The VISTA Extragalactic Infrared Legacy Survey (VEILS) DR1

Abstract

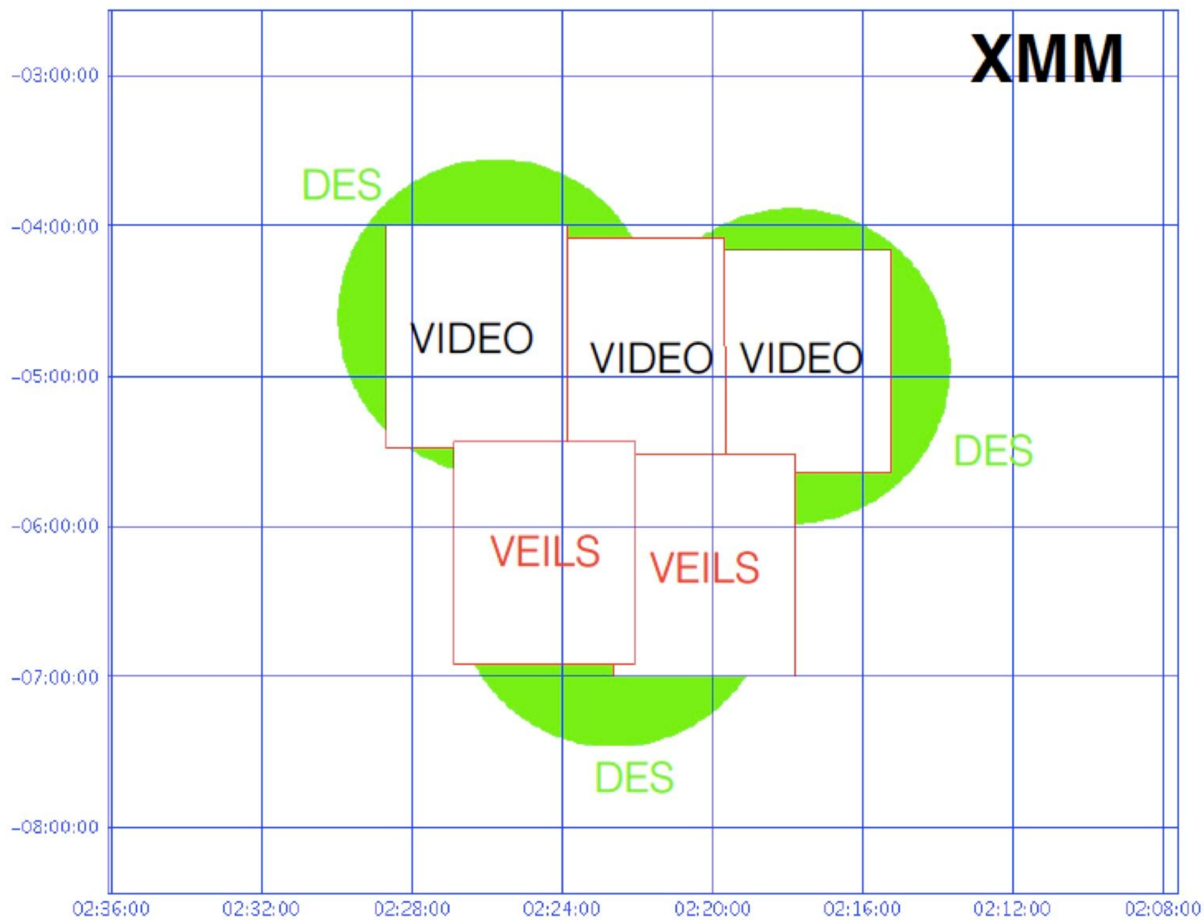
The VISTA Extragalactic Infrared Legacy Survey (VEILS; Program ID:198.A-2005) is a deep J and Ks-band transient and wide-field survey being conducted using the VIRCAM camera with the primary goals of understanding the epoch of reionisation, the build-up of massive galaxies, and constraining the cosmological equation of state using both Type 1a supernovae and AGN dust lag measurements. VEILS is covering 9 sq-deg of the extragalactic sky over three fields: ES1 (RA=00h30m, Dec=-43d00m), CDFS (RA=03h36m, Dec=-28d00m) and XMM-LSS (RA=02h22m, Dec=-06d00m). Each field requires two separate pointings of the camera to image. A total of 14-16 epochs are required per year per field for the transient science and by the end of the survey we expect around 30-40 epochs of observations per field. The single epoch depth requirements dictated by the transient science mean only half-tiles (i.e. 3 pawprints) are observed as part of a single ESO Observing Block (OB).

The current and first data release comprises of pawprints (239 in J-band, 225 in K-band) and stacked images of each pawprint (72 in total: 36 per filter over the 3 fields) together with associated confidence maps and single-band J and Ks catalogues. The number of epochs varies for each pointing. We also release band-merged J and Ks cross-matched catalogues for each of the 36 pawprints.

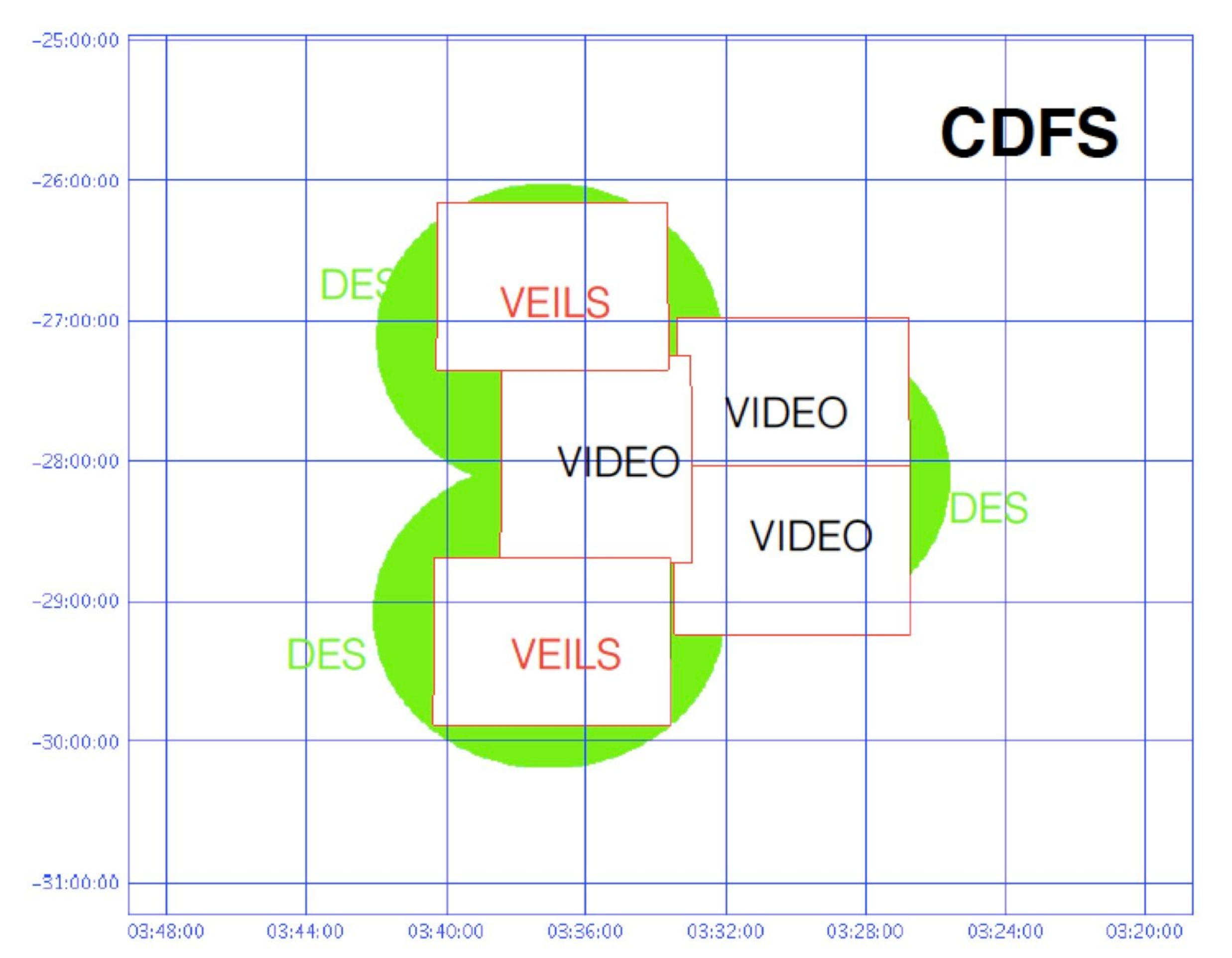
Overview of Observations

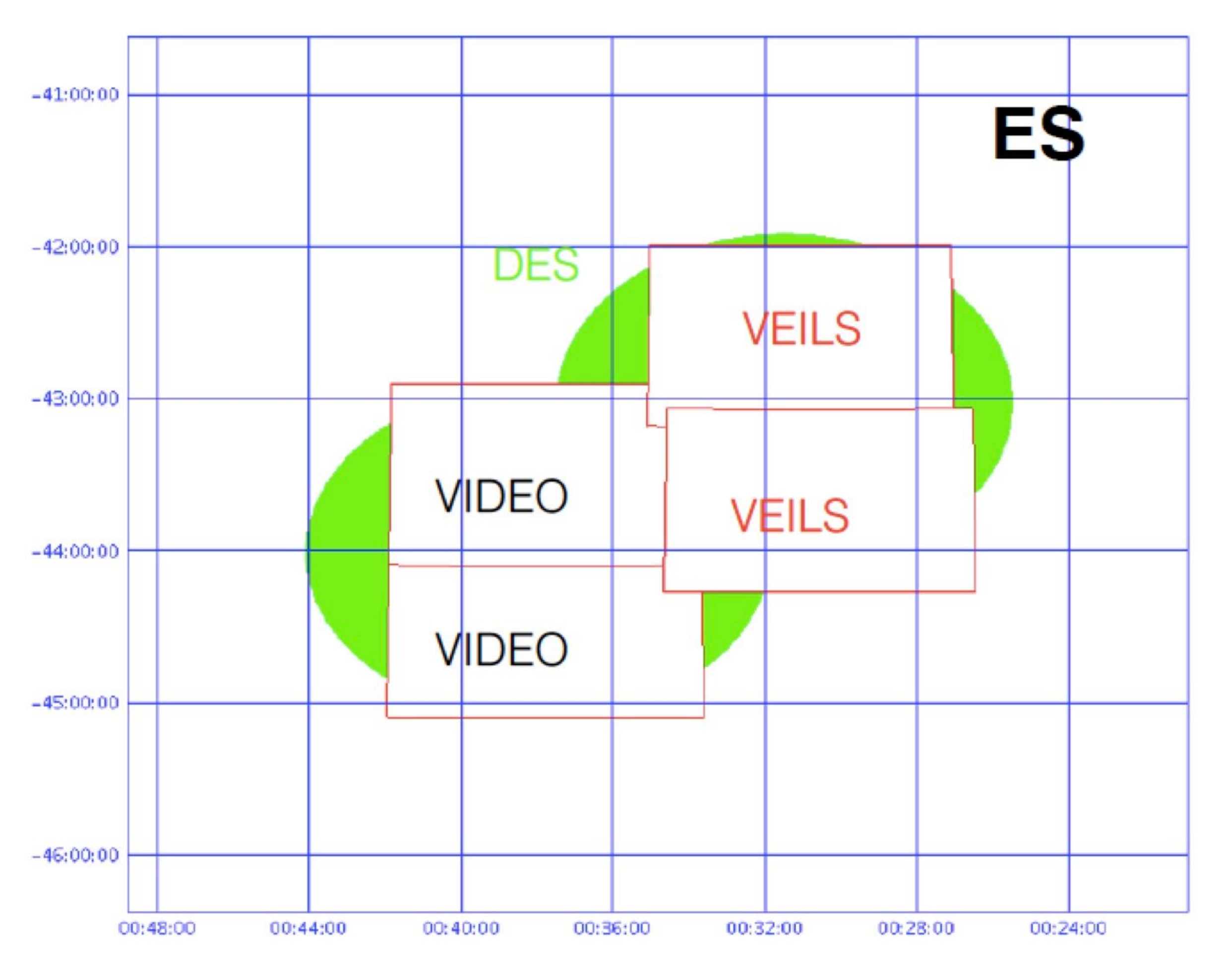
The VEILS observations are conducted in three separate extragalactic fields (XMM-LSS, CDFS and ELAIS-S1. Each field is imaged with two pointings of the VIRCAM camera. VEILS extends the near infra-red coverage of these fields already obtained as part of the ESO VIDEO survey (Jarvis et al. 2013). It is also designed to complement optical observations in these fields obtained as part of the Dark Energy Survey (DES). The VEILS field locations together with the VIDEO and DES field locations are shown below.

VEILS is imaging all fields in the J and Ks-bands over multiple epochs. In this data release we provide the single epoch photometry from the stacked pawprints in both filters in all fields.



XMM
DES
VIDEO
VIDEO
VIDEO
DES
VEILS
VEILS
DES
−03:00:00
−04:00:00
−05:00:00
−06:00:00
−07:00:00
−08:00:00
02:36:00
02:32:00
02:28:00
02:24:00
02:20:00
02:16:00
02:12:00
02:08:00


CDFS
DES
VEILS
VIDEO
VIDEO
VIDEO
DES
DES
VEILS
-25:00:00
-26:00:00
-27:00:00
-28:00:00
-29:00:00
-30:00:00
-31:00:00
03:48:00
03:44:00
03:40:00
03:36:00
03:32:00
03:28:00
03:24:00
03:20:00



Release Content

This first data release comprises of pawprints (239 in J-band, 225 in K-band) and stacked images of each pawprint (72 in total: 36 per filter over the 3 fields) together with associated confidence maps and single-band J and Ks catalogues. We also release band-merged J and Ks cross-matched catalogues for each of the 36 pawprints. This data release covers the period from 2016-10-22 to 2017-09-25 (P98-P99).

There are 1966880 sources in the band-merged catalogues in total in this release.

Field	RA	Dec	Band	Limiting AB Magnitude (5 σ)	Average Seeing	Number of epochs
ES1 Pointing 1 3px p0	7.717	-42.49	J	23.5	2.6	12
ES1 Pointing 1 3px p1	7.717	-42.58	J	23.5	2.4	12
ES1 Pointing 1 3px p2	7,717	-42.68	J	23.5	2.5	12
ES1 Pointing 1 3px p0	7.728	-42.48	Ks	22.5	3.0	11
ES1 Pointing 1 3px p1	7.727	-42.58	Ks	22.5	3.1	11
ES1 Pointing 1 3px p2	7.727	-42.67	Ks	22.5	2.8	11
ES1 Pointing 1 3nx p0	7.967	-42.49	J	23.5	3.0	13
ES1 Pointing 1 3nx p1	7.967	-42.58	J	23.5	3.0	13
ES1 Pointing 1 3nx p2	7.968	-42.67	J	23.5	2.7	13
ES1 Pointing 1 3nx p0	7.974	-42.49	Ks	22.5	3.1	13
ES1 Pointing 1 3nx p1	7.974	-42.58	Ks	22.6	3.5	13
ES1 Pointing 1 3nx p2	7.975	-42.67	Ks	22.6	2.9	13
ES1 Pointing 2 3px p0	7.975	-43.75	J	23.3	2.3	9
ES1 Pointing 2 3px p1	7.975	-43.66	J	23.3	2.4	9
ES1 Pointing 2 3px p2	7.974	-43.57	J	23.3	2.5	9
ES1 Pointing 2 3px p0	7.970	-43.75	Ks	22.3	2.3	8
ES1 Pointing 2 3px p1	7.969	-43.66	Ks	22.3	2.4	8
ES1 Pointing 2 3px p2	7.969	-43.57	Ks	22.4	2.3	8
ES1 Pointing 2 3nx p0	7.722	-43.75	J	23.2	2.3	8
ES1 Pointing 2 3nx p1	7.722	-43.66	J	23.3	2.3	8
ES1 Pointing 2 3nx p2	7.722	-43.57	J	23.3	2.1	8
ES1 Pointing 2 3nx p0	7.723	-43.75	Ks	22.1	1.9	8
ES1 Pointing 2 3nx p1	7.723	-43.66	Ks	22.2	1.9	8
ES1 Pointing 2 3nx p2	7.723	-43.57	Ks	22.2	1.8	8

CDFS Pointing 1 3px p0	54.129	-26.84	J	22.9	3.4	4
CDFS Pointing 1 3px p1	54.129	-26.75	J	23.0	3.1	4
CDFS Pointing 1 3px p2	54.129	-26.66	J	23.0	2.7	4
CDFS Pointing 1 3px p0	54.134	-26.84	Ks	21.9	2.8	3
CDFS Pointing 1 3px p1	54.134	-26.75	Ks	21.8	3.5	3
CDFS Pointing 1 3px p2	54.134	-26.65	Ks	21.8	3.6	3
CDFS Pointing 1 3nx p0	53.931	-26.84	J	23.2	2.6	5
CDFS Pointing 1 3nx p1	53.931	-26.74	J	23.2	2.5	5
CDFS Pointing 1 3nx p2	53.931	-26.65	J	23.2	2.3	5
CDFS Pointing 1 3nx p0	53.927	-26.84	Ks	22.0	2.9	4
CDFS Pointing 1 3nx p1	53.927	-26.75	Ks	22.0	3.1	4
CDFS Pointing 1 3nx p2	53.928	-26.66	Ks	22.0	3.3	4
CDFS Pointing 2 3px p0	54.132	-29.38	J	22.8	2.4	2
CDFS Pointing 2 3px p1	54.132	-29.28	J	22.9	2.5	2
CDFS Pointing 2 3px p2	54.131	-29.19	J	22.8	2.6	2
CDFS Pointing 2 3px p0	54.142	-29.38	Ks	21.6	2.6	2
CDFS Pointing 2 3px p1	54.142	-29.28	Ks	21.6	2.5	2
CDFS Pointing 2 3px p2	54.141	-29.19	Ks	21.6	2.5	2
CDFS Pointing 2 3nx p0	53.930	-29.37	J	23.0	2.4	3
CDFS Pointing 2 3nx p1	53.930	-29.28	J	23.0	2.4	3
CDFS Pointing 2 3nx p2	53.931	-29.19	J	23.0	2.5	3
CDFS Pointing 2 3nx p0	53.927	-29.38	Ks	21.7	2.4	2
CDFS Pointing 2 3nx p1	53.927	-29.28	Ks	21.6	2.3	2
CDFS Pointing 2 3nx p2	53.927	-29.19	Ks	21.7	2.4	2
XMM Pointing 1 3px p0	36.088	-6.11	J	22.7	2.1	6
XMM Pointing 1 3px p1	36.090	-6.11	J	23.2	2.2	6

XMM Pointing 1 3px p2	35.998	-6.11	J	23.2	2.1	6
XMM Pointing 1 3px p0	36.088	-6.11	Ks	22.2	2.3	6
XMM Pointing 1 3px p1	35.996	-6.11	Ks	22.2	2.1	6
XMM Pointing 1 3px p2	35.904	-6.11	Ks	22.2	2.1	6
XMM Pointing 1 3nx p0	36.091	-6.29	J	23.2	2.1	6
XMM Pointing 1 3nx p1	35.999	-6.29	J	23.2	2.2	6
XMM Pointing 1 3nx p2	35.907	-6.29	J	23.1	2.3	6
XMM Pointing 1 3nx p0	36.094	-6.30	Ks	22.2	2.6	6
XMM Pointing 1 3nx p1	36.002	-6.30	Ks	22.2	2.5	6
XMM Pointing 1 3nx p2	35.909	-6.30	Ks	22.3	2.3	6
XMM Pointing 2 3px p0	35.097	-6.03	J	23.0	4.4	6
XMM Pointing 2 3px p1	35.004	-6.03	J	23.0	3.6	6
XMM Pointing 2 3px p2	34.912	-6.03	J	23.1	3.1	6
XMM Pointing 2 3px p0	35.091	-6.02	Ks	22.1	2.7	6
XMM Pointing 2 3px p1	34.999	-6.02	Ks	22.1	2.6	6
XMM Pointing 2 3px p2	34.907	-6.02	Ks	22.1	2.9	6
XMM Pointing 2 3nx p0	35.094	-6.20	J	23.1	1.9	5
XMM Pointing 2 3nx p1	35.002	-6.20	J	23.1	1.9	5
XMM Pointing 2 3nx p2	34.910	-6.20	J	23.1	1.9	5
XMM Pointing 2 3nx p0	35.096	-6.20	Ks	22.0	3.4	6
XMM Pointing 2 3nx p1	35.003	-6.20	Ks	22.1	3.6	6
XMM Pointing 2 3nx p2	34.911	-6.20	Ks	22.1	3.4	6

Release Notes

Data Reduction and Calibration

This data release is based on the CASU version v1.5 pipeline. Full details of the data pipeline procedure and the version changes can be found at:
http://apm49.ast.cam.ac.uk/surveys-projects/vista/data-processing/

The photometric and astrometric calibrations are both derived from the 2MASS Point Source Catalogue. The photometric calibration includes an additional colour term designed to correct for the effect of interstellar extinction on the 2MASS to VISTA/VIRCAM photometric transformations. Magnitudes are in a Vega-like system, and absolute zero point offsets and AB transformation can be found in Gonzalez Fernandez et al., 2018.

The CASU pipeline derives aperture photometry for all detected sources on each image. Detection criteria require potential sources to have 4 adjacent pixels that are above 1.25 times the local background dispersion. Magnitudes are aperture-corrected using a curve-of-growth method, and in the case of mosaic images, each source has had a correction applied that compensates the seeing variation in the individual pawprint images that make the mosaic. This process is known as grouting, and more detail can be found in Gonzalez Fernandez et al., 2018.

The photometric catalogues contain calibrated aperture photometry, the limiting magnitudes correspond to the aperture photometry and the saturation limit for the point sources.

Data Quality

Detailed information about pipeline performance can be found in Gonzalez Fernandez et al., 2018. Photometric consistency in J and Ks is of 2% for the linear dynamic range of the instrument. Astrometric errors are of around 50 mas for stacked pawprints.

No systematic errors are detected at these levels, either in astrometry or photometry, except for known issues detailed in the next section.

Stacked pawprints are visually inspected both for stacking errors and variations in sky background.

Data Catalogues

Multiband merges are done using J photometry as the reference frame. The WCS information contained in the catalogues is used to define a standard coordinate transformation between J and Ks as the basis for further refinement of the differential astrometry and subsequent matching. The matching is done iteratively in three passes using progressively smaller maximum search radii and progressively fainter sets of objects. At each iteration the standard coordinates of the comparison catalogues are robustly matched to the reference set by computing an updated standard 6 coordinate linear differential "plate" transform. Matching uses a binary search algorithm to flag all matches within the search radius and the nearest flagged object defines the best match. The final pass uses a 2.5 arcsec search radius.

Known issues

VIRCAM is host to a set of issues like "holes" in chip #1 and anomalous response of the top half of chip #16. These are detailed in Sutherland et al.2015, A&A, 575, A25.

Previous Releases:

N/A

Data Format

Files Types

There are 7 types of files, all in FITS format. Single pawprint images (file names ending with _st.fits.fz) and associated weight maps (file names ending with _st_conf.fits.fz) and associated catalogues (file names ending with _st_cat.fits). There are also deep-stack pawprint images (file names ending in "_p0.fits.fz" or "_p1_fits.fz" or "_p2.fits.fz"), associated weight maps (file names ending in "p?_conf.fits.fz") and pawprint catalogues (file names ending in "p?_cat.fits"), and merged catalogues containing the J and Ks band magnitudes of the sources per pawprint (file names ending in "p?_cat_mer.fits"). The nx and px in the names are the "positive" and "negative" offsets of the half-tiles with 3 pointings each; p0, p1, p2.

Catalogue Columns

More information is available at
http://casu.ast.cam.ac.uk/surveys-projects/vista/technical/catalogue-generation

Below are the catalogue columns for pawprint catalogues (except column 63; see explanation in the table) and deep-stack catalogues.

No.	Name	Column Description
1	Seq No.	running number for ease of reference, in strict order of image detections
2	Isophotal flux	standard definition of summed flux within detection isophote, apart from detection filter is used to define pixel connectivity and hence which pixels to include. This helps to reduce edge effects for all isophotally derived parameters.
3	X coord	intensity–weighted isophotal centre–of–gravity in X
4	Error in X	estimate of centroid error
5	Y coord	intensity–weighted isophotal centre–of–gravity in Y
6	Error in Y	estimate of centroid error
7	Gaussian sigma	these are derived from the three general intensity–weighted second moments
8	Ellipticity	the equivalence between them and a generalised elliptical Gaussian
9	Position angle	
10	Areal profile 1	number of pixels above a series of threshold levels relative to local sky.
11	Areal profile 2	levels are set at T, 2T, 4T, 8T . . . 128T where T is the threshold. These
12	Areal profile 3	can be thought of as a sort of poor man's radial profile. Note that for now
13	Areal profile 4	deblended, i.e. overlapping images, only the first areal profile is computed
14	Areal profile 5	and the rest are set to –1 flagging the difficulty of computing accurate
15	Areal profile 6	profiles
16	Areal profile 7	
17	Areal profile 8	for blended images this parameter is used to flag the start of the sequence of the deblended components by setting the first in the sequence to 0
18	Peak height	in counts relative to local value of sky - also zeroth order aperture flux
19	Error in pkht	

20	Aperture flux 1	These are a series of different radii soft-edged apertures designed to adequately sample the curve-of-growth of the majority of images and to provide fixed-sized aperture fluxes for all images. The scale size for these apertures is selected by defining a scale radius <FWHM> for site+instrument. In the case of VIRCAM this “core” radius (rcore) has been fixed at 1.0 arcsec for convenience in inter-comparison with other datasets. A 1.0 arcsec radius is equivalent to 3.0 pixels for normal data. In 0.8 arcsec seeing an rcore-radius aperture contains roughly 75% of the total flux of stellar images. [In general the rcore parameter is user specifiable and hence is recorded in the output catalogue FITS header.] The aperture fluxes are sky-corrected integrals (summations) with a soft-edge (ie. pro-rata flux division for boundary pixels). However, for overlapping images they are more subtle than this since they are in practice simultaneously fitted top-hat functions, to minimise the effects of crowding. Images external to the blend are also flagged and not included in the large radius summations.
21	Error in flux	
22	Aperture flux 2	
23	Error in flux	
24	Aperture flux 3	Recommended if a single number is required to represent the flux for ALL
25	Error in flux	images - this aperture has a radius of rcore.
26	Aperture flux 4	
27	Error in flux	Starting with parameter 20 the radii are: 1/2× rcore, 1/sqrt(2)× rcore, rcore, sqrt(2)× rcore, 2× rcore, 2sqrt(2)× rcore, 4× rcore, 5× rcore, 6× rcore, 7× rcore,
28	Aperture flux 5	8× rcore, 10× rcore, 12× rcore
29	Error in flux	
30	Aperture flux 6	Note 4× rcore, ensures ~ 99% of PSF flux
31	Error in flux	
32	Aperture flux 7	extras for generalised galaxy photometry further spaced
33	Error in flux	
34	Aperture flux 8	in radius to ensure reasonable sampling further out.
35	Error in flux	
36	Aperture flux 9	
37	Error in flux	
38	Aperture flux 10	Note these are all corrected for pixels from overlapping neighbouring images
39	Error in flux	
40	Aperture flux 11	

41	Error in flux	
42	Aperture flux 12	
43	Error in flux	
44	Aperture flux 13	The biggest with radius 12× rcore ie. about 24 arcsec diameter
45	Error in flux	The aperture fluxes can be combined with later-derived aperture corrections for general purpose photometry and together with parameter 18 (the peak flux) give a simple curve–of–growth measurement which forms the basis of the morphological classification scheme
46	Petrosian radius	rp as defined in Yasuda et al. 2001 AJ 112 1104
47	Kron radius	rk as defined in Bertin and Arnouts 1996 A&A Supp 117 393
48	Half-light radius	rh estimate of half-light radius
49	Petrosian flux	flux within circular aperture to k x rp with k=2
50	Error in flux	
51	Kron flux	flux within circular aperture to k x rk with k=2
52	Error in flux	
53	Half-light flux	flux within circular aperture to k x rh with k=1
54	Error in flux	
55	Error bit flag	bit pattern listing various processing error flags initially set to the no. of bad pixels within aperture of radius "rcore" - note this can be fractional due to soft-edged apertures
56	Sky level	local interpolated sky level from background tracker
57	Sky rms	local estimate of variation in sky level around image
58	Av conf	average confidence level within default rcore aperture useful for spotting spurious outliers in various parameter selection spaces
		The following are accreted after standard catalog generation
59	RA	RA and Dec explicitly put in columns for overlay programs that cannot,
60	Dec	in general, understand astrometric solution coefficients – note r*4 storage precision accurate only to ~ 50mas. Astrometry can be derived more precisely from WCS in header and XY in parameters 5 & 6
61	Classification	Flag indicating most probable morphological classification: eg. –1 stellar, +1 non–stellar, 0 noise, –2 borderline stellar (Saturated images can be flagged by comparing the peak height + local sky with the SATURATE keyword in the header.)
62	Statistic	An equivalent N(0,1) measure of how stellar–like an image is, used in deriving parameter 61 in a 'necessary but not sufficient' sense. Derived mainly from the curve-of-growth of flux using the well-defined stellar locus as a function of magnitude as a benchmark

		(see Irwin et al. 1994 SPIE 5493 411 for more details).
63	MJDOff	**For tile catalogues only (not part of this release)** this column represents the median MJD offset of the object with respect to the MJD of the day of observation (recorded in the header as MJD_DAY).
64	Blank64	
65	Blank65	
66	Blank66	
67	Blank67	
68	Blank68	
69	Blank69	
70	Blank70	
71	Blank71	
72	Blank72	
73	Blank73	
74	Blank74	
75	Blank75	
76	Blank76	
77	Blank77	
78	Blank78	
79	Blank79	
80	Blank80	

Below are the columns of the band merged catalogues.

1	Std_coord_Xi	Standard coordinate of the object in arcsec in the reference catalogue (as in REFFILE keyword)

2	Std_coord_Xn	Standard coordinate of the object in arcsec in the reference catalogue (as in REFFILE keyword)
3	Ref_core_fluxap	Flux at APCOR3 aperture in reference catalogue for the object
4	Ref_flux_error	Error in flux at APCOR3 aperture in reference catalogue for the object
5	Ref_class	Classification statistic for the object in the reference catalogue
6	Ref_pointer	ID number of object in the reference catalogue
7	Del_Xi_1	Distance in Xi for the object between reference and comparison catalogues (as in COMFILE keyword)
8	Del_Xn_1	Distance in Xn for the object between reference and comparison catalogues (as in COMFILE keyword)
9	Com1_core_fluxap	Flux at APCOR3 aperture in comparison catalogue for the object
10	Com1_flux_error	Error in flux at APCOR3 aperture in comparison catalogue for the object
11	Com1_class	
12	Com1_pointer	
13	RA	Celestial coordinates of the object taken from reference catalogue
14	DEC	Celestial coordinates of the object taken from reference catalogue

Acknowledgements

Any publication making use of this data, whether obtained from the ESO archive or via third parties, must include the following acknowledgment:

- "Based on data products created from observations collected at the European Organisation for Astronomical Research in the Southern Hemisphere under ESO programme 198.A-2005 "

If the access to the ESO Science Archive Facility services was helpful for you research, please include the following acknowledgment:

- "This research has made use of the services of the ESO Science Archive Facility."

Science data products from the ESO archive may be distributed by third parties, and disseminated via other services, according to the terms of the [Creative Commons Attribution 4.0 International license](). Credit to the ESO origin of the data must be acknowledged, and the file headers preserved.