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Multiwave Continuum Data Reduction at RATAN-600

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Abstract. The RATAN-600 radio telescope allows us to carry out simultaneous multi-frequency observations using wide-band radiometers. Thus, we can account for the influence of the atmosphere using high frequency observations and the Galactic background using low frequencies, or observe instantaneous spectra of radio sources. Using these features a flexible astronomical data processing system (FADPS), operating on different UNIX platforms, was created. Methods of the FADPS construction are described. The system supports Gauss-fit analysis (to estimate parameters of sources and to decompose them into individual components), non-linear smoothing and averaging, background calculation and subtraction, interpolation, convolution, visualization using X-Windows and PostScript, and reading and writing of data in FITS format. FADPS commands may be executed directly in UNIX, in scripts, or using a special shell for our data processing system in the X-Window system. FADPS also operates on spectra of radio sources, recorded as FITS TABLE data. The system allows us to fit a spectrum by a set of curves with weighted spectral points, and to calculate spectral indices and fluxes. This system is connected to the CATS database, operated at the RATAN-600. Different stages of data reduction and results are shown in figures.

1. Introduction

The RATAN-600 (Parijskij & Korolkov 1986) is a transit radio telescope with a variable profile allowing simultaneous multi-frequency observations using different feed horns. At present, the wide-band radiometers at 0.968, 2.31, 3.95, 7.69, 11.1, and 22 GHz are mounted on feeder cabin No. 1. The large number of frequencies allows observations of instantaneous spectra of radio sources. A high sensitivity to extended sources permits deep sky surveys, detection of new radio sources, and studies of the fluctuations of the microwave background radiation. At the higher frequencies (11.1, 22 GHz) we may account for the influence of the atmosphere, and at lower frequencies (0.968 GHz) we may obtain the Galactic background level, and clean the data at intermediate frequencies (Parijskij & Korolkov 1986).

The result of a single observation at the RATAN-600 from one receiver is a one-dimensional scan of the sky. This data vector contains points of measured antenna temperatures of the sky with a constant registration interval in sidereal time.

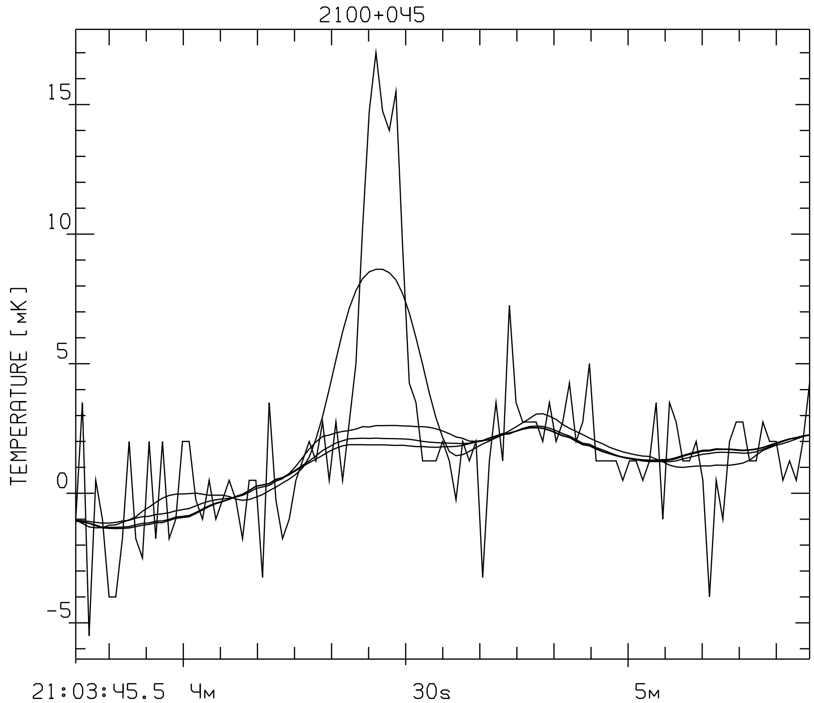

Figure 1. Four iterations of the FADPS background curve calculation.

Based on these features we have created a "Flexible Astronomical Data Processing System" (FADPS, Verkhodanov et al. 1993), operating under different flavors of UNIX (Linux, Solaris, etc.).

2. Data Reduction

The usual stages of the RATAN-600 data reduction are the following. After observation, the registration program automatically removes interference spikes by resampling the raw data using robust methods (Shergin et al. 1997). The user may then further smooth the data using the same algorithms to estimate the low noise component or the background (Figure 1). After subtraction of the background from the primary data, Gauss-fit analysis may be used to find components of the source and estimate their parameters.

3. Realization

Our approach in the construction of FADPS follows the main principles of operation of programs in a data processing system and the rules of operation in UNIX.

The command languages of UNIX (Bourne shell and C shell) are used as the command languages of our system. These languages have loop, condition, and local transition operators. The process of data reduction is a consecutive application of operators (commands) to the user's data recorded as equidistant

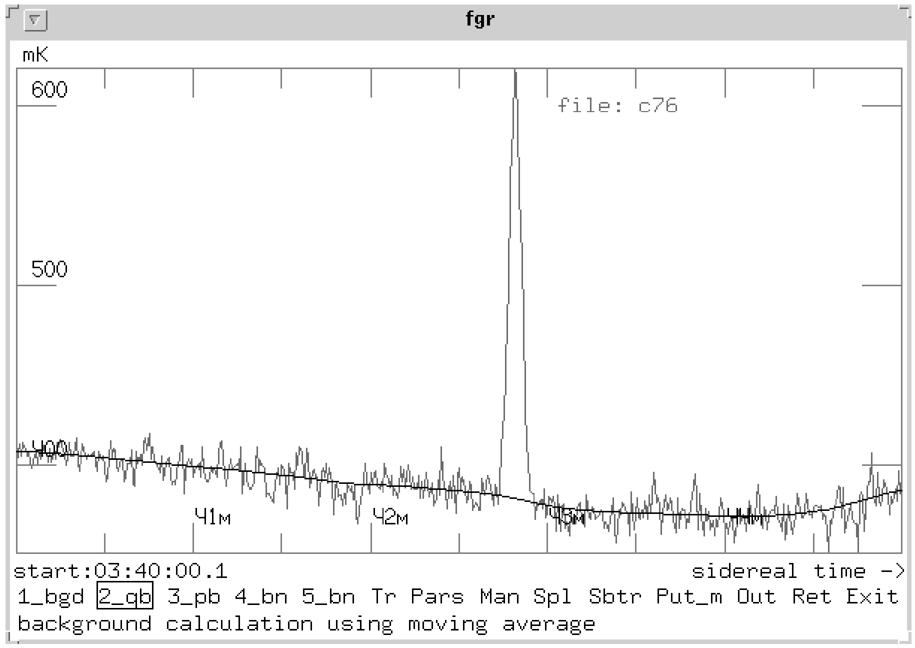

Figure 2. The screen of the *fgr* program with the menu and drawn data.

measurements and stored in separate files. Each operator corresponds to a specific command called a "module." Using a set of such modules and a basic knowledge of UNIX the user may construct his/her own data processing system or simply type a sequence of modules to obtain the desired result. The command modules can read data from standard input and write data to standard output and may be used as filters in UNIX pipes. Let us consider some vector containing observational data of a radio source. To obtain the parameters of a source we have to fit a Gaussian to our record. The standard analysis consists of the consecutive application of two operators: the background subtraction operator F_{bgd} and the Gauss-fit operator F_{gauss}:

$$\mathbf{R} = F_{gauss}(F_{bgd}(\mathbf{D})),$$

where $\mathbf{D}$ is the initial vector and $\mathbf{R}$ is the resulting vector. Under UNIX the application of both operators corresponds to the following command string:

$$\texttt{bgd} \quad -\texttt{w} \quad \texttt{10} \quad < \quad \texttt{D} \quad | \quad \texttt{gauss} \quad -\texttt{n} \quad \texttt{0.020} \quad > \quad \texttt{R},$$

where *bgd* is the program for background subtraction, *gauss* is the program for Gaussian fitting, the key "`-w`" defines that the subsequent parameter is the size of the window for smoothing, the key "`-n`" defines that the subsequent parameter is the lower amplitude level of the Gauss-fit.

4. Basic Functions

The system includes the commands to perform the following: Gauss-fit analysis (to estimate the parameters of sources and to decompose them into separate components), fitting of tabular beam patterns, non-linear smoothing and averaging on the basis of robust algorithms (Shergin et al. 1997), background calculation and subtraction, interpolation, convolution, Fourier cleaning, visualization in X-Windows or in PostScript, and reading and writing files in FITS and FITS BINARY TABLE format.

These commands may be executed as UNIX scripts or using our own graphics shell for our data processing system in the X-Window system. The shell scripts may be used in ASCII terminal mode. The interactive mode of the FADPS is available in the graphics program *fgr* (Files GRaphics), where a user may select required operations from a menu and see the result of the execution in the X-Windows screen of *fgr* (Figure 2). *fgr* also permits the execution of external users' filters.

FADPS also operates with spectra of radio sources recorded as FITS TABLEs. The system supports fitting a spectrum with a set of curves using different weights for different spectral points. It calculates spectral indices and fluxes at any desired frequency. The graphics program *spg* (SPectra Graphics) operates with these functions (see Figure 2 in Verkhodanov et al. 1997). The *spg* menu provides a least-squares fit of a spectrum with several curves. The choice among these curves is either automatic or via mouse clicks. The mouse also allows a manual fitting (when the cursor delineates the curve) and the deletion of unreliable or unwanted data points (or attaching a zero weight to them). Data points may be weighted in different ways: using equal weights, weights by flux density errors, or on a point-by-point basis. This system is connected with the CATS database of radio catalogs (Verkhodanov et al. 1997) operated at the RATAN-600.

5. Epilogue

At present the FADPS is used at the RATAN-600 and in some others Russian institutes as the system to operate on one-dimensional vectors of data recorded in FITS format. An additional Tcl/Tk interface over the FADPS modular structure is being developed. The software is written in the algorithmic language "C" and may be freely distributed.

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References

Parijskij, Y. N., & Korolkov, D. V. 1986, Ap.Sp.Sci.Rev., Ser. D 5, 40

Shergin, V. S., Verkhodanov, O. V., Chernenkov, V. N., Erukhimov, B. L., & Gorokhov, V. L. 1997, this volume, 46

Verkhodanov, O. V., Erukhimov, B. L., Monosov, M. L., Chernenkov, V. N., & Shergin, V. S. 1993, Bull. of SAO, 36, 132.

Verkhodanov, O. V., Trushkin, S. A., Andernach, H., & Chernenkov, V. N. 1997, this volume, 322