ESO Phase 3 Data Release Description

Data Collection	*VVV_VAR*
Release Number	1
Data Provider	D. Minniti, P. Lucas and the VVV team
Date	9.1.2014

Abstract

The VVV Survey data delivered in this part of ESO Data Release 1 (DR1) includes the VISTA/VIRCAM paw-print and tile images that were acquired until September 30, 2010, and processed by the Cambridge Astronomical Survey Unit (CASU). This "VVV_VAR" data release contains data for every source in DR1 that has been provisionally classified as variable. Only a few simple parameters are provided (mean magnitude, amplitude and probability that it is a genuine variable) owing to the small number of epochs in DR1. The corresponding images have already been released in the part of DR1 identified as "VVV" in the ESO archive. VVV_VAR contains 268 tile catalogues (only 200 fields have >1 epoch in VVVDR1, we found small numbers of potential variables in other fields, because of overlap regions.).

Overview of Observations

The VVV photometry is divided into different disk and bulge tiles. The tile nomenclature goes from d001 to d152 in the disk, and from b201 to b396 in the bulge. The map with the field IDs is shown in Figures 1a and 1b, overlapped on the extinction map of the inner Milky Way from Schlegel et al. 1997.
For each VISTA tile, the Ks images at each epoch were usually obtained in an OB that included 4 tiles. The exception is the master images, which were obtained in an OB with contemporaneous JHKs photometry. The integration time on source was usually 16 s at each epoch, with the exception of the master images in the disk region, which had 80 s integration time on source.

Release Content

The VVV Survey observations planned for Year 1 (ESO Period 85) comprised JHKs maps as first priority, ZY maps as second priority, and 5 epochs in the Ks-band to test for variability, for the entire bulge and disk fields (all 348 tiles covering >520 sq., deg).

The VVV Survey Year 1 variability data is illustrated in Figure 2. The files in this VVV Survey DR1 include images and their respective photometric catalogues that have passed the Quality Control (QC).

The coordinates given in the catalogues are an average of the coordinates in each passband, weighted according to the errors. In total, the catalogues contain 2.08×10^8

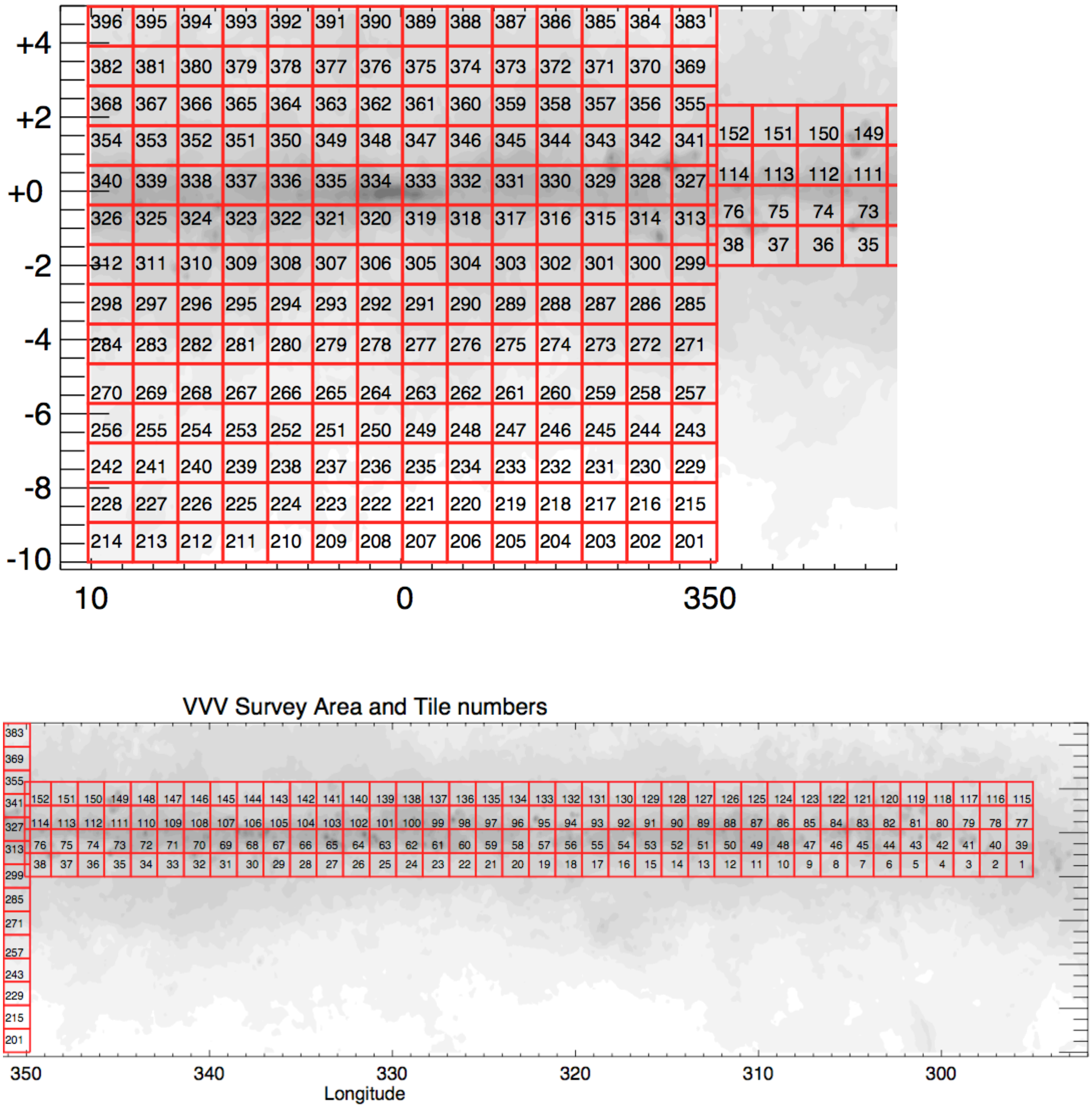

Figure 1. Maps showing the VVV tile numbers for: (a) bulge (upper panel); and (b) disk (lower panel).

sources, although about 10% of these are duplicate detections because of the overlaps between adjacent tiles. Of these, ~680,000 are provisionally classified as variable sources. Catalogues in the disc region are deeper than the bulge region, owing to lower source confusion. The 5 sigma photometric limits for isolated sources in the disc region are typically Ks=17.2 for the 16 s integrations and Ks=18.0 for the 80 s integrations. In the bulge region the limits vary widely, so it is not useful to quote a single figure for each passband. Note that the quoted errors do not take account of blending between adjacent sources, although the aperture photometry does deblend the fluxes in adjacent overlapping apertures.

Sources are provisionally classified as variables and included in this VVV_VAR collection if the r.m.s. variation in the Ks magnitudes was more than 3 times the expected variation, which was calculated from a polynomial fit to the modal r.m.s. variation as a function of mean magnitude.

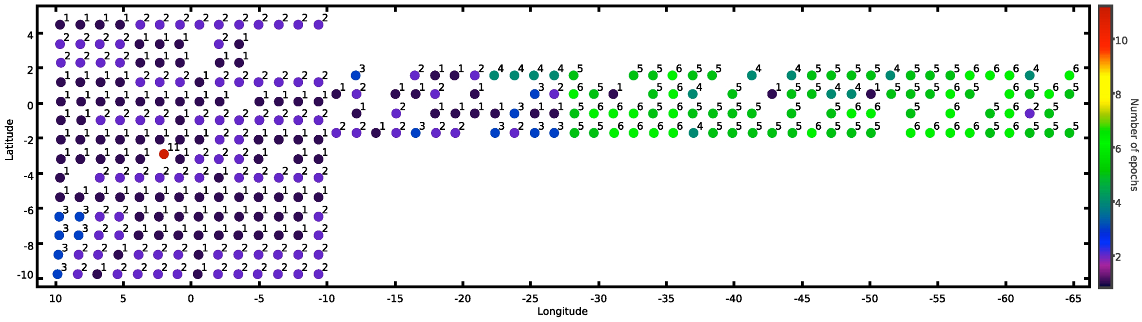

Figure 2. Colour coded plot showing the number of Ks epochs of observation for each tile in this release. Only the Baade's window tile (a Science Verification target) has N>6 epochs.

Release Notes

Data Reduction and Calibration

The pipeline is composed of the following mains steps: reset correction, dark current subtraction, linearity correction, flat field correction, sky background correction, de-striping (removal of a consistent electronic signal pattern from the arrays), illumination correction, image stacking into tiles, catalogue generation and then astrometric and photometric calibration. The sky background correction is based on the combination of 24 distinct VISTA pointings over 2 consecutive tiles imaged in the same OB, which has proven to be sufficient to remove stars in crowded VVV fields.)

The following procedures are done on an individual tile basis.
The photometric calibration on to the VIRCAM (Vega-based) photometric system is derived from the 2MASS Point Source Catalogue, using relatively blue 2MASS sources with JHKs detections with <0.1 mag uncertainties in all 3 passbands, 0<(J-Ks)<2 (as observed in 2MASS) and 0 < (J-Ks) < 1 (after dereddening the 2MASS sources individually using a prescription involving the Schlegel COBE/DIRBE extinction maps. Linear transformations between the 2MASS and VIRCAM photometric systems were applied that incorporate a colour term (based on 2MASS colours) and an extinction term based on the Schlegel maps). Aperture corrections are different for the 96 different sections of each VIRCAM tile (made from 6 pointings of the 16 arrays) and this is accounted for in the calibration after generation of the tiles and construction of initial tile catalogues.

An overlap analysis between adjacent tiles was used to confirm that nearly all tiles have consistent calibrations, though further small improvements are being made as the pipeline is continuously improved.

Aperture-corrected source magnitudes are provided in a 2 arcsec diameter apertures, known as aperture 3, hence the name ksapermag3 for the magnitues given in this “VVV_MPHOT_KS” data collection.
The astrometric calibration is relative to the 2MASS Point Source Catalogue, with a typical precision of 0.08 arcsec for bright isolated stars.

Source detection requires 4 contiguous simply-connected pixels to be above a detection threshold set at 1.5 times the r.m.s. sky noise. Prior to source detection, the tile images are spatially filtered to remove the pattern of joins between the 96 components sections of a tile using a ~30 arcsec spatial filter. Nebulosity on smaller scales (e.g. in star formation regions) is not removed and this can affect detection and photometry of faint stars. Note that the spatial filter was not used on the tile images in the “VVV” data collection, only from the images used for source detection.

Quality Control

The DR1 is based on version v1.1 of the data reduction pipeline developed by the Cambridge Astronomical Survey Unit (CASU).

Visual Quality Control was performed in different steps. The jpeg images of each tile were inspected to remove tiles with obvious defects, e.g. highly non-uniform background. Then, visual Quality control of VVV tiles was made on a fraction of the FITS images. A word of caution: this intense activity is continuing, and even though we checked the images for defects, we are still identifying images that need to be reprocessed or reacquired.

The Quality Control for the Phase 3 data from v1.1 was performed on the paw-prints with involvement of most of the scientists from the team. We checked image defects, telescope problems, seeing, zero points, magnitude limits, ellipticities, airmass, etc. There are a number of well known image defects intrinsic to VISTA, many of which are illustrated with pictures in the CASU and VVV web pages (document vvv_defects.pdf).

Algorithmic quality control cuts to remove images with low zero points (after correcting for the seasonal trend), seeing that was significantly outside specification, or high average ellipticity were also applied. These were based on the v1.0 reduction pipeline, but no significant changes are expected in the v1.1 data.

Known Issues

Users of the catalogues should be aware that ~1% of the area of each tile (at the top right, in pixel coordinates) suffers less reliable photometric calibration (particularly in the Z, Y and J passbands) owing to the poor quality of VISTA/VIRCAM detector no.16, whose quantum efficiency is highly variable in the upper part of the array. The region affected, and any other regions of below average data quality in a given tile, can be seen by inspecting the confidence images in the “VVV” data collection.

Users should also note that the sections of each tile near the left and right edge (in pixel coordinates) have half the normal exposure time since they lie at the edge of the standard VISTA tiling pattern. These sections are each 0.092 degrees in width. Again, they can be seen by inspecting the confidence images in the “VVV” data collection.

Bright saturated stars produce local maxima around them which are interpreted as detections by the extraction software. These spurious objects are typically classified as extended and many of them have large ellipticities.

Saturated objects also have a "hole" in their centre visible as a dark spot in the images. This is due to the double correlated sampling used during image readout.

The completeness of the tile catalogues is good in the “disk” portion of the VVV survey but less good in the bulge, where source confusion is highest. This is discussed in detail in the VVV DR1 publication (Saito et al.2012).

INCONSISTENCY in variable numbers between VVV-CAT and VVV-VARCAT:
The inconsistency arises from design of the VDFS data pipeline, which uses a master source list derived from a seamless merged-band table derived from the deepest images in each band. In the VVV, this is the single epoch ZYJH and deep Ks. VVV-VARCAT lists all objects drawn from this master table which are classified as variables. The VVV-CAT consists of sources in this linked to the contempory colours data, the single epoch ZYJHKs. Those that are flagged as variables in VAR-CAT have the additional constraint that they are detected in the single Ks-band epoch. This is true for >99.9% of the sources, but not the case for all.

Data Format

Files Types

There is only 1 type of file in this data collection: the multi-epoch Ks tile catalogue FITS files.

Catalogue Columns

The formats are as follows. “A” = character string. “K”=64 bit integer. “D”=double precision. “E”= single precision. “I”=16 bit integer. “J”=32 bit integer.

IAUNAME; 29A; Unique identifier, following the IAU naming convention

sourceID; K; UID of this merged detection as assigned by merge algorithm

ksmeanMag; E; Mean Ks magnitude

KSMEANMAG is the mean magnitude of the good measurements (ppErrBits=0 or 16 - no problems or blended) in the aperture which gives the lowest rms for that source (see Cross et al.

2009, MNRAS, 399, 1730 for details).
We calculate the rms in apertures 1 - 5 (radius = 0.5", 0.707", 1.0", 1.414", 2") and find the minimum rms. We originally only used data with no quality issues (ppErrBits=0), but this excluded almost everything in parts of the VVV where the density of objects was very high, so for this survey we use ppErrBits=0 or 16 (photometry potentially affected by deblending).

KsAmpl; E; Amplitude of variable in Ks-band

KSAMPL is the difference between the maximum and minimum magnitude for the good measurements (see definition in KSMEANMAG) in the best aperture (see definition in KSMEANMAG)

ksprobVar; E; Probability of variable from chi-square (and other data)

KSPROBVAR is the probability that an object is variable assuming that the data points are from a distribution at the same mean magnitude with the noise properties of a non-variable star. This is a complex affair, which involves fitting a simple noise model to the locus of non-variable stars in the KSMEANMAG, KSMAGRMS distribution, calculating the reduced chi-squared of the data to the model (i.e. a simple mean-magnitude) and integrating the reduced chi-squared distribution between 0 and the reduced chi-squared. This is laid out in detail in Section 4.3 of Cross et al. 2009, MNRAS, 399, 1730.

Acknowledgements

Credit: the VVV team. The References are:
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