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A variant of description of dissimilar astronomical data

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Abstract. The problem of unified description of heterogeneous astronomical data for the processing system FADPS, database of the astrophysical catalogues CATS, system of processing of continuous radio spectra SPG, database of distributions of energy in spectra of galaxies SEDs, and Bank of observational data ODA–R is discussed. Key words for parameters of observations and approximation curves of spectra, and also the ways of their incorporation into the local FITS standards are considered. Examples of data description in the proposed standards are presented.

Key words: methods: data analysis — methods: numerical

1. Introduction

The problem of unification of diversified (having different structure) data and creation of common interfaces for reading and visualisation is getting as urgent in practical astronomy as the solution to the problem of unified physical description of celestial objects. The different programme systems including the standard processing system FADPS, database of the radio astronomy catalogues CATS, system of processing of continuous radio spectra SPG, database of distribution of energy in spectra of galaxies SEDs and Bank of observational data ODA–R are concerned with different binary and ASCII Tables. We have closely approached the point of not only analysing data by the standard packages but also having an opportunity to represent them graphically.

To solve all these problems in general, it suffices to use the FITS format (Wells et al., 1981) and its extensions FITS ASCII Table and FITS Binary Table (Harten et al., 1985; 1988; Cotton et al., 1995; Hanisch et al., 2001). In so doing, when programming the systems of data decoding, a possibility of usage of several types of extensions and, as a consequence, organization of several visualization windows should be taken into account. At the moment, such programmes are not known to us yet.

In the above-mentioned systems of access to organized data, the users are faced with quite various sets of descriptions. Nevertheless, we are trying to follow the standards adopted by the International Astronomical Union and allowing some structures of data to be described with sufficient universality.

2. Examples

It will be recalled that the FITS format data contain the ASCII heading with basic parameters which describe all the rules of organization of the data following the heading. In the case of standard extensions, the FITS provides for the availability of additional headings and blocks of data corresponding to them. Thus it is possible to unite quite dissimilar data.

There is a problem consisting in that the number of standard parameters in the FITS headings is generally insufficient to describe some modes of observations. Although the FITS format admits introduction of additional key words, which are disjoint with the sets of the reserved names, different systems (even extensively used) may response to such additions in a rather specific manner. In other words, there is a contradiction: on the one hand, some local systems can use additional parameters for more accurate description of their data without violation of the standard FITS convention, on the other hand, certain difficulties may arise in the data communication.

As an alternative of solving this problem, we still suggest using new key words in the local systems, however, when conversing to the canonical format, placing corresponding parameters inside the fields COMMENT which are not processed by the standard packages but can be identified and reduced by the local systems.

We present below some examples of descriptions in which non-standard key words are in bold type.

2.1. The processing system FADPS and the Bank of observational data ODA–R

Since 1994 (Verkhodanov et al., 1994), the system of processing of radio astronomy data FADPS has used

```
XTENSION='BINTABLE'         / Type of FITS extension
...................
TFORM#='1000I'              / Size and type of data in the field #
TDIM#='(1000,1)'            / Field # as a multidimensional array
TTYPE#='Channel #'          / Name of the field #
TUNIT#='K'                  / Physical units for the field #
TSCAL#=                     / Scale factor for values in the field #
TZERO#=0                    / Offset for values in the field #
TDELT#=0.3                  / Discrete along the 1st axis of the field # in CTYPE1 units
TCP-C#=int                  / Shrinking factor
TNS-T#=float                / Temperature of the noise generator, K
TCAL1#=55                   / First calibration, counts
TCAL2#=53                   / Second calibration, counts
TRCL1#=2                    / Estimate of standard deviation of 1st calibr., counts
TRCL2#=4                    / Estimate of standard deviation of 2nd calibr., counts
TBAS1#=0                    / Robust estimate of the level after 1st calibr., counts
TBAS2#=0                    / Robust estimate of the level after 2nd calibr., counts
TLAMB#=0.08                 / Wavelength, m
TSTOK#=I                    / Stokes parameter (I,U,Q)
TRCVM#=SH                   / Observational mode of the receiver (BS,SH,RH)
TWCAR#=float                / Position of the west horn on the carriage, m
TECAR#=float                / Position of the east horn on the carriage, m
TTWSH#=float                / Displacement of west horn in sidereal time
TTESH#=float                / Displacement of east horn in sidereal time
TTAU#=float                 / Integration time, s
TARF#=A+B*X+C*X*X           / Formula of the antenna area vs altitude

CTYPE1=TIME                 / Common units for channels along X axis, s
APERTURE=float              / Antenna aperture, degrees (is not entered yet)
REGIMOBS=D                  / Mode of a source observation (D,S,C,V,D3,S3,3,V3)
VELO-CAR=float              / Velocity of the carriage movement, m/s
ZERO-CAR=float              / Initial position of the carriage before its movement, m
DSACCOE=float               / Coefficient of movement mismatch cariage/source, %
CARRIAGE=float              / Position of carriage in the feed focus, m
SIDTIME=float               / Sidereal time of culmination, s
DECTIME=float               / Decret time of culmination, s
TM-START=float              / Sidereal time of observation beginning, s
TM-END=float                / Sidereal time of observation end, s
HFWHM=float                 / Horizontal size of BP halfwidth, arcsec/m
FOCUS=float                 / Antenna focus, m

SP-FORMU=A+B*X+C*F(X)       / Formula of radio source spectrum:
                            / log flux density vs log frequency

T-OUTSID=char               / Outside temperature, °C
CLOUDS=char                 / Cloudness
PRESSURE=char               / Pressure
END
```

Figure 1: *An example of extension header of FITS Binary Table-like format for data taken with continuum radiometers.*

the FITS Binary Table-like format describing multifrequency observations in the continuum as a single file. All the archival data of the broad-band radiometers were later translated completely to the given format (Kononov, Pavlov, 1999; Kononov et al., 1999).

It will be emphasized that along with the files containing multifrequency data, a format describing monofrequency data, which is close to the classical

Basic FITS, has also been used at RATAN–600 in the every-day processing.

A detailed description of the format has already been given by Verkhodanov et al. (1994, 1995 a, b). We shall note here only some of the key words of the extension heading which are shown in Fig. 1.

We direct attention to the fact that in the given example, practically all the key words, but for the descriptors of the fields TFORM#, TDIM#, TTYPE#, TUNIT#, TSCAL# TZERO#, are non-standard, and in recoding to the canonical FITS they can be commented-out in the lines COMMENT. Besides, as experience shows, the basic names of additional parameters describing the fields must not end in numbers (for instance, TCAL1 and TCAL2), because the addition of the standard numerical postfix # to them presents problems in subsequent identification.

2.2. The Database of the astrophysical catalogues CATS

The FITS ASCII Table format of data presentation consists of the ASCII heading describing the fields and the FORTRAN formats of data, measurement units, history of operation with the file, and, particularly, the data themselves with the structure of symbol table. We use two types of formats easily recoded from one to another: the detailed CATS format (FITS ASCII Table-like) and the S format with omitted standard descriptions of the fields (Verkhodanov et al., 1997).

The CATS format heading consists of two parts: the former describes the common properties and features of the format, the latter describes the parameters of the fields and the data themselves. Accordingly, the former begins with the key word SIMPLE and ends in the word END. The latter begins with the word XTENSION and also ends in END.

```
SIMPLE=T            / Indicator of FITS
                    / header
BITPIX=8            / 8 bits per pixel
NAXIS=0             / No image data
EXTEND=T            / Standard extension
                    / is available
OBJECT=CATS SEARCH  / Result of searching
                    / in CATS
ORIGIN=SAO RAS      / Origin of file
DATE=01/01/1997     / Date of file creation
END
```

The second part of the header contains the following general information:

```
XTENSION=TABLE   / Indicator of TABLE
                 / extension header
BITPIX=8         / 8 bits per pixel
NAXIS=2          / Simple 2-dimensional
                 / matrix
NAXIS1=93        / Number of symbols in row
NAXIS2=1000      / Number of rows
                 / (i.e. selected objects)
TFIELDS=15       / Number of fields in row
EXTNAME=CATS     / Type of extension:
                 / CATS format
```

The CATS output data include the source name, right ascension, declination (and their errors), frequency, flux density and the error, coordinates' epoch. Below is presented a shortened example of field description of the FITS ASCII Table-like format (we show only one out of 15 fields):

```
TTYPE2=RAH   / Type of record in field 2:
             / hours of right ascension
TBCOL2=18    / Field begins in position 18
TFORM2=I2    / FORTRAN format of record
             / in field
TUNIT2=HR    / Units of values
             / in field 2: hours
TNULL2=00    / Null value
```

After the key word END, table data are presented.

A simplified header given in Fig. 2 is used in the S format. A significant parameter in this format is SP–AP1 that describes the spectrum of the source by the formula where X is the logarithm of frequency in MHz.

2.3. The system of analysis of energy distribution in the spectra of galaxies SEDs

The distribution of energy in the spectrum is described by three parameters in the frames of the FITS ASCII Table approximation:

```
TTYPE1='LAMBDA'   / Wavelength, angstroms
TBCOL1=1          / Beginning in column 1
TFORM1='F9.5'     / FORTRAN format,
                  / 9-valued field
TTYPE2='LOG FD'   / Data type: logarithm of
                  / flux density
TBCOL2=11         / Beginning in column 11
TFORM2='F9.5'     / FORTRAN format,
                  / 9-valued field
TTYPE3='LOG dFD'  / Data type: logarithm of
                  / relative error
TBCOL3=21         / Beginning in column 21
TFORM3='F9.5'     / FORTRAN format,
                  / 9-valued field
```

In the given example, the description corresponds fully to the standard.

```
SIMPLE=T                  / Indicator of FITS-like format
BITPIX=8                  / Number of bits per pixel
NAXIS=2                   / Number of axes
NAXIS1=78                 / Number of symbols in row
NAXIS2=20                 / Number of rows
TFIELDS=15                / Number of fields in row
EXTNAME=S                 / Format type (S-format)
OBJECT=0003-0021          / Object name
DATE=13/11/96             / Date of the file creation
RA-OPTIC=0.063564         / Accurate coordinates of the object: RA (hours)
DE-OPTIC=-0.351858        / Accurate coordinates of the object: Dec (degrees)
EPOCH=1950.               / Coordinates' epoch
SP-NAP=1                  / Number of approximation intervals
SP-AP1=2.549-0.629*X      / Formula of spectrum approximation in 1st interval
SP-BF1=0.                 / Initial border of the 1st interval
SP-EF1=1000000.           / Trailing border of the 1st interval
ORIGIN=SAO RAS            / Place of the file creation
END
```

Figure 2: *An example of S-format header of astrophysical catalogues' database CATS.*

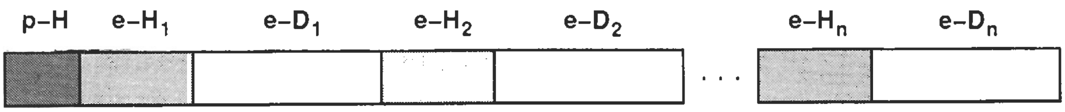

Figure 3: *A version of dissimilar data representation as a single FITS or FITS-like file.*

3. Conclusions

Attention is drawn to the used key words in the example of the processing system FADPS — SP-FORMU (the formula of the radio source spectrum) and TARF# (the formula of the antenna area at the corresponding wavelength). For the rest of the parameters they differ in that they contain analytical formulae. The spectrum approximation formulae in the CATS data analysis system are specified in a similar manner. To describe the shape of the spectrum, the key word SP-AP# is used, the spectrum can be broken up here into individual portions. For analysing such analytical records, a special library was developed in the language *C*, which recognizes the formula terms and substitute the functional values of specified arguments.

To describe the present-day data, we propose a structure that unifies observational results (including the computed effective areas of the antenna which provide for fast calibration by analytical formulae), two-dimensional sky areas in the optical and radio ranges, recorded in binary codes and also the data of radio and optical spectra presented in the form of ASCII Tables. The dissimilar data must be presented as extensions, and appropriate unpacking and visualizing programmes must be able to decode them. The version of this structure presented as a single FITS or FITS-like file is displayed in Fig. 3, where p-H is the primary FITS header, e-H_i and e-D_i are the header and the data of the i-th extension.

Besides, the current libraries of reading (for instance, in the language *C*) of FITS data must be able to deal with analytical formulae and additional key words incorporated in the lines of the header COMMENT.

It is probable that these directions will be basic in creation of new standards of presentation of information in the electron systems of access being developed at the radio telescope RATAN-600.

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