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DETECTORS FOR THE MMT SPECTROGRAPH

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1. INTRODUCTION

A big telescope and spectrograph are no better than the light detectors at the back end. The first time this point came home to me was nearly 20 years ago when, as a young and impressionable graduate student, I read a paper by Rogerson, Spitzer, and Bahng (1959) describing a pioneering effort to measure stellar spectra with a photon-counting detector on the 100-inch coudé. I was shocked when I read that out of every 5000 photons heading towards the 100-inch primary, only one actually got detected. I had the mental picture of a great rain of photons splashing on the 100-inch mirror, but only an occasional drip of detected events coming out the bottom. Actually, matters were even worse than this, because the Princeton detector could only look at one wavelength at a time and had to be scanned through successive wavelengths in order to build up a picture of the spectrum. In contrast to this early work, the first spectroscopic observations on the MMT (see figure 1) were made with a photon-counting Reticon system which detected one out of every 50 photons, simultaneously at nearly 1000 independent wavelengths. This rather unfair comparison suggests that we have made much more progress with the detectors in the past 20 years than we have with collecting area in the 60 years since the Hooker telescope went into operation. We are still far short of that impossible dream of counting every photon at every wavelength, but we are now getting close enough that factors of two improvement are getting hard to achieve.

The development of new instruments for the MMT, and especially of new detectors, is now a major activity at both the University of Arizona and the Smithsonian Astrophysical Observatory. In Cambridge serious efforts to develop a detector suitable for the MMT spectrograph began two years ago. We wanted to start even earlier than this, but there always seemed to be bills for concrete and steel that had to be paid first. We decided to concentrate on a detector suitable for faint-object spectroscopy, because we felt this capability would be the most likely to give early scientific payoffs with the MMT. Our basic philosophy was to choose a proven detector concept, so that we could get a system into operation quickly on our 60-inch telescope, and then to work hard to upgrade the weaknesses that became apparent in actual use. We chose to build an intensified photon-counting Reticon, copying many of the ideas and designs pioneered by Steve Shectman (1976). We insisted from the beginning that the detector should be computer controlled and supported by powerful software and displays, so that the observer could assess the progress of his observations in real time.

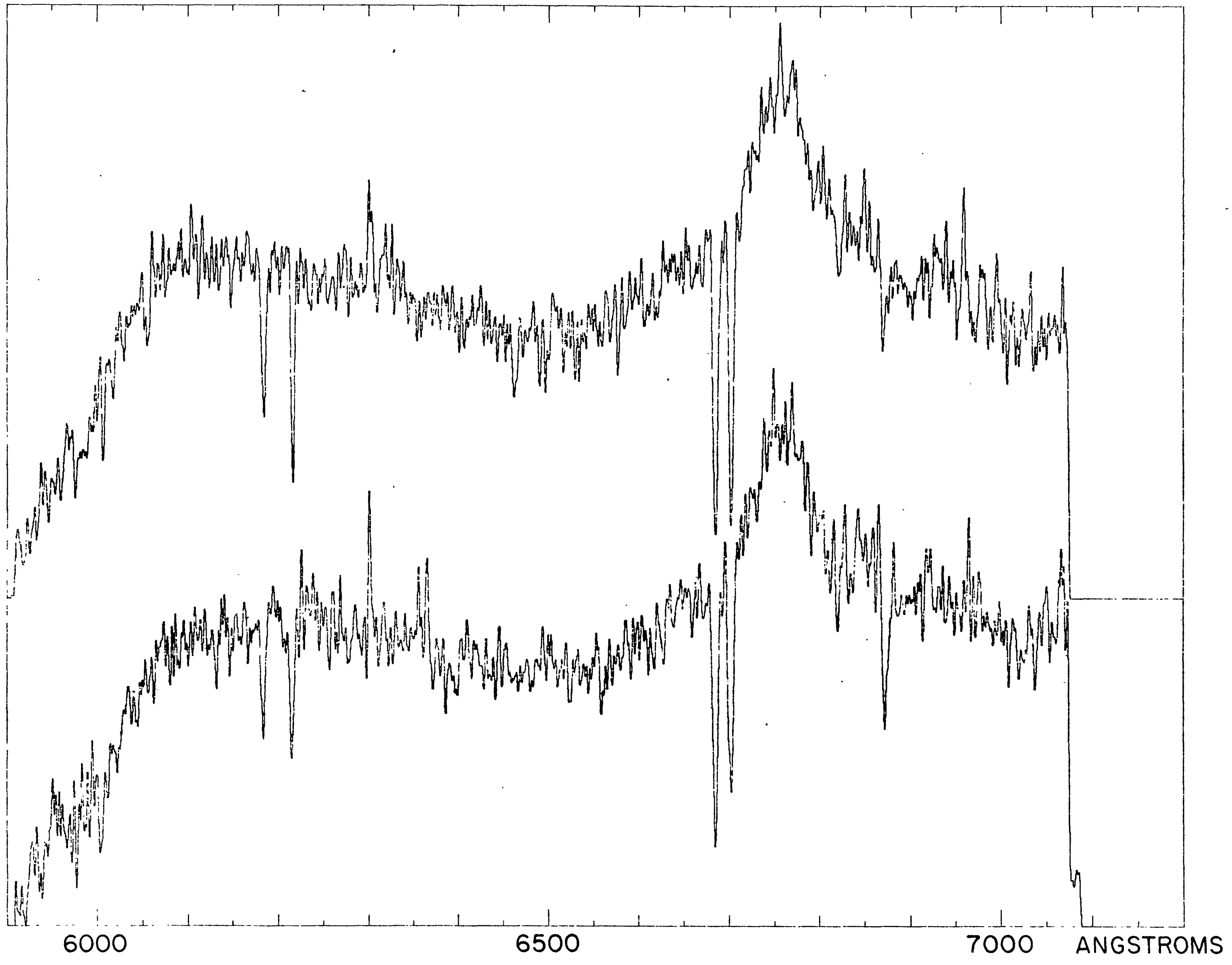

Figure 1. Spectra of the Twin QSO's observed April 19, 20 and 21 by N. Carleton, F. Chaffee, M. Davis, and R. Weyman using the SAO photon-counting Reticon spectrograph on the MMT. The main emission feature is Mg II 2795 and 2802 blended at a redshift of 1.4149, while the same two lines are resolved in absorption at almost exactly the same redshift of 1.3915 in both QSO's.

The first version of our photon-counting Reticon went to the mountain in February 1978 and has been in almost continuous use since then. Nearly every month we have made changes to the system, several of them major improvements. In our view the interaction between the users on the mountain, trying to accomplish difficult observations, and the laboratory scientists back in Cambridge (often users themselves) trying to prepare a field retrofit in order to improve the performance, has been essential to the success of the detector. Based on this first year of experience we are now building a new version of the system that is more nearly optimized for the MMT spectrograph.

The basic idea of the photon-counting Reticon is to use a high-gain image intensifier package to produce individual light flashes for each initial photoelectron, which can then be detected and located using a self-scanned diode array as the readout. The performance of the version now in operation has been described in detail elsewhere (Davis and Latham, 1978) and does not need to be repeated here. Instead I will point out some of the places where the MMT version will be different. In effect this gives me a chance to talk about a few of the most crucial aspects of the detector.

2. MMT PHOTON-COUNTING RETICON

An immediate consequence of the image-stacking mode of the MMT spectrograph is that the format at the focal plane, as well as at the entrance slit, is six times taller than for a single-telescope scheme. Each of the two linear diode arrays in our detector must be correspondingly taller in order to squeeze all the light onto the arrays. For this reason we are using a custom dual array consisting of two standard RL1024S single-line Reticon chips packaged on the same substrate so that there is only 1 mm dead space between the arrays. The individual diodes are 2.5 mm tall spaced on 0.025 mm centers, so there should be plenty of room along the diode height for the stacked images.

The detective quantum efficiency of an intensified photon-counting detector can never be better than the quantum yield of the first cathode, and the resolution of a centroiding system can never exceed the performance of the first stage. Selection of the first-stage intensifier for optimum spectral sensitivity is especially important, because differences of a factor of two or more from one tube to the next are not uncommon. For the detector now in operation at Mt. Hopkins we used a 25-mm Gen II microchannel-plate tube (Varo 3603 with special phosphor) sandwiched between two 40-mm Gen I electrostatic diode inverters (Varo 8605). The first stage was selected for especially high red sensitivity, but the cathode response drops off shortward of 450 nm because the input window is a fiber-optic faceplate (see figure 2).

For the MMT detector we are keen to put together a blue/near-ultraviolet intensifier package to complement the present red system. In order to achieve good resolution in the near ultraviolet over the full 40-mm field

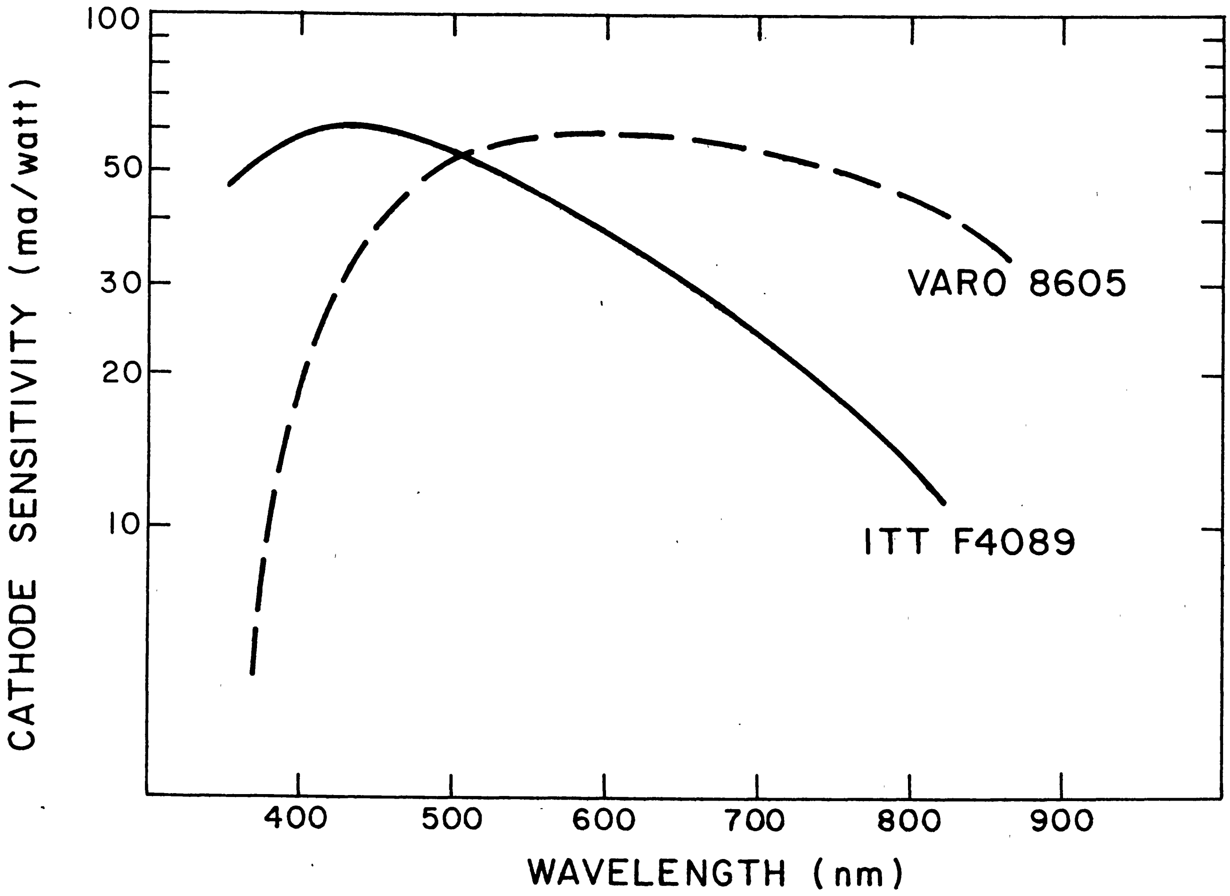

Figure 2. Cathode spectral sensitivities. All tubes were measured in Cambridge and are reported on the EG&G scale (Davis and Latham, 1978).

of the MMT spectrograph camera, we see no alternative to a magnetically focused tube. We have settled on the ITT F4089 for the first stage. In Cambridge we are putting together a package that uses a fiber-optic taper to couple an existing F4089 to three stages of 25-mm proximity-focused diodes for the back stages (Proxitronic Funk BV 2503 MX). If this fairly radical approach works, the package will be dedicated to the dual RL 1024 S Reticon. We have also undertaken the procurement of four more ITT F4089 tubes, which will be packaged into a more conventional 4-stage configuration in Rich Cromwell's lab at Steward Observatory. This package should have decent resolution even without a centroiding readout and thus should be useable for analog or integrating readouts as well as for the Reticon. One of the key features of our approach is that the Reticon is modular, with its own fiber-optic input. If necessary, it can be moved from one image-tube package to the next without a lot of difficulty.

Over the past year we have learned how to package a chain of image tubes with a monolithic pot of GE RTV511, complete with integral power supplies. Where necessary, fiber-optic plugs are used between tubes so that large voltages can be dropped between stages, and both the input and output windows can be run at ground potential. Cooling to about -30 C is accomplished by circulating coolant through a rubber hose potted in a spiral around the tubes. The cooling tube also provides pneumatic relief for the expansion and contraction of the potting compound with temperature. With this approach, even our hot red military cathodes achieve a dark rate of about 15 events/cm^2/sec. Throughout this work we have consulted closely with Rich Cromwell and Roger Angel and have benefited enormously from their experience and advice.

3. DIRECT ILLUMINATED CCD

We have recently undertaken the development of a cooled CCD camera that may be well suited for the cross-dispersed echellette mode of the MMT spectrograph. The camera will use the new RCA buried-channel chip, which has a 320 by 512 format (30 μ pixels and unusually large size of 9.6 by 15.4 mm) with essentially no dead spaces and a peak quantum efficiency of 60 percent in the red. Shortward of 500 nm the quantum efficiency drops quickly, so this CCD is no replacement for a cathode detector in the blue. One of the appealing characteristics of the new RCA chip is that it does not have the severe modulation in the red tail of the spectral response that is encountered with the back-illuminated devices such as the Texas Instruments chips. The risk with the RCA chip is that it is still a developmental device that may never go into production.

4. ACKNOWLEDGMENTS

The MMT spectrograph and its detectors are a true collaboration between the University of Arizona and the Smithsonian Astrophysical Observatory, with many scientists involved on both sides. In Cambridge, John Geary, Charlie Hughes, and Peter Crawford round out our detector development team. Steve Shectman and Marc Davis played crucial roles in the development of our

first photon-counting Reticon, and many others have contributed to its success. From the beginning Herb Gursky has been a staunch supporter of our detector development.

5. REFERENCES

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