Boksenberg (Hazard and McMahon 1985) measured the redshift, $z = 3.67$, of the southern quasar 0055-2659 discovered by objective prism spectra with the UK Schmidt Telescope in Australia.

Branduardi-Raymont, Mason, Murdin and Martin (1985) have identified four faint X-ray sources in an Exosat deep survey field as active galaxy nuclei, with magnitudes 17.1 to 19.5. The relatively large number identified implies that AGN have a soft X-ray excess over the extrapolation from high energies.

Chlewicki, van der Zwet, van IJzendoorn, Greenberg and Alvarez (1985) have confirmed a new diffuse interstellar line at 6234Å at about 2% central depth in the spectra of stars in the Cyg OB2 association and, from the shape of the complex profile of the 6270Å feature proposed that the lines represent unresolved rotational envelopes of vibronic transitions of large molecules.

PART B: THE JACOBUS KAPTEYN TELESCOPE

1. DESIGN PHILOSOPHY

In the early 1960's there was a flourishing school of photographic astrometry at the Royal Greenwich Observatory. It was found that very accurate proper motions could be determined by comparing plates taken fifty or more years apart with the same telescope. It was essential that only plates taken with the same telescope were compared so that as far as possible all defects of optical imaging should cancel out. Too strict a reliance on old telescopes was not a policy which could be pursued indefinitely and our thoughts turned to the design of a dedicated astrograph incorporating the latest technology, especially in optical design. No doubt these ideas were inspired by the USNO 1.5 metre telescope at Flagstaff which was built at that time with much the same consideration in mind.

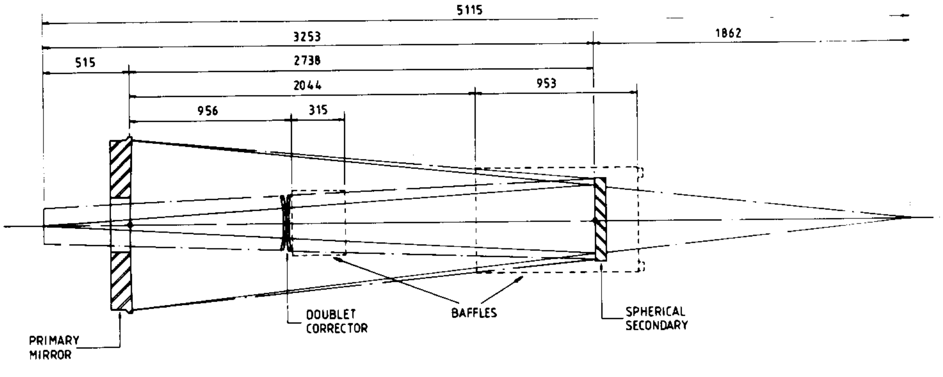
Nothing came of this idea at the time but its germ was incorporated into the Northern Hemisphere Observatory. The 1973 Scientific Case for the NHO called for three telescopes, the smallest to be a one-metre similar to the Boller and Chivens telescope of that size on Siding Spring Mountain. This telescope has f/8 and f/18 secondaries interchangeable with a flip top arrangement. The f/8 arrangement is a Ritchey-Chrétien which requires an elliptical primary. Thus the f/18 is not a true Cassegrain which requires a parabolic primary. The Ritchey-Chrétien is free from coma by design and the field is limited by astigmatism which amounts to an arcsecond 20 arcminutes from the axis. Moreover the optimal focal plane is curved concave to the secondary with a radius of 135 cm.

While this design is not the ideal astrograph it was quickly realized by those who had been urging the case for a new astrograph that the differences in specification were small enough to be negotiable. Nevertheless it was clear that there was no ideal astrograph and that each parameter of the final design must be a compromise between trade-offs in different directions.

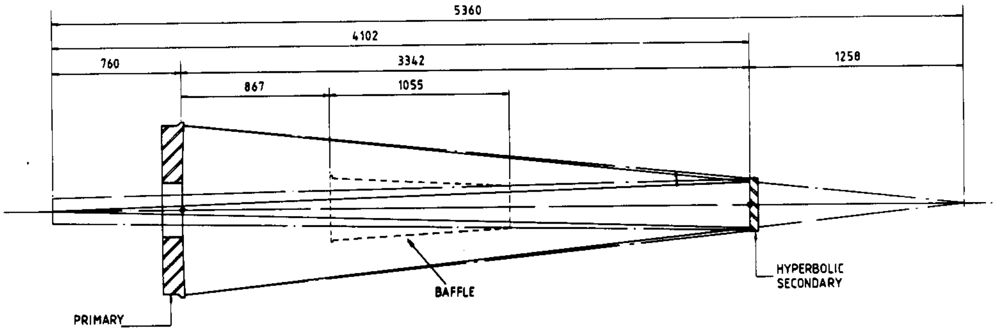
In the early days of the project there were suggestions that the primary diameter might be 1.2 or 1.5 metres but these suggestions were quickly abandoned when it was realized how much this would increase the expense, especially in view of the strict astrographic specification. The next parameter to establish was the effective focal length. f/8 had been chosen for the Siding Spring telescope because this matched a seeing disc of one arcsecond to the granularity of the Eastman 103aO emulsion. Since that time finer grain emulsions such as the Kodak III range have been introduced but by a happy accident the seeing on La Palma has proved better than anticipated so the eight metre focal length does introduce a marked mis-match. If you move to shorter focal lengths then you undersample the detector (photographic plate) for stellar images but gain in speed on extended subjects because each unit area of plate receives more photons. Unhappily this is also true of the brightness of the night sky which limits the exposure during which the emulsion can register fewer photons so that the signal/noise suffers. Because of its granularity the photographic plate can only store so much information per unit area, with fine grain emulsions able to store much more. As you increase the focal length of the telescpe the seeing discs are spread over a greater area of emulsion which can contain more information if the exposure is long enough to gather it. This argument implies that the limiting magnitude of a telescope is purely a function of its focal length; the only limitation is the prohibitive length of the exposures. (cf. W A Baum 1962)

Having decided on an overall focal length of eight metres we are still free to fix the focal length of the primary. A short focal length to the primary implies a shorter tube so that the telescope can be covered by a smaller dome. As the dome can cost a large fraction of the total cost of the project, and this cost rises sharply with size, this is a powerful consideration. Likewise, it is easier to construct the telescope tube with the requisite stiffness when it is comparatively short. Thirdly any two-mirror wide field system requires sky baffles to prevent extraneous light falling on the plate. These baffles inflict a penalty in the amount of free aperture they obstruct and this penalty is reduced as the focal length of the primary is reduced. The strongest argument for a longer focal length arises indirectly from the astrographic requirement that the field must be flat. With a curved focal plane the plate must be bent in two directions during exposure which results in internal stresses. These stresses are relieved when the plate is removed from the plate-holder for processing and ultimately for measurement. To reduce the measurements it is necessary to assume that both the glass plate and its thin coating of emulsion behave purely elastically under stress. This was felt to be a dangerous assumption in the most precise astrometry so it was specified that the field should be flat. Now Petzval's theorem (by Born & Wolf 1964, page 225) implies a direct connection between the field curvature and the focal length of the primary in a two-mirror system so that a flat field requires a primary focal length of 4.6 metres, a metre longer that the Siding Spring telescope. The astrographic requirement was felt to be the overriding consideration and the focal length of the primary was fixed at 4.6 metres in spite of the contrary arguments rehearsed above. The only other argument in favour of such a long focal length was the reduced amount of ceramic which had to be ground away and the relative ease of polishing and figuring.

With the focal lengths of the two mirrors fully specified the astronomer is still free to decide on the field size. Obviously he wants the biggest field possible but must pay a penalty in increased obstruction by the sky baffles, quite apart from the inordinate cost of photographic plates. More importantly he must discuss his requirements carefully with the optical designer because the larger the field the more difficult it is to design a system with acceptably small aberrations. For precise astrometry symmetrical aberrations like astigmatism are less dangerous than asymmetric ones like coma. Because the photographic plate is a non-linear detector the apparent centre of an asymmetric image varies with the length of exposure and this is quite unacceptable in an astrograph. Equally unacceptable is for the apparent separation of two stars to be a function of their colours. With these requirements in mind we embarked on a series of conversations with Prof C G Wynne FRS and C F W Harmer to design a telescope with a field in excess of one degree and acceptably small, symmetric images whose positions were independent of colour. The outcome was a field diameter of 1.5 degrees with symmetrical images nearly all smaller than $0''.5$ over the wavelength range 365-852nm. The design was published by Harmer and Wynne (1976). The parabolic primary could provide a conventional Cassegrain with a hyperbolic secondary but in the wide-field mode used a spherical secondary, totally insensitive to disalignments about its centre of curvature. The wide field correction is provided by an afocal doublet in the middle of the tube, with all surfaces spherical for ease of fabrication. Both components are of the same glass type so that there are no chromatic effects. For a one-metre telescope the corrector lens is 326mm in diameter which implies that this design cannot be extrapolated to very large telescopes.



f/8·06 HARMER-WYNNE SYSTEM



f/15 CASSEGRAIN SYSTEM

Fig. 8. Optical configurations of the JKT. A change of secondary and insertion of the corrector is needed to switch from the conventional f/15 Cassegrain system to the f/8 Harmer-Wynne system.

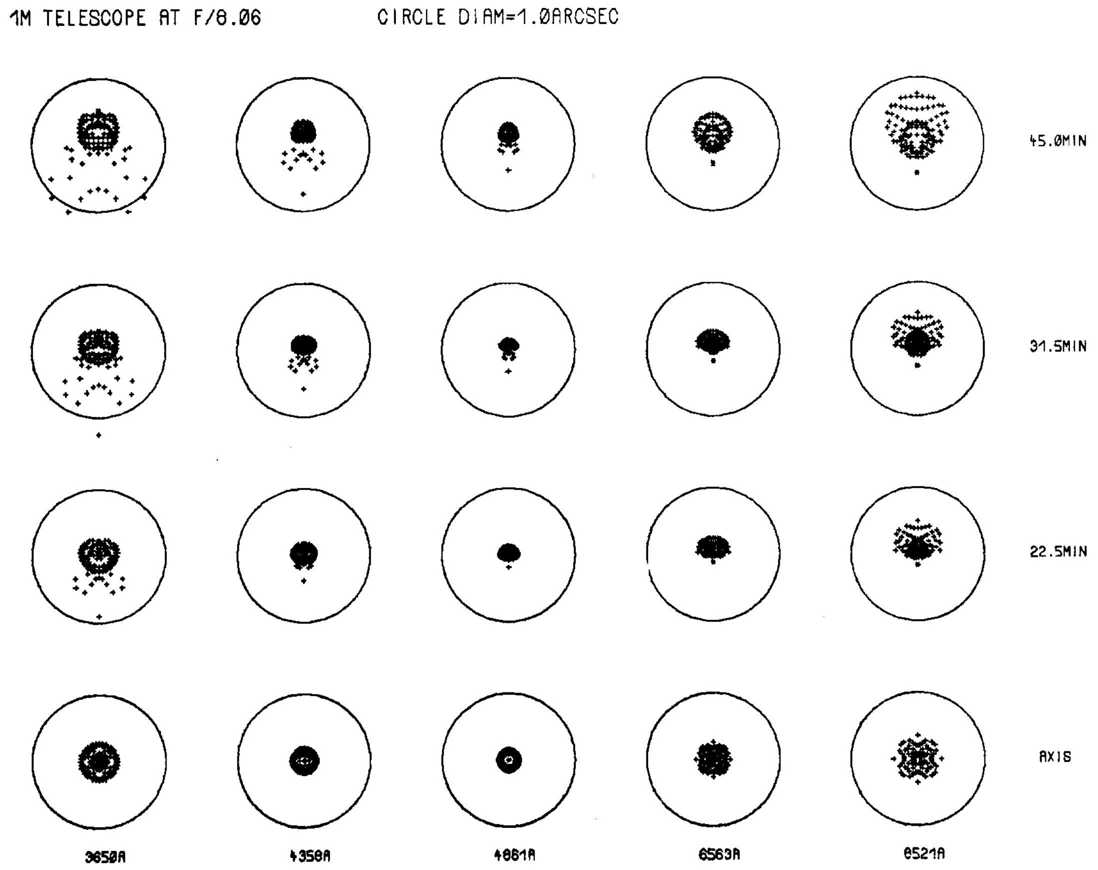


Fig. 9. Spot diagrams of the JKT at f/8.

The outline optical design for the f/8 and f/15 modes is shown in Fig. 8 and a selection of spot diagrams for the f/8 mode in Fig. 9. The sky baffles obscure 38 and 17 percent respectively for the two focal ratios.

2. DESCRIPTION OF THE TELESCOPE

The JKT and instruments are described in detail by Pettini (1984).

The design of the telescope was fixed by 1977 well in advance of the SERC decision to support the NHO project or the firm decision to site the observatory on La Palma. The order to build the telescope came from the Department of Trade and Industry, inspired by the then socialist government of Great Britain in an effort to relieve unemployment in Newcastle upon Tyne. The firm of Sir Howard Grubb Parsons were asked for a conventional one-metre telescope suitable for sale to a wide range of customers. The RGO produced a User Specification for the instrument but the engineering specification was produced by Grubb Parsons. Their intention was to provide a conventional analogue control system which would operate by itself or which could easily be interfaced with a computer, whichever the customer wished. Thus the RGO had little control over the detailed design of the telescope and the adaptation of the design to computer control caused much more trouble than either party had expected.

The telescope is shown in outline in Fig. 10. The telescope is bolted to its single pier by a sole plate in an arrangement which permits adjustment of the pole in altitude and azimuth. This sole plate had its one moment of fame when, during shipment to La Palma on a Spanish cargo ship, an enthusiastic Harrier pilot landed his aircraft on it. It proved sufficiently strong to survive such treatment. The polar axis is a torque tube which permits the Right ascension Counter Weight to be placed close to the pier and not immediately opposite the telescope as in a classical German mounting. This position of the counterweight makes it much easier to provide a rising floor. The telescope has an open tube of a Serurrier truss design which gives equal and parallel deflections to the primary and secondary mirrors at all orientations of the telescope. The weight of the primary mirror is relieved radially by twelve counter weights acting through levers and located radially by three push rods. The axial support is provided by twelve pneumatic pistons in a similar manner to the 4.2-metre telescope. There are three load cells and a servo mechanism to vary the air pressure in the pistons so that the mean load on the load cells remains zero at all orientations of the telescope.

The secondary mirrors are supported radially and axially by systems each of six levers. The two separate secondaries have separate top ends to the tube which are interchangeable. They live on dedicated trolleys when not on the telescope and may be readily presented to the horizontal telescope by using the rising floor. An end change takes two skilled people about two hours.

The telescope is equipped with a 20cm finder of 325cm focal length attached kinematically to the tube. The eccentric loading by the finder is balanced by an electronic rack on the opposite side of the tube, which holds electronics for the different auxiliary instruments.

The Right Ascension and Declination drives consist of worm worm-wheel arrangements which carry out both slewing and guiding. The worms are equipped with flywheels to prevent lock up of the gears. The worms are continuously lubricated and maximum angular velocity transmitted to the telescope is 2 degrees s^{-1}. A power cut during a fast slew would be extremely dangerous to the gearing so the worms are fitted with spring loaded absorbers. In addition to the drive motors there are anti-backlash torque motors to keep the worms consistently in mesh on one flank of the worm wheel.

The position of the telescope is encoded by incremental encoders mounted on the worm shafts, each bit of which corresponds to $0\overset{\prime\prime}{.}05$ in the pointing of the telescope. The encoders are cleared at

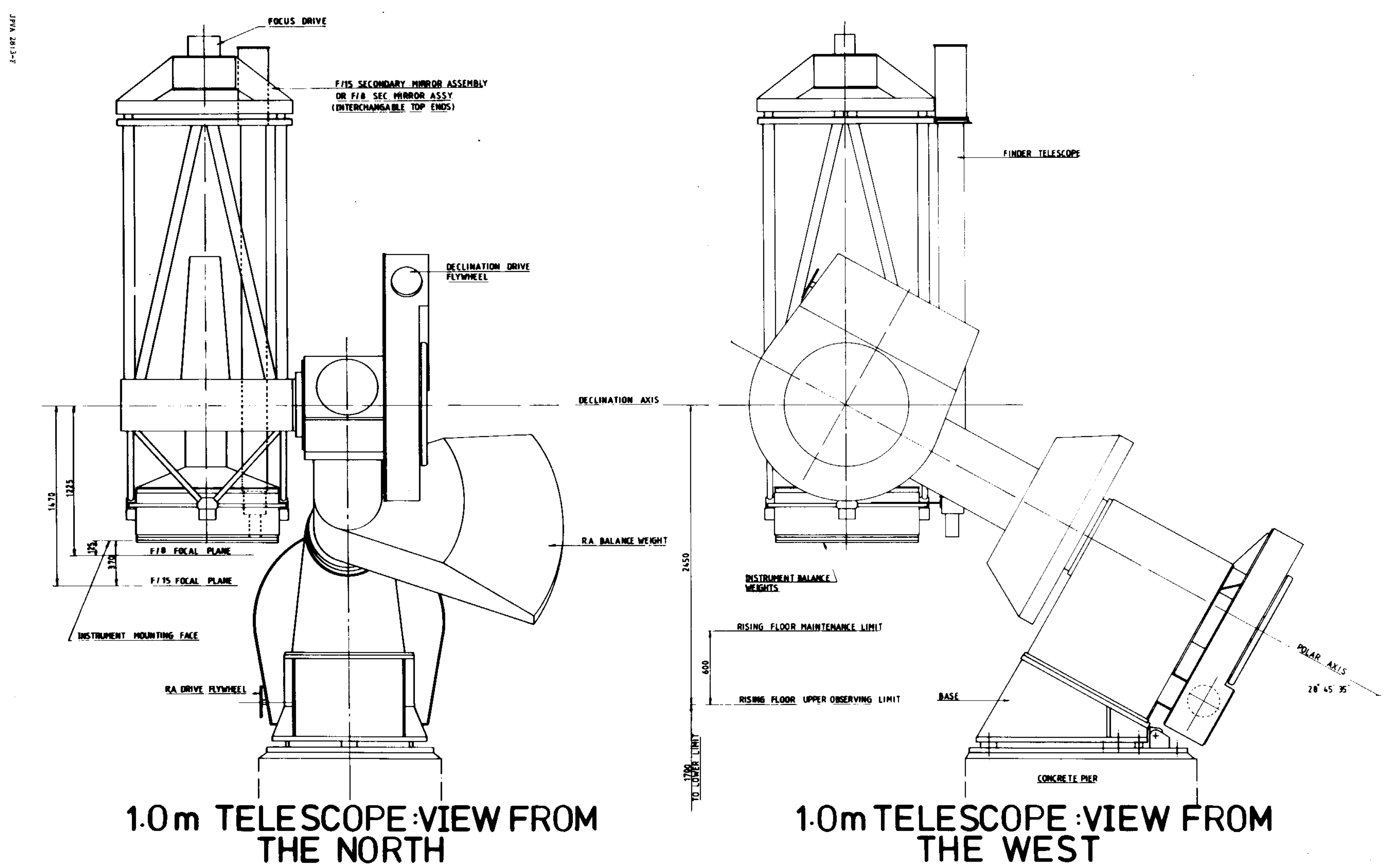


Fig. 10. Outline Drawings of the JKT.

the beginning of each night's work by driving the telescope past fixed opto-encoders near the zenith and meridian. From then on the encoder pulses are read by a CAMAC up-down counter interfaced to the telescope control computer, a Perkin-Elmer 8/16E. CAMAC is used as the interface for all the computer's tasks; position readout, demands on the power amplifiers, input of the time service and dome azimuth. The drive program which controls the telescope reads the encoders ten times a second and sends corrections to the drive motors proportional to the difference between actual and demanded co-ordinates. Corrections for the geometry of the mounting are made at this stage. The telescope software of the JKT is very similar to that of the INT.

3. AUXILIARY INSTRUMENTS

The telescope is equipped with an instrument turntable attached to the rear of the primary which is designed to support instruments weighing up to 270kg and with a maximum moment 95kg m measured from the mounting face. The turntable is controlled manually from the mirror cell and is motor driven in either direction. Its orientation is encoded and may be read, but not driven, by the 8/16E.

3.1 Wide field camera

This is the only instrument intended for the f/8 focus and is designed to exploit the powerful performance of the Harmer-Wynne optical design. The 90 arcminute diameter highly corrected field is centered at one end of a 25x20cm plate, leaving a free strip at the other end for the calibration spots and the plate number. The plate scale is 25.6 arcsecond mm^{-1}.

Filters are held in holders which slide into the camera in front of the shutter. There are full size filters for UBVRI (with the appropriate emulsions) with broad band anti-reflection coatings. In addition there are holders modified to accept 100mm square interference filters such as 5007Å and 6563Å.

The plate holders have conventional dark slides and can be flushed with dry nitrogen prior to exposure. The nitrogen treatment can be continued during exposure because the nitrogen is trapped behind the filter. There are three miniature lamps which project spots on to unexposed parts of the plate, intended as controls on the relative position of plate and telescope in subsequent astrometric measurements. For photometric calibration there is a 25 step spot sensitometer of the KPNO design, Schoening, (1976). This projects continuously on to an unexposed area of the plate throughout the exposure. Subsequent to exposure each plate is unambiguously identified by projecting on to an unexposed corner the information on the plate's index card.

The plate holders are supplemented by a parfocal knife edge and a Plössl scout eyepiece of 50mm focal length. The latter is mounted in an r,θ arrangement so that all points in the telescope's field can be reached and both attach to the camera in the same way as the plate holders.

There is a guiding probe mounted on X,Y slides which can cover a complete quadrant of the telescope field. This images stars onto a pair of illuminated cross wires which can be viewed by an eyepiece mounted in a goose-neck. The telescope can be visually guided during exposure by this arrangement but it is infinitely preferable to re-direct the image by means of a small prism into the autoguider. The autoguider designed by D Thorne is based on an FW-130 photomultiplier with image dissector coils. The position of the star on the cathode is sensed by scanning the sensitive spot across it and any movement of the star is presented as an error signal to the 8/16E drive program.

3.2 Acquisition Box

The f/15 instruments are mostly mounted onto the acquisition unit whose principal function is to hold the Westinghouse intensified Television. This is provided with a flat mirror which can be driven into the beam, giving a field of 4x3 arcminutes. The acquisition unit also provides the spectroscopic comparison lamps and slit viewing optics to reflect light from the slit jaws of the Richardson Brearley Spectrograph into the television camera.

3.3 People's Photometer

First among the f/15 instruments is the People's photometer. This instrument was designed a decade ago by R Bingham and five were built, for various observatories throughout the world. These instruments are conventional two channel photoelectric photometers, most frequently used in a star-sky mode where the separation of the two apertures is 172″. Each channel has an independent filter slide to take six filters; typically Kron-Cousins UBVRI or Strömgren uvby and Hβ. When the transparency is variable it is possible to use only one aperture and put a neutral beam splitter immediately behind it which sends the light into the two different photomultipliers. By selecting different filters for the two channels one may measure colours in non-photometric conditions even when it is impossible to measure magnitudes; the best example is the Hβ index. It is possible to replace the neutral beam splitter with a Foster prism which forms a polarising beam splitter, and at the same time insert a rotating waveplate in the beam above the aperture. This combination modulates the light from a polarised source by an amount proportional to its polarisation. A half wave plate produces a modulation at four times the frequency of the plate rotation which is solely dependent on the linear polarisation of the source. A quarter wave plate is also sensitive to the linear polarisation but the modulation has only half the amplitude; however there is an additional modulation at twice the plate frequency proportional to the circular polarisation of the source.

The People's Photometer is controlled by a PE3220 computer which is the dedicated instrumentation computer for the telescope. The computer controls both filter slides, the apertures and the star-sky/beam-splitter selection by pneumatic pistons, colloquially known as digital trombones, interfaced like every other function, via CAMAC. This interface is likewise used to count the pulses from the photomultipliers and pass the counts to the computer which stores them first on disc and subsequently on magnetic tape. At the same time the computer provides approximate real time reductions to inform the observer of the progress and accuracy of his observations so that he may pursue the most effective strategy. The speed at which the system works can be chosen to suit the programme. For constant or slowly varying stars a sampling period of one second is usual. When used as a polarimeter the wave plate rotates with a period of 960 msecs and the data is read in samples of 10 msecs so that the modulation is fully resolved. For particularly fast phenomena it is possible to use external memory in the CAMAC crate which can be addressed with sampling intervals of 4 microseconds in two channels. A typical recent result from the People's Photometer is shown in Fig. 11.

3.4 Multi-purpose Photometer

The telescope is also provided with a multi-purpose photometer (known as MPF after its Dutch initials) built by J Tinbergen. In this instrument light passes through an optional calibrator and is focussed on to a single or double diaphragm; the latter is for sky-chopping. After passing through an optional polarizer for linear polarimetry, the beam continues through two optional neutral density wedges and three optional neutral density filters to the collimator and an electro-mechanical shutter. The dichroic beam splitter assembly yields up to six beams; three beams between 3000 and 6000Å, the other three between 4500 and 9000Å. Each of these beams is then split again, normally by a neutral beamsplitter, to form a pair for Hβ type photometry. The final beams pass through three-position filter slides and Fabry lenses to the photocathodes.

3.5 Richardson-Brearley spectrograph

A further f/15 instrument is the Richardson Brearley spectrograph built by R Edwin at the University of St Andrews, following the original design by Richardson & Brearley (1973). It is an efficient, lightweight, yet robust and stable, off-axis spectrograph, intended primarily for low- and medium-resolution stellar spectroscopy. It is operated manually and uses photographic plates to record the spectra.

3.6 CCD Camera

Currently under construction at Herstmonceux is a CCD camera for the f/15 focus. This focus was chosen because, with the good seeing routinely available at the Roque de los Muchachos, the chip would be under-sampled at f/8. The camera is provided with its own acquisition and guidance unit which has been developed with remote operations in mind. It embraces an acquisition TV Camera and a drift scan table. Initially it will have a GEC front illuminated P8600 chip with 385x576 pixels each 22 microns square. It is hoped to provide an RCA chip later and the design allows for larger chips when they become available. It carries UBVRI and Gunn Z filters and narrow band filters can be substituted when required. In addition to direct imaging it is also capable of low dispersion spectroscopy with the aid of two grisms which together cover the wavelength range 3500-10500Å.

4. THE DOME AND BUILDING

It was an initial user requirement that the telescope should have an uninterrupted horizon in all directions so that whenever a supernova, bright comet or other interesting transient object appeared, at least one of the LPO telescopes should always be able to observe it. For this reason the JKT was sited to the south of the INT and 22 metres above it close to the Caldera lip. A limiting condition was the ruling by the National Parks Authority (ICONA) that all the telescopes must be below the skyline when viewed from Cumbrecita on the opposite Caldera Wall so as not to destroy the beauty of the national park. The ability to view the horizon in all directions is aided by the telescope's cross axis mounting design which allows any star in the sky to be observed from above the intersection of the axes.

4.1 The Dome

The hemispherical dome protects the telescope against the weather and the input of undesirable heat during the day. The dome has a cavity structure with insulation betweenn the inner and outer skins; the dome walls, shutters and windscreen are of aluminium. The dome is rotated by drive units mounted on the building which can achieve a rotation in four minutes at top speed. The azimuth of the dome is encoded and interfaced to the telescope control computer. Because of the cross axis mount the azimuth of the dome is not in general equal to the azimuth of the telescope but this divergence can be handled by a simple algorithm. The dome is opened to a width of two metres by two shutters moving horizontally. In addition there is a windscreen which may be stowed horizontally or raised to a zenith distance of 15°. Mounted near the top of the dome is a one tonne hoist which may be used to lift equipment from the basement through to the upper levels. This hoist is also used to lower the primary mirror to the basement when it is taken to the INT for re-aluminising.

4.2 The building

The building is a twelve metre square in plan and extends to three floors, with the basement half-concealed by the steeply sloping hill. It is a concrete structure surrounded by a reflecting screen to minimize radiation heating during the day. There is a gap between the solar screens and the outer building wall where air near ambient temperature is free to convect away any transmitted heat.

The basement contains the electrical intake room, the water tank and store rooms. It has a bay with large double doors to bring equipment in and out. The building is plumbed by a series of hatches so that equipment may be conveniently lifted to the rising floor using the one tonne hoist on the dome. The ground floor embraces the office, dark room, rest room and instrument store. In addition there is a room containing the air conditioning unit, the 8/16E telescope control

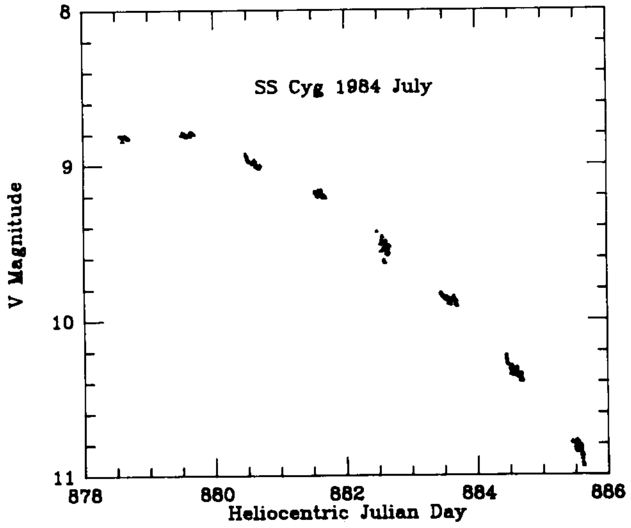


Fig. 11. Outburst light curve of SS Cygni in 1984 July observed by R W Argyle and C D Pike with the People's Photometer on the JKT. The abscissa is Hel.J.D. - 2445000. The observations were made in an attempt to find orbital modulation but none was found above the 0.02 mag. level. Observations were possible on eight successive nights although HJD 882.5 was marginally photometric.

computer, the telescope drive amplifiers and the time service. The upper floor contains the telescope console area, a room for the 3220 computer and an instrument bay to hold auxiliary instruments not in use. However the majority of this level is taken up by the rising floor which carries observers and equipment to convenient positions beneath the telescope. It is particularly useful when setting up instruments, for exchanging the two top end rings and their corresponding sky baffles, and when removing the primary mirror. It has a load carrying capacity of two tonnes and a total travel of 2.3 metre from the control room level. The rising floor was incorporated in the original design because it was an important part of the Siding Spring 1-metre design, from which the present telescope developed. In those days it was regarded as essential by the observers and as a nuisance by the engineers. However in the years needed to bring the project to fruition attitudes have changed. The majority of instruments are now so highly automated that there is little need for an observer to reach the eyepiece, even when one exists. While observers no longer require the rising floor it is accepted as essential by the engineering staff who can carry out many routine operations much more easily with its help.

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