9. INSTRUMENTS AND TECHNIQUES (INSTRUMENTS ET TECHNIQUES)

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1. INTRODUCTION

This report is a summary of the communications received from members of the Commission, condensed as required by the limitation placed by the Executive Committee. The report is therefore not intended to be a comprehensive summary of progress and problems in the broad topics included under this commission. It should be noted that the international collaboration in this area of the large telescope projects has developed avenues of communication on a group to group basis outside the formal structure of Commission 9. For brevity most references have been deleted. References will be furnished upon request.

2. REPORTS FROM MEMBERS

A. Baranne (Observatoire de Marseille, France)

Après la mise en service des spectrographes Echel EC et ROUCASS à l'Observatoire de Haute Provence, le Laboratoire d'Optique de l'Observatoire de Marseille a réalisé les optiques complètes de deux télescopes Ritchey-Chrétien de 1 m de diamètre, l'une équipera le MARLY I du Chiran, station d'altitude de l'Observatoire de Haute Provence, l'autre destinée au MARLY II implanté au Gornergrat (Suisse).

Le principe d'asphérisation des dioptres par déformation élastique a été développé. Les nouvelles méthodes imaginées ont été employées avec succès pour la taille des lames des Schmidt à $F/1{,}1$ de l'expérience Skylab-S183. Une lame de 50 cm $F/2{,}7$ a été taillée pour l'Observatoire de Lyon ainsi qu'une lame de 62 cm qui remplace depuis 1975 l'ancienne lame du Telescope de Schmidt $F/3{,}5$ de L'Observatoire de Haute-Provence. Un miroir flexible à focale variable a été construit pour compenser le champ d'un spectromètre astronomique par transformée de Fourier.

Le Laboratoire d'Optique de Marseille en collaboration avec l'Observatoire de Genève achève la construction des deux spectromètres Coravel (Spectromètres à corrélation de type Griffin). En collaboration avec le Laboratoire d'Optique du DAO, Marseille prépare plusieurs projets de spectrographes destinés au Télescope d'Hawaii.

W. A. Baum (Lowell Observatory)

Baum and Nielsen (Copenhagen University Observatory) measured the photon energies at a common wavelength from distant galaxies and nearby objects and showed that these photons have the same energies, establishing the time invariance Planck's constant. Noting that the aberration constant is also constant for these two groups of objects and that 21 cm redshifts are identical to optical redshifts, they concluded that h, c, and e are constant with time to a high degree of accuracy. The photomultiplier tube used for the photon energy experiment was provided by EMI and used a special suppressor grid 5 mm behind the cathode so that photo-electron energies could be measured.

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A. Dollfus, M. Duchesne (Observatoire de Paris)

We are in the last stages of testing of a new instrument which is a tunable high selectivity birefringent filter of solar physics. The Instrument is based upon the principle of the Lyot's birefringent filter. It was improved to reach a spectral selectivity of 0.15 Å, and is tunable for any wavelength within the spectral range 5300 to 7500 Å. Thus, the instrument can select Fraunhofer lines of solar physics interest, with a band width of the order of the width of the line itself. The telescope is 30 cm aperture diameter, the field accepted by the filter is 12′ X 12′ with a surface of 30 X 30 mm. The diameter of the solar disk in the final focal plane is 9 cm, the spatial resolution is 0.5″. A spectroscope/spectrograph attached to the instrument helps the adjustment of the spectrum and permits a photographic record of the spectral composition of the light transmitted by the filter.

One can obtain photographic pictures at different distances from the center of Hα on the wings of magnetic lines and Doppler lines, and so on. The final goal is to use the instrument with vidicon tubes in such a mode that we can visualize in real time the distribution of the velocities and of the magnetic fields within the field of view of the instrument. The displays of these parameters in real time will be of importance for immediate interpretations, and also to help monitoring and optimizing the observation program of other solar physics instruments.

Le Laboratoire de Physique Astronomique au cours de ces dernières années a poursuivi l'étude et la réalisation de 2 types de caméras électroniques, l'un à focalisation électrostatique et l'autre à focalisation électromagnetique.

Les études poursuivies despuis plusieurs années à l'aide d'un banc d'optique électronique ont permis d'améliorer la qualité des images et d'augmenter le champ de la caméra électronique électrostatique. Une caméra à champ de 30 mm de diamètre (grandissement 0,6) a été réalisée et mise en service en 1974, comme récepteur des spectrographes 'Echelec' de l'Observatoire de Haute Provence et de l'Observatoire Européen Austral de la Silla. Au cours d'une mission en Juin 1974 à l'Observatoire de Haute Provence, nous avons testé l'ensemble de l'appareillage; son fonctionnement a été satisfaisant et les premiers résultats obtenus montrent la diversité des problèmes qui pourront être envisagés en spectroscopie. Parallèlement aux caméras fonctionnant dans le visible avec des cellules de type S 11, les performances des caméras électrostatique infrarouge utilisant des couches de type S 1 ont été également améliorées, surtout en ce qui concerne la stabilité et l'homogénéité des couches. Nous avons poursuivi avec ce type de caméra au foyer Newton du télescope de 193 cm de l'Observatoire de Haute Provence, l'étude morphologique de la nébuleuse d'Orion et de quelques nébuleuses planétaires à différentes longueurs d'onde. Pour cette étude, nous avons utilisé des filtres interférentiels à bandes étroites qui nous ont permis de réaliser des photographies en isolant plusieurs éléments tels: A III (7751 Å), S III (9060 Å), P8 (9546 Å), S III (9532 Å), S II (10 284, 10 318 et 10 336 Å), et He I (10 830 Å). Nous avons, en particulier, obtenu des clichés monochromatiques inédits de la partic centrale de la nébuleuse d'Orion à ces longueurs d'onde.

La réalisation d'une caméra électronique à champ s'est montrée nécessaire pour faire des mesures photométriques précises sur les amas et associations d'étoiles et, en particulier, dans les Nuages de Magellan. La séparation et le champ angulaires ainsi obtenus permettent d'avoir l'amas entier sur un seul cliché, sans recouvrements ou identification difficiles. A cela s'ajoutent les avantages de l'électronographie sur la photographie classique. Après les études de principe et les essais préliminaires, un prototype a été réalisé et a donné entière satisfaction. Le diamètre de la photocathode est de 90 mm; le grandissement est de 1, la focalisation étant électromagnétique. Au cours d'une mission à l'Observatoire de Haute Provence, la caméra a été utilisée avec le télescope de 1,93 m et les premiers résultats astronomiques ont été obtenus. Ils ont prouvé son bon fonctionnement et la version destinée à l'étude des Nuages de Magellan à l'Observatoire de l'ESO au Chili a aussitôt été entreprise.

G. Godoli (Observatorio Astrofisico, Catania)

The Astrophysical Observatory has been deeply involved in matters of astronomical seeing,

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especially of solar seeing. Measurements were made on Tenerife (Canary Islands), Cape Feto (Western Sicily), Lampione Island, all parts of the Italian JOSO site testing program. Radiosonde flights measured the temperature fluctuations up to 15 km, using bare wire sensors. Above the ground effects the fluctuations were in the range of 0.01 to 0.02 °C but at the tropopause they increased again to the range of 0.1 to 0.2 °C in a layer 0.5 km thick.

A. Hunter (Royal Greenwich Observatory)

The establishment of a British Northern Hemisphere Observatory was affirmed with a 4.5 m telescope to be its prime instrument. The 2.5 m Isaac Newton telescope would be transferred from Herstmonceux to the new site. A decision on the site is still to be made.

The Anglo-Australian telescope has been placed in operation. The intermediate dispersion spectrograph was tested on the 2.5 m INT and found to exhibit flexure from the grating and collimater mounts, now corrected by suitable modifications. Flexure of the instrument structure, however, has been difficult to solve.

The auxiliary instrumentation at the South Astronomical Observatory has recently been augmented by a new spectrograph having a Wynne F 11.4 camera and 3-stage EMI image tube, and an infrared photometer.

The revisions to the prime focus cage of the 2.5 m INT have been suspended pending relocation of the telescope. Experiments with insulation of the INT coude spectrograph support beams were done to attempt to reduce temperature-induced problems, without apparent success. The Interdata computer, originally installed as part of the Michelson interferometer has been enhanced to become a general purpose instrumentation computer for the telescope.

Electronographic Tube development has resulted in a tube with a 10 cm cathode and 8 cm mica window. Improved leak-testing methods capable of detecting small leaks in mica windows has eliminated loss of sensitivity from this cause. Silicon chip arrays 2 × 512 diodes have been tested successfully for incorporation in an image tube for spectrographic use.

C. de Jager (Space Research Laboratory, Utrecht)

Coherent detection in astronomy in the infrared and the relative merits of heterodyne detection spectroscopy and interferometer were studied. A ratio between optimal noise equivalent powers (NEP's) was determined for coherent and incoherent detection.

W. C. Livingston (Kitt Peak National Observatory)

The 60 cm vacuum telescope has been placed in daily observation to observe magnetic and velocity circulation field structure on a synoptic basis. New optical features include the use of oversize mirrors and windows to avoid thermal edge effects, and the placement of the coelostat feed outside the vacuum. While the goal was to achieve diffraction limited performance, but the telescope has a MTF of 0.2 at 61 mm^{-1} whereas it should be at 201 mm^{-1}. Part of the problem is the figure of the image forming mirror, but much is still due to the atmosphere. Comparisons with the McMath solar telescope, however, show that the good morning seeing is extended by one or two hours when the prevailing winds are from the south where the mountain face effect is beneficial.

Full disc magnetograms and photoheliograms show excellent performance even though the goal of diffraction limited performance is not reached.

An integrated diode array solar magnetograph of 2 × 512 diodes has been completed. When used with a 1.5 m telescope photospheric flux as small as 5×10^{16} Mx is detected, corresponding in intensity to $\Delta I/I$ of 3×10^{-4} at 0.8688 μm. An equivalent noise of 95 ν electrons at the input is observed for a bandwidth of 3×10^5 Hz at room temperature. Noise and cooling characteristics indicate this type of detector has promise as a low light level sensor. The application of these diode arrays with interactive data procession to the photometry of extended objects has been evaluated.

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N. Mikhel'son (Moscow, U.S.S.R.)

I. *Telescopes*

A 1.5 m reflecting telescope in the Struve Astrophysical Observatory in Tyravere, Esthonian S.S.R. and a 6.0 m reflecting telescope (Ioannisiani) have been put into experimental operation.

The Ritchey-Chretien reflecting telescope (D=1.25 m) for photo-electric investigations has been mounted at the Abastumany Astrophysical Observatory. The telescope is fully automated (Salukvadze).

Mounting of a 2.6 m telescope is nearing completion at the Bjurakan Astrophysical Observatory.

All the telescopes are equipped with modern light detectors and control systems, including digital computers.

At the Special Astrophysical Observatory a 0.6 m (1:20) reflecting telescope for testing new methods involving TV has been mounted. The reflector has an English yoke type mount.

At the Main Astronomical Observatory of the Acadeny of Sciences of the Ukrainian S.S.R. and Kitab double astrographs (D=0.4 m) made by VEB, Carl Zeiss, Jena, have been put into operation. The Pulkovo photographic zenith tube (D=0.25 m) has been moved to Kitab.

The theory of alt-azimuth mounting is developed. The automation of the telescopes and construction of the automatic photoelectric guiders including those using storing of error signal (Kuteva and Sabinin, Kuteva and Makarova) and TV techniques are used.

The automatic lens design method on a digital computer is used for computing complex astronomical optics.

Great attention is paid to modifications and improvements to designs of large telescopes. Therefore the technology of figuring big optical surfaces is being improved. New methods of its testing are also being developed.

New astrophysical and astrometric instruments are carefully tested. Piningin has shown that right ascensions observed with the Sukharev horizontal meridian circle (Pulkovo Observatory) can be measured to an accuracy of ±0.11 s. Gershberg *et al.* have developed a method of adjustment of the Shain reflector (Crimean Observatory).

a. *Pulkovo Observatory*

A flight of the stratospheric solar balloon-borne observatory with a 1 m telescope took place in 1973, July 20 (Krat). A microphotometer capable of recording output signals in digital form on punchcards has been constructed. Its printing rate is 3 mm s^{-1} and accuracy 0.3%.

A coherent spatial spectrum analyzer for the study of the Solar fine structure has been created. A working model of automatic plate measuring instrument has been built (Zatsiorsky).

After preliminary work (Bagil'dinsky and Shkutov) a coordinate measuring engine for reduction of the star tracks obtained with photographic vertical circle has been put into operation. Its accuracy is ~0.7 μm.

b. *Crimean Astrophysical Observatory*

A method for precise determination of the coordinates of the faint objects moving rapidly among stars has been developed. A number of star spectrophotometers have been constructed jointly by the Crimean Astrophysical and Pulkovo Observatories.

c. *Special Astrophysical Observatory*

Among the new instrumentation at the Special Astrophysical Observatory the following should be mentioned:

Star magnetometer for measuring the longitudinal component of the stellar magnetic field. It was developed and built on the base of the Fabry-Pérot interferometer design. Its resolution is 0.1 Å.

An electronic photometer for the *UBVR* system with the exposure time 0.001–10 s and an exit to the electronic computer.

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A comparator for measuring spectrograms to an accuracy of 1 μm.
An electronic planimeter.

d. *Siberian Institute of Geomagnetism*

A panoramic solar magnetograph has been installed here. Its sensitivity is as high as 20 G.

A new solar magnetograph is used at the Institute. It has the pulse-code modulation of the signal and a two-band wide angular interference-polarization filter for the Ba II 4554 Å and Hβ 4861 Å lines. The filter has a half bandwidth equal to 0.08 Å and a moving band.

e. *Ural University Observatory (Kourovka)*

A solar spectrophotometer with a rate of spectrum scanning equal to 3000 Å s^{-1} (Rozhavsky) and that of sun scanning 50 scan s^{-1} has been installed.

f. *Radiophysical Observatory of the Academy of Sciences of the Latvian S.S.R.*

Spectrophotometers for the *UBVR* and 0.1–2.5 μm regions have been constructed (Spulgis, *Novaya Tekhnika v Astronomii*). Accessory with an iris diaphragm for measuring stellar magnitude has been designed for a coordinate-measuring machine of the 'Ascorecord' type.

g. *Schemaha Astrophysical Observatory of the Academy of Sciences of the Azerbaijan S.S.R.*

A three-band microphotometer for simultaneous recording of the stellar spectrum, comparison spectrum, and calibration spectrum has been put into practice.

h. *Engelgardt Astronomical Observatory (Kazan)*

A semi-automatic machine for measuring limb photographs has been designed. Its accuracy is ±1 μm and measuring rate 3 frames per minute.

i. *The Struve Observatory (Tartu, Esthonian S.S.R.)*

An automatic microphotometer has been installed for on-line functioning in conjunction with an electronic computer (Kipper).

j. *Astrophysical Institute of the Kazakh Academy of Sciences (Alma-Ata)*

A number of instruments for the photometry of the extended celestial objects (Zodiacal light, Milky Way, nebulae) have been put into practice (Zavarzin).

k. *Site Testing*

Many observatories take part in organizing site-testing expeditions. Most active are the Sternberg Astronomical Institute (Novikov and Shcheglov) and the Astronomical Institute of the Academy of Sciences of the Uzbek S.S.R. (Schevchenko).

II. *Radiation Detectors*

A conference concerning spectral techniques, stellar photoelectric photometers, and radiation detectors was held in the Crimea, September 1973. The conference papers were published in the book *Novaya Tekhnika v Astronomii*, 1975, No. 5. A monograph *TV in Astronomy* by Abramenko A. N. *et al.* (ed. by V. B. Nikonov) has come out. It summarizes TV methods in astronomy.

a. *Electronography*

New electronographical converters of images for very faint objects have been worked out. They give an exposure 10 times shorter than that of the photographic film and 60 – 40 pairs of lines mm^{-1} resolution.

b. *Image Converters*

Photo-electronic image devices are used for spectroscopic investigations of the unstable processes occurring in the Universe. For the study of the spectrum the exposure time achieved is

20 s. At the Special Astrophysical Observatory a one-camera photo-electronic image converter of the M9WB type is employed. It has a field of 25 mm and resolution of 50 pairs of lines mm^{-1}. It is also supplied with a multi-alkali photocathode and a fiber optic screen. At the Crimean astrophysical observatory and Astrophysical Institute in Kazakhstan image converters proved effective in the observations of distant space probes.

Polosukhina N.S. and Chuvaev K. K. have made some efforts to detect rapid spectral variations of the magnetic variable star HD 215441. The observations were made with a spectrograph and a three-stage image tube (with a multi-alkali photocathode) at the Nasmyth focus of the 2.6 m telescope of the Crimean observatory. The dispersion was about 37 Å mm^{-1} at Hα, 46 Å mm^{-1} at Hβ, exposure times being 60 s and 25 s for Hα and Hβ respectively.

c. *Television*

At the Pulkovo observatory Kuprevich N. F. develops and employs TV techniques for the investigation of the Moon in the infrared range and for the study of the atmospheric instabilities as well.

At the Crimean astrophysical observatory TV techniques were applied to the study of the planets, and extremely rapid variations of the NPO 532 and Cyg-X1 pulsars. It was shown that television could be used for the stellar photometry.

d. *Photomultipliers*

At the Crimean astrophysical observatory and Struve observatory in Tartu, Estonia, new special optical benches for absolute calibration of the photomultipliers were constructed.

G. Sedmak (Osservatorio Astronomico, Trieste)

A high time resolution photometer for the absolute timing of optical pulsars was placed in operation at Asiago observatory. A joint program for using four-color two-beam computer interactive photometers with high time resolution was initiated, located at Catania, Napoli, Milano and Trieste. A spectrophotometer using a 512 channel Reticon photodiode was tested at the solar tower of the Rome Observatory. A highly flexible data acquisition system was installed at the Rome Observatory utilizing two PDP 11/10 computers, supported with a disc and cassette tape operating system, linked to the UNIVAC 1110 computer at the University of Rome. The system will be used in real time on the solar tower.

S. D. Sinvhal (Uttar Pradesh State Observatory)

The 104-cm telescope (*IAU Trans.* **XIVA**, 65, 1970) has been in operation since the Spring of 1972. Facilities available include Cassegrain plate holder (field 47′), Meinel camera (field 37′), single channel photoelectric photometer with off-set device, Cassegrain spectrograph (dispersions 24–50 Å mm^{-1} and automatic star changing device.

The horizontal solar spectrograph (*IAU Trans.* **XIVA**, *ibid.*) has been operational since the fall of 1973. Facilities available include photographic, photoelectric and image tube registration of spectra.

Optics shop facilities have been developed to grind and polish up to 75-cm aperture jobs. An aluminizing unit of 60-cm aperture capacity has been set up. Both these facilities are under expansion.

3. REPORTS OF WORKING GROUPS

Only one report has been received by the President, as given below. Reports will be provided at the General Assembly in Grenoble. Rosch reported that the Working Group on Large Telescopes had been supplanted by the close working cooperation that has developed between the several national groups having individual or collective large telescope projects. The same

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type of spontaneous cooperation has developed in the subject areas of Automation and Data Acquisition and Infrared Techniques. West has only recently begun to organize the newest Working Group on Photographic Problems.

A. *Photoelectric Image Tubes (M. Walker)*

I. *Introduction*

This report has been prepared mainly from replies received to a circular letter sent to all members of Commission 9 and to the Directors of Observatories and Astronomical Institutes, and is intended primarily to reflect the status of work currently in progress. It does not include work in the U.S.S.R., as this will be discussed in the general report to Commission 9 being prepared by Dr N. N. Mikhel'son.

II. *Conferences and Symposia*

Five conferences and symposia on photoelectronic image devices and their application in astronomy were held during the period covered by this report:

(1) A Symposium on 'Astronomical Observations with Television-Type Sensors', University of British Columbia, Vancouver, May 15–17, 1973.

The Proceedings (ed. by J. W. Glaspey and G. A. H. Walker), have been published by the Institute of Astronomy and Space Sciences, University of British Columbia, 1973.

(2) A Conference on 'Electrography and Astronomical Applications', McDonald Observatory, University of Texas, Austin, March 11–12, 1974. The Proceedings (ed. by G. Chincarini, P. J. Griboval, and H. J. Smith), have been published by the Astronomy Department, University of Texas, 1974.

(3) The 'Sixth Symposium on Photo-Electronic Image Devices', Imperial College, London, September 9–13, 1974. The Proceedings will be published in *Advances in Electronics and Electron Physics.*

(4) A Conference on 'Image Processing Techniques in Astronomy', Utrecht, March 24–25, 1975. The Proceedings will be published by D. Reidel, Dordrecht, The Netherlands.

(5) A Conference on 'Imaging in Astronomy', Cambridge, Mass., June 18–21, 1975. A Technical Digest of the papers presented has been published by the sponsors of this meeting, who included: the American Astronomical Society, Harvard College Observatory, Optical Society of America, and the Society of Photographic Scientists and Engineers.

Since many details of the work discussed in the following sections of this report are referred to in papers presented at these conferences, these will be hereinafter referred to according to their listing above, i.e., a paper in the Vancouver Symposium will be referred to as (Ref. 1, page).

a. *Electronography*

A review article on electronographic image tubes has been published by Kron (1974).

α. *Developmental work.* Developmental work on electronographic image tubes continued in Paris, Meudon, London, Herstmonceux, and Austin. At the Paris Observatory, development work on an electrostatically-focussed electronic camera having a field 30 mm in diameter and an electronic magnification of 0.6 was completed by Duchesne and his collaborators. The cameras are provided with both S 11 and S 1 photocathodes. Developmental work has also continued in Paris by Lallemand and his co-workers on a large-field, magnetically-focussed electronic camera. This camera, which has a field diameter of 90 mm, is intended for photometric observations of extended fields of stars, nebulae, and galaxies. Preliminary tests have been made with the camera on the 1.93-m reflector at Haute Provence (Lallemand *et al.*, Ref. 2, 29). At the Meudon Observatory, development work has continued on the systems described in the previous report: an electrostatically-focussed electronic camera having a valve to protect the photocathode while changing the nuclear plates, and a magnetically focussed camera using a strong magnetic field provided by a superconducting magnet. The valve-type camera, which has a cathode diameter of 20 mm, magnification 0.7 and resolution 40 lp mm^{-1} over the entire field, is now operational, and modifications are being studied to permit its use at the prime focus of the CFH telescope; an operational version of the magnetically focussed tube, with a $50 \times 15\ mm^2$ photocathode and a resolution of 200 lp mm^{-1}, is being constructed.

In London, the Applied Physics Group of the Physics Department, Imperial College, was disbanded in October, 1973, subsequent to the retirement of Prof. McGee. Since that time, production of the Lenard-window Spectracon tubes has been restricted to a very few for in-house use. Commercial production of the Spectracon was undertaken by Instrument Technology Ltd. However, technical difficulties have so far limited their ability to provide tubes of satisfactory quality. Prior to termination of activities in October 1973, the following experiments and modifications of the Spectracon were carried out by McGee:

(1) Use of a barium layer on the mica window end of the tube was found to inhibit cathode slump during operation of the tube. (2) The introduction of a small channel through the encapsulation through which a probe can be inserted to make possible direct measurement of the photocathode sensitivity was found to be effective and to have no undesirable side effects. (3) An experimental batch of six large-field Spectracons having cathode and window dimensions $20 \times 30\ mm^2$ was constructed. Some have been used on telescopes; no window was broken during actual use. (4) Preliminary tests were made of the feasibility of constructing a very large window Spectracon, with dimensions $30 \times 40\ mm^2$. These tests indicated that the construction of a Spectracon with these window dimensions should be entirely feasible.

At the Royal Greenwich Observatory, Herstmonceux, the image tube group under D. McMullan has built and put into operation a reprocessible magnetically focussed electronic camera having a 40-mm diameter photocathode. As described in the previous report, this camera has a mica window between the photocathode and the nuclear emulsion, and a valve system to prevent the window from being subjected to atmospheric pressure. Cathode lives of several years for these tubes can now be predicted with confidence (McMullan *et al.*, Ref. 2, 37; Ref. 3). The first of these cameras, which has an S 20 photocathode (typically 150 μÅ l^{-1}) and a resolution of 50 lp mm^{-1} (using pneumatic hold-down of the emulsion to the mica) has been used since the beginning of 1975 on the 40-inch *f*/7 Cassegrain reflector of the Wise Observatory, Israel, to make over 600 direct electrographs, and as the detector for a polarimeter of the Pickering-Appenzeller type. A second camera has been completed for use on the telescopes at Herstmonceux. A similar camera having a photocathode 80 mm in diameter has also been built and tested in the laboratory, where a low level of tube background has been attained. It is planned to equip this tube with a quadrant silicon diode mounted inside the tube for use as an auto-guider sensor. Development of a slot-window tube similar in size and characteristics to the Spectracon is planned, and preliminary designs have been worked out for a larger slot-window tube with a mica window 80 mm long and 5 or 10 wide for coudé spectroscopy.

In Austin, Griboval has continued the development of the electronic camera with 50-mm field described in the previous report. Owing to permeability problems, the Al_2O_3 barrier membrane between the photocathode and recording emulsion has now been replaced by a 7 μ thick DuPont plastic (polyamide) film, aluminized on both sides. The camera body is being redesigned to reduce its size and weight, and the Viton front window gasket is being replaced with a low melting temperature metal compound (Griboval, Ref. 2, 55; Ref. 3; Ref. 5, th B7-1).

β. Use in ground-based astronomy. The Lallemand electronic camera has continued to be used at Haute Provence for direct observations of BL Lac objects (Wlérick, Ref. 2, 307) and N. Galaxies (Lelievre, Ref. 2, 323). The new 30-mm field electrostatic camera developed by Duchesne has been used for spectroscopic work at Haute Provence and on La Silla. In addition to spectroscopic applications, this camera has been used at the Newtonian focus of the 193-cm reflector at Haute Provence for interference filter electronography of the Orion nebula and a number of planetary nebulae (Andrillat and Duchesne, 1974a, 1974b, Ref. 3).

Kron-type electronic cameras have been used at the U.S. Naval Observatory, Flagstaff, the tube was used for photometry of globular clusters (Hewitt and Kron, Ref. 2, 267), for photometry of the brightest stars in the Wolf-Lundmark-Mellottee galaxy by Ables and Ables, by

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Ables and Dahn to establish magnitude sequences for calibration of electronographic plates in seven areas, each 7′ in diameter, uniformly spaced around the sky at declinations between +28° and +30°, and by Newell, O'Neal and Norris for surface *UBV* photometry of the nucleus of M 15. At Kitt Peak, the Kron camera was used on the 4-m reflector by Ables and Newell to continue their photometric study of the globular clusters around M 86, by Walker for photometric observations of individual stars in Leo I and Leo II, and by Newell to study the distant clusters Pal 12, and 13, the globular clusters around NGC 4594, and the background light distribution in clusters of compact galaxies. At Mount Hopkins, the Kron camera has been used by Chaffee, Peterson, and Ladd with the Cassegrain echelle spectrograph of the 60-inch telescope; this system was found to be significantly more efficient than the 200-inch coudé, used photographically. At the McDonald Observatory, the Kron camera was mounted and used for both direct electronography and spectroscopy by Chincarini and Heckathorn (Ref. 2, 343; Ref. 3). In January, 1975, the McDonald Kron Camera was taken by Chincarini and Heckathorn to the Mauna Kea Observatory where it was used at the Cassegrain focus of the 88-inch reflector. A Kron-type electronic camera has been taken to the Mount Stromlo Observatory by Kron, who plans to use it to measure the integrated surface brightness of star clusters in the Small Magellanic Cloud.

Spectracons have been used during the report period at a number of observatories. At Lick, a mounting was constructed to permit using the Spectracon for direct electronography at the prime-focus of the 120-inch reflector and the Cassegrain focus of the 24-inch reflector. Using Spectracons supplied by McGee, observations were made by Walker, Pike and McGee of star clusters and extragalactic objects (Walker *et al.*, 1974a, 1974b; Walker, Ref. 2, 221; Ref. 3). In addition, control circuitry was developed to enable the Spectracon to be used as a Pulsar detector (Walker, Ref. 2, 221; Ref. 3). At RGO, the Spectracon was used by a number of observers from different institutions for direct observations at the prime focus, and for spectroscopic observations at the Cassegrain focus of the Isaac Newton reflector. A program of narrow-band photometry of planetary nebulae was undertaken by Coleman, Reay, and Worswick (Ref. 3; 1975) using Spectracons mounted on the Isaac Newton telescope, the 60-inch Boyden reflector, the 20-inch Mons reflector on Tenerife, and the 42-inch Lowell reflector. In collaboration with Coleman, Reay, and Worswick, Baum used the Spectracon on the 1.8 m Perkins reflector at Lowell to observe faint clusters of galaxies and the satellites of Uranus and Neptune. Detector systems employing Spectracons for use in direct imaging and in high and low dispersion spectroscopy are being developed at the NASA Johnson Space Center, Huston, by Martins and his co-workers. Preliminary narrow- and broad-band direct observations of planets, H II regions, star clusters, and galaxies have been made with the equipment at the McDonald Observatory using the 0.76 m telescope.

As mentioned above, the 40-mm field electronic camera developed by McMullan has been in use at the Wise observatory since the beginning of 1975. The 40-mm aperture corresponds to 20′, and unfiltered electrographs on Ilford G5 reach about 22 mag. to 30 min. The system has been used by Bingham, Fosbury, McMullan, Netzer, Powell, Wehinger and Wyckoff for both broad- and narrow-band filter observations of Seyfert and compact galaxies, the Crab nebula, the Orion nebula and planetary nebulae (Wyckoff *et al.*, 1975).

γ. *Use in space astronomy.* Carruthers has continued his important applications of electronography in space astronomy, discussed in the preceding report. Discussion of data obtained during the Apollo-16 mission has continued and new instrumentation has been developed, in particular a micro-channel plate electronographic camera for use with a concave grating spectrograph in the 300–2000 Å range. Studies of mesh-based semitransparent photocathodes (Carruthers, 1975) have also been made. In addition, electronographic images of Comet Kohoutek in the 1100–1500 Å range were obtained using electronographic cameras mounted on a sounding rocket and carried on board the Skylab space station.

δ. *Reduction of electronographic observations.* During the past five years, Newell has been working on the development of techniques for the measurement and reduction of electrographs using the PDS microdensitometer, at Kitt Peak. Two readout modes are available:

(1) single star scans in which a stellar or near-stellar image is scanned using a small (e.g., 81 × 81-point) raster and (2) large area scans, where frames up to 2 cm in diameter are scanned with a 2000 × 2000 data point raster. The resulting data tapes are then processed using the facilities of the Kitt Peak Image Processing Laboratory, built around a COMTAL display device. Interactive graphics facilities are utilized to monitor the program activity and to input information when operator intervention is required. This reduction program is now being prepared and documented for visitor use at KPNO.

Reduction procedures using the PDS microphotometer have also been studied by Purgathofer and Benedict, Chincarini, Heckathorn, and Wray (Ref. 2, 205), and an automatic microphotometer for stellar photometry on electronographic plates has been developed by Pilloud (Ref. 2, 133). Problems involved in stellar photometry by means of electronography have been studied by Wlérick, Michet, and Labeyrie (Ref. 2, 177).

b. *Image intensifiers*

As discussed in the previous report, image intensifier tubes (almost exclusively commercially available types) are now very widely used in astronomy for both direct observations and for spectroscopy. A complete résumé of these installations and types of programs undertaken would be beyond the scope of this report. Consequently, only a few newer installations described in the responses received to the circular letter will be mentioned. At Palomar, a 90 mm diameter single stage magnetically focussed intensifier is used for direct observations at the prime focus of the 200-inch reflector and the Cassegrain focus of the 60-inch reflector. A Varo tube with S 20 photocathode has been installed at the focus of the 32-inch camera of the Mount Wilson 100-inch coudé spectrograph for use in the region from Hα to 800 Å. A 90-mm S 25 cathode image intensifier has been installed at the focus of the 2.7- and 1.8-m cameras of the Palomar 200-inch coudé spectrograph, while for the 91-cm camera of the same instrument, 40-mm intensifiers with S 25 and S 1 responses have become available. At the Steward Observatory, a two-stage Carnegie tube is used regularly with the Cassegrain spectrograph of the 90-inch reflector, and a single-stage 140 mm ITT tube is used for direct observations. At Las Campanas, an RCA C33063 two-stage magnetically focussed intensifier has been installed at the focus of the Cassegrain spectrograph of the 1-m reflector. At La Silla, direct image tube photography and spectroscopy are carried out at the Cassegrain foci of the ESO 1-m and 1.5-m reflectors, using ITT F-4708 and F-4089 intensifiers. RCA C 33011 and C 33063 image intensifiers have been used at Haute Provence for direct and spectroscopic observations with the 193-cm reflector (Comte and Monnet, 1974). At Marseille (Laboratory for Space Astronomy), the use of image converters sensitive to the far ultraviolet on board rockets has been continued by Deharveng. Using CsTe and CsI tetrod converters, images of the Pleiades and M 31 were obtained at 1500 Å and 2500 Å.

At present, one of the most important uses of image intensifiers is as the primary detectors in photon counting systems for both one and two-dimensional image recordings, such as the Robinson Wampler scanner at Lick, the intensified image dissector scanner at Kitt Peak, and the Steward Observatory photon counting spectrometer discussed in the section on electrical output detectors.

c. *Electrical output detectors*

During the report period, the greatest activity has occurred in the area of the electrical output detectors, which includes television-type, diode array, and microchannel plate detectors, and involves applications in both ground-based and space astronomy. Developments to May 1973, are reviewed in Reference 1; this report will be primarily concerned with activities since that time.

α. *Television type systems.* The use of television systems for field acquisition and guiding, as discussed in the previous report, has continued to expand. Equipment of this type has now been installed at the Cassegrain focus of the Lick 120-inch reflector for use with the image tube scanner system, and at the Cassegrain focus of the Kitt Peak 4-m reflector and the Cassegrain focus of the Anglo-Australian telescope.

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A 70-mm SEC television camera tube is being developed by Lowrance at Princeton for the Large Space Telescope, and an SEC system for high dispersion spectroscopy has been used on the McMath Solar telescope at Kitt Peak (Chiu *et al.*, Ref. 5, Fbio-1).

The television type device which has received the most attention during the report period is the silicon intensifier target (SIT) vidicon. At the Hale Observatories, Westphal and Kristian have continued to use SIT tubes for two-dimensional photometry. While the response is slightly non-linear, the calibration and reduction techniques have been refined so that a photometric accuracy close to 1% is now obtained. Comparisons with broad-band photometric sequences in the range $12 < V < 22$ indicate a scatter of 2% at the bright end and 5% at the faint end, due to a combination of photon noise, accuracy of the photoelectric magnitudes, and tube noise.

With the 200-inch reflector, stars are measurable to fainter than $V = 24$ on a 10-min exposure. A photon-counting television system employing a intensified SIT tube has been built by Lowrance at Princeton and used on the Palomar telescopes (Lowrance *et al.*, Ref. 3). The system detected and recorded single photoelectron events in a 256 × 256 pixel array, but the ultimate signal-to-noise ratio was not achieved due to multiple counting of single events caused by incomplete erasure and splitting of the signal between adjacent scan lines during readout. These problems are correctable by electronic logic, but the high cost of the devices has curtailed further development because of the expectation that equal performance at lower cost will soon be available with the intensified charge coupled devices. The SIT system used in the photometry program has also been used by Westphal and Kristian for low- and high-resolution spectroscopy (Westphal *et al.*, 1975); spectra that are essentially photon-noise limited have been obtained. An SIT tube has also been adapted for use as the detector with the coudé spectrograph of the 100-inch reflector at Mount Wilson, and a cooled integrating SIT camera for spectroscopic work is being constructed by Gunn. Considerable work with SIT and ISIT vidicons has also been done at Kitt Peak as part of a Panoramic Detector Program supervised by Lynds. By operating the tubes in an equilibrium mode, where the target is read continually at a rate determined by the scene illumination and the degree of intensification so that an equilibrium is maintained between target discharge and landing current, a linear response has been obtained in laboratory tests and in direct photometric applications at the telescope over a dynamic range of 10^4. This system has also been applied to the three-stage image-tube Cassegrain spectrograph of the 84-inch Kitt Peak reflector. At the Steward observatory, a two-line photon-counting spectrometer is now in use on the 90-inch Cassegrain spectrograph. The system consists of a three-stage Varo tube followed by a SIT tube with 250 elements per line. Other applications of the SIT are discussed in Reference 5.

β. Diode array detectors. A very important advance in recent years has been the development of silicon diode arrays and detectors. The characteristics of these devices were reviewed by Livingston. These arrays have the advantages over other electrical output image devices of fixed geometry, and a determined and fixed transfer function, and they open the possibility of making two-dimensional photometric measurements equal in precision to those made with photomultipliers. It appears likely that, following additional development, these detectors will replace most of the television-type systems now in use. These arrays are sensitive both to incident photons and electrons. However, as photon detectors, the devices are detector noise limited even with refrigeration except for moderately high light levels. This limitation can be largely overcome by using the array to read the photoelectrons produced by a photocathode, the optical output of an image intensifier, or the electrical output of a microchannel plate. Types of arrays now commercially available include the Intergrated Diode Arrays (IDA) and the Charge Coupled or Charge Injection Devices (CCD or CID).

During the report period, greatest use has been made of the Reticon, the one- or two-dimensional self-scanning IDAs manufactured by the Reticon Corporation. In Austin, Tull, in collaboration with Electronic Vision Corporation, has developed and placed in operation a self-scanned Digicon using either a single linear array of 1024 diodes or two parallel linear arrays of 1024 elements each, in which the total readout noise is of the order of 0.3 times the single electron shot noise for all photon flux levels producing at least one photoelectron per diode every 10th readout. This device avoids the limitation in the original Digicon on the number of possible elements imposed by the fact that in the Digicon parallel outputs connect each diode separately to an external amplifier. The system is currently in routine use for high dispersion coudé spectroscopy with the 107-inch McDonald reflector. A spectrum-scanning system has been developed by McNall at the University of Wisconsin in which a 512-element linear array Reticon is optically coupled to the output of a Varo 25-mm microchannel inverter intensifier. At high intensifier gain, photon noise predominates. At Kitt Peak, a solar magnetograph for use with the Vacuum Telescope has been developed by Livingston, Harvey, Trumbo, and Slaughter which uses two 512-element linear Reticons as the photon detectors, possible because of the high photon flux levels involved. Tests by Livingston *et al.* and by Geary and Gilbert at Steward Observatory indicate that the Reticon can be operated at the temperature of liquid nitrogen, suggesting that this detector has some promise as a detector at low light levels.

At Kitt Peak, the Panoramic Detector Program group, discussed in Section c. α above, is investigating a number of diode array detectors, including the IDA Reticon in both 512-element linear and 32 X 32 element two-dimensional arrays, a General Electric CID having a 100 X 100 element array, a Fairchild CID having a 1000-element linear array, and a Fairchild CCD having a 100 X 100 element array. Of particular significance has been the development of a non-destructive readout mode for the General Electric CID, which has permitted stored pictures to be read several times 10^4 times without significant degradation. The importance of this development is that it will permit all sources of spatially incoherent system noise to be reduced, seemingly without limit, by averaging multiple readouts.

At the Goddard Space Flight Center, the Advanced Senior Group in the Laboratory for Optical Astronomy headed by Sobieski is developing a two-dimensionsl photon-counting system using a thinned CCD operating in an electron bombardment mode. Present devices have a 100 X 160 pixel format, proximity focussing and a Bi-alkali cathode, and are designed to test feasibility. Second generation devices now on order will have the same format but magnetic focussing will detect single photo electrons. Development of a CCD with a 400 X 250 pixel format is under way.

Digicon-like tubes incorporating CCD arrays have been constructed by Currie, at the University of Maryland, in cooperation with Electronic Vision Corporation, and by Eberhardt at ITT. In the former instrument, a Fairchild 100 X 100 array was used, and in the latter a Texas Instruments 100 X 160 element array. A difficulty in this approach is that of shielding the electronics of the CCD from the high-energy electrons incident on the array.

γ. *Microchannel detectors.* In the X-ray and extreme ultraviolet regions, microchannel plates can be used directly as photo-detectors. In consequence, a number of one- or two-dimensional microchannel plate detectors are being developed for applications in space astronomy. Their use appears particularly attractive in light of a new design by Mullars, Ltd., in which the channels are curved to prevent ion feedback.

The development of an electronographic microchannel plate detector was discussed in Section a.γ. A second microchannel plate system for use at soft X-ray, extreme ultraviolet and far ultraviolet wavelengths is the Ranicon, developed by Lampton and Paresce at Berkeley. The detector consists of a microchannel plate coupled to a large-area resistive anode, and offers the advantages of large area, high spatial resolution, good efficiency, low background, and linearity of response. With an auxiliary semitransparent photocathode, it could be used in the visible region of the spectrum. At Kitt Peak, two systems are being studied by Broadfoot: A single microchannel plate fiber-optically coupled to a standard linear Reticon, and a double microchannel plate proximity coupled to a specially modified Reticon. The latter system is to be used in an XUV experiment aboard a NASA-JPL space mission, Mariner Jupiter/Saturn.

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