THE APPLICATION OF OPTICAL FIBRE TECHNOLOGY TO SCHMIDT TELESCOPES

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ABSTRACT: The potential of the Schmidt optical system, when combined with optical fibres and linear detectors, is assessed. Recent work on the use of optical fibres at the U.K. Schmidt Telescope is described together with anticipated developments. In conclusion, there is a speculative consideration of the construction of a large, alt-azimuth Schmidt telescope (LAST).

INTRODUCTION

The combination of the Schmidt telescope and the photographic plate is one of the most potent in the astronomer's armoury. But, because of its relative cheapness, the photographic plate is used in a rather indiscriminate fashion, only ~1% of the capacity of the emulsion actually containing data on astronomical images. Optical fibre technology permits us to be much more discriminating about the images we choose to record. It is now possible to transfer these selected images from the focal surface to the outside of the telescope for analysis. Such systems have already been tested on a number of conventional reflectors (e.g. Hill et al., 1980; Gray, 1983) but none, as yet, has been applied to the singularly appropriate case of a wide-angled Schmidt telescope.

CURRENT DEVELOPMENTS AT UKSTU

At the U.K. Schmidt Telescope, we are currently constructing a multi-object fibre-optics coupler (Watson and Dawe, 1983). This will transfer the light of several hundred images from the telescope to fast spectrographs on the dome floor. The fibres are supported by a thin 14x14 inch aperture plate which, in turn, is held in much the same manner as the photographic plate it replaces. The spherical mandrel behind the plate is perforated to permit the passage of fibres, and the plate itself may be rotated through several arcminutes. All-silica fibres are to be used, having a numerical aperture of 0.25

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(f/2) and an attenuation of ~0.025 dB/metre at 500nm. With a core diameter of 50μm, they subtend 3.4 arcseconds on the sky. The aperture plates will be either metal, pre-drilled to accept fibres terminated in small ferrules (Gray, loc.cit.), or glass positive copy plates of the target field with the fibres cemented directly to them (Watson and Dawe, loc.cit.). The positional accuracy required will be ±25μm, and will be limited by (a) the precision of the fibre location in the curved focal surface, (b) differential refraction over the 6°.6 field (Watson, 1983), and (c) temperature effects.

Initial experiments, looking at a few tens of images, are to be performed using the ROE CCD Imaging Spectropolarimeter (ISP) (Mclean et al., 1980), with the polarization elements removed. Eventually, it is hoped to construct one or more optimized Schmidt-type spectrographs, when the efficiency of the whole optical train is likely to be ~14%. It should thus be possible to observe galaxies of surface brightness 18 magnitudes/square arcsecond, with a velocity resolution of 60km/s and a signal/noise of 50, in less than 20 minutes.

COMPARISON OF SCHMIDT VERSUS CONVENTIONAL REFLECTOR

Consider a telescope of aperture, A, having a field of view, θ, and equipped with n fibres. If the population of objects to be sampled has a number density on the sky, σ, greater than n/θ^2, all the fibres may be used simultaneously. A measure of the "effective aperture", a, will then be $\sqrt{n}\,A$. If the number density of objects is so low that only one can be sampled at a time (i.e. $\sigma < 1/\theta^2$), the effective and physical apertures will coincide. For the intermediate range of number densities ($1/\theta^2 < \sigma < n/\theta^2$), $a = \theta\sqrt{\sigma}\,A$, and we may write:

$$\log a = \log \theta A + 1/2 \log \sigma \qquad (1)$$

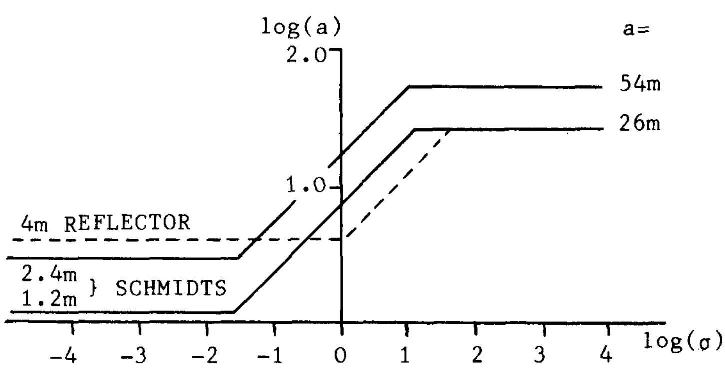

Figure 1. Effective aperture versus no. density.

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These three cases are illustrated in Fig. 1 where we compare a conventional reflector (A=4m; $\theta=1^{\circ}$; n=50) with two Schmidt telescopes ($\theta=6.^{\circ}6$; n=500) of apertures A=1.2m and 2.4m, respectively. It is readily apparent that even the smaller Schmidt telescope is competitive with the 4m reflector. It may be argued that the values of n assigned to the telescopes are arbitrary (though we believe them to be realistic); even so, there will always be a range of σ over which the 4m reflector cannot compete, no matter how many fibres it has available.

The appropriateness of a fibre-equipped Schmidt for a given astronomical programme thus depends directly upon the number density of objects to be sampled. Such disparate entities as galaxies and Cepheids, quasars and M-type stars can all be found at sufficiently high densities to make such an approach attractive. This statement must be qualified by noting that, for objects fainter than the sky contribution (equivalent to 19.7 magnitudes in V over the fibre cross-section to be used at UKST), it becomes difficult to compensate for the use of a small aperture by increasing the integration time. We are thus led to consider further the larger Schmidt telescope, where the sky contribution amounts to 21.3 magnitudes over a 50μm fibre.

A LARGE ALT-AZIMUTH SCHMIDT TELESCOPE

In another paper (Dawe and Watson, 1983), we propose a large alt-azimuth Schmidt telescope (LAST) of 2.4m aperture, working with the well-proven Palomar/UKST combination of $6.^{\circ}6$ field and f/2.5 speed. Novel features include:

(a) an alt-azimuth mount with co-rotating building. The focal-surface instrumentation is mounted on a ring girder, which rotates under laser control to compensate for field-rotation;

(b) a thin spherical mirror mounted on an active support similar to that used by the U.K. Infrared Telescope (Humphries, 1978);

(c) the separate mounting of various correctors and prisms on quadrant girders co-rotating with the main telescope (again under laser guidance);

(d) the use of a false focal cap, placed about 1/3 metre behind the true focus, onto which pallets of standard sizes can be mounted. Three types of detector would be accommodated in these pallets; viz., photographic plates, limited arrays of CCD's and large arrays of fibre optics.

The cost of the LAST would be about one-half that of a conventional 4m reflector. Unlike multi-mirror telescopes or arrays of small telescopes, it would truly exploit the statistical nature of observational astronomy, using a single optical train to look at many objects simultaneously.

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DISCUSSION

T. SHANKS: What is the timescale for the completion of a practical fibre opticsfor the present UK Schmidt?

J. DAWE: We hope to undertake the initial positioning tests, photographically, towards the end of the year. Spectroscopic tests should take place in the first half of 1984, using the ISP, though these will be limited to only a small number of fibres.