Collaboration on the Use of the 4 cm and 9 cm McMullan Electronographic Cameras at the Danish 1.5 m Telescope

K. Gyldenkerne, R. Florentin Nielsen and D. McMullan

Two electronographic cameras have now been operating at the Danish 1.5 m telescope on La Silla during several months. They assure an efficient use of this fine telescope and many exciting photos have already been obtained. Drs. K. Gyldenkerne and R. Florentin Nielsen of the Copenhagen University Observatory and Dr. D. McMullan of the Royal Greenwich Observatory explain how these cameras work and inform about some of the far-reaching observing programmes that have been initiated.

The commissioning of the Danish 1.5 m telescope at the European Southern Observatory (ESO) at Cerro La Silla in Chile has been reported by Andersen, Florentin and Gyldenkerne (1979), who described the first tests of the telescope and gave a brief summary of its auxiliary instrumentation. Additional test periods include various observational programmes using direct photography, spectro-photometry, and photometry with these instruments. In particular, the 4 cm and 9 cm electronographic cameras developed and constructed by D. McMullan and his collaborators at the Royal Greenwich Observatory (RGO) (McMullan et al. 1972, 1976; McMullan and Powell 1976, 1979) are being used extensively for direct electronography. The observations with these cameras on the 1.5 m telescope are part of a collaboration between the RGO and the Copenhagen University Observatory (CUO).

A basic requirement for the optical specification of the Danish 1.5 m telescope was that it should have a Ritchey-Chrétien mirror system with a useable field of a little less than one degree and thus be complementary to the ESO 1.5 m spectroscopic telescope. Furthermore, it was anticipated by the initiators of the telescope project, Professors A. Reiz and B. Strömgren, that an electronographic camera would be available with such a large cathode area that it would cover the uncorrected 80 mm diameter (20′) Cassegrain field.

During the telescope construction period it became clear to the Danish scientists responsible for the auxiliary equipment that the electronographic cameras developed at the RGO would be very suitable for the 1.5 m telescope. After the Austin conference on "Electrography and Astronomical Applications" in 1974 (Chincarini, Griboval and Smith 1974) it was decided to initiate a collaboration between the RGO Physics Laboratory and the CUO Astroelectronics Laboratory on the further development of the cameras. The principal goal was to provide a Danish 4 cm camera and to use this camera and the first RGO 9 cm camera on the Danish telescope during its test period. In the winter of 1974–75 R. Florentin Nielsen spent six months at the RGO Physics Laboratory and contributed to the completion of the first 4 cm camera, which was then taken

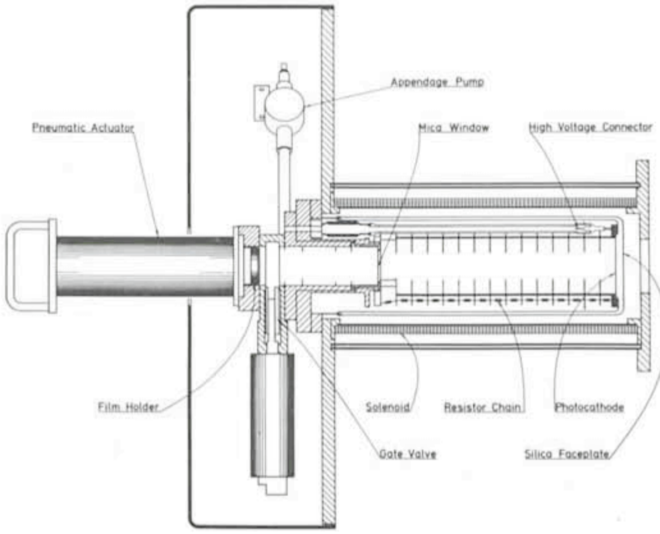

Fig. 1: *The RGO 4 cm electronographic camera (schematically).*

to the Wise Observatory in Israel for regular observational use. Then, in 1976–78, a Danish engineer, Finn Johannessen, participated in the camera projects at the RGO for about 18 months. Finally, the present authors commenced the tests of the two cameras on the 1.5 m telescope in the fall of 1978. The cameras, the observational programmes for the test period, and some of the results are described here.

The Electronographic Camera

The performance characteristics of an electronographic system can be summarized as follows:

(1) The detective quantum efficiency may approach the responsive quantum efficiency of the photocathode, because every photoelectron entering the emulsion leaves a developable track.

(2) The spectral range is wide, depending on the characteristics of the photocathode, with quantum efficiencies significantly higher than with photography over the entire spectral range (3000–9000 Å).

(3) There is no reciprocity failure.

(4) The detection process is linear; that is, the density of the developed image increases linearly with exposure, up to densities of 4 or 5 in the case of certain nuclear emulsions.

(5) The dynamic range of nuclear emulsions is high because of their fine grain and the possibility of exposing to high density. The fog level is very low.

(6) The spatial resolution can be better than what is needed in conventional astronomical recording.

The historical development of electronographic cameras will not be described in detail here but mention must be made of the pioneering work of A. Lallemand; however, the operation of his Caméra Électronique is rather complicated and time-consuming. Another pioneer, J. D. McGee, developed the "Spectracon" mica window image tube which is very easy to use and is commercially available but has the disadvantage that its photocathode area is limited to 25 × 15 mm². The cameras developed at RGO are also of the mica window type but the design permits the incorporation of larger photocathodes, 44 mm and 93 mm diameter respectively in the two available versions.

The 4 cm camera is shown schematically in figure 1. The photocathode is normally of the S.20 type which has a spectral response extending into the near infrared; ideally it should be formed on the silica glass faceplate but for the time being a separate thin silica substrate is used because of technical difficulties (which however should be overcome soon). The processing of the photocathodes is carried out in a way which prevents contamination of the tube interior with alkali metals and results in very low dark current. The photoelectrons are accelerated to 40 keV and focussed by parallel electric and magnetic fields onto the mica window which is 40 mm diameter and 4 μm thick. Its purpose is to isolate the photocathode from the gases evolved from the nuclear emulsion which would cause an immediate loss of photosensitivity, while permitting a large proportion of the accelerated photoelectrons to pass through. The window is protected from atmospheric pressure by a vacuum lock through which the electronographic film (nuclear research emulsion on a Melinex base) is introduced and pressed into contact with the mica by an air pressure of ~ 15 Torr. The resulting mechanical stresses in the mica are very small and there is no danger of breaking the window.

The loading and unloading of the film through the vacuum lock is carried out by an automatic electropneumatic system which incorporates a number of safety interlocks to safeguard the tube against operator error or faults in the control system. The films commonly used are Ilford L 4 fine-grain nuclear research emulsion and the more rapid Ilford G 5 emulsion. The resolution under optimum conditions is 60 line pairs per mm corresponding to 10 μm or 0.15 arc second at the 1.5 m telescope f/8.5 Cassegrain focus.

The tube is of demountable construction, so that in the event of failure, for example of the photocathode, the tube can be reprocessed easily (and at a moderate cost). However, because of the stringent leak testing procedures that are followed, the photocathode should have little loss in sensitivity over a period of years unless a small leak opens up or the cathode is damaged by exposure to too high a light level.

Operation of the tube is easy, and it can be used under the most humid conditions and at observatories at the highest altitudes. Further details regarding the use of the tube and its maintenance are given in an "Operational Manual" and a "Maintenance Manual". The loading of the film and the dark-room work are done as in normal photography, and the development and fixing techniques are similar to those for III a-J plates.

In the 9 cm electronographic camera the diameter of the mica window is 85 mm but a demagnification in the electron optics makes the useful cathode diameter 93 mm. Since it has not so far been possible to make the large tube envelope of fused silica (as with the 4 cm tube) Pyrex glass is used and this causes a lower sensitivity in the ultraviolet. Otherwise the construction of the larger tube differs only in minor respects from the small one, and the same control electronics is used for control and supply of both cameras.

A standard set of optical filters is provided and mounted in two wheels in front of the camera. Large area filters which can be used with both cameras include the standard Johnson broad-band U, B, V filters, a red filter, and a "dark sky blue" (DSB) filter. The latter has a very sharp bandpass transmission curve 800 Å wide centred at 4900 Å and is used in order to reduce the effect of night sky emission lines. In addition a set of standard Strömgren intermediate-band filters (u, v, b, y) and another red filter are available for the 4 cm camera only. There are also spare positions in the smaller wheel for special filters to be used with the 4 cm camera.

The Observations

Various electronographic programmes were planned for the test period; we shall briefly mention these and describe a few results in more detail.

In the initial test period in November 1978 R. Florentin Nielsen in collaboration with Karen T. Johansen observed a series of first rank E0 galaxies in clusters of galaxies, mainly of the Bautz-Morgan type III having similar richness. This is a pilot programme for the study of the evolution of elliptical galaxies for selection of an evolution parameter in cosmological distance scale determinations.

In a search of faint extensions of galaxies (Disney 1976) R. Florentin Nielsen initiated a galaxy morphology programme. The galaxies observed cover a wide range of types und were selected from the Hubble Atlas. Observations were made partly with the 4 cm and partly with the 9 cm camera to match the angular size of the galaxies. V and DSB filters, and in a few cases also B and R, were used; the DSB filter was particularly useful in obtaining maximum contrast to the sky background and thus reaching a very low limiting surface brightness.

In the second moon-free period K. Gyldenkerne in collaboration with J.G. Bolton (Parkes) and co-workers made electronographic observations (V and DSB filters) of selected faint radio sources for a more precise morphological classification of optical counterparts than what is possible in normal photography. In another dark period P.A. Wehinger (Heidelberg), Susan Wyckoff (Ohio State University) and K. Gyldenkerne using a special filter (Schott OG5 70) searched for underlying structure surrounding low redshift quasars and also studied structure and orientation of radio galaxies in the optical area with respect to their radio structure, i.e. double and triple radio lobes.

B. Thomsen and S. Frandsen (Aarhus) also studied "metric" diameters of galaxies belonging to selected clusters. In addition, they carried out U, B, V, R photometry (R red filter) of BL-Lac objects with the purpose of detecting outer areas of galaxies possibly surrounding these objects. Thomsen and Frandsen are also studying globular clusters belonging to nearby galaxies (B, V, R) in order to compare the spatial distribution with the surface density of the other halo stars, to determine the luminosity function for globular clusters belonging to different galaxies, and, if possible, to derive a correlation between cluster colours and distance from the galaxy centre.

P. Grosbøl made u, b, y, R observations of spiral galaxies in order to compare the observed colour distributions with those calculated theoretically by himself and C. Yuan on the basis of the density-wave theory.

The above observations were all made on dark nights. In addition, standard sequences were observed in various fields. Thus K. Gyldenkerne in collaboration with J.G. Bolton, R. Cannon and A. Savage started observations of sequences down to 20 mag for the application to the quasar search programme described by Bolton and Savage (1978).

The first moon period in December 1978 was taken up with a programme of narrow-band electronography of hot-spot galaxies. The work is a collaboration between D.J. Axon (University of Sussex), K. Taylor (RGO) and K. Gyldenkerne.

The first results of this programme were most promising. The nucleus of NGC 1808 was studied in detail, electronographic images being obtained in the majority of the prominent emission-lines (Hα, [N II], [S II], [O II], [O III], Hβ, etc.) together with some intermediate continuum bands. Examples of these data, which are being prepared for publication (Gyldenkerne, Axon and Taylor 1979) at this time, are presented in figure 2.

As further indication of the power of this telescope-detector system, we obtained sky-limiting exposures of NGC 1808 in the Johnson V band and as a result discovered a beautiful system of filaments emanating from the disc

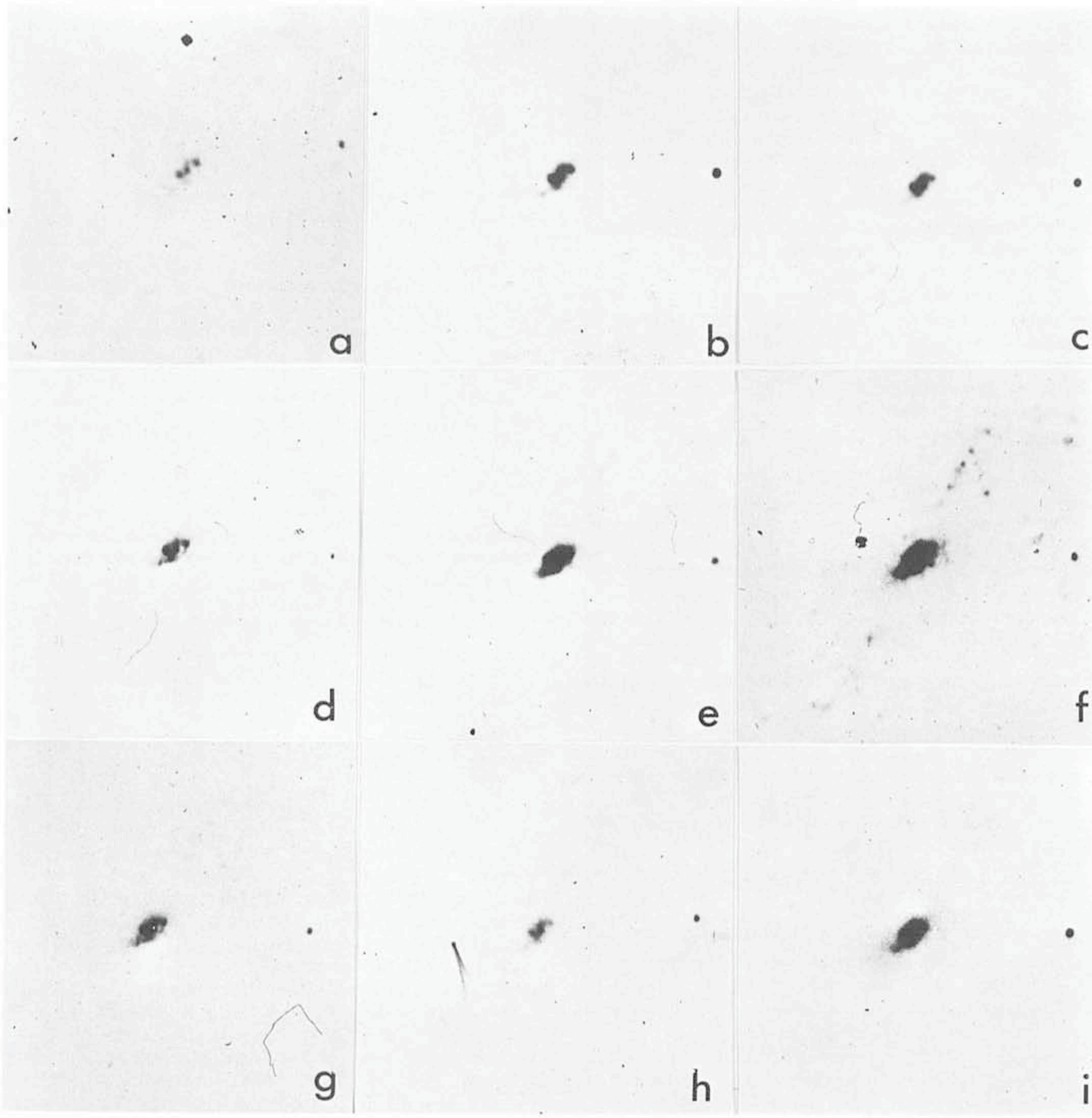

Fig. 2: *Narrow-band electronographic exposures of the active galaxy NGC 1808, obtained with the 4 cm McMullan camera on the Danish 1.5 m telescope. Emulsion Ilford G 5. Filter halfwidths around 15 Å. (a) Negative 6547: [O II], 60 min; (b) Neg. 6546: [O III], 60 min; (c) Neg. 6551: continuum near 6400 Å; 30 min; (d) Neg. 6545: Hα, 60 min; (e) Neg. 6550: Hα, 180 min; (f) Neg. 6548: Hα, 360 min; (g) Neg. 6556: [N II], 90 min; (h) Neg. 6544: [S II], 30 min; (i) Neg. 6549: [S II], 150 min. Note the difference between the lines, due to differences in temperature and pressure in the central regions. The Hα photos show H II regions. There are some unavoidable plate faults; the "comet" in (h) is one of these.*

region of the galaxy, very similar to the filaments in that other famous southern hot-spot galaxy NGC 1097 (Wolstencroft and Zealey 1975).

Summary

The experience with the 4 cm and 9 cm cameras in combination with the 1.5 m telescope has been extremely satisfactory. The power of the large camera is illustrated by figure 3 which should be compared with the 30-minute electronograph of the same area shown in *Messenger* No. 16, p. 1. The Ilford emulsions used from the beginning of the test period have turned out to be of good quality and with very few defects occurring, so that practically all the films provided could be used.

With the good seeing experienced in the 1.5 m telescope dome and the very fine external seeing occurring occasionally, coupled with the high quality of the telescope optics (Andersen and Niss 1979), the electronographic resolution mentioned above will permit a very faint limiting magnitude with this combination of instruments. Limits of about 26 magnitude for stars and 27 magnitude per square arc second for extended objects should be obtained under optimum weather conditions.

The collaboration described has thus been successful. It should be added that the achievements during the period in question have also, at least partly, encouraged the production of similar electronographic equipment for other non-British telescopes such as the ESO 3.6 m telescope on La Silla.

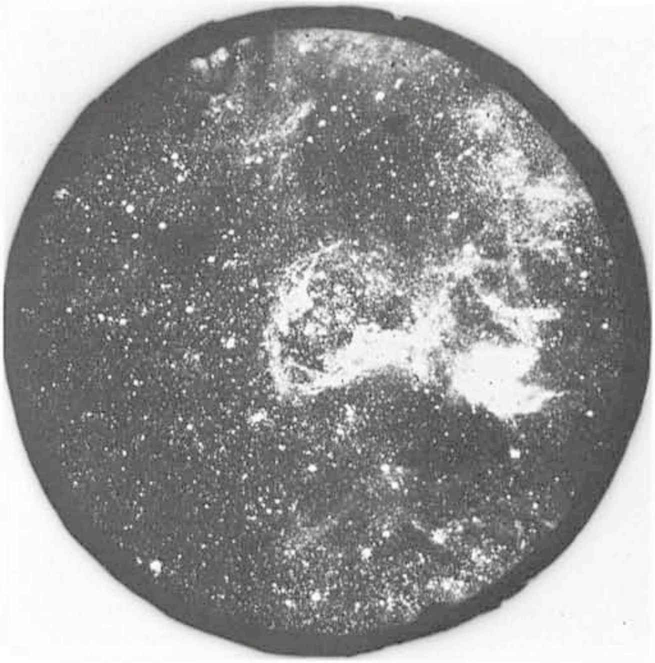

Fig. 3: *A 90-minute exposure of a region around NGC 2081 in the LMC, taken with the 9 cm McMullan camera on the Danish 1.5 m telescope. Emulsion Ilford G 5 and filter "Dark Sky Blue". The exposure may be compared with the one shown on page 1 of Messenger No. 16.*

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LATEST NEWS

Discovery of a New Eclipsing Dwarf Nova: OY Carinae

The weather at the beginning of the night April 29/30, 1979 was not excellent on La Silla: Most clouds were gone, but many of them were just waiting near the horizon and threatened to come back. After twilight I pointed the ESO 1 m telescope to the southern dwarf nova OY Car, which is a faint variable star of about 16^m. The first photoelectric measurement, however, revealed $14^m.8$, a bit brighter than normal, and it seemed to brighten up rapidly. Of course, this is not unusual for a dwarf nova: OY Car just was beginning one of its eruptions. I left the telescope on the star monitoring it continuously in 3-second time intervals. After five minutes, however, a new surprise showed up: the intensity began to drop! I checked the diaphragm: the star was properly centred. I looked at the sky: No visible clouds in the field. But the signal diminished more and more, and within a few minutes the star was five times fainter than before! This did not last long: the intensity began to rise again, even faster than the decline, and reached its previous value five minutes later. Could this have been caused by the unstable weather conditions? I kept the telescope on OY Car and found out that the darkening of this star repeated periodically every 91 minutes: no cloud is known to pass so regularly!

There was no doubt that I had discovered a new eclipsing dwarf nova with an extremely short period. Figure 1 shows the first eclipse ever observed: the star was still faint ($\sim 15^m$) at this time. Two totality phases appear like "steps" in the lightcurve. According to recent dwarf nova models, the first "step" corresponds to the total eclipse of the central parts of the disk and of the white dwarf, while the second