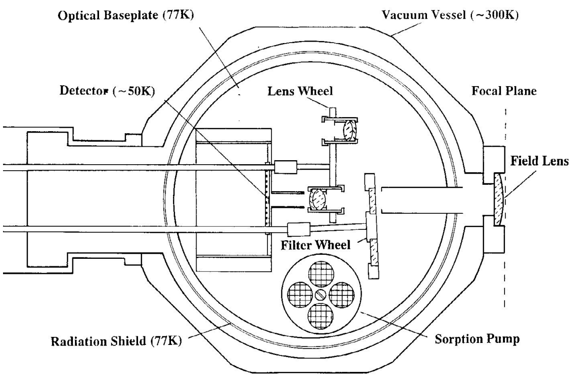


Fig 10: Layout of the IRCAM HgCdTe 64 x 64 pixel camera. The window was the field lens for the focal reducers.

This camera was designed for use on the 74-inch with autoguiding and TV acquisition. The detector was cooled to about 50K by solid (pumped-on) nitrogen. The thermal load on the solid nitrogen was kept low by means of a liquid nitrogen radiation shield.

I designed a focal reducer system using BaF_2/LiF achromatic doublets to give focal plane scales of 1" and 0.5" per pixel. The optical and expansion characteristics of the crystalline materials had to some extent to be guessed. Though I got this camera working, the detector chip was of such poor quality that nothing much more than pictorial data could be obtained. A K-band image of the Galactic Centre was published on the cover of one of the SAAO Annual Reports. A full description of this rather heartbreaking project and sample results are given in *MNASSA* **50**, 58, 1991.

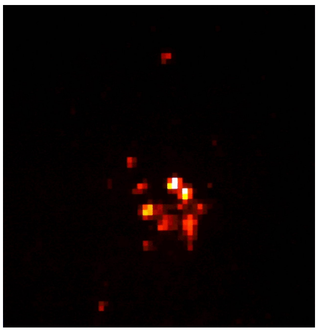


Fig 11: 3.8-micron image of the Galactic Centre taken with the IRCAM. This is qualitatively similar to the nbL image taken later with the InSb camera (below).

Infrared Camera No 2 (PANIC)

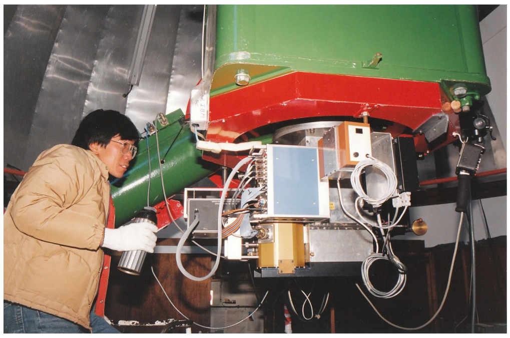


Fig 12: K Sekiguchi filling the PANIC camera.
The Styrofoam funnel can be seen to the right of his head. The blue box contained the 4-channel Transputer controller.

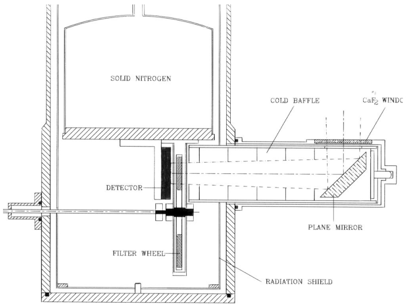


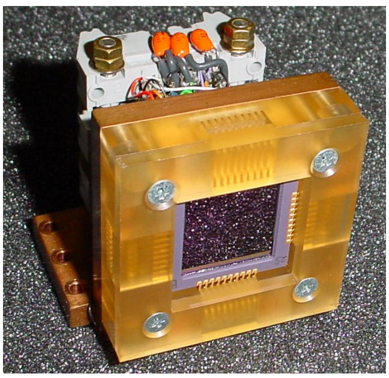
Fig 13: Partial section of the PANIC camera. At first, the cold baffle tube was about half the length.

The PANIC camera was based on a large format (effectively 1040 x 520 pixel) monolithic PtSi chip manufactured by Mitsubishi for use in thermal imaging cameras. Because it used purely silicon technology it was uniform in response and generally free of bad pixels. These detectors were made available to us through contacts in the University of Tokyo and M Ueno of Tokyo City University. It was the largest format array used in infrared astronomy. Its main drawbacks were very low quantum efficiency (1% at K) and poor charge transfer efficiency. In fact, the somewhat higher background at K than at J and H proved useful in overcoming charge leakage.

Flat fielding was accomplished using a biscuit tin covered with white paper and with lights inside. This was placed over the secondary mirror of the 30-inch telescope where the camera was used. It was intended to simulate the exit pupil of the telescope. In practice, it was found that flat fielding did not make any improvement to the photometry. Some idea of the variation of photometric response across the chip was obtained by exposing on an open cluster centred at many different locations. It was assumed in the end to be flat and probably was, within two or three percent.

A large number of dummy readouts were done before every exposure.

This camera was to prove extremely useful. It was employed over several years for the Jupiter/Shoemaker-Levy observations and for the search for long-period variables near the Galactic Centre *(qv)* and in Magellanic Cloud clusters.



The Mk I infrared photometer was modified to carry the PANIC and later the PICNIC cameras. The offset guider was altered to allow the use of a simple autoguider and later improved by installing better slides.

Fig 14: The PANIC PtSi chip in its mount.

See: A.G. Davis Philip et al (eds), *IAU Symposium 167*, Kluwer Academic Publishers, Dordrecht, p.109, 1995. See also Tanabe et al *(?)*

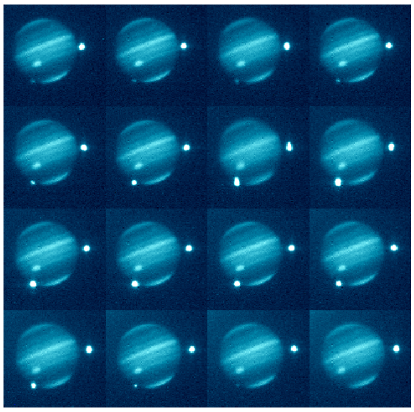


Fig 15: Collision of a piece of Comet Shoemaker-Levy with Jupiter, recorded with the PtSi camera. I wrote a special high-speed readout programme for this event, which received much TV and press coverage.
K Sekiguchi was the observer and G Woodhouse wrote a programme at the 11th hour to make the data presentable.

Infrared Camera No 3 (PICNIC)

This camera used a NICMOS 256 x 256 HgCdTe chip, made available by a friend, similar to that in the Hubble Space Telescope. The cutoff wavelength was just beyond the K (2.2μm) band. It made use of the cryostat and filter wheel from the PANIC camera. Initially a cold baffle system similar to that on the PANIC camera was used but to further reduce the background from outside the telescope pupil a miniature Offner relay with a cold stop was later introduced to match the exit pupil of the telescope.

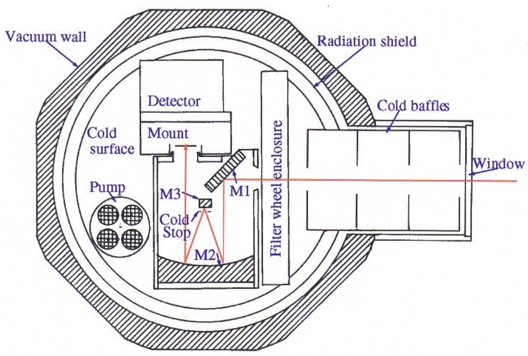


Fig 16: Infrared camera no 3 used the same Dewar as No 2 with a NICMOS HgCdTe 256 x 256 chip. The all-mirror Offner relay with cold stop was introduced later.

See MNASSA, **58**, 147, 1999 for more information.

This camera was used chiefly by Tom Lloyd Evans for identifying IRAS sources.

Infrared Camera No 4 (InSb)

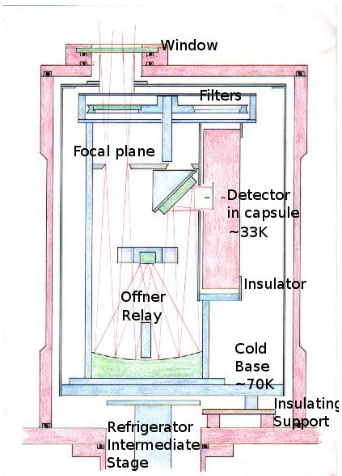


Fig 17: Outline of the InSb camera. For scale, the inside diameter of the vacuum container was 152 mms. The cold base was connected to the intermediate stage of the Helium closed-circuit refrigerator by thick copper braids and the Detector Capsule was connected to the cold tip by a thin copper braid. The insulators were made of fiberglass. In the final version, the refrigerator was decoupled mechanically from the base by a metal bellows. Two multi-pin electrical connectors were mounted in the base. There were several temperature-monitoring diodes.

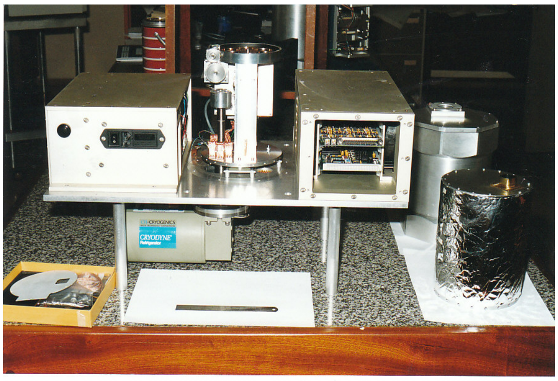


Fig 18: The InSb camera under construction, before the installation of the radiation shield and the outer vacuum container. An isolated sub-chassis was added later to control vibration from the refrigerator. The filter wheel is supported by the box containing the Offner relay. Behind in this view is the capsule containing the detector. The cold finger is seen to the left of centre with a sorption pump on top of it.

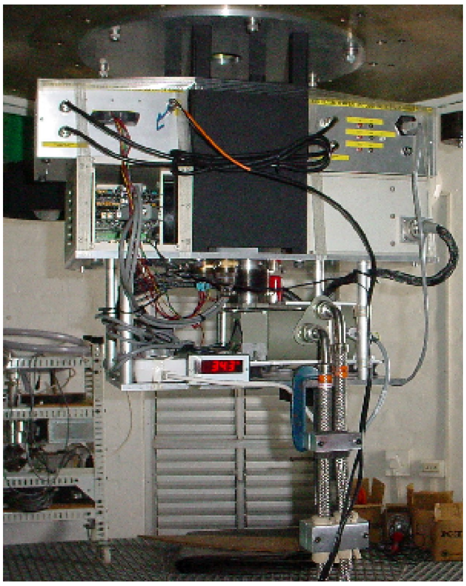


Fig: The InSb camera in its final form, mounted on the IRSF. The vacuum vessel was behind the black part and the helium refrigerator is seen below. The latter was mounted on a sub-chassis with vibration isolators. To left and right are the electronic modules. The convoluted stainless steel tubing leading downwards connects the refrigerator head to the helium compressor.

This camera was based on a quarter-functional Aladdin InSb chip with 512 x 512 pixels on loan from the National Observatory of Japan. It was an "Engineering Grade" array, which meant it was pretty terrible cosmetically, with a bright corner and an extended crack. It was operated at around 33K and was cooled by a two-stage closed-cycle helium refrigerator. The optical parts, mainly consisting of an Offner relay and a filter box, were kept at about 75K by the intermediate stage of the cooler. Filters for JHKL' and a narrow band at 3.6 (?) were used. There were 8 outputs and the electronics were purchased from UCSD. There were 4 data channels with 16-bit A-D converters on each of two boards. In principle, it should have been possible to co-add exposures on-board but we did not have adequate software for this feature to work, so all data had to be downloaded and summed in the controlling PC. This meant that the time spent in exposing was only about 50% of that possible. The UCSD software, written in Java, that placed the incoming data at the top of the control PC memory, remained somewhat mysterious to me.

To overcome the chip defects, a set of exposures was made at a number of positions around a small circle, the precise offsetting facility of the IRSF being controlled directly to accomplish this. The offsets were recorded on the FITS headers of each exposure. During the reduction, each image was automatically re-centred before re-combination to a single image. The programme for this was called “KISS” – Keep It Straight and Simple. Background variations between each of the circular exposures were taken care of by adjusting the overall levels of the images according to the modal pixel values. Flat fields were obtained by median averaging several fields nearby in time.

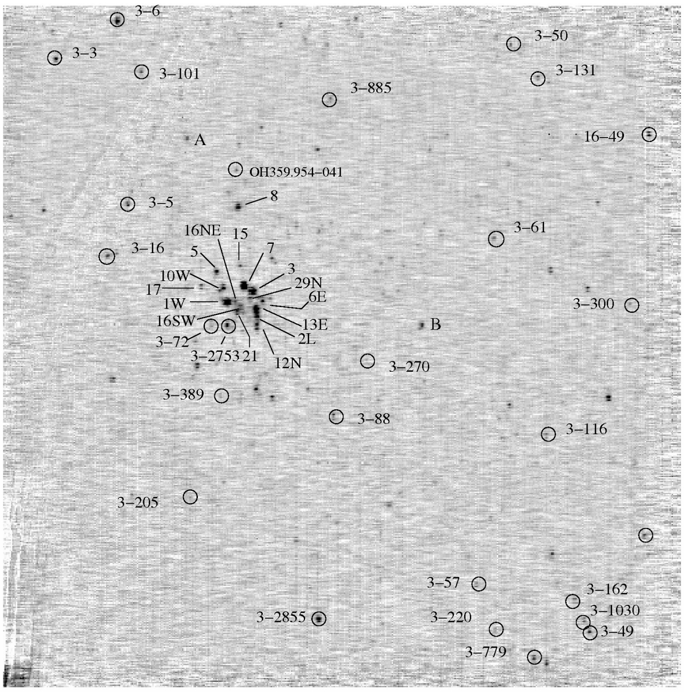


Fig: Narrow-band L image of the Galactic Centre with known sources, mainly late-type variables, labeled.

As will be seen from the accompanying nbL image of the Galactic Centre, all the images are extended vertically. I spent a great deal of time trying to trace the cause, including re-mounting the refrigerator in a vibration-free manner. I also sought an optical cause by building a very precise point source projector. In the end, after I had retired and returned the chip to Japan, I heard that the wiring diagram supplied with the chip had two of its vertical clock lines interchanged. With a good chip and properly functioning on-controller co-adding of images there is no doubt that this camera would have been a useful addition to the capabilities of the IRSF.

I was sorry to say goodbye to this camera, which cost me at least two years of effort. I abandoned work on this instrument after my last post-retirement contract with SAAO expired at the end of 2005.

For a fuller description, please see *MNASSA*, **63**, 28, 2004.

CCD Array camera for the “Unit” Spectrograph on the 74-inch

When the Boksenberg imaging photon counting detector (IPCS) that spent a couple of years at SAAO was about to be sent on to the AAO, I suggested that a somewhat similar device due to S Schectman and W Hiltner should be acquired. I spoke to Schectman during a visit to Cambridge MA in 1978 and he was quite willing to help.

I also made extensive inquiries around this time about a “Digicon”, a sort of electronographic image tube with a solid state detector at the output end, inside the vacuum. I don’t think these were ever wholly successful.

It appeared that for us to acquire a Boksenberg system would be very expensive.

In the end, when the “Unit Spectrograph” “Boksenberg Device” went to the AAO this detector was ultimately replaced by an intensified Reticon system, similar to the Schectman design, built at RGO, which endured for a number of years. Both these detectors were limited in sensitivity by the quantum efficiency of the available photocathodes and by the Wynne f/1.5 spectrograph camera that they were coupled to. When CCDs became available, the first idea was to install a cryogenic Schmidt camera. However, as this was likely to take some time (it came to fruition in 2015!) around 1990 I suggested a temporary arrangement using for the most part components that we had available

A long-format SITE CCD chip with high quantum efficiency came on the market. I showed how it could be adapted to one of the old f/2.2 cameras that had originally been supplied with the spectrograph, with a large improvement in efficiency. The idea was to build a flat pancake vessel connected with a 45-degree evacuated arm and a cold finger to a standard cryostat. The angle was necessary because the camera beam emerged that way. The camera had to be placed right against the cryostat window and there was no room for an O-ring seal, so “Glyptal” was used at first.

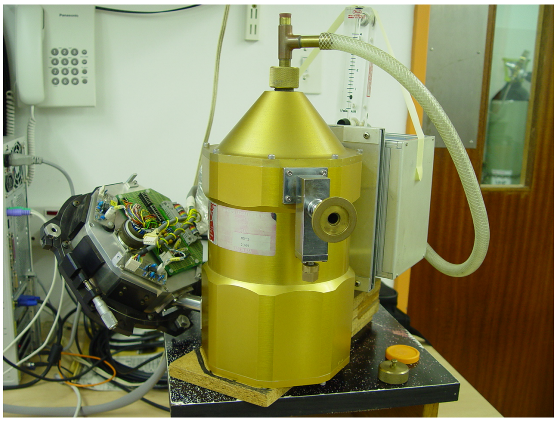


Fig: The spectrograph CCD in a pancake dewar attached to a liquid nitrogen storage vessel with a vacuum-insulated “cold finger”, as constructed. The cover of the pancake attachment was not in place when this photo was taken. It was probably being tested for nitrogen boil-off rate at the time.

I should say that I merely suggested the optical arrangement and Dewar concept and that the details were designed by others.

Proposal for a Large Telescope

In 1987 I wrote an article for *MNASSA* (**46**, 147, 1987) advocating that we should acquire a large telescope at Sutherland. My suggestion was to copy the ESO NTT 3.5m altazimuth.

This attracted considerable attention and the SAAO Board asked the Director for a more formal proposal.

However, nothing came of this until RS Stobie became director in 1992, with a mandate to produce a serious large telescope proposal. An elaborate document was prepared (*South African Large Telescope, A Proposal for Funding*, Stobie, R.S., Glass, I.S., Buckley, D.A.H., SAAO, 1993, ~100pp) with the aid of consulting engineers and a cost estimate was prepared, considering sites at Sutherland and the Gamsberg in Namibia. We visited ESO to talk about their NTT and also the Italian Galileo Telescope Project, as well as various potential contractors in Germany and Italy to gather information. It became obvious that the cost had been about 50% higher than ESO usually advertised, mainly because a lot of work had been done internally by them.

Though it was a most interesting experience, this project failed to fly.

Later, the opportunity arose to copy the Hobby-Eberly telescope in Texas, a revolutionary design that offered a large collecting area at a bargain price. This project was taken up enthusiastically in South Africa. The design of the telescope, which ultimately became the South African Large Telescope (SALT), was unfortunately more suited to visual and near-visual region spectroscopy than to infrared work beyond about 1.5μm because of the presence of large moving thermally radiating room-temperature structures in an ever-changing pupil. For this reason, I took little interest in it.

Glass-Boksenberg Report

This was a review of the technical needs of the SAAO undertaken at the request of the SAAO Board in 1980. Most of the effort fell on me and I solicited opinions from the rest of the scientific staff. It was finalized in June 1980.

Items mentioned were the provision of an intensified Reticon pulse counting detector for the spectrograph on the 1.9m, a chopping secondary for the 1.9m infrared, a possible spectrograph for the 1m, acquisition TV systems, improved photometers , CCD detectors, computer facilities.

Most of these things were already being implemented to some extent or were carried out later on.

Our remarks on the need for new personnel in various areas were censored and not included in the final approved report.

Administrative Responsibilities

I was early on put in charge of the 74-inch (1.9m) telescope, then the largest we had. The improvements that I instigated have already been described.

For quite some time I was in charge of the Workshops of the SAAO, starting with Electronics. The direct management was under Guy Woodhouse. At first, being rather an impatient person, I thought his way of doing things was very slow but he was in fact very professional and I soon came to appreciate the thoroughness of his methodic approach.

I had more difficulty in exercising control over the Instrument Workshop due to a lack of support from the then director, RS Stobie. In the early years this had functioned well with DT Ellis as chief of design and R Etherton as foreman of the workshop.

Ellis was an exceptionally able person unafraid of any projects whether large scale rough engineering or at the instrument making level. It was a great pity that he eventually became disillusioned and decided to leave. I cannot comment further.

Infrared Laboratory and other technical activities

In order to support the infrared efforts a considerable amount of laboratory developmental work and testing was necessary.

Even while a visitor from RGO in the early 1970s I was assigned the former McClean spectroscopic laboratory to work in. This was a very convenient location with a central stone bench suitable for optical work. To it I added a long electronics bench and also I also had a wooden mechanical workbench erected with a drill press and a vice. I always kept a toolbox with my own special tools. Most of the infrared instruments were assembled here.

The chopper mirrors had to be re-aluminised from time to time and, when replaced, re-aligned perpendicular to their rotation axes. In the early days, it was necessary to change the Fabry (field) lenses of the photometers to take account of the different f-ratios of the telescopes that we used. Robin Catchpole sometimes also helped with laboratory issues.

The biases for the InSb detectors had to be set very precisely to ensure that the electronic noise was minimized and for this a special "noise box" was constructed that measured the electronic noise in several low-frequency bands..

When the Technical Building was built *ca* 1987 we were assigned a laboratory that we moved to and fitted out in much the same way as the McClean laboratory.

Apart from the instruments that I have described, I constructed a moving chopped source for checking the alignment of the field lenses. I also built a black-body source with accurate temperature control for calibration purposes. I had a microscope and later on a mass-spectrometer leak detector for finding small leaks in the cryostats. Previously leak-testing had to be carried out at the National Accelerator Centre in Faure. I designed pump outfits for preparing cryostats in Sutherland and Cape Town as well as pump outfits for liquid nitrogen and liquid helium. We had a number of 25-litre storage vessels for liquid nitrogen, these being small enough to pour from by hand into the Thermos flasks that were used to fill the detector cryostats through Styrofoam funnels. In addition I had 10- and 25-l cryostats for storing and transporting liquid helium as well as an electronic dipstick and transfer tubes for the latter.

The Infrared Survey Facility (IRSF)

This project originated with a proposal by T Hasegawa in Japan entitled "Thorough Study of the Magellanic Clouds" that envisaged construction of a 1.4m Alt-Azimuth telescope and a simultaneous 3-colour (JHK) imager called SIRIUS (Simultaneous InfraRed Imager for Unbiased Survey). Prof Shuji Sato was in charge of this project from Nagoya University.

On 18 August 1998 an agreement was signed between SAAO and the University of Nagoya governing the construction of these instruments, their installation at Sutherland and the division of available telescope time.

I had the job of organizing the South African end of the programme, which involved the design of the building in conjunction with the engineering company Zietsman, Lloyd and Hiemstra, a dome from the USA and construction by a company from Worcester.

My files for the project, now in the SAAO Archives, must have several thousand entries. Most of the history of the project can be found in the book "10 Years of IRSF and the Future", Proceedings of a conference in Nagoya, 2010, eds Nagayama, T., Sato, S. and Wakamatsu, K.

The telescope was opened on time on 15 Nov 2000. The main parts were constructed by the Nishimura Telescope Co and the control system was built at Nagoya University. It achieves state-of-the-art pointing and tracking accuracy and is essentially automatic.

The name "Infrared Survey Facility" was used because Stobie feared that if the instrument was called a "telescope" it might have prejudiced the application for the larger SALT telescope!