ESO Phase 3 Data Release Description

Data Collection	ATLAS DR1
Release Number	1
Data Provider	T Shanks
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Abstract

The data being released are the VLT Survey Telescope (VST) ATLAS stacked reduced images and associated source lists taken from the start of observations by VST in August 2011, through to end September 2012 under ESO id 177.A-3011. The passbands covered are the SDSS *u,g,r,i,z* bands reaching approximately the same depth (*r~22*) as the SDSS survey in the Northern Hemisphere. Seeing is specified to be between 1-1.4arcsec. The total sky coverage in DR1 is ~1200-2000deg^2 of sky depending on band, out of the target of ~4000deg^2 at high Galactic latitudes. Each ATLAS field comprises a stacked pawprint composed of 2 pawprints offset by 25 arcsec in X and 85 arcsec in Y which takes out most of the inter-chip gaps between the 32 OmegaCAM CCDs. There are also 2arcmin overlaps in both RA and Dec between fields to allow cross-calibration in the final data release. The ATLAS survey is particularly aimed at survey cosmology but can be exploited for many other branches of extragalactic and Galactic astronomy. Its wide wavelength coverage from the *u* to the *z* bands complements the VISTA Hemisphere and VIKING Surveys in the *YJHK* bands.

Overview of Observations

Table 1 summarises the basic characteristics of the ATLAS DR1 data release:

Table 1 – Basic VST ATLAS DR1 summary

	u	g	r	I	z
Exposure (s)	2x60s	2x50s	2x45s	2x45s	2x45s
No. of Fields	1284	1531	1759	2015	2057
No. of Stacked Pawprints	1662	1694	1975	2506	2840
~Area (deg^2)	1200	1430	1640	1880	1920
Median Mag Lim.	21.08	23.20	22.56	21.58	20.32
Median Seeing (")	1.12	1.03	0.96	0.92	0.96
APASS AB-Vega	(0.85) ±0.05	-0.05± 0.03	0.13±0.03	0.37 ±0.04	(0.21)± 0.04
Expected AB-Vega	0.96	-0.09	0.16	0.39	0.54

Notes: rows (2,3), The number of stacked pawprints is more than the number of fields covered because of the inclusion of repeated observations in DR1. row(5): Median 5σ magnitude limit for ATLAS DR1 . row (7): APASS - VST offsets from m<16 mag stars over 240 fields in the GAMA region. The errors are the clipped standard deviations of the distributions in Fig. 3. The u an i offsets are in brackets since they have been estimated from APASS B and V in the case of u and from i and J in case of z, explaining the difference with values in row(8).

These exposure times are longer than the ~55s of SDSS to take into account the 0.21arcsec pixels of VST OmegaCam compared to the 0.4 arcsec SDSS pixels and produces approximately similar S/N as SDSS despite the larger contribution of read-out noise. Note that ATLAS OBs are generally composed of a concatenation of 17 fields in a given band, taken in fixed Declination strips in the direction of increasing RA. The *ugr* images are taken in dark time and the *iz* images are taken in grey/bright time.

Images and source lists for all ESO Grades are being supplied. The specified survey quality is limited to ESO Grade A, B and occasionally C, in cases where only a single field in a 17 field concate-

nation was at C grade. Otherwise C and D grade fields either have been or will be repeated. But all available data are being supplied in this release, partly because ~4% of images have no ESO grades available. This causes the total number of stacked pawprints (10677) to be larger than the total number of fields observed (8646) (see also Table 1). The TL_RA and TL_DEC header keywords are identical for all data belonging to the same field. The most recent stacked pawprint of a given field and filter is generally the one with OBSTATUS = Completed.

Fig. 1 below shows the ATLAS coverage at 30/9/12 on which the DR1 release is based. A different map applies to each band.

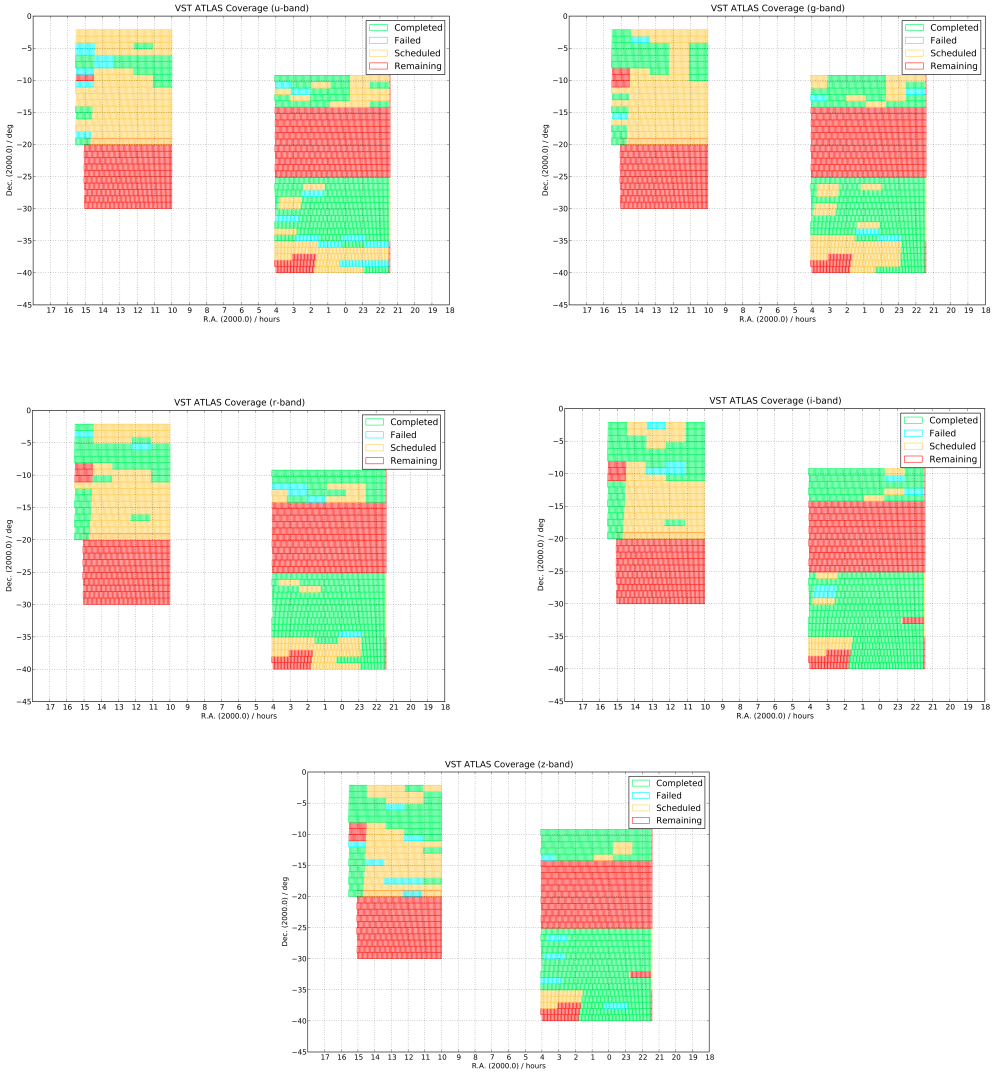
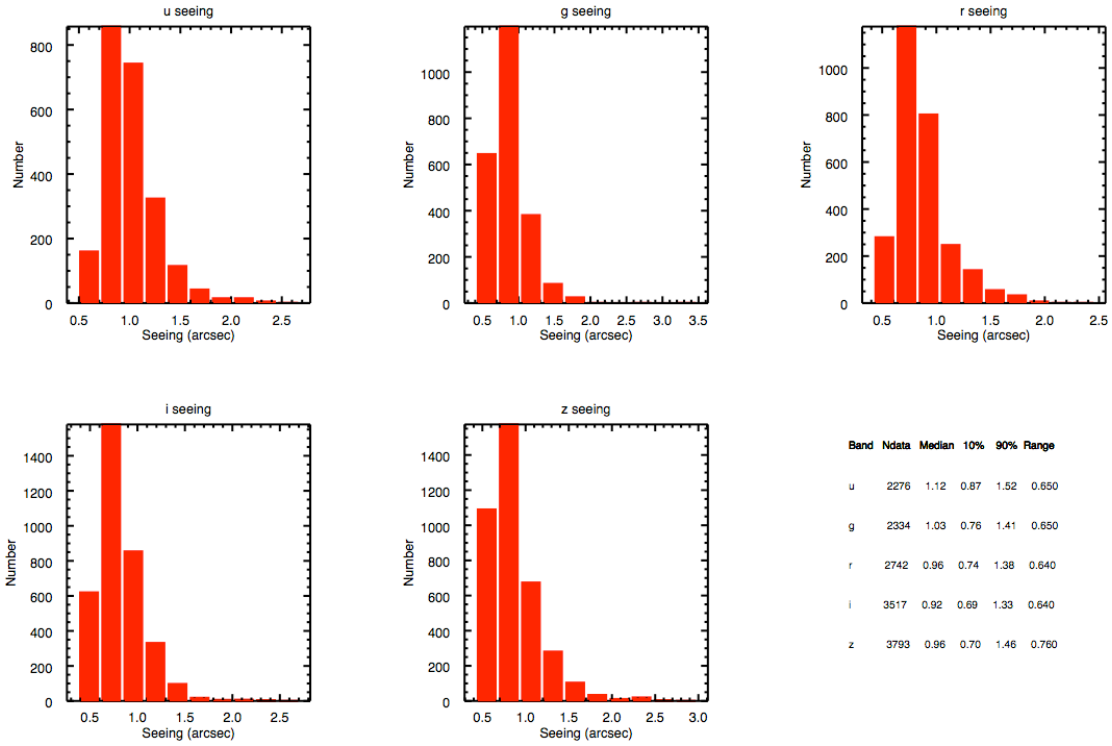


Fig.1. VST ATLAS coverage of fields in the DR1 data release. From top left ugriz bands. Green means fields successfully completed by end of September 2012. Blue means failed, yellow means OB submitted and red means no OB submitted by this same date. DR1 includes most of the fields marked green and blue.

Release Content

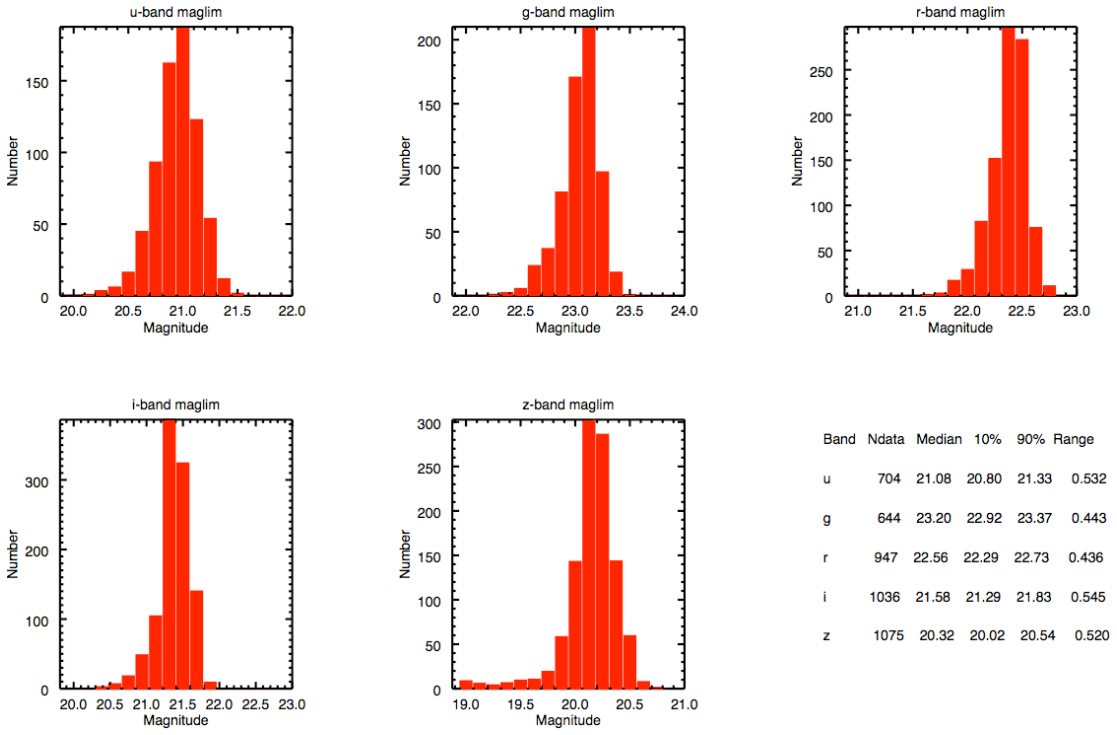
The imaging data comprises the combination of the two individual pawprint images which goes to make an ATLAS stacked pawprint in each field. Each file is in a multi-extension fits (MEF) format with an extension for each of the 32 OmegaCam CCDs in the stacked pawprint. Individual CCDs originally contained 2048x4096 pixels and the stacked pawprint extensions contain approximately 2165x4500 pixels to cover the two 25"x85"offset CCDs that make up each extension in a stack. Along with the imaging data, we are also releasing statistical confidence maps in the same format. The seeing is specified to be <1.4 arcsec FWHM and the distributions by passband are shown in Fig. 2. The distribution of limiting magnitudes at the 5σ detection level by

are shown in Fig. 2. The distribution of limiting magnitudes at the 5σ detection level by passband is shown in Fig. 3. DR1 comprises a total of 32031 data files occupying a total of ~6Tb uncompressed or ~3Tb in its default Rice compression. The total area covered is ~1000 deg^2. The 2-pointing dither leaves 14 small (2x80x20arcsec^2) holes amounting to 1/3% of the total area. Since different bands are observed at different times some fields have currently only partial passband coverage.



Band	Ndata	Median	10%	90%	Range
u	2276	1.12	0.87	1.52	0.650
g	2334	1.03	0.76	1.41	0.650
r	2742	0.96	0.74	1.38	0.640
i	3517	0.92	0.69	1.33	0.640
z	3793	0.96	0.70	1.46	0.760

Fig. 2. Seeing (FWHM) distributions from ATLAS data release DR1.



Band	Ndata	Median	10%	90%	Range
u	704	21.08	20.80	21.33	0.532
g	644	23.20	22.92	23.37	0.443
r	947	22.56	22.29	22.73	0.436
i	1036	21.58	21.29	21.83	0.545
z	1075	20.32	20.02	20.54	0.520

Fig. 3. ugriz 5σ magnitude limit distributions from ATLAS data release DR1.

The source list data covers the same pixel areas as the stacked pawprints (see above). The derived object source lists are also stored as multi-extension FITS files using FITS binary tables, one for each image extension with the primary header unit containing the telescope and observation-specific information. The source list extension headers contain a copy of the relevant detector-specific information. Each detected object has an attached set of descriptors, forming the columns of the binary table and summarising derived position, shape and intensity information. During further processing stages ancillary information such as the sky properties, seeing and so on are derived from the source lists and stored in the FITS headers attached to each source list extension. All derived parameters are stored as floating point numbers. A full description of the source list columns is given at
http://apm49.ast.cam.ac.uk/surveys-projects/vst/technical/catalogue-generation

Release Notes

Astrometric calibration is via the numerous unsaturated 2MASS point sources available in each field. By stacking residuals from a series of standard Tangent Plane astrometric fits based on 2MASS we can see (as in the example in Fig. 4 below) that there are no significant astrometric distortions over the whole field of view. The individual detector astrometric solutions achieve rms accuracies of around 70-80mas per star - generally dominated by rms errors in 2MASS stars. Even at high Galactic latitudes there are sufficient calibrators to give systematic residuals at the ~25mas level per detector. The global systematics from stacking multiple solutions are better than this as can be seen in Fig. 4. A Tangent Plane projection (TAN) is being used for all data products.

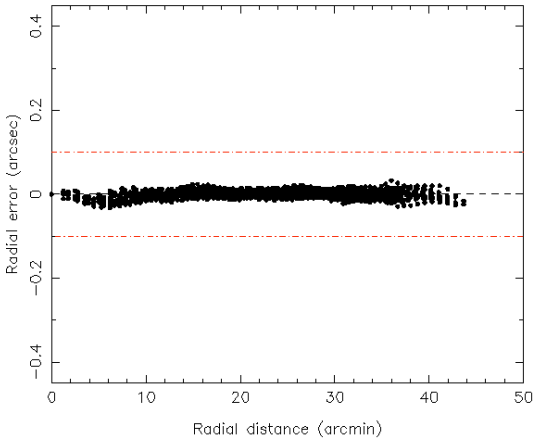


Fig. 4. Astrometric VST-2MASS residuals for stars as a function of distance from field centre.

The overall photometric calibration of each pointing is currently based on the limited number of standard fields observed VST each night. The calibration is currently in a VST Vega-like system, but as the average standard star SED and the detector response drops rapidly in the UV it would be surprising if there were not issues in at least the *u*-band calibration. Note that the current zero-points are still based on the original source lists rather than the illumination-correction fixed source lists (see below).

In addition there are available a few extra calibration OBs taken with shorter exposures in photometric conditions to give an independent photometric calibration of fields within the ATLAS footprint of the *ugriz* sequences from http://www-star.fnal.gov/Southern-ugriz/www/Fieldindex.html . In total, twelve of these fields lie within the ATLAS region, split evenly between our SGC and NGC areas. Ultimately these can be used along with the 2arcmin field overlaps and external surveys such as the AAVSO Photometric All-Sky Survey (APASS-http://www.aavso.org/apass) to anchor the global calibration in the final ATLAS release.

Data Reduction and Calibration

The data processing of the science products released in this data release comes from version 1.0 of the VST Data Flow System (VDFS) pipeline running at the Cambridge Astronomical Survey Unit (CASU), but unlike VPHAS did not require the additional use of the nebulosity filter prior to source extraction. Saturated stars can be automatically flagged post-processing accoring to use needs. The reflection artefacts around heavily saturated bright stars can generate spurious detections but the contamination is reduced if source lists are matched during band-merging. As specified in the Survey Management Plan, source lists for individual pawprints are supplied with no attempt to reject overlaps. Such a catalogue will be produced for the final, globally calibrated survey. The astrometric reference catalogue is 2MASS. The Vega photometric reference system currently is based on the *ugriz* standards specified by ESO, but future ATLAS releases will include an AB zeropoint based on science data matches with the APASS survey. The illumination correction is already made from a comparison of each month of data from all VST public surveys with the APASS survey. This correction has been applied to source list photometry but not to image pixels. Global calibration will be addressed in the final release. Stellar aperture corrections are supplied for each photometric aperture used in the source list and these can be used to estimate total fluxes or magnitudes for stars. PSF magnitudes will be produced for the final data release. Source fluxes in the binary tables are in ADUs and require corrections for aperture loss, airmass (relative to unity), and application of the appropriate magnitude zeropoint. The relevant information is supplied in the source list headers. No correction for Galactic extinction has been applied or supplied, in part because the correction is specific to the extinction model adopted.

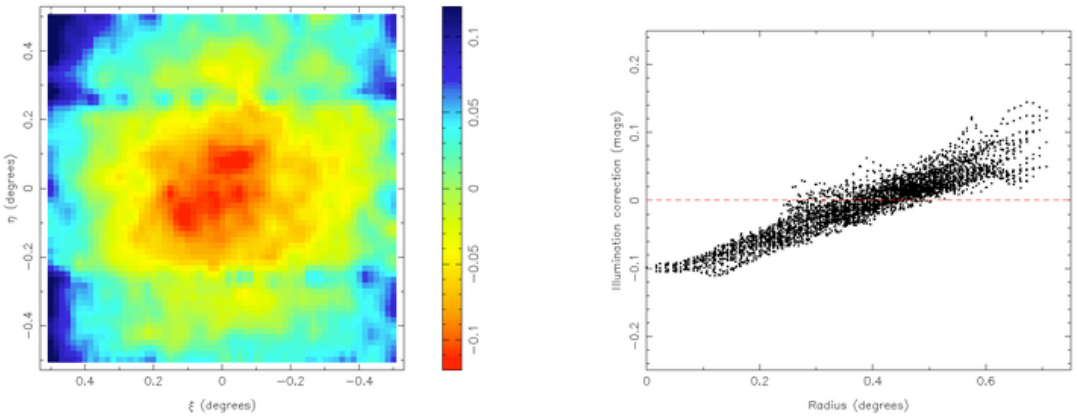


Fig 5. The illumination correction in the i-band as measured by residuals from APASS photometry. The released source lists have had the illumination correction applied based on source position in the image plane.

Data Quality

The astrometric calibration is uniform across the survey to an *rms* accuracy of 25mas relative to 2MASS. Indeed, various fields scattered across the ATLAS area have already been used as the basis for 2dF fibre observations with no astrometric problem. The main problem in the released images is a non-uniform photometric response across the field caused by the presence of scattered light in the VST flat-fields. with a pattern across the pawprint which typically looks like that shown in Fig. 5. The scattered light is made up of multiple components having different symmetries and scales causing effects ranging in scale from ten arcsec with x-y rectangular symmetry, e.g. due to scattering off masking strips of CCDs, to large fractions of the field due to radial concentration in the optics and to non-astronomical scattered light entering obliquely in flats. The illumination correction removes the dominant reproducible components of this effect in the source lists leaving the zeropoint across the field uniform to ~±0.003mag. In addition, one detector, #82, otherwise known as CCD #10 in the MEF extensions, had a gain which intermittently varied by up to 0.5 mag until the video board replacement in June 2012; this may not always be taken out by the flatfield.

The present zeropoint calibration is good to ±0.05mag between fields across the survey (see rows 7 and 8 of Table 1 and Fig. 6). This applies across all filters and epochs. Zeropoints of colour indices may thus be good to ~±0.07mag. Note that the AB-Vega offsets in row 7 are only ap-

proximate in *u* and *z* because of the extrapolations involved in transforming APASS B and V to *u* and APASS i and J to z.

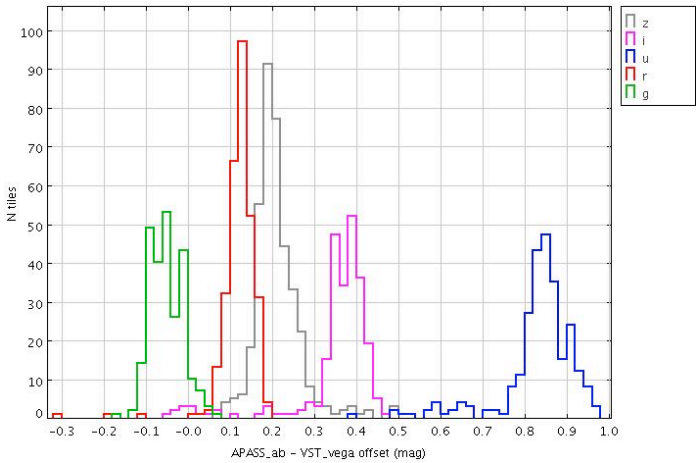


Fig 6. The ugriz distributions of APASS AB-VST Vega offsets for m<16mag stars from ~240 fields in the SGP GAMA region. The means and standard deviations are given in Table 1.

Quality of magnitudes have been better checked for point sources than for galaxies. It may be possible to extend depth for galaxies by specific smoothing of image before source detection.

Contamination of the source list by spurious sources is at the <5% level down to the limiting magnitudes estimated in the headers. The source lists are estimated to be ~50% complete at the quoted 5σ limiting magnitudes.

Finally, in Fig. 7 we show for a science example, colour-colour diagrams for g<22.5 stars in one ATLAS field as recently used to select quasars for the 2dF QSO Dark Energy Survey pilot at the Anglo-Australian Telescope (AAT).

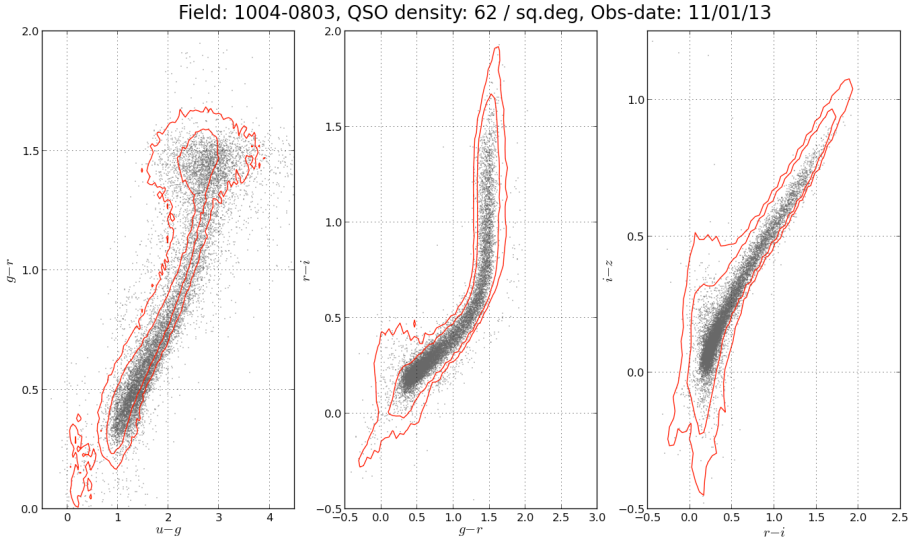


Fig. 7. ugr, gri and riz colour-colour diagrams for stellar objects to g~22.5 in an ATLAS field as used to select QSO targets for AAT 2dF. The red contours are from SDSS selected stars for comparison.

Known issues

The illumination correction for scattered light in the flatfields has only been applied to source lists and not the image pixels. This problem will have to be addressed before attempting surface photometry of very large galaxies but even then the additive scattered light present in all images may preclude achieving reliable surface photometry at faint magnitudes.

We also note the occasional presence of pickup noise in some observations at the level of ±10ADU caused by guide/wavefront sensor readout happening at same time as science frame read-out. A similar pickup pattern occurs on all 32 detectors and is fixable in post-processing. This problem was (mostly) fixed by some modifications to control software in Autumn 2012.

Note that in observations taken in approximately the first 2 months of the survey, ie before 3/10/11, the 25 arcsec dither in X(~RA) between the two pawprints that make up the stacked pawprint was gradually reduced as each of the 17 fields in a Group for a given RA range was observed, due to a VST technical problem. This means that the main CCD gaps in the Dec direction are not filled in as well as they should be in the stacked pawprint. Data taken after the above date were taken as concatenations and should be unaffected by this problem.

For source lists, the correct keyword values that characterise the observation at large (e.g. T/EXPTIME, MJD-OBS, TELESCOP etc) are to be taken from the primary header, and not from the extension header.

Previous Releases

DR1 is the first data release for VST ATLAS.

Data Format

Files Types

The image files are in multi-extension FITS (MEF) format with an extension for each of the 32 CCDs in each stack**.** The derived object source lists are also stored in multi-extension FITS files as FITS binary tables, one extension for each image extension with the primary header unit containing the telescope and observation-specific information. The source list extension headers contain a copy of the relevant detector-specific information.

Both images and source list filenames are in the form o20110914_00092 where the night of observation is followed by the ESO VST nightly run number. The suffix _st indicates that the image or source list is based on a stacked pawprint. A suffix _cat indicates that the file corresponds to a source list. A suffix _conf indicates that the file contains the statistical confidence map for the field. The file type fits.fz indicates Rice compressed FITS file and these can be de-compressed using e.g. CFITSIO *funpack*.

Source list Columns

A full description of the source list columns is given at
http://apm49.ast.cam.ac.uk/surveys-projects/vst/technical/catalogue-generation

Acknowledgements

Please use the following statement in your articles when using these data:

Based on data products from observations made with ESO Telescopes at the La Silla Paranal Observatory under programme ID *177.A-3011(A,B,C)* (see Shanks et al in preparation.)