ALMA Science Archive FITS Data product requirements and recommendations.

Version 1.8

Revisions history

Version number	Note	Author	date
Original document	Spreadsheet notes	M. Lacy	2012
Ver 1	Transferred to document format.	E. Muller	2013
Ver 1.1-1.5	Various refinements to keywords following recommendations from A. Richards and F. Stoehr.	E.Muller	2013
Ver 1.6-1.7	Updated re. E.Villard (QA2flag) & Stoehr (SPW,OBSTYPE).	E. Muller	Feb 2015
ver 1.8	Correct MJD-OBS and MJD-AVG format. Add ZSOURCE	E. Muller	Nov, 2015

Contents

1. Scope

This document contains the recommendations and requirements for ALMA FITS products of the Inter-ARC ALMA Science Archive Working Group (ASAWG) with the view to including a metadataset that is complete and easily accessible by the ALMA Science Archive (ASA). The recommendations made here are formulated by the Science Archive Working Group after consultation throughout the members' respective ARCs, with the considered and assumed preferences of the ALMA user-base in mind.

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2. Motivation

The recommendations made here are made considering both the minimum and anticipated benefit for archive researchers. The focus is towards enabling access to a dataset whereby archive researchers can easily and efficiently access and filter through the ALMA science archive, to locate data relevant for analysis and publication. Additional priorities include accurate archiving of associated publications, minimizing effort of the Pipeline and Archive group, and to provide a reference document for the pipeline and archive groups.

The recommendations made here are in the context of standardizing the ALMA-archived science data structure, not to redefine the operation of CASA. They pertain only to the products held in ALMA science Archive.

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3. FITS keywords

FITS keywords following are sorted into a categories, based on their role and the source of the standard (if any). Some keywords my appear redundant and accessible from other existing keywords (e.g. BND-CNT, the band centre, can be computed from CRVAL, CDELT and CRPIX values) - in these cases, providing the computation-less value is more useful for the the Archive and general archive users.

For simplicity, Archive FITS products will have a single primary header, without extensions.

3.1.Required keywords: Primary HDU

This section is more simply a requirement by FITS standard 3.0, and is included for completeness. The primary head must contain at least the five keywords with the order shown on the right.

Note that ALMA will not have extensions in the FITS products, and the primary header will contain all FITS keywords.

Required HDU keyword order.

1. SIMPLE
2. BITPIX
3. NAXIS
4. NAXISn
5. END

SIMPLE *(Mandatory FS3.0)*

Description: Signifies FITS file structure conforms to FITS 3.0 standard.
Type: logical
Required value: T
Currently exists in CASA FITS products.

BITPIX *(Mandatory FS3.0)*

Description: Indicates bits per data value. Exact Value for ALMA use is not mandated
Type: integer
Currently exists in CASA FITS products.

NAXIS *(Mandatory FS3.0)*

Description: Number of axes in the associated data array.
Type: Integer (limited 4 in ASA).
Required values: ALMA science archive will provide only:
1. Continuum/integrated (velocity/frequency collapsed) images with two celestial axes and one polarization axis) (on degenerate axis)
2. Spectral line cubes, with two celestial axes, one frequency or velocity axis, and one polarization axes.
Currently exists in CASA FITS products.

NAXISn *(Mandatory FS3.0)*

Description: Number of elements along axis n of a data array (n = 1-NAXIS). ASA data *must* have four NAXIS terms.
Type: integer.
Required value: n=1 to 4
Currently exists in CASA FITS products

END *(Mandatory FS3.0)*

Description: Required keyword to bracket end of primary header (and any other headers). No associated value.

3.2. WCS & Coordinate information

PC##i##j *(Reserved kwd FS3.0)*

Description: Linear transformation matrix between pixel axes j and intermediate coordinate axes i.
Type: Float
Required value: N(N-1)/2 of these terms will exist, i.e. for four dimensions (two spatial, one frequency and one polarization axis, 6 PC terms must be incorporated into the header.
Pipeline produced data PC terms will = 0 when i=j, and 0 otherwise (i.e. the trivial case).
Currently exists in CASA FITS products.

PVi_m *(Reserved kwd FS3.0)*

Description: Numeric parameter values for intermediate world coordinate axis i, (m is parameter number).
Type: Float
Required value: No restrictions.

CTYPEn *(Standard FS3.0)*

Description: FITS WCS keywords, describing type of axis n (where n is a value between 1 and NAXIS). The format of this keyword implicitly describes the linearity.
Type: String
Required values: Numbering of CTYPE axes will be hierarchically arranged i.e. he highest to lowest CTYPE number will describe the axes; polarization - velocity/frequency - celestial dimension. The fourth axis *must* exist, but may be degenerate.

Currently exists in CASA FITS products
- Permitted celestial axis types :
  - RA--SIN/DEC-SIN
- Permitted frequency axis types :
  - 'FREQ' (linear CUNIT='Hz'),
- Permitted velocity axis types :
  - 'VELO-LSRK' (nonlinear, CUNIT='Hz'),
- Permitted Polarisation axis types :
  - 'STOKES' (no unit)
  - CRVALn = 1, -5 or -6 for unpolarized, XX linear or YY linear,respectively)

CTYPE1 *must be* Celestial
CTYPE2 *must be* Celestial
CTYPE3 *must be* Freq,
CTYPE 4 *must be* Stokes

CRVALn *Reserved kwd FS3.0*

Description: Coordinate value of position in degrees, specified in CRPIX.
Type: Float
Currently exists in CASA FITS products.

Permitted values for CRVALn for polarisation axes for ALMA science archive are limited to:

CRVAL	Polarization	Stokes
1	Unpolarised	I
2	Linear	Q
3	Linear	U
4	Circular	V
-5	Linear	XX
-6	Linear	YY

CDELTn *Reserved kwd FS3.0*

Description: Increment-per-pixel of axis n, in degrees
Type: Float
Required Vaues: Cannot be zero.
Currently exists in CASA FITS products

CRPIXn *Reserved kwd FS3.0*

Description: Reference pixel (or fraction thereof), dimensionless, for data axis n.
Type: Float.
Required values. ALMA will deliver data with CRPIXn set to = Round(NPIXEL/2.)
Currently exists in CASA FITS products

CUNITn *Reserved kwd FS3.0*

Description: Units of axis n
Type: Character
Required value:
Permitted units for celestial axes:
'degrees '
Permitted units for polarisation axes:
' '
Permitted units for frequency axes:
'Hz '
Currently exists in CASA FITS products.

RA *new ALMA keyword*

Description: The Right Ascension coordinate of image center, in the system specified in EQUINOX and RADESYS.
Type: Float
Required units: Degrees
Does not exist in CASA FITS products.

DEC *new ALMA keyword*

Description: The Declination coordinate of image center, in the in the system specified in EQUINOX and RADESYS.
Type: Float
Required units: Degrees
Does not exist in CASA FITS products.

RA_TARG *new ALMA keyword*

Description: The Right Ascension coordinate of target (computed or specified from user and OT), in in the system specified in EQUINOX and RADESYS.
Type: Float
Required value: Degrees
Does not exist in CASA FITS products.

DEC_TARG *new ALMA keyword*

Description: The Declination coordinate of target (computed or specified from user and OT), in in the system specified in EQUINOX and RADESYS.
Type: Float
Required value: Degrees
Does not exist in CASA FITS products.

RADESYS *(Reserved kwd FS3.0)*

Description: Name of the reference frame of equatorial or ecliptic coordinates.
Type: Character
Required value: ‘ICRS’
Currently exists in CASA FITS products.

RESTFRQ *(Reserved kwd FS3.0)*

Description: Contingent on the type of measurements being made:
For transition line measurements: the rest frequency of the of the spectral feature of interest in Hz.
For continuum measurements: the centre of the band of the spectral window.
Type: Float
Required units: Hz
Currently exists in CASA FITS products.

SPECSYS *(Reserved kwd FS3.0)*

Description: Reference frame for freq axis.
Type: Character
Required value: ‘LSRK’
Currently exists in CASA FITS products.

ZSOURCE *(Reserved kwd FS3.0)*

Description: Redshift of course.
Type: Float
Does not exist in CASA FITS products.

3.3. Observations Time information

TIMESYS *(Suggested. kwd FS3.0)*

Description: The principal time system for time-related keywords and data.
Type: Character
Required value: 'UTC'
Currently exists in CASA FITS products.

DATE *Reserved kwd FS3.0*

Description: FITS file creation date (specifically, the date the HDU was created).
Type: String
Required format: Date string of format: YYYY-MM-DDThh:mm:ss[.sss. . .].
Currently exists in CASA FITS products.

DATE-OBS *(Reserved kwd FS3.0)*

Description: Observation start time.
Type: Character
Required format: Date string with a format of YYYY-MM-DDThh:mm:ss[.sss. . .].
Does not exist in CASA FITS products.

DATE-END *(new ALMA keyword)*

Description: Time of end observation
Type: Character
Required format: Date string with a format of YYYY-MM-DDThh:mm:ss[.sss. . .].
Does not exist in CASA FITS products.

MJD-OBS *(Reserved kwd FS3.0)*

Description: Modified Julian Date (JD – 2,400,000.5) of start of observation,
Type: Float
Required format: Float with a format of F5.5
Does not exist in CASA FITS products.

MJD-AVG *(Reserved kwd FS3.0)*

Description: Modified Julian Date (JD – 2,400,000.5) of the mid-point of the observation.
Type: Float
Required format: Float with a format of F5.5
OBSGEO-? [X/Y/Z] must be correct at the time given by MJD-AVG.
Does not exist in CASA FITS products.

EQUINOX *(Reserved kwd FS3.0)*

Description: Epoch of the mean equator and equinox in years, This keyword is the standard replacement for "EPOCH".
Type: Float
Required value: 2.000000000000E+03
Currently exists in CASA FITS products.

3.4. Image and Beam properties

BMAJ *(AIPS memo #117, 2012)*

Description: Restoring beam FWHM major axis
Type: Float
Required units: Degrees
Currently exists in CASA FITS products.

BMIN *(AIPS memo #117, 2012)*

Description: Restoring beam FWHM minor axis
Type: Float
Required units: Degrees
Currently exists in CASA FITS products.

BPA *(AIPS memo #117, 2012)*

Description: Restoring beam position angle
Type: Float
Required units: Degrees
Currently exists in CASA FITS products.

BSCALE *(Reserved kwd FS3.0)*

Description: Value used to linearly scale pixel values
Type: Float
Required value: 1.0
Currently exists in CASA FITS products.

BZERO *(Reserved kwd FS3.0)*

Description: Value used to numerically offset pixel values
Type: Float
Required value: 0.0
Currently exists in CASA FITS products.

BTYPE *(Reserved kwd FS3.0)*

Description: FITS flux scale type
Type: Character
Required value: 'Intensity'
Currently exists in CASA FITS products.

Included for backwards compatibility with AIPS

BUNIT *(Reserved kwd FS3.0)*

Description: FITS flux scale unit
Type: Character
Required value: 'JY/BEAM'
Currently exists in CASA FITS products.

DATAMAX *(Reserved kwd FS3.0)*

Description: maximum valid physical value represented by the array
Type: Float
Required units: Jy/Beam
Does not exist in CASA FITS products.

DATAMIN *(Reserved kwd FS3.0)*

Description: minimum valid physical value represented by the array.
Type: Float
Required units: Jy/Beam
Does not exist in CASA FITS products.

DYNRANGE *new ALMA keyword*

Description: Estimation of Dynamic range of interferometer data. Equal to DATAMAX/CHANRMS
Type: Float
Does not exist in CASA FITS products.

NPOL *new ALMA keyword*

Description: Number of orthogonal polarizations observed and contributing to the data
Type: integer
Required value: This will only ever be = 1 (only linear XX) or =2 (linear XX and linear YY observed).
Does not exist in CASA FITS products.

STOKES *new ALMA keyword*

Description: List of data Stokes parameters
Type: Character
Required value: some, or all of 'I', 'Q', 'U' or 'V'
Note some overlap WITH CTYPEn='STOKES' and CRVALn
Does not exist in CASA FITS products.

BNDCTR *new ALMA keyword*

Description: The center frequency of data in the FITS array
Type: Float
Required units: Hz
Note, there is some overlap in scope of this keyword with CTYPE='FREQ'.
Does not exist in CASA FITS products.

BNDWID *new ALMA keyword*

Description: The effective bandwidth of data in the FITS array
Type: Float
Required units: Hz
Note, there is some overlap in scope of this keyword with CTYPE='FREQ'.
Does not exist in CASA FITS products.

BNDRES *new ALMA keyword*

Description: Effective frequency resolution of data in the FITS array
Type: Float
Required units: Hz
Note: overlap with CDELT (CTYPE='FREQ')
Does not exist in CASA FITS products.

MAXANGSC *new ALMA keyword*

Description: The maximum angular scale resolved by the 12m array
Type: Float
Required units: arcseconds
Computed with: (0.6 X lambda [m])/(minimum projected basline [m])
Does not exist in CASA FITS products.

CHANRMS *(AIPS memo #117, 2012)*

Description: Computed RMS of calibrated dataset
Type: Float
Required units: Jy/Beam
Does not exist in CASA FITS products.

SPATRES *new ALMA keyword*

Description: Geometric average of the min and the max beam axes.
Type: Float
Required units: arcseconds
Does not exist in CASA FITS products.
Note: some overlap with BMAJ and BMIN

UVRANGE *new ALMA keyword*

Description: Median, first and third quartile of the UV length distribution.
Type: Float
Required units: kilowavelengths
Does not exist in CASA FITS products.
Note: some overlap with MAXANGSC

SIDLOB *new ALMA keyword*

Description: Ratio of intensity PSF peak to first sidelobe, Computed from the dirty beam (12m, ACA, TP combined).
Type: Float
Required units: dimensionless, expressed a percentage.
Does not exist in CASA FITS products.

UVNOISE *new ALMA keyword*

Description: RMS of all visibilities (12m, ACA, TP) combined
Type: Float
Required units: Jy/Beam
Does not exist in CASA FITS products.

FOV *new ALMA keyword*

Description: The total field of view of the image
Type: Float
Required value: Degrees^2
Does not exist in CASA FITS products.
Note: populating keyword is the jurisdiction of ASA

EFFDIAM *new ALMA keyword*

Description: Effective Diameter of field of view.
Type: Float
Required value: Degrees
Computed with: 2 x sqrt(AREA/pi)
Does not exist in CASA FITS products.
Note: populating keyword is the jurisdiction of ASA

FOOTPRINT *new ALMA keyword*

Description: String list of RA and DEC coordinates defining the 50% FHWP of the observed area (12m and ACA combined if necessary).
Type: Long string
Required value: Character (with values as RA & De coordinates in J2000)
Does not exist in CASA FITS products.
Note: populating keyword is the jurisdiction of ASA

SPW *new ALMA keyword*

Description: Identification numbers (may be list), of spectral window, from ASDM
Type: Integer list
Does not exist in CASA FITS products.

3.5. Telescope & Data acquisition information.

OBSGEO-X *(Reserved kwd FS3.0)*

Description: X–coordinate in cartesian geocentric terrestrial reference frame, specifying the location the observation took place at time given in MJD-AVG.
Type: Float
Required units: m
Currently exists in CASA FITS products.

OBSGEO-Y *(Reserved kwd FS3.0)*

Description: Y–coordinate in cartesian geocentric terrestrial reference frame, specifying the location the observation took place at time given in MJD-AVG.
Type: Float
Required units: m
Currently exists in CASA FITS products.

OBSGEO-Z *(Reserved kwd FS3.0)*

Description: Z–coordinate in cartesian geocentric terrestrial reference frame, specifying the location the observation took place at time given in MJD-AVG.
Type: Float
Required units: m
Currently exists in CASA FITS products.

LONPOLE *(Reserved kwd FS3.0)*

Description: Longitude in the coordinate system of celestial system's north pole.
Type: Float
Required units: Degrees
Currently exists in CASA FITS products.

LATPOLE *(Reserved kwd FS3.0)*

Description: Latitude in the coordinate system of celestial system's north pole.
Type: Float
Required units: Degrees
Currently exists in CASA FITS products.

TELESCOP *(Reserved kwd FS3.0)*

Description: Observatory name
Type:
Required value: "ALMA"
Currently exists in CASA FITS products.

MINELTP *new ALMA keyword*

Description: Minimum Elevation range achieved during observations of target data, of total power ants
Type: Float
Required units: Degrees , NaN for no data
Does not exist in CASA FITS products.

MINEL12 *new ALMA keyword*

Description: Minimum Elevation range achieved during observations of target data of 12m ants
Type: Float
Required units: Degrees.
Does not exist in CASA FITS products.

MINEL7 *new ALMA keyword*

Description: Minimum Elevation range achieved during observations of target data, of 7m ants
Type: Float
Required units: Degrees. NaN for no data
Does not exist in CASA FITS products.

EPHEMERI *TBC*

Description: Telescope tracking
Type: TBD
Required value: TBD
Currently exists in CASA FITS products.

OBSMODE *new ALMA keyword*

Description: List of observing modes contributing data to the image
Type:
Permitted values:

"MOSAIC"	(For mosaic pointings)
"SINGLEP"	(for single pointings)
"OTF"	(For On the Fly maps)
"NUTATED"	(For nutator obs, TBD)

Does not exist in CASA FITS products.

EXPTIMTP *new ALMA keyword*

Description: Integration time of Total power ants.
Type: Float
Required units: Seconds, 0 for no data
Does not exist in CASA FITS products.

EXPTIM12 *new ALMA keyword*

Description: Integration time of 12m ants
Type: Float
Required units: Seconds, 0 for no data
Does not exist in CASA FITS products.

EXPTIM7 *new ALMA keyword*

Description: Integration time of 7m ants
Type: Float
Required units: Seconds, 0 for no data
Does not exist in CASA FITS products.

INSTRUME *(Reserved kwd FS3.0)*

Description: The receiver band used for the image observations
Type: Character
Required values: 'BX', where X= integer 3-9.
Does not exist in CASA FITS products.

OBSTYPE *new ALMA keyword*

Description: Intent of observation as described in the OT (regardless of actual role in dataset - e.g. the bandpass source is still "bpcal", even if for some reason, it was not used to calibrate the data). Values can be combined as necessary.
Type: Character
Required values:

"bcal"	(bandpass cal observations),
"pcal"	(Phase cal observations)
"gcal"	(amplitude cal observations)
"target"	(Observations of science target)

Does not exist in CASA FITS products.

CALIBR *new ALMA keyword*

Description: Calibrator observing strategy
Type: Comma-separated string with: *intent calname* e.g. "phaseTP 3c249, bpass c234"
Required value: Sanitized to remove characters likely to interfere with normal linux operations.
Does not exist in CASA FITS products.

ALMASW *new ALMA keyword*

Description: ALMA Software version
Type: Character
Required Format: consistent with ALMA software version format rules
Does not exist in CASA FITS products.

MINPRBL *new ALMA keyword*

Description: Minimum projected baseline
Type: Float
Required units: m
Does not exist in CASA FITS products.

MAXPRBL *new ALMA keyword*

Description: Maximum projected baseline
Type: Float
Required units: m
Does not exist in CASA FITS products.

NANTTP *new ALMA keyword*

Description: Number of ALMA ACA total power antennas contributing to data
Type: Integer
Required format: 0 for no data.
Does not exist in CASA FITS products.

NANT12M *new ALMA keyword*

Description: Number of ALMA 12 m main-array antennas contributing to data.
Type: Integer
Required format: No limitations.
Does not exist in CASA FITS products.

NANT7M *new ALMA keyword*

Description: Number of ALMA ACA 7 m antennas contributing to data
Type: Integer
Required format: 0 for no data.
Does not exist in CASA FITS products.

PADLIST *new ALMA keyword*

Description: List of ALMA pad names contributing to data
Type: Character
Does not exist in CASA FITS products.

3.6. PI & Proposal and PI information.

PROPCODE *new ALMA keyword*

Description: Proposal code
Type: Character
Required format: WWWW.X.YYYYY.Z
WWWW = four digit year
X = one digit Cycle number
Y = four digit proposal number
Z = one character proposal type
Does not exist in CASA FITS products.

OBSERVER *(Reserved kwd FS3.0)*

Description: Name of Primary investigator
Type: Character
Required value: name will be of format:
lastname,fnitical, firstname
Does not exist in CASA FITS products.

COILIST *new ALMA keyword*

Description: Names of coinvestigators
Type: Character
Required format: Names for each CO-I will be in the format of *lastname, initial, firstname.*
The name list will be semi-colon separated.
Does not exist in CASA FITS products.

TITLE *(Reserved kwd FS3.0)*

Description: Parent project name
Type: Character
Required format: No limitations
Does not exist in CASA FITS products.

3.7. Pipeline, Archive and Request information.

OBJECT *(Reserved kwd FS3.0)*

Description: Name for source observed
Type: Character
Required format: (Sanitized) character string
Currently exists in CASA FITS products.

PIPVER *new ALMA keyword*

Description: Pipeline processing version
Type: Character string
Required value: No limitations
Does not exist in CASA FITS products.

PPRNAME *new ALMA keyword*

Description: Proposal request
Type: String
Required value: Value will be sanitized to remove characters likely to interfere with normal UNIX operations
Does not exist in CASA FITS products.

CASAVER *new ALMA keyword*

Description: CASA version
Type: Character
Required value: No limitations
Does not exist in CASA FITS products.

ORIGIN *(Reserved kwd FS3.0)*

Description: Organization responsible for dataset
Type: Character
Required value: “JAO”
Does not exist in CASA FITS products.

ASDMLIST *new ALMA keyword*

Description: ASDMs contributing to the data
Type: Character
Required values: No limits. Value will be sanitized to remove characters likely to interfere with normal UNIX operations
Does not exist in CASA FITS products.

COMBLEVL *new ALMA keyword*

Description: Level of combination of data in FITS
Type: String
Required value: “GROUP” or “MEMBER”

GROUP *new ALMA keyword*

Description: Group observing unit set status uid
Type: String
Required value: Value will be sanitized to remove characters likely to interfere with normal UNIX operations
Does not exist in CASA FITS products.

MEMBER *new ALMA keyword*

Description: Member observing unit set status uid
Type:
Required value:
Does not exist in CASA FITS products.

SGOALNME *new ALMA keyword*

Description: Group observing unit set name
Type:
Required value:
Does not exist in CASA FITS products.

SGOAL *new ALMA keyword*

Description: Group observing unit set status uid
Type:
Required value:
Does not exist in CASA FITS products.

SBNAMES *new ALMA keyword*

Description: List of scheduling block names contributing to dataset
Type: Character
Required value: Value will be sanitized to remove characters likely to interfere with normal UNIX operations
Does not exist in CASA FITS products.

SBUIDS *new ALMA keyword*

Description: Scheduling block UIDs contributing to dataset.
Type: Character
Required value: TBD
Does not exist in CASA FITS products.

DATATAG *new ALMA keyword*

Description: Data tag
Type: Long String
Required value: “This paper makes use of the following ALMA data: ADS/JAO.ALMA# [Project code]. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ.”
Does not exist in CASA FITS products.

LINTRN *new ALMA keyword*

Description: List of line transitions in pipeline-produced data.
Type: Character
Required format: Line transition names will be formatted consistently with the convention outlined in XXXXXX. i,e. 12CO(1-0).
Does not exist in CASA FITS products.

QA2FLAG *new ALMA keyword*

Description: QA2 status
Type: String
Required value: “PASS”, “SEMIPASS” or FAIL”
Does not exist in CASA FITS products.
Note: populating keyword is the jurisdiction of ASA

HISTORY *(Reserved kwd FS3.0)*

Description: Processing history
Type: Character
Required format: “HISTORY ddd mmm hh;mm;ss yyyy process name and process parameters’
History list will follow all other keywords except “END”.
Currently exists in CASA FITS products.

4.Appendix II- Keywords altered from version 1.1

SPATRES - returned keyword
UVRANGE - added keyword
SIDELOB - added keyword
UVNOISE - added keyword
CTYPEn - modified to accept only RA/DEC: LSRK, and CTYPE4 is only polarization. CYTPE4 must be Stokes.
OBSRA and OBSDEC removed
RATARG, DECTARG -> RA_TARG, DEC_TARG
RADECSYS - required type now ICRS
SPECSYS - required value now LSRK
RESTFREQ - now defined for line transition and continuum measurements.
BUNIT - required value now 'JY/BEAM'
DATAMIN, DATAMAX - added required units: Jy/Beam
DYNRANGE - modified to specify "Equal to DATAMAX/CHANRMS"
Added MAXANGSC - maximum angular scale.
CHANNELRMS - changed to "CHANRMS"
CHANRMS - added required units Jy/beam
FOOTPRINT - added keyword
OBSERVAT - removed keyword
MINBL, MAXBL - changed to MINPRBL and MAXPRBL & modified so they are the max/min projected baselines.
PAD### - changed to PADLIST
COI### - changed to COILIST
OUSID, GOUSID, MOUSID, POUSID, SGOUSID - removed keyword
OUSSID, OUSNME - removed keyword
POUSNAME PRJSTUID, POUSSID- removed keyword
MOUSNME GOUSNME- removed keyword
PPRNAME - type changed to "String" and Required value to explain it will be sanitized.
ORIGIN - defined as "organisation responsible for dataset " - we now require this to be "JAO"
GOUSSID/MOUSSID/SGOUSSID - change to GROUP/MEMBER/SGOAL
SGOUSNME - changed to SGOALNAME
COMBLEVL - keyword added, to hold string for level of combination of data in FITS ("GROUP" or "MEMBER")
DATATAG - modified : "string" type, and required value is publications' acknowledgment text
LINTRN - Modified to remove reference to continuum parameter (non-existent parameter)
QA2REPOR - keyword removed
QA2FLAG - type specified (string), and required value is "pass", "semipass" or "fail".
PLPAR### - keyword removed.

5.Appendix III- Keywords altered from version 1.0

BND-CTR -> BNDCTR
BND-WID -> BNDWID
BND-RES -> BNDRES
RA_TARG -> RATARG
DEC_TARG -> DECTARG
RA_NOM -> RA
DEC_NOM -> DEC
COI### -> COI
Other changes:

1. EXPTIM, NANT and MINEL are now =0 when no data exists (for TP and 7m ants)
2. OBSERVER now has *lastname,initial,firstname*
3. COI field no has *lastname,initial,firstname; lastname, initial, firstname... ...*
4. CALIBR -> description and type updated.
5. Sundry modifications/additions to section 5.

Previous changes:

OBSID	The observing project uid.
PROCR###	The list of processors contributing data to the observation.
IMAGEUID	The image uid
OBJ-TYPE	The source type
CATALOG	The source catalog
SPATRES	Angular resolution
IM-COSYS	The right ascension and declination of the coordinate system
MIN-AZ, MAX-AZ	Azimuth range
BLPA-RMS	Rms of baseline position angle

PIPEUID	The pipeline results entity uid
BL-MAJ	Rms of baseline major axis
BL-MAJ	Rms of baseline minor axis
BLPA-RMS	Rms of baseline position angle

6.Appendix IV - Annotated example FITS header

REQUIRED KEYWORDS:

```
SIMPLE = T                          / Standard FITS
BITPIX = -32                        / Floating point (32 bit)
NAXIS = 4                           / Number of axes in the associated data array.
NAXIS1 = 240                        / NAXIS 1 dimension
NAXIS2 = 240                        / NAXIS 2 dimension
NAXIS3 = 1                          / NAXIS 3 dimension
NAXIS4 = 1                          / NAXIS 4 dimension
```

WCS & COORDINATE INFORMATION

```
PC001001 = 1.000000000000E+00       / Transformation matrix terms
PC002001 = 0.000000000000E+00       / Transformation matrix terms
PC003001 = 0.000000000000E+00       / Transformation matrix terms
PC004001 = 0.000000000000E+00       / Transformation matrix terms
PC001002 = 0.000000000000E+00       / Transformation matrix terms
PC002002 = 1.000000000000E+00       / Transformation matrix terms
PC003002 = 0.000000000000E+00       / Transformation matrix terms
PC004002 = 0.000000000000E+00       / Transformation matrix terms
PC001003 = 0.000000000000E+00       / Transformation matrix terms
PC002003 = 0.000000000000E+00       / Transformation matrix terms
PC003003 = 1.000000000000E+00       / Transformation matrix terms
PC004003 = 0.000000000000E+00       / Transformation matrix terms
PC001004 = 0.000000000000E+00       / Transformation matrix terms
PC002004 = 0.000000000000E+00       / Transformation matrix terms
PC003004 = 0.000000000000E+00       / Transformation matrix terms
PC004004 = 1.000000000000E+00       / Transformation matrix terms
PV2_1 = 0.000000000000E+00          / Parameter value #1 for world coordinate axis #2,
PV2_2 = 0.000000000000E+00          / Parameter value #2 for world coordinate axis #2,
CTYPE1 = 'RA---SIN'                 / WCS term: type of Axis 1
CRVAL1 = 2.853708750000E+02         / WCS term: Reference pixel value, axis 1
CDELT1 = -4.444444444444E-05        / WCS term: Increment per pixel, axis1
CRPIX1 = 1.210000000000E+02         / WCS term: Reference pixel number, axis 1
CUNIT1 = 'deg '                     / WCS term: Unit of axis 1
CTYPE2 = 'DEC--SIN'                 / WCS term: type of Axis 2
CRVAL2 = -3.703011111111E+01        / WCS term: Reference pixel value, axis 2
CDELT2 = 4.444444444444E-05         / WCS term: Increment per pixel, axis 2
CRPIX2 = 1.210000000000E+02         / WCS term: Reference pixel number, axis 2
CUNIT2 = 'deg '                     / WCS term: Unit of axis 2
CTYPE3 = 'FREQ '                    / WCS term: type of Axis 3
CRVAL3 = 2.315424966698E+11         / WCS term: Reference pixel value, axis 3
CDELT3 = 3.870856771975E+09         / WCS term: Increment per pixel, axis 3
CRPIX3 = 1.000000000000E+00         / WCS term: Reference pixel number, axis 3
CUNIT3 = 'Hz '                      / WCS term: Unit of axis 3
CTYPE4 = 'STOKES '                  / WCS term:  type of Axis 4
CRVAL4 = 1.000000000000E+00         / WCS term: Reference pixel value, axis 4
CDELT4 = 1.000000000000E+00         / WCS term: Increment per pixel, axis 4
CRPIX4 = 1.000000000000E+00         / WCS term: Reference pixel number, axis 4
CUNIT4 = ' '                        / WCS term: Unit of axis 4
RA = 2.853708750000E+02             / [deg] Image centre RA
DEC = -3.703011111111E+01           / [deg] Image centre Dec
RA_TARG = 2.853708750000E+02        / PI-defined target RA
DEC_TARG = -3.703011111111E+01      / PI-defined target Dec
RADESYS = 'ICRS '                   / Teference system for equatorial coordinates
RESTFRQ = 2.315424966698E+11        / Rest Frequency (Hz)
SPECSYS = 'LSRK'                    / Spectral reference frame
ZSOURCE = 0.000485787               / Redshift of Source
```

OBSERVATIONS TIME INFORMATION

TIMESYS = 'UTC ' / Time system for time-related keywords and data in the HDU
DATE = '2012-10-11T09:27:32.760000' / Date FITS HDU file was written
DATE-OBS = '2012-06-17T05:56:15.792000' / Date and time of start of observations comprising data in array
MJD-OBS = 55927.50000 / Modified Julian Date of start of the observation,
MJD-AVG =55928.54321 / Modified Julian Date of the mid-point of the entire observation.
DATE-END = '2012-06-18T05:56:15.792000' / Date and time of last observations comprising data in array
EQUINOX = 2.000000000000E+03 / Equinox of source coordinates and uvw

IMAGE & BEAM PROPERTIES

BMAJ = 2.228875623809E-04 / [deg] Restoring beam FWHM major axis
BMIN = 1.697528362274E-04 / [deg] Restoring beam FWHM minor axis
BPA = 5.713778686523E+01 / [deg] Restoring beam position
BSCALE = 1.000000000000E+00 / PHYSICAL = PIXEL*BSCALE + BZERO
BZERO = 0.000000000000E+00 / PHYSICAL = PIXEL*BSCALE + BZERO
BTYPE = 'Intensity' / Brightness (pixel) unit (may be depreciated)
BUNIT = 'JY/BEAM ' / Physical units in which the quantities in array
DATAMAX = 1.5 / Maximum valid physical value represented by the array
DATAMIN = -.05 / Minimum valid physical value represented by the array
DYNRANGE = 5.0 / Actual achieved Dynamic range in dataset.
NPOL = 2 / Number of orthogonal polarizations observed
STOKES = 'I ' / List of data Stokes parameters
BNDCTR = 2.315424966698E+11 / [Hz] Center frequency of data in the FITS array
BNDWID =1.875E+9 / [Hz] Effective bandwidth of data in the FITS array
BNDRES =0.488281E+6 / [Hz] Effective frequency resolution of data in the FITS array
MAXANGSC = 2000.0 / Maximum angular scale of data in FITS
CHANRMS = 0.0003 / RMS per channel of FITS in Jy/Beam
SPATRES = 0.7 / Geometric average of the min and the max beam axes in arcsec
UVRANGE = 202345 123456 345677 / Median, 1st and 3rd quartile of the UV length distribution in klambda.
SIDLOB = 0.003 / Ratio of dirty beam peak to first sidelobe
UVNOISE - 0.34 / Visibility noise in Jy/Beam
FOV = 0.1234 / [deg^2] Total field of view of the image
EFFDIAM = 0.1 / [Deg] Effective diameter of the field of view
FOOTPRINT = " Union ICRS (Polygon 213.915594 19.180544 213.915557 19.180542 213.915518
19.180655 213.915189 19.181873 213.915225 19.181853 213.915225 19.181882
Polygon 213.914501 19.180928 213.914424 19.180931 213.914391 19.180994
213.914396 19.181031 213.914428 19.181054 213.914428 19.181025 213.914450
19.181030 213.914469 19.181071 213.914469 19.181042 213.914505 19.181051
213.914500 19.181014 213.914535 19.181023)" / Footprint outlining region as polygon with vertices in RA/Dec J2000
SPW = 23 45 67 89 / Spectral window identification number, derived from ASDM

TELESCOPE & DATA ACQUISITION INFORMATION

OBSGEO-X = 2.225142180269E+06 / [m] X–coordinate of observation position wrt Geocentric reference
OBSGEO-Y = -5.440307370349E+06 / [m] Y–coordinate of observation position wrt Geocentric reference
OBSGEO-Z = -2.481029851874E+06 / [m] Z–coordinate of observation position wrt Geocentric reference
LONPOLE = 1.800000000000E+02 / [deg] Long. in native coordinate system of celestial system's north pole.
LATPOLE = -3.703011111111E+01 / [deg] Lat in native coordinate system of celestial system's north pole,
TELESCOP = 'ALMA ' / Telescope name
MINELTP = 65.0 / [deg] Minimum elevation of ALMA total power antennas (0 for no data)
MINEL12 = 25.0 / [deg] Minimum elevation of ALMA 12 m main array antennas
MINEL7 = 65.0 / [deg] Minimum elevation of ALMA 7 m ACA antennas (0 for no data)
EPHEMERI = ' ' / Ephemeris details, if any
OBSMODE = 'std interferometery, RSTR' / List of observing modes contributing data
EXPTIMTP = 720 / [s] On-source obs time of ALMA ACA total power antennas (0 for no data)
EXPTIM12 = 300 / [s] On-source obs time of ALMA 12 m main array antennas
EXPTIM7 = 1440 / [s] On-source obs time of ALMA ACA 7 m antennas (0 for no data)
INSTRUME = 'BAND6 ' / ALMA name for observations Band
OBSTYPE = 'science' / Intent of observation
CALIBR = 'phaseTP 3c249, phase12 c234' / Calibrator observing strategy
ALMASW = 'R.1.10 ' / ALMA Software version
MINPRBL = 7 / [m] Minimum baseline
MAXPRBL = 6000 / [m] Maximum baseline
NANTTP =4 / Number of ALMA ACA total power antennas used in data (0 for no data)
NANT12M = 55 / Number of ALMA 12 m main-array antennas used in data
NANT7M = 7 / Number of ALMA ACA 7 m ACA antennas used in data (0 for no data)
PADLIST = 'J501, J503, J503' / List of ALMA pad names contributing to data

PROPOSAL & PI INFORMATION

PROPCODE = '2011.0.00101.S' / ALMA proposal ID
OBSERVER = 'feynman,p, richard' / ALMA Ident of PI
COILIST = 'sagan, e, carl; hawking, w, stephen' / ALMA ident of COIs
TITLE = 'An astronomy project with ALMA' / ALMA proposal title

PIPELINE, ARCHIVE & REQUEST INFORMATION

OBJECT = 'Lup_25 ' / PI name for the object observed.
PIPVER = '1.0' / Pipeline version used to produce FITS data
PPRNAME = 'uid://A005/X006/X007 ' / Pipeline processing request name
CASAVER = 'CASA 3.4.0 (release r19988)' / Version of CASA used by pipeline to produce FITS data
ORIGIN = 'JAO' / Organisation responsible for producing dataset.
ASDMLIST = 'uid___A002_X433c46_X4d2' / uid names of executionblocks contributing to data
COMBLEVL = "GROUP / Level at which data is combined in this FITS
GROUP = 'uid://A005/X006/X007' / Group observing unit set status ID
MEMBER = 'uid://A008/X009/X010' / Member observing unit set status ID
SGOAL = 'uid://A009/X010/X011' / Science Goal Observing unit set ID
SGOALNME = 'ExampleSGOUSname' / Science Goal Observing unit set name
SBNAMES = 'exampleSB1 ' / Names of scheduling blocks contributing to data in array
SBUIDS = 'uid://A017/X018/X019' / IDs of scheduling blocks contributing to data in array
DATATAG = 'This paper makes use of the following ALMA data: ADS/JAO.ALMA# [Project code]. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ '
LINTRN = '12CO(1-0)' / List of line transitions in pipeline-produced data
QA2FLAG = 'PASS' / QA2 flag description

HISTORY AND END

HISTORY Thu Oct 11 02:45:18 2012 Dummy history data
HISTORY Thu Oct 11 02:45:18 2012 More dummy history data
HISTORY Thu Oct 11 02:45:18 2012 Still more dummy history data
HISTORY Thu Oct 11 02:45:18 2012 and yet more dummy history data
END / End of HDU

7.Appendix V- Current Example FITS header

```
SIMPLE  =                    T /Standard FITS
BITPIX  =                  -32 /Floating point (32 bit)
NAXIS   =                    4
NAXIS1  =                  240
NAXIS2  =                  240
NAXIS3  =                    1
NAXIS4  =                    1
BSCALE  =   1.000000000000E+00 /PHYSICAL =
PIXEL*BSCALE + BZERO
BZERO   =   0.000000000000E+00
BMAJ    =   2.228875623809E-04
BMIN    =   1.697528362274E-04
BPA     =   5.713778686523E+01
BTYPE   = 'Intensity'
OBJECT  = 'Lup_25  '
BUNIT   = 'JY/BEAM '           /Brightness (pixel) unit
EQUINOX =   2.000000000000E+03
RADESYS = 'FK5     '
LONPOLE =   1.800000000000E+02
LATPOLE =  -3.703011111111E+01
PC001001=   1.000000000000E+00
PC002001=   0.000000000000E+00
PC003001=   0.000000000000E+00
PC004001=   0.000000000000E+00
PC001002=   0.000000000000E+00
PC002002=   1.000000000000E+00
PC003002=   0.000000000000E+00
PC004002=   0.000000000000E+00
PC001003=   0.000000000000E+00
PC002003=   0.000000000000E+00
PC003003=   1.000000000000E+00
PC004003=   0.000000000000E+00
PC001004=   0.000000000000E+00
PC002004=   0.000000000000E+00
PC003004=   0.000000000000E+00
PC004004=   1.000000000000E+00
CTYPE1  = 'RA---SIN'
CRVAL1  =   2.853708750000E+02
CDELT1  =  -4.444444444444E-05
CRPIX1  =   1.210000000000E+02
CUNIT1  = 'deg     '
CTYPE2  = 'DEC--SIN'
CRVAL2  =  -3.703011111111E+01
CDELT2  =   4.444444444444E-05
CRPIX2  =   1.210000000000E+02
CUNIT2  = 'deg     '
CTYPE3  = 'FREQ    '
CRVAL3  =   2.315424966698E+11
CDELT3  =   3.870856771975E+09
CRPIX3  =   1.000000000000E+00
CUNIT3  = 'Hz      '
CTYPE4  = 'STOKES  '
CRVAL4  =   1.000000000000E+00
CDELT4  =   1.000000000000E+00
CRPIX4  =   1.000000000000E+00
CUNIT4  = '        '
PV2_1   =   0.000000000000E+00
PV2_2   =   0.000000000000E+00
RESTFRQ =   2.315424966698E+11 /Rest Frequency (Hz)
SPECSYS = 'TOPOCENT'           /Spectral reference frame
ALTRVAL =  -0.000000000000E+00 /Alternate frequency
reference value
ALTRPIX =   1.000000000000E+00 /Alternate frequency
reference pixel
VELREF  =                  259 /1 LSR, 2 HEL, 3 OBS, +256
Radio
COMMENT casacore non-standard usage: 4 LSD, 5 GEO, 6
SOU, 7 GAL
TELESCOP= 'ALMA    '
OBSERVER= 'mschreiber'
DATE-OBS= '2012-06-17T05:56:15.792000'
TIMESYS = 'UTC     '
OBSRA   =   2.853708750000E+02
OBSDEC  =  -3.703011111111E+01
OBSGEO-X=   2.225142180269E+06
OBSGEO-Y=  -5.440307370349E+06
OBSGEO-Z=  -2.481029851874E+06
DATE    = '2012-10-11T09:27:32.760000' /Date FITS file was
written
ORIGIN  = 'CASA 3.4.0 (release r19988)'
HISTORY CASA START LOGTABLE
HISTORY 2012-10-11T07:39:32 INFO
SRCCODE='imager::clean()'
HISTORY 2012-10-11T07:39:32 INFO
SRCCODE='imager::clean()'
HISTORY Thu Oct 11 02:45:18 2012  HISTORY
im::calcuvw() [fields = [1], refcode =
HISTORY > J2000, reuse = 0] UVW and visibilities changed
with calcuvw
HISTORY Thu Oct 11 02:45:45 2012  HISTORY flagcmd []
taskname = flagcmd
HISTORY Thu Oct 11 02:45:45 2012  HISTORY flagcmd []
vis      = "uid___A002_X433
HISTORY >c46_X4d2.ms"
HISTORY Thu Oct 11 02:45:45 2012  HISTORY flagcmd []
inpmode = "table"
HISTORY Thu Oct 11 02:46:46 2012  HISTORY flagcmd []
taskname = flagcmd
HISTORY Thu Oct 11 02:46:46 2012  HISTORY flagcmd []
vis      = "uid___A002_X433
HISTORY >c46_X4d2.ms"
HISTORY Thu Oct 11 02:46:46 2012  HISTORY flagcmd []
inpmode = "table"
HISTORY Thu Oct 11 02:50:12 2012  HISTORY
calibrater::setdata [Beginning selectv
HISTORY >is--(MSSelection version)-------, chanmode=none
nchan=1 start=0 step=1
HISTORY >Start='0km/s' mStep='0km/s' msSelect='']
HISTORY Thu Oct 11 02:50:24 2012  HISTORY
calibrater::correct [] Beginning corre
HISTORY >ct----------------------------
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
taskname=applycal
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
version: 3.4.0 3.4.0 rev.
HISTORY > 19988 Sat 2012/06/09 04:50:50 UTC
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
vis         = "uid___A002_
HISTORY >X433c46_X4d2.ms"
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
field       = "0"
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
spw         = "17,19"
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
intent      = ""
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
selectdata  = True
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
timerange   = ""
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
uvrange     = ""
HISTORY Thu Oct 11 02:50:37 2012  HISTORY applycal []
antenna     = ""
```

HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
scan   = ""
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
observation = ""
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
msselect   = ""
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
gaintable   = ['uid___A002
HISTORY >_X433c46_X4d2.ms.tsys',
'uid___A002_X433c46_X4d2.ms.wvr.smooth', 'uid__
HISTORY >A002_X433c46_X4d2.ms.antpos']
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
gainfield   = ['0', '', ''
HISTORY >]
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
interp   = ['linear,lin
HISTORY >ear']
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
spwmap   = [[0, 1, 2, 3
HISTORY >, 4, 5, 6, 7, 8, 9, 9, 11, 11, 13, 13, 15, 15, 9, 9,
11, 11], [], []]
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
gaincurve   = False
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
opacity   = []
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
parang   = False
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
calwt   = True
HISTORY Thu Oct 11 02:50:37 2012 HISTORY applycal []
flagbackup = False
HISTORY Thu Oct 11 02:50:38 2012 HISTORY
calibrater::setdata [Beginning selectv
HISTORY >is--(MSSelection version)-------, chanmode=none
nchan=1 start=0 step=1
HISTORY >Start='0km/s' mStep='0km/s' msSelect='']
HISTORY Thu Oct 11 02:50:50 2012 HISTORY
calibrater::correct [] Beginning corre
HISTORY >ct----------------------------
HISTORY Thu Oct 11 02:50:58 2012 HISTORY applycal []
taskname=applycal
HISTORY Thu Oct 11 02:50:58 2012 HISTORY
.
.
<snip 7 pages of history>
.
.
HISTORY CASA END LOGTABLE
END