The second UltraVISTA data release

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1 Abstract

UltraVISTA is a ultra-deep near-infrared survey which targets a sub-area of the COSMOS field (Scoville et al. 2007).

This document describes the second UltraVISTA-TERAPIX data release, DR2. This release comprises stacked images and source lists in all filters of the UltraVISTA survey ($YJHK_{\mathrm{s}}$ and the NB118 narrow-band filter). The principal difference with respect to the DR1 release is a substantial increase in exposure time in the four "ultra-deep stripes" regions (see Table 2). Similar data processing techniques were used as in our previous release, DR1; these are described fully in McCracken et al. (2012).

1.1 Acknowledging these data products

Any publications which use data products must include this text:

"Based on data products from observations made with ESO Telescopes at the La Silla Paranal Observatory under ESO programme ID 179.A-2005 and on data products produced by TERAPIX and the Cambridge Astronomy Survey Unit on behalf of the UltraVISTA consortium."

In addition a reference to the UltraVISTA DR1 survey paper should be included: McCracken et al. (2012).

2 Overview of observations

This release contains as input all CASU processed UltraVISTA images from December, 2009 to approximately May 2012 as available in September 2012. The dates of all the ∼20,000 individual images used are given in the provenance tables in each image, see below.

This comprises three complete observing seasons: however, very little data was taken in 2010-2011 due to VISTA primary mirror being re-coated during the UltraVISTA observing season.

3 Release Content

In this release we are making available five stacked images and their corresponding weight maps for Y, J, H, K_s, and NB118 narrow-band data taken during first three years of public survey operations for the UltraVISTA survey. In addition, single band individual source lists and source lists created in dual-image mode (using the K_s image as a detection image) are provided. Total data volume is unchanged from previous release, i.e., $\sim$ 88Gb in total, including source lists. The total unmasked survey area is 1.5deg^2.

4 Release notes

4.1 Data reduction and calibration

We downloaded from CASU individual sky-subtracted images, the corresponding sky frames, flat-fields, bad pixel maps and stacked `_st` images. At this initial stage, no selection was applied. As before, we do not use the confidence maps provided by CASU, but create our own weight-maps from the supplied flat-fields and bad pixel maps. Note that this image selection also includes data we had already processed for the DR1 release; however these images had since been re-processed by a new version of the CASU pipeline and we wished also to take advantage of improvements in the TERAPIX pipeline.

We note that all DR1 images had been visually inspected. During this inspection process we found that a small number of images taken early in the survey had doubled point-spread-functions due to the loss of auto-guiding. These problems were since resolved and do not affect subsequent data. Although we did not visually re-inspect the DR2 images, we preserved the grades from the DR1 processing and used it to reject the images with failed tracking in DR2.

Finally, there were a small subset of images on which we were not able to run the TERPIX quality assessment tools. These were mostly H images from the 2011-2012 season. They were excluded from subsequent processing steps.

Images were processed almost identically to DR1: full details can be found in McCracken et al. (2012). In addition, the data reduction is also described in the DR1 release[1]. To briefly summarise the data production process: we first generate source lists and weight maps from the initial CASU sky-subtracted data and generate first-pass stacks. These first-pass stacks are used to generate object masks which are then used to compute sky frames for each of the individual images. The sky frames are subtracted from the individual images (after the sky-frame generated by CASU are first added back). De-striping (in both $x-$ and $y-$ directions) is carried out as well as a large-scale gradient removal before weight-maps and source lists are re-generated

[1] `http://www.eso.org/sci/observing/phase3/data_releases/ultravista_dr1.html`

once more for each individual images. Once astrometric solutions are computed, the images are coadded to the final COSMOS astrometric grid using a pre-defined tangent point.

Resampling the images onto the final COSMOS astrometric grid represented, however, a challenge. This is because of the large number of images involved (almost 10,000 16-extension VIRCAM images and their corresponding weight maps for the K_s data and an equivalent numbers of images for the other four filters combined). Resampling images directly on the COSMOS grid all at once would have required a large amount of intermediate disk space (around 40Tb). In addition, despite using highly optimised software (`swarp`) the image resampling and coaddition at the COSMOS pixel scale would have taken prohibitively long on single machine. In order to overcome these difficulties, images were sorted into pawprints and subsets of ~ 150 images per pawprint were coadded separately simultaneously on different machines (with the exception of the NB data). As the intermediate image stacks are already on the COSMOS astrometric grid, no further image resampling is needed to create the final stacks. As before, we produce sigma-clipped stacks, using a modified version of `swarp`. By sorting the images by overlapping pawprint, we ensure that we can reliably calculate statistics for each output pixel. Using this technique, the final K_s stack can be assembled in only a few days of wall-clock time.

4.2 Data quality

In Figure 1 we compare the total magnitudes of stars in our source list (`mag_auto`) with those in the 2MASS all-sky point source catalogue (Skrutskie et al. 2006). (Note also that 2MASS is used for the initial photometric calibration of the survey by CASU.) Of course, a significant limitation of this comparison is that the magnitude range over which sources in UltraVISTA and 2MASS overlap is relatively small, and furthermore that the UltraVISTA instrumental photometric system is not the same as the 2MASS system (this is described in more detail in McCracken et al.).

Nevertheless, the result of this test is shown in Fig. 1 where we plot UltraVISTA-2MASS magnitudes for all non-saturated stellar sources and for a total photometric error in (2MASS and UltraVISTA, summed in quadrature) of less than 0.2mag . The thick solid line shows a running median which is always within 0.05 magnitudes of zero for $15.0 < \text{mag} < 17.0$. These curves are very similar to those plotted in McCracken et al., considering the uncertainties in the 2MASS photometry at these magnitudes.

In Figure 2 we show the magnitude difference δ between stars in the previous DR1 release of UltraVISTA and this release. We selected point-like sources in the flux-radius magnitude plane and measured the differences between $7''$ aperture magnitudes in DR1 and in DR2 as a function of K_s total magnitude in the range $16 < K_s < 19$. In most cases, the median magnitude differences (shown by the thick green line) are less than 0.05mag from zero. In the Y-band, however, there is an offset of almost ~ -0.05 mag. The origin of this difference is due to changes in how CASU calculate the absolute photometric calibration for the Y band since since DR1[2].

Limiting magnitudes are calculated the same way as in McCracken et al.: first, `SEXtractor` is run on each stack using the same detection threshold parameters as used for source list generation. All pixels belonging to objects to this detection limit are flagged. Next, we measure fluxes in

[2] `http://apm49.ast.cam.ac.uk/surveys-projects/vista/technical/photometric-properties`

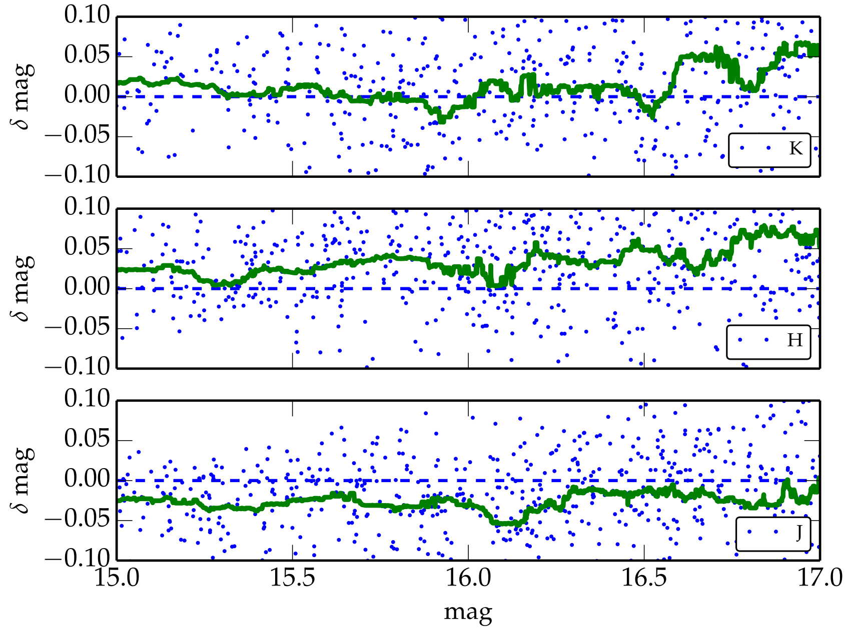

Figure 1: Magnitude difference δ between total J, H, and K_s magnitudes of stars in UltraVISTA DR2 with sources in 2MASS. The green line corresponds to a running median computed over 100 points.

apertures of diameter $2''$ over the entire mosaic; any aperture which contains object pixels is discarded. The limiting magnitude is then simply computed from the standard deviation of fluxes measured in these apertures. These measurements were carried out on each stripe in all bands for all images. Our measurements are summarised in Table 1. Note that, in the limiting magnitude header values supplied to ESO, a aperture correction of -0.3 magnitudes has been applied.

We measured the seeing on all the image stripes using `PSFex`. We find that the seeing (parameter `FHWM_MEAN`) is $0.9''$ for all stripes.

4.3 Known issues

As a consequence of the varying exposure time between the different stripes, it is impossible to assign a single gain value which is appropriate for the entire image. For this reason, no `GAIN` keyword is included in the image headers.

4.4 Previous releases

This release should be considered as superseding the previous release, DR1. The total depth has increased over the entire image, and substantially increased in the deep stripes area.

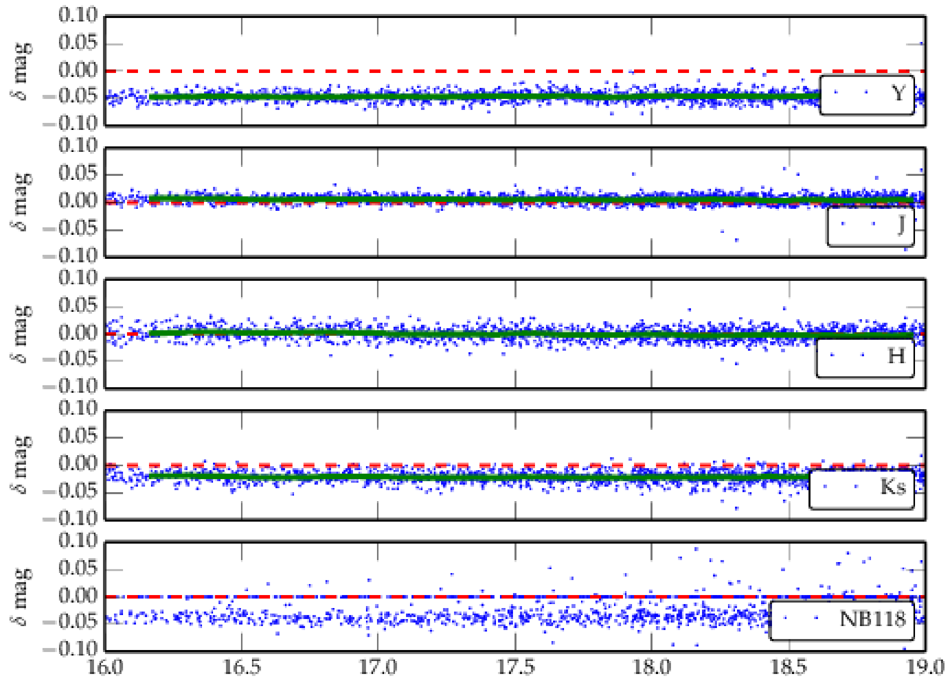

Figure 2: Magnitude difference δ between $7.1''$ aperture J, H, and K_s magnitudes of stars in UltraVISTA DR1 with the corresponding sources in DR2 release. The green line corresponds to a running median computed over 100 objects.

Filter	Exposure time (hrs)		Limiting mag. $5\sigma(2'')$	
	Ultra-deep	Deep	Ultra-deep	Deep
Y	53.2	11.1	25.4	24.8
J	34.9	12.8	25.1	24.6
H	29.4	13.3	24.7	24.7
K_s	81.5	10.6	24.8	23.98
NB118	22.8	-	23.6	-

Table 1: Characteristics of the images, including typical exposure time per pixel and limiting magnitudes in both deep and ultra-deep regions. Note that these magnitudes differ from the image header `ABLIM` values as the offset to total magnitudes of 0.3 has not been subtracted

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5 Data format

5.1 File types

All images and source lists are distributed in standard FITS format. In this release, we are making available five stacked images and their corresponding weight maps for Y, J, H, K_s, and NB118 narrow-band data first year three years of public survey operations of the UltraVISTA survey.

Given the deep and ultra-deep sections have considerably different exposure times, this has the important consequence that the signal-to-noise ratio for an object of a given magnitude will vary across the image. Rather than providing the higher signal-to-noise zones as separate images, we instead provide for each band the complete image. An inspection of the weight map provided with each image will indicate the location of the deeper zones.

These images have a zero point of 30.0 AB magnitudes for a one second equivalent exposure time and a pixel scale of $0.15''$/pixel. The images all have a common tangent point, in decimal RA, DEC (J2000) of (150.116,2.2000), corresponding to the tangent point of the publicly available IRSA/COSMOS images. Each image is $\sim$ 9Gb in size.

Following the ESO Phase 3 standard, the FITS files for the 5 stacks are multi-extension FITS files, with the stack in the primary HDU (header data unit) and with a so-called provenance table in the first (and only) extension. The provenance table lists all the raw images that — after processing at CASU and TERAPIX — were combined to make the given stack. The FITS files for the weight maps for the stacks have the same provenance tables as the FITS files for the stacks.

5.2 Complete list of distributed products

Tables 2 and 3 lists the imaging and source list data products distributed in this release. Five images are provided, as well as their corresponding weight maps. These weight-maps correspond to the `MAP_WEIGHT` images produced by `swarp` and have pixel values proportional to the inverse variance.

We provide two sets of source lists: "dual-mode" ones, in which the K_s image is used as the detection image and each of the other images in turn is used as the measurement image; and "single band" images in which each individual image is used in turn as both measurement and detection image. Dual mode source lists have the advantage that, as the same number of entires is present in all source lists, colours can be easily computed for each object. The second source list type contains, in principle, all sources to a given detection threshold (1.8σ). Source Lists were extracted using `SExtractor` (Bertin & Arnouts 1996) version 2.19.4 downloaded from the public SVN on astromatic.net[3]. A partial list of source list parameters is given in Table 4. Source Lists are delivered in FITS format.

For each source in the source list we provide flux measurements in 18 photometric apertures. The diameter in pixels of these apertures is as follows:

[3] `http://www.astromatic.net/repositories`

Filename	Description
UVISTA_Y_02_09_13_allpaw_skysub_015_dr2_v2.fits	$Y-$band stack
UVISTA_Y_02_09_13_allpaw_skysub_015_dr2_v2.weight.fits	$Y-$band weight
UVISTA_J_08_06_13_allpaw_skysub_015_dr2_v2.fits	$J-$band stack
UVISTA_J_08_06_13_allpaw_skysub_015_dr2_v2.weight.fits	$J-$band weight
UVISTA_H_15_06_13_allpaw_skysub_015_dr2_v2.fits	$H-$band stack
UVISTA_H_15_06_13_allpaw_skysub_015_dr2_v2.weight.fits	$H-$band weight
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2.fits	K_s-band stack
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2.weight.fits	K_s-band weight
UVISTA_NB118_31_07_13_allpaw_skysub_015_dr2_v2.fits	NB118-band stack
UVISTA_NB118_31_07_13_allpaw_skysub_015_dr2_v2.weight.fits	NB118-band weight

Table 2: Summary of stacked images distributed in the UltraVISTA DR2 data release. All images have a zero point of 30.0 AB for a one second equivalent exposure time and an image scale of 0.15″/pixel.

Filename	Detection	Measurement
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2_Y.cat.fits	K_s	Y
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2_J.cat.fits	K_s	J
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2_H.cat.fits	K_s	H
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2_Ks.cat.fits	K_s	K_s
UVISTA_Ks_01_09_13_allpaw_skysub_015_dr2_v2_NB118.cat.fits	K_s	NB118
UVISTA_Y_02_09_13_allpaw_skysub_015_dr2_v2.cat.fits	Y	Y
UVISTA_J_08_06_13_allpaw_skysub_015_dr2_v2.cat.fits	J	J
UVISTA_H_15_06_13_allpaw_skysub_015_dr2_v2.cat.fits	H	H
UVISTA_NB118_31_07_13_allpaw_skysub_015_dr2_v2.cat.fits	NB118	NB118

Table 3: Single-mode and dual-mode source lists distributed in this release.

```
13.33,20.00,47.33,3.33,3.93,4.63,5.46,6.44,7.59,8.94,10.54,
12.43,14.65,17.26,20.35,23.99,28.28,33.33.
```

This corresponds to three apertures of 2″, 3″and 7.1″and logarithmically spaced apertures from 0.5″ to 5″.

6 Acknowledgements

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Column name	Description
SOURCE_ID	UltraVISTA source designation (DR2)
NUMBER	Running object number
ALPHA_J2000	Right ascension of barycenter in decimal degrees (J2000)
DELTA_J2000	Declination of barycenter in decimal degrees (J2000)
X_IMAGE	Object position along x
Y_IMAGE	Object position along y
FLUX_APER	vector fixed aperture flux
FLUX_APER_ERR	vector fixed aperture flux error
FLUX_AUTO	vector automatic aperture flux
FLUX_AUTO_ERR	vector automatic aperture flux error
FLUX_RADIUS	Radius of aperture containing half the flux of MAG_AUTO
FLAGS	SExtractor's FLAGS parameter. Non-saturated non blended objects have FLAGS==0.

Table 4: Selected source list parameters in source lists distributed with this release.

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