II. SYMPOSIUM SUR LES INSTRUMENTS ASTRONOMIQUES

Mardi, 9 *septembre* 1952

Deux séances ont été tenues le mardi, 9 Septembre.

Séance du matin: MM. A. Colacevich (*Président*); R.P. J. de Kort (*Secrétaire*); M. Laffineur, G. M. Sisson (*Traducteurs*).

1. THE SCHMIDT CAMERA AND ITS VARIANTS

By E. H. Linfoot, *Cambridge, England*

An important step forward in astronomical optics, and one of an entirely novel kind, was made by Bernhard Schmidt in 1930 when he introduced the new type of optical system which bears his name. As you will remember, the Schmidt camera consists of a spherical mirror together with a nearly plane-parallel figured plate situated at the centre of curvature of the mirror, as shown in Fig. 1. The mirror is larger than the plate, in order to receive the off-axis pencils. The field surface is curved, and is concentric with the mirror. The object of the plate is to 'pre-correct' the wave-fronts in the parallel pencils entering the system, so that they may be spherical after reflection by the mirror and so converge to a sharp focus.

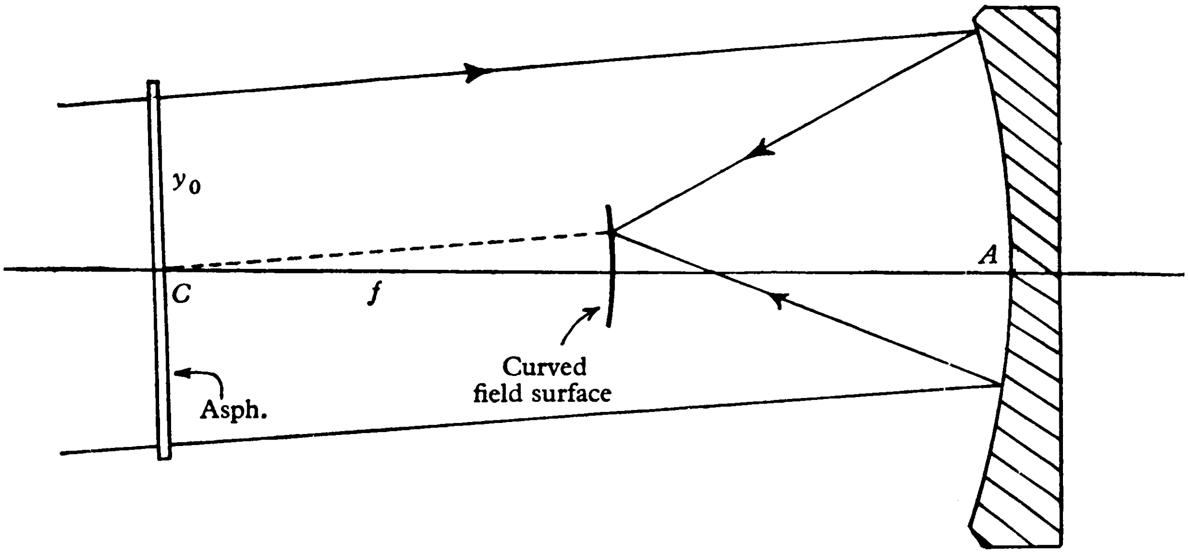

Fig. 1. The Schmidt camera.

It is well known that this goal can only be achieved approximately In the earlier Schmidt cameras—and in nearly all the later ones also—the design of the corrector plate aimed at bringing to a sharp focus the rays of a pencil, of selected wave-length near the middle of the spectral range, entering parallel to the axis of the system. To a good approximation, the figuring of the aspheric plate profile which achieves this is given by the equation

$$\eta = \frac{1}{32(n-1)f^3}(y^4 - ay_0^2y^2). \tag{1}$$

Here η denotes the 'figuring thickness' on the aspheric surface of the corrector plate (that is to say the thickness of glass* which, laid on to a plane surface, would produce the required surface profile), n is the refractive index of the plate in the selected wave-length,

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* It is convenient to allow η to take both positive and negative values.

f is the focal length of the system; y_0 denotes the radius of the edge zone of the corrector plate; and a is a parameter which determines the 'neutral zone' of the plate. When a has the commonly adopted value 3/2, the neutral zone is at 0·866 of the full radius; when $a=2$, the neutral zone is at the edge of the plate.

In Schmidt telescopes working at focal ratios near $f/3$ over fields of something like five degrees angular diameter, the predominant optical aberration is sphero-chromatic aberration, approximately uniform over the whole field. It arises from the variation of the refractive index of the corrector plate in different parts of the spectrum, which causes over-correction of the spherical aberration of the mirror by the plate in blue light and under-correction in red. It is true that in these telescopes the monochromatic image-spread at the edge of the field is comparable with the chromatism; but, owing to the special form of the monochromatic aberrations, four-fifths of the light of each monochromatic image is contained in a small lozenge-shaped central area (see Fig. 2) and this has the result stated. Because of this peculiarity of the images, the usual method of calculating overall image spreads is not a very reliable guide to the performance of a Schmidt camera. An alternative procedure is to use spot diagrams (obtained by tracing rays through a lattice of points filling the aperture stop and plotting their intersections with the image surface) or to assess the images by calculating the mean square deviations of the ray-intersections from the centre of gravity of the image. Both these methods have their limitations, but they are better than a crude comparison of overall image-spreads. When they are applied to a Schmidt telescope of focal ratio near $f/3$, it appears that the best value of the parameter a is about 1·33, corresponding to a neutral zone at about 0·82 of the full aperture of the corrector plate.

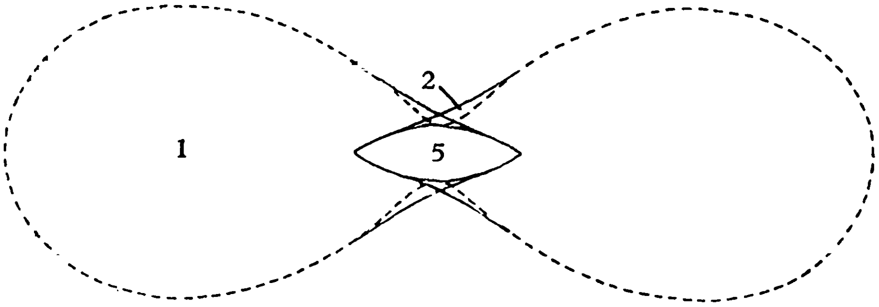

Fig. 2. Monochromatic images of the 'classical' Schmidt camera. The images are all similar and increase in size as the square of the off-axis distance; the largest diameter of each image points towards the field centre. The numbers state the degree of many-sheetedness of the image. The dotted line corresponds to the edge of the aperture stop. The area labelled '5' contains about four-fifths of the light.

When the focal ratio is shortened to $f/1·5$ or $f/1$, and the angular field-size increased to keep the central obstruction ratio near to the convenient values 1/4 or 1/3, the monochromatic aberrations become dominant near the edge of the field, while the colour aberration remains dominant near its centre. In such high-aperture systems, the approximate equation (1) for the corrector-plate profile is no longer sufficiently exact. Moreover, a slight reduction in the strength of the corrector plate and a small change in the curvature of the receiving surface give a worth-while improvement in the image quality over the field as a whole.

The best choice of a now depends on the spectral range to be covered. In an $f/1$ system intended for stellar photography, a should be about 1·5; while in a system ntended to work over a very narrow spectral range we should take $a=2$, putting the neutral zone at the edge of the aperture stop.

The field-flattened Schmidt camera. In a large Schmidt camera the inconvenience of the curved field is not very serious, provided the angular field size is not too great. Thin glass photographic plates, cut into disks or squares, can be held pressed against a spherical backing-surface during the exposure; on removal from the holder the plates spring flat again.

However, the field can be flattened, at the cost of some increase in the optical aberrations, by placing a plano-convex lens with its flat side very close to the focal surface. The strength of the lens is such as to annul the Petzval curvature of the system in light from the middle of the effective spectral range.

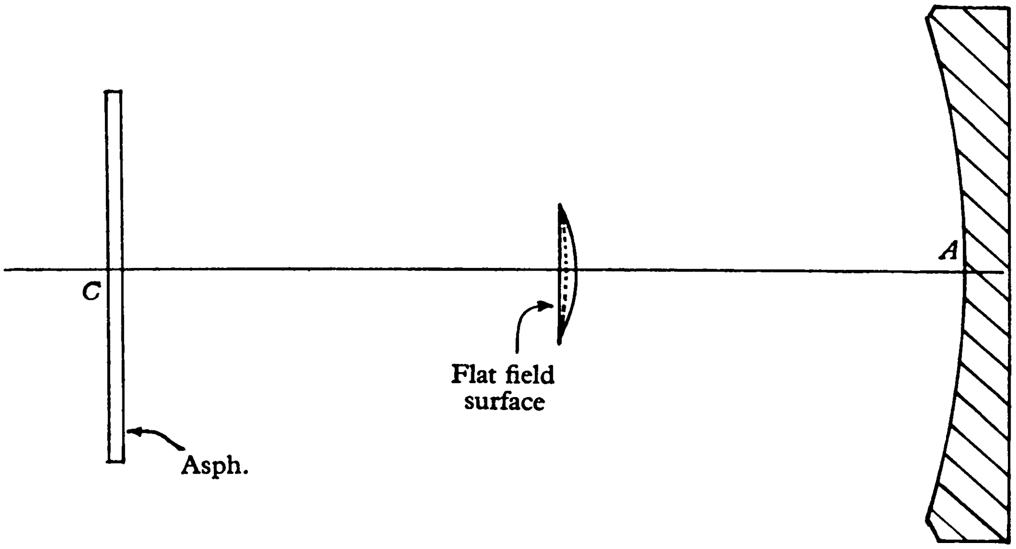

Fig. 3. The field-flattened Schmidt camera.

If the field-flattening lens is simply added to an ordinary Schmidt camera, the drop in performance is appreciable; but if the colour error is rebalanced by giving a the value 1·7 and the coma rebalanced by moving the corrector plate a small distance along the axis towards the mirror, then the aberrations of the field-flattened Schmidt camera (Fig. 3) are not much larger than those of the 'straight' Schmidt.

The chief theoretical drawback to the system is the presence of a very small amount of residual coma in the off-axis images. However, in an $f/3$ system working over a 5-degree field, the residual coma-spread nowhere exceeds 0″·2 of arc.

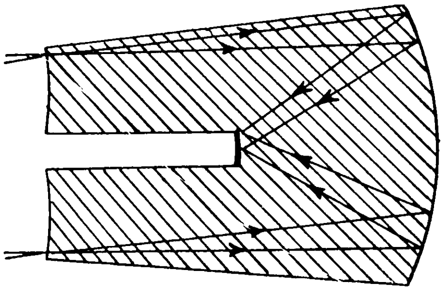

Fig. 4a. Solid Schmidt camera.

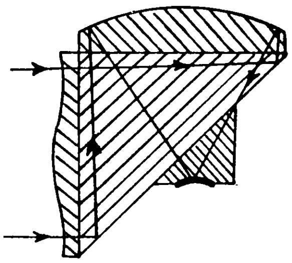

Fig. 4b. Folded solid Schmidt camera.

Schmidt spectrograph cameras. Time does not allow more than a brief mention of four interesting designs of fast Schmidt systems developed for use as spectrograph cameras. The first of these is the solid Schmidt, shown in Fig. 4a, which, constructed in glass of refractive index n, is n^2 times faster than the ordinary Schmidt of the same dimensions. Effective speeds of $f/0·35$ are practicable in small sizes. The glass is cut away behind the field surface to allow access to the photographic film, which is oiled on to the spherical field surface. The inconvenience of having the field surface in the middle of a solid glass block was overcome in an elegant and ingenious way by D. O. Hendrix in his folded solid

Schmidt, shown in Fig. 4*b*. Here the aspheric first surface and the mirror are cemented to the perpendicular faces of a right-angled prism; a smaller prism cemented to the centre of the diagonal face carries the field surface. Another way of rendering the field of the solid Schmidt accessible is shown in Fig. 4*c*. The resulting system, known as the thick-mirror Schmidt, is inferior to the solid Schmidt in theoretical optical performance but is sometimes to be preferred in practice.

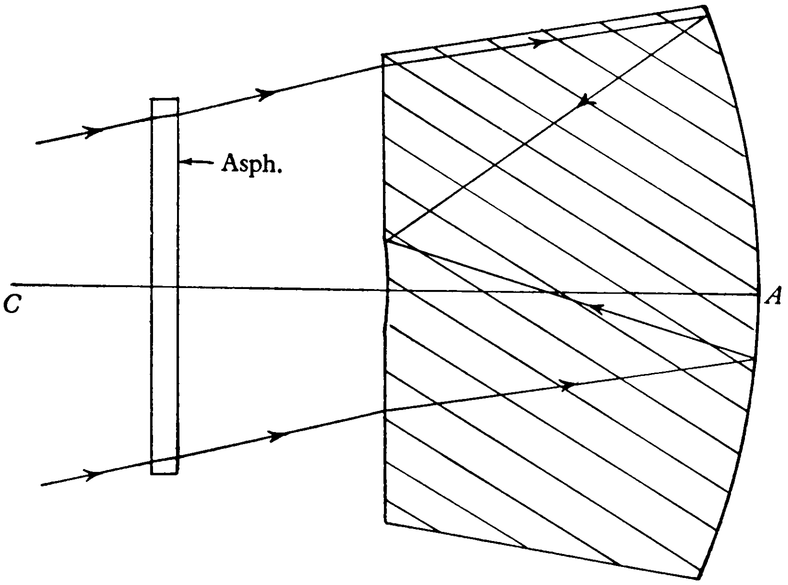

Fig. 4*c*. Thick-mirror Schmidt camera.

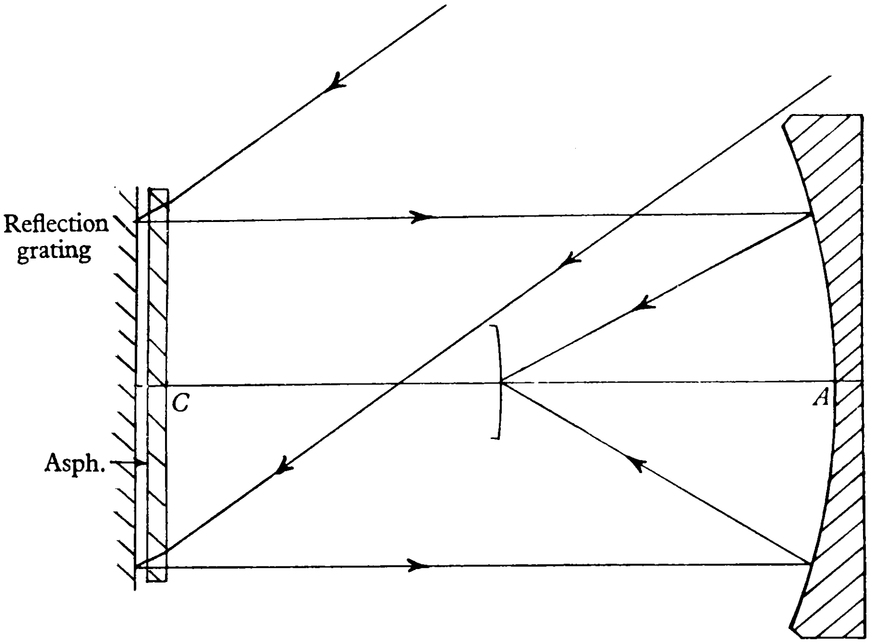

Fig. 5. Schmidt spectrograph camera—Bowen.

The fourth design, due to Dr I. S. Bowen, is especially suited to the case where a large camera of short focal ratio is needed. The corrector plate, of approximately half the usual strength, is placed almost in contact with a reflection grating, and is traversed twice by the light (see Fig. 5). The advantage of this arrangement is that the size of mirror and corrector plate is less than it would be with a 'straight Schmidt'

The Schmidt Cassegrain systems. In recent years, systems based on the idea of flattening the field of the Schmidt camera by the addition of a convex secondary mirror (Fig. 6) have been investigated by J. G. Baker, C. R. Burch and the writer. A system of this type was also proposed independently by H. Slevogt.

So far as I know, the first systems of this type actually to be constructed were two small models of 8-inch aperture made by me in Bristol in 1943 and 1944. I wanted to investigate their aberrations experimentally, since at that time there was no fifth-order aberration theory of Schmidt Cassegrain systems. Important contributions towards such a theory have recently been made by P. A. Wayman.

In 1946 the University of St Andrews in Scotland decided to build a Schmidt Cassegrain telescope and to combine the actual construction with a thorough investigation of the optical and mechanical problems involved. Mr Robert Waland of the St Andrews Observatory staff undertook the constructional work and I was asked to do the optical designing, the whole project being under the direction of Prof. E. Finlay-Freundlich.

We decided to begin with a half-scale pilot model, of 15 inches clear aperture and 45 inches focal length, and this model has now been completed and put into service.

Waland began by constructing optical and mechanical workshops in the basement of the observatory.

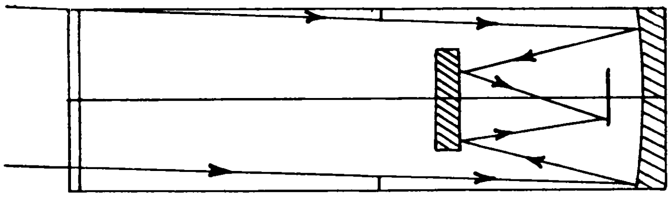

Fig. 6. Schmidt Cassegrain telescope.

The illustration (Fig. 7) shows a microphotograph of the image of an artificial star near one corner of the 4 × 4-inch flat field. The smaller diameter of the main part of the image is 0·0012 inch (0·03 mm.). The image agrees well with the theoretical light-distribution corresponding to nearly pure astigmatism.

This microphotograph provides in a certain sense an answer to the question whether the Schmidt Cassegrain systems with both mirrors spherical can give sufficiently good resolution for high-definition astronomical photography.

I have had to leave unmentioned one or two important variants of the Schmidt camera, in particular the meniscus Schmidt and the essentially similar super-Schmidt, but I believe Dr Whipple is going to speak about the super-Schmidt later on in the Symposium.

Discussion

Dr Haffner (Göttingen): Astronomers have found the images of the Schmidt camera too sharp for accurate photometric work. This can be avoided by modifying the profile of the corrector plate. In Göttingen, with a $f/5{\cdot}5$ camera, we have even obtained good photometric results by removing the corrector plate.

Answer. Perhaps I may venture first to remark that it is no criticism of an optical system to say that the images it forms are too sharp! A few years ago I suggested a modification of the Schmidt camera, in which a small fraction of the asphericity on the plate is transferred to the mirror. This gives nearly uniform images over the whole field and the light distribution in the images is much more suitable for photometry than that of Fig. 2. The images are still very small however.

Fr. Treanor (Oxford): Was a specially fine-grained emulsion used for the photograph of the image?

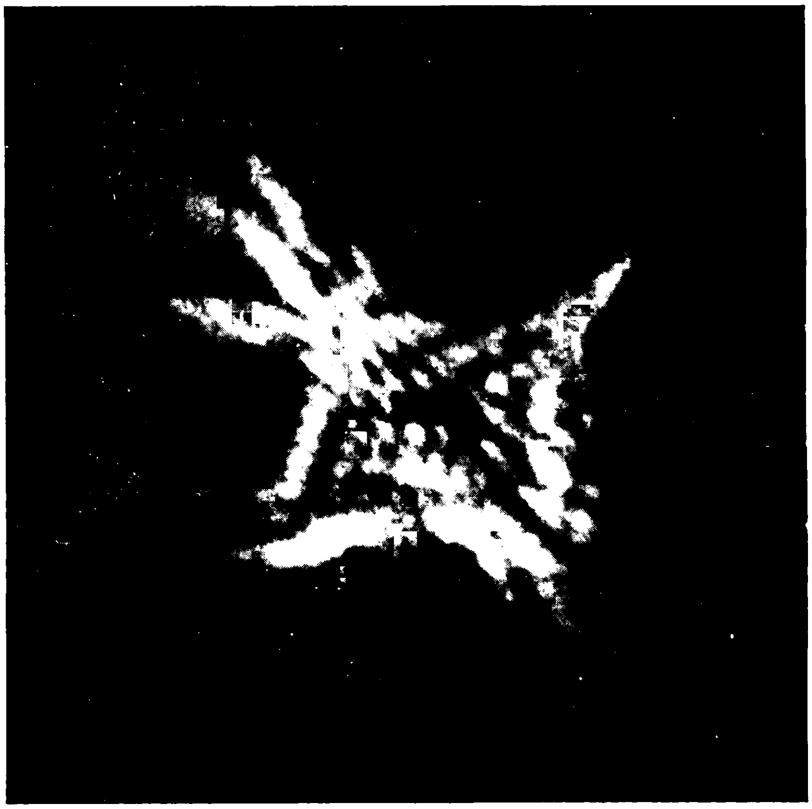

Fig. 7. St Andrews Schmidt Cassegrain (15-inch $f/3$) pilot telescope. Microphotograph (×850) of image near edge of field. The light source was a pinhole imaged down by a micro-objective; a 19-inch paraboloid mirror was used as collimator.

Answer. No. The photograph is a microphotograph, taken with a 6 mm. objective on Kodak Super XX film and subsequently enlarged.

Nous plaçons ici une communication de M. Whipple, se rapportant au sujet traité par M. Linfoot, quoique cet exposé ait été fait, pour des raisons matérielles, au début de l'après-midi.

2. EXPERIENCES WITH THE BAKER SUPER-SCHMIDT METEOR CAMERAS

By FRED L. WHIPPLE, *Harvard College Observatory*

The Super-Schmidt Meteor Camera was designed by James G. Baker and manufactured by the Perkin-Elmer Corporation for the Bureau of Ordnance of the United States Navy, to be used by the Harvard Observatory. The camera, of fine optical components including a spherical mirror, has an aperture of 12·3 inches, a focal length of 8·0 inches and covers a field of 55° with a spherical focal surface of 7·3 inches diameter. The optical focal ratio is nominally $f/0{\cdot}65$ and effectively $f/0{\cdot}85$.

The first complete telescope was installed in New Mexico during the summer of 1951. Since March 1952 two of them have been operating at two stations for the simultaneous photography of meteors.

Rotating shutters break the exposure for meteors 60 times per second and admit 25% of the light for stationary objects in the sky. Special equipment has been designed at the Harvard Observatory for moulding flat photographic film to a radius of curvature of 8·0 inches by means of heat. The moulding technique is completely successful and requires 2 minutes per film. The optical system of the camera is opened for loading the film. The operation requires about 3 minutes. The film is held on a spherical surface by vacuum to a precision of about 0·0005 inch. With Eastman X-Ray film and with the rotating shutter, the maximum exposure on the sky is 12 minutes; the operating cycle is 15 minutes.

The Super-Schmidt cameras give the optical performance of high quality wide-angle lens systems with about 80% of the light contained in a 25-micron disk near the optical axis and in about a 50-micron disk near the edge of the field. Lack of achromatism is small in the wave-length range 3800–4500 A., but becomes quite appreciable in the red end of the spectrum.

Some 200 meteors have been doubly photographed in the interval March through July 1952 with a rate of about one meteor per 30 minutes of exposure time. This effective rate for meteor photography is from 50 to 100 times greater than with any previous lens systems used for the purpose.

3. SUR LES PHENOMENES THERMIQUES NUISIBLES DANS LES TELESCOPES A REFLEXION

Par A. COUDER, *Paris, France*

Les phénomènes dont je vais parler sont de deux ordres différents. J'examinerai en premier lieu les effets qui résultent des différences de température qui existent dans l'air, à l'intérieur d'un instrument et dans son voisinage immédiat, sur le trajet du faisceau lumineux: c'est là ce qu'on pourrait appeler la micrométéorologie de l'observation télescopique. Comme résultat de cette étude je décrirai brièvement les dispositions qui ont été introduites dans l'installation du télescope de 193 cm. actuellement en cours de réalisation à l'Observatoire de Haute-Provence, comme une tentative pour améliorer ces conditions micrométéorologiques.

Dans une seconde partie je considérerai les déformations thermiques des miroirs eux-mêmes. Sans revenir bien longuement sur le description de ces déformations, connues