Analysis of Coudé Reticon Spectra

After a coudé run in late December 1985 with the 1872 Reticon and the 600 l/mm mosaic grating , A. Fullerton and T. Bolton (DDO, University of Toronto) noticed that their reduced spectra appeared to have excessive noise, which manifested itself as sharp jags cutting the line profiles. Figure 3 illustrates typical (though by no means extreme) examples of this phenomenon. The "ratty" appearance of their line profiles concerned them because such noise is usually smoothed out by the steep gradients associated with the wings of absorption lines. The problem was discussed with CFHT staff prior to a second run in June 1986, and some data were obtained to test ideas about the origin of the noise. In addition, some engineering time was devoted to the problem during the night of U.T. July 1, 1986.

After considerable work, the origin of the "rattiness" has been traced and Fullerton and Bolton have concluded that both the spectrograph and detector are conforming to expectations. The ratty appearance of the spectra was caused by a combination of residual 8-point pattern and telluric features. Both of these conclusions have some subtleties which are outlined below.

The CFHT Reticon is relatively free from the usual 4- or 8-point patterns which plague Reticon detectors. Consequently, Fullerton and Bolton did not perform 4-point normalization in their IDL reduction package, but rather Fourier-filtered the spectra at discrete spatial frequencies of 0.125, 0.250 and 0.375 pixel^{-1}. That is, they evaluated the Fourier transform of their flat-fielded, rectified spectra and set the amplitude of the transform at the above frequencies equal to the average of the 4 nearest neighboring frequencies. Inverting the transform completed the procedure, which is extremely effective in removing low-amplitude periodic signals.

However, their spectral coverage (roughly 5745-5930 Å) included the interstellar Na I D lines. These sharp, strong features introduced many pronounced features into the low-spatial-frequency regime of the Fourier transforms of the spectra. One of these strong dips happened to occur very close to the 8-point frequency of 0.125 pixel^{-1}. By averaging over the nearest neighbor frequencies, the residual 8-point pattern in the spectra was enhanced.

These findings are illustrated in the attached diagrams. Figure 4 is a plot of the actual S/N (determined by taking the ratio of the mean signal to standard deviation evaluated in two bands of continuum) versus the expected S/N given the exposure level and observational configuration (8 baselines, readout noise of 3.0 electrons, 4 flat fields in mean flat spectrum). The poor comparison between the two estimates is due to the observed S/N which is systematically low because of the enhanced 8-point residual. This is clearly shown in Figure 5, which portrays a "clean" spectrum of HD 155806 (with the 8-point pattern removed by filtering a portion of the spectrum which did not include the D lines), the same spectrum before cleaning (offset by 20%), and the ratio of the two (offset by 10%). After "cleaning" the residual 8-point pattern, the two estimates of S/N were in acceptable agreement.

Small telluric features were elusive to track down because of small wavelength shifts and the lack of a good reference source. When the positions of all the telluric features identified in the solar spectrum atlas of Moore et al. were plotted, it became immediately clear that the features were present in the stellar spectra, although sometimes the entire pattern had to be shifted by several pixels in order for the two to be in exact registration. Once mismatches of the entire pattern were allowed for, there was an excellent correspondence between the positions of telluric features and many of the jags in the line profiles, particularly in the He I 5876 line. The changing air mass of a particular star as well as nightly differences in water vapor opacity probably accounts for the impression that the jagged blips moved through the line profiles.

As a final observation, Fullerton and Bolton noted that there is essentially no 8-point signal in the raw stellar spectrum, but that all the flat fields (see a typical power spectrum in Figure 6) have a discernible 8-point pattern. This is hypothesized to mean that the diode array is overfilled when illuminated by the flat field lamp, and that some light falls on the shift registers, thereby introducing the 8-point pattern. Thus, division of a stellar spectrum by a flat field could introduce an 8-point pattern into the spectrum, simply because the lamp and stellar illumination characteristics of the array are not sufficiently similar.

Note in addition to the presence of the 4 and 8 point components, the presence of three other spatial frequencies (0.28846, 0.29808 and 0.30769 pixel^{-1}). These frequencies, also present in raw stellar spectra, are postulated to arise from spatial variations along the surface of the Reticon, since the central frequency of this triplet has also been observed in spectra obtained with the ESO 1872 Reticon (Baade and Lucy 1987).

In summary, it is clear that the residual 8-point enhancement seen in the 600 l/mm grating spectra of Fullerton and Bolton was a slightly bizarre artifact of both the Fourier reduction technique and the particular waveband of observations chosen. As such, it is unlikely to be encountered by other observers. It is hoped that this work will help to enhance the reputation of the CFHT coudé spectrograph!

A. Fullerton

New Editor For *Information Bulletin*

This issue of the *Information Bulletin* will be the last one edited by Rick Crowe. *Bulletin No. 18* will be handled by Olivier Le Fèvre, who became a CFHT Resident Astronomer on April 1 of this year. The *Bulletin* has undergone some major changes under Dr. Crowe's editorship, the most important of which was the implementation of a single bilingual version. Readers will note the new computer typeset format in this issue.

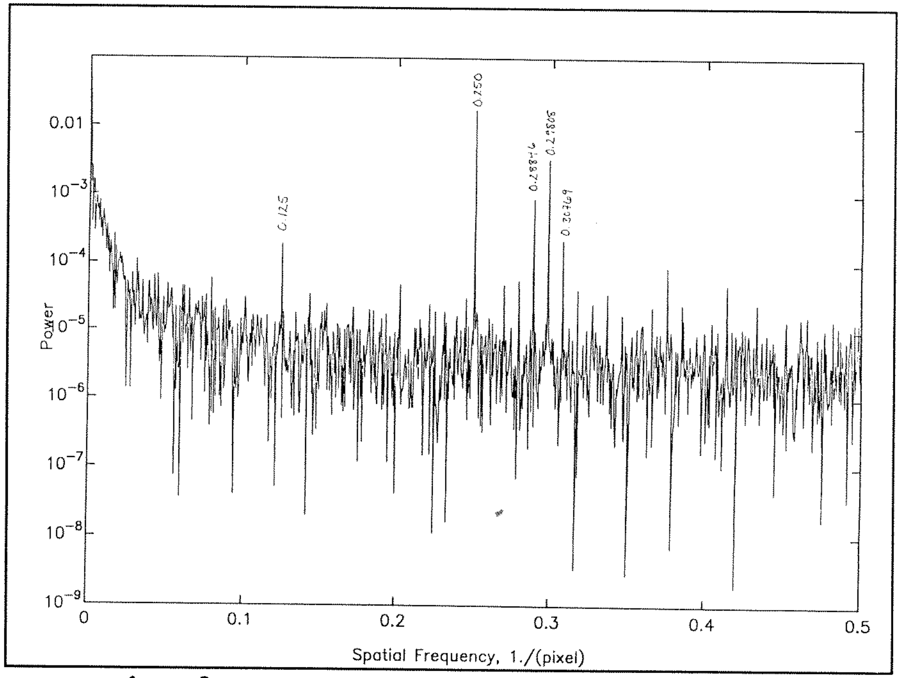
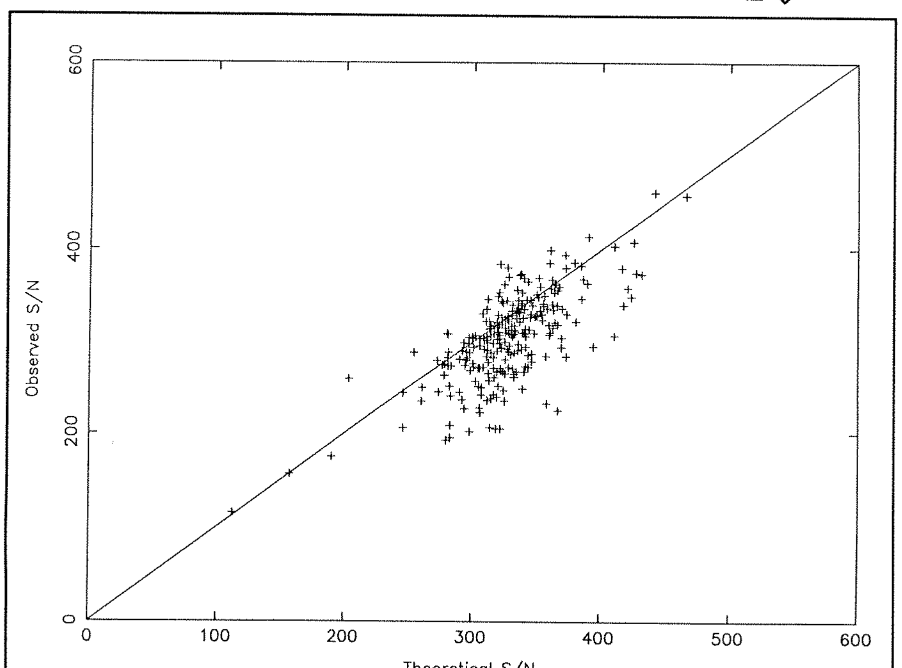


Figure 6 ⇑

⇓ Figure 4



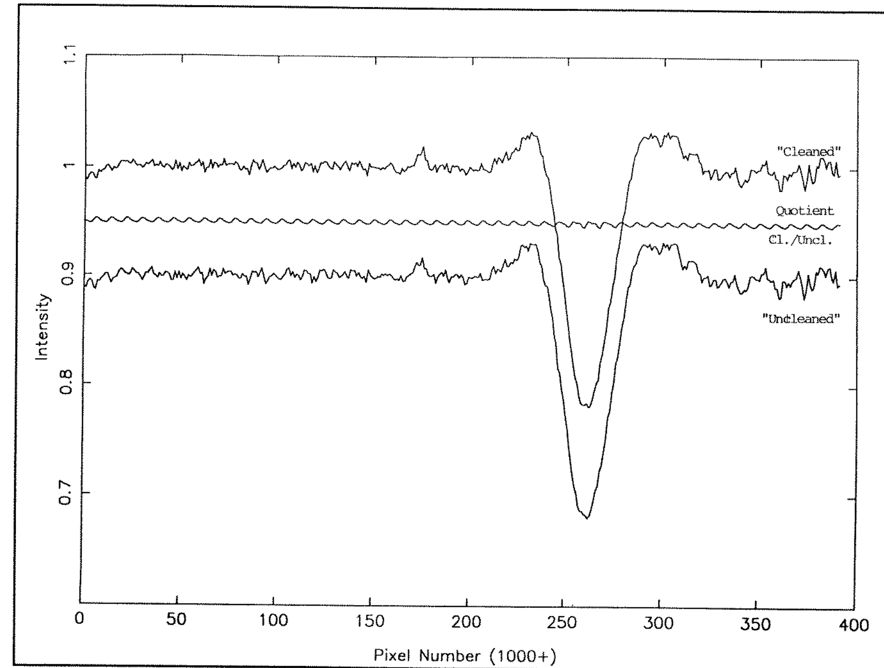


Figure 5 ⇑

⇓ Figure 3