

Data Flow System

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Document Prepared by:	Jim Lewis Peter Bunclark Simon Hodgkin (CASU)	Signature and Date:	
Document Approved by:	Mike Irwin (CASU Manager)	Signature and Date:	
Document Reviewed by:	Will Sutherland (Project Scientist)	Signature and Date:	
Document Released by:	Malcolm Stewart (VDFS Manager)	Signature and Date:	

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Change Record

Issue	Date	Sections Affected	Reason/Initiation/Documents/Remarks
1.0	2004-12-17	All	New Document
1.1	2005-05-03	All	post-FDR revision
1.2	2005-08-12	4	post DICB comments
1.3	2005-12-25	All	Consistency with DRL v0.1, JRL, MJI, PSB updates
1.4	2006-06-15	All	Many changes to all sections to help bring the document into line with DRL 0.3
1.5	2006-09-28	0,5,6,7	Explanations of dummy products expanded. Expanded list of fatal and non-fatal errors for recipes. Many other smaller changes

Notification List

The following people should be notified by email that a new issue of this document is available.

IoA	Will Sutherland
RAL	Gavin Dalton
QMC	Jim Emerson

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1 Introduction

This document forms part of the package of documents for the design of the Data Flow System for VISTA, the Visible and Infra-Red Survey Telescope for Astronomy.

1.1 Scope

This document describes the VISTA Infra-Red Camera Data Reduction Library Design for the output from the 16 Raytheon VIRGO IR detectors in the Infra Red-Camera for VISTA (VIRCAM). The baseline requirements for calibration are included in the VISTA Infra-Red Camera Data Flow System User Requirements [AD2], and the Calibration Plan is described in [AD3].

1.2 Applicable Documents

- [AD1] *Data Flow for the VLT/VLTI Instruments Deliverables Specification*, VLT-SPE-ESO-19000-1618, issue 2.0, 2004-05-22.
- [AD2] *VISTA Infra Red Camera DFS Impact*, VIS-SPE-IOA-20000-00001, issue 1.3, 2005-12-25.
- [AD3] *VISTA Infra Red Camera DFS Calibration Plan*, VIS-SPE-IOA-20000-00002, issue 1.3, 2005-12-25.
- [AD4] *VISTA Infra Red Camera DFS Data Reduction Library Specification*, VIS-SPE-IOA-20000-00003, issue 1.0, 2005-02-08.
- [AD5] *Data Interface Control Document*, GEN-SPE-ESO-19940-0794, issue 3, 2005-02-01.
- [AD6] *Common Pipeline Library User Manual*, VLT-MAN-ESO-19500-2720, issue 2.0.1, 2005-04-14
- [AD7] *Common Pipeline Library Reference Manual*, VLT-MAN-ESO-19500-2721, issue 2.0, 2005-04-08

1.3 Reference Documents

- [RD 1] *VISTA IR Camera Software Functional Specification*, VIS-DES-ATC-06081-00001, issue 2.0, 2003-11-12.
- [RD 2] *IR Camera Observation Software Design Description*, VIS-DES-ATC-06084-0001, issue 3.2 2005-02-24.
- [RD 3] *VISTA Science Requirements Document*, VIS-SPE-VSC-00000-0001, issue 2.0, 2000-10-26
- [RD 4] *Overview of VISTA IR Camera Data Interface Dictionaries*, VIS-SPE-IOA-20000-0004, 0.1, 2003-11-13
- [RD 5] *Definition of the Flexible Image Transport System (FITS)*, NOST 100-2.0
- [RD 6] *The FITS image extension*, Ponz et al, Astron. Astrophys. Suppl. Ser. **105**, 53-55, 1994
- [RD 7] *Representations of world coordinates in FITS*, Griesen, & Calabretta, A&A, **395**, 1061.2002
- [RD 8] *Representations of celestial coordinates in FITS*, Calabretta & Griesen, A&A, **395**, 1077, 2002

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- [RD 9] *Detectors and Data Analysis Techniques for Wide Field Optical Imaging*, Irwin M.J., 1996, Instrumentation for Large Telescopes, VII Canary Islands Winter School, eds. J.M. Rodríguez Espinosa, A. Herrero, F. Sánchez, p35. Also available from <http://www.ast.cam.ac.uk/~mike/processing.ps.gz>
- [RD 10] *INT WFS pipeline processing*, Irwin M and Lewis J, New Astronomy Reviews, **45**, Issue 1-2, p105, 2001.
- [RD 11] *VISTA Data Flow System: pipeline processing for WFCAM and VISTA*, Irwin et al, Ground-based telescopes, ed. Oschmann, proc SPIE, **5493**, p411, 2004
- [RD 12] *Automatic analysis of crowded fields*, Irwin M. 1985 MNRAS 214,575
- [RD 13] *Understanding Robust and Exploratory Data Analysis*, Hoaglin, Mosteller & Tukey 1983, Wiley.
- [RD 14] *Analysis of astronomical images using moments*, Stobie R, British Interplanetary Journal (Image Processing), **33**, p323, 1980

1.4 Abbreviations and Acronyms

2MASS	2 Micron All Sky Survey
ADU	Analogue to Digital Unit
CDS	Correlated Double Sampling
DFS	Data Flow System
DIT	Digital Integration
FITS	Flexible Image Transport System
FWHM	Full Width at Half Maximum
HOWFS	High-Order Wavefront Sensor
LUT	Look Up Table
MAD	Median Absolute Deviation from median
MEF	Multi-Extension FITS
NDR	Non-Destructive Read
RHS	Right Hand Side
RRR	Reset-Read-Read mode
VDFS	VISTA Data Flow System
VIRCAM	VISTA Infra Red Camera
VISTA	Visible and Infrared Survey Telescope for Astronomy
WCS	World Coordinate System
WFCAM	Wide Field Camera (on UKIRT)

1.5 Glossary

CDS	Correlated-Double Sampling; before the charge of each pixel is transferred to the output node of the detector, the output node is reset to a reference value. The pixel charge is then transferred to the output node. The final value of the charge assigned to this pixel is the difference between the reference value and the transferred charge.
Confidence Map	An integer array, normalised to a median of 100%, which is associated with an image. Combined with an estimate of the

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sky background variance of the image, it assigns a relative weight to each pixel in the image and automatically factors in an exposure map. Bad pixels are assigned a value of 0. It is especially important in image filtering, mosaicing and stacking.

DAS

Data Acquisition System

DIT

Digital Integrations mean that separate readouts are summed digitally.

Exposure

The stored product of many individual **integrations** that have been co-added in the DAS. The sum of the integration times is the exposure time.

Integration

A simple snapshot, within the **DAS**, of a specified elapsed time. This elapsed time is known as the integration time.

Jitter (pattern)

A pattern of **exposures** at positions each shifted by a small movement (<30 arcsec) from the reference position. Unlike a **microstep** the non-integral part of the shifts is any fractional number of pixels. Each position of a jitter pattern can contain a **microstep** pattern.

Mesostep

A sequence of **exposures** designed to completely sample across the face of the detectors in medium-sized steps, in order to monitor residual systematics in the photometry.

Microstep (pattern)

A pattern of **exposures** at positions each shifted by a very small movement (<3 arcsec) from the reference position. Unlike a **jitter** the non-integral part of the shifts are exact fractions of a pixel, which allows the pixels in the series to be interlaced in an effort to increase resolution. A microstep pattern can be contained within each position of a **jitter** pattern.

OB

Observation Block

Object

In the context of image analysis, an astronomical object.

Pawprint

16 non-contiguous images of the sky produced by VIRCAM with its 16 non-contiguous chips (see Fig 2-2 of [AD3]). The name is from the similarity to the prints made by the padded paw of an animal (the terminology was more appropriate to 4-chip cameras).

Preset

A telescope slew to a new position requiring a reconfiguration of various telescope systems.

Robust Estimate

A statistical estimator that is resilient to small perturbations on the assumed shape of the underlying distribution.

Tile

A filled area of sky fully sampled (filling in the gaps in a pawprint) by combining multiple **pawprints**. Because of the detector spacing the minimum number of pointed observations (with fixed offsets) required for reasonably uniform coverage is 6, which would expose each piece of sky, away from the edges of the tile, to at least 2 camera pixels. The pipeline does not combine **pawprints** into tiles.

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2 Mathematical Description

In this section we include a mathematic description of some of the methods we will use to calibrate and correct data from VIRCAM. The main technical challenges in processing VISTA data stem from the fact that: IR detectors are currently inherently more unstable than their optical counterparts; the sky emission, roughly 100 times brighter than most objects of interest, varies in a complex spatial and temporal manner; and the large data volume that arises from NIR mosaic cameras. To minimise the subsequent data volume several basic pre-processing steps will be carried out in the VISTA data-acquisition system, including reset-correction and co-addition of successive DITs from the same exposure.

The first stage of the VDFS pipeline will be to apply a linearity correction as outlined in section 2.2. Subsequent processing steps including: dark and reset-anomaly correction; flat-fielding and inter-channel gain correction; and sky artefact removal (e.g. fringe patterns), are designed to remove the instrumental and residual sky signatures from the images.

The algorithms used in the VIRCAM pipeline are the result of 25 years development in the analysis of digital images. An excellent and detailed review of the mathematical techniques involved in wide-field image analysis is given in [RD 9]. In particular, the robust estimator is detailed and an in-depth description of image detection and parameterization, as used in section 2.13, is given. Several of the effects included in this section may not even exist in VIRCAM data; it is prudent however to make arrangements for dealing with such issues if early experience with the data shows the effects to be present.

We outline in the following sections the salient points of the mathematical operations to be performed, for further detail see [AD2], [AD3] and [AD4].

2.1 Reset Correction

As with most electronic detectors infrared detectors are given a pedestal bias level by the driving electronics. As such the first step in any reduction of such data is to remove that bias. For VIRCAM this will be done in the DAS. This removes the need for explicit bias removal in the pipeline.

2.2 Non-Linearity

The Calibration Plan [AD3] lays out the necessity and the methodology for calibrating and correcting for the expected non-linearity in the response of the detector system to incident radiation.

2.2.1 Correcting for non-linearity

In default CDS reset-read-read (RRR) mode, downstream of the data acquisition system (DAS) the output that we see is

$$\Delta I' = I'_2 - I'_1 = f(I_2) - f(I_1) \quad (2-1)$$

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where I'_1 and I'_2 denote the non-linear first (i.e. the reset-frame) and second readouts respectively and I_1 and I_2 the desired linear quantities. The non-linear function $f(I)$ maps the distortion of the desired linear counts to the non-linear system I' . If we define the inverse transform $g(I')$ that maps measured counts I' to linearized counts I as the inverse operator $g() = f^{-1}()$ then

$$I = g(I') \text{ and } I_1 = g(I'_1) \quad I_2 = g(I'_2) \quad (2-2)$$

If I'_1 and I'_2 were directly available this is a one-to-one mapping and can be done efficiently and accurately using Look Up Tables (LUT). This is the conventional way of implementing the correction prior to other image manipulation operations. However, if I'_1 and I'_2 are not separately available and all we have to work from is the difference $\Delta I'$ then a simple LUT transformation is not possible.

For example, taking the simplest case where the illumination level across the detector has not changed during the course of the RRR and no on-board co-addition is happening then, in principle given only ΔI and knowledge of the timing of the RRR operations we can deduce I_1 and I_2 by using the effective integration time for each to estimate their scaling to the measured difference ΔI such that,

$$I_1 = k\Delta I \text{ and } I_2 = (1+k)\Delta I \quad (2-3)$$

Unfortunately, the ratio k will not be constant for the non-linear quantities I'_1 and I'_2 forcing us to adopt a scheme along the following lines.

Given $\Delta I'$ and defining the non-linear operator $f()$ as a polynomial with coefficients a_m (typically up to quartic) we have

$$\Delta I' = \sum_m a_m (I_2^m - I_1^m) = \sum_m a_m [(1+k)^m \Delta I^m - k^m \Delta I^m] \quad (2-4)$$

The quantity we want ΔI is buried in the non-linearity of the RHS and we have to solve an equation like this for every pixel. This is possible, and relatively simple to program using something like a Gauss-Seidel iterative scheme, but is more inefficient than a direct mapping.

If we wanted to use a completely general LUT approach we would require a 2D LUT for all possible values of I_1 and I_2 i.e. $65k \times 65k$ in size, or 4.3×2 Gbytes. Most likely we would need a different correction for each “channel” making a total of 256×8.6 Gbytes = 2.2 Tbytes of LUT for the VIRCAM! Of course if the range of values of k is limited via exposure time quantisation this decreases the size of the total number

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of LUTs required considerably for the constant illumination case, but would be an ugly and possibly impractical solution.

Practical considerations (e.g. data volume), suggest two alternative solutions for nonlinearity correction: either correct the individual frames directly in the DAS by measuring and downloading the appropriate LUTs, or polynomial coefficients, to the DAS; or use a non-linear inversion on the reset-corrected frames as outlined here. This methodology is not generally applicable, e.g. to multi-NDR/gradient fitting readouts, but is directly applicable to co-added (or co-averaged) frames of the same exposure times, assuming constant illumination over the series.

For reset-corrected data, the non-linear inversion is competitive with complex operations on LUTs and much simpler to implement. It also has the added advantage of removing all aspects of the non-linearity correction from the DAS. The main disadvantages are the method is restricted to CDS RRR mode, and if the illumination level is rapidly varying (e.g. twilight) the effective scale factors k_i may be hard to compute accurately - although for all realistic practical situations the knock-on effect is likely to be negligible.

2.2.2 Measuring non-linearity

If all that is available are reset-corrected data from say a time series of dome flats, it is still feasible to directly compute the non-linearity coefficients.

Given a series of measurements $\{i\}$ of $\Delta I'_i$ and using the previous notation and polynomial model

$$\Delta I'_i = \sum_m a_m (I_2^m - I_1^m) = \sum_m a_m \Delta I_i^m [(1 + k_i)^m - k_i^m] \quad (2-5)$$

where k_i are the exposure ratios under the constant illumination. In general $\Delta I_i = s t_i$ where t_i is the exposure time of the i th reset-corrected frame in the series and s is a fixed (for the series) unknown scale factor. The k_i are computable from a knowledge of the exposure times and the reset-read overhead, t_i and $\Delta I'_i$ are measured quantities leaving the polynomial coefficients a_m and the scaling s to be determined. Thus the model is defined by

$$\Delta I'_i = \sum_m a_m (I_2^m - I_1^m) - \sum_m a_m s^m t_i^m [(1 + k_i)^m - k_i^m] \quad (2-6)$$

and can be readily solved by standard linear least-squares methods using the following sleight-of-hand. Since the scaling s and hence the polynomial solution a_m are coupled, by simply (and logically) requiring in the final solution $a_1 = 1$, computation of s can be completely avoided.

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Rewriting the previous equation in the following form makes this more apparent

$$\Delta I'_i = \sum_m (a_m s^m) t_i^m [(1 + k_i)^m - k_i^m] = \sum_m b_m t_i^m [(1 + k_i)^m - k_i^m] \quad (2-7)$$

where now b_m are the coefficients to be solved for. The final step is to note that

$$a_m = b_m / s^m = b_m / b_1^m \quad (2-8)$$

since by definition $a_1 = 1$.

2.3 Gain Correction

In the case of a single detector camera the mean flat field image is normalised to a value of 1. This ensures that when the flat field correction is done the average counts in the output image is the same as in the input. For multi-detector instruments, we normalise the mean flat field image for each detector by:

$$V = \frac{\sum_{i=1}^n \langle I \rangle_i}{N} \quad (2-9)$$

where $\langle I \rangle_i$ is a robust estimate of the average flux in the combined flat field image for the i th detector. Normalising in this way ensures that when doing flat field correction we also include a factor that removes the differences in mean gain of each detector.

2.4 Measurement of Read Noise and Gain

The read noise and gain can be measured using two dome flat frames of similar illumination and two similarly observed (in terms of exposure and integration times) dark frames. Forming the difference of the two flat frames gives a variance for the difference frame σ_f^2 . Doing the same for the two dark frames yields σ_d^2 . If the background means of the flat and dark frames are: m_{f1} , m_{f2} and m_{d1} , m_{d2} the local gain in electrons per ADU is:

$$\varepsilon = ((m_{f1} + m_{f2}) - (m_{d1} + m_{d2})) / (\sigma_f^2 - \sigma_d^2) \quad (2-10)$$

and the readout noise in electrons is

$$\sigma_{ro} = \varepsilon \sigma_d / \sqrt{2} \quad (2-11)$$

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2.5 Dark-correction, flat-fielding and sky-correction

If the fringe spatial pattern is stable and if flat fields can be generated without fringing present, it is possible to decouple sky correction and fringe correction and apply a de-fringing method similar to the one we have developed for optical imaging [RD 11]. This involves creating a series of master fringe frames which are scaled by a suitable factor for each object frame. The scale factors are adjusted to minimise the fringe pattern in the processed frame.

Standard NIR processing recipes often subtract sky first and then flat-field. We can see why this can be advantageous compared with dark-correcting, flat-fielding and sky-correcting by considering the following encapsulation of the problem

$$D(x, y) = ff(x, y)[S(x, y) + F(x, y) + O(x, y) + T(x, y)] + dc(x, y) \quad (2-12)$$

where $D(x, y)$ is observed, $ff(x, y)$ is the flat-field function, $S(x, y)$ is the sky illumination, $F(x, y)$ is the fringe contribution, $O(x, y)$ is the object contribution, $T(x, y)$ is the thermal contribution, $dc(x, y)$ is the dark current, and without loss of generality we have excluded any explicit wavelength and time-dependence for clarity.

Stacking a series of dithered object frames with rejection produces an estimate of the terms

$$\hat{I}(x, y) = ff(x, y)[S(x, y) + F(x, y) + T(x, y)] + dc(x, y) \quad (2-13)$$

therefore,

$$D(x, y) - \hat{I}(x, y) = ff(x, y)O(x, y) \quad (2-14)$$

obviating the need for dark-correcting and fringe removal as both separate data gathering requirements and as separate data processing steps; and minimising the effect of systematic and random errors in the flat-field function by removing the largest potential error terms.

In the event that the dark correction stage fails to remove the reset anomaly completely, the residual background variation is analogous to the problem of dealing with short-term variations in sky structure and can be dealt with using the methodology above.

The caveats here of course are that this method may well remove parts of large extended objects, large area nebulosity, and large low surface brightness objects and so on, unless suitable offset skies are used in the sky frame construction. Unfortunately this then opens the door for spatial and temporal variability of the sky background, leaving residual patterns.

The optimal strategy to use depends on the stability of the flat-fields, and the time constants for sky fringe pattern variations, and will be dealt with by assessing these characteristics during commissioning and then invoking suitable processing recipes.

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The alternative is to treat the dark correction $dc(x, y)$, flat field $ff(x, y)$, and fringe pattern $F(x, y)$, as accurately known master library frames, in which case data processing involves solving the following variant of the problem

$$D(x, y) = ff(x, y) [S(x, y) + k.F(x, y) + O(x, y) + T(x, y)] + dc(x, y) \quad (2-15)$$

where k is a scale factor to be determined by the fringe-removing algorithm. In this case applying the master frames leads to

$$D'(x, y) = S(x, y) + O(x, y) + T(x, y) \quad (2-16)$$

reducing the problem to one of detecting astronomical objects on an additive, slowly spatially varying, background. This could be the method of choice for analysing large scale astronomical surface brightness variations.

2.6 Fringe Removal

Atmospheric emission lines may cause interference fringes to be present in the sky background at the level of a few percent of sky. Since the fringes can have complex spatial structures on a range of physical scales on the detector, removing them successfully is a multi-stage process.

First we note that fringing is an additive effect, so if removed as part of a procedure that used night sky data as a flat field source, this would introduce a systematic error in the photometry. To perform sky fringe removal effectively requires the flat fielding to be decoupled from the defringing by, for example, using twilight sky exposures to construct the flat-field frames, where the contribution from sky emission lines is negligible.

Consequently, the first stage of the process is to flat-field the dark sky science data correctly and to use a sequence of offset sky exposures to construct a fringe frame. These input frames are combined after suitable scaling to match the background levels and sigma-clipping to remove astronomical objects.

The defringing process then requires solving for the fringe scale factor k in the following equation:

$$D(x, y) = S(x, y) + kF(x, y) + O(x, y) + T(x, y) \quad (2-17)$$

where S is the sky contribution, O is the astronomical object contribution and T is the contribution from the thermal background.

Since the fringe pattern is characterised by more rapidly varying spatial structure than the sky and thermal contributions, the overall background variation on the target and fringe frame is temporarily removed by use of a robust low-pass filter such that:

$$D'(x, y) \approx kF(x, y) + O(x, y) \quad (2-18)$$

The objects are localised, therefore a simple robust background noise estimator based on the Median of the Absolute Deviation (MAD) from the median can be used iteratively to find the scale factor k that minimises the background noise in $D'(x, y)$.

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Allowing the scale factor to vary ensures that the relative contribution of the sky emission lines, which may vary in strength, is correctly dealt with.

More complex options involving decomposing the seasonal fringe patterns into eigen-fringe maps may be required at later stages in the processing but this is outside of the scope of the standard calibration pipeline.

The success, or otherwise, of fringe removal is monitored by the computed fringe map scale factor and also by a robust measure of the change (ratio) of the global background noise/variation after fringing. This is encoded in the FRINGE_RATIO QC1 parameter.

2.7 Image persistence

Astronomical images, and artefacts from preceding frames, can persist and be present on the current image. Strategies for dealing with this involve assessing the time decay characteristics and adjacency effects (i.e. image spreading) if present. In the case of no image adjacency effects, correcting for image persistence will either involve updating and maintaining a persistence mask (for combination with the confidence map), or accumulating with suitable temporal decay, a persistence map, running over a night if necessary, to subtract from the current image. For example, in the simplest case

$$I_k^{obs}(x, y, t) = I_k^{true} + f \times I_{k-1}^{obs}(x, y, t - \Delta t) \times e^{-\Delta t / \tau} \quad (2-19)$$

where k is the image sequence number, f is the fraction of the image persisting after frame reset(s), Δt is the time interval between frames, and τ is the persistence decay constant which may be different for each detector.

It is possible that image persistence may include some sort of adjacency effects. These will have to be characterised at commissioning.

2.8 Crosstalk

Images from one detector channel may produce secondary images (ghosts) on other channels either positive or negative in sign and may also even cross from one detector to another. In a stable environment, it is feasible to measure the contribution of crosstalk from one channel to another by using bright point-like sources, and thereby define a comprehensive crosstalk matrix $C_{j,k}$. Since this is environment specific, determining the final form of this matrix will be one of the commissioning tasks, although earlier laboratory-based measurements will be used to characterise its likely impact and to investigate ways of minimising the effect.

Providing the cross-talk terms are small (i.e. <1%, the most likely scenario), then the following simple single-pass additive correction scheme will be used to correct for this problem,

$$I'_j = I_j - \sum_{k \neq j} I_j C_{j,k} \quad (2-20)$$

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where I_j is the observed frame and I'_j the corrected version. The typical error in making a single pass correction is approximately $\langle C_{j,k} \rangle_{j \neq k}^2$, which governs the requirement on the magnitude of the cross-talk terms. Note also that the matrix C will in general not be symmetric.

2.9 Astrometric Calibration

From the optical design studies of VISTA we know that, to a good approximation, the astrometric distortion shows negligible variation with wavelength and is well described by a radially symmetric polynomial distortion model of the form

$$r_{true} = k_1 \times r + k_3 \times r^3 + k_5 \times r^5 + \dots \quad (2-21)$$

where r_{true} is an idealised angular distance from the optical axis, r is the measured distance, and k_1 is the scale at the centre of the field, usually quoted in arcsec/mm. VISTA will have a central field scale, i.e. k_1 value of roughly 17.09 arcsec/mm. The term due to k_5 is usually negligible and, until real sky data is available, is not worth pursuing, since other similarly sized distortions may be present. Dropping this term and rearranging the preceding equation to a more convenient form gives

$$r_{true} = r' \times \left(1 + \frac{k_3}{k_1^3} \times r'^2\right) = r' + k \times r'^3 \quad (2-22)$$

where r' is the measured distance from the optical axis in arcsec using the k_1 scale. If we convert all units to radians the “r-cubed” coefficient is conveniently scaled (in units of radians/radian³) and has a theoretical value of around 42 for VISTA, but will have a slight wavelength dependence.

Although this type of distortion generally presents no problem for accurate calibration of individual pointings, it can lead to various complications when stacking data taken at various locations, e.g. dither sequences. This is caused by the differential non-linear distortions across individual detectors being comparable to, or larger than, the pixel size of the detector. In these cases stacking involves resampling and interpolation of some form. While these are inevitable in combining pointings to form contiguous tiled regions, they may be avoided at earlier stages, such as stacking individual detector dither sequences, by suitably limiting dither offsets and thereby both simplify and speed up the data processing.

The effective scale due to the radial distortion is given by

$$dr_{true} / dr' = 1 + 3k \times r'^2 \quad (2-23)$$

which describes the local change in relative pixel scale as a function of radial distance. For example, for VISTA at 0.8 degree radius, the differential distortion term is about 2.5%. This means that a 10 arcsec shift in the centre corresponds to a 10.25 arcsec shift at the outer corners of the arrays. For the outer detectors a large fraction of this distortion occurs across individual detectors.

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In anticipation of this problem, we will implement a range of interpolation schemes that offer a trade off between maintaining independent pixel noise and resolution degradation.

For further information see the report at

<http://www.ast.cam.ac.uk/vdfs/docs/reports/astrom/>.

2.10 World Coordinate System

We intend, at least initially, to characterise the WCS using the ZPN projection [RD 7] and [RD 8], i.e. ARC + polynomial distortion, using a 3rd order parameterisation (equation 2.22). The coefficients for this are encoded in the FITS header using the keywords PV2_1 and PV2_3.

2.11 Effect of Scale Change on Photometry

In addition to astrometric effects the change in scale as a function of radius also has photometric implications. The aim of conventional flat fielding is to create a flat background by normalising out perceived variations from (assumed) uniformly illuminated frames. If the sky area per pixel changes then this is reflected in a systematic error in the derived photometry.

However, since it much simpler to deal with “flat” backgrounds, this problem is either usually ignored or corrected during later processing stages, together with other systematic photometry effects. The effect is simplest to envisage by considering what happens to the area of an annulus on sky when projected onto the detector focal plane. The sky annulus of $2\pi r dr$ becomes $2\pi' r' dr'$ on the detector, which using k to denote k_3 / k_1 leads to a relative area of

$$(1 + k \times r'^2) \cdot (1 + 3k \times r'^2) \approx (1 + 4k \times r'^2) \quad (2-24)$$

or in other words roughly $4 \times$ the linear scale distortion.

However, since other more unpredictable factors, such as scattered light, will also play a significant role, it is simpler procedurally to bundle all the effects together and correct all the photometric systematics in one operation. The VDFS calibration plan [AD3] describes a procedure for achieving this as an illumination correction.

2.12 Confidence Maps

We define a confidence map c_{ij} as a normalised¹ i.e. $\langle c_{i,j} \rangle_j = 1$ inverse variance weight map denoting the “confidence” associated with the flux value in each pixel j of frame i . This has the advantage that the map is always finite and can also be used to encode for hot, bad or dead pixels, by assigning zero confidence. Furthermore, after image stacking the confidence map also encodes the effective relative exposure time for each pixel, thereby preserving all the relevant intra-pixel information for further optimal weighting.

¹ In practice we use a 16-bit integer map such that the median level is 100%

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The initial confidence map for each frame is derived from regular analysis of the master calibration flat-field and dark frames and is unique for each filter/detector combination due to the normalisation. As such it also encodes individual pixel sensitivities and also allows, for example, vignetted regions to be correctly weighted when combining frames. To use the confidence maps for weighted co-addition of frames then simply requires an overall estimate of the average noise properties of the frame. This can readily be derived from the measured sky noise, in the Poisson noise-limited case, or from a combination of this and the known system characteristics (e.g. gain and readout noise).

All processed frames (stacked individual detectors, tiled mosaiced regions) have an associated derived confidence map which is propagated through the processing chain in the following manner.

Defining the signal s_i in frame i with respect to some reference signal level s_{ref} as $s_i = f_i s_{ref}$, where f_i denotes the relative throughput (which in photometric conditions would be \propto exposure time), the optimum weight to use for combining the j th pixel of (suitably aligned) frames i in order to maximise the signal:to:noise of sky-limited objects is defined by

$$x'_j = \frac{\sum_i w_{ij} x_{ij}}{\sum_i w_{ij}} \quad w_{ij} = c_{ij} f_i / \sigma_i^2 \quad (2-25)$$

where σ_i^2 is the average noise variance in frame i , x_{ij} is the flux in pixel j on the i th frame and x'_j is the combined output flux. The effective exposure time is that of s_{ref} .

The output confidence map, which is $\propto outputnoise_j^{-2}$, is therefore given by

$$c'_j = \frac{(\sum_i c_{ij} f_i / \sigma_i^2)^2}{\sum_i c_{ij} f_i^2 / \sigma_i^2} \quad (2-26)$$

Special cases of this occur when $f_i = 1$, e.g. equal length exposures in stable photometric conditions, or the more general Poisson noise limited case, when $f_i / \sigma_i^2 = 1$, and the special variant of this when $f_i = 1$. These cases are given below, prior to renormalisation.

$$c'_j = \sum_i c_{ij} / \sigma_i^2 \quad c'_j = \frac{(\sum_i c_{ij})^2}{\sum_i c_{ij} f_i} \quad c'_j = \sum_i c_{ij} \quad (2-27)$$

2.13 Catalogue generation

In order to provide quality control, and astrometric and photometric calibration information, it is necessary to generate detected object (i.e. stars, galaxies) catalogues for each target frame.

The catalogue generation software (e.g. [RD 12], [RD 9]) will make direct use of the confidence maps for object detection and parameterisation, and will produce the requisite information via the use of standard object descriptors. For completeness we

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give here a brief description of how this will be accomplished by use of the following steps:

- estimate the local sky background over the field and track any variations at adequate resolution to eventually remove them;
- detect objects/blends of objects and keep a list of pixels belonging to each blend for further analysis;
- parameterise the detected objects, i.e. perform astrometry, photometry and some sort of shape analysis.

2.13.1 Background analysis and object detection

The possibly-varying sky background is estimated automatically, prior to object detection, using a combination of robust iteratively-clipped estimators.

Any variation in sky level over the frame will be dealt with by forming a coarsely sampled background map grid. Within each background grid pixel, typically equal to 64×64 image pixels, an iteratively k-sigma clipped median value of “sky” will be computed based on the histogram of flux values within the grid pixel zone. A robust estimate of sigma can be computed using the Median of the Absolute Deviation (MAD) from the median (e.g. [RD 13]). This will then be further processed to form the frame background map (e.g. [RD 9]).

After removing the, possibly, varying background component, a similar robust estimate of the average sky level and sky noise per pixel can be made. This forms part of the quality control measures and also helps to robustly determine the detection threshold for object analysis.

Individual objects will be detected using a standard matched filter approach (e.g. [RD 12]). Since the only images difficult to locate are those marginally above the sky noise, assuming constant noise is a good approximation (after factoring in the confidence map information) and the majority of these objects will have a shape dominated by the point spread function (PSF), which thereby defines the filter to use.

2.13.2 Image parameterisation

The following image parameters can be computed efficiently and are directly used as part of the image quality control and calibration analysis.

Isophotal Intensity - the integrated flux within the boundary defined by the threshold level; i.e. the 0th object moment

$$I_{iso} = \sum_i I(x_i, y_i) \quad (2-28)$$

For Gaussian images, this is related to the total intensity by the factor $(1 - I_t / I_p)^{-1}$, where I_p is the peak flux and I_t the threshold level (all relative to sky).

Position - computed as an intensity-weighted centre of gravity; i.e. 1st moment

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$$x_0 = \sum_i x_i \cdot I(x_i, y_i) / \sum_i I(x_i, y_i) \quad (2-29)$$

$$y_0 = \sum_i y_i \cdot I(x_i, y_i) / \sum_i I(x_i, y_i)$$

Covariance Matrix - the triad of intensity-weighted 2nd moments is used to estimate the eccentricity/ellipticity, position angle and intensity-weighted size of an image

$$\sigma_{xx} = \sum_i (x_i - x_0)^2 \cdot I(x_i, y_i) / \sum_i I(x_i, y_i) \quad (2-30)$$

$$\sigma_{xy} = \sum_i (x_i - x_0) \cdot (y_i - y_0) \cdot I(x_i, y_i) / \sum_i I(x_i, y_i)$$

$$\sigma_{yy} = \sum_i (y_i - y_0)^2 \cdot I(x_i, y_i) / \sum_i I(x_i, y_i)$$

The simplest way to derive the ellipse parameters from the 2nd moments is to equate them to an elliptical Gaussian function having the same 2nd moments. It is then straightforward to show (e.g. [RD 14]) that the scale size, $\sqrt{\sigma_{rr}}$, is given by $\sigma_{rr} = \sigma_{xx} + \sigma_{yy}$; the eccentricity, $ecc = \sqrt{(\sigma_{xx} - \sigma_{yy})^2 + 4 \cdot \sigma_{xy}^2} / \sigma_{rr}$; and the position angle, θ is defined by, $\tan(2\theta) = 2 \cdot \sigma_{xy} / (\sigma_{yy} - \sigma_{xx})$. The ellipticity, e , which is simpler to interpret for estimating potential image distortions (e.g. trailing), is related to the eccentricity by $e = 1 - \sqrt{(1 - ecc)/(1 + ecc)}$

Areal Profile - a variant on the radial profile, which measures the area of an image at various intensity levels. Unlike a radial profile, which needs a prior estimate of the image centre, the areal profile provides a single pass estimate of the profile

$$ArealProfile \rightarrow T + p_1, T + p_2, T + p_3, \dots, T + p_m \quad (2-31)$$

where $p_j; j = 1, \dots, m$ are intensity levels relative to the threshold, T , usually spaced logarithmically to give even sampling.

The peak height, I_p , is a useful related addition to the areal profile information and is defined as

$$I_p = \max[I(x_i, y_i)]_i \quad (2-32)$$

or alternatively measured by extrapolation from the areal profile if the image is saturated. The areal profile provides a direct method to estimate the seeing of objects in an image by enabling the average area of stellar images (point sources) at half the peak height, $\langle A \rangle$, to be estimated. The seeing, or FWHM, is then given by $FWHM = 2\sqrt{\langle A \rangle / \pi}$.

Finally a series of aperture fluxes are required for object morphological classification (see below).

Aperture flux is defined as the integrated flux within some radius r of the object centre

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$$I_{ap}(r) = \sum_{i \in r}^N I_i - N \times sky \quad (2-33)$$

Where boundary pixels are weighted pro-rata (soft-edged aperture photometry). A series of these is used to define the curve-of-growth, $I_{ap}(r)$ -v- r , for each object.

2.13.3 Morphological Classification

The object detection software will produce a series of background-corrected flux measures for each object in a set of “soft-edged” apertures of radius $r/2$, $r/\sqrt{2}$, r , $\sqrt{2}r$, $2r$ $32r$, where r is typically fixed as the median seeing for the site+telescope+camera. The average curve-of-growth for stellar images is used to define automatically an aperture correction for each aperture used and also forms the basis for object morphological classification (required for isolating stellar images for seeing and trailing quality control).

The curve-of-growth of the flux for each object is compared with that derived from the (self-defining) locus of stellar objects, and combined with information on the ellipticity of each object, to generate the classification statistic. This statistic is designed to preserve information on the “sharpness” of the object profile and is re-normalised, as a function of magnitude, to produce the equivalent of an $N(0,1)$ measure, i.e. a normalised Gaussian of zero-mean and unit variance. Objects lying within $2-3\sigma$ are generally flagged as stellar images, those below 3σ (i.e. sharper) as noise-like, and those above $2-3\sigma$ (i.e. more diffuse) as non-stellar.

A by-product of the curve-of-growth analysis is the estimate of the average PSF aperture correction for each detector.

2.14 Photometric Zeropoint

For the purposes of quality control (e.g. sky transparency and system performance) a primary photometric zeropoint will be determined for each observation by direct comparison of instrumental magnitudes with the magnitudes of 2MASS stars. An alternative cross-check on the photometric calibration will be applied retrospectively given a complete night of observations including regular exposures in VISTA photometric standard fields.

The internal gain-correction, applied at the flat-fielding stage, should place all the detectors on a common zeropoint system (at least to first order i.e. ignoring colour equation variations between the detectors), and given a stable instrumental setup, the apparent variation of zeropoint then directly measures the change in “extinction” without the need to rely solely on extensive standard field coverage over a range in airmass. Therefore for any given observation of a star in a particular passband:

$$m^{cal} = m^{inst} + ZP - \kappa (X - 1) = m^{std} + ce^{std} + \varepsilon \quad (2-34)$$

where ZP is the zeropoint in that passband (i.e. the magnitude at airmass unity which gives 1 count/second at the detector), m^{cal} is the calibrated instrumental magnitude, m^{inst} is the measured instrumental magnitude ($-2.5 \times \log_{10}[\text{counts/sec}]$), κ is the extinction coefficient, X is the airmass of the observation, ce^{std} is the colour term to

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convert to the instrumental system, and ε is an error term. This assumes that the second-order extinction term and colour-dependency of κ are both negligible. By robustly averaging the zeropoints for all the matching stars on the frame an overall zeropoint for the observation can be obtained.

Typically, the zeropoint of the instrument + telescope system should be stable throughout the night. Long-term decreases in the sensitivity of the instrument, and hence a decreasing ZP , could be caused by for example the accumulation of dust on the primary mirror.

On photometric nights the extinction coefficient κ should be constant in each passband. The extinction κ can be monitored through each night either by assuming the true instrumental zeropoint only varies slowly as a function of time (and using the individual 2MASS calibrations to monitor it) or by making measurements over a range of airmass.

2.15 Illumination Correction

The two methods of determination of illumination correction differ in that the first described below requires either a rich standard star field or a series of fields with known photometry, but the second can be used before such information is available.

2.15.1 Standard Star Fields

Errors in the large scale structure of the illumination of the flat fields used in signature removal can cause position dependent systematic errors in photometry. This can be a result of a varying scattered light profile between twilight (nominally when the flat field exposures would have been made) and the time when the observation was done. We can map this out by first dividing an observation of a rich photometric standard field into cells or by dividing a series of calibrator fields from, for example, 2MASS into cells. For each cell we define a median zero point of all the stars in that cell:

$$zp_j = \langle m^{cal} - m^{inst} \rangle \quad (2-35)$$

(It is safe to ignore the extinction term for this exercise.) The illumination correction is then defined for each cell as:

$$ic_j = \langle zp \rangle - zp_j \quad (2-36)$$

where $\langle zp \rangle$ is the median value of zp_j over all the cells. This is defined such that a star in the j th cell is calibrated by:

$$m^{cal} = m^{inst} + ZP - \kappa (X - 1) - ic_j \quad (2-37)$$

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2.15.2 Mesostep Analysis

We assume that the spatial sensitivity of each detector can be approximated by a polynomial surface, i.e. a magnitude offset as a function of (x, y) measured from the centre of the detector, e.g.

$$ZP(x, y) = \sum_{hk} a_{hk} x^h y^k \quad (2-38)$$

For example, in quadratic form, at positions i and j :

$$ZP(x_i, y_i) = a_{00} + a_{10}x_i + a_{01}y_i + a_{20}x_i^2 + a_{11}x_iy_i + a_{02}y_i^2 \quad (2-39)$$

$$ZP(x_j, y_j) = a_{00} + a_{10}x_j + a_{01}y_j + a_{20}x_j^2 + a_{11}x_jy_j + a_{02}y_j^2 \quad (2-40)$$

The difference in sensitivity/zeropoint between two positions i and j is then:

$$\begin{aligned} \Delta ZP(x_i, x_j, y_i, y_j) = & a_{10}(x_i - x_j) + (a_{01}(y_i - y_j) + a_{20}(x_i^2 - x_j^2) \\ & + a_{11}(x_iy_i - x_jy_j) + a_{02}(y_i^2 - y_j^2) \end{aligned} \quad (2-41)$$

If we make two observations of the same star at offset positions i (x_i, y_i) and j (x_j, y_j) , we sample this function such that the difference in magnitude measured is Δm_{ij} then:

$$\Delta m_{ij} = \Delta ZP(x_i, x_j, y_i, y_j) \quad (2-42)$$

In the simplest case, observing the same star in a number of different places would allow one to measure the Δm_{ij} as a function of (x_i, y_i) and (x_j, y_j) . One could then fit a polynomial using least-squares and solve for the a_{hk} . The multiple observations of multiple stars in a grid across the array ensure we can solve for the polynomial coefficients accurately.

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3 Functional Description

Science data from VIRCAM is processed by a single recipe, namely `vircam_jitter_microstep_process`. Various other recipes are provided to generate the calibration data essential for instrumental-signature removal. A variation of the science recipe, `vircam_standard_process`, is used on observations of standard fields (which will contain many standard stars) to produce a photometric zeropoint. The recipes will work for both the Paranal and Garching pipeline environments, but it is expected that higher-quality results will be obtained at Garching where complete nights of data will be analysed.

An overview of the whole VIRCAM pipeline is illustrated in Figure 3-1.

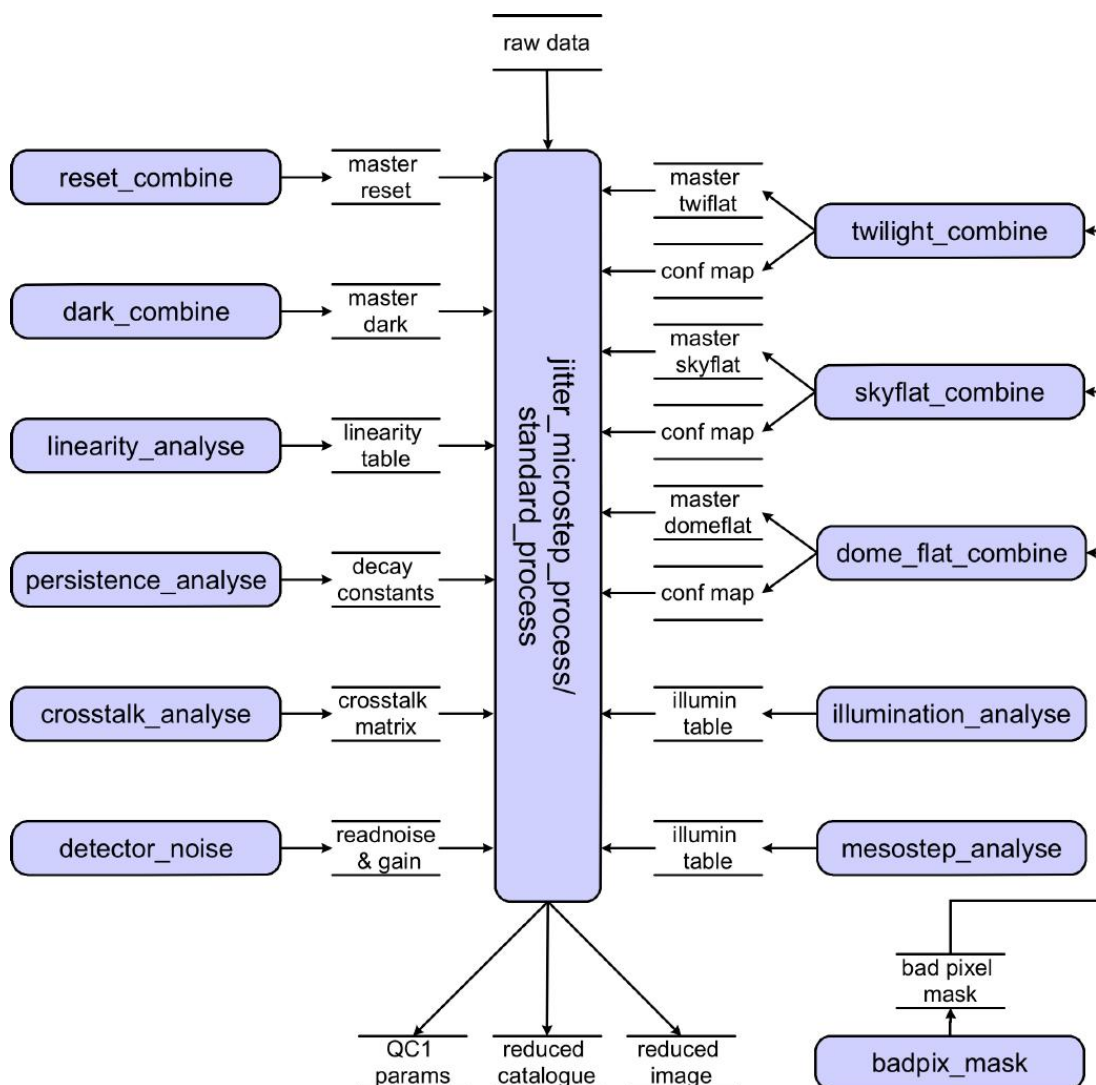


Figure 3-1 Relationship between recipes, calibration data and data products.

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There will initially be no calibration data, and so the pipeline must be “bootstrapped” by executing the recipes in the order shown in Figure 3-2. After this, there should be the minimum set of library calibration data to run the whole pipeline in production mode.

recipe:	linearity	dark	dome flat	dark current	detector noise	reset combine	twilight	meso step	persistence	cross talk
data:	domes, darks	darks	domes	darks	flats darks	resets	twilights			
static:	channel table									
products	channel table + linearity	←	←			←	←			
	Master BPM		←		←	←	←			
		Master Dark	←							
			Master dome flat							
			Master dark current							
					read/gain file					
					Master reset					
						Master twilight flat Master confidence Map				

Figure 3-2 Bootstrapping table relating Calibration Observations, Recipes and Calibration Products.

3.1 Recipes

The following figures illustrate the decomposition of the processing recipes into their component functions, shown in shaded yellow circles and with the leading “vircam” stripped for clarity. Open circles show further processing carried out within the recipe and shaded mauve rectangles the QC outputs.

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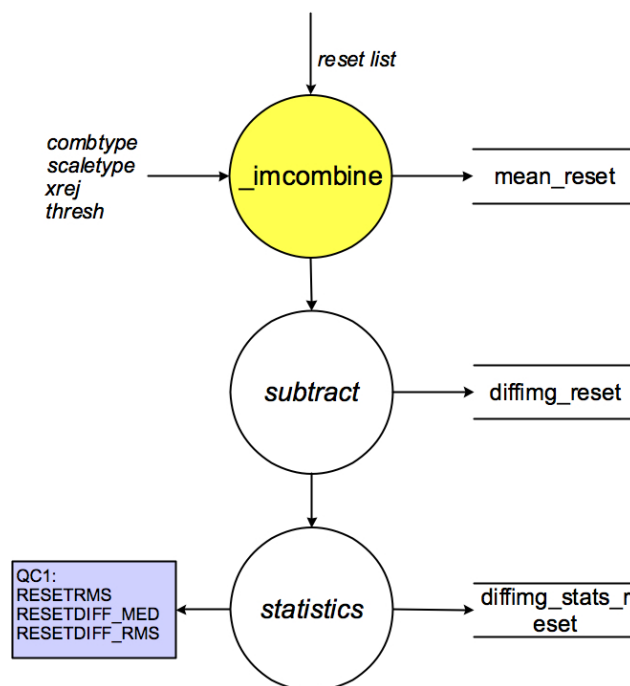


Figure 3-3 vircam_reset_combine

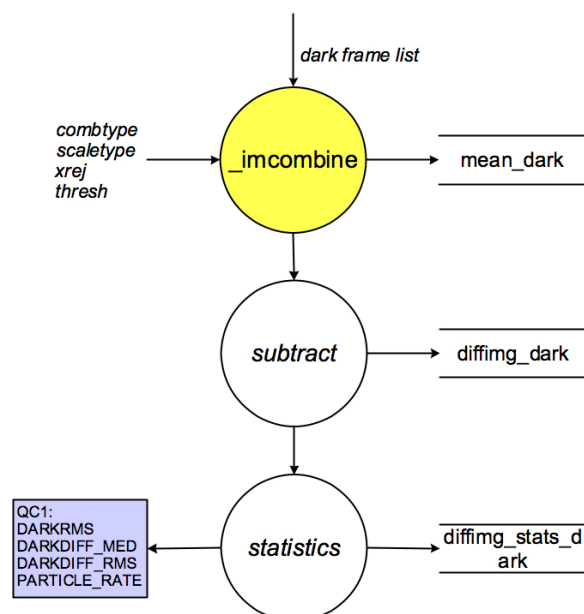


Figure 3-4 vircam_dark_combine

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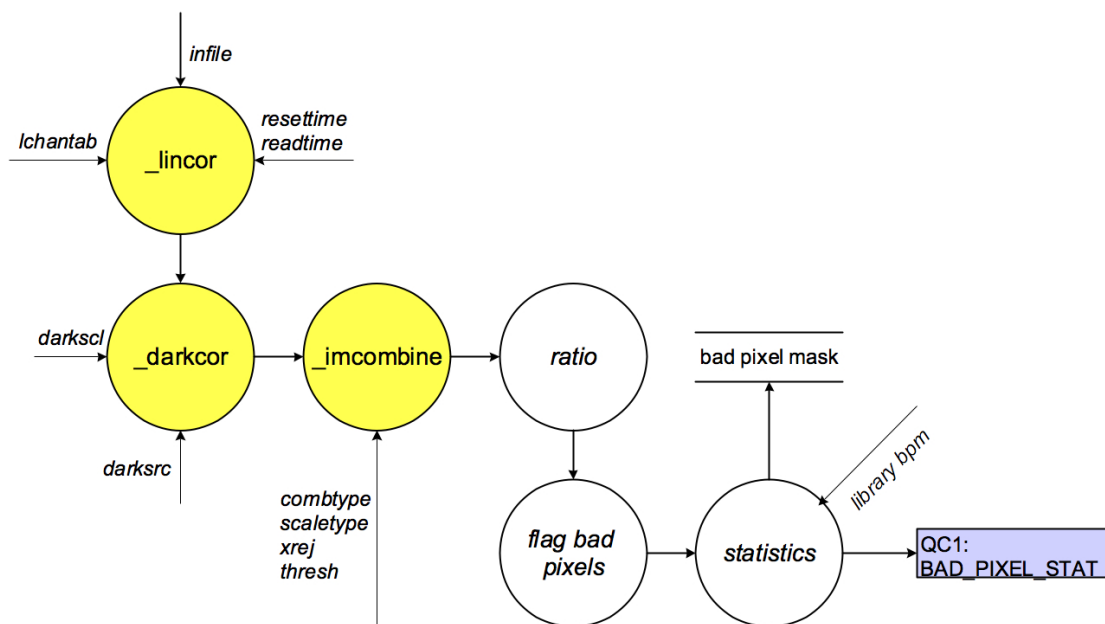


Figure 3-5 vircam_badpix_mask

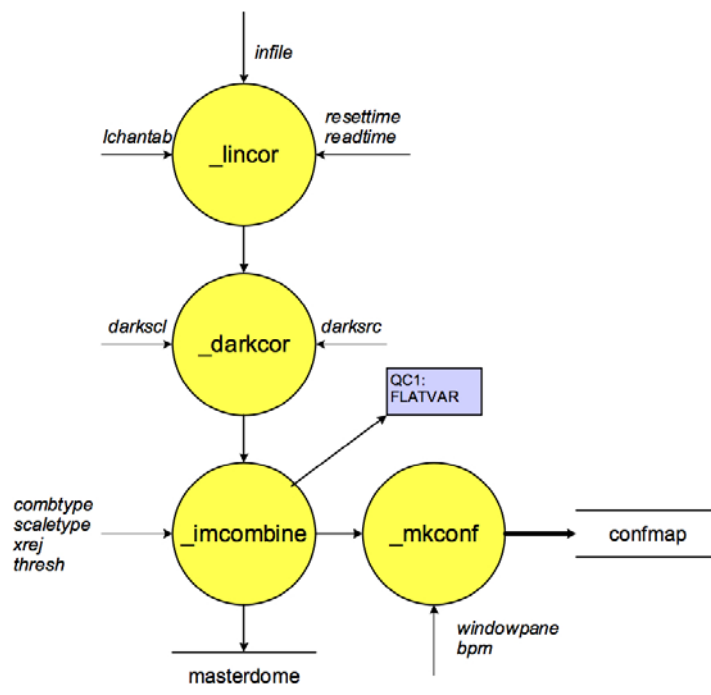


Figure 3-6 vircam_dome_flat_combine

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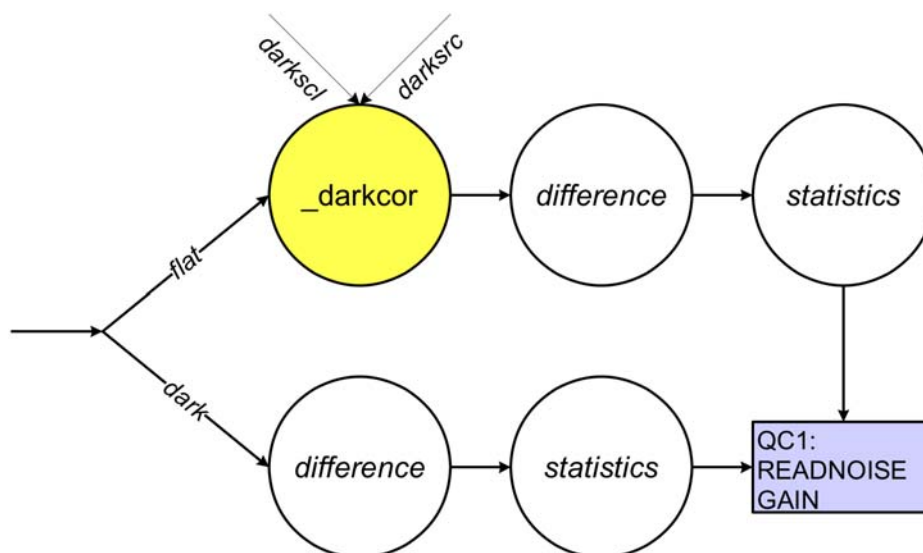


Figure 3-7 vircam_detector_noise

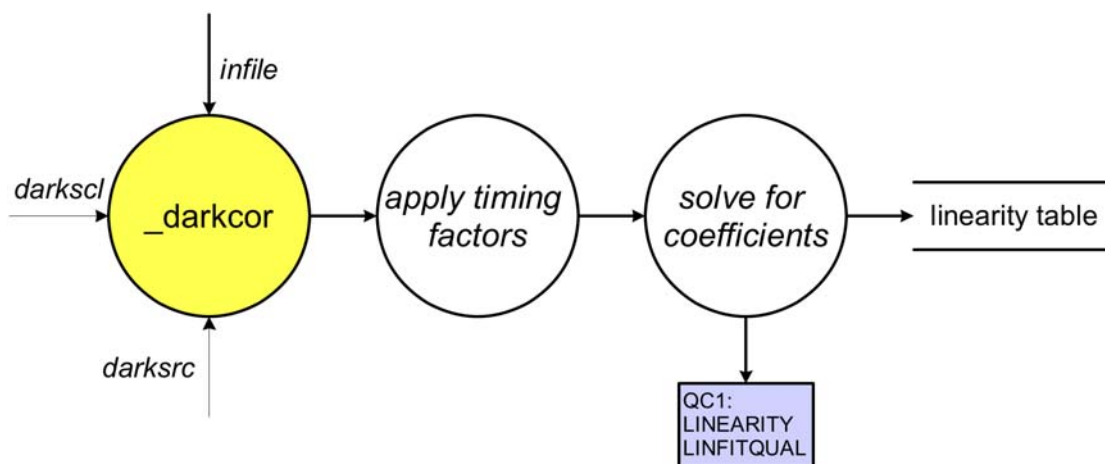


Figure 3-8 vircam_linearity_analyse

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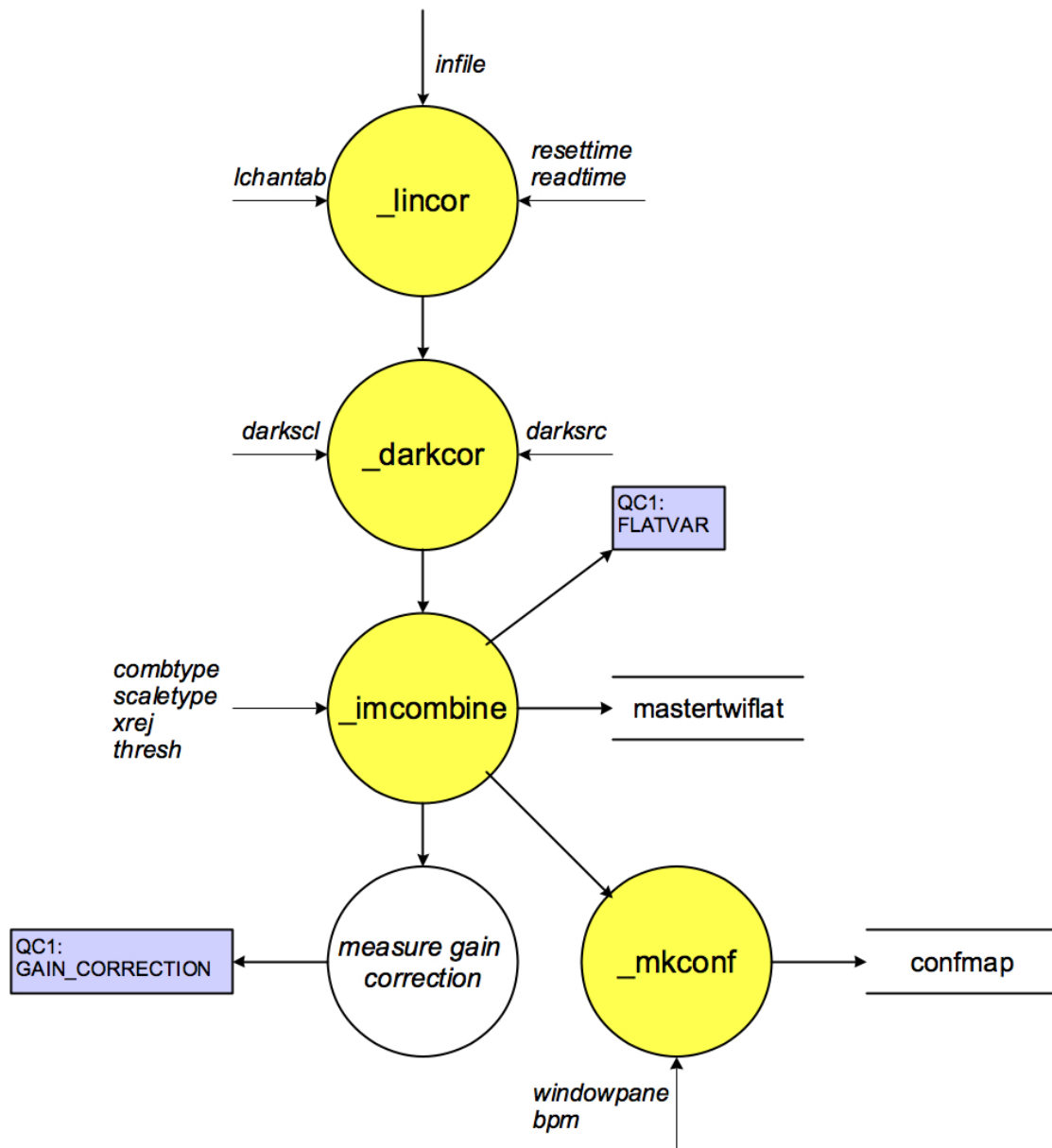


Figure 3-9 vircam_twilight_combine

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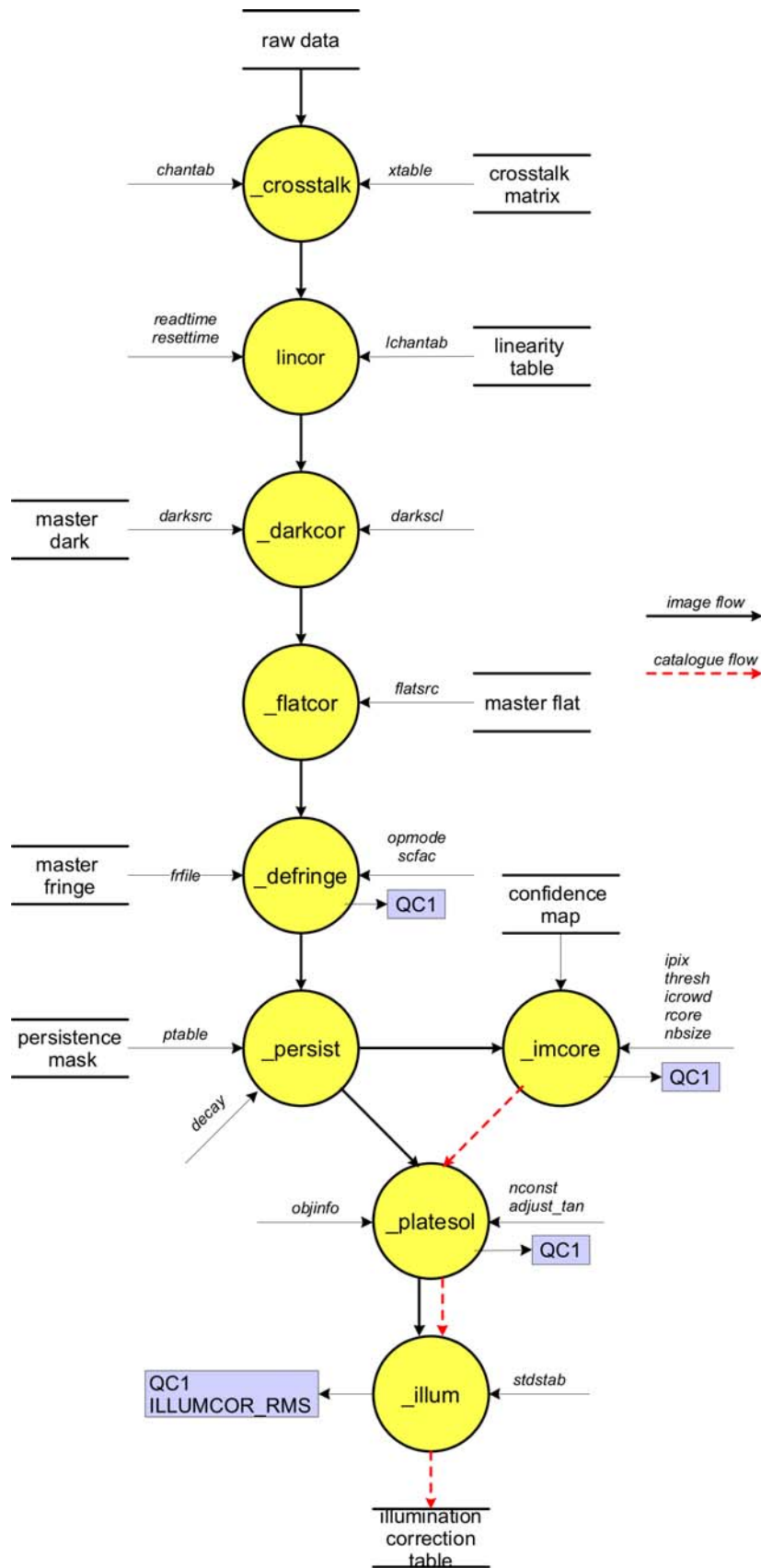


Figure 3-10 vircam_illumination_analyse

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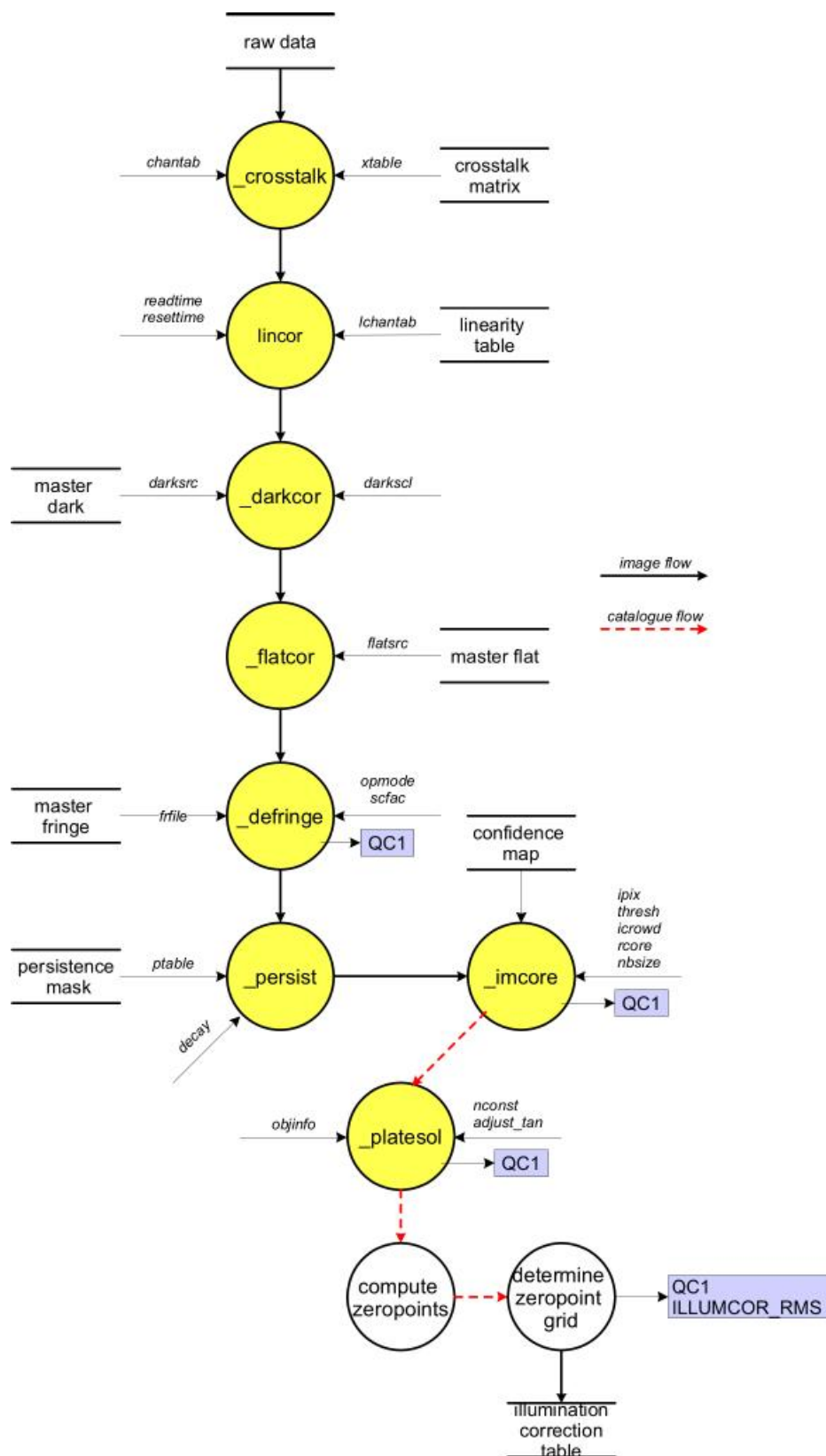


Figure 3-11 vircam_mesotep_analyse

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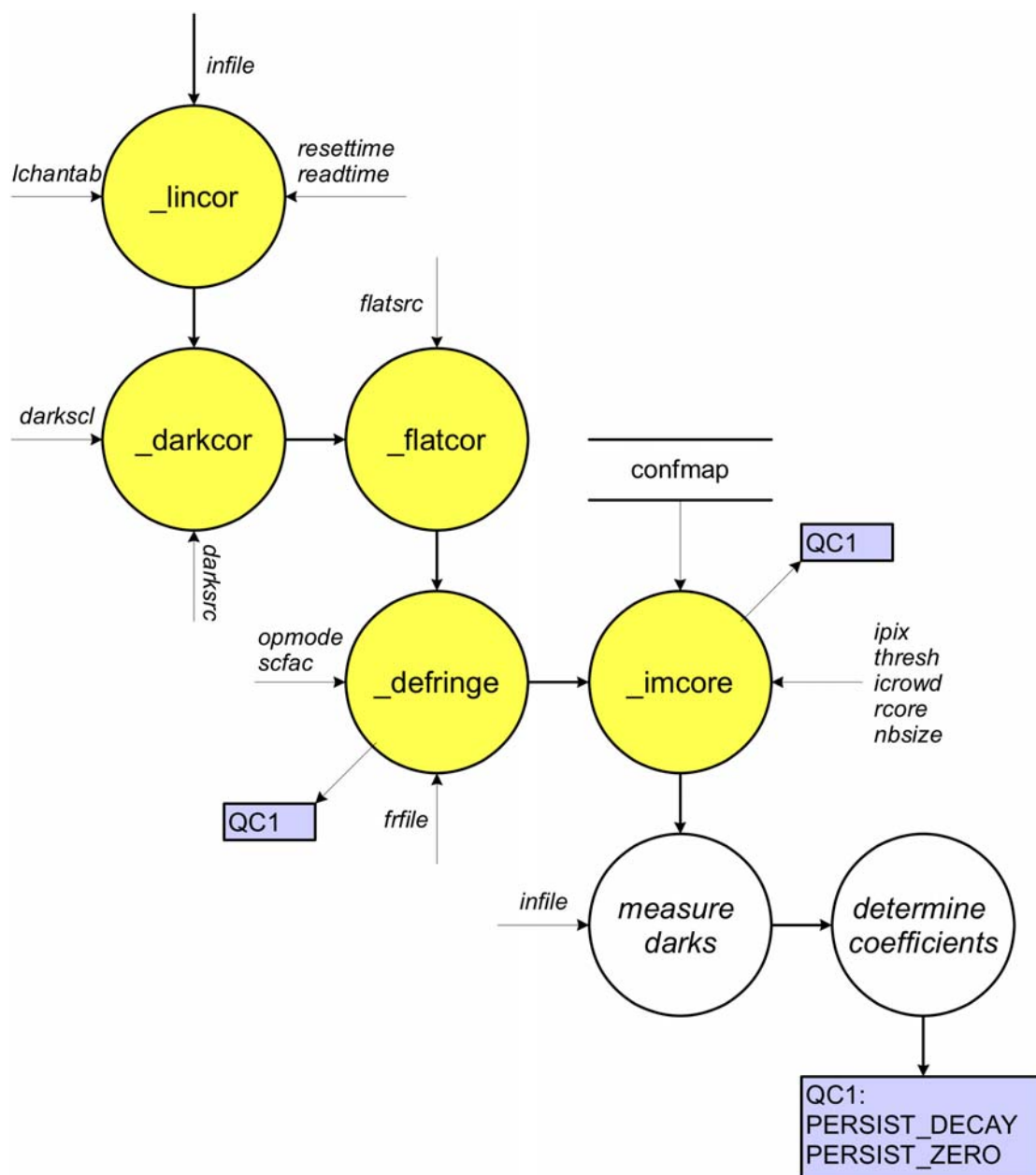


Figure 3-12 vircam_persistence_analyse

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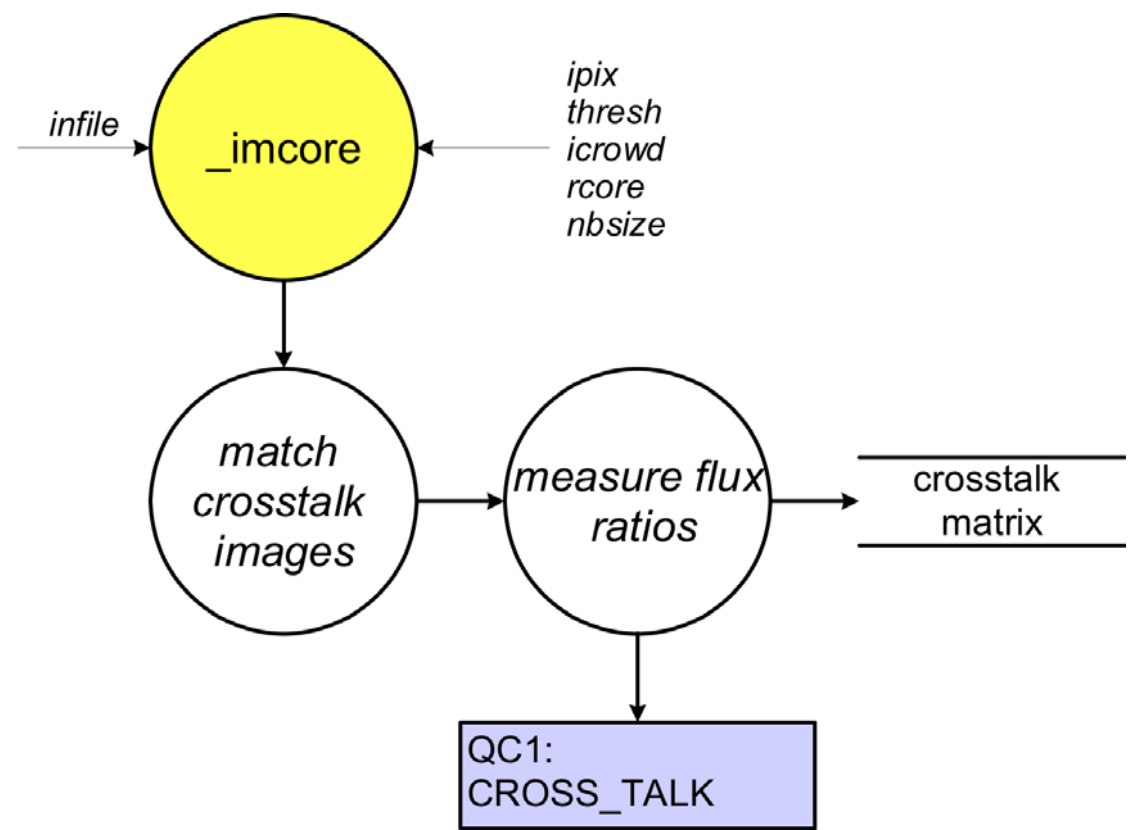


Figure 3-13 vircam_crosstalk_analyse

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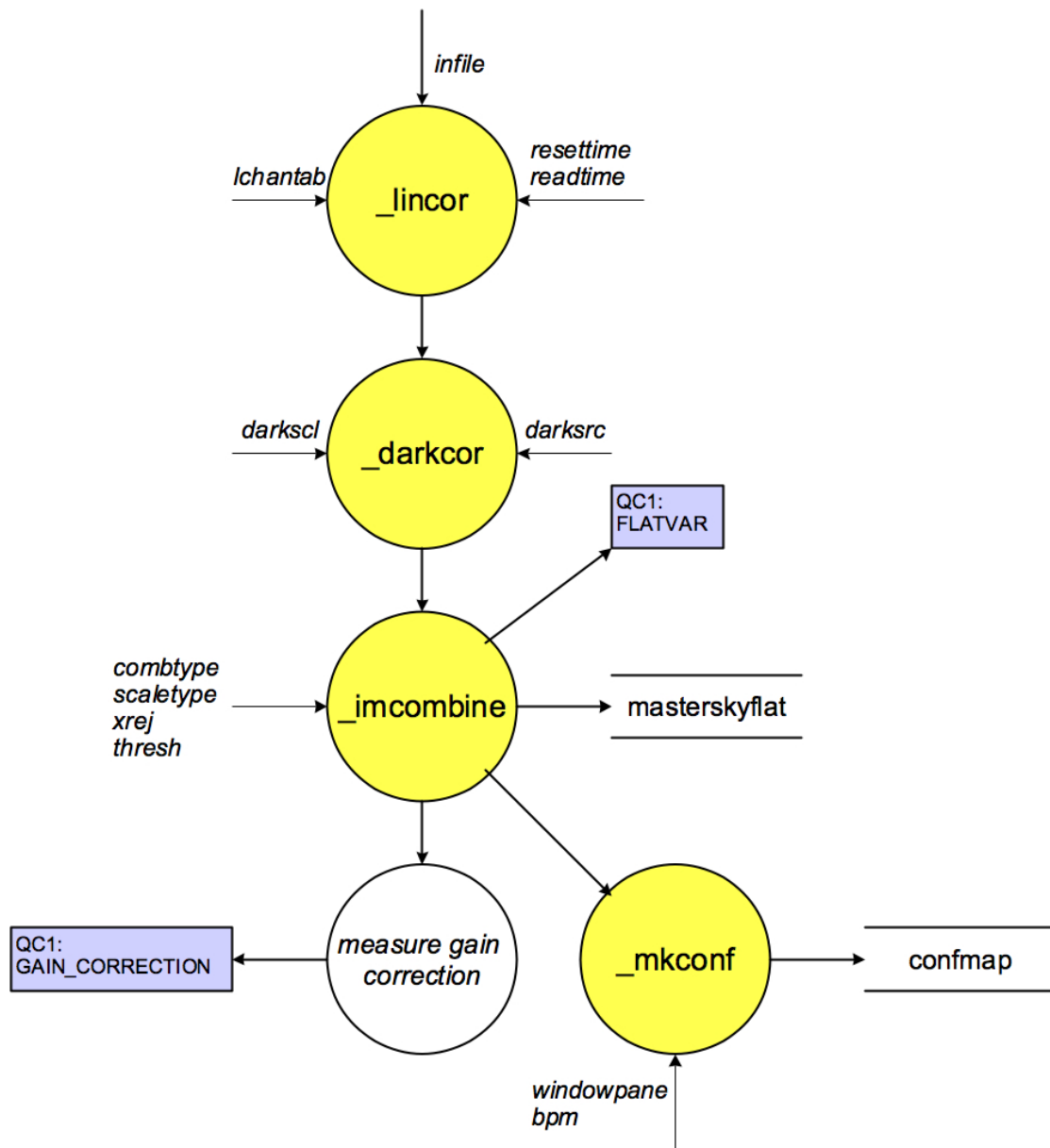


Figure 3-14 vircam_sky_flat_combine

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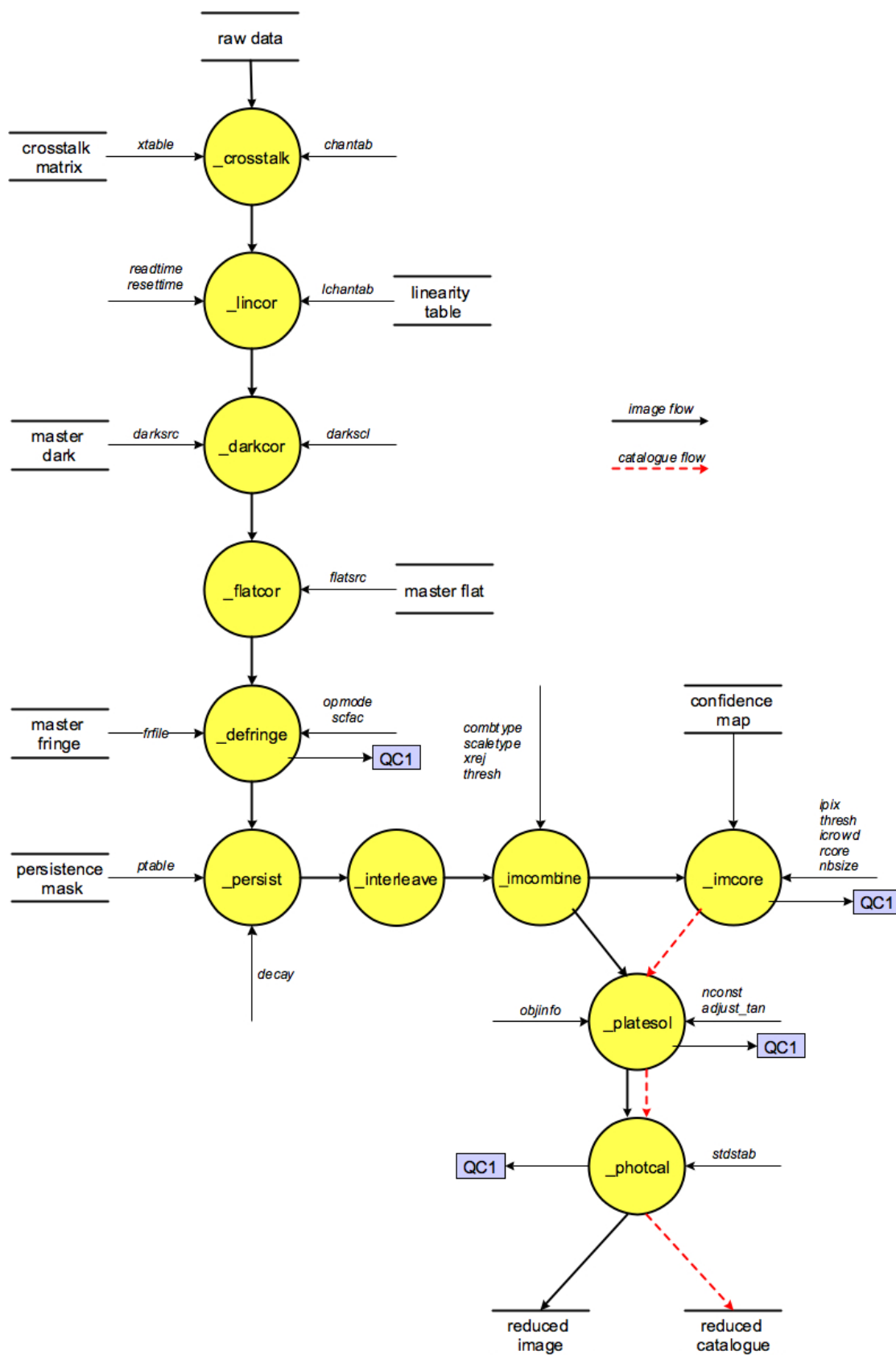


Figure 3-15 vircam_jitter_microstep_process

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4 Instrument Data Description

There is only one data format, used in both IMAGING and HOWFS modes; but note, however, HOWFS data is analysed in real time on the instrument workstation and is not passed to the pipeline, and so will not be further considered here. Data frames will be in ESO modified standard FITS format [RD 5], the ESO modifications being limited to the hierarchical header proposal, and compliant with DICB standards [AD5]. The headers are also compliant with the final World Coordinate System (WCS) specification [RD 8]. Data from the full set of chips are stored in Multi Extension Format (MEF) as 32-bit signed integers [RD 6]. Offset 16-bit format is not used because data will be co-added in the data acquisition system before output. Though not a requirement, the integer format enables the use of highly efficient lossless compression.

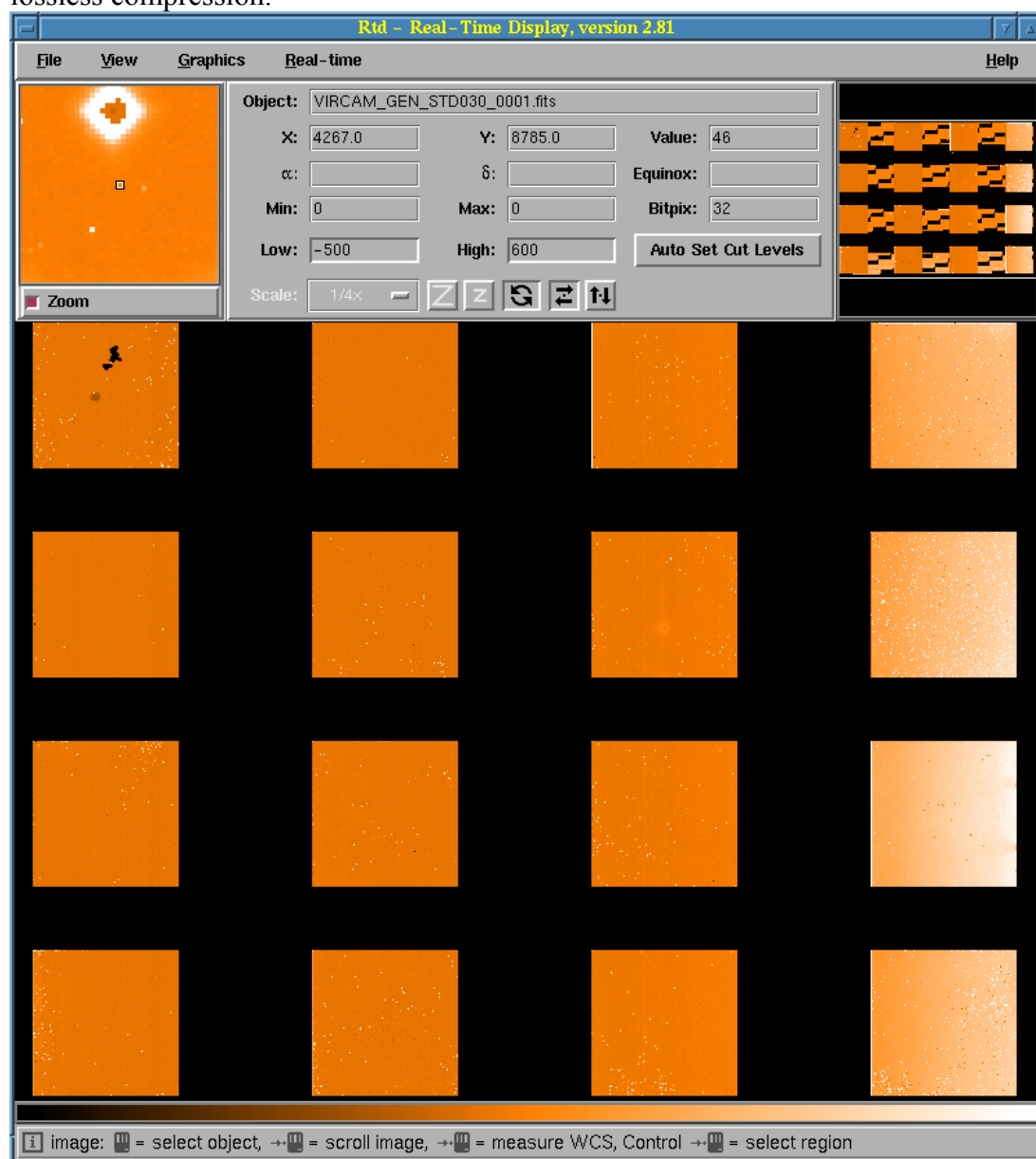


Figure 4-1 A VIRCAM engineering readout shown displayed in the ESO-VLT Real-Time Display Tool

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Raw VIRCAM data will contain headers from ESO standard DPR, OBS, TPL dictionaries and at least the following set of data dictionaries (and see [RD 2]):

- ESO-VLT-DIC.VIRCAM_CFG
- ESO-VLT-DIC.VIRCAM_HOWFS
- ESO-VLT-DIC.VIRCAM_ICS
- ESO-VLT-DIC.VIRCAM_OS
- ESO-VLT-DIC.VTCS
- ESO-VLT-DIC.IRACE

A full simulated FITS header is illustrated in the appendix (section 11).

A full 256MByte VIRCAM exposure simulation is shown in Figure 4-1, and two examples shown organised by GASGANO in Figure 4-2 demonstrate the compliance of the data format design with ESO data-interface standards.

The flow from raw data types and the templates which generate them, through the processing recipes and required calibration data, to final data products is shown in the data-processing table (Table 4-1, below).

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GASGANO Version: 2.1.2 psb / SunOS

File Selected files Tools Help

Group by Telescope expand Find entry: find 1

Displaying 2 files grouped by telescope. Unfiltered.

ESO-VISTA

68.A-0281(A) VIRCAM J.Lewis

666 deep-tile

File	CLASSIFICATION	TPL.ID	ORIGFILE	TPL.EXPNO	TPL.NEXP
VIRCAM.2004-11-24T14:44:0.123.fits	JITTER_OBJ	VIRCAM_img_obs_paw...	VIRCAM_Ima.1.fits	2	6
VIRCAM.2004-11-24T15:49:0.123.fits	JITTER_OBJ	VIRCAM_img_obs_paw...	VIRCAM_Ima.1.fits	2	6

/data/cass55b/psb/Vista/art/data/VIRCAM.2004-11-24T15:49:0.123.fits VIRCAM_Ima.1.fits JITTER_OBJ

Extension: IMAGE, WIN1.CHIP1.OUT1, 1 Find in header: find Load Filter Filter Auto Display

Keyword	Value
TELENCLMOONSCR.STATE	1
TELENCLWINDSCR1.STATE	OPEN
TELENCLWINDSCR2.STATE	UP
TELENCLVENT1.STATE	SHUT
TELENCLVENT2.STATE	HALF
TELENCLVENT3.STATE	OPEN
TEL.M2.LOOP1.STATE	CLOSED
TEL.M2.LOOP2.STATE	OPEN
TEL.M2.LOOP3.STATE	CLOSED
TEL.M2.LOOP4.STATE	CLOSED
TEL.M2.LOOP5.STATE	CLOSED
TEL.M2.CENX	1.51
TEL.M2.CENY	1.52
TEL.M2.TILTX	1.53
TEL.M2.TILTY	1.54
TEL.M1.ACTUATORFAILED	1
EXTENSION	IMAGE, WIN1.CHIP1.OUT1, 1
XTENSION	IMAGE
BITPIX	32
NAXIS	2
NAXIS1	2048
NAXIS2	2048
PCOUNT	0
GCOUNT	1
EXTNAME	WIN1.CHIP1.OUT1
EXTVER	1

Figure 4-2 Synthetic VISTA data shown organised by GASGANO

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DATA FILE	VIRCAM_TEMPLATE	DPR CATG	DPR TYPE	DPR TECH	RECIPE	HEADER INPUTS	CALIB DB	PRODUCTS
HOWFS reset frame	howfs_cal_reset	TECHNICAL	BIAS	IMAGE	HOWFS data is processed on the instrument workstation			
HOWFS Dark Frame	howfs_cal_dark	TECHNICAL	DARK	IMAGE				
HOWFS dome flat	howfs_cal_domeflat	TECHNICAL	FLAT,LAMP	IMAGE				
HOWFS wavefront	howfs_obs_exp	ACQUISITION	OBJECT, PSF-CALIBRATOR	IMAGE				
HOWFS wavefont	howfs_obs_wfront	ACQUISITION	OBJECT, PSF-CALIBRATOR	IMAGE				
Test observation	img_obs_exp	TEST	OBJECT	IMAGE	Test not processed			None
Reset Frame	img_cal_reset	CALIB	BIAS	IMAGE	reset_combine	Exposure parameters	library reset frame	Mean reset
Dark Frame	img_cal_dark	CALIB	DARK	IMAGE	dark_combine	Exposure parameters	library dark frame	Mean dark
Dark Current	img_cal_darkcurrent	CALIB	DARK, DARKCURRENT	IMAGE	dark_current	Exposure parameters		Dark Current map
Persistence sky measure	img_cal_persistence	CALIB	OBJECT, PERSISTENCE	IMAGE	persistence_analyse	Exposure parameters WCS set	linearity channel table library dark frame library flat field	Persistence constants
Persistence dark measure		CALIB	DARK, PERSISTENCE	IMAGE		Exposure parameters		
Dome Flat	img_cal_domeflat	CALIB	FLAT, LAMP	IMAGE	dome_flat_combine	Exposure parameters	library bad-pixel map library dark frame linearity channel table	Mean Dome Flat Dome confidence map

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DATA FILE	VIRCAM_TEMPLATE	DPR CATG	DPR TYPE	DPR TECH	RECIPE	HEADER INPUTS	CALIB DB	PRODUCTS
Linearity Measure	img_cal_linearity	CALIB	FLAT, LAMP, LINEARITY	IMAGE	linearity_analyse	Exposure parameters	library dark frame channel map	Linearity channel table Bad pixel map
Noise & Gain	img_cal_noisgain	CALIB	FLAT, LAMP, GAIN	IMAGE	detector_noise	Exposure parameters	linearity channel table	Noise and gain values
Twilight Flat	img_cal_twiflat	CALIB	FLAT, TWILIGHT	IMAGE	twilight_combine	Exposure parameters	library bad-pixel map library dark frame linearity channel table	Mean twilight flat Sky confidence map Gain correction
Cross-Talk obs	img_cal_crosstalk	CALIB	OBJECT, CROSSTALK	IMAGE	crosstalk_analyse	Exposure parameters	library dark frame linearity channel table library flat field library confidence map persistence constants	cross-talk matrix
Mesostep sequence	img_cal_illumination	CALIB	STD, ILLUMINATION	IMAGE	mesostep_analyse	Exposure parameters WCS set	library dark frame linearity channel table library flat field library confidence map read/gain file persistence constant crosstalk matrix library fringe map photometric catalogue	illumination map

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DATA FILE	VIRCAM_TEMPLATE	DPR CATG	DPR TYPE	DPR TECH	RECIPE	HEADER INPUTS	CALIB DB	PRODUCTS
Standard star field	img_cal_std	CALIB	STD, FLUX	IMAGE, JITTER	standard_process	Exposure parameters WCS set	library dark frame linearity channel table library flat field library confidence map read/gain table persistence constants crosstalk matrix library fringe map photometric catalogue	photometric coefficients
Pawprint	img_obs_paw	SCIENCE	OBJECT	IMAGE, JITTER	jitter_microstep_process	Exposure parameters WCS set	library dark frame linearity channel table library flat field library confidence map read/gain file persistence constants library fringe map crosstalk matrix photometric catalogue	Reduced Paw Prints Associated confidence maps Object catalogues Sky map (e.g. for de-fringing, when input criteria met)
Pawprint Extd object		SCIENCE	OBJECT, EXTENDED	IMAGE, JITTER				
Tile	img_obs_tile	SCIENCE	OBJECT	IMAGE, JITTER	jitter_microstep_process			
Tile extended		SCIENCE	OBJECT, EXTENDED	IMAGE, JITTER				
non-standard tile pattern	img_obs_offsets	SCIENCE	OBJECT	IMAGE, JITTER	jitter_microstep_process			
non-standard tile of extended source		SCIENCE	OBJECT, EXTENDED	IMAGE, JITTER				

Table 4-1 Data Processing Table

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5 DRL Data Structures

5.1 Introduction to Data Products

The main pipeline products will be images stored as image extensions in multi-extension FITS files, and derived parameters from the processing stored as FITS keyword/value pairs in the appropriate FITS header units.

All science frames will be corrected for the standard instrumental signatures such as flat fielding and dark current, and for other possible electronic artefacts, such as crosstalk, persistence and reset anomalies. In addition all pawprint images will be astrometrically and photometrically calibrated, with the calibration information being stored as FITS header keywords in each image extension. A header keyword that associates each FITS image file with its confidence map file will also be included in the primary header unit. This keyword is in the form of a timestamp and is stored in the key ESO DRS VIR_TIME.

The pipeline will also generate detected object catalogues for each science image which will be used in deriving much of the QC and calibration information. These will be stored as multi-extension FITS binary tables with a copy of the FITS header information from the FITS image files and a one-to-one correspondence of table and image extensions. Derived QC and calibration information will be added to these FITS catalogue files and also propagated to the FITS image files as described in [AD5]. In general the pipeline products fall into one of the following classes:

Science Images:

- images of single exposures
- pawprints arising from combining (stacking) jitter and microstep sequences

Object Catalogues:

- lists of detected parameterised objects for each science image (see 5.12)

Derived On-sky Calibration Information:

- Photometric zero points
- WCS coefficients
- other QC parameters (see Appendix for full specification)

Confidence Maps:

- Bad pixel masks derived from dome flat sequences
- Single image confidence maps derived from twilight flats and bad pixel masks
- Stacked/interleaved image confidence maps which also include effective exposure maps

Calibration Maps:

- Master combined dark frames
- Master combined flat field images
- Master eigen-fringe frames

Other Calibration Products:

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- Non-linearity coefficients for each data channel of each detector
- Persistence coefficients for each detector
- A 256x256 crosstalk matrix for the entire focal plane
- Illumination correction tables

Products from these lists that require extra explanation are discussed in the rest of this chapter. Below is a table with the data products and their PRO.CATG and DO.CATG keyword values (where values can be used as input and output the values of these keywords are the same).

Product	PRO.CATG/DO.CATG
<i>Master reset frame products</i>	
Master reset frame	MASTER_RESET
Master reset frame difference image	DIFFIMG_RESET
Master reset frame difference image stats table	DIFFIMG_STATS_RESET
<i>Master dark frame products</i>	
Master dark frame	MASTER_DARK
Master dark frame difference image	DIFFIMG_DARK
Master dark frame difference image stats table	DIFFIMG_STATS_DARK
<i>Master dome flat products</i>	
Master dome flat frame	MASTER_DOME_FLAT
Master dome flat frame ratio image	RATIOIMG_DOME_FLAT
Master dome flat frame ratio image stats table	RATIOIMG_STATS_DOME_FLAT
<i>Master twilight flat products</i>	
Master twilight flat frame	MASTER_TWILIGHT_FLAT
Master twilight flat frame ratio image	RATIOIMG_TWILIGHT_FLAT
Master twilight flat frame ratio image stats table	RATIOIMG_STATS_TWILIGHT_FLAT
Master confidence map	MASTER_CONF
<i>Static calibration data</i>	
Channel table (initial)	CHANNEL_TABLE
Photometric calibration table	PHOTCAL_TAB
<i>Linearity calculation products</i>	
Channel table (revised)	CHANNEL_TABLE
Bad pixel mask	MASTER_BPM
<i>Detector noise products</i>	
Dark current image	MASTER_DARK_CURRENT
Detector noise table	READGAIN_TABLE
Crosstalk matrix	XTALK_TABLE
Persistence mask table	PERSIST_MASK
<i>Standard star products</i>	
Standards table	STANDARDS_TABLE
Matched standards table	MATCHED_STANDARDS_TABLE
Illumination correction table	ILLCOR_TAB
<i>Raw input data</i>	
Reset frame	RESET_IMAGE
Dark frame	DARK_IMAGE
Twilight flat frame	TWILIGHT_FLAT
Dome flat frame	DOME_FLAT
Science frame	SCIENCE_IMAGE

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Product	PRO.CATG/DO.CATG
<i>Final science data products</i>	
Output single science images	SIMPLE_IMAGE
Output interleaved images	INTERLEAVED_IMAGE
Output stacked image	JITTERED_IMAGE
Output interleaved and stacked image	INTERLEAVED_STACKED_IMAGE
Output stacked/interleaved confidence map	CONFIDENCE_MAP
Output object catalogues	OBJECT_CATALOGUE

Table 5-1 DO and PRO categories for data products

It is imperative that a recipe continue on as best it can until all frames in the input frameset are processed. Thus in the event of some sort of failure, the recipe may have to generate ‘dummy’ data products. These are images, tables etc. that are written to a FITS extension in the place of the data product that you would have normally expected from the given recipe. Dummy products are necessary in the event that you are processing many/all of the available extensions in one go. The dummy frames hold a position in the output data product FITS file where the real product should have gone, had there not been a failure. The type of failure that will generate dummy products are: the headers of the input frames indicate that detector was dead during the observation; an inability to load the necessary FITS image extensions for a particular detector; missing header information etc. A dummy product will be flagged with the boolean header item ESO DRS IMADUMMY.

5.2 Channel Table

Each VIRCAM detector will be split into 16 different data channels, each with its own electronics. This means that some reduction tasks will rely on knowing the location and readout timing information for each data channel. The location and linearity information will be provided by the ‘channel table’. The information will be stored in a multi-extension FITS file with each extension being a FITS binary table (one for each detector). Each of the tables will contain the columns listed in below (although perhaps not in this order). The extension name should match the extension names for the input images. It is worth remembering here that there is no zeroth order coefficient, so the number of coefficient columns is the same as the polynomial order.

Column	Name	Type	Units	Description
1	channum	int		Number of the data channel, which is an integer from 1-16. This is a unique ID for the data channel in the context of the detector of which it is a part.
2	ixmin	int	pixels	The X coordinate of the lower left corner of the data channel
3	ixmax	int	pixels	The X coordinate of the upper right corner of the data channel
4	iymin	int	pixels	The Y coordinate of the lower left corner of the data channel
5	iymax	int	pixels	The Y coordinate of the upper right corner of the data channel

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6	dcrpix1	int	pixels	The X coordinate of the location within the data channel where the first pixel is read out.
7	dcrpix2	int	pixels	The Y coordinate of the location within the data channel where the first pixel is read out.
8	dcd1_1	int		Can take the values (-1,0,1). Gives the partial derivative of the fast readout axis with respect to the X axis.
9	dcd1_2	int		Can take the values (-1,0,1). Gives the partial derivative of the fast readout axis with respect to the Y axis.
10	dcd2_1	int		Can take the values (-1,0,1). Gives the partial derivative of the slow readout axis with respect to the X axis.
11	dcd2_2	int		Can take the values (-1,0,1). Gives the partial derivative of the slow readout axis to the Y axis.
12	qualfit	double		The quality of the linearity fit for this channel
13	lin_10000	double		The percentage non-linearity for the current channel at a level of 10000 ADU
14	norder	int		The order of the polynomial used in the fit.
15	coeff_1	double		The first coefficient in the fit. This must be set to 1 always
.				
.				
.				
14+n	coeff_n	double		The nth order coefficient, where n=norder

5.3 Bad Pixel Mask

As we mentioned in section 2.12 on confidence maps, it is essential for many of the operations of the pipeline to know exactly which pixels in each image are always likely to be bad. This is done initially using a bad pixel mask. This will take the form of a FITS container file with an image extension of type byte for each detector. The values in the data array will be set to one for bad pixels and zero for good ones.

5.4 Confidence Maps

Confidence maps combine bad pixel information with variance information in composite images, as described fully in 2.12. The maps are kept as FITS MEF files in

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short integer format in which zero equates to completely bad pixel and 100 to completely good pixel.

5.5 Dark Current Image

Dark current is calculated by a looking at the time rate of change of the data in a series of dark frames taken with a variety of exposure times on a pixel by pixel basis. The result is a map with an estimate of the dark current (in ADU/sec) for each pixel.

5.6 Crosstalk Matrix

Detector crosstalk is described in section 2.8. In order to correct for this effect we need a factor that defines the effect of one channel on a second one, i.e. a crosstalk matrix. This will be generated on an occasional basis and will be stored in the form of a FITS binary table with the following columns:

Column	Name	Type	Units	Description
1	source	int		The channel index of the crosstalk source
2	victim	int		The channel index of the victim of the crosstalk
3	coef	float		The scaling factor required to remove the source crosstalk from the victim.

The information in this table will be used by the crosstalk correction routine in conjunction with the channel table (5.1).

5.7 Illumination Correction Table

The effect of large scale background variation in the flat field images (usually due to scattered light) are described in section 2.15. An illumination correction table is generated by dividing the image plane into a number of boxes, using the systematic photometric zeropoint changes across the image to define the correction for each box. This is used to correct the instrumental magnitudes of subsequent observations for positional biases. This will be stored in the form of a series of binary FITS tables (one per detector) in a single MEF container with the following columns:

Column	Name	Type	Units	Description
1	xmin	int	pixels	The X position of lower left corner of the box
2	xmax	int	pixels	The X position of upper right corner of the box
3	ymin	int	pixels	The Y position of lower left corner of the box
4	ymax	int	pixels	The Y position of upper right corner of the box
5	illcor	float	mag	The illumination correction for the box

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5.8 Difference/Ratio Images

Some of the recipes will attempt to monitor performance of the detectors by comparing current images with library versions (e.g. dark frames). For additive effects like reset and dark current this can most easily be achieved with a difference image. This is simply the difference of two images in the sense of the master subtracted from the current image. Similarly for multiplicative effects like flat fielding this is most easily achieved with a ratio image which is the current image divided into the master image.

5.9 Difference/Ratio Image Statistics Tables

For recipes that monitor detector performance in particular, it is often worthwhile to keep statistical information on difference/ratio images. This is because frames are often compared to library frame either by forming a difference or a ratio and the statistics in cells or subsections across the output image can be a useful diagnostic to detector performance. A difference/ratio image statistics table will be a FITS table with the following columns defined:

Column	Name	Type	Units	Description
1	xmin	int	pixels	The X position of lower left corner of the cell
2	xmax	int	pixels	The X position of upper right corner of the cell
3	ymin	int	pixels	The Y position of lower left corner of the cell
4	ymax	int	pixels	The Y position of upper right corner of the cell
5	chan	int		The data channel to which this cell belongs. This is only useful if the whole cell fits into a data channel.
5	mean	float	adu	The mean value in the cell
6	median	float	adu	The median value in the cell
7	variance	float	adu	The variance of the values in the cell
8	mad	float	adu	The median absolute deviation from the median of the values in the cell.

5.10 Persistence Mask Table

Dealing with image persistence properly requires knowledge of observations that were done previous to the current one. In the on-line pipeline this can be approximately accomplished by processing the observations from a particular template with respect to the times that they were done. This sort of information then can be used in conjunction with the persistence decay time constant and the end time of the current exposure to decide which frames will have affected the current image and how to scale them to correct the problem. The columns for the persistence mask table are:

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Column	Name	Type	Units	Description
1	srcimage	char		The name of the source image
2	srcetime	int	seconds	The end time of the source observation in seconds from 1 Jan 2000.

5.11 Standards Table

During the course of the pipeline reductions it will be necessary to extract information from standard astrometric and photometric catalogues. The results of this extraction will be in an Extracted Standards Table and will contain the following columns:

Column	Name	Type	Units	Description
1	xpredict	float	pixels	The X position of the matching standard as predicted from the image WCS and the object's equatorial coordinates.
2	ypredict	float	pixels	The Y position of the matching standard as predicted from the image WCS and the object's equatorial coordinates.
3	RA	float	degrees	The standard's RA
4	Dec	float	degrees	The standard's Dec
5 – n	mags	float	mags	Any photometric information that might exist in the standard star catalogue

5.12 Object Catalogues

The derived object catalogues are stored in multi-extension FITS files as binary tables, one for each image extension. Each detected object has an attached set of descriptors, forming the columns of the binary table, and summarising derived position, shape and intensity information (see section 2.13 for more details).

The following columns are present:

Column	Name	Description
1	Sequence number	Running number for ease of reference, in strict order of image detections
2	Isophotal_flux	Standard definition of summed flux within detection isophote.
3	X_coordinate	The <i>x</i> , <i>y</i> coordinates and errors with (1, 1) defined to be the centre of the first active pixel in the image array. See 2.13.2.
4	X_coordinate_err	
5	Y_coordinate	
6	Y_coorindate_err	
7	Gaussian_sigma	Second moment parameters. See 2.13.2

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8	Ellipticity	The number of pixels above a series of threshold levels, relative to local sky. The levels are set at T, 2T, 4T, 8T, 16T, 32T, 64T and 128T where T is the analysis threshold
9	Position_angle	
10	Areal_1_profile	
11	Areal_2_profile	
12	Areal_3_profile	
13	Areal_4_profile	
14	Areal_5_profile	
15	Areal_6_profile	
16	Areal_7_profile	Peak intensity and its error in ADU relative to local value of sky
17	Areal_8_profile	
18	Peak_height	Flux and error within a specified radius aperture, typically set so that $R_{aperture} = \langle FWHM \rangle$ where the quantity in angle brackets is the mean FWHM of all stellar images. This is also known as the “core radius”. The apertures here correspond to $(0.5, 1/\sqrt{2}, 1, \sqrt{2}, 2, 2\sqrt{2}, 4, 5, 6, 7, 8, 10, \text{ and } 12)$ times the core radius.
19	Peak_height_err	
20	Aper_flux_1	
21	Aper_flux_1_err	
22	Aper_flux_2	
23	Aper_flux_2_err	
24	Aper_flux_3	
25	Aper_flux_3_err	
26	Aper_flux_4	
27	Aper_flux_4_err	
28	Aper_flux_5	
29	Aper_flux_5_err	
30	Aper_flux_6	
31	Aper_flux_6_err	
32	Aper_flux_7	
33	Aper_flux_7_err	
34	Aper_flux_8	
35	Aper_flux_8_err	
36	Aper_flux_9	
37	Aper_flux_9_err	
38	Aper_flux_10	
39	Aper_flux_10_err	
40	Aper_flux_11	
41	Aper_flux_11_err	
42	Aper_flux_12	
43	Aper_flux_12_err	
44	Aper_flux_13	
45	Aper_flux_13_err	
46	Petr_radius	Petrosian radius r_p in pixels as defined in Yasuda, et al. 2001, AJ, 112, 1104.
47	Kron_radius	Kron radius r_k in pixels as defined by Bertin and Arnouts 1996, A & A Supp, 117, 393.
48	Hall_radius	Hall radius r_h in pixels as defined by Hall and Mackay 1984, MNRAS, 210, 979.
49	Petr_flux	

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50	Petr_flux_err	Petrosian flux and error to $2r_p$
51	Kron_flux	Kron flux and error to $2r_k$
52	Kron_flux_err	
53	Hall_flux	Hall flux and error to $5r_h$. Alternative total flux.
54	Hall_flux_err	
55	Error_bit_flag	Bit pattern listing various processing error flags. Currently this is the number of bad pixels included in the aperture flux
56	Sky_level	Local interpolated sky level from background tracker
57	Sky_rms	Local estimate of variation in sky level around images
58	Parent_or_child	Flag for parent or part of de-blended deconstruct.
59	RA	RA and Dec of each object in degrees. These are added during WCS refinement
60	Dec	
61	Classification	simple flag indicating most probably classification for object: -9: Saturated -2: Object is compact (maybe stellar) -1: Object is stellar 0: Object is noise 1: Object is non-stellar
	Statistic	an equivalent N(0,1) measure of how stellar-like an image is. It is used in deriving the classification (25) in a “necessary but not sufficient” sense. This statistic is computed from a discrete curve-of-growth analysis from the peak and aperture fluxes and also factors in ellipticity information. The stellar locus is used to define the “mean” and “sigma” as a function of magnitude such that the “statistic” can be normalised to an approximate N(0,1) distribution.
63-80	blank	

5.13 Matched Standards Table

When doing astrometric and/or photometric reduction it is necessary to match astronomical objects that appear on an image with objects from a standard catalogue. The output from such a matching algorithm is called a Matched Standards Table and will contain all the columns from both input tables (cf. 5.11 and 5.12).

5.14 Readnoise/Gain File

This is a multiextension FITS file where each extension is a null FITS image. Each extension will have at least the following keywords in its header:

Keyword	Type	Description
chipname	char	The name of the chip to for the current noise values
readnois	float	The readout noise of the chip in units of electrons.
gain	float	The gain of the chip in units of electrons per ADU

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5.15 Photometric Calibration Table

This is a table used to define the transformation from instrumental to standard magnitudes.

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Column	Name	Type	Description
1	filter	char	The name of the filter
2	extinction	float	The extinction coefficient for airmass of unity for the given filter.
3	offset	float	A pedestal value to be added to the instrumental magnitude once the colour equation has been applied.
4	columns	char	The standard magnitude columns from the matched standards catalogue to be used. This is the names of the columns separated by a comma.
5	coleg	char	The colour equation coefficients. There should be one coefficient for each of the columns mentioned in the columns field. This should be formatted as a series of floating point numbers separated by commas.

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6 DRL Functions

In what follows we describe the low level functions that will be driven by the VIRCAM pipeline. The parameter list describes the full API for each function. Many of the functions make use of the following structures:

- **vir_fits:** This is a convenience structure that binds the **cpl_image** object for a particular image with the name of the originating FITS file, the image extension number, the primary header propertylist and the propertylist for the extension header.
- **vir_tfits:** In a similar way, functions that get information from an existing FITS table will have parameters declared **vir_tfits**. This wraps a **cpl_table** object with the same ancillary information as above for **vir_fits**.
- **vir_mask:** This is provided as a means to load and manipulate stand-alone bad pixel masks. These can come from a bad pixel mask FITS file or a confidence map.

A feature of the DRL functions is an inherited status parameter. This is always the last in the parameter list and it is also the return value from each function. Each function will test the status value as its first action and return immediately if the status is bad. The error messages will be passed through the CPL error structure and hence information on the origin and cause of any error will not be lost by using inherited status.

CPL currently has no facility for generating or manipulating the information required for a full World Coordinate System. As this is a vital piece of information for any astronomical observation we have sought to rectify this situation by importing a WCS package into the VIRCAM software. This package is called **wcslib** and was written by Mark Callabretta, who is one of the leading authorities on the representation of world coordinate systems in astronomy. The VIRCAM pipeline accesses the functions in **wcslib** through a simple set of wrapper routines. These were written in anticipation that CPL itself would eventually provide this kind of functionality. When it does, then just the internals of the wrapper routines will need rewriting.

In this chapter we have simplified the descriptions of the functions by omitting both very obvious and repetitive features. A list of these shortcuts is included below.

- We have not enumerated very obvious keywords in the input or output header lists. These include things like the data array size, data type and data dimensionality.
- Inherited bad status will cause each function to return immediately without updating the CPL error message.
- A fatal error condition in a function will cause an appropriate CPL error message to be set and will cause the function to return to the calling routine immediately where the pipeline can take the necessary steps to terminate gracefully. We do not include segmentation violations, arithmetic exceptions and the like in the definition of a fatal error.

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- Very obvious error conditions such as corrupted input files, running out of disc space, etc have been omitted for brevity.
- Any function parameters that refer to image data will have the expected data type in square brackets next to the parameter name.

6.1 *vircam_crosstalk*

6.1.1 General

Name:

vircam_crosstalk

Purpose:

Remove electronic crosstalk from an image

General Description

Electrical crosstalk is removed from each data channel in the input images by means of a crosstalk matrix (see section 5.6). The latter consists of factors by which the data from one channel affects another. The applicability is to be decided during laboratory and on-sky tests.

Mathematical Description:

See section 2.8 for a full mathematic description of crosstalk removal.

6.1.2 Function Parameters

None

6.1.3 Input Images and Required FITS Header Information.

infile (float)

The input science container-file to be corrected; this must contain a full list of all the source and victim images.

6.1.4 Input Tables

xtable

The crosstalk matrix (see 5.6)

chantab

The channel table (see 5.2)

6.1.5 Output Images

outfile (float)

The output science image; if this is the same as the value for **infile** or is blank, then the output will overwrite the input.

keyword	type	description
DRS XTCOR	char	The name of crosstalk matrix table used

6.1.6 Output Tables

None

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6.1.7 Other Output

None

6.1.8 QC1 Outputs

None

6.1.9 Quality Assessment

Crosstalk artefacts are removed to with the expected sky noise

6.1.10 Error Conditions

- There are no fatal error conditions.
- There are no non-fatal error conditions

6.2 *vircam_darkcor*

6.2.1 General

Name:

vircam_darkcor

Purpose:

Remove reset anomaly and dark current using a library mean dark frame of matching exposure/integration time if available.

General Description

The data array of the input dark frame is multiplied by a predetermined factor such that it matches the scale of the reset anomaly in the target object frame. The scaled dark frame is then subtracted from the target frame.

Mathematical Description:

$$I_i^{out} = I_i^{in} - kD_i$$

where I is the input data, D is the mean dark frame data and k is the scaling factor.

6.2.2 Function Parameters

vir_fits ***infile** [float]

The input science image to be corrected. This will be overwritten by the corrected image

vir_fits ***darksrc** [float]

The input mean dark image

float **darkscl**

An input scaling factor. This corresponds to the value of k in the mathematical description above.

int ***status**

Input/output status from function.

6.2.3 Required Input FITS Header Information

None

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6.2.4 Output FITS Header Information

The following will be appended to the extension header for **infile**.

keyword	type	description
DRS DARKCOR	char	The name of the master dark file specified in darksrsc
DRS DARKSCL	float	The scale factor used in the subtraction

6.2.5 QC1 Outputs

None

6.2.6 Quality Assessment

Reset anomaly ramp removed

6.2.7 Fatal Error Conditions

- Mismatched data array dimensionality between the input images
- The image data fails to load

6.2.8 Non-Fatal Error Conditions

None

6.3 *vircam_defringe*

6.3.1 General

Name:

vircam_defringe

Purpose:

Remove fringe patterns from an image using a mean fringe frame and a scaling algorithm

General Description

Large scale variations are removed from the input frame by dividing the image into squares over which a background median can be determined and then constructing an interpolated background correction. The fringe image is scaled by a value and subtracted from the input image. Statistics of the image show whether the scale factor used was too high or too low. The scale factor is adjusted and the fit is attempted again. This is repeated to convergence. Once convergence is achieved, then the fringes are removed with the correct scale factor. The background map variation is then added back in.

Mathematical Description:

$I_i = I_i - k * Fr_i$ where I is the input image data, k is the fringe scaling factor and Fr is the fringe data. For a full description of how the scale factor and the fringe data are computed see section 2.6.

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6.3.2 Function Parameters

int **opmode**

The operational mode of the algorithm; a value of 1 means that the scale factor will be determined automatically, a value of 2 means that the scale factor will be taken from the parameter **scfac**.

float **scfac**

If the value of **opmode** is such that we want to set the fringe scale manually, then this should have the value of the desired scale. Otherwise this parameter is ignored.

6.3.3 Input Images and Required FITS Header Information

infile (float)

The input science image to be corrected.

keyword	type	Description
EXPTIME	int	The exposure time of the input data

frfile (float)

The input mean fringe image.

keyword	type	description
EXPTIME	int	The exposure time of the fringe data

6.3.4 Input Tables

None.

6.3.5 Output Images

outfile (float)

The output science image; if this is the same as the value for **infile** or is blank, then the output will overwrite the input.

keyword	type	description
DRS FRINGEn	char	The name of the fringe file used in the nth defringing pass
DRS FRNGSCn	float	The scale factor for the nth defringing pass.

6.3.6 Output Tables

None

6.3.7 Other Output

None.

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6.3.8 QC1 Outputs

FRINGE_RATIO

6.3.9 Quality Assessment

QC1 parameter FRINGE_RATIO shows significant improvement in sky noise

6.3.10 Error Conditions

- The following conditions will cause fatal errors
 - Zero or negative exposure times
 - Mismatched data array dimensionality
- The following conditions will cause non-fatal errors
 - Negative fringe-scale factor (e.g. as occasionally produced in conditions following a solar flare).

6.4 *vircam_flatcor*

6.4.1 General

Name:

vircam_flatcor

Purpose:

Remove large and small scale gain variations by dividing science frames by a mean flat field frame.

General Description

The data array of the input image is divided by that from a mean flat field image. The mean flat field should have been normalised in the manner described in section 2.3. This ensures that during this reduction step we perform both for the flat field correction and the detector gain correction.

Mathematical Description:

$$I_i^{out} = I_i^{in} / F_i$$

where I is the input data and F is the mean flat field data.

6.4.2 Function Parameters

vir_fits ***infile** [float]

The input science image to be corrected. This gets overwritten by the corrected image

vir_fits ***flatsrc** [float]

The input mean flat field image

int ***status**

Input/output status from function

6.4.3 Required Input FITS Header Information

None

6.4.4 Output FITS Header Information

The following will be appended to the extension header for **infile**.

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keyword	type	description
DRS FLATCOR	char	The name of the flat field image specified in flatsrc

6.4.5 QC1 Outputs

None

6.4.6 Quality Assessment

Robust estimates of the background of each detector image agree c.f. to expected sky noise.

6.4.7 Fatal Error Conditions

- Mismatched data array dimensionality between the input images
- The image data fails to load

6.4.8 Non-Fatal Error Conditions

None

6.5 *vircam_genlincur*

6.5.1 General

Name:

vircam_genlincur

Purpose:

Generate linearity coefficients given a list of dome flat field exposures.

General Description:

A series of dark corrected exposures of a stable dome light source with a range of exposure times should be given. From the known readout, reset, dit-delay and exposure times a timing map is constructed for each pixel according to the algorithm outlined in section 2.2.2. The results are written to a new channel table.

Mathematical Description:

This function implements the mathematical description in section 2.2.2

6.5.2 Function Parameters

vir_fits ****imlist** [float]

The list of input dark corrected dome flat images

int **nimages**

The number of images in the list

vir_tfits ***chantab**

The input channel table for the detector represented in the input image list.

This is described in section 5.2.

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int **norder**

The order of the polynomial to use in the expansion; note that because the zeroth term is defined to be zero, then the number of coefficients this routine will derive is the same as the polynomial order

int **kconst**

A flag, which, if set, signals that the value of k defined in section 2.2.2 is constant for all pixels in a given image

unsigned char ***bpm**

A bad pixel mask.

cpl_table ***lchantab**

The output channel table.

int ***status**

Input/output status from function

6.5.3 QC1 Outputs

None

6.5.4 Required Input FITS Header Information

The following values need to be included in the extension headers of each of the files in **imlist**.

keyword	type	description
EXPTIME	float	The exposure time for the image
ESO DET MINDIT	float	The minimum DIT time
ESO DET DITDELAY	float	A delay between the reset and the first read

6.5.5 Output FITS Header Information

None

6.5.6 Quality Assessment

The value of the **qualfit** and **lin_10000** columns are reasonable for all channels.

6.5.7 Fatal Error Conditions

- Invalid channel table.
- Inability to map the data arrays of input images

6.5.8 Non-Fatal Error Conditions

- Failed fit for a channel

6.6 **vircam_getstds**

6.6.1 General

Name:

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vircam_getstds

Purpose:

Given an input FITS header, extract a list of standard stars from a catalogue that should appear on the relevant image.

General Description:

The header of an input image is parsed to locate and read the standard WCS FITS header keywords. The WCS is used to define the coverage of the image in equatorial coordinates. The coverage is used to select objects from the 2MASS point source catalogue. (The catalogue is expected to be made available in FITS table form.) Once the stars have been selected the information about them is written to an extracted standards table (5.11) along with their expected x,y positions based on the input WCS.

Mathematical Description:

N/A

6.6.2 Function Parameters

cpl_propertylist *plist

The propertylist representing the FITS header of an input image. This header must have all of the keywords listed in the FITS header section below.

int cache

A flag, which, if set, indicates that a local cache should be set up to store catalogues that you have extracted. If used, this can significantly reduce the amount of searching that is required of the whole 2MASS catalogue and hence cut down the amount of time this routine takes. This is especially important when many exposures are being done in the same part of the sky.

char *path

The full path to the directory where the 2MASS FITS tables are held.

cpl_table *index

An index table for the catalogue FITS files – this parameter must be NULL on entry for the first time this routine is called and must be deleted explicitly after the last time this routine is called.

cpl_table **stds

The output table of standards

int *status

Input/output status from function

6.6.3 Required Input FITS Header Information

The following must be available in the input propertylist **plist**.

keyword	type	description
CRPIX1	double	All of the standard FITS WCS keywords that are relevant for the projection model to be used with VIRCAM (nominally ZPN). See [RD 8] for more specific information
CRPIX2	double	
CTYPE1	char	
CTYPE2	char	
CRVAL1	double	
CRVAL2	double	
CD1_1	double	

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CD1_2	double	
CD2_1	double	
CD2_2	double	
PV2_1	double	
PV2_3	double	

6.6.4 Output FITS Header Information

None

6.6.5 QC1 Outputs

None

6.6.6 Quality Assessment

N/A

6.6.7 Fatal Error Conditions

- Inability to read the index table.
- Inability to read the catalogue tables.

6.6.8 Non-Fatal Error Conditions

- No objects found in the catalogue

6.7 *vircam_illum*

6.7.1 General

Name:

vircam_illum

Purpose:

Work out the spatial corrections in the photometric zero point.

General Description:

This function takes a table of photometric standards and a table of objects extracted from an image. The objects in both of the input tables are matched up. The pixel space of the original image is divided up into cells of **nbsize** pixels on a side. The mean zero point for each cell is calculated. Next the ensemble-mean zero point is calculated for all the cells. The illumination correction is then defined for each cell as the residual zero point from that mean. The sense of the illumination correction for a cell is such that it must be subtracted from the mean frame zero point for objects in that cell.

Mathematical Description:

This function implements the mathematical description in section 2.15

6.7.2 Function Parameters

int **nbsize**

The size of the cells in pixels to use when dividing up the input data.

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6.7.3 Input Images and Required FITS Header Information

None

6.7.4 Input Tables

stdtab

The photometric standards table as defined in 5.11

objtab

The table of objects extracted from an image of a standard star field. This is described in section 5.12

6.7.5 Output Images

None

6.7.6 Output Tables

illcortab

The illumination correction table as defined in section 5.7.

6.7.7 Other Output

None

6.7.8 QC1 Outputs

ILLUMCOR_RMS

6.7.9 Quality Assessment

Applying the correction table to the input file should result in a magnitude zero point with an RMS consistent with the mean RMS of the source photometric catalogue. This can be seen with the keyword DRS MAGZERR which is generated by **vircam_photcal** (6.18).

6.7.10 Error Conditions

- The following conditions will cause fatal errors
 - No matching objects
- There are no non-fatal error conditions

6.8 **vircam_imcombine**

6.8.1 General

Name:

vircam_imcombine

Purpose:

Combine a list of images into an output image. Allow for *x,y* shifting, intensity biasing, intensity scaling, image weighting and bad pixel rejection.

General Description:

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A list of images is combined to form an output image. The output image can be either a mean of the input pixels or a median. The images can have the following done to them before combination:

- the input data values for a given output pixel can be scaled by a preset amount for each input image
- the input data values for a given output pixel can be biased by a preset amount for each input image
- outliers can be masked and rejected

Mathematical Description:

None

6.8.2 Function Parameters

vir_fits ****fset** [float]

The input list of images to be combined.

int **nfits**

The number of input images

int **combtype**

A flag to determine whether the output should be a mean or a median of the input frames. 1 == median, 2 == mean

int **scaletype**

A flag to determine how the input will be scaled or biased before combining.

0: No scaling or biasing

1: Input files are biased additively to a common background median

2: Input files are scaled multiplicatively to a common background median

3: Input files are first scaled by exposure time and then biased to a common background.

int **xrej**

If set, then an extra rejection cycle will be performed. This is quite useful doing combinations in the region of bright objects.

float **thresh**

The rejection threshold in units of the background noise.

cpl_image ****outimage** [float]

The output combined image

unsigned char ****rejmask**

The output rejection mask. The value for each pixel tells how many input pixels were rejected at that position.

unsigned char ****rejplus**

The output positive residual rejection mask. The value for each pixel tells how many input pixels were rejected for having residuals that were positive. This is good for determining the number of cosmic ray hits there were on the input images.

cpl_propertylist ****drs**

An output propertylist for the provenance keywords to go in the DRS extension of the output file header.

int ***status**

Input/output status from function

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6.8.3 Required Input FITS Header Information

The following is required to be in the extension header for each image in **fset**.

keyword	type	description
EXPTIME	float	The exposure time for each input image. This is used when doing multiplicative scaling

6.8.4 Output FITS Header Information

The following will appear in the extension header of **outimage**.

keyword	type	description
DRS PROVXXXX	char	A set of keywords that describes the provenance of the output file.

6.8.5 QC1 Outputs

None

6.8.6 Quality Assessment

N/A

6.8.7 Fatal Error Conditions

- Unable to map input data arrays
- Unable to create output data arrays

6.8.8 Non-Fatal Error Conditions

- Input frame set is empty

6.9 *vircam_imcore*

6.9.1 General

Name:

vircam_imcore

Purpose:

Generate a catalogue of objects on an image.

General Description:

This function is the main object extraction routine. It generates object catalogues for the purposes of astrometric and photometric calibration, generating catalogues of the form described in section 5.12. As a final step each object is given a stellar/non-stellar classification.

Mathematical Description:

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This function implements the mathematical description in section 2.13

6.9.2 Function Parameters

vir_fits ***infile** [float]

The input frame from which to extract the objects

vir_fits ***conf** [int]

The input confidence map

int **ipix**

The minimum size of an object in pixels in order for that object not to be considered spurious.

float **thresh**

The detection threshold measured in units of the mean background noise

int **icrowd**

If set, then the function will attempt to de-blend merged objects

float **rcore**

The core radius in pixels for the default profile fit.

int **nbsize**

The size in pixels of the grid squares used for background estimation.

int **cattype**

The output catalogue type. This can be:

1. The 32 column INT Wide Field Camera format
2. The 80 column WFCAM format
3. A very minimal format which is just fine if only positions are required.
4. An object mask

NB: option 1 corresponds to the catalogues described in section 5.12.

float **filtfwhm**

The FWHM of the smoothing kernel used in the detection algorithm

cpl_table ****outtab**

The output table of all the detected objects

cpl_propertylist ****extra**

A propertylist with QC information that one can append to a FITS header

int ***status**

Input/output status from function

6.9.3 Required FITS Header Information

The following information is required from the extension header of **infile**.

keyword	type	Description
EXPTIME	int	The exposure time of the input data in seconds

6.9.4 Output FITS Header Information

The following will be written to the extension propertylist of the input image

keyword	type	Description
DRS SKYLEVEL	float	The mean sky level in the image
DRS SKYNOISE	float	The mean sky noise in the image

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DRS THRESHOL	float	The threshold in ADUs for the image detection
DRS RCORE	float	The core radius in pixels as specified in the parameter list
DRS FILTFWHM	float	The FWHM of the smoothing kernel in the detection algorithm
DRS SEEING	float	The derived seeing in pixels
DRS CLASSIFD	int	If set, then this catalogue has been classified
DRS MINPIX	int	The minimum number of pixels an object should cover
DRS CROWDED	int	If set, then the deblending software has been run on this catalogue

6.9.5 QC1 Outputs

SATURATION
MEAN_SKY
SKY_NOISE
SKY_RESET_ANOMALY
NOISE_OBJ
IMAGE_SIZE
APERTURE_CORR
ELLIPTICITY

6.9.6 Quality Assessment

N/A

6.9.7 Fatal Error Conditions

- Negative threshold value
- Zero or negative sky noise estimate
- Unable to map input data arrays

6.9.8 Non-fatal Error Conditions

- No objects found

6.10 *vircam_imdither*

6.10.1 General

Name:

vircam_imdither

Purpose:

Dither all the images in a jitter sequence into a single output image

General Description:

This function takes all the images and their associated confidence maps from a jitter sequence and dithers them into a single output image and confidence map.

Mathematical Description:

None

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6.10.2 Function Parameters

vir_fits ****infile** [float]

The input images to dither

vir_fits ****inconf**s [int]

The associated input confidence maps

int **ninputs**

The number of input images in the jitter sequence

int **nconf**s

The number of input confidence maps. If this is the same as **ninputs** then it is assumed that each confidence map in the input list is associated with the image located in the same place of the input image list. If this is less than **ninputs** then the first confidence map in the list will be used for all of the input images.

cpl_propertylist ***p**

An output property list which can be used for the extension header for the output image. This will be the extension header for the first image in the list, but with appropriate modifications to the WCS.

cpl_image ****out**

The output dithered image.

cpl_image ****outc**

The output confidence map for the dithered image

int ***status**

Input/output status from function

6.10.3 Required FITS Header Information

The following information is required from the extension header of **infile**.

keyword	type	Description
EXPTIME	int	The exposure time of the input data in seconds
DRS XOFFDITHER	float	The jitter offset in <i>x</i>
DRS YOFFDITHER	float	The jitter offset in <i>y</i>

6.10.4 Output FITS Header Information

The following will be written to the extension propertylist of the input image

keyword	type	Description
DRS PROVXXXX	char	A set of keywords that describes the provenance of the output file.

6.10.5 QC1 Outputs

None

6.10.6 Quality Assessment

N/A

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6.10.7 Fatal Error Conditions

- No images to combine.
- Confidence map dimensions don't match image dimensions

6.10.8 Non-fatal Error Conditions

- None

6.11 *vircam_imstack*

6.11.1 General

Name:

vircam_imstack

Purpose:

Stack a list of images into an output by mapping the input WCSs onto an output grid.

General Description:

A list of images is combined to form an output image. The full range of equatorial coordinates in the input file list is used to define an output grid. Each of the input pixels is mapped onto an appropriate pixel on the output grid. The resulting stacks can be either averaged or medianed to an output value. The images can have the following done to them before combination:

- the input data values for a given output pixel can be scaled by a preset amount for each input image
- the input data values for a given output pixel can be biased by a preset amount for each input image
- outliers can be masked and rejected
- known bad pixels can be masked and rejected
- individual pixels can be weighted by confidence

Mathematical Description:

None

6.11.2 Function Parameters

int calctype

A flag to determine whether the output should be a mean or a median of the input frames

int usezeros

If set, then the images will be biased by an amount specified in the image headers

int usescales

If set, then the images will be multiplied by a factor specified in the image headers

int wtflag

A flag to determine how to weight the pixels; the options are:

- Ignore pixel weights altogether

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- Weight bad pixels to 0 and all others to 1.
- Use weights implied by the input confidence maps

int **rejalgo**

A flag to specify the rejection algorithm used to flag outliers. This will include standard Poisson rejection based on the read noise and gain as well as other popular algorithms.

float **lsigma**

The lower threshold for clipping outliers in units of sigma.

float **hsigma**

The upper threshold for clipping outliers in units of sigma.

6.11.3 Input Images and Required FITS Header Information

inlist (float)

The list of input files to be stacked.

keyword	type	description
CRPIX1	double	All of the standard FITS WCS keywords that are relevant for the projection model to be used with VIRCAM (nominally ZPN). See [RD 8] for more specific information.
CRPIX2	double	
CTYPE1	char	
CTYPE2	char	
CRVAL1	double	
CRVAL2	double	
CD1_1	double	
CD1_2	double	
CD2_1	double	
CD2_2	double	
PV2_1	double	
PV2_3	double	

6.11.4 Input Tables

None

6.11.5 Output Images

outfile (float)

The output file.

keyword	type	description
DRS VXXXX	char	A set of FITS keywords that list the files that were combined to form this output file. This establishes the provenance of the output file.

outconf (short int)

The output confidence map.

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6.11.6 Output Tables

None

6.11.7 Other Output

None

6.11.8 QC1 Outputs

None

6.11.9 Quality Assessment

N/A

6.11.10 Error Conditions

- The following conditions will cause a fatal error
 - No or incomplete WCS defined in an input file header
- There are no non-fatal error conditions.

6.12 *vircam_interleave*

6.12.1 General

Name:

vircam_interleave

Purpose:

Interleave the pixels from a microstepped sequence to form an output frame and confidence map.

General Description:

The fractional microstep and offsets defined by the WCS in the input file headers are used to define the size and scale of the output grid. The input data is then mapped directly onto the output grid using known offsets. The result is a frame where the input pixels have been interwoven to form a finer grid. The images can have the following done to them before combination:

- the input data values for a given output pixel can be scaled by a preset amount for each input image
- the input data values for a given output pixel can be biased by a preset amount for each input image

No pixel rejection is possible

Mathematical Description:

None

Quality Assessment:

N/A

6.12.2 Function Parameters

vir_fits ****infiles**

The list of input microstepped observation images

int **ninputs**

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The number of input files in **infiles**.

vir_fits ****inconf**s

The list of input confidence maps. If the list is NULL or has a size of zero, then no output confidence map will be created. If the list has a size that is less than the size of the input file list (**infiles**), then only the first one will be used (i.e. each input image has the same confidence map). If the list has the same number of maps as the input images, then all the listed confidence maps will be used to form the output confidence map.

int **nconf**s

The number of confidence maps in **inconf**s.

int **nsteps**

The number of steps in the microstep pattern, e.g. for a 3x3 microstep pattern, this should be set to 3.

cpl_propertylist ****p**

A propertylist that will be used for the output image. This will be the header for the first image in the input image frameset (**infiles**), with the appropriate modifications to the WCS.

cpl_image ****outimage**

The output interleaved image

cpl_image ****outconf**

The output confidence map (if any)

int ***status**

Input/output status from function

6.12.3 Required Input FITS Header Information

The following information is required from the extension header of the first file in the **infiles** list.

keyword	type	description
CRPIX1	double	All of the standard FITS WCS keywords that are relevant for the projection model to be used with VIRCAM (nominally ZPN). See [RD 8] for more specific information.
CRPIX2	double	
CTYPE1	char	
CTYPE2	char	
CRVAL1	double	
CRVAL2	double	
CD1_1	double	
CD1_2	double	
CD2_1	double	
CD2_2	double	
PV2_1	double	
PV2_3	double	

The following information is required from the extension header from each of the files in the **infiles** list.

keyword	type	description
DRS XOFFMICRO	float	The X offset in pixels of the current image relative to the

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		first image in the microstep sequence.
DRS YOFFMICRO	float	The Y offset in pixels of the current image relative to the first image in the microstep sequence.
DRS BACKMED	float	The median value of the background

6.12.4 Output FITS Header Information

WCS keywords as above modified for the new sampling. These are written to the output propertylist **p**. The following will also appear in **p**.

keyword	type	description
DRS PROVXXX	char	A set of keywords that describes the provenance of the output file.

6.12.5 QC1 Outputs

None

6.12.6 Quality Assessment

N/A

6.12.7 Fatal Error Conditions

- Failure to access input data
- Input frame list has no entries

6.12.8 Non-Fatal Error Conditions

None

6.13 *vircam_lincor*

6.13.1 General

Name:

vircam_lincor

Purpose:

Use linearity coefficients and timing information to put input data onto a linear scale.

General Description

The linearity coefficients for each data channel are combined with readout timing information in the manner described in section 2.2.1 to create a linearised data array for the input file.

Mathematical Description:

This function implements the mathematical description given in section 2.2.1. See that section for a full description.

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6.13.2 Function Parameters

vir_fits *infile

The input image to be linearised

vir_tfits *lchantab

The channel table which is appropriate for this image.

int kconst

If set, then the value of k in section 2.2 is constant for all pixels in the image.

int *status

Input/output status from function

6.13.3 Required Input FITS Header Information

The following items are required from the extension header of **infile**.

keyword	type	description
EXPTIME	float	The exposure time for the image
ESO DET MINDIT	float	The minimum DIT time
ESO DET DITDELAY	float	A delay between the reset and the first read

6.13.4 Output FITS Header Information

The following items will appear in the extension header of **infile**:

keyword	type	description
DRS LINCOR	char	The name of the FITS file of the channel table used to linearise the data

6.13.5 QC1 Outputs

None

6.13.6 Quality Assessment

N/A

6.13.7 Fatal Error Conditions

- Inability to map input data.
- Channel table has incorrect information

6.13.8 Non-Fatal Error Conditions

None

6.14 *vircam_matchstds*

6.14.1 General

Name:

vircam_matchstds

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Purpose:

Match a list of standard stars (from *vircam_getstds*) to the (x,y) positions of objects on an image.

General Description:

This routine matches the objects found on an image with a list of objects that have been extracted from a standard catalogue. The (x,y) coordinates in both lists are compared and Cartesian offsets are found which cause the maximum number of objects to match. Output will be to a matched standards table (5.13).

Mathematical Description:

N/A

6.14.2 Function Parameters

`cpl_table *objtab`

The input table with the programme objects. Must have columns called **X_coordinate** and **Y_coordinate** (as one gets from *vircam_imcore*).

`cpl_table *stdstab`

The input table with the template objects. Must have columns called **xpredict** and **ypredict** (as one gets from *vircam_getstds*)

`float srad`

A search radius in pixels. This helps to define the number of points used in the grid search

`cpl_table **outtab`

The output table with both sets of Cartesian coordinates plus any extra information that appears in **stdstab**.

`int *status`

Input/output status from function

6.14.3 Required FITS Header Information

None

6.14.4 Output FITS Header Information

None

6.14.5 QC1 Outputs

None.

6.14.6 Quality Assessment

N/A

6.14.7 Fatal Error Conditions

- Input tables do not have the required columns

6.14.8 Non-Fatal Error Conditions

- One of the input catalogues has no objects
-

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6.15 *vircam_matchxy*

6.15.1 General

Name:

vircam_matchxy

Purpose:

Work out relative jitter offsets by cross-correlating the locations of objects on a set of frames.

General Description:

Two catalogues of objects derived from two images (a programme image and a template image) are given. A search algorithm is used to try and maximise the number of objects that match between the two lists, by varying the Cartesian offsets. No axis flipping or rotation is allowed. The output is the *x,y* offsets. These can be applied to a whole group of files by the calling routine in order to define the relative offsets for a complete jitter sequence. The offsets are defined in the sense:

$$\Delta X = X_{\text{template}} - X_{\text{programme}}$$

In order to minimise the effect of the astrometric distortion on the offset solution, it is generally advisable that the input coordinates of the programme table should be biased by offsets that have been calculated from the initial WCS in the input images.

Mathematical Description:

None

6.15.2 Function Parameters

cpl_table ***progtab**

The table of objects appearing on the 'programme' frame. Must have columns **X_coordinate** and **Y_coordinate**.

cpl_table ***temptab**

The table of objects appearing on the 'template' frame. Must have columns **X_coordinate** and **Y_coordinate**.

float **srad**

The search radius in pixels. This is used to define the number of points for the grid search.

float ***xoffset**

The returned value of the *x* Cartesian offset

float ***yoffset**

The returned value of the *y* Cartesian offset

int ***nm**

The number of objects that matched between the two input lists

int ***status**

Input/output status from function

6.15.3 Required FITS Header Information

None

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6.15.4 Output FITS Header Information

None

6.15.5 QC1 Outputs

None

6.15.6 Quality Assessment

N/A

6.15.7 Fatal Error Conditions

- The input tables do not have the required columns.

6.15.8 Non-Fatal Error Conditions

- One of the tables has no objects.

6.16 *vircam_mkconf*

6.16.1 General

Name:

vircam_mkconf

Purpose:

Make an initial confidence map from two flat field images

General Description:

A mean flat field image and a bad pixel mask are given. The good pixels are given a confidence value as described below and the bad ones are assigned a value of zero.

Mathematical Description:

‘Good’ pixels will be given a confidence of:

$$C_i = 100F_i / \langle F \rangle$$

where F_i is the pixel’s value in the input flat field map, and $\langle F \rangle$ is the mean value in the flat field map. A maximum confidence of 110 is allowed.

Quality Assessment:

N/A

6.16.2 Function Parameters

cpl_image ***flat**

The input flat field image

char ***flatfile**

The file from which **flat** originated

vir_mask ***bpm**

The input bad pixel mask image

cpl_image ****outconf**

The output confidence map image

cpl_propertylist ****drs**

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A propertylist to be used to store the output DRS keywords
int *status

The input/output function status

6.16.3 Required FITS Header Information

None

6.16.4 Output FITS Header Information

keyword	type	description
DRS FLATIN	char	The name of the FITS file from which the flat data originated.
DRS BPMIN	char	The name of the FITS file from which the bad pixel map data originated

6.16.5 QC1 Outputs

None

6.16.6 Quality Assessment

N/A

6.16.7 Fatal Error Conditions

- One or other of the input images is unreadable.

6.16.8 Non-Fatal Error Conditions

None

6.17 *vircam_persist*

6.17.1 General

Name:

vircam_persist

Purpose:

Remove effects of image persistence

General Description:

Images can persist on an IR detector after it has been read and reset. This persistence can be characterised by an exponential decay time. To correct this, a list of all the images that have been taken before the current image should be passed into this routine, along with their respective observational end times (in seconds from some zero point). This is the persistence mask defined in section 5.10. Using this information, an appropriate decay model and the ending time of the current exposure, a persistence map is built up. This map is then subtracted from the input image.

Mathematical Description:

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This function implements the mathematical description in section 2.7.

6.17.2 Function Parameters

float **decay**

The decay constant in seconds as described in section 2.7.

float **fract**

The fraction of the ambient intensity that persists right after reset (i.e. no decay time).

6.17.3 Input Images and Required FITS Header Information

infile (float)

The input science image to be corrected.

keyword	type	description
EXPTIME	int	The exposure time of the input data
DATE-OBS	char	The UTC date of the start of the exposure

6.17.4 Input Tables

ptable

The persistence mask. See section 5.10.

6.17.5 Output Images

outfile (float)

The output science image; if this is the same as the value for **infile** or is blank, then the output will overwrite the input.

keyword	type	description
DRS PERMASK	char	The name of the persistence mask used

6.17.6 Output Tables

None

6.17.7 Other Output

None.

6.17.8 QC1 Outputs

None

6.17.9 Quality Assessment

Persistent images removed to within the mean sky noise.

6.17.10 Error Conditions

- The following conditions will cause fatal errors
 - Negative or zero exposure time.
 - Mismatched dimensionality of data arrays.

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- There are no non-fatal error conditions

6.18 *vircam_photcal*

6.18.1 General

Name:

vircam_photcal

Purpose:

Work out the photometric zero point for stars in an image

General Description:

The instrumental and standard magnitudes of objects on a frame are compared and a photometric zero point is calculated.

Mathematical Description:

This function implements the mathematical description in section 2.14

6.18.2 Function Parameters

vir_fits ****images**

The input list of images

cpl_table ****mstds**

The list of matched standards tables (section 5.13), one for each input image

cpl_propertylist ****pl**

An array of propertylists representing the headers of the object catalogues that were derived from the input images.

int **nimages**

The number of images, matched standards catalogues and propertylists.

char ***filt**

The name of the filter for these observations.

cpl_table ***photcal**

The photometric calibration table (section 5.15)

cpl_table ***illcor**

The illumination correction table (section 5.7)

int ***status**

The input/output function status

6.18.3 Required FITS Header Information

The following information is required in the extension header of the catalogues (see the parameter **pl**)

keyword	type	description
EXPTIME	float	The exposure time in seconds
APCOR3	float	The aperture correction for aperture 3 as calculated by vircam_imcore
APCOR5	float	The aperture correction for aperture 5 as calculated by vircam_imcore
ESO QC SATURATION	float	The saturation level in counts
ESO DRS RCORE	float	The core radius used in the object detection

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The following information is required from the primary header of the images

keyword	type	description
ESO TEL AIRM START	float	The airmass at the start of the observation.

6.18.4 Output FITS Header Information

This routine calculates a zeropoint for two different apertures. It calculates these for each individual image and calculates a collective zeropoint for all the images in the list. In the table below the suffix “im” refers to results on an image by image basis and ‘all’ refers to the collective solution.

keyword	type	description
DRS ZPIM3	float	The calculated photometric zero point for the image in aperture 3
DRS ZPSIGIM3	float	The RMS of the photometric zero point for the image in aperture 3
DRS ZPIM5	float	The calculated photometric zero point for the image in aperture 5
DRS ZPSIGIM5	float	The RMS of the photometric zero point for the image in aperture 5
DRS LIMIT_MAG3	float	The 5 sigma limiting magnitude for this image in aperture 3
DRS LIMIT_MAG5	float	The 5 sigma limiting magnitude for this image in aperture 5
DRS MAGNZPTIM	int	The number of stars used in the zero point calculation in this image
DRS ZPALL3	float	The calculated photometric zero point for all images in aperture 3
DRS ZPSIGALL3	float	The RMS of the photometric zero point for all images in aperture 3
DRS ZPALL5	float	The calculated photometric zero point for all images in aperture 5
DRS ZPSIGALL5	float	The RMS of the photometric zero point for all images in aperture 5
DRS MAGNZPTALL	int	The number of stars used in the zero point calculation in all images

6.18.5 QC1 Outputs

MAGZPT
MAGZERR
MAGNZPT
LIMITING_MAG

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6.18.6 Quality Assessment

The RMS of the zeropoint is with the expected limits of the 2MASS catalogue, notwithstanding the quality of the observing conditions.

6.18.7 Fatal Error Conditions

- Photometric calibration table is incomplete
- No input images
- No rows in matched standards catalogue
- Missing header information in standards catalogue or image

6.18.8 Non-Fatal Error conditions

None

6.19 *vircam_platesol*

6.19.1 General

Name:

vircam_platesol

Purpose:

Work out a plate solution for an image given the RA, Dec, x , y values for objects on that image.

General Description:

Cartesian and equatorial coordinates are fitted to standard plate solution models of either 4 or 6 constants (4-constant model being more robust but at the cost of assuming zero shear and no scale difference. The default therefore is 6). If so desired, the difference in the predicted x,y coordinates and the true x,y coordinates can be used to adjust the tangent point first to block correct for telescope pointing error. The median difference of the equatorial coordinates between that implied from the two sets of Cartesian coordinates is used to update the tangent point. A full least-squares solution is performed and the results are written back to the given FITS WCS header structure.

Mathematical Description:

For a 6 constant model, fits are done with the input standards for the equations:

$$\xi = ax + by + c \quad (6-1)$$

$$\eta = dx + ey + f \quad (6-2)$$

to find values of a , b , c , e , d and f . For a 4-constant model the same equations are used, but with the constraint that $a = e$ and $b = d$. See section 2.9 for information on how the expected projection geometry will be incorporated.

6.19.2 Function Parameters

cpl_propertylist *plist

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The propertylist which represents the FITS header for an input image. It must have a rough FITS WCS already if the tangent point is going to be repositioned.

cpl_table ***matchedstds**

A matched standards table containing at least the following columns:

X_coordinate, Y_coordinate, xpredict, ypredict, ra, dec.

int **nconst**

The number of plate constants to be used. This can be either 6 (default) or 4.

int **shiftn**

If set, then the difference between the predicted and the true cartesian coordinates of the objects in the matched standards catalogue will be used to redefine the equatorial coordinates of the reference point of the WCS.

int ***status**

The input/output function status.

6.19.3 Required FITS Header Information

keyword	type	description
CRPIX1	double	All of the standard FITS WCS keywords that are relevant for the projection model to be used with VIRCAM (nominally ZPN). See [RD 8] for more specific information. NB: These will all be modified by this function on output.
CRPIX2	double	
CTYPE1	char	
CTYPE2	char	
CRVAL1	double	
CRVAL2	double	
CD1_1	double	
CD1_2	double	
CD2_1	double	
CD2_2	double	
PV2_i, i=1~5	double	
NAXIS1	int	The X size of the data array from which the catalogue was generated
NAXIS2	int	The Y size of the data array from which the catalogue was generated

6.19.4 Output FITS Header Information

As above, but modified by the fit done in this routine, also:

keyword	type	description
DRS STDCRMS	float	The RMS of the WCS fit.
DRS NUMBRMS	int	The number of stars used in the WCS fit
DRS WCSRAOFF	float	The equatorial coordinates of the central pixel of the image is calculated both before and after the plate solution is found. This is the difference in the RA (in arcseconds)

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DRS WCSDECOFF	float	The equatorial coordinates of the central pixel of the image is calculated both before and after the plate solution is found. This is the difference in the DEC (in arcseconds)
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6.19.5 QC1 Outputs

WCS_DCRVAL1
 WCS_DCRVAL2
 WCS_DTHETA
 WCS_SCALE
 WCS_SHEAR (6-constant model)
 WCS_RMS

6.19.6 Quality Assessment

DRS STDCRMS is within the expected internal consistency of the input astrometric data convolved with a centring error.

6.19.7 Fatal Error Conditions

- Unsupported value of **nconst**.
- Too few standards for the fit.
- Required columns don't exist in input matched standards table.

6.19.8 Non-Fatal Error conditions

None

6.20 *vircam_sky_flat_combine*

6.20.1 General

Name:

vircam_sky_flat_combine

Purpose:

Combine sky or object observations to create a mean sky flat and confidence map.

General Description:

- Process the images to linearize and remove dark current
- Combine the images with biasing and rejection.
- Normalise each detector's flat-field by the ensemble median level over all the detectors' flat-fields. The normalised level in each image is the detector gain correction.
- Create the confidence map from the mean flat field and the master bad pixel mask

Mathematical Description:

None

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6.20.2 Function Parameters

float **low**

The lower limit to define an under exposed flat field image

float **high**

The upper limit to define a saturated flat field image

6.20.3 Input Images and Required FITS header information

Input Data:

- A series of exposures of a sparse patch of sky. These can either be target images or offset sky images.
- Library mean dark frame for the given exposure and integration time.
- Linearity channel table
- Library bad pixel mask

Parameters:

6.20.4 Input Tables

None

6.20.5 Output Images

Outputs:

- Mean sky flat field for the given passband (MASTERSKYFLAT)
- Confidence map for the given passband (CONFMAP)

6.20.6 Output Tables

None

6.20.7 Other Output

None

6.20.8 QC1 Outputs

GAIN_CORRECTION

FLATVAR

6.20.9 Quality Assessment

N/A

6.20.10 Error Conditions

Fatal Error Conditions:

- Missing library master images
- Missing library master tables
- All flat images either under or over exposed

Non-fatal Error Conditions:

- Missing library bad pixel mask (No pixels flagged as bad)

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7 Data Reduction CPL Plugins

Each recipe has a direct correspondence to a CPL plugin; but the correspondence between raw data-types and recipes is not one-to-one because, in some cases, science data are used to produce calibration frames. Each plugin is documented below. Where a calibration product is created by the recipe, the value in parenthesis after the file specifies the value of the PRO CATG keyword in the output file header. The parenthesis after the input data specifications indicate whether the data are required or optional and the DO CATG keyword that must appear in the sof file.

The plugins may receive error messages from the functions that they call. If these are considered by the function to be fatal, then the plugin will exit gracefully. If the errors are considered to be just a warning the plugin may choose to proceed with caution, to get the information it needs from another source or fail gracefully. As in the previous section we do not include conditions such as segmentation violations and arithmetic exceptions in the list of fatal errors. Only error conditions that occur within the plugin, and outside of the VIRCAM functions documented in section 6 will be documented here. In addition, all error conditions which would lead to the writing of a dummy product will be documented here. All recipes will fail if they are unable to identify RAW and CALIB frames or if they cannot make sense of the DO CATG values specified in the sof file.

All of the parameters that can be changed on the command line are listed for each recipe. It is worth noting that **esorex** allows the user to change parameters in a semi-permanent way using environment variables. Full details on the names of these environment variables can be found by using the **-man-page** switch with **esorex**. Finally all recipes have a parameter that is in addition to the ones documented below. This is **ext** and it defines the FITS extension number for the input files that are to be processed by the recipe. This allows the recipe to either process a single extension or all extensions (**ext** = 0).

7.1 *vircam_reset_combine*

Name:

vircam_reset_combine

Purpose:

Combine a sequence of reset frames to form a mean frame. Compare to a library reset frame to provide information on the stability of the pedestal and reset structure

Type:

Detector calibration

Input Data:

- List of reset frames (required, RESET_IMAGE)
- Library mean reset frame (optional, MASTER_RESET)
- Channel table (optional, CHANNEL_TABLE)
- Library bad pixel map (optional, MASTER_BPM) or library confidence map (optional, MASTER_CONF)

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Parameters:

int **combtype**

Determines the type of combination that is done to form the output map. Can take the following values

1. The output pixels are medians of the input pixels
2. The output pixels are means of the input pixels

int **scaletype**

Determines how the input data are scaled or offset before they are combined. Can take the following values:

0. No scaling or biasing
1. All input frames are biased additively to bring their backgrounds to a common median level.
2. All input frames are biased multiplicatively to bring their backgrounds to a common median level.
3. All input frames are scaled to a uniform exposure time and then additively corrected to bring their backgrounds to a common median level.

int **xrej**

If set, then an extra rejection cycle will be run.

int **thresh**

The rejection threshold in numbers of background sigmas.

int **ncells**

If a difference image statistics table is being done, then this is the number of cells in which to divide each readout channel. The value must be a power of 2, up to 64

Algorithm:

- Combine the sequence of reset frames into a single mean with rejection.
- Calculate RMS of mean reset frame.
- If a library master reset frame is given, then subtract it from the mean frame created here to form a difference image. Calculate a mean and RMS of the difference image.
- If a channel map is included, then this is used to split each data channel of the difference image into cells and do a robust median and RMS estimate in each. The results of this analysis are written to a difference image statistics table.
- If a master bad pixel mask or a master confidence map is included these are used to mask out bad pixels in the above statistical analyses.

Outputs:

- New master reset frame (MASTER_RESET)
- Difference image (DIFFIMG_RESET)
- Reset difference image statistics table (DIFFIMG_STATS_RESET)

QC1 Parameters:

RESETRMS
RESETDIFF_MED
RESETDIFF_RMS

VIRCAM Functions Used:

vircam_imcombine

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Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- No reset frames in the input frameset
- Inability to save output products

Non-fatal Error Conditions:

- Missing calibDB reset frame (No comparison with master frame done and no output difference image)
- Missing or invalid channel table (No difference image statistics table made)
- Missing bad pixel map or missing confidence map (No bad pixel rejection during statistical analysis)

Conditions Leading To Dummy Products:

- Reset frame image extensions won't load
- The detector for the current image extension has been disabled
- Failure in combination routine
- Master reset frame image extension won't load or is a dummy
- Channel table FITS extension won't load, is invalid or is a dummy

7.2 *vircam_dark_combine*

Name:

vircam_dark_combine

Purpose:

Combine a series of dark frames taken with a particular integration and exposure time combination. Compare with a similarly observed master dark frame. Calculate variation in the reset anomaly structure and scale.

Type:

Detector calibration

Input Data:

- List of dark frames (required, DARK_IMAGE)
- Library mean dark frame (optional, MASTER_DARK)
- Library bad pixel mask (optional, MASTER_BPM) or library confidence map (optional, MASTER_CONF)
- Channel table (optional, CHANNEL_TABLE)

Parameters:

int **combtype**

Determines the type of combination that is done to form the output map. Can take the following values

1. The output pixels are medians of the input pixels
2. The output pixels are means of the input pixels

int **scaletype**

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Determines how the input data are scaled or offset before they are combined. Can take the following values:

0. No scaling or biasing
1. All input frames are biased additively to bring their backgrounds to a common median level.
2. All input frames are biased multiplicatively to bring their backgrounds to a common median level.
3. All input frames are scaled to a uniform exposure time and then additively corrected to bring their backgrounds to a common median level.

int **xrej**

If set, then an extra rejection cycle will be run.

int **thresh**

The rejection threshold in numbers of background sigmas.

int **ncells**

If a difference image statistics table is being done, then this is the number of cells in which to divide each readout channel. The value must be a power of 2, up to 64

Algorithm:

- Combine the sequence of dark frames with rejection.
- In conjunction with bad pixel map or confidence map, assess the number of rejected pixels with positive residuals to give an indication of the rate of cosmic ray hits and their properties.
- Work out a robust median in a region that is unaffected by reset anomaly.
- If a library master dark frame is given, then subtract it from the mean frame created here to form a difference image. Calculate a mean and RMS of the difference image.
- If a channel map is included, then this is used to split each data channel of the difference image into cells and do a robust median and RMS estimate in each. The results of this analysis are written to a difference image statistics table.
- If a master bad pixel mask or a master confidence map is included these are used to mask out bad pixels in the above statistical analyses

Outputs:

- New mean dark frame (MASTER_DARK)
- Dark frame difference image (DIFFIMG_DARK)
- Dark difference image statistics table (DIFFIMG_STATS_DARK)

QC1 Parameters:

DARKRMS
DARKDIFF_MED
DARKDIFF_RMS
PARTICLE_RATE

VIRCAM Functions Used:

vircam_imcombine

Fatal Error Conditions:

- Null input frameset

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- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- No dark frames in the input frameset
- Inability to save output products

Non-fatal Error Conditions:

- Missing calibDB dark frame (No comparison with master frame done and no output difference image)
- Missing or invalid channel table (No difference image statistics table made)
- Missing bad pixel map or missing confidence map (No bad pixel rejection during statistical analysis)

Conditions Leading To Dummy Products:

- Dark frame image extensions won't load
- The detector for the current image extension has been disabled
- Failure in combination routine
- Master dark frame image extension won't load or is a dummy
- Channel table FITS extension won't load, is invalid or is a dummy

7.3 *vircam_dark_current*

Name:

vircam_darkcurrent

Purpose:

Calculate the dark current of a detector using a series of dark exposures with varying exposure times.

Type:

Detector Calibration

Input Data:

- A series of dark exposures at a variety of different exposure times (required, DARK_IMAGE)
- Library bad pixel mask (optional, MASTER_BPM) or library confidence map (optional, MASTER_CONF)

Parameters:

float **thresh**

The threshold in units of background sigma above or below the local mean value. This defines whether a data point in the fit is bad or not.

Algorithm:

- Perform robust iterative linear fit across all exposures at each pixel position
- At each pixel position, the slope of the fit represents the dark current expressed in units of ADUs per second.
- Where the bad pixel mask is set the output value is set to zero.

Outputs:

- Dark current map (MASTER_DARK_CURRENT)

QC1 Parameters:

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DARKCURRENT

VIRCAM Functions Used:

None

Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- Not enough dark frames in the input frameset
- Missing exposure times in input headers
- Inability to save output products

Non-fatal Error Conditions:

- Missing bad pixel map or missing confidence map (No bad pixel rejection during statistical analysis)

Conditions Leading To Dummy Products:

- Dark frame image extensions won't load
- The detector for the current image extension has been disabled

7.4 *vircam_dome_flat_combine*

Name:

vircam_dome_flat_combine

Purpose:

Combine a series of dome flat images to create a mean dome flat. Compare with a similarly observed master dome flat frame.

Type:

Detector calibration

Input Data:

- List of dome flat exposures all taken with the same exposure parameters (required, DOME_FLAT)
- Master dark frame of the same exposure parameters as above (required, MASTER_DARK)
- Master mean dome flat (optional, MASTER_DOME_FLAT)
- Channel map (optional, CHANNEL_TABLE)
- Master bad pixel mask (optional, MASTER_BPM) or master confidence map (optional, MASTER_CONF)

Parameters:

float **lthr**

Any input flat with a mean value of less than this will be excluded as being underexposed.

float **hthr**

Any input flat with a mean value of more than this will be excluded as being overexposed.

int **combtype**

Determines the type of combination that is done to form the output map. Can take the following values

1. The output pixels are medians of the input pixels
2. The output pixels are means of the input pixels

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int scaletype

Determines how the input data are scaled or offset before they are combined. Can take the following values:

0. No scaling or biasing
1. All input frames are biased additively to bring their backgrounds to a common median level.
2. All input frames are biased multiplicatively to bring their backgrounds to a common median level.
3. All input frames are scaled to a uniform exposure time and then additively corrected to bring their backgrounds to a common median level.

int xrej

If set, then an extra rejection cycle will be run.

int thresh

The rejection threshold in numbers of background sigmas.

int ncells

If a ratio image statistics table is being done, then this is the number of cells in which to divide each readout channel. The value must be a power of 2, up to 64

Algorithm:

- Remove any images that are saturated or underexposed.
- Process remaining images to linearise and remove dark current.
- Combine the dome flat exposures with rejection.
- If a library master dome flat frame is given, then divide the mean frame created here into the master to form a ratio image. Calculate a mean and RMS of the ratio image.
- If a channel map is included, then this is used to split each data channel of the ratio image into cells and do a robust median and RMS estimate in each. The results of this analysis are written to a ratio image statistics table.
- If a master bad pixel mask or a master confidence map is included these are used to mask out bad pixels in the above statistical analyses

Outputs:

- New master dome flat (MASTER_DOME_FLAT)
- Ratio image (RATIOIMG_DOME_FLAT)
- Ratio image statistics table (RATIOIMG_DOME_FLAT_STATS)

QC1 Parameters:

FLATRMS

FLATRATIO_MED

FLATRATIO_RMS

VIRCAM Functions Used:

vircam_imcombine, vircam_darkcor, vircam_lincor

Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- No dome flat frames in the input frameset

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- No master dark frame in input frameset
- Inability to save output products

Non-fatal Error Conditions:

- Missing calibDB dome frame (No comparison with master frame done and no output ratio image)
- Missing or invalid channel table (No ratio image statistics table made)
- Missing bad pixel map or missing confidence map (No bad pixel rejection during statistical analysis and no linearisation done)

Conditions Leading To Dummy Products:

- Dome frame image extensions won't load
- The detector for the current image extension has been disabled
- All the dark corrected images are either below the under-exposure threshold or above the over-exposure threshold.
- Master dark frame image extension won't load or is a dummy
- Failure in combination routine
- Channel table FITS extension won't load, is invalid or is a dummy

7.5 *vircam_detector_noise*

Name:

vircam_detector_noise

Purpose:

Measure the detector readout noise and gain

Type:

Detector calibration

Input Data

- Two dome flat frames taken with the same exposure parameters (required, DOME_FLAT)
- Two dark frames taken with the same exposure parameters as the dome flats (required, DARK_IMAGE)
- A master bad pixel mask (optional, MASTER_BPM) or master confidence map (MASTER_CONF)

Parameters:

float **thresh**

The threshold in units of background sigma above or below the local mean value. This is used during the statistical analyses of the input images and difference images.

Algorithm:

- Form difference images of the two dome flats and the two dark frames
- Do statistics as outlined in section 2.4 to give an estimate of read noise and gain

Outputs:

- Read noise and gain estimates for each extension. These are written to a paf file.
- Read noise and gain estimates for each extension written to a detector noise table (READGAIN_TABLE)

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QC1 Parameters:

READNOISE

GAIN

VIRCAM Functions Used:

None

Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- Insufficient dark or flat exposures
- Inability to save output products

Non-fatal Error Conditions:

- Missing bad pixel map or missing confidence map (No bad pixel rejection during statistical analysis and no linearisation done) No stats are calculated.

Conditions Leading To Dummy Products:

- The image extensions won't load
- Unphysical statistical result
- The detector for the current image extension is flagged dead.

7.6 *vircam_linearity_analyse*

Name:

vircam_linearity_analyse

Purpose:

Create detector channel linearity curves and bad-pixel maps

Type:

Detector calibration

Input Data:

- A series of dome flat exposures taken under constant illumination with varying integration times (required, DOME_FLAT).
- Channel map (required, CHANNEL_TABLE)
- A list of raw dark frames containing a series of dark exposures with the same exposure parameters for each of the input dome flat exposures (required, DARK_IMAGE)

Parameters:

int **nord**

The order of the polynomial to be fit to the linearity curve of each channel

float **lthr**

The lower threshold in the ratio maps to define a pixel as bad. Units are in background sigma of the ratio map.

float **hthr**

The upper threshold in the ratio maps to define a pixel as bad. Units are in background sigma of the ratio map

float **overexp**

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The maximum number of ADUs a dome flat image may have on average before it is considered to be over-exposed.

Algorithm:

- Combine all sets of raw dark images into mean dark images
- Process each flat exposure by removing the reset anomaly with the appropriate dark frame
- Combine the dome series with rejection into a normalised mean flat field
- Divide the series by the mean frame
- Find pixels in the ratio maps whose values are over or under the input threshold value and flag them as bad
- Compute the number of bad pixels in this new bad pixel mask.
- Combine timing information from channel map and known read and reset times to derive the k factors needed as indicated in section 2.2.2.
- Solve for coefficients and store them in a new channel table.

Outputs:

- Output channel table with new linearity information (CHANTAB)
- Output bad pixel mask (MASTER_BPM)

QC1 Parameters:

LINEARITY
LINFITQUAL
BAD_PIXEL_STAT

VIRCAM Functions Used:

vircam_darkcor, vircam_genlincur

Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- No dark or dome flat frames in input frameset
- No channel table in input frameset
- Inability to save output products

Non-fatal Error Conditions:

- Not enough dome flats in the series for the requested order of fit. Order is adjusted downwards.

Conditions Leading To Dummy Products:

- The dark/dome image extensions won't load
- Channel table fits extension won't load, won't verify or is flagged as a dummy.
- The detector for the current image extension is flagged dead.
- vircam_genlincur failed

7.7 vircam_twilight_flat_combine

Name:

vircam_twilight_flat_combine

Purpose:

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Combine a series of twilight flat images to create a mean twilight flat and initial confidence map. Compare with a similarly observed master twilight flat frame.

Type:

Detector calibration

Input Data:

- List of twilight flat exposures all taken with the same exposure parameters (required, TWILIGHT_FLAT)
- Master dark frame of the same exposure parameters as above (required, MASTER_DARK)
- Master mean twilight flat (optional, MASTER_TWILIGHT_FLAT)
- Channel map (optional, CHANNEL_TABLE)
- Master bad pixel mask (optional, MASTER_BPM) or master confidence map (optional, MASTER_CONF)

Parameters:

float **lthr**

Any input flat with a mean value of less than this will be excluded as being underexposed.

float **hthr**

Any input flat with a mean value of more than this will be excluded as being overexposed.

int **combtype**

Determines the type of combination that is done to form the output map. Can take the following values

1. The output pixels are medians of the input pixels
2. The output pixels are means of the input pixels

int **scaletype**

Determines how the input data are scaled or offset before they are combined. Can take the following values:

0. No scaling or biasing
1. All input frames are biased additively to bring their backgrounds to a common median level.
2. All input frames are biased multiplicatively to bring their backgrounds to a common median level.
3. All input frames are scaled to a uniform exposure time and then additively corrected to bring their backgrounds to a common median level.

int **xrej**

If set, then an extra rejection cycle will be run.

int **thresh**

The rejection threshold in numbers of background sigmas.

int **ncells**

If a ratio image statistics table is being done, then this is the number of cells in which to divide each readout channel. The value must be a power of 2, up to 64

Algorithm:

- Remove any images that are saturated or underexposed.

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- Process remaining images to linearise and remove dark current.
- Combine the twilight flat exposures with rejection. Normalise by its median.
- If a library master twilight flat frame is given, then divide the mean frame created here into the master to form a ratio image. Calculate a mean and RMS of the ratio image.
- If a channel map is included, then this is used to split each data channel of the ratio image into cells and do a robust median and RMS estimate in each. The results of this analysis are written to a ratio image statistics table.
- If a master bad pixel mask or a master confidence map is included these are used to mask out bad pixels in the above statistical analyses
- Use the mean flat and bad pixel map to create an initial confidence map.

Outputs:

- New master twilight flat (MASTER_TWILIGHT_FLAT)
- Ratio image (RATIOIMG_TWILIGHT_FLAT)
- Ratio image statistics table (RATIOIMG_TWILIGHT_FLAT_STATS)
- New master confidence map (MASTER_CONF)

QC1 Parameters:

FLATRMS
FLATRATIO_MED
FLATRATIO_RMS

VIRCAM Functions Used:

vircam_imcombine, vircam_mkconf, vircam_darkcor, vircam_lincor

Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- No twilight flat frames in input frameset
- No master dark frame in input frameset
- Inability to save output products

Non-fatal Error Conditions:

- No master twilight flat. No ratio image formed
- No master bad pixel map or confidence map. All pixels considered to be good.
- No channel table in input frameset. No ratio image stats table or linearisation will be done.

Conditions Leading To Dummy Products:

- The twilight frame image extensions won't load
- The detector for the current image extension is flagged dead.
- All the dark corrected images are either above the over exposure threshold or just below the under exposure threshold.
- Master dark extension won't load or is flagged as a dummy
- vircam_imcombine failed
- Master twilight flat image failed to load or flagged as a dummy
- Channel table fits extension failed to load or flagged as a dummy

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7.8 *vircam_mesostep_analyse*

Name:

vircam_mesostep_analyse

Purpose:

Create a map of illumination corrections using a mesostep sequence of a standard stars

Type:

Detector calibration

Input Data:

- A series of exposures of a sparse secondary standard field that has been offset in a regular raster
- A master dark frame for the given integration time
- A master flat field for the given passband
- A master confidence map for the given passband
- Linearity channel table
- Persistence mask
- Crosstalk table
- Photometric standard catalogue

Parameters:

float **thresh**

Detection threshold for object extraction.

Algorithm:

- Process the observations by linearising, dark correction and flat fielding
- Compute the zero-point of standard stars on a grid of each of a series of meso-stepped exposures.
- Work out the residual zero-point at each position on the detector relative to the zero-point at the centre.
- Write the illumination correction table.

Outputs:

- Illumination correction table (see 5.7) (ILLCORTAB)

QC1 Parameters:

ILLUMCOR_RMS

VIRCAM Functions Used:

vircam_darkcor, vircam_lincor, vircam_flatcor, vircam_defringe,
vircam_persist, vircam_crosstalk, vircam_imcore, vircam_getstds,
vircam_platesol, vircam_matchstds

Fatal Error Conditions:

- Missing master calibration frames
- Missing master calibration tables
- Missing photometric standard catalogue

Non-fatal Error Conditions:

None

7.9 *vircam_persistence_analyse*

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Name:

vircam_persistence_analyse

Purpose:

Analyse an image of bright stars and subsequent dark exposures to compute the persistence decay rate

Type:

Detector calibration

Input Data:

- An observation of bright stars taken close to saturation
- A master dark frame for the given integration time
- A master flat field for the given passband
- A master confidence map for the given passband
- Linearity channel table
- A series of dark exposures taken at regular time intervals afterwards

Parameters:

float **thresh**

Detection threshold for object extraction

Algorithm:

- Process the observation by linearising, dark correction and flat fielding
- Compute the flux and position of bright stars on an image.
- Look on subsequent dark exposures at the same location and compute the flux.
- Fit the flux vs. Δt curve to an exponential to work out the characteristic decay constant, τ_0 and the flux at zero time.

Outputs:

- Persistence decay time constant
- Persistence fraction at zero time

QC1 Parameters:

PERSIST_DECAY

PERSIST_ZERO

VIRCAM Functions Used:

vircam_darkcor, vircam_lincor, vircam_flatcor, vircam_defringe,
vircam_imcore

Fatal Error Conditions:

- Missing master calibration frames
- Missing master calibration tables
- No dark frames available after star observation.

Non-fatal Error Conditions:

None

7.10 *vircam_crosstalk_analyse*

Name:

vircam_crosstalk_analyse

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Purpose:

Analyse a series of images to work out the crosstalk matrix for all detector sections

Type:

Detector calibration

Input Data:

- A series of exposures of a bright star. The star should be centred in each of the instrument's data channels.
- Master flat and confidence map for the given passband
- Master dark frame for the given exposure time
- Channel table

Parameters:

float **thresh**

Detection threshold for object extraction

Algorithm:

- Locate objects on each exposure.
- Use channel table to predict location of crosstalk images of the bright star and locate the crosstalk image in the object catalogue.
- Create crosstalk matrix from the ratio of the fluxes for a given channel combination.

Outputs:

- Crosstalk matrix as described in 5.6 (XTALK)

QC1 Parameters:

CROSS_TALK

VIRCAM Functions Used:

vircam_imcore

Fatal Error Conditions:

- Missing channel table or confidence map

Non-fatal Error Conditions:

None

7.11 *vircam_jitter_microstep_process*

Name:

vircam_jitter_microstep_process

Purpose:

Process a sequence of target data that may have been both jittered and microstepped. If sufficient qualifying data were taken, combine into a mean sky map.

Type:

Science

Input Data:

- A jittered and/or microstepped sequence of exposures of a target region.
- Library mean dark frame for the given exposure and integration time.
- Library mean flat field frame for the given passband

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- Library confidence map for the given passband *or* a library bad pixel mask
- Library fringe frame
- Linearity channel table
- Readnoise/gain file
- Photometric calibration table
- Crosstalk matrix
- Persistence mask
- Astrometric standard data (through VIRCAM interface to 2MASS)
- Photometric standard data (through VIRCAM interface to 2MASS)

Parameters:

int **ipix**

The minimum size of an object in pixels in order for that object not to be considered spurious.

float **thr**

The detection threshold measured in units of the mean background noise

int **icrowd**

If set, then the function will attempt to de-blend merged objects

float **rcore**

The core radius in pixels for the default profile fit.

int **nb**

The size in pixels of the grid squares used for background estimation

char **catpath**

The full path to the 2MASS catalogue FITS files

int **savecat**

If set, then the catalogue generated during the astrometric and photometric calibration will be saved.

Algorithm:

- Remove crosstalk images
- Process the images by linearising and removing dark current and flat fielding
- De-fringe
- Remove persistent images
- Work out microstep offsets using header information
- Combine the images into super-frames by interleaving using the microstep offsets
- Work out jitter offsets by cross-correlating stellar object positions on super-frame images
- Combine the super-frame images with offsets into a single stacked image
- Generate a catalogue of objects on the stacked image and do a morphological classification
- Fit a WCS using astrometric standards that appear in the stacked image catalogue. Update the FITS headers of the stacked image as well as those of the super-frames and the single exposure images.
- Calculate photometric zero point using instrumental magnitudes, magnitudes of photometric standards, and illumination corrections.

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- Apply illumination correction to catalogue

Outputs:

- Single exposure images that corrected for linearity, dark current, flat field, sky, image persistence and crosstalk. A full WCS will appear in the header (SIMPLE_IMAGE)
- Interleaved super-frame images from the above if microstepping has been done as part of the observing sequence. (INTERLEAVED_IMAGE)
- Stacked jitter images from the super-frames. Full WCS and photometric zero point will appear in the FITS header. (JITTERED_IMAGE)
- Associated confidence maps for each of the above output images. (CONFIDENCE_MAP)
- Object catalogue in the form of a FITS table if the **savecat** parameter has been set (OBJECT_CATALOGUE)

QC1 Parameters:

FRINGE_RATIO
 SATURATION
 MEAN_SKY
 SKY_NOISE
 SKY_RESET_ANOMALY
 NOISE_OBJ
 IMAGE_SIZE
 APERTURE_CORR
 ELLIPTICITY
 MAGZPT
 MAGZERR
 MAGNZPT
 LIMITING_MAG
 WCS_DCRVAL1
 WCS_DCRVAL2
 WCS_DTHETA
 WCS_SCALE
 WCS_SHEAR
 WCS_RMS

VIRCAM Functions Used:

vircam_darkcor, vircam_lincor, vircam_flatcor, vircam_defringe,
 vircam_persist, vircam_matchxy, vircam_crosstalk, vircam_imcore,
 vircam_getstds, vircam_platesol, vircam_matchstds, vircam_sky_flat,
 vircam_imdither, vircam_photcal

Fatal Error Conditions:

- Null input frameset
- Input frameset headers incorrect meaning that RAW and CALIB frames cannot be distinguished
- No science frames in input frameset
- Missing master calibration frames or unreadable extensions in input frameset
- Inability to save output products

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Non-fatal Error Conditions:

None

Conditions Leading To Dummy Products:

- Missing calibration images, calibration images that won't load or are flagged as dummy.
- A detector has been signaled dead.
- Processing routines fail.

7.12 *vircam_standard_process*

Name:

vircam_standard_process

Purpose:

Process sequence of photometric standard data that may have been both jittered and microstepped; if sufficient standards are present, also compute an illumination map.

Type:

Science

Input Data:

- A jittered and microstepped sequence of exposures of a standard star region.
- Library mean dark frame for the given exposure and integration time.
- Library mean flat field frame for the given passband
- Library confidence map for the given passband
- Library fringe frame
- Linearity channel table
- Crosstalk matrix
- Persistence mask
- Astrometric standard data
- Photometric standard data

Parameters:

float **persist**

Persistence time constant for the detector

float **thresh**

Detection threshold in units of background sigma for object extraction

Algorithm:

- Process the images by linearising and removing dark current and flat fielding
- De-fringe
- Remove persistent images
- Remove crosstalk images
- Work out microstep offsets using header information
- Combine the images into super-frames by interleaving using the microstep offsets

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- Work out jitter offsets by cross-correlating object positions on super-frame images
- Combine the super-frame images with offsets into a single stacked image
- Generate a catalogue of objects on the stacked image and do a morphological classification
- Fit a WCS using astrometric standards that appear in the stacked image catalogue. Update the FITS headers of the stacked image as well as those of the super-frames and the single exposure images.
- Calculate photometric zero point using instrumental magnitudes and magnitudes of photometric standards.
- Apply illumination correction to catalogue

Outputs:

- Single exposure images that corrected for linearity, dark current, flat field, sky, image persistence and crosstalk. A full WCS will appear in the header
- Interleaved super-frame images from the above.
- Stacked jitter images from the super-frames. Full WCS and photometric zero point will appear in the FITS header.
- Associated confidence maps for each output image (CONFMAP)
- Object catalogue in the form of a FITS table (OBJCAT)

QC1 Parameters:

WCS_DCRVAL1
 WCS_DCRVAL2
 WCS_DTHETA
 WCS_DSCALE
 WCS_SHEAR
 WCS_RMS
 SATURATION
 MEAN_SKY
 SKY_NOISE
 SKY_RESET_ANOMALY
 FRINGE_RATIO
 NOISE_OBJ
 IMAGE_SIZE
 APERTURE_CORR
 ELLIPTICITY
 ZPT_STDS
 LIMITING_MAG
 ILLUMCOR_RMST

VIRCAM Functions Used:

vircam_darkcor, vircam_lincor, vircam_flatcor, vircam_defringe,
 vircam_persist, vircam_matchxy, vircam_crosstalk, vircam_imcore,
 vircam_getstds, vircam_platesol, vircam_matchstds, vircam_imstack,
 vircam_illum

Fatal Error Conditions:

- Missing master calibration frames
- Missing master calibration tables
- Object catalogues don't match – unable to work out jitter offsets

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- Microstep non-integral offsets deviate too much from 0.5 pixel

Non-fatal Error Conditions:

- Failure to match object catalogue entries to astrometric standards. (Recipe will proceed with WCS as defined in the raw telescope header)
 - Failure to match object catalogue entries to photometric standards. (Recipe will proceed to the end without a photometric zero point.)
-

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8 Validation tests

Validation procedures will be developed for each function defined in chapter 6 and every recipe defined in chapter 7. In the case of the latter data described later in this chapter will be used to validate results. In the case of the former, recipe plugins have been written to test each function individually. What appears in this chapter is the set of test recipes as they currently stand, rather than the complete planned set. As these recipes may prove useful in themselves, these will be installed in the same tree as the reduction recipes. A very brief discussion of each test recipe is included in the next sections. As in previous recipe descriptions, each recipe has a parameter **ext** which is used to tell the recipe which of the FITS extensions you want to process. This parameter has been left of the parameter list for each recipe for the sake of brevity. The final section describes the test data that will be provided.

8.1 *vircam_darkcor*

Name:

vircam_darkcor

Purpose:

Test the function **vircam_darkcor** (section 6.2) by subtracting a dark frame from an input science frame.

Input Data:

- A raw science frame (required, SCIENCE_IMAGE)
- Master dark frame of the same exposure parameters as above (required, MASTER_DARK)

Parameters:

float **darksel**

The factor by which to scale the dark frame before subtracting.

8.2 *vircam_flatcor*

Name:

vircam_flatcor

Purpose:

Test the function **vircam_flatcor** (section 6.4) by dividing a flat field image into an input science frame.

Input Data:

- A science frame (required, SCIENCE_IMAGE). For best results, this should have been previously dark corrected.
- Master twilight flat frame (required, MASTER_TWILIGHT_FLAT)

Parameters:

None

8.3 *vircam_getstds*

Name:

vircam_getstds

Purpose:

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Test the function **vircam_getstds** (section 6.6) by extracting standard stars from the 2MASS catalogue that should appear on an input image.

Input Data:

- A science frame (required, SCIENCE_IMAGE).

Parameters:

char ***catpath**

The full path to the 2MASS PSC FITS tables.

8.4 *vircam_imcombine*

Name:

vircam_imcombine

Purpose:

Test the function **vircam_imcombine** (section 6.8) by combining a list of input images into a single output image.

Input Data:

- A list of science frames (required, SCIENCE_IMAGE).

Parameters:

int **comb**

Determines the type of combination that is done to form the output map. Can take the following values

1. The output pixels are medians of the input pixels
2. The output pixels are means of the input pixels

int **scale**

Determines how the input data are scaled or offset before they are combined. Can take the following values:

0. No scaling or biasing
1. All input frames are biased additively to bring their backgrounds to a common median level.
2. All input frames are biased multiplicatively to bring their backgrounds to a common median level.
3. All input frames are scaled to a uniform exposure time and then additively corrected to bring their backgrounds to a common median level.

int **xrej**

If set, then an extra rejection cycle will be run.

int **thr**

The rejection threshold in numbers of background sigmas.

8.5 *vircam_imcore*

Name:

vircam_imcore

Purpose:

Test the function **vircam_imcore** (section 6.9) by extracting objects from a science frame and writing them to a FITS table.

Input Data:

- A science frame (required, SCIENCE_IMAGE).

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- An appropriate confidence map (required, CONFIDENCE_MAP or MASTER_CONF)

Parameters:

int **ipix**

The minimum size of an object in pixels in order for that object not to be considered spurious.

float **thr**

The detection threshold measured in units of the mean background noise

int **icrowd**

If set, then the function will attempt to de-blend merged objects

float **rcore**

The core radius in pixels for the default profile fit.

int **nb**

The size in pixels of the grid squares used for background estimation.

int **cattype**

The output catalogue type. This can be:

1. The 32 column INT Wide Field Camera format
2. The 80 column WFCAM format
3. A very minimal format which is just fine if all you want is positions
4. An object mask

NB: option 2 corresponds to the catalogues described in section 5.12.

8.6 *vircam_imdither*

Name:

vircam_imdither

Purpose:

Test the function **vircam_imdither** (section 6.10) by dithering a list of input files and their associated confidence maps into a single output map

Input Data:

- A list of science frames (required, SCIENCE_IMAGE).
- A list of confidence maps (required, CONFIDENCE_MAP or MASTER_CONF)

Parameters:

None

8.7 *vircam_interleave*

Name:

vircam_interleave

Purpose:

Test the function **vircam_interleave** (section 6.12) by interleaving a set of input science frames

Input Data:

- A set of science frame (required, SCIENCE_IMAGE)
- An appropriate set of confidence maps (required, MASTER_CONF)

Parameters:

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None

8.8 *vircam_lincor*

Name:

vircam_lincor

Purpose:

Test the function **vircam_lincor** (section 6.13) by linearising a science frame.

Input Data:

- A science frame (required, SCIENCE_IMAGE). For best results, this should have been previously dark corrected and flat field.
- A channel table (required, CHANNEL_TABLE)

Parameters:

None

8.9 *vircam_matchstds*

Name:

vircam_matchstds

Purpose:

Test the function **vircam_matchstds** (section 6.14) by matching an object catalogue with a standards table.

Input Data:

- An object catalogue (required, OBJECT_CATALOGUE).
- An extracted standards catalogue (required, STANDARDS_TABLE)

Parameters:

None

8.10 *vircam_matchxy*

Name:

vircam_matchxy

Purpose:

Test the function **vircam_matchxy** (section 6.15) by matching two object catalogues and working out the Cartesian positional difference.

Input Data:

- Two object catalogues (required, OBJECT_CATALOGUE).

Parameters:

None

8.11 *vircam_mkconf*

Name:

vircam_mkconf

Purpose:

Test the function **vircam_mkconf** (section 6.16) by creating a confidence map from a master flat and a master bad pixel mask.

Input Data:

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- A master flat field (required, MASTER_TWILIGHT_FLAT).
- A master bad pixel mask or master confidence map (required, MASTER_BPM or MASTER_CONF)

Parameters:

None

8.12 *vircam_platesol*

Name:

vircam_platesol

Purpose:

Test the function **vircam_platesol** (section 6.19) by fitting a plate constant model to a matched standards catalogue.

Input Data:

- A science frame with an initial WCS (required, SCIENCE_IMAGE)
- A matched standards table of objects on the science frame (required, MATCHED_STANDARDS_TABLE).

Parameters:

int **nconst**

The number of plate constants to fit. This must be either 4 or 6.

int **shiftan**

If this is set, then the position of the tangent point will be moved to take poor telescope pointing into account.

8.13 *Validation Test Data*

Test data will be provided for all of these validation procedures. In some cases this will consist of laboratory test data using the real VISTA focal plane detectors. In others, data from other instruments, namely WFCAM will be made to look like VISTA data. Where nothing else is available, simulated data will be generated and wrapped to look like VISTA data files. In the table below we give a list of the test data files that will be available for use in the validation procedures. Each FITS file will contain data for all sixteen detectors. The ‘rich_field’ files will consist of observations of a medium rich stellar field, which can be used for many of the validation tests we require. The series will be a 5 point jitter series, where each jitter point is also a 4 point microstep sequence.

Included in the test suite will be files that can be used in comparison with output from the test procedures. These will be monitored to ensure that:

- the image data arrays and table columns all contain exactly the same data
- a selection of relevant FITS header keywords have been created and are consistent with the test output files.
- output QC1 parameters match the known values from the test suite.

A selection of SOF files will also be included to insure that the tests are always done using the same files. Below is a list of test data to be expected in the test data suite.

datafile	comment
----------	---------

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bpm.fits	A bad pixel mask
chantab.fits	The channel table (5.2)
dark_after_richXX.fits	A series of dark frames taken after the last rich_fieldXX frame.
darkXX.fits	A list of dark frames with the same exposure time as rich_fieldXX
darkXX_exp.fits	A series of dark frames with exposure times the same as those for domeflatXX_raw.fits
domeflatXX.fits	A series of dome flat exposures done with a series of exposure times with constant illumination. These have been dark corrected.
domeflatXX_raw.fits	A series of dome flat exposures done with a series of exposure times with constant illumination. These have not been dark corrected.
fringe.fits	A mean fringe frame
illumtab.fits	An illumination correction table for rich_field01.fits
match_stds.fits	Matched standards table of objtab01.fits matched to stds_2mass.fits
meanconf.fits	A confidence map arising from twiflatXX.fits.
meandark.fits	A mean dark frame formed from the list darkXX.fits
meandomeflat.fits	A mean dome flat formed from domeflatXX.fits
meanreset.fits	A mean reset frame formed from the list resetXX.fits
meantwiflat.fits	A mean twilight flat field frame formed from twiflatXX.fits
objtab01.fits objtab02.fits	The object tables for rich_field01_sig.fits and rich_field02_sig.fits for a given set of extraction parameters
persistmask.fits	A persistence mask for the rich_fieldXX series
resetXX.fits	A list of reset frames
rich_comb.fits	The rich_field_sig series combined with no coordinate offsets
rich_comb_conf.fits	The confidence map formed from combining rich_field_sig files with no coordinate offsets.
rich_field01_dark.fits	The first rich_field file – dark corrected using meandark.fits
rich_field01_flat.fits	The first rich_field file – flat fielded using meantwiflat.fits
rich_field01_lin.fits	The first rich field file – linearised using lchantab.fits
rich_field01_sigf.fits	The first rich field file with linearity, dark, and flat corrections applied
rich_fieldXX.fits	A raw microstep and jitter sequence of a rich photometric standard field
rich_fieldXX_meso.fits	A raw meso-stepped series of the rich_field region.
rich_fieldXX_sig.fits	The rich field series with linearity, dark, flat and fringe corrections applied
rich_stack.fits	A stack of rich_fieldXX_sig.fits series.
rich_stack_conf.fits	A confidence map formed from stacking the rich_fieldXX_sig.fits series
rich_super.fits	A super frame of the first microstep sequence in the rich_fieldXX_sig series.

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rich_super_conf.fits	The confidence map formed from interleaving the first microstep sequence in the rich_fieldXX_sig series.
stds_2mass.fits	A list of 2mass standards that appear on rich_field01.fits
twiflatXX.fits	A list of twilight flat field frames in one colour. These have been linearity and dark corrected
twiflatXX_raw.fits	A list of raw twilight flat field frames in one colour
xtalk.fits	A full crosstalk matrix

Table 8-1 Description of test data files

In the tables below we give a list of each of the VIRCAM functions and plugins from chapters 6 and 7 and the input files required from the test data suite. The files in the column 'output test files' will be used in to test consistency of result with the output of each function or plugin.

function	input test files	output test files
vircam_crosstalk	rich_field01.fits	xtalk.fits
vircam_darkcor	rich_field01.fits meandark.fits	rich_field01_dark.fits
vircam_defringe	rich_field01_sigf.fits fringe.fits	rich_field01_sig.fits
vircam_flatcor	rich_field01.fits meantwiflat.fits	rich_field01_flat.fits
vircam_genlincor	domeflatXX.fits chantab.fits	lchantab.fits
vircam_getstds	rich_field01.fits	stds_2mass.fits
vircam_illum	rich_field01_sig.fits	illumtab.fits
vircam_imcombine	rich_fieldXX_sig.fits meanconf.fits	rich_comb.fits rich_comb_conf.fits
vircam_imcore	rich_field01_sig.fits meanconf.fits	objtab01.fits
vircam_imstack	rich_fieldXX_sig.fits	rich_stack.fits rich_stack_conf.fits
vircam_interleave	rich_fieldXX_sig.fits	rich_super.fits rich_super_conf.fits
vircam_lincor	rich_field01.fits lchantab.fits	rich_field01_lin.fits
vircam_matchstds	objtab01.fits stds_2mass.fits	match_std.fits
vircam_matchxy	objtab01.fits objtab02.fits	
vircam_mkconf	twiflatXX.fits	meanconf.fits
vircam_persist	rich_fieldXX_sig.fits dark_after_richXX.fits	
vircam_photcal	rich_stack.fits stds_2mass.fits	
vircam_platesol	rich_field01_sig.fits match_std.fits	

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Table 8-2 Files to be used to test each vircam function

plugin	input test files	output test files
vircam_reset_combine	resetXX.fits	meanreset.fits
vircam_dark_combine	darkXX.fits	meandark.fits
vircam_dome_flat_combine	domeflatXX.fits	meandomeflat.fits
vircam_detector_noise	domeflatXX.fits darkXX.fits	
vircam_linearity_analyse	domeflatXX_raw.fits darkXX_exp.fits chantab.fits	lchantab.fits bpm.fits
vircam_twilight_combine	twiflatXX_raw.fits meandark.fits lchantab.fits bpm.fits	meantwiflat.fits meanconf.fits
vircam_mesostep_analyse	rich_fieldXX_meso.fits meandark.fits meantwiflat.fits lchantab.fits fringe.fits	illumtab.fits
vircam_persistence_analyse	rich_fieldXX.fits meandark.fits meantwiflat.fits lchantab.fits meanconf.fits	
vircam_crosstalk_analyse	rich_fieldXX.fits meandark.fits meantwiflat.fits lchantab.fits meanconf.fits	xtalk.fits
vircam_sky_flat_combine	rich_fieldXX.fits meandark.fits meantwiflat.fits fringe.fits lchantab.fits meanconf.fits bpm.fits	rich_comb.fits rich_comb_conf.fits
vircam_jitter_microstep_process	rich_fieldXX.fits meandark.fits meantwiflat.fits fringe.fits lchantab.fits meanconf.fits xtalk.fits persistmask.fits	rich_stack.fits rich_stack_conf.fits

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vircam_standard_process	rich_fieldXX.fits meandark.fits meantwiflat.fits fringe.fits lchantab.fits meanconf.fits xtalk.fits persistmask.fits	rich_stack.fits rich_stack_conf.fits illumtab.fits
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Table 8-3 Files to use in testing each vircam plugin

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9 Development Plan

Following [AD1] the DRL development is summarised in Table 9-1. In keeping with the fact that VISTA will (initially) be a single-instrument telescope, and so will essentially have a single commissioning period (no COM2), milestone 5 is omitted in order to keep the numbering consistent with general VLT planning.

Act ID	Milestone	Timeline	Deliv. ID	Deliverables
M-02	FDR	-4w	DR2	This document
	PAE	-6m	-	Data Reduction Library prototype with some basic dome-flat capability; will test instrument simulation data-interface compatibility.
M-03	PAE	-4w	DR3	Data Reduction Library v0.1 Including: all basic planned functionality such that laboratory data from the instrument may be pipelined.
M-04	COM1	-4w	DR4	Data Reduction Library v0.5 Including: bug fixes found at PAE plus any new (previously unplanned) functionality required as a result of PAE detector characterisation.
M-06	PAC	-4w	DR6	Data Reduction Library v1.0 Including: more bug fixes and any refinements and additions to analysis required as a result of experience gained with real commissioning data.
M-09	SO1	+8w	DR11	Data Reduction Library v1.y Including: more of above, and feedback from early science users.
		+8w	DR11	Final version this document

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10 Appendix: QC1 Parameters

```

*****
# E.S.O. VISTA project
#
#  "@(#) $Id: dicVIRCAM_QC.txt,v 0.8 2004/07/29 12:05:28 vltscm Exp $"
#
# VIRCAM_QC dictionary
#
# who          when          what
#-----
# pbunclark    2004-10-05      Original
# pbunclark    2004-11-19      Many clarifications
#                                     DID parameter added
#                                     POINTING -> WCS set
#                                     SEEING -> IMAGE SIZE
# mji          2004-11-22      Updated comments and descriptions
#                                     and rationalized order
# jrl          2004-12-08      add FRINGE_RMS, ILLUMCOR_RMS
# jrl          2004-12-13      change FRINGE_RMS to FRINGE_RATIO,
#                                     add LINFITQUAL
# psb          2005-12-13      RESETVAR changed to RESETRMS, improved
#                                     comments on DARKRMS, PARTICLE_RATE & RESETRMS
# jrl          2005-12-19      add RESETDIFF_RMS DARKDIFF_RMS
# jpe          2006-02-03      improve couple of descriptions.
# jrl          2006-03-24      add RESETDIFF_MED, DARKDIFF_MED,
#                                     FLATRATIO_MED, FLATRATIO_RMS
# jrl          2006-06-05      add MAGZPT, MAGZERR and MAGNZPT
# psb          2006-06-06      add QC.RESET_MED & QC.DARKMED
#
# NAME
# ESO-DFS-DIC.VIRCAM_QC - Data Interface Dictionary for VIRCAM Quality
# control (level 1) parameters.
#-----
Dictionary Name:  ESO-VLT-DIC.VIRCAM_QC
Scope:            ESO VISTA VIRCAM
Source:           ESO VLT
Version Control:  @(#) $Id: 0.8 $
Revision:         $Revision: 0.9 $
Date:             2006-06-06
Status:           Development
Description:       VIRCAM Quality-Control

Parameter Name:   QC DID
Class:            header
Context:          process
Type:             string
Value Format:      %30s
Unit:
Comment Format:    Data dictionary for VIRCAM QC.
Description:       Name/version of ESO DID to which QC keywords comply.

Parameter Name:   QC DARKCURRENT
Class:            header
Context:          process
Type:             double
Value Format:      %f
Unit:             adu/sec
Comment Format:    average dark current on frame [adu/sec].
Description:       measured using the median of the pixel values,
                  can later be compared similar darks for trends

Parameter Name:   QC DARKRMS
Class:            header
Context:          process
Type:             double
Value Format:      %f
Unit:             adu

```

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Comment Format: RMS noise of combined dark frame [adu].
Description: RMS is defined here as the Gaussian equivalent MAD ie.
1.48*median-of-absolute-deviation from median
The RMS can later be compared with library values
for darks of the same integration and exposure times.

Parameter Name: QC RESETDIFF_RMS
Class: header
Context: process
Type: double
Value Format: %f
Unit: adu
Comment Format: [adu] RMS new-library reset frame
Description: measure the RMS of the difference of a new
mean reset frame and a library reset frame.

Parameter Name: QC DARKDIFF_RMS
Class: header
Context: process
Type: double
Value Format: %f
Unit: adu
Comment Format: [adu] RMS new-library dark frame
Description: measure the RMS of the difference of a new
mean dark frame and a library dark frame.

Parameter Name: QC PARTICLE_RATE
Class: header
Context: process
Type: double
Value Format: %f
Unit: count/s/detector
Comment Format: cosmic ray/spurion rate [count/s/detector].
Description: average no. of pixels rejected during
combination of dark frames, used to give
an estimate of the rate of cosmic
ray hits for each detector. This can
later be compared with previous estimates
and monitored.

Parameter Name: QC RESETRMS
Class: header
Context: process
Type: double
Value Format: %f
Unit:
Comment Format: RMS noise in combined reset frame.
Description: variation is defined here as the Gaussian
equivalent MAD ie.
1.48*median-of-absolute-deviation from
unity after normalising by median level ie.
measuring the RMS reset level variation.
The RMS can later be compared with
library values for troubleshooting problems.

Parameter Name: QC READNOISE
Class: header
Context: process
Type: double
Value Format: %f
Unit: electron
Comment Format: readnoise [electron].
Description: measured from the noise properties of the
difference in two consecutive dark frames,
using a MAD estimator as above for
robustness against spurions.
The noise properties of each detector should
remain stable so long as the
electronics/micro-code have not been modified.

Parameter Name: QC FLATRMS
Class: header
Context: process

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Type: double
 Value Format: %f
 Unit: fraction
 Comment Format: RMS flatfield pixel sens per detector [fraction].
 Description: RMS is defined here as the Gaussian equivalent MAD ie.
 1.48*median-of-absolute-deviation from unity after normalising by median level ie. measuring the RMS sensitivity variation. The RMS can later be compared with library values for troubleshooting problems.

Parameter Name: QC_GAIN
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: e/ADU
 Comment Format: gain [e/ADU].
 Description: determined from pairs of darks and flatfields of the same exposure/integration time and illumination by comparing the measured noise properties with the expected photon noise contribution. The gain of each detector should remain stable so long as the electronics/micro-code have not been modified.

Parameter Name: QC_BAD_PIXEL_STAT
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: scalar
 Comment Format: fraction of bad pixels/detector [scalar].
 Description: determined from the statistics of the pixel distribution from the ratio of two flatfield sequences of significantly different average count levels. The fraction of bad pixels per detector (either hot or cold) should not change significantly with time.

Parameter Name: QC_GAIN_CORRECTION
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: scalar
 Comment Format: detector median flatfield/global median [scalar].
 Description: the ratio of median counts in a mean flat exposure for a given detector relative to the ensemble defines the internal gain correction for the detector. These internal relative detector gain corrections should be stable with time.

Parameter Name: QC_LINEARITY
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: percentage
 Comment Format: percentage average non-linearity [percentage].
 Description: derived from measured non-linearity curves for each detector interpolated to 10k counts (ADUs) level. Although all infrared systems are non-linear to some degree, the shape and scale of the linearity curve for each detector should remain constant. A single measure at 20k counts can be used to monitor this although the full linearity curves will need to be examined quarterly [TBC] to look for more subtle changes.

Parameter Name: QC_LINFITQUAL

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Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit:
 Comment Format: RMS fractional error in linearity fit
 Description: Derived by applying the linearity coefficients to the image data that were used to measure them. This is the RMS of the residuals of the linearised data normalised by the expected linear value

Parameter Name: QC SATURATION
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: ADU
 Comment Format: saturation level of bright stars [ADU].
 Description: determined from maximum peak flux of detected stars from exposures in a standard bright star field.
 The saturation level*gain is a check on the full-well characteristics of each detector.

Parameter Name: QC PERSIST_DECAY
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: s
 Comment Format: mean exponential time decay constant [s].
 Description: the decay rate of the persistence of bright images on subsequent exposures will be modelled using an exponential decay function with time constant tau. Requires an exposure on a bright star field followed a series of darks.

Parameter Name: QC PERSIST_ZERO
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit:
 Comment Format: fractional persistence at T0 (extrapolated).
 Description: determined from the persistence decay behaviour from exponential model fitting.
 Requires an exposure on a bright star field followed a series of darks (as above)

Parameter Name: QC CROSS_TALK
 Class: header
 Context: process
 Type: double
 Value Format: %f
 Unit: scalar
 Comment Format: average values for cross-talk component matrix [scalar].
 Description: determined from presence of +ve or -ve ghost images on other channels/detectors using exposures in bright star fields. Potentially a fully populated 256x256 matrix but likely to be sparsely populated with a small number of non-zero values of band-diagonal form. This QC summary parameter is the average value of the modulus of the off-diagonal terms.
 Values for the cross-talk matrix should be very stable with time, hardware modifications notwithstanding.

Parameter Name: QC WCS_DCRVAL1
 Class: header
 Context: process
 Type: double
 Value Format: %e
 Unit: deg

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Comment Format: actual WCS zero point X - raw header value [deg].
Description: measure of difference between dead-reckoning pointing and true position of the detector on sky. Derived from current polynomial distortion model and 6-constant detector model offset.

Parameter Name: QC WCS_DCRVAL2
Class: header
Context: process
Type: double
Value Format: %e
Unit: deg
Comment Format: actual WCS zero point Y - raw header value [deg].
Description: measure of difference between dead-reckoning pointing and true position of the detector on sky. Derived from current polynomial distortion model and 6-constant detector model offset.

Parameter Name: QC WCS_DTHETA
Class: header
Context: process
Type: double
Value Format: %e
Unit: deg
Comment Format: actual WCS rotation PA - raw PA header value [deg].
Description: measure of difference between dead-reckoning PA and true position angle of the detector. Derived from current polynomial distortion model and 6-constant detector model effective rotation term.

Parameter Name: QC WCS_SCALE
Class: header
Context: process
Type: double
Value Format: %e
Unit: deg/pixel
Comment Format: measured WCS plate scale per detector [deg/pixel].
Description: measure of the average on-sky pixel scale of detector after correcting using current polynomial distortion model

Parameter Name: QC WCS_SHEAR
Class: header
Context: process
Type: double
Value Format: %e
Unit: deg
Comment Format: power of cross-terms in WCS solution [deg].
Description: measure of WCS shear after normalising by plate scale and rotation, expressed as an equivalent distortion angle. Gives a simple measure of distortion problems in WCS solution.

Parameter Name: QC WCS_RMS
Class: header
Context: process
Type: double
Value Format: %e
Unit: arcsec
Comment Format: robust RMS of WCS solution for each detector [arcsec].
Description: robust average of residuals from WCS solution for each detector. Measure of integrity of WCS solution.

Parameter Name: QC MEAN_SKY
Class: header
Context: process
Type: double
Value Format: %f
Unit: ADU
Comment Format: mean sky level [ADU].
Description: computed using a clipped median for each detector
Sky levels (perhaps not at Ks) should vary smoothly over the night. Strange changes in values may indicate a

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hardware fault.

Parameter Name: QC SKY_NOISE
Class: header
Context: process
Type: double
Value Format: %f
Unit: ADU
Comment Format: RMS sky noise [ADU].
Description: computed using a MAD estimator with respect to median sky after removing large scale gradients. The sky noise should be a combination of readout-noise, photon-noise and detector quirks. Monitoring the ratio of expected noise to measured provides a system diagnostic at the detector level.

Parameter Name: QC SKY_RESET_ANOMALY
Class: header
Context: process
Type: double
Value Format: %f
Unit: ADU
Comment Format: systematic variation in sky across detector [ADU].
Description: robust average variation in background level for each detector, computed by measuring the large scale variation from a filtered 64x64 pixel background grid, where each background pixel is a clipped median estimate of the local sky level. Effectively generates an 32x32 sky level map and computes the MAD [TBC] of these values with respect to the global detector median. Monitoring the non-flatness of this gives a measure of reset-anomaly problems.

Parameter Name: QC NOISE_OBJ
Class: header
Context: process
Type: integer
Value Format: %d
Unit: number
Comment Format: number of classified noise objects per frame [number].
Description: measured using an object cataloguer combined with a morphological classifier. The number of objects classified as noise from frame-to-frame should be reasonably constant; excessive numbers indicate a problem.

Parameter Name: QC IMAGE_SIZE
Class: header
Context: process
Type: double
Value Format: %f
Unit: arcsec
Comment Format: mean stellar image FWHM [arcsec].
Description: measured from the average FWHM of stellar-classified images of suitable signal:to:noise. The seeing will obviously vary over the night with time, wavelength (filter) and as airmass^{0.6}. This variation should be predictable given local site seeing measures. A comparison with the expected value can be used as an indication of poor guiding, poor focus or instrument malfunction.

Parameter Name: QC APERTURE_CORR
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: 2 arcsec [mag] diam aperture flux correction.
Description: the aperture flux correction for stellar images due to flux falling outside the aperture. Determined using a curve-of-growth of a series of fixed-size apertures. Alternative simple measure of image profile properties,

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particularly the presence of extended PSF wings, as such monitors optical properties of system; also required for limiting magnitude computations.

Parameter Name: QC ELLIPTICITY
Class: header
Context: process
Type: double
Value Format: %f
Unit: scalar
Comment Format: mean stellar ellipticity [scalar].
Description: the detected image intensity-weighted second moments will be used to compute the average ellipticity of suitable signal:to:noise stellar images. Shot-noise causes even perfectly circular stellar images to have non-zero ellipticity but more significant values are indicative of one of: optical, tracking and autoguiding, or detector hardware problems.

Parameter Name: QC ZPT_2MASS
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: 1st-pass photometric zeropoint [mag].
Description: the magnitude of a star that gives 1 detected ADU/s (or e-/s) for each detector, derived using 2MASS comparison stars for every science observation. This is a first pass zero-point to monitor gross changes in throughput. Extinction will vary over a night, but detector to detector variations are an indication of a fault.

Parameter Name: QC ZPT_STDS
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: photometric zeropoint [mag].
Description: the magnitude of a star that gives 1 detected ADU/s (or e-/s) for each detector, derived from observations of VISTA standard star fields. Combined with the trend in long-term system zero-point properties, the ensemble "average" zero-point directly monitors extinction variations (faults/mods in the system notwithstanding) The photometric zeropoints will undoubtedly vary (slowly) over time as a result of the cleaning of optical surfaces etc.

Parameter Name: QC LIMITING_MAG
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: limiting mag ie. depth of exposure [mag].
Description: estimate of 5-sigma limiting mag for stellar-like objects for each science observation, derived from QCs ZPT_2MASS, SKY_NOISE, APERTURE_CORR. Can later be compared with a target value to see if main survey requirements (ie. usually depth) are met.

Parameter Name: QC FRINGE_RATIO
Class: header
Context: process
Type: double
Value Format: %f
Unit: scalar
Comment Format: [scalar] Ratio of sky noise before/after fringe fit
Description: A robust estimate of the background noise is done before the first fringe fitting pass.

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Once the last fringe fit is done a final background noise estimate is done. This parameter is the ratio of the value before fringe fitting to the final value after defringing.

Parameter Name: QC ILLUMCOR_RMS
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: [mag] RMS in illumination correction
Description: The RMS of the illumination correction over all of the frame.

Parameter Name: QC RESETDIFF_MED
Class: header
Context: process
Type: double
Value Format: %f
Unit: adu
Comment Format: Median new-library reset frame [adu].
Description: Measure the median of the difference of a new mean reset frame and a library reset frame.

Parameter Name: QC DARKDIFF_MED
Class: header
Context: process
Type: double
Value Format: %f
Unit: adu
Comment Format: Median new-library dark frame [adu].
Description: Measure the median of the difference of a new mean dark frame and a library reset frame.

Parameter Name: QC FLATRATIO_MED
Class: header
Context: process
Type: double
Value Format: %f
Unit: scalar
Comment Format: Median new/library flat frame [scalar].
Description: Measure the median of the ratio of a new mean flat frame and a library flat frame.

Parameter Name: QC FLATRATIO_RMS
Class: header
Context: process
Type: double
Value Format: %f
Unit: scalar
Comment Format: RMS new/library flat frame [scalar].
Description: Measure the RMS of the ratio of a new mean flat frame and a library flat frame.

Parameter Name: QC MAGZPT
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: Photometric zero point [mag].
Description: A measure of the photometric zero point using an aperture of 1* the core radius.

Parameter Name: QC MAGZERR
Class: header
Context: process
Type: double
Value Format: %f
Unit: mag
Comment Format: Photometric zero point error [mag].

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Description: A measure of the RMS photometric zero point error using an aperture of 1* the core radius.

Parameter Name: QC MAGNZPT
Class: header
Context: process
Type: double
Value Format: %f
Unit:
Comment Format: Number of stars in zero point calc.
Description: The number of stars on this image used to calculate the photometric zeropoint.

Parameter Name: QC RESET_MED
Class: header
Context: process
Type: double
Value Format: %f
Unit:
Comment Format: median reset level
Description: median reset level

Parameter Name: QC DARKMED
Class: header
Context: process
Type: double
Value Format: %f
Unit:
Comment Format: median dark counts
Description: median counts in dark frames.

The above dictionary is illustrated as a FITS header extract as it will appear in the per-detector extension header:

```

HIERARCH ESO QC APERTURE_CORR= 0.456000      / 2 arcsec [mag] diam aperture fl
HIERARCH ESO QC BAD_PIXEL_STAT= 0.006000     / fraction of bad pixels/detector
HIERARCH ESO QC CROSS_TALK   = 1.000000     / average values for cross-talk c
HIERARCH ESO QC DARKCURRENT  = 200.000000    / average dark current on frame [
HIERARCH ESO QC DARKDIFF_MED = 0.000000     / Median new-library dark frame [
HIERARCH ESO QC DARKDIFF_RMS = 0.000000     / [adu] RMS new-library dark fram
HIERARCH ESO QC DARKMED      = 0.000000     / median dark counts
HIERARCH ESO QC DARKRMS     = 3.456000     / RMS noise of combined dark fram
HIERARCH ESO QC DID          = 'ESO-VLT-DIC.VIRCAM_QC' / Data dictionar
HIERARCH ESO QC ELLIPTICITY  = 0.021100     / mean stellar ellipticity [scala
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 FLATRMS     = 0.000000     / RMS flatfield pixel sens per de
HIERARCH ESO QC FRINGE_RATIO = 0.000000     / [scalar] Ratio of sky noise bef
HIERARCH ESO QC GAIN         = 1.600000     / gain [e/ADU].
HIERARCH ESO QC GAIN_CORRECTION= 0.950000    / detector median flatfield/globa
HIERARCH ESO QC ILLUMCOR_RMS = 0.000000     / [mag] RMS in illumination corre
HIERARCH ESO QC IMAGE_SIZE   = 0.500000     / mean stellar image FWHM [arcsec
HIERARCH ESO QC LIMITING_MAG = 24.567000    / limiting mag ie. depth of expos
HIERARCH ESO QC LINEARITY    = 0.030000     / percentage average non-linearit
HIERARCH ESO QC LINFITQUAL   = 0.000000     / RMS fractional error in lineari
HIERARCH ESO QC MAGNZPT      = 0.000000     / Number of stars in zero point c
HIERARCH ESO QC MAGZERR      = 0.000000     / Photometric zero point error [m
HIERARCH ESO QC MAGZPT       = 0.000000     / Photometric zero point [mag].
HIERARCH ESO QC MEAN_SKY     = 12345.120000  / mean sky level [ADU].
HIERARCH ESO QC NOISE_OBJ    = 150          / number of classified noise obje
HIERARCH ESO QC PARTICLE_RATE= 20.500000    / cosmic ray/spurion rate [count/
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 READNOISE    = 150.000000    / readnoise [electron].
HIERARCH ESO QC RESETDIFF_MED= 0.000000     / Median new-library reset frame
HIERARCH ESO QC RESETDIFF_RMS= 0.000000     / [adu] RMS new-library reset fra
HIERARCH ESO QC RESETRMS     = 0.000000     / RMS noise in combined reset fra
HIERARCH ESO QC RESET_MED    = 0.000000     / median reset level
HIERARCH ESO QC SATURATION   = 65535.000000 / saturation level of bright star

```

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```

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 WCS_DCRVAL1    = 5.555550e-04    / actual WCS zero point X - raw h
HIERARCH ESO QC WCS_DCRVAL2    = -5.555500e-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_RMS        = 9.444400e-06    / robust RMS of WCS solution for
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 ZPT_2MASS      = 26.500000      / 1st-pass photometric zeropoint
HIERARCH ESO QC ZPT_STDS       = 26.400000      / photometric zeropoint [mag].

```

The following table references the QC parameters with the functions and recipes where they are generated:

QC PARAMETER	FUNCTION	RECIPE
APERTURE_CORR	imcore	jitter_microstep_process standard_process
BAD_PIXEL_STAT		linearity_analyse
CROSS_TALK		crosstalk_analyse
DARDIFF_MED		dark_combine
DARKCURRENT		dark_current
DARKDIFF_RMS		dark_combine
DARKMED		dark_combine
DARKRMS		dark_combine
ELLIPTICITY	imcore	jitter_microstep_process standard_process
FLATRATIO_MED		dome_flat_combine twilight_combine
FLATRATIO_RMS		dome_flat_combine twilight_combine
FLATRMS		dome_flat_combine twilight_combine
FRINGE_RATIO	defringe	jitter_microstep_process standard_process
GAIN		detector_noise
GAIN_CORRECTION		twilight_combine
ILLUMCOR_RMS	illum	mesostep_analyse standard_process
IMAGE_SIZE	imcore	jitter_microstep_process standard_process
LIMITING_MAG	photcal	jitter_microstep_process standard_process
LINEARITY		linearity_analyse
LINFITQUAL		linearity_analyse
MAGNZPT	photcal	jitter_microstep_process
MAGZERR	photcal	jitter_microstep_process
MAGZPT	photcal	jitter_microstep_process
MEAN_SKY	imcore	jitter_microstep_process

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		standard_process
NOISE_OBJ	imcore	jitter_microstep_process standard_process
PARTICLE_RATE		dark_combine
PERSIST_DECAY		persistence_analyse
PERSIST_ZERO		persistence_analyse
READNOISE		detector_noise
RESETDIFF_MED		reset_combine
RESETDIFF_RMS		reset_combine
RESETRMS		reset_combine
RESET_MED		reset_combine
SATURATION	imcore	jitter_microstep_process standard_process
SKY_NOISE	imcore	jitter_microstep_process standard_process
SKY_RESET_ANOMALY	imcore	jitter_microstep_process standard_process
WCS_DCRVAL1	platesol	jitter_microstep_process standard_process
WCS_DCRVAL2	platesol	jitter_microstep_process standard_process
WCS_DTHETA	platesol	jitter_microstep_process standard_process
WCS_RMS	platesol	jitter_microstep_process standard_process
WCS_SCALE	platesol	jitter_microstep_process standard_process
WCS_SHEAR	platesol	jitter_microstep_process standard_process
ZPT_2MASS		jitter_microstep_process standard_process
ZPT_STDS	photcal	standard_process

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11 Appendix: DRS Dictionary

#####

E.S.O. VISTA project

#

"@(#) \$Id: ESO-VLT-DIC.VIRCAM_DRS,v 0.1 2005/04/04 vltscm Exp \$"

#

#

VIRCAM_DRS dictionary

#

who when what

#-----

pbunclark 2005-04-04 Original

jrl 2005-04-15 various tidyups

jrl 2006-03-23 add BACKMED, corrections

jrl 2006-04-28 added CLASSIFD, THRESHOL, MINPIX and CROWDED

jrl 2006-06-05 modified photometric zeropoint entries and

Dictionary Name: ESO-VLT-DIC.VIRCAM_DRS

Scope: DFS

Source: ESO VLT

Version Control: "@(#) \$Id: 0.1 \$"

Revision: 0.3

Date: 2006-06-06

Status: Development

Description: VIRCAM Processing keywords

#-----

General keywords

#

Parameter Name: DRS DID

Class: header

Context: PROCESS

Type: string

Value Format: %30s

Unit:

Comment Format: Data dictionary for VIRCAM DRS

Description: Name/version of ESO DID to which DRS
keywords comply.

Parameter Name: DRS XTCOR

Class: header

Context: PROCESS

Type: string

Value Format: %s

Unit:

Comment Format: Crosstalk matrix table

Description: Name of the crosstalk matrix table used to process
this image

Parameter Name: DRS DARKCOR

Class: header

Context: PROCESS

Type: string

Value Format: %s

Unit:

Comment Format: dark image

Description: The name of the dark image specified in
darksrc

Parameter Name: DRS DARKSCL

Class: header

Context: PROCESS

Type: double

Value Format: %f

Unit:

Comment Format: Dark scale factor

Description: The scale factor used in the dark subtractionon

Parameter Name: DRS FRINGEi

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Class: header
 Context: PROCESS
 Type: string
 Value Format: %s
 Unit:
 Comment Format: Fringe file of nth pass
 Description: The name of the fringe file used in the nth defringing pass

Parameter Name: DRS FRNGSCi
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit:
 Comment Format: scale factor nth defringe pass
 Description: The scale factor for the nth defringing pass

Parameter Name: DRS FLATCOR
 Class: header
 Context: PROCESS
 Type: string
 Value Format: %s
 Unit:
 Comment Format: flat field image
 Description: The name of the flat field image specified in flatsrc

Parameter Name: DRS ZPIM1
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] photometric zeropoint
 Description: The calculated photometric zeropoint for stars on the current image only through an aperture of 1* the core radius.

Parameter Name: DRS ZPSIGIM1
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] RMS in photometric zeropoint
 Description: The calculated RMS in photometric zeropoint for stars on the current image only through an aperture of 1* the core radius.

Parameter Name: DRS ZPIM2
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] photometric zeropoint
 Description: The calculated photometric zeropoint for stars on the current image only through an aperture of 2* the core radius.

Parameter Name: DRS ZPSIGIM2
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] RMS in photometric zeropoint
 Description: The calculated RMS in photometric zeropoint for stars on the current image only through an aperture of 2* the core radius.

Parameter Name: DRS LIMIT_MAG1

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Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] Limiting magnitude 1*core radius
 Description: The calculated 5 sigma limiting magnitude through an aperture of 1* the core radius

Parameter Name: DRS LIMIT_MAG2
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] Limiting magnitude 2*core radius
 Description: The calculated 5 sigma limiting magnitude through an aperture of 2* the core radius

Parameter Name: DRS MAGNZPTIM
 Class: header
 Context: PROCESS
 Type: integer
 Value Format: %d
 Unit:
 Comment Format: Number of stars used photometric zeropoint calc.(h)
 Description: The number of stars used to calculate the photometric zeropoint for this image only.

Parameter Name: DRS ZPALL1
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] photometric zeropoint
 Description: The calculated photometric zeropoint for stars on all the images reduced together through an aperture of 1* the core radius.

Parameter Name: DRS ZPSIGALL1
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] RMS in photometric zeropoint
 Description: The calculated RMS in photometric zeropoint for stars on all the images reduced together through an aperture of 1* the core radius.

Parameter Name: DRS ZPALL2
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] photometric zeropoint
 Description: The calculated photometric zeropoint for stars on all the images reduced together through an aperture of 2* the core radius.

Parameter Name: DRS ZPSIGALL2
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: mag
 Comment Format: [mag] RMS in photometric zeropoint
 Description: The calculated RMS in photometric zeropoint for stars on all the images reduced together through an aperture of 2* the core radius.

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Parameter Name: DRS MAGNZPTALL
 Class: header
 Context: PROCESS
 Type: integer
 Value Format: %d
 Unit:
 Comment Format: Number of stars used photometric zeropoint calc.(h)
 Description: The number of stars used to calculate the photometric zeropoint for all the images reduced together.

Parameter Name: DRS XOFFMICRO
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit:
 Comment Format: X-pixels to microstep input image
 Description: The number of pixels in X by which to microstep the current input image relative to the output grid.

Parameter Name: DRS YOFFMICRO
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit:
 Comment Format: Y-pixels to microstep input image
 Description: The number of pixels in Y by which to microstep the current input image relative to the output grid.

Parameter Name: DRS XOFFDITHER
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit:
 Comment Format: X-pixels to jitter input image
 Description: The number of pixels in X by which to jitter the current input image relative to the output grid.

Parameter Name: DRS YOFFDITHER
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit:
 Comment Format: Y-pixels to jitter input image
 Description: The number of pixels in Y by which to jitter the current input image relative to the output grid.

Parameter Name: DRS PROVXXXX
 Class: header
 Context: PROCESS
 Type: string
 Value Format: %s
 Unit:
 Comment Format: Input file #
 Description: A set of FITS keywords that lists the files that were combined to form this output file. This establishes the provenance of the output file.

Parameter Name: DRS SKYLEVEL
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: ADU
 Comment Format: [ADU] Mean sky level

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Description: The mean sky level in the image

Parameter Name: DRS SKYNOISE
Class: header
Context: PROCESS
Type: double
Value Format: %f
Unit: ADU
Comment Format: [ADU] Mean sky noise
Description: The mean sky noise in the image

Parameter Name: DRS LINCOR
Class: header
Context: PROCESS
Type: string
Value Format: %s
Unit:
Comment Format: Channel table
Description: The name of the channel table used in the linearisation

Parameter Name: DRS FLATIN
Class: header
Context: PROCESS
Type: string
Value Format: %s
Unit:
Comment Format: flat field used
Description: The name of the flat field frame that was used to create this confidence map

Parameter Name: DRS BPMIN
Class: header
Context: PROCESS
Type: string
Value Format: %s
Unit:
Comment Format: bad pixel map used
Description: The name of the bad pixel mask image that was used to create this confidence map

Parameter Name: DRS PERMASK
Class: header
Context: PROCESS
Type: string
Value Format: %s
Unit:
Comment Format: persistence mask used
Description: The name of the persistence mask image that was used to create this confidence map

Parameter Name: DRS STDCRMS
Class: header
Context: PROCESS
Type: double
Value Format: %f
Unit: arcsec
Comment Format: [arcsec] RMS of the WCS fit
Description: The RMS of the WCS fit

Parameter Name: DRS NUMBRMS
Class: header
Context: PROCESS
Type: integer
Value Format: %d
Unit:
Comment Format: no. of stars in WCS fit
Description: Number of stars in the WCS fit

Parameter Name: DRS WCSRAOFF
Class: header
Context: PROCESS
Type: double

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Value Format: %f
Unit: arcsec
Comment Format: [arcsec] diff in RA after proc.
Description: The equatorial coordinates of the central pixel of the image is calculated both before and after the plate solution is found. This is the difference in the RA (in arcseconds).

Parameter Name: DRS WCSDECOFF
Class: header
Context: PROCESS
Type: double
Value Format: %f
Unit: arcsec
Comment Format: [arcsec] diff in DEC after proc.
Description: The equatorial coordinates of the central pixel of the image is calculated both before and after the plate solution is found. This is the difference in the DEC (in arcseconds).

Parameter Name: DRS BACKMED
Class: header
Context: PROCESS
Type: double
Value Format: %f
Unit:adu
Comment Format: [adu] Background median value
Description: The most recent estimate of the background

Parameter Name: DRS CLASSIFD
Class: header
Context: PROCESS
Type: integer
Value Format: %d
Unit:
Comment Format: Catalogue has been classified.
Description: Set if the classification software has been run on this catalogue.

Parameter Name: DRS THRESHOL
Class: header
Context: PROCESS
Type: double
Value Format: %f
Unit:adu
Comment Format: [adu] Isophotal analysis threshold
Description: Isophotal analysis used in object detection.

Parameter Name: DRS MINPIX
Class: header
Context: PROCESS
Type: integer
Value Format: %d
Unit: pixels
Comment Format: [pixels] Minimum size for images
Description: Minimum number of pixels for an object to cover

Parameter Name: DRS CROWDED
Class: header
Context: PROCESS
Type: integer
Value Format: %d
Unit:
Comment Format: Crowded field analysis flag
Description: If set, then the deblending software has been used to extract the objects in this catalogue.

Parameter Name: DRS RCORE
Class: header
Context: PROCESS
Type: double
Value Format: %f
Unit: pixels

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Comment Format: [pixels] Core radius
 Description: The core radius. This is set to the approximate expected FWHM of all the stellar images

Parameter Name: DRS SEEING
 Class: header
 Context: PROCESS
 Type: double
 Value Format: %f
 Unit: pixels
 Comment Format: [pixels] The estimated seeing
 Description: The seeing esimated from the stellar images on the current frame.

12 Appendix: Raw FITS Header

```

SIMPLE =                               T / Standard FITS format (NOST-100.0)
BITPIX =                               8 / # of bits storing pix values
NAXIS  =                               0 / # of axes in frame
EXTEND  =                               T / Extension may be present
ORIGIN  = 'ESO'                        / European Southern Observatory
DATE    = '2006-03-21T15:06:48'        / Date this file was written
TELESCOP= 'VISTA'                      / ESO Telescope Name
INSTRUME= 'VIRCAM'                    / Instrument used.
OBJECT  = 'OBJECT'                    / Original target.
RA      =          318.346792          / 21:13:23.2 RA (J2000) pointing (deg)
DEC     =          -88.93761           / -88:56:15.3 DEC (J2000) pointing (deg)
EQUINOX =          2000.               / Standard FK5 (years)
RADECSYS= 'FK5'                      / Coordinate reference frame
EXPTIME =          10.0000000          / Integration time
MJD-OBS =          53815.62973579      / Obs start
DATE-OBS= '2006-03-21T15:06:49.1726'   / Observing date
UTC     =          54270.829           / 15:04:30.829 UTC at start (sec)
LST     =          80333.420           / 22:18:53.420 LST at start (sec)
PI-COI  = 'J.Lewis-P.Bunclark' / PI-COI name.
OBSERVER= 'Peter Bunclark' / Name of observer.
ORIGFILE= 'VIRCAM_IMG_OBS080_0001.fits' / Original File Name
COMMENT VISTA IR Camera OS $Revision: 0.21 $
HIERARCH ESO ADA ABSROT END =          0.00000 / Abs rot angle at exp end (deg)
HIERARCH ESO DPR CATG      = 'TEST' / Observation category
HIERARCH ESO DPR TECH      = 'IMAGE,FILTOFFSET' / Observation technique
HIERARCH ESO DPR TYPE      = 'STD,STRAYLIGHT' / Observation type
HIERARCH ESO INS DATE      = '2005-12-14' / Instrument release date (yyyy-mm-d
HIERARCH ESO INS FILT1 DATE = '2006-01-27T10:02:27' / Filter index time
HIERARCH ESO INS FILT1 FOCUS =          0.000 / Filter focus offset [mm]
HIERARCH ESO INS FILT1 ID   = 'SLOT8' / Filter unique id
HIERARCH ESO INS FILT1 NAME = 'Y' / Filter name
HIERARCH ESO INS FILT1 NO   =          25 / Filter wheel position index
HIERARCH ESO INS FILT1 WLEN =          0.000 / Filter effective wavelength [nm]
HIERARCH ESO INS HB1 SWSIM  =          F / If T, heart beat device simulated
HIERARCH ESO INS ID        = 'VIRCAM/1.56' / Instrument ID
HIERARCH ESO INS LSC1 OK    =          T / If T, controller is operational
HIERARCH ESO INS LSC1 SWSIM =          F / If T, lakeshore ctrllr simulated
HIERARCH ESO INS LSM1 OK    =          T / If T, controller is operational
HIERARCH ESO INS LSM1 SWSIM =          F / If T, lakeshore monitor simulated
HIERARCH ESO INS LSM2 OK    =          T / If T, controller is operational
HIERARCH ESO INS LSM2 SWSIM =          F / If T, lakeshore monitor simulated
HIERARCH ESO INS LSM3 OK    =          T / If T, controller is operational
HIERARCH ESO INS LSM3 SWSIM =          F / If T, lakeshore monitor simulated
HIERARCH ESO INS PRES1 ID   = 'Vac1' / Pressure sensor type
HIERARCH ESO INS PRES1 NAME = 'Vacuum gauge 1' / Pressure sensor name
HIERARCH ESO INS PRES1 UNIT = 'mbar' / Pressure unit
HIERARCH ESO INS PRES1 VAL  =          0.000 / Pressure [mbar]

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HIERARCH ESO INS SW1 ID      = 'INPOS   ' / Switch ID
HIERARCH ESO INS SW1 NAME    = 'Filter In-position Switch' / Switch name
HIERARCH ESO INS SW1 STATUS  = 'INACTIVE' / Switch status
HIERARCH ESO INS SW2 ID      = 'REFSW   ' / Switch ID
HIERARCH ESO INS SW2 NAME    = 'Filter Reference Select' / Switch name
HIERARCH ESO INS SW2 STATUS  = 'PRIMARY ' / Switch status
HIERARCH ESO INS SW3 ID      = 'HOME    ' / Switch ID
HIERARCH ESO INS SW3 NAME    = 'Filter Reference Switch' / Switch name
HIERARCH ESO INS SW3 STATUS  = 'INACTIVE' / Switch status
HIERARCH ESO INS TEMP1 ID    = 'Amb     ' / Temperature sensor type
HIERARCH ESO INS TEMP1 NAME  = 'Ambient temperature' / Temperature sensor name
HIERARCH ESO INS TEMP1 UNIT  = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP1 VAL   =      302.580 / Temperature [K]
HIERARCH ESO INS TEMP10 ID   = 'CC1_2   ' / Temperature sensor type
HIERARCH ESO INS TEMP10 NAME = 'Cryo cooler 1 2nd' / Temperature sensor name
HIERARCH ESO INS TEMP10 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP10 VAL  =      24.105 / Temperature [K]
HIERARCH ESO INS TEMP12 ID   = 'CC2_2   ' / Temperature sensor type
HIERARCH ESO INS TEMP12 NAME = 'Cryo cooler 2 2nd' / Temperature sensor name
HIERARCH ESO INS TEMP12 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP12 VAL  =      27.791 / Temperature [K]
HIERARCH ESO INS TEMP14 ID   = 'CC3_2   ' / Temperature sensor type
HIERARCH ESO INS TEMP14 NAME = 'Cryo cooler 3 2nd' / Temperature sensor name
HIERARCH ESO INS TEMP14 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP14 VAL  =      22.735 / Temperature [K]
HIERARCH ESO INS TEMP15 ID   = 'WFSN    ' / Temperature sensor type
HIERARCH ESO INS TEMP15 NAME = 'WFS CCD assembly PY' / Temperature sensor name
HIERARCH ESO INS TEMP15 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP15 VAL  =       1.000 / Temperature [K]
HIERARCH ESO INS TEMP16 ID   = 'WFSS    ' / Temperature sensor type
HIERARCH ESO INS TEMP16 NAME = 'WFS CCD assembly NY' / Temperature sensor name
HIERARCH ESO INS TEMP16 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP16 VAL  =     123.550 / Temperature [K]
HIERARCH ESO INS TEMP17 ID   = 'Dt1AB   ' / Temperature sensor type
HIERARCH ESO INS TEMP17 NAME = 'Science detector 1AB' / Temperature sensor name
HIERARCH ESO INS TEMP17 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP17 VAL  =      73.583 / Temperature [K]
HIERARCH ESO INS TEMP18 ID   = 'Dt1CD   ' / Temperature sensor type
HIERARCH ESO INS TEMP18 NAME = 'Science detector 1CD' / Temperature sensor name
HIERARCH ESO INS TEMP18 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP18 VAL  =      73.002 / Temperature [K]
HIERARCH ESO INS TEMP19 ID   = 'Dt2BA   ' / Temperature sensor type
HIERARCH ESO INS TEMP19 NAME = 'Science detector 2BA' / Temperature sensor name
HIERARCH ESO INS TEMP19 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP19 VAL  =      74.668 / Temperature [K]
HIERARCH ESO INS TEMP2 ID    = 'Win     ' / Temperature sensor type
HIERARCH ESO INS TEMP2 NAME  = 'Cryostat window cell' / Temperature sensor name
HIERARCH ESO INS TEMP2 UNIT  = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP2 VAL   =     176.710 / Temperature [K]
HIERARCH ESO INS TEMP20 ID   = 'Dt2DC   ' / Temperature sensor type
HIERARCH ESO INS TEMP20 NAME = 'Science detector 2DC' / Temperature sensor name
HIERARCH ESO INS TEMP20 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP20 VAL  =      74.106 / Temperature [K]
HIERARCH ESO INS TEMP21 ID   = 'Dt3AB   ' / Temperature sensor type
HIERARCH ESO INS TEMP21 NAME = 'Science detector 3AB' / Temperature sensor name
HIERARCH ESO INS TEMP21 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP21 VAL  =      74.677 / Temperature [K]
HIERARCH ESO INS TEMP22 ID   = 'Dt3CD   ' / Temperature sensor type
HIERARCH ESO INS TEMP22 NAME = 'Science detector 3CD' / Temperature sensor name
HIERARCH ESO INS TEMP22 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP22 VAL  =      75.485 / Temperature [K]
HIERARCH ESO INS TEMP23 ID   = 'Dt4BA   ' / Temperature sensor type
HIERARCH ESO INS TEMP23 NAME = 'Science detector 4BA' / Temperature sensor name
HIERARCH ESO INS TEMP23 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP23 VAL  =      74.778 / Temperature [K]
HIERARCH ESO INS TEMP24 ID   = 'Dt4DC   ' / Temperature sensor type
HIERARCH ESO INS TEMP24 NAME = 'Science detector 4DC' / Temperature sensor name
HIERARCH ESO INS TEMP24 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP24 VAL  =      74.544 / Temperature [K]
HIERARCH ESO INS TEMP25 ID   = 'FPA     ' / Temperature sensor type
HIERARCH ESO INS TEMP25 NAME = 'FPA thermal plate' / Temperature sensor name
HIERARCH ESO INS TEMP25 UNIT = 'K        ' / Temperature unit
HIERARCH ESO INS TEMP25 VAL  =      69.997 / Temperature [K]

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HIERARCH ESO INS TEMP26 ID   = 'WFSpl   ' / Temperature sensor type
HIERARCH ESO INS TEMP26 NAME = 'WFS plate' / Temperature sensor name
HIERARCH ESO INS TEMP26 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP26 VAL  =      108.360 / Temperature [K]
HIERARCH ESO INS TEMP3 ID   = 'Tube     ' / Temperature sensor type
HIERARCH ESO INS TEMP3 NAME = 'Cryostat tube' / Temperature sensor name
HIERARCH ESO INS TEMP3 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP3 VAL  =      33.256 / Temperature [K]
HIERARCH ESO INS TEMP4 ID   = 'LNtnk    ' / Temperature sensor type
HIERARCH ESO INS TEMP4 NAME = 'Liquid nitrogen tank' / Temperature sensor name
HIERARCH ESO INS TEMP4 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP4 VAL  =     103.180 / Temperature [K]
HIERARCH ESO INS TEMP5 ID   = 'Baff     ' / Temperature sensor type
HIERARCH ESO INS TEMP5 NAME = 'Baffle    ' / Temperature sensor name
HIERARCH ESO INS TEMP5 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP5 VAL  =     21.332 / Temperature [K]
HIERARCH ESO INS TEMP6 ID   = 'Lens     ' / Temperature sensor type
HIERARCH ESO INS TEMP6 NAME = 'Lens barrel' / Temperature sensor name
HIERARCH ESO INS TEMP6 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP6 VAL  =     100.570 / Temperature [K]
HIERARCH ESO INS TEMP7 ID   = 'FwShd   ' / Temperature sensor type
HIERARCH ESO INS TEMP7 NAME = 'Filter wheel shield' / Temperature sensor name
HIERARCH ESO INS TEMP7 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP7 VAL  =     124.420 / Temperature [K]
HIERARCH ESO INS TEMP8 ID   = 'FwHub    ' / Temperature sensor type
HIERARCH ESO INS TEMP8 NAME = 'Filter wheel hub' / Temperature sensor name
HIERARCH ESO INS TEMP8 UNIT = 'K       ' / Temperature unit
HIERARCH ESO INS TEMP8 VAL  =     109.570 / Temperature [K]
HIERARCH ESO INS THERMAL DET MEAN=      0.00 / Detector mean temperature [K]
HIERARCH ESO INS THERMAL DET TARGET=  70.00 / Detector target temperature [K]
HIERARCH ESO INS THERMAL ENABLE=      F / If T, enable thermal control
HIERARCH ESO INS VAC1 OK      =      T / If T, controller is operational
HIERARCH ESO INS VAC1 SWSIM   =      F / If T, vacuum sensor simulated
HIERARCH ESO OBS DID         = 'ESO-VLT-DIC.OBS-1.11' / OBS Dictionary
HIERARCH ESO OBS GRP         = '0       ' / linked blocks
HIERARCH ESO OBS ID          =      -1 / Observation block ID
HIERARCH ESO OBS NAME        = 'Maintenance' / OB name
HIERARCH ESO OBS PI-COI ID   =      0 / ESO internal PI-COI ID
HIERARCH ESO OBS PI-COI NAME = 'M.Caldwell-A.Born' / PI-COI name
HIERARCH ESO OBS PROG ID     = 'Maintenance' / ESO program identification
HIERARCH ESO OBS START       = '2006-01-30T13:54:10' / OB start time
HIERARCH ESO OBS TPLNO       =      1 / Template number within OB
HIERARCH ESO OCS DET1 IMGNAME= 'VIRCAM_GEN_STD' / Data File Name.
HIERARCH ESO OCS RECIPE      = 'DEFAULT ' / Data reduction recipe to be used
HIERARCH ESO OCS REQTIME     =     10.000 / Requested integration time [s]
HIERARCH ESO TEL ABSROT START=      0.000 / Abs rotator angle at start
HIERARCH ESO TEL AIRM END    =      0.000 / Airmass at end
HIERARCH ESO TEL AIRM START  =      0.000 / Airmass at start
HIERARCH ESO TEL ALT         =     25.691 / Alt angle at start (deg)
HIERARCH ESO TEL AMBI FWHM END=     -1.00 / Observatory Seeing queried from AS
HIERARCH ESO TEL AMBI FWHM START=    -1.00 / Observatory Seeing queried from AS
HIERARCH ESO TEL AMBI PRES END=    750.00 / Observatory ambient air pressure q
HIERARCH ESO TEL AMBI PRES START=   750.00 / Observatory ambient air pressure q
HIERARCH ESO TEL AMBI RHUM   =      12. / Observatory ambient relative humi
HIERARCH ESO TEL AMBI TAU0    =     0.000000 / Average coherence time
HIERARCH ESO TEL AMBI TEMP    =     10.00 / Observatory ambient temperature qu
HIERARCH ESO TEL AMBI WINDDIR=      0. / Observatory ambient wind directio
HIERARCH ESO TEL AMBI WINDSP =     10.00 / Observatory ambient wind speed que
HIERARCH ESO TEL AO ALT      =     0.000000 / Altitude of last closed loop a0
HIERARCH ESO TEL AO DATE     = ' ' / Last closed loop a0
HIERARCH ESO TEL AO M1 DATE  = '2006-03-21T15:06:47' / Last M1 update
HIERARCH ESO TEL AO M2 DATE  = '2006-03-21T15:06:46' / Last M2 update
HIERARCH ESO TEL AO MODES    =      0 / Which a0 modes corrected closed lo
HIERARCH ESO TEL AZ         =     0.317 / Az angle at start (deg) S=0,W=90
HIERARCH ESO TEL DATE       = 'not set ' / TCS installation date
HIERARCH ESO TEL DID        = 'ESO-VLT-DIC.TCS-01.00' / Data dictionary for TEL
HIERARCH ESO TEL DID1       = 'ESO-VLT-DIC.VTCS-0.2' / Additional data dict. fo
HIERARCH ESO TEL DOME STATUS = 'FULLY-OPEN' / Dome status
HIERARCH ESO TEL ECS FLATFIELD=      0 / Flat field level
HIERARCH ESO TEL ECS MOONSCR =      0.00 / Moon screen position
HIERARCH ESO TEL ECS VENT1   =      0.00 / State of vent i
HIERARCH ESO TEL ECS VENT2   =      0.00 / State of vent i
HIERARCH ESO TEL ECS VENT3   =      0.00 / State of vent i

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HIERARCH ESO TEL ECS WINDSCR =          0.00 / Wind screen position
HIERARCH ESO TEL FOCU ID    = 'CA      ' / Telescope focus station ID
HIERARCH ESO TEL FOCU VALUE =          0.000 / M2 setting (mm)
HIERARCH ESO TEL GEOELEV    =          2530. / Elevation above sea level (m)
HIERARCH ESO TEL GEOLAT     =        -24.6157 / Tel geo latitude (+=North) (deg)
HIERARCH ESO TEL GEOLON     =        -70.3976 / Tel geo longitude (+=East) (deg)
HIERARCH ESO TEL GUID FWHM  =          0.00 / Seeing measured by autoguider
HIERARCH ESO TEL GUID STATUS = 'OFF      ' / Status of autoguider
HIERARCH ESO TEL ID         = 'v 0.44  ' / TCS version number
HIERARCH ESO TEL M2 ACENTRE  =          0.00 / M2 centring alpha
HIERARCH ESO TEL M2 ATILT    =          0.00 / M2 tilt alpha
HIERARCH ESO TEL M2 BCENTRE  =          0.00 / M2 centring beta
HIERARCH ESO TEL M2 BTILT    =          0.00 / M2 tilt beta
HIERARCH ESO TEL M2 Z        =          0.00000 / Focussing position of M2 in Z coor
HIERARCH ESO TEL MOON DEC    =        -27.46744 / -27:28:02.7 DEC (J2000) (deg)
HIERARCH ESO TEL MOON RA     =        253.667459 / 16:54:40.1 RA (J2000) (deg)
HIERARCH ESO TEL OPER        = 'Operator name not set' / Telescope Operator
HIERARCH ESO TEL PARANG END  =          0.000 / Parallactic angle at end (deg)
HIERARCH ESO TEL PARANG START=          0.000 / Parallactic angle at start (deg)
HIERARCH ESO TEL POSANG      =          0.000 / Rot position angle at start
HIERARCH ESO TEL TARG ALPHA  =        211323.230 / Alpha coordinate for the target
HIERARCH ESO TEL TARG COORDTYPE= 'M      ' / Coordinate type (M=mean A=apparent)
HIERARCH ESO TEL TARG DELTA  =        -885615.400 / Delta coordinate for the target
HIERARCH ESO TEL TARG EPOCH  =          2000.000 / Epoch
HIERARCH ESO TEL TARG EPOCHSYSTEM= 'J      ' / Epoch system (default J=Julian)
HIERARCH ESO TEL TARG EQUINOX=          2000.000 / Equinox
HIERARCH ESO TEL TARG PARALLAX=          0.000 / Parallax
HIERARCH ESO TEL TARG PMA    =          0.000000 / Proper Motion Alpha
HIERARCH ESO TEL TARG PMD    =          0.000000 / Proper motion Delta
HIERARCH ESO TEL TARG RADVEL  =          0.000 / Radial velocity
HIERARCH ESO TEL TH M1 TEMP   =          0.00 / M1 superficial temperature
HIERARCH ESO TEL TH STR TEMP  =          0.00 / Telescope structure temperature
HIERARCH ESO TEL TRAK STATUS  = 'NORMAL  ' / Tracking status
HIERARCH ESO TPL DID          = 'ESO-VLT-DIC.TPL-1.9' / Data dictionary for TPL
HIERARCH ESO TPL EXPNO        =          1 / Exposure number within template
HIERARCH ESO TPL ID           = 'VIRCAM_gen_tec_StrayLight' / Template signature
HIERARCH ESO TPL NAME         = 'VIRCAM stray light investigation' / Template nam
HIERARCH ESO TPL NEXP         =          6 / Number of exposures within templat
HIERARCH ESO TPL PRESEQ       = 'VIRCAM_gen_tec_StrayLight.seq' / Sequencer scrip
HIERARCH ESO TPL START        = '2006-01-30T13:54:10' / TPL start time
HIERARCH ESO TPL VERSION      = '$Revision: 0.13 $' / Version of the template
NJITTER =          0 / Number of jitter positions
NOFFSETS=          0 / Number of offset positions
NUSTEP   =          0 / Number of microstep positions
OBSNUM   =          1 / Observation number
REQTIME  =          10.000 / Requested integration time [s]
END

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XTENSION= 'IMAGE  ' / IMAGE extension
BITPIX   =          32 / # of bits per pix value
NAXIS    =          2 / # of axes in data array
NAXIS1   =          2048 / # of pixels in axis1
NAXIS2   =          2048 / # of pixels in axis2
PCOUNT   =          0 / number of random group parameters
GCOUNT   =          1 / number of random groups
EXTNAME   = 'DET1.CHIP9' / Extension name
EXTVER    = 1 / Extension version
ORIGIN    = 'ESO      ' / European Southern Observatory
DATE      = '2006-01-30T13:54:47.7333' / Date the file was written
EXPTIME   =          10.000000 / Integration time
MJD-OBS   =          53765.57956362 / Obs start 2006-01-30T13:54:34.297
DATE-OBS  = '2006-01-30T13:54:34.2967' / Observing date
CTYPE1    = 'RA---ZPN' / Coord type of celestial axis 1
CTYPE2    = 'DEC--ZPN' / Coord type of celestial axis 2
CRVAL1    = 318.346791667 / RA at reference pixel
CRVAL2    = -88.937611111 / Dec at reference pixel
CRPIX1    =          5401.6 / Pixel coordinate at ref point
CRPIX2    =          6860.8 / Pixel coordinate at ref point
CDELT1    = 9.494444444444444E-05 / Coordinate increment
CDELT2    = -9.494444444444444E-05 / Coordinate increment
CD1_1     = 5.81347849634012E-21 / WCS transform matrix element
CD1_2     = 9.494444444444444E-05 / WCS transform matrix element
CD2_1     = -9.494444444444444E-05 / WCS transform matrix element

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CD2_2    = -5.81347849634012E-21 / WCS transform matrix element
HIERARCH ESO DET CHIP ID      = 'ESO-Virgo45' / Detector ID
HIERARCH ESO DET CHIP LIVE    = T / Detector live or broken
HIERARCH ESO DET CHIP NAME    = 'Virgo' / Detector name
HIERARCH ESO DET CHIP NO      = 9 / Unique Detector Number
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 CHIP TYPE    = 'IR' / The Type of Det Chip
HIERARCH ESO DET CHIP VIGNETD = F / Detector chip vignetted?
HIERARCH ESO DET CHIP X       = 3 / Detector position x-axis
HIERARCH ESO DET CHIP Y       = 4 / Detector position y-axis
HIERARCH ESO DET CHOP FREQ    = 0 / Chopping Frequency
HIERARCH ESO DET CON OPMODE   = 'NORMAL' / Operational Mode
HIERARCH ESO DET DID          = 'ESO-VLT-DIC.IRACE-1.34' / Dictionary Name and Re
HIERARCH ESO DET DIT          = 10.0000000 / Integration Time
HIERARCH ESO DET DITDELAY     = 0.000 / Pause Between DITs
HIERARCH ESO DET EXP NAME     = 'VIRCAM_GEN_STD030_0001' / Exposure Name
HIERARCH ESO DET EXP NO       = 3 / Exposure number
HIERARCH ESO DET EXP UTC      = '2006-01-30T13:54:47.7333' / File Creation Time
HIERARCH ESO DET FRAM NO      = 1 / Frame number
HIERARCH ESO DET FRAM TYPE    = 'INT' / Frame type
HIERARCH ESO DET FRAM UTC     = '2006-01-30T13:54:46.7037' / Time Recv Frame
HIERARCH ESO DET IRACE ADC1 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC1 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC1 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC1 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC1 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC1 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC10 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC10 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC10 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC10 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC10 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC10 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC11 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC11 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC11 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC11 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC11 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC11 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC12 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC12 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC12 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC12 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC12 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC12 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC13 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC13 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC13 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC13 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC13 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC13 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC14 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC14 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC14 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC14 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC14 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC14 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC15 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC15 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC15 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC15 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC15 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC15 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC16 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC16 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC16 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC16 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC16 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC16 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC2 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC2 ENABLE= 1 / Enable ADC Board (0/1)

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HIERARCH ESO DET IRACE ADC2 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC2 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC2 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC2 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC3 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC3 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC3 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC3 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC3 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC3 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC4 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC4 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC4 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC4 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC4 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC4 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC5 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC5 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC5 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC5 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC5 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC5 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC6 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC6 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC6 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC6 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC6 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC6 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC7 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC7 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC7 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC7 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC7 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC7 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC8 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC8 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC8 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC8 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC8 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC8 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE ADC9 DELAY= 7 / ADC Delay Adjustment
HIERARCH ESO DET IRACE ADC9 ENABLE= 1 / Enable ADC Board (0/1)
HIERARCH ESO DET IRACE ADC9 FILTER1= 0 / ADC Filter1 Adjustment
HIERARCH ESO DET IRACE ADC9 FILTER2= 0 / ADC Filter2 Adjustment
HIERARCH ESO DET IRACE ADC9 HEADER= 1 / Header of ADC Board
HIERARCH ESO DET IRACE ADC9 NAME= 'VISTA-AQ-GRP' / Name for ADC Board
HIERARCH ESO DET IRACE SEQCONT= 'F' / Sequencer Continuous Mode
HIERARCH ESO DET MINDIT      = 1.0011000 / Minimum DIT
HIERARCH ESO DET MODE NAME   = '' / DCS Detector Mode
HIERARCH ESO DET NCORRS      = 2 / Read-Out Mode
HIERARCH ESO DET NCORRS NAME = 'Double' / Read-Out Mode Name
HIERARCH ESO DET NDIT        = 1 / # of Sub-Integrations
HIERARCH ESO DET NDITSKIP     = 0 / DITs skipped at 1st.INT
HIERARCH ESO DET RSPEED      = 1 / Read-Speed Factor
HIERARCH ESO DET RSPEEDADD    = 0 / Read-Speed Add
HIERARCH ESO DET VOLT1 CLKHI1= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI10= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI11= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI12= 5.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI13= 1.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI14= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI15= 0.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI16= 2.5000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI2= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI3= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI4= 5.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI5= 1.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI6= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI7= 0.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI8= 2.5000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHI9= 4.0000 / Set Value High-Clock
HIERARCH ESO DET VOLT1 CLKHINM1= 'clk1Hi pmc' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM10= 'clk10Hi FrameStart' / Name of High-Clock

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HIERARCH ESO DET VOLT1 CLKHINM11= 'clk11Hi UcResetEnable' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM12= 'clk12Hi VHiRowEnable' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM13= 'clk13Hi VLoRowEnable' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM14= 'clk14Hi VHiReset' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM15= 'clk15Hi VLoReset' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM16= 'clk16Hi VpOut' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM2= 'clk2Hi FrameStart' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM3= 'clk3Hi UcResetEnable' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM4= 'clk4Hi VHiRowEnable' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM5= 'clk5Hi VLoRowEnable' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM6= 'clk6Hi VHiReset' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM7= 'clk7Hi VLoReset' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM8= 'clk8Hi VpOut' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHINM9= 'clk9Hi pmc' / Name of High-Clock
HIERARCH ESO DET VOLT1 CLKHIT1= 4.0283 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT10= 4.0234 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT11= 4.0234 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT12= 5.0244 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT13= 1.0352 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT14= 4.0283 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT15= 0.0439 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT16= 2.5293 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT2= 4.0283 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT3= 4.0283 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT4= 5.0195 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT5= 1.0352 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT6= 4.0332 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT7= 0.0439 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT8= 2.5293 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKHIT9= 4.0430 / Tel Value High-Clock
HIERARCH ESO DET VOLT1 CLKLO1= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO10= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO11= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO12= 5.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO13= 1.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO14= 4.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO15= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO16= 9.7500 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO2= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO3= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO4= 5.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO5= 1.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO6= 4.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO7= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO8= 9.7500 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLO9= 0.0000 / Set value Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM1= 'clk1Lo pmc' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM10= 'clk10Lo FrameStart' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM11= 'clk11Lo UcResetEnable' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM12= 'clk12Lo VHiRowEnable' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM13= 'clk13Lo VLoRowEnable' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM14= 'clk14Lo VHiReset' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM15= 'clk15Lo VLoReset' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM16= 'clk16Lo VpOut' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM2= 'clk2Lo FrameStart' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM3= 'clk3Lo UcResetEnable' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM4= 'clk4Lo VHiRowEnable' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM5= 'clk5Lo VLoRowEnable' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM6= 'clk6Lo VHiReset' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM7= 'clk7Lo VLoReset' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM8= 'clk8Lo VpOut' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLONM9= 'clk9Lo pmc' / Name of Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT1= 0.0391 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT10= 0.0391 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT11= 0.0439 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT12= 4.9609 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT13= 1.0254 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT14= 4.0283 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT15= 0.0342 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT16= 9.4824 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT2= 0.0391 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT3= 0.0293 / Tel Value Low-Clock
HIERARCH ESO DET VOLT1 CLKLOT4= 4.9609 / Tel Value Low-Clock

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HIERARCH ESO DET VOLT1 CLKLOT5= 1.0303 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT1 CLKLOT6= 4.0234 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT1 CLKLOT7= 0.0342 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT1 CLKLOT8= 9.4775 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT1 CLKLOT9= 0.0439 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT1 DC1 = -2.3600 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC10 = -3.3500 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC11 = 0.0000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC12 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC13 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC14 = 3.5000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC15 = 2.2000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC16 = 3.3000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC2 = -3.3500 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC3 = 0.0000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC4 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC5 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC6 = 3.5000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC7 = 2.2000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC8 = 3.3000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DC9 = -2.3600 / Set value DC-Voltage
 HIERARCH ESO DET VOLT1 DCNM1 = 'DC1 VIdle' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM10= 'DC10 VSlew' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM11= 'DC11 VRstUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM12= 'DC12 VDetCom' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM13= 'DC13 VnUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM14= 'DC14 VpUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM15= 'DC15 VnOut' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM16= 'DC16 RefBias' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM2 = 'DC2 VSlew' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM3 = 'DC3 VRstUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM4 = 'DC4 VDetCom' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM5 = 'DC5 VnUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM6 = 'DC6 VpUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM7 = 'DC7 VnOut' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM8 = 'DC8 RefBias' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCNM9 = 'DC9 VIdle' / Name of DC-voltage
 HIERARCH ESO DET VOLT1 DCTA1 = -2.3633 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA10= -3.3594 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA11= 0.0000 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA12= 0.7031 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA13= 0.7031 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA14= 3.5010 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA15= 2.1973 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA16= 3.3008 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA2 = -3.3545 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA3 = 0.0049 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA4 = 0.6982 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA5 = 0.6982 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA6 = 3.5010 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA7 = 2.1973 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA8 = 3.2959 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTA9 = -2.3682 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT1 DCTB1 = -2.3535 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB10= -3.3203 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB11= 0.0000 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB12= 0.6982 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB13= 0.7031 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB14= 3.5010 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB15= 2.1826 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB16= 3.2959 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB2 = -3.3154 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB3 = 0.0000 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB4 = 0.6982 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB5 = 0.6982 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB6 = 3.4961 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB7 = 2.1826 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB8 = 3.2959 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT1 DCTB9 = -2.3584 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT2 CLKHI1= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI10= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI11= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI12= 5.0000 / Set Value High-Clock

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HIERARCH ESO DET VOLT2 CLKHI13= 1.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI14= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI15= 0.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI16= 2.5000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI2= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI3= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI4= 5.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI5= 1.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI6= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI7= 0.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI8= 2.5000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHI9= 4.0000 / Set Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM1= 'clk1Hi pmc' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM10= 'clk10Hi FrameStart' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM11= 'clk11Hi UcResetEnable' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM12= 'clk12Hi VHiRowEnable' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM13= 'clk13Hi VLoRowEnable' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM14= 'clk14Hi VHiReset' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM15= 'clk15Hi VLoReset' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM16= 'clk16Hi VpOut' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM2= 'clk2Hi FrameStart' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM3= 'clk3Hi UcResetEnable' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM4= 'clk4Hi VHiRowEnable' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM5= 'clk5Hi VLoRowEnable' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM6= 'clk6Hi VHiReset' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM7= 'clk7Hi VLoReset' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM8= 'clk8Hi VpOut' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHINM9= 'clk9Hi pmc' / Name of High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT1= 4.0283 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT10= 4.0234 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT11= 4.0186 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT12= 5.0098 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT13= 1.0400 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT14= 4.0283 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT15= 0.0488 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT16= 2.5342 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT2= 4.0234 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT3= 4.0283 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT4= 5.0195 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT5= 1.0352 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT6= 4.0283 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT7= 0.0488 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT8= 2.5342 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKHIT9= 4.0430 / Tel Value High-Clock
 HIERARCH ESO DET VOLT2 CLKLO1= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO10= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO11= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO12= 5.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO13= 1.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO14= 4.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO15= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO16= 9.7500 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO2= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO3= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO4= 5.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO5= 1.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO6= 4.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO7= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO8= 9.7500 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLO9= 0.0000 / Set value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM1= 'clk1Lo pmc' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM10= 'clk10Lo FrameStart' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM11= 'clk11Lo UcResetEnable' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM12= 'clk12Lo VHiRowEnable' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM13= 'clk13Lo VLoRowEnable' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM14= 'clk14Lo VHiReset' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM15= 'clk15Lo VLoReset' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM16= 'clk16Lo VpOut' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM2= 'clk2Lo FrameStart' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM3= 'clk3Lo UcResetEnable' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM4= 'clk4Lo VHiRowEnable' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM5= 'clk5Lo VLoRowEnable' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM6= 'clk6Lo VHiReset' / Name of Low-Clock

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HIERARCH ESO DET VOLT2 CLKLONM7= 'clk7Lo VLoReset' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM8= 'clk8Lo VpOut' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLONM9= 'clk9Lo pmc' / Name of Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT1= 0.0537 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT10= 0.0488 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT11= 0.0439 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT12= 4.9512 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT13= 1.0352 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT14= 4.0234 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT15= 0.0439 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT16= 9.4678 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT2= 0.0488 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT3= 0.0488 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT4= 4.9609 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT5= 1.0449 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT6= 4.0283 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT7= 0.0488 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT8= 9.4678 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 CLKLOT9= 0.0586 / Tel Value Low-Clock
 HIERARCH ESO DET VOLT2 DC1 = -2.3600 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC10 = -3.3500 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC11 = 0.0000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC12 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC13 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC14 = 3.5000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC15 = 2.2000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC16 = 3.3000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC2 = -3.3500 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC3 = 0.0000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC4 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC5 = 0.7000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC6 = 3.5000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC7 = 2.2000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC8 = 3.3000 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DC9 = -2.3600 / Set value DC-Voltage
 HIERARCH ESO DET VOLT2 DCNM1 = 'DC1 VIdle' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM10= 'DC10 VSlew' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM11= 'DC11 VRstUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM12= 'DC12 VDetCom' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM13= 'DC13 VnUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM14= 'DC14 VpUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM15= 'DC15 VnOut' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM16= 'DC16 RefBias' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM2 = 'DC2 VSlew' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM3 = 'DC3 VRstUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM4 = 'DC4 VDetCom' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM5 = 'DC5 VnUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM6 = 'DC6 VpUc' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM7 = 'DC7 VnOut' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM8 = 'DC8 RefBias' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCNM9 = 'DC9 VIdle' / Name of DC-voltage
 HIERARCH ESO DET VOLT2 DCTA1 = -2.3535 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA10= -3.3447 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA11= 0.0049 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA12= 0.7031 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA13= 0.7031 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA14= 3.4961 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA15= 2.1973 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA16= 3.2959 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA2 = -3.3447 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA3 = 0.0049 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA4 = 0.6982 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA5 = 0.6982 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA6 = 3.4961 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA7 = 2.1973 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA8 = 3.2959 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTA9 = -2.3535 / Tel Value 1 for DC
 HIERARCH ESO DET VOLT2 DCTB1 = -2.3438 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT2 DCTB10= -3.3057 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT2 DCTB11= 0.0049 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT2 DCTB12= 0.6982 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT2 DCTB13= 0.7031 / Tel Value 2 for DC
 HIERARCH ESO DET VOLT2 DCTB14= 3.4912 / Tel Value 2 for DC

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HIERARCH ESO DET VOLT2 DCTB15= 2.1826 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB16= 3.2910 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB2 = -3.3057 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB3 = 0.0049 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB4 = 0.6982 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB5 = 0.6982 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB6 = 3.4912 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB7 = 2.1777 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB8 = 3.2910 / Tel Value 2 for DC
HIERARCH ESO DET VOLT2 DCTB9 = -2.3438 / Tel Value 2 for DC
HIERARCH ESO DET WIN NX      = 2048 / # of Pixels in X
HIERARCH ESO DET WIN NY      = 2048 / # of Pixels in Y
HIERARCH ESO DET WIN STARTX  = 1 / Lower left X ref
HIERARCH ESO DET WIN STARTY  = 1 / Lower left Y ref
HIERARCH ESO DET WIN TYPE    = 0 / Win-Type: 0=SW/1=HW
INHERIT = T / Extension inherits primary header
PV2_1   = 1. / WCS parameter value term
PV2_2   = 0. / WCS parameter value term
PV2_3   = 42. / WCS parameter value term
PV2_4   = 0. / WCS parameter value term
PV2_5   = 0. / WCS parameter value term
END

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