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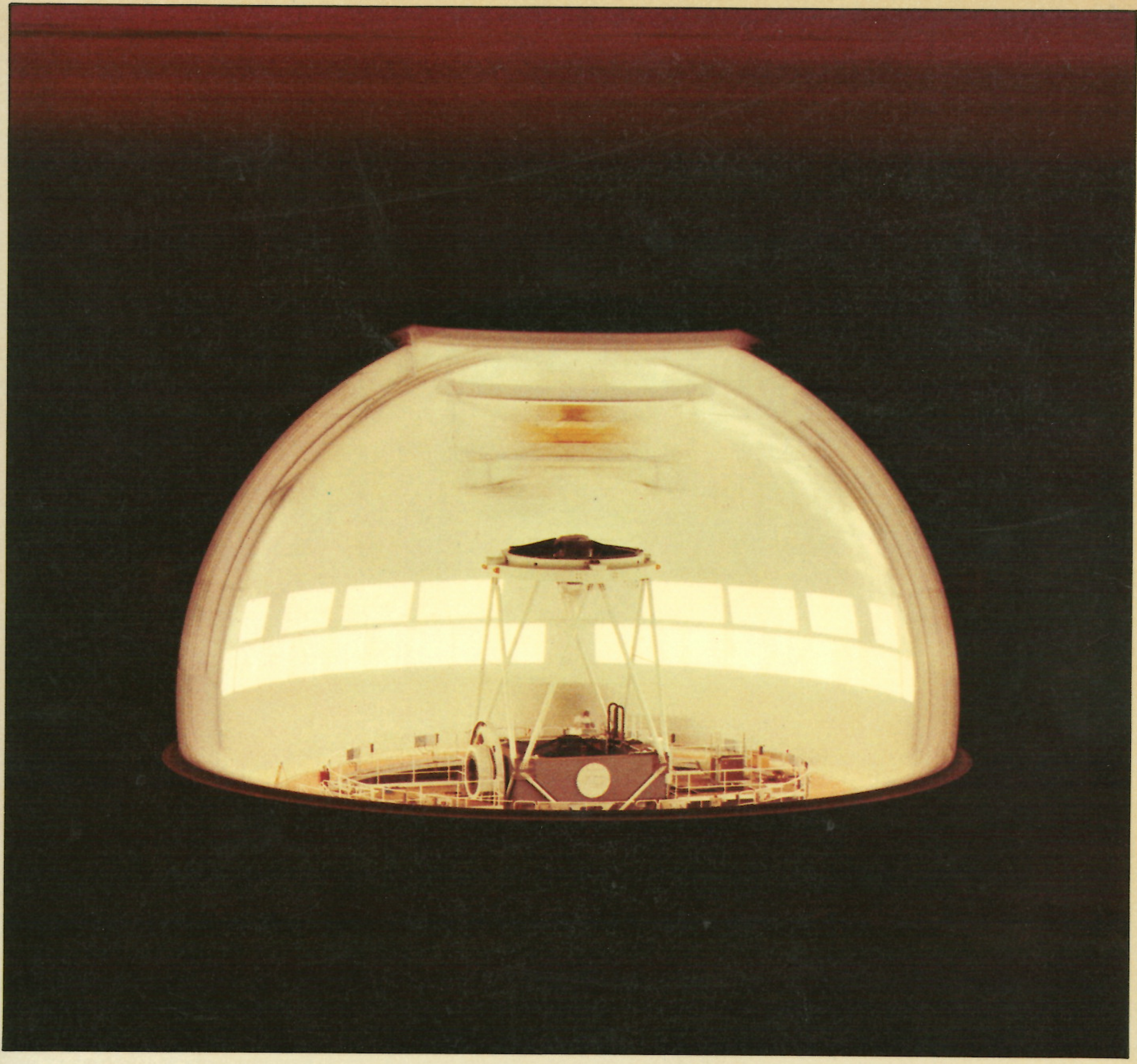

TELESCOPES INSTRUMENTS RESEARCH AND SERVICES

October 1 1985 – September 30 1987

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The William Herschel Telescope

The WHT, which is the third largest single-mirror telescope in the world, was completed in July 1987.

Telescope erection on La Palma

Installation of the telescope started in the autumn of 1985 when a part shipment containing the azimuth bearings and the hydraulic pumping system arrived on site from the UK. RGO staff who formed the installation team then started the critical job of installing the azimuth bearings and the plant. The bearings were then grouted in place by a contractor using a special epoxy grouting system designed to maintain maximum stiffness between the bearings and the concrete pier.

The major shipment of all the remaining telescope components including the drive system, mirrors and aluminizing plant was arranged for the spring. The M.V. Ston was chartered earlier because of the special facilities on the ship for lifting heavy loads. It sailed on 2 April 1986, arriving in La Palma eight days later. Pickfords then transported the major parts of the telescope, which totalled 350 tonnes, to site over the next four weeks. Some of the loads were very large, 6 × 8 metres and weighing 30 tonnes. These presented the haulage contractor with a number of difficult problems negotiating the very tight bends and steep gradients on the mountain road.

Installation started as soon as loads began to arrive on site and very good progress was made by the RGO team and its subcontractors during the rest of 1986. The installation of the cables and control room progressed in parallel, and commissioning using the telescope control computer started in March 1987. The mirror was aluminized in May and installed in the telescope shortly afterwards.

The azimuth and altitude bearings were the first major items to be commissioned and initial tests indicated that the design natural frequency of 4 Hz for the structure and bearings had been achieved in practice. This justified the careful mechanical design and analysis the RGO put into the telescope and eased the task of the servo control system and software design. Astronomers will like the accurate tracking, rapid offsetting and resistance to wind shake which this produces.

Primary and secondary mirrors

The Cervit primary mirror and its secondary met the full specification and they were completed by Grubb Parsons in time to be shipped with the telescope. The quality of the mirror is extremely good. The optical wavefront reflected from the mirror differs from perfection by only about one wavelength of visible light, peak to peak. The profile errors in the surface itself are, of course, half that, and the slope of the mirror surface has errors of only 0.04 arcsec root-mean-square on baselines of eight centimetres. The quality of this mirror will never limit the resolving power of the telescope, even in the excellent seeing conditions at the La Palma site.

Aluminizing plant

The plant was produced by Balzers of Liechtenstein who subcontracted the large vacuum vessel to Grazebrook Limited, a UK firm. The plant has been installed in the WHT plant room and the commissioning tests successfully carried out. During the aluminizing process, a total of 28 g of aluminium is evaporated, 4.4 g being deposited on the 13 m^2 surface of the primary mirror, to create a reflective surface 125 nm thick. The power consumption of the plant rises to 85 KVA for the 15 seconds duration of the evaporation stage. It is planned to re-aluminize the mirrors once a year.

Building and dome

The dome, which weighs 320 tonnes, was completed by the Canadian firm Brittain Steel in 1984. Large fabrications were assembled in Vancouver and shipped to La Palma where they were erected to form the ring girder carrying the transport system and the arch girder which supports the shutters and wind shield. The skin of the dome was fabricated on site from 6.3 mm steel plate and the wind shield and shutters were constructed from aluminium alloy. A 35 tonne crane, supported from the arch girder, is built into the upper part of the dome. This was used during the telescope construction; it will remain in place to remove the mirror for aluminizing and for telescope maintenance.

Astronomical commissioning

The real test of an astronomical telescope is how it performs when turned towards celestial objects.

The first stellar images were obtained at the Cassegrain focus during June 1987. Initially, there were problems with the support mechanism of the primary mirror; there were gas leaks and the electronic control system had faults. Another difficulty occurred with the mounting of the Cassegrain secondary mirror. However, by the end of July, after solutions to these problems had been found, good images had been otbained with integrating TV systems at both the Cassegrain and prime foci. At this stage, the pointing of the telescope was reliable to an accuracy of 5 arcsec (rms) over the whole sky and the tracking was good. Dome following was in operation with no noticeable vibration of the telescope.

It had been agreed that some astronomical observations would be undertaken as soon as the performance of the WHT fulfilled certain criteria. In this way, the later stages of commissioning would benefit through the feedback from astronomers using the telescope. Consequently, the new TAURUS II interferometer and IPCS II detector were mounted on the WHT on 12 August. On the morning of 15 August, the first complete TAURUS observation was made. The first observing run relating to a PATT application took place from 22 August to 7 September. This was for a programme called 'TAURUS observations of rotation curves, intergalactic gas and star forming regions'. Although the original allocation of three weeks was curtailed to two because of troubles with the dome shutter drive, much good astronomical data was obtained. The Principal Investigator, Dr E. A. Valentijn from the Kapteyn Astronomical Institute in Groningen, wrote a report entitled "The William Herschel Telescope is excellent" which described the pioneering TAURUS run.

For any large modern telescope, assembling all the hardware combined with writing computer software and testing the whole system is a complex operation. The first astronomical observations with the WHT were made after an encouragingly short time. Although many commissioning tasks remain, none of these appears to present a fundamental problem.

Michael Morris
October 1987

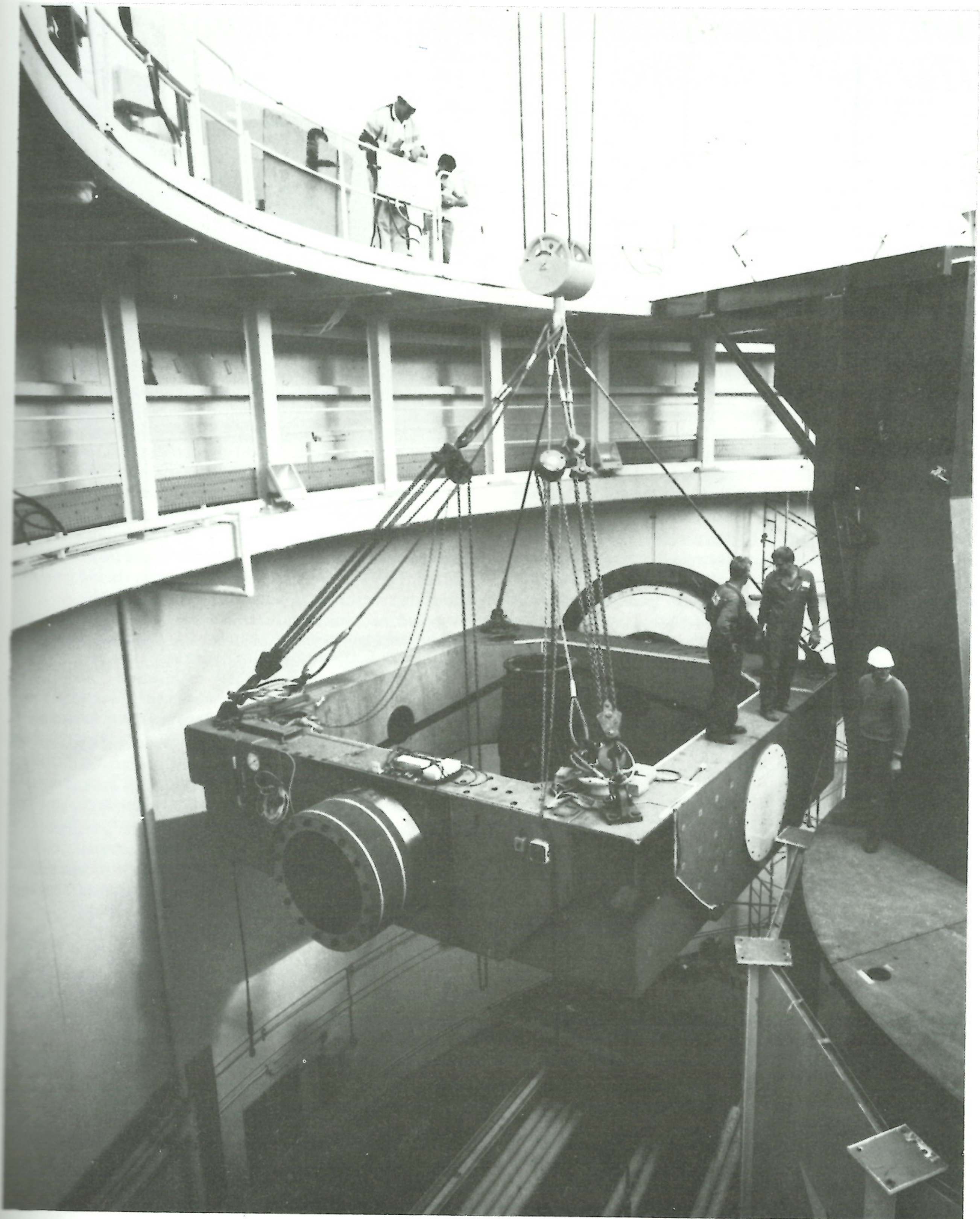


Fig. 1 The centre section of the William Herschel Telescope about to be lifted into position on the telescope forks. Note the altitude drive gear on the far side of the section.

The instrumentation system for the William Herschel Telescope

With the telescope now working well and the interim observing programme under way, attention must now focus on the final instrumentation system. A range of instruments and detectors together with their supporting infrastructure are being developed and constructed by the RGO in collaborations with universities and other groups both in the UK and Netherlands.

The instrumentation system will become progressively more versatile as individual components are completed. The interim package of instrumentation consists of TAURUS II and the Faint Object Spectrograph (FOS II). These use two stand-alone detectors: a laboratory CCD system, and the prototype CCD IPCS developed by UCL. The interim Acquisition and Guidance (A & G) Unit, which has been designed at the RGO, was manufactured under contract.

Acquisition and guidance facilities

The interim Cassegrain A & G Unit contains two probes: a manually retractable slit viewing system for use with the FOS, and a fixed probe for offset guiding for use with the FOS and TAURUS. Both systems feed a Westinghouse ISEC TV camera mounted on a slide to accommodate the differing focal plane positions. Simple, but effective, autoguiding has been implemented using error signals from the TV microprocessor.

The final Cassegrain Acquisition and Guidance Unit is more complex, containing:

A slit assembly.
An acquisition probe.
A calibration/comparison system which uses the reverse side of the acquisition mirror to allow simultaneous calibration of the first object whilst acquiring the second object.
A large feed flat for use with aperture plates and optical fibres.
A small feed probe to feed small instruments, for example a CCD camera at the position of the aperture plate.
An autoguider system.
Colour and neutral density filters.

The final A & G Unit wll have fully automatic control of its systems commanded by local microprocessors interfaced to the system computer.

The design of the mechanical components for the full A & G Unit is complete and manufacture is well advanced. The optical design has also been finished and various parts procured. Lenses and mirrors provide a choice of four different images on the TV used in this unit: the direct sky image, the slit field of the spectrograph, and each of these at a reduced scale for field viewing. The focal reducers are parfocal so that the focus adjustment at the TV camera when changing images (which does not disturb the telescope in any event) is very small and hence fast. This is achieved by the use of a relatively weak lens which converges the f/11 beam to an intermediate focus, followed by a small 1:1 relay lens which places the f/4 focus at the same position as the f/11 focus. This configuration leads to an aberration-corrected design. Other optics provide for a comparison lamp source, correctly imaged to simulate the telescope over a wide field, and for the image used by the autoguider.

The autoguider detector is to be a Peltier-cooled CCD. Experiments have been carried out to determine the degree of cooling necessary and the noise performance achievable from a Peltier-cooled CCD as these limit the performance of the overall control system. It has been determined that a two-stage cooler is necessary, and that a readout noise of around 15 electrons rms is possible with GEC CCDs. However, some chips have been found to have a large temperature-dependent l/f noise that makes them unsuitable for Peltier-cooled applications. Careful selection of devices is therefore necessary in this application. A prototype head has been designed, manufactured externally and tested. Tracking an artificial star has been demonstrated.

To minimize thermal effects arising from the Peltier cooler and the other heat-generating components within the autoguider region of the unit (~ 50 W), the lower section of the A & G case is partially sealed and fan ventilated to within 1.5°C of dome ambient. A local glycol radiator is being considered to reduce further this temperature difference.

The TV finder, a squat tube supported on a small Serrurièr truss structure, will be mounted on the top face of the main telescope centre section. It is a Cassegrain system of effective focal ratio f/6.5 with a 40 cm aperture f/2 main mirror. The Westinghouse ISEC TV camera should provide integrated sensitivity to better than 17th magnitude. A proposed mechanical and optical design is finished, and contracts for construction are to be placed. The assembly should be complete by the middle of 1988.

ISIS and FOS II

The ISIS (Intermediate dispersion Spectroscopic and Imaging System) triple spectrograph is currently under construction at the RGO in collaboration with the University of Oxford. ISIS is an extremely versatile instrument, and in particular the slit area is extremely complex, requiring a high degree of engineering precision. It includes an anamorphotic lens system, the slit components themselves (providing long slit, multislit or fibre-optic facilities), dekker and filter assemblies and polarization slides. A large percentage of the components in the slit has been manufactured in the RGO workshops and is ready for integration with the control electronics. ISIS has two camera systems of similar format each with a focal length of 50 cm. The 'red' camera is optimized for use with a CCD, and the 'blue' camera for use with the IPCS. The camera components are currently being manufactured at RGO, and an optical test bench has been assembled.

Further finite-element analysis has been carried out on the main ISIS structure, the camera components and the collimator. Installation of the SAP80 finite-element analysis programme on the IBM PC/AT at RGO has allowed a finer mesh to be used, and for the mathematical models to be refined in relation to the previous finite-element analysis programs running at the Rutherford Appleton Laboratories. The main support structure, the collimator extension and the ISIS handling system have been manufactured under contract, and the Oxford University workshops have manufactured some smaller components including the collimator assembly, slit alignment, cross dispersion units and Hartmann shutters. By the end of 1987 it is planned that individual assemblies will be undergoing tests on the telescope simulator at the RGO.

FOS II, the Faint Object Spectrogaph, is a joint project between the RGO and Durham. The project was accelerated to provide spectroscopy on the WHT in 1987 and 1988, and FOS II and its interim support structure (which will later be

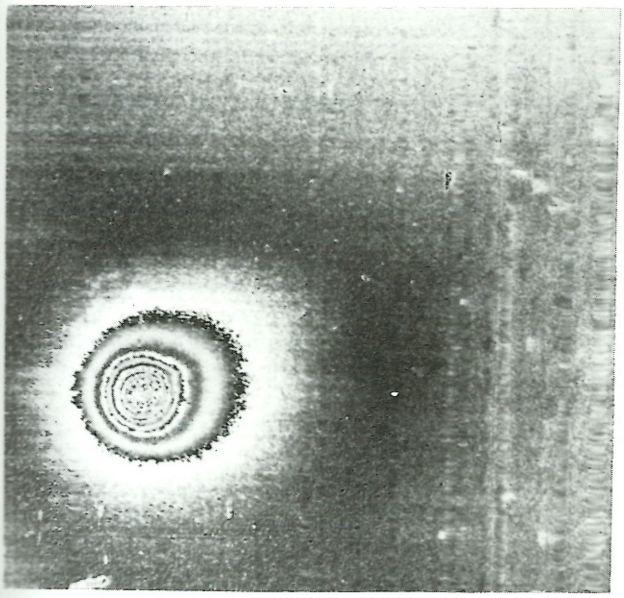


Fig. 2 An image of Comet Halley taken on the 36-inch telescope at Herstmonceux using a GEC MA703 (1500 × 1500 pixel) CCD.

replaced by ISIS) are being commissioned on the telescope in September and October 1987. (Some aspects of the optical design of FOS II and other WHT instrumentation are discussed elsewhere in this report in 'Optics at the RGO'.)

Extensive work has continued on both solid-state detectors with analogue readout (CCDs) and photon-counting area detectors. Although of lower quantum efficiency, the latter have an important part to play in observations where time variations and absence of readout noise or thresholding effects are important. Work on these detectors is described in the next two sections. Most of this research has important implications for other WHT instruments in addition to ISIS.

CCDs

The supply of small CCDs remains a problem although the situation has eased somewhat with the opening of the new production line for GEC CCDs at EEV in Chelmsford. The first devices received from this line were extremely good, having virtually none of the low light level traps which were a feature of devices produced at the Hirst Research Centre, and showing much better charge-transfer efficiency. Unfortunately, EEV later encountered production difficulties and were unable to make any working devices for several months. These problems now seem to have been solved and further chips have recently been received. With standard CCD chips, most of the blue and ultraviolet radiation is absorbed by the electrodes before reaching the photon-detecting region. To overcome this disadvantage, chips can be thinned and illuminated from the 'back'. A contract with EEV, funded jointly by the AAO and RGO, to produce a thinned blue-sensitive version of the P8603 has continued. Although working devices with enhanced blue sensitivity have been produced, the project has been delayed by a lack of CCDs with which to experiment and there still seem to be difficulties in getting the devised procedures to work reliably. The project is therefore still some way from completion.

An alternative way of getting blue sensitivity is to coat a thick CCD with a mixture of fluorescent laser dyes. The techniques to do this have been developed at ESO and they have now coated several chips for the RGO. These have been tested in the RGO photometry laboratory and found to have a very useful UV and blue response. One device was also measured at ESO and this has allowed a comparison of our photometric standard to be made. It is hoped that in the near future FOS I, FOS II, the IDS and the JKT will all be equipped with coated GEC chips of high quality.

Tektronix are still having difficulty in producing astronomical grade CCDs. Two small (512 × 512 pixel) set-up grade devices, one thick and one thinned, have been received and tested but these are not sufficiently good to be astronomically useful. A top-grade device is still awaited and production of the large (2048 × 2048 pixel) devices is not being attempted until the problems with the small devices have been solved.

Several CCDs from Thomson-CSF have been tested. These are similar in format to the GEC devices but use four-phase clocks which in principle can provide better charge-transfer efficiency. Their performance is very similar to that of the GEC devices except that they have a threshold of about $300e^-$. A recent design modification by Thomson is said to have overcome this threshold effect but none of these new devices has yet been bought or tested.

Thomson are engaged in two development programmes which may be of future interest. The first is to produce a buttable version of their standard small device. A pair of chips will be able to be butted together on one of their short sides to give a 2 chip 'building block' which can be extended to a 2 × n array by further butting on the long sides. The second project is a large (1000 × 1000 pixel) monolithic device. Both these programmes are being partially funded by potential customers but they will also become available, albeit somewhat later and at a higher price, to those who have not sponsored the development.

The involvement of the RGO in the AAO-funded large (1500 × 1500 pixel) GEC CCD development is now over. The fourth and final batch contained several working devices but only one of these had sufficiently good charge-transfer efficiency to be useful for astronomy, and it was fairly poor cosmetically. Most of the devices have now been sent to the AAO where they are considering using this 'good' device on the AAT if they can overcome the problem of the silicon breaking away from the CCD package, which has occurred in several of the devices they have run.

CCDs are no longer being made at GEC's Hirst Research Centre and the new production line at Chelmsford is not capable of making a device as large as 40 × 40mm. However, funding approval has just been obtained for the development of a 30 × 10mm 'spectroscopic' CCD by GEC, and this project has a much greater chance of success for the following reasons. The active area of this CCD ($3\,cm^2$) is much less than that of the (1500 × 1500 pixel) chip ($16\,cm^2$) and the production yield of CCDs is a strong function of their area. The production line at Chelmsford is modern and dedicated to CCD production unlike the old, general purpose facility at Hirst Research; finally, payment will only be made if the devices meet an agreed specification.

The new-generation CCD controller for the 4.2m WHT is being developed in a collaboration with NFRA, Netherlands. The overall design is nearly complete and most of the circuits have been constructed as prototype PCBs. Tests to confirm that the data from an array of CCDs, all driven, read out and digitized to 16 bit accuracy from one controller, have proved successful. The final prototype system is due for delivery in December 1987. A fibre optic data link to transfer the data at high speed from the telescope has been installed and commissioned. An interface to accept the data from an array of CCDs (being read out at the same time) and to transfer them into a VME system has also been completed and commissioned.

Photon-counting detectors

Production of the electronics of the engineered version of the CCD IPCS is nearing completion at UCL. Successful tests of the UCL prototype have been carried out on the INT Intermediate Dispersion Spectograph (IDS). It was also the detector used on TAURUS for the first successful observing run on the WHT in August/September 1987. Plans have been made to use it on the Manchester Echelle, also on the WHT, later in the year. The new CCD IPCS shows improved detective quantum efficiency and resolution over the plumbicon readout IPCS I.

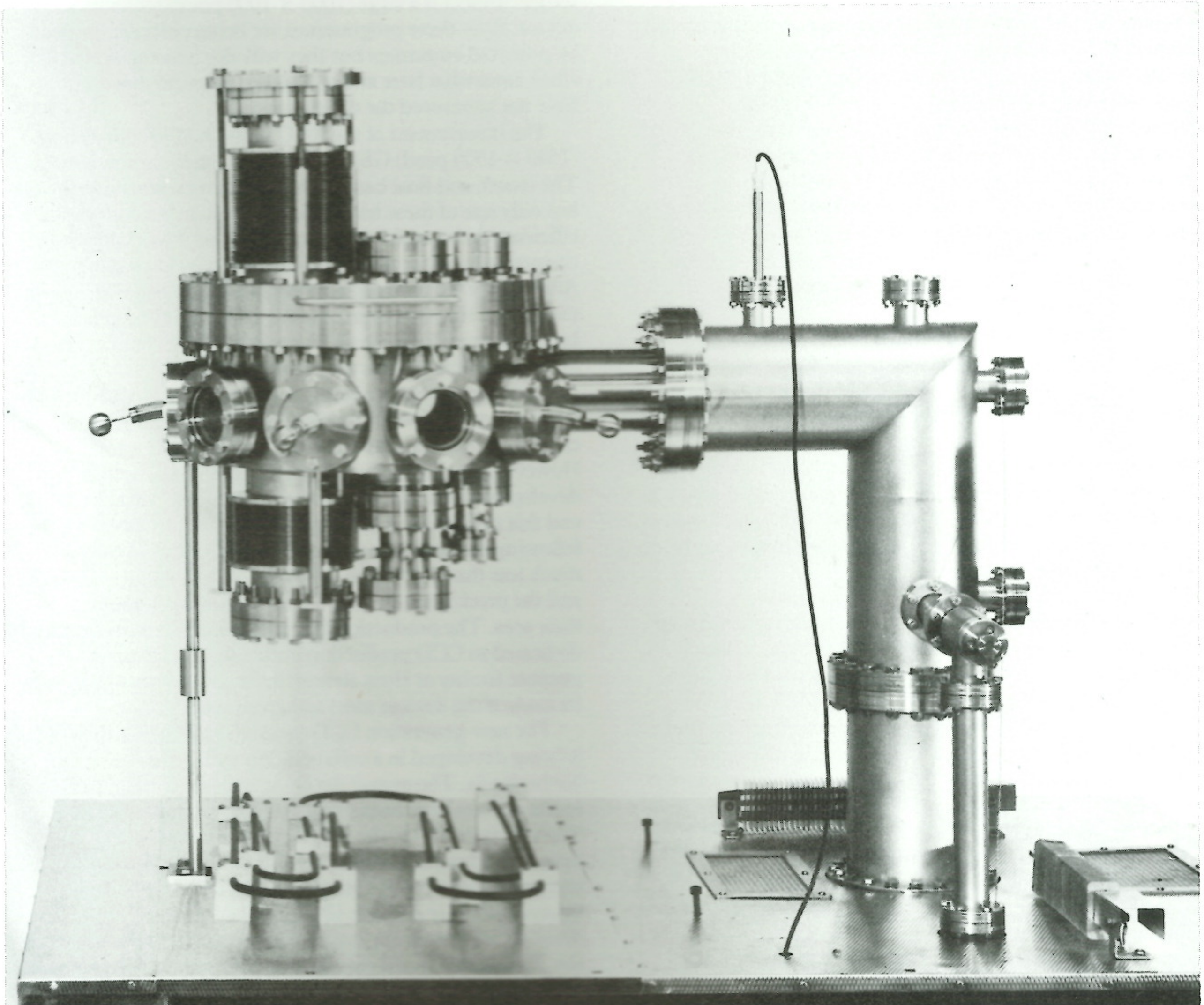
The collaboration between RGO, Imperial College and Instrument Technology Ltd continues on the development of a 40 mm microchannel plate intensifier. This collaboration now also involved UCL, whose CCD IPCS prototype has proved invaluable for two-dimensional imaging tests on completed intensifiers. Despite limited funds, the report period has been particularly successful for the project. Two astronomically usable tubes have been produced on the RGO-funded processing chamber at the ITL factory in Hastings. This chamber allows two cathodes to be made for each intensifier and the better one to be selected while still under vacuum. Removal of field emission points can be carried out during processing by high voltage cathode spot knocking. During manufacture, the microchannel plates must be scrubbed to remove residual gases from the glass substrate. This process is monitored both in terms of the gases released and the pulse-height distribution of events seen at the phosphor. From this, it is possible to establish the correct optimisation between gain and cleanliness. This leads to optimum lifetime characteristics.

The tubes have been tested both in the laboratory and on the 30-inch telescope at Herstmonceux. The following are the most important results:

(i) A resolution of 33 microns full-width half-maximum resolution has been achieved across the full 40 mm field. Further improvements are expected in the future.
(ii) A gain of 10^7 photons per event with no optical feedback from the phosphor is typical of both devices.
(iii) Differential event pulse-height distributions show a peak to valley ratio of 3:1, indicating space charge limited operation of the channel plates.
(iv) On the first tube, the red sensitivity at 8000 Å has dropped by only a few percent over a period of eight months of extensive testing. The second tube, which benefitted from results with the first tube, has shown no loss of sensitivity over a period of four months.

These results show that we now have the capacity to produce an astronomically usable tube with good resolution, efficiency and lifetime.

Fig. 3 The production chamber for 40 mm diameter cathode microchannel plate image tubes.



Other instrumentation

TAURUS II is a wide-field imaging Fabry-Perot interferometer which has been built in collaboration with the Kapteyn Sterrenwacht Werkgroep in Roden, The Netherlands. It is designed for multi-object work and can accommodate a number of dedicated aperture masks. Like other instruments on the WHT, the instrument is fully microprocessor controlled allowing, for instance, remote selection of an aperture mask or one of the four etalons. Each etalon can be remotely and independently tuned to a defined frequency passband. Two TAURUS II units have been produced, one for the AAT and one for the WHT. Both have been successfully commissioned, and the WHT version was used during August 1987 for the first PATT-allocated observing session on the new telescope. This session was extremely successful.

The Utrecht Echelle Spectrograph (UES) is being designed and manufactured at the University Observatory at Utrecht, under a contract placed by RGO with the Netherlands Foundation for Radio Astronomy. A formal specification was issued in May 1986 and at that time design work was already well under way.

The instrument is intended to be similar from the astronomer's viewpoint to one being produced for the Anglo-Australian Telescope by a team at University College London. It is hoped that this similarity will be beneficial in the use of the spectrographs and data reduction as well as in the production phase. The two groups are working closely with each other and with RGO.

The role of the RGO optics group in these two projects has included the design of the spectrograph cameras (700mm focal length). Also, jointly with UCL, the group has selected and tested material for the large cross-dispersing prisms; nine wedges of optical grade fused silica are to be assembled into three 54° prisms with 30cm base width and 15 cm apex length. All the optics, including the echelle and the optical table for the UES, are being procured by RGO.

Optical coating for the large optics in both the AAT and WHT instruments is being carried out at RGO. This has involved the design of special supports for these exceptionally valuable items in a planetary gear which ensures uniform coating thickness.

An acquisition and guider facility is to be produced for the UES. The integrated instrument will be mounted at the drive-side Nasmyth focus of the WHT and is due for commissioning during the first half of 1989.

In June of this year the Joint Steering Committee approved the Ground-based High Resolution Imaging Laboratory (GHRIL) for installation on the non-drive side Nasmyth focus. It is hoped that the facilities that it will include are a large optical table, an environmental enclosure, a detector and data acquisition system, a link to the on-site data-reduction VAX and an integral optical alignment facility.

Infrastructure

The Utility Network forms the backbone for communications between the system computer and the microprocessor controlled instrument. The hardware conforms to the IEEE802.3 Ethernet specification; the local area network (LAN) with a bandwidth of 10 Mbit/second can support up to 1024 nodes spread over a total distance of more than 2.5km. All units on the WHT will initially interface to the Utility Network via 4-port asynchronous concentrators, manufactured by Sension Ltd, Cheshire. The network protocols conform to International Standards at the lowest two layers, and support an in-house 'transport' layer.

The procurement and testing of the network hardware has now been completed. The message protocol has been developed and tested in Forth, and is currently being implemented in Fortran on the VAX. During August 1987 the first part of the network was commissioned on the WHT, allowing communication between the FOS microprocessor and the interim CCD VME system. A Detector Memory System is being produced at RGO for use with both IPCS II and CCD detectors. The system is based around the high performance VME bus and uses the 32bit 68020 microprocessor running a Forth system. Its main functions are to collect data from either of the detector systems, to store that data in a large (probably 32 Mbyte) VME semiconductor memory, to display the raw data on a high-resolution colour monitor, and to transfer the images to the system computer for data reduction. The detector memory system will also provide a fast and efficient means of image assessment. In particular, it will enable an IPCS image to be displayed as integration proceeds, and CCD images to be manipulated with simple image-cleaning functions.

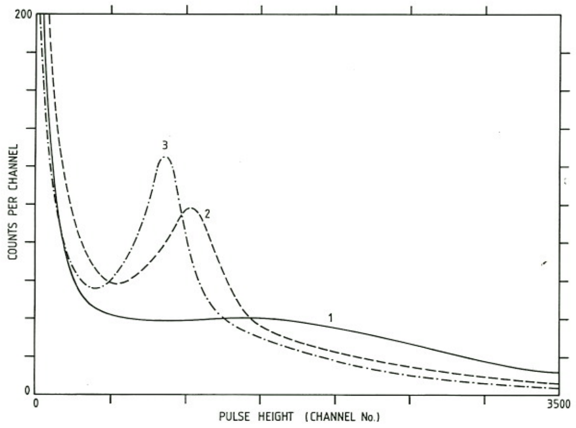
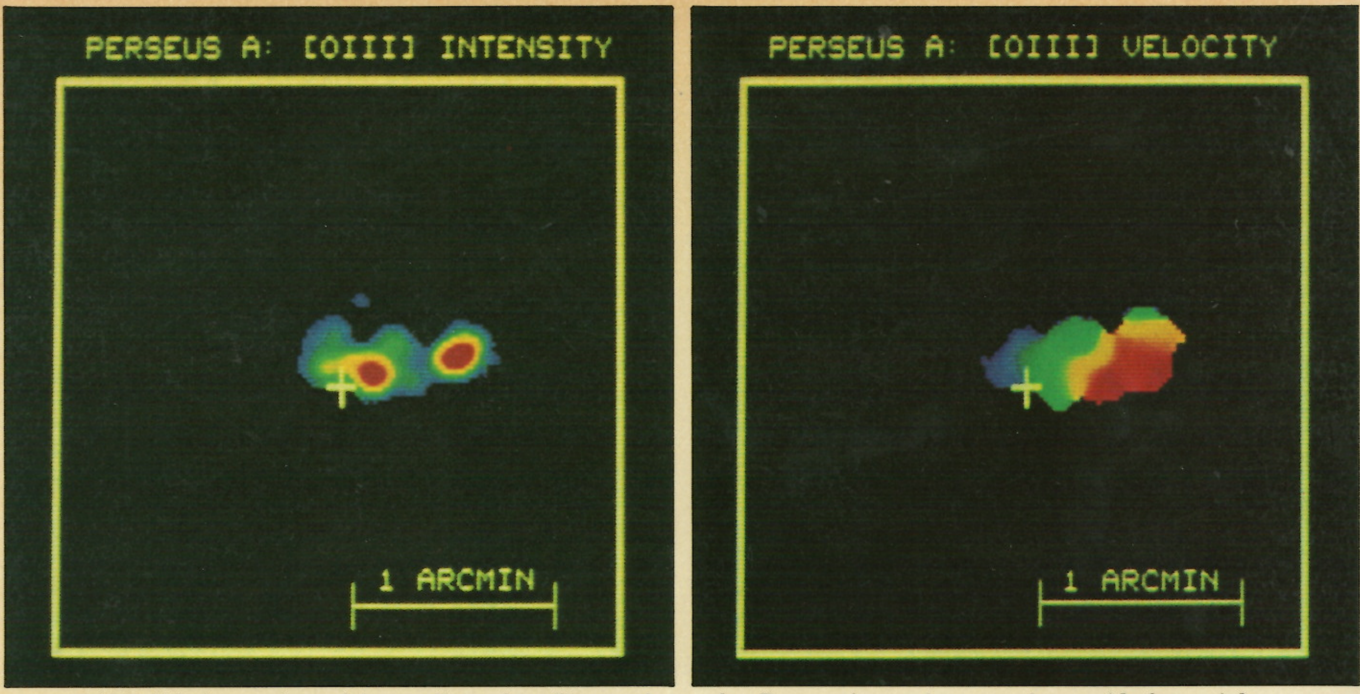


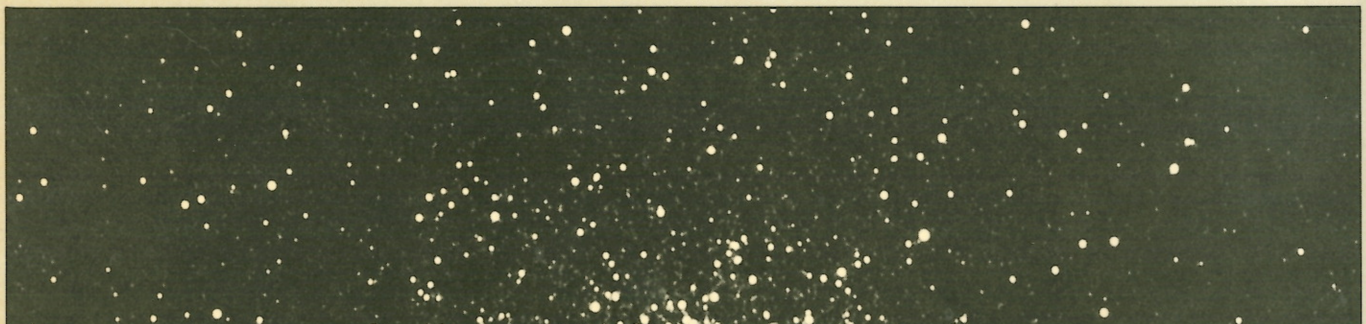
Fig. 4 The pulse-height distribution for a microchannel plate during scrubbing in the processing chamber. Note the decrease in gain and improvement in shape of the distribution as scrubbing proceeds. The sharper the maximum, the easier it is to discriminate between true signal pulses and signal-induced noise.

The hardware for the VME system consists mostly of individual VME boards purchased from a variety of manufacturers. The integration of these into the Detector Memory System is complete. In addition a high speed detector interface (DICI), common to both IPCS and CCDs, has been developed at RGO. It utilizes bit-slice microprocessors to enable it to carry out windowing the paging of IPCS Images 'on the fly' at up to 200KHz or to accept and sort pixel data from multiple CCDs simultaneously.

Michael Morris
October 1987



TAURUS observations of the peculiar galaxy Perseus A show a twin peaked intensity distribution of gas and its graded orderly velocity field. These results from the first scientific observations with the Herschel Telescope imply that Perseus A contains a rotating toroid of material, whose origin is obscure, but is presumably connected with the extraordinary nature of the radio galaxy.



The globular cluster M13, in a plate obtained at the Cassegrain focus of the Herschel Telescope to test image quality. At the crowded centre and on the fringes of the cluster, the star images are as good as expected.

Front cover picture. *The 4.2m William Herschel Telescope in its dome at night. The dome has been made to "disappear" in this time exposure by rotating the open shutter of the dome across the telescope, lit up inside.*