Data Collection	VPHAS-DR1
Release Number	1
Data Provider	J. E. Drew
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Abstract

The primary goal of the VST Photometric Ha Survey of the Southern Galactic Plane and Bulge (VPHAS+) is to collect single-epoch ugri broad-band and Ha narrow-band photometry across the southern Galactic Plane within the latitude range $-5^o < b < +5^o$ down to point source magnitudes of ~21 or better. The VPHAS+ footprint also includes the inner Galactic Bulge, defined as a 20 x 20 deg^2 box around the Galactic Centre: this assures optical coverage of the full VVV footprint. For all massive OBA stars this survey is deep enough to explore all but the most heavily obscured locations of the southern Plane, reaching to at least ~4 kpc from the Sun. These data will increase the number of known southern emission line stars by up to an order of magnitude, yielding much better statistics on important short-lived types of object. The wide-area uniform photometry obtained will also facilitate stellar population studies, capable of tracing structure over much of the southern Plane. VPHAS+ will trawl the star-formation history of the Galaxy as seen in stellar remnants of all types. Its sensitivity range is well-matched to that of ESA's Gaia mission.

Finally, a well-validated catalogue will be made available that provides 5 optical photometric data points per source at an external (systematic) precision of 0.02—0.03 magnitudes on around 200 million objects. This data release covers the first 9 months of data-taking in which a tenth of the survey footprint was observed to desired quality. These first pointings have favoured the Galactic equator and some well-known open clusters of interest to the Gaia-ESO Survey. Reduced images and unstacked single-band source lists are provided.

Overview of Observations

The originally-proposed survey plan identified a preference for obtaining contemporaneous 5-band photometry in all fields, so that the data would amount to optical snapshots of stellar spectral energy distributions that would lend themselves well to federation with NIR photometric catalogues, so serving a broad range of Galactic Plane science applications. As the VST was commissioned, it became clear that observations seeking exposures from u- to i-band would be too heavily constrained to allow the survey to proceed at a tolerable rate. Hence it was agreed to adopt the alternative strategy included in the original proposal of splitting the data-taking into blue (u, g, r)and red (Ha, r, i) filter sets, that can be combined post-observation using the r-band repeats as aids to calibration and checks on variability. This permits tailoring of the requested observations to suit the filters in each colour set, with the Moon constraints on u, g, r being more exacting than those on Ha, r, i. As a result of this difference, and the fact that it is impractical to constrain the elapsed time between the acquisition of the blue and red data, the latter are being collected more rapidly than the former.

The plot below shows the entire VPHAS+ survey footprint, and picks out the fields that are included in this release. It is immediately apparent that significantly more red observations than blue have been completed so far.

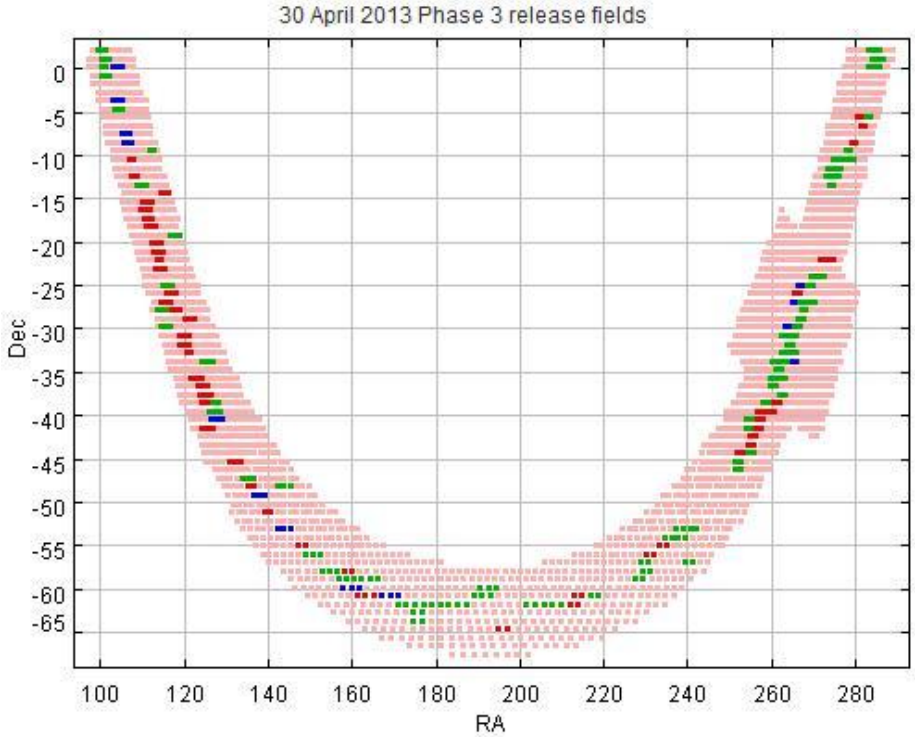

Fig 1: The VPHAS+ footprint (pink, 2269 fields), with the fields in this release picked out. Those in green (183) are fields for which both blue and red filter set are available. In addition, there are 116 fields for which just the red-filter data are released. Another 35 are represented in this release by blue-filter data only.

Two exposures are obtained per field in each broadband filter (u,g,r,i), with the second taken at an offset with respect to the first of -588 arcsec in RA, and 660 arcsec in Dec. In the case of narrowband Ha, three exposures are obtained (to deal with the extra vignetting of this segmented filter), such that the second and third are offset by -300, -588 arcsec in RA and 350, 660 arcsec in Dec with respect to the first pointing. It should be noticed that since r-band data are obtained at two essentially random epochs, there are in fact two 'duplicate' sets of images and catalogues in this one band.

The exposure times per filter are as follows:
u: 2x150 sec
g: 2x30 sec
r: 2x25 sec (at each of 2 epochs)
i: 2x25 sec
Ha: 3x120 sec

Note that within the VST collection of filters, the Ha filter is named as NB_659.

Release Content

This release includes data obtained between 28/12/2011 and 15/09/2012. Reduced images are one of the two major components of this release. These are presented as native 32-CCD OmegaCam pawprint, each representing a tile of 1 x 1 sq.deg. These are unstacked. Altogether there are 299 x 7 Ha/r/i images, and 218 x 6 u/g/r images plus 8 fortuitous repeat exposures (3409 total).

The other major component is made up of the single-band catalogues extracted by the CASU pipeline from the reduced image data. There are as many of these as there are images, although the number of detected objects in them varies from ~ten thousand up to hundreds of thousands, depending on pointing and filter.

The sky region covered is shown in Figure 1. It amounts to close to 183 sq.deg covered in all survey filters, and a further 151 sq.deg observed in either the red or the blue filter set. The frame-to-frame overlap achieved in the single-pass pattern of field centres has been kept small at 1.5 arcmin – the stronger linkage between adjacent fields is achieved via the ~10, 11 arcmin offsets used.

Figure 2 below shows the cumulative distribution of seeing achieved in the released dataset according to filter. In all filters the median is better than 1 arcsec (in most fields the OB seeing constraint is set at 1.2 arcsec). As expected. The greatest challenge at the telescope is presented by u, drawn in blue. Among the other filters the systematic differences are modest.

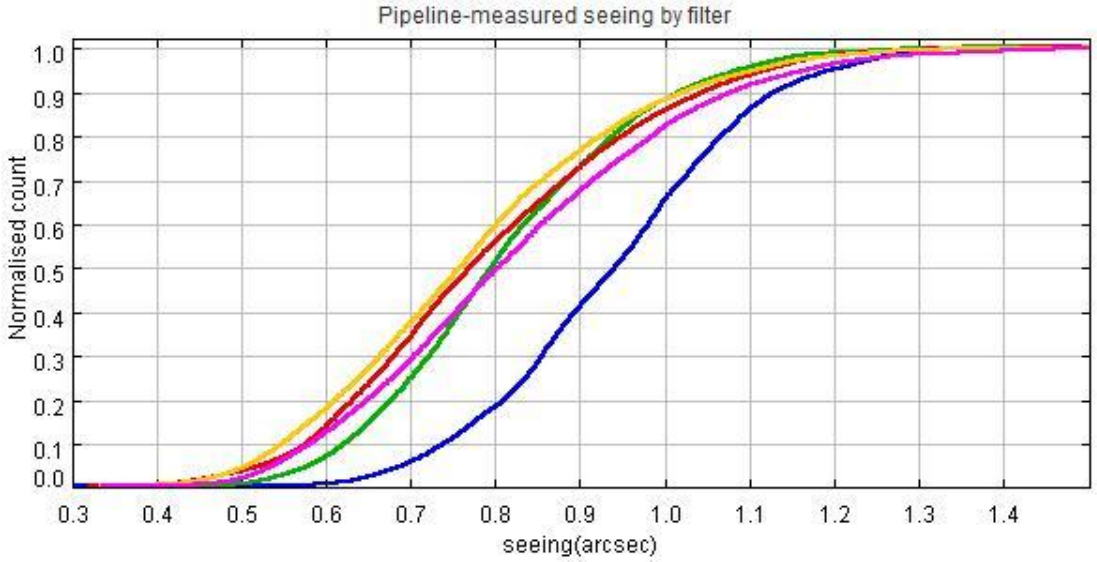

Figure 2: Cumulative distributions of seeing as measured per CCD by the data pipeline, in arcsec, colour-coded according to filter. The curves are coloured as follows: i, gold; Ha magenta; r red; g green; u blue.

The pattern of 5σ limiting Vega magnitudes in this release is illustrated next, in figure 3.

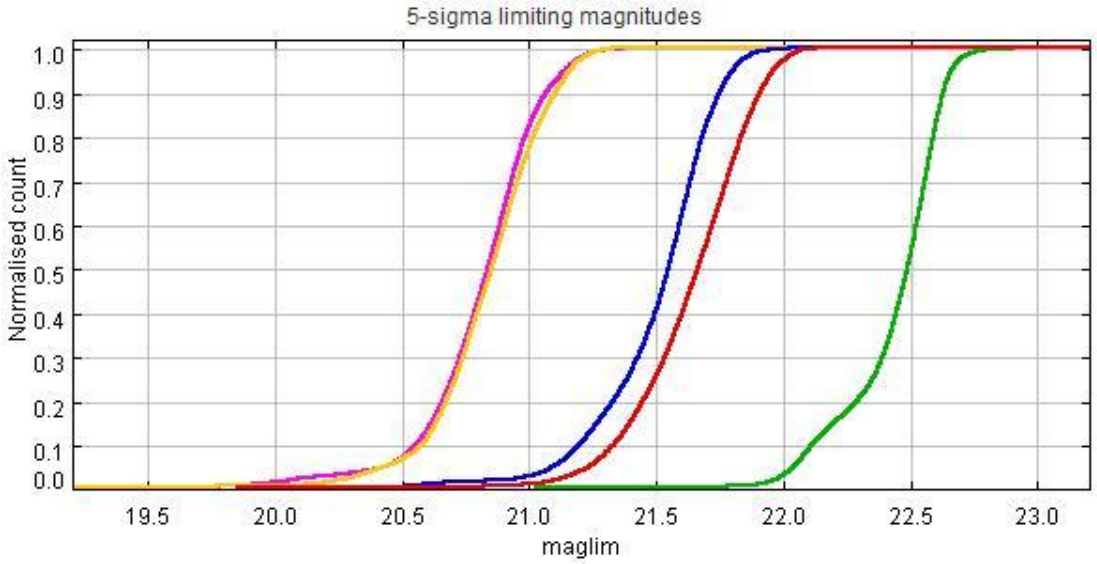

Figure 3: Cumulative distributions of 5-sigma limiting magnitudes reported per CCD by the data pipeline. Colours used are as in Figure 2.

The leftmost curves in gold and magenta are for the i and narrowband Ha filters respectively. Offset to fainter magnitudes by 0.7—0.8 are the u and r cumulative curves (drawn in blue, and

red). Finally, offset again by almost one magnitude, shown in green, is the curve for the g filter exposures. The progression of fainter magnitude limits from i to g is by design to combat the high reddening encountered in much of the Galactic plane, thereby achieving better comparability of source numbers in these key broad bands. The somewhat brighter limiting magnitudes in both Ha (relative to r) and u (relative to g), the filters exposed for longest, are the expected consequence of the practical compromise that renders this survey feasible. We are finding that the sensitivities achieved through these lower-transmission filters are sufficient to provide the good discrimination of special object types that was a major driver for VPHAS+.

The total number of uploaded files is 6866 (of which 48 are confidence maps). The catalogue records (rows) number 530 027 619, and the total data volume is 749 GB.

Release Notes

Data Reduction and Calibration

The data pipeline used to process the raw survey data is operated by the Cambridge Astronomical Survey Unit (CASU) and has many features in common with the VISTA Data Flow System. The latter is described at:
http://casu.ast.cam.ac.uk/surveys-projects/vista/technical/data-processing.
Specifics relating to VST data are presented at:
http://casu.ast.cam.ac.uk/surveys-projects/vst/technical

In brief, the current method of source detection is aperture photometry, applied to the images after the adaptive removal of 'smooth' background due to both telluric and astronomical sources (nebulosity) using CASU's *nebuliser* software. The pipeline includes the morphological classification of all detected sources that distinguishes a range of object types, from high-probability point objects (stars) through to clearly extended objects and noise-like features. At this early stage it is premature to combine catalogues to produce wider-area single filter catalogues – this will begin to be undertaken using band-merged catalogues as more of the survey footprint has been covered. The astrometric calibration is achieved by reference to the 2MASS catalogue. The current photometric calibration of the (Vega) zeropoint is established using nightly standards. As a by-product of making the illumination correction, the calibration of the extracted source fluxes is improved by making comparisons with APASS stellar photometry. Zeropoints in the AB system will become available once a final release of APASS becomes available. The calibration of the Ha data is tied to that of the r–band data, a practice already used to good effect in the IPHAS survey (Drew et al 2005, Gonzalez-Solares et al 2008). No reddening corrections are applied.

Data Quality

The astrometric quality as measured in the pipelining is very good, and uniform across the large field – typical mean RMS errors with respect to 2MASS are 70-80 mas. At this early stage the photometric calibration is provisional and only as good as the comparisons with APASS allow. This means in practice that g, r and i are expected to be relatively secure with external errors comparable to those of APASS (~0.03 magnitudes). In the u band, there is greater uncertainty that at present is hard to quantify. However the early signs are that a good uniformity is being achieved from CCD to CCD across the native 32-CCD OmegaCam pawprint, which may in the long run support the determination of simple photometric offsets per field in achieving a satisfactory final global calibration.

In preparing this release, we have computed the median and standard deviation of all single-filter magnitude differences ($m_1 - m_2$), in the magnitude range 12 to 19 for i and Ha, 13 to 20 for u and r, 14 to 21 for g, to look for unstable observing conditions and other problems that might cause unwanted measured flux variations within tiles and hinder their ultimate calibration. In the vast majority of single-band catalogue pairs, the median difference is below 0.01, with the standard deviation ranging from 0.03 to 0.06 (except where there were video card problems – see below).

The figures below are illustrative photometric diagrams constructed from catalogues for one pointing toward a moderately-dense well-reddened field, with some moderate Ha nebulosity, observed in ~third quartile conditions (i.e. a bit worse than median in seeing and/or limiting magnitude) a few degrees away from the Galactic centre. The data have been 'cleaned' to the extent of limiting to probable stars (broad-band morphology codes -1,-2), requiring average confidence better than 90 percent, and better than 10-sigma detection in the noisiest filter included. It is testament to the uniformity of the extracted data that it is possible to construct plots of this quality for the *entire* 1x1 sq.deg field.

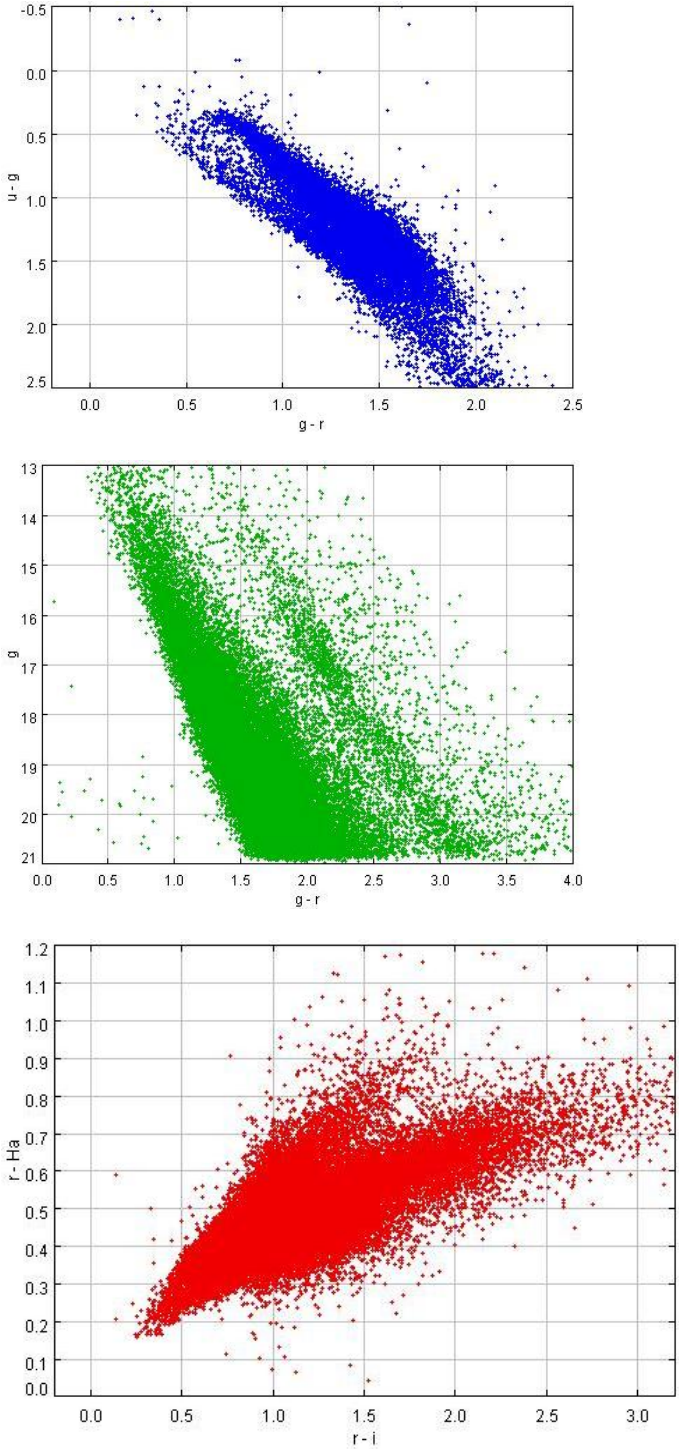

Figure 4. Photometric diagrams for the 1x1 sq.deg field centred on RA 17 54 58 Dec -24 58 40 (J2000). Top: u-g versus g-r for a selection of 18,200 stars. Middle: g versus g-r for 44,500 stars.

Bottom: r-Ha versus r-i for 56,500 stars. The cleaning applied here reduces the detected objects by factors of two to three.
In order to select data to produced well-behaved photometric diagrams it is recommended that average-confidence and morphology-class cuts are applied routinely (in addition to magnitude and/or error-level cuts). The specific cuts applied in the example shown usually give good results. Thresholding on average confidence is particularly effective at ensuring the impact of vignetting due to the CCD-electronics cover stripes, field edges and Ha segment dividers is minimal.

Known issues

From mid-March through May 2012 there was an intermittent video card problem that resulted in significant zero-level flux offsets in, most commonly, CCD 10. Inevitably this affected both sky exposures and flat fields from time to time. When it happens, it is visible in the image data and typically introduces deviant CCD 10 magnitudes, which are easily spotted by comparing single-filter offset pointings. Since the main sky offset we use is greater than the individual CCD dimension, there is almost always an alternative measurement of affected sources available.

A second minor issue affecting 26 sets of narrowband Ha images obtained up to late January 2012 is that the pattern of offsetting used initially contained an error such that none of the three Ha frames is at the same offset as the *second* broad band exposures (as intended). This was fixed in time for all data taken from the beginning of February 2012.

Previous Releases: None

Data Format

File Types

There are two major file types: (i) reduced fits images, (ii) single-band fits catalogues of detected objects. Calibration files are also provided. They are named according to a simple unique convention that specifies the date on which the night of observation started, and the run number for the night.
Image naming format: o<yyyymmdd>_<runno>.fits.fz
Catalogue naming format o<yyyymmdd>_<runno>_cat.fits.fz
Calibration files, e.g. confidence maps: <filter>_<conf>_<date>.fits.fz

Also see:

http://casu.ast.cam.ac.uk/surveys-projects/vst/technical/naming-convention

Note that 'pawprint' and 'tile' are synonymous in the VST/VPHAS+ context.

Catalogue Columns

For a specification of the layout, see
http://casu.ast.cam.ac.uk/surveys-projects/vst/technical/catalogue-generation

Acknowledgements

The appropriate journal reference for the use of VPHAS+data is to: Drew et al, in preparation. If making use of data from this release, please use the following statement in the acknowledgements: "Based on data products from observations made with ESO Telescopes at the La Silla Paranal Observatory under public survey programme ID 177.D-3023(B,C)" .