HIGH SIGNAL TO NOISE OBSERVATIONS WITH A PHOTON COUNTING ARRAY

A.W.Rodgers, P.Harding, G.Bloxham and M.S.Bessell
Mount Stromlo and Siding Spring Observatories
The Australian National University
Private Bag Woden ACT 2606
AUSTRALIA

ABSTRACT. A simple high speed image widener is described which allows effective count rates of up to 100hz to be achieved with photon counting detectors thus allowing rapid accumulation of high signal to noise data in bright star spectroscopy.

1. INTRODUCTION

A significant limitation of photon counting detectors arises in saturation effects associated with high photon rates per pixel incident of the system.

While current versions of photon counting systems are able to provide detective quantum efficiencies, at low counting rates (below ca. 0.6Hz), which are equal to the diodic quantum efficiencies of the first cathode in the system, they compare unfavourably with analogue devices at high incident illumination levels. In the case of the Mount Stromlo photon counting array (Stapinski et al, 1981) and previous generation system such as the IPCS (Boksenberg et al, 1972) photon counting is achieved by optical detection of an intensified photon event using a TV type device such as a video camera or CCD operated in the line transfer mode. Among other properties, the basic limit is set on photon detection at high incidence rates when a significant proportion of the photons fall on the same pixel within the frame time of the CCD. Our photon counting arrays operate at up to 15 MHz clock frequencies and have frame subtraction circuitry to eliminate effects due to phosphor decay. Nevertheless, on point sources, count rates much above 1Hz show co-incidence effects which limit the use of the system for accurate photometric work.

Even with the highest resolutions available to us (up to 500,000) normal échelle spectroscopy of bright stars becomes inefficient when high signal to noise data is required due to the long exposure times required to accumulate the 10^4 to 10^6 counts necessary. This is additionally true for the acquisition of flat fields, which if they are to be useful in correcting pixel to pixel variations in high S/N data, must contain a significantly greater number of recorded photons.

G. Cayrel de Strobel and M. Spite (eds.), The Impact of Very High S/N Spectroscopy on Stellar Physics, 23–25.

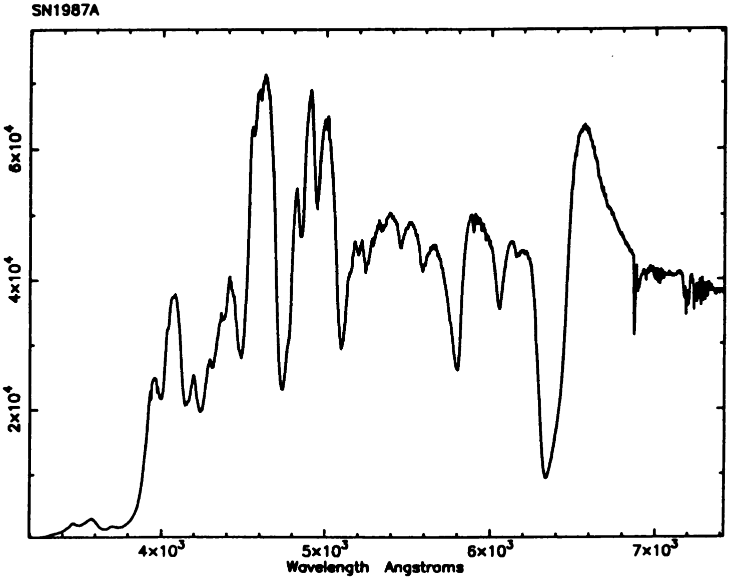

Figure 1. Spectrum of SN 1987A, the supernova in the Large Magellanic Cloud, obtained on the 74-in telescope with a resolution of 40 kmsec^{-1} with a S/N > 100 which was obtained in an exposure time of 600 seconds.

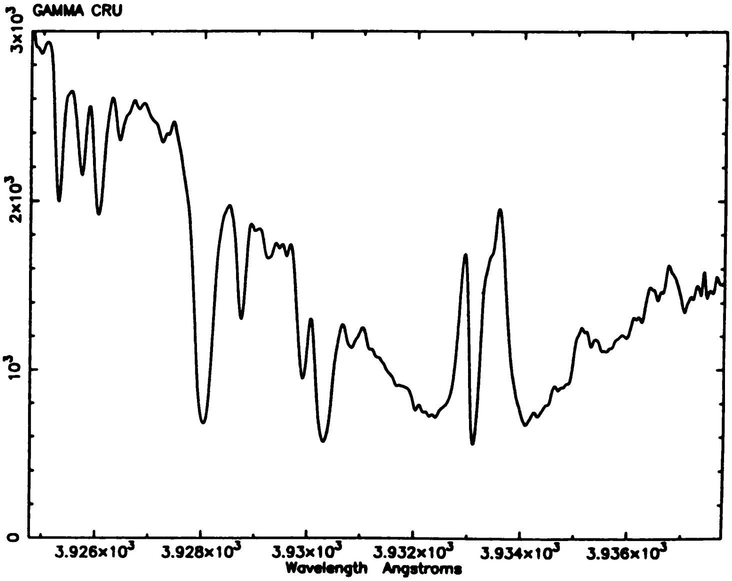

Figure 2. The region of the Ca II K line reversal in the M3 giant γ Crucis. The exposure was 40 min and in the wings of the line and in the other orders of the échelle image the effective count rate was 25Hz.

We describe below a simple and very effective device allowing high count rates on bright stars to be achieved.

2. THE RAPID WIDENER

In the Mount Stromlo photon counting arrays typical frame times lie between 7 and 20 msec. In typical seeing, a stellar image falls on 1 to 2 pixels perpendicular to the dispersion of the spectrum: essentially all the light is concentrated in one or two rows of the array. It is therefore clear that by spreading the light over the width of the array, typically 200 pixels, the total effective count read can be increased by between 100 and 200. Inefficient techniques, such as insertion of neutral filters and defocusing, can of course be used to keep the spectrum intensity below the system limit; however, as discussed above, it becomes logistically impossible to collect high signal to noise data in this way. Therefore we determined to widen the spectrum in a fashion that was analogously done in the era of photographic stellar spectroscopy. It is, of course, true that the widening rates used then would not spread the light along the slit in times small compared with the CCD frame time. We have therefore placed in front of the slit a hexagonal prism which is rotated at a speed of 6000 rpm which, through its rotation, wipes the star along the slit as each face of the hexagon is in turn presented to the incoming beam. Because of the hexagonal nature of the prism, on 6000 rpm it displaces the star image along the slit each 3 msec, a time which is short compared with the frame time of the CCD in the photon counting array system so that the photon counting array sees the spectrum as a uniformly illuminated strip.

In the case of the 74-in telescope coudé spectrograph the hexagon has a distance between its parallel faces of 42 mm and produces a widening at the slit of 22 mm. With the 32-in coude camera with 6-in beam size an image of the spectrum 3 mm or 100 pixels wide is recorded by the detector. Thus with a count rate per pixel of 0.5Hz a 1,000 second exposure we can record a total of 5 x 10^5 counts.

Since the coudé focus of the 74-in telescope has a focal ratio of f/32, negligible aberrations are introduced into the beam. Secondly, and most importantly, guiding from light reflected from the slit back through the hexagon to the video guider is possible since the guider sees a stationary star and the slit image behind it being oscillated backwards and forwards at 300Hz.

We present in Figures 1 and 2 examples of recent spectra obtained using the rapid widener. It is clear that such a device as the rapid widener will allow high signal to noise ratio spectra to be obtained with reasonable efficiency in the blue spectral region of many bright southern stars in wavelength regions of interest.

REFERENCES

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Stapinski, T.E., Rodgers, A.W. and Ellis, M.J., 1981 *P.A.S.P.*, 93, 242.