were proposed, seconded and carried. The result of the Ballot was then announced as follows: *President*, H. Dingle; *Vice-Presidents*, T. G. Cowling, Sir Harold Spencer Jones, H. S. W. Massey, W. M. Smart; *Treasurer*, L. M. Milne-Thomson; *Secretaries*, A. Hunter, Flora M. McBain; *Foreign Secretary*, F. J. M. Stratton; *Council*, A. Armitage, H. Bondi, E. H. Collinson, V. C. A. Ferraro, J. S. Hey, F. M. Holborn, J. Jackson, R. A. Lyttleton, R. W. B. Pearse, D. H. Sadler, Rev. P. J. Treanor, G. J. Whitrow. A vote of thanks was passed to the Scrutineers of the Ballot. The Meeting was then adjourned until 1953 February 13.

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday, 1952 March 14 at $16^h\ 30^m$

Professor H. Dingle, *President*, in the Chair

Secretaries: A. Hunter
Flora M. McBain

The Minutes of the February meeting were read, confirmed and signed. The President announced that Dr. Edwin Hubble had accepted the Council's invitation to deliver the George Darwin Lecture on 1952 October 10. Among the list of presents received since the last meeting, the Secretaries announced that a collection of astronomical books had been presented to the Society by the executors of the late Arthur Henry Phayre.

The President. We are pleased to welcome here this evening Prof. Larink, the Deputy-Director of the Hamburg Observatory, and I will ask him to tell us about his institution.

Prof. J. Larink. The Hamburg Observatory was founded in 1833, being formerly Repsold's private observatory. In 1900, the observatory moved some 20 kms. to the east of Hamburg, to Bergedorf. Prof. Schorr, who died a few months ago, made many observations with the main instrument at that time, a 24-inch visual refractor, with an additional photographic objective. Prof. Graff also used this instrument for his work on planets, variable stars and general photometry. We have a 40-inch parabolic mirror, with which Baade made his classic investigations of variable stars in clusters and the Milky Way. Our Lippert astrograph was extensively used for the Bergedorf Durchmusterung. The meridian circle, routine observations with which are continued, is one of the only two such instruments in Germany (the other being in Heidelberg). Plans for development include a 40-inch/32-inch Schmidt camera of 96-inch focal length. The dome has been erected, and the mirror by Zeiss finished; we hope to have the instrument working by 1953. Schmidt was a member of the observatory's staff.

I am honoured to be among my British colleagues, and would like to express my thanks for the hospitality which they have extended to me during my visit here.

The President. We are very grateful to Prof. Larink for having given us this interesting account, and offer him our best wishes for the work of his observatory. Fellows will now see a film showing the grinding of the 98-inch mirror for the Isaac Newton Telescope. This film "Grinding a 98-inch Telescope Mirror", is shown by the courtesy of the Carborundum Co. Ltd.

After this film, which was much appreciated by the Meeting, had been shown, the President invited Prof. Ferraro to give an account of a paper by himself and Mr. D. J. Memory, on "Oscillation of a Star in its own magnetic field".

Prof. Ferraro. In 1947 H. W. Babcock discovered that certain variable stars possessed magnetic fields of the order of a few thousand gauss and that in certain cases these magnetic fields were not only variable but that, as in the case of HD 125248, the direction of the magnetic field was reversed. (Only those stars whose axis of rotation points towards the observer have been considered by Babcock to avoid broadening of spectral lines due to rotation). It was suggested by S. K. Runcorn in 1948 that this variability and even the reversal of the magnetic field might be explained as the result of radial pulsation of the star in its magnetic field. For, in a highly conducting medium, such as a star, the magnetic lines of force are "frozen" in the medium and so move with it. Thus, the lines of force are bent towards the surface or away from it (i.e. towards the line of sight) according as the star is contracting or expanding. It can be shown that in this case, it is possible for the integrated Zeeman effect of the higher harmonics to indicate a reversal of the integrated magnetic field.

In 1949, Martin Schwarzschild made a first attempt to investigate this problem by considering the oscillations of a highly idealised star in its magnetic field. He made the following simplified assumptions:—

(1) the electrical conductivity of the star is infinite
(2) the material is homogeneous and incompressible
(3) gravity variations are neglected
(4) the magnetic field of the star is uniform.

Of these only the first is justified. Schwarzschild derives a formula for the period of a free oscillation of the star involving the density and radius of the star and the intensity of the uniform magnetic field. Assuming this period to be the same as that found by Babcock for HD 125248 viz. $9\frac{1}{4}$ days, he inferred the value of the magnetic field to be of the order of a million gauss. This he identified with the central value of the magnetic field of the star. As there appeared to be no justification for this identification, Mr. Memory and I have repeated Schwarzschild's analysis making the same assumptions as he did *except* that account was taken of the increase of the magnetic field of the star with depth; this was assumed to be due to a central magnetic pole. The problem is then one of magneto-hydrodynamics and using spherical harmonic analysis we find that the period of small oscillations is $2\pi a(4\pi\rho)^{\frac{1}{2}}(H_s x_1^3)^{-1}$, where H_s is the surface value of the permanent magnetic field, ρ and a are respectively the density and radius of the star, and x_1 is an eigen-value. For the first spherical harmonic, the first three eigen values are 1·63, 2·35, 2·79 approximately, and for the second harmonic, 1·68, 2·35, 2·79 nearly. Taking, with Babcock, the radius and density of HD 125248 to be comparable with that of Sirius A ($a = 1·1 \times 10^{11}$ cm, $\rho = 0·96$ gm/cc) we find the period of the fundamental mode of the first and second harmonic to be 2½ years instead of 9¼ days. This shows that Schwarzschild's identification of his uniform magnetic field with the *central* value of the stellar magnetic field is incorrect and that he should have used instead a value comparable with the surface field.

This fact can be brought out in another way. If u denotes the amplitude of the (radial) velocity of the star at the poles and h the amplitude of the magnetic field variations there, then it can be shown that $h = 5(4\pi\rho)^{\frac{1}{2}}x_1^{-3}u$. Now Babcock states that for HD 125248 u varies between 3 and 10 km/sec. Putting $x_1 = 1·63$ and $\rho = 0·93$ in this formula, we find $h = 4$ million gauss for $u = 10$ km/sec. This shows that Schwarzschild's uniform magnetic field is about one thousand times too large.

Whilst free oscillations of the star must be ruled out as a possible explanation of variable magnetic fields, it is possible that this, as well as the reversal of polarity, may be explained as forced oscillations of the star in which the exciting mechanism is that occurring in pulsating stars. In this case, for a period of 9¼ days x_1 is about 7·48 and the first of the two formulae shows that amplitude of the magnetic field of the induced current is decreased in the ratio $(1·63/7·48)^3$ to a value of about 10^4 gauss for $u = 10$ km/sec and about one-third of this value for $u = 3$ km/sec. These are comparable with the observed surface magnetic fields of the star.

The President. This paper is now open for discussion.

Prof. Cowling. This problem is one on which I have been working, and my own results confirm and to some extent carry forward those of Prof. Ferraro and Mr. Memory. Prof. Ferraro did not mention Schwarzschild's least defensible assumption, namely that the gravitational effects could be neglected. The gravitational effect of the equatorial and polar bulges can in fact become predominant. When it is considered, it is difficult to make the star vibrate slowly enough. A first step in discussing this problem has been made by Miss Gjellestad who has considered the interaction of these two kinds of forces.

Another criticism of Schwarzschild's results is that they do not really provide for a reversal of the field, but merely for the superposition of a small varying field on a much larger static field. However, by modifying the mechanism a sufficiently slow overtone oscillation can be found that will produce a reversal in the observed field.

Mr. Bondi. Prof. Cowling's remarks fit in very well with the theory of stellar structure in which the enormous magnitude of the gravitational forces is clearly evident. Radial oscillations of a compressible star in which magnetic energy interacts with the energy flow of luminosity are more likely to lead to periods of the right order and may be amenable to treatment.

Mr. Gold. I do not understand why consideration has been restricted to oscillations in which there is no motion across planes of constant longitude. Torsional surface oscillations, in which the motion is confined to the surface, like the motion of an orange skin relative to the orange, could be controlled by a magnetic field and could have the required period. The effect of the distortion of the lines of force by this motion would be far more marked for small amplitudes.

Prof. Ferraro. I agree with Prof. Cowling that the gravitational effects of the deformations of the star cannot be neglected. But our object was to show that even for Schwarzschild's simple model the desired observed period is not, in fact, obtained. To Mr. Gold's query, my answer is that we discussed radial oscillations because they too formed part of Schwarzschild's model. I agree that torsional vibrations are much more hopeful in that gravitational effects are likely to be negligible, but I think that they may prove to be of interest only in connection with theories of sunspot magnetic fields.

Prof. Cowling. Rotational broadening of spectral lines is generally absent in magnetic stars, and this is interpreted as signifying that such stars are generally oriented with their axes towards the observer, the magnetic and mechanical axis are supposed co-incident. Under these conditions torsional vibrations would produce no change in the observed integrated field.

The President. This is evidently a fertile field for investigation and discussion, and we must thank Prof. Ferraro for presenting this paper by Mr. Memory and himself. I now ask Dr. Ramsay to give us a paper by B. Miles and himself, on the internal structure of Jupiter and Saturn.

Dr. W. H. Ramsey. This investigation by Mr. Miles and myself on "The Internal Structures of Jupiter and Saturn" is a development of my earlier work on the major planets. These two planets are composed mainly of hydrogen, the proportion in Jupiter being about 80 per cent by mass and in Saturn about 60 per cent by mass. In the earlier calculations it was assumed that the heavier elements are distributed uniformly through each planet. In the present investigation the heavier elements are assumed to be in part concentrated at the centre and in part uniformly distributed.

The speaker considers the origin of the Solar System to be still an open question. The planets could have been formed from material ejected from the Sun or a star, or they could have condensed from a gaseous cloud. In the latter case each large planet should contain a central concentration of the heavier and less volatile materials since only these could have been captured during the early stages of developnent. Such a central condensation of mass would decrease the computed moment of inertia of the planet and so could be detected from the polar flattening due to its axial rotation. The calculated ratio (I/MR^2) for Jupiter is 0·28 if the heavier elements are assumed to be distributed uniformly, and 0·22 if all the heavier elements are assumed to be concentrated at the centre. The empirical value must lie between these extremes. The value deduced from Jupiter's polar flattening using the Radau-Darwin approximation is 0·25. This approximation however ignores second and higher powers of the ellipticity and is based on other assumptions which are inaccurate. The ratio (I/MR^2) derived from Jupiter's polar flattening by a purely numerical method is 0·27, which is closer to that corresponding to chemical homogeneity. The computed value of (I/MR^2) for Saturn is 0·28 if the heavier elements are distributed uniformly and 0·19 if they are entirely concentrated at the centre. The value derived from the polar flattening using the Radau-Darwin formula is about 20 per cent too low; the correct value is 0·26. The models giving the best agreement with the observations for the two planets are

	Total Mass of Planet	*Mass of Central Core*
Jupiter	318 M_E	$11 \pm 10\, M_E$
Saturn	95 M_E	$5 \pm 4\, M_E$

M_E being the mass of the Earth. Thus the present empirical data do not demand central concentration of heavy materials.

If the planets were formed by an accretion process one would expect Jupiter and Saturn each to contain central cores at least as massive as Neptune, 17 M_E. The principal constituents of the cores would probably be water, methane, ammonia and terrestrial materials. The Mass 17 M_E is compatible with the data for Jupiter but it would appear not for Saturn. Little weight should however be attached to this discrepancy as the above errors assume that the rotation periods are correct. The rotation period at Saturn's poles is about 11^h, and at the equator $10^h\ 14^m$; a mean value of $10^h\ 38^m$, as given by Russell, Dugan and Stewart, has been assumed, but if the *lowest* period is taken, the estimated mass of the core becomes 17 M_E. The origin of the circulation currents, which are in opposite sense to those on the Earth, is uncertain.

One interesting result in support of the aggregation theories should be mentioned. On such theories, the central core should have the same mass in both cases, and the fact that the material captured by Jupiter cannot be less rich in hydrogen than that captured by Saturn sets an upper limit of 19 M_E for the mass of each core. On the other hand, the mass cannot be less than 17 M_E the mass of Neptune. The mass of the central condensations of heavy materials is therefore restricted to narrow limits, and the proportion of hydrogen in the captured material is the same for the two planets, namely 85 per cent. Thus the compositions of Jupiter and Saturn are related in a definite way, and one degree of arbitrariness has been removed from the problem.

The President. The meeting is now open for discussion on this interesting paper. We are pleased to see Prof. Born here this evening; would he care to make any comment on this work?

Prof. M. Born. I am afraid that the data are not familiar to me, and I would not care to make any comment, although I have listened to Dr. Ramsey with interest.

Mr. F. Hoyle. I do not see how this analysis, important as it is, helps to discriminate between the various current theories of the origin of the solar system, which all suppose a similar development of the planets from condensations in a cloud of gas which supplies the angular motion. The differences are in the mechanism by which such a cloud arises.

Prof. Jeffreys. I am not quite clear on the restriction giving rise to the larger of the extreme values of (I/MR^2) for each planet.

Dr. Ramsey. The smaller value in each case is calculated from a model in which all the heavy elements are concentrated at the centre of the planet; the larger value corresponds to uniform distribution throughout the planet.

The President. I ask you to return your thanks to Dr. Ramsey and

Mr. Miles. Prof. Greaves and Dr. Ellison will now give us an account of the new Schmidt telescope at Royal Observatory, Edinburgh.

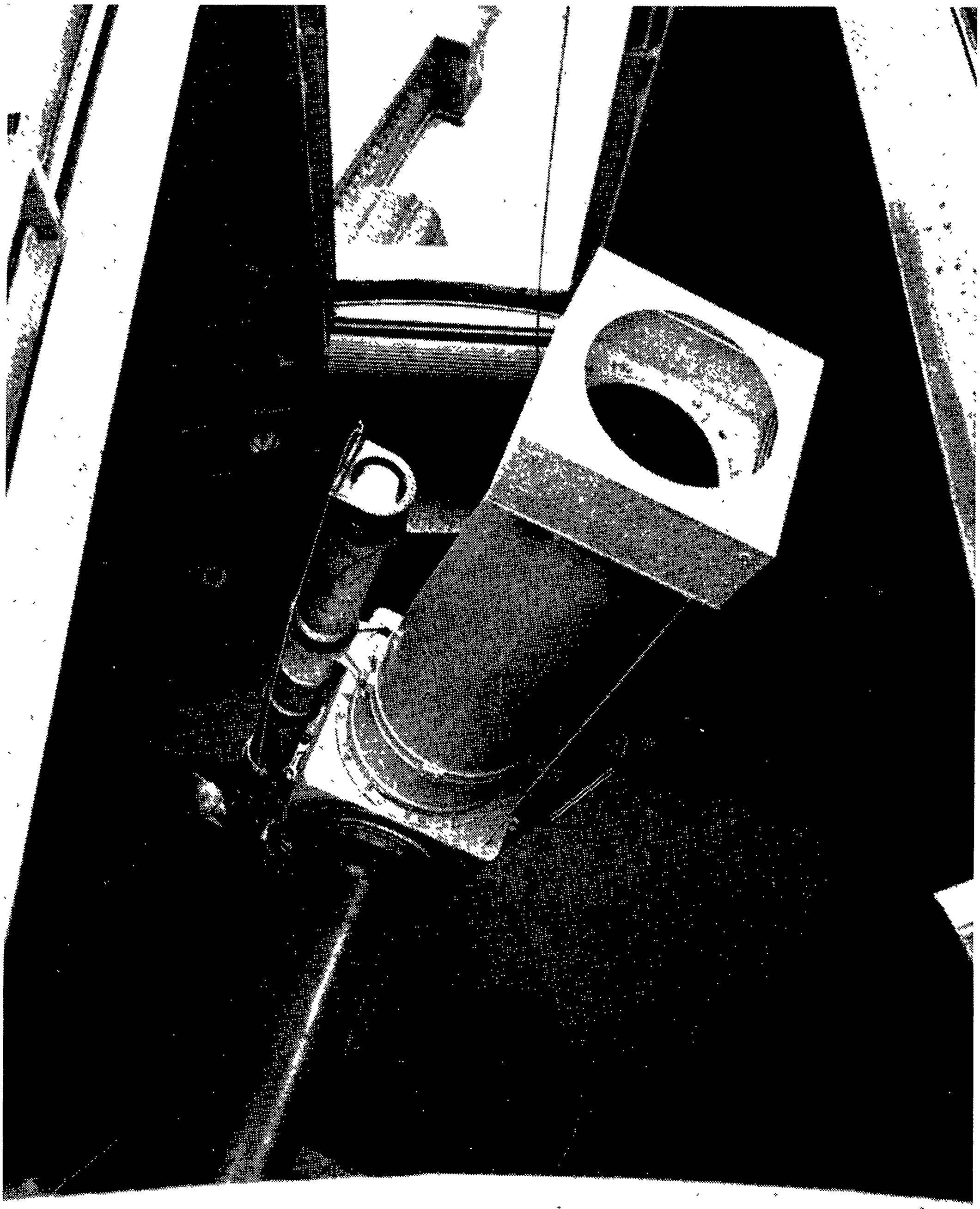
Prof. Greaves. In 1947 we decided to replace our 15-inch visual refractor at Edinburgh by a Schmidt camera. The mounting of this refractor was supplied by Messrs. Sir Howard Grubb, Parsons and Co. in 1932; this mounting and drive is of high quality and so we decided to retain it and to install the new Schmidt camera on the existing mounting. In addition to the 15-inch a camera was also installed on the same mounting and it was decided to provide a new mounting and drive for this camera which is by Sir Howard Grubb, Parsons and Co. and which employs a triplet lens of 60 inches focal length and 10 inches aperture.

The whole contract was carried through by Messrs. Cox, Hargreaves and Thomson Ltd. associated with Messrs. John Bowton Ltd., engineers. The Schmidt camera was specified to incorporate a 24-inch spherical mirror of 120 inches radius and a 16-inch corrector plate. Dr. Ellison, who is in immediate charge of the two instruments, will describe the Schmidt, but first I wish to show a slide of the 10-inch camera on its new mounting which, as you will see, is of the fork type. I wish to pay tribute to the excellence of the mechanical work and to the high performance of the new drive. This incorporates a synchronous motor which can be fed either directly from the mains or from the output of a power oscillator whose frequency can be controlled at will. We have been unable to find any periodic error in this drive and the whole installation is a very fine example of mechanical craftsmanship. The optical work of the Schmidt camera and the structural work involved in installing it on the existing mounting are also very fine, but I will leave it to Dr. Ellison to describe this new Schmidt, the acquisition of which we regard with immense satisfaction.

Dr. M. A. Ellison. As the principal user of this new instrument I should like to pay my tribute to its designers and constructors—and in particular to Mr. Hargreaves. It is the largest of his instruments in actual use, though, as we know, it is unlikely to remain so for very long.

This particular Schmidt telescope incorporates three major improvements the value of which we have proved in practice. First, it is a *visual* instrument. A right-angled prism and projector lens have been installed as an integral part of the film holder, and when the film has been removed the principal focus is projected to the side of the tube so that the instrument then becomes essentially a Newtonian. This device enables us, before making an exposure, to do two things (*a*) to apply the Foucault test to the whole optical train *in situ*, and (*b*) to achieve precise focus. For this operation a knife-edge of tin-foil is cemented to a dummy clear film which is permanently secured in a spare film holder. This film holder has a small hole at its centre through which a cone of rays passes to the right-angled prism behind. The knife-edge test and focusing are performed upon any bright star, preferably near the zenith so as to reduce the scintillation shadows passing over the mirror. However good the figure of a mirror may appear to be in the workshop, it is the ultimate performance in the telescope tube that matters and this should be frequently checked by the Foucault and Hartmann tests during use. Only thus can the effects of the mirror suspension and of heat gain and loss be investigated.

The second improvement is the method of covering the mirror and of



THE 24–16-INCH SCHMIDT TELESCOPE, ROYAL OBSERVATORY, EDINBURGH

(Constructed by Cox, Hargreaves and Thomson Ltd., London)

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preserving the aluminium film. A latex pad, precisely shaped to fit the curve of the mirror, is surfaced with a chamois cloth. This is pressed into firm contact with the aluminium film so as to exclude air circulation and to prevent deposition of dew. The pad is dried out once a week. When the telescope is about to be used an ingenious device removes the pad (which is also the mirror cover) and places it in a dust free container without the need for opening the telescope tube. After one year of this treatment the aluminium film is visually as reflective as when it was received.

Thirdly, there is the anti-reflection coating to the surfaces of the corrector plate. Before the plate was "bloomed", the images of bright stars were surrounded by a sharp-edged halo, 1·3 mm. in diameter and not quite concentric with the main image. We were able to prove that this halo arose from an internal reflection in the corrector plate, and it was feared that it might cause trouble when we came to use the instrument for accurate photometry by giving rise to irregular fogging of the clear film in dense star-fields. After some exploratory work, kindly carried out for us by Dr. Hunter with the Greenwich vacuum aluminising plant, the coatings of magnesium fluoride were finally applied by the firm of J. Pearson & Sons, of Stamford Hill, under Mr. Hargreaves' supervision. The remedy has been most satisfactory; the haloes round bright stars have been eliminated, and, of course, the light grasp has been improved.

We have found this halo in evidence on films taken with other large Schmidt telescopes, but as yet there seems to have been no reference to it in the literature of these instruments.

As you can see from the illustrations on the screen, the star images are extremely round and uniform all over the field of 4 degrees diameter. The smallest images have a diameter of 30 microns. The back of the mirror is convex and concentric with the optical surface, so that if the mirror does shift laterally on its supports during an exposure the image will be unmoved.

Mr. Hargreaves. It was really an act of faith on the part of Professor Greaves to entrust the construction of these two instruments to our new firm. We very much appreciated this trust, and we are glad to hear from him that it has been justified. Professor Greaves mentioned that the mirror construction was unorthodox. At the time that we received this order we were not satisfied about the homogeneity of large discs of low-expansion glass then available. We fell back on an idea which originated with Sir Charles Parsons, of welding together a number of thin plates of glass. We had already made a parabolic mirror from one of his experimental discs made in this way, and found it quite satisfactory. To avoid the risk of grinding through the top plate and to reduce the amount of grinding, the plates were welded in a mould with a convex floor, to which they conformed when they became plastic.

One feature of the telescope is that we have attempted to balance focal changes due to temperature by introducing a suitable length of invar into the supports for the film holder. The idea is that the effective length of the aluminium tube is such that its expansion corresponds to the change in focal length of the mirror.

The haloes to which Dr. Ellison referred are in fact extra-focal images of stars formed by light doubly reflected internally at the surfaces of the

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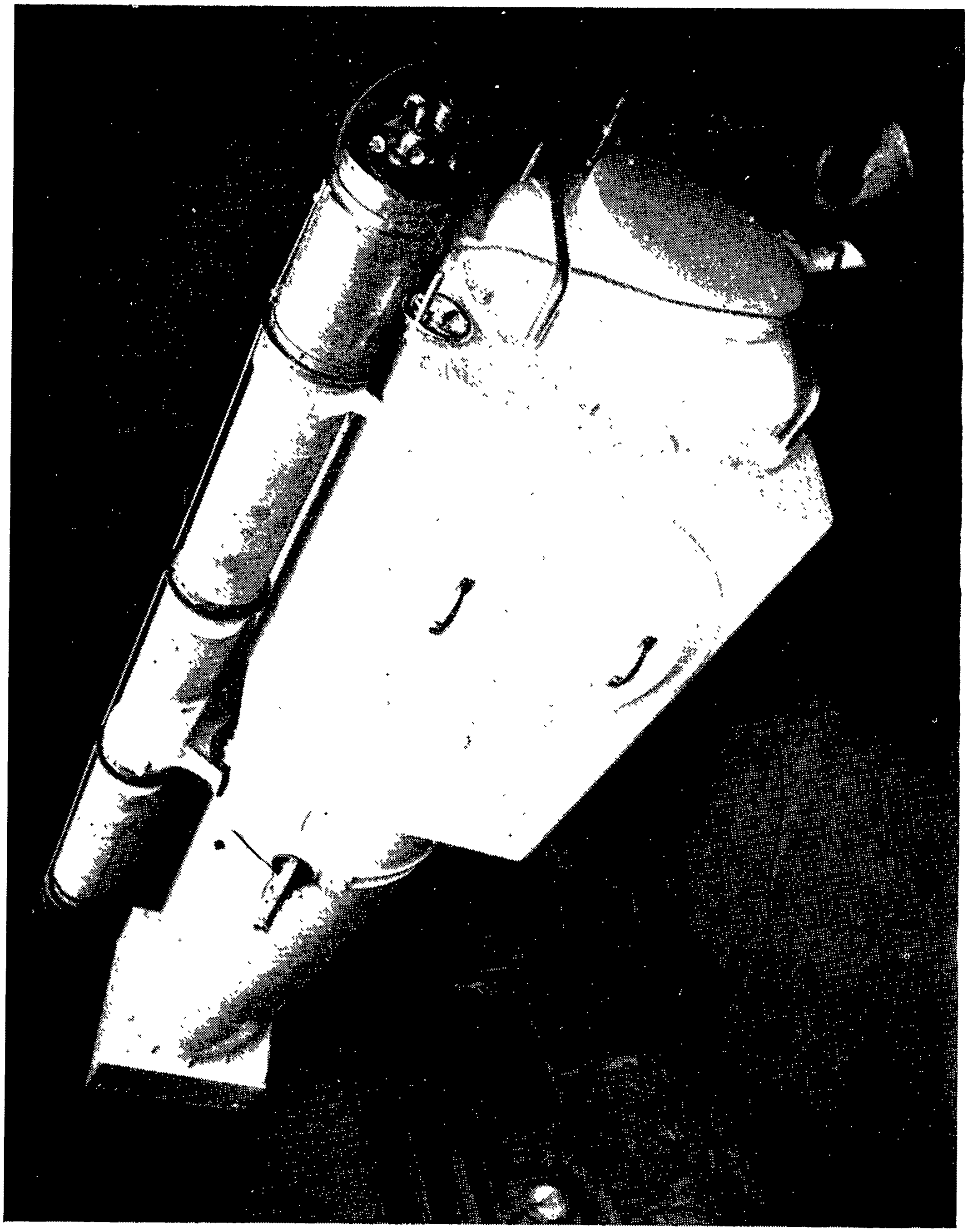

THE 24-16-INCH SCHMIDT TELESCOPE, ROYAL OBSERVATORY, EDINBURGH
(Constructed by Cox, Hargreaves and Thomson Ltd., London)

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corrector plate. The reflection at the aspherical surface of the plate has the effect of strongly over-correcting the spherical aberration of the mirror for this reflected light, thereby producing an extra-focal image in which the light is concentrated at its margin. The sharpness or otherwise of these haloes is therefore an indication of the quality of the corrector plate. They are not quite concentric with the star images because the surfaces of the corrector plate before figuring were inclined to one another by a few seconds of arc. This error has no effect whatever on the images themselves, but as there are two reflections the eccentricity of the haloes is four times the error of parallelism, and therefore quite noticeable.

The equatorial fork mounting for the ten-inch astrographic camera is a copy of one designed and made for his own use by Capt. G. T. Smith-Clarke to carry an 18-inch Newtonian reflector.

Not only did he allow us to use his design, but he presented us with his original drawings and the patterns for the castings, thereby materially reducing the cost of the mounting.

It is due to Capt. Smith-Clarke's kindness and generosity therefore, that we were able to make the astrographic camera available for use independently of the Schmidt camera, without undue expense to the Observatory.

The President. We have a little time left, and Dr. Ellison has some flare photographs which he is showing on behalf of Dr. Helen Dodson.

Dr. M. A. Ellison. I am showing these photographs on behalf of Dr. Helen Dodson, of the McMath-Hulbert Observatory. Her valuable work on flares and prominences is well known to members of the Society.

On 1951 May 8 Dr. Dodson was fortunate in securing a remarkable series of photographs and spectra of a great flare which occurred on the Sun's E. limb. This began at about 15^h 05^m U.T. over the great sunspot group which was then just beyond the limb. The sunspot reached the C.M. on May 16 and had a maximum area of 4850 millionths—one of the greatest on record.

These beautiful records deserve the warmest congratulations. A fuller account of them will appear in the *Astrophysical Journal*. The flare was not observed at Edinburgh, but we obtained a fine record of the ionospheric effect caused by the burst of ultra-violet radiation from the flare (an S.E.A. record on 27 Kc/s. was shown on the screen) beginning with great suddenness at 15^h 06^m. A great magnetic storm began on May 9 17^h, giving a travel time for the flare particles of about 26 hours. This is very close to the mean travel time for the storm particles, as deduced from many cases by Mr. Newton.

The President. We are most grateful to Dr. Dodson and to Dr. Ellison for letting us see these fine plates. The meeting is now adjourned until Wednesday, 1952 April 9.