Royal Greenwich Observatory Oct 1970 - Sept 75

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I arrived about the start of October 1970 at the Royal Greenwich Observatory, then in Herstmonceux Castle, a beautiful moated brick structure whose outer walls date from 1441 but whose inside is mostly 20th century.

As explained in my reminiscence about Caltech, I was encouraged to join RGO by Michael Penston, who was working at Santa Barbara Street, the headquarters of Mount Wilson. I was interviewed by Donald Lynden-Bell, then visiting Caltech. This was rather an un-nerving experience but he seems to have approved of me!

I worked for the RGO for five years, the central three of which were spent at the Royal Observatory, Cape/SAAO. At first I was a Senior Research Fellow. Later I became a Senior Scientific Officer and finally a Principal Scientific Officer. Shortly before I left I became an Established Civil Servant.

1970-71

I was assigned to work in a new part of the West Building, in a group [Bill Matthews, Dave Bonnick, Ralph Powell, Noel Curtis…] led by Dennis McMullan. McMullan was the inventor of the Scanning Electron Microscope and had been hired to develop electronographic image tubes (This was long before CCD detectors). Such tubes gave promise of much higher quantum efficiency than traditional photographic plates and the images they produced did not suffer from non-linearity. The McGee Spectracon had been used moderately successfully with the "Unit" spectrographs developed for the Isaac Newton Telescope and the Radcliffe 74-inch (South Africa). At first McMullan and his group produced improved versions of the Kron electronographic camera. They later worked on a magnetically focused system of a new design. Though these cameras worked, they were not very successful in astronomy, mainly due to quality control problems with the recording medium, a type of nuclear emulsion on a flexible base. The technology employed was formidable, involving deposition of state-of-the-art photocathodes, ultra-high vacua, Lenard windows and complex glass and fused silica tubes that involved fusing together more than a dozen different glasses.

Physically, I was located in the Instrument Development Department, close by, with Don Palmer, Arthur Milsom and others.

My basic plan was to develop an infrared photometer using as far as possible the already developed techniques that functioned well at Caltech, minimally modified to include a few necessary improvements. Making equipment that functions on a lab bench is only one part of building an astronomical instrument, a fact that many of the other UK groups then starting infrared work did not at first appreciate, coming fresh as they did from a physics background. It was necessary to build equipment that could operate reliably under field conditions, in an exposed telescope dome, sometimes at freezing temperatures. It had to be ready to use at a moment's notice, whenever the weather permitted. Further, it had to be supported with data acquisition, recording and

reduction software to make the actual observing process efficient and the annotation of the raw data trustworthy. It had to be possible to check the quality of the data in real time to watch out for sudden cloud or guiding errors. The task of complying with all these requirements benefited greatly from what I had learned at Caltech. Most of the other groups in the UK had not had this kind of experience and had to learn everything from scratch as we plainly saw when Mike Penston, David Allen and I visited the Infrared Flux Collector on Tenerife in 1974-5.

Soon after arriving I received a typical curt phone call from the director, Sir Richard Woolley. No introduction. "Come down here, would you". End of call. This was a summons to meet him in his office in his corner of the Castle. I knocked and went in. McMullan was with me. The first thing said was to McMullan. "Too bad they bust that bloody mirror". This referred to a large coudé camera mirror for the Isaac Newton Telescope that had slipped during cleaning and had broken in half. I was asked to determine how much money I would need to build up an infrared photometric outfit.

Accordingly, over the next few days I prepared an estimate which came to something like £10,000. I saw Sir Richard again and he said he could not approve it without agreement from higher up in the SRC (Science Research Council). He duly phoned their London office and was told to check out the project with Prof Jim Ring of Imperial College, then the Grand Panjandrum of UK infrared astronomy. I was instructed to go to London and make sure that Ring approved.

It soon emerged that Ring was afraid that this money would have to come from the overall UK infrared budget, which was then about £60,000. I so informed Sir Richard, who promptly phoned Ring and threatened him that this is what was likely to happen unless he approved spending the money from the RGO budget forthwith! Needless to say, he promptly complied.

The next problem was to get the photometer drawn up. I went to the head of the Drawing Office, only to be told that they would have no capacity for something like this for at least two years! I then suggested that I would make the drawings myself but amateur drawings were so alien to the workshops, who had no spare capacity anyway, that this was not going to be workable.

I talked to McMullan about this impasse and pointed out that there was no point in my being there if this was the situation. Somehow, it was arranged that I could have the services of David Chapman, a technician with a background at the University of Sussex, who had just been hired, to work directly with me. This solved the problem and we worked amicably together for the next few months. The many necessary drawings I made on squared paper. I also had a good deal of help from Bill Matthews, who worked for McMullan but had some time to spare. He built many of the electronic items that I needed and made cables etc. The instrument makers of the main workshop were of course highly unionized and it was impossible for me to use any of the machines myself. However, McMullan had a smaller workshop attached to his laboratory and I could do a certain amount there. His staff were generally very helpful.

My notebook for these first few months show that I spent a lot of time searching for suppliers of all sorts of components, making drawings and preparing purchase orders. Mr Everest of the purchasing department had a lot to do on my behalf.

I did not have to do much computer work. There was an ICL machine that I must have used from time to time. I think that I worked through Dorothy Hobden.

McMullan lived in London at the weekends and stayed near the RGO only on Monday to Thursday nights.

At a certain time there was an optical exhibition in Brighton. Several of us thought it would be a good idea to go there. Unfortunately McMullan was not around to ask on that day. So the whole lab decided to go anyway for the afternoon, only to meet him at the event. He was somewhat annoyed but had to accept the situation.

The technical challenges

Optical Components

The best detectors then used for the infrared JHKL bands (1.25 to 3.4 microns) depended on lead sulphide (PbS). The only ones that worked really well were photoconductors made by Santa Barbara Research Corp. This had been found out by experience as the astronomical use of infrared detectors involved much lower light levels than the more typical laboratory spectroscopy and military applications They were fortunately supplied free of charge as samples. Their (somewhat unpredictable) resistance at liquid nitrogen temperature was the critical factor – it had to be as high as possible - and I was fortunate enough to receive two fairly good ones. These detectors were 0.5mm x 0.5mm square and consisted of a 0.5mm wide chemically-deposited strip between two gold pads on a printed circuit base. To connect to them one had to use indium-based solder as otherwise the gold would dissolve! They were held in place with double-sided sticky tape.

By far the best filters were made in California by OCLI and I had to motivate specially to participate in a couple of large batch orders with some US institutions. This was cheaper than ordering them individually and also ensured that most institutions had precisely similar filters. They were multi-layer interference filters that depended on bulk material properties to block transmission outside the desired bands and on interference properties of the layers to give more-or-less square actual passbands. Their characteristics changed slightly on cooling to liquid nitrogen temperature. Low temperatures were necessary as they were like black-body emitters outside their passbands.

In the focal plane of the telescope was an aperture wheel that limited the part of the sky to be measured. It was necessary to use the smallest aperture that would admit the whole image (which depended on seeing conditions). The larger the aperture, the greater was the unwanted background (which increased the background noise).

In front of the detector was mounted a CaF_2 field or Fabry lens (Ordinary glasses do not transmit beyond about 2.5μm). This had two purposes: to limit the entrance pupil to

match the F-ratio of the telescope and to make the sensitivity uniform across the measuring aperture. Several field lenses were made to accommodate telescopes ranging from F/10 to F/18. These were necessarily quite tiny. According to Dick Jennings (University College, London) these were made for BDH Chemicals by somebody working in a shed at the bottom of his garden – but he may have been pulling my leg. The refractive index of the material varied somewhat across the wavelength range that was being measured, so that a compromise was necessary. However, a uniformity approaching 2% as a stellar image moved across the aperture was achievable. I made a movable chopped light source to help set up the focus of these lenses. Of course, by centring a star carefully one could do far better than the 2%.

The filter wheel and lens mounts had to be designed so that they did not crush these components by contracting when cooled down to 77K. Cryogenic data on materials was sometimes impossible to find and intelligent estimates were required.

Light was admitted by a `'window" of a suitable material. At first I used Al_2O_3 (sapphire), purchased already bonded into a steel holder, but later I changed over to CaF_2, which was more efficient.

The wiring was done with Teflon-coated Constantan, but later I switched to very thin copper. The vacuum feed-thrus for the electronics were often unreliable, giving rise to leaks. Such leaks were usually very slow ones and required a mass spectrometer leak detector to find.

The throughput of the system was the product of the reflectivity of three aluminized surfaces (telescope and chopper), the transmissions of 4 air/CaF_2 surfaces and that of the in-band part of the relevant filter.

Detector Cryostats

I visited the University College, London, IR group (Dick Jennings, David Aitken, Babs Jones) who I had met a couple of years before and got along well with while flying high-altitude balloons from Palestine, Texas. They had developed a very reliable type of cryostat whose inner was of copper and stainless steel, vacuum-brazed together. This design was far better than any other kind, such as the early cryostats produced by Infrared Laboratories Inc, because conventional brazing usually led to corrosion. I designed a cryostat with octagonal aluminium sides and an inner of stainless steel and copper. This worked without problems for over 30 years! Most cryostats then used radiation shields cooled by the evolving cryogen (by heat sinking them halfway up the filling tube) but I chose to use multiple layers of crinkled-up aluminized Melinex (Mylar) that turned out very satisfactorily. Another technical problem was how to turn the filter and aperture wheels from outside without losing vacuum integrity if conventional rotary seals were used. Becklin had a very elaborate solution using cranks inside flexible bellows but I tried off-the-shelf simple rotary seals from Edwards. It turned out that the zeolite-based cryopump in the cryostat was able to absorb any leakage that occurred and the vacuum was maintainable for many weeks if not months. The nitrogen "hold time" of the cryostat was about 36 hours, which was ideal for use with daily fillings. This I had not been able to predict, so it was a relief that it turned out so well.

The detector was a photoconductor that changed its resistance when radiation fell on it. To see the changes in resistance, a current had to be passed through it and the voltage across it was measured. A battery was used to feed the detector through a low-noise high ohms wirewound resistor. The signals were very feeble and very low frequency – usually 12.5 Hz. The preamplifiers had to deal with this low frequency and therefore used very low-noise transistors. The signals were fed first into a not very satisfactory phase-sensitive detector that had been acquired by RGO for an unsuccessful experiment conducted some time before by Alex Boksenberg, (Later, towards the end of 1972, I changed to a much better Brookdeal Lock-in amplifier). I had to have a custom-built counter-timer and data serialiser made by a company called Watesta (who had won a competitive bid). The idea was to both print the results and punch them on tape, though the latter system was not implemented immediately. The output was also recorded on a continuous paper chart recorder that gave an instant view of the signal strength etc, very useful for setting up and centring stars and checking for clouds.

Before cooling the cryostat the vacuum insulating space had to be pumped on to empty the zeolite sorption pump. This could be achieved adequately with a good mechanical pump and a liquid nitrogen trap (to avoid ingress of oil vapour). Liquid nitrogen was introduced through a styrofoam funnel made from an old piece of packing material and a stainless steel tube. It usually took about 3 litres to cool the vessel and fill it. Liquid nitrogen could be bought from the University of Sussex in Brighton. It was kept in 25-litre Dewars made by Union Carbide. These were light enough to lift up and pour from, usually into ordinary Thermos flasks. The procedure I used would never meet the requirements of present-day safety inspectors. This was long before the days of cooled CCD detectors, but McMullan usually kept a supply of LN2 for cryopumping his image tubes.

To cover the longer 5, 10 and 20 micron bands, I bought a ready-made cryostat and doped-germanium bolometer system from Infrared Laboratories Inc, a company owned by the infrared astronomer Frank Low, This had to be cooled with supercooled liquid helium. Liquid helium cannot simply be poured as it vapourises instantly due to its low latent heat. Instead, it has to be transferred using a vacuum-jacketed siphon. I had to set up a complete handling system with storage vessel, controllable vacuum pumping and electronic dipstick. The handling processes were self taught and required some experience to perfect.

The bolometer cryostat did not need a sorption pump as the helium froze out any residual gases. The only bad thing was that it had to be pumped before each occasion on which it was used.

The liquid He storage vessel I bought was made by a company called Kelvin Vessels. It held 10 litres of helium. Surrounding this was an outer contained of liquid nitrogen. The latter boiled off in about 3 days, after which the helium evaporated very rapidly. The outlet of the helium part had a simple valve to make sure that air could not enter, but altitude changes still presented problems.
I visited the factory where this vessel was made. It was in an industrial part of London and was amazingly primitive – almost Dickensian. I often wondered how they had acquired the necessary technology.

In using the long-wavelength detector, the first thing was to pump the helium transfer line and then the vacuum space. Then the interior was pre-cooled with liquid nitrogen (cost similar to beer!) for about an hour. This was then decanted and liquid helium (cost similar to whisky) was transferred. Judging the moment when it was full by the vapour plume was an art. Then the vacuum hose was connected up and the liquid was pumped on gently until the pressure indicated that it was below the lambda-point (transition to superfluid state at 2.2K). Following that, it was pumped on at full blast to reduce the temperature to about 1.2K, the operating temperature of the bolometer. I built up a special pump outfit with the necessary pressure gauges and control valves. A long reinforced hose connected it to the helium pump fitting on the cryostat.

I replaced the crude reflective field optics originally supplied by Infrared Labs with KBr lenses that transmitted out past 20 microns. These are deliquescent and had to be handled carefully. Like the Calcium fluoride lenses, they were plano-convex and only a few mms in diameter and had to be specially made. The bolometer was also 0.5mm square.

Both cryostats had to be mounted on adjustable mounts since the small sizes of the detectors made it impossible to align the "antenna pattern" of the system precisely enough ahead of time.

The photometer

This was provided with two chopping systems. One was of the sectored-mirror type and the other was a stepwise oscillating mirror similar to that I had developed at Caltech.

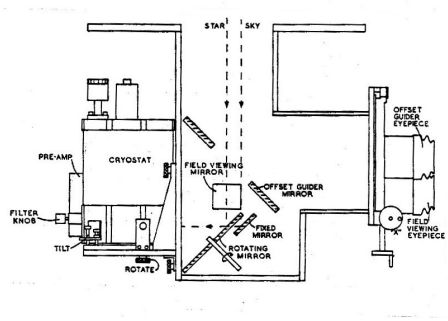

Fig: The Mk I infrared photometer.

An offset guider was included. This was highly necessary for interchanging the star and sky apertures by moving the telescope in declination (a process called nodding) after every two 10-sec integrations. In addition, the central field could be viewed for object acquisition using a retractable mirror and periscopic system. The eyepieces were "awful Erfles" designed for tank periscopes or something of that kind and were not really suitable for the relatively large F-ratios of Cassegrain telescopes.

The adaptor plate could be changed to match different telescopes. The need to keep the cryostats upright meant that the focal plane was usually quite far below the design Cassegrain focus of the telescope.

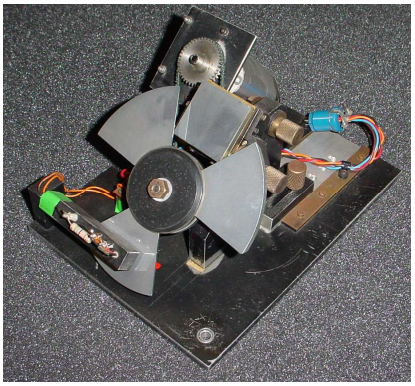

Fig: The rotary chopper unit. The sectored mirror had to be mounted precisely perpendicular to the rotation axis and the rear mirror cold be adjusted to null out the telescope background.

It was not always possible to use good high-vacuum techniques but the sorption pump took care of many

sins. For example, I used GE varnish to tie down the wiring and double-sided sticky tape to hold the detector in place. Black anodizing is not black in the infrared and so I used ordinary tin-can black matt spray, which worked well but sometimes tended to flake. In later cryostats I used a two-part automotive etching primer that stuck well, underneath the matt black.

On-Telescope testing

As mentioned, getting a piece of astronomical equipment ready in a laboratory is one thing but getting it into a useful state for observing with a telescope is another.

The trials that I conducted at Herstmonceux were mainly on the 36-inch Yapp telescope. This is one of the "Equatorial Group" of copper domes connected together with cobbled walkways, impossible to wheel equipment over, and interspersed with ponds, ideal for falling into in the dark – which I was told had happened at least twice. Deep hahas around the periphery of the group added to the potential excitement. This complex was raved over by architectural critics but frequently cursed by astronomers.

The weather at Herstmonceux is not at all suited to photometric work either in the visible or the infrared but in June 1971 I had a sufficient number of clearish nights to test out the equipment at 10μm and solve some of the more obvious teething problems. Getting into a truly productive observing mode had to await my move to the Cape.

Recollections of Life at the RGO and Herstmonceux in 1970-71

The first item on my agenda had been to find a place to live. I ended up sharing a Council house with Alan Penny in Dacre Rd, Herstmonceux. This was in pretty grotty condition, with ancient furniture and hot water that only worked when the Aga stove was lit. I was keen to put in storage heaters to make the place more comfortable, even if I was only going to be there for a short time, but Alan was unwilling to share the expense. The main advantage was that the rent was negligible. It was one of a number of houses that the RGO was assigned when they moved down to Herstmonceux after WW2.

My boxes from California duly arrived in London and, to my disgust, cost as much to clear and ship to RGO as they had cost from Long Beach docks in Los Angeles to London.

I found some of the work habits rather strange after the USA. For one thing, the Trade Unions were taken very seriously and there were all kinds of complicated allowances and time-off arrangements for those who went observing. Every 4 hours of nighttime work was considered to be a "duty" and daytime could be taken off to the same amount. I think we were paid a small sum for each duty also. In the USA you just did your job and that was that. A book called the "Conditions of Employment Memoranda" was known by heart by many people.

The time taken to have material delivered was often extraordinary. I remember, in particular, that vacuum equipment sometimes took a few months to arrive – some businesses were so inefficient they would never have lasted in the USA. I had to make a kind of PERT chart to make sure that everything came together on time.

The traditional tea breaks were incredibly long, particularly for those who were working away from the workshops and had to be fetched and delivered back each time. I also found it very strange that the Isaac Newton Telescope was stood down completely during the short nights in June.

However, once the initial cultural shock had worn off, I began to enjoy and even in recollection cherish some of the more "traditional" things around me. The dining room in the Castle, with its "High Table" and Mrs Marples' gooseberry pie, for example.

I used the library a lot. Louise Webster told me that she liked to come in the door and go immediately into the stacks, the aim being to see how long it took Joan Perry to succumb to her curiosity and come downstairs from her office on the balcony to see who had just come in!

The grounds with their walled garden, lawns and woods were delightful to walk in after lunch. There was a folly and a pond with waterlilies at the end of the property. I recollect we were playing once with a Frisbee which ended up in a clump of nettles, David Branch, an American then working at RGO, did not know about nettles and rushed in to fetch the Frisbee, getting horribly stung.

Michael Feast was visiting RGO from Radcliffe around the beginning of my time there and I got to know him a bit. He had been interested in infrared observations of RCB stars with Lee.

Every so often many of us would go up to London to attend the Royal Astronomical Society. As a SSO, I was allowed to travel first class by train, but like most of the others I never did this. The last train left London at 23h58, so we had to be sure not to miss it.

We sometimes got groups together to go to theatrical events. I recollect going to Chichester to see Cedric Hardwick in Caesar and Cleopatra by GB Shaw and also to Noah's Fludde by Britten at the De La Warr pavilion in Bexhill.

Herstmonceux village was quite traditional. One custom in that part of Sussex is the celebration around Guy Fawkes day (5 November) with parades by the bonfire societies culminating in fireworks and huge bonfires. These are supposedly in remembrance of protestant martyrs in the 16th and 17th centuries and tend to get pretty wild at times, especially in the nearby town of Lewes. I was able to watch one of these parades in Herstmonceux. Bernadette Devlin, the Northern Irish firebrand, was said to have been burned in effigy one year.

There was a very rural pub, the "Donkey", [officially "The Welcome Stranger" or "The Donkey" or "The Kicking Donkey" on account of a painting over the fireplace depicting the said animal in action] down the side road where RGO was situated. Being out of sight, it tended not to worry too much about licensing hours. One of their items on tap was Merrydown cider which, though delightful to drink, caused a massive hangover the next day. There were various other hostelries that we went to, in Herstmonceux itself, in Windmill Hill and in Wartling.

The decimalization of the pound occurred in early 1971 and was resented by some of the locals, who called it “foreign money”.

There were some traditional village shops. I once asked the local grocer if he stocked peppercorns. “How many do you need?” I replied “about enough to fill a peppergrinder a couple of times”. “In that case you will need about a pennyworth”. He duly weighed out about an ounce and put them in a bag for me.
The local butcher was an Irishman from Wexford who was always pleasant to chat to. It surprised me how he had settled down happily in such a traditional village.

There was a vegetable garden where you could go with the gardener and specify which growing cabbage you would like to buy.

The local church, near Herstmonceux Castle, had Lord Hailsham, a well-known Conservative cabinet member, as a parishioner. An old lady who was cleaning the church when we looked inside told us how you could hear those lions roar when he read the story of Daniel in the lion’s den.

The traditional product of Herstmonceux was the trug basket, made a bit like a clinker-built boat. I believe the small factory still exists. They would have made lovely presents but were extremely expensive.

The local fire brigade was a voluntary one, called together when necessary by a siren. I saw them having to push the fire engine to get it started on one occasion.

The area was thoroughly Conservative politically. Mike Penston related that a local on seeing a Liberal Party bumper sticker on his car remarked “Oh, you must be from the Observatory”.

The Sundial restaurant was a fancy and expensive one. I took my friend Jim Elliot there one lunchtime. We were amused by the conversation at a nearby table where a lady was sounding off about her nephew, “a beastly socialist“.

I bought a second-hand MGB-GT while living at Herstmonceux from a rather dubious dealer somewhere towards the northern end of Sussex. Though I thought I knew MGs by then, this was rather a lemon and had been driven hard in rough places. The front and rear windows leaked and soon the head gasket also. It sprayed coolant onto the distributor and I had to have a new head gasket put in. After a few months I tried to sell it via a dealer in Crawley, but he was very chary and offered very little for it. However, Bernard Rodemark in Windmill Hill eventually bought it one day when I went to him for petrol and I wasted no time in cashing his cheque! The bank sent a representative to the Castle once each week for our convenience and my sale was on that day!

Science

I did not get much science done during this period as I was preoccupied with building equipment.

Mike Penston was to join RGO in October 1971. David Allen was in Cambridge for the summer of 1972 and joined RGO at the start of October that year. Mike had experience of infrared at the Hale Observatories in California and David had been with the University of Minnesota group and I think about a year with Neugebauer. We thus had the makings of an infrared group. Louise Webster (later Turtle) was also quite interested in infrared possibilities.

David was concerned early-type stars with emission lines and was keen to look at the bright ones in the southern hemisphere.

Mike was interested in RW Aurigae stars and in the nuclei of active galaxies. At Mount Wilson he had been observing Seyfert galaxy nuclei but infrared technology was then not very sensitive and the results he got on variability were not of high statistical significance. This was an area that I was to work a lot on later after the equipment was improved.

Occultation using the 28-inch refractor at Herstmonceux

With Leslie Morrison of the Nautical Almanac Office I observed a lunar occultation of 31 Leo (K4 III) on the 28-inch refractor on 1971 May 3, possibly the last serious observation before it was sent back to Greenwich. This was done in unfiltered visible light and the output from the photomultiplier was sent to a high-speed chart recorder that we dug up somewhere. The surface brightness agreed well with the Barnes-Evans relation (*MN* **175**, 57P, 1976). A curious aspect of this was that we had to keep it low-profile as Sir Richard did not approve of occultation work, apparently because of the criticisms of David Evans's observations of the diameter of Antares by Thomas Gold.

One of the most exciting and interesting discoveries made around that time at RGO was that by Louise Webster and Paul Murdin of a massive invisible object in the Cyg X-1 system from radial velocity observations of the B0Ib supergiant HD226868. This was the first black hole to be identified in our galaxy.

Boksenberg with his team (the "Flying Circus") from University College London occasionally observed with the Isaac Newton 98-inch telescope (INT). I went to watch the activities on a couple of occasions. Mike Penston provided most of the astronomical input. Boksenberg's detector was uniquely efficient for the time. It used many stages of image intensification to feed a television camera. Photon counting was achieved by event-centring logic and a digital memory.

There was a model of Isaac Newton's first reflecting telescope in a glass case just next to the visitors' gallery in the INT dome. On the side not visible to them was a sign "In case of emergency, break glass".

Assignment to South Africa (Oct 1971- Sept 1974)

In order to work in a good climate I asked to be sent to the Cape South, with which RGO had close connections. In due course Sir Richard issued me with a sort of "order" that I

had to have to be able to buy tickets etc. He was already Director-designate of the forthcoming SAAO and was obviously looking forward to going there. He had been interviewed by the Guardian and was hoping they would ask him why he was going to work for the Apartheid state. His answer was going to be "I've worked in Franco's Spain, in Nasser's Egypt and in Saud's Saudi Arabia and if the Devil gives me a telescope I'll work for him in Hell"! To his great disappointment, the question was not asked.

I duly prepared myself, packed the equipment and ordered a new MGB for export. The car was late in being delivered and had to be sent out later by freighter.

I arrived in Cape Town around 1 October 1971. The Royal Observatory, Cape of Good Hope, was still in existence and was under the direction of George Harding as Officer-in-Charge. Only on 1 January 1972 did the SAAO come into being. Sir Richard then took over.

Though my mother was South African and I had spent six months in Natal as a child, I had little real idea of what to expect. There were two nations living in one country, one first world and the other third world and the apartheid system was designed to keep them as separate as possible.

I stayed for the first month at the Glendower hotel in Rosebank, an old, mainly residential, hotel that is now a student residence of UCT (University of Cape Town). It offered typical old-fashioned South African hotel fare, such as curry and rice and delights such as "monkey-gland steak". I eventually found a flat in College Road, Rondebosch that I had to furnish. Until my car arrived at the end of December I took the train to Observatory. The service was safe and frequent in those days and even operated through the night, which was useful when observing. Like many other things, the trains and stations were segregated, with whites at one end and blacks at the other. I remember fighting my way to the Observatory from the station against the violent Southeasters.

Many of the senior staff at the Cape were seconded from RGO. Brian Carter, Arthur Cordwell, Ray Foord, Geoff Harvey, Brian Hucklesby, Arthur Shortland. Later on, Bill Martin, Neil Harding, Pete Read and Emrys Davies were there at various times. I was, strictly speaking, a visitor. The head of admin was Peter Cook from SRC head office. We were given various allowances which made us considerably better off than we would have been in England. The UK group were a welcoming lot and I attended many outings with them. On the local staff were Alan Cousins, Joe Churms, Drummond Laing and several others, many near retirement age. Even more than at Herstmonceux, the UK staff referred constantly to the SRC Conditions of Employment Memoranda and enjoyed trying to trip up the Treasurer, Oscar Fiammingo, on obscure points concerning allowances. However, he rarely lost an argument. He had joined the Navy in Alexandria in WW2 and was the possessor of Egyptian, Greek, Italian, British and South African passports! Electronics was manned by Ray Foord and Willie Pearson, the latter a clever fault-finder who was particularly adept at the Teletype machines that were used as computer terminals in the early days. A good fraction of their time was taken up with a time service installation for Sutherland.

Communication with the UK was mostly by airmail, which then took about 4 days. It now takes about 2 weeks! We could also use Telex for urgent messages.

Segregation was practiced at various levels at the Observatory. Not just the straightforward black vs white. Among the black staff were Xhosas, Zulus and Tswanas and they did not mess together. The "coloured" staff also kept themselves separate. The white instrument workshop staff had their own tearoom. The "top people", Harding, Cousins, Stimpson and the Secretary (head of admin) had their morning tea in one room and the remainder of the white staff in another! Alan Penny and I one day invaded the top people group, with the result that they decided to join the rest of us thereafter. Afternoon tea was even more fragmented. I used to have mine with Rona Banfield in the Photometry Department. She was a delightful person who acted as a kind of mother to all the lonely bachelors.

There was no librarian when I first arrived. The incoming journals were first sent to George Harding as Officer in Charge, then I think to some others, before they appeared for the rest of us to see. I protested in a letter to Harding in December 1971 and asked that all newly arrived journals should be put on display. I also asked that ApJ should be got by airmail as otherwise we were going to be at least a month behind. Another nuisance was that Joe Churms had borrowed literally hundreds of books from the library, holding on to them for years. Eventually – probably a few years later - I got the other research staff to sign a round robin with me, protesting about this, and the point was finally conceded.

Harding was very much an administrator with the construction of the Sutherland Observatory at the top of his stack. I think he regarded all other activities of the Observatory as unnecessary distractions.

The black staff carried out all the menial tasks. They were usually, though not always, called by their first names. There were several gardeners, a messenger cum "tea boy", two assistants who cleaned up the machines and swept up the swarf in the workshop and a driver. They always took off their overalls and dressed neatly like businessmen when leaving work. Arthur Rose, the carpenter, was "coloured" and enjoyed more respect than most.

Quite a few of the astronomical staff, seconded or local, lived in houses on the grounds and the SRC owned or rented three extra houses in the nearby suburb of Pinelands.

Fig: Infrared laboratory in Cape Town in the McClean telescope building, around 1980. Now the Astronomical museum

I needed a lab in which to get my equipment set up and I was assigned an old workshop/store room near the Liesbeek river for a few months until the McClean Laboratory could be made ready. I had to share the latter with the ladies who developed the glass plates

every morning and prepared the photographic chemicals. However, it had a convenient central stone bench, suitable for optical experiments. I had extra plugs put in and also had a large side bench made where I installed a vice and a drill press. Arthur Rose, the carpenter mentioned, and an electrician called Rigby who, however, were occupied for several months in converting part of the Main Building into a flat for Woolley.

Sutherland was not going to be ready until the following year and my first observing at Radcliffe was not until June. Accordingly I negotiated with Cousins for a week each month on the 18-inch reflector that he normally used.

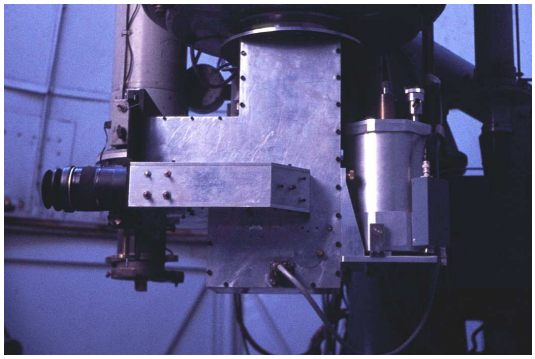

Fig: The Mk I photometer on the 18-inch telescope in Cape Town about 1971.

Special adaptor plates had to be constructed in the workshop but preparations for Sutherland had priority. I was assigned Mr Brown, the least productive person, who was on the verge of retirement and had to be jollied along constantly to get any work out of. Eventually it was ready. The focus of the photometer was about 53 cm below the mounting plate, much further out than Cousins's photometers. We had to make special studs to move the secondary mirror forward 25mm or so and eventually got the telescope to focus, using the beacon on Devil's Peak as a target. There was a lot of cabling to do. The lock-in amplifier and chart recorder were kept on the rotating observing platform adapted from the original Repsold observing chair. The data machine was in the alcove. The paper tape recorder was not operational at first, so before each observation a number had to be written on the printer tape. In addition, a special coding form was used to record the object name, filter, aperture, time and other details. It was very difficult to work without an assistant and worse, all the data had to be put on punched cards for reduction. This was mostly done at the UCT computer centre, which had a Univac. Once the paper tape machine was running I could have the tapes converted to punched cards, which were more efficient and easier to edit. There was usually a turnaround time of several hours for running programmes and this meant that several trips were often necessary. The SAAO had an English Electric card punching machine that did not, however, print along the edge. I had a long battle to get the Observatory to acquire a more modern IBM punch only to find when I succeeded that I could get very little time on it because it was so popular. Sometime in this period the SAAO obtained a Nova minicomputer with a limited memory but I did not feel the effort to convert my programmes to run on it was worthwhile as I would not be there for very long.

Peter Warren, then at Radcliffe but affiliated with the Cape, kindly got the Neugebauer reduction programme to run on the CSIR IBM 360 computer in Pretoria.

After one or two observing runs in Cape Town I felt that the system was sufficiently well understood to start taking real data. This must have been at about the beginning of January 1972 as the HKL filters from the joint order did not arrive until then.

The first aim was to set up a system of southern JHKL standard stars linked to HL Johnson's standards in the northern hemisphere. With Cousins's advice, I made a computerized list of suitable bright stars with the sidereal times at which they passed 1.3 airmasses, so as to keep extinction uncertainties to a minimum. I simply copied the extinction coefficients that Neugebauer had used in California and these proved reasonably adequate. The new southern standards were observed several times each and the measurements were tied into whatever Johnson stars were available in the southern sky. As they were few in number, some RA-dependent errors were introduced in this way (*MNASSA* **33**, 53, 1974; errata **33**, 71, 1974). Several years later, this work was refined by Brian Carter on the 0.75m telescope in Sutherland as an MSc project that I was supervisor of.

As very few observations had been made in the Southern hemisphere in the IR by that time, one of the things that occurred to me to do was to make observations of what might be considered unusual or unique Southern objects. The sensitivity using the 18-inch telescope was very limited. About the first object I tried was R136, the central object of the 30 Doradus nebula. I made several observations with varying apertures and also looked at some of the bright stars nearby. Although there was no "infrared excess", I wrote up a short paper that was published in *Nature Phys Sci,* **237**, 7, 1972.

The weather was often very good in Cape Town except during the winter, though the seeing could be appalling when the southeaster was blowing. Occasionally it was impossible to do photometry even through the largest apertures. On the other hand, when the wind blew from the NW, the smoke from the steam trains in the Salt River marshalling yards made photometry impossible (Today, with the development of squatter camps on the Cape Flats and the disappearance of steam trains, the situation is reversed). Calm conditions usually brought a plague of mosquitoes from the vleis (swamps) nearby. Light pollution was a problem even then, though not when observing bright stars.

Liquid nitrogen was got from the Physical Chemistry Lab at UCT who owned a Philips liquefier that produced a few litres per hour. Only many years later did it become commercially available.

I visited Sutherland for the first time around Easter 1972, with Ron Olowin, Ed Nather and Woolley. Though the 20-inch was ready, we were not allowed to use it until June 1972. This was particularly frustrating for Nather who by then had only a few months remaining in South Africa.

As a visitor, I had to apply for 74-inch time at Radcliffe as a RGO staff member through the LTUP (Large Telescope Users' Panel) and was awarded several useful observing runs of a few nights each during 1972-1974. Woolley had seen to it that I and other seconded astronomers at the Cape would not have any particular right to Sutherland time and would have to apply through the LTUP (Large Telescope Users' Panel of the SRC), though I think he did in fact give me some time directly (For the first 15 or so years the running of the SAAO was 1/3 financed through the SRC in the UK).

In June 1972 I had my first observing run at the Radcliffe Observatory in Pretoria. The weather there was at its best in winter. I drove up in my MGB followed by the

Observatory's El Camino bakkie driven by Alton Thomsana. Travelling with a black was complicated by the apartheid laws. Hotels usually had special rooms at the back for accompanying servants and drivers. However, at the Radcliffe Observatory in Pretoria, the presence of a Xhosa was a problem and it was probably illegal for one to sleep over. However, some solution was found.

On the way up, while I was having lunch in Beaufort West, Thomsana moved the bakkie and grazed another vehicle very slightly. He came running into the café where I was, saying he was in trouble. Sure enough a crowd had gathered with a policeman in attendance. After a long negotiation, the aggrieved party agreed that if I paid him R5 (then less than about £3) he would be satisfied! The policeman would act as witness. Of course I paid. What I had not expected was the bureaucratic furore this caused when we got back to Cape Town, with many letters flying back and forth to the SRC! However, I think they did pay me out in the end!

At the time I arrived in Cape Town, astrophysics was at a low ebb and practiced by just a few people. Tim Hawarden was involved in a study of open clusters. Cousins was mainly interested in precision aspects of photometry. Tony Fairall at UCT was involved in active galaxies as I was. PAT Wild was also at UCT but not very active. Over the next year or so, Jack Penfold arrived from Cambridge where he had been working on a PhD. Peter Warren had completed one there but was based at first at Radcliffe. Alan Penny appeared from RGO in June 1972 to make use of a McMullan/Kron electronographic camera, which required a two-dimensional microdensitometer for data extraction. Geoff Harvey was there from RGO and doing photometry. Gary Wegner was recruited from Oxford. Most of the remaining staff were fairly elderly routine observers on the Transit Circle or on the photographic programmes. A major addition to the circle was the arrival of Brian Warner from Texas as professor at UCT.

RE (Ed) Nather must have arrived for a year at UCT from Texas at about the same time that I arrived in Cape Town. He had been working with Brian Warner on pioneering high-speed photometry of the Crab Nebula pulsar. He brought with him a very neat photometer built in Texas to a modern design, with various modules that could be inserted for polarimetry etc. He had a huge influence on the development of instrumentation in SA astronomy by introducing us to the Nova Minicomputer, for which he had designed a very smart interface board that allowed for pulse counting, oscilloscopic displays, stepper motor controlling etc. This formed the basis for the many high-speed photometry programmes pursued by Warner's group. Later, Nather's hardware was duplicated at SAAO and used in our own photometry and radial velocity programmes. I once witnessed him writing a programme directly in binary using the front panel switches of a Nova!

There were no regular astronomical colloquia in those days. Tony Fairall (UCT) and I formed an Astrophysical Journal club around March 1972 that met weekly, the rule being that any participant had to make presentations when it was his turn. This worked well for some time but eventually became diluted by non-participants. When Sir Richard came he joined in and seemed pleased by the development. Warner arrived as professor of astronomy, I think in 1972.

Ron Olowin, a fount of enthusiasm, had joined the Observatory a little before this time and was quite outspoken and unwilling to kow-tow to Sir Richard. "I had a long "talk" with RW two weeks ago and said my piece (nearly got "sacked" as he put it but was saved "cuz I was born on he other side of the ocean and am thus naturally outspoken" – saved by a stereotype!) … Actually the OM is reachable, but it takes some doing and lots of patience, as well as intestinal fortitude". Another time he wrote "Had a real run in, knock 'em down, drag 'em out session w/ RW and am apparently out from under his yoke as well as his good graces. He was really P.O.'d … but I refuse to be intimidated."

George Harding got Sutherland up and running. After the arrival of Sir Richard in January 1972 he became second in command and on his shoulders fell most administrative and personnel matters. The mechanical engineer Stimpson was very difficult to deal with and he did not last long after Sir Richard arrived.

In 1972 I met Hettie, my wife-to-be, and in June 1973 we got married in Pretoria and honeymooned in the Seychelles. We lived in a very old cottage in Fish Hoek, about 20 miles down the Cape Peninsula, with a pretty beach.

Incidentally, Hettie's family had been friendly with that of Adriaan Wesselink, who had worked some years before at Radcliffe, so she knew that Observatory as a child.

The MkII Infrared Photometer at SAAO

Since I was likely to return to the RGO and take the MkI photometer with me, Feast had already proposed in September 1973 that a copy of it should be made for SAAO. Instead of copying it directly, it was somewhat redesigned by the draughtsman Brian Hucklesby. When it was assembled, around January 1975, it was evident that it had some serious problems due to a lack of understanding of various technical aspects. I was accordingly asked to go to Cape Town for two weeks to sort matters out. I do not remember all the points, but the various focal planes were not at the same distance, there were through holes instead of blind ones in the vacuum vessel and the Brookdeal lock-in amplifier had an obscure fault which turned out to be a manufacturing error (John Fuller of Electronics found that a wrong transistor had been inserted).

Astropolitics

Meanwhile, back in the UK, Lynden-Bell had been appointed to succeed Redman as Prof at Cambridge, resulting in Fred Hoyle leaving in a huff. Later in the year, Margaret Burbidge had taken up the Directorship of RGO (around September 1972). There was then war between the Hoyle/Burbidge faction and the rest of British astronomy. Geoff Burbidge wrote a strong letter to Nature (September 8, 1972, pp 117-8) complaining about most of the policies pursued by the SRC and the British astronomical community. This led to the Burbidges being "carpeted" in an old fashioned authoritarian manner by the head of the SRC. Mrs B. only lasted about a year at RGO before she too resigned. Many of the complaints brought up by Burbidge about British astronomy were, in the view of us younger people with overseas experience, justified.

Also around this time a rumour began to circulate that the 74-inch in Pretoria was about to be closed down. As early as June 1972 Olowin heard that it was to come to Sutherland, though no mention was made of the exact date. In reply to a letter from me, Margaret Burbidge (2 Nov 1972) said that the decision had already been taken but that she would use my letter in support of the idea that it should remain open until the AAO was ready. I also wrote to Prof Redman of Cambridge on 30th November about the proposed Northern Hemisphere Observatory and decrying the shut-down of Radcliffe. In his reply he said that as far as he knew, no final decision had yet been made!

In the end the Radcliffe was kept open until about October 1974, about when the AAO was ready. This was about when I left South Africa to return to the RGO. The 74-inch telescope and dome were purchased by the South African CSIR and moved to Sutherland. The library went to the Anglo-Australian Observatory. Several of its staff members accepted offers to join SAAO: Feast, Lloyd Evans and Catchpole. Thackeray also moved to Cape Town and became a professor at the University.

Mike Penston also lobbied Wal Sargent, Margaret B and Sir Fred Hoyle on this issue. The Northern Hemisphere Observatory was at the time still not decided upon.

According to a letter to me from Mike Penston, the Burbidges were disagreeing as to whether "British astronomy could be saved". Geoff insisted he should be given the directorship of the NHO or else co-directorship of RGO!

In January 1974 the decision was taken by the SRC to make a 120-inch infrared flux collector on Hawaii the highest priority for future investment. This made the UK potentially more interesting for infrared astronomers.

While waiting for the 40-inch to be ready at Sutherland we conducted an extensive correspondence in the hope of getting time on the Bloemfontein 60-inch. This never materialized, perhaps fortunately, as that telescope had many serious problems.

A letter of 22 Oct 1973 from Dave Allen told of Mrs B's resignation and also her involvement in a serious car crash. Alan Hunter was then appointed Director.

We were then concentrating on getting time on the IRFC on Tenerife as I was going to be back in the UK in less than a year. In June Allen reported that he was on the steering committee for the 120-inch telescope and that his suggestions had been well received.

On several occasions I heard complaints about Hunter's indecisiveness. "Sir Dick was heaven compared", according to one person.

Real science at last

In Pretoria I mostly stayed in a residential hotel in the city but during the actual observing periods I could sometimes live in the "Cape Cottage" at the Radcliffe Observatory. If the latter was occupied there was an uncomfortable and often freezing "Night Observer's Hut", furnished with a one-plate electric hotplate and magazines such as "The Listener" from the 1940s to read!

Radcliffe was a small outfit, owned by a foundation that had rather too little money to run it efficiently, and had been for some years partly funded by the UK Science Research Council in exchange for observing time made available to outsiders. It only had the one telescope, the 74-inch, which shared with a similar one in Australia the distinction of being the largest telescope in the southern hemisphere. However, the 74-inch was woefully old-fashioned and its controls were relatively crude. AD Thackeray was the director, mainly known for the discovery of RR Lyrae variables in the Small Magellanic Cloud that had led to a "doubling of the size of the Universe", by providing the first of a long series of revisions of the Hubble Constant as determined by Hubble. MW Feast was First Assistant and PJ Andrews was Second. These three lived in official houses on the site. In addition there were four astronomers seconded from the RGO and PR Warren from the SAAO/CSIR. Tom Lloyd Evans was a Temporary Assistant. In general, the scientific atmosphere was productive, Thackeray having followed the model of Mount Wilson Observatory in California. The technical side was weak and generally the Observatory had to rely on the RGO for new instruments. Dennis Pullen, the mechanical technician, could only be got to help by relying on his insatiable curiosity. There was no point in asking him directly to do something but if one started doing it he would eventually join in!

It must be said, however, that the Radcliffe was a stimulating place to visit.
The astronomers there, both permanent and visiting, were very enthusiastic and teatime discussions were usually very interesting. Of course, we youngsters were amused by the foibles of the older staff members. Its isolation as a rather closed expatriate community on an isolated hilltop led to a certain atmosphere that had its good and bad points!

To my mind, the Radcliffe had put and was putting too much effort into observing the radial velocities of southern early-type stars, a classical programme from the 1930s that had formed part of the original justification for the move of the Observatory from Oxford to Pretoria. However, there were plenty of other more worthwhile programmes going on in the background, particularly on peculiar emission-line objects of various kinds. I felt they should have put more effort into the new discoveries that were coming in thick and fast in the early 1970s – x-ray sources, molecular radio sources, quasars, pulsars and active galaxies.

Fig: Outing to False Bay with Robin Catchpole, Louise Webster, Margaret Burbidge and Alan Penny.

During most of the occasions I visited Radcliffe, I would spend lunch times with Tom Lloyd Evans, Louise Webster (a long-term visitor from RGO) and Robin Catchpole, chatting on the stoep of the Cape Cottage. Sometimes Bill Martin was there also. Apart from astronomy, the talk was often of the foibles of the Radcliffe staff who formed a kind of isolated community. Certain people could do most amusing imitations of Thackeray and others. I apparently was also imitated (when not present, of course). I collaborated with just about all the staff at one

time or another as almost everybody had some favourite object or class for which infrared observations would be desirable.

The Cape Cottage overlooked a small meadow whose grass would grow very long and in the dry winter become a fire hazard. The grounds staff would eventually be told to cut it. Their technique was to make a spiral path through the grass to a clearing in the centre, where they would spend most of each day sleeping. Finally, after several weeks, Thackeray would remonstrate at the time it was taking and the remaining grass would be cut within a day or two!

Alan Powell used to get into amazing scrapes. For example, while he was parked on a street in Pretoria, the traffic Department came along and put up a "No Parking" sign and he came back to find a ticket on his car. He went to court and was able to prove what had happened.

I took lots of advice and most of my first papers were collaborative, many with Michael Feast. I took the view that any papers resulting from my equipment should include me as a collaborator and in general I took care to understand the science (after all I had come from a non-astronomical background). I remember Louise Webster warning me to be careful as to whom I told about my results as "certain people" were regarded as unscrupulous about appropriating them.

In those days the only high-resolution photographic atlas of the sky was the Palomar one, limited to declinations higher than -42°. South of this we were limited to the Union Charts and the Franklin-Adams atlas, of poor resolution and depth. We had to make Polaroid copies of the fields of the objects we were interested in, identifying them by means of transparent overlays. I borrowed some of the old Radcliffe finding charts of the bright stars in the Magellanic Clouds. They were made of tracing paper (Toilet paper?) and were terrible to use. Objects were often specified in 1950 or 1900 other coordinates, which had to be precessed to the current epoch! The telescope could not be set very precisely. One was lucky to be within a couple of arcmin, so the finder often had to be looked through - quite awkward at several metres above the floor.

RCB Stars in the IR

One of my first papers was a survey with MW Feast of RCB and RCB-like stars, the observations being made in June 1972. R CrB and RY Sgr were already known to show strong infrared signals from likely carbon dust shells and the aim was to observe as complete a sample as possible. I made models that combined stars with photospheric temperatures between 4000 and 6000K with dust shells of 800 to 900K that fitted the data quite well in the J-K/K-L two-colour diagram. The hotter star V348 Sgr also seemed to have a hotter shell. Some helium stars and hydrogen-deficient carbon stars were also looked at but these did not show dust shells (Feast and Glass, *MNRAS*, **161**, 293, 1973).

Globular Clusters

One of Feast's interests was to obtain bolometric corrections for the late type giants in 47 Tuc and Omega Cen. The hope was to shed light on why the latter cluster was so anomalous (Glass and Feast, *MNRAS*, **163**, 245, 1973).

RW Aurigae Stars

In this programme with MW Penston IR photometry of 89 variables of the poorly defined RW Aurigae class were looked at at JHKL, some from Penston's previous work in the northern hemisphere. Most were young objects of the T Tau and Orion populations and showed infrared excess indicative of dust emission (Glass and Penston, *MNRAS*, **167**, 237, 1974).

Southern Emission-line stars

This work with David Allen was done mostly at the 40-inch telescope in Sutherland. The sample chosen was of compact planetary nebulae and emission-line stars and the idea was to look for dust continua at infrared wavelengths. About half the "compact planetary nebulae" showed evidence for dust shells and were either symbiotic stars or early-type forbidden line emission stars (Allen and Glass, *MNRAS*, **167**, 337, 1974).

BL Lac Objects

The spectroscopically then apparently featureless object AP Lib (PKS1514-24) and the N-galaxy PKS0521-36 were among the earliest known examples of their class and were observed by me in the infrared. I persuaded Andrews (Radcliffe) and Hawarden (SAAO) to observe them in visible light. They are both variable and become redder when fainter, as with BL Lac (*MNRAS,* **167**, 7p, 1974).

Brightest Stars in the LMC – identification of VV Cephei stars

These stars I selected from a famous paper of Feast, Thackeray and Wesselink (1960) and were some of the most luminous then known. As such, they were likely to be unstable and seemed to be obvious candidates for an infrared investigation. Several of the F and G supergiants show excess infrared radiation indicative of dust shells arising from mass-loss. Some of the stars with peculiar emission-line spectra (FeII and [FeII]) were shown to be probably of VV Cephei type as in the infrared they have the colours like late-type supergiants, indicating the presence of red components that were overwhelmed in the visible part of the spectrum (Glass, *MNRAS*, **168**, 249, 1974).

Observing at Radcliffe

At Radcliffe I had to work from high ladders or even a sort of movable tower. At the start of an observing run, the position of the cryostat had to be tweaked to match its antenna pattern to the output pupil of the telescope and the chopper had to be adjusted to null as far as possible any offset signal arising from the telescope's own radiation. The object of interest had to be centred in the acquisition eyepiece and then an offset guide star had to be found because of the necessity for nodding the telescope every 20 seconds. The filter and aperture wheels had to be controlled from the back of the photometer, often difficult to reach. To make observing even moderately efficient I had to have help with recording the data as I could not keep running up and down ladders. The recording person had to mark the paper tape from the printer and also enter object names, time, filter and aperture data on special card coding forms. Especially at first I was helped by astronomers Balona and Martin and sometimes by various ad-hoc

students and amateurs that the Observatory called in. Peter Warren very kindly modified the computer reduction programme so that it ran on the IBM computer at the CSIR. The data on the printer tape had to be transferred to punched cards and this was also done by card typists at the CSIR.

Liquid nitrogen could be got from CSIR in Pretoria but Liquid Helium had to come from Wits University in Johannesburg. The latter was complicated logistically. On nights when I worked at long wavelengths, the procedure started at 3pm with a pumping followed by a pre-cool of the bolometer cryostat using liquid nitrogen. After an hour, this was discarded and liquid helium was transferred in. The cryostat was then mounted on the telescope and connected to the helium pump. At first it had to be pumped gradually, but when it became a superfluid it was pumped vigorously to reach about 1.2K. Then I would grab a bite to eat and after that it was time to open the dome and commence the alignment etc. Then it was observing until 6am or so. Very tiring!

The University College London group visited Radcliffe for observing and I was able to help them with the loan of some of my equipment. We also saw Mike Smyth from Edinburgh (known to us as Smith-Smythe) on at least one occasion.

Infrared of active Galaxies

One of my own long term interests was to study "active" galaxies. At that time, the number of known active nuclei was small. [Bill Martin, working at Radcliffe, had discovered that NGC3783 is a Seyfert and had submitted a paper about it to MNRAS. It was rejected on the grounds that "Seyferts were two to a penny", to which Thackeray remarked: "In that case, we have about a shilling's worth".] I was particularly interested in galaxies with bright nuclei, such as Seyferts and the objects studied by Sersic and Pastoriza. My first paper in this area was about the members of a quartet consisting of NGC7552, 7582 and some others. Their NGC positions were not accurate and I got some measurements done from a CAZ plate at the Observatory in Cape Town. The results were most encouraging as their colours were unlike those of ordinary galaxies but showed infrared excesses at longer wavelengths due to hot circumnuclear dust. Peter Andrews helped me by getting visible-region colours (Glass, *MN* **162**, 35p, 1973).

My first major paper on *The JHKL Colours of Galaxies* (Glass, *MN* **164**, 155, 1973) contained results for the nuclei of 27 southern galaxies and created quite a lot of interest. A few Seyferts were included and a number of other bright-nucleus galaxies showed infrared emission at longer wavelengths. One of these, NGC1808 is now recognized to be a Seyfert. NGC7582 and NGC7552, members of the Grus Quartet, have strong star formation and possible Seyfert activity in their nuclei.

A second paper extended this list, showing that NGC1808, NGC7582 and the Seyfert IC4329A had strong excesses, while NGC5236 had a weak one (Glass, *MNRAS* **175**, 191, 1976).

X-ray sources

Cyg X-1

On 26 June 1972 I observed Cyg X-1 (the star with a black hole companion) at JHKL but the colours seemed appropriate for a B0Ib star with reddening of A_V = 3.39 mag. This was not published because it was done at a zenith angle of about 60 degrees, without a nearby standard star.

Identification of the X-ray Source GX2+5 (GX1+4)

Another programme of my own was to study the visible counterparts of x-ray sources. At this time not many counterparts were known because only a very few sources had well-determined positions, usually from lunar occultations. One of these was GX2+5 (also known as GX1+4), observed by Hawkins et al *(Nature Phys Sci*, **241**, 109, 1975.). I searched an area of 4' x 4' around the x-ray position on 26 May 1973 and found an object with K = 8.1. Later on, I would have dismissed this as just another red giant of no significance! Fortunately then I knew no better so I got Mike Feast to observe it spectroscopically about a month later. He found it to have broad H-alpha and a high Balmer decrement, indicating perhaps a symbiotic star with heavy reddening. Louise took a plate of the area to see if there had been any remarkable changes, but there had not. The result was published in (Glass & Feast) *Nature Phys Sci*, **245**, 39, 1973. This source has subsequently been studied very extensively and is now known to be a low-mass binary pulsar.

Work with Webster on Emission-line objects

One of the specialities of the Radcliffe Observatory had been the observations of emission-line objects. Louise Webster suggested I should look at 16 of these in the JHKL region. She was an expert in planetary nebulae and related objects. When possible they were examined at 10 and 20 microns also. A cool stellar component was detected for the first time in three objects and confirmed in eight known symbiotic stars. The Yellow Symbiotic Stars VV8 and HD330036 were shown to have dust shells. One of the most curious objects, RR Tel, had a rather flat spectrum in F_ν and was interpreted as having strong infrared free-free and free-bound emission. This interpretation is now known to be wrong as repeated observations have shown that the infrared emission is due to a Mira-like variable component (*MN* **165**, 77, 1973) that just happened to be at a level that made the free-free interpretation plausible. The planetary nebulae M-2-9 and VV80 were seen to have strongly emitting dust components.

A second paper with Louise, "The Coolest Wolf-Rayet Stars", was about M4-18, He2-113, CPD -56 8032 and V348 Sgr, which were interpreted as late-type carbon Wolf-Rayet stars (WC10) with strong cool shells around 600-800K (*MNRAS,* **166**, 491, 1974).

"Old Novae" in the IR

This class has more recently been called ``symbiotic novae''. The infrared was an excellent region for showing up their cool components. I selected some of these from old Radcliffe publications and Feast added some others. Late-type components were found in TCrB, RS Oph and RT Ser. TiO bands were detected by Feast in RR Tel, which he then suspected might be a SRV.
The secondary of the recurrent nova TCrB has J-H, H-K colours appropriate to a red giant of about type M4, in spite of losing mass to the white dwarf primary. This system

was later found to exhibit flickering phenomena and to be a hard x-ray source. A late-type component was detected for the first time in the RT Ser system (Feast and Glass MN **167**, 81, 1974).

R CrA Association

With Penston I carried out a programme of stars in and around the dark cloud of this association, many of them anonymous. These were examined in the two-colour diagrams but no new dust shells were found. However, the dark cloud was found to have a visual absorption of about 8 mag (Glass & Penston, *MNRAS*, **172**, 227, 1975).

Interstellar extinction

Work with Whittet and Van Breda used the St Andrews scanner on the 1m telescope in Sutherland in the visible in combination with JHKL photometry for 22 bright early-type stars to investigate variations in the interstellar extinction law. Near the Ophiucus Dark Cloud, anomalously high values of R were found (*MNRAS* **177**, 625, 1976).

HII region G333.6-0.2

This very luminous region, previously examined by Becklin et al in 1963, was scanned for at K and L and the region was photographed in the R band. It was found that it was just visible on the plate and that the previous published position was in error (Churms et al *MNRAS* **169**, 39p, 1974).

Second Period at RGO (1974-5)

After my three years assignment to South Africa, I returned to RGO and stayed another year before resigning. On the way back, having a full fare ticket, we could stop off in various places. Originally we intended to go to Greece, but they decided to have a revolution just then and we went to Rome instead, without booking. We carried on to Florence and then decided to fly to Vienna where we had friends.

We had hardly arrived in Herstmonceux when Hettie learned that her aunt and godmother had died in Holland. She spent about a month there to clear up affairs. This coincided with my first observing trip to Tenerife.

Later we stayed in the Allens' house in Hailsham for a few weeks around this time, either just before or just after Herstmonceux Castle.

For a month we lived in the Castle, in a large room above the Director's (Hunter's) office and had the use of a kitchenette. We had a beautiful view over the walled garden on one side and the moat on the other. Unfortunately, the floor was very resonant and we had many complaints from Dr Hunter in the office below about the noise we made when we walked about. We eventually found a rented house to live in, in Bexhill. Such places were difficult to find at the time because of rent laws that very much favoured the tenant. Our landlady was a friend of Dorothy Hobden, which helped matters (Afterwards she met and married Alfred Bader, a Canadian, who purchased the Castle

from the SRC and presented it to his old university, Queens University, Ontario). Dorothy was the daughter of the head of the Royal School, Armagh, where my father and my brother had been to school.

I had brought back my MGB and we bought an old Morris Minor for Hettie to use. She was pregnant with our first daughter who was born in May 1975. We slowly made a good number of friends among the families of similar age at the RGO, especially after our baby arrived. Between us and the Woods, who had a baby about the same time as we did, we brought the average age in our Bexhill neighbourhood down considerably. Hettie was able to practice baby-handling on the Penston twins, who were born slightly before our daughter.

RGO celebrated its tercentenary in 1975. I remember just before a visit from Princess Anne I came upon some workmen fixing one of the two-bar fences at the north end of the estate and one of them informed me with a deadpan expression that they were improving the security. I also heard that the security men checking out the Castle before the Royal visit threw up their hands in horror at the amount of clutter in the average astronomer's office.

On the actual day of the visit, we were rather late and headed for a couple of empty seats in the corner of the refreshment tent and almost sat down before we realized it was the table occupied by the Princess and various other bigwigs! The security was quite discreet, but sharpshooters could be seen on the tops of the Castle towers.

Françoise was born in Eastbourne in May 1975. It was a very good summer weatherwise and we had guests almost constantly. We ourselves rented a house from one of Hettie's cousins in the Ardèche and spent two weeks there, driving in the MGB. We had a crash in Paris on the way back, but fortunately no injuries.

Also in connection with the Tercentenary we attended a service at Westminster Abbey and were allowed to park our ancient Morris Minor in the Dean's Yard, between the limousines. Françoise had to be left with a cousin in north central London.

More Recollections

By the time I returned to Herstmonceux I had a respectable number of papers to my credit and I was given an office in the Castle, more appropriate to an astronomer. My immediate boss was Bob Dickens, though I saw him mostly only for formal requests. My office I shared with Janet Sinclair. It was next to the Drummer's Room, a remnant of the medieval castle. Once I was taking a short cut to the administrative offices through the said room, while reading something. I walked straight into the medieval stone door frame at the other end and banged my head so hard that I had to sit down for about a quarter of an hour.

Typing was then done by the typing pool, which was very inconvenient for people in the West Building.

We had colloquia in the chapel on a weekly basis. These were often quite entertaining, especially if Donald Lynden-Bell or Bernard Pagel were talking, as they liked to knock

spots off each other. They were usually attended by William McCrea and Roger Tayler from Sussex. Another chapel activity was the bread and cheese lunches held for charity.

Woolley Stories

Many years after I left RGO I met Tommy Gold while I was giving a lecture at Cornell. Of course, he hated Woolley. He told me a story that Murray, then quite junior, was giving a talk in the Chapel, when Woolley entered quarter of an hour late and peremptorily told him to start again!

While in South Africa I got to know Woolley a little better. Though he was still quite authoritarian, he occasionally showed a humorous ironic side. He liked, for example, to read "Private Eye" and used to pass it on to the sitting room in the hostel at Sutherland.

He owned a summer house at the seaside village of Rooi Els, on the far side of False Bay. After he had retired, this was made available to several of us for a very nominal rent and we went there for weekends on several occasions.

He decided to learn Afrikaans, possibly in order to impress his masters in Pretoria. He also dabbled in painting.

Lady (Gwyneth) Woolley was as remote a figure in Cape Town as I gather she had been in Herstmonceux. Though very impractical, she knew who was in love with whom and what babies were due. Woolley was extraordinary tender towards her and put up uncomplainingly with her many foibles. Once at the end of a visit when Alan, Hettie and I were with him at Rooi Els (Lady W. was not there), to our surprise he got down on his hands and knees and washed the floor before we left.

He was rather sensitive about the "utter bilge" story and claimed that he had been misquoted and that he had been referring to interplanetary travel, which is still *pace Elon Musk*, utter bilge.

The Wegners, Hettie and I were once invited to dinner with the Woolleys, near the end of Sir Richard's period as director of SAAO. At the end of a very pleasant meal, Lady Woolley suggested that the ladies should withdraw. Neither of them had ever heard of this custom, and indeed I had only encountered it once before. The gentlemen then had a glass of port. Woolley mentioned that it had been his aim to turn RGO into a primarily astrophysical group but that he had found great difficulty in getting hold of as many suitable people as he would have liked.

He was, of course, known for his steamrollering of items through committees. One of his techniques was to make sure that his brother Astronomer Royal, Brück, backed him up in debates. It was surprisingly effective when the rest of a committee acted as individuals. However, in the end he probably made a lot of enemies.

He mentioned that under the Admiralty the RGO had been an insignificant item on a budget filled with warships and the like. At the annual naval budget meeting, the chairman would say something like: "Astronomer Royal, you have the smallest budget, so let's get you out of the way first. I see you have 10 items on your list but I'm afraid we

can't support them all. Can you suggest something to eliminate?" "If necessary we can remove item 7" might be the reply. Of course, it had been included for this very purpose. "Well Astronomer Royal, if that is satisfactory to you, you can go".

He was for some reason against the trend of using mini-computers for all sorts of astronomical tasks. Several were however bought in the guise of "Instrument Controllers".

Woolley would have a brainwave every now and then and would propose some programme that would take up a lot of the available astronomical manpower to execute. Quite often he would have forgotten about it within a few days. One programme, however, that did turn out to be very useful was on the VRI photometry of Cepheid variables. The main results were published by, Warren & Feast (*MNRAS* **188**, 139, 1979). He approached me on one occasion about how best to do photometry beyond the Paschen limit, in the near infrared. I suggest that he should acquire one of the then new GaAs photomultipliers that had good sensitivity at these wavelengths. He asked me to acquire the necessary tube, housing and filters. Needless to say, this took some time and Woolley had lost interest by the time the equipment came. The equipment was standing idle, but Cousins heard about it and was keen to try work in the R and I photometric bands. He took over and this was the beginning of his work on the VRI Kron-Cousins system, which was to become standard at many observatories.

It was suggested that PAT Wild of the University of Cape Town and Woolley should find a project on which to collaborate, but Sir Richard did not find this particularly funny!

Science

I had a lot of contact with Michael Penston, Louise Webster and David Allen, the main RGO people interested in infrared. Together with these and Paul Murdin, I applied for a three-year post at the Anglo-Australian Observatory, which was then almost ready. I was selected as a back-up for Louise, in case she turned it down, but she didn't.

With Penston and Allen, I obtained observing time on two occasions on the "Infrared Flux Collector" on Tenerife. This was a fairly chaotic installation, operated by the Imperial College infrared group. There was nearly always something wrong with it but somehow we managed to overcome the difficulties. For example, on one run we had to point on a star as low down in the south as possible and stand outside the dome on the coudé room roof to turn the focus spindle with a spanner.

I was interested in red dwarf stars; Penston and I observed T-Tauri and related objects, while David Allen was interested in Be stars. Usually we stayed at the nearby Parador (rabbit stew or pork chops, *muy hecho, por favor*) but, when observing, the unused coudé room of the observatory sometimes served as a bedroom.

Occasionally there were power failures at the Observatory but we had to wait for the local television station to close down before we were allowed to re-connect, as it had absolute priority and the surge might trigger a further shutdown. On one occasion we had a visit from the Minister in charge of broadcasting of the Franco government and

his party, on the Island for Carnival. They were a most pleasant and appreciative group. I scored a great hit by lending one of the wives my duvet jacket!

In the bottom of the crater near the Parador where we usually stayed, Penston, Allen and I laid out a big sign in stones, saying "RGO". To our annoyance, the next time we were there it had been changed with minimal effort to "ROE".

Astronomical Results from Tenerife

While I was in South Africa, Catchpole compared the colours of late type stars among my measured standards to models produced by Gingerich and Kumar. As is well-known the positions of late-type giants in the J-H/H-K diagram deviate considerably from the black-body line thanks to the H^- opacity minimum around 1.6μm.

In Tenerife I carried out a programme of observations of K and M dwarfs. Mould (1975) had made some models for them. In the J-H/H-K two-colour diagram they were quite separate from the K and M giants, those without emission agreeing quite well with the models. This was a consequence of the differing H^- opacities in their atmospheres.

Instrumentation

During this period, photovoltaic InSb detectors began to be available but they were attended at first with a certain mystique. I installed a Barnes detector in the photometer. Being photovoltaic, it was not necessary to apply a voltage across it and so 1/f noise could be avoided. Instead, it was operated to produce a current at zero voltage using a cryogenic preamplifier designed by Hall et al and a very high resistance feedback resistor for minimal Johnson noise. This detector was much superior to the PbS one but improvements to the cold optical shielding were necessary before I got the best performance. The setting up of the preamplifier for minimum noise took some further understanding. Also, the J filter turned out to have a small long-wavelength leak that had not mattered with PbS because of its shorter cut-off wavelength but now became apparent.

David Allen left for the AAO in March 1975 and Mike Penston around September. Sad to say, both of these friends died relatively young of cancers, as did also Louise Webster (later Louise Turtle).

In April I became a member of the steering committee for the 3.8m flux collector project in Hawaii (later known as UKIRT) but by then I had accepted a post at SAAO after much hesitation, partly due to the unstable politics in South Africa but also because of the good astronomical weather and easy access to telescopes. The idea of regular observing allocations was very appealing to me. Hettie was a little homesick also and staying at home, pregnant, while I went to work each day was boring for her, especially at first. We had also spent a lot of time looking for a suitable place to live but had not found anywhere that really appealed to us.

I negotiated with Dr Hunter to bring out the photometer (now called the Mk I) to South Africa again. There had been some feeling that it should be kept at RGO for possible use

at the proposed Northern Hemisphere Observatory. The SAAO-built Mk II was afterwards dedicated to the 30-inch.

I had been awarded AAO time with David Allen and in December 1975 I went there (though by then based at SAAO). I brought along the MkI photometer. This was difficult to operate from the Cassegrain cage because it still had to be done manually.

The rather poor weather that we had experienced since moving to Bexhill cleared up for the summer of 1975 and we either had guests staying with us or were away in France ourselves for almost the whole three months. This season turned out to be the most enjoyable part of our year.

I said goodbye to RGO at the end of September 1975 and we took ship from Southampton for Cape Town on the SA Vaal.