

Nordic Optical Telescope



Data Acquisition System

Requirements and Development plan

Jacob Clasen
Thomas Augusteijn

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1 Introduction

1.1 Aim

The aim of this document is to define the requirements and a development plan for a Data Acquisition System (from here-on DAS) to be used with the detector controller being developed by NBI.

The DAS will be centred on the CCD3 control program that has been made by Jeppe J. Andersen from NBI, and as a basis point for the system the functionality of the current “BIAS” data acquisition program are taking.

1.2 Scope

The scope of this document is to provide a description of a DAS that is capable of operating the NBI detector controller in a way that all required exposure types can be executed and result in a FITSimage file stored on disk compliant with the current NOT format and including the standard set of headers. The system must be capable of operating conventional CCDs as well as the NOTCam IR array.

1.3 Assumptions

As a basis for this document the following is assumed:

- the NBI detector controller meets the requirements as described in ‘Nordic Optical Telescope - Detector Controller User Requirements’ (authors Thomas Augusteijn & Graham Cox)
- the current version of the CCD3 control program made at NBI is a fault free working program and has the following capabilities:
 - Sending low level commands to the controller and receiving replies
 - Receiving and internally store the controller telemetry data
 - through commands control all geometry parameters related facilities of the controller (X-size, Y-size, X-begin, Y-begin, X-bin, Y-bin, on-chip over-scan, artificial over-scan)
 - through commands control all exposure related functions (shutter control for dark exposures, pre-clear for focus exposures, auto-readout after exposure for focus exposures, hold, resume, forced readout, ”frame” readout (for the IR array)
 - Reading out the image after the exposure ends and store it on hard-disk in FITS format
 - Providing the stored FITS image with a header, containing the following keywords: SIMPLE, BITPIX, NAXIS, NAXIS1, NAXIS2, EXTEND, COMMENT, SYSTEM, FILENAME, EXPTIME, DETNAME, CHIPID, DATAMIN, DATAMAX, END.
 - Displaying the image while it is being read out via XPA in an image display (e.g. DS9)
 - Attaching to a TCP socket so that the external command interface can send commands to the program

2 Requirements

Below a description is given of the requirements for the DAS and the corresponding development that is needed of the existing CCD3 program.

2.1 Hardware

The hardware needed for running the DAS must be a commercially available PC type computer. The DAS must not rely on other specific hardware than the interface card needed to connect the host computer with the controller via the optical fibre. The communication over the optical fibre from the data acquisition computer to the detector controller must tolerate up to three junctions.

2.2 Modes of operation

The CCD3 program need to be capable of operating in the following modes. Only the command method, the status display and the image display is different in the different modes.

- Engineering mode

In this mode the user can give commands in the corresponding command window. The controller status is provided via commands and printed out in the command window. In this mode the following things are not in operation:

- Status display
- Image display

This basically corresponds to the current functionality, but with complete FITS headers in images. This will normally only be used when operating the controller for test purposes.

- Normal mode

In this mode the user can either give commands in the command window or via external (Sequencer) commands. The user has a status display that shows the relevant information and there is an image display where the image is displayed during and after readout.

3 Developments

Here the specific areas in which significant development of the current CCD3 program is needed.

3.1 Command interface

The command interface shall consist of a series of UNIX commands that when executed sends a particular command to the CCD3 program via the socket interface described in 1.3. There shall be one UNIX command for each of the internally available CCD3 commands.

One command must not block until the task has been completed, but allow for the subsequent command to be send and processed by the CCD3 programme.

This command interface will add the NOT sequencer functionality to the DAS.

3.2 FITS header information

The images produced by the DAS should contain a full set of headers following the format as defined in <http://www.not.iac.es/instruments/development/fitsV0.6.pdf>. As a minimum the same header information should be provided as that given in the current FITS images. Example image headers for the different instruments detectors at NOT to be operated with the DAS are added as appendices to this document.

A specific requirement is that the keywords that provide information about the detector, controller and control program are written directly by the CCD3 program.

The specific keywords are:

SIMPLE, BITPIX, NAXIS, EXTEND, BZERO, BSCALE, DETNAME, DATE, DATE-OBS, FILENAME, OBJECT, IMAGETYP, EQUINOX, EXPTIME, TM_START, TM_END, GAINM, AMPLMODE, CCDTEMP, LN2TEMP, MPP, CHIPID, DATAMIN, DATAMAX, XOVERSC, YOVERSC, P_DEWAR, SHSTAT, DETXBIN, DETYBIN, NWINDOWS, DETWIN1 and EXPMODE (only for NOTCam)

The remainder of the FITS keywords are considered external to the CCD3 program, and this FITS information should be written in the resulting image file by a external module. The way this external module is connected to the CCD3 program is described in Sect. 3.3.

3.3 External communication

In order for external entities (such as the FITS writer module) to communicate with the CCD3 program it should be possible to 'subscribe' to the value of a certain parameter where the external entity is notified of the value at the appropriate time. The specific parameters are:

- Type of integration being started [DARK/BIAS/NORMAL/FOCUS]
- Start/end of integration
- Start/end of readout
- Opening/closing of shutter
- Programme startup/shutdown
(This applies to all programs that use the communications system)

The communication system should also be non-specific to one host computer, and support communication between processes on different hosts. A simple message bus system is likely to cover these requirements.

3.4 Status information

To provide sufficiently flexible in its integration and operation the CCD3 program must be able to store telemetry (status) information both internally and externally (preferably to an SQL database).

As a minimum the status information must contain the following information:

- Camera mode (idle/integrating/readout etc. (if applicable))
- Total detector size in X,Y, window start in X,Y (for each window if applicable)
- Window size in X,Y (for each window if applicable)
- Window id if applicable
- Binning in X,Y
- Detector temperature
- Dewar/cold-head temperature
- Dewar pressure
- Auto shutter (or implementation equivalent)
- Auto pre-clear (or implementation equivalent)
- Auto readout (or implementation equivalent)
- Shutter delay
- Over-scan in X and Y (both on-chip and synthetic if applicable)
- Total exposure time
- Exposure time left
- Line of image being read out (or detector dependent equivalent)
- Amplifier mode
- Gain mode (if applicable)
- Image storage path
- Current filename
- Next filename

- Auto-save mode
- Remote-save mode (if applicable)
- Total number of multiple exposures ordered (if applicable)
- Number of current multiple exposures

The CCD3 program must keep this information up-to-date at a frequency of not less than once per second, and must be able to provide it to local as well as remote “clients”.

In this way the CCD3 program can be installed and functional independently, but it can be integrated into a more advanced observing systems if needed. Also, the DAS Status display can then be a completely stand-alone application that can either obtain it’s information directly from the CCD3 program or indirectly from, e.g., a connected SQL database.

3.5 Run time configuration

For ease of use (both for the installation and operation) it must be possible for the CCD3 programme of a certain detector to change the run time configuration without the need to recompile the CCD3 software. In principle this can be simply accomplished through a configuration file that can be edited and is read-in at start-up.

3.6 Timing

Actions that require time information such as event handling, log information and similar actions, should use the data acquisition computer clock as the source. The timing of this computer will be connected to our time server.

The final absolute timing of an exposure is primarily determined by the varying delay between the time of sending a command to the detector controller and the actually time the command is received and executed. These delays are likely to be small, but we require the accuracy of the time of mid-exposure to be better than 0.1 sec. The accuracy of the relative timing of events in the controller is assumed to be better than 0.001 sec.

It would be very desirable if accurate timing of events would be provided by the controller through the synchronisation with an external (GPS) timer.

3.7 Logging

Each of the programmes included in the DAS (the CCD3 programme and the FITSwriter programme) must log their activity to a log file. If no performance degradation will result, the UNIX `syslog` facility should be used.

The following types of activities must be logged

- Commands. Both internally to the CCD3 programme and externally received commands
To be logged by the CCD3 programme.
- Status changing. Such as start/end of integration, start/end of readout. Shutter activity
To be logged by the CCD3 programme.
- Events received. For external modules subscribing to events on the communications system.
To be logged by external modules and the CCD3 (if applicable).
- Errors. Any error occurring not in direct relation with other activity.
To be logged by all.

Log messages belonging in the above categories should be divided in the following levels

- Informational. Provides information about normal activities.
- Debug messages. Provides information used during testing and debugging of the program
- Warnings. Provides information about events that does not impair the technically correct execution of the programme(s).
- Errors. Provides information about events or situations that require the user to take corrective action in order to continue.

4 Distribution of the development work

It is clear that the various parts to the proposed development of the DAS that can best be done by personnel from NBI (primarily Jeppe J. Andersen) or from NOT (primarily Jacob Clasen) that have most experience in the various areas. Below a general division of tasks is given as related to the different items specified in Sect. 3.

No specific amounts of time are indicated as this requires a more precise definition of what needs to be done and how to do it, which requires a more in-depth discussion (specifically between Jeppe J. Andersen and Jacob Clasen). However, we do think that a reasonable estimate for the amount of work will be in the order of 1 FTE in total.

- The part that covers FITS information from the CCD3 program described in Sect. 3.2 should be done by NBI. The part that covers the external FITS information should be done by NOT
Work: NBI (15%), NOT (85%)
- The development of the external communication described in Sect. 3.3 should be distributed between NBI and NOT as is involves both the current CCD3 control program and new future modules
Work: NBI (50%), NOT (50%)

- The development of the CCD3 control program to supply the status information to external users described in Sect. 3.4 is a task for NBI. The external user interface itself will be made by NOT with some assistance needed from NBI.
Work: NBI (30%), NOT (70%)
- The development need to make it possible for the CCD3 program of a certain detector to change the run time configuration without the need to recompile the software will be done by NBI.
Work: NBI (100%)
- The development of the logging facilities in the different parts of the DAS is described in Sect. 3.7. Only for the CCD3 program part this should be done at NBI, and the rest at NOT.
Work: NBI (30%), NOT (70%)
- Full documentation (including User manual, Maintenance manual and Technical manual should be provided for the whole DAS, where the work will be distributed between NBI and NOT and the amount of work will be proportional to the amount of programming needed to complete the above tasks.
Work: NBI (50%), NOT (50%)

5 Ownership and other users

In principle the detector controller and the DAS form a unit that can be offered to other users. As the DAS will be developed jointly by NBI and NOT there are some issues as for ownership and proprietary rights. Furthermore, it seems likely that other (potential) users of the detector controller and the associated DAS will likely have some specific user requirements or specific installations which will require some additional development work which would require some availability of manpower from NOT.

The precise details of the conditions for any agreement on this is beyond the scope of this document and needs to be defined by the director of NOT and the NBI.

A ALFOSC FITS header

```

SIMPLE = T / file does conform to FITS standard
BITPIX = 16 / number of bits per data pixel
NAXIS = 0 / number of data axes
EXTEND = T / FITS dataset may contain extensions
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
ORIGIN = 'NOTSA ' / Nordic Optical Telescope Scientific Associatio
OBSERVAT= 'LaPalma '
TELESCOP= 'NOT '
INSTRUME= 'ALFOSC_FASU '
DETNAME = 'EEV 2k x 2k '
DATE = '2008-08-20T16:57:52' / file creation date (YYYY-MM-DDThh:mm:ss UT)
DATE-OBS= '2008-08-20T16:56:31' / Start of observation
FILENAME= 'ALrh200001.fits'
OBJECT = ' '
OBSERVER= ' '
IMAGETYP= ' '
EQUINOX = 2000.0 / Equinox of RA and DEC
EXPTIME = 1.000
TM_START= 60991 / 16:56:31 UT start time
TM_END = 61072 / 16:57:52 UT end time
GAINM = 'HIGH ' / High or Low
AMPLMODE= 'A ' / A / B or AB
CCDTEMP = -119.9
LN2TEMP = -187.2
MPP = 0
CHIPID = 'EEV42-40, 2Kx2K '
DATAMIN = 338
DATAMAX = 507
XOVERSC = 50
YOVERSC = 0
P_DEWAR = 'Not available '
TM-START= 60991 / 16:56:31 UT start time
SHSTAT = 'OPEN '
DETXBIN = 1
DETYBIN = 1
NWINDOWS= 1
DETWIN1 = '[ 1:2198, 1:2052] '
ALAPRTNM= 'MOS0037 ' / ALFOSC aperture wheel. Name
ALAPRTID= 42 / ALFOSC aperture wheel. ID
ALAPRPOS= 5 / ALFOSC aperture wheel. Slot Position
ALAPRSTP= 199024 / ALFOSC aperture wheel. Step Position

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ALAPRALG= 'N      ' / ALFOSC aperture wheel. Aperture aligned
ALFLTNM = 'Open   ' / ALFOSC filter wheel. Name
ALFLTID =           0 / ALFOSC filter wheel. NOT filter number
ALFLTPOS=           7 / ALFOSC filter wheel. Slot Position
ALFLTSTP=          281250 / ALFOSC filter wheel. Step Position
ALGRNM  = 'Open (Lyot) ' / ALFOSC grism wheel. Name
ALGRID  =           0 / ALFOSC grism wheel. ID
ALGRPOS =           7 / ALFOSC grism wheel. Slot Position
ALGRSTP =          280100 / ALFOSC grism wheel. Step Position
ALGRALG = 'Y      ' / ALFOSC grism wheel. Grism aligned
ALFOCUS =           1810 / ALFOSC camera focus position
ALCENWAV= 'N/A    ' / ALFOSC spectroscopy center wavelength
FAFLTNM = 'Open   ' / FASU filter wheel 1/A Name
FAFLTID =           0 / FASU filter wheel 1/A NOT filter number
FAFLTPOS=           0 / FASU filter wheel 1/A Slot position
FBFLTNM = 'Open   ' / FASU filter wheel 2/B Name
FBFLTID =           0 / FASU filter wheel 2/B NOT filter number
FBFLTPOS=           0 / FASU filter wheel 2/B Slot position
CLAMP1  =           0 / FASU calibration lamp #1 is off
CLAMPNM1= 'He     ' / FASU calibration lamp #1 name
CLAMPID1= 'OSRAM He/10 inst. 13-11-2006' / FASU calibration lamp #1 id
CLAMP2  =           0 / FASU calibration lamp #2 is off
CLAMPNM2= 'Ne     ' / FASU calibration lamp #2 name
CLAMPID2= 'OSRAM Ne/10 c9 Germany' / FASU calibration lamp #2 id
CLAMP3  =           1 / FASU calibration lamp #3 is on
CLAMPNM3= 'Halogen' / FASU calibration lamp #3 name
CLAMPID3= 'OSRAM 64415 w448 10W 12V' / FASU calibration lamp #3 id
CLAMP4  =           0 / FASU calibration lamp #4 is off
CLAMPNM4= 'ThAr Hollow Cathode' / FASU calibration lamp #4 name
CLAMPID4= 'Cathodeon 3UAXTh S/N B77779' / FASU calibration lamp #4 id
CMIRROR =           1 / FASU calibration mirror is in
FARETARD= 'OUT    ' / Position of Retarder Plate
FARETANG= '-9999  ' / Retarder Plate Angle
ALAPRSLX=          1050 / Current aperture detector X pos.
ALAPRSLY=          1007.02 / Current aperture detector Y pos.
UT      =          16.942222222 / TCS UTC at start (16h:56m:32.0s)
ST      =          13.710000000 / Sidereal time at start (13h:42m:36.0s)
RA      =          205.1870726345 / Right ascension at start (13h:40m:44.90s)
DEC     =          29.0279326621 / Declination at start ( 29d:1m:40.6s)
RADECSYS= 'FK5    '
TELALT  =           89.74 / Telescope altitude
AZIMUTH =           119.00 / Telescope azimuth
AIRMASS =          1.0000100136 / Airmass at start (sec(z))
FIELD   =           35.35 / Field rotation at start
ROTPOS  =           -90.00 / Rotator angle at start
CCDPROBE= 'split  ' / CCD probe

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AUXPOS = 1198 / Autoguider probe X position
AUYPOS = 4998 / Autoguider probe Y position
AUBXXPOS= 255 / Autoguider box X position
AUBXYPOS= 255 / Autoguider box Y position
AUSTATUS= 'off ' / Autoguider status
TELFOCUS= 24122 / Telescope focus at start
TCSTGT = ' ' / TCS Catalogue Entry
OBJRA = 83.822100000 / Catalogue RA in decimal deg.
OBJDEC = -5.391110000 / Catalogue DEC in decimal deg.
OBJPMRA = 0.000000000 / Catalogue proper motion in RA
OBJPMDEC= 0.000000000 / Catalogue proper motion in DEC
OBJEQUIN= 2000.0 / Catalogue equinox for coordinates
CREATOR = 'NOT2MEF V1.5' / rev. date: 2006-06-29, CFITSIO V2.51
OBSGEO-X= 5327395.9638 / Cartesian Coordinate X
OBSGEO-Y= -1719170.4876 / Cartesian Coordinate Y
OBSGEO-Z= 3051490.766 / Cartesian Coordinate Z
OBS_MODE= 'Imaging '
DATE-AVG= '2008-08-20T16:56:31.5' / Midpoint of observation
QCRDATE = '2004-11-24' / Instrument rotation centre reference date

XTENSION= 'IMAGE ' / IMAGE extension
BITPIX = 16 / number of bits per data pixel
NAXIS = 2 / number of data axes
NAXIS1 = 2198 / length of data axis 1
NAXIS2 = 2052 / length of data axis 2
PCOUNT = 0 / required keyword; must = 0
GCOUNT = 1 / required keyword; must = 1
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
BUNIT = 'count ' / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords
CTYPE1 = 'RA---TAN' / Gnomonic projection
CTYPE2 = 'DEC--TAN' / Gnomonic projection
CRVAL1 = 205.1870726345 / [deg] RA at reference point
CRVAL2 = 29.0279326621 / [deg] Dec at reference point
CUNIT1 = 'deg ' / Unit of 1st axis
CUNIT2 = 'deg ' / Unit of 2nd axis
CRPIX1 = 1085. / Reference pixel on 1st axis
CRPIX2 = 997. / Reference pixel on 2nd axis
CD1_1 = -2.95938359946396E-05 / Transformation matrix for primary WCS
CD1_2 = -4.17196281278054E-05 / Transformation matrix for primary WCS
CD2_1 = -4.17196281278054E-05 / Transformation matrix for primary WCS
CD2_2 = 2.95938359946396E-05 / Transformation matrix for primary WCS
EXTNAME = 'IM1 ' / Extension name
IMAGEID = 1
CCDNAME = 'CCD8 '

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CCDSUM = '1 1' / On-chip binning factors
DARK = 0. / [e-/hr/pix]
QCDDATE = 'UNDEFINED' / Detector characteristics reference date
RDNOISE = 5.3 / [e-]
GAIN = 0.736 / [e-/ADU]
BIASSEC = '[3:52,1:2052]' / Location of bias region

```

B NOTCam FITS header

```

SIMPLE = T / file does conform to FITS standard
BITPIX = 16 / number of bits per data pixel
NAXIS = 0 / number of data axes
EXTEND = T / FITS dataset may contain extensions
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
ORIGIN = 'NOTSA' / Nordic Optical Telescope Scientific Associatio
OBSERVAT= 'LaPalma'
TELESCOP= 'NOT'
INSTRUME= 'NOTCAM'
DETNAME = 'Hawaii 1k - engin. grade array (8-344R#1 #131)'
DATE = '2007-01-30T17:08:07' / file creation date (YYYY-MM-DDThh:mm:ss UT)
DATE-OBS= '2007-01-30T17:07:57.0' / Start of sequence
FILENAME= 'NCqa300001.fits'
OBJECT = 'dark'
TM_START= 61677 / 17/07/57 UT start time
TM_END = 61686 / 17/08/06 UT end time
COMMENT = ''
EXPMODE = 'dark 0'
OBSERVER= ''
IMAGETYP= ''
CHIPID = 'HAWAII SWIR'
TM-START= 61677 / 17/07/57 UT start time
SHSTAT = 'CLOSED'
APERTUR = 'Free small' / NOTcam aperture wheel. Step pos: 17578
FILT1 = 'OPEN' / NOTcam filter wheel 1. Description
FILT1ID = 0 / NOTcam filter wheel 1. NOT filter number
FILT1POS= 98438 / NOTcam filter wheel 1. Step position
FILT2 = 'Kprime' / NOTcam filter wheel 2. Description
FILT2ID = 205 / NOTcam filter wheel 2. NOT filter number
FILT2POS= 77344 / NOTcam filter wheel 2. Step position
STOP = '15mm ring' / NOTcam stop wheel. Step pos: 77080
GRISM = 'OPEN' / NOTcam grism wheel. Step pos: 7031

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```
LENS      = 'HR Camera'          / NOTcam lens wheel. Step pos: 36562
CAMERA    =                      5 / NOTcam internal camera step position
DETTEMP   =                    -199.00 / NOTcam detector temperature
COLDTBL   =                    -201.60 / Cold Table temperature
OUTVESS   =                      9.50 / Outer Vessel temperature
CNTWHEEL  =                    -200.10 / Center Wheel temperature
PRESSUR   =                     4.88E-05 / NOTcam pressure
UT        =                    17.1331000000 / TCS UTC at start ( 17h:7m:59.2s)
ST        =                     0.5784833336 / Sidereal time at start ( 0h:34m:42.5s)
RA        =                     8.2747574855 / Right ascension at start ( 0h:33m:5.94s)
DEC       =                    28.9370272568 / Declination at start (28d:56m:13.3s)
RADECSYS= 'FK5'
TELALT    =                      89.80 / Telescope altitude
AZIMUTH   =                     119.70 / Telescope azimuth
AIRMASS   =                    1.0000063013 / Airmass at start (sec(z))
FIELD     =                      38.85 / Field rotation at start
ROTPOS    =                    -90.00 / Rotator angle at start
CCDPROBE= 'park'                / CCD probe
AUXPOS    =                      1202 / Autoguider probe X position
AUYPOS    =                      5002 / Autoguider probe Y position
AUSTATUS= 'off'                 / Autoguider status
TELFOCUS=                      23718 / Telescope focus at start
TCSTGT    = 'SDSSJ1335+01'      / TCS Catalogue Entry
OBJRA     =                    13.592997223 / Catalogue RA in decimal deg.
OBJDEC    =                    1.3013888889 / Catalogue DEC in decimal deg.
OBJPMRA   =                    0.0000000000 / Catalogue proper motion in RA
OBJPMDEC=  0.0000000000 / Catalogue proper motion in DEC
OBJEQUIN=  2000.0 / Catalogue equinox for coordinates
CREATOR   = 'NOT2MEF V1.5'      / rev. date: 2006-06-29, CFITSIO V2.51
EQUINOX   =                      2000.0
OBSGEO-X=  5327395.9638 / Cartesian Coordinate X
OBSGEO-Y= -1719170.4876 / Cartesian Coordinate Y
OBSGEO-Z=  3051490.766 / Cartesian Coordinate Z
OBS_MODE= 'Imaging'
COMMENT For keywords GAINn, RDNOISEn, CCDSEDCn, DATASECn, TRIMSECn, CRXn, CRYn:
COMMENT keyword1 corresponds to amplifier Q0
COMMENT keyword2 corresponds to amplifier Q1
COMMENT keyword3 corresponds to amplifier Q3
COMMENT keyword4 corresponds to amplifier Q2
QCDDATE   = '2006-05-11'       / Amplifier characteristics reference date
GAIN1     =                     2.82E+00 / [e-/ADU] Gain
GAIN2     =                     2.73E+00 / [e-/ADU] Gain
GAIN3     =                     2.70E+00 / [e-/ADU] Gain
GAIN4     =                     2.80E+00 / [e-/ADU] Gain
RDNOISE1=  9.60E+00 / [e-] Read-out noise
RDNOISE2=  9.30E+00 / [e-] Read-out noise
```

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RDNOISE3=          1.00E+01 / [e-] Read-out noise
RDNOISE4=          1.00E+01 / [e-] Read-out noise
DETSEC1 = '[1:512,1:512]'    / Location in final mosaic
DETSEC2 = '[513:1024,1:512]' / Location in final mosaic
DETSEC3 = '[1:512,513:1024]' / Location in final mosaic
DETSEC4 = '[513:1024, 513:1024]' / Location in final mosaic
CCDSEC1 = '[1:512,1:512]'    / Location in amplifier mosaic
CCDSEC2 = '[513:1024,1:512]' / Location in amplifier mosaic
CCDSEC3 = '[1:512,513:1024]' / Location in amplifier mosaic
CCDSEC4 = '[513:1024, 513:1024]' / Location in amplifier mosaic
DATASEC1= '[1:512,1:512]'    / Location of data pixels
DATASEC2= '[513:1024,1:512]' / Location of data pixels
DATASEC3= '[1:512,513:1024]' / Location of data pixels
DATASEC4= '[513:1024, 513:1024]' / Location of data pixels
TRIMSEC1= '[1:512,1:512]'    / Location of useful data
TRIMSEC2= '[513:1024,1:512]' / Location of useful data
TRIMSEC3= '[1:512,513:1024]' / Location of useful data
TRIMSEC4= '[513:1024, 513:1024]' / Location of useful data
CRX1   =          4.734E+02 / Reference pixel on 1st axis
CRX2   =          -3.860E+01 / Reference pixel on 1st axis
CRX3   =          4.734E+02 / Reference pixel on 1st axis
CRX4   =          -3.860E+01 / Reference pixel on 1st axis
CRY1   =          5.545E+02 / Reference pixel on 2nd axis
CRY2   =          5.545E+02 / Reference pixel on 2nd axis
CRY3   =          4.250E+01 / Reference pixel on 2nd axis
CRY4   =          4.250E+01 / Reference pixel on 2nd axis
QCRDATE = '2006-05-11'      / Instrument rotation centre reference date

XTENSION= 'IMAGE'          / IMAGE extension
BITPIX  =          16 / number of bits per data pixel
NAXIS   =          2 / number of data axes
NAXIS1  =          1024 / length of data axis 1
NAXIS2  =          1024 / length of data axis 2
PCOUNT  =          0 / required keyword; must = 0
GCOUNT  =          1 / required keyword; must = 1
BZERO   =          32768 / offset data range to that of unsigned short
BSCALE  =          1 / default scaling factor
BUNIT   = 'count'         / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords
CTYPE1  = 'RA---TAN'      / Gnomonic projection
CTYPE2  = 'DEC--TAN'      / Gnomonic projection
CRVAL1  =          8.2747574855 / [deg] RA at reference point
CRVAL2  =          28.9370272568 / [deg] Dec at reference point
CUNIT1  = 'deg'          / Unit of 1st axis
CUNIT2  = 'deg'          / Unit of 2nd axis
CRPIX1  =          538. / Reference pixel on 1st axis

```

```
CRPIX2 = 519.2 / Reference pixel on 2nd axis
CD1_1 = 1.73051654213629E-05 / Transformation matrix for primary WCS
CD1_2 = -1.39385917128237E-05 / Transformation matrix for primary WCS
CD2_1 = -1.39385917128237E-05 / Transformation matrix for primary WCS
CD2_2 = -1.73051654213629E-05 / Transformation matrix for primary WCS
EXTNAME = 'IM1' / Extension name
IMAGEID = 1
CCDNAME = 'SWIR1'
CCDSUM = '1 1' / On-chip binning factors
EXPTIME = 0. / [s] Exposure time for this extension
DATE-OBS= '2007-01-30T17:08:00.6' / Start of exposure
DATE-AVG= '2007-01-30T17:08:00.6' / Midpoint of exposure

XTENSION= 'IMAGE' / IMAGE extension
BITPIX = 16 / number of bits per data pixel
NAXIS = 2 / number of data axes
NAXIS1 = 1024 / length of data axis 1
NAXIS2 = 1024 / length of data axis 2
PCOUNT = 0 / required keyword; must = 0
GCOUNT = 1 / required keyword; must = 1
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
BUNIT = 'count' / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords
CTYPE1 = 'RA---TAN' / Gnomonic projection
CTYPE2 = 'DEC--TAN' / Gnomonic projection
CRVAL1 = 8.2747574855 / [deg] RA at reference point
CRVAL2 = 28.9370272568 / [deg] Dec at reference point
CUNIT1 = 'deg' / Unit of 1st axis
CUNIT2 = 'deg' / Unit of 2nd axis
CRPIX1 = 538. / Reference pixel on 1st axis
CRPIX2 = 519.2 / Reference pixel on 2nd axis
CD1_1 = 1.73051654213629E-05 / Transformation matrix for primary WCS
CD1_2 = -1.39385917128237E-05 / Transformation matrix for primary WCS
CD2_1 = -1.39385917128237E-05 / Transformation matrix for primary WCS
CD2_2 = -1.73051654213629E-05 / Transformation matrix for primary WCS
EXTNAME = 'IM2' / Extension name
IMAGEID = 2
CCDNAME = 'SWIR1'
CCDSUM = '1 1' / On-chip binning factors
EXPTIME = 0. / [s] Exposure time for this extension
DATE-OBS= '2007-01-30T17:07:57.0' / Start of exposure
DATE-AVG= '2007-01-30T17:07:57.0' / Midpoint of exposure
```

C FIES FITS header

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SIMPLE = T / file does conform to FITS standard
BITPIX = 16 / number of bits per data pixel
NAXIS = 0 / number of data axes
EXTEND = T / FITS dataset may contain extensions
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
ORIGIN = 'NOTSA' / Nordic Optical Telescope Scientific Associatio
OBSERVAT= 'LaPalma'
TELESCOP= 'NOT'
INSTRUME= 'FIES'
DETNAME = 'EEV 2k x 2k'
DATE = '2007-04-03T14:53:40' / file creation date (YYYY-MM-DDThh:mm:ss UT)
DATE-OBS= '2007-04-03T14:52:20' / Start of observation
FILENAME= 'FIqd030001.fits'
OBJECT = '
OBSERVER= '
IMAGETYP= '
EQUINOX = 2000.0 / Equinox of RA and DEC
EXPTIME = 0.000
TM_START= 53540 / 14:52:20 UT start time
TM_END = 53620 / 14:53:40 UT end time
GAINM = 'HIGH' / High or Low
AMPLM = 'B' / A / B or AB
CCDTEMP = -119.9
LN2TEMP = -165.7
MPP = 1
CHIPID = 'E2V42-40Roy 1.5s'
DATAMIN = 211
DATAMAX = 235
XOVERSC = 0
YOVERSC = 0
P_DEWAR = 'N/A' / Dewar pressure not available
TM-START= 53540 / 14:52:20 UT start time
SHSTAT = 'CLOSED'
DETXBIN = 1
DETYBIN = 1
STFLTNM = 'Clear_no126' / Stancam Filter Name
STFLTID = 0 / Stancam Filter Number
STFLTPOS= 8 / Stancam Filter Position
UT = 14.8725000000 / TCS UTC at start (14h:52m:21.0s)
ST = 2.4508333333 / Sidereal time at start ( 2h:27m:3.0s)
RA = 36.4499706444 / Right ascension at start ( 2h:25m:47.99s)

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DEC      =      28.9201593008 / Declination at start (28d:55m:12.6s)
RADECSYS= 'FK5      '
TELALT   =      89.88 / Telescope altitude
AZIMUTH  =      119.65 / Telescope azimuth
AIRMASS  =      1.0000000000 / Airmass at start (sec(z))
FIELD    =      46.74 / Field rotation at start
ROTPOS   =      -90.00 / Rotator angle at start
CCDPROBE= 'park      ' / CCD probe
AUXPOS   =      2255 / Autoguider probe X position
AUYPOS   =      5002 / Autoguider probe Y position
AUSTATUS= 'off       ' / Autoguider status
TELFOCUS=      24045 / Telescope focus at start
TCSTGT   = 'v404     ' / TCS Catalogue Entry
OBJRA    =      20.401100000 / Catalogue RA in decimal deg.
OBJDEC   =      33.867500000 / Catalogue DEC in decimal deg.
OBJPMRA  =      0.0000000000 / Catalogue proper motion in RA
OBJPMDEC=      0.0000000000 / Catalogue proper motion in DEC
OBJEQUIN=      2000.0 / Catalogue equinox for coordinates
FIFOCUS  =      126 / FIES internal focus position
FILSL    = 'Halogen   ' / FIES Lamp selector name
FILSLPOS=      1021 / FIES Lamp selector pos
CALSHUT  =      0 / FIES Calibration shutter state
FIFMSKMN= 'F1 LowRes ' / FIES Fiber Mask positon name
FIFMSKID=      5 / FIES Fiber Mask ID
FIFMSKPS=      1105014 / FIES Fiber Mask positon
FICARMNM= 'F1 LowRes Halogen ' / FIES Calibration arm name
FICARMID=      1 / FIES Calibration arm ID
FICARMPN=      40000 / FIES Calibration arm position
FILMP1   =      0 / FIES calibration lamp status
FILMPNM1= 'Halogen   ' / FIES calib lamp name
FILMPID1= 'LMP1234 ' / FIES calib lamp ID
FILMP2   =      0 / FIES calibration lamp status
FILMPNM2= 'Neon     ' / FIES calib lamp name
FILMPID2= 'LMP1234 ' / FIES calib lamp ID
FILMP3   =      0 / FIES calibration lamp status
FILMPNM3= 'Hg       ' / FIES calib lamp name
FILMPID3= 'LMP1234 ' / FIES calib lamp ID
FILMP4   =      0 / FIES calibration lamp status
FILMPNM4= 'ThAr    ' / FIES calib lamp name
FILMPID4= 'LMP1234 ' / FIES calib lamp ID
FILMP6   =      0 / FIES fiber head calibration lamp 1 status
FILMPNM6= 'Halogen   ' / FIES fiber head calib lamp 1 name
FILMPID6= 'Ha12345 ' / FIES fiber head calib lamp 1 ID
FILMP7   =      0 / FIES fiber head calibration lamp 2 status
FILMPNM7= 'Th/Ar   ' / FIES fiber head calib lamp 2 name
FILMPID7= 'Th12345 ' / FIES fiber head calib lamp 2 ID

```

```

CREATOR = 'NOT2MEF V1.5' / rev. date: 2006-06-29, CFITSIO V2.51
OBSGEO-X= 5327395.9638 / Cartesian Coordinate X
OBSGEO-Y= -1719170.4876 / Cartesian Coordinate Y
OBSGEO-Z= 3051490.766 / Cartesian Coordinate Z
OBS_MODE= 'Spectroscopy'
DATE-AVG= '2007-04-03T14:52:20.0' / Midpoint of observation

XTENSION= 'IMAGE ' / IMAGE extension
BITPIX = 16 / number of bits per data pixel
NAXIS = 2 / number of data axes
NAXIS1 = 2148 / length of data axis 1
NAXIS2 = 2052 / length of data axis 2
PCOUNT = 0 / required keyword; must = 0
GCOUNT = 1 / required keyword; must = 1
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
BUNIT = 'count ' / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords
CTYPE1 = 'X ' / Coordinate type of 1st axis
CTYPE2 = 'Y ' / Coordinate type of 2nd axis
CRVAL1 = 1 / X at reference point
CRVAL2 = 1 / Y at reference point
CUNIT1 = 'pixel ' / Unit of 1st axis
CUNIT2 = 'pixel ' / Unit of 2nd axis
CRPIX1 = 1 / Reference pixel on 1st axis
CRPIX2 = 1 / Reference pixel on 2nd axis
CDELTA1 = 1 / Increment on 1st axis
CDELTA2 = 1 / Increment on 2nd axis
EXTNAME = 'IM1 ' / Extension name
IMAGEID = 1
CCDNAME = 'CCD13 '
CCDSUM = '1 1 ' / On-chip binning factors
DARK = 0. / [e-/hr/pix]
QCDDATE = 'UNDEFINED' / Detector characteristics reference date
RDNOISE = 3.3 / [e-]
GAIN = 0.71 / [e-/ADU]

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D MOSCA FITS header

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SIMPLE = T / file does conform to FITS standard
BITPIX = 16 / number of bits per data pixel
NAXIS = 0 / number of data axes

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EXTEND = T / FITS dataset may contain extensions
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
ORIGIN = 'NOTSA ' / Nordic Optical Telescope Scientific Associatio
OBSERVAT= 'LaPalma '
TELESCOP= 'NOT '
INSTRUME= 'MOSAIC 4*2kx2k '
DETNAME = '2K3EB-MOSAIC '
DATE = '2007-01-11T15:53:32' / file creation date (YYYY-MM-DDThh:mm:ss UT)
DATE-OBS= '2007-01-11T15:52:55.0' / Start of observation
FILENAME= 'M0qa110001.fits'
OBJECT = ' '
EXPTIME = 0.000
TM_START= 57175 / 15:52:55 UT start time
TM_END = 57212 / 15:53:32 UT end time
GAINM = 'HIGH ' / High or Low
AMPLMODE= 'A4RR ' / A / B or AB
CCDTEMP = -116.0
LN2TEMP = -190.7
MPP = 1
CHIPID = '2K3EB-MOSAIC '
DATAMIN = 247
DATAMAX = 290
XOVERSC = 0
YOVERSC = 0
P_DEWAR = 9.0E-07
TM-START= 57175 / 15:52:55 UT start time
SHSTAT = 'CLOSED '
OBSERVER= ' '
IMAGETYP= ' '
FAFLTNM = 'Halp 656_3' / FASU filter wheel 1/A Name
FAFLTID = 21 / FASU filter wheel 1/A NOT filter number
FAFLTPOS= 4 / FASU filter wheel 1/A Slot position
FBFLTNM = 'Open ' / FASU filter wheel 2/B Name
FBFLTID = 0 / FASU filter wheel 2/B NOT filter number
FBFLTPOS= 0 / FASU filter wheel 2/B Slot position
UT = 15.8828166665 / TCS UTC at start (15h:52m:58.1s)
ST = 22.0762888887 / Sidereal time at start ( 22h:4m:34.6s)
RA = 330.7997968513 / Right ascension at start ( 22h:3m:11.95s)
DEC = 28.9293134506 / Declination at start (28d:55m:45.5s)
RADECSYS= 'FK5 '
TELALT = 89.83 / Telescope altitude
AZIMUTH = 119.85 / Telescope azimuth
AIRMASS = 1.0000041793 / Airmass at start (sec(z))
FIELD = 41.59 / Field rotation at start
ROTPOS = -90.00 / Rotator angle at start

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```

CCDPROBE= 'park      ' / CCD probe
AUXPOS   =           1201 / Autoguider probe X position
AUYPPOS  =           5002 / Autoguider probe Y position
AUSTATUS= 'off      ' / Autoguider status
TELFOCUS=           23815 / Telescope focus at start
TCSTGT   = 'BlankUH ' / TCS Catalogue Entry
OBJRA    =           13.129972222 / Catalogue RA in decimal deg.
OBJDEC   =           36.252222221 / Catalogue DEC in decimal deg.
OBJPMRA  =           0.000000000 / Catalogue proper motion in RA
OBJPMDEC=           0.000000000 / Catalogue proper motion in DEC
OBJEQUIN=           1950.0 / Catalogue equinox for coordinates
CREATOR  = 'NOT2MEF V1.5' / rev. date: 2006-06-29, CFITSIO V2.51
EQUINOX  =           2000.0
OBSGEO-X=           5327395.9638 / Cartesian Coordinate X
OBSGEO-Y=          -1719170.4876 / Cartesian Coordinate Y
OBSGEO-Z=           3051490.766 / Cartesian Coordinate Z
OBS_MODE= 'Imaging '
DATE-AVG= '2007-01-11T15:52:55.0' / Midpoint of observation
QCRDATE  = 'UNDEFINED' / Instrument rotation centre reference date
XTENSION= 'IMAGE    ' / IMAGE extension
BITPIX   =           16 / number of bits per data pixel
NAXIS    =           2 / number of data axes
NAXIS1   =           1026 / length of data axis 1
NAXIS2   =           1019 / length of data axis 2
PCOUNT   =           0 / required keyword; must = 0
GCOUNT   =           1 / required keyword; must = 1
BZERO    =           32768 / offset data range to that of unsigned short
BSCALE   =           1 / default scaling factor
BUNIT    = 'count    ' / Physical unit of data array
INHERIT  =           T / Extension inherits primary header keywords
CTYPE1   = 'RA---TAN' / Gnomonic projection
CTYPE2   = 'DEC--TAN' / Gnomonic projection
CRVAL1   =           330.7997968513 / [deg] RA at reference point
CRVAL2   =           28.9293134506 / [deg] Dec at reference point
CUNIT1   = 'deg      ' / Unit of 1st axis
CUNIT2   = 'deg      ' / Unit of 2nd axis
CRPIX1   =           1092. / Reference pixel on 1st axis
CRPIX2   =           1057. / Reference pixel on 2nd axis
CD1_1    = 4.00119445317531E-05 / Transformation matrix for primary WCS
CD1_2    = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_1    = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_2    = -4.00119445317531E-05 / Transformation matrix for primary WCS
EXTNAME  = 'IM1      ' / Extension name
IMAGEID  =           1
CCDNAME  = 'CCD7    '
CCDSUM   = '2 2     ' / On-chip binning factors

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DARK      =                0.3 / [e-/hr/pix]
QCDDATE  = '2005-05-04'      / Detector characteristics reference date
RDNOISE  =                8.828 / [e-]
GAIN     =                1.316 / [e-/ADU]
DETSEC   = '[1:2048,1:2039]' / Location in final mosaic
CCDSEC   = '[1:2048,1:2039]' / Location on CCD
DATASEC  = '[1:1024,1:1019]' / Location of data region
TRIMSEC  = '[2:1023,1:1018]' / Section of useful data

XTENSION= 'IMAGE'          / IMAGE extension
BITPIX   =                16 / number of bits per data pixel
NAXIS    =                2 / number of data axes
NAXIS1   =               1026 / length of data axis 1
NAXIS2   =               1019 / length of data axis 2
PCOUNT   =                0 / required keyword; must = 0
GCOUNT   =                1 / required keyword; must = 1
BZERO    =               32768 / offset data range to that of unsigned short
BSCALE   =                1 / default scaling factor
BUNIT    = 'count'         / Physical unit of data array
INHERIT  =                T / Extension inherits primary header keywords
CTYPE1   = 'RA---TAN'      / Gnomonic projection
CTYPE2   = 'DEC--TAN'      / Gnomonic projection
CRVAL1   =           330.7997968513 / [deg] RA at reference point
CRVAL2   =           28.9293134506 / [deg] Dec at reference point
CUNIT1   = 'deg'           / Unit of 1st axis
CUNIT2   = 'deg'           / Unit of 2nd axis
CRPIX1   =                38. / Reference pixel on 1st axis
CRPIX2   =               1057. / Reference pixel on 2nd axis
CD1_1    = 4.00119445317531E-05 / Transformation matrix for primary WCS
CD1_2    = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_1    = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_2    = -4.00119445317531E-05 / Transformation matrix for primary WCS
EXTNAME  = 'IM2'           / Extension name
IMAGEID  =                2
CCDNAME  = 'CCD10'        /
CCDSUM   = '2 2'          / On-chip binning factors
DARK     =                1.5 / [e-/hr/pix]
QCDDATE  = '2005-05-04'   / Detector characteristics reference date
RDNOISE  =                8.894 / [e-]
GAIN     =                1.338 / [e-/ADU]
DETSEC   = '[2049:4096,1:2039]' / Location in final mosaic
CCDSEC   = '[1:2048,1:2039]' / Location on CCD
DATASEC  = '[1:1024,1:1019]' / Location of data region
TRIMSEC  = '[2:1023,1:1018]' / Section of useful data

XTENSION= 'IMAGE'          / IMAGE extension

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```

BITPIX = 16 / number of bits per data pixel
NAXIS = 2 / number of data axes
NAXIS1 = 1026 / length of data axis 1
NAXIS2 = 1019 / length of data axis 2
PCOUNT = 0 / required keyword; must = 0
GCOUNT = 1 / required keyword; must = 1
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
BUNIT = 'count' / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords
CTYPE1 = 'RA---TAN' / Gnomonic projection
CTYPE2 = 'DEC--TAN' / Gnomonic projection
CRVAL1 = 330.7997968513 / [deg] RA at reference point
CRVAL2 = 28.9293134506 / [deg] Dec at reference point
CUNIT1 = 'deg' / Unit of 1st axis
CUNIT2 = 'deg' / Unit of 2nd axis
CRPIX1 = 1092. / Reference pixel on 1st axis
CRPIX2 = 8. / Reference pixel on 2nd axis
CD1_1 = 4.00119445317531E-05 / Transformation matrix for primary WCS
CD1_2 = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_1 = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_2 = -4.00119445317531E-05 / Transformation matrix for primary WCS
EXTNAME = 'IM3' / Extension name
IMAGEID = 3
CCDNAME = 'CCD12'
CCDSUM = '2 2' / On-chip binning factors
DARK = 2.7 / [e-/hr/pix]
QCDDATE = '2005-05-04' / Detector characteristics reference date
RDNOISE = 9.175 / [e-]
GAIN = 1.192 / [e-/ADU]
DETSEC = '[1:2048,2040:4078]' / Location in final mosaic
CCDSEC = '[1:2048,1:2039]' / Location on CCD
DATASEC = '[1:1024,1:1019]' / Location of data region
TRIMSEC = '[2:1023,1:1018]' / Section of useful data

XTENSION= 'IMAGE' / IMAGE extension
BITPIX = 16 / number of bits per data pixel
NAXIS = 2 / number of data axes
NAXIS1 = 1026 / length of data axis 1
NAXIS2 = 1019 / length of data axis 2
PCOUNT = 0 / required keyword; must = 0
GCOUNT = 1 / required keyword; must = 1
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
BUNIT = 'count' / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords

```

```

CTYPE1 = 'RA---TAN'           / Gnomonic projection
CTYPE2 = 'DEC--TAN'           / Gnomonic projection
CRVAL1 =          330.7997968513 / [deg] RA at reference point
CRVAL2 =          28.9293134506 / [deg] Dec at reference point
CUNIT1 = 'deg'                / Unit of 1st axis
CUNIT2 = 'deg'                / Unit of 2nd axis
CRPIX1 =          38. / Reference pixel on 1st axis
CRPIX2 =          8. / Reference pixel on 2nd axis
CD1_1  = 4.00119445317531E-05 / Transformation matrix for primary WCS
CD1_2  = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_1  = 4.50823834888741E-05 / Transformation matrix for primary WCS
CD2_2  = -4.00119445317531E-05 / Transformation matrix for primary WCS
EXTNAME = 'IM4'                / Extension name
IMAGEID =          4
CCDNAME = 'CCD11'              /
CCDSUM  = '2 2'                / On-chip binning factors
DARK    =          3.2 / [e-/hr/pix]
QCDDATE = '2005-05-04'         / Detector characteristics reference date
RDNOISE =          8.946 / [e-]
GAIN    =          1.349 / [e-/ADU]
DETSEC  = '[2049:4096,2040:4078]' / Location in final mosaic
CCDSEC  = '[1:2048,1:2039]'     / Location on CCD
DATASEC = '[1:1024,1:1019]'     / Location of data region
TRIMSEC = '[2:1023,1:1018]'     / Section of useful data

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E StanCam FITS header

```

SIMPLE =          T / file does conform to FITS standard
BITPIX =          16 / number of bits per data pixel
NAXIS  =          0 / number of data axes
EXTEND =          T / FITS dataset may contain extensions
BZERO  =          32768 / offset data range to that of unsigned short
BSCALE =          1 / default scaling factor
ORIGIN = 'NOTSA'          / Nordic Optical Telescope Scientific Associatio
OBSERVAT= 'LaPalma'      ,
TELESCOP= 'NOT'          ,
INSTRUME= 'StanCam'      ,
DETNAME  = 'TEK 1k x 1k' ,
DATE     = '2007-03-03T03:46:14' / file creation date (YYYY-MM-DDThh:mm:ss UT)
DATE-OBS= '2007-03-03T03:45:31.0' / Start of observation
FILENAME= 'STqc020001.fits'
OBJECT  = 'bias'          ,

```

```

OBSERVER= '      '
IMAGETYP= '      '
EQUINOX =          2000.0 / Equinox of RA and DEC
EXPTIME =          0.000
TM_START=          13531 / 03/45/31           UT start time
TM_END   =          13574 / 03:46:14         UT end time
GAINM   = 'HIGH   ' / High or Low
AMPLMODE= 'A      ' / A / B or AB
CCDTEMP =          -94.8
AMBTEMP =           16.0
MPP     =           0
CHIPID  = 'TEK1024 v1.0 '
DATAMIN =           341
DATAMAX =           372
XOVERSC =           0
YOVERSC =           0
P_DEWAR =
TM-START=          13531 / 03/45/31           UT start time
SHSTAT  = 'CLOSED '
DETXBIN =           1
DETYBIN =           1
NWINDOWS=          1
DETWIN1 = '[ 1:1124, 1:1024]'
FILTER  = 'R_no10 ' / Stancam Filter Name
FILTPOS =           4 / Stancam Filter Position
UT      =           3.7591666667 / TCS UTC at start ( 3h:45m:33.0s)
ST      =           13.2702777778 / Sidereal time at start (13h:16m:13.0s)
RA      =           205.4391740643 / Right ascension at start (13h:41m:45.40s)
DEC     =           28.4970299691 / Declination at start (28d:29m:49.3s)
RADECSYS= 'FK5   '
TELALT  =           84.42 / Telescope altitude
AZIMUTH =           271.29 / Telescope azimuth
AIRMASS =           1.0047700405 / Airmass at start (sec(z))
FIELD   =           0.00 / Field rotation at start
ROTPOS  =           85.62 / Rotator angle at start
CCDPROBE= 'ccd   ' / CCD probe
AUXPOS  =           13875 / Autoguider probe X position
AUYPOS  =           129153 / Autoguider probe Y position
AUSTATUS= 'off   ' / Autoguider status
TELFOCUS=          23158 / Telescope focus at start
TCSTGT  = 'AS26  ' / TCS Catalogue Entry
OBJRA   =           13.6959000000 / Catalogue RA in decimal deg.
OBJDEC  =           28.4972000000 / Catalogue DEC in decimal deg.
OBJPMRA =           0.0000000000 / Catalogue proper motion in RA
OBJPMDEC=           0.0000000000 / Catalogue proper motion in DEC
OBJEQUIN=          2000.0 / Catalogue equinox for coordinates

```

```
CREATOR = 'NOT2MEF V1.5' / rev. date: 2006-06-29, CFITSIO V2.51
OBSGEO-X= 5327395.9638 / Cartesian Coordinate X
OBSGEO-Y= -1719170.4876 / Cartesian Coordinate Y
OBSGEO-Z= 3051490.766 / Cartesian Coordinate Z
OBS_MODE= 'Imaging '
DATE-AVG= '2007-03-03T03:45:31.0' / Midpoint of observation
QCRDATE = '2006-03-25' / Instrument rotation centre reference date
XTENSION= 'IMAGE ' / IMAGE extension
BITPIX = 16 / number of bits per data pixel
NAXIS = 2 / number of data axes
NAXIS1 = 1124 / length of data axis 1
NAXIS2 = 1024 / length of data axis 2
PCOUNT = 0 / required keyword; must = 0
GCOUNT = 1 / required keyword; must = 1
BZERO = 32768 / offset data range to that of unsigned short
BSCALE = 1 / default scaling factor
BUNIT = 'count ' / Physical unit of data array
INHERIT = T / Extension inherits primary header keywords
CTYPE1 = 'RA---TAN' / Gnomonic projection
CTYPE2 = 'DEC--TAN' / Gnomonic projection
CRVAL1 = 205.4391740643 / [deg] RA at reference point
CRVAL2 = 28.4970299691 / [deg] Dec at reference point
CUNIT1 = 'deg ' / Unit of 1st axis
CUNIT2 = 'deg ' / Unit of 2nd axis
CRPIX1 = 428. / Reference pixel on 1st axis
CRPIX2 = 517. / Reference pixel on 2nd axis
CD1_1 = -4.888866666666667E-05 / Transformation matrix for primary WCS
CD1_2 = -0. / Transformation matrix for primary WCS
CD2_1 = -0. / Transformation matrix for primary WCS
CD2_2 = 4.888866666666667E-05 / Transformation matrix for primary WCS
EXTNAME = 'IM1 ' / Extension name
IMAGEID = 1
CCDNAME = 'CCD1 '
CCDSUM = '1 1 ' / On-chip binning factors
DARK = 0. / [e-/hr/pix]
QCDDATE = 'UNDEFINED' / Detector characteristics reference date
RDNOISE = 5.28 / [e-]
GAIN = 1.68 / [e-/ADU]
```