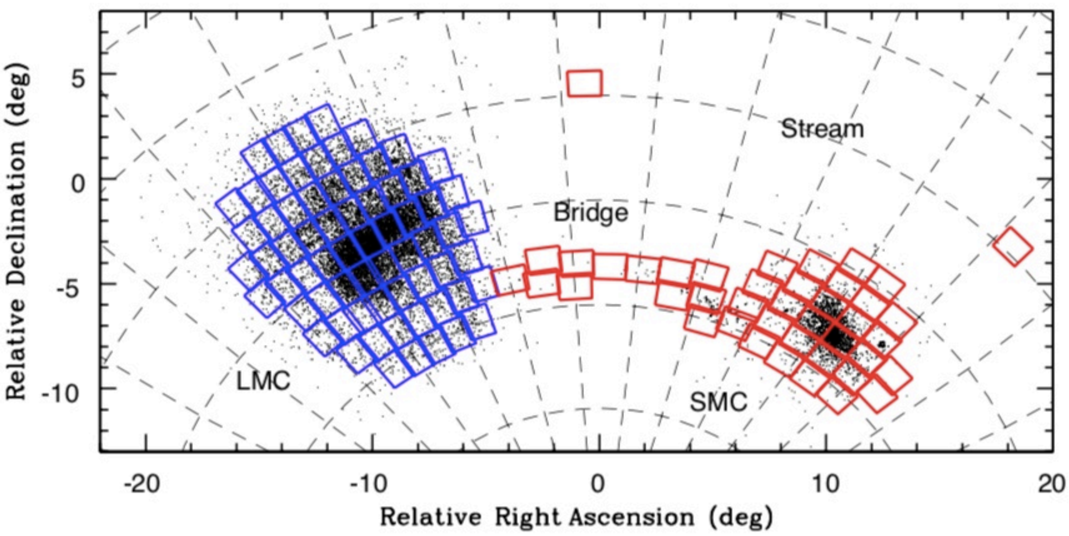
VISTA survey of the Magellanic Clouds system

Abstract

Observations were obtained with the VISTA telescope as part of the VISTA survey of the Magellanic Cloud system (VMC; ESO program 179.B-2003) in three filters: Y, J and K_s. The main goals of the VMC survey are the determination of the spatially resolved star formation history and the three-dimensional geometry of the Magellanic system. The sensitivity of the data is designed to reach sources below the oldest main-sequence turn off point of the stellar population and the multi-epochs to measure accurate K_s mean magnitudes for pulsating variable stars, e.g. RR Lyrae stars and Cepheids.

This data release is based on the observations of 42 VMC survey tiles encompassing the Small Magellanic Clouds (SMC), the Magellanic Bridge and the Magellanic Stream components of the survey. Observations were acquired between February 2010 and October 2016. This release provides reduced and calibrated deep co-added tile images and catalogues (separately for each filter), for both individual tiles and combined, as well as band-merged catalogues. Catalogues with PSF magnitudes, for each tile, are also provided. This release is complementary to the previous release because it refers to additional data products. The total sky coverage of this release is ~40 deg^2 in the SMC, ~ 20 deg^2 in the Bridge and ~3 deg^2 in the Stream.



Overview of Observations

The figure above shows the Magellanic system as tiled by the VMC survey (blue) and tiles for which data are released (red). Underlying small dots indicate the distribution of carbon stars, stellar clusters and associations.

Tile numbering begins from the bottom right corner, increasing from right to left and from bottom to top. The first SMC tile is 2_2, the first Bridge tile is 1_2 and Stream tile 1_1 is right above the Bridge while Stream tile 2_1 is to the right of the SMC.

Each survey tile has at least 2 OBs in Y and J filters, respectively (providing 800 s exposure time per pixel each) and 11 OBs in K_s with 750 s exposure time per pixel each. There are also pairs (YJ, JK_s, and YK_s) of shallow observations corresponding to half the exposure times.

Release Content

This release comprises of first data for 22 tiles in the SMC and 11 tiles in the Bridge, as well as new data for the 5 tiles in the SMC, 2 tiles in the Bridge and 2 tiles in the Stream, previously released, reprocessed with v1.5 of the pipeline.

Tile	RA	DEC	TL_OFFAN
STR 1_1	03:30:03.936	-64:25:23.880	+0.0005
STR 2_1	00:11:59.424	-64:39:30.960	+0.0004
BRI 1_2	01:49:51.432	-74:43:25.320	-16.8805
BRI 1_3	02:11:34.464	-75:05:00.960	-11.6212
BRI 2_3	02:14:46.584	-74:00:47.520	-10.8627
BRI 2_4	02:35:28.440	-74:56:20.400	-5.8932
BRI 2_7	03:39:50.712	-74:04:51.240	+9.5439
BRI 2_8	04:00:21.072	-73:46:37.560	+14.4905
BRI 2_9	04:19:21.528	-73:22:10.560	+19.0897
BRI 3_3	02:17:36.600	-72:56:20.400	-10.2104
BRI 3_4	02:37:26.016	-73:08:16.080	-5.4372
BRI 3_5	02:57:33.288	-73:12:52.200	-0.5877
BRI 3_6	03:17:45.000	-73:10:02.640	+4.2769
BRI 3_7	03:37:39.240	-72:59:54.600	+9.0465
BRI 3_8	03:57:04.968	-72:42:31.680	+13.7448
SMC 2_2	00:21:43.920	-75:12:04.320	-6.7623
SMC 2_3	00:44:35.904	-75:18:13.320	-1.2924
SMC 2_4	01:07:33.864	-75:15:59.760	+4.2022
SMC 2_5	01:30:12.624	-75:05:27.600	+9.6169
SMC 3_1	00:02:39.912	-73:53:31.920	-11.3123
SMC 3_2	00:23:35.544	-74:06:57.240	-6.3137
SMC 3_3	00:44:55.896	-74:12:42.120	-1.2120
SMC 3_4	01:06:21.120	-74:10:38.640	+3.9099
SMC 3_5	01:27:30.816	-74:00:49.320	+8.9671
SMC 3_6	01:48:06.120	-73:43:28.200	+13.8809
SMC 4_1	00:05:33.864	-72:49:12.000	-10.6178
SMC 4_2	00:25:14.088	-73:01:47.640	-5.9198
SMC 4_3	00:45:14.688	-73:07:11.280	-1.1369
SMC 4_4	01:05:19.272	-73:05:15.360	+3.6627
SMC 4_5	01:25:11.016	-72:56:02.040	+8.4087
SMC 4_6	01:44:34.512	-72:39:44.640	+13.0368
SMC 5_2	00:26:41.688	-71:56:35.880	-5.5717
SMC 5_3	00:44:49.032	-72:01:36.120	-1.2392
SMC 5_4	01:04:26.112	-71:59:51.000	+3.4514
SMC 5_5	01:23:04.944	-71:51:47.880	+7.6718
SMC 5_6	01:41:28.800	-71:35:47.040	+12.3004
SMC 6_2	00:27:39.960	-70:51:12.600	-5.3423
SMC 6_3	00:45:48.768	-70:56:08.160	-1.0016
SMC 6_4	01:03:49.944	-70:53:34.440	+3.1075
SMC 6_5	01:21:22.488	-70:46:10.920	+7.5039
SMC 7_3	00:46:04.728	-69:50:38.040	-0.9389
SMC 7_4	01:03:00.480	-69:48:58.320	+3.1144

SMC, BRI, and STR tiles were oriented with the Y axis along the right ascension direction. Each tile covers about 1.771 deg^2 where the central (1.475 x 1.017)=1.501 deg^2 corresponds to the nominal depth of the survey and the remaining area to half the exposure time in each band. Tile centres given in Right Ascension (RA), Declination (DEC) and the telescope position angle (TL_OFFAN) are listed in the table above.

Individual tile catalogues and co-added tile images, with associated confidence maps and catalogues, are released per band per field. Preview images in JPEG format are associated to each FITS image. They comprise observations obtained from February 2010 to October 2016 included.

Data Quality

Catalogues were created from images that were filtered for nebulosity with size of the order of 30 arcsec, but to the images released here the filtering process was not applied. See Irwin (2010, UKIRT Newsletter 26, 14).

The VMC constraints for the tiles in this release correspond to ellipticity <0.1 arcsec and seeing of 0.8-0.9 arcsec at K_s, 0.9-1.0 arcsec at J and 1.0-1.1 arcsec at Y, but good quality observations have a tolerance of ~10% on top of these values. The two values specified for seeing indicate constraints for crowded and uncrowded regions, respectively. The tiles that refer to tighter seeing constraints are: SMC 3_5, SMC 3_6, SMC 4_3, SMC 4_4, SMC 4_5, SMC 5_3, SMC 5_4, and SMC 5_5.

Tiles observed outside VMC constraints (those that refer to observations with higher seeing and/or ellipticity than those listed above), pawprints that are not associated to any tile, and problematic images are excluded from co-added tiles. The sensitivity of co-added tile images is by construction higher than that of single tile images. The sensitivity is usually equal to the sum of the times indicated for single tiles, but times may be larger in case of extra good quality images (those that meet the VMC observing constraints) or smaller due to the exclusion of problematic images.

Quality error bit flags assigned during post processing are listed at *http://horus.roe.ac.uk/vsa/ppErrBits.html*. These flags refer to quality issues of varying severity. For each pass-band nine quality issues are implemented as follows, where the corresponding value of the ppErrBit is given in parenthesis. Source is deblended (16), has bad pixel(s) in default aperture (64), has low confidence in default aperture (128), lies within detector #16 regions of a tile (4096), is close to saturation (65536), has photometric calibration probably subject to systematic errors (131072), lies within a dither offset fo the stacked frame boundary (4194304), lies within a dithered offset of the stacked frame boundary (4194304), lies within an underexposed strip of a tile (8388606) or within an underexposed region of a tile due to missing detector (16777216), and corresponds to a bright tile detection, but no detection in pawprints (67108864). To select only sources without quality issues the user can filter on ppErrBits=0, but note that the majority of the sources will have at least ppErrBits=16 due to the dense stellar field, and to include only sources with minor quality issues use ppErrBits<256.

The SHARP and STAR_PROB parameters, listed in the catalogue, could be used to disentangle point-like sources. For example, for stellar objects use STAR_PROB>0.77 and SHARP<0.5. The efficiency of these parameters depends on the FWHM and S/N ratio of the image. Compared to aperture photometry, the PSF photometry reaches sources on average 3 magnitudes fainter with uncertainties <0.1 mag. The magnitude difference may be larger in crowded stellar field, especially in the Y band, or smaller in less crowded fields and in the Ks band. The completeness of the catalogue was evaluated from artificial star tests and PSF photometry. The mean completeness and standard deviation among all of the tiles included in this release is listed in the table below.

Band	Mean 80%	Uncertainty 80%	Mean 50%	Uncertainty 50%
Y	21.82	1.15	22.48	1.00
J	21.53	1.01	22.07	0.98
K_s	20.54	0.88	21.01	0.63

Release Notes

The data for this release were prepared by the Wide Field Astronomy Unit (WFAU), and the VMC team. The main processing steps are described in Cross et al. (2012, A&A 548, A119) and Cross et al. (2009, MNRAS 399, 1730). Sources were extracted from individual tile images using the software suite provided by the Cambridge Astronomy Survey Unit (CASU) with version 1.5. Co-added images were outgested from the VISTA Science Archive and were produced only from data that met the observing constraints for the VMC survey. Epoch-merged and band-merged catalogues were extracted from deep tiles using the same software and outgested from the VISTA Science Archive. Sources are unique within each tile where PRIORSEC>0 signifies that a source is located in a region of overlap with an adjacent tile. The information about the variablitiy of sources was derived using only VMC data from the current release (see Cross et al. 2009 for details).

The PSF detection (Rubele et al. 2015, MNRAS, 449, 639) was made separately in each Y, J and Ks band, then the catalogues were correlated using a radial distance threshold of 1 arcsec. The uniformity of limiting magnitude on the final deep tile is intrinsically dependent on differences in the detector sensitivity and stellar crowding. The PSF magnitudes, originally adjusted to aperture magnitudes from previous releases (performed with v1.3 or earlier of the CASU software), have been aligned to the aperture magnitudes of this release (obtained with v1.5 of the CASU software) by adding the median shifts obtained from the cross-correlation between aperture catalogues, taking only sources detected in all three bands, with minor quality issues and with photometric uncertainties <0.1 mag, and PSF catalogues of each tile separately. The average values of the magnitude and colour shifts are indicated in the table that follows. The IAUNAME of sources in the PSF catalogues may not be unique. At this stage, sources in the overlap of tiles will appear with the same IAUNAME. Furthermore, the IAUNAME is rounded to two decimal points in arcsec, hence, it may be possible that two sufficiently close extractions result in two sources with the same IAUNAME.

Magnitude	Mean	Error	Colour	Mean	Error
Y	-0.029	0.016	Y-J	-0.042	0.029
J	0.013	0.024	$Y-K_s$	-0.022	0.018
K_s	-0.007	0.008	$J-K_s$	0.006	0.025

The catalogues contain parameters that link the sources, extracted with PSF photometry, with those extracted with aperture photometry as in the VISTA Data Flow System pipeline. The SOURCEID parameter identifies sources in VMC_CAT that correspond to sources in VMC_PSF. Note that there can be more PSFIDs corresponding to the same SOURCEID. The DISTANCEMINS parameter indicates the distance in arcmin between the RA2000 and DEC2000 coordinates of a VMC_CAT source and similar coordinates for a VMC_PSF source. The catalogue contains also the SHARP parameter for each band. SHARP is a measure of the difference between the observed width of the object and the width of the PSF model. Stars should have a sharpness value ~0.0, resolved objects sharpness values >0.0, and cosmic rays and similar blemishes sharpness values <0.0.

Data Reduction and Calibration

The procedures to reduce and calibrate the data are described in detail at:
http://casu.ast.cam.ac.uk/surveys-projects/vista/technical/data-processing.

The astrometric and photometric quality of the data is described in detail at
http://casu.ast.cam.ac.uk/surveys-projects/vista/technical.

In addition, the quality erro bit flags assigned during post processing are listed at *http://horus.roe.ac.uk/vsa/ppErrBits.html*. These flags refer to quality issues of varying severity such as it is a deblended source or it contains bad pixels in the default aperture. They also indicate if a source is located in the under-exposed area of a tile or in detector #16. They appear as ppErrBits in the catalogues and can be used to refine object samples.

Catalogues were created from images that were filtered for nebulosity with size of the order of 30 arcsec (Irwin 2010, UKIRT Newsletter 26, 14). Individual pass-band detections are merged into multi-colour lists. The band-merging procedure is outlined in detail at *http://horus.roe.ac.uk/vsa/dboverview.html*. It is based on matching pairs of frames from long (Ks) to short (Y) wavelength, and early to late epochs. The pairing tolerance for the VMC survey is of 1.0 arcsec. This radius is larger than the typical astrometric errors and may induce some level of spurious matches. Matching objects in the overlap regions of detectors are ranked according to their filter coverage, then their quality error flags and finally their proximity to a detector edge. The final band-merged catalogue includes only sources that do not have duplicate measurements.

The calibrated pawprint images were combined using SWARP to generate a uniform sky subtracted final deep tile image. Artifacts in the pawprint images were removed masking contaminated regions during the co-addition. The PSF in each detector on each pawprint image was normalized to a constant PSF reference model using a Fourier deconvolution technique before to combine them. The deep multi-filter YJKs PSF catalogues were generated correlating the three filters PSF catalogues using a 1 arcsec maximum radius.

Magnitudes are given in the Vega system and are not corrected for reddening.

Known issues

These VISTA data may present the following issues, for which a full description is given in http://casu.ast.cam.ac.uk/surveys-projects/vista/technical/known-issues. A variable depth due to bad pixels in detectors #1, #4 and #16 as well as some bad rows. Point-like objects residuals of flatfielding, variable vignetting and spurious detections around bright stars. Some of these issues are recorded in the quality error bits flags assigned during post processing. Note also that 15% of each tile, corresponding to two edges, has only half the total effective exposure time.

Previous Releases

This data release consists of 42 VMC survey tiles and it complements the CASU products previously released. It also replaces the band-merged catalogues previously released due to the processing with the version 1.5 of the CASU software and spatial overlap with the newly released tiles.

The photometric calibration of VISTA was improved by using new colour equations for the transformation of 2MASS calibrators into the VISTA system. A new prescription to account for interstellar reddening is also incorporated. This release also fixes bugs in the tile photometry, addressing a 0.05 mag pattern remaining in these due to a faulty distortion correction when transforming from ZPN to TAN projections. All these changes are detailed in Gonzalez-Fernandez et al. (2018).

Data Format

Files Types

There are 252 co-added tile images/confidence maps, where the name is constructed as project_release_ra/dec_tile_band_type_multiframeID.fits and multiframeID uniquely identifies each FITS image. These have 252 associated JPEG images and refer to the 42 fields. Then, there are 42x3x12= 1512 associated deep pawprints and their confidence maps. Finally, there are 42x3=126 individual tile base lists.

There are 42 epoch-merged and band-merged master source catalogues in YJKs, one per tile, where the name is constructed as project_release_ra/dec_bands_typeofCat_framesetID.fits and framesetID uniquely identifies the tile as follows:

558345748522 STR 1_1
558345748521 STR 2_1

558345748483 SMC 2_2
558345748481 SMC 2_3
558345748482 SMC 2_4
558345748484 SMC 2_5
558345748494 SMC 3_1
558345748490 SMC 3_2
558345748488 SMC 3_3
558345748489 SMC 3_4
558345748492 SMC 3_5
558345748496 SMC 3_6
558345748507 SMC 4_1
558345748503 SMC 4_2
558345748501 SMC 4_3
558345748502 SMC 4_4
558345748506 SMC 4_5
558345748509 SMC 4_6
558345748512 SMC 5_2
558345748510 SMC 5_3
558345748511 SMC 5_4
558345748513 SMC 5_5
558345748514 SMC 5_6
558345748517 SMC 6_2
558345748515 SMC 6_3
558345748516 SMC 6_4
558345748518 SMC 6_5
558345748519 SMC 7_3
558345748520 SMC 7_4
558345748486 BRI 1_2
558345748485 BRI 1_3
558345748493 BRI 2_3
558345748487 BRI 2_4
558345748491 BRI 2_7
558345748495 BRI 2_8
558345748497 BRI 2_9
558345748505 BRI 3_3
558345748500 BRI 3_4
558345748498 BRI 3_5
558345748499 BRI 3_6
558345748504 BRI 3_7
558345748508 BRI 3_8

A MetaData file, vmc_er5_ksjy_catMetaData.fits, accompanies the release. Its name refers to project_release_bands_typeofCat.fits.

There are 42 multi-epoch source catalogues per band, one per tile. Their name is constructed as project_relase_ra/dec_band_typeofCat_framesetID.fits and framesetID uniquely identify the tile as above. MetaData files, vmc_er5_y(j)(ks)_mPhotMetaData.fits, accompany the release. Their names refer to project_release_band_typeofCat.fits.

There are 42 PSF catalogues in YJKs, one per tile. Their name is constructed a project_release_ra/dec_bands_typeofCat_framesetID.fits and framesetID uniquely identifies the tile as above. A MetaData file, vmc_er5_yjks_psfSrcMetaData.fits, accompanies the release. Its name refers to project_release_bands_typeofCat.fits.

There are 42 catalogues for variable stars. Their name is constructed as project_release_ra/dec_bands_typeofCat_frameseID.fits and frameset ID uniquely identifies the tiles as above. A MetaData file, vmc_er5_yjks_varCatMetaData.fits, accompanies the release. Its name refers to project_release_bands_typeofCat.fits.

Catalogue Columns

Each epoch-merged and band-merged catalogue contains 96 columns listed below of which the 15 most relevant to guide user selections are: IAUNAME, sourceID, ra2000, dec2000, mergedClass, yAperMag3, yAperMag3Err, yErrBits, jAperMag, jAperMag3Err, jErrBits, ksAperMag3, ksAperMag3Err, ksErrBits, VARFLAG.

Number; name; format; description
1; IAUNAME; 36A; IAU Name (not unique)
2; SOURCEID; K; UID (unique over entire VSA via programme ID prefix) of this merged detection as assigned by merge algorithm
3; CUEVENTID; J; UID of curation event giving rise to this record
4; FRAMESETID; K; UID of the set of frames that this merged source comes from
5; RA2000; D; Celestial Right Ascension
6; DEC2000; D; Celestial Declination
7; L; D; Galactic longitude
8; B; D; Galactic latitude
9; LAMBDA; D; SDSS system spherical co-ordinate 1
10; ETA; D; SDSS system spherical co-ordinate 2
11; PRIORSEC; K; Seam code for a unique (=0) or duplicated (!=0) source (eg. flags overlap duplicates).
12; YMJPNT; E; Point source colour Y-J (using aperMag3)
13; YMJPNTERR; E; Error on point source colour Y-J
14; JMKSPNT; E; Point source colour J-Ks (using aperMag3)
15; JMKSPNTERR; E; Error on point source colour J-Ks
16; YMJEXT; E; Extended source colour Y-J (using aperMagNoAperCorr3)
17; YMJEXTERR; E; Error on extended source colour Y-J
18; JMKSEXT; E; Extended source colour J-Ks (using aperMagNoAperCorr3)
19; JMKSEXTERR; E; Error on extended source colour J-Ks
20; MERGEDCLASSSTAT; E; Merged N(0,1) stellarness-of-profile statistic
21; MERGEDCLASS; I; Class flag from available measurements (1|0|-1|-2|-3|-9=galaxy|noise|stellar|probableStar|probableGalaxy|saturated)
22; PSTAR; E; Probability that the source is a star
23; PGALAXY; E; Probability that the source is a galaxy
24; PNOISE; E; Probability that the source is noise
25; PSATURATED; E; Probability that the source is saturated
26; KSMJD; D; Modified Julian Day in Ks band
27; KSPETROMAG; E; Extended source Ks mag (Petrosian)
28; KSPETROMAGERR; E; Error in extended source Ks mag (Petrosian)
29; KSAPERMAG3; E; Default point source Ks aperture corrected mag (2.0 arcsec diameter)
30; KSAPERMAG3ERR; E; Error in default point/extended source Ks mag (2.0 arcsec diameter)
31; KSAPERMAG4; E; Point source Ks aperture corrected mag (2.8 arcsec diameter)
32; KSAPERMAG4ERR; E; Error in point/extended source Ks mag (2.8 arcsec diameter)
33; KSAPERMAG6; E; Point source Ks aperture corrected mag (5.7 arcsec diameter)
34; KSAPERMAG6ERR; E; Error in point/extended source Ks mag (5.7 arcsec diameter)
35; KSAPERMAGNOAPERCORR3; E; Default extended source Ks aperture mag (2.0 arcsec diameter)
36; KSAPERMAGNOAPERCORR4; E; Extended source Ks aperture mag (2.8 arcsec diameter)
37; KSAPERMAGNOAPERCORR6; E; Extended source Ks aperture mag (5.7 arcsec diameter)
38; KSGAUSIG; E; RMS of axes of ellipse fit in Ks
39; KSELL; E; 1-b/a, where a/b=semi-major/minor axes in Ks
40; KSPA; E; ellipse fit celestial orientation in Ks
41; KSERRBITS; J; processing warning/error bitwise flags in Ks
42; KSAVERAGECONF; E; average confidence in 2 arcsec diameter default aperture (aper3) Ks
43; KSCLASS; I; discrete image classification flag in Ks
44; KSCLASSSTAT; E; N(0,1) stellarness-of-profile statistic in Ks
45; KSPPERRBITS; J; additional WFAU post-processing error bits in Ks
46; KSSEQNUM; J; the running number of the Ks detection
47; KSXI; E; Offset of Ks detection from master position (+east/-west)

48; KSETA; E; Offset of Ks detection from master position (+north/-south)
49; JMJD; D; Modified Julian Day in J band
50; JPETROMAG; E; Extended source J mag (Petrosian)
51; JPETROMAGERR; E; Error in extended source J mag (Petrosian)
52; JAPERMAG3; E; Default point source J aperture corrected mag (2.0 arcsec diameter)
53; JAPERMAG3ERR; E; Error in default point/extended source J mag (2.0 arcsec diameter)
54; JAPERMAG4; E; Point source J aperture corrected mag (2.8 arcsec diameter)
55; JAPERMAG4ERR; E; Error in point/extended source J mag (2.8 arcsec diameter)
56; JAPERMAG6; E; Point source J aperture corrected mag (5.7 arcsec diameter)
57; JAPERMAG6ERR; E; Error in point/extended source J mag (5.7 arcsec diameter)
58; JAPERMAGNOAPERCORR3; E; Default extended source J aperture mag (2.0 arcsec diameter)
59; JAPERMAGNOAPERCORR4; E; Extended source J aperture mag (2.8 arcsec diameter)
60; JAPERMAGNOAPERCORR6; E; Extended source J aperture mag (5.7 arcsec diameter)
61; JGAUSIG; E; RMS of axes of ellipse fit in J
62; JELL; E; 1-b/a, where a/b=semi-major/minor axes in J
63; JPA; E; ellipse fit celestial orientation in J
64; JERRBITS; J; processing warning/error bitwise flags in J
65; JAVERAGECONF; E; average confidence in 2 arcsec diameter default aperture (aper3) J
66; JCLASS; I; discrete image classification flag in J
67; JCLASSSTAT; E; N(0,1) stellarness-of-profile statistic in J
68; JPPERRBITS; J; additional WFAU post-processing error bits in J
69; JSEQNUM; J; the running number of the J detection
70; JXI; E; Offset of J detection from master position (+east/-west)
71; JETA; E; Offset of J detection from master position (+north/-south)
72; YMJD; D; Modified Julian Day in Y band
73; YPETROMAG; E; Extended source Y mag (Petrosian)
74; YPETROMAGERR; E; Error in extended source Y mag (Petrosian)
75; YAPERMAG3; E; Default point source Y aperture corrected mag (2.0 arcsec diameter)
76; YAPERMAG3ERR; E; Error in default point/extended source Y mag (2.0 arcsec diameter)
77; YAPERMAG4; E; Point source Y aperture corrected mag (2.8 arcsec diameter)
78; YAPERMAG4ERR; E; Error in point/extended source Y mag (2.8 arcsec diameter)
79; YAPERMAG6; E; Point source Y aperture corrected mag (5.7 arcsec diameter)
80; YAPERMAG6ERR; E; Error in point/extended source Y mag (5.7 arcsec diameter)
81; YAPERMAGNOAPERCORR3; E; Default extended source Y aperture mag (2.0 arcsec diameter)
82; YAPERMAGNOAPERCORR4; E; Extended source Y aperture mag (2.8 arcsec diameter)
83; YAPERMAGNOAPERCORR6; E; Extended source Y aperture mag (5.7 arcsec diameter)
84; YGAUSIG; E; RMS of axes of ellipse fit in Y
85; YELL; E; 1-b/a, where a/b=semi-major/minor axes in Y
86; YPA; E; ellipse fit celestial orientation in Y
87; YERRBITS; J; processing warning/error bitwise flags in Y
88; YAVERAGECONF; E; average confidence in 2 arcsec diameter default aperture (aper3) Y
89; YCLASS; I; discrete image classification flag in Y
90; YCLASSSTAT; E; N(0,1) stellarness-of-profile statistic in Y
91; YPPERRBITS; J; additional WFAU post-processing error bits in Y
92; YSEQNUM; J; the running number of the Y detection
93; YXI; E; Offset of Y detection from master position (+east/-west)
94; YETA; E; Offset of Y detection from master position (+north/-south)
95; VARFLAG; J; Classification of objects across all bands.
96; PRIMARY_SOURCE; I; Primary source 1; secondary source 0

The format refers to the fits notation as follows:
A - string 32 characters; D - double floating point (8 bytes); E - real floating point (4 bytes); I - short integer (2 bytes); J - integer (4 bytes); K - long integer (8 bytes).

The variability flag is described in detail in Cross et al. (2009, MNRAS, 399, 1730). It is set to true (1) or false (0) using the sum of the weighted ratios of the intrinsic standard deviation to the expected noise. The weighting in each filter depends on the number of observations in each filter. At least five observations in one filter are needed for an object to be counted as variable. Thus, for the VMC data this is driven by observations in the K_s band only.

Each multi-epoch source catalogue contains the columns listed below where the format is as described earlier. The example is for the Y band. In the J and Ks bands the name and description, for magnitude, error and post-processing flag, will change accordingly.

Number; name; format; description

1; PHOT_ID; K; UID for observation
2; IAUNAME; 36A; IAU Name (not unique)
3; SOURCEID; K; UID (unique over entire VSA via programme ID prefix) of this merged detection as assigned by merge algorithm
4; MJD; D; Modified Julian Day in Y band
5; YMAG; E; Default point/extended source Y aperture corrected mag (2.0 arcsec diameter)
6; YERR; E; Error in default point/extended source Y mag (2.0 arcsec diameter)
7; YPPERRBITS; J; additional WFAU post-processing error bits in Y

PSF catalogues contain 47 columns as follows, where the format is as previously described.

Number; name; format; description

1; IAUNAME; 29A; IAU Name (not unique)
2; SOURCEID; K; UID (unique over entire VSA via programme ID prefix) of this merged detection as assigned by merge algorithm
3; DISTANCEMINS; E; Angular separation between neighbours
4; PSFSOURCEID; K; UID of VMC PSF extracted objects
5; FIELDNAME; 8A; ID of field
6; FRAMESETID; K; frame set ID, linked to vmcMergeLog, assigned by merging procedure
7; CUEVENTID; J; UID of curation event giving rise to this record
8; RAY; D; PSF fit RA centre Y filter
9; DECY; D; PSF fit Dec centre Y filter
10; YPSFMAG; E; 3 pixels PSF fitting magnitude Y filter
11; YSFMAGERR; E; PSF error Y filter
12; YSHARP; E; PSF fitting shape parameter Y filter
13; RAJ; D; PSF fit RA centre J filter
14; DECJ; D; PSF fit Dec centre J filter
15; JPSFMAG; E; 3 pixels PSF fitting magnitude J filter
16; JPSFMAGERR; E; PSF error J filter
17; JSHARP; E; PSF fitting shape parameter J filter
18; RAKS; D; PSF fit RA centre Ks filter
19; DECKS; D; PSF fit Dec centre Ks filter
20; KSPSFMAG; E; 3 pixels PSF fitting magnitude Ks filter
21; KSPSFMAGERR; E; PSF error Ks filter
22; KSSHARP; E; PSF fitting shape parameter Ks filter
23; RA2000; D; PSF Y,J,Ks average RA centre
24; DEC2000; D; PSF Y,J,Ks average Dec centre
25; CX; D; unit vector of spherical co-ordinates
26; CY; D; unit vector of spherical co-ordinates
27; CZ; D; unit vector of spherical co-ordinates
28; HTMID; K; Hierarchival Triangular Mesh (HTM) index, 20 deep, for equatoial co-ordinates
29; L; D; Galactic longitude
30; B; D; Galactic latitude
31; PRIORSEC; K; Seam code for a unique (=0) or duplicated (!=0) source (eg. Flags overlap duplicates)
32; LCOMPY; E; Local completeness in Y calculated on bins of +/-0.05 [magnitude] on a ring of radius 0.025 [degrees]
33; LCOMPJ; E; Local completeness in J calculated on bins of +/-0.05 [magnitude] on a ring of radius 0.025 [degrees]
34; LCOMPKS; E; Local completeness in Ks calculated on bins of +/-0.05 [magnitude] on a ring of radius 0.025 [degrees]

35; SYSERRY; E; Local photometric systematic error in Y, calculated on bins of +/-0.05 magnitude on a ring of radius 0.025 [degrees]
36; SYSERRJ; E; Local photometric systematic error in J, calculated on bins of +/-0.05 magnitude on a ring of radius 0.025 [degrees]
37; SYSERRKS; E; Local photometric systematic error in Ks, calculated on bins of +/-0.05 magnitude on a ring of radius 0.025 [degrees]
38; STARPROB; E; Discrete star probability 1=100% to be a star, 0.0% probability to be a star
39; NY; J; Number of stars used to calculate the completeness in Y
40; NJ; J; Number of stars used to calculate the completeness in J
41; NKS; J; Number of stars used to calculate the completeness in Ks
42; YMJPSF; E; Y-J 3 pixels PSF fitting colour
43; YMJPSFERR; E; Error on Y-J 3 pixels PSF fitting colour
44; JMKSPSF; E; J-Ks 3 pixels PSF fitting colour
45; JMKSPSFERR; E; Error on J-Ks 3 pixels PSF fitting colour
46; YMKPSF; E; Y-Ks 3 pixels PSF fitting colour
47; YMKPSFERR; E; Error on Y-Ks 3 pixels PSF fitting colour

Variability catalogues contain 11 columns as follows, where the format is described above.

Name; format; description

1; IAUNAME; 29A; IAU Name (not unique)
2; sourceID; K; UID (unique over entire VSA via programme ID prefix) of this merged detection as assigned by merge algorithm
3; ymeanMag; E; Mean Y magnitude
4; yAmpl; E; Amplitude of variable in Y-band
5; yprobVar; E; Probability of variable from chi-square (and other data)
6; jmeanMag; E; Mean J magnitude
7; jAmpl; E; Amplitude of variable in J-band
8; jprobVar; E; Probability of variable from chi-square (and other data)
9; ksmeanMag; E; Mean Ks magnitude
10; ksAmpl; E; Amplitude of variable in Ks-band
11; ksprobVar; E; Probability of variable from chi-square (and other data)

Acknowledgements

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If you use the VMC data in general please reference Cioni et al. (2011, A&A, 527, A116) and if you specifically use the PSF catalogues please reference Rubele et al. (2018, MNRAS 478, 501).