MIDAS data frames are saved so that they can be maintained when restored from tape into MIDAS.

The CASPEC package has been improved by a better flat-field correction, an absolute flux calibration scheme, and a more flexible determination of the instrument chromatic response. The wavelength calibration was also made more automatic to simplify it and to minimize user interaction.

The COMPUTE/IMAGE command has been optimized in the case when all image operands have the same world coordinate limits. Gains of more than 50 % in execution speed have been recorded for expressions involving several large frames. A set of routines for vector operations are now used so that computers with fast vector instructions can be easily utilized later.

A set of routines for analysis of optical interferograms (Pirenne et al. 1986, *The Messenger* **42,** p. 2) has been included. Although the main application of these routines are within the area of evaluation of optical systems, they are also useful in astronomy e. g. for location of echelle orders.

2. Measuring Machines

The OPTRONICS measuring machine will be modified in order to optimize its use for positional measurements and to enable fast scans of large plates. A new optical system has been designed and includes an LED light source, a CCD full field camera for position determinations, and a 1-dimensional diode array for photometric scans. Also a new computer control system based on VME modules will be installed and linked to the main computer facilities through an Ethernet. The design objectives have been to provide fast automatic measurements of stellar positions with an accuracy of the order of 1 μ and to make it possible to scan a 900 cm^2 plate area with a step of 10 μ and a dynamic range of at least 2.5 density units within a 12-hour period.

The new optical system will be implemented and tested on the OPTRONICS in the time from May 5 to May 30 during which period the machine will not be available. From June 2, manual measurements of positions on plates will be possible while the photometric scan mode first will become available towards the end of the year. It is anticipated that the OPTRONICS will be reserved two weeks each month for testing of the photometric system until this option is released.

3. Move to New Wing

The building extension of the ESO headquarters in Garching contains space for the new computer room and image processing user areas. It is foreseen that the technical preparations for the move of the computer equipments to these new locatations are finished in June 1986. Due to the total relocation of the main computer facilities the normal operation will be disrupted for several weeks in the period June–July. The exact dates for the closure will first be known in May. During this period only very limited computer and image processing facilities will be available such as the measuring machine facility and some IHAP stations. Visitors who want to use ESO data reduction facilities in the time June to August are kindly requested to check the availability of the equipment needed.

On the MIDAS Reduction Package for CASPEC Spectra

D. PONZ and E. BRINKS, ESO

"Le CASPEC n'est plus un CASSE-TÊTE"

1. Introduction

The échelle package inside MIDAS has been used for the reduction of CASPEC spectra for more than one year, over 500 scientific frames have been reduced, and many astronomical results have already been published. The reduction scheme has evolved during this time, due mainly to the invaluable user feedback. Algorithms have been improved and the operation optimized so that the required user interaction is reduced to a minimum.

In a previous note (1) we have considered the accuracy of CASPEC spectra in two critical points of the reduction, namely the wavelength determination and the flat-field correction. The results confirmed the suitability of CASPEC for velocity determinations and for the detection and measurement of faint spectral features. In the present note we discuss three other aspects: the definition of the background an the correction for the instrumental response, which are relevant in the determination of the flux scale, and the session concept which provides a simple and natural way to control the reduction. This paper, together with the previous reference, gives an overall view of the status of the reduction method.

2. Background Definition

As pointed out by several CASPEC users (see for example reference (2)), the determination of the background is one of the critical aspects in the reduction of échelle spectra, and much care has to go in understanding the contribution of the different background components. The background of CASPEC images consists of:

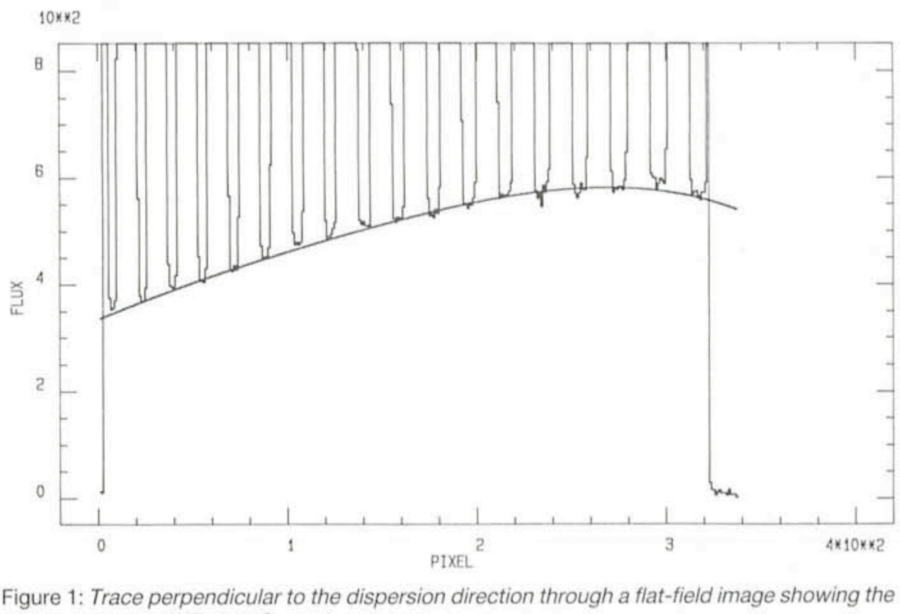

Figure 1: *Trace perpendicular to the dispersion direction through a flat-field image showing the fitted background (Flux in Counts).*

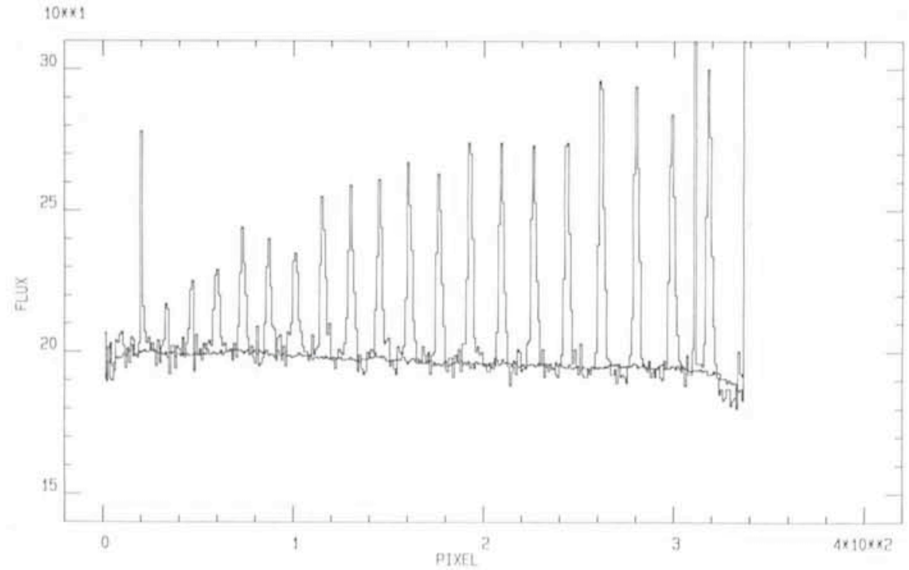

Figure 2: *Trace perpendicular to the dispersion direction through an object frame in the blue range accessible to CASPEC showing the estimated background (Flux in Counts).*

- a constant offset introduced by the electronics (bias),
- an optional constant pedestal due to the pre-flashing of the CCD,
- the dark current,
- general scattered light,
- diffuse light in the interorder space coming from adjacent orders.

The bias, the component of light added by pre-flashing and the dark current can be determined by taking special exposures. These contributions can then be subtracted from the regular frames. Regarding the general scattered light and the diffuse light in the interorder spacings, a simple analysis of flat-field images shows that, in the long wavelength range, the background distribution does not follow the distribution of the order information. This means for a high level of exposure that most of the background contribution at this wavelength range is coming from general scattered light. For images taken at shorter wavelengths, and/or with a lower exposure level, the diffuse light from adjacent orders is the main component to the background.

The background is estimated from points located in the interorder space; these points are used to approximate the observed background by a surface. The background of flat-field images is usually well modelled by a 2-D polynomial of degrees 3 along and 4 perpendicular to the orders. The agreement of the model is typically better than 1 % of the background level. Figure 1 shows a trace perpendicular to the dispersion direction through a flat-field frame and the background fitted to the interorder locations. For object exposures the signal-to-noise ratio is normally much lower, as is the actual background level. A polynomial of a lower degree should then be employed. If the components due to bias, pre-flashing and dark current are subtracted from the scientific frame, a plane is very often a good approximation to the background component. Because small errors in the determination of the background are carried through the whole rest of the reduction and are even amplified at the edges of the orders, care should be taken in the background fitting. If no dark or (pre-flashed) bias frames are available, the background definition might be slightly less accurate because the modelling procedure has to take into account these contributions too. The accuracy with which the background can be determined depends on the exposure level of the frame and on the interorder space. If the interorder space is too small, the background level will be overestimated by an unknown amount. Given sufficient space between the orders, the systematic deviations are estimated to be less than 1 %. Figure 2 shows a trace perpendicular to the dispersion direction through an object frame in the blue region of the spectrum and the total estimated background. Figure 3 shows the individual components which contribute to this background.

3. Response Correction Using Standard Stars

The extracted orders, resampled using the dispersion relation described in reference (1), define the observed flux as a function of the wavelength for each order. This flux has to be corrected for two effects in order to get a relative flux scale, i.e. the échelle blaze effect and the wavelength dependent response of the instrument. For a given configuration, the blaze effect is a function of the position in the order, while the instrument response is, essentially, a function of the wavelength. The solution adopted is to use a standard star to correct for both, blaze effect and instrument response, simultaneously. The standard star, observed with the same configuration as the object, is reduced using the corresponding normalized flat-field frame. After that, correction factors are calculated by comparing the flux values in a table containing absolute fluxes for the standard star to the observed counts which are sampled at the same wavelength intervals as the fluxes in the table. The resulting response is normalized to an exposure time of one second. The observed flux is computed as

$$F_\lambda = R_\lambda \frac{D}{t} \qquad (1)$$

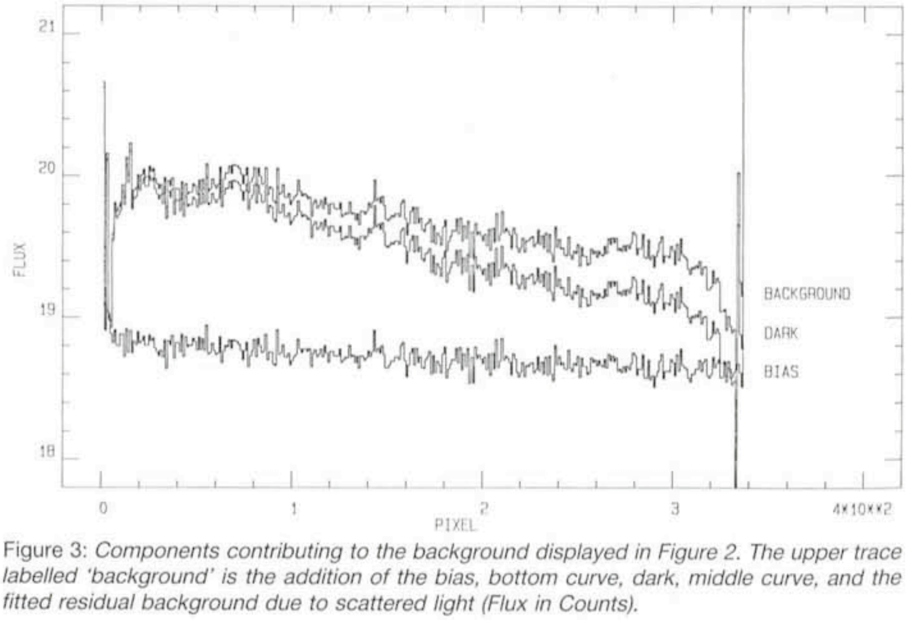

Figure 3: *Components contributing to the background displayed in Figure 2. The upper trace labelled 'background' is the addition of the bias, bottom curve, dark, middle curve, and the fitted residual background due to scattered light (Flux in Counts).*

where F_λ is the absolute flux (in erg $cm^{-2} Å^{-1} s^{-1}$), R_λ is the computed response (in erg $cm^{-2} Å^{-1} DN^{-1}$), D is the extracted Data Number (in DN) and t is the exposure time in seconds.

To illustrate how well this correction works we show in Figure 4a comparison between the observed standard star Feige 110 and the tabulated values taken from reference (3). In this figure the standard star observation is treated as if it was a science frame and the response of the instrument, as derived on the basis of the same standard star observation, was applied to it.

The accuracy of the flux calibration, i.e. the correction for the blaze effect and the chromatic response, can be judged from the following figures. Figure 5 shows three adjacent orders extracted from a raw observation, reflecting the influence of the blaze effect. Figure 6 shows the same three orders after subtraction of the background, flat-fielding and flux calibration using a standard star. In the areas of overlap the orders coincide to within 3 % of the signal level.

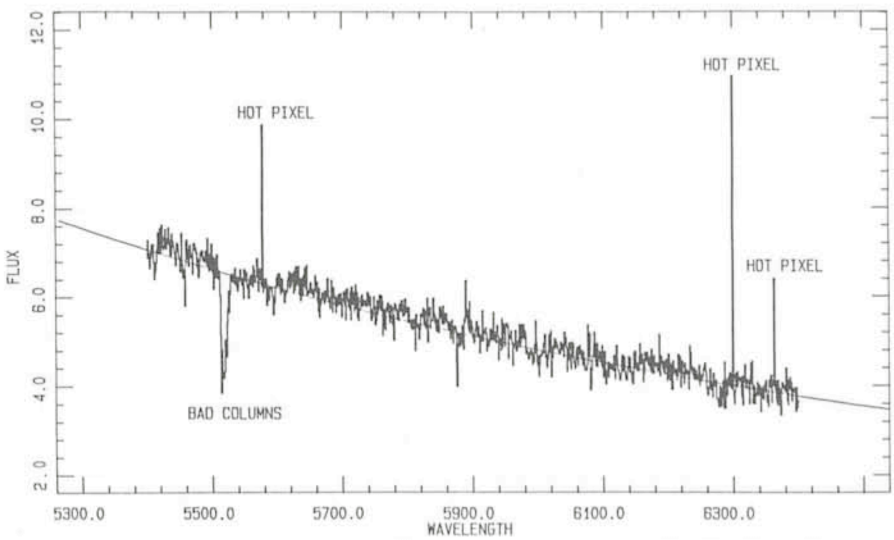

Figure 4: *Comparison between the observed standard star Feige 110 and the tabulated values from reference (3).*

4. Response Correction Using the Blaze Function

If no standard star is available with the same instrumental configuration as the object frame under consideration, a different approach is also available at this stage as an alternative to the method described above. It consists of correcting for the blaze effect introduced by the échelle grating by using a suitable model for the blaze function. In this approach, no correction for the chromatic response of the instrument is applied. The échelle blaze correction is an old problem in the reduction of IUE high resolution spectra; in our case the problem is even more complicated given the different possible configurations of the instrument. From the related literature we have selected two algorithms.

The first one is a modification of the method suggested by Ahmad (4); this algorithm approximates the blaze function by a sinc squared and finds the function parameters by a non-linear least squares fit to the order profile. The method is suitable for objects without strong emission or absorption features. The second method is based on Barker (5); this algorithm uses the overlapping region of adjacent orders to estimate, in a few iterations, the correct parameters of the blaze function which is, as before, assumed to be a sinc squared. This method is applicable to spectra with strong features. In both methods the blaze function R at wavelength λ is approximated by

$$R(\lambda) = \frac{\sin^2 \pi \alpha X}{(\pi \alpha X)^2} \qquad (2)$$

where α is a grating 'constant', and $X = m\,(1 - \lambda_c/\lambda)$, in which m is the order number, and λ_c is the central wavelength of order m. Both parameters are related through the grating 'constant' k by $k = m\lambda_c$. The results of both methods agree within 1 % of the signal level when applied to the same object frame. Figure 7 shows an extracted order with the corresponding fitted blaze function. The parameter α is not dependent on the order number and can be considered a constant for a given exposure with values between 0.5 and 1 depending on the actual alignment of the instrument, while the parameter k is a function of the order number with mean values 568746 for the 31.6 lines/mm échelle and 344705 for the 52 lines/mm échelle.

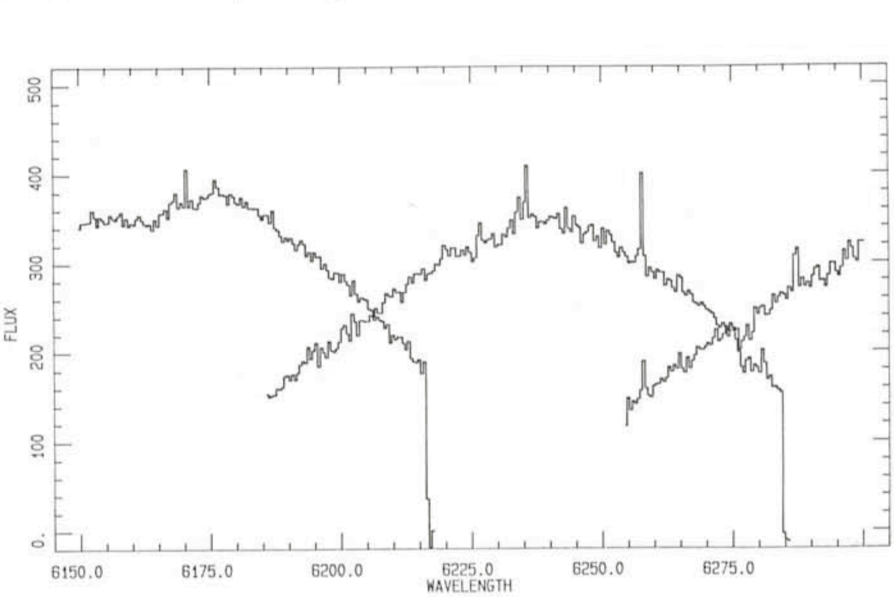

Figure 5: *Extracted data numbers from three adjacent orders showing the échelle blaze effect (Flux in relative units).*

5. The Session Concept

It is a concern that because of the complications associated to the data processing of data in échelle format, the state at which CASPEC data are reduced is not as fast as it could be. The user does not only want to access sophisticated algorithms, but also to access them in an easy way. With this idea in mind we have developed the concept of a *session*. The session consists of a set of data, usually the observations and the auxiliary information in the form of tables and parameters related to a certain instrument configuration. The concept, and the actual operation is very similar to the idea of the observing run: In both cases, the observer/user will spend some time in defining with care the observing/processing parameters and then will proceed with the actual observation/process. The parameters will remain unchanged for the whole observing run. The session concept provides also a way of docu-

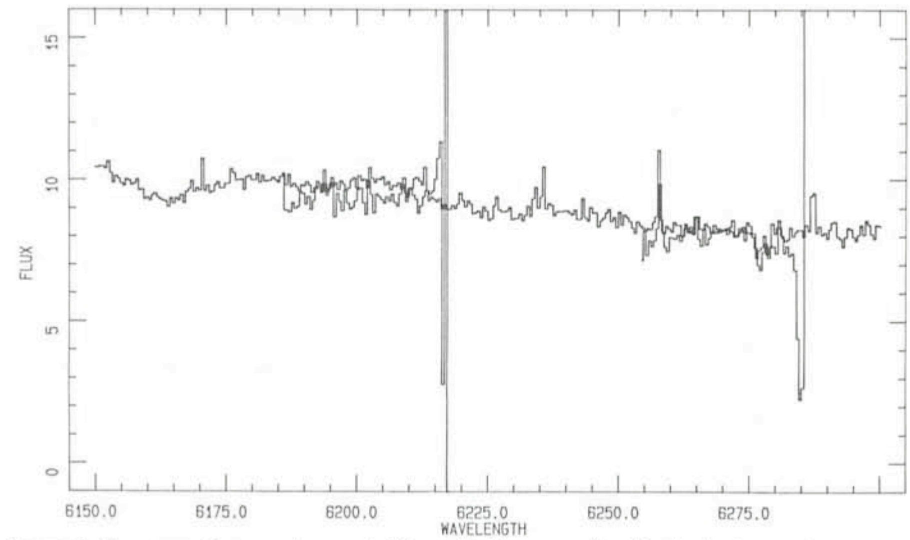

Figure 6: *The same three orders as in Figure 5 after correction for the instrument response using a standard star (Flux in relative units).*

menting the process and can be saved for later reference.

After defining the session parameters, the user has to execute only four procedures: The first one processes the wavelength reference image and computes the dispersion coefficients; the second command normalizes the flat-field; the third command computes (optionally) the instrument response from the standard star frame and finally, the fourth command performs the full reduction of the object frame. The total time required for the reduction of an object and the corresponding standard star ranges between 30 and 45 minutes.

6. Useful Tips to the Observers

The échelle reduction package within MIDAS has matured to a user-friendly, flexible and powerful system. Observations with CASPEC can now routinely be reduced in the different instrument modes: from the red, using the 31.6 lines/mm échelle, to the blue, with the 52 lines/mm échelle, in normal or in binned mode. Considerable experience has been accumulated during the past year in understanding the instrumental characteristics and their impact on the final results. This experience can be used not only on how to reduce the data but moreover on how to optimize the actual observing run.

It is a good practice to do the observations in batches with the same configuration, including optionally the standard star(s), in such a way that only few parameters which define the set-up of the instrument are varied. The observer will benefit greatly from this when he defines the parameters during the reduction sessions.

Given that one critical point in the reduction is the definition of the background, it is advised to subtract the bias and dark from each frame before the background is fitted. To this end, a set of short, optionally pre-flashed, dark exposures should be gathered which can be averaged to produce a bias frame. Further one needs a set of long dark exposures which, after smoothing to reduce the noise, can be subtracted from the science frames. As explained above, the contribution to the background by the scattered light is determined by points located between the orders. If the interorder space gets too small, what might occur in the blue spectral range, the determination of the background becomes cumbersome, as reported in reference (2). The obvious way to avoid these problems is to choose the appropriate échelle, i.e. the 52 lines/mm, to have an increased interorder spacing.

The results of the tests to monitor the precision and stability of the instrument show that small variations of the dispersion coefficients are expected depending on the telescope pointing, therefore it is recommended to take flat-field and wavelength comparison frames before or after each object exposure (and optional standard stars). The reduction procedures have been optimized in such a way that, for a given instrument configuration, only the first set of dispersion coefficients have to be computed interactively, subsequent dispersion coefficients are computed using the previous ones as guesses, in a completely automatic mode.

In those cases where one needs a good overall relative calibration and one wants to ensure a good overlapping of the orders, standard stars should be included in the observations, at least one for each instrument configuration, with the corresponding flat-field and wavelength comparison exposures.

7. Acknowledgements

During the development of the échelle package we have greatly benefitted from the feedback provided by users inside and outside ESO. In particular, M. Iye and U. Heber contributed with suggestions during the early stages of the development. Special thanks are due to S. D'Odorico, responsible for the CASPEC project, for many discussions and suggestions. We want to thank also future users of the package coming with ideas for improvements and extensions.

References

(1) D'Odorico, S., Ponz, D., 1984 *The Messenger,* **37,** 24.
(2) Finkenzeller, U., Basri, G., 1986, *The Messenger,* **42,** 20.
(3) Stone, R.P.S., 1977, *Astrophys. J.,* **218,** 767.
(4) Ahmad, I.A., 1981, *NASA IUE Newsletter,* **14,** 129.
(5) Barker, P.K., 1984, *Astron. J.,* **89,** 899.

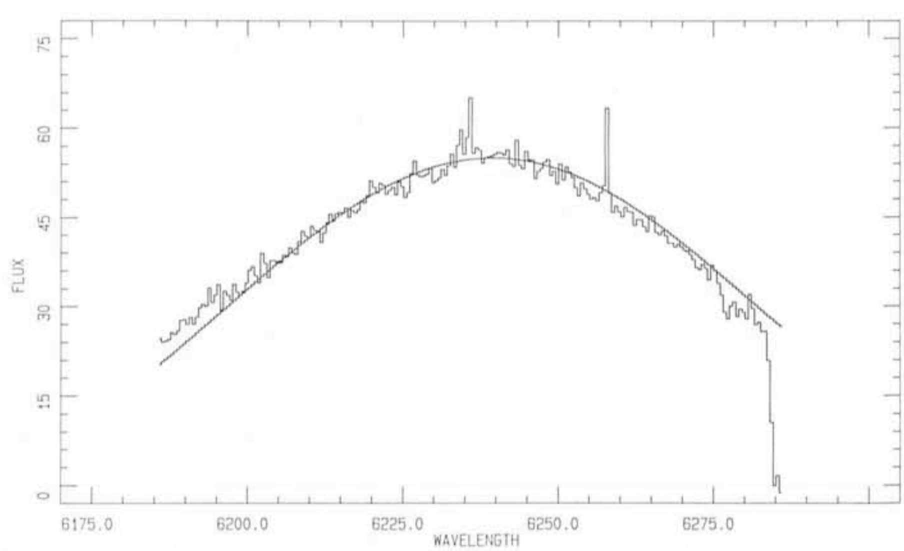

Figure 7: *Order profile and the corresponding fitted function used to correct the échelle blaze effect in case no standard star is available. The trace corresponds to the central order in Figures 5 and 6 (Flux in relative units).*