9. COMMISSION DES INSTRUMENTS ASTRONOMIQUES

Report of Meetings

PRESIDENT: I. S. Bowen.

SECRETARY: G. Wlérick.

First Meeting, 26 August 1964

The President proposed that G. Wlérick serve as Secretary during the Twelth General Assembly. After having asked for proof corrections of the Draft Report, he discussed the structure of Commission 9. The following points were proposed by him and adopted:

The growing interest in 'image tubes', amply justifies the continuation of the Working Group headed by Prof. McGee.

It has also seemed reasonable to continue the present Working Group on 'image quality and site testing' (Chairman Prof. J. Rösch).

The need for new large telescopes, mentioned at the beginning of the Draft Report, suggests that enough time be devoted in Hamburg to discussions of the problems that they bring (an informal meeting of specialists was arranged) and to hear reports from the different projects.

The President announced also that an IAU Symposium on instruments will be held in 1965, probably in the spring, in the western part of the U.S.A. It will be devoted to the construction of large telescopes.

At the suggestion of the Executive Committee, the President had exchanged correspondence with Dr Denisse, President of Commission 40. They have agreed that the visual and radio techniques are at present so different that there is no immediate need for common meetings between Commissions 9 and 40. However, Commission 40 will become more and more the commission of radioastronomy instruments, so the problems of common interest may become more numerous. With regard to Commission 44, 'Extraterrestrial Observations', the instrumental problems concerning the optical designs appear similar, the difference coming from the necessity of telemetering. The problem of relations with Commissions 40 and 44 was opened for discussion.

The discussion was mainly devoted to the relation with Commission 44. Dr Atkinson and Prof. Gratton expressed the view that presently Commission 44 is mainly concerned with instrumental problems and that indeed the optical problems are of the same nature as those pertaining to ground observations. There is thus a large interaction between Commission 9 and Commission 44. Prof. McGee recognized this interaction but pointed out that there are marked differences between the space and ground based Astronomy; the necessity to observe in the vacuum ultra-violet and also to integrate images for long periods and then convert them to television signals demands what amounts to a new family of image transducers.

The President announced that he had just been informed of the nomination of new members of the Commission:

Eleven astronomers at the request of National Committees. They are all new Members of the Union.

Thirteen astronomers at the request of the Commission. There were obvious gaps regarding some countries. For instance the host country of this Assembly had no representatives.

SCIENTIFIC REPORTS

A. Miscellaneous subjects

(1) *A. Samaha* circulated a summary concerning the Kottamia 74-inch telescope and invited foreign astronomers to use this instrument.

(2) *Sedden* added some comments to the initial report of Peter Felgett already printed in the Draft Report. He insisted on the large possibilities of automation in astronomy and discussed the recent developments in that direction at the Royal Observatory, Edinburgh.

(3) *L. Gratton* described the following instrumental developments concerning the new Laboratory of Astrophysics of the University of Rome (Monte Albani, near the town of Monte Parzio Catone, altitude around 350 meters).

(*a*) Study of a 36-inch Ritchey-Chrétien reflector (aperture 1/7·5 and coudé focus).
(*b*) Construction and test of image intensifiers.
(*c*) Automatic measurements of stellar spectra. A machine, called MISA, permits the measurements of a large number of spectra very similar to each other, as in radial velocity work or for the determination of the equivalent widths in many stars of the same type.

(4) *W. A. Hiltner* showed slides of a rotatable telescope designed to minimize systematic errors in polarization measurements. The precision is $\approx$ 0·01 magnitude. It is used to observe the Sun and magnetic stars and also to study the change in polarization with wavelength.

(5) *Jean Rösch* described laboratory experiments that he has conducted with H. Camichel and M. Hugon. They show a systematic effect in the measurement of the diameter of a disk (either bright or dark) with a double image micrometer. This effect explains quantitatively why the diameter of Mercury measured with a double image micrometer, during the passage of 7 November 1960, is smaller by 0″20 (at unit distance) than the diameter measured by the Hertzsprung photometric method.

(6) *Hector C. Ingrao* gave information in addition to those printed in the Draft Report concerning new patrol cameras. Six cameras have been constructed and two are already on their way to Bloemfontein. These cameras take 8 × 10 (inch) glass plates from $\frac{1}{32}$ to $\frac{1}{8}$ (inch) thickness. Tests of the first three cameras show that the total composite error of the drive is of the order of 30 seconds of arc. Moreover, with the introduction of a torque motor on the polar axis, the backlash of the drive is eliminated and constant pressure is provided on the teeth of the gears. The instrumental pole can be set with a precision of 1 second of arc using two dial indicators mounted on the base of the camera.

The gear drive is powered by a tuning fork oscillator (stability 1 part in 10^5) and power amplifier. During the tests a variable frequency oscillator was also used to set the proper speed of the drive to compensate for the atmospheric refraction for a certain α and δ. From all the plates made at Agassiz Station with 103 a-D emulsion, the yellow corrected objective, GG 7 Schott filter and 2 hours' exposure time, the following values of image sizes were obtained as representative of the upper and lower sizes: 21 microns × 75 microns (54 microns trailing) and 19 microns × 47 microns (28 microns trailing). The upper value is governed only by the atmospheric refraction; the second shows an error in the drive, compensating accidentally the atmospheric refraction.

Fourth Meeting, 31 August 1964

B. Large telescopes

The fourth meeting was devoted to the plans of different countries for large telescopes. At least 10 important instruments are planned. In addition reports were given for two stellar telescopes nearly completed, for the largest solar telescope and for the largest astrometric

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telescope. The order of presentation of the communications had no relation to the advancement of the different projects.

(1) *Ch. Fehrenbach* reported on the European Southern Observatory, which will be constructed on the site: 'La Silla', 100 km north-east of La Serena, 500 km north of Santiago de Chile. Altitude 2400 m. The administrative center and laboratories will be located at Santiago. Instruments are in order of completion,

(*a*) Photometric telescope, $D = 1$ m, Cassegrainian built by Praademakus (Holland).

(*b*) Spectrographic telescope, $D = 1{\cdot}5$ m, Cassegrainian and coudé, built by REOSC (Paris).

(*c*) Schmidt telescope, corrector plate $D = 1$ m, $F = 3{\cdot}05$ m, mirror $D = 1{\cdot}6$ m. Optics built by Zeiss-Oberkochen. Mounting designed at Hamburg. It will complete the 'Palomar Survey' and will also use objective prisms.

(*d*) The Fehrenbach objective prism will be transferred from South Africa to Chili.

(*e*) A Danjon astrolabe will be put into operation.

(*f*) Large telescope, $D = 3{\cdot}5$ m.
Optics: α. Main System: Ritchey-Chrétien, $f/8$, computed by Köhler (Zeiss-Oberkochen), with corrector for flat field, of 30′ with $0''{\cdot}25$ images.
β. The prime focus $f/3$ will be corrected with a three-lens system, computed by A. Baranne, from Marseille Observatory. The diameter of the largest lens is 25 cm and only one of the six surfaces is aspheric. This system, located near the focus, is very light and gives a field of 1° with monochromatic images of 25 microns and images of 50 microns in a wide spectral range (3700–5000 Å or 5000–7000 Å). A correction will be attempted for this effect.
γ. The coudé focus, $f/30$, has a field of 4′.
δ. The main mirror will be made of silica. An agreement is discussed between ESO and CNRS for figuring the mirror at the O.H.P., under the direction of A. Couder. The type of mounting has not yet been decided. Comparison between ESO studies and those of Kitt Peak indicates similar conclusions. It will probably be a modified 'horse shoe' mounting. The center of gravity and the declination axis are in the plane of the horse shoe.

(2) *Ch. Fehrenbach* then described the French project. There is agreement to build a 3·5 m telescope that will be connected with the Haute-Provence Observatory. This project is very similar to the ESO project. The main mirror will be of quartz or pyrex. Two studies are being conducted of the mounting: one of a modified 'horse shoe', taking into account the latitude of the site, the other of a light English mounting, more convenient for coudé work. The mirror will be figured at the O.H.P., after the ESO mirror.

(3) A report was given by *V. B. Nikonov* on the 6 m telescope being constructed in the U.S.S.R. The main mirror is parabolic. There will be two main optical systems: the prime focus and the nasmyth. The mounting is altazimuth. This type of mounting seems to be a very good one from a mechanical point of view. The much more complicated drive of an altazimuth telescope, compared with an equatorial one, does not involve serious difficulties, when modern computer techniques are applied. The mounting is a 'horizontal platform', which is an azimuthal version of the 'polar platform' of the 2·6 m telescope of the Crimean Astrophysical Observatory.

The design of most of the parts of the telescope has been carried out and some of these are under construction now. The chief engineer of the project is Dr Ing. B. K. Joannisiani. The location of the telescope is to be the mountain region of northern Caucasus, at the height of nearly 2000 m. The exact location will be fixed soon.

(4) *D. L. Crawford* indicated that the design for the Kitt Peak 150-inch telescope project has now been underway for about 2 years. It is not a general design study of large telescopes, but only that of an efficient, versatile, modern 150-inch telescope.

The optics are similar to those described by Ch. Fehrenbach: large field prime focus and a Ritchey-Chrétien Cassegrain. It will have a horizontal coudé spectrograph. The telescope will be located on Kitt Peak (altitude 2100 m, latitude 32° N) and thermal and seeing studies are underway.

Two preliminary design contracts are just completed: Westinghouse Manufacturing Corp., Sunnyvale, California, has studied the mounting: deflections, weight, configuration, drives, etc. Skidmore, Owens and Merrill, Chicago, Illinois, have studied the dome and building. The declination axis is 150 feet above ground. This may be lowered on the basis of seeing studies. The rotating dome geometry is similar to the 200-inch telescope dome.

Finally, the primary mirror will be of fused quartz.

(5) *B. J. Bok* described an Anglo-Australian project for a 150-inch telescope. A committee and a technical sub-committee are at work. There are three possible sites in Australia, none being high.

(6) *O. Heckmann* reported on a German project for a telescope of at least 120-inch aperture. It will be sponsored by all the German observatories and universities. The location will not be in Germany. It may be in the Mediterranean region or in the southern hemisphere.

(7) *A. E. Whitford* indicated that the University of California astronomers have made tentative plans for a large telescope, needed to supplement the already overloaded 120-inch reflector at Lick Observatory. A site survey group has already started work in Australia. Both the Stock double beam telescope and the Babcock image-motion meter will be used for the tests of seeing. A general purpose reflector is envisioned, with no marked departure from previously tested design features. The size depends on the financial support that can be obtained.

In addition to the survey in the southern hemisphere, consideration is being given to a site for a new dark-sky observing station in California.

(8) *I. S. Bowen* reported that, looking forward to a possible duplication of the 200-inch Hale telescope in the southern hemisphere, the Carnegie Institution of Washington has started a site survey in Chile and Australia. H. W. Babcock's seeing monitor is being used. It is hoped that this survey will provide a basis of comparison between the two regions and between the previous surveys that have been carried out in them.

(9) Livio Gratton is secretary of a committee, headed by G. Righini, that has obtained agreement of the Italian Government for the study of a national observatory. The main telescope will have a diameter of 120 inches, prime focus, Cassegrain and coudé arrangements. A 60-inch spectrographic reflector is also foreseen. A site campaign around Rome and in Sicily will begin soon.

(10) *R.v.d.R. Woolley* reported that the Isaac Newton telescope, built by Grubb-Parson, will be delivered around December 1965. The mounting includes a very strong 'polar disk'. The coudé system uses five mirrors.

(11) *Jorge Sahade* gave additional comments to those included in the Draft Report concerning the duplication in Argentina of the 84-inch Kitt Peak telescope. The image quality in the site chosen in west Argentina will be compared with that of the Tololo site in Chile.

(12) *A. Samaha* emphasized the excellent climate of the Kottamia Observatory and gave some details concerning the 74-inch telescope.

(13) *K. Pierce* reported that the McMath Solar Telescope is now in operation at Kitt Peak. Its diameter is more than twice the diameter of the previously largest solar telescope. The following additional informations concerning this instrument, already described in pages 61 and 124 of the Draft Report was given.

(*a*) The 200 feet of the optical path above ground and the 300 feet below ground are surrounded by cooling panels. The cool water plus antifreeze is brought in at the bottom and taken out at the top so that there is a gradient of temperature of about 4°C between top and bottom, giving a stable air column. The dust particles in the air are nearly motionless. Both good (less than ½ second of arc displacement) and bad (about 2 seconds of arc) seeing have been observed with a small telescope over the internal optical path. The cause of the bad seeing is not known. Seeing on stars has been as good as 0″·2 of arc on rare occasions.

(*b*) The 289-foot focal length aluminum mirror, 63 inches in diameter, with 7-inch deep ribs, 1 inch wide, has held its figure over the past 2 years. The surface is irregular by a fraction of a wave so that there are broad wings on a stellar image. There is a sharp core of about 0·75 second of arc diameter with scattered light of about 2 seconds diameter. They have not yet learned to polish the Kanigen coated aluminum to a smooth regular surface.

(14) *K. Strand* gave an account of the 61-inch astrometric reflector of the U.S. Naval Observatory located at the station in Flagstaff, Arizona. The configuration of the telescope was determined from the requirements of using it for high precision astrometric work such as the determination of stellar parallaxes.

The telescope has a parabolic *f*/10 primary mirror and a flat secondary mirror reflecting the light to a focus behind the primary in a Cassegrain arrangement. Both mirrors are solid disks of fused silica. The primary has a free aperture of 61 inches and a thickness of 10½ inches, while the secondary has a diameter of 35 inches and a thickness of 6 inches.

The axial support of the primary is provided by an air bag with a variable air pressure applied depending upon the position of the telescope. The axial support system for the secondary mirror is provided by a vacuum. Radial supports of the mirrors are provided hydrostatically by means of buoyant neoprene tubes filled with mercury. The support system functions extremely well. Hartmann tests of the combined mirror system in the telescope gave a Hartmann constant of 0·11 with 74% of the light within a 25 micron diameter circle and 99% within a 50 micron (0″·7) diameter circle.

The telescope mounting is of the fork type. The tests of the tube indicate a very small flexure of the order of 12″ semi-amplitude going from 5 hours east to 5 hours west of the meridian with a declination set at + 90°. The tube flexure is also small. If the telescope is collimated at the zenith, there is a change of 3 mm in the position of the optical axis at a 45° zenith angle. This flexure is a combination of flexures on the tube and in the secondary cage.

A built-in collimation system records automatically on each photographic plate fiduciary marks from which the position of the optical axis on the photographic plate can easily be determined as well as whether the mirrors were in collimation.

Since the regular program was started in April 1964, approximately 1200 plates have been taken with the camera which has automatic exposure timing and plate transport. Guiding is carried out directly on the right ascension and declination drives of the telescope by means of a photo-electric guider of the pyramid type.

(15) Finally, *E. Vandekerkhove* described a deviator for objective-prism observations.

Seconde Séance, 27 Août 1964

PRÉSIDENT DE SÉANCE: J. Rösch.

SECRÉTAIRE: J. Dommanget.

C. Qualité des images

En ouvrant la séance à $10^h\ 45^m$, J. Rösch fait part à l'Assemblée de ce que le Prof. I. S. Bowen, Président de la Commission 9, lui a proposé de présider la présente séance, uniquement consacrée à la *qualite des images*. Il suggère comme secrétaire de séance, J. Dommanget et demande à l'Assemblée de marquer son accord sur cette double proposition.

Le Président de séance rappelle tout d'abord la fusion de l'ancienne Sous-Commission 9*b* traitant de la Qualité des Images et du Groupe de Travail pour le Choix des Sites et fait ensuite le bilan de l'activité du nouveau Groupe de Travail ainsi constitué. On n'en trouvera que peu de traces dans le Draft Report puisque cette activité fut axée principalement sur le Symposium no. 19 de l'UAI, tenu à Rome en Octobre 1962, et que c'est dans les comptes-rendus de ce Symposium, qui seront incessamment distribués, que figurent réunies toutes les indications à ce sujet.

Le Président signale également qu'à la suite de ce Symposium, quelques astronomes ayant participé à ses travaux, ont été invités par la Royal Meteorological Society à participer à son 'Summer Meeting' à Cambridge, en Septembre 1963.

Par ailleurs, à la suite d'un voeu émis à Rome, une note a été publiée dans le *Bulletin d'Information* no. 12, pp. 8–10, de l'UAI concernant les recherches qu'il y aurait lieu de faire sur les corrélations susceptibles d'exister entre la qualité des images d'une part et les conditions météorologiques locales d'autre part.

Le Président insiste sur le fait que les observations demandées ne doivent aucunement perturber l'exécution normale des programmes poursuivis aux instruments, par suite du peu de temps que ces observations réclament et par suite de l'adaptation évidemment nécessaire des techniques d'observation de la qualité des images aux circonstances dans lesquelles chacun de ces programmes est mené. Toutefois, il apparait fondamental d'uniformiser les principes d'observation afin de rendre les résultats comparables et significatifs.

Bowen fait remarquer que dans le cas des grands instruments, il n'est pas possible de procéder à des estimations de la qualité des images dans plusieurs directions, mais il est d'avis qu'il est nécessaire de consacrer un minimum de temps à ce genre d'observation (sur l'étoile guide par exemple), et qu'il faut procéder d'autre part, autant que possible, simultanément, à des observations météorologiques. Il estime également indispensable de se mettre d'accord sur une échelle commune d'estimation, basée par exemple, sur la valeur du diamètre de l'image.

Le Président rappelle que pour les petits instruments, il ne paraît pas y avoir de problème à ce sujet, si l'on adopte l'échelle de Danjon basée sur l'aspect des anneaux de diffraction, mais que pour les grands instruments, il faut en effet trouver autre chose, comme paramètre, par exemple, le diamètre de l'image.

Wlérick insiste également sur la nécessité de ne se référer qu'à un seul paramètre, mais craint que le diamètre d'image, par exemple, dépende trop de l'aspect intérieur (répartition d'énergie) de l'image ainsi que du facteur temps.

La discussion s'engageant sur ce dernier point, le Président propose d'entendre tout d'abord deux exposés relatifs précisément aux deux problèmes fondamentaux soulevés par la mise en application du programme de recherche de corrélations entre qualité d'images et facteurs météorologiques.

Dans le premier, *J. Rösch* présente un appareil simple mis au point au Pic du Midi (*C. r. hebd. Séanc. Acad. Sci., Paris.* **259,** 1003, 1964) et permetant de mesurer un 'diamètre équivalent' indépendamment de la loi de répartition de l'énergie à l'intérieur de la tache de diffraction et quel que soit le diamètre du télescope employé. Il consiste essentiellement en une lame de verre se translatant dans son plan sur laquelle on a métallisé une mince bande de largeur variable dans la direction de la translation et sur laquelle on forme l'image de l'étoile. Le dispositif comporte un jeu de réflexions tel que l'oeil observe deux images de l'objectif, l'une fournie par la partie centrale de l'image qui tombe sur la bande réfléchissante, l'autre par les parties extérieures, qui passent de part et d'autre de cette bande. On translate la lame pour faire varier la largeur interceptée; la 'largeur équivalente' de l'image s'obtient par l'égalisation des éclairements moyens des deux images de l'objectif.

Dans le second, *J. Dommanget* s'emploie à montrer que la recherche de corrélations entre la qualité des images et les facteurs météorologiques ne pose pas de problèmes bien difficiles. Il cite, à titre d'exemple, un travail effectué tout récemment à l'Observatoire Royal de Belgique et indique la voie suivie dans la mise en évidence d'une corrélation entre la qualité des images et la pression de vapeur d'eau dans l'atmosphère. Ce travail fait l'objet d'une publication dans les *Communs Obs. r. Belg.* no. 231, 1964.

Les deux orateurs insistent sur la simplicité des procédés mis en oeuvre et sur le minimum de temps à consacrer à de telles recherches.

A la suite de ces exposés, le Président demande aux astronomes présents désireux de participer activement à la campagne d'observations, dans le sens évoqué par la note parue dans le *Bulletin d'Information*, de se faire connaître afin que l'on puisse se rendre compte de la participation que l'on peut espérer pour un tel programme. Les représentants de plusieurs grands observatoires donnent leur acceptation.

Walker demande si la mesure du diamètre ne peut dépendre de la magnitude. *Rösch* et *Wlérick* ne le pensent pas. *Mikesell* attire l'attention sur le fait que les observations au télescope (y compris le guidage) seront de plus en plus automatiques, mais que des dispositifs automatiques fournissent eux-mêmes de l'information sur la qualité de l'image. *Rösch* conclut que même dans la perspective de ces nouvelles techniques, on peut et on doit étudier les corrélations avec les conditions atmosphériques. *Wlérick* demande encore si les mouvements d'images ne peuvent affecter les mesures faites par le procédé de *J. Rösch.* Celui-ci répond qu'il n'en est rien car la mesure consiste à réaliser l'équivalence des éclats extrêmes des deux images (l'une au maximum, l'autre au minimum).

Le Président de séance propose ensuite que la Commission 9 adopte une recommandation destinée à promouvoir systématiquement des observations astronomiques de qualité d'images dans les grands instruments et simultanément des observations météorologiques.

Wlérick demande ce qu'il faut entendre par *grands* instruments. *Rösch* répond qu'il n'y a pas à fixer de limite inférieure, mais qu'on insiste pour que *les plus grands* instruments soient effectivement utilisés à cet effet. *Bowen* se déclare en faveur de cette recommandation, en faisant remarquer que l'effort demandé est minime et qu'il s'agit surtout de normaliser des observations qui sont déjà habituellement faites. *Atkinson* se déclare opposé à la recommandation, en estimant qu'elle imposerait des servitudes pour un résultat problématique. *Terrien* propose que les termes de la recommandation soient tels que les observateurs n'y voient aucune contrainte. (Le texte finalement adopté a été remis au Secrétariat à Hambourg).

Le Président donne ensuite la parole à *Mme Kallistrova*, qui résume un travail sur l'interprétation de la distance de corrélation dans les ombres volantes, et sur la variation de la scintillation en fonction de la distance zénithale.

Enfin, *S. Van den Bergh* rend compte d'une étude sur la corrélation entre les fluctuations de la différence de température entre les deux extrémités du tube du télescope et la qualité des images.

La séance est levée à $12^h 15^m$.

RÉSOLUTION

La Commission 9,

Considérant que l'avènement de nouvelles possibilités d'observation grâce à des engins extra-terrestres ne doit pas faire se relâcher l'effort d'amélioration des techniques d'observation à partir du sol,

Considérant que les progrès acquis dans la réalisation des grands télescopes optiques rendent impérieuse la nécessité de choisir leurs emplacements de telle sorte que l'atmosphère terrestre limite le moins possible leurs performances et leur rendement réel,

Considérant que l'étude, dans les observatoires existants, des corrélations entre la qualité des images données par un grand instrument et les conditions atmosphériques locales serait un apport fondamental aux critères de choix du site d'un nouvel observatoire,

Exprime le voeu que les astronomes disposant de grands instruments acceptent de contribuer à cette étude au moins en y consacrant l'effort minimum proposé par le Groupe de Travail pour la Qualité des Images et le Choix des Sites (*Bulletin UAI* no. 12 (février 1964) pages 8–10) qui a été conçu de façon à ne pas perturber les programmes courants d'observation.

WORKING GROUP ON IMAGE TUBES FOR ASTRONOMY

PRESIDENT: J. D. McGee.

INTERPRETER: G. Wlérick.

Third Meeting, 28 August 1964

The session of Commission 9 from $10^h 45^m$ to $12^h 30^m$ on 28 August 1964 was devoted to a meeting of the Working Group on Image Tubes for Astronomy.

The first item of business was to consider the Draft Report of the Group. This was approved with minor typographical corrections.

The second item was raised by M. Walker, who proposed that consideration should be given by the Group to the standardization of the measurement of photocathode sensitivity. After considerable discussion it was agreed that, while present methods of measurement were far from standardized or consistent, it was not a question to which there was a simple, practicable answer. It was therefore agreed to appoint an informal committee to consider the problem in detail and report back.

The Chairman suggested that the same committee should also consider the problem of assessment of image quality of photo-electronic tubes. This was agreed and the following members were nominated to form the sub-committee: A. Lallemand, J. D. McGee, M. Walker, G. Wlérick, W. L. Wilcock, M. Duchesne, J. Terrien.

This group subsequently held two informal meetings, the conclusions of which are summarized in Appendix A.

There being no further business the Chairman called upon members to give brief reports on image tube progress since the compilation of the Draft Report. There follow summaries of the reports that were given.

I. RECHERCHES MENÉES À L'OBSERVATOIRE DE PARIS

A. Lallemand

(1) Il est commode de définir le facteur de mérite d'un tube image par la relation $\frac{T_p}{T_1}\frac{R_1^2}{R_p^2}$ où T_p et T_1 sont respectivement les temps de pose pour obtenir sur la plaque photographique classique et avec le tube image, toutes choses égales d'ailleurs, une même densité; R_1 et R_p étant respectivement la résolution en nombre de lignes par millimètre du tube image et de la plaque photographique classique. L'application de cette relation dans le cas des flux lumineux très faibles, utilisés en astronomie, peut donner lieu à des conclusions contestables, car la densité n'est pas un critère adéquat des information enregistrées par le récepteur. D'autre part R_1 et R_p sont déterminés au moyen de mires à contraste maximum et dans des conditions d'éclairement les plus favorables, alors que dans le cas des observations astronomiques c'est souvent de très faibles contrastes dont il s'agit et avec des niveaux de lumière très faibles.

(2) Avec la photographie électronique on est parvenu à utiliser des cathodes sensibles au proche infra-rouge (type S.1) avec une sensibilité qui se conserve très longtemps et qui donne un bruit suffisamment faible pour rendre possible des mesures de rayonnement IR au moyen de la méthode du comptage des traces d'électrons.

II. MISE EN OEUVRE DE LA CAMÉRA ÉLECTRONIQUE

G. Wlérick

A. *Questions particulières*

(1) *La distorsion.* L'optique électronique actuelle introduit une distorsion en croissant. Celle-ci n'entraine pas de perte de définition mais dans certains cas elle peut être gênante. On peut la compenser par une distorsion opposée du système d'optique de verre. Nous essayons actuellement, au Pic du Midi, un raccord optique construit par M. Burcher de la firme SRPI. Celui-ci grandit l'image donnée par le télescope de 1·05 m par un facteur 2·5, sans courbure de champ et avec une distorsion en barillet égale et de signe contraire à celle de la caméra.

(2) *Lumière diffusée* (A. Grosse et G. Wlérick). Son taux a été réduit de 10% environ à moins de 1%. Pour arriver à ce résultat, il a fallu faire une étude physique de la couche Sb-Cs et en particulier mesurer son indice de diffraction; celui-ci est élevé:

$$n_{\mathrm{Sb-Cs}} \approx 3.$$

(3) *Photométrie.* On sait que la sensibilité des photocathodes varie d'un point à un autre. Pour en tenir compte, on prend des clichés de contrôle avec une lumière uniforme. Il est raisonnable d'en prendre au moins deux pour chaque couleur pour distinguer entre les défauts de la photocathode et les défauts de l'émulsion.

(4) *Optique électronique.* Nous avons utilisé pendant sept ans l'optique électronique de grandissement 0·75, dessinée par A. Lallemand et M. Duchesne. Nous cherchons à modifier cette optique pour travailler dans certains cas avec un grandissement plus grand.

(5) *Programmes astronomiques.* Les programmes suivants sont en cours:

(*a*) *Au Pic du Midi*, en collaboration avec J. Rösch, M. Combes, P. Lacques. Continuation des programmes de photographie de planètes et d'étoiles doubles. La mise en service du réflecteur de 1·05 m, dû à Z. Kopal et J. Rösch, nous a permis de photographier Jupiter et Saturne dans les trois couleurs U, B, V: avec l'agrandisseur optique, l'ouverture numérique est $f/37$. Pour Jupiter, en couleur V (filtre jaune), avec une cathode moyenne, le temps de pose est 1/20 s avec émulsion Ilford K5, 1/50 à 1/80 s avec plaque Ilford G5.

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Pour les étoiles doubles, le réflecteur permet de travailler en utilisant toute la lumière du violet au rouge.

(*b*) *A Meudon*, le programme de spectroscopie solaire va pouvoir reprendre, car le télescope solaire et le spectrographe associé sont terminés.

(*c*) *A l'Observatoire de Haute-Provence*, en collaboration avec A. Lallemand et Ch. Fehrenbach. On prépare actuellement un programme de photographie d'astres faibles avec une longueur focale moyenne (20 à 30 mètres). Selon les idées de divers astronomes, en particulier de I. Bowen et Ch. Fehrenbach, les poses électroniques avec une longeur focale suffisante devraient permettre de reculer la magnitude limite.

B. *Problèmes généraux*

Après six années d'utilisation de la caméra électronique, il est peut-être opportun de considérer certains aspects généraux de la photographie électronique.

(1) *Gain et contenu en informations*. Le problème du gain en temps de pose, par rapport à la photographie classique, à contenu en informations égal, est important lorsque les temps de pose classiques sont prohibitifs ou lorsque les phénomènes étudiés dépendent du temps (étoiles explosives, éclipses de Soleil . . .).

Mais le problème d'augmenter le contenu en informations d'un cliché est au moins aussi important. Par exemple les clichés classiques de planètes sont pauvres en information, d'où l'utilisation du compositage. Les clichés électroniques sont plus riches mais pas toujours assez riches. Prenons le cas d'une image de Jupiter de diamètre 8 mm. Un cliché sur plaque Ilford K5 posé 1/20 s sera beaucoup plus intéressant qu'un cliché sur plaque Ilford G5 posé 1/80 s, lorsqu'on aura eu la chance que la turbulence reste faible pendant 1/20 s.

(2) *Caractéristique linéaire*. C'est la meilleure carte à jouer de l'électronographie, car elle permet d'entreprendre des études impensables ou très difficiles en photographie classique (exemple: mesure de la brillance de l'anneau de crêpe de Saturne).

(3) *Capacité de la caméra électronique*. Avec une photocathode de 18 mm et douze plaques, on a déjà réussi à prendre des clichés ou des spectres plus intéressants, plus riches en informations que les photographies ou les spectres classiques. Mais pourquoi se limiter là? Il n'y a pas de raison fondamentale. Il y a seulement de grandes difficultés technologiques. Il est souhaitable de disposer prochainement d'une caméra dont la photocathode ait un diamètre de 5 cm et dont la capacité en plaques soit égale ou supérieure à 100. Wlérick a donc demandé à A. Lallemand d'envisager la construction d'une caméra contenant 1000 plaques.

III. STORAGE CAPACITY OF ELECTRONOGRAPHIC IMAGE TUBES

Gerald E. Kron, *I. I. Papiashvili* and *J. B. Breckinridge*
(Lick Observatory, University of California)

The Lick-Stromlo image tube has been used in a series of laboratory and astronomical tests to determine the data storage capacity as compared with photography for image tubes of the electronographic (Lallemand) type. Three emulsions were tested in the image tube, Ilford nuclear track emulsions type G5, K5, and L4. These emulsions are similar to each other, except that the grain size is graded from fine for G5 to very fine for L4.

Density versus exposure data were obtained by microdensitometer measurements based on 15 plates containing a total of about 200 exposures of a regulated artificial light source. We found that all three emulsions gave a growth of density that was a linear function of the exposure from a density of about 0·3 to a density of about 4·5; hence, none of the emulsions had started to saturate at densities below 4·5. The limit of density 4·5 was set not by evidence that saturation had set in, but by our inability to measure densities greater than this value with confidence. This evidence shows that electronographic pictures can be exposed to densities at least twice as high as photographic densities without showing evidence of saturation, and therefore, for this reason alone, the storage capacity of the electronograph must be at least twice that of the photograph.

Storage capacity depends not only upon the maximum allowable density, but also upon the number of picture elements per unit area of the emulsion that can be formed before saturation effects become evident. By means of grain counts on G5, K5 and L4 emulsions exposed at 30 kV to equal densities compared with grain counts on Eastman IIa-0 emulsion at the same density, we established that the electronographs have roughly three, four and five times as many grains per unit of area as the photograph. Clearly, this represents a second source of superior storage capacity for the electronographs, making the improvement equal to factors of 6, 8 and 10 for the three emulsions respectively.

This large storage capacity should be useful for extending the magnitude limit of direct recordings of star fields and slitless spectra fields, as well as the limit of detection of faint continuous sources above the background of the sky. If L4 emulsion is used, the improvement in limiting magnitude should be of the order of $2\frac{1}{2}$, provided the storage capacity is filled. The very long exposure times implied will not be needed, because of the quantum efficiency advantage of the image tube over the photographic plate. Experimental exposures up to $2\frac{1}{2}$ hours long have been made at the Lick Observatory on the Carnegie 20-inch astrographic telescope. Simple technological difficulties have interfered with achieving the hoped-for magnitude gain, but the gain in limiting magnitude as a function of exposure for densities up to 3·3 of the background indicates that, if anything, the improvement in storage capacity given above is an underestimate.

IV. WORK DONE AT THE LICK OBSERVATORY

M. F. Walker

M. F. Walker amplified the brief account given in the Draft Report of his work (since published in *Publ. astr. Soc. Pacif.*, **75**, 420, 1963) with a Lallemand electronic camera at the Lick Observatory.

He emphasized that it is important to improve the optical designs of spectrographs for use with image tubes so that the gain of these devices as compared with the best photographic emulsions will not be largely off-set by the relatively inefficient optical systems that must be used with the tubes. With this end in view a new type of coudé spectrograph camera is being designed in conjunction with I. S. Bowen which should enable a focal ratio of $f/1$ to be achieved in the near future and by the use of a Schmidt corrector this may be improved to $f/0·6$ in the future.

He then discussed the three following types of observation that can be done successfully with the present mounting of the tube.

(1) *Spectra of planetary nebulae* (work carried out with L. H. Aller). In this programme advantage is taken of the linear response of electronographic emulsion (Ilford G.5) to input light to facilitate the determination of emission line intensities for fainter lines than can be observed by photo-electric scanning or indeed by photography. Ten nebulae have now been observed. The supposed linearity of the tube record was checked against known lines previously observed by photo-electric scanning and it was found to hold. Also this linearity has been confirmed in laboratory tests to a density of 3·4.

(2) *Spectra of nuclei of extra-galactic nebulae.* The large scale of the coudé spectrograph permits the detection of changes in velocity of matter within very small angular distances and the linear response of the tube can be used in deriving the energy curves of the nuclei. A photograph of a spectrum of the nucleus of NGC 1068, taken with the Lallemand camera, was shown. This shows the existence, within 2 to 4 seconds of arc of the nucleus, of four or five discrete gas clouds, which are being ejected with velocities of up to 800 km/s and internal dispersions of $\sim$ 600 km/s. These and other important details had not been detectable using conventional photography.

(3) *High time-resolution spectroscopy.* This is a continuation of the work first reported at the Eleventh IAU General Assembly. In the new observations made just before the Twelfth IAU meeting in Hamburg, the star image was trailed once along the slit at an accurately controlled rate. In this way, one plate can be used to record the spectroscopic activity of the object during an interval of 80 minutes with a time resolution of about 5 minutes compared with about 15 minutes previously obtained on successive plates. Thus the eight plates available in one loading of the tube were sufficient to record the activity of a star throughout 1 or 2 (summer) nights. Exposures for 80 minutes show no parasitic background and this was low enough to allow exposures of 10 to 12 hours. The spectra taken in this way show a tremendous amount of detail not previously recorded. Full details of these observations will be published elsewhere.

V. REPORT OF WORK DONE IN THE APPLIED PHYSICS DEPARTMENT, IMPERIAL COLLEGE, LONDON

J. D. McGee

Work continues on three image tube projects of interest to astronomers:

(1) The Lenard window electronographic tube (for brevity referred to in future as the 'Spectracon').

(2) The cascade image intensifier.

(3) The charge storage, signal-generating image transducer.

(1) Considerable progress has been made by Khogali, Ganson and Jamini in clearing up the problems listed under (*a*) to (*k*) in the Draft Report. The reliability of the mica window, the quality of the vacuum and the ability of the tube to stand high potentials have all been improved. The cause of image drift has been traced and methods of countering it devised. Techniques have been devised for activating cathodes of different types independently and then introducing them into the image tube and mounting them on the input-end window for better optical efficiency.

Techniques have been developed in collaboration with the manufacturers (Messrs Ilford Ltd.) for coating electron sensitive emulsions on to Melinex plastic sheet 50 μ thick. This can be used safely for making contact prints against the mica window and care has been exercised to ensure that the results in respect of speed, resolution and fog background are not inferior to those achieved with stripping emulsion. Slides were shown to illustrate the progressive decrease in information content per unit area of images recorded on L4, G5 and XM emulsions with a corresponding increase in speed by factors of about $\times 4$ and $\times 6$ respectively.

Experiments have continued on the transmission of electrons through the mica windows and the effect this has on the efficiency of recording of the electron image.

(2) Continuing work on the cascade image intensifier by Airey, Aslam and Powell has concentrated on improving the quality of the output image both as regards resolution and granularity. This depended mainly on the texture of the phosphor screens and by improving

these the resolution of the three-stage tube has been increased to 30 to 35 lp/mm, and the granularity has improved. The improvement in image quality of the reproduced Baum test pattern is very marked.

(3) In the work on the charge storage, signal-generating tube by Twiddy, Mende and Filby, an important advance has been made in the development of a new type of charge-storage target. Preliminary experiments (R. S. Filby, S. B. Mende, M. E. Rosenbloom and N. D. Twiddy, *Nature*, **201,** 801, 1964) give promise that the incorporation of this target will enable an effective image transducer of this type to be developed.

VI. DETECTIVE QUANTUM EFFICIENCIES OF EMULSIONS

W. L. Wilcock

(Applied Physics Section, Imperial College, London)

Detective quantum efficiencies have been determined for samples of baked Eastman Kodak IIa-O emulsion and for an electronographic image tube, of the type described by Hiltner and Niklas but without an aluminium oxide membrane. The experiment involved the measurement of density as a function of absolute exposure, and of mean square fluctuation of density as a function of density. The light source was nearly monochromatic, of mean wavelength 4400 Å, and for the photographic measurements the exposure time was 60 seconds, although this is not important since baked IIa-O emulsion is known to show negligible reciprocity failure.

The detective quantum efficiency of baked IIa-O emulsion was found to have a maximum value 6×10^{-3} at density 0·23 above fog (corresponding to an exposure of 25 photons/sq. micron); at density 0·6 above fog the detective quantum efficiency had fallen to 3×10^{-3}. For the image tube the relation between density and exposure was found to be nonlinear above density 0·4, for reasons not understood, but the detective quantum efficiency corresponding to the linear region was $1{\cdot}7 \times 10^{-2}$. This is in reasonable agreement with the responsive quantum efficiency of the photocathode (type S.11) inferred from its luminous sensitivity of 6·4 μ A/L, and implies that the electronographic emulsion (Ilford G5) is an efficient means of recording electrons of the energy used (20 kV). From the results it may be inferred that, over a wide range of exposures to blue light and under conditions where the object is easily resolved, the speed gain over classical photography to be hoped for with an average antimony-caesium photocathode is somewhere between 15 and 20. The fact that this falls below earlier predictions by a factor of about 5 arises from under-estimation of the detective quantum efficiency of photographic emulsions.

VII. WORK OF THE CARNEGIE IMAGE TUBE COMMITTEE

W. K. Ford, Jr., reported on the work of the Carnegie Image Tube Committee (M. A. Tuve, Chairman, W. A. Baum, J. S. Hall and L. Marton). This committee has sponsored the development of cascade image intensifiers suitable for astronomy and W. K. Ford, Jr. has been responsible for the testing and evaluation of the tubes supplied.

The preferred tube at present is a two-stage cascade tube, that is a tube with one multiplying screen consisting of a thin membrane with a phosphor screen and photocathode on opposite sides. The output phosphor was P.11 type. The tubes were made by a group at the Electron Tube Division of RCA Lancaster, Pennsylvania, U.S.A., headed by Allen L. Morehead.

The method of utilizing this system has been to use roughly twice the dispersion going into the tube in order to match with the intensifier system the resolving power of a direct plate. The phosphor screen is photographed with unity magnification and a plate is obtained that has considerably less resolution than a plate exposed directly to the test pattern. But the important point is that the low resolution plate has a resolving power comparable with unaided plates at half the dispersion. Since, in general, the optical system with twice the dispersion is one-fourth as fast, the rate-of-blackening gain is reduced to a speed gain (for resolution equal to the photographic emulsion directly) of about 10 for the best tube.

A scheme of using twice dispersion with the image tube system has the effect of de-emphasizing the plate grain compared with direct plates of half the dispersion. Hence the signal-to-noise of the intensifier system with unity magnification is slightly superior to direct plates. It is concluded that gain in the rate of acquiring information is at least a factor of 10.

This advantage has been demonstrated in spectrograms obtained with the DTM spectrograph on the Ronnie Morgan 24-inch telescope and on the Perkins 69-inch telescope of Ohio State University and Ohio Wesleyan University at Lowell Observatory.

The performance of two sample experimental tubes (type no. C 70 056) made by RCA for the Carnegie Image Tube Committee can be judged from the following data:

A certain blue light source and grey step wedge in the laboratory requires an exposure of roughly 300 minutes on baked IIa-O plates to obtain a density of 0·6 or 0·8 in the middle of the wedge. With the image tube system (and the same blue sensitive emulsion used to photograph the blue P.11 phosphor), the same density is obtained with exposures of $7\frac{1}{2}$ to 10 minutes. Thus, a rate-of-blackening gain has been measured for one tube and, from other photometric data, a gain of 40 has been estimated for the second. A comparison of microphotometer traces, with a small aperture, indicates that the image tube plates have only slightly more r.m.s. noise than the direct plates at equal densities. It is believed that very little of this increased noise is due to phosphor granularity, but rather is due to some of the single photo-electrons producing multiple blackened grains in the photographic emulsion.

The image tube plates show a resolution of 25 to 30 line-pairs per mm. Somewhat more than this ($\sim$ 40 lp/mm) can be seen when viewing the screen directly with a microscope. The resolution on the plates is limited by the relay optics and also by the finite resolution of the plate itself.

Appendix A

The informal sub-committee nominated above met for two sessions, the first being devoted to photocathode sensitivity measurement and the second to overall image assessment.

It was agreed that present measurements were neither uniform for different manufacturers and experimenters nor sufficiently definitive even when the same method was used. For example sensitivity is often specified in μA/lumen together with the S designation of the American JEDEC specification.

However, the temperature of the filament of the tungsten lamp used as a standard light sources varies from one country to another and for cathodes of the same S type there may still be large departures from the typical equal-energy response curve.

The measurement of a complete equal-energy response curve is a major operation that few manufacturers and fewer users are prepared to undertake. It was agreed that it would be desirable to reach agreement on the temperature of the standard lamp, preferably at that accepted by the International Standards Laboratory (Paris) for light sources, namely 2854°K, and to measure the response at a reasonable number of wavelength bands provided by reliable filters of agreed types. For example, these might be: one band in the near UV, three in the visible, and two in the infra-red. There was considerable dicussion of the types of filters at present in use and it was clear that there was no consistency in present practice. In view of the confusion of the situation it was agreed that it should be reviewed critically and Dr W. L. Wilcock kindly accepted the task of doing this and reporting his findings.

In the second informal meeting it was clear that there is wide diversity in methods of image quality assessment. There appear to be three aspects of this: (I) resolution, contrast, halation, image geometry; (II) background; (III) image shift.

(I) As a basis of discussion the Chairman put forward the Baum pattern (*Adv. Electronics and Electron Phys.*, **16**, 391, 1962) as a suitable test for image recording devices. While agreeing that it has great merits, two objections were raised. First, it has no test for astigmatism and second, it can only test a small area of the field of a device at one time.

The first objection can be overcome by simply turning the test pattern through 90° for tests at the same area of the device, but the second objection is quite valid. On the other hand it did not seem practicable to incorporate a test satisfactory for extreme resolutions (e.g. 80 line pairs/mm) and large scale geometrical fidelity into one test chart and projector. It seemed to be generally agreed that it would be necessary to have two separate tests, the first dealing with ultimate resolution, contrast, granularity, halation, etc. on separate, small areas of the picture, and the second designed to assess the large scale picture quality. It was suggested that the test pattern used by Prof. Lallemand and his colleagues might be a suitable one to adopt for this purpose.

(II) Since, in using image tubes, background increases proportionally to the length of exposure, it is a very important characteristic and no assessment of the speed of such a device means much unless a measure of its background is also given. It was suggested that tests should be made giving the density resulting from background after exposures of specified emulsion for 1 second, 1 minute, 1 hour and 5 hours, and that the equivalent light flux in photons/cm^2 of specified light to give this same density should be measured.

(III) Image shift during exposure is a phenomenon peculiar to photo-electronic image tubes and is probably due to slowly changing charges on insulating areas of the tube walls, etc. It was agreed that this should be tested by making two short exposures ($\sim$ 1 second) of a test pattern in the same position with a time interval of 30 minutes between them, all other operating conditions being kept constant. Any image shift is clearly visible on the superimposed images.

Dr Wilcock agreed to undertake also a review of this image assessment problem, especially item I.