WFCAM
UKIRT

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CHANGE RECORD

Issue	*Date*	*Section affected*	*Change Description*
0.1	*2002-Oct-16*	*all*	*1st version for time of Software CDR*
0.2	*2003-Feb-10*	*all*	*Tables include comment records; new headers including "TSCAN"s*
0.3	*2003-Feb-13*	*all*	*Correction of typos (thanks to Jim Lewis); some additional comments; addition of sections listing example headers.*
0.4	*2003-Feb-14*	*all*	*"TSCAN" becomes "JITTER"; added READOUT; expanded environment headers (from JAC); updated examples.*
0.5	*2003-Feb-24*	*all*	*Document title changed form WFCAM FITS headers to WFCAM HDS container and FITS headers*
			New section on contents of HDS container
			New astrometric (WCS) headers: CDi_j and
			New examples
0.6	*2003-Mar-05*	*all*	*Removed NOFFSETS header*
			Added SURVEY, SURVEY_I, DETECTID, PCSYSID, SDSUID, CAMROLE and GAIN headers
			New HDSTRACE and examples
1.0	*2003-Oct-21*	*all*	*Added TILENUM, MJD-OBS*
			Revised WCS items following discussions
			Added section on WFCAM WCS usage
			Added types for FITS values
			New HDSTRACE and examples
1.1	*2003-Oct-27*	*3.1*	*PV3_3 corrected to PV2_3*
		4	*Minor changes and corrections*

Table of contents

1.

2. INTRODUCTION 4

3. WFCAM HDS CONTAINER 4

3.1 Example HDSTRACE of WFCAM container file 5

4. WFCAM FITS HEADERS 6

4.1 Definition of top level FITS headers 7

4.1.1 Example of top level FITS headers 10

4.2 Definition of frame level FITS headers 11

4.2.1 Example of frame level FITS headers 12

5. WFCAM WCS USAGE 13

5.1 CTYPEn FITS items 13

5.2 CRVAL and CRPIX FITS items 13

5.3 CD FITS items 13

5.4 PV FITS items 13

2. INTRODUCTION

This document illustrates the contents of a typical HDS container file into which WFCAM data is written and provides a list of FITS headers for that instrument. The FITS headers were based initially on those used for imaging with UIST but have been modified in the light of discussions, primarily in the area of the World Coordinate System headers.

3. WFCAM HDS CONTAINER

Data from each of the four WFCAM cameras is to be written as NDF structures into separate HDS container files, usually as one file for each camera for each frame in a microstep pattern.

For a microstep frame, each container holds two NDF structures:

- *The first, named I1, holds the image data frame, typically a 2048 by 2048 array of type _REAL. Associated with this is an array of character strings in MORE.FITS that contains the FITS headers specifically associated with this frame.*

- *The second NDF structure is named HEADER and is a repository for a more comprehensive array FITS headers associated with the observation, again in a MORE.FITS extension. As all NDF structures must, HEADER contains its own DATA_ARRAY but in this case it is simply a dummy one.*

The reason for having separate HEADER and I1 structures is to make it possible to add additional I2, I3 etc structures in the same container, with the contents of HEADER being common to all the frames. At present, this facility will be exploited for focus tests, with frames at multiple focus positions being written as separate NDF structures into the one container, each with its own focus setting encoded in its own frame level MORE.FITS .

See the following section for a listing of the typical structure of a WFCAM HDS container file.

3.1 Example HDSTRACE of WFCAM container file

The following listing illustrates the structure of a typical WFCAM container file, generated using the HDSTRACE command.

```
X20031020_00008  <UKIRT_HDS>

   I1              <NDF>           {structure}
      DATA_ARRAY      <ARRAY>         {structure}
         DATA(2048,2048)  <_INTEGER>     5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,5,
                                         ... 21,21,21,21,21,21,21,21,21,21,21
         ORIGIN(2)       <_INTEGER>      1,1

      HISTORY         <HISTORY>       {structure}
         CREATED         <_CHAR*24>      '2003-OCT-20 22:04:46.000'
         CURRENT_RECORD   <_INTEGER>     1
         RECORDS(10)     <HIST_REC>      {array of structures}

         Contents of RECORDS(1)
            DATA            <_CHAR*24>      '2003-OCT-20 22:04:46.000'
            COMMAND         <_CHAR*9>       '<unknown>'
            USER            <_CHAR*5>       'wfcam'
            HOST            <_CHAR*15>      'wfdr2.roe.ac.uk'
            DATASET         <_CHAR*48>      '/home/wfcam/data/raw/20031020/...'
            TEXT(2)         <_CHAR*72>      'Arguments: <unknown>','Softwar...'

      AXIS(2)         <AXIS>          {array of structures}

      Contents of AXIS(1)
         DATA_ARRAY      <ARRAY>         {structure}
            DATA(2048)      <_REAL>         0.5,1.5,2.5,3.5,4.5,5.5,6.5,
                                            ... 2044.5,2045.5,2046.5,2047.5
            ORIGIN(1)       <_INTEGER>      1

      MORE            <EXT>           {structure}
         FITS(4)         <_CHAR*80>      'UTSTART =             14.409722 /...'
                                         ... 'FOC_OFF =                     0.00...'

   HEADER          <NDF>           {structure}
      DATA_ARRAY      <ARRAY>         {structure}
         DATA(1,1)       <_REAL>         0
         ORIGIN(2)       <_INTEGER>      1,1

      HISTORY         <HISTORY>       {structure}
         CREATED         <_CHAR*24>      '2003-OCT-20 22:04:47.000'
         CURRENT_RECORD   <_INTEGER>     1
         RECORDS(10)     <HIST_REC>      {array of structures}

         Contents of RECORDS(1)
            DATE            <_CHAR*24>      '2003-OCT-20 22:04:47.000'
            COMMAND         <_CHAR*9>       '<unknown>'
            USER            <_CHAR*5>       'wfcam'
            HOST            <_CHAR*15>      'wfdr2.roe.ac.uk'
            DATASET         <_CHAR*52>      '/home/wfcam/data/raw/20031020/...'
            TEXT(2)         <_CHAR*72>      'Arguments: <unknown>','Softwar...'

      MORE            <EXT>           {structure}
         FITS(129)       <_CHAR*80>      ' ','                              ...'
                                         ... 'DET_TEMP=                     25....'

End of Trace.
```

4. WFCAM FITS HEADERS

Two tables are provided:

- *A table in section 3.1 of top level headers which appears in the MORE.FITS section of an NDF structure called HEADER in the HDS container file;*
- *A table in section 3.2 of frame level headers that appear in the MORE.FITS section of each integration within the HDS container file.*

Each table lists the:

- *FITS keyword of the header;*
- *comment field in the FITS string;*
- *source of the FITS value when WFCAM is used on UKIRT (see below);*
- *usual source of the FITS value during engineering tests;*
- *type of the FITS value (either logical, character string, integer or floating point).*

The possible sources of the FITS value are:

- *fix - the value is fixed in the header definition table;*
- *om - set from the sequencer level of observation control via the OM Translator and the OOS task. This is likely to be blank (see below) when WFCAM is run from its non-OM engineering interface;*
- *inst - set from the instrument control level (the WFIS);*
- *TCS - read from the telescope control system;*
- *EPICS - obtained from an EPICS database. When this is not available during engineering tests, this may be a fixed value;*
- *data - obtained as attribute alongside data received from camera controller;*
- *DHS - set within the DHS system;*
- *CSO - obtained from CSO monitor task;*
- *blank - the FITS value field will be blank*

Note that these sources are as seen from the point of view of the DHS. The ones in the "om" may, in turn, originate in some aspect of a survey definition, be specified by the Observer, or be specified or derived in some other way, for example from an entry in a lookup table read by the OT.

4.1 Definition of top level FITS headers

FITS name	FITS comment	UKIRT source	Eng source	Type
	Identification:			
TELESCOP	Telescope name	fix	fix	string
INSTRUME	Instrument	fix	fix	string
CAMNUM	Number of this camera	data	data	integer
DHSVER	Data handling version	fix	fix	string
HDTFILE	Name of global hdt file	fix	fix	string
HDTFILE2	Name of camera-specific hdt file	fix	fix	string
OBSERVER	Observers names	om	om	string
USERID	Userid logged in as	om	om	string
OBSREF	PATT or other reference	om	om	string
PROJECT	Time-allocation code	om	om	string
SURVEY	Survey name	om	om	string
SURVEY_I	Pointing ID within survey	om	om	string
MSBID	Id min.schedulable block	om	om	string
OBJECT	Object name from telescope	TCS	blank	string
	Data reduction:			
RECIPE	Data reduction recipe to be used	om	om	string
OBSTYPE	Type (BIAS|DARK|FLAT|OBJECT|SKY|FOCUS)	inst	inst	string
OBSNUM	Observation number	DHS	DHS	integer
GRPNUM	Group number applied to all members	DHS	DHS	integer
GRPMEM	Group membership	om	om	logical
TILENUM	Tile number applied to all members	DHS	DHS	integer
STANDARD	Is the target a standard star	om	om	logical
NJITTER	Number of positions in telescope jitter pattern	om	om	integer
JITTER_I	Serial number in this telescope jitter pattern	om	om	integer
JITTER_X	[arcsec] X (RA) offset in telescope jitter pattern	om	om	float
JITTER_Y	[arcsec] Y (Dec) offset in telescope jitter pattern	om	om	float
NUSTEP	Number of positions in microstep pattern	om	om	integer
USTEP_I	Serial number in this microstep pattern	om	om	integer
USTEP_X	[arcsec] X (RA) offset in microstep pattern	om	om	float
USTEP_Y	[arcsec] Y (Dec) offset in microstep pattern	om	om	float
NFOC	Number of positions in focus scan	inst	inst	integer
NFOCSCAN	Number of focus scans in focus test	inst	inst	integer
	Astrometric and time information:			
UTDATE	UT date as integer in yyyymmdd format	inst	inst	string
DATE-OBS	Date and time (UTC) of start of observation	data	data	string
DATE-END	Date and time (UTC) of end of observation	data	data	string
MJD-OBS	DATE-OBS as Modified Julian Date	data	data	float
WCSAXES	Number of axes in world co-ordinate system	fix	fix	integer
RADESYS	Mean IAU 1984 equatorial co-ordinates	fix	fix	string
EQUINOX	[yr] Equinox of object position	TCS	fix	float
CTYPE1	Algorithm type for axis 1	fix	fix	string
CTYPE2	Algorithm type for axis 2	fix	fix	string

WFCAM

UKIRT

CRPIX1	*[pixel] Reference pixel along axis 1 (RA)*	*inst*	*inst*	*float*
CRPIX2	*[pixel] Reference pixel along axis 2 (Dec)*	*inst*	*inst*	*float*
CRVAL1	*[deg] Right ascension at the reference pixel*	*TCS*	*fix*	*float*
CRVAL2	*[deg] Declination at the reference pixel*	*TCS*	*fix*	*float*
CRUNIT1	*Unit of right ascension co-ordinates*	*fix*	*fix*	*string*
CRUNIT2	*Unit of declination co-ordinates*	*fix*	*fix*	*string*
CD1_1	*Transformation matrix element*	*inst*	*inst*	*float*
CD1_2	*Transformation matrix element*	*inst*	*inst*	*float*
CD2_1	*Transformation matrix element*	*inst*	*inst*	*float*
CD2_2	*Transformation matrix element*	*inst*	*inst*	*float*
PV2_1	*Pol. coeff. for pixel -> celestial coord.*	*inst*	*inst*	*float*
PV2_2	*Pol. coeff. for pixel -> celestial coord.*	*inst*	*inst*	*float*
PV2_3	*Pol. coeff. for pixel -> celestial coord.*	*inst*	*inst*	*float*
RABASE	*[h] Right ascension of base position*	*TCS*	*fix*	*float*
DECBASE	*[deg] Declination of base position*	*TCS*	*fix*	*float*
TRAOFF	*[arcsec] Right ascension telescope offset*	*TCS*	*fix*	*float*
TDECOFF	*[arcsec] Declination telescope offset*	*TCS*	*fix*	*float*
AMSTART	*Airmass at start of observation*	*TCS*	*fix*	*float*
AMEND	*Airmass at end of observation*	*TCS*	*fix*	*float*
TELRA	*[h] Current telescope right ascension*	*TCS*	*fix*	*float*
TELDEC	*[deg] Current telescope declination*	*TCS*	*fix*	*float*
GSRA	*[h] Right ascension of guide star*	*TCS*	*fix*	*float*
GSDEC	*[deg] Declination of guide star*	*TCS*	*fix*	*float*
	Instrument detector configuration:			
DETECTOR	*Type of detector array used*	*fix*	*fix*	*string*
DETECTID	*Serial number of detector array*	*data*	*data*	*string*
NINT	*Number of integrations in observation*	*data*	*data*	*integer*
DROWS	*[pixel] Number of detector rows*	*data*	*data*	*integer*
DCOLUMNS	*[pixel] Number of detector columns*	*data*	*data*	*integer*
RDOUT_X1	*Start column of array readout*	*data*	*data*	*integer*
RDOUT_X2	*End column of array readout*	*data*	*data*	*integer*
RDOUT_Y1	*Start row of array readout*	*data*	*data*	*integer*
RDOUT_Y2	*End row of array readout*	*data*	*data*	*integer*
PIXLSIZE	*[arcsec] Pixel size*	*inst*	*inst*	*float*
	Detector controller:			
PCSYSID	*PC system identifier*	*inst*	*inst*	*string*
SDSUID	*Serial number of SDSU controller*	*inst*	*inst*	*string*
READMODE	*Name of camera readmode*	*inst*	*inst*	*string*
CAPPLICN	*Name of camera readout application*	*data*	*data*	*string*
CAMROLE	*Camera role (master|slave|unsync)*	*inst*	*inst*	*string*
READOUT	*Camera readout (CDS|NDR|SAR|RRR)*	*data*	*data*	*string*
EXP_TIME	*[s] Integration time per exposure*	*inst*	*inst*	*float*
NEXP	*Number of exposures in integration*	*inst*	*inst*	*integer*
READINT	*[s] Interval between reads*	*data*	*data*	*float*
NREADS	*Number of reads per exposure*	*data*	*data*	*Integer*
GAIN	*[electrons/ADU] Detector gain*	*data*	*data*	*float*
	Instrument optical configuration:			
FILTER	*Filter name*	*EPICS*	*EPICS*	*string*

WFCAM
UKIRT

FOC_MM	*[mm] Base focus position*	*EPICS*	*EPICS*	*string*
	Environment:			
AIRTEMP	*[degC] Air temperature*	*EPICS*	*fix*	*float*
BARPRESS	*Ambient pressure*	*EPICS*	*fix*	*float*
DEWPOINT	*[degC] Dewpoint*	*EPICS*	*fix*	*float*
DOMETEMP	*[degC] Dome temperature*	*EPICS*	*fix*	*float*
HUMIDITY	*Relative humidity*	*EPICS*	*fix*	*float*
MIRRBSW	*[degC] Temperature mirror B SW*	*EPICS*	*fix*	*float*
MIRR_NE	*[degC] Mirror temperature NE*	*EPICS*	*fix*	*float*
MIRR_NW	*[degC] Mirror temperature NW*	*EPICS*	*fix*	*float*
MIRR_SE	*[degC] Mirror temperature SE*	*EPICS*	*fix*	*float*
MIRR_SW	*[degC] Mirror temperature SW*	*EPICS*	*fix*	*float*
MIRRBTNW	*[degC] Mirror bottom temp. NW*	*EPICS*	*fix*	*float*
MIRRTPNW	*[degC] Mirror top temp. NW*	*EPICS*	*fix*	*float*
SECONDAR	*[degC] Temperature of secondary*	*EPICS*	*fix*	*float*
TOPAIRNW	*[degC] Top air NW*	*EPICS*	*fix*	*float*
TRUSSENE	*[degC] Truss leg ENE*	*EPICS*	*fix*	*float*
TRUSSWSW	*[degC] Truss leg WSW*	*EPICS*	*fix*	*float*
WIND_DIR	*[deg] Wind direction, azimuth*	*EPICS*	*fix*	*float*
WIND_SPD	*[km/h] Wind speed*	*EPICS*	*fix*	*float*
CSOTAU	*Tau at 225 GHz from CSO*	*CSO*	*fix*	*float*
TAUDATE	*Time and date of Tau reading*	*CSO*	*fix*	*string*
TAUSRC	*Source of opacity data*	*CSO*	*fix*	*string*
	Engineering:			
CNFINDEX	*Configuration index*	*EPICS*	*EPICS*	*integer*
DET_TEMP	*[K] Array temperature*	*EPICS*	*EPICS*	*float*
	< More camera engineering data will go here >			

4.1.1 Example of top level FITS headers

```
                                  Identification:
TELESCOP= 'UKIRT              ' / Telescope name
INSTRUME= 'WFCAM              ' / Instrument
CAMNUM  =                     2 / Number of WFCAM camera (1, 2, 3 or 4)
DHSVER  = 'UKDHS 2002 Oct 31  ' / Data handling version
HDTFILE = 'wfcam.hdt          ' / Name of global hdt file
HDTFILE2= 'wfcam2.hdt         ' / Name of camera-specific hdt file
OBSERVER= 'Mrs Observer'        / Observers names
USERID  = 'abc     '            / Userid logged in as
OBSREF  = 'notPATT99'           / PATT or other reference
PROJECT = 'Example WFCAM data'  / Time-allocation code
SURVEY  = 'Demo survey 123'     / Survey name
SURVEY_I= 'B1.99.4 '            / Pointing ID within survey
MSBID   = '42      '            / Id min.-schedulable block
OBJECT  = 'Laboratory wall'     / Object name from telescope

                                  Data Reduction:
RECIPE  = 'QUICK_LOOK'          / Data reduction recipe to be used
OBSTYPE = 'OBJECT  '            / BIAS|DARK|SKYFLAT|DOMEFLAT|OBJECT|SKY|FOCUS
OBSNUM  =                     8 / Observation number
GRPNUM  =                     8 / Group number applied to all members
GRPMEM  =                     T / Group membership
TILENUM =                     0 / Tile number applied to all members
STANDARD=                     F / Is the target a standard star observation?
NJITTER =                     4 / Number of positions in tel jitter pattern
JITTER_I=                     1 / Serial number in this tel jitter pattern
JITTER_X=                  0.00 / [arcsec] X (RA) offset in tel jitter pattern
JITTER_Y=                  0.00 / [arcsec] Y (Dec) offset in tel jitter pattern
NUSTEP  =                     4 / Number of positions in microstep pattern
USTEP_I =                     1 / Serial number in this microstep pattern
USTEP_X =                  0.00 / [arcsec] X (RA) offset in microstep pattern
USTEP_Y =                  0.00 / [arcsec] Y (Dec) offset in microstep pattern
NFOC    =                     0 / Number of positions in focus scan
NFOCSCAN=                     0 / Number of focus scans in focus test

                                  Astrometric and time information:
UTDATE  = '20031020'            / UT date as integer in yyyymmdd format
DATE-OBS= '2003-10-20T14:24:35Z' / Date and time (UTC) of start of observation
DATE-END= '2003-10-20T14:24:39Z' / Date and time (UTC) of end of observation
MJD-OBS =        52932.60040 / DATE-OBS as Modified Julian Date
WCSAXES =                     2 / Number of axes in world co-ordinate system
RADESYS = 'FK5     '            / Mean IAU 1984 equatorial co-ordinates
EQUINOX =              2000.000 / [yr] Equinox of object position
CTYPE1  = 'RA---ZPN'            / Algorithm type for axis 1
CTYPE2  = 'DEC--ZPN'            / Algorithm type for axis 2

CRPIX1  =               -1000.0 / [pixel] Reference pixel along axis 1 (RA)
CRPIX2  =               -1000.0 / [pixel] Reference pixel along axis 2 (Rec)
CRVAL1  =             300.16419 / [deg] Right ascension at the reference pixel
CRVAL2  =            29.9749447 / [deg] Declination at the reference pixel
CRUNIT1 = 'deg     '            / Unit of right ascension co-ordinates
CRUNIT2 = 'deg     '            / Unit of declination co-ordinates

CD1_1   =          0.000000E+00 / Transformation matrix element
CD1_2   =         -1.000000E+00 / Transformation matrix element
CD2_1   =          5.000000E-01 / Transformation matrix element
CD2_2   =         -5.000000E-01 / Transformation matrix element

PV2_1   =          1.000000E+00 / Pol.coeff. for pixel -> celestial coord
PV2_2   =          0.000000E+00 / Pol.coeff. for pixel -> celestial coord
PV2_3   =          7.500000E+01 / Pol.coeff. for pixel -> celestial coord

RABASE  =            20.0109458 / [h] Right ascension of base position
DECBASE =            29.9749447 / [deg] Declination of base position
TRAOFF  =                 0.000 / [arcsec] Right ascension telescope offset
TDECOFF =                 0.000 / [arcsec] Declination telescope offset
AMSTART =                 1.771 / Airmass at start of observation
AMEND   =                 1.769 / Airmass at end of observation
TELRA   =            20.0123456 / [h] Current telescope right ascension
TELDEC  =            29.9876543 / [deg] Current telescope declination
GSRA    =            20.0103456 / [h] Right ascension of guide star
```

```
GSDEC   =          29.9806543 / [deg] Declination of guide star

                                Instrument detector configuration:
DETECTOR= 'RSC Hawaii 2'      / Type of detector array used
DETECTID= 'a.bc.234'          / Serial number of detector array
NINT    =                   1 / Number of integrations in observation
DROWS   =                2048 / [pixel] Number of detector rows
DCOLUMNS=                2048 / [pixel] Number of detector columns
RDOUT_X1=                   1 / Start column of array readout
RDOUT_X2=                2048 / Start column of array readout
RDOUT_Y1=                   1 / Start row    of array readout
RDOUT_Y2=                2048 / Start row    of array readout
PIXLSIZE=              0.4000 / [arcsec] Pixel size

                                Detector controller:
PCSYSID = 'wfacq2  '          / PC system identifier
SDSUID  = '00223   '          / Serial number of SDSU controller
READMODE= 'CDS_v1  '          / Name of camera readmode
CAPPLICN= 'applic01'          / Name of camera readout application
CAMROLE = 'master  '          / Camera role (master|slave|unsync)
READOUT = 'CDS     '          / Camera readout (CDS|NDR|SAR|RRR)
EXP_TIME=            1.000000 / [s] Integration time per exposure
NEXP    =                   1 / Number of exposures in integration
READINT =            1.000000 / [s] Interval between reads
NREADS  =                   0 / Number of reads per exposure
GAIN    =                 1.0 / [electrons/ADU] Detector gain

                                Instrument optical configuration:
FILTER  = 'whatever'          / Filter name
FOC_MM  =               12.34 / [mm] Base focus position

                                Environment:
AIRTEMP =               5.785 / [degC] Air temperature
BARPRESS=             650.000 / Ambient pressure
DEWPOINT=               2.000 / [degC] Dewpoint
DOMETEMP=               7.095 / [degC] Dome temperature
HUMIDITY=              35.450 / Relative humidity
MIRRBSW =               7.123 / [degC] Temperature mirror B SW
MIRRNE  =               7.124 / [degC] Mirror temperature NE
MIRRNW  =               7.125 / [degC] Mirror temperature NW
MIRRSE  =               7.126 / [degC] Mirror temperature SE
MIRRSW  =               7.127 / [degC] Mirror temperature SW
MIRRBTNW=               7.128 / [degC] Mirror bottom temp. NW
MIRRTPNW=               7.129 / [degC] Mirror top temp. NW
SECONDAR=               7.130 / [degC] Temperature of secondary
TOPAIRNW=               7.131 / [degC] Top air NW
TRUSSENE=               7.132 / [degC] Truss leg ENE
TRUSSWSW=               7.133 / [degC] Truss leg WSW
WIND_DIR=             106.987 / [deg] Wind direction, azimuth
WIND_SPD=              16.089 / [km/h] Wind speed
CSOTAU  =               0.047 / Tau at 225 GHz from CSO
TAUDATE = '2001-11-30T04:07'  / Time and date of Tau reading
TAUSRC  = 'CSO     '          / Source of opacity data

                                Engineering:
CNFINDEX=                   1 / Configuration index
DET_TEMP=                25.0 / [K] Detector array temperature
```

4.2 Definition of frame level FITS headers

FITS name	*FITS comment*	*UKIRT source*	*Eng source*	*Type*
UTSTART	*[h] Start time of integration*	*data*	*data*	*float*
UTEND	*[h] End time of integration*	*data*	*data*	*float*
FOC_I	*Serial number in focus scan*	*data*	*data*	*integer*
FOC_OFF	*[mm] Offset from base focus position*	*data*	*data*	*float*

4.2.1 Example of frame level FITS headers

```
UTSTART =            14.409722 / [h] Start time of integration
UTEND   =            14.410833 / [h] End time of integration
FOC_I   =                    0 / Serial number in focus scan
FOC_OFF =                0.000 / [mm] Offset from base focus position
```

5. WFCAM WCS USAGE

Several items in the top-level FITS headers are concerned with World Coordinate System (WCS) information. Thanks to Andy Vick for the explanations.

Note that all but the CTYPEn values are candidates for being updated with new values during commissioning.

5.1 CTYPEn FITS items

CTYPE1 and CTYPE2 give the output format. That is to say, they give the format for the coordinates after you have applied all the transformations. In our case CTYPE1 is "RA---ZPN" and CTYPE2 is "DEC--ZPN". This implies that the transformation is a zenithal polynomial one.

5.2 CRVAL and CRPIX FITS items

These define the position of the reference pixel, which will initially be set to as near the optical axis of the instrument as possible.

5.3 CD FITS items

The CD FITS items (CD1_1, etc) specify a transformation from pixel space with respect to reference point to projection plane coordinates with respect to reference point.

5.4 PV FITS items

A comment in the FITS WCS document states in order to do a radial expansion, as in ZPN, then the coefficients go in the PV matrix keywords appropriate for the 'latitude' axis, which in our case is the second axis. The information is carried by the FITS keywords of the form PV2_n, and the PV1_n keywords are not used.

The initial values are:

- *PV2_1 = 1.0*
- *PV2_2 = 0.0*
- *PV2_3 = 75.0*