VIKING (VISTA Kilo-degree Infrared Galaxy Survey)
Data Release 1.

Release date (will be set by ESO)

Alastair Edge and Will Sutherland, for the VIKING team

Abstract:

The VIKING survey with VISTA (ESO programme ID 179.A-2004) is a wide area (eventually ~ 1500 sq.degrees), intermediate-depth (5-sigma detection limit J ~ 21 on Vega system) near-infrared imaging survey, in the five broadband filters Z,Y,J,H,Ks.

The planned sky coverage is at high galactic latitudes, and includes two main stripes ~ 70 x 10 deg each: one in the South Galactic cap near Dec ~ -30 deg, and one near Dec ~ 0 in the North galactic cap; in addition, there are two smaller outrigger patches called GAMA09 and CFHLS-W1.

Science goals include z > 6.5 quasars, extreme brown dwarfs, and multiwavelength coverage and identifications for a range of other imaging surveys, notably VST-KIDS and Herschel-ATLAS.

This first public data release of data taken between the 12th of November 2009 and the 13th of February 2011 includes 151 tiles (55 in GAMA09/12/14, 91 in SGP and 5 in CFHLS-W1) i.e. 226 square degrees, and includes approximately 14,773,385 total sources (including low-reliability single-band detections) and the imaging and source lists total 314.4GB.

Overview/layout of observations

The basic unit of observations is the VISTA **tile**, made from combining six offset "pawprints" to fill in gaps between the individual detectors. All VIKING tiles are observed in the default (zero) rotator-sky angle; thus each tile covers a rectangle approximately 1.5 degrees in RA by 1.0 deg in Dec to full exposure.

This data release 1 consists of a total of 151 tiles (226 sq.deg): this is subdivided into 55 tiles in the GAMA09/12/14 regions, 91 tiles in the SGP stripe, and 5 tiles in the CFHLS-W1 region. These comprise most of the data observed up to October 2011, and have overlap with the GAMA redshift survey in GAMA09/12/14, the Herschel-ATLAS submm survey (in both GAMA09/12/14 and SGP), and medium-deep CFHT Legacy Survey visible data in W1.

Region	RA range	Dec range	Tiles

GAMA-09	08h 34m to 09h 24m	-2.0 to +3.0 deg	36
GAMA-12	11h 38m to 12h 22m	-2.0 to +3.0 deg	13
GAMA-14	14h 12m to 14h 41m	-2.0 to +3.0 deg	6
CFHTLS-W1	02h 16m to 02h 28m	-6.7 to -2.7 deg	5
SGP	22h 05m to 03h 32m	-34.0 to -31.0 deg	91

Table 1: Approximate boundaries of sky coverage for the current release.

Release content

Exposure times per passband are as given in the following table; note that exposure times per source are the median values (and correspond to pixels with value 100 in the associated confidence-maps); pixels in detector overlap regions receive more exposure, while pixels near the top and bottom in detector x-coordinate (North/South) receive half the median exposure.

Filter	Integration/ tile	Integration/ source	Njitter	NDIT x DIT (sec)	Mag.lim (median)
Z	1440 sec	480 sec	4	1 x 60s	22.1
Y	1200 sec	400 sec	4	2 x 25s	21.3
J	2 x 600 sec	2 x 200 sec	2 x 2	2 x 25s	20.8
H	900 sec	300 sec	3	5 x 10s	19.7
Ks	1440 sec	480 sec	4	6 x 10s	19.3

Table 2: Integration times per tile, per source (median), number of jitter positions (per pawprint) and individual exposure lengths. Also shows median 5-sigma (Vega) magnitude limit for each passband.

Note that each tile was observed in two separate observing blocks (OBs) of approximately 70 minutes duration each: one for J,Y,Z filters, and the other for J,Ks,H; these are taken in either order, with the J exposure time divided between the two OBs. The time-span between the two blocks may be months or (sometimes) years; thus, the split J-band is intended to flag objects which may have moved or varied between the two blocks. Observations for band pairs Y/Z and Ks/H are in one OB, separated by a time-lag typically 25 minutes.

Release Notes

The data reduction follows the standard CASU infrared imaging pipeline. In brief, the reduction steps are as follows:

- **Reset correction:** This occurs in the data acquisition system, i.e. a VISTA data frame is a difference of two non-destructive detector readouts separated by DIT seconds. Then, NDIT of these frames are co-added within the data acquisition system, before saving to hard disk.
- **Dark subtraction:** using exposures with the dark filter inserted, matching the DIT values of the given science exposure.
- **Linearity correction:** the VIRCAM detectors show non-linearity, typically a few percent at 10,000 ADUs. A correction polynomial (one per detector) is derived from a fit to observations of the dome screen with varying exposure times, and

applied to the counts.

- **De-striping:** this step removes a low-level horizontal striping intrinsic to the VIRCAM detector readout electronics, which is correlated across blocks of 4 detectors.
- **Flat-field correction:** the frame is divided by a flat-field frame, derived from a set of twilight sky flats in the matching filter band.
- **Bad pixel rejection:** Pixels showing substantial deviance from the linearity frames are masked as bad, and assigned zero weight in subsequent combinations.
- **Sky background correction:** this removes large-scale background variation.
- **Jitter stacking:** the set of individual jittered frames for one pawprint-filter combination are combined into a pawprint image, with bad-pixel rejection. These individual pawprint images are available in the data release (see below).
- **Photometric and astrometric calibration:** This is based on matching with 2MASS stars (see details below).
- **Tiling:** The six individual pawprint images for one filter are combined into a full tile image.
- **Grouting:** When combining images into a full tile, there are non-negligible PSF variations, due mainly to seeing variations between the six individual pawprints, and also slight variation in image quality with off-axis distance. Different pairs of pawprints contribute to different regions in the tile, thus the aperture correction varies with position. A specific correction for this (aka "grouting") is applied to the photometry in the source lists.

Astrometric Calibration

The main astrometric calibration is based on 2MASS stars; there are typically 50 unsaturated 2MASS stars per VIRCAM detector, and astrometric transformations from detector coordinates to RA, Dec are derived from these. The typical rms is 0.15 arcsec per star per coordinate, which is dominated by photon noise in the 2MASS data. External comparisons with UKIDSS and SDSS (in the GAMA09 region) show that the astrometry is good, with typical rms per coordinate around 0.09 arcsec and mean offsets below 0.03 arcsec. Small correlated residuals (generally between pawprints) are seen at the level of approx 0.05 arcsec; these may be improved in a future data release.

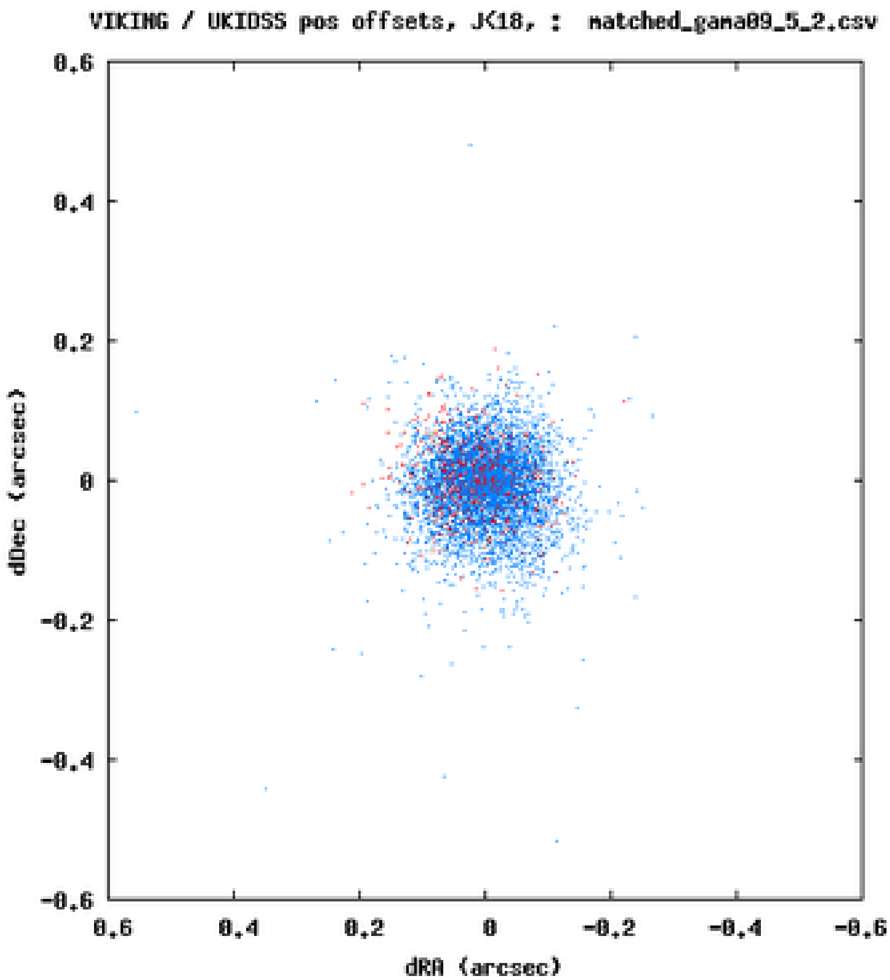

Figure 1: Position offsets in RA, Dec (VIKING-UKIDSS) for one tile, for objects with J < 18; stellar objects are blue, extended objects in red.

Photometric Calibration

Photometric calibration is also derived from 2MASS stars. A set of colour equations is used to predict VISTA native magnitudes from the observed 2MASS J,H,Ks colours; these are given by slight modifications of those for UKIDSS (see Hodgkin S. et al., 2009, MNRAS, 394, 675). The adopted VIKING colour terms are:

$$Z_V = J_{2M}+1.025(J_{2M}-H_{2M})$$

$$Y_V = J_{2M}+0.610(J_{2M}-H_{2M})$$

$$J_V = J_{2M}-0.077(J_{2M}-H_{2M})$$

$$H_V = H_{2M}+0.032(J_{2M}-H_{2M})$$

$$Ks_V = Ks_{2M}+0.01(J_{2M}-Ks_{2M})$$

where in the above, subscript 2M denotes 2MASS and V denotes VIKING. The above equations give the predicted VISTA-system magnitudes of 2MASS stars, and comparing these to instrumental counts for these stars, a zeropoint is determined for each image. The *internal* photometric zeropoint stability, as deduced from repeated measurements of stars in overlapping regions of adjacent tiles, are stable to ~ 0.03 mag rms. Externally, comparison against UKIDSS measurements in the GAMA09 region shows good consistency in the H,Ks bands: the per-tile mean offset is close to zero, and tile-to-tile dispersion in the mean is typically 0.03 mag rms. For bluer bands, there are non-negligible mean zero point offsets, approximately 0.05 mag in J-band and 0.09 mag in the Y-band, both in the sense that VIKING magnitudes are brighter than UKIDSS for the same object. This is probably caused by a combination of two factors: the stellar locus in Y-J, J-Ks is slightly non-linear, and almost all the matching 2MASS stars are substantially later than A0 spectral type, so the extrapolation of the stellar locus using the above colour terms does not quite pass through (0,0). The Z band global zeropoint is slightly more uncertain, since the extrapolation from 2MASS is larger, and also the SDSS z-band has a significantly different response function shape (approximately triangular) from VIKING Z (approximately box-car). Preliminary comparisons suggest the current VIKING Z zeropoint may be too bright by approximately 0.10 mag.

Star-galaxy classification.

A star-galaxy classification parameter (ClassStat) is provided in the list files; this is intended to be approximately Gaussian N(0,1) for stellar objects, and extends to large positive values for galaxies. Also an integer-based classification (Class); see description below. The band-merged catalogue file (_finalSourceCat_) contains also merged statistics based on a quasi-Bayesian combination of the single-band classifications. In addition to the above, colour-based classification using near-infrared colours (especially including Ks band) can also provide an effective discriminant between stars and galaxies. For the current dataset, using the Z-J, J-Ks two-colour diagram appears to be the best choice (especially at faint magnitudes where the morphological classification becomes indecisive). This two-colour diagram shows a well-defined boomerang-shaped stellar locus, flattening off near J - Ks ~ 0.80, and a large cloud of galaxies at redder J-Ks values, typically 1 < J-Ks < 2. (This behaviour is caused by a combination of several factors: late giant stars have redder J-Ks colours than dwarfs; galaxies can have internal extinction, while stars have minimal extinction in these high-latitude fields; and especially the 1.6 micron bump feature in the SED of late-type stars. Redshifting of the 1.6 micron bump towards the Ks filter causes galaxy J-Ks colours to shift redwards from z ~ 0 to z ~ 0.4, then flatten off above this).

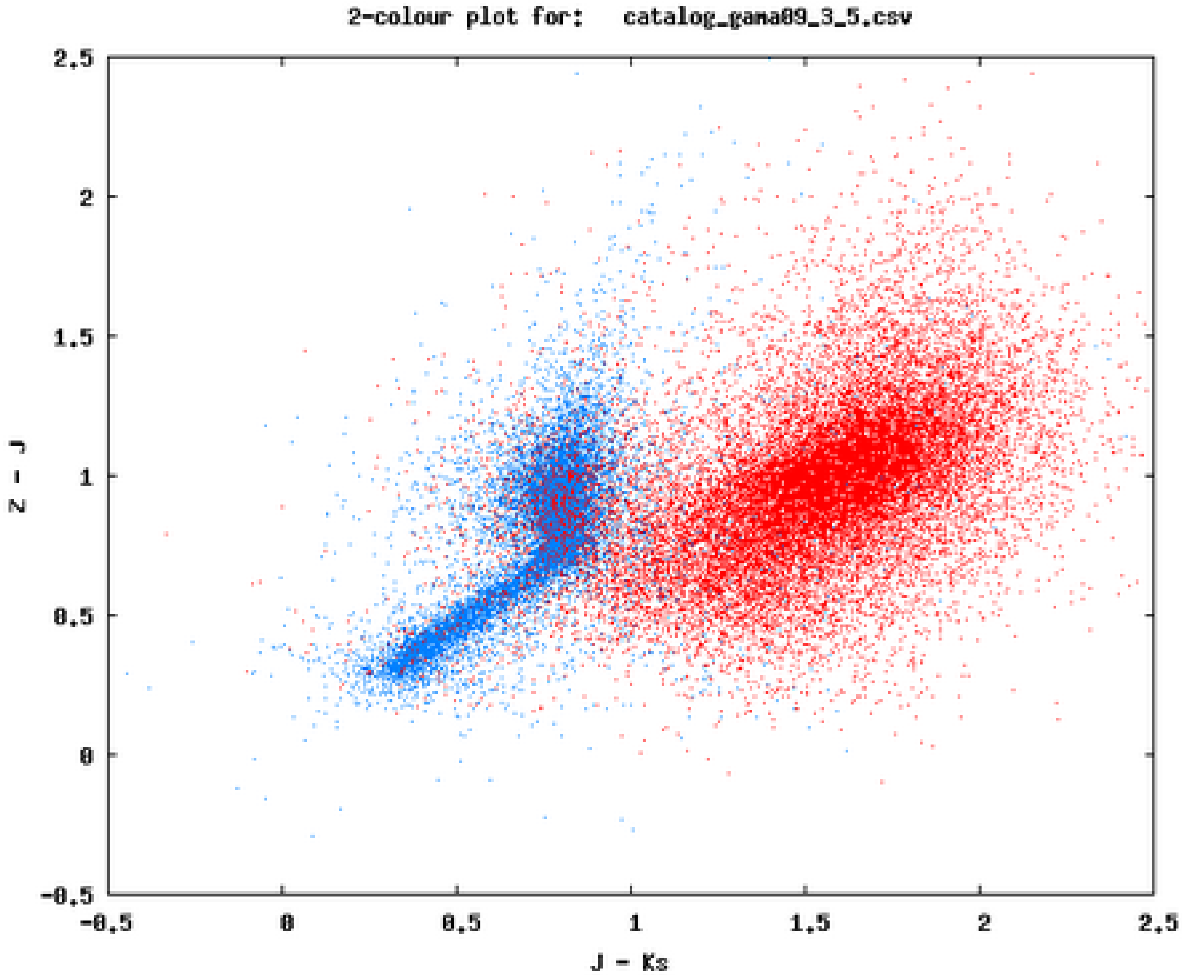

Figure 2: Two-colour diagram, Z-J vs J-Ks, for one tile, selecting objects with J < 20. Stellar objects are blue points, extended objects are red points.

In future, when visible band (u,g,r,i) data is available from the KIDS survey, even better colour-based classification is likely to be deliverable using for example the (g - i, J-Ks) two-colour diagram, as shown by Baldry et al (2010, MNRAS 404, 86).

Inspection of samples of "discrepant" objects, defined as those where the morphological and ZJKs two-colour classifications disagree, shows the following general trends:

- The majority of "discrepant" objects arise from blending issues, e.g. close pairs of objects where the dominant component is a star, or objects affected by halos around bright stars.
- There are a small fraction of genuine blue galaxies close to the stellar colour locus, mostly bright low-z late-type galaxies.
- There are some quasars/AGNs appearing as stellar objects in the red cloud.

Data files and conventions

Here follows a description of the types of files in this release, associated files, and naming conventions used.

The files in this data release have the following naming conventions:

- File names follow the general convention: `viking_er1_HHhMM-DDDdMM_[tile|offN]_F_[type]_NNNNN.ext`

Meanings are as follows:

- `HHhMM-DDDdMM` labels RA/Dec of the pointing centre in hours/minutes of RA, and degrees/arcmins of Dec.
- The next part is either "tile" for a full tile, or one of `off0 - off5 inclusive denoting a single pawprint.`
- The next part "F" is one of z,y,j,h,ks denoting the filter.
- The "type" is one of: image (FITS image); conf (FITS confidence map); cat (single-band source list); jpeg (jpeg of the corresponding image or conf); also, J-band files are denoted deepimage or deepconf to denote the stack of the two individual epochs.
- The six-digit integer `NNNNNN` is a unique identifier assigned by the VSA to each image. Source list and jpeg files have numbers NNNNNN matching the parent FITS image, while confidence maps have integer increased by 1 from the matching image.
- The extension `.ext` denotes file format, and is one of: .fits.fz (Rice-compressed FITS file), .fits (uncompressed FITS file), or .jpg (JPEG image file).

In addition to the above, there are also band-merged source catalogues containing "_zyjhks_finalSourceCat_" after the RA/Dec string. Note that pawprint-based data "offN" only have "image" and "conf" types, not jpegs or source lists. Thus, a full tile with all 5 bands observed will have 48 associated data files:

- One deep tile in J plus its associated confidence image (2 files).
- Six deep pawprints in J plus their associated confidence images (12 files).
- Two shallow tiles in J plus their associated confidence images (4 files).
- Shallow tiles in Z, Y, H and K plus their associated confidence images (8 files).
- Jpegs of the 7 tiles (one deep and six shallow) and confidence images (14 files).
- Source lists from each of the 7 tiles (7 files).
- One band-merged source catalogue for each tile (1 file).

Entries in source lists.

As noted above, source lists comprise single-band versions (filename containing _cat_), and one band-merged catalogue per tile (filename containing _finalSourceCat_). Table names are somewhat different between these, as described below. For the single-band detections, a complete listing is given in the VISTA Science Archive browser table: the column descriptions are given by the **vikingDetection** schema of the VSA database. Here for convenience we provide a summary of the key parameters in the single-band source list files above. In most cases there is also a corresponding entry with name ending in "Err", for the error on the relevant parameter.

- `x, y` Position in x,y image pixels.
- `ra, dec` RA, Dec in J2000 decimal degrees.
- `l, b` Galactic coordinates in decimal degrees.
- `lambda, eta` Spherical coordinates in SDSS system.

- `htmID` Hierarchical triangular mesh integer derived from RA, Dec (useful for indexed searches).

- `AperMagN`, `AperFluxN`, `AperMagNoAperCorrN` (for N = 1 to 13): Aperture magnitude or flux in successive soft-edged circular apertures: AperMag1 is aperture diameter 1.0 arcsec, then consecutive apertures increase by a factor of sqrt(2), up to AperMag7 with diameter 8.0 arcsec. (Note AperMag3 gives the commonly used 2.0 arcsec diameter). Larger apertures, Apermag8 to AperMag13, use diameters of respectively 10, 12, 14, 16, 20, 24 arcsec.
  By default AperMag1-7 **do include** an aperture correction to "total" magnitude for a stellar object, while AperMag8-13 **do not** include any aperture correction. The AperMagNoAperCorrN (N = 1-7) give the corresponding values without an aperture correction.
- `petroMag`, `petroFlux` Petrosian magnitude/flux.
- `kronMag`, `kronFlux` Kron magnitude/flux (see below).
- `aprofN` (N = 1-8) isophotal areas for 8 pre-defined levels.
- `psfMag` PSF-fitted magnitude.
- `class` Integer flag for probable classification: -1 = star, 0 = noise, 1 = galaxy.
- `classStat` Real-valued classification parameter, intended to be approximately Gaussian N(0,1) for point sources.
- `ppErrBits` Integer flag containing sequence of warning/error flags. Value Zero = no warnings, 1-255 indicates "Warning" level, and ppErrBits > 256 indicates potentially more serious problems.

The contents of the passband-merged catalogues are given by the **vikingSource** schema of the VSA database.

A summary of the most relevant parameters in the band-merged catalogue files is given below:

- `ra, dec` : RA, Dec in J2000 decimal degrees.
- `l, b` : Galactic coordinates, decimal degrees.
- `zXi, zEta, yXi, yEta,` etc: Source offsets from master position in each of the five bands z,y,j,h,ks; in arcsec East and North respectively.

- `priOrSec` : Integer flag for "primary" or "secondary" source. Objects with priOrSec = 0 are unique to this tile. Objects with priOrSec = frameSetID are "primary" objects on this tile, with a secondary detection on another tile. Objects with priOrSec > 0 and priOrSec != framesetID are "secondary" objects with a "primary" detection on a different tile.
- `zSeqNum, ySeqNum,` etc: Sequence number, enabling matching this entry to the corresponding single-band detection.

- `zmyPnt, ymjPnt, jmhPnt, hmksPnt` : Respectively colours Z-Y, Y-J, J-H, H-Ks assuming a point source, from the corresponding AperMag3 values.
- `zmyExt, ymjExt, jmhExt, hmksExt` Respectively colours Z-Y, Y-J, J-H, H-Ks assuming an extended source (using 2 arcsec aperture with no aperture correction).
- `zAperMag3, zAperMag4, zAperMag6, zAperMagNoAperCorr3, zPetroMag, zSerMag, zPsfMag,` etc. A subset of the various magnitude measures for all the single passbands, beginning with one of z,y,j,h,ks denoting passband. Here, a subset is given to reduce line length: of the many AperMagN values, only AperMag3,4,6 are given here, and the corresponding versions without aperture correction.

- `zClass`, `zClassStat`, etc: Respectively integer and real classification flag for each of the single bands.
- `mergedClass`, `mergedClassStat` : Band-merged integer and real classification, based on a quasi-Bayesian combination of the individual passbands.
- `pStar`, `pGalaxy`, `pNoise`, `pSaturated` : Probability that the object is stellar/galaxy/noise /saturated, respectively.
- `zppErrBits`, `yppErrBits`, etc: Integer error bits code for each of z,y,j,h,ks bands.

Known problems

As noted in more detail above, there are likely to be modest zero-point offsets (approx 0.06 mag at J, 0.09 mag at Y-band) in the sense that VIKING magnitudes may be too bright. These appear relatively stable across tiles.

In the current release, the most common source of spurious images is associated with diffraction halos and filter-reflection ghosts around bright stars; these are localised around the parent star, and are easily recognised in the parent images. There are also occasional single-band linear features from artificial satellite trails, meteors or aircraft, which can cause a chain of spurious images. Most such spurious images do not match-up between passbands, therefore multi-band matched detections are generally reliable (especially with 3 or more bands), but we emphasise that **all single-band detections should be treated as unreliable,** unless verified by inspection of images.

There are also "bad patches" on certain detectors, namely a large region on Detector#16 (South-East corner) which does not flat-field well, and a strip along an edge of detector#12 which likewise does not correct well and leads to occasional horizontal lines of spurious images.

Cross-talk between detector channels is essentially negligible.

Image persistence (latent images after a bright star lands on a pixel) is generally small, but not quite negligible: since VIRCAM has no shutter, very bright stars can occasionally cause curved "streaks" of persistence as they move in non-straight paths during telescope offsets.

There are a small number (<100) sources in the single band and band-merged catalogs that have very large (>100mag) errors due to them being close to the detection limit. These sources should be flagged manually and will be excluded in future releases. However, given they are so rare (<0.0006% of the band-merged sources) they should not be a major contaminant in any VIKING study.

Queries

Questions concerning this data release should be addressed initially to alastair.edge@durham.ac.uk

Acknowledgements

Please use the following statement in any publication using these data: "This publication has made use of data from the VIKING survey from VISTA at the ESO Paranal Observatory, programme ID 179.A-2004. Data processing has been contributed by the VISTA Data Flow System at CASU, Cambridge and WFAU, Edinburgh".