

## SOFTWARE TOOLS FOR DIGITIZATION OF ASTRONOMICAL PHOTOGRAPHIC PLATES\*

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**ABSTRACT.** In this paper we present tools for helping the process of digitization of astronomical photographic plates. The requirements of Virtual Observatory presume that any FITS file, which contains a digital image, has to be equipped with a complete header. Wide-Field Plate Database (WFPDB) offers most of the meta-data needed for the creation of FITS header. The `header2011` software gives the user an appropriate tool for connecting WFPDB catalogues to digitized plate images. The use of modern scanners sometimes imposes conversion of files from the inner format of the scanner (or driver) into FITS format. The `tif2fits` software converts VueScan row-tiff format to FITS and also separates plate image and wedge image in case of scanning with grayscale wedge.

**1. Introduction.** The Wide-Field Plate Database (WFPDB) is the basic source of data for the wide-field (larger than or equal to 1 square degree) astronomical photographic plates obtained with professional telescopes world-wide

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(see [1], [9]). It consists of four parts: Catalogue of Wide-Field Plate Archives (CWFPAs); Catalogue of Wide-Field Plate Indexes (CWFPIs) with regular version updates (now for 563 600 plates); Data Bank of digitized plate images (at low resolution for quick plate visualization and easy on-line access, and at high resolution intended for photometric and astrometric measurements); Links to on-line services and cross-correlation with other existing catalogues and journals (see [9], [4]).

Flexible Image Transport System or FITS is a digital file format used to store, transmit, and manipulate scientific and other images (see [5]). A major feature of the FITS format is that image meta-data is stored in a human-readable ASCII header. Each FITS file consists of a header containing ASCII card images (80 character fixed-length strings) that carry keyword/value pairs and an image data block. The creation of a complete FITS header is an important part of the plates digitization. Because photographic plates are a specific type of astronomical observations, we attempt to make a standard of the keywords in the FITS header, specially for astronomical photographic plates. The corresponding software implementation for this standard has also been created. It is written in C++ using the Qt cross platform application [6]. The WFPDB catalogues are used for obtaining the most important meta-data for the plates at the generation of the FITS header.

**2. FITS Header Standard for Photographic Plates.** Our proposal for a FITS header standard for photographic plate images is based on the AIP archive of historic Carte du Ciel scans [3] and our experience with meta-data from various plate archives. The FITS header must contain the complete meta-data for the plate, the telescope, the place of the observation, the scanning process, etc. The main part of these data can be extracted from the corresponding WFPDB catalogues. This approach presumes that the collection of plates for digitization (plate archive) is already described in WFPDB. The second part of the data consists of constant values, and the third part can be calculated using the other parts. Tables 1 and 2 present our proposal for a standardization and also the sources of the data in the header fields.

The abbreviations in the first column of the tables define how the value in the corresponding line is filled.

- **fixed:** the value is fixed in the case of plates;

Table 1. FITS header standard for photographic plates. Part I

|          |          |                       |   |
|----------|----------|-----------------------|---|
| fixed    | SIMPLE   | T                     | file does conform to FITS standard [T/F]      |
| fixed    | BITPIX   | 16                    | number of bits per data pixel [16]            |
| fixed    | NAXIS    | 2                     | number of data axes [2]                       |
| tif2fits | NAXIS1   | 15024                 | length of data axis 1 [int]                   |
| tif2fits | NAXIS2   | 15024                 | length of data axis 2 [int]                   |
| fixed    | EXTEND   | T                     | FITS dataset may contain extensions [T/F]     |
| fixed    | BZERO    | 65536                 | [65536]                                       |
| fixed    | BSCALE   | 1                     | [1]   |
| fixed    | INVERTED | T                     | T — big-endian & F — little-endian            |
| tif2fits | DATE     | '2011-07-01 11:36:42' | last change of file [yyyy-MM-dd hh:mm:ss]     |
| calc     | FILENAME | 'BAM010C001397.fits'  | source file name                              |
| calc     | PLATENUM | '1397 '               | in the original observation catalogue         |
| calc     | PLATE-ID | 'BAM010C001397 '      | WFPDB identifier of plate                     |
| md       | FIELD    | '-90 DEG '            | field name                                    |
| man      | OBJECT   |                       | star name                                     |
| md       | RA       | '00:00:56 '           | center of plate FK5 [hh:mm:ss]                |
| md       | DEC      | '-89:47:52 '          | center of plate FK5 [sgg:mm:ss]               |
| fixed    | EQUINOX  | 2000.0                | definition of equatorial coordinates          |
| calc/md  | RAEPOBS  | '01:00:00 '           | center of plate at epoch of observation       |
| calc/md  | DECEPOBS | '-90:00:00 '          | center of plate at epoch of observation       |
| calc/md  | EPOCH    | 1963.72328767         | epoch of plate [years]                        |
| md       | DATE-OBS | '1963-09-22 '         | date of observation [yyyy-MM-dd]              |
| md       | TIME-OBS | '22:19:00 '           | UT at start of observation [hh:mm:ss]         |
| md       | EXPTIME  | 60.0                  | exposure time [minutes]                       |
| calc     | TIME-END | '23:19:00 '           | UT at end of observation [hh:mm:ss]           |
| calc     | UT       | '1963-09-22 22:49:00' | date and UT at mean epoch                     |
| calc     | JD       | 2438295.45069400      | JD at mean epoch                              |
| calc/not | ST       | '00:08:50 '           | ST at the start of the observation [hh:mm:ss] |
| md       | MULTIEXP | 1                     | number of exposures of the plate [int]        |
| man      | DETNAM   | 'Photographic Plate'  |   |
| md       | EMULSION | 'GEVAERT '            | photoemulsion type                            |
| md       | FILTER   | 'NO '                 | filter type                                   |

Table 2. FITS header standard for photographic plates. Part II

|          |          |                       |   |
|----------|----------|-----------------------|---|
| md       | COLOR    | 'Pg '                 |   |
| md       | PRIZMANG | 'NO '                 | prism angle [YES/NO]                        |
| man      | INSTRUME | ' '                   |   |
| man      | DISPERS  |                       | dispersion [A/mm]                           |
| man      | WEDGE    | ' '                   | type of photometric step-wedge              |
| qual     | PQUALITY | '1 '                  | quality of plate                            |
| calc/md  | PLATESZ  | '16 × 16'             | plate size [cm] × [cm]                      |
| calc     | CUNIT1   | 15.05                 | X field size [deg]                          |
| calc     | CUNIT2   | 15.05                 | Y field size [deg]                          |
| obser    | OBSERVER | 'KNIGGE '             | observer name                               |
| cat      | OBSERVAT | 'Dr. Remeis Obs.'     | observatory name                            |
| cat      | SITELONG | '+26:24:18.0 '        | longitude of the observatory<br>[sgg:mm:ss] |
| cat      | SITELAT  | '-29:02:18.0 '        | latitude of the observatory<br>[sgg:mm:ss]  |
| cat      | SITEALTI | 1387                  | altitude of the observatory [m]             |
| cat      | TELESCOP | 'ASTROGRAPH'          | telescope name                              |
| cat      | TELAPER  | 0.1                   | clear aperture [m]                          |
| cat      | TELFOC   | 0.61                  | focal length [m]                            |
| calc     | TELSCALE | 338.57                | telescope scale [arcsec/mm]                 |
| man      | SCANNER  | 'EPSON V750'          | scanner name                                |
| man      | SCANRES  | 2400                  | scan resolution                             |
| calc     | XPIXELSZ | 10.5833               | X pixel size [microns]                      |
| calc     | YPIXELSZ | 10.5833               | Y pixel size [microns]                      |
| fixed    | SCANHCUT | 255                   | scan Hcut                                   |
| fixed    | SCANLCUT | 0                     | scan Lcut                                   |
| fixed    | SCANGAM  | 1.0                   | scan gamma value [1.0]                      |
| fixed    | SCANFOC  | 0.0                   | scan focus                                  |
| tif2fits | DATE-SCN | '2011-04-26 12:42:40' | scan date and time [yyyy-MM-dd hh:mm:ss]    |
| man      | AUTHOR   | 'M. Tsvetkov '        | author of scan                              |
| man      | ORIGIN   | ' '                   |   |
| man      | REFERENC | ' '                   | reference                                   |
| man      | URL      | 'www.wfpdb.org '      | base URL of VO Service to retrieve data     |
| man      | COMMENT  |                       |   |
| fixed    | END      |                       |   |

- **md**: the value is copied from the `maindata` file of CWFPIs
- **not**: the value is copied from the `notes` file of CWFPIs
- **obser**: the value is copied from the `observers` file of CWFPIs
- **cat**: the value is copied from the CWFPA's file
- **calc**: the value is obtained by calculation using other values
- **man**: this value must be inserted manually
- **tif2fits**: the correct value is replaced here at the second step by `tif2fits` program

The second column contains the keywords; the third column – the values and some comments are placed in the last column. The values are only model ones but they show the type and format of the datum — integer or floating point number, coordinate, date and time; text or numeric field, etc.

### **3. A Software Tool for FITS Header Formation.**

Simultaneously with the scanning of plates, we have to create meta-data for FITS files (FITS header). The user interface (Fig. 1) of the program `header2011` offers a choice of file name for CWFPIs and identifier of a plate in this catalogue. The user can traverse the list of plate names using the keys `Next` and `Prev`. In some cases it is appropriate to sort the catalogue with respect to plate identifiers. Some value fields of the header are colored to indicate:

- fixed values for all plates (green)
- values, which depend on other fields' values and are updated immediately when the user changes those values (light blue)
- values, which are not up-to-date at the time of using this tool (in dark blue).

A plain text file is used to save the FITS header generated by this program.

**4. A Software Tool for Producing FITS Files.** This software is designed for converting row-tiff files, produced by VueScan [8], to FITS format

| Field Number | Field Name | Value               | Description                              |
|--------------|------------|---------------------|--|
| 10.          | DATE       | 2011-10-29 12:04:55 | last change of file                      |
| 11.          | FILENAME   | KON060_005018.fits  | source file name                         |
| 12.          | PLATENUM   | 5018                | in original observing catalogue          |
| 13.          | PLATE-ID   | KON060 005018       | WFPDB plate identifier                   |
| 14.          | FIELD      | PER                 | field name                               |
| 15.          | OBJECT     |                     | center star name                         |
| 16.          | RA         | 03:16:20            | plate center in FK5                      |
| 17.          | DEC        | +42:34:02           | plate center in FK5                      |
| 18.          | EQUINOX    | 2000.00             | FK5                                      |
| 19.          | RAEPOBS    |                     | plate center in the epoch of observation |
| 20.          | DECEPOBS   |                     | plate center in the epoch of observation |
| 21.          | EPOCH      | 1973.161347         | epoch of observation [years]             |
| 22.          | DATE-OBS   | 1973-02-28          | date of observation                      |
| 23.          | TIME-OBS   | 21:35:30            | UT at start of observation               |
| 24.          | EXPTIME    | 15.00               | exposure time [minutes]                  |
| 25.          | TIME-END   | 21:50:30            | UT at end of observation                 |
| 26.          | UT         | 1973-02-28 21:43:00 | date and UT at mean epoch                |
| 27.          | JD         | 2441742.404861      | JD at mean epoch                         |
| 28.          | ST         | 09:29:17            | ST at start of the observation           |
| 29.          | MULTIEXP   | 1                   | number of exposure of the plate          |

KON060 005018 031620+423402 19730228213530 PER F 15.0103aO 161601100  
 KON060 005018 TIME MAY BE CENTRAL EUROPEAN  
 KON060 005018 LOVAS, MIKLOS

Fig. 1. The user interface of header2011 software tool

files which satisfy the VO requirements [7]. The input data for a plate consist of an image file and a header file. In the conversion process the values in fields DATE-SCN (the scan date and time) and DATE (last change of file) are updated to restore the scanning date and to fix the file creating date and time. The image size is changed as well — the fields NAXIS1 and NAXIS2. All other header fields

are copied from the input header file. In the case of scanning with a wedge, the program separates the wedge part of the image and produces two FITS files — one for the plate and one for the wedge.

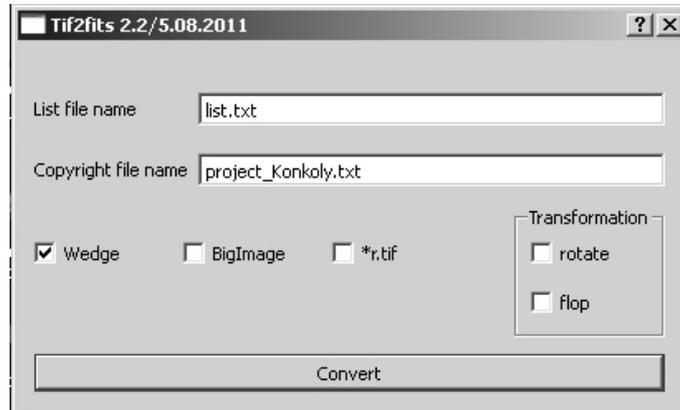


Fig. 2. The user interface of the `tif2fits` software tool

The user interface offers a small window for choosing a list file and a copyright file. The list file must be a plain text file with the list of plate identifiers (in WFPDB format), which the `tif2fits` program will convert. The text of the copyright file is included in the FITS header in the form of a comment.

**5. Our Experience.** As a result of the complete digitization of an astronomical photographic plate, at least six files are produced. Table 3 gives an example of the file names and file attributes of a digitized plate with WFPDB identifier K0N060 005018.

We use the tools for several types of plates (Table 4). The archive names in the first column of the table are given from the CWFPAs.

**6. Conclusions.** The presented software is a part of a technology (full pipe-line) for digitization of astronomical photographic plates. It speeds up the processing time and decreases the possibility of errors in FITS header. Separating image with grayscale step wedge is a new feature in such software. Nevertheless it needs to be improved in several directions:

- to bring the FITS header in line with the requirements of the new FITS standard 3.0 (see [2], [5]);

Table 3. Files produced by the system as a result of the digitization of a plate

| File name           | Size | Type            | Produced by | Comment |
|---------------------|------|-----------------|-------------|---------|
| KON060_005018.jpg   | 1.4M | color image     | –           | preview |
| KON060_005018.tif   | 477M | 16bit grayscale | VueScan     | scan    |
| KON060_005018.hdr   | 6K   | text            | header2011  | header  |
| KON060_005018.fits  | 440M | 16bit grayscale | tif2fits    | plate   |
| KON060_005018.hdrf  | 7K   | text            | tif2fits    | header  |
| KON060_005018w.fits | 38M  | 16bit grayscale | tif2fits    | wedge   |

Table 4. Some parameters of digitized plates from different archives

| Telescope<br>(archive) | Scale<br>(arcsec/mm) | Plate size<br>(cm×cm) | Resolution<br>(dpi) | File size<br>(MB) |
|------------------------|----------------------|-----------------------|---------------------|-------------------|
| POT015                 | 138                  | 20×20                 | 2400                | 681               |
| POT080                 | 17                   | 16×16                 | 1600                | 193               |
| BAM010C                | 338                  | 16×16                 | 2400                | 440               |
| BON030                 | 138                  | 16×16                 | 2400                | 440               |
| HAR025C                | 167                  | 20×25                 | 1600                | 430               |
| ROZ050                 | 120                  | 16×16                 | 2400                | 440               |
| ROZ200                 | 13                   | 16×16                 | 2400                | 440               |
| KON060                 | 144                  | 16×16                 | 2400                | 440               |

- to include validation rules for some fields in the header software, especially for coordinates, numerical values, etc.
- to implement the algorithm for calculating the coefficients for converting local plate coordinates to the World Coordinate System.

REFERENCES

- [1] TSVETKOVA K. P., M. K. TSVETKOV. Catalogue of Wide-Field Plate Archives: version 5.0. In: Virtual Observatory: Plate Content Digitization, Archive Mining and Image Sequence Processing (Eds M. Tsvetkov, V. Golev, F. Murtagh, R. Molina), Heron Press, Sofia, 2006, 45–53.
- [2] PENCE W. D. et al. Definition of the Flexible Image Transport System (FITS), version 3.0, A&A 524, A42, 2010.
- [3] AIP Archive of historic Carte du Ciel scans. <http://vo.aip.de/plates>, 5.03.2012
- [4] CDS Catalogues. <http://cdsarc.u-strasbg.fr/cats/VI.htx>, 5.03.2012
- [5] FITS – The Astronomical Image and Table Format. <http://fits.gsfc.nasa.gov/>, 5.03.2012
- [6] Qt – A cross platform application and UI framework. <http://qt.nokia.com/>, 5.03.2012
- [7] The European Virtual Observatory EURO-VO. <http://www.euro-vo.org/>, 5.03.2012
- [8] VueScan scanning software. <http://www.hamrick.com/>, 5.03.2012
- [9] Wide-Field Plate Database (WFPDB). <http://www.wfpdb.org/>, 5.03.2012

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