FITS header format

From Astroplate Wiki

Contents

Introduction

This document [1] proposes FITS header keywords, value types and overall layout for storing metadata of digitized astronomical photographic plates. The header format is intended to suit various cases: direct images with single exposures, multiple exposures of a single object/field, exposures of different objects/fields, objective-prism spectra, etc.

A FITS header format for astronomical photographic plates has been proposed by Kirov et al. (2012, Serdica J. Computing, Vol. 6, 67–76) [2], hereafter Paper I. The introduced FITS keywords have been implemented in the header2011 software that creates headers for inclusion in the FITS files of scanned plates. The header2011 software is tightly related with the Wide-Field Plate Database (WFPDB) [3], as the software uses the WFPDB files [4] as a source of plate metadata.

In this document, we propose a refinement to the header format of Paper I, closely following the FITS Standard [5] (version 3.0). The modifications are described in Section 2, a complete sample header is shown in Section 3, and a sample header created with the header2011 software is given in Section 4.

Proposed FITS header format

For better readability of headers, we propose organizing keyword records into

groups of related keywords and separating the groups with keywords that have a blank name:

```
KEYWORD1= 'value   '           / sample keyword
KEYWORD2= 'value   '           / sample keyword
        ---------------------------------- Original data of the observation
KEYWORD3= 'value   '           / sample keyword
KEYWORD4= 'value   '           / sample keyword
        ------------------------------------------------- Photographic plate
KEYWORD5= 'value   '           / sample keyword
KEYWORD6= 'value   '           / sample keyword
        ---------------------------------- Computed data of the observation
KEYWORD7= 'value   '           / sample keyword
KEYWORD8= 'value   '           / sample keyword
```

In the next subsections we denote the omitted and missing keywords with a hyphen (-).

Lowercase n and i in keyword names denote numbering: for example, RAn becomes RA1, RA2, RA3, etc. Numbers in keywords are not padded with zeros.

Group 1 – mandatory and array-description keywords

Keyword	Paper I	Type	Comment
SIMPLE	SIMPLE	logical	(FITS Standard) File conforms to FITS Standard.
BITPIX	BITPIX	integer	(FITS Standard) Number of bits per data pixel.
NAXIS	NAXIS	integer	(FITS Standard) Number of data axes.
NAXIS1	NAXIS1	integer	(FITS Standard) Length of data axis 1 (number of pixels in a row).
NAXIS2	NAXIS2	integer	(FITS Standard) Length of data axis 2 (number of rows).
BSCALE	BSCALE	float	(FITS Standard) For unsigned 16-bit integer data, the value should be 1.0.
BZERO	BZERO	integer	(FITS Standard) For unsigned 16-bit integer data, the value should be 32768.
-	EXTEND	logical	Not required by FITS Standard, even if the FITS file does contain extensions.
END	END	no value	(FITS Standard) Marks the end of the header.

Main differences with Paper I:

- EXTEND → omit
- BZERO = 65536 → 32768

Example:

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                18904 / length of data axis 1
NAXIS2  =                18904 / length of data axis 2
BSCALE  =                  1.0 / physical_value = BZERO + BSCALE * array_value
BZERO   =                32768 / physical_value = BZERO + BSCALE * array_value
END
```

Group 2 – original data of the observation

This group of keyword records provides the original information about the observation, as described in the observation logbook and other sources.

Keyword	Paper I	Type	Comment
DATEORIG	-	string	Original recorded date of the observation (evening date)
TMS-ORIG	ST	string	Original recorded time of the start of the observation (format "TZ hh:mm:ss", where TZ is time zone). Time zone can be 'ST' (sidereal time), 'UT' (universal time), or any time zone. Multiple time notations are separated with commas (e.g. 'UT 18:13, ST 02:44').
TME-ORIG	-	string	Original recorded time of the end of the observation. See TMS-ORIG for details.
TIMEFLAG	-	string	Quality flag of the recorded observation time: 'error', 'missing', 'uncertain'.
RA-ORIG	RAEPOBS	string	Original recorded right ascension of the telescope pointing (plate center)
DEC-ORIG	DECEPOBS	string	Original recorded declination of the telescope pointing (plate center)
COORFLAG	-	string	Quality flag of the recorded coordinates (right ascension and declination): 'error', 'missing',

			'uncertain'.
OBJECT	OBJECT FIELD	string	(FITS Standard) Name of the observed object or field. If there are more than one field observed, then the value shall be 'multiple' and individual names shall be given with the OBJECTn keywords.
OBJTYPE	-	string	Object type (literal text), as listed in the WFPDB
EXPTIME	EXPTIME	float	Exposure time of the first exposure, expressed in seconds
NUMEXP	MULTIEXP	integer	Number of exposures
DATEORn	-	string	Original recorded date of the n-th exposure (n = 1…99), if exposures were made on multiple nights. Not used, when all exposures are from one night, given by DATEORIG.
TMS-ORn	-	string	Original recorded time of the start of the n-th exposure (n = 1…99). See TMS-ORIG for details.
TME-ORn	-	string	Original recorded time of the end of the n-th exposure (n = 1…99). See TMS-ORIG for details.
RA-ORn	-	string	Original right ascension of the telescope pointing during the n-th exposure (n = 1…99). Not used, if only one pointing was used.
DEC-ORn	-	string	Original declination of the telescope pointing during the n-th exposure (n = 1…99). Not used, if only one pointing was used.
OBJECTn	-	string	Object (field) name on the n-th exposure (n = 1…99). Not used, if only one object (field) was observed.
OBJTYPn	-	string	Object type that corresponds to OBJECTn (n = 1…99)
EXPTIMn	-	float	Exposure time of the n-th exposure (n = 1…99)
OBSERVAT	OBSERVAT	string	Observatory name
SITENAME	-	string	Observatory site name. Useful if the observatory has more than one observing site.
SITELONG	SITELONG	float	East longitude of the observing site, in decimal degrees
SITELAT	SITELAT	float	Latitude of the observing site, in decimal degrees
SITEELEV	SITEALTI	float	Elevation of the observatory site [m]. Keyword SITEELEV is more widely used than SITEALTI.
TELESCOP	TELESCOP	string	(FITS Standard) Telescope name

TELAPER	TELAPER	float	Clear aperture of the telescope [m]
TELFOC	TELFOC	float	Focal length of the telescope [m]
TELSCALE	TELSCALE	float	Plate scale of the telescope [arcsec/mm]
INSTRUME	INSTRUME	string	(FITS Standard) Instrument name
DETNAM	DETNAM	string	Detector name: 'photographic plate'
METHOD	-	string	Observation method (literal text). A list of possible values is given in the WFPDB.
FILTER	FILTER	string	Filter type
PRISM	-	string	Information about the objective prism used
PRISMANG	PRIZMANG	string	Angle of the objective prism (format "deg:min")
DISPERS	DISPERS	float	Dispersion [Angstrom/mm]
GRATING	-	string	Information about the grating used
FOCUS	-	float	Focus value (from logbook). Used when a single value is given in the logs.
FOCUSn	-	float	Focus value of the n-th exposure (n = 1…99)
TEMPERAT	-	float	Air temperature (from logbook).
CALMNESS	-	string	Calmness (seeing conditions), scale 1–5 (German: Ruhe)
SHARPNES	-	string	Sharpness, scale 1–5 (German: Schärfe)
TRANSPAR	-	string	Transparency, scale 1–5 (German: Durchsicht, Klarheit)
SKYCOND	-	string	Notes on sky conditions (from logbook)
OBSERVER	OBSERVER	string	(FITS Standard) Observer name
OBSNOTES	-	string	Observer notes (from logbook)
NOTES	-	string	Miscellaneous notes

We propose expressing exposure times in seconds. This is different from Paper I and the WFPDB that specify exposure time in decimal minutes, rounded to the first decimal place.

In case of multiple exposures (NUMEXP is greater than 1), exposure times of all sub-exposures can be given with the EXPTIMn keywords, where n is the exposure number in the range 1…99. The EXPTIME and EXPTIM1 keywords have the same value.

Example:

```
EXPTIME =                600.0 / [s] exposure time (of exposure 1)
NUMEXP  =                    3 / number of exposures of the plate
EXPTIM1 =                600.0 / [s] exposure time of exposure 1
EXPTIM2 =                 60.0 / [s] exposure time of exposure 2
EXPTIM3 =                  2.0 / [s] exposure time of exposure 3
```

In case of a single exposure, EXPTIM1 keyword is omitted:

```
EXPTIME =               1800.0 / [s] exposure time (of exposure 1)
NUMEXP  =                    1 / number of exposures of the plate
```

We propose expressing SITELONG and SITELAT in decimal degrees, instead of a character string in hexagesimal format.

Main differences with Paper I:

- new keywords DATEORIG, TMS-ORIG, TME-ORIG, TIMEFLAG, and COORFLAG
- ST → TMS-ORIG (provided that the original time is given as sidereal time)
- RAEPOBS, DECEPOBS → RA-ORIG, DEC-ORIG
- FIELD → OBJECT
- EXPTIME expressed in minutes → seconds
- MULTIEXP → NUMEXP
- new keywords DATEORn, TMS-ORn, TME-ORn, RA-ORn, DEC-ORn, OBJECTn, OBJTYPn, EXPTIMn, where n is the exposure number in the range of 1…99
- new keywords OBJTYPE and METHOD, based on the WFPDB
- new keyword SITENAME
- SITELONG, SITELAT expressed in sexagesimal format → decimal degrees
- SITEALTI → SITEELEV
- PRIZMANG → PRISMANG
- new keyword GRATING
- new keywords TEMPERAT, SEEING, SHARPNES, TRANSPAR, SKYCOND, OBSNOTES, and NOTES

Example:

```
       ---------------------------------------- Original data of the observation
DATEORIG= '1910-08-02'         / recorded date of the observation
TMS-ORIG= 'ST 18:11:16'        / recorded time of the start of the observation
TME-ORIG= '        '           / recorded time of the end of the observation
TIMEFLAG= 'uncertain'          / quality of the recorded time
RA-ORIG = '19:11:42'           / recorded right ascension of telescope pointing
DEC-ORIG= '15:04:00'           / recorded declination of telescope pointing
COORFLAG= 'uncertain'          / quality of the recorded coordinates
OBJECT  = 'SA 87   '           / name of the observed object or field
OBJTYPE = 'field   '           / object type
EXPTIME =               1800.0 / [s] exposure time (of exposure 1)
NUMEXP  =                    1 / number of exposures of the plate
OBSERVAT= 'Astrophysikalische Observatorium Potsdam' / observatory name
SITENAME= 'Potsdam-Telegrafenberg' / observatory site name
SITELONG=            13.064167 / [deg] East longitude of the observatory
SITELAT =            52.380556 / [deg] latitude of the observatory
```

```
SITEELEV=                  107 / [m] elevation of the observatory
TELESCOP= 'Zeiss Triplet 15 cm' / telescope name
TELAPER =                 0.15 / [m] clear aperture of the telescope
TELFOC  =                  1.5 / [m] focal length of the telescope
TELSCALE=               137.68 / [arcsec/mm] plate scale of the telescope
INSTRUME= '         '           / instrument
DETNAM  = 'photographic plate' / detector
METHOD  = 'direct photograph'  / method of observation
FILTER  = 'none     '           / filter type
PRISM   = '         '           / objective prism
PRISMANG= '         '           / prism angle “deg:min”
DISPERS =                       / [Angstrom/mm] dispersion
GRATING = '         '           / grating
FOCUS   =                  32.2 / focus value
TEMPERAT=                  21.8 / [deg C] air temperature (degrees Celsius)
CALMNESS= '2-3      '           / sky calmness (scale 1-5)
SHARPNES= '2        '           / sky sharpness (scale 1-5)
TRANSPAR= '1-2      '           / sky transparency (scale 1-5)
SKYCOND = 'moonlight'           / sky conditions
OBSERVER= 'W. Muench'           / observer name
OBSNOTES= 'bad guiding'         / observer notes
NOTES   = 'SA 87 = Kapteyn Selected Area 87' / miscellaneous notes
```

Example 2 (multiple time notations):

```
       ---------------------------------------- Original data of the observation
DATEORIG= '1964-01-02'          / recorded date of the observation
TMS-ORIG= 'UT 18:13, ST 02:44' / recorded time of the start of exposure 1
TME-ORIG= 'UT 19:13, ST 03:44' / recorded time of the end of exposure 1
TIMEFLAG= '         '           / quality of the recorded time
EXPTIME =               3600.0 / [s] exposure time (of exposure 1)
NUMEXP  =                    1 / number of exposures of the plate
```

Example 3 (multiple exposures):

```
       ---------------------------------------- Original data of the observation
DATEORIG= '1934-04-01'          / recorded date of the observation
TMS-OR1 = 'ST 10:52'            / recorded time of the start of exposure 1
TMS-OR2 = 'ST 10:54'            / recorded time of the start of exposure 2
TMS-OR3 = 'ST 10:57'            / recorded time of the start of exposure 3
TME-OR1 = 'ST 10:53'            / recorded time of the end of exposure 1
TME-OR2 = 'ST 10:56'            / recorded time of the end of exposure 2
TME-OR3 = 'ST 11:01'            / recorded time of the end of exposure 3
TIMEFLAG= '         '           / quality of the recorded time
RA-ORIG = '         '           / recorded right ascension of telescope pointing
DEC-ORIG= '         '           / recorded declination of telescope pointing
COORFLAG= 'missing '            / quality of the recorded coordinates
OBJECT  = 'RY UMa  '            / name of the observed object or field
OBJTYPE = 'variable star'       / object type
EXPTIME =                  60.0 / [s] exposure time (of exposure 1)
NUMEXP  =                     3 / number of exposures of the plate
EXPTIM1 =                  60.0 / [s] exposure time of exposure 1
EXPTIM2 =                 120.0 / [s] exposure time of exposure 2
EXPTIM3 =                 240.0 / [s] exposure time of exposure 3
OBSERVAT= 'Astrophysikalische Observatorium Potsdam' / observatory name
SITENAME= 'Potsdam-Telegrafenberg' / observatory site name
SITELONG=             13.064167 / [deg] East longitude of the observatory
SITELAT =             52.380556 / [deg] latitude of the observatory
SITEELEV=                  107 / [m] elevation of the observatory
TELESCOP= 'Zeiss Triplet 15 cm' / telescope name
TELAPER =                 0.15 / [m] clear aperture of the telescope
TELFOC  =                  1.5 / [m] focal length of the telescope
TELSCALE=               137.68 / [arcsec/mm] plate scale of the telescope
INSTRUME= '         '           / instrument
DETNAM  = 'photographic plate' / detector
```

```
METHOD  = 'direct photograph, multi-exposure' / method of observation
FILTER  = 'none    '           / filter type
PRISM   = '        '           / objective prism
PRISMANG= '        '           / prism angle “deg:min”
DISPERS =                      / [Angstrom/mm] dispersion
GRATING = '        '           / grating
FOCUS   =                34.4 / focus value
TEMPERAT=                   8 / [deg C] air temperature (degrees Celsius)
CALMNESS= '        '           / sky calmness (scale 1-5)
SHARPNES= '        '           / sky sharpness (scale 1-5)
TRANSPAR= '        '           / sky transparency (scale 1-5)
SKYCOND = 'clouds  '           / sky conditions
OBSERVER= 'W. Muench'          / observer name
OBSNOTES= 'poor transparency'  / observer notes
NOTES   = '        '           / miscellaneous notes
```

Group 3 – information about the photographic plate

Keyword	Paper I	Type	Comment
PLATENUM	PLATENUM	string	Plate number in original observation catalogue
WFPDB-ID	PLATE-ID	string	Plate identification in the WFPDB
SERIES	-	string	Series or survey in which the plate belongs, e.g. Carte du Ciel, Kapteyn Selected Areas, etc.
PLATEFMT	-	string	Plate format (e.g. '9x12', '20x20')
PLATESZ1	PLATESZ	float	Plate size along axis 1
PLATESZ2	PLATESZ	float	Plate size along axis 2
FOV1	CUNIT1	float	Field of view along axis 1
FOV2	CUNIT2	float	Field of view along axis 2
EMULSION	EMULSION	string	Type of the photographic emulsion
-	COLOR		The use of this keyword is not explained in Paper I.
DEVELOP	-	string	Plate development information (developer, time)
PQUALITY	PQUALITY	string	Quality of the plate
PLATNOTE	-	string	Notes about the plate (e.g. contact copy of the original plate)

We propose giving the plate size separately for both axes, thus replacing the PLATESZ keyword (character string) with PLATESZ1 and PLATESZ2 (floating-point numbers).

We specify the field of view along both axes with the FOV1 and FOV2 keywords,

replacing CUNIT1 and CUNIT2 that are reserved for the WCS.

Main differences with Paper I:

- PLATE-ID → WFPDB-ID
- new keyword SERIES
- PLATESZ → PLATESZ1, PLATESZ2
- CUNIT1, CUNIT2 → FOV1, FOV2
- COLOR → omit
- new keyword PLATNOTE

Example:

```
       ------------------------------------------------- Photographic plate
PLATENUM= '317     '           / plate number in original observation catalogue
WFPDB-ID= 'POT015_000317'      / plate identification in the WFPDB
SERIES  = 'Kapteyn Selected Areas' / plate series
PLATEFMT= '20x20   '           / plate format in cm
PLATESZ1=                  20.0 / [cm] plate size along axis 1
PLATESZ2=                  20.0 / [cm] plate size along axis 2
FOV1    =                  7.65 / [deg] field of view along axis 1
FOV2    =                  7.65 / [deg] field of view along axis 2
EMULSION= 'Schleussner'        / photographic emulsion type
DEVELOP = '        '           / plate development information
PQUALITY= 'broken  '           / quality of plate
PLATNOTE= 'contact copy of original plate that is not available' / plate notes
```

Group 4 – computed data of the observation

In this group of keyword records, we provide data of the observation that are computed on the basis of the original data.

Keyword	Paper I	Type	Comment
DATE-OBS	DATE-OBS TIME-OBS	string	(FITS Standard) UT date and time of the start of the observation (format "YYYY-MM-DDThh:mm:ss", or "YYYY-MM-DD" if time is not specified). The date may differ from DATEORIG, because the original date usually refers to the evening of the observing night.
DT-OBSn	-	string	UT date and time of the start of the n-th exposure (n = 1…99)
DATE-AVG	UT	string	(FITS Standard) UT date and time of the mid-point of the first exposure (format "YYYY-MM-DDThh:mm:ss")

DT-AVGn	-	string	UT date and time of the mid-point of the n-th exposure (n = 1…99)
DATE-END	DATE-OBS TIME-END	string	UT date and time of the end of the first exposure (format "YYYY-MM-DDThh:mm:ss")
DT-ENDn	-	string	UT date and time of the end of the n-th exposure (n = 1…99)
YEAR	-	float	Decimal year of the start of the first exposure
YEARn	-	float	Decimal year of the start of the n-th exposure (n = 1…99)
YEAR-AVG	EPOCH	float	Decimal year of the mid-point of the first exposure
YR-AVGn	-	float	Decimal year of the mid-point of the n-th exposure (n = 1…99)
JD	-	float	Julian date at the start of exposure 1
JDn	-	float	Julian date at the start of the n-th exposure (n = 1…99)
JD-AVG	JD	float	Julian date at the mid-point of the first exposure
JD-AVGn	-	float	Julian date at the mid-point of the n-th exposure (n = 1…99)
HJD-AVG	-	float	Heliocentric Julian date at the mid-point of the first exposure
HJD-AVn	-	float	Heliocentric Julian date at the mid-point of the n-th exposure (n = 1…99)
RA	RA	string	Right ascension of the telescope pointing (equinox J2000, sexagesimal format "h:m:s")
DEC	DEC	string	Declination of the telescope pointing (equinox J2000, sexagesimal format "d:m:s")
RAn	-	string	Right ascension of the telescope pointing, n-th exposure (n = 1…99). Used only when different fields were exposed on the same plate.

DECn	-	string	Declination of the telescope pointing, n-th exposure (n = 1…99). Used only when different fields were exposed on the same plate.
RA_DEG	-	float	Right ascension of the telescope pointing in decimal degrees (equinox J2000)
DEC_DEG	-	float	Declination of the telescope pointing in decimal degrees (equinox J2000)
RA_DEGn	-	float	Right ascension of the telescope pointing in decimal degrees, n-th exposure (n = 1…99). Used only when different fields were exposed on the same plate.
DEC_DEn	-	float	Declination of the telescope pointing in decimal degrees, n-th exposure (n = 1…99). Used only when different fields were exposed on the same plate.

We replace the EPOCH keyword (Paper I) with YEAR-AVG. The EPOCH keyword is deprecated in the FITS Standard. It was previously used to give the equinox in years for the celestial coordinate system in which positions were expressed. We reserve the EQUINOX keyword for the World Coordinate System, as required by the FITS Standard.

The RA, DEC, RA_DEG, and DEC_DEG keywords provide the precessed coordinates of the original recorded coordinates to the equinox J2000.

Main differences with Paper I:

- DATE-OBS, TIME-OBS → DATE-OBS
- TIME-END → DATE-END
- UT → DATE-AVG
- date format "YYYY-MM-DD hh:mm:ss" → "YYYY-MM-DDThh:mm:ss"
- EPOCH → YEAR-AVG
- JD → JD-AVG
- new keywords YEAR, HJD-AVG
- new keywords RA_DEG, DEC_DEG
- numbered keywords for multiple exposures
- EQUINOX → if necessary, specify with the WCS keywords

Example:

```
       ------------------------------------ Computed data of the observation
DATE-OBS= '1910-08-02T22:21:01' / UT date of the start of the observation
```

```
DATE-AVG= '1910-08-02T22:36:01' / UT date of the mid-point of exposure 1
DATE-END= '1910-08-02T22:51:01' / UT date of the end of exposure 1
YEAR    =       1910.583561644 / decimal year of the start of exposure 1
YEAR-AVG=       1910.583561644 / decimal year of the mid-point of exposure 1
JD      =       2418886.441678 / Julian date at the start of exposure 1
JD-AVG  =       2418886.441678 / Julian date at the mid-point of exposure 1
HJD-AVG =       2418886.441678 / heliocentric JD at the mid-point of exposure 1
RA      = '19:15:48'           / right ascension of pointing (J2000) "h:m:s"
DEC     = '+15:13:20'          / declination of pointing (J2000) "d:m:s"
RA_DEG  =           288.950000 / [deg] right ascension of pointing (J2000)
DEC_DEG =            15.222222 / [deg] declination of pointing (J2000)
```

Example 2:

```
        ------------------------------------ Computed data of the observation
DATE-OBS= '1934-01-25T20:36:56' / UT date of the start of exposure 1
DT-OBS1 = '1934-01-25T20:36:56' / UT date of the start of exposure 1
DT-OBS2 = '1934-01-25T20:45:55' / UT date of the start of exposure 2
DT-OBS3 = '1934-01-25T20:55:53' / UT date of the start of exposure 3
DT-OBS4 = '1934-01-25T20:57:53' / UT date of the start of exposure 4
DATE-AVG= '1934-01-25T20:40:56' / UT date of the mid-point of exposure 1
DT-AVG1 = '1934-01-25T20:40:56' / UT date of the mid-point of exposure 1
DT-AVG2 = '1934-01-25T20:48:25' / UT date of the mid-point of exposure 2
DT-AVG3 = '1934-01-25T20:56:23' / UT date of the mid-point of exposure 3
DT-AVG4 = '1934-01-25T20:58:53' / UT date of the mid-point of exposure 4
DATE-END= '1934-01-25T20:44:55' / UT date of the end of exposure 1
DT-END1 = '1934-01-25T20:44:55' / UT date of the end of exposure 1
DT-END2 = '1934-01-25T20:50:54' / UT date of the end of exposure 2
DT-END3 = '1934-01-25T20:56:53' / UT date of the end of exposure 3
DT-END4 = '1934-01-25T20:59:52' / UT date of the end of exposure 4
YEAR    =        1934.06806018 / decimal year of the start of exposure 1
YEAR1   =        1934.06806018 / decimal year of the start of exposure 1
YEAR2   =        1934.06807726 / decimal year of the start of exposure 2
YEAR3   =        1934.06809621 / decimal year of the start of exposure 3
YEAR4   =        1934.06810001 / decimal year of the start of exposure 4
YEAR-AVG=        1934.06806779 / decimal year of the mid-point of exposure 1
YR-AVG1 =        1934.06806779 / decimal year of the mid-point of exposure 1
YR-AVG2 =        1934.06808202 / decimal year of the mid-point of exposure 2
YR-AVG3 =        1934.06809716 / decimal year of the mid-point of exposure 3
YR-AVG4 =        1934.06810192 / decimal year of the mid-point of exposure 4
JD      =        2427463.35898 / Julian date at the start of exposure 1
JD1     =        2427463.35898 / Julian date at the start of exposure 1
JD2     =        2427463.36522 / Julian date at the start of exposure 2
JD3     =        2427463.37214 / Julian date at the start of exposure 3
JD4     =        2427463.37353 / Julian date at the start of exposure 4
JD-AVG  =        2427463.36176 / Julian date at the mid-point of exposure 1
JD-AVG1 =        2427463.36176 / Julian date at the mid-point of exposure 1
JD-AVG2 =        2427463.36696 / Julian date at the mid-point of exposure 2
JD-AVG3 =        2427463.37249 / Julian date at the mid-point of exposure 3
JD-AVG4 =        2427463.37422 / Julian date at the mid-point of exposure 4
HJD-AVG =                      / heliocentric JD at the mid-point of exposure 1
RA      = '         '          / right ascension of pointing (J2000) "h:m:s"
DEC     = '         '          / declination of pointing (J2000) "d:m:s"
RA_DEG  =                      / [deg] right ascension of pointing (J2000)
DEC_DEG =                      / [deg] declination of pointing (J2000)
```

Group 5 – scan details

This group contains information about scanner hardware and software settings, also the name of the scan author and the date of the scan.

Keyword	Paper I	Type	Comment
SCANRES1	SCANRES	integer	Scan resolution along axis 1 [dpi]
SCANRES2	SCANRES	integer	Scan resolution along axis 2 [dpi]
PIXSIZE1	XPIXELSZ	float	Pixel size along axis 1 [μm]
PIXSIZE2	YPIXELSZ	float	Pixel size along axis 2 [μm]
SCANSOFT	-	string	Name of the scanning software
-	SCANHCUT		Omit: scan high-cut value
-	SCANLCUT		Omit: scan low-cut value
SCANGAM	SCANGAM	float	Scan gamma value
SCANFOC	SCANFOC	string	Scan focus (e.g. 'glass')
WEDGE	WEDGE	string	Type of photometric step-wedge
DATESCAN	DATE-SCN	string	Scan date and time (UTC, format "YYYY-MM-DDThh:mm:ss")
SCANAUTH	AUTHOR	string	Author of the scan
SCANNOTE	-	string	Notes about the scan (e.g. scan orientation)
-	REFERENC		We propose omitting this keyword

We propose replacing the SCANRES keyword with the SCANRES1 and SCANRES2 keywords, indicating scan resolution along both image axes separately.

By FITS Standard, the AUTHOR and REFERENCE keywords are used when the data in the FITS file were compiled from a publication or multiple sources. For digitized photographic plates, these keywords are not appropriate for specifying the author of the scan nor acknowledging any funding sources. We propose replacing the AUTHOR keyword with SCANAUTH and providing acknowledgments with the COMMENT keyword (Group 8).

Main differences with Paper I:

- SCANRES → SCANRES1, SCANRES2
- XPIXELSZ → PIXSIZE1
- YPIXELSZ → PIXSIZE2
- PIXSIZE1, PIXSIZE2 unit: [microns] → [um]
- new keywords SCANSOFT, SCANNOTE
- SCANHCUT, SCANLCUT → omit
- SCANFOC type: float → string

- date format "YYYY-MM-DD hh:mm:ss" → "YYYY-MM-DDThh:mm:ss"
- AUTHOR → SCANAUTH
- REFERENC → COMMENT

Example:

```
       ---------------------------------------------------------------- Scan
SCANNER = 'Epson Expression 10000XL' / scanner name
SCANRES1=                 2400 / [dpi] scan resolution along axis 1
SCANRES2=                 2400 / [dpi] scan resolution along axis 2
PIXSIZE1=              10.5833 / [um] pixel size along axis 1
PIXSIZE2=              10.5833 / [um] pixel size along axis 2
SCANSOFT= 'VueScan '           / name of the scanning software
SCANGAM =                  1.0 / scan gamma value
SCANFOC = 'glass'              / scan focus
WEDGE   = 'Danes-Picta TG21S'  / type of photometric step-wedge
DATESCAN= '2011-05-17T10:33:26' / scan date and time
SCANAUTH= 'K. Tsvetkova'       / author of scan
```

Group 6 – data files

Keyword	Paper I	Type	Comment
FILENAME	FILENAME	string	Filename of the plate scan (this file)
FN-SCNi	-	string	Filename of the i-th scan of the same plate (i = 1…99)
FN-WEDGE	-	string	Filename of the wedge scan
FN-PRE	-	string	Filename of the preview image (annotated plate)
FN-COVER	-	string	Filename of the plate cover (envelope) image
FN-LOGB	-	string	Filename of the logbook image
FN-NTBi	-	string	Filename of the i-th notebook image (i = 1…99)
-	URL		We propose omitting this keyword.
ORIGIN	ORIGIN	string	(FITS Standard) Institute responsible for creating the FITS file
DATE	DATE	string	(FITS Standard) Date and time of the last change of the file

Main differences with Paper I:

- new keywords FN-SCNi, FN-WEDGE, FN-PRE, FN-COVER, FN-LOGB, and FN-NTBi

- URL → omit

Example:

```
       ------------------------------------------------------------ Data files
FILENAME= 'POT015_000317.fits' / filename of this file
FN-WEDGE= 'POT015_000317w.fits' / filename of the wedge scan
FN-PRE  = 'POT015_000317_pre.jpg' / filename of the preview image
FN-COVER= '         '           / filename of the plate cover image
FN-LOGB = 'POT015_000317-000334.jpg' / filename of logbook image
ORIGIN  = 'Leibniz-Institut fuer Astrophysik Potsdam (AIP)'
DATE    = '2013-04-09T12:00:00' / last change of this file
```

Example 2:

```
       ------------------------------------------------------------ Data files
FILENAME= 'LA00508x.fits'      / filename of this file
FN-SCN1 = 'LA00508x.fits'      / filename of scan 1
FN-SCN2 = 'LA00508y.fits'      / filename of scan 2
FN-WEDGE= '         '          / filename of the wedge scan
FN-PRE  = 'LA00508_pre.jpg'    / filename of the preview image
FN-COVER= 'LA00508_cover.jpg'  / filename of the plate cover image
FN-LOGB = 'LA-PV01-LA00501_00510.jpg' / filename of logbook image
FN-NTB1 = 'LA-LB04-1916-10-18a.jpg' / filename of notebook image 1
FN-NTB2 = 'LA-LB04-1916-10-18b.jpg' / filename of notebook image 2
FN-NTB3 = 'LA-LB04-1916-10-18c.jpg' / filename of notebook image 3
FN-NTB4 = 'LA-LB04-1916-10-18d.jpg' / filename of notebook image 4
FN-NTB5 = 'LA-LB04-1916-10-18e.jpg' / filename of notebook image 5
FN-NTB6 = 'LA-LB04-1916-10-18f.jpg' / filename of notebook image 6
ORIGIN  = 'Hamburger Sternwarte' /
DATE    = '2013-12-12T13:42:00' / last change of this file
```

Group 7 – World Coordinate System (WCS)

The astrometric information are given with the World Coordinate System (WCS) keywords, as described in the FITS Standard.

If the EQUINOX keyword is not given, then coordinates are assumed to refer to the International Celestial Reference System (ICRS).

When the WCS solution is not possible through matching stars in the scan, the WCS keywords can be used to provide the approximate coordinates, based on the plate scale and the precessed coordinates of the original telescope pointing.

Example:

```
       ---------------------------------------- World Coordinate System (WCS)
WCSAXES =                    2 / number of axes in the WCS description
RADESYS = 'FK5     '           / name of the reference frame
EQUINOX =               2000.0 / epoch of the mean equator and equinox in years
CTYPE1  = 'RA---TAN'           / TAN (gnomonic) projection
CTYPE2  = 'DEC--TAN'           / TAN (gnomonic) projection
CUNIT1  = 'deg     '           / physical units of CRVAL and CDELT for axis 1
CUNIT2  = 'deg     '           / physical units of CRVAL and CDELT for axis 2
CRPIX1  =               9452.5 / reference pixel for axis 1
CRPIX2  =               9452.5 / reference pixel for axis 2
CRVAL1  =               288.95 / right ascension at the reference point
```

```
CRVAL2  =            15.222222 / declination at the reference point
CD1_1   =        -0.0004047524 / transformation matrix
CD1_2   =                  0.0 / transformation matrix
CD2_1   =                  0.0 / transformation matrix
CD2_2   =         0.0004047524 / transformation matrix
LONPOLE =                  0.0 / native longitude of the celestial pole
```

Group 8 – modification history and acknowledgements

Modification history is given with the HISTORY keyword.

Comments and acknowledgements are given with the COMMENT keyword.

Example:

```
        ------------------------------------------------- Modification history
HISTORY Header written with PyPlates at 2013-12-18T12:00:00
HISTORY WCS modified by T. Tuvikene (AIP) at 2013-12-19T12:00:00
        ------------------------------------------------------ Acknowledgements
COMMENT The digitization of this plate was funded by the German Research
COMMENT Foundation (DFG) grant STE: 710/6-1,20.11.2009 and partially by the
COMMENT grants of the Bulgarian Ministry of Education and Science
COMMENT DO-02-273/275,18.12.2009. The 2011 May-June stay of K. Tsvetkova at AIP
COMMENT was funded by DO-02-275 MON.
COMMENT
COMMENT Publications based on this digitized photographic plate are requested to
COMMENT include the following acknowledgement.
COMMENT
COMMENT Based on photographic data of the Leibniz-Institut fuer Astrophysik
COMMENT Potsdam (AIP). The Kapteyn Selected Areas Survey was obtained with the
COMMENT 80-cm Great Refractor and the 15-cm Zeiss Triplet telescope at
COMMENT Potsdam-Telegrafenberg in 1910-1933. The project of plate digitization
COMMENT was funded by the grants of the German Research Foundation (DFG) and the
COMMENT Bulgarian Ministry of Education and Science.
```

Complete sample header

```
SIMPLE  =                    T / file conforms to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                18904 / length of data axis 1
NAXIS2  =                18904 / length of data axis 2
BSCALE  =                  1.0 / physical_value = BZERO + BSCALE * array_value
BZERO   =                32768 / physical_value = BZERO + BSCALE * array_value
        ---------------------------------------- Original data of the observation
DATEORIG= '1910-08-02'         / recorded date of the observation
TMS-ORIG= 'ST 18:11:16'        / recorded time of the start of the observation
TME-ORIG= '        '           / recorded time of the end of the observation
TIMEFLAG= 'uncertain'          / quality of the recorded time
RA-ORIG = '19:11:42'           / recorded right ascension of telescope pointing
DEC-ORIG= '15:04:00'           / recorded declination of telescope pointing
COORFLAG= 'uncertain'          / quality of the recorded coordinates
OBJECT  = 'SA 87   '           / name of the observed object or field
OBJTYPE = 'field   '           / object type
EXPTIME =               1800.0 / [s] exposure time (of exposure 1)
NUMEXP  =                    1 / number of exposures of the plate
OBSERVAT= 'Astrophysikalische Observatorium Potsdam' / observatory name
SITENAME= 'Potsdam-Telegrafenberg' / observatory site name
SITELONG=            13.064167 / [deg] East longitude of the observatory
SITELAT =            52.380556 / [deg] latitude of the observatory
SITEELEV=                  107 / [m] elevation of the observatory
```

```
TELESCOP= 'Zeiss Triplet 15 cm' / telescope name
TELAPER =                 0.15 / [m] clear aperture of the telescope
TELFOC  =                  1.5 / [m] focal length of the telescope
TELSCALE=               137.68 / [arcsec/mm] plate scale of the telescope
INSTRUME= '        '           / instrument
DETNAM  = 'photographic plate' / detector
METHOD  = 'direct photograph'  / method of observation
FILTER  = 'none    '           / filter type
PRISM   = '        '           / objective prism
PRISMANG= '        '           / prism angle “deg:min”
DISPERS =                      / [Angstrom/mm] dispersion
GRATING = '        '           / grating
FOCUS   =                 32.2 / focus value
TEMPERAT=                 21.8 / [deg C] air temperature (degrees Celsius)
CALMNESS= '2-3     '           / sky calmness (scale 1-5)
SHARPNES= '2       '           / sky sharpness (scale 1-5)
TRANSPAR= '1-2     '           / sky transparency (scale 1-5)
SKYCOND = 'moonlight'          / sky conditions
OBSERVER= 'W. Muench'          / observer name
OBSNOTES= 'bad guiding'        / observer notes
NOTES   = 'SA 87 = Kapteyn Selected Area 87' / miscellaneous notes
        ------------------------------------------------------ Photographic plate
PLATENUM= '317     '           / plate number in original observation catalogue
WFPDB-ID= 'POT015_000317'      / plate identification in the WFPDB
SERIES  = 'Kapteyn Selected Areas' / plate series
PLATEFMT= '20x20   '           / plate format in cm
PLATESZ1=                 20.0 / [cm] plate size along axis 1
PLATESZ2=                 20.0 / [cm] plate size along axis 2
FOV1    =                 7.65 / [deg] field of view along axis 1
FOV2    =                 7.65 / [deg] field of view along axis 2
EMULSION= 'Schleussner'        / photographic emulsion type
DEVELOP = '        '           / plate development information
PQUALITY= 'broken  '           / quality of plate
PLATNOTE= 'contact copy of original plate that is not available' / plate notes
        ---------------------------------------- Computed data of the observation
DATE-OBS= '1910-08-02T22:21:01' / UT date of the start of the observation
DATE-AVG= '1910-08-02T22:36:01' / UT date of the mid-point of exposure 1
DATE-END= '1910-08-02T22:51:01' / UT date of the end of exposure 1
YEAR    =       1910.583561644 / decimal year of the start of exposure 1
YEAR-AVG=       1910.583561644 / decimal year of the mid-point of exposure 1
JD-AVG  =       2418886.441678 / Julian date at the mid-point of exposure 1
HJD-AVG =       2418886.441678 / heliocentric JD at the mid-point of exposure 1
RA      = '19:15:48'           / right ascension of pointing (J2000) "h:m:s"
DEC     = '+15:13:20'          / declination of pointing (J2000) "d:m:s"
RA_DEG  =           288.950000 / [deg] right ascension of pointing (J2000)
DEC_DEG =            15.222222 / [deg] declination of pointing (J2000)
        ------------------------------------------------------------------ Scan
SCANNER = 'Epson Expression 10000XL' / scanner name
SCANRES1=                 2400 / [dpi] scan resolution along axis 1
SCANRES2=                 2400 / [dpi] scan resolution along axis 2
PIXSIZE1=              10.5833 / [um] pixel size along axis 1
PIXSIZE2=              10.5833 / [um] pixel size along axis 2
SCANSOFT= 'VueScan '           / name of the scanning software
SCANGAM =                  1.0 / scan gamma value
SCANFOC = 'glass'              / scan focus
WEDGE   = 'Danes-Picta TG21S'  / type of photometric step-wedge
DATESCAN= '2011-05-17T10:33:26' / scan date and time
SCANAUTH= 'K. Tsvetkova'       / author of scan
        ------------------------------------------------------------ Data files
FILENAME= 'POT015_000317.fits' / filename of this file
FN-WEDGE= 'POT015_000317w.fits' / filename of the wedge scan
FN-PRE  = 'POT015_000317_pre.jpg' / filename of the preview image
FN-COVER= '        '           / filename of the plate cover image
FN-LOGB = 'POT015_000317-000334.jpg' / filename of logbook image
ORIGIN  = 'Leibniz-Institut fuer Astrophysik Potsdam (AIP)'
DATE    = '2013-04-09T12:00:00' / last change of this file
        ---------------------------------------- World Coordinate System (WCS)
WCSAXES =                    2 / number of axes in the WCS description
RADESYS = 'FK5     '           / name of the reference frame
EQUINOX =               2000.0 / epoch of the mean equator and equinox in years
```

```
CTYPE1  = 'RA---TAN'           / TAN (gnomonic) projection
CTYPE2  = 'DEC--TAN'           / TAN (gnomonic) projection
CUNIT1  = 'deg     '           / physical units of CRVAL and CDELT for axis 1
CUNIT2  = 'deg     '           / physical units of CRVAL and CDELT for axis 2
CRPIX1  =               9452.5 / reference pixel for axis 1
CRPIX2  =               9452.5 / reference pixel for axis 2
CRVAL1  =               288.95 / right ascension at the reference point
CRVAL2  =            15.222222 / declination at the reference point
CD1_1   =        -0.0004047524 / transformation matrix
CD1_2   =                  0.0 / transformation matrix
CD2_1   =                  0.0 / transformation matrix
CD2_2   =         0.0004047524 / transformation matrix
LONPOLE =                  0.0 / native longitude of the celestial pole
        ------------------------------------------------------ Modification history
HISTORY Header written with PyPlates at 2013-12-18T12:00:00
HISTORY WCS modified by T. Tuvikene (AIP) at 2013-12-19T12:00:00
        ------------------------------------------------------ Acknowledgements
COMMENT The digitization of this plate was funded by the German Research
COMMENT Foundation (DFG) grant STE: 710/6-1,20.11.2009 and partially by the
COMMENT grants of the Bulgarian Ministry of Education and Science
COMMENT DO-02-273/275,18.12.2009. The 2011 May-June stay of K. Tsvetkova at AIP
COMMENT was funded by DO-02-275 MON.
COMMENT
COMMENT Publications based on this digitized photographic plate are requested to
COMMENT include the following acknowledgement.
COMMENT
COMMENT Based on photographic data of the Leibniz-Institut fuer Astrophysik
COMMENT Potsdam (AIP). The Kapteyn Selected Areas Survey was obtained with the
COMMENT 80-cm Great Refractor and the 15-cm Zeiss Triplet telescope at
COMMENT Potsdam-Telegrafenberg in 1910-1933. The project of plate digitization
COMMENT was funded by the grants of the German Research Foundation (DFG) and the
COMMENT Bulgarian Ministry of Education and Science.
END
```

Original sample header (created with the header2011 software)

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                18904 / length of data axis 1
NAXIS2  =                18904 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
BZERO   =                65536 /
BSCALE  =                    1 /
INVERTED=                    T / T -  big-endian, F - little-endian
DATE    = '2011-06-30 10:53:40' / last change of file
FILENAME= 'POT015_000317.fits' / source file name
PLATENUM= '317             ' / in original observation catalogue
PLATE-ID= 'POT015_000317   ' / WFPDB ident. of plate
OBJECT  = 'SA 87           ' / field name and/or star name
EMULSION= '                ' / photoemulsion type
EXPTIME = 3.000000000000E+01 / exposure time [minutes]
DISPERS =                    / dispersion [A/mm]
MULTIEXP=                    1 / number of exposure of the plate
PQUALITY= '                ' / quality of plate
DATE-OBS= '1910-08-02      ' / date of observation
RA      = '19:15:48        ' / center of plate FK5
DEC     = '+15:13:20       ' / center of plate FK5
EQUINOX = 2.000000000000E+03 / equatorial coordinates definition
UT      = '1910-08-02 22:36:01' / date and UT at mean epoch
ST      = '18:11:16        ' / ST at start of the observation
JD      = 2.418886441678E+06 / JD at mean epoch
TIME-OBS= '22:21:01        ' / UT at start of observation
TIME-END= '22:51:01        ' / UT at end of observation
```

```
RAEPOBS = '                ' / center of plate at epoch of observation
DECEPOBS= '                ' / center of plate at epoch of observation
EPOCH   = 1.910583561644E+03 / epoch of plate
PLATESZ = '20x20           ' / plate size [cm]x[cm]
CUNIT1  = 7.650000000000E+00 / X field size [deg]
CUNIT2  = 7.650000000000E+00 / Y field size [deg]
DETNAM  = 'Photographic Plate' /
OBSERVER= 'W.Muench        ' / observer name
OBSERVAT= 'AO Potsdam      ' / observatory name
INSTRUME= '                ' /
TELESCOP= 'Zeiss Triplet 15 cm Potsdam-Telegrafenberg' / telescop name
SITELONG= '-13:03:51.0     ' / longitude of the obsrvatory
SITELAT = '+52:22:50.0     ' / latitude of the observatory
SITEALTI=                  107 / altitude of the observatory
COLOR   = 'Pg              ' /
FILTER  = 'NO              ' / filter type
PRIZMANG= 'NO              ' / prism angle
TELAPER = 1.500000000000E-01 / clear aperture [m]
TELFOC  = 1.500000000000E+00 / focal length [m]
TELSCALE= 1.376800000000E+02 / telescope scale  [arcsec/mm]
SCANNER = 'EPSON EXPRESSION 10000XL' / scanner name
SCANRES =                 2400 / scan resolution
XPIXELSZ= 1.058330000000E+01 / X pixel size [microns]
YPIXELSZ= 1.058330000000E+01 / Y pixel size [microns]
SCANHCUT=                  255 / focal length [m]
SCANLCUT=                    0 / scan shadow value
SCANGAM = 1.000000000000E+00 / scan gamma value
SCANFOC = 0.000000000000E+00 / scan focus
DATE-SCN= '2011-05-17 10:33:26' / scan date and time
AUTHOR  = 'K. Tsvetkova    ' / author of scan
ORIGIN  = 'Leibniz IAP - WFPDB - Sofia' /
REFERENC= 'May-June DFG Stay of K.Tsvetkova  in AIP, DO-02-275 MON' / reference
URL     = 'vo.aip.de, www.wfpdb.org' / base URL of VO Service to retrieve data
COMMENT
       Based on photographic data of the Leibniz Astrophysical Observatory
       Potsdam - Kapteyn Selected Areas Survey obtained using the 80 cm Great
       Refractor and 15 cm Zeiss Triplet telescope at Telegrafenberg - Potsdam
       in the period 1910-1933. The plates were digitized using professional
       flatbed scanners EPSON 10000XL/V700 and processed in the present digital
       form. The project of Plate digitization was funded by a German DFG grant
       STE: 710/6-1,20.11.2009 and partially of the grants of Bulgarian
       Ministry of Education and Science DO-02-273/275,18.12.2009.

       Investigators using these scans are kindly requested to include the
       above acknowledgements in any publications.

       Copyright (c) Leibniz Astrophysical Institute Potsdam.
       All rights reserved.
END
```

1. ↑ Online version of an unpublished paper written and edited by T.Tuvikene, S.Schmalz, H.Enke, A.Partl (AIP) in 2013–2014.
2. ↑ *Software Tools for Digitization of Astronomical Photographic Plates* (http://serdica-comp.math.bas.bg/index.php/serdicajcomputing/article/view/144) in: Serdica Journal of Computing, vol. 6, no. 1, pp. 67–76 (2012).
3. ↑ *WFPDB* (http://www.wfpdb.org)
4. ↑ *Wide-Field Plate Database (Tsvetkov+ 1997)* (http://cdsarc.u-strasbg.fr/viz-bin/Cat?VI/90) on VizieR
5. ↑ *FITS Standard Document* (http://fits.gsfc.nasa.gov/fits_standard.html)

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