

# VISTA DATA FLOW SYSTEM (VDFS)

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for VISTA & WFCAM data

**Pipeline / Science Archive Interface Control Document**

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## 1 SCOPE

This Interface Control Document (ICD) for the VISTA Data Flow System (VDFS) describes the data flow subsystem interface between the data processing centre (CASU at the IoA, Cambridge) and the science archive centre (WFAU at the IfA, Edinburgh). Details of the types and specifications of VISTA/WFCAM processed data being transferred, along with the transfer protocols (file naming, transfer method and procedure), are given. The details of this ICD have been agreed between CASU and WFAU. The present document is derived from a similar ICD concerning WFCAM data only (VDF-WFA-VSA-004, Issue 3), and has been updated and generalised to be applicable to data from both instruments.

The ICD is intended to be a formal interface control agreement between the data processing centre at CASU and the archive centre at WFAU in Edinburgh. The processing centre/archive centre interface is the final subsystem interface in the data flow chain, and is subject to the rules laid out herein. The ICD concerns VISTA and WFCAM data only; all other data ingested into VDFS science archives are outside the scope of interface control (the archives also ingest publicly released data products, e.g. SDSS and 2MASS etc., from other non-CASU sources). **Any toolkit codes delivered to WFAU from CASU must produce data products that adhere to the rules laid out here, but details of those codes are outwith the scope of this document.**

The ICD is meant to be a technical reference: its intended audience is the software engineers and scientists working on processing and archiving in the data flow. It takes the form of a formal agreement between CASU and WFAU, but must also satisfy other external bodies, namely the JAC and the UKIDSS survey science consortium for WFCAM, and analogous oversight and survey science groups for VISTA.

## 2 OVERVIEW

This document is structured as follows. In Section 3, we describe the fundamental rules that the interface shall adhere to, including a statement of the primary data format, FITS. Then, in Section 4, we describe the top-level specifications for data being transferred between Cambridge and Edinburgh, including a description of FITS conventions, keywords, file naming conventions, units and systems of physical quantities. Sections 5 and 6 go on to describe in explicit detail the data structures that are transferred. Then, Section 7 describes the transfer methods and procedures that achieve the data flow from Cambridge to Edinburgh. Finally, security issues are dealt with in Section 8.

Generally, this document is modelled on the ESO Data Interface Control Document [1], and follows as closely as possible the specifications provided therein. For WFCAM, a data flow system overview is provided in [2], and fundamental metadata description (i.e. FITS frame headers and keywords) is given in [3]. The WFCAM JAC/CASU interface is defined and described in [4]; CASU pipeline processing for VISTA and WFCAM data is described in documents available at [5]. Other applicable data flow system documents are listed in Section 11.

## 3 FUNDAMENTALS

### 3.1 WFAU Ingest

The archives at WFAU shall ingest data from CASU; there will be no transfer of WFCAM data between JAC and WFAU for example, nor will there be any direct transfer of VISTA data from Chile to WFAU.

### 3.2 Data transfer method

WFAU shall ingest data via the internet; tapes and/or ‘pluggable’ disks will not be employed. The implications for required network bandwidth are discussed in AD01. More details are given in Section 7.

### 3.3 Format

WFCAM data output from CASU shall be provided in standard FITS format (as specified in [6]) only. VISTA data shall be expressed in ESO hierarchical FITS, as described in [1]. Data shall not be expressed in any other format, e.g. the UK Starlink Hierarchical Data Structure format (NDFs). The FITS standard is mature, universally accepted and ideal for transporting both bulk pixel and catalogue data. We note that CASU and WFAU both use the CFITSIO library [7] to read and write FITS files.

Images (32 bit integer) and confidence maps (16 bit integer) shall be supplied as losslessly compressed files with an anticipated  $\sim \times 4$  saving in transfer and storage requirements (see later). FITS binary tables shall be in native format.

### 3.4 Transferred data

Data transferred from CASU shall consist of processed pixels (where the processing steps are specified by the observing protocol used), confidence maps, derived source catalogues and associated description data; no raw pixel data will be transferred to (or held in) the archives. Where irreversible stages such as stacking or mosaicing have been done as part of the reduction procedure, the individual component images and catalogues shall be transferred also. Library calibration frames shall be transferred (e.g. dark frames, flat fields, master skies) for use by users (not for any processing at the archive end).

## 4 TOP-LEVEL DATA SPECIFICATION

### 4.1 Preliminaries

Processed frames shall be stored in FITS format, following the guidelines set out in [1]:

- the images comprising a multi-device image frame shall be stored in different image extensions of the same FITS container file (a multi-extension FITS, or MEF, file); data pixels belonging to one chip’s image shall be stored in one image extension (guideline-2);
- the primary data array in the MEF file shall be empty (guideline-3);
- keywords describing the dataset in the MEF file as a whole shall be written into the HDU of that extension (guideline-5); keyword `INHERIT` shall be set to `TRUE` to indicate this;
- **single mosaic image products may be written in standard FITS primary HDU files OR in MEF files with one extension, depending on the application code that generates them. DON’T LIKE THIS — complicates application codes unnecessarily — why not always MEFs?**

Derived source catalogues corresponding to each image extension shall be written as FITS binary tables in extensions of a single, separate MEF file with a similarly empty primary array. The headers for the catalogue MEF shall contain all the information of image MEF headers plus ancillary processing keywords and values.

## 4.2 General FITS keywords

Keywords shall follow the standards set out in [1] and [6] and as described in [3] (for WFCAM data) and [15] (for VISTA). All keywords and associated values written to the HDS container files produced by the WFCAM DAS must be propagated through the JAC/CASU interface, through the data processing pipeline and into the science archive. Similarly, all VISTA camera DAS metadata must be propagated through the data flow system.

The first keyword in any extension HDU must be `XTENSION`, and its value shall take on only `'IMAGE'` or `'BINTABLE'`; the `EXTNAME` keyword is used to identify the extension with a particular device detector and a unique ID for each device used in the respective infrared cameras must be propagated through the data flow via an assigned keyword. Binary tables shall have every column described by keywords `TTYPEn`, `TFORMn` and `TUNITn` (see later).

World Co-ordinate System (WCS; ie. astrometric) information shall be propagated using a set of standard keywords described in the latest FITS WCS proposals [11, 12] by Greisen and Calabretta.

## 4.3 Physical units

Physical units shall comply with SI units and their derivatives with a few exceptions for astronomical convenience (see [1] Section 9, Table 14).

Celestial co-ordinates shall be expressed in a system described by primary HDU keyword `RADESYS`; it is anticipated that this will have `ICRS` (i.e. Hipparcos/Tycho) over the lifetime of WFCAM, but this may of course change for VISTA. The keyword `EQUINOX` shall be included for backwards compatibility to explicitly give an equinox for older software.

## 4.4 File naming conventions

For WFCAM, CASU/JAC/ATC have an agreed policy on filenames; furthermore, it is UKIRT policy to use run numbers that reset back to 1 each night. For ease of tracking files through the data flow system, the CASU/WFAU interface follows the same policy, with conventions for processed products, as follows:

- at the telescope, the DAS produces files called `wayyyymmdd_12345.sdf`, `wbyyyymmdd_12345.sdf` and so on, where the a,b,c,d correspond to detector, w stands for wfcam and 12345 is the 5 digit run number;
- CASU shall create 2D raw MEF files from the individual NDFs as a precursor to input to the processing pipeline front-end, with names of the form `w_yyyymmdd_nnnnn.fit` and processed filenames of the form `w_yyyymmdd_nnnnn_suffix.fit` where `yyymmdd` is the UT date of observation, `nnnnn` is the UKIRT DAS running number (reset to 1 on a nightly basis) and `_suffix` is a combination of an underscore character plus two-letter abbreviations indicating pipeline processing actions: `_sf` = interleaved superframe, `_st` = stack, `_sf_st` = stacked superframe, `_sf_t1` = tiled superframe etc. Catalogues generated from frames shall be `rootname_cat.fits` and confidence maps for frames `rootname_conf.fit`, etc.

When a file is the result of a combination of several files, the run number of the first file in the list of combined files shall be used for the filename of the combined data file.

**For VISTA, the file naming convention shall be as expressed in [1], Section 11.**

## 4.5 Convention for null values

The ANSI/IEEE-754 floating-point number standard defines certain special values that are used to represent such quantities as not-a-number (NaN), denormalized, underflow, overflow, and infinity (see the Appendix in the NOST FITS standard [6] or the NOST FITS User's Guide for a list of these values). The CFITSIO routines that read floating point data in FITS files recognize these IEEE special values and by default interpret the overflow and infinity values as being equivalent to a NaN, and convert the underflow and denormalized values into zeros. In cases where programmers may want access to the raw IEEE values without any modification by CFITSIO, this can be done by calling the `fits_read_img` or `fits_read_col` routines while specifying 0.0 as the value of the `NULLVAL` parameter. This will force CFITSIO to simply pass the IEEE values through to the application program without any modification.

Since most of the binary tables contain floating point numbers there is no need to specify null values as these can be specified transparently in CFITSIO. Null floats shall be set to `FLOATNULLVAL` (equivalent to IEEE not-a-number) and the CFITSIO routines used as normal. For any integer columns, the FITS null value shall be explicitly defined by the `TNULLn` keyword.

**Is this really what happens?! Or do we simply get zeros from you?**

## 5 DETAILED DATA SPECIFICATION: WFCAM

### 5.1 Data obtained at the time of observation

Observations shall be described via the keywords `OBSERVER`, `USERID`, `OBSREF`, `PROJECT`, `MSBID`, `OBJECT`, `SURVEY` and `SURVEY_I` keywords. Instrumental characteristics, set-ups and parameters shall be described by keywords as detailed in [3], including instrument detector configuration (e.g. array used `DETECTOR`; number of integrations `NINT`), detector controller information (e.g. camera read mode `READMODE`; read-out application `CAPPLICN`), optical configuration (e.g. filter name `FILTER`; base focus position `FOC_MM`) and observing conditions/environment (e.g. air temperature `AIRTEMP`; relative humidity `HUMIDITY`; opacity data `CSOTAU`). All these FITS keys will be propagated through the data flow chain from the DAS to the WFCAM Science Archive (WSA).

### 5.2 Data products

#### 5.2.1 Corrected pixel data

The CASU pipeline corrects WFCAM pixels into a product that is instrument-signature free. The reduction steps involved in doing so, the derived astrometric and (first-cut) photometric calibrations and resulting DQC information generated shall be propagated into the WSA using FITS keys detailed in the appendices in Section 9. Appendix 9.1 shows example FITS keys for the primary HDU; Appendix 9.2 shows an example of an extension set. Differences in the FITS keys in primary extension HDUs for combined frame products shall be limited to the propagation of provenance information, i.e. a list of the individual frames that have been combined in the pipeline to create a combined frame product will be listed as a set of `PROVnnn` keywords. Library calibration frames shall have identical FITS keys to science frames, but library frame keywords for library frames will not refer to other frames (e.g. library flatfields will not be flatfielded, etc).

Pixel data values shall be represented in 4-byte integer numbers (i.e. `BITPIX=+32`) and CFITSIO 'Rice' tile compression [14] shall be employed to facilitate efficient storage and network transfer. Whenever possible, all processing will maintain the original units, i.e. if the original raw data run from 0 to 100,000

ADU, the range in data numbers in processed frames will be similar. At this stage, we allow for the possibility of use of BSCALE and BZERO FITS keywords and values to recast 4-byte integers into floating point numbers.

### 5.2.2 Source catalogues

The standard set of CASU source detection parameters can be found in [5]. An example FITS header for a catalogue MEF is given in Appendix 9.3. The following are an extract of the corresponding FITS binary table details for each catalogue attribute (TFORM is 1E throughout):

| No. | Name                   | TTYPE                  | TUNIT   |
|-----|------------------------|------------------------|---------|
| 1   | Seq. no.               | Sequence_number        | -       |
| 2   | Isophotal flux         | Isophotal_flux         | ADU     |
| 3   | X co-ordinate          | X_coordinate           | pixels  |
| 4   | Error in X             | X_coordinate_error     | pixels  |
| 5   | Y co-ordinate          | Y_coordinate           | pixels  |
| 6   | Error in Y             | Y_coordinate_error     | pixels  |
| 7   | Gaussian sigma         | Gaussian_sigma         | pixels  |
| 8   | Ellipticity            | Ellipticity            | -       |
| 9   | Position angle         | Position_angle         | degrees |
| 10  | Areal profile 1        | Areal_1_profile        | pixels  |
| .   | .                      | .                      | .       |
| 17  | Areal profile 8        | Areal_8_profile        | pixels  |
| 18  | Peak height            | Peak_height            | ADU     |
| 19  | Peak height error      | Peak_height_error      | ADU     |
| 20  | Aperture flux 1        | Aperture_flux_1        | ADU     |
| 21  | Aperture flux 1 error  | Aperture_flux_1_error  | ADU     |
| 22  | Aperture flux 2        | Aperture_flux_2        | ADU     |
| 23  | Aperture flux 2 error  | Aperture_flux_2_error  | ADU     |
| .   | .                      | .                      | .       |
| 44  | Aperture flux 13       | Aperture_flux_13       | ADU     |
| 45  | Aperture flux 13 error | Aperture_flux_13_error | ADU     |
| 46  | Petrosian radius       | Petrosian_radius       | pixels  |
| 47  | Kron radius            | Kron_radius            | pixels  |
| 48  | Hall radius            | Hall_radius            | pixels  |
| 49  | Petrosian flux         | Petrosian_flux         | ADU     |
| 50  | Petrosian flux error   | Petrosian_flux_error   | ADU     |
| 51  | Kron flux              | Kron_flux              | ADU     |
| 52  | Kron flux error        | Kron_flux_error        | ADU     |
| 53  | Hall flux              | Hall_flux              | ADU     |
| 54  | Hall flux error        | Hall_flux_error        | ADU     |
| 55  | Error bit flag         | Error_bit_flag         | flag    |
| 56  | Sky level              | Sky_level              | ADU     |
| 57  | Sky variance           | Sky_variance           | ADU     |
| 58  | Child/parent           | Parent_or_child_flag   | flag    |
| 59  | Right Ascension        | RA                     | radians |
| 60  | Declination            | DEC                    | radians |
| 61  | Classification         | Classification         | flag    |



|    |                     |                     |         |
|----|---------------------|---------------------|---------|
| 62 | Profile statistic   | Class_statistic     | N-sigma |
| 63 | PSF flux            | PSF_flux            | ADU     |
| 64 | PSF flux error      | PSF_flux_error      | ADU     |
| 65 | PSF fitted X        | PSF_fit_X           | pixels  |
| 66 | PSF fitted X error  | PSF_fit_X_error     | pixels  |
| 67 | PSF fitted Y        | PSF_fit_Y           | pixels  |
| 68 | PSF fitted Y error  | PSF_fit_y_error     | pixels  |
| 69 | PSF fit chi-squared | PSF_fit_chi2        | -       |
| 70 | nu                  | PSF_fit_dof         | -       |
| 71 | 1D Sersic flux      | 1D_Sersic_flux      | ADU     |
| 72 | Scale length        | 1D_Sersic_scale_len | -       |
| 73 | Power law index     | 1D_Sersic_index     | -       |
| 74 | Error in 1D fit     | 1D_Sersic_fit_chi2  | -       |
| 75 | 1D Sersic fit nu    | 1D_Sersic_fit_nu    | -       |
| 76 | 2D Sersic flux      | 2D_Sersic_flux      | ADU     |
| 77 | Scale length        | 2D_Sersic_scale_len | -       |
| 78 | Power law index     | 2D_Sersic_index     | -       |
| 79 | Error in 2D fit     | 2D_Sersic_fit_chi2  | -       |
| 80 | 2D Sersic fit nu    | 2D_Sersic_fit_nu    | -       |

The attribute set and binary table format for CASU standard list-driven source re-measurement (known colloquially as ‘co-located list-driven photometry’) shall be the same as the standard 80 parameter set described above, but some attributes will of course have subtle changes in their precise meanings as follows:

- RA and Dec shall be the input position, not a derived position;
- X and Y shall be the derived centre-of-gravity within a default aperture as opposed to the first moments of the thresholded, connected pixel distribution.

Aperture sizes and PSFs shall be specified as before; note that fluxes may of course go negative due to noise in a given aperture at a given position. The reasons for keeping the list-driven format as close as possible to the standard isophotal parameter format is to maintain maximum flexibility in the system, and to ensure that existing software (e.g. classifying, source merging etc.) can work in the same way for both types of extracted source lists.

## 6 DETAILED DATA SPECIFICATION: VISTA

In general, the only difference between VISTA FITS and WFCAM FITS data shall be in the use of ESO hierarchical FITS headers. Of course, the exact keyword set used to describe VISTA data will be different to that for WFCAM. Appendix 9.4 gives example VISTA FITS headers, which illustrate use of ESO hierarchical FITS. This example is taken from AD06, where more details can be found.

### 6.1 Data obtained at the time of observation

Instrumental characteristics, set-ups and parameters shall be described by keywords as detailed in AD06; example FITS headers can be seen in Appendix 9.4.

## 6.2 Data products

Post-pipeline, and pre-archive, some extra header items will be added, notably the Quality-Control Measures; keyword sets shall be similar to the examples given in the Appendices for WFCAM data.

### 6.2.1 Corrected pixel data

In addition to those referenced above, keyword categories as described in [1] shall be employed, e.g. *Process* (PR0) and *Quality Control* (QC) etc. Additional example sets of hierarchical keywords are given in Appendix 9.4.3.

### 6.2.2 Source catalogues

VISTA source extraction parameters shall be the same as those for WFCAM (see Section 5.2.2).

## 7 TRANSFER METHODS & PROCEDURES

### 7.1 Method

Transfer shall be via the internet using standard methods. The data to be transferred shall reside in Cambridge on specific RAID arrays attached to a linux PC cluster. WFAU has an account on this system. Directories of processed nights data are set up as the pipeline is running. While processing and writing to a given directory is still running a directory lock file is used to denote the ‘in progress’ operations. After completion of processing, the lock file is removed and a semaphor file (‘OK\_TO\_COPY’) is written enabling a remote client task to automatically initiate data transfer to Edinburgh. Once the transfer is complete, the WFAU transfer application writes a semaphor file (‘SUCCESSFULLY\_READ’) into the nightly directory. WFAU shall not copy any directory that has no OK\_TO\_COPY file present, and of course will not recopy any directory with SUCCESSFULLY\_READ present. CASU shall not move or alter data in any way in the interval between OK\_TO\_COPY being flagged and SUCCESSFULLY\_READ being written; after successful transfer, CASU are free to move/delete data as and when necessary. In AD01 we give details of on-going network bandwidth experiments with large data volumes and employing various transfer protocols; transfer methods tested include ftp, scp, GridFTP and sftp. Currently, a bespoke multithreaded scp application is employed to transfer WFCAM data from CASU to WFAU, and it is anticipated that a similar solution will be employed for VISTA data.

### 7.2 Procedure

Location of data is guaranteed by the pipeline and will be in an observation-date-driven directory structure to which WFAU will have secure, direct access. ‘Handshaking’, e.g. notification of readiness, is achieved using a lockfile system as outlined above; verification of successful transfer includes automatic checking within the transfer utility employed via the number and size of files transferred.

In AD02, we give more details of the transfer task software, including error handling and transfer logging.

### 7.3 Updates

In the event of pipeline reruns over previous data (e.g. because of improvements in instrumental correction and/or source extraction software) the interface as a whole will be the same regardless

of whether data being transferred is first-run or re-run as long as the archive system can cope with overwriting issues within and storage of repeat data. These are dealt with in the database design presented in AD02.

## 8 SECURITY ISSUES

Nightly processed data shall be held online at CASU until transfer of those data to WFAU is verified. As noted before, secure transfer protocols will be employed between CASU and WFAU to protect data from malicious corruption or access by unauthorised users. Although not strictly speaking a CASU/WFAU interface issue, raw data will be held online in Cambridge (and also offline in a tape store in another building) as the primary UK backup in case of any catastrophic data loss further down the data flow (raw WFCAM data is archived offline at JAC, and raw VISTA and WFCAM survey data at ESO/Garching).

## References

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## 9 APPENDICES

### 9.1 Primary HDU FITS keys from CASU pipeline-processed WFCAM image data

```

SIMPLE = T / file does conform to FITS standard
BITPIX = 8 / number of bits per data pixel
NAXIS = 0 / number of data axes
EXTEND = T / FITS dataset may contain extensions
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
TELESCOP= 'UKIRT ' / Telescope name
INSTRUME= 'WFCAM ' / Instrument
DHSVER = 'UKDHS 2002 Oct 31 ' / Data handling version
HDTFILE = 'wfcam.hdt ' / Name of global hdt file
OBSERVER= ' ' / Observers names
USERID = ' ' / Userid logged in as
OBSREF = ' ' / PATT or other reference
PROJECT = 'U/UKIDSS/GPS7' / Time-allocation code
SURVEY = ' ' / Survey name
SURVEY_I= ' ' / Pointing ID within survey
MSBID = '122600944ce2aa61f97fcc0f755df41f' / Id min.-schedulable block
RMTAGENT= 'none ' / Name of remote agent
AGENTID = 'none ' / Unique identifier for remote agent
OBJECT = 'gps_10b10:0_0:0_0' / Object name from telescope
RECIPE = 'JITTER ' / Data reduction recipe to be used
OBSTYPE = 'OBJECT ' / BIAS|DARK|SKYFLAT|DOMEFLAT|OBJECT|SKY|FOCUS
OBSNUM = 204 / Observation number
GRPNUM = 204 / Group number applied to all members
GRPMEM = T / Group membership
TILENUM = 204 / Tile number applied to all members
STANDARD= F / Is the target a standard star observation?
NJITTER = 2 / 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
UTDATE = '20060428' / UT date as integer in yyyymmdd format
DATE-OBS= '2006-04-28T12:29:18.010' / Date time (UTC) of start of observation
DATE-END= '2006-04-28T12:29:24.499' / Date time (UTC) of end of observation
MJD-OBS = 53853.52035 / 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
TRACKSYS= 'J2000 ' / Telescope tracking coordinate system
RABASE = 17.1331306 / [h] Right ascension of base position
DECBASE = -23.5104778 / [deg] Declination of base position
TELRA = 17.1331306 / [h] Current telescope right ascension
TELDEC = -23.5104778 / [deg] Current telescope declination
GSRA = 17.1305500 / [h] Right ascension of guide star
GSDEC = -23.5137889 / [deg] Declination of guide star
TRAOFF = 0.000 / [arcsec] Telescope offset in RA
TDECOFF = 0.000 / [arcsec] Telescope offset in Dec
AMSTART = 1.397 / Airmass at start of observation
AMEND = 1.398 / Airmass at end of observation
NINT = 1 / Number of integrations in observation
READMODE= 'CDS ' / Name of camera readmode
EXP_TIME= 5.000000 / [s] Integration time per exposure
NEXP = 1 / Number of exposures in integration
READINT = 0.000000 / [s] Interval between reads

```

```

NREADS =          2 / Number of reads per exposure
AIRTEMP =         0.363 / [degC] Air temperature
BARPRESS=        614.262 / [mbar] Ambient pressure
DEWPOINT=       -32.433 / [degC] Dewpoint
DOMETEMP=         0.671 / [degC] Dome temperature
HUMIDITY=         6.412 / Relative Humidity
MIRR_NE =         5.046 / [degC] Mirror temperature NE
MIRR_NW =         3.413 / [degC] Mirror temperature NW
MIRR_SE =         1.782 / [degC] Mirror temperature SE
MIRR_SW =         2.348 / [degC] Mirror temperature SW
MIRRBTNW=        7.324 / [degC] Mirror bottom temp. SW
MIRRTPNW=        5.652 / [degC] Mirror top temp. SW
SECONDAR=       -0.650 / [degC] Temperature of secondary
TOPAIRNW=        1.415 / [degC] Top air NW
TRUSSENE=        2.540 / [degC] Truss leg ENE
TRUSSWSW=        0.089 / [degC] Truss leg WSW
WIND_DIR=       93.152 / [deg] Wind direction, azimuth
WIND_SPD=       10.313 / [km/h] Wind speed
CSOTAU =         0.050 / Tau at 225 GHz from CSO
TAUDATE = '2006-04-28T12:24' / Time and date of Tau reading
TAUSRC = 'CSO225GHZ' / Source of opacity data
M2_X =          -0.800 / [mm] M2 X (E-W) raw position
M2_Y =           0.000 / [mm] M2 Y (N-S) raw position
M2_Z =           2.256 / [mm] M2 Z (focus) raw position
M2_U =           2.600 / [mrad] M2 U (N-S tilt) raw position
M2_V =           3.100 / [mrad] M2 V (E-W tilt) raw position
M2_W =           0.000 / [mrad] M2 W (axial rotation) raw position
TCS_FOC =       -0.420 / telescope (TCS) focus
FOC_POSN=        0.220 / [mm] Internal focus position
FOC_ZERO=        3.500 / [mm] Focus zero-point position
FOC_OFFS=        0.000 / [mm] Focus offset
FOC_FOFF=        0.220 / [mm] Focus filter offset
FILTER = 'J' / Filter name
UTSTART =       12.488334 / [h] Start time of integration
UTEND =         12.490000 / [h] End time of integration
FOC_I =          0 / Serial number in focus scan
FOC_OFF =        0.000 / [mm] Offset from nominal focus pos
RQ_MINSB= '15.5' / [mag/arcsec**2] requested min J sky brightness
RQ_MAXSB= '100.0' / [mag/arcsec**2] requested max J sky brightness
RQ_MNSEE= '0.00' / [arcsec] requested min seeing
RQ_MXSEE= '0.7' / [arcsec] requested max seeing
RQ_MINCL= '0' / [percentage] requested min cloud coverage
RQ_MAXCL= '0' / [percentage] requested max cloud coverage
RQ_MNTAU= '0' / requested min tau constraint
RQ_MXTAU= ' ' / requested max tau constraint
RQ_MINMN= '0' / [percentage] req. min illumination moon
RQ_MAXMN= '100' / [percentage] req. max illumination moon
HABASE =       -8.8497245 / [deg] Hour angle
APER_X =         0.000 / [arcsec] Aperture X axis coordinate
APER_Y =         0.000 / [arcsec] Aperture Y axis coordinate
ISU2PORT= 'Lost' / ISU2 port name
ISU2POFF=        0 / ISU2 port offset
ISU2TOFF=        0 / ISU2 tilt offset
GUIDING = 'ON' / Guider status: OFF|ON|PAUSED
GUIDFFOC= ' ' / Fast guider CCD fine focus
AGFREQ =        20.000 / Autoguider: Frequency
FGMODE = 'Fast Guider' / Fast guider mode
IZ5 =           0.000 / Astigmatism: IZ5
HZ5SH =       -310.000 / Astigmatism: HZ5SH
HZ5CH =         12.000 / Astigmatism: HZ5CH
HZ5SD =       -119.000 / Astigmatism: HZ5SD
HZ5CD =         421.000 / Astigmatism: HZ5CD
IZ6 =          -856.000 / Astigmatism: IZ6
HZ6SH =       -893.000 / Astigmatism: HZ6SH
HZ6CH =         583.000 / Astigmatism: HZ6CH
HZ6SD =       -274.000 / Astigmatism: HZ6SD
HZ6CD =         915.000 / Astigmatism: HZ6CD
Z7 =          -405.000 / Coma: Z7
Z8 =          1450.000 / Coma: Z8
WEBEAM =       -405.000 / Topend: W-E beam
NSBEAM =         45.000 / Topend: N-S beam
IZ9 =          1299.000 / Trefoil: IZ9
HZ9SH =         277.000 / Trefoil: HZ9SH

```

```

HZ9CH = -730.000 / Trefoil: HZ9CH
HZ9SD = -188.000 / Trefoil: HZ9SD
HZ9CD = -1106.000 / Trefoil: HZ9CD
IZ10 = 398.000 / Trefoil: IZ10
HZ10SH = 121.000 / Trefoil: HZ10SH
HZ10CH = 80.000 / Trefoil: HZ10CH
HZ10SD = -136.000 / Trefoil: HZ10SD
HZ10CD = -299.000 / Trefoil: HZ10CD
Z11 = 52.000 / Spherical: Z11
AAMP = 949.670 / Astigmatism: amplitude
APHI = 29.199 / Astigmatism: angle
TAMP = 469.433 / Trefoil: Amplitude
TPHI = 49.843 / Trefoil: angle
TEL_FOFF= -3.350 / focus offset for inst. filter
DETTEMPB= 74.4 / [K] DET_TEMP alternate sensor
DETTEMPS= 75.0 / [K] Det temperature setpoint
DET_HTP = 78.0 / [percent] Det heater level
CCD_TEMP= 160.3 / [K] AG CCD temperature
CCDTEMPS= 160.0 / [K] AG CCD temperature setpoint
CCD_HTP = 12.0 / [percent] AG CCD heater level
FS_TEMP = 66.6 / [K] CCC 1st stage temperature
LNC_TEMP= 91.6 / [K] LN can temperature
SS_TEMP = 17.9 / [K] CCC 2nd stage temperature
M3_TEMP = 111.3 / [K] M3 temperature
TR_TEMP = 120.5 / [K] Top ring temperature
RS_TEMP = 134.2 / [K] Rad shield temperature
CP_TEMP = 192.8 / [K] Cor plate temperature
SC_TEMP = 275.5 / [K] SCSU cab temperature
CC_PRES = 4.20000e-06 / [mbar] Cryostat Pressure
HISTORY 20060502 12:44:20
HISTORY $Id: cir_wfcam_convert.c,v 1.6 2005/10/19 09:13:45 jim Exp $
HISTORY 20060615 16:02:07
HISTORY $Id: cir_compress_fits.c,v 1.8 2005/04/19 12:36:53 jim Exp $
MAGZPT = 24.16 / Photometric ZP (mags) for default extinction
MAGZRR = 0.01 / Photometric ZP error (mags)
EXTINCT = 0.05 / Extinction coefficient (mags)
WSA_TIME= ' ' / WSA time stamp
WSA_MFID= 0 / WSA Multiframe ID
END

```

## 9.2 Extension HDU FITS keys from CASU pipeline-processed WFCAM image data

```

XTENSION= 'BINTABLE' / binary table extension
BITPIX = 8 / 8-bit bytes
NAXIS = 2 / 2-dimensional binary table
NAXIS1 = 8 / width of table in bytes
NAXIS2 = 4133 / number of rows in table
PCOUNT = 13902564 / size of special data area
GCOUNT = 1 / one data group (required keyword)
TFIELDS = 1 / number of fields in each row
TTYPE1 = 'COMPRESSED_DATA' / label for field 1
TFORM1 = '1PB(3599)' / data format of field: variable length array
EXTNAME = 'COMPRESSED_IMAGE' / name of this binary table extension
ZIMAGE = T / extension contains compressed image
ZBITPIX = 32 / data type of original image
ZNAXIS = 2 / dimension of original image
ZNAXIS1 = 4133 / length of original image axis
ZNAXIS2 = 4133 / length of original image axis
ZTILE1 = 4133 / size of tiles to be compressed
ZTILE2 = 1 / size of tiles to be compressed
ZCMPATYPE= 'RICE_1' / compression algorithm
ZNAME1 = 'BLOCKSIZE' / compression block size
ZVAL1 = 32 / pixels per block
CANNUM = 1 / Number of WFCAM camera (1, 2, 3 or 4)
HDTFILE2= 'wfcam2.hdt' / Name of camera-specific hdt file
CTYPE1 = 'RA---ZPN' / Algorithm type for axis 1
CTYPE2 = 'DEC--ZPN' / Algorithm type for axis 2
CRPIX1 = 5.9923252E+03 / Dither offset X
CRPIX2 = -1.8867648E+03 / Dither offset Y

```

```

CRVAL1 =      2.5699976E+02 / [deg] Right ascension at the reference pixel
CRVAL2 =     -2.3510918E+01 / [deg] Declination at the reference pixel
CRUNIT1 = 'deg'           / Unit of right ascension co-ordinates
CRUNIT2 = 'deg'           / Unit of declination co-ordinates
CD1_1 =     -1.6019899E-07 / Transformation matrix element
CD1_2 =     -5.5693643E-05 / Transformation matrix element
CD2_1 =      5.5711880E-05 / Transformation matrix element
CD2_2 =     -1.6556235E-07 / Transformation matrix element
PV2_1 =      1. / Pol.coeff. for pixel -> celestial coord
PV2_2 =      0.000000E+00 / Pol.coeff. for pixel -> celestial coord
PV2_3 =     -50.
DETECTOR= 'RSC Hawaii 2' / Type of detector array used
DETECTID= 'RSC:H2:60'    / Serial number of detector array
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
PCSYSID = 'wfacq1'      / PC system identifier
SDSUID = '1eid1c17'    / Serial number of SDSU controller
CAPPLICN= 'do_mean_wfcam_cds' / Name of camera readout application
CAMROLE = 'master'     / Camera role (master|slavel|sync)
CAMPOWER= 'On'        / Camera power (On|Off)
RUNID = '/home/wfcam/ucam/data/run00000345' / Name of raw data file
READOUT = 'CDS'       / Camera readout (CDS|NDR|SAR|RRR)
GAIN =      4.500 / [electrons/ADU] Detector gain
DET_TEMP=   74.4 / [K] Detector array temperature
CNFINDEX=  13865262 / Configuration index
READNOIS=   25. / Readnoise estimate
DARKCOR = 'Done with: dark_20060428_5_CDS_1.fit[1] and scale 1'
FLATCOR = 'Done with: pJ_flat_may2006.fit[1]'
CIR_CPM = 'w20060428_00204_sf_st_conf.fit[1]' / Confidence Map
DECURTN = 'Done'      / De-curtaining done
CURTNRNG=  49.65332 / Range of decurtain correction
XTALK = 'Done'
SKYSUB = 'Done with sky_20060428_204_J.fit[1] and scale factor 1'
CIR_XOFF=    0. / Dither offset X
CIR_YOFF=   15.98773 / Dither offset Y
CIRMED =    627.9613 / Latest estimate of background
CIR_BVAR=   159.1486 / Latest estimate of background variance
CIR_ZERO=  -4.644684 / Pedestal value relative to group average
CIR_SCAL=    1. / Background scale relative to group maximum
SKYLEVEL=   628.18 / Sky level estimate from IMCORE
SKYNOISE=    8.78 / Sky noise estimate from IMCORE
PROV0000= 'w20060428_00204_sf_st.fit[1]: formed from imdither of:' / Output file
PROV0001= 'w20060428_00204_sf.fit[1]' / Card # 1
PROV0002= 'w20060428_00208_sf.fit[1]' / Card # 2
SEEING =     5.395313 / Average FWHM (pixels)
NUMBRMS =    2089
STDCRMS =    0.1114304
WCSPASS =     2
RAZP02 =    10.09369 / [arcsec] Ref RA shift pass 0 to 2 (new - old)
DECZP02 =   -1.578503 / [arcsec] Ref Dec shift pass 0 to 2 (new - old)
ELLIPTIC=   0.2457458 / Ellipticity estimate from IMCORE
MAGZPT =    24.16 / Photometric ZP (mags) for default extinction
MAGZRR =     0.01 / Photometric ZP error (mags)
EXTINCT =    0.05 / Extinction coefficient (mags)
HISTORY 20060502 12:44:20
HISTORY $Id: cir_compress_fits.c,v 1.8 2005/04/19 12:36:53 jim Exp $
HISTORY 20060615 16:02:07
HISTORY $Id: cir_compress_fits.c,v 1.8 2005/04/19 12:36:53 jim Exp $
HISTORY 20060615 17:30:00
HISTORY $Id: cir_create_file.c,v 1.10 2004/09/03 10:48:45 jim Exp $
HISTORY 20060615 17:30:02
HISTORY $Id: cir_stage1.c,v 1.11 2005/12/15 14:44:04 jim Exp $
HISTORY 20060615 17:31:04
HISTORY $Id: cir_qblkmed.c,v 1.9 2005/08/12 14:35:19 jim Exp $
HISTORY 20060615 17:32:36
HISTORY $Id: cir_xtalk.c,v 1.5 2005/10/17 14:58:50 jim Exp $
HISTORY 20060615 20:01:58
HISTORY $Id: cir_arith.c,v 1.8 2005/02/25 10:14:55 jim Exp $

```



```

HISTORY 20060615 20:36:17
HISTORY $Id: cir_create_file.c,v 1.10 2004/09/03 10:48:45 jim Exp $
HISTORY 20060615 20:36:22
HISTORY $Id: cir_imcombine.c,v 1.35 2005/06/10 08:38:35 jim Exp $
HISTORY 20060615 20:37:29
HISTORY $Id: cir_imcore.c,v 1.11 2004/09/07 14:18:52 jim Exp $
HISTORY 20060615 20:37:44
HISTORY $Id: cir_create_file.c,v 1.10 2004/09/03 10:48:45 jim Exp $
HISTORY 20060615 20:40:34
HISTORY $Id: cir_imcore.c,v 1.11 2004/09/07 14:18:52 jim Exp $
HISTORY 20060615 20:43:35
HISTORY $Id: cir_platesol.c,v 1.10 2005/08/09 11:04:52 jim Exp $
PERCORR = 0. / Percentage sky correction
PROJP1 = 1. /
PROJP3 = -50. /
NUMZPT = 2920 / Number of standards used
NIGHTZPT= 22.77 / Average photometric ZP (mags) for night
NIGHTZRR= 0.24 / Photometric ZP sigma for night (mags)
BSCALE = 0.7071 /
END

```

BSCALE and BZERO shall default to 1.0 and 0.0 respectively if absent from the keyword list. FLATCOR is used to tell the pipeline how to do the flat fielding. If done, then it has the words 'Done with' and the name of the flat field file. RSTANOM is the reset anomaly correction. This example shows that it has been done with a median-linear filter with box sizes of 50 and 25 pixels respectively. CIR\_CPM is the confidence map.

PROV0000 simply gives the name of the current output image, while PROVnnnn gives a list of the images that went to forming this image. Note: RAZPmn and DECZPmn – the WCS is fit twice. WCSPASS = 0 is just a WCS from header information. WCSPASS = 1 is a fit to just the bright stars and WCSPASS = 2 is a fit to all stars in the generated catalogue. RAZPmn, DECZPmn is the zero-point shift between WCSPASS = m and WCSPASS = n. For m = 0, n = 1 it's an indication of how good the telescope pointing is. For m = 1, n = 2, it's an indication of how good the fit is (e.g. do we even have the right region here?) since for this combination the zeropoint should be very small.

Note that the processed image data will be 32 bit integer. Although if one coaverages a set of dithered frames (not to mention flatfielding and so on) all the arithmetic is done using real numbers internally. When one creates the output product, to approximately maintain the original quantisation accuracy of the ADC one can 'scale' the data on-the-fly using the normal CFITSIO routines by doing something along the following lines: if one sets up the output file with, say:

```

BITPIX = 32 /
BZERO = 0.0 /
BSCALE = 0.1 /

```

and then writes it out as call `ftppre(outunit,1,1,npix,map,status)` where `map` is an `r*4` array and reads it back via call `ftgpve(outunit,1,1,npix,nullval,sap,anynull,status)` one gets an rms error of 0.037; c.f. 0.37 with default BSCALE of 1.0; if we use BSCALE = 1 / no-of-frames-in-stack we stay at the ADC quantisation noise we started with, as if we had coadded them.

This works perfectly well and other packages (eg. DS9) read in the data correctly as one would expect. Furthermore, pixel data files expressed in this way also compress more or less the same as normal `int*4` files i.e. by roughly a factor of 4 (although more extensive checks are needed to see if this is really a typical factor and how the compression changes with the number of images in a stack). Note that  $\pm 0.5$  quantisation noise is totally negligible in NIR imagers but we feel the above is a sensible and conservative approach, and that lossless compression of integer data numbers is preferred to (albeit negligibly) lossy compression of floating point data numbers.

### 9.3 Example FITS keys from a catalogue MEF

Primary HDU (excluding keys inherited from corresponding image data):

```
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
COMMENT FITS (Flexible Image Transport System) format is defined in Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
END
```

Each extension HDU:

```
XTENSION= 'BINTABLE' / binary table extension
BITPIX =          8 / 8-bit bytes
NAXIS  =          2 / 2-dimensional binary table
NAXIS1 =          320 / width of table in bytes
NAXIS2 =          12874 / number of rows in table
PCOUNT =          0 / size of special data area
GCOUNT =          1 / one data group (required keyword)
TFIELDS =         80 / number of fields in each row
TTYPE1 = 'Sequence_number' / label for field 1
TFORM1 = '1E ' / data format of field: 4-byte REAL
TUNIT1 = 'Number ' / physical unit of field
TTYPE2 = 'Isophotal_flux' / label for field 2
TFORM2 = '1E ' / data format of field: 4-byte REAL
TUNIT2 = 'ADU ' / physical unit of field
TTYPE3 = 'X_coordinate' / label for field 3
TFORM3 = '1E ' / data format of field: 4-byte REAL
TUNIT3 = 'Pixels ' / physical unit of field
TTYPE4 = 'X_coordinate_err' / label for field 4
TFORM4 = '1E ' / data format of field: 4-byte REAL
TUNIT4 = 'Pixels ' / physical unit of field
TTYPE5 = 'Y_coordinate' / label for field 5
TFORM5 = '1E ' / data format of field: 4-byte REAL
TUNIT5 = 'Pixels ' / physical unit of field
TTYPE6 = 'Y_coordinate_err' / label for field 6
TFORM6 = '1E ' / data format of field: 4-byte REAL
TUNIT6 = 'Pixels ' / physical unit of field
TTYPE7 = 'Gaussian_sigma' / label for field 7
TFORM7 = '1E ' / data format of field: 4-byte REAL
TUNIT7 = 'Pixels ' / physical unit of field
TTYPE8 = 'Ellipticity' / label for field 8
TFORM8 = '1E ' / data format of field: 4-byte REAL
TUNIT8 = 'Number ' / physical unit of field
TTYPE9 = 'Position_angle' / label for field 9
TFORM9 = '1E ' / data format of field: 4-byte REAL
TUNIT9 = 'Degrees ' / physical unit of field
TTYPE10 = 'Areal_1_profile' / label for field 10
TFORM10 = '1E ' / data format of field: 4-byte REAL
TUNIT10 = 'Pixels ' / physical unit of field
TTYPE11 = 'Areal_2_profile' / label for field 11
TFORM11 = '1E ' / data format of field: 4-byte REAL
TUNIT11 = 'Pixels ' / physical unit of field
TTYPE12 = 'Areal_3_profile' / label for field 12
TFORM12 = '1E ' / data format of field: 4-byte REAL
TUNIT12 = 'Pixels ' / physical unit of field
TTYPE13 = 'Areal_4_profile' / label for field 13
TFORM13 = '1E ' / data format of field: 4-byte REAL
TUNIT13 = 'Pixels ' / physical unit of field
TTYPE14 = 'Areal_5_profile' / label for field 14
TFORM14 = '1E ' / data format of field: 4-byte REAL
TUNIT14 = 'Pixels ' / physical unit of field
TTYPE15 = 'Areal_6_profile' / label for field 15
TFORM15 = '1E ' / data format of field: 4-byte REAL
TUNIT15 = 'Pixels ' / physical unit of field
TTYPE16 = 'Areal_7_profile' / label for field 16
TFORM16 = '1E ' / data format of field: 4-byte REAL
```

```

TUNIT16 = 'Pixels ' / physical unit of field
TTYPE17 = 'Areal_8_profile' / label for field 17
TFORM17 = '1E ' / data format of field: 4-byte REAL
TUNIT17 = 'Pixels ' / physical unit of field
TTYPE18 = 'Peak_height' / label for field 18
TFORM18 = '1E ' / data format of field: 4-byte REAL
TUNIT18 = 'ADU ' / physical unit of field
TTYPE19 = 'Peak_height_err' / label for field 19
TFORM19 = '1E ' / data format of field: 4-byte REAL
TUNIT19 = 'ADU ' / physical unit of field
TTYPE20 = 'Aper_flux_1' / Fitted flux within 1/2* core radius
TFORM20 = '1E ' / data format of field: 4-byte REAL
TUNIT20 = 'ADU ' / physical unit of field
TTYPE21 = 'Aper_flux_1_err' / Error in fitted flux within 1/2* core radius
TFORM21 = '1E ' / data format of field: 4-byte REAL
TUNIT21 = 'ADU ' / physical unit of field
TTYPE22 = 'Aper_flux_2' / Fitted flux within 1/sqrt(2)* core radius
TFORM22 = '1E ' / data format of field: 4-byte REAL
TUNIT22 = 'ADU ' / physical unit of field
TTYPE23 = 'Aper_flux_2_err' / Error in fitted flux within 1/sqrt(2)* core rad
TFORM23 = '1E ' / data format of field: 4-byte REAL
TUNIT23 = 'ADU ' / physical unit of field
TTYPE24 = 'Aper_flux_3' / Fitted flux within 1* core radius
TFORM24 = '1E ' / data format of field: 4-byte REAL
TUNIT24 = 'ADU ' / physical unit of field
TTYPE25 = 'Aper_flux_3_err' / Error in fitted flux within 1* core radius
TFORM25 = '1E ' / data format of field: 4-byte REAL
TUNIT25 = 'ADU ' / physical unit of field
TTYPE26 = 'Aper_flux_4' / Fitted flux within sqrt(2)* core radius
TFORM26 = '1E ' / data format of field: 4-byte REAL
TUNIT26 = 'ADU ' / physical unit of field
TTYPE27 = 'Aper_flux_4_err' / Error in fitted flux within sqrt(2)* core radiu
TFORM27 = '1E ' / data format of field: 4-byte REAL
TUNIT27 = 'ADU ' / physical unit of field
TTYPE28 = 'Aper_flux_5' / Fitted flux within 2* core radius
TFORM28 = '1E ' / data format of field: 4-byte REAL
TUNIT28 = 'ADU ' / physical unit of field
TTYPE29 = 'Aper_flux_5_err' / Error in fitted flux within 2* core radius
TFORM29 = '1E ' / data format of field: 4-byte REAL
TUNIT29 = 'ADU ' / physical unit of field
TTYPE30 = 'Aper_flux_6' / Fitted flux within 2*sqrt(2)* core radius
TFORM30 = '1E ' / data format of field: 4-byte REAL
TUNIT30 = 'ADU ' / physical unit of field
TTYPE31 = 'Aper_flux_6_err' / Error in fitted flux within 2*sqrt(2)* core rad
TFORM31 = '1E ' / data format of field: 4-byte REAL
TUNIT31 = 'ADU ' / physical unit of field
TTYPE32 = 'Aper_flux_7' / Fitted flux within 4* core radius
TFORM32 = '1E ' / data format of field: 4-byte REAL
TUNIT32 = 'ADU ' / physical unit of field
TTYPE33 = 'Aper_flux_7_err' / Error in fitted flux within 4* core radius
TFORM33 = '1E ' / data format of field: 4-byte REAL
TUNIT33 = 'ADU ' / physical unit of field
TTYPE34 = 'Aper_flux_8' / Fitted flux within 5* core radius
TFORM34 = '1E ' / data format of field: 4-byte REAL
TUNIT34 = 'ADU ' / physical unit of field
TTYPE35 = 'Aper_flux_8_err' / Error in fitted flux within 5* core radius
TFORM35 = '1E ' / data format of field: 4-byte REAL
TUNIT35 = 'ADU ' / physical unit of field
TTYPE36 = 'Aper_flux_9' / Fitted flux within 6* core radius
TFORM36 = '1E ' / data format of field: 4-byte REAL
TUNIT36 = 'ADU ' / physical unit of field
TTYPE37 = 'Aper_flux_9_err' / Error in fitted flux within 6* core radius
TFORM37 = '1E ' / data format of field: 4-byte REAL
TUNIT37 = 'ADU ' / physical unit of field
TTYPE38 = 'Aper_flux_10' / Fitted flux within 7* core radius
TFORM38 = '1E ' / data format of field: 4-byte REAL
TUNIT38 = 'ADU ' / physical unit of field
TTYPE39 = 'Aper_flux_10_err' / Error in fitted flux within 7* core radius
TFORM39 = '1E ' / data format of field: 4-byte REAL
TUNIT39 = 'ADU ' / physical unit of field
TTYPE40 = 'Aper_flux_11' / Fitted flux within 8* core radius
TFORM40 = '1E ' / data format of field: 4-byte REAL
TUNIT40 = 'ADU ' / physical unit of field

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TTYPE41 = 'Aper_flux_11_err' / Error in fitted flux within 8* core radius
TFORM41 = '1E ' / data format of field: 4-byte REAL
TUNIT41 = 'ADU ' / physical unit of field
TTYPE42 = 'Aper_flux_12' / Fitted flux within 10* core radius
TFORM42 = '1E ' / data format of field: 4-byte REAL
TUNIT42 = 'ADU ' / physical unit of field
TTYPE43 = 'Aper_flux_12_err' / Error in fitted flux within 10* core radius
TFORM43 = '1E ' / data format of field: 4-byte REAL
TUNIT43 = 'ADU ' / physical unit of field
TTYPE44 = 'Aper_flux_13' / Fitted flux within 12* core radius
TFORM44 = '1E ' / data format of field: 4-byte REAL
TUNIT44 = 'ADU ' / physical unit of field
TTYPE45 = 'Aper_flux_13_err' / Error in fitted flux within 12* core radius
TFORM45 = '1E ' / data format of field: 4-byte REAL
TUNIT45 = 'ADU ' / physical unit of field
TTYPE46 = 'Petr_radius' / label for field 46
TFORM46 = '1E ' / data format of field: 4-byte REAL
TUNIT46 = 'Pixels ' / physical unit of field
TTYPE47 = 'Kron_radius' / label for field 47
TFORM47 = '1E ' / data format of field: 4-byte REAL
TUNIT47 = 'Pixels ' / physical unit of field
TTYPE48 = 'Hall_radius' / label for field 48
TFORM48 = '1E ' / data format of field: 4-byte REAL
TUNIT48 = 'Pixels ' / physical unit of field
TTYPE49 = 'Petr_flux' / label for field 49
TFORM49 = '1E ' / data format of field: 4-byte REAL
TUNIT49 = 'ADU ' / physical unit of field
TTYPE50 = 'Petr_flux_err' / label for field 50
TFORM50 = '1E ' / data format of field: 4-byte REAL
TUNIT50 = 'ADU ' / physical unit of field
TTYPE51 = 'Kron_flux' / label for field 51
TFORM51 = '1E ' / data format of field: 4-byte REAL
TUNIT51 = 'ADU ' / physical unit of field
TTYPE52 = 'Kron_flux_err' / label for field 52
TFORM52 = '1E ' / data format of field: 4-byte REAL
TUNIT52 = 'ADU ' / physical unit of field
TTYPE53 = 'Hall_flux' / label for field 53
TFORM53 = '1E ' / data format of field: 4-byte REAL
TUNIT53 = 'ADU ' / physical unit of field
TTYPE54 = 'Hall_flux_err' / label for field 54
TFORM54 = '1E ' / data format of field: 4-byte REAL
TUNIT54 = 'ADU ' / physical unit of field
TTYPE55 = 'Error_bit_flag' / label for field 55
TFORM55 = '1E ' / data format of field: 4-byte REAL
TUNIT55 = 'Number ' / physical unit of field
TTYPE56 = 'Sky_level' / label for field 56
TFORM56 = '1E ' / data format of field: 4-byte REAL
TUNIT56 = 'ADU ' / physical unit of field
TTYPE57 = 'Sky_rms' / label for field 57
TFORM57 = '1E ' / data format of field: 4-byte REAL
TUNIT57 = 'ADU ' / physical unit of field
TTYPE58 = 'Parent_or_child' / label for field 58
TFORM58 = '1E ' / data format of field: 4-byte REAL
TUNIT58 = 'Number ' / physical unit of field
TTYPE59 = 'RA ' / label for field 59
TFORM59 = '1E ' / data format of field: 4-byte REAL
TUNIT59 = 'RADIANS ' / physical unit of field
TTYPE60 = 'DEC ' / label for field 60
TFORM60 = '1E ' / data format of field: 4-byte REAL
TUNIT60 = 'RADIANS ' / physical unit of field
TTYPE61 = 'Classification' / label for field 61
TFORM61 = '1E ' / data format of field: 4-byte REAL
TUNIT61 = 'Flag ' / physical unit of field
TTYPE62 = 'Statistic' / label for field 62
TFORM62 = '1E ' / data format of field: 4-byte REAL
TUNIT62 = 'N-sigma ' / physical unit of field
TTYPE63 = 'Blank63 ' / label for field 63
TFORM63 = '1E ' / data format of field: 4-byte REAL
TUNIT63 = 'Blank63 ' / physical unit of field
TTYPE64 = 'Blank64 ' / label for field 64
TFORM64 = '1E ' / data format of field: 4-byte REAL
TUNIT64 = 'Blank64 ' / physical unit of field
TTYPE65 = 'Blank65 ' / label for field 65

```

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TFORM65 = '1E'      / data format of field: 4-byte REAL
TUNIT65 = 'Blank65' / physical unit of field
TTYPER65 = 'Blank66' / label for field 66
TFORM66 = '1E'      / data format of field: 4-byte REAL
TUNIT66 = 'Blank66' / physical unit of field
TTYPER66 = 'Blank67' / label for field 67
TFORM67 = '1E'      / data format of field: 4-byte REAL
TUNIT67 = 'Blank67' / physical unit of field
TTYPER67 = 'Blank68' / label for field 68
TFORM68 = '1E'      / data format of field: 4-byte REAL
TUNIT68 = 'Blank68' / physical unit of field
TTYPER68 = 'Blank69' / label for field 69
TFORM69 = '1E'      / data format of field: 4-byte REAL
TUNIT69 = 'Blank69' / physical unit of field
TTYPER69 = 'Blank70' / label for field 70
TFORM70 = '1E'      / data format of field: 4-byte REAL
TUNIT70 = 'Blank70' / physical unit of field
TTYPER70 = 'Blank71' / label for field 71
TFORM71 = '1E'      / data format of field: 4-byte REAL
TUNIT71 = 'Blank71' / physical unit of field
TTYPER71 = 'Blank72' / label for field 72
TFORM72 = '1E'      / data format of field: 4-byte REAL
TUNIT72 = 'Blank72' / physical unit of field
TTYPER72 = 'Blank73' / label for field 73
TFORM73 = '1E'      / data format of field: 4-byte REAL
TUNIT73 = 'Blank73' / physical unit of field
TTYPER73 = 'Blank74' / label for field 74
TFORM74 = '1E'      / data format of field: 4-byte REAL
TUNIT74 = 'Blank74' / physical unit of field
TTYPER74 = 'Blank75' / label for field 75
TFORM75 = '1E'      / data format of field: 4-byte REAL
TUNIT75 = 'Blank75' / physical unit of field
TTYPER75 = 'Blank76' / label for field 76
TFORM76 = '1E'      / data format of field: 4-byte REAL
TUNIT76 = 'Blank76' / physical unit of field
TTYPER76 = 'Blank77' / label for field 77
TFORM77 = '1E'      / data format of field: 4-byte REAL
TUNIT77 = 'Blank77' / physical unit of field
TTYPER77 = 'Blank78' / label for field 78
TFORM78 = '1E'      / data format of field: 4-byte REAL
TUNIT78 = 'Blank78' / physical unit of field
TTYPER78 = 'Blank79' / label for field 79
TFORM79 = '1E'      / data format of field: 4-byte REAL
TUNIT79 = 'Blank79' / physical unit of field
TTYPER79 = 'Blank80' / label for field 80
TFORM80 = '1E'      / data format of field: 4-byte REAL
TUNIT80 = 'Blank80' / physical unit of field
EXTNAME = 'APM-BINARYTABLE' / name of this binary table extension
DATE = '2006-06-15T19:39:35' / file creation date (YYYY-MM-DDThh:mm:ss UT)
.
.
.
SKYLEVEL=          628.18 / Median sky brightness (counts/pixel)
SKYNOISE=          8.78 / Pixel noise at sky level (counts)
HISTORY 20060615 20:37:29
HISTORY $Id: cir_imcore.c,v 1.11 2004/09/07 14:18:52 jim Exp $
HISTORY 20060615 20:37:44
HISTORY $Id: cir_create_file.c,v 1.10 2004/09/03 10:48:45 jim Exp $
.
.
.
NXOUT =           4133 / X-axis size of image
NYOUT =           4133 / Y-axis size of image
THRESHOL=        10.97 / Isophotal analysis threshold (counts)
MINPIX =           4 / Minimum size for images (pixels)
CROWDED =          1 / Crowded field analysis flag (0 none, 1 active)
RCORE =           5.00 / Core radius for default profile fit (pixels)
SEEING =          5.395313 / Average FWHM (pixels)
HISTORY 20060615 20:40:34
HISTORY $Id: cir_imcore.c,v 1.11 2004/09/07 14:18:52 jim Exp $
NUMBRMS =         2089
WCSPASS =          2
STDCRMS =         0.111430391669273

```

```

HISTORY 20060615 20:43:43
HISTORY $Id: cir_catcoord.c,v 1.7 2004/08/19 11:34:23 jim Exp $
ELLIPTIC= 0.2457458 / Average stellar ellipticity (1-b/a)
CLASSIFD= T / Class flag: -1 stellar, 1 non-stellar, 0 noise
SATURATE= 12497.84 / Average saturation level in frame
APCORPK = 4.261357 / Stellar aperture correction - peak height
APCOR1 = 1.537767 / Stellar aperture correction - 1/2x core flux
APCOR2 = 1.027226 / Stellar aperture correction - core/sqrt(2) flux
APCOR3 = 0.5166855 / Stellar aperture correction - core flux
APCOR4 = 0.2371197 / Stellar aperture correction - sqrt(2)x core flu
APCOR5 = 0.09944248 / Stellar aperture correction - 2x core flux
APCOR6 = 0.04034615 / Stellar aperture correction - 2sqrt(2)x core fl
APCOR7 = 0. / Stellar aperture correction - 4x core flux
COMMENT Symbolic translation for GAIA ellipse plotting.....
SYMBOL1 = '{Ellipticity Position_angle Areal_1_profile Classification} {el'
SYMBOL2 = 'lipse blue (1.0-$Ellipticity) $Position_angle+90 {} $Classific'
SYMBOL3 = 'ation==1} {sqrt($Areal_1_profile*(1.0-$Ellipticity)/3.142)} : {'
SYMBOL4 = 'Ellipticity Position_angle Areal_1_profile Classification} {el'
SYMBOL5 = 'lipse red (1.0-$Ellipticity) $Position_angle+90 {} $Classific'
SYMBOL6 = 'ation==1} {sqrt($Areal_1_profile*(1.0-$Ellipticity)/3.142)} : {'
SYMBOL7 = '{Ellipticity Position_angle Areal_1_profile Classification} {el'
SYMBOL8 = 'lipse green (1.0-$Ellipticity) $Position_angle+90 {} $Classifi'
SYMBOL9 = 'cation==0} {sqrt($Areal_1_profile*(1.0-$Ellipticity)/3.142)}'
HISTORY 20060615 20:43:43
HISTORY $Id: cir_classify.c,v 1.15 2006/03/17 11:30:27 jim Exp $
MAGZPT = 24.16 / Photometric ZP (mags) for default extinction
MAGZRR = 0.01 / Photometric ZP error (mags)
EXTINCT = 0.05 / Extinction coefficient (mags)
NUMZPT = 2920 / Number of standards used
PERCORR = 0.00 / Percentage sky correction
HISTORY $Id: photom_wfcam v0.6 MJI prototype toolkit $
NIGHTZPT= 22.77 / Average photometric ZP (mags) for night
NIGHTZRR= 0.24 / Photometric ZP sigma for night (mags)
HISTORY $Id: photom_wfcam v0.6 MJI prototype toolkit $
HISTORY $Id: photom_wfcam v0.7 MJI prototype toolkit $
END

```

## 9.4 Example VISTA hierarchical FITS keywords for image data

### 9.4.1 Primary HDU keywords

```

SIMPLE = T / Standard FITS (NOST-100-2.0)
NAXIS = 0 / number of axes of data array
BITPIX = 8 / number of bits per pixel value
EXTEND = T / FITS file extension may be present
RA = 123.123457 / 00:00:00.123 RA of telescope
DEC = -12.123457 / -00:00:00.12 Dec of telescope
RADECSYS= 'ICRS ' / Name of celestial reference frame
EQUINOX = 2000.0 / Equinox of celestial reference frame.
ORIGIN = 'ESO ' / European Southern Observatory
TELESCOP= 'ESO-VISTA' / ESO <TEL>
INSTRUME= 'VIRCAM ' / Instrument used
OBJECT = 'Sirius ' / Target description
IMAGETYP= 'OBJECT ' / Exposure type
AIRMASS = 1.12346 / Averaged airmass
DATE = '2004-12-13T12:31:46.000' / Date this file was written
DATE-OBS= '2004-12-25T09:00:00.123' / UTC date at start of exposure.
UTC = 86399.123 / 00:00:00.123 UTC s at start since midnight
REQTIME = 5.000 / Requested integration time
EXPTIME = 5.123 / Actual integration time
LST = 80000.123 / 00:00:00.123 LST seconds since midnight
MJD-OBS = 54321.12345678 / Modified Julian Date at start
OBSERVER= 'SERVICE ' / Name of observer
PI-COI = 'J Lewis ' / Name(s) of proposer(s)
COMMENT General comment
HISTORY Historical Fact
ESO-LOG
ORIGFILE= 'VIRCAM_Ima.1.fits' / Original File Name
ARCFILE = 'VIRCAM.2006-03-05T07:25:0.000.fits ' / Archive File name

```

```

CHECKSUM= 'Pd3jPc3hPc3h' / ASCII 1s-complement checksum
RECIPE = 'QUICK_LOOK' / Data-reduction recipe to be used
OFFSTNUM= 1234 / Value of first OBSNUM in current tile sequence
OBSNUM = 12345678 / Observation Number
GRPNUM = 666 / Group number applied to all members
GRPMEM = T / Group membership
STANDARD= F / Standard-star observation
NOFFSETS= 6 / Number of offset positions in a field
OFFSET_I= 2 / Serial Number of offset
NJITTER = 6 / Number of positions in a tel jitter pattern
JITTRNUM= 1236 / Value of first OBSNUM in current jitter sequenc
JITTER_I= 3 / Serial number of this tel jitter pattern
JITTER_X= 3.330 / X offset in jitter pattern
JITTER_Y= 0.000 / Y offset in jitter pattern
NUSTEP = 4 / Number of positions in microstep pattern
USTEPNUM= 1237 / Value of first OBSNUM in current microstep sequ
USTEP_I = 1 / Serial number of microstep pattern
USTEP_X = 1.123 / X offset in microstep pattern
USTEP_Y = 1.123 / Y offset in microstep pattern
HIERARCH ESO DPR DID = 'ESO-VLT-DIC.DPR-1.8' / DPR Dictionary
HIERARCH ESO DPR CATG = 'SCIENCE' / Observation ca
HIERARCH ESO DPR TYPE = 'OBJECT' / Observation ty
HIERARCH ESO DPR TECH = 'IMAGE' / Observation te
HIERARCH ESO OBS DID = 'ESO-VLT-DIC.OBS' / OBS Dictionary
HIERARCH ESO OBS ID = 666 / Observation block ID
HIERARCH ESO OBS NAME = 'deep-tile' / OB name
HIERARCH ESO OBS GRP = 'ABCD' / linked blocks
HIERARCH ESO OBS OBSERVER = 'Bunclark' / Observer Nam
HIERARCH ESO OBS PI-COI ID = 162 / ESO internal PI-COI ID
HIERARCH ESO OBS PI-COI NAME = 'Lewis' / PI-COI name
HIERARCH ESO OBS PROG ID = '68.A-0281(A)' / ESO program identificati
HIERARCH ESO OBS TPLNO = 2 / Template number within OB
HIERARCH ESO OBS TARG NAME = 'South Pole' / OB target na
HIERARCH ESO OBS START = '2006-03-05T07:20:00.123' / OB start time
HIERARCH ESO OBS EXEETIME = 0 / Expected execution time
HIERARCH ESO TPL PRESEQ = 'VIRCAM_img_obs_paw.seq' / Sequencer script
HIERARCH ESO TPL START = '2006-03-05T07:20:00.123' / TPL start time
HIERARCH ESO TPL DID = 'ESO-VLT-DIC.TPL-1.9' / Data dictionar
HIERARCH ESO TPL ID = 'VIRCAM_img_obs_paw'
HIERARCH ESO TPL NAME = 'VIRCAM Jittered pawprint sequence'
HIERARCH ESO TPL NEXP = 6 / Number of exposures within temp
HIERARCH ESO TPL EXPNO = 2 / Exposure number within template
HIERARCH ESO TPL VERSION = '@(#) $Revision: 1.5 $' / Version of the template
HIERARCH ESO TEL FOCU LEN = 4.120 / Focal length (m)
HIERARCH ESO TEL FOCU SCALE = 24.000 / Focal scale (arcsec/mm)
HIERARCH ESO TEL FOCU VALUE = 12345.120 / M2 setting (mm)
HIERARCH ESO TEL PARANG END = 45.000 / Parallaxtic angle at end (deg)
HIERARCH ESO TEL PARANG START = 47.000 / Parallaxtic angle at start (deg)
HIERARCH ESO TEL AIRM END = 1.001 / Airmass at end
HIERARCH ESO TEL AIRM START = 1.002 / Airmass at start
HIERARCH ESO TEL TRAK STATUS = 'ON' / Tracking status
HIERARCH ESO TEL TRAK RATEA = 0.000000 / Tracking rate in RA (arcsec/sec)
HIERARCH ESO TEL TRAK RATED = 0.000000 / Tracking rate in DEC (arcsec/se)
HIERARCH ESO TEL DOME STATUS = 'FULLY-OPEN' / Dome status
HIERARCH ESO ADA GUID STATUS = 'ON' / Status of autoguider
HIERARCH ESO ADA GUID RA = 180.000000 / 00:00:00.123 Guide star RA J200
HIERARCH ESO ADA GUID DEC = -45.000000 / %DEGREE Guide star DEC J2000
HIERARCH ESO ADA POSANG = 33.000000 / Position angle at start
HIERARCH ESO ADA ABSROT START = 2.000000 / Abs rot angle at exp start (deg)
HIERARCH ESO TEL ID = 'v 3.45' / TCS version
HIERARCH ESO TEL DID = 'ESO-VLT-DIC.TCS-1.33' / Data dictio
HIERARCH ESO TEL DATE = '2006-05-03' / TCS installation date
HIERARCH ESO ADA ABSROT END = 3.000000 / Abs rot angle at exp end (deg)
HIERARCH ESO ADA ABSROT PPOS = 'posit' / sign of probe position
HIERARCH ESO ADA WFS1 RA = 12.123457 / RA of WFS star 1
HIERARCH ESO ADA WFS1 DEC = -75.987654 / Dec of WFS star 1
HIERARCH ESO ADA WFS2 RA = 12.123457 / RA of WFS star 2
HIERARCH ESO ADA WFS2 DEC = -75.987654 / Dec of WFS star 2
HIERARCH ESO TEL ALT = 80.000 / Alt angle at start (deg)
HIERARCH ESO TEL AZ = 10.000 / Az angle at start (deg) S=0,W=9
HIERARCH ESO TEL GEOELEV = 2335 / Elevation above sea level (m)
HIERARCH ESO TEL GEOLAT = -29.2543 / Tel geo latitude (+=North) (deg)
HIERARCH ESO TEL GEOLON = -70.7346 / Tel geo longitude (+=East) (deg)

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HIERARCH ESO TEL OPER          = 'Senor Operador          ' / Telescope 0
HIERARCH ESO TEL FOCU ID       = 'CA          ' / Telescope focus station ID
HIERARCH ESO TEL TH M1 TEMP    =          8.12 / M1 superficial temperature
HIERARCH ESO TEL MOON RA       =    10.000000 / 00:00:00.123 RA (J2000) (deg)
HIERARCH ESO TEL AMBI FWHM START=          0.50 / Observatory Seeing queried from
HIERARCH ESO TEL AMBI FWHM END =          0.70 / Observatory Seeing queried from
HIERARCH ESO TEL AMBI TEMP     =          4.20 / Observatory ambient temperature
HIERARCH ESO TEL AMBI RHUM     =          5    / Observatory ambient relative hu
HIERARCH ESO TEL AMBI WINDDIR  =          340 / Observatory ambient wind direct
HIERARCH ESO TEL AMBI WINDSP   =          15.00 / Observatory ambient wind speed
HIERARCH ESO TEL MOON DEC      =    20.000000 / %DEGREE DEC (J2000) (deg)
HIERARCH ESO TEL ENCL MOONSCR STEP=          1 / Moonscreen positions step
HIERARCH ESO TEL ENCL WINDSCR1 STATE= 'OPEN    ' / Louvre state
HIERARCH ESO TEL ENCL WINDSCR2 STATE= 'UP      ' / up/down slide state
HIERARCH ESO TEL ENCL VENT1 STATE= 'SHUT     ' / Vent 1 door state
HIERARCH ESO TEL ENCL VENT2 STATE= 'HALF     ' / Vent 2 door state
HIERARCH ESO TEL ENCL VENT3 STATE= 'OPEN     ' / Vent 3 door state
HIERARCH ESO TEL M2 LOOP1 STATE = 'CLOSED   ' / Focus-loop switch state
HIERARCH ESO TEL M2 LOOP2 STATE = 'OPEN     ' / Centroiding-loop switch state
HIERARCH ESO TEL M2 LOOP3 STATE = 'CLOSED   ' / Tilt-loop switch state
HIERARCH ESO TEL M2 LOOP4 STATE = 'CLOSED   ' / Astigmatic-loop switch state
HIERARCH ESO TEL M2 LOOP5 STATE = 'CLOSED   ' / Trefoil-loop switch state
HIERARCH ESO TEL M2 CENX       =    1.510000 / X-Centre reading 1
HIERARCH ESO TEL M2 CENY       =    1.520000 / Y-Centre reading 2
HIERARCH ESO TEL M2 TILTX     =    1.530000 / X-tilt reading 3
HIERARCH ESO TEL M2 TILTY     =    1.540000 / Y-tilt reading 4
HIERARCH ESO TEL M1 ACTUATORFAILED=          1 / Number of failed actuator
HIERARCH ESO TEL ENCL FFLAMP1 ID= '123      ' / Dim tungsten lamp pair
HIERARCH ESO TEL ENCL FFLAMP1 NAME= 'VIS_DOM_DIM' / Dim tungsten lamp pair
HIERARCH ESO TEL ENCL FFLAMP1 STATE= 'OFF     ' / ON/OFF state of flat lamp 1
HIERARCH ESO TEL ENCL FFLAMP2 ID= '234      ' / Bright tungsten lamp pair
HIERARCH ESO TEL ENCL FFLAMP2 NAME= 'VIS_DOM_BRIGHT' / Bright tungsten lamp pair
HIERARCH ESO TEL ENCL FFLAMP2 STATE= 'ON      ' / ON/OFF state of flat lamp 2
HIERARCH ESO TEL ENCL FFLAMP3 ID= '345      ' / Halogen lamp pair
HIERARCH ESO TEL ENCL FFLAMP3 NAME= 'VIS_DOM_HALOGEN' / Dim tungsten lamp pair
HIERARCH ESO TEL ENCL FFLAMP3 STATE= 'OFF     ' / ON/OFF state of flat lamp 3
HIERARCH ESO INS THERMAL ENABLE=          T / If T, enable thermal control lo
HIERARCH ESO INS THERMAL DET TARGET=    130.00 / Detector target temperature
HIERARCH ESO INS THERMAL WIN DELTA=          0.0 / Window target temp wrt ambien
HIERARCH ESO INS THERMAL TUB DELTA=          0.0 / Tube target temp wrt ambient
HIERARCH ESO INS ID           = 'VIRCAM      ' / Instrument ID
HIERARCH ESO INS DID          = 'ESO-VLT-DIC.VIRCAM_ICS ' / Data dictionar
HIERARCH ESO INS OPER        = '          ' / Instrument ope
HIERARCH ESO INS SWSIM       = 'UNKNOWN     ' / Software simulation
HIERARCH ESO INS MODE        = 'IMAGE      ' / Instrument mode
HIERARCH ESO INS PATH        = 'UNKNOWN     ' / Optical path
HIERARCH ESO INS FILT SWSIM  =          UNKNOWN / If T, function software simulat
HIERARCH ESO INS FILT STOFF  =          0    / Offset [steps] to be applied
HIERARCH ESO INS FILT USESW  =          UNKNOWN / If T, in-position switch is use
HIERARCH ESO INS FILT IDi    = 'UNKNOWN     ' / Filter unique id
HIERARCH ESO INS FILT NAMEi  = 'UNKNOWN     ' / Filter name
HIERARCH ESO INS FILT FOCUSi=          1.235 / Filter focus offset [m]
HIERARCH ESO INS FILT DENSITYi=          1.2 / Filter optical density
HIERARCH ESO INS FILT NO     =          0    / Filter wheel position index
HIERARCH ESO INS FILT DATE   = 'UNKNOWN     ' / Filter index time
HIERARCH ESO INS FILT ERROR  =          0    / Last filter wheel error [Enc]
HIERARCH ESO INS HB DEVNAME  = 'UNKNOWN     ' / Name of the ICS device.
HIERARCH ESO INS HB DEVDESC  = 'UNKNOWN     ' / Description of the ICS de
HIERARCH ESO INS HB LCUID    =          0    / ID of the LCU managing the devi
HIERARCH ESO INS HB SWSIM    =          UNKNOWN / If T, function software simulat
HIERARCH ESO INS HB FREQUENCY=          1.2 / Square wave frequency.
HIERARCH ESO INS HB PIN      =          0    / Output pin.
HIERARCH ESO INS SENSORi SWSIM=          / If T, function software simulat
HIERARCH ESO INS LSMi SWSIM  =          UNKNOWN / If T, function software simulat
HIERARCH ESO INS LSMi OK     =          UNKNOWN / If T, controller was operationa
HIERARCH ESO INS LSCi SWSIM  =          UNKNOWN / If T, function software simulat
HIERARCH ESO INS LSCi OK     =          UNKNOWN / If T, controller was operationa
HIERARCH ESO INS LSCi SETPi  =          1.23 / Set-point.
HIERARCH ESO INS VACi SWSIM  =          UNKNOWN / If T, function software simulat
HIERARCH ESO INS VACi OK     =          UNKNOWN / If T, controller was operationa
HIERARCH ESO INS CCCi SWSIM  =          UNKNOWN / If T, function software simulat
HIERARCH ESO INS CCCi OK     =          UNKNOWN / If T, controller was operationa
HIERARCH ESO INS SENSi ID    = 'UNKNOWN     ' / Sensor type

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HIERARCH ESO INS SENSi NAME = 'UNKNOWN' / Sensor name
HIERARCH ESO INS SENSi VAL = 1.235 / Sensor value
HIERARCH ESO INS SENSi STAT = 'UNKNOWN' / Sensor string value
HIERARCH ESO INS SENSi MIN = 1.235 / Minimum value
HIERARCH ESO INS SENSi MAX = 1.235 / Maximum value
HIERARCH ESO INS SENSi MEAN = 1.235 / Average value
HIERARCH ESO INS SENSi RMS = 1.235 / RMS of samples over exposure
HIERARCH ESO INS SENSi TMMEAN= 0.000 / Time weighted average
HIERARCH ESO INS SENSi GRAD = 1.235 / Linear regression slope
HIERARCH ESO INS SENSi LRCONST= 0.000 / Linear regression constant
HIERARCH ESO INS SENSi LRRMS = 1.235 / Linear regression RMS
HIERARCH ESO INS SENSi DETCOEF= 0.000 / Lin. reg. determination coeff.
HIERARCH ESO INS SENSi UNITi = UNKNOWN / Sensor unit
HIERARCH ESO INS PRESi ID = 'UNKNOWN' / Pressure sensor type.
HIERARCH ESO INS PRESi NAME = 'UNKNOWN' / Pressure sensor name.
HIERARCH ESO INS PRESi VAL = 1.235 / Pressure.
HIERARCH ESO INS PRESi MIN = 1.235 / Minimum pressure.
HIERARCH ESO INS PRESi MAX = 1.235 / Maximum pressure.
HIERARCH ESO INS PRESi MEAN = 1.235 / Average pressure.
HIERARCH ESO INS PRESi RMS = 1.235 / RMS of samples over exposure.
HIERARCH ESO INS PRESi TMMEAN= 0.000 / Time weighted average.
HIERARCH ESO INS PRESi GRAD = 1.235 / Linear regression slope.
HIERARCH ESO INS PRESi LRCONST= 0.000 / Linear regression constant.
HIERARCH ESO INS PRESi LRRMS = 1.235 / Linear regression RMS.
HIERARCH ESO INS PRESi DETCOEF= 0.000 / Lin. reg. determination coeff..
HIERARCH ESO INS PRESi UNITi = UNKNOWN / Pressure unit.
HIERARCH ESO INS SW1 ID = 'UNKNOWN' / Switch ID
HIERARCH ESO INS SW1 NAME = 'Filter in-position switch' / Switch name
HIERARCH ESO INS SW1 STATUS = 'CLOSED' / Switch status
HIERARCH ESO INS TEMP1 ID = 'ID1' / ID of sensor 1
HIERARCH ESO INS TEMP1 NAME = 'Ambient temperature' / Location of sensor 1
HIERARCH ESO INS TEMP1 VAL = 260.100 / Temperature sensor 1 reading
HIERARCH ESO INS TEMP1 MIN = 260.100 / Minimum value
HIERARCH ESO INS TEMP1 MAX = 260.100 / Maximum value
HIERARCH ESO INS TEMP1 MEAN = 260.100 / Average value
HIERARCH ESO INS TEMP1 RMS = 260.100 / RMS of amples over exposure
HIERARCH ESO INS TEMP1 TMMEAN = 260.100 / Time weighted average
HIERARCH ESO INS TEMP1 GRAD = 0.010 / Linear regression slope
HIERARCH ESO INS TEMP1 LRCONST = 120.120 / Linear regression constant
HIERARCH ESO INS TEMP1 LRRMS = 260.100 / Linear regression RMS
HIERARCH ESO INS TEMP1 DETCOEF = 260.100 / Lin. reg. determination coeff
HIERARCH ESO INS TEMP1 UNIT = 'KELVIN' / Temperature unit
HIERARCH ESO INS TEMP2 ID = 'ID2' / ID of sensor 2
HIERARCH ESO INS TEMP2 NAME = 'Cryostat window temperature' / Location of se
HIERARCH ESO INS TEMP2 VAL = 260.100 / Temperature sensor 2 reading
HIERARCH ESO INS TEMP2 MIN = 260.100 / Minimum value
HIERARCH ESO INS TEMP2 MAX = 260.100 / Maximum value
HIERARCH ESO INS TEMP2 MEAN = 260.100 / Average value
HIERARCH ESO INS TEMP2 RMS = 260.100 / RMS of amples over exposure
HIERARCH ESO INS TEMP2 TMMEAN = 260.100 / Time weighted average
HIERARCH ESO INS TEMP2 GRAD = 0.010 / Linear regression slope
HIERARCH ESO INS TEMP2 LRCONST = 120.120 / Linear regression constant
HIERARCH ESO INS TEMP2 LRRMS = 260.100 / Linear regression RMS
HIERARCH ESO INS TEMP2 DETCOEF = 260.100 / Lin. reg. determination coeff
HIERARCH ESO INS TEMP2 UNIT = 'KELVIN' / Temperature unit
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.
.
HIERARCH ESO INS TEMP26 ID = 'ID26' / ID of sensor 26
HIERARCH ESO INS TEMP26 NAME = 'WFS plate' / Location of sensor 26
HIERARCH ESO INS TEMP26 VAL = 260.100 / Temperature sensor 26 reading
HIERARCH ESO INS TEMP26 MIN = 260.100 / Minimum value
HIERARCH ESO INS TEMP26 MAX = 260.100 / Maximum value
HIERARCH ESO INS TEMP26 MEAN = 260.100 / Average value
HIERARCH ESO INS TEMP26 RMS = 260.100 / RMS of amples over exposure
HIERARCH ESO INS TEMP26 TMMEAN = 260.100 / Time weighted average
HIERARCH ESO INS TEMP26 GRAD = 0.010 / Linear regression slope
HIERARCH ESO INS TEMP26 LRCONST = 120.120 / Linear regression constant
HIERARCH ESO INS TEMP26 LRRMS = 260.100 / Linear regression RMS
HIERARCH ESO INS TEMP26 DETCOEF = 260.100 / Lin. reg. determination coeff
HIERARCH ESO INS TEMP26 UNIT = 'KELVIN' / Temperature unit
HIERARCH ESO INS HOWFS DATE = '2006-03-05T01:02:03.123' / Time of new coeffs
END

```

## 9.4.2 Extension HDU FITS keys

```

XTENSION= 'IMAGE'      / Extension first keyword
NAXIS    =              2 / number of axes of data array
NAXIS1   =              2048 / Size of first axis
NAXIS2   =              2048 / Size of second axis
BITPIX   =              32 / number of bits per pixel value
EXTNAME  = 'WIN1.CHIP1.OUT1' / FITS extension name
EXTVER   =              1 / Detector index
INHERIT  =              T / Extension inherits primary header
DET_LIVE =              T / This detector is alive
RADECSYS= 'ICRS'      / Name of celestial reference frame
EQUINOX  =              2000.0 / Equinox of celestial reference frame.
CTYPE1   = 'RA---ZPN'  / Type of celestial axis 1
CTYPE2   = 'DEC--ZPN'  / Type of celestial axis 2
CRPIX1   =              6860.80 / Pixel coordinate of reference in axis 1
CRPIX2   =              -3507.20 / Pixel coordinate of reference in axis 2
CRVAL1   =              270.000000000000 / RA of reference point
CRVAL2   =              -75.000000000000 / Dec of reference point
CD1_1    = -9.444444E-05 / Transformation matrix element
CD1_2    = 0.000000E+00 / Transformation matrix element
CD2_1    = 0.000000E+00 / Transformation matrix element
CD2_2    = 9.444444E-05 / Transformation matrix element
PV2_1    = 1.000000E+00 / linear term in ZPN
PV2_2    = 0.000000E+00 / quadratic term in ZPN
PV2_3    = 4.200000E+01 / cubic term in ZPN
PV2_4    = 0.000000E+00 / forth-order term in ZPN
PV2_5    = 0.000000E+00 / fifth-order term in ZPN
HIERARCH ESO DET MINDIT = 1.7726000 / Minimum DIT
HIERARCH ESO DET MODE NAME = ' ' / DCS Detector Mode
HIERARCH ESO DET MODEi NAME = ' ' / DCS Detector Mode
HIERARCH ESO DET NC IDIV = 1 / # of Sub-Divs for R-0
HIERARCH ESO DET NC NSAMPPIX = 1 / # of Samples/Pixel
HIERARCH ESO DET NCORRS = 0 / Read-Out Mode
HIERARCH ESO DET RSPEED = 1 / Read-Speed Factor
HIERARCH ESO DET IRACE ADCi NAME= 'VIRGO' / Name for ADC Board
HIERARCH ESO DET IRACE ADCi HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADCi ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADCi FILTERi= 1 / ADC Filter Adjustment
HIERARCH ESO DET IRACE ADCi DELAY= 15 / ADC Delay Adjustment
HIERARCH ESO DET NCORRS NAME = 'DblCor' / Read-Out Mode Name
HIERARCH ESO DET NDIT = 10 / # of Sub-Integrations
HIERARCH ESO DET NDITSKIP = 0 / DITs skipped at 1st.INT
HIERARCH ESO DET NDSAMPLES = 0 / # of Non-Dest. Samples
HIERARCH ESO DET NDSKIP = 0 / Samples skipped per DIT
HIERARCH ESO DET RSPEEDADD = 0 / Read-Speed Add
HIERARCH ESO DET VOLTi CLKHINMi= '3.3' / Name of High Clock
HIERARCH ESO DET VOLTi CLKHITi= 0.0000 / Tel Value High Clock
HIERARCH ESO DET VOLTi CLKHIi= 0.0000 / Set Value High Clock
HIERARCH ESO DET VOLTi CLKLONMi= ' ' / Name of Low Clock
HIERARCH ESO DET IRACE SEQCONT= F / Sequencer Cont. Mode
HIERARCH ESO DET IRACE SEQINT= / Sequencer Intr. at Stop
HIERARCH ESO DET VOLTi CLKLOTi= 0.0000 / Tel Value Low Clock
HIERARCH ESO DET VOLTi DCNmi = 'FRED' / Name of DC Voltage
HIERARCH ESO DET VOLTi DCTAi = 4.9000 / Tel Value 1 for DC
HIERARCH ESO DET VOLTi CLKLOi= 0.1000 / Set Value Low Clock
HIERARCH ESO DET VOLTi DCi = 0.0000 / Set Value DC Voltage
HIERARCH ESO DET CHIP TYPE = 'RAYTHEON' / The Type of Det Chip
HIERARCH ESO DET CON OPMODE = 'SIMULATION' / Operational Mode
HIERARCH ESO DET FRAM TYPE = 'DIT' / Frame type
EXPTIME = 20.1234500 / Integration time
ORIGFILE= ' ' / Original File Name
HIERARCH ESO DET CHOP CYCSKIP= 0 / # of Chop Cycles to Skip
HIERARCH ESO DET CHOP NCYCLES= 0 / # of Chop Cycles
HIERARCH ESO DET CHOP ST = / Chopping On/Off
HIERARCH ESO DET CHOP FREQ = 0.000000 / Chopping Frequency
HIERARCH ESO DET CHIP ID = 'VM301-S/N-022' / Detector ID
HIERARCH ESO DET CHIP NAME = 'VIRGO' / Detector name
HIERARCH ESO DET CHIP NX = 2048 / Pixels in X
HIERARCH ESO DET CHIP NY = 2048 / Pixels in Y
HIERARCH ESO DET CHIP PXSPACE= 2.000e-05 / Pixel-Pixel Spacing
HIERARCH ESO DET EXP NO = 9876 / Exposure Number
HIERARCH ESO DET FRAM UTC = '2006-03-05T10:11:12' / Time Recv Frame

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HIERARCH ESO DET FRAM NO      =          2 / Frame number
HIERARCH ESO DET VOLTi DCTBi =         0.0000 / Tel Value 2 for DC
HIERARCH ESO DET WIN NX      =          2048 / # of Pixels in X
HIERARCH ESO DET DID        = '          ' / Dictionary Name and Revision
HIERARCH ESO DET DIT         =         0.0000000 / Integration Time
HIERARCH ESO DET DITDELAY    =          0.000 / Pause Between DITs
HIERARCH ESO DET EXP UTC     = '2006-03-05T10:11:12' / File Creation Time
HIERARCH ESO DET EXP NAME    = '          ' / Exposure Name
HIERARCH ESO DET WIN NY      =          2048 / # of Pixels in Y
HIERARCH ESO DET WIN STARTX  =         1.000000 / Lower Left X Ref
HIERARCH ESO DET WIN STARTY  =         1.000000 / Lower left Y Ref
HIERARCH ESO DET WIN TYPE    =          0 / Win-Type
END

```

### 9.4.3 Additional example keywords for processed VISTA data

```

HIERARCH ESO QC DID          = 'ESO-VLT-DIC.VIRCAM_QC          ' / Data dictionar
HIERARCH ESO QC DARKCURRENT =         200.000000 / average dark current on frame [
HIERARCH ESO QC DARKRMS     =         3.456000 / RMS noise of combined dark fram
HIERARCH ESO QC RESETDIFF_RMS=         0.000000 / [adu] RMS new-library reset fra
HIERARCH ESO QC DARKDIFF_RMS=         0.000000 / [adu] RMS new-library dark fram
HIERARCH ESO QC PARTICLE_RATE=        20.500000 / cosmic ray/spurion rate [count/
HIERARCH ESO QC RESETRMS    =         0.000000 / RMS noise in combined reset fra
HIERARCH ESO QC READNOISE   =        150.000000 / readnoise [electron].
HIERARCH ESO QC FLATRMS     =         0.000000 / RMS flatfield pixel sens per de
HIERARCH ESO QC GAIN        =         1.600000 / gain [e/ADU].
HIERARCH ESO QC BAD_PIXEL_STAT=         0.006000 / fraction of bad pixels/detector
HIERARCH ESO QC GAIN_CORRECTION=         0.950000 / detector median flatfield/globa
HIERARCH ESO QC LINEARITY   =         0.030000 / percentage average non-linearit
HIERARCH ESO QC LINFITQUAL  =         0.000000 / RMS fractional error in lineari
HIERARCH ESO QC SATURATION  =        65535.000000 / saturation level of bright star
HIERARCH ESO QC PERSIST_DECAY=         40.000000 / mean exponential time decay con
HIERARCH ESO QC PERSIST_ZERO =         0.800000 / fractional persistence at T0 (e
HIERARCH ESO QC CROSS_TALK  =         1.000000 / average values for cross-talk c
HIERARCH ESO QC WCS_DCRVAL1 =         5.55550e-04 / actual WCS zero point X - raw h
HIERARCH ESO QC WCS_DCRVAL2 =        -5.55550e-04 / actual WCS zero point Y - raw h
HIERARCH ESO QC WCS_DTHETA  =         1.000000e-02 / actual WCS rotation PA - raw PA
HIERARCH ESO QC WCS_SCALE   =         9.444400e-05 / measured WCS plate scale per de
HIERARCH ESO QC WCS_SHEAR   =         1.000000e-04 / power of cross-terms in WCS sol
HIERARCH ESO QC WCS_RMS     =         9.444400e-06 / robust RMS of WCS solution for
HIERARCH ESO QC MEAN_SKY    =         12345.120000 / mean sky level [ADU].
HIERARCH ESO QC SKY_NOISE   =         2000.000000 / RMS sky noise [ADU].
HIERARCH ESO QC SKY_RESET_ANOMALY=        123.450000 / systematic variation in sky acr
HIERARCH ESO QC NOISE_OBJ   =          150 / number of classified noise obje
HIERARCH ESO QC IMAGE_SIZE  =         0.500000 / mean stellar image FWHM [arcsec
HIERARCH ESO QC APERTURE_CORR=         0.456000 / 2 arcsec [mag] diam aperture fl
HIERARCH ESO QC ELLIPTICITY =         0.021100 / mean stellar ellipticity [scala
HIERARCH ESO QC ZPT_2MASS   =         26.500000 / 1st-pass photometric zeropoint
HIERARCH ESO QC ZPT_STDS    =         26.400000 / photometric zeropoint [mag].
HIERARCH ESO QC LIMITING_MAG =        24.567000 / limiting mag ie. depth of expos
HIERARCH ESO QC FRINGE_RATIO =         0.000000 / [scalar] Ratio of sky noise bef
HIERARCH ESO QC ILLUMCOR_RMS =         0.000000 / [mag] RMS in illumination corre
HIERARCH ESO QC RESETDIFF_MED=         0.000000 / Median new-library reset frame
HIERARCH ESO QC DARKDIFF_MED =         0.000000 / Median new-library dark frame [
HIERARCH ESO QC FLATRATIO_MED=         0.000000 / Median new/library flat frame [
HIERARCH ESO QC FLATRATIO_RMS=         0.000000 / RMS new/library flat frame [sca
HIERARCH ESO QC MAGZPT      =         0.000000 / Photometric zero point [mag].
HIERARCH ESO QC MAGZERR     =         0.000000 / Photometric zero point error [m
HIERARCH ESO QC MAGNZPT     =         0.000000 / Number of stars in zero point c
HIERARCH ESO QC RESET_MED   =         0.000000 / median reset level
HIERARCH ESO QC DARKMED     =         0.000000 / median dark counts
HIERARCH ESO DRS DID        = 'ESO-VLT-DIC.VIRCAM_DRS          ' / Data dictionar
HIERARCH ESO DRS XTCOR      = 'UNKNOWN ' / Crosstalk matrix table
HIERARCH ESO DRS DARKCOR    = 'UNKNOWN ' / dark image
HIERARCH ESO DRS DARKSCL    =         0.000000 / Dark scale factor
HIERARCH ESO DRS FRINGEi    = 'UNKNOWN ' / Fringe file of nth pass
HIERARCH ESO DRS FRNGSCi    =         0.000000 / scale factor nth defringe pass
HIERARCH ESO DRS FLATCOR    = 'UNKNOWN ' / flat field image
HIERARCH ESO DRS ZPIM1      =         0.000000 / [mag] photometric zeropoint
HIERARCH ESO DRS ZPSIGIM1   =         0.000000 / [mag] RMS in photometric zeropo
HIERARCH ESO DRS ZPIM2      =         0.000000 / [mag] photometric zeropoint

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HIERARCH ESO DRS ZPSIGIM2 = 0.000000 / [mag] RMS in photometric zero po
HIERARCH ESO DRS LIMIT_MAG1 = 0.000000 / [mag] Limiting magnitude 1*core
HIERARCH ESO DRS LIMIT_MAG2 = 0.000000 / [mag] Limiting magnitude 2*core
HIERARCH ESO DRS MAGNZPTIM = 0 / Number of stars used photometri
HIERARCH ESO DRS ZPALL1 = 0.000000 / [mag] photometric zeropoint
HIERARCH ESO DRS ZPSIGALL1 = 0.000000 / [mag] RMS in photometric zero po
HIERARCH ESO DRS ZPALL2 = 0.000000 / [mag] photometric zeropoint
HIERARCH ESO DRS ZPSIGALL2 = 0.000000 / [mag] RMS in photometric zero po
HIERARCH ESO DRS MAGNZPTALL = 0 / Number of stars used photometri
HIERARCH ESO DRS XOFFMICRO = 0.000000 / X-pixels to microstep input ima
HIERARCH ESO DRS YOFFMICRO = 0.000000 / Y-pixels to microstep input ima
HIERARCH ESO DRS XOFFDITHER = 0.000000 / X-pixels to jitter input image
HIERARCH ESO DRS YOFFDITHER = 0.000000 / Y-pixels to jitter input image
HIERARCH ESO DRS PROVXXXX = 'UNKNOWN ' / Input file #
HIERARCH ESO DRS SKYLEVEL = 0.000000 / [ADU] Mean sky level
HIERARCH ESO DRS SKYNOISE = 0.000000 / [ADU] Mean sky noise
HIERARCH ESO DRS LINCOR = 'UNKNOWN ' / Channel table
HIERARCH ESO DRS FLATIN = 'UNKNOWN ' / flat field used
HIERARCH ESO DRS BPMIN = 'UNKNOWN ' / bad pixel map used
HIERARCH ESO DRS PERMASK = 'UNKNOWN ' / persistence mask used
HIERARCH ESO DRS STDCRMS = 0.000000 / [arcsec] RMS of the WCS fit
HIERARCH ESO DRS NUMBRMS = 0 / no. of stars in WCS fit
HIERARCH ESO DRS WCSRAOFF = 0.000000 / [arcsec] diff in RA after proc.
HIERARCH ESO DRS WCSDECOFF = 0.000000 / [arcsec] diff in DEC after proc
HIERARCH ESO DRS BACKMED = 0.000000 / [adu] Background median value
HIERARCH ESO DRS CLASSIFD = 0 / Catalogue has been classified.
HIERARCH ESO DRS THRESHOL = 0.000000 / [adu] Isophotal analysis thresh
HIERARCH ESO DRS MINPIX = 0 / [pixels] Minimum size for image
HIERARCH ESO DRS CROWDED = 0 / Crowded field analysis flag
HIERARCH ESO DRS RCORE = 0.000000 / [pixels] Core radius
HIERARCH ESO DRS SEEING = 0.000000 / [pixels] The estimated seeing
HIERARCH ESO PRO CATG = 'INTERLEAVED_IMAGE' / Category of pipeline produc
HIERARCH ESO PRO DID = '?Dictionary?' / Data dictionary for PRO
HIERARCH ESO PRO CATG = 'INTERLEAVED_IMAGE' / Category of pipeline produc
HIERARCH ESO PRO TYPE = 'REDUCED' / Product type
HIERARCH ESO PRO REC1 ID = 'vircam_jitter_microstep_process' / Pipeline reci
HIERARCH ESO PRO REC1 DRS ID = 'cpl-2.1.2' / Data Reduction System identifier
HIERARCH ESO PRO REC1 PIPE ID= 'vircam/0.3.0' / Pipeline (unique) identifier
HIERARCH ESO PRO REC1 RAW1 NAME= 'VIRCAM_IMG_OBS185_0001.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW1 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW2 NAME= 'VIRCAM_IMG_OBS185_0002.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW2 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW3 NAME= 'VIRCAM_IMG_OBS185_0003.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW3 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW4 NAME= 'VIRCAM_IMG_OBS185_0004.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW4 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW5 NAME= 'VIRCAM_IMG_OBS185_0005.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW5 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW6 NAME= 'VIRCAM_IMG_OBS185_0006.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW6 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW7 NAME= 'VIRCAM_IMG_OBS185_0007.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW7 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW8 NAME= 'VIRCAM_IMG_OBS185_0008.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW8 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW9 NAME= 'VIRCAM_IMG_OBS185_0009.fits' / File name of ra
HIERARCH ESO PRO REC1 RAW9 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW10 NAME= 'VIRCAM_IMG_OBS185_0010.fits' / File name of r
HIERARCH ESO PRO REC1 RAW10 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW11 NAME= 'VIRCAM_IMG_OBS185_0011.fits' / File name of r
HIERARCH ESO PRO REC1 RAW11 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO REC1 RAW12 NAME= 'VIRCAM_IMG_OBS185_0012.fits' / File name of r
HIERARCH ESO PRO REC1 RAW12 CATG= 'SCIENCE_IMAGE' / Category of raw frame
HIERARCH ESO PRO DATANCOM = 12 / Number of combined frames
HIERARCH ESO PRO REC1 CAL1 NAME= 'master_dark.fits' / File name of calibration f
HIERARCH ESO PRO REC1 CAL1 CATG= 'MASTER_DARK' / Category of calibration frame
HIERARCH ESO PRO REC1 CAL1 DATAMD5= '27f574cb01a69896697c062ac5af4e35' / MD5 sig
HIERARCH ESO PRO REC1 CAL2 NAME= 'master_twilight_flat.fits' / File name of cali
HIERARCH ESO PRO REC1 CAL2 CATG= 'MASTER_TWILIGHT_FLAT' / Category of calibratio
HIERARCH ESO PRO REC1 CAL2 DATAMD5= 'c1b152ef3bcb93f36c06f333ddc2ea87' / MD5 sig
HIERARCH ESO PRO REC1 CAL3 NAME= 'master_confidence_map.fits' / File name of cal
HIERARCH ESO PRO REC1 CAL3 CATG= 'MASTER_CONF' / Category of calibration frame
HIERARCH ESO PRO REC1 CAL3 DATAMD5= 'b150c2ba2d1c09833dc9837bf31f94' / MD5 sig
HIERARCH ESO PRO REC1 CAL4 NAME= 'channel3.fits' / File name of calibration fram

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HIERARCH ESO PRO REC1 CAL4 CATG= 'CHANNEL_TABLE' / Category of calibration frame
HIERARCH ESO PRO REC1 CAL4 DATAMD5= '351aaf8a8b5efe614d2b6f5018773d61' / MD5 sig
HIERARCH ESO PRO REC1 CAL5 NAME= 'phot.fits' / File name of calibration frame
HIERARCH ESO PRO REC1 CAL5 CATG= 'PHOTCAL_TAB' / Category of calibration frame
HIERARCH ESO PRO REC1 CAL6 NAME= 'master_readgain.fits' / File name of calibrati
HIERARCH ESO PRO REC1 CAL6 CATG= 'READGAIN_TABLE' / Category of calibration fram
HIERARCH ESO PRO REC1 CAL6 DATAMD5= '' / MD5 signature of calib frame
HIERARCH ESO PRO REC1 PARAM1 NAME= 'ipix' / no comment
HIERARCH ESO PRO REC1 PARAM1 VALUE= '5' / no comment
HIERARCH ESO PRO REC1 PARAM2 NAME= 'thr' / no comment
HIERARCH ESO PRO REC1 PARAM2 VALUE= '2' / no comment
HIERARCH ESO PRO REC1 PARAM3 NAME= 'icrowd' / no comment
HIERARCH ESO PRO REC1 PARAM3 VALUE= 'false' / no comment
HIERARCH ESO PRO REC1 PARAM4 NAME= 'rcore' / no comment
HIERARCH ESO PRO REC1 PARAM4 VALUE= '4' / no comment
HIERARCH ESO PRO REC1 PARAM5 NAME= 'nb' / no comment
HIERARCH ESO PRO REC1 PARAM5 VALUE= '64' / no comment
HIERARCH ESO PRO REC1 PARAM6 NAME= 'catpath' / no comment
HIERARCH ESO PRO REC1 PARAM6 VALUE= '/data/cass55c/vista/v2mass' / no comment
HIERARCH ESO PRO REC1 PARAM7 NAME= 'savecat' / no comment
HIERARCH ESO PRO REC1 PARAM7 VALUE= 'true' / no comment
HIERARCH ESO PRO REC1 PARAM8 NAME= 'ext' / no comment
HIERARCH ESO PRO REC1 PARAM8 VALUE= '1' / no comment
HIERARCH ESO DRS NDITCOR = T / Corrected for NDITs
HIERARCH ESO DRS DARKCOR = 'master_dark.fits[DET1.CHIP1]' / Image used for d
HIERARCH ESO DRS DARKSCL = 1. / Scaling factor used in dark correction
HIERARCH ESO DRS LINCOR = 'channel3.fits' / no comment
HIERARCH ESO DRS FLATCOR = 'master_twilight_flat.fits[DET1.CHIP1]' / Image u
HIERARCH ESO DRS BACKMED = -50.49648 / no comment
HIERARCH ESO DRS XOFFMICRO = 0. / no comment
HIERARCH ESO DRS YOFFMICRO = 0. / no comment
HIERARCH ESO DRS PROV0001 = 'VIRCAM_IMG_OBS185_0001.fits[DET1.CHIP1]' / Input
HIERARCH ESO DRS PROV0002 = 'VIRCAM_IMG_OBS185_0002.fits[DET1.CHIP1]' / Input
HIERARCH ESO DRS PROV0003 = 'VIRCAM_IMG_OBS185_0003.fits[DET1.CHIP1]' / Input
HIERARCH ESO DRS PROV0004 = 'VIRCAM_IMG_OBS185_0004.fits[DET1.CHIP1]' / Input

```

## 10 ACRONYMS & ABBREVIATIONS

ADnn : Applicable Document No. nn  
 CASU : Cambridge Astronomical Survey Unit  
 DAS : Data Acquisition System  
 ESO : European Southern Observatory  
 FITS : Flexible Image Transport System  
 GCS : Galactic Clusters Survey (UKIDSS)  
 GPS : Galactic Plane Survey (UKIDSS)  
 GridFTP : Grid File Transfer Protocol  
 HDS : Hierarchical Data System  
 HDU : Header Data Unit (FITS nomenclature)  
 JAC : Joint Astronomy Centre  
 LAS : Large Area Survey (UKIDSS)  
 MEF : Multi-Extension FITS  
 NDF : N-dimensional Data Format  
 RAID : Redundant Array of Inexpensive Disks  
 SDSS : Sloan Digital Sky Survey  
 VDFS : VISTA Data Flow System  
 UKIDSS : UKIRT Deep Infrared Sky Survey  
 UKIRT : United Kingdom Infrared Telescope  
 VISTA: Visible and Infrared Survey Telescope for Astronomy  
 WCS : World Co-ordinate System  
 WFAU : Wide Field Astronomy Unit (Edinburgh)  
 WSA : WFCAM Science Archive  
 2MASS : 2 Micron All-Sky Survey

## 11 APPLICABLE DOCUMENTS

|      |   |  |
|------|---|--|
| AD01 | Science Archive Hardware Design [9]     | VDF-WFA-VSA-006<br>Issue: 1.0, September 2006    |
| AD02 | Science Archive Database Design [10]    | VDF-WFA-VSA-007<br>Issue: 1.0, September 2006    |
| AD03 | UKIDSS Proposal [13]                    |  |
| AD04 | ESO Data Interface Control Document [1] | GEN-SPE-ESO-19940-794<br>Issue: 2.0              |
| AD05 | WSA Overview Document [2]               | VDF-WFA-WSA-001<br>Issue: 1.0, 1/04/03           |
| AD06 | VDFS Data Reduction Library Design [15] | VIS-SPE-IOA-20000-0010<br>Issue: 1.0, 17/12/2004 |

## 12 CHANGE RECORD

| Issue           | Date        | Section(s) Affected | Description of Change/Change Request Reference/Remarks |
|-----------------|-------------|---------------------|--|
| Draft 0.1       | 11/01/2005  | All                 | New document based on VDF-WFA-WSA-004, Issue 3.0       |
| Final draft 1.0 | August 2006 | All                 | Revised for current WFCAM and putative VISTA headers   |

## 13 NOTIFICATION LIST

The following people should be notified by email whenever a new version of this document has been issued:

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