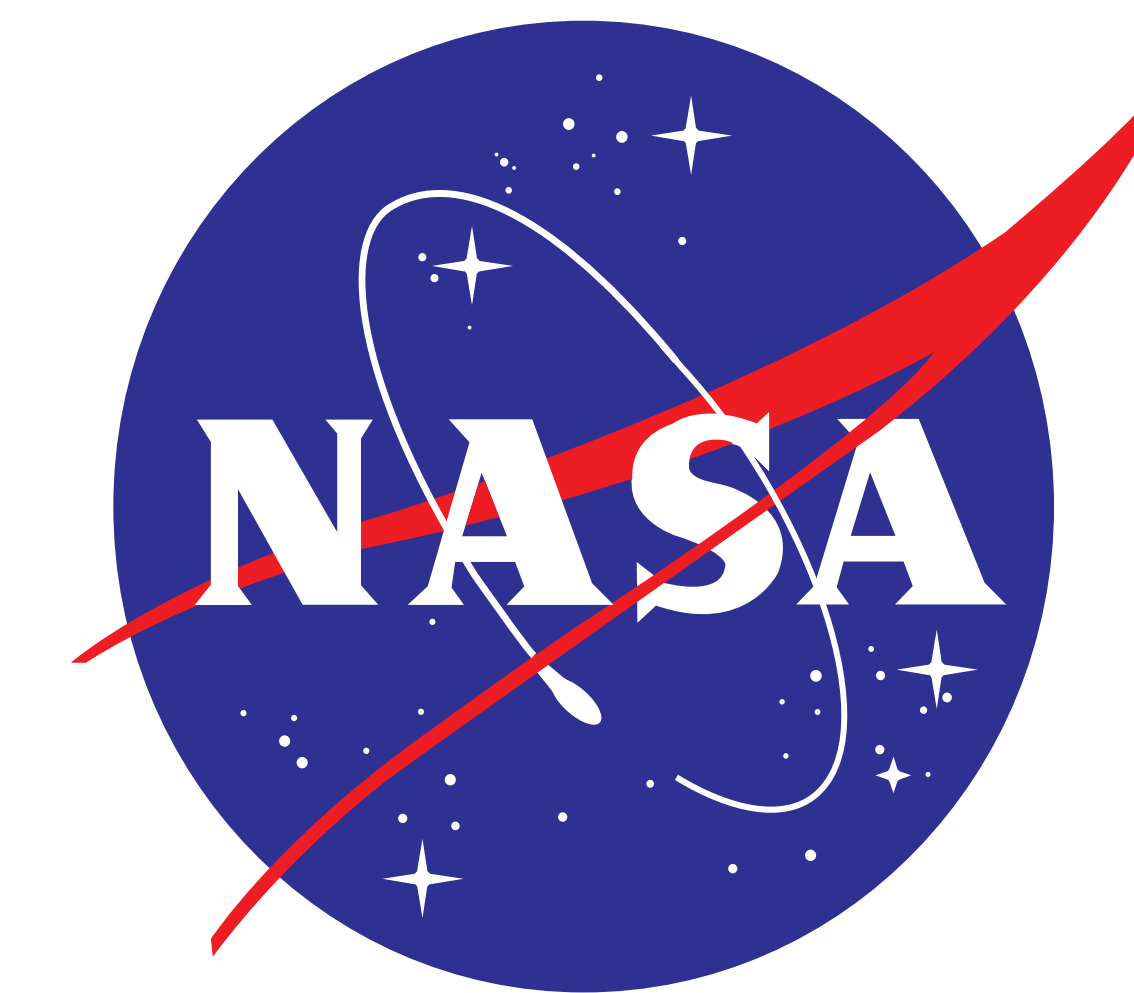


Recommendations for FITS Headers



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We present an example of best practices for FITS Headers to improve documentation and accessibility of solar physics data distributed as FITS files.

We build on existing norms and standards, including 'Proposed Keywords for SOHO' and the FITS World Coordinate System (WCS) conventions, and include recommendations on the use of FITS features and extensions to help make data stored and distributed in FITS better suited for both present-day usage and for long-term archiving.

Our goals include:

1. Allow both solar physicists and non-discipline scientists to easily understand what's in a file from an instrument they've never dealt with before
2. Allow scientists to quickly determine if the data is useful for their purposes.
3. Allow scientists to find where to get documentation on how to use the data.
4. Reduce the likelihood of keywords or data being misunderstood.
5. Give data providers a template to work from when designing FITS headers for new missions.
6. Allow scientists to determine which keywords are FITS or solar physics standards, and which are mission- or instrument-specific.
7. Ensure the data is accessible, understandable and usable over the long-term.
8. Reduce barriers to acknowledgment and citation of data.
9. Provide for identification of files and observations to enable scientists to check if data has been deprecated and obtain an appropriate replacement.

References:

DeForest, (1998). 'FITS Keywords used by ZTOOLS v1.02'.
<ftp://sohofp.nascom.nasa.gov/solarsoft/packages/ztools/fits-definitions.html>

Howard & Thompson, (2002). 'Proposed Keywords for SOHO'
http://stereo.gsfc.nasa.gov/~thompson/soho_keywords.pdf

Library of Congress, (2012). 'Sustainability of Digital Formats'
<http://www.digitalpreservation.gov/formats/>

Pence, Chiappetti, Page, Shaw & Stobie, (2010). 'Definiton of the Flexible Image Transport System (FITS), version 3.0'
<http://adsabs.harvard.edu/abs/2010A&A26A...524A..42P>

Thompson, (2006). 'Coordinate Systems for Solar Image Data'
<http://adsabs.harvard.edu/abs/2006A&A26A...449..791T>

SIDC, (2012). 'PROBA2 Science Center: SWAP Analysis Manual'
<http://proba2.sidc.be/index.html/swap/>

CLEARLY IDENTIFY THE FILE AS FITS, AND PROVIDE A REFERENCE TO THE FITS STANDARDS DOCUMENTATION

PROVIDE AN E-MAIL ADDRESS OR OTHER CONTACT INFORMATION

PROVIDE URLS TO DOCUMENTATION (SEE POSTER #201.27)

PROVIDE THE ORIGINAL FILENAME OR OTHER UNIQUE IDENTIFIER

FULLY SPELL OUT ABBREVIATIONS OR OTHER CODED VALUES

PROVIDE A DESCRIPTION OF THE DATA IN GENERIC TERMS

INCLUDE MEASURES OF DATA QUALITY AND COMPLETENESS

CONSIDER THE INTENDED AUDIENCE: IF ONLY THE PI TEAM CAN MAKE USE OF A GIVEN FIELD, CONSIDER STORING IT IN A SUPPLEMENTARY DATABASE

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1 SIMPLE = T / Conforms to the FITS standard
2 COMMENT = FITS (Flexible Image Transport System) format is defined in 'Astronomy
3 COMMENT = and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
4 COMMENT = http://adsabs.harvard.edu/abs/2001A&A26A...376..359H
5 COMMENT = Additional information on FITS available at http://fits.gsfc.nasa.gov/
6 BITPIX = 16 / number of bits per data pixel
7 NAXIS = 2 / number of data axes
8 NAXIS1 = 1024 / length of data axis 1
9 NAXIS2 = 1024 / length of data axis 2
10 COMMENT = -----
11 COMMENT = ---Documentation & Contact Information-----
12 COMMENT = This is a level-1 SWAP FITS file produced by p2sw_prep v1.1 at the Royal
13 COMMENT = Observatory of Belgium. If you have difficulty with this file or wish
14 COMMENT = to make suggestions for improvements, please contact the SWAP
15 COMMENT = Instrument Team via email at swap_lyra@oma.be.
16 COMMENT = For information on data rights, keyword definitions, citing this data
17 COMMENT = and up-to-date reports on known problems and data quality, see:
18 COMMENT = http://dx.doi.org/10.5067/example/PROBA2_SWAP_Level1
19 COMMENT = -----
20 COMMENT = ---Observation Identification-----
21 FILENAME = 'swap_lv1_20110806_000614.fits' / FITS filename
22 FILE_TMR = 'swap_00908512694209_a56942a.fits' / SWTMR filename
23 FILE_RAW = 'BINSWAP201108060006280000379138PROCESSED' / raw telemetry filename
24 FILE_TAR = 'BINSWAP_5354_SVA1_2011.08.06T03.26.56.tar' / raw telemetry package
25 COMMENT = -----
26 COMMENT = ---Temporal Information-----
27 DATE = '2011-08-06T03:37:49' / UTC time of FITS file creation
28 DATE-OBS = '2011-08-06T00:06:14.708' / UTC time of observation
29 COMMENT = -----
30 COMMENT = ---Instrument & Processing Summary-----
31 LEVEL = 1 / data processing level
32 CREATOR = 'P2SW_PREP.PRO v1.1' / FITS creation software
33 ORIGIN = 'ROB' / Royal Observatory of Belgium
34 TELESCOP = 'PROBA2' / satellite name
35 INSTRUME = 'SWAP' / instrument name
36 OBJECT = 'Sun EUV' / object observed
37 FILTER = 'Al' / Aluminum filter
38 DETECTOR = 'CMOS 1Kx1K' / HAS CMOS detector 1024x1024 pixels
39 WAVELNTH = 174 / [Angstrom] bandpass peak response
40 PHSPARA = 'INTENSITY' / Physical parameter represented in the data
41 COMMENT = -----
42 COMMENT = ---Readout Mode, Data Scaling & Statistics-----
43 OBS_MODE = 'Variable off-pointing' / sun_cen, fix_off, var_off, cme_track
44 CAP_MODE = 'CDS' / (DS,CDS) capture mode
45 EXPTIME = 10.0000 / [s] commanded exposure time
46 BSCALE = 0.00625000 / ratio of physical to array value at 0 offset
47 BZERO = 204.800 / physical value for the array value 0
48 BUNIT = 'DN/s/pixel' / unit of physical value
49 DATAMIN = 0.00000 / minimum valid physical value
50 DATAMAX = 371.100 / maximum valid physical value
51 DATAVALS = 1048576 / [count] number of data values
52 MISSVALS = 0 / [count] number of missing values
53 TOTVALS = 1048576 / [count] expected number of data values
54 PERCENTD = 100.0 / [percent] ratio of data to expected values
55 SNAVINT = 13.2449 / [DN/s] average intensity in calibrated image
56 COMMENT = -----
57 COMMENT = ---Detector Readout-----
58 FIRSTROW = 1 / first read-out detector row
59 LASTROW = 1024 / last read-out detector row
60 FIRSTCOL = 1 / first read-out detector column
61 LASTCOL = 1024 / last read-out detector column
62 REBIN = 'off' / on-board rebin (2x2 pixel average)
63 COMMENT = -----
64 COMMENT = ---Projection & Pointing-----
65 WCSNAME = 'Helioprojective-cartesian' / aligned with solar North
66 CTYPE1 = 'HPLN-TAN' / WCS axis X
67 CTYPE2 = 'HPLT-TAN' / WCS axis Y
68 CUNIT1 = 'arcsec' / WCS axis X units
69 CUNIT2 = 'arcsec' / WCS axis Y units
70 CD1_1 = 3.16226783969 / WCS coordinate description matrix
71 CD1_2 = 0.00000 / WCS coordinate description matrix
72 CD2_1 = 0.00000 / WCS coordinate description matrix
73 CD2_2 = 3.16226783969 / WCS coordinate description matrix
74 CDELT1 = 3.16226783969 / [arcsec] average pixel scale along axis 1
75 CDELT2 = 3.16226783969 / [arcsec] average pixel scale along axis 2
76 CRVAL1 = 0.00000 / [arcsec] reference point WCS axis X
77 CRVAL2 = 0.00000 / [arcsec] reference point WCS axis Y
78 CRPIX1 = 355.053 / [pixel] reference point axis 1
79 CRPIX2 = 493.145 / [pixel] reference point axis 2
80 LONPOLE = 180.000 / [deg] native longitude of the celestial pole
81 CROTA1 = 0.00000 / [deg] axis 1 to WCS rotation angle
82 CROTA2 = 0.00000 / [deg] axis 2 to WCS rotation angle
83 SXCEN = 355.160 / [pixel] axis 1 location of solar center in lv0
84 SWYCN = 503.870 / [pixel] axis 2 location of solar center in lv0

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INCLUDE UNITS IN THE CARD'S COMMENTS

INCLUDE A DESCRIPTION OF EACH KEYWORD IN THE CARD'S COMMENTS

PROVIDE ANY SIGNIFICANT CAVEATS IN COMMENT CARDS ESPECIALLY IMPORTANT: MARKING NON-SCIENCE QUALITY (EG. NRT IMAGES) AND MISLEADING VALUES (EG. SOHO TIMES)

IF REDUCED (BINNED, SUBSETTED) DATA, PROVIDE LINKS TO THE FULL OBSERVATION

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85 COMMENT = -----
86 COMMENT = ---Spacecraft Location (WCS) and Environment-----
87 DTPLAR1 = 442.000 / [s] predicted time to prev large angle rotation
88 DTPLAR2 = 2000.00 / [s] predicted time to next large angle rotation
89 P2_X0 = -0.000939076308338 / [deg] s/c yaw
90 P2_Y0 = 0.136016732901 / [deg] s/c pitch
91 P2_ROLL = 270.002914893 / [deg] s/c roll
92 SOLAR_EP = 3.93240510615 / [deg] s/c ecliptic North to solar North angle
93 HGLT_OBS = 6.09954735628 / [deg] s/c heliographic latitude
94 HGLN_OBS = -0.00256070883134 / [deg] s/c heliographic longitude
95 RSUN_ARC = 946.000717646 / [arcsec] photospheric solar radius
96 DSUN_OBS = 151753900282. / [m] s/c distance from Sun
97 HEEX_OBS = 151753900116. / [m] s/c Heliocentric Earth Ecliptic X
98 HEFY_OBS = -6575934.40209 / [m] s/c Heliocentric Earth Ecliptic Y
99 HEFZ_OBS = 2675581.07891 / [m] s/c Heliocentric Earth Ecliptic Z
100 GSEY_OBS = -17950.7202980 / [m] s/c Geocentric Solar Ecliptic X
101 GSEZ_OBS = 6575934.40210 / [m] s/c Geocentric Solar Ecliptic Y
102 GSEY_OBS = 2675581.07891 / [m] s/c Geocentric Solar Ecliptic Z
103 LOS_ALT = 720813.145355 / [m] s/c LOS altitude (1000000-no atmosphere)
104 TRAPPROT = 0.00000 / [ct/cm^2/s] AP-8 MAX > 10MeV @ 725km model
105 TRAPELEC = 0.00000 / [ct/cm^2/s] AE-8 MAX > 1MeV @ 725km model
106 GEOD_ALT = 721479.056001 / [m] s/c WGS84 altitude
107 GEOD_LAT = 5.35086988157 / [deg] s/c sub-point geodetic latitude
108 GEOD_LON = -88.2890113983 / [deg] s/c sub-point longitude
109 CAR_ROT = 2091.00 / Carrington rotation at s/c
110 COMMENT = -----
111 COMMENT = ---Temperatures-----
112 TEMP1DET = 2.30999100000 / [Celsius] detector temperature (SW HK T CF)
113 TEMP2DET = 2.23000500000 / [Celsius] detector temperature (SW HK T CF)
114 TTMP1 = '2011-08-06T00:05:51.000' / UTC time of detector temp 1st sample
115 TTMP2 = '2011-08-06T00:06:21.000' / UTC time of detector temp 2nd sample
116 TEMPDRK = 2.24678072991 / [Celsius] temperature used in dark subtraction
117 COMMENT = -----
118 COMMENT = ---SWAP Commanding-----
119 IS_PROC = 1 / on-board image processing
120 TRANTIME = 908512694209. / [OBT] transferring time
121 SACOTIME = 908512466474. / [OBT] start acquisition time
122 EACOTIME = 908512694209. / [OBT] end acquisition time
123 LANG_ROT = -0.707106781900 / commanded large angle rotation component
124 PAV_ROT0 = 0.00000 / commanded paving rotation component 0
125 PAV_ROT1 = -0.00120000000000 / commanded paving rotation component 1
126 HASSTDBY = 0 / HAS detector standby mode
127 READRDIV = 0 / read-out rate divider
128 PGA_OFFS = 59 / PGA offset
129 PGA_GAIN = 1 / PGA gain
130 LED_POW = 'off' / calibration LED power
131 LED_SEL = 'a' / calibration LED selection
132 HASBLACK = 4 / HAS detector black level
133 HASOFFST = 11 / HAS detector offset level
134 ARTEFX = 'on' / (off,on,cosmic rays) on-board artefact removal
135 RECODING = 'fixed' / (off, fixed, adaptive) on-board recoding
136 RECNUM = 3600 / recoding upper limit
137 RECBIAS = 10 / recoding lower limit
138 COMPRESS = 'jpeg' / (off,lzw,jpeg) on-board compression algorithm
139 LZWDCCOR = 'off' / LZW decorrelation
140 PN = 120 / on-board priority number
141 SZCOMP1 = 664688 / size of on-board compressed image
142 NPRESCR = 0 / # preserved pixels - cosmic rays
143 NPRESLZW = 0 / # preserved pixels - LZW decorrelation
144 COMMENT = -----
145 COMMENT = ---Fixity-----
146 CHECKSUM = 'FFD7HD97F0A7FD97' / HDU checksum updated 2011-08-06T03:37:50
147 DATASUM = '1341923158' / data unit checksum updated 2011-08-06T03:37:50
148 COMMENT = -----
149 COMMENT = ---Provenance-----
150 COMMENT = ID: swap_fits_template 3732 2010-09-28 20:42:23Z bogdan $
151 HISTORY SWTMR 132602
152 HISTORY SWEDG 132606
153 HISTORY FITSHEADSTRUCT run at: Sat Aug 6 03:37:43 2011
154 HISTORY p2sw_hdrchk v1.1 Computed detector temp.: 2.2467807 Celsius
155 HISTORY p2sw_pmcdiv v1.1 Reverted wrt swap_pmc_20100308_164500.fits
156 HISTORY p2sw_pixrep v1.1 Replaced wrt swap_satcds_20100113_152800.fits
157 HISTORY p2sw_drksub v1.1 Subtracted modeled dark with coefficients in
158 HISTORY p2sw_drksub v1.1 swap_dark_coefs_20110101_000000.save using
159 HISTORY p2sw_drksub v1.1 T=275.40 K, dt=10.0000 s
160 HISTORY p2sw_pmcprep v1.1 Reverted wrt swap_pmc_20100308_164500.fits
161 HISTORY p2sw_flatcds v1.1 Flat-field: swap_flatcds_20100308_164500.fits
162 HISTORY p2sw_despike v1.1 Despiked at the 6.0-sigma level (8548 pix)
163 HISTORY p2sw_imgcor v1.1 Image scaled to square pixels
164 HISTORY p2sw_imgcor v1.1 Image rotated to solar North up
165 HISTORY p2sw_exnorm v1.1 Exposure time normalized data (DN/s/pixel)
166 HISTORY Written by IDL: Sat Aug 6 03:37:49 2011
167 END

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GROUP TOGETHER KEYWORDS THAT DESCRIBE RELATED CONTENT

USE COMMENT CARDS TO SEPARATE GROUPINGS

MARK INSTRUMENT-SPECIFIC (NON-STANDARD) KEYWORDS. THOSE FIELDS MAY LATER BE OFFICIALLY DEFINED IN AN INCOMPATIBLE WAY.

TRANSLATE ENGINEERING METADATA (EG. VOLTAGES, FILTER WHEEL POSITIONS) INTO SCIENTIFICALLY USEFUL VALUES.

PROVIDE CHECKSUMS TO VERIFY FILE INTEGRITY

DESCRIBE THE PROCESSING APPLIED

PROVIDE VERSIONS OF SOFTWARE AND CALIBRATION USED

INCLUDE FITS STANDARD KEYWORDS, EVEN IF IT IS POSSIBLE TO DERIVE THOSE VALUES

Still to be done:

Determine what fields are official & de facto standards, and which are necessary for various types of analysis & processing.