DISCUSSION: SECTION IV

Prokof'eva (to Latham): Are your figures for quantum efficiency the true responsive quantum efficiency or not?

Latham: The detective quantum efficiency for most CCDs is nearly the same as the quantum yield (electrons per photon) over the range of illumination for which the signal charge is well above the readout noise but well below the large-scale nonuniformities.

Maillard: What is your opinion about the capability of CCDs for doing accurate photometry?

Latham: For surface photometry accuracies of ±2% were reported at the conference. The limit appears to be set by inadequacies in the flat-fielding. Similar accuracies were reported for stellar magnitudes.

Maillard: What is the future of CCDs in the infrared?

Latham: The future for infrared imagers is very bright indeed. Already a CID sensitive at 10μm has been used for arc-second imaging at the telescope by a consortium involving Goddard Space Flight Center, the Smithsonian Astrophysical Observatory, and the University of Arizona. Undoubtedly infrared CCDs are being developed for military imaging, and hopefully it is only a matter of time before they see astronomical use.

Picat: Do you have information about the use of CCDs in the electron bombardment mode, for example for pulse counting?

Latham: There has been some experimental work with electron bombarded CCDs. ITT in Fort Wayne was able to make a CCD work in the same bottle with a cathode. However, I notice that they are now pushing systems which use external diode arrays coupled to a phosphor screen with fiber optics, and I suspect reliability was a major problem with the electron bombarded devices.

Petrov: What is the practical limit to the size of a chip, the fabrication technology or the data handling problem?

Latham: The data handling problem will be very severe for the larger chips, and only the major observatories and consortia will be able to afford modern high-powered image processing facilities. Jim Westphal has even suggested (facetiously) that chips with more than 256 x 256 pixels should be outlawed. However, the present limit is set in the fabrication technology. It is hard to get cosmetically perfect devices with more than 1 cm^2 area. But, if there were a commercial or military market for larger devices, I am sure these problems would be overcome. The present limit then would become the 75mm diameter of the wafers used by most companies, but even this is not a fundamental limit.

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Beckers: There is another way of handling the so called "data glut" resulting from large pixel number detectors. Solar astronomers have had to face this problem earlier. They have started to use "data crunching" in which they compress the amount of data collected by real time analysis using for example array processors. Then they have to record only the intermediate or final results. The original data is of course not preserved which may require a change of habits of the astronomers.

Rylov: I am very impressed by the MMT photon counting intensified Reticon system described by D. Latham. But we should remember that it is both complicated and expensive. These days there are many complicated systems usually equipped with TV cameras or image tubes of various types and a lot of electronics. To my mind such systems are like a train with a fixed number of fare-paying passengers (photoelectrons) but the more cars the train has,then the more there are non-paying passengers hitching a ride (the noise electrons). At each station inspectors try to remove the non-paying travellers from the cars but it is difficult and the train comes to the terminus filled with a mixture of paying and non-paying passengers and we need special means to find how many of each have come in each car. And so, in complicated observation systems, the more components there are in the system the greater the output noise. Though the sensitivity of such systems is high, noise is inserted by each component and we need much time to obtain useful output information.

For example, in my opinion, the scanner of Robinson and Wampler gives a lot of noise. This is seen from following data. The paper by E. Robinson and J. Faulkner (Astrophys. J. 1975, 200, L 23-25) says that they obtained with their scanner on the Lick telescope, 173 scans of a spectrum 1000Å wide (star AM CVn, 14^m) and the observation time for this was 346 min. The real resolution was 5Å. Then all the 173 scans were added and the resulting spectrum was published. The same measurements were obtained from 16 spectra with the BTA 6m telescope using a fast prime focus spectrograph equipped with one camera image tube (M9) and an output fiber plate. The gain of the tube was 40. The spectral width was 1500Å and the resolution 4Å. The image tube had practically no noise. Each of the 16 spectra took 2 min. The 16 spectra were added and to our surprise the resulting noise on the spectrogram was the same as that of Robinson and Faulkner. Using my method of calculating the information efficiency for telescope and their instrumentation (these Proceedings) and taking the number of gradations (denoted in my paper by m) to be equal, we find that $t'_o/t''_o=346/32=10.8$ and $I''/I'=n''_x n''_y/n'_x n'_y = 1.8$. Hence $I''_{eff}/I'_{eff} =19$ approximately. If we take into account the diameters of the BTA and Lick telescopes, then the gain of BTA system is approximately 5 times that of Lick.

Some other examples could be given to confirm this result but to be brief, I should like to say that complicated systems do not always satisfy us and there is a large need to develop simple systems, particularly image tubes with low noise, CCD arrays in vacuum tubes and Digicons etc.

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Latham (to Harmer, D.L.): What was the readout noise and how many reads did this require?

Harmer: 250 electrons per pixel with 10^7 reads.

Latham (to Balega): Have you measured the pulse-height distribution and counting efficiency of your photon counters?

Balega: We have measured the integral and differential event amplitude distributions for the camera with the 3-stage magnetically focussed image intensifier, using separate frames digitilized with an A/D converter. Each event was taken into account only once. The integral pulse-height distribution has a counting plateau and the corresponding differential distribution shows a clear peak. The amplitude distribution for the camera with a microchannel plate intensifier has a tail which is longer than in the first case.

The counting efficiency for the magnetically focussed camera was measured taking into account the quantum efficiency of the photocathode, which was previously estimated using calibrated sources. The value obtained is about 80%. For the microchannel intensified camera this value is a factor of 2 lower because of the loss of counting efficiency due to the microchannel intensification.

Karachentsev: My question is about your TV picture of M101. This well known galaxy has an angular diameter about 1^o. What is the focal length of the telescope that was used to obtain this picture? How was it possible to locate the M101 image on your TV target?

Balega: The image of M101 was projected on the TV target using a 3-stage magnetically focussed intensifier from the photographic picture. It was one of the wide range of laboratory tests. During this simulation the light flux in the region of the image was about 50 events/pixel hour. All the tests were made with the photon counting system on the 0.6-meter telescope of the Observatory.

Murdin (to Nebelitskii): How, using the 6m telescope, do you observe the necessary bright standard stars?

Nebelitskii: Only by using neutral density filters. Generally we also use a screen which has 256 holes in it and decreases the flux by a factor $\simeq$13.6.

Boulesteix: Did you measure or compute the detective quantum efficiency which you estimated as 5%? If you measured it, what method did you use?

Nebelitskii: We measured the fluxes from stars with known spectral distributions. In this we took into account the extinction of the atmosphere, the optics and so on. The slit was very wide to register all of the flux. We calibrated the photomultiplier in the laboratory and then calibrated the special lamp before examining our system.

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Wlérick: How far can you work in the UV?

Nebelitskii: In practice we work from 3700 Å, but we observe the lines in comparison spectra from ≃3500 Å.

Lelièvre (to Wlérick): Pouvez-vous nous donner une idée de la dégradation introduite par la caméra comparé à la magnitude ultime théorique? Pensez-vous pouvoir étendre l'emploi de la caméra grand champ au premier foyer CFH afin de bénéficier du correcteur grand champ et des "grens" sur un champ de 20 à 25 min d'arc?

Wlérick: La dégradation introduite par le récepteur (cathode + émulsion) est faible, de l'ordre de 30%. Pour la détection et la mesure des astres faibles, cela correspond à une modeste diminution de magnitude: $\Delta m = 0.30/2 = 0.15$. Il serait d'ailleurs intéressant de réaliser des cathodes encore plus sensibles que celles actuellement utilisées; par exemple, pour le domaine 400-500nm, des cathodes bialcalines.

A votre deuxième question, je répondrai qu'il est effectivement très tentant d'envisager l'utilisation de la C.E. grand champ au premier foyer de divers télescopes et particulièrement du télescope C.F.H. Il faut donc réfléchir aux modifications à apporter au récepteur pour rendre cette utilisation possible.

Chountonov: In the case of bright stars what is the relative intensity between the core and the surrounding diffracted light?

Wlérick: In the case of a bright star like the one in the field of 3C66, the optical density at the center of the optical image is too high to be measured with a microdensitometer such as a Joyce-Loebl or P.D.S.

Boulesteix: Avez vous déjà observé avec des photocathodes S20 et la caméra grand champ?

Wlérick: Pas encore; cependant une photocathode S20 a déjà été préparée dans une ampoule pour caméra grand champ et nous pensons l'utiliser dans les prochains mois.

Dokuchaeva: What are the most important parameters of the emulsions used with your electronographic camera?

Wlérick: We used ILFORD L-4 and its Kodak equivalent, Kodak Electron Image and Kodak Electron Microscope. These last two emulsions are quite homogeneous, free of defects, commercially available and rather cheap.

Rylov (to Petrov): What is the real gain in exposure time of the electronographic tube?

Petrov: We have not estimated the gain for real conditions of astronomical observation because the spectrograph we used is not suitable for observations with plates. Laboratory testing of the EIC gives the gain as 10 to 20.

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Richardson: A "Spectracon" electronographic tube was purchased in the mid-70's for use on a Cassegrain spectrograph of the 1.8 meter telescope at the D.A.O., and was in operation for a few years. The astronomers found it difficult to use because of the tiny piece of film pressed against the mica window, had difficulty getting good nuclear emulsions, were disappointed at the reduction in observing time, and were troubled by jumps or drift of the spectra on long exposures resulting in poor resolution. When an EMI tube was purchased (also made in England) it proved to be more popular with the astronomers than any other detector that was tried, and the Spectracon was abandoned. The EMI tube was first used only with film but is now equipped with a Reticon and will also have a CCD.

Murdin: The reaction of astronomers who used the electronographic camera at the Anglo Australian Observatory was generally similar to that reported by Dr. Richardson. I believe that electronography may be of value in a specialised use, but is not for common users.

Harmer, D.L.: I believe the preference for electronographic or cascade image tubes is a matter of personal experience and the nature of the observation being undertaken. I myself use these detectors for high dispersion spectroscopy, and have enjoyed good Spectracons and McMullan electronographic tubes, and been frustrated by poor ones. The same is true of EMI and similar tubes, but for these it is much more difficult to obtain quality spectrophotometry at high S/N because of extra calibration difficulties and poorer photographic emulsion properties. Multiple amplification stages also degrade line profiles in comparison with the cleaner photon image to electron image conversion in the electronographic tubes. Choosing the right detector for the application is what is important.

Lelièvre (to Picat): The Electronographic camera you described is a powerful instrument. With a gain of the order of 50 to 100 compared to a photographic plate, it gives improved efficiency at the CFHT, in particular the time lost between exposures is reduced to a minimum (2 or 3 minutes at the most).

Shvartsman: What is the typical accuracy and exposure time during your observations of double quasar Q 0957 + 501?

Picat: The typical exposure time in V is 5 min and the accuracy is about 2%.

Dodonov: What was the distance between the window of your camera and the photocathode?

Picat: 55mm.

Lipatov: I would like to report that a new photomultiplier has been developed at the Institute of Optical and Physical Measurements (Moscow) for the detection of faint sources. It has excellent dark count rates (1-5 pulses sec^{-1} at 20^{o}C, 0.1-1 pulse sec^{-1} at -79^{o}C), good stability

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(0.1%) for photon counting, and nanosecond time resolution. The spectral response extends from 115mm (CaF window) or 220nm (YT glass window) to 700nm (S11) or 850nm (S20). It has been used successfully at the Crimean Observatory and compares well with other commercially available PMT's.

Brown: As this colloquium will shortly be ending I have a general question to instrument users about the usefulness of CAMAC as an instrument/computer interface. Does CAMAC actually make it any easier to transfer instruments from one telescope to another? If so, would other standards be desirable in astronomy for the future?

Shcheglov: I can now use my dictatorship as chairman to make some concluding remarks. First, as our great image tube man, V.I. Krassovskii, often said to me when I studied the art of handling image converters, all the simple things have already been done and only the complicated ones remain. Next, I want to show you some colour slides of the 31/7/81 solar eclipse seen here in the USSR. And finally, as you all know, astronomy is a fascinating science. Since we have many French participants here, I am reminded that Napoleon considered that an alternative activity of his could be astronomy; he wrote to La Lande, then about 80 years old, saying how beautiful it was to divide the nights between astronomical observations and his newly married Josephine de Beauharnais. Well, with that we must end this meeting. Thank you all.

Richardson: I would like to add that this has been the most pleasant conference that I have ever attended and certainly it took place in the most spectacular astronomical conference hall in the world! I wish to thank not only Dr. Rylov and his organising committee but all of the employees of the Special Astrophysical Observatory for taking such good care of us. I hope that international colloquia at this Observatory will become a regular event in the future.

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