Microphotometer Digital Data Processing

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In the past several years many, if not most, observatory microphotometers have been made or adapted to give digital output. At the same time, astronomers have been faced with the task of specifying exactly all the folk lore and experience necessary to reduce microphotometer output, so that the task can be performed by a computer. In addition to the speed and accuracy gains therefore, we have also been obliged to separate the subjective from the objective in this processing, and this may be the most important improvement of all.

Knowing that many other observatories have developed similar programming systems, this paper presumably does not contain much that is startlingly new, but it is hoped that it may promote the exchange of ideas desirable to overcome common difficulties and avoid duplication (or multiplication) of effort.

The Dominion Astrophysical Observatory programming system is designed to have a large range of application, avoiding excessive complication by the use of a fair amount of predata in addition to the digitized tracing itself. The existing microphotometer has been adapted to digitization, while a new instrument, designed for digital operation, is on the drawing boards. The digitizing pulse is derived from an accurately milled 100 tooth wheel fixed to the 1 mm pitch screw, thus giving an interval of 10 μm per digital output point. The voltage from the tube is sampled on the run and a maximum rate of some 10 points per sec is used. Simultaneously, a fast pen recorder produces an analog density tracing with a fiducial mark every 100 digital points. The use of this analog output is essential in determining the predata before running the computer reduction. Step wedge calibrations are recorded monochromatically at as many positions as desired for the present version of the program, although the desirability of continuous dispersed calibration is recognized. An accurately linear light response means that calibrations may be run at different light levels (and hence times) from the main tracing, and used for several spectra on one plate.

Briefly, the program operates as follows. A dispersion curve is derived, either by finding the positions of some specified spectral features or as prespecified by the operator (as e.g. in Hγ of B stars). The data are then interpolated to a linear dispersion at prespecified wavelength intervals. The calibration is applied and a continuum derived by a number of different possible ways, and the final spectrum presented as rectified and normalized to the continuum level. Additions, subtractions, means of more than one spectrum may be derived if desired, and a number of different output forms are available.

Figure 1 shows the predata required for each tracing. The difficulty of obtaining these depends on the length and complexity of the spectrum tracing as well as the astronomer's competence and familiarity with the problem, in the usual way. Predata for a simple run such as a Balmer profile and equivalent width in a B star may be prepared in a couple of minutes. The quantities marked need not be exact and are derived from knowledge of the digitizing procedure and inspection of the monitor tracing. The calibration cards are produced by the computer and edited by hand in conjunction with inspection of the monitor tracing. This is quite quick and enables the operator to select the portion of the calibration applicable to the density range of the spectrum and to look for flaws, Eberhard effect etc., which would be extremely complicated to program. The calibration and continuum may be fitted as one or more polynomials of any specified order according to the judgement of the operator.

Figure 2 shows the operation of the programs, which are executed sequentially on an IBM 1130 computer with 8K storage bytes. A large degree of flexibility and operator control of the processing is possible by use of the signal cards in Figure 1 and data switch operations built into the program. Thus, the finding of the standard wavelength lines may be checked from the printer output and the operator may decide to omit or change lines which for some reason do not fit the dispersion curve. Most commonly he is able to correct his own errors in identifying lines or punching cards. Similar loop-back possibilities are built into the calibration and continuum fitting, and a compressed "mini-plot" of the final output is produced as a final check before embarking on the full scale output operation.

The standard lines are located by searching for a minimum (or maximum in the case of emission

lines) in the region indicated and tested for significance by searching a specified distance on either side of this turning point. A curve is then fitted through the central points of the line, highly deviant points rejected, and finally the algebraic turning point of the curve taken as the line position. The dispersion may also be defined by the operator, by-passing the line fitting routine, or a zero point correction to a standard dispersion curve derived, using only one line in the tracing. The continuum is normally found by fitting a curve through the mean positions and densities of a number of continuum "regions". These

PREDATA

Wavelength range and desired resolution in points per Angstrom.
*Approximate dispersion of plate, sampling interval and standard line widths in A.
*Approximate positions of standard lines (or set wavelength).
Starting wavelength and extent of each continuum region (or density and wavelength values of set continuum).
Dark and clear and calibration cards as punched (edited if necessary).

SIGNALS

Standard line search, set dispersion, or zero point change.
Continuum search or prespecified: Number and degree of calibration curve fits; Number and degree of continuum curve fits and limits in terms of continuum regions.
Output plotter scales: add, subtract or store and tracing weight type and number of output cycles.

Fig. 1

regions are specified by a starting wavelength and a length, from a knowledge of the spectrum of the star. Highly deviant points are rejected and a mean continuum point derived for each region. The spacing of the continuum regions should therefore be properly arranged to obtain a balanced curve-fit. If desired, the exact continuum positions may be decided by inspection of the monitor tracing and fed in on the predata.
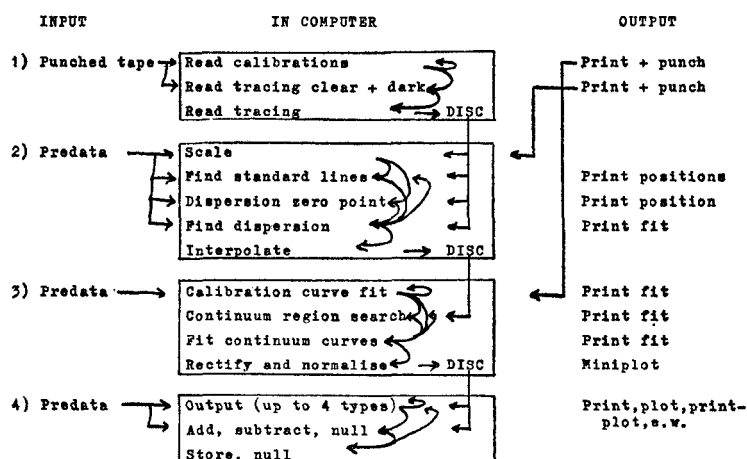

Fig. 2

Output is available as plot (on any scale), printed plot, tabular print and integrated equivalent width and may be produced as frequently as desired (with different or the same scale, wavelength limits, etc.), by keyboard input. Output may be made on a newly processed spectrum both before and after addition or subtraction operations on previously accumulated spectra. Thus one may obtain weighted mean spectra (from plates of different dispersions if desired) or differences to look for spectral changes, in addition to the normal one-shot processing. Figure 3 shows some examples of processed spectra.

Further developments will be a dispersed calibration, line profile fitting to separate blends, and
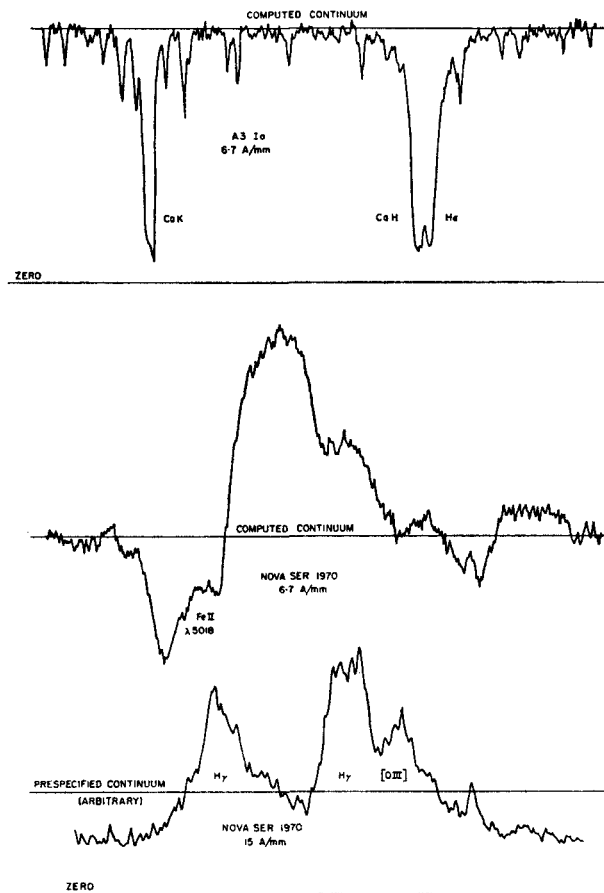
Fig. 3

Fourier smoothing techniques. All of these are presently working in prototype form. Dr S. C. Morris was responsible for adapting the program for use on the IBM 1130 computer.

DISCUSSION

L. ROBINSON: Do you have a disk store on the IBM 1130?

J. B. HUTCHINGS: Yes, a standard disk with one million words capacity.