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DOCUMENT

FITS keyword requirements

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APPROVAL

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CHANGE RECORD

Issue 1	**Revision** 1		
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Update after discussion with F. Bernardi , 08 Aug 2013	08 Aug 2013	all	
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Delete OBSERVER in section 5.6 as it was a duplication	20 Oct 2013	14	5.6
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Reason for change	**Date**	**Pages**	**Paragraph(s)**
TIMEOBS replaced with TIME-OBS - typo!	18 Mar 2014	10	5.2
For EXTEND = T the 'R' was missing			
Issue 1	**Revision** 5,6		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Added a sentence to explain that we do not want units specified in square brackets.	01 Aug 2014	8	REQ-070
EXTEND = T is only required if really there is an extension. Updated accordingly.			
Typo: 'SIDEREAL' replaces 'SIDERIAL'		13	5.4
Updated the text on the HISTORY keyword - the date/time for the correction is not really required as it should be given in the DATE keyword.		14+15	

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1 INTRODUCTION

1.1 Purpose and Scope of the Document

This document describes the FITS keywords that shall be used in headers of images, which are dealt with by the SSA-NEO programme of ESA. Initially, the idea was that this document describes keywords that should be understood by the 'image database' reading software of the SN-V contract. It was then realized that it may be also relevant for contracts like the GSTP contract 'Test Bed Telescope' which will define keywords to be generated with image data. It is thus possible that there are still additional keywords which could be defined in future versions of this document.

For now, the scope is the following: All data providers shall ensure that their images contain at least the required keywords; they should consider adding in their data writing software the optional keywords. All software developers having to read FITS data shall ensure that the SSA-NEO software can handle all keywords - both mandatory and optional - and interpret them properly. The reading software shall be such that if only the mandatory keywords are present it shall be possible to do its job; if the optional keywords are present it shall allow additional data interpretation.

1.2 Applicable documents

AD 01. Definition of the Flexible Image Transport System (FITS), Version 3.0, 18 Nov 2010 (available via http://fits.gsfc.nasa.gov/standard30/fits_standard30aa.pdf; last accessed 15 Jun 2013)

1.3 Reference documents

n/a

1.4 Acronyms

AD	Applicable Document
ASCII	American Standard Code for Information Interchange
CCD	Charged-Coupled Device
DN	Digital Number
ESA	European Space Agency
FITS	Flexible Image Transport System
NEO	Near-Earth Object (an asteroid or comet coming close to the Earth)
OS	Operating System
RA	Right Ascension
RD	Reference Document
REC	Recommendation
REQ	Requirement
RS	Requirements Specification
SSA	Space Situational Awareness (an ESA programme)
UTC	Universal Time Coordinated

2 OVERVIEW AND GENERAL REMARKS

For astronomical image data, the FITS format is a standard supported by most camera and data evaluation software. The main concept of the FITS format is that the image data is stored in a binary format, preceded by a human-readable ASCII header. Each header record (i.e. line) defines one `keyword = value` pair. Keywords must have a length less or equal to 8 characters. A very small number of keywords are mandatory. A large number of keywords exist and have developed as de-facto standards (e.g. `'RA = ...'` for the Right Ascension of the center of the image). Completely new keywords can also be defined. Figure 1 shows an example of an image file with a very simple FITS header; Figure 2 is the corresponding image, visualized by a standard FITS reader (QFitsView for MAC OS).

```
SIMPLE  =                    T /image conforms to FITS standard
BITPIX  =                   16 /bits per data value
NAXIS   =                    2 /number of axes
NAXIS1  =                 1024 /
NAXIS2  =                 1024 /
EXTEND  =                    T /file may contain extensions
DATE    = '2012-12-03'         / Creation UTC (CCCC-MM-DD) date of FITS header
UTC-DATE= '2010-12-12'         /UTC date in yyyy-mm-dd
UTC-TIME= '21:16:32'           /UTC time in hh:mm:ss
UTC-MSEC=                  758 /milliseconds
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode 2001A&A...376..359H
END

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Ø™∞™±≠≥∫≤°π∂≤œπø∏¥π∂∏Ω¿¿œ…¬µ∫»¬∏œπÃ¿°œÃ√ÃÕ«À√
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/ÈÍÈÊÔ·ÓÊ„ÔÈ‰ËÒÂÍÂÏÍÈfiÌÈÍÊÎÏÍÏ„ÁÁ‹‡,›‡È›◊–‰’‹
/ŸÊÈ„È€Δ„„‰ÏÂ„„fl›Á‹ÍÊ›‰‡€,Ó·Â¯,Í‹Í‰’Á,ŸfiÊfi÷Á
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49343=<67?6/*2-0444$2+..+'*%&''%(GÇm7)*,.%$#
%8OVU?6HVaD0/3#"    !
```

Figure 1: Sample header of a FITS image file.

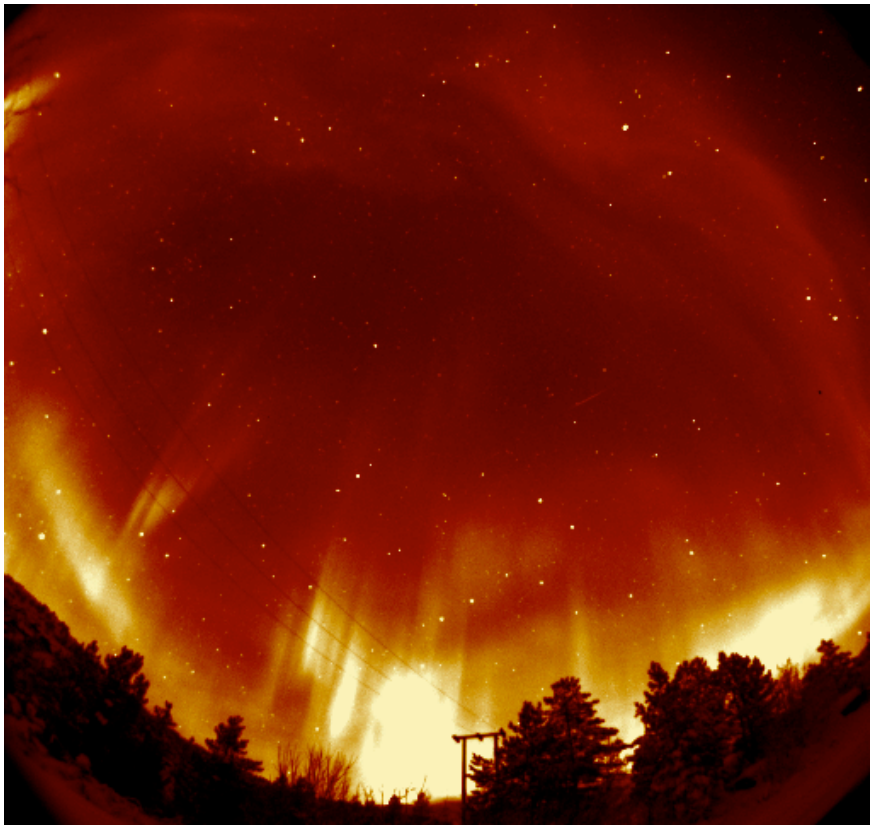

Figure 2: The image stored in the file shown above.

For quite a few header items, the same information can be described by several keywords (e.g. `DATETIME`, `DATE-OBS`, `TIME-OBS`, `UTC-DATE`, `UTC-TIME`). In that case one often finds that the image writing software writes the same information in more than one keyword.

While a standard, it does allow quite some flexibility in the usage and definition of keywords. The underlying understanding is that images used within the SSA-NEO segment must comply with the FITS standard. This document provides additional information to prescribe certain keywords. If there is a conflict in this document with the FITS standard, then there is a mistake in this document. Please notify the author if you think that you have identified a conflict.

The idea of the FITS header, which precedes binary data describing the image information, is to give all available information about the image. We divide this information into the following areas:

(a) FITS required keywords

(b) Time information (data and time of image, is it the begin or middle of exposure? The exposure time, equinox, optionally the time basis)

(c) Location information (enough information must be available so that longitude, latitude, and elevation of the telescope can be derived)

(d) Telescope information (aperture, tracking, number of mirrors…)

(e) Camera information (name and type of camera, sensor type, pixel scale, CCD temperature, gain)

(f) Image information (calibration status, pointing information, optionally distortion information, filter)

3 DETAILED REQUIREMENTS

REQ-010: All headers shall follow the FITS standard as defined in AD 01.

REQ-020: All times shall be given in UTC.

REQ-030: The given image time shall correspond to the time of the start of the exposure.

REQ-040: The following file name extensions shall be recognized as FITS files: .fit, .fits, .fts.

REQ-050: Keywords in the FITS headers shall follow the definitions in the tables in the section "Supporting tables" (Section 5 of this document).

REQ-060: If available, the 'World Coordinate System (WCS)' standard as described in AD 01 shall be used to describe pointing and distortion of the images.

REQ-070: Physical units endorsed by the IAU shall be used (Tables 3 and 4 in AD01). When used in connection with a keyword the unit should be given in the comment field of the keyword. Note: Other than recommended (and recommended only) in the FITS requirements document AD01, we do *not* use units in square brackets. The reason for this is that it is not following the NIST standard specifying that the square brackets are used to denote 'unit of xx is'.

Example:

```
EXPTIME = 1000. / exposure time in seconds
```

The following 'requirements' shall be fulfilled as a goal:

GOAL-010: With the exception of some requirements by the FITS standard, the order of the keywords is not important. It is recommended, though, to stick to the order as proposed in this document. This will allow a human reader to make it easier understanding the header.

GOAL-020: Most FITS readers to not accept images in extensions. It is therefore recommended that extensions be *not* used in image files.

GOAL-030: It is recommended to use the ISO-8601 standard to give date and time together in DATE related keywords, as follows

```
CCYY-MM-DDThh:mm:ss[.sss…]
```

GOAL-040: The processing log stored in the **HISTORY** records of the resulting image should contain enough information so that it could be converted into a procedure in the associated pipeline to reproduce the process at a later stage.

4 OPEN POINTS

It was suggested to have required Boolean keywords to indicate the calibration. This would be easier to handle with automated software. I.e. `BIASCORR= 'T' | 'F', FLATCORR= 'T' | 'F', DARKCORR= 'T' | 'F'.` However, for example STSC is using these keywords but as switches as to what needs to be done with the images. Unless we find another standard already defined the author suggests to keep the calibration information in the HISTORY keyword as this is what he sees most commonly used.

5 SUPPORTING TABLES

For the supporting tables, see the following pages.

To interpret the tables, note these conventions:

Note 1: The '|' indicates an 'or'. 'R' means 'required', 'O' is optional.

Note 2: If two keywords are listed below each other within the same table row, either one of them can be used. Priority should be given to the first one.

5.1 FITS required keywords

Keyword	Value, type of value, or format of value	Comment in header	Description	R/O?
SIMPLE =	T	/ file conforms to FITS standard	Must be the first keyword	R
BITPIX =	8 | 16 | 32 | 64 | -32 | -64	/ number of bits per data pixel	Must be the second keyword	R
NAXIS =	2	/ number of data axis	Must be the third keyword	R
NAXIS1 =	*int*	/ number of pixels of axis 1	Must be the fourth keyword	R
NAXIS2 =	*int*	/ number of pixels of axis 2	Must be the fifth keyword	R
BZERO =	*Float*		Follow FITS standard for value, e.g. 0	R
BSCALE =	*Float*		Follow FITS standard for value, e.g. 1	R
EXTEND =	T | 'T'		Must be there following FITS standard if the file contains an extension	R/O (1)
END			Must be at the end of the header (follow the FITS standard – must be at the end of the last 2880-byte FITS block)	R

(1) If the file contains extensions, this keyword must be there. If the file does not contain extensions (which would be the 'normal' case for the applications discussed here) this keyword is optional.

5.2 Time and object information

Keyword	Value, type of value, or format of value	Comment in header	Description	R/O?
EXPTIME = EXPOSURE=	*Float*	/ exposure time in s		R
DATE =	As 'DATE-OBS'	/ Date/time of file creation	This keyword gives the date and possibly time of the creation of the file (!). I.e. if in the raw file coming from a telescope, we'd expect this keyword to contain information close to DATE-OBS. If in a calibrated file, it may be hours later, whenever the file was calibrated.	O
DATE-OBS= UTC-DATE=	'dd/mm/yy' | 'yyyy-mm-ddThh:mm:ss[.sss]'	/ Date of observation	The date and time of the observation must be given down to at least one second by any combination of DATE, DATE-OBS, TIME-OBS. All dates/times shall be given in UTC. Note: The decimal seconds are required only when observing fast-moving objects or occultations.	R(1)
TIME-OBS =	'hh:mm:ss[.sss]'	/ UTC Time of observation	Note: The decimal seconds are required only when observing fast-moving objects or occultations.	R
EPOMJD =	*Float*	/ Modified Julian Date	For example 55950.1487 is 21 Jan 2012, 03:34:09	O
OBJECT =	*String*	/ Target object	For example: '2014AA', 'NEOCP'. Note: This keyword should be used whenever a specific object was the target of the observation. E.g. for a follow-up observation of a known object or lightcurve observations. It is not required for survey observations, since no specific target was aimed at then.	O

(1) If DATE-OBS is given in the complete CCSDS format, DATE or TIME-OBS are not needed.

5.3 Location information

Keyword	Value, type of value, or format of value	Proposed comment in header	Description	R/O?
TELESCOP=	*String*	/ Name of telescope	For example 'OGS', 'Gemini North', '40 cm Cassegrain f/10'	R
OBSCODE =	*String*	/ IAU observatory code	Gives the three-letter observatory code assigned by the Minor Planet Center, e.g. 'J04', 'B12'	O
SITELONG=	*Float* | *String*	/ longitude of telescope in decimal degrees	Longitude of the telescope in decimal degrees, could East as positive	R(1)
SITELAT =	*Float* | *String*	/ latitude of telescope in decimal degrees	Latitude of the telescope in decimal degrees or as string 'sdd mm ss' where the first 's' is either '+' or '-'. If omitted, it is interpreted as '+'	R(1)
ELEVATIO=	*Float*	/ elevation of telescope in m	Elevation of the telescope above sea level in m	R(1)
Add weather information			Temp in dome, outside, ...	O

(1): If the OBSCODE keyword is set these keywords are optional (but still highly recommended to avoid issues with updating the file referencing the observatory code).

5.4 Telescope information

Keyword	Value, type of value, or format of value	Proposed comment in header	Description	R/O?
APTDIA =	*Float*	/ aperture diameter in mm	Diameter of telescope aperture in mm	R/O(1)
APERTUR =	*Float*	/ aperture area in mm2	Area of telescope aperture in mm2	O/R(1)
OBSTRUC =	*Float*	/ obstruction (0..1)	Obstruction in values from 0 to 1	R
FOCALLEN= FLENGTH =	*Float*	/ focal length	Focal length of telescope in mm	R
NREFLECT=	*Float*	/ number of reflections in path	Number of reflections in optical path - 0 would mean a refracting telescope	R
TRACKING=	'SIDEREAL' | 'FIXED' | 'OFFSET'	/ tracking of telescope	Can be sidereal (= following the stars), fixed (w.r.t. the Earth, e.g. used for observing geostationary objects), or offset.	R(1)
OBSERVER=	*String*	/ name of observer		R
RATRACK =	*Float*	/ Offset tracking in "/min	Only if TRACKING= 'OFFSET'	O/R(2)
DECTRACK=	*Float*	/ Offset tracking in "/min	Only if TRACKING= 'OFFSET'	O/R(3)
GUIDING =	'GUIDER' | 'COMMANDED'	/ Guding method in case of offset tracking	Only if TRACKING= 'OFFSET'. 'GUIDER' means that a guiding chip was used, 'COMMANDED' means that only the telescope controller was told to induce the offsets.	O

(1) Either APTDIA or APERTURE must be given. Note that the first is the diameter, the second the area.
(2) This will be required for Space Debris observations. In the NEO case, if not there, assume sidereal tracking.
(3) Only required if TRACKING= 'OFFSET'.

5.5 Camera information

Keyword	Value, type of value, or format of value	Proposed comment in header	Description	R/O?
INSTRUME=	*Float*		Camera name, e.g. 'SBIG ST-10 3 CCD camera'; 'Space Debris Camera'	R
XBINNING=	*Int*	/ binning in axis 1	*e.g.* XBINNING= 2	R
YBINNING=	*Int*	/ binning in axis 2	*e.g.* YBINNING= 2	R
GAIN = EGAIN =	*Float*	/ Gain in e-/DN	Gain in electrons / DN	R
CHIPTEMP= CCD-TEMP=	*Float*	/ CCD temperature in deg C	The temperature of the CCD. This must be given at least if the images are not calibrated, preferably all the time	O/R(1)
FILTER =		/ Filter band	Use standard filter designations, give a s string. E.g. 'U', 'B', 'V', 'R', 'none', 'IR block'	R

(1) Only required if the image is not calibrated.

5.6 Image information

Keyword	Value, type of value, or format of value	Proposed comment in header	Description	R/O?
OBSTYPE =	'ASTROMETRY' 'PHOTOMETRY' 'SPECTROSCOPY' 'BIAS' 'FLAT' 'DARK' 'MASTERBIAS' 'MASTERFLAT' 'MASTERDARK' ...	/ Describes for which use was the image taken	Images just taken for the follow-up of asteroids may not be good enough for performing absolute photometry. An image containing a spectrum will not be useful for astrometry. This keyword will indicate what the data was obtained for. It will also denote whether this image is a calibration frame. 'MASTER...' denotes images which were produced by stacking. Ideally, a HISTORY entry exists which refers to the original images used for stacking.	R(1)
RA =	*Float*	/ RA of center of image in decimal degrees	Give in decimal degrees	R(2)
DEC =	*Float*	/ Dec of center of image in decimal degrees	Give in decimal degrees	R(2)
EQUINOX =	2000.0	/ used coordinate system	The J2000 system should be used	R
SCALE =	*Float*	/ pixel scale in arcsec of one unbinned px	E.g. 0.62 – Note: This is the scale of an *unbinned* pixel. I.e. if XBINNING=2 and SCALE=0.62, then the actual pixel scale is 1.24.	R
HISTORY =	'Image was flat-corrected [on *date*]'		This is a text field which states that the image has been flat-fielded. The precise text is free. The date/time can be included, but is not required as it should be given via the DATE keyword.	R(3)
HISTORY =	'Image was dark-corrected [on		This is a text field which states that the image has been dark corrected. The precise text is free. The	R(3)

	date^]'		date/time can be included, but is not required as it should be given via the DATE keyword.	
HISTORY =	'Image was bias-corrected [on *date*]'		This is a text field which states that the image has been bias corrected. The precise text is free. The date/time can be included, but is not required as it should be given via the DATE keyword.	R(3)

(1): If not present, assume 'ASTROMETRY'.
(2): The information given here shall be the best knowledge of the center of the image coordinates. *I.e.* if the image just came from the telescope, it will contain the commanded pointing of the telescope. After plate solving, these values should contain the image center as obtained by the plate solving. It is recommended to either add a comment or a HISTORY keyword to specify which information the RA/DEC values are based on.
(3): This keyword is only required if the image has indeed been flat-corrected or bias-corrected. Alternatively, the keyword PROCSTAT= could be used, with the values 'Bias-subtracted' or 'Bias-processed'; 'Dark-subtracted' or 'Dark-processed'; 'Flat-divided' or 'Divided by flat' or 'Flat-processed' or a combination thereof (e.g. PROCSTAT= 'Bias-processed, Dark-processed, Flat-processed').
(4): In case of LN2-cooled CCD cameras, a dark correction may not be needed as long as the bias is subtracted. Then this keyword can be omitted.