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My years as an Astronomer

Ian Glass SAAO

Abstract: Unlike many astronomers, my interest in the subject did not begin until my student years. I started out as a physicist with an interest in cosmic rays that eventually led me towards astrophysics in general. As a graduate student I began with Solar Wind studies but afterwards moved into the nascent field of X-ray astronomy. During this time I also got involved with stellar interferometry and this ultimately led me to infrared photometry which became the main theme of my career.

I grew up in a village called Malahide, near Dublin, until I was 12, and my early education was in a local school that was unusual for the Ireland of the time in that it had children of both sexes and both religions (Catholic and Protestant). My father was an electrical engineer. I had two cousins who were university students studying chemistry and a neighbour who was a physicist working on cosmic rays. So I had some exposure to science quite early on.

We moved when I was a teenager to Dublin to be nearer to secondary schools. Mine was a small one with boys from many different backgrounds. It had about 220 pupils and my strongest subject was mathematics. One of my hobbies of those years was electronics - receivers and transmitters for radio and television. Themionic valves had not yet been displaced by solid-state devices.

I entered Trinity College Dublin in 1957 to study Mathematics and Natural Sciences. The student body numbered about 3000. Physics as taught there was rather "soft core", ie non-mathematical, even though ETS Walton, the department head, was a Nobel prize winner. There was very little astronomical or physical research going on in Ireland. Today, things are very different since Ireland is now a prosperous country that is part of the European Union and various European scientific organisations. I got to know most of the local practicing researchers of the time but I felt that it was not sensible to pursue a reseach career locally. I resolved to go to the USA for my PhD.

I was awarded a Research Assistantship at MIT. This required that I spend about a third of my time working, usually on some kind of research for an academic staff member. In my case this was Prof Frank Scherb who was part of the team that first studied the Solar Wind, using an early space probe (Explorer X). A PhD usually took about 5 years, of which the first two at least were occupied with lecture courses. The main hurdle, before starting on a thesis, was to pass a tough "General Examination" on all of classical and modern physics. During the first few years, between attending lecture courses, I worked on analysing satellite data and later on a prototype device to detect deuterium in the Solar Wind using the nuclear reaction t(d,n)α. At that time I built up some interesting vacuum systems and ion sources to test instruments used for Solar Wind flux measurements.

The 1960s were particularly exciting years in astrophysics through the opening up of new spectral regions for exploitation. One can think of the discovery of pulsars, quasars, the cosmic microwave background, radio spectral lines, celestial γ-rays, X-ray sources and infrared excesses, to mention just a few things. MIT groups were involved in many of these. So it was a good place to be to participate in new developments.

X-rays from space had only recently been discovered and for my PhD thesis I worked with Prof George Clark on hard X-rays from the Crab nebula, attempting to see if there were any lines in the spectrum (between about 20 and 70 keV). This involved developing a complete instrument with large-area proportional counters and flying it on a high-altitude balloon. Like other students I had to take on responsibility for quite a large project. Following a successful flight and the analysis of the data it produced, my PhD was awarded in 1968, somewhat delayed by the fact that I was knocked out for quite a long period by illness.

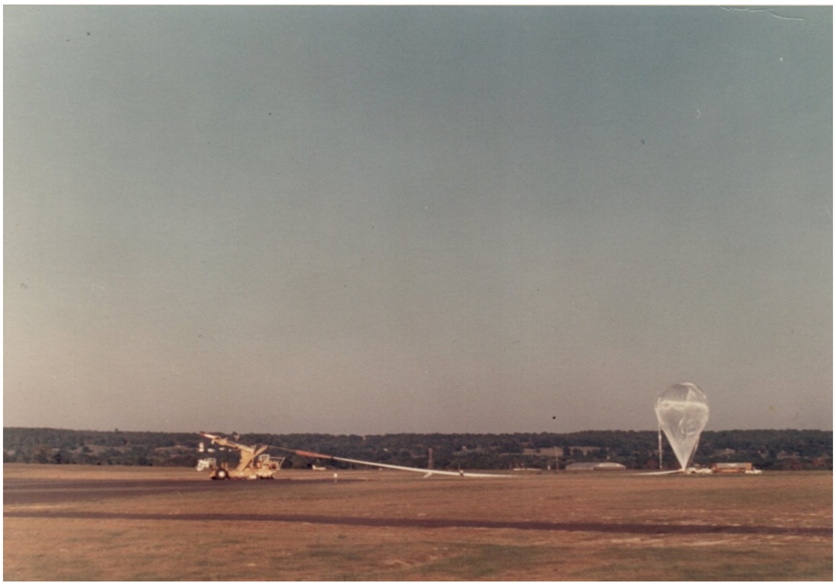

Fig 1. A 10 million cu ft balloon ready for launch. Only the top is filled with helium and when it is let go the launch vehicle manoeuvres until the balloon is taking the load before releasing it. The balloon fills out as it reaches. There is a parachute above the payload that allows a slow descent at the end of the flight.

I carried on in X-rays as a post-doc. My main project was to work on another aspect of the hard X-rays from the Crab Nebula, viz. timing each photon arrival to about a millisec, so that its X-ray "light curve" could be studied modulo the pulsar period. This showed that what had been the interpulse actually became the dominant one at higher energies.

As a kind of private project during the period I spent at MIT I was interested in stellar interferometry. This I carried out in collaboration with Jim Elliot (then a Harvard graduate student and later famous for the discovery of the rings around Uranus). It was the first successful attempt to make quantitative measurements of interference fringes from a Michelson-type stellar interferometer and was an important step in the development of the subject. This work attracted the attention of Gerry Neugebauer, one of the pioneers of infrared astronomy and he invited me to work at Caltech as a post-doc.

Thus in 1969 I switched wavelengths to the infrared, in which I worked for the rest of my scientific career. At Caltech I gained experience in infrared equipment design, which involved vacuum, cryogenic, optical, electronic and computational expertise beyond the competence of conventional astronomers. I worked frequently at Mounts Wilson and Palomar. The 200-

inch was then the largest telescope in the world and I met many of the best-known astronomers of the time. My US visa had however expired and I was lucky enough to meet Donald Lynden-Bell at Caltech who suggested I should go to work in England at the Royal Greenwich Observatory (RGO).

My first year at RGO was spent in developing an infrared photometer that covered the atmospheric transmission bands from 1.25μm to 20μm. While there, I met Michael Feast (who was visiting), Michael Penston, David Allen and Louise Webster, all of whom were keen to make infrared observations. The UK climate is not a good one for photometry and so I arranged to be sent in October 1971 as a visitor to the Cape where the Sutherland Observatory was under construction and the observing weather was expected to be much better.

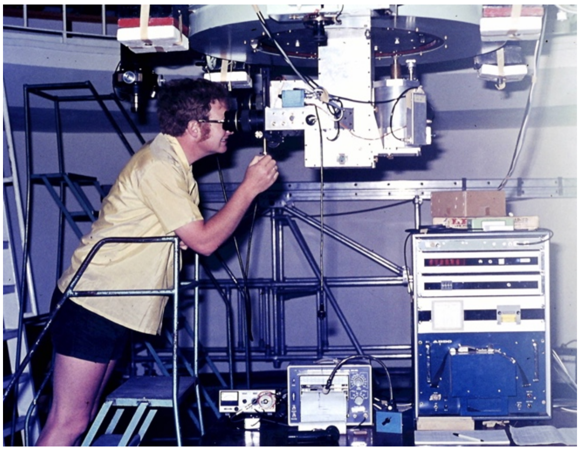

Fig 2. My first photometer on the 1.0 m telescope in Sutherland around 1973. Data were recorded primarily on punched tape. On-line reductions started ca 1980

Looking back, the three years I spent observing with the 18-inch telescope in Cape Town, the 74-inch telescope in Pretoria and the 40-inch in Sutherland were the real beginning of a productive career. The Southern hemisphere was then almost virgin territory in the infrared and many types of objects had not yet been explored at these wavelengths. Further, interstellar extinction is very much less than at visual wavelengths, so that even the Galactic Centre with ca 30 magnitudes of visual extinction becomes visible in the *K*-band at 2.2μm and is open to investigation. Even in the North, little was known of the infrared properties of many kinds of objects. My first task was to set up a network of accurate infrared standards in the South, tied to Johnson's in the North. This was done with the 18-inch, by observing bright non-variable stars at constant altitude and spaced around the sky. The 1m telescope was not ready at Sutherland until November 1972, so I observed at the Radcliffe Observatory in Pretoria, then still the joint-largest telescope in the South. In Pretoria, I benefitted from collaborations with colleagues there such as Michael Feast, Louise Webster and Robin Catchpole. Others from the RGO – Michael Penston and David Allen - came out to work with me and I was soon producing many papers per year – in fact, I think I wrote the majority of papers from the SAAO in some of its early years, although in principle I was a member of the Royal Greenwich Observatory at that time.

As my photometers and spectrometers came to be in demand by other users, they had to be idiot-proofed and their use simplified and automated as far as possible. New and improved detectors required updates of the equipment from time to time to make the most efficient use of the telescopes.

I observed many emission-line objects such as old novae and ultra-luminous stars in the Magellanic Clouds, often finding anomalous infrared emission indicating the presence of red stars in multiple systems and strong mass-loss.

In the early 1970s, very few X-ray sources had been identified and, of course, this naturally interested me. They were not particularly expected to be interesting in the infrared, but I decided to go for them anyway. One object that I found was the stellar counterpart of GX1+4, whose identity was clinched by Feast through spectroscopy that revealed broad emission lines. I also worked on Cir X-1 and found it to exhibit cyclic flaring.

In extragalactic astronomy the QSO 3C273 and a few Seyfert galaxies were already known to exhibit unexpected amounts of infrared emission and I made a point of studying these and other galaxies with peculiar nuclei. Several of the latter showed anomalous infrared emission.

I returned to the RGO in 1974 but could not observe as easily as from the Cape, having to mount expeditions to a 60-inch telescope in Tenerife and to the AAO in Australia which had just then started work. However, Sir Richard Woolley, then head of SAAO, had made me an offer to work here. A South African wife and the opportunity of observing frequently at Sutherland overcame my qualms about the political situation and I joined SAAO in 1975.

Some of my most significant discoveries were in the field of red variables – Miras, and Semi-regulars. My colleague Tom Lloyd Evans had found a number of Miras in the LMC and SMC and I observed these over a few years, finding that they obeyed a period-*K* ($2.2\mu m$) magnitude relation. Infrared was the key to success since the visual region of late-type giants is eaten into by deep molecular bands and is not representative of the bolometric output of these stars. The discovery of this relation led to many further investigations and, for example, the use of Miras as distance indicators.

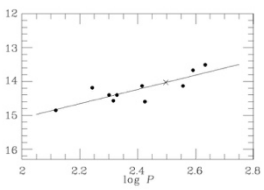

Fig 3. First evidence for the period-luminosity diagram for Mira variables (Glass & Lloyd Evans).

Follow-up papers compared the properties of long-period and irregular variables in different environments, such as the Galactic Centre, the Magellanic Clouds and the Solar Neighbourhood. The nearby stars were then difficult to characterise because their distances were not precisely determined (pre-Gaia) and even their periods were not always well known. Recent automatic repetetive photometric surveys with computerised reductions are yielding improvements here.

Another significant discovery arose from a second long-term monitoring programme – this time, of active galaxies, particularly Seyferts. By 1976, infrared detectors had improved greatly, making it easier to observe faint objects such as BL Lacs and QSOs. I also made further studies of emission-line galaxies with peculiar nuclei that often turned out to be strong infrared emitters. Interspersed with other programmes over many years I observed repeatedly 41 of the brightest Seyferts that were then known, having been discovered through morphological studies and X-ray surveys. One of these, Fairall 9, happened to be studied simultaneously by the IUE satellite and the cross-coorrelation of these observations with mine showed a long delay of over a year between the ultraviolet variations and the infrared response. The implication is that the infrared is emitted by a dust shell at about a light-year distance from the central luminous black hole. This was an important confirmation of the "standard model" for active galactic nuclei. Most Seyfert nuclei were shown to vary but the spectral shape of the variable part of the flux was shown to stay constant. The study of "Flux Variation Gradients", (in collaboration with Hartmut Winkler) turned out to be a powerful method for separating and sudying the nuclear component of active galaxies, separately from the underlying stellar and gaseous emission.

Before the advent of infrared array detectors, images could only be made by raster scanning. The central $1° \times 2°$ of the galaxy had been surveyed only basically and I decided that it could be mapped in much greater detail, given our access to time on the 1.9m telescope. I designed a special triple (simultaneous 3-colour) photometer working simultaneously at *JHK* (1.25 to $2.2\mu\mathrm{m}$). Whitelock wrote the data acquisition software and Catchpole generated the final images. The joint observations involved 477 10-minute scans over three observing seasons!

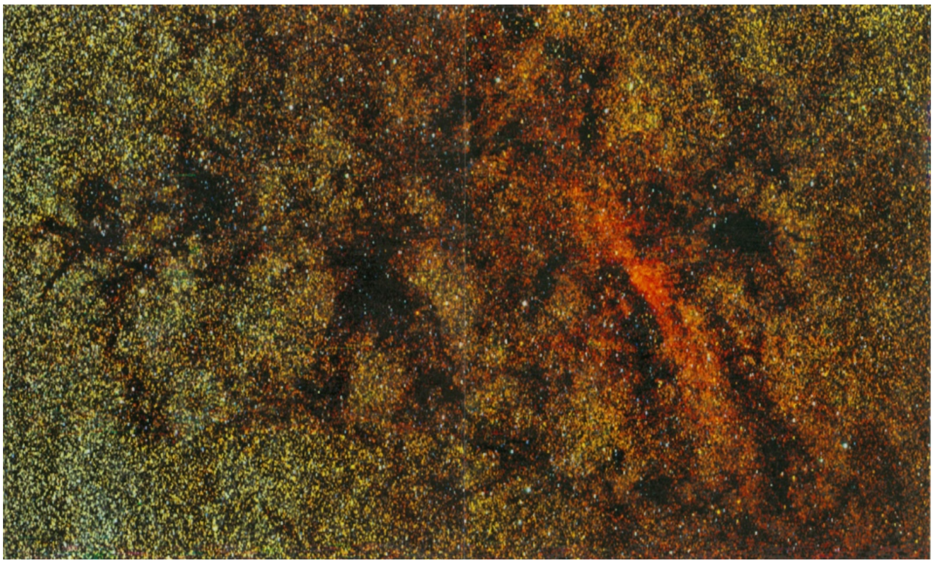

Fig 4. JHK map of the central $1° \times 2°$ of the Galaxy. This was the best such image at the time and shows the dark cores of dense molecular clouds against the stellar background.

When infrared array detectors were developed, several years after conventional CCDs, the best ones were not available to South Africa users because of military sanctions. I spent a considerable amount of my time on building cameras using such arrays as were available, often with less than desirable characteristics. An early success used a Mitsubishi device with very low quantum efficiency but very large format (1040 × 1040 pixels). Using this, we searched an area of $24 \times 24\,\mathrm{arcmin}^2$ around the centre of the Galaxy for Mira variables using the PtSi camera (see below), obaining periods and light curves for several hundred of them.

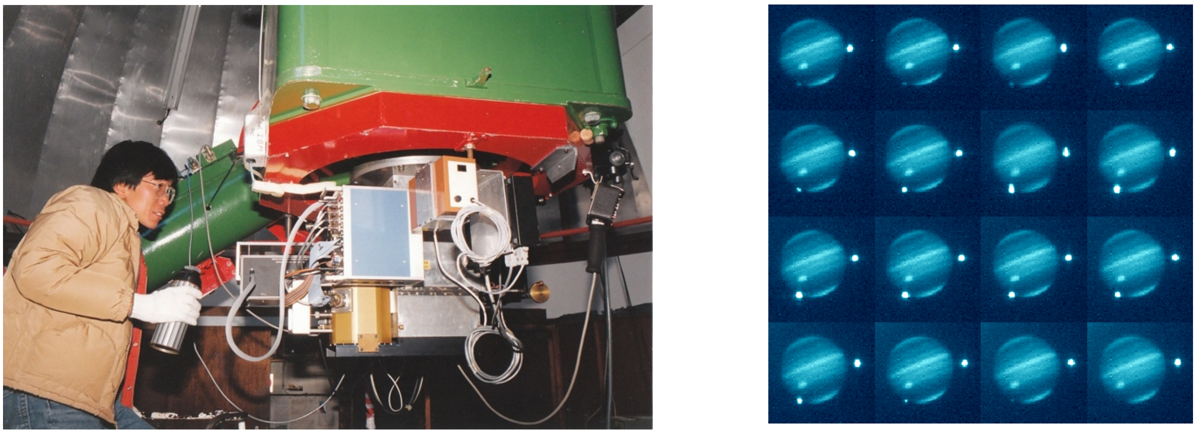

Fig 5 . Left K Sekiguchi filling the Dewar of the PtSi infrared camera. Right: One of the fragments of comet Shoemaker-Levy colliding with Jupiter in July 1994, photographed at 2.2 μm. Our infrared photographs created a sensation on the Internet.

Infrared satellites such as IRAS, ISO and their successors have extended the range of wavelengths beyond those that could be observed from the ground. The Centre of the Milky Way galaxy passes overhead but cannot be observed at visible wavelengths because of dense intervening interstellar dust clouds. I made a point of looking for the near-IR counterparts of obscured IRAS sources near the Centre, which in some cases turned out to be ultraluminous. One of the most interesting is the “Quintuplet”, a cluster of luminous young starsthat I observed futher with Andrea Moneti and others using early imaging equipment at ESO, Chile.

In the 1990s I became involved with the ISO infrared satellite launched by ESA. I proposed that it should observe “Baade’s Windows” of low interstellar extinction, close to the Galactic Centre that can be observed even in visible light. Stars here have the advantage that they are essentially at the same distance and their absolute magnitudes can easily be compared. Using variability data mined from the MACHO gravitational lensing experiment together with previous spectroscopic surveys and ISO long-wavelength observations it was possible to form a well-defined sample of semiregular variables. Their mass-loss rates were examined as a function of luminosity and pulsation period. This and some other work showed that variability and mass-loss in late-type stars started in earlier spectral types than had been realised. Some of this work was done with colleagues at the the European Southern Observatory and the Institute of Astrophysics in Paris.

I was not usually involved in planetary work, though on occasion I observed occultations by circum-planetary rings with my student friend Jim Elliot and his group. We observed several events involving Uranus and Neptune helping to delineate their ring structures. This work required the development of special electronics capable of yielding milliseond resolution.

I have given here a very abbreviated account of just some of my scientific work and I should emphasize that much of it was done in collaboration with colleagues, many of whom have already passed away. For various lengths of time I visited other institutes such as the University of Arizona, ESO, Cambridge (non-Mass), IAP (Paris) and PRL (Ahmedabad) where I was involved in many fruitful collaborations. Altogether, I was author or co-author of 220 or so papers in my career with over 10,000 citations and an H-index of 57. I also wrote a textbook on infrared astronomy.

Not mentioned above is my extensive technical work, which sometimes took up as much as half my time. Without advances in instrumentation, astronomy itself does not advance! Over the years I designed and largely constructed several infrared and other instruments, among which were photometers, spectrometers and cameras. I was even involved in updating the pointing and control system of the early SAAO telescopes to achieve quicker setting and greater pointing accuracy. When CCD detectors became available easily (the first system at SAAO was suppied by University College, London) I designed sensitive acquisition cameras for the 1.9m and 1.0m telescopes that made use of them. I also designed a CCD detector system for the 1.9m spectrograph. These devices had much higher quantum efficiencies, several times higher than the photoelectric tubes used up to that time. Of course, a lot of this work was in collaboration with the excellent technical staff at SAAO.

Fig 6. Infrared laboratory in the McClean building, ca 1985. [Photo: RM Catchpole].

As an individualist, I enjoyed working in a field where an individual or a small group could still build a piece of equipment, use it and write up the results. So far as infrared is concerned, the era of this type of astronomy has now passed and it is virtually impossible to avoid working as a member of a large team.

Fig 7. Dewar graveyard: Some of the camera and photometer cryostats that I designed, about the time I retired finally (2005).

In retirement I have worked on astronomical history, and have written several books. Themes that have interested me include the Grubb telescope company, the French astronomer N-L de La Caille who was the first serious astronomer to work at the Cape, Proxima Centauri and the history of the Royal Observatory, Cape. I have tried to encourage an interest in the history of astronomy in South Africa and further afield and also in saving and preserving such records and historical instruments as remain.