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Acquisition & Guider Unit for the Cassegrain Focus of the 4.2m William Herschel Telescope

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Preliminary investigative work on the requirements, designs and layout of the A&G Unit was commenced in April 1980. Subsequent discussions with the then Project Scientist, Paul Murdin, resulted in a Draft Functional/Technical Specification which was later circulated to the Astronomical Community for comments and/or requests for additions or modifications to the facilities contained within the unit. Feedback from astronomers was then incorporated into the design where feasible. Subsequent issues of the Functional/Technical Specification were produced with different Project Scientists at the helm, until the final issue in April 1985. There were of course spatial constraints imposed by the telescope design in the form of maximum swept radius and distance from the instrument rotator to the nominal Cassegrain focus, and interaction with the electronics cubicles on the instrument rotator. The spatial problems increased exponentially as the requests from astronomers for WIBNI's (Wouldn't it be nice if) flowed in. When the specification and the design were finally frozen, the A&G Unit provided the following facilities:

a) A full field of 15 arc min. diameter (and obviously the requirements for TAURUS and ISIS namely 9 arc min. and 4 arc min. diameter respectively) at the nominal telescope focus, 15cm. below the A&G to instrument interface.

b) An Acquisition facility, via an extendible probe carrying a mirror feeding the TV Camera, provides a 1.5 arc min. field direct, or 4 arc min. field with a focal reducing system interposed. The focal reducer changes the field scale from the nominal telescope scale of 4.46 arc sec/mm to 12 arc sec/mm.

c) Slit Viewing of the angled slit (7.5 degrees) of ISIS, or any other instrument, via a one to one transfer lens and flat into the same TV Camera, with field sizes identical to those provided by the Acquisition system.

d) The original design catered for a large mirror feed to a focal position at right angles to the main telescope beam, and external to the case structure, to enable the use of fiber optic aperture plates and fibers to feed a spectrograph or other instrument. The field size available, 10.8 arc min., was considered too small. Redesign of the autoguider to provide more space -in the upper section of the case, enabled the Fiber Optic field to be increased to the full 15 arc min. diameter. Guiding in this configuration is not possible with the internal autoguider due to obscuration by the feed mirror, therefore the use of large fiber bundles on suitable stars at the edge of the field will have to be used for guiding. The aperture in the case wall is of sufficient diameter to allow the fitting of a small automatic fiber positioning system (MINIAUTOFIB?) or an Image Stabilisation System,

e) An alternative mirror (Small Feed Flat). may be extended from the opposite side of the case, coplanar with the Fibre Optic Feed mirror to feed small instrument (i.e. a CCD camera, a photometer, or other small instrument) at the Fiber Optic focus. The field available is 4.5 arc min. with the added facility of the internal autoguider.

f) The Autoguider itself comprises a CCD detector head fed by a right angled prism and focal reducing optical system, with a field diameter of 1.8 arc min. the center of which rotates about the center of the main field at a radius of 110 to 150mm (8.2 to 11.2 arc min), thus the extreme edge of the autoguider field is partially vignetted, but only by about 5%. The CCD housing is remotely focusable, and the entire probe assembly has a radial displacement of 40mm. The autoguider has a "theta" scan of 180 degrees. Total area scanned at a field scale of 4.46 arc sec./mm equals 152 square arc min. or 0.04 square degrees (log 1/0.04 = 1.37). This ensures at least one star brighter than 12 mag. @ 0~90 degrees Galactic Lat., 11 mag. @ Galactic Equator, and 13 mag, @ Galactic Pole. (Astrophysical Quantities).

g) A Comparison/Calibration system is provided consisting of an integrating sphere into which light is fed directly from two hollow cathode lamps (Cu-Ar and Cu-Ne), and light from a further six lamps (a choice from Cs-Ne, Fe-Ar, Fe-Ne, Th-Ar, Al/Ca/Mg-Ne. Na/K-Ne, and Deuterium) imaged via fused silica lenses onto 3 mm diameter fused silica light guides. Any combination of lamps may be used simultaneously. The exit pupil of the integrating sphere is fitted with an obscuring disk to simulate the telescope entrance, aperture obscuration, i.e. the secondary mirror structure. The reverse side of the acquisition mirror is used to feed the calibration light to the interfaced instrumentation. This enables simultaneous object acquisition and spectral calibration.

h) Two Filter Slides situated below the autoguider assembly provide Color and Neutral Density filtering. Each slide carrying five-filters in cells (filter diameter 85mm), may be retracted out of the full field, and in this position filter changing is facilitated via an interlocked access door (protected by proximity switch and software to instrument shutter). The filter cell carrier may be removed and alternative cells fitted. The cells all carry descrete bat coding for filter identification, The range of ND filtering will probably be identical to that available in the INT A&G Unit namely 0 to 3 in 0.3 steps (refer to Table 2.6 of the La Palma Observers Guide).

i) The TV Camera, a Westinghouse ISEC system, has a photocathode diameter of 25 mm. It is provided with a filter wheel with six filter positions, five for ND or Color and one clear (UBK7), filter diameter 30 mm.

j) The Autoguider also has a similar filtering facility, but with filters of 23mm diameter.

k) Two eight position filter wheels are provided for the Comparison System. Neutral Density and Color filters similar to the set used on the INT A&G Comparison System will be provided (cf. RGO/La Palma Technical Note no. 22) to give a range of densities from 0 to 5. Two filter positions in each wheel are available for color filters. Diameter of filters 75mm.

l) For Polarizer module calibration, a special double cell containing two dichroic polymer filters (i.e. Polaroid) with their polarizing axes mutually at right angles, may be fitted to the carrier. Further cells containing either a calcite or quartz crystal may be used for broader wavelength coverage, but as yet this facility has not been fully discussed with the polarization PI, Jaap Tinbergen. There may be some spatial problems if the required crystal thickness is too great. This also applies to the use of two parallel silica plates for partial polarization.

Technical Specification

The basic A&G case consists of a cylindrical fabricated steel structure 150 cm in diameter by 65 cm deep, split roughly into two equal sections, Upper and Lower. The sections are suitably flanged and gussetted for attachment to the telescope instrument rotator above and the instrument below. The Upper section contains the Acquisition/Comparison Probe, Slit Viewing Probe, Small Feed Flat Probe, Fiber Optic Feed Mirror, Calibration System, TV Camera, and Focal Reducing Lenses. The Lower section contains the Autoguider Assembly and the Main Filter Slides.

Upper Section

The Acquisition, Slit Viewing, and Small Feed Flat Probes are of similar configuration, consisting of a hollow steel quill vee grooved longitudinally on its outer surface to run in Schneeberger recirculating ball units. The InOut movement of the quill is accomplished using a recirculating ball nut and screw shaft driven by a stepper motor. A fail safe magnetic brake (energised release) is mounted on the motor's extension shaft to prevent the screw shaft running back, due to its high efficiency (circa 97%), under gravity load. The ball nut "floats" between disk springs to enable a slight preload when the quill reaches its mechanical end stops. A steel slug on the floating ball nut actuates proximity switches at extremes of quill stroke, disabling motor and brake.

The Fiber Optic Feed Flat carriage runs in Schneeberger recirculating linear bearings mounted on a baseplate. This baseplate is fixed to the upper section lower plate. The drive system is identical to that used for the probes, extremes of stroke being determined by mechanical stops and encoded by proximity switches.

The Calibration system bolted to the case side directs comparison light from an integrating sphere via two fixed imaging lenses (UBK7) and retractable flat into the interfaced instrument. The two filter wheels are interposed between the sphere, and the lenses. Filter position encoding by three proximity switches per wheel and BCD flags.

The TV Camera mounts on a Hepco vee bearing slide and is again driven as in the case of the probes. The focusing movement, ± 1 cm, being monitored by a DC/DC LVDT (Linear Variable Differential Transformer) and limited by proximity switches. Bellows fitted between the camera and the case prevent ingress of light to the TV.

Two Focal Reducing Lens systems (parfocal) mounted on a motor driven ball glide (system similar to probes) and positioned to feed the TV Camera, can be selected to obtain a larger field from the Acquisition or Slit Viewing mirrors. A third position, with no optics, provides direct viewing, i.e. a smaller field, for both probes. The two extreme positions are defined by mechanical stops, the central position by step mounting from either end.

Lower Section

This section is a sealed hollow toroid by virtue of a brush seal between the autoguider "theta" scan bearing and the lower plate of the Upper section. Filtered cooled air is sucked into this chamber to remove excess heat generated by the CCD Peltier cooler, drive motors etc., and exhausted to the dome. Thus the heat generated is prevented from rising into the downcoming telescope beam.

The Autoguider Assembly consists of a probe containing the optics which has attached to it a cradle locating the CCD housing. The cradle runs on Schneeberger linear bearings which provide the ± 4 mm focusing movement by way of a stepper motor driven screw and anti-backlash nut. Focus position is monitored by a DC/DC LVDT. The assembly thus described is itself mounted within a steel fork-shaped fabrication by another set of Schneeberger linear bearings, to provide the 40 mm displacement previously mentioned. This movement is motivated by a stepper motor driven screw and anti-backlash nut, and encoded by a DC/DC LVDT. A six position filter wheel assembly is positioned between the optical train and the CCD.

The Autoguider Assembly is mounted on 130 degrees of the top surface of a large precision needle roller radial/thrust bearing (maximum TIR of radial runout 0.006 mm). On the remaining 230 degrees is mounted a wormwheel sector. This drive sector engages a stepper motor driven worm. The worm to sector engagement being determined by the worm mounting plate which is pivotted to allow contact adjustment. This mounting plate also serves as the mount for a 131072 bit absolute optical encoder and its anti-backlash drive worm wheel. Gear ratios have been selected such that 300 teeth in 180 degrees of the sector engage the single start worm which in turn engages the 328 tooth encoder drive. Allowing for a possible 1 bit loss on the encoder, one step of the stepper motor equals 0.999 bits. One step also equals 10.8 arc sec. angular movement of probe, equivalent to 0.035 arc sec. on the sky. The gears are all ultra high precision and conform to BS 721 Grade 1, with pitch tolerance to Class A. Tests carried out at the manufacturers works on a Pearson Gear Measuring M/c, on both the sector and the anti-backlash gear, showed a maximum pitch error of 0.004 mm at a radius of 241 mm equivalent to 0.008 arc sec on the sky at the maximum radius of the autoguider probe (150 mm).

Each Main Filter Slide runs on Tsubaki miniature recirculating slideways, and is driven by an Acme screw, shaft with a plain phosphor bronze nut. The drive shaft is motivated by a stepper motor. No brake is provided on the drive as the screw to nut helix and resulting friction is sufficient to prevent run back of the carriage. Positional encoding is by step counting from a datum proximity switch at one extreme end of the travel. It was not possible to position the bar code reader heads in an orientation such that the filter cells could be read when in the center of field, this would have caused vignetting of the main field. At the start of observing the carriage must be indexed sequentially from the parked position and the bar code reader head output/filter position relationship stored in the control computer for display on the monitor menu.

Maximum tolerable image displacements for 6 hours or 90^o tracking

a.	On TV photocathode from Acquisition Mirror	x = ± 0.1"	z = ± 0.1"
b.	On TV photocathode from Slit-viewing Mirror	x = ± 0.3"	z = ± 0.3"
c.	On instrument entrance aperture from Comparison Mirror	x = ± 0.1"	y = ± 0.1"
d.	At FiberOptic Focus from feed mirror	x = ± 0.45"	z = ± 0.45"
e.	At FiberOptic Focus from small feed flat	x = ± 0.1"	z = ± 0.1"
f.	On CCD from Autoguider Prism and Optics	x = ± 0.05"	z = ± 0.05"

Changes in focus hould not produce a change in area of a 1 arc sec image by more than ± 10%. The angular displacements above are in terms of arc seconds 'on the sky´ , and the coordinates are in the plane of the image.