Geometric Rectification of PCD and ST-FOC Data with MIDAS

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It is now about six months since ESA's Photon Counting Detector (PCD), the ground-based counterpart to the Faint-Object Camera (FOC) to be flown with the Hubble Space Telescope, was put into operation at La Silla and made available to Visiting Astronomers. There it proved to be very reliable and, also thanks to good weather conditions, was very productive. By now, quite a few readers of the *Messenger* will be busy analysing their own PCD observations.

The PCD owes its high sensitivity and its ability to count single photon events to a three-stage image intensifier which is the technical heart of the instrument. The price to be paid is the S-like geometrical distortion which is a typical and inevitable property of image tubes. Unlike e.g. the IPCS (Boksenberg 1972) where this distortion is corrected for in one dimension by the hardware so that the correction only needs to be done in the second coordinate, PCD (and FOC) images require a bi-dimensional rectification. To this end, a regular grid of reseaux marks are etched on the first photocathode to provide the necessary reference points. However, they can only be used in the direct imaging mode since only then they stand out dark against the brighter sky background. By contrast, in the long-slit spectroscopic mode the opposite principle has to be adopted where separate calibration images with bright spots are obtained by observing an arc spectrum through a mask with a series of equidistant holes parallel to the spectrograph slit.

So far there was no dedicated software available at ESO to cope with those special requirements of PCD data. On the other hand, the number of totally different steps necessary to reduce any kind of optical astronomical data is not all that large. Owing to the modular structure of MIDAS, it might therefore be possible to merely adapt some existing programs from the growing pool of MIDAS software to this problem.

Let us briefly summarize what one would like to expect from the solution:

(1) find and identify the reseaux marks and comparison spectrum features, respectively,
(2) determine a parametrization of the geometric distortion,
(3) conserve the flux on a small local scale,
(4) handle undersampled data like those of some of the FOC modes,
(5) correct spectral data for geometric distortion and non-linearity of the wavelength scale in one step in order to avoid unnecessary degradation of the data due to multiple rebinning.

The detection and identification of features which combine to a rather similar pattern as in the long-slit spectroscopic mode of the PCD is one of the major steps during the course of the reduction of CASPEC data (cf. MIDAS manual). In fact, in MIDAS this PCD related task can be done on the command procedure level by combining existing CASPEC software modules (Ponz and di Serego Alighieri, in preparation). The MIDAS TABLE system furthermore supports a two-dimensional polynomial regression analysis (so far mostly used for the CASPEC data reduction) required for point 2 on the list above.

Only for the rebinning a new main program had to be written in order to also cope with severely undersampled point spread functions having a FWHM of the order of one detector element (such as in the f/48 mode of the ST-FOC, but also in ground-based PCD data obtained under exceptionally good seeing conditions). Assuming (or in more sophisticated future versions also knowing) the point spread function, the data are first effectively deconvolved and each input pixel subdivided into 3 × 3 sub-pixels holding the result of the deconvolution. According to the prescriptions found by the two-dimensional regression analysis, the input flux is then dropped sub-pixel by sub-pixel into the grid of again regular-sized pixels defining the geometrically rectified (output) image.

This procedure is faster than to strictly project each sub-pixel onto the output grid because varying (across the image) input-to-output pixel size ratios and orientations do not permit one to define one fixed algorithm to be followed across the entire image. The trade-off is with the local flux conservation whose accuracy obviously deteriorates with increasing size of the sub-pixels. For very high S/N data there is an option to replace each sub-pixel by a number of still smaller units ("substepping", no further interpolation done). Without this additional subdivision an image with uniform flux distribution shows after the rectification little "cracks" with an amplitude of the order of 1 %. Their number is increased but their amplitude is reduced by making use of the sub-stepping option. From the varying input-to-output pixel size ratio it is clear that a small large-scale modulation of the flux density must necessarily be present and that the quality criterion can only be the smoothness of this modulation. The penalty to be paid in terms of CPU time for the usage of a large additional sub-stepping factor is high and only justified in extreme cases.

The most critical test of the usefulness of the polynomial "Ansatz" is obviously provided by the long-slit spectroscopic mode where in the same step not only the geometrical rectification but also the linearization of the wavelength scale is to be accomplished. The results for a test frame with 1024 × 256 pixels containing a series of 8 vertically offset spectra of a He-Ar lamp in the range 3700 to 5200 Å and with a dispersion of 2.2 Å/pixel are shown in Figures 1a and b. The degree of the polynomial was 3 in both wavelength and position perpendicular to the dispersion direction (the MIDAS regression analysis program used is unusual in that it includes *all* terms $x^m y^n$ with m ≤ degree in x, n ≤ degree in y). A pairwise cross-correlation analysis between the 8 spectra yielded perfectly symmetric cross-correlation functions with a FWHM only 5 % larger than the auto-correlation function of one spectrum. The inferred off-set in wavelength between the individual spectra was at most 0.35 Å or one-sixth of a pixel. A subsequent secondary analysis of the spectral dispersion in the reduced data confirmed the linearity of the wavelength scale on the same level. Execution time (without additional substepping) for the 2-D regression analysis and the rebinning was close to 20 minutes CPU time on a VAX 780 thus identifying this step of the PCD data reduction as a typical

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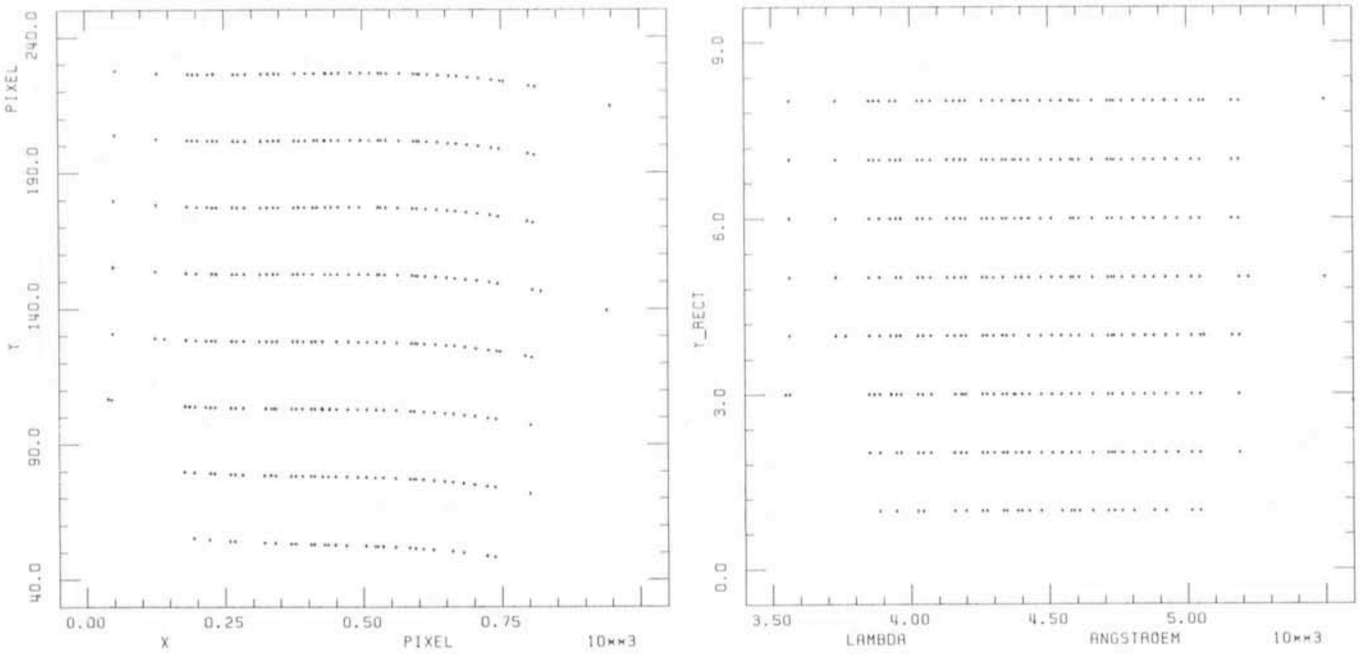

Figures 1 a and b: *The positions of the stronger arc lines (a) in the raw data and (b) after the simultaneous geometrical rectification and rebinning to wavelength. (In Figure 1 a the vertical and horizontal scales are different in order to enhance the visibility of the distortion. The step size in y has been changed from Figure 1 a to b; this is of no relevance.)*

batch task to be executed only at night time. This can be conveniently done, since once reseaux marks and/or comparison spectra are correctly identified, no further user intervention is necessary.

We have written this short note about the reduction of PCD data within MIDAS in order to inform PCD observers about this new possibility to treat their data. We furthermore believe that it is a good example of the growing maturity of MIDAS because more and more problems can now be treated by simply using MIDAS as a high-level problem solving language, often without having to do any FORTRAN coding. After some further improvements have been included, the software described will be available to the MIDAS users community.

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Variations of the High Resolution Hα-line Profiles of the Very Young Stars: HR 5999 and HD 163296

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Introduction

It was recognized long ago that the Hα line (6563 Å) is very important for the study of stellar winds in pre-main sequence (PMS) stars (Kuhi 1964). There are two reasons for this. Firstly, the Hα line is usually the most intense emission line in the visible spectrum of PMS stars. It is expected to be formed in an extended region of the wind, thus providing a good global insight tool on the structure of the wind. Secondly, the location of the Hα line in the optical spectrum is such that this line can be very easily observed with Reticon and CCD detectors.

Two southern emission-line stars, HR 5999 and HD 163296, drew much attention lately because these bright A-type objects possess most of the spectacular properties of the so-called Herbig Ae/Be stars (Thé et al. 1985a and Thé et al. 1985b). This class of Herbig (1960) stars was shown by Strom et al. (1972) to consist of younger than main-sequence objects.

In the present short communication the remarkable variations of the Hα profile in HR 5999 during a space/ground-based coordinated campaign in September 1983, and at other epochs, will be discussed. The emission line star HD 163296, originally intended as a comparison star, was also observed at the same observing runs as HR 5999; its Hα profile variation will be shown as well. Suggestions for an interpretation of the Hα-line formation are then presented.

Some Properties of the Hα line in PMS Stars

Finkenzeller and Mundt (1984) have surveyed 57 candidate Herbig Ae/Be stars in the line of Hα, NaI D and HeIλ5876. They conclude that the Herbig Ae/Be stars can be devided in 3 subclasses according to the shape of the Hα-line profile: (1) with a double peak, comprising 50 % of the whole sample; (2) with a single peak (25 %), and (3) with a P Cygni profile (20 %).

A similar survey was reported for T Tauri stars by Kuhi