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S P E F O

U S E R ' S   M A N U A L

Release 1.2 of the manual: July 28, 2010

COMPLETE REDUCTIONS
OF DIGITIZED SPECTROGRAMS

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Foreword

Program SPEFO has a long history of development, which started at the Stellar Department of the Astronomical Institute of Academy of Sciences in Ondřejov. The first (FORTRAN) program of this name was developed in seventies by J. Krpata to be used on the computers of early generation (e.f. EC 1040, i.e. clones of the IBM series 360/370) and allowed to reduce the photographic spectrograms which were digitized with a Czech-made scanner DIGIGRAF. The program allowed the conversion of the spectra to the form of wavelength- and intensity-calibrated plots printed on a large-format printer.

When the personal computers became available after about 1990, a brand new program SPEFO was gradually developed by Jiří Horn. This program was written in the Pascal programming language and was designed for interactive reductions of digitized spectra using the computer screen. Besides the initial reductions (wavelength and flux calibration), the program also allowed radial-velocity (RV hereafter), line intensity and equivalent width measurements. A special menu in the program allowed the user to reduce also photographic spectra recorded with a five-channel microdensitometer constructed by Josef Zicha at Ondřejov. A brief description of the program was published by Horn et al. (1996). The latest version of this program is the release SPEFO 3.26 from October 13, 1994. Shortly thereafter, Jiří Horn passed away.

A few additional modifications of the program were then carried out by Dr. Petr Škoda from Ondřejov. He also published the first more detailed description of the program – see Škoda (1996). His latest version is SPEFO 3.30 from April 29, 1995.

In about 1993 when colleagues at the Astronomical Institute of the Slovak Academy of Sciences put into regular operation their own microdensitometer, Dr. R. Komžík modified a part of SPEFO after consultations with Jiří Horn to permit the reductions of digitized spectra from their microdensitometer. This modified version names MF2SPEFO from May 18, 2001 with some advice how to use it is available at

http://www.sto.astro.sk/mikrofotometer

Since 2003, new and rather substantial developement of the latest version of the Pascal program SPEFO, developed by Horn and Škoda, has been carried out by the author of the original SPEFO, Jiří Krpata. He gradually implemented improvements suggested mainly by him and by Petr Harmanec and later by several other regular users of the program. All these modifications are denoted as SPEFO JK with respective release number.

We felt that to allow the users to fully exploit the possibilities of the new program, a detailed User's manual is needed and this is the first result of our effort in this direction.

Very regrettably, also Mr. Jiří Krpata died before the planned modifications and a complete manual were finished. Since rel. 1.2 of the manual, Petr Harmanec is responsible for all modifications and additions. At present, nobody is further developing SPEFO so this manual refers to the latest functioning version which Jiří Krpata put into public use: SPEFO JK 2.63 .

We make this package available to all interested colleagues upon the condition that its usage will be acknowledged in any publication based on data reduced with it, for instance, by a reference to the paper by ....

The full packet of the programs and data files described here can be obtained via anonymous

http://astro.mff.cuni.cz/ftp/hec/spefo.263 .

We strongly recommend you to notify us via e-mail about your becoming a user of this software. Your e-mail address will be registered and you will be notified of any future improvement or extension of the software package.

Contents

1 PURPOSE, GENERAL BACKGROUND AND LITERATURE

1.1 1. Purpose and an overview of tasks which can solved with SPEFO

The basic operations available in SPEFO are:

1. Interactive or automatic measurements of the positions of comparison lines for the comparison spectra exither exposed on both sides of the stellar spectrum (photographic spectra) or taken prior and after the respective stellar exposure (electronic spectra) and determination of wavelength calibration via a polynomial fit up to fifth degree. The program automatically omits lines whose positions deviate from the fit for more than twice the rms error but the user - guided by a plot of residua - can interactively undelete or delete individual comparison lines before accepting the fit. The final wavelength calibration is then applied to the respective stellar (flat-fielded) spectrum. At this stage, the user is asked to type the heliocentric wavelength correction. The resulting wavelength calibrated stellar spectrum has extension .uui; it is still stored in original pixels but contains the coefficients of the polynomial fit and heliocentric RV correction.
A practical comment: Since the dispersion of a grating spectrograph is given by a sine formula and considering that the Taylor series of the sin(x) function only contains terms with odd power of x, it is appropriate to choose a polynomial of either third of fifth degree when modelling the dispersion via polynomial fit.

2. Interactive rectification of the spectra. The user can insert up to 100 rectification points defining the continuum using a graphical display of the unrectified spectrum. The program immediately shows a line defining the continuum which connects all chosen points via Hermite polynomials (as in the early programs developed by Graham Hill at the DAO). It is not a bad idea to compare the rectified spectrum to a suitably chosen synthetic spectrum to get a better feeling where exactly the continuum should be placed. The rectified spectrum is displayed on the screen and stored in a file with extension RUI. The user can return back and modify rectification whenever desired.
Practical advice: When one starts reductions of the spectra of a particular star, it is advisable to choose first a spectrum with a good signal-to-noise ratio (S/N hereafter). Once the first spectrum is rectified, SPEFO automatically uses the rectification points from the previously rectified spectrum and places them to the same wavelengths also for the next rectified spectrum (as long as the user has not left the program). This way, the user can only slightly correct the positions of the rectification points in the follow-up spectra. It is a good practice to use the option COMPARE (see below) to compare each rectified spetrum to the first, good one, and to correct the placement of the rectification points immediately as soon as some systematic deviation is noted. This way, one maintains a uniform rectification of all spectra.

3. Cleaning the spectra from cosmics and flaws. This operation is carried out interactively with the help of VIEW/EDIT option. The user can delete and undelete individual data points affected by the flaws (using the DELETE and INSERT keystrokes) and the program replaces the deleted points by values resulting from a linear interpolation between the neighbouring undeleted data points. Every such action is immediately reflected on the screen display, so it is possible to modify the initial action to obtain the best results. The resulting file is stored with extension RCI. After the user leaves the program, it is not possible to see again which points were deleted. However, as long as the corresponding .rci file is in the same directory as its .uui file, it is possible to modify the original rectification of the .uui file and the program creates a new .rci file where all pointd deleted previously will again be deleted.
Practical advice: Note that you must properly enlarge the wavelength scale on the display to see individual data points which you are going to delete. On the other hand, be cautious not to enlarge the wavelength scale too much since you would loose contrast and may no longer be able to detect the flaws by your eye. It is always good at the end of cleaning to shrink the scale again to verify that you deleted all bad points properly.

Note also that SPEFO assumed that the first three characters identify the object name and the remaining five are running numbers (created now by SPEFO if you allow for the automatic mode.)

2   INITIAL REDUCTIONS

2.1   Bias subtraction and flatfielding

2.2   Wavelength calibration

2.3   Flux calibration

3   RECTIFICATION

4   REMOVAL OF COSMICS AND FLAWS WITH VIEW/EDIT

5   RADIAL-VELOCITY MEASUREMENTS

6   EQUIVALENT-WIDTH AND CENTRAL INTENSITY MEASUREMENTS

Choose **eWic** → **eq. widths** from the main panel. A list of measured lines with .STL extension must be in the working directory or in outer directories. The program displays a neighbourhood of the first line from the list and shows the line limits in blue. Using DEL and TAB and right and left arrows, modify the line limits in such a way to reach the continuum level at both line edges. Use INS and the program displays a line cursor. Using right and left arrows, move the cursor to the line centre and use INS again. This will record EW, FWHM and Ic asking the user to specify the group where to put the measurement. Normally, it is possible to use group 1 for all measurements. The program then displays the next line from the list and you can proceed as before. An important warning: For currently unknown reason, the value of FWHM is unreliable and should not be used. So, the only usable quantities are EW and Ic. These are stored, line by line, in a file with extension .EWQ.

Just to mention the obligatory types of extentions defining the types of files:

- UUI ... unrectified 1-D spectrum in SPEFO format

- RUI ... rectified spectrum

- CON ... auxiliary file with data points defining the continuum

   in the corresponding RUI file. Note that up to 100 rectification points can be used during interactive rectification.

- RCI ... rectified cleaned file. Using the option VIEW/EDIT in SPEFO, you can interactively remove cosmics and other flaws. If you later decide to change the rectification for some reason, SPEFO creates a new RCI file automatically for you omitting/interpolating the same data points as before.

- RFI ... rectified filtered file (in cases of low S/N you can apply a numerical filter)

- RV ... file with individual RV measurements; it is used for all spectra in a given directory by the procedure RVRESULT to create the file with the name of the project and extension .RVS which contains a matrix of HJDs and up to 10 columns with RVs measured and averaged in groups 1 to 10.

- RVR ... file with a detailed account on RV measurements

- EQW ... file with the results of measurements of equivalent widths, full width at half maximum and central (or peak) intensities

- DAT ... An ASCII file which allows you to enter some foreign spectrum to SPEFO. It has the obligatory format first record: wavelength of the first data point and a step in wavelength all other records contain flux values and it is necessary that they are equidistant in wavelength. See the file 'sample.dat' attached. I produced an auxiliary program KOS which transforms ASCII files in the form wavelength - flux to a DAT file equidistant in wavelength. This would be another possibility how to get your spectra into SPEFO in the case the problem with FITS conversion would persist.

- ASC ... SPEFO can produce ASCII file just in the form wavelength - flux to be used, e.g. for some plots or preparation of input data for KOREL disentangling program.

References

[1] Hill G. 1982 Publ. Dominion Astrophys. Obs. 16, 67

[2] Horn J., et al. 1996 A&A 309, 521

[3] Škoda P. 1996 ASP Conf. Ser. 101, 187