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SPECIAL FEATURES

REGULAR FEATURES

THIS ISSUE

We are delighted to welcome John Isles as a regular contributor to *Astronomy Now* in the first of his 'Variable Star Scene' columns. John is a well-known variable star observer, now based in the sunnier climes of Cyprus, a location envied by many of his British colleagues. Another experienced amateur and reknowned astrophotographer, Michael Maunder, recounts his preparations for the total solar eclipse last March - his sixth to date. Other reports from the Far East are also included.

Amateur astronomers often wonder what it would be like to take up their hobby as a profession. Dr. Paul Murdin, who started out as an amateur, recounts his experiences on a recent observing run with the William Herschel Telescope on La Palma. We also welcome Professor Arnold Wolfendale to our columns with a feature on that most elusive of modern cosmological problems, the search for anti-matter in the universe.

As always, there is the usual selection of regular features, including details of astronomical objects on view this month.

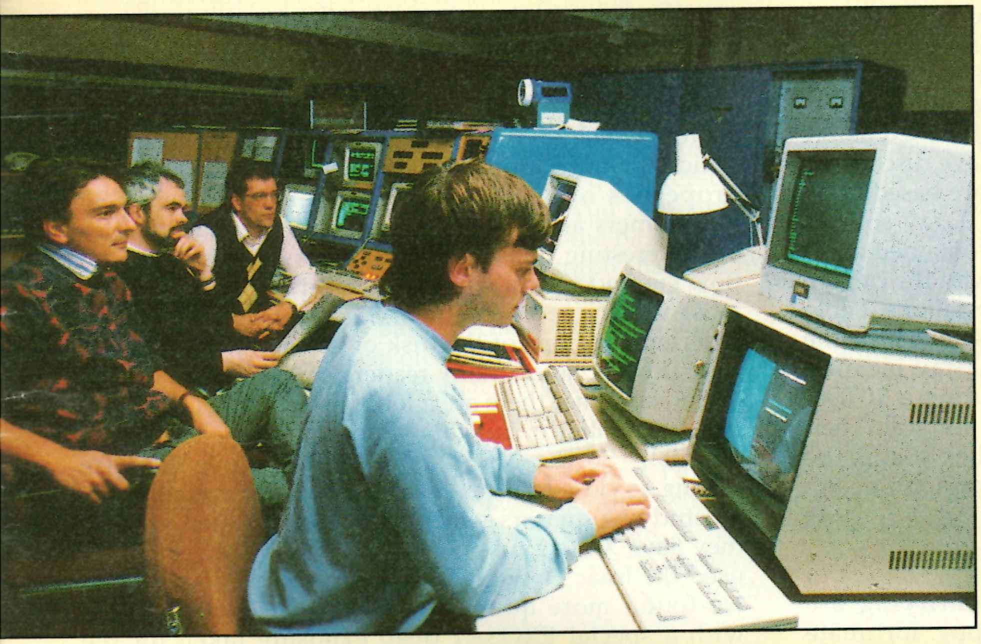
Cover Illustration: Scorpius, the Scorpion, is a magnificent constellation, and is particularly well placed during June. Unfortunately, it is rather too low in the southern sky for British observers to see it well, but from sites south of the equator it is a splendid sight. This photograph, taken by Australian observer Michael Toms on Fujichrome 400 film, shows the region from the Scorpion's 'sting' through to the lovely open cluster M7 (left). The exposure time was 15 minutes using an f/3.5, 135 mm telephoto lens guided to follow the stars. The brightest star of the sting is Shaula (Lambda Scorpii), with the rather fainter Upsilon Scorpii close to it marking the tip of the sting itself. The line of the Scorpion's tail is shown by the two stars Kappa and Iota Scorpii, which are below and to the right of Shaula in the picture.

SPECIAL FEATURE

A Night On The William Herschel Telescope

PAUL MURDIN

The newly commissioned 4.2-metre (165-inch) William Herschel Telescope on La Palma is now in full operation, and is proving to be as good as any in the world. Already it is being used to make new and exciting discoveries. Here a top professional astronomer gives a fascinating first-hand account of a night's observing with the telescope



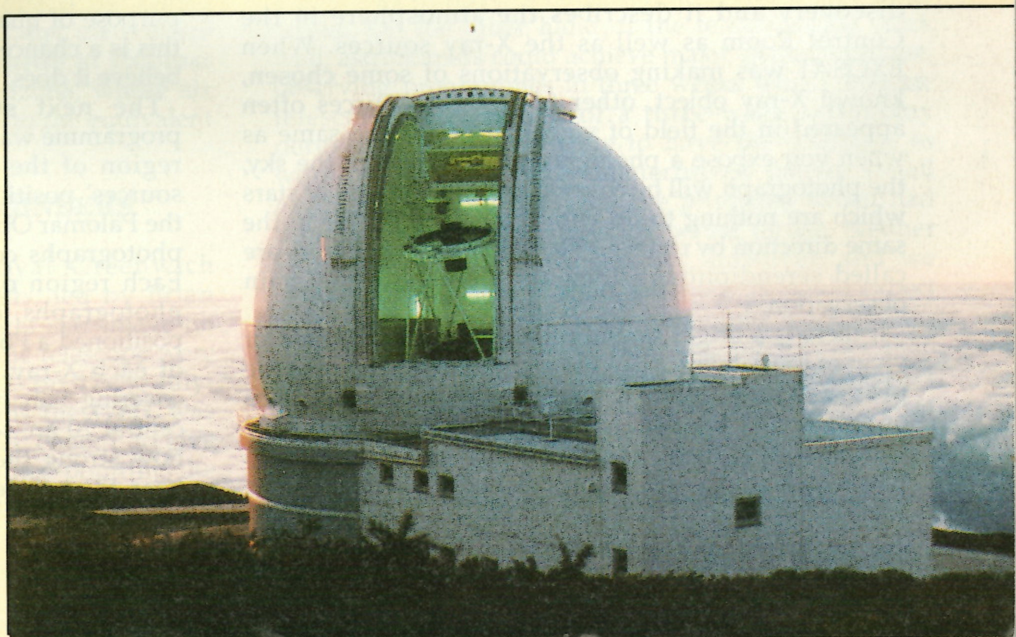
Above: *Panoramic view of the Roque de los Muchachos Observatory on La Palma. From left to right can be seen: the rectangular building of the Carlsberg Automatic Meridian Circle, the dome of the William Herschel Telescope, the domes of the Isaac Newton and Jacobus Kapetyn telescopes, and the Swedish Solar Tower.*

Left: *In the Control Room of the William Herschel Telescope are (left to right) Paolo Giommi, Jeremy Allington-Smith, Paul Murdin and Jon Mittaz. Jon operates the Faint Object Spectrograph, and is looking at a spectrum produced by the instrument.*

All photographs in this article courtesy of the Royal Greenwich Observatory and Keith Mason of Mullard Space Science Laboratory.

Right: *With the cloud deck below looking like a frozen ocean, the open dome of the William Herschel Telescope glints in the light of the setting Sun.*

Facing page: *Northern circumpolar star trails over the dome of the 4.2-metre William Herschel Telescope, situated at an altitude of 2,400 metres (7,870 feet) above sea level at the Roque de los Muchachos Observatory on La Palma.*



A NIGHT ON THE HERSCHEL TELESCOPE

PROLOGUE

I am writing this article in the Control Room of the William Herschel Telescope on the island of La Palma in the Canary Islands. It is the middle of the night of 1988 February 12/13, and away to my left is the control desk. On the TV monitor screen is the image of a faint star. The telescope has been tracking the star for the last half an hour, and the image of the star's spectrum has just appeared on a colour display. The astronomers in the Control Room drop their papers and converge excitedly around the display.

Jeremy Allington-Smith squats down and peers at the screen: "It's certainly got emission lines," he announces. The astronomers all turn to the data reduction display and Jon Mittaz pecks furiously away at the keyboard. A third display unit flicks into life. 'FAINT OBJECT SPECTROGRAPH', it says, 'Flux in micro-Janskys', 'Wavelength in Angstroms'. A graph springs onto the screen, showing enormous spectral lines. The blue star is obviously a quasar. The tension of anticipation relaxes and the astronomers are obviously pleased with their discovery of a quasar which no-one has ever seen before. But what is its red-shift? The identifications of the lines, the wavelengths at which they appear and the red-shift all have to fit in a consistent story. Keith Mason gazes abstractedly at the spectrum and consults a list of spectral lines. "I don't understand all that mess in the middle, but if the big one on the left is magnesium-II, and the big one on the right is H-beta with oxygen-III beside it, then the red-shift is 0.8," he says; "what are the wavelengths of the Fe-II lines?"

Paolo Giommi and Gianpiero Tagliaferri exchange grins: this is the 24th quasar which we have discovered in six nights' use of the WHT. Our data are based upon their measurements of the positions of X-ray sources with the EXOSAT satellite. The satellite contained an X-ray sensitive camera and pictures taken with the camera are the ones analysed for X-ray source positions. Paolo and Gianpiero have had to make assessments of the reality of the faint X-ray sources in the X-ray pictures. Twenty photons from a faint source during a 10,000-second exposure with the satellite is not atypical. Their assessments are turning out to be reliable and the positions which they measured are proving accurate.

SERENDIPITY

The X-ray sources which we are identifying are 'serendipitious'. The word means a happy, fortunate discovery and it describes the atmosphere in the Control Room as well as the X-ray sources. When EXOSAT was making observations of some chosen, known X-ray object, other faint X-ray sources often appeared in the field of view. (It is just the same as when you expose a photograph to a galaxy in the sky, the photograph will be covered with the images of stars which are nothing to do with the galaxy but lie in the same direction by chance.) These faint X-ray sources are called serendipitous - they are a bonus to the main observation.

If there is a bright serendipitous source in the field of view of the satellite, then the astronomers who take the picture usually follow it up, but they do not recognise or bother with the faint ones. Paolo and Gianpiero have been analysing these. They are Italian astronomers who work at ESTEC, the technical headquarters of the European Space Agency, based at Noordwijk in the Netherlands, where the EXOSAT observatory now is. The collection of images which EXOSAT took in its three-year lifetime are archived there, and Paolo and Gianpiero have developed programmes to analyse the archive images to look for serendipitous sources.

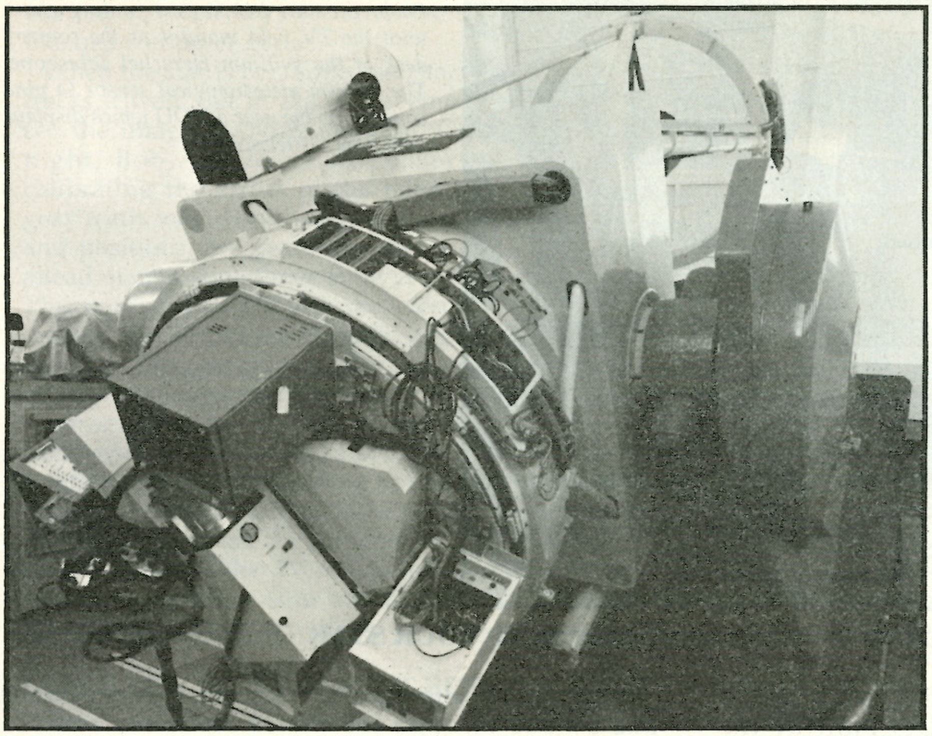
Once you determine the existence of an X-ray source, it is natural to want to find out what it is. It could be a white dwarf at a distance of about 100 light years, or alternatively it might be a quasar at 1,000 million light years. It could also be a more normal galaxy, somewhere in between. Identifying the sources by finding their optical counterparts is clearly essential.

SOME DETECTIVE WORK

Foggy ESTEC lies on the coast below sea-level and is over-shadowed by a large and, one hopes, strong dyke, on the other side of which is the North Sea. From there the story moved to the Mullard Space Science Laboratory, in a country house on a hill-side in Holmbury St. Mary, overlooking the Surrey countryside in southern England. It is part of University College, London, where Keith Mason leads a group of astronomers studying X-ray sources. Jon Mittaz is a graduate student there. Keith and his colleague Graziella Branduardi-Raymont (with the two of whom I have enjoyed working for 15 years), arranged a collaboration with the ESTEC astronomers to identify the EXOSAT sources.

The motives of the two groups are not quite the same. The ESTEC astronomers want to classify all the X-ray sources which they are finding with EXOSAT, using the optical identifications. This helps them determine the properties of X-ray sources in general. The MSSL astronomers are using the X-ray characteristics to pick out interesting quasars. EXOSAT was sensitive to soft (low energy) X-rays which, in quasars, according to the most widely accepted theory, come from the heated innermost regions of the disk of gas accreting onto the central black hole. (Many readers of this magazine will understand that there are a lot of assumptions built into this last sentence, but this is not the article to go into details!) So the MSSL astronomers think they are getting as close to black holes as they conceptually can, by studying quasars which have been selected because they have X-ray emission. When Keith, Graziella and I used the Isaac Newton Telescope a couple of years ago we found more quasars than we expected, working with a special EXOSAT deep exposure taken for the purpose of quasar-hunting, and we want to find out if this is a chance result, or has the significance which we believe it does.

The next step in the EXOSAT identification programme was to chart the stars which lie in the same region of the sky as the X-ray sources. The X-ray sources' positions were superimposed on prints from the Palomar Observatory Sky Survey (POSS), an atlas of photographs covering the whole of the northern sky. Each region of the sky is represented by a pair of photographs, one red and one blue. Jon accurately positioned a Polaroid camera on the precise coordinates of each X-ray source and took pictures of the area, covering 5 arc minutes. The X-ray source lies within the central 20 arc seconds or so - the accuracy depends on how strong the source is, and whether its image lay near the centre of the field of view of the EXOSAT



The cluster of instruments at the Cassegrain focus of the 2.5-metre Isaac Newton Telescope at the Roque de los Muchachos Observatory. It was with this telescope that Keith Mason, Graziella Branduardi-Raymont and the author found more quasars than expected a couple of years ago, when using a special EXOSAT exposure taken for the purpose of quasar hunting. The recent work on the Herschel Telescope was organised to establish whether this has some significance or if it was just a chance result.

camera, or off to the side where there are distortions. Usually there are several stars and galaxies in the central area of each X-ray source position. At most, only one of these is the optical counterpart of the X-ray source.

One initial clue as to which is the true identification is the colour of each star. X-ray stars are often quasars or white dwarfs - and these are blue. Blue stars are rare; most stars are cool and yellow, or red - interstellar reddening only makes stars redder. If you compare the blue and red photographs of the pair, the blue stars are relatively stronger in the blue photograph than the red stars; conversely, the red stars are stronger in the red photo. Keith and Jon paid special attention to any blue stars which they discovered in the region of the X-ray sources, in the expectation that the blue stars were the prime candidates for the X-ray source identifications.

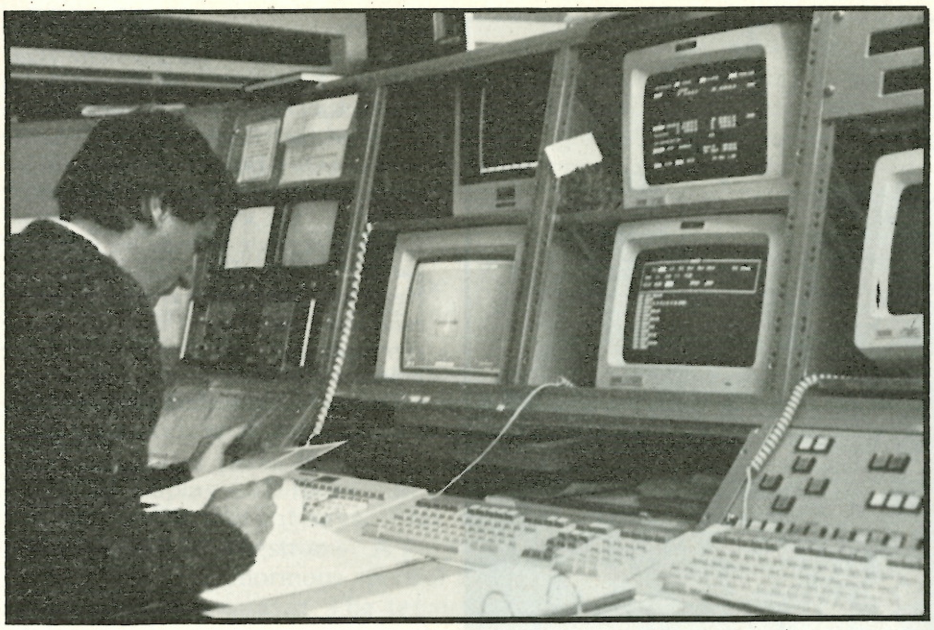
The blue colour is indicative but is not enough. What is really needed is the spectrum of the stars. However, the stars are faint - a typical quasar identified this way is 18th magnitude and some are as faint as 22nd magnitude. Only the biggest telescopes can take spectra of stars this faint. And that, of course, is where the William Herschel Telescope (WHT) comes in. With its 4.2-metre mirror, the Herschel telescope is the fourth largest optical telescope in the world, after the 6-metre telescope at Zelenchukskaya, the 5-metre at Palomar and the Multi-Mirror Telescope in Arizona, whose six smaller mirrors sum in collecting area to the equivalent of a single 4.5-metre mirror.

A COMPROMISE WITH THE ENGINEERS

The WHT was completed by Royal Greenwich Observatory engineers and scientists, led by Brian Mack, in June 1987, seeing its first-light star image on the first of the month. Full details of the telescope were given in *Astronomy Now* Vol 1, No.2, pp 17-25, July-September 1987. Within three months the WHT was operational, with its optics aligned well enough to give round images, and its control computer pointing the telescope with sufficient accuracy to pick out a given star and track it well enough to keep the star on the telescope axis. It is unusual to get a telescope of this complexity commissioned so fast, but this was a deliberate policy of the RGO Director, Alec Boksenberg. The WHT is a scientific instrument, intended to generate science. The aim was to get astronomers using the telescope as quickly as possible, so as to get the most out of it at the earliest opportunity. Moreover, it is not necessary that everything has to be there on day 1; if the telescope does some basic things, like point and track, with good images at one focus, then the additional functions can be added later. At the same time, a complex telescope takes up a lot of tuning up. It is even the case that - I am obliged to make an admission which will not astonish anyone - some things do not work first time. Engineers need access to the telescope to complete it over the next year, at least. So a balance has to be found between astronomy and engineering.

For the WHT the plan for the first year was like this: some groups of astronomers were to be allowed to use the telescope for periods of three weeks. This is a long time to observe, and at RGO we thought that, given this amount of time, astronomers would be tolerant if not everything worked well throughout the whole three weeks. On the other hand, if the telescope did work well, astronomers could achieve major, perhaps unique, observing programmes in three weeks with a 4-metre telescope. At the end of a three-week astronomy period, the engineers were to have the telescope to work on, getting a long, uninterrupted time to install new features, and really fix the problems which had been identified in the previous period of use. Neither side was to have it exclusively, however, and we cautiously estimated that the astronomers would expect to spend half their time on commissioning work.

Actually the plan has worked out much better than we expected, and the telescope has come together remarkably cleanly. By August 1987 the first instruments were being installed on the telescope. These were chosen to be the ones which were most tolerant if the telescope was not performing well.



Paolo Giommi compares a finding chart with the TV field monitor at the control desk of the William Herschel Telescope. The interim meteorological sensor (a pine cone) is visible near a VDU which displays data from the telescope.

GETTING THE TEAM TOGETHER

The instrument which we have on the telescope now is the Faint Object Spectrograph (FOS) built by the University of Durham and the RGO. It is unlike a conventional astronomical spectrograph in that it has no versatility at all - you point it at a star and expose its detector (a Charge Coupled Device) to the whole spectrum, and you see everything between 3,400 Ångstroms and 10,000 Ångstroms, that's it. The power of the idea behind the FOS is that, being so simple, it can be made incredibly efficient. We are taking spectra of stars at the 20th magnitude in half an hour. The FOS is especially efficient in combination with the WHT. In December 1987, a group of astronomers were snapping spectra here at a peak rate of one very 4 minutes, and determined the redshifts of 1,500 galaxies in their observing run.

In 1986 no-one knew how effectively the WHT would be working in 1988. It was September 1986 when Keith Mason got together with Paolo Giommi and I to propose the X-ray source identification scheme for one of the three-week observing slots. We wanted to use the FOS and we invited Jeremy, who built it, to join in. We needed his expertise on this superb instrument to ensure the programme's success. He had worked at MSSL before moving to Durham.

We were successful in our application, and scheduled to use the WHT in February 1988. Part of our team assembled at the Roque de los Muchachos Observatory on La Palma during the day before our run began, to try to learn about the mechanics of operating the telescope. Lorella Angelini from ESTEC, and Graziella and Mark Cropper from MSSL would arrive later to relieve some of us in the middle of the three-week run. We were happy to discover how sinple the whole telescope was to use, and how easy it was to concentrate on the astronomy. This was just the plan conceived by WHT project scientist Charles Jenkins. When you are seated at the control desk it is impossible to know that there is a telescope next door - the telescope and the vast dome rotate remarkably quietly. Only the displays tell you that the telescope is moving. Paolo and Gianpiero feel quite at home in the control room - it is just like a satellite observatory, the only difference being that the 'satellite' is just 20 metres away.

FIRST FIND YOUR STAR

So now, a week into the observing run, we are working one by one through the list of 100 X-ray sources, obtaining spectra of the several selected stars near each one. Jon has measured their positions to the accuracy that the telescope requires. Each star has been given a name and we keyed the stars' Right Ascension and Declination coordinates into the computer at the beginning of the week. When we want to set the telescope on a star, we name it, and the computer converts its coordinates into the position in the sky to which the telescope must be pointed at that time.

The WHT is an altazimuth mounted telescope, so the Right Ascension and Declination must be converted to Altitude (elevation) and Azimuth (bearing from true north); corrections for precession and refraction by the Earth's atmosphere are automatically applied. Already there is, written into the computer program by RGO astronomer Robert Laing, a model of the telescope's main imperfections - small misalignments of the axes and flexure under gravity of the telescope tube. Because of the altazimuth design the computer model is very simple; this is one reason for the WHT's accuracy.

The telescope slews to the named star and stops. The telescope already points better than any telescope that I know. The stars all come within 3 arc seconds of the centre of the TV screen (r.m.s. 1.6 arc seconds).

We gingerly turn up the gain of the intensified TV camera which looks up the telescope. We have to do this carefully in case there are bright stars in the field of view (we know that there are none on our charts, but we might have made a mistake in the coordinates we keyed in). In a 4.2-metre telescope, bright stars are so dazzling that they can destroy the TV tubes, and a stern notice by the gain knob reminds us of this. The TV image is digitised by a small microprocessor system and displayed. Within a minute we can see not only the star which we know is on the Palomar Sky Survey, but several that are too faint to appear on the 30-year old photographs - they are magnitude 21 or so. We have, in fact, chosen one of the blue stars, which does not appear on the red print at all. Here it is clearly visible.

There is no conventional handset on the WHT to move the star to the slit: instead there is a keyboard like a home computer. We type 'HANDSET', and then we use the arrowed keys to move the star to the slit, just like in a computer game.

When the star is positioned satisfactorily, the telescope tracks it well, but in the best seeing conditions we can see the images moving slightly. During our learning night, Bob Argyle, of the observatory staff, was calibrating the errors of the telescope drive. Because gear teeth inevitably have small errors in their shapes and positions, the gears sometimes push the telescope ahead of, and sometimes allow it to fall behind, the star. This produces a wobble in the telescope of about 0.4 arc second. The errors are periodic - you can identify each wheel in the gear train by the ratio of the periods. You can only measure the gear errors to the necessary accuracy after the telescope has been erected. These gear errors will be fitted to some form of mathematical function which can then be applied by the computer program to the telescope tracking and pointing. When this has been done, the star images will all fall directly on the centre of the TV screen, meeting the target of 1 arc second pointing error, and the telescope will track to better than 0.05 arc second.

USING THE FAINT OBJECT SPECTROGRAPH

Having moved the WHT so that the star falls onto the spectrograph slit, we begin the exposure. A typical exposure time for a star this faint is 1,500 seconds - say half an hour. Sometimes they need more, but we then make a series of half hour exposures. The reason is that the CCD detector is vulnerable to cosmic rays, which make spots on the image; longer than half an hour and the image looks like it has suffered an attack of measles!

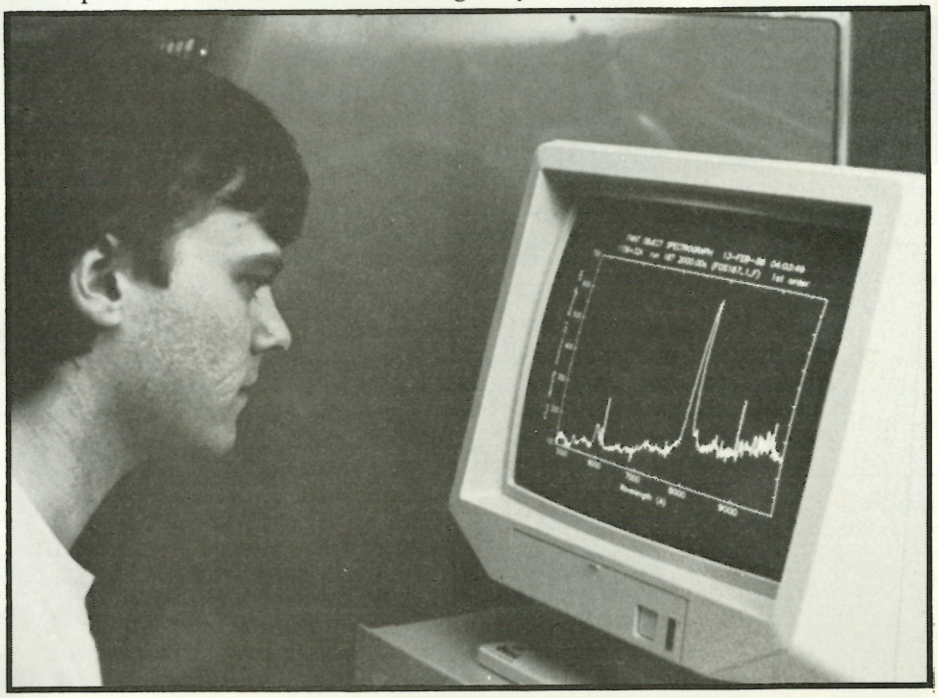
While the exposure is being made, we bring up on the TV viewing screen an effete pink-coloured cross (this is 'designer astronomy', and the designer in question was RGO instrument scientist David Thorne). We position the cross on a star adjacent to the one we are measuring. The centre of this star is then computed and, if it drifts off the position where it was found, then a correction signal is sent to the telescope to bring it back. This drift might or might not be due to some imperfection in the telescope, or it could be atmospheric. Refraction by the atmosphere, which can 'lift' star images by several arc minutes, depends on the air temperature and pressure, and, if they change from the values which we feed in at the beginning of the night, the star will not be on track. In the future the computer will know of any such changes, but the weather equipment has not yet been connected. Jon has brought back a pine cone, collected during a walk down the mountain, and we have hung it up in the control room amongst the displays, with a label: 'WHT - Interim Enviromental Monitoring Station'.

When the FOS has finished its exposure, the instrument computer reads the CCD and displays the image. An automatic program reduces the image to a spectrum, eliminating the cosmic ray hits, subtracting contamination by the sky background, calibrating for wavelength, correcting for the absorption of the Earth's atmosphere, and finally, correcting for the instrument's efficiency. Thirty seconds after the end of the exposure we have a plot from a laser printer of the spectrum. The data reduction and plot are of publishable quality - the observation is completely finished. If, however, we need another spectrum of the same star, because this one is unclear for any reason - a weak exposure, or a cosmic ray hit in a vital place - we can immediately expose again. Otherwise we move on to the next star.

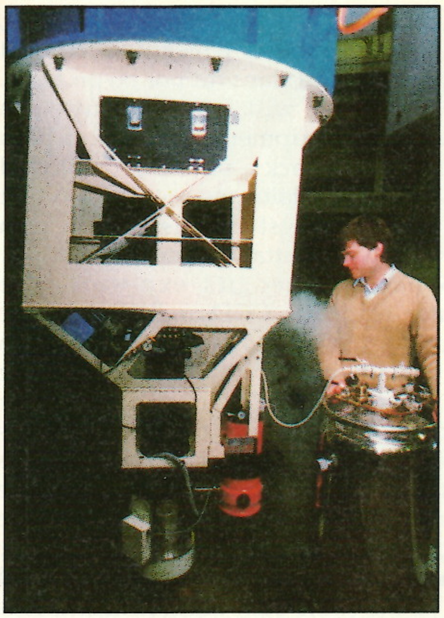
SOME INTERESTING DISCOVERIES

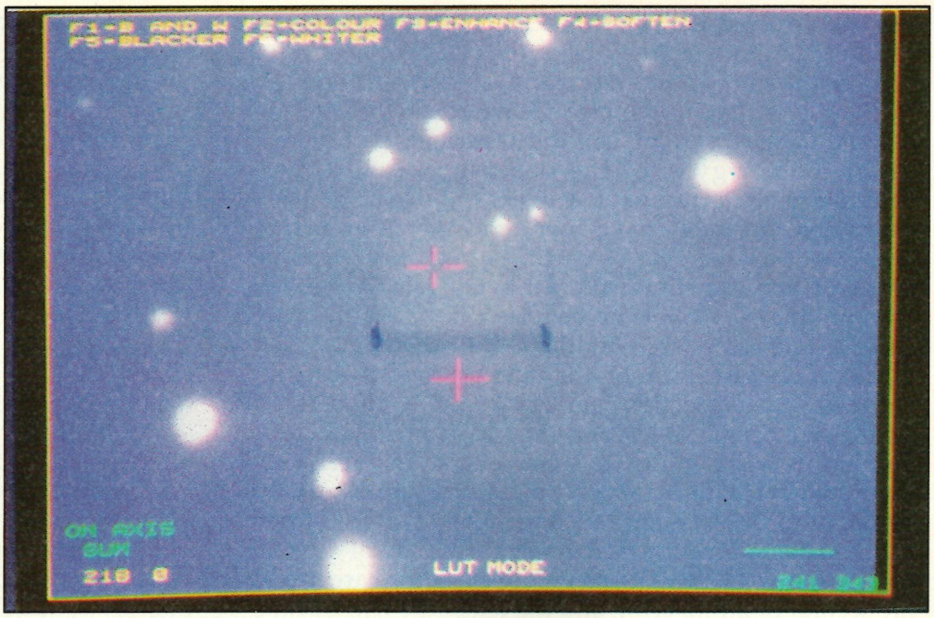
I write this article six nights into the three-week run. We had to close the telescope for a few hours because of winds which gusted up to 120 km/h, but it has been clear all the time, so far. We have had half a night with 0.5 arc second seeing. We have identified 40 of the X-ray sources: about half of them have been quasars and active galaxies, six have been white dwarfs.

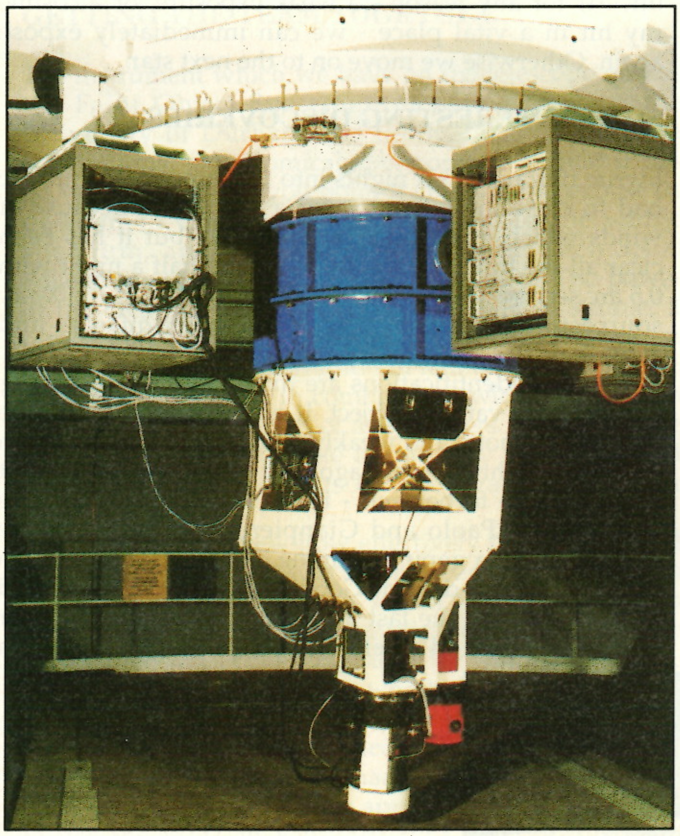
The other identifications are miscellaneous, including one peculiar variable object. It appears strongly on the blue POSS photo, and weakly on the red photo taken on the same night 30 years ago. But when we set on it, it was nowhere to be seen - it has faded by about five magnitudes. Paolo and Gianpiero have immediately christened it "la gepu", meaning "it has disappeared" in Milanese Italian dialect. Gepu may really be blue, and have faded over the last 30 years: maybe it is a quasar which has turned itself off. Or perhaps Gepu is a



Jon Mittaz is the first human to see the spectrum of a quasar discovered during the observing programme described in this article. The large peak near 8000 Å is the line due to hydrogen-alpha, normally at rest at 6563 Å, and here showing a redshift of (8000/6563 - 1), i.e. z = 0.2.





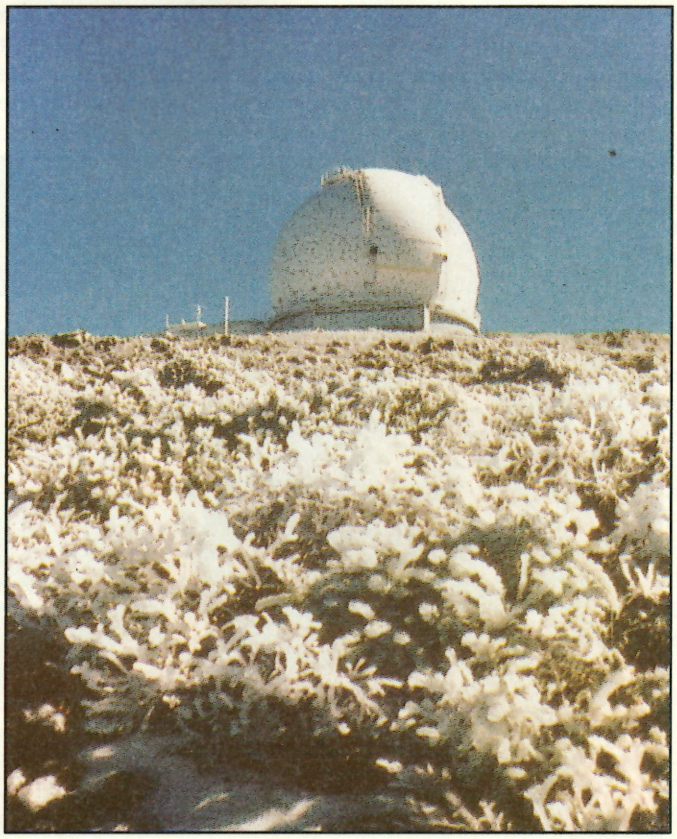


Above: Star images reflected off the spectrograph faceplate. A black rectangular slot, its ends marked with ink on the monitor screen, is the light which passes into the spectrograph. A pink broken cross marks the central axis of the telescope. When the telescope points to a star, it appears in the central gap of the cross.

Above left: Jon Mittaz fills the red dewer of the Faint Object Spectrograph with liquid nitrogen (clouds of condensation and frost are an accompaniment to this twice-a-night excitement). The liquid nitrogen cools a Charge Coupled Device (CCD) inside the spectrograph camera (shiny container at bottom). The open frame structure is where the main spectrograph will later be installed.

Left: The Faint Object Spectrograph, constructed jointly by the University of Durham and the Royal Greenwich Observatory, at the Cassegrain focus of the Herschel Telescope.

Below: The dome of the William Herschel Telescope, pictured the day after an ice-storm at the Roque de los Muchachos Observatory.



cataclysmic variable star, caught by chance in a flare during the blue POSS exposure, and infrequently visible. We will re-visit the region of this X-ray source from time to time throughout our run on the William Herschel Telescope, to see if Gepu comes back.

In the meantime we have two dozen quasar spectra to look at, quasars which are unknown to everyone except us, and were secret from everyone including us until we turned this fine telescope skywards in the clear La Palma nights. ■

__Dr. Paul Murdin,__ well known for his many books, articles and broadcasts, is a regular contributor to Astronomy Now. He is head of the Royal Greenwich Observatory's Astronomy Division at Herstmonceux and has been heavily involved in the installation and commissioning of the William Herschel Telescope. He was awarded the OBE in the New Year's Honours List for his many services to the science of astronomy.