AIA/SDO FITS Keywords for Scientific Usage and Data Processing at Levels 0.0, 0.5, 0.9, and 1.0

(A document in progress)

Keyword Nomenclature:
(Telemetry keywords are ***bold italic***; derived keywords are **bold**; & potential keywords are *italic*)
{# = Integer (~ 0-999); @ = Optional single character A-Z; & = Alpha-numeric}

LL@#	Lower Left corner pixel for row (X) / column (Y) for ROI # on CCD
NAXIS@#	Dimension (in pixels) along row (X) / column (Y) for ROI # on CCD
A@&&&&&&	Originating from telemetry data (@: H = HDR, F = FRB, I = ISP)

(Note: The definitions of the output data levels included below have been extracted from the Stanford SDO DRMS and SUMS computer database data to a certain level.)

1. Basic Image Information for Level 0 (and Above)

Definition of Level 0

1. Image Header
   Generated from metadata consists only of keywords derived directly from the image camera header data and its characteristics, such as image size, date of observation, telescope, instrument, etc.
2. Image Data
   Decompressed raw data recompressed using gzip (see http://www.gzip.org/).

From science data packet image header (HDR) information (definition in Doc. AIA02019):

AHAPID = Packet APID (11b; from HDR)
AHTCS = Time Code Seconds (32b; from HDR)
AHTCSS = Time Code Sub Seconds (32b; from HDR)
AHFSN = Frame Serial Number (32b; from HDR)
AHT1RN = Target 1 Row Number (7b; from HDR) for center pixel (to nearest 32nd row or column)
AHT1CN = Target 1 Column Number (7b; from HDR) for center pixel
AHT2RN = Target 2 Row Number (7b; from HDR) for center pixel
AHT2CN = Target 2 Column Number (7b; from HDR) for center pixel
AHFDBID = Frame Definition Block ID (8b; from HDR)
AHTAPC = TAP Code (4b; from HDR)
AHBITID = Bit Select ID (4b; from HDR)
AHCPIDN = Compression parameter *n* (4b; from HDR)
AHCPIDK = Compression parameter *k* (4b; from HDR)
AHLUTID = Lookup Table ID (8b; from HDR)

It is proposed to utilize the 2 highest order bits in the Frame Serial Number to specify the AIA telescope number, **TELESCOP** , associated with the data image, such that

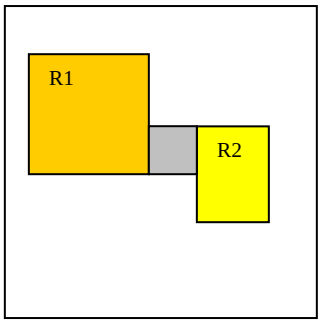
AHFSN = **ATLID** (2b; telescope # -1) + **AFSN** [Frame Serial Number (least significant 30b)],

where **ATLID =** [0, 1, 2, 3] = **TELESCOP** – 1, or **TELESCOP** = **ATLID** + 1 = [1, 2, 3, 4].

From Frame Definition Block (generated and stored in database (GDB) on the ground):

AFDBID = Frame Definition Block ID (8b; from GDB)
AFCRM = CCDReadoutMode (4b; from GDB) for number of ports: 1, 2, 4 (= 3, 2, 1)
AFDBSM = SummingMode (4b; from GDB) for summing: 1x1, 2x2, 4x4 (= 0, 1, 2)
AFDBNW = NumWindows (4b; from GDB) for number of ROI windows (= 0, 1, 2)
AFNR1 = NumRows1 (16b; from GDB) for length of region 1 in pixels
AFNC1 = NumCols1 (16b; from GDB) for height of region 1 in pixels
AFNR2 = NumRows2 (16b; from GDB) for length of region 2 in pixels
AFNC2 = NumCols2 (16b; from GDB) for height of region 2 in pixels
AFDBRL = RowLength (16b; from GDB) for length of row for extracted regions

Using the basic keywords above for the center pixel of the 2 target regions of interest (ROI) and for the lengths and heights of the regions, together with the following figure from the AIA Sequence Control Document (#AIA02019), the derived keywords below can be determined for each of the ROI, 1, 2, and ROI 3 in between if the first two are overlapping in columns but not rows, as shown.



Derived Keywords:

NUMWIN = ***AFDBNW*** **+** TBD	[number of window regions of interest: = 0 for full (4kx4k) CCD = 1 for 1 ROI; = 2 for 2 ROI; = 3 for extra region when first 2 regions have overlapping columns but not rows, as in the figure.]
LLX1 = ***AHT1RN*** * 32 – ***AFNR1*** / 2	[region 1 (R1) lower left corner, X variable]
LLY1 = ***AHT1CN*** * 32 – ***AFNC1*** / 2	[R1 lower left corner, Y variable]
LLX2 = ***AHT2RN*** * 32 – ***AFNR2*** / 2	[R2 lower left corner, X variable]
LLY2 = ***AHT2CN*** * 32 – ***AFNC2*** / 2	[R2 lower left corner, Y variable]
LLX3 = **LLX1** + ***AFNR1***	[gray region (R3) lower left corner, X variable]
LLY3 = **LLY1**	[R3 lower left corner, Y variable]
NAXISX1 = ***AFNR1***	[R1 number of pixels along X axis]
NAXISY1 = ***AFNC1***	[R1 number of pixels along Y axis]

NAXISX2 = ***AFNR2*** [R2 number of pixels along X axis]
NAXISY2 = ***AFNC2*** [R2 number of pixels along Y axis]
NAXISX3 = ***AFDBRL*** – ***AFNR1*** – ***AFNR2*** [R3 number of pixels along X axis]
NAXISY3 = **LLY2** + ***AFNC2*** – **LLY1** [R3 number of pixels along Y axis]
NAXIS = 2, 2, 1, 1 [corresponds to number of axes of images for **NUMWIN** = 0, 1, 2, 3 to not confuse simple FITS file readers.]
NAXIS1 = 4096, **NAXISX1,** total number of pixels in area**,** total number of pixels in area
NAXIS2 = 4096, **NAXISX2,** 0, 0
[both correspond to the axis length for **NUMWIN** = 0, 1 and **NAXIS1** to total number of pixels for **NUMWIN** = 2, 3 with NAXIS2 = 0 to not confuse simple FITS file readers.]

Quality/Sanity Check of FDB ID:

Does ***AHFDBID = AFDBID ?***

Reconstructing the acquired image requires in addition the appropriate use of ***AHCPIDN***, ***AHCPIDK***, ***AHTAPC, AHBITID, AHLUTID, AFDBSM,*** and ***AFCRM.*** The observation time can be determined (TBD) from ***AHTCS*** and ***AHTCSS***.

INSTRUME = AIA	Name of instrument	
SIMPLE	True if conforming FITS file	(HMI uses as T in L0)
BITPIX	Bits/pixel, negative for floating point	(HMI uses as 16 in L0)
DATE-END	End date/time of observation	
DATE-OBS	Date of observation, usually start time	
DATE_OBS	DATE-OBS with light travel correction	
MJD	Modified Julian Day (long interger used in conjunction with **TIME** to provide efficient binary time representation in SSW)	
MJD-OBS	Modified Julian Date of observation	
TIME	Milliseconds of day	

2. Additional Information for Level 0.5 (and Above)

Definition of Level 0.5 (Note: The intended use of this level is for the planner in near-real time.)

1. Image Header
   Metadata for Level 0 plus that generated from the associated image status packet. (See accompanying/latest image status packet (ISP) list)
2. Image Data
   Decompressed raw data recompressed using gzip. (Same as that for Level 0)

More Basic Keywords for ROI Quality/Sanity Check:

AICRE = *A8390* = AIA_IMG_CCD_ROW_END (16b; from ISP)
AICRS = *A838F* = AIA_IMG_CCD_ROW_START (16b; from ISP)
AIR1CE = *A839A* = AIA_IMG_ROI_1_COL_END (16b; from ISP)
AIR1CS = *A8396* = AIA_IMG_ROI_1_COL_START (16b; from ISP)
AIR2CE = *A839B* = AIA_IMG_ROI_2_COL_END (16b; from ISP)
AIR2CS = *A8397* = AIA_IMG_ROI_2_COL_START (16b; from ISP)

ROI Quality/Sanity Check (using ISP & FDB keywords to obtain the same derived keywords as above):

LLX1 = ***AICRS***	[R1 lower left corner, X variable]
LLY1 = ***AIR1CS***	[R1 lower left corner, Y variable]
LLX2 = ***AGCRE*** – ***AFNR2***	[R2 lower left corner, X variable]
LLY2 = ***AIR2CS***	[R2 lower left corner, Y variable]
LLX3 = **LLX1** + ***AFNR1***	[R3 lower left corner, Y variable]
LLY3 = **LLY1**	[R3 lower left corner, Y variable]
NAXISX1 = ***AFNR1***	[R1 number of pixels along X axis]
NAXISY1 = ***AIR1CE*** – **LLY1**	[R1 number of pixels along Y axis]
NAXISX2 = ***AFNR2***	[R2 number of pixels along X axis]
NAXISY2 = ***AIR2CE*** – **LLY2**	[R2 number of pixels along Y axis]
NAXISX3 = **LLX2** – **LLX1** – ***AFNR1***	[R3 number of pixels along X axis]
NAXISY3 = ***AIR2CE*** – **LLY1**	[R3 number of pixels along Y axis]

AICNTC = *A8317* = AIA_IMG_CENTER_COL (16b; from ISP)
AICNTR = *A8316* = AIA_IMG_CENTER_ROW (16b; from ISP)
AICSFT = *A8319* = AIA_IMG_COL_SHIFT (16b; from ISP)
AIRSFT = *A8318* = AIA_IMG_ROW_SHIFT (16b; from ISP)

CCD Information

AIPSM = *A838B* = AIA_IMG_PAR_SUM_MODE (8b; from ISP)
AISSM = *A8388* = AIA_IMG_SER_SUM_MODE (8b; from ISP)

Quality/Sanity Check with FDB Summing Mode (TBD)

2.1 Instrument, Mechanisms, & Observable Information

AISTATE = *A8284* = AIA_IMG_STATE (3b; from ISP)
from which the telescope number, **TELESCOP,** can be sanity checked and the ISS status bit on, **ISS,** can be obtained.
AIASEN = *A82BF* = AIA_IMG_AS_ENCODER (16b; from ISP)
AIFWEN = *A8292* = AIA_IMG_FW_ENCODER (8b; from ISP)
AIAECTYP = (?) (2b; from ISP [TBD])
WAVELNTH = (?) (8b; from ISP [TBD]) Wavelength of observation (character or Angstroms)

Exposure Information:

AIMGSHEN = A8296 = AIA_IMG_SH_ENCODER (8b; from ISP)
AIMGOTS = A8285 = AIA_IMG_OBT_TIME_SH_SEC (32b; from ISP)
AIMGOTSS = A8286 = AIA_IMG_OBT_TIME_SH_SS (16b; from ISP)
AIMGSHCE = A8213 = AIA_IMG_SH_CMDED_EXPOSURE (16b; from ISP)
AIMSHOBC = A853E = AIA_IMG_SH_OPEN_BOT_CENTR (24b; from ISP)
AIMSHOBE = A853F = AIA_IMG_SH_OPEN_BOT_EDGE (24b; from ISP)
AIMSHOTC = A8540 = AIA_IMG_SH_OPEN_TOP_CENTR (24b; from ISP)
AIMSHOTE = A8541 = AIA_IMG_SH_OPEN_TOP_EDGE (24b; from ISP)
AIMSHCBC = A8214 = AIA_IMG_SH_CLOSE_BOT_CENTR (24b; from ISP)
AIMSHCBE = A8291 = AIA_IMG_SH_CLOSE_BOT_EDGE (24b; from ISP)
AIMSHCTC = A853C = AIA_IMG_SH_CLOSE_TOP_CENTR (24b; from ISP)
AIMSHCTE = A853D = AIA_IMG_SH_CLOSE_TOP_EDGE (24b; from ISP)

EXPTIME Exposure time in seconds

2.2 Time Information

ATCSO27 = APID027_TIMECODE_SECONDS (32b; from ISP)
ATCSS027 = APID027_TIMECODE_SUBSECS (32b; from ISP)

Another Quality/Sanity Check can be performed for the observation time

Sequence/State Information

ASQFGSN = AIA_SEQ_FRAME_SN (32b; from ISP)
ASQFGID = AIA_SEQ_FRAME_ID (32b; from ISP)
AIFCPS = A8225 = AIA_IMG_FC_POSITION (16b; from ISP)
AIFDBID *= A8315* = AIA_IMG_FDB_ID (16b; from ISP)
AIAECDL = A82F6 = AIA_IMG_AEC_DELAY (16b; from ISP)
AIAECTI = A82CA = AIA_IMG_AEC_TABLE_ID (16b; from ISP)
AIAECST = A8215 = AIA_IMG_AEC_STATUS (8b; from ISP)
TBD = AIA_SEQ_EXP
TBD = AIA_SEQ_FL_REL_TIME
TBD = AIA_SEQ_FRLIST_POS
TBD = AIA_SEQ_FTSID
TBD = AIA_SEQ_FLID
TBD = AIA_SEQ_STATE
TBD = AIA_SEQ_FRAME_COUNT
TBD = Target type for AEC

Quality/Sanity Check of FDB ID:

Does ***AIMFDBID = AFDBGID*** **?**

3. Other Keywords

Coordinate Information (including instrument & spacecraft pointing)

CD#_#@	Dimensioned transformation matrix
CDELT#@	Pixel spacing along axis #
CROTA#	Coordinate rotation (see footnote 1)
CRPIX#@	Reference pixel along axis #
CRVAL#@	Reference value along axis #
CTYPE#@	Type of coordinate axis #
CUNIT#@	Units along axis #
PC#_#@	Transformation matrix
XCEN	X co-ordinate of array center (float)
YCEN	Y co-ordinate of array center (float)

Observation Planning Information

OBJECT	Name of object
OBJ_ID	Object identifier, e.g. active region number
OBSERVER	Name of observer
OBS_PROG	Name of the observing program
SCI_OBJ	The science objective of the observation

Temperature Information:

AIMCCTP1 = A8282 = AIA_IMG_CEB_CCD_TEMP1 (8b; from ISP)
AIMCCTP2 = A8283 = AIA_IMG_CEB_CCD_TEMP2 (8b; from ISP)

Data and Image Data Information

AIMGCPPR = A838C = AIA_IMG_COMPR_PAR (32b; from ISP)
AIMPCGT1 = A830C = AIA_IMG_PIX_COUNT_GT_TH1 (16b; from ISP)
AIMPCGT2 = A830D = AIA_IMG_PIX_COUNT_GT_TH2 (16b; from ISP)
AIMPCGT3 = A830F = AIA_IMG_PIX_COUNT_GT_TH3 (16b; from ISP)
AIMPCGT4 = A8310 = AIA_IMG_PIX_COUNT_GT_TH4 (16b; from ISP)
AIMPCLT1 = A8311 = AIA_IMG_PIX_COUNT_LT_TH1 (16b; from ISP)
AIMPCLT2 = A8312 = AIA_IMG_PIX_COUNT_LT_TH2 (16b; from ISP)
AIMPCLT3 = A8313 = AIA_IMG_PIX_COUNT_LT_TH3 (16b; from ISP)
AIMPCLT4 = A8314 = AIA_IMG_PIX_COUNT_LT_TH4 (16b; from ISP)

EXTEND	FITS file may contain extensions
COMMENT	ASCII comment (can be multiple)
HISTORY	ASCII history record (can be multiple)
FILENAME	Name of the data file

TBD: keywords for focus, GT statistics, H/K packet #, S/C info., orbit info., etc., when available and derived keywords, e.g., statistics, bad pixels, flat fielding, image center, etc.

Reformatter Information

DATE	FITS creation date
ORIGIN	Responsible organization or institution

VERSION
QUALITY
LEVEL NUMBER
PIPELINE VERSION

More level definitions

Definition of Level 0.9

1. Header
   Metadata for Level 0.0 plus that generated from the associated image status packet and from the spacecraft and other ancillary metadata, such as roll angle, orbital information, fine-pointing information, etc., to provide the lowest level of scientifically-useful data, expressed in terms of the accompanying AIA/SDO FITS keyword names list, where applicable.
2. Data
   Decompressed raw data recompressed using gzip. (Same as that for Level 0.0)

Definition of Level 1.0

1. Header
   Metadata for Level 0.0 plus that generated from the associated image status packet and from spacecraft and other ancillary metadata, such as roll angle, orbital information, fine-pointing information, calibration information on flat field used and missing pixel correction value, etc., to provide the lowest level of scientifically-useful data, expressed in terms of the accompanying AIA/SDO FITS keyword names list, where applicable. Additional keywords will be added, when needed.
2. Data
   Decompressed raw data (level 0) calibrated for exposure time and flat field plus corrected for missing pixels. Possible other corrections may be added where needed. Recompress processed data using gzip.