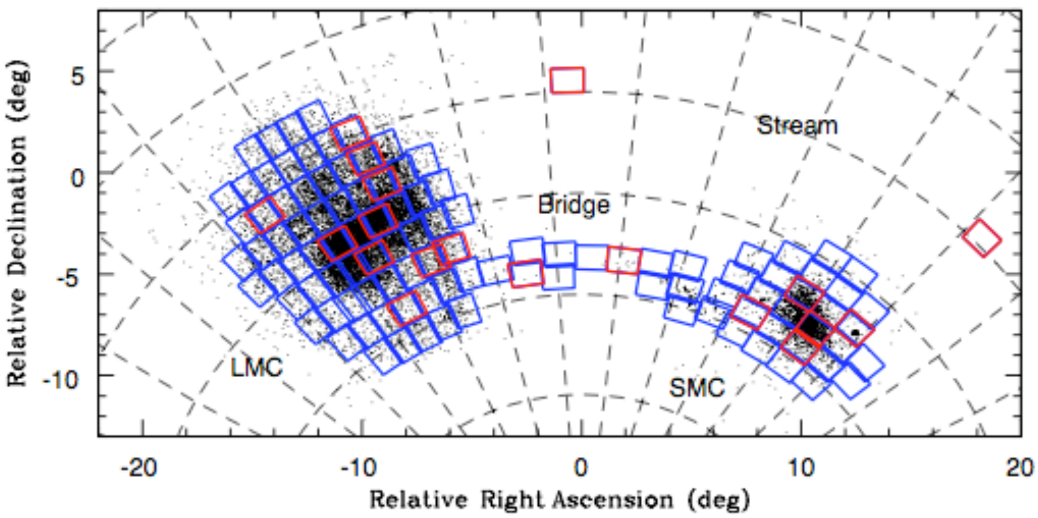
Data Collection	VMC
Release Number	4
Data Provider	Maria-Rosa Cioni
Date	8.03.2017

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 twelve new VMC survey tiles LMC 3_5, 4_2, 4_3, 7_3, 9_3, SMC 4_3, 5_2, 5_4, BRI 2_8, 3_5, and STR 1_1, 2_1. Observations were acquired between November 2009 and August 2013. This release provides reduced and calibrated tile images belonging to individual observations ('single OBs'), in addition to the corresponding pawprints (6 per tile), deep co-added images, and source lists (separately for each filter). This release is complementary to the previous release, because all images and source lists of the previous VMC release number 3 refer to different tiles. There are at least three tiles in Y and J filters and twelve tiles in K_s filter per field.

This release provides also band-merged catalogues for both new and previously released images taking into accounts of the new overlaps. Catalogues with PSF magnitudes, for each tile, and confirmed variable stars, in some tiles, are also provided. The total sky coverage of this release is ~8 deg² in the LMC, ~5 deg² in the SMC, ~3 deg² in the Bridge and ~3 deg² 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), including tiles in releases number 3 and 4. 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 LMC tile is 2_3, 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 2_1 is to the right of the SMC.

Each survey tile has at least 3 OBs in Y and J filters, respectively (providing 800 s exposure time per pixel each) and 12 OBs in K_s with 750 s exposure time per pixel each.

Release Content

This release comprises of new data for five tiles in the Large Magellanic Cloud: LMC 3_5, 4_2, 4_3, 7_3 and 9_3, three tiles in the Small Magellanic Cloud: SMC 4_3, 5_2 and 5_4, two tiles in the Bridge: BRI 2_8 and 3_5, and the two tiles in the Stream: STR 1_1 and 2_1.

LMC tiles were oriented with the Y axis more or less along the declination direction while for SMC, BRI, and STR tiles the Y axis is 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 below.

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
SMC 4_3	00:45:14.688	-73:07:11.280	-1.1369
SMC 5_2	00:26:41.688	-71:56:35.880	-5.5717
SMC 5_4	01:04:26.112	-71:59:51.000	+3.4514
BRI 2_8	04:00:21.072	-73:46:37.560	+14.4905
BRI 3_5	02:57:33.288	-73:12:52.200	-0.5877
LMC 3_5	05 22 43.056	-73 43 25.320	-93.0788
LMC 4_2	04 41 30.768	-71 49 16.320	-102.7172
LMC 4_3	04 55 19.51	-72 01 53.400	-99.4885
LMC 7_3	05 02 55.200	-67 42 14.760	-97.7044
LMC 9_3	05 06 40.632	-64 48 40.320	-96.8439

Individual tile images and co-added tile images, with associated confidence maps and source lists, are released per band per field. Preview images in JPEG format are associated to each FITS image. They comprise observations obtained from November 2009 to August 2013 included.

In the variable stars catalogues, VMC Ks magnitudes are listed together with V and I magnitudes from OGLE-III/IV and V magnitudes from EROS-2 for each star, if available. Periods and modes of pulsation are also from the optical-band data. Reddening values, if present, were derived by Muraveva et al. (2016, MNRAS, in preparation) for RR Lyrae stars or from Haschke, Grebel & Duffau (2011, AJ, 141, 158).

The Eclipsing Binary stars included in this release are initially extracted from the EROS-2 and OGLE III surveys. Only 70% of tile LMC 8_8 was covered by these surveys and the variable stars in the remaining area of the tile, as well as in tiles LMC 3_5 and 4_2 have yet to be discovered.

The classical Cepheid stars included in this release are initially extracted from the OGLE-III (tile LMC 6_6, SMC 4_3, 5_2 and 5_4) and EROS-2 (tile LMC 8_8 and SMC 5_4) surveys. Tile LMC 8_8 is only 70% covered (see above). Anomalous and Type II Cepheids, extracted also from the OGLE III survey, are present for tiles LMC 5_5, 6_4, 6_6, 7_3, and 8_8.

The RR Lyrae stars included in this release are initially extracted from the OGLE IV survey.

Data Quality

Source lists 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.

Tiles observed outside VMC constraints are also released and their quality parameters are included in the headers, they refer to observations with higher seeing and/or ellipticity then those listed above. In total 60 tile images and their corresponding pawprints are affected. These refer to tiles: STR 1_1 (4), STR 2_1 (4), SMC 4_3(7), SMC 5_2 (10), SMC 5_4 (4), BRI 2_8 (8), LMC 3_5 (2), LMC 4_2 (4), LMC 4_3 (7), LMC 7_3 (3), and LMC 9_3 (7). Note that the sensitivity of tile images is by construction higher than that of pawprint images. For co-added tiles they are 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) and in the regions with >2 detector overlaps. They can also be 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 region of a tile (4096), is close to saturation (65536), has photometric calibration probably subject to systematic errors (131072), lies within a dither offset of the stacked frame boundary (4194304), lies within the underexposed strip of a tile (8388606), and lies within an underexposed region of a tile due to missing detector (16777216).
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 parameter, listed in the catalogues, could be used to disentangle point-like sources. The efficiency of this parameter 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 fields, especially in the Y-band, or smaller in less crowded fields and in the K_s-band

The completeness of the catalogues was evaluated from artificial star tests and PSF photometry. Results are indicated in the table below.

Tile	Filter	95%	90%	75%	50%
SMC 4_3	Y	17.80	18.57	19.98	21.08
	J	17.48	18.35	19.85	20.95
	Ks	16.92	17.75	19.45	20.61
SMC 5_2	Y	12.47	16.25	19.50	21.80
	J	12.10	15.70	18.98	21.40
	Ks	12.10	15.15	18.55	20.51
SMC 5_4	Y	18.35	19.32	20.70	21.68
	J	18.02	19.03	20.48	21.45
	Ks	17.45	18.57	20.11	20.51
STR 1_1	Y	21.75	21.95	22.15	22.40
	J	21.25	21.57	21.90	22.26
	Ks	20.45	20.80	21.08	21.35
STR 2_1	Y	21.71	21.93	22.13	22.47

	J	21.25	21.52	21.81	22.10
	Ks	20.38	20.76	21.02	21.30
BRI 2_8	Y	21.48	21.73	21.98	22.23
	J	20.95	21.18	21.47	21.78
	Ks	20.45	20.78	21.08	21.23
BRI 3_5	Y	21.54	21.85	22.10	22.45
	J	21.25	21.63	21.92	22.20
	Ks	20.43	20.76	21.00	21.20
LMC 3_5	Y	19.65	20.55	21.60	22.20
	J	19.40	20.30	21.35	21.95
	Ks	18.85	19.85	20.71	21.07
LMC 4_2	Y	19.68	20.60	21.65	22.28
	J	19.45	20.33	21.35	21.92
	Ks	18.85	19.85	20.78	21.09
LMC 4_3	Y	19.20	20.05	21.20	22.08
	J	18.92	19.90	21.02	21.89
	Ks	18.40	19.48	20.58	20.98
LMC 7_3	Y	18.10	19.08	20.30	21.32
	J	17.73	18.75	20.07	21.09
	Ks	17.25	18.45	19.81	20.58
LMC 9_3	Y	19.65	20.48	21.70	22.28
	J	19.45	20.30	21.40	21.98
	Ks	18.97	19.88	20.71	21.07

Release Notes

The data for this release were prepared by the Cambridge Astronomy Survey Unit (CASU), 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). Images were reduced and source lists extracted from individual tile images using the software suite provided by CASU (v1.3). Co-added images were outgested from the VISTA Science Archive and were produced only from data that meet 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. Deep tiles are produced only from data that meet the observing criteria for the VMC survey.

Sources are unique within each tile. Where PRIORSEC>0 signifies that a source is located in a region of overlap with an adjacent tile that is not yet part of the current release.

The tile area over which the variability analysis is performed (VMC_CAT.VARFLAG) is about 26.2 deg^2. The ears of tiles are excluded because of their lower exposure time compared to the tile centre and the region covered by detector #16 is also excluded because of the variable quantum efficiency.

The point spread function (PSF) detection was made separately in each Y, J and K_s band, than the catalogues were correlated using a radial distance threshold of 1 arcsec. The uniformity of limited magnitude on the final deep tile is intrinsically dependent on differences in the detector sensitivity and stellar crowding.

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.

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 catalogues contain 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 sharpness values of ~0.0, resolved objects sharpness values >0.0, and cosmic rays and similar blemishes sharpness values <0.0.

Full details about the extraction and analysis of variable stars are given in: Ripepi et al. 2012, MNRAS 424, 1807 for LMC Classical Cepheids; Ripepi et al. 2014, MNRAS 437, 2307 for LMC Anomalous Cepheids; Ripepi et al. 2015, MNRAS 446, 3034 for LMC Type II Cepheids; Ripepi et al. 2016, ApJS, 224, 21 for SMC Classical Cepheids; Muraveva et al. 2014, MNRAS, 443, 432 for Eclipsing binary stars; and Muraveva et al. 2016, MNRAS, submitted for RR Lyrae stars.

Note that in Ripepi et al. (2012) IAUNAMEs may differ slightly from those included in this release. The right ascension components may differ by 0.01 s and the declination components are rounded to one decimal point.

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 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 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 outlines 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 (contrary to previous releases), 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 YJK_s PSF catalogues were generated correlating the three filters PSF catalogues using a 1 arcsec maximum radius.

The magnitudes were 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.

Data in this release comprise observations obtained prior to 20 November 2009 when detector #6 had an intermittently bad channel. Note also that 15% of the tile, corresponding to two edges, has only half the total effective exposure time.

Tiles suffer from a complex 10-20 mas systematic pattern due to residual WCS errors from the component pawprints and prior to 01.08.2012 to an inconsistent use of the ZPN projection, which results in a complex residual radial distorsion of up to +/- 100 mas.

The astrometry in deep tiles suffer from a complex 10-20 mas systematic pattern due to residual WCS errors from the component pawprints of individual tiles.

Previous Releases

This data release consists of twelve new VMC survey tiles and it complements the seven existing tiles, which were previously released in VMC Data Release 3. This data was reduced with the version of CASU software 1.3. Furthermore, this release replaces some of the band-merged catalogues previously released due to the spatial overlap with the newly released tiles.

The previous Data Release (3) referred to catalogues extracted from the reduced images available in VMC Data Release 3. The present Data Release (4) refers to catalogues extracted from the reduced images available in VMC Data Release 4.

Data Format

Files Types

There are 319 individual tile images, each with six corresponding pawprints, and associated confidence maps and source lists with the adopted naming convention:

Pawprint images: v????????_?????_st.fits.fz
Associated confidence map: v????????_?????_st_conf.fits.fz
Source list per pawprint: v????????_?????_st_cat.fits
where the name is constructed as observing-date_number_type.fits(.fz)

Tile images: v????????_?????_st_tl.fits.fz
Associated confidence map: v????????_?????_st_tl_conf.fits.fz
Source list per tile: v????????_?????_st_tl_cat.fits
where the name is constructed as observing-date_number_type.fits(.fz)

There are 72 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 72 associated JPEG images and refer to the twelve new fields. Then, there are 12x3x12=432 associated deep paw-prints and their confidence maps. Finally, there are 12x3=36 individual tile base lists.

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

558345748481 SMC 3_3
558345748482 SMC 3_5
558345748483 BRI 2_8
558345748484 LMC 3_5
558345748485 BRI 3_5
558345748486 SMC 4_3
558345748487 LMC 4_3
558345748488 SMC 5_4
558345748489 SMC 5_2
558345748490 LMC 4_2
558345748491 LMC 5_5
558345748492 LMC 6_6
558345748493 LMC 6_4
558345748494 LMC 7_3
558345748495 LMC 8_8
558345748496 LMC 8_3
558345748497 LMC 9_3
558345748498 STR 2_1
558345748499 STR 1_1.

A MetaData file, vmc_er4_ksjy_catMetaData.fits, accompanies the release. Its name refers to project_release_bands_typeofCat.fits.

Nineteen multi-epoch source catalogues per band, one per tile, are released. Their name is constructed as project_release_ra/dec_band_typeofCat_framesetID.fits and framesetID uniquely identify the tile as above. MetaData files, vmc_er4_y(j)(ks)_mPhotMetaData.fits , accompany the release. Their names refer to project_release_band_typeofCat.fits.

Nineteen PSF catalogues in YJKs, one per tile, are released. Their name is constructed as project_release_ra/dec_bands_typeofCat_framesetID.fits and framesetID uniquely identifies the tile as above. A MetaData file, vmc_er4_yjks_psfCatMetaData.fits, accompanies the release. Its name refers to project_release_bands_typeofCat.fits.

Several catalogues for variable stars are released. Their name is constructed as project_release_ra/dec_bands_typeofCat_framesetID.fits
and framesetID uniquely identifies the tile as above. MetaData files accompany the release and their names refers to project_release_bands_typeofCat.fits.

There are eight eclipsing binary catalogues that refer to tiles LMC 4_3, 5_5, 6_4, 6_6, 7_3, 8_3, 8_8 and 9_3. There are Cepheid catalogue for all tiles in the SMC (Classical Cepheids only) and for five tiles in the LMC as follows: tiles LMC 6_6 and 8_8 (Classical Cepheids); tiles LMC 5_5, 6_4, 6_6, 7_3 and 8_8 (Anomalous and Type II Cepheids). There are RR Lyrae star catalogues for all SMC tiles.

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; Unique identifier in IAU naming convention
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 aperture diameter)
30; KSAPERMAG3ERR; E; Error in default point/extended source Ks mag (2.0 arcsec aperture diameter)
31; KSAPERMAG4; E; Point source Ks aperture corrected mag (2.8 arcsec aperture diameter)
32; KSAPERMAG4ERR; E; Error in point/extended source Ks mag (2.8 arcsec aperture diameter)
33; KSAPERMAG6; E; Point source Ks aperture corrected mag (5.7 arcsec aperture diameter)
34; KSAPERMAG6ERR; E; Error in point/extended source Ks mag (5.7 arcsec aperture diameter)
35; KSAPERMAGNOAPERCORR3; E; Default extended source Ks aperture mag (2.0 arcsec aperture diameter)
36; KSAPERMAGNOAPERCORR4; E; Extended source Ks aperture mag (2.8 arcsec aperture diameter)
37; KSAPERMAGNOAPERCORR6; E; Extended source Ks aperture mag (5.7 arcsec aperture 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 aperture diameter)
53; JAPERMAG3ERR; E; Error in default point/extended source J mag (2.0 arcsec aperture diameter)
54; JAPERMAG4; E; Point source J aperture corrected mag (2.8 arcsec aperture diameter)
55; JAPERMAG4ERR; E; Error in point/extended source J mag (2.8 arcsec aperture diameter)
56; JAPERMAG6; E; Point source J aperture corrected mag (5.7 arcsec aperture diameter)
57; JAPERMAG6ERR; E; Error in point/extended source J mag (5.7 arcsec aperture diameter)
58; JAPERMAGNOAPERCORR3; E; Default extended source J aperture mag (2.0 arcsec aperture diameter)
59; JAPERMAGNOAPERCORR4; E; Extended source J aperture mag (2.8 arcsec aperture diameter)
60; JAPERMAGNOAPERCORR6; E; Extended source J aperture mag (5.7 arcsec aperture 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 aperture diameter)
76; YAPERMAG3ERR; E; Error in default point/extended source Y mag (2.0 arcsec aperture diameter)
77; YAPERMAG4; E; Point source Y aperture corrected mag (2.8 arcsec aperture diameter)
78; YAPERMAG4ERR; E; Error in point/extended source Y mag (2.8 arcsec aperture diameter)
79; YAPERMAG6; E; Point source Y aperture corrected mag (5.7 arcsec aperture diameter)
80; YAPERMAG6ERR; E; Error in point/extended source Y mag (5.7 arcsec aperture diameter)
81; YAPERMAGNOAPERCORR3; E; Default extended source Y aperture mag (2.0 arcsec aperture diamter)
82; YAPERMAGNOAPERCORR4; E; Extended source Y aperture mag (2.8 arcsec aperture diameter)
83; YAPERMAGNOAPERCORR6; E; Extended source Y aperture mag (5.7 arcsec aperture 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; Unique identifier for epoch observation. Combination of source UID and detection UID
2; IAUNAME; 36A; Unique identifier in IAU naming convention
3; SOURCEID; K; UID of this merged detection
4; MJD; D; Modified Julian Day in Y band
5; YMAG; E; Default point/extended source Y aperture corrected mag (2.0 arcsec aperture diameter)
6; YERR; E; Error in default point/extended source Y mag (2.0 arcsec aperture diameter)
7; YPPERRBITS; J; additional WFAU post-processing error bits in Y

PSF catalogues contain 35 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 of this merged detection as assigned by merge algorithm
3; DISTANCEMINS; E; Angular separation between neighbours
4; PSFID; K; UID of VMC PSF extracted objects
5; FIELDID; 8A; ID of field
6; CUEVENTID; J; UID of curation event giving rise to this record
7; RAY; D; PSF fit RA centre Y filter
8; DECY; D; PSF fit Dec centre Y filter
9; YPSFMAG; E; 3 pixels PSF fitting magnitude Y filter
10; YSFMAGERR; E; PSF error Y filter
11; YSHARP; E; PSF fitting shape parameter Y filter
12; RAJ; D; PSF fit RA centre J filter
13; DECJ; D; PSF fit Dec centre J filter
14; JPSFMAG; E; 3 pixels PSF fitting magnitude J filter
15; JPSFMAGERR; E; PSF error J filter
16; JSHARP; E; PSF fitting shape parameter J filter
17; RAKS; D; PSF fit RA centre Ks filter
18; DECKS; D; PSF fit Dec centre Ks filter
19; KSPSFMAG; E; 3 pixels PSF fitting magnitude Ks filter
20; KSPSFMAGERR; E; PSF error Ks filter
21; KSSHARP; E; PSF fitting shape parameter Ks filter
22; RA2000; D; PSF Y,J,Ks average RA centre
23; DEC2000; D; PSF Y,J,Ks average Dec centre
24; LCOMPY; E; Local completeness in Y
25; LCOMPJ; E; Local completeness in J
26; LCOMPKS; E; Local completeness in Ks
27; NY; J; Number of stars used to calculate the completeness in Y
28; NJ; J; Number of stars used to calculate the completeness in J
29; NKS; J; Number of stars used to calculated the completeness in Ks
30; YMJPSF; E; Y-J 3 pixels PSF fitting colour
31; YMJPSFERR; E; Error on Y-J 3 pixels PSF fitting colour
32; JMKSPSF; E; J-Ks 3 pixels PSF fitting colour
33; JMKSPSFERR; E; Error on J-Ks 3 pixels PSF fitting colour
34; YMKPSF; E; Y-Ks 3 pixels PSF fitting colour
35; YMKPSFERR; E; Error on Y-Ks 3 pixels PSF fitting colour

Similarly, each catalogue of eclipsing binary stars contains the following columns.

Number; name; format; description

1; IAUNAME; 29A; Unique identifier in IAU naming convention
2; SOURCEID; K; UID of this merged detection as assigned by merged algorithm
3; VARID; K; UID of VMC variables
4; FIELDID; 8A; ID of field
5; CUEVENTID; J; UID of curation event giving rise to this record
6; CATALOGUE; 16A;Name of external catalogue containing the counterparts
7; EXTERNALID; 32A; Identification from EROS-2 or OGLE III catalogues
8; RA2000; D; Celestial Right Ascension
9; DEC2000; D; Celestial Declination
10; NEPOCHS; J; Number of epochs in the Ks band
11; KSMAX; Ks magnitude at maximum light, determined by fitting with GRATIS
12; KSMAXERR; Error on Ks magnitude at maximum light
13; PERIOD; E; Period from the external catalogue
14; EPOCHMIN; E; Epoch of minimum light (JD-2,400,000)
15; NOTES; 16A; EROS: “cont.-like”, “non-contact”; OGLE: “checked” (by GRATIS), “n/c”
16; ORIGVSAREL; 16A; VSA release from which Ks data was used
17; ORIGVSASOURCEID; K; VSA sourceID in VSA release from which Ks data was used.

Each catalogue of Cepheid variable stars contains the following columns.

Number; name; format; description

1; IAUNAME; 29A; Unique identifier in IAU naming convention
2; SOURCEID; K; UID of this merged detection as assigned by merged algorithm
3; VARID; K; UID of VMC variables
4; FIELDID; 8A; ID of field
5; CUEVENTID; J; UID of curation event giving rise to this record
6; RA2000; D; Celestial Right Ascension
7; DEC2000; D; Celestial Declination
8; CEPHTYPE; 5A; Type of Cepheid, e.g. DCEP
9; CEPHSUBTYPE; 5A; Sub-type of Cepheid
10; CEPHMODE; 5A; Mode of Cepheid; e.g. F0
11; PERIOD; E; Period of first mode of oscillation
12; YNEPOCHS; J; Number of Y magnitude epochs
13; YMEANMAG; E; Intensity-averaged Y band magnitude
14; YMAGERR; E; Error in intensity-averaged Y band magnitude
15; YAMPL; E; Peak-to-Peak amplitude in Y band
16; YAMPLERR; E; Error in Peak-to-Peak amplitude in Y band
17; JNEPOCHS; J; Number of J magnitude epochs
18; JMEANMAG; E; Intensity-averaged J band magnitude
19; JMAGERR; E; Error in intensity-averaged J band magnitude
20; JAMPL; E; Peak-to-Peak amplitude in J band
21; JAMPLERR; E; Error in Peak-to-Peak amplitude in J band
22; KSNEPOCHS; J; Number of Ks magnitude epochs
23; KSMEANMAG; E; Intensity-averaged Ks band magnitude
24; KSMAGERR; E; Error in intensity-averaged Ks band magnitude
25; KSAMPL; E; Peak-to-Peak amplitude in Ks band
26; KSAMPLERR; E; Error in Peak-to-Peak amplitude in Ks band
27; NOTES; 8A; Additional information
28; ORIGVSAREL; 16A; VSA release from which Ks data was used
29; ORIGVSASOURCEID; K; VSA sourceID in VSA release from which Ks data was used
30; CATALOGUE; 16A; Name of external catalogue containing the counterparts
31; EXTERNALID; 32A; Identification from the EROS-2 or OGLE III catalogues.

Each catalogue of RR Lyrae stars contains the following columns.

Number; name; format; description

1; IAUNAME; 29A; Unique identifier in IAU naming convention
2; SOURCEID; K; UID of this merged detection as assigned by merged algorithm
3; VARID; K; UID of VMC variables
4; FIELDID; 8A; ID of field
5; CUEVENTID; J; UID of curation event giving rise to this record
6; RA2000; D; Celestial Right Ascension
7; DEC2000; D; Celestial Declination
8; NKSEPOCHS; J; Number of epochs in the Ks band
9; KSMEAN; E; Mean Ks magnitude derived with GRATIS
10; KSMEANERR; E; Uncertainty in mean Ks magnitude provided by GRATIS
11; KSAMPL; E; Amplitude in Ks band provided by GRATIS
12; RRLYRMODE; 16A; Mode F0 fundamental mode
13; IMEANMAG; E; Mean I band magnitude from OGLE IV survey
14; VMEANMAG; E; Mean V band magnitude from OGLE IV survey
15; PERIOD; E; Period from the external catalogue
16; EPOCHMAX; E; Epoch of minimum light (JD-2,400,000)
17; EVI; E; The dust extinction value E(V-I)
18; ORIGVSAREL; 16A; VSA release from which Ks data was used
19; ORIGVSASOURCEID; K; VSA sourceID in VSA release from which Ks data was used
20; CATALOGUE; 16A; Name of external catalogue containing the counterparts
21; EXTERNALID; 32A; Identification from EROS-2 or OGLE IV catalogues

Acknowledgements

Please reference Cioni et al. 2011, A&A, 527, A116 for the general use of VMC data and add the following statement in your articles: Based on data products from observations made with ESO Telescopes at the La Silla Paranal Observatory under programme ID 179.B-2003.

Please reference the use of specific catalogues as follows.

- PSF catalogues: Rubele et al. 2012, A&A, 537, A106 (LMC); 2015, MNRAS 449, 639 (SMC)
- Eclipsing binary catalogues: Muraveva et al. 2014, MNRAS, 443, 432
- SMC Cepheids: Ripepi et al. 2016, ApJS, 224, 21
- LMC Cepheids: Ripepi et al. 2012, MNRAS, 424, 1807 (Classical); 2014, MNRAS, 437, 2307 (Anomalous); 2015, MNRAS 446, 3034 (Type II)
- RR Lyrae stars catalogue: Muraveva et al. 2016, MNRAS, submitted.