VISTA PUBLIC SURVEY STATUS REPORT
(87th OPC MEETING)

This report has to be returned to the Observing Programmes Office of the European Southern Observatory (opo@eso.org) before October 31, 2010.

PROPOSAL ESO No.: 179.A-2010
TITLE: The VISTA Hemisphere Survey (VHS)
PRINCIPAL INVESTIGATOR: Richard McMahon

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1. Scientific Aims (brief description)

The aim of the Vista Hemisphere Survey (VHS) is to carry out a near Infra-Red survey, which when combined with other VISTA Public Surveys will result in coverage of the whole southern celestial hemisphere (~20,000 deg^2) to a depth 30 times fainter than 2MASS/DENIS in at least two wavebands (J and K_s), with an exposure time of 60 seconds per waveband to produce median 5σ point source (Vega) limits of J = 20.2 and K_S = 18.1. In the South Galactic Cap, ~5000 deg^2 will be imaged deeper with an exposure time of 120 seconds and also including the H band producing median 5σ point limits of: J = 20.6; H = 19.8; K_s = 18.5. In this 5000deg^2 region of sky deep multi-band optical (grizY) imaging data will be provided by the Dark Energy Survey (DES). The remainder of the high galactic latitude (|b|>30°) sky will be imaged in YJHK for 60sec per band to be combined with ugriz waveband observations from the VST ATLAS survey.

The medium term scientific goals of VHS include:

- the discovery of the lowest-mass and nearest stars
- deciphering the merger history our own Galaxy via stellar galactic structure
- measurement of large-scale structure of the Universe out to z~1 and measuring the properties of Dark Energy
- discovery of the first quasars with z>7 for studies of the baryons in the intergalactic medium during the epoch of reionization

In addition the VHS survey will provide essential multi-wavelength support for the ESA Cornerstone missions; XMM-Newton, Planck, Herschel and GAIA.

2. Detailed progress report with respect to initial estimate from the Survey Management Plan (including preliminary results, whether published or not).

2.1. Progress report

ESO has taken a substantial amount of useful VHS data during Dry Run observations during Period 84 and during Period 85. Figure 1 shows the current sky coverage of the VHS survey based on all observations taken up to October 6th, 2010 and processed through the VDFS pipeline at CASU, Cambridge. All this data is available as FITS

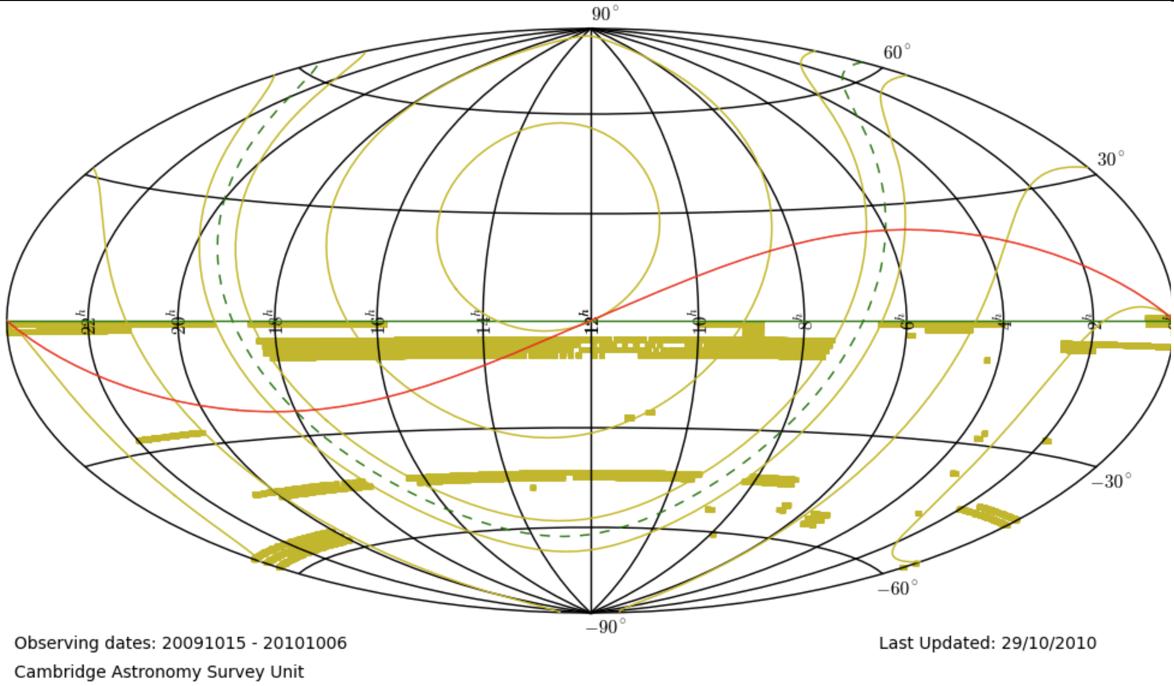

Figure 1: Sky coverage of the VHS survey in equatorial coordinates and the equal area Hammer-Aitoff project based on all CASU processed data upto 6th Oct, 2010 including data for all Period 85 and the VISTA Dry Run observations carried out in Period 84.

format files for QC by the VHS team. CASU processing of VISTA data has reached a stable state and is released in monthly quanta. CASU also provide a very useful FITS format QC table that contains metadata including QC parameters for all their data products. This pipeline product with over 200 columns of metadata has been used to generate many of the plots in this report.

While the photometric and astrometric calibrated paw-print level image and catalogue products have now reached a stable state, the mosaiced tile products are still under going QC evaluation by CASU and VHS.

The calculation of the unique geometric area in each waveband for VHS is in progress using the mangle software package. For this we need to exclude OBs that do not pass the VHS QC acceptance thresholds. Currently we have a total of around 3700 tiles in Y, J, H or K which will give a total useful observed area of ~1700deg^2 assuming a typical coverage of 1.5deg^2 and assuming an OB rejection rate of 10% based on QC thresholds.

With a sky coverage target of ~18,000deg^2 (20,000deg^2 excluding sky with |b|<5° and the VVV, VMC and VIKING footprints) over 10 observing periods the current progress is not a serious cause for concern based on current analysis, especially if observing overheads can be reduced. We were allocated 410hrs in Period 85 and 311hrs in Period 86 compared with our nominal request of 311hrs per period as specified in the VHS SMP.

Observing overhead concerns

The current charging for observing overheads is higher than we assumed in the VHS SMP. VHS has three survey components each with slightly different OB structure with the common theme that each OB produces a tile with a full complement of the wavebands that have to be acquired for a tile.

1. VHS-GPS: J and K; 60 seconds per waveband
2. VHS-ATLAS: Y, J, H, and K; 60 seconds per waveband
3. VHS-DES: J, H and K; 120 seconds per waveband

Each VISTA tile requires 6 sparse filled pawprints. Thus the total on-sky time for the 3 components above are 360, 720 and 1080 seconds respectively. In our accepted SMP, based on information provided by ESO and the VISTA project we estimated the total elapsed time including overheads as 600, 1199 and 1491 seconds respectively. The execution time charged within P2PP for Period 85 is 829, 1510 and 1809 seconds which is an increase in the observing overheads of 4-5 minutes per OB. We also requested a change to the jitter pattern which should have reduced the overheads but this overhead reduction was not taken into account in P2PP.

We hope that the VISTA observing overheads are being investigated and will become lower in future.

Example colour-magnitude and colour-colour diagrams

Figure 2 shows colour-magnitude and colour-colour diagrams for two typical fully reduced example high galactic latitude tiles. Some examples of problem tiles identified during VHS QC are shown in Figure 3 [see also discussion in section 3]. The blue points are objects classified as stars and the grey points are objects classified in K as non-stellar.

These QC diagrams demonstrate the precision of the photometry and star-galaxy separation. The J-K-v-K stellar locus clearly delineates the distinct disk dwarf and halo giant populations which show up as two separate populations with J-K<1.0. The non-stellar objects which are mainly external galaxies have J-K>1.0. Figure 2a shows the first completed VHS OB obtained during the Dry Run observations in Nov 3rd 2009 and Figure 2b shows a more recent observation from Sep 20th, 2010.

2.2 Publications

No submitted journal publications. A publication in a refereed journal associated with the first public data release is planned.

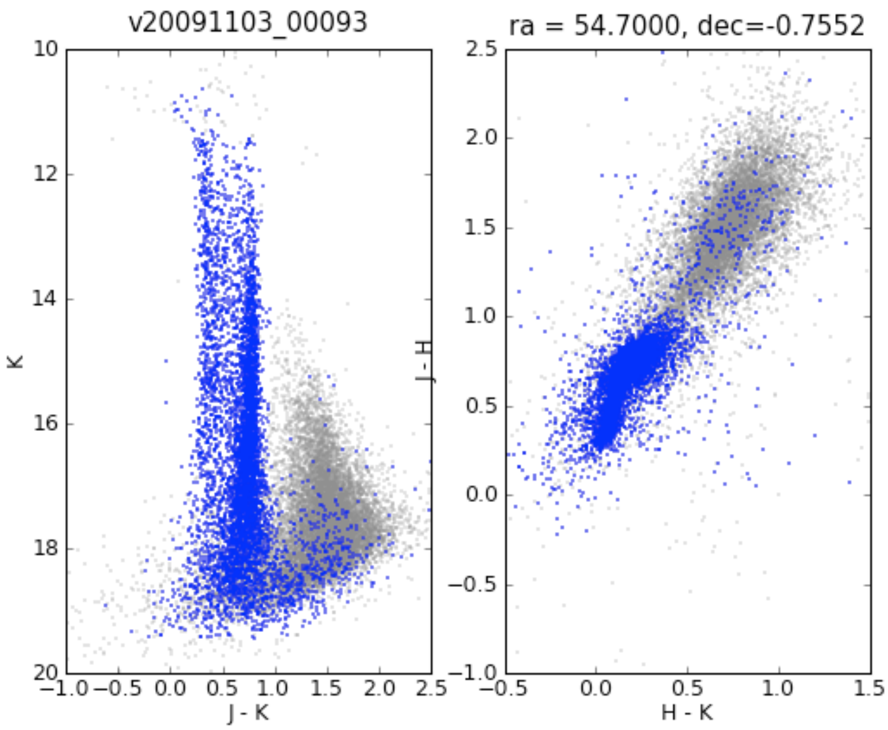

Figure 2(a): First completed VHS OB from Nov 3rd, 2009. Magnitudes are in Vega system. Blue points are starlike objects; Grey points are non-stellar objects.

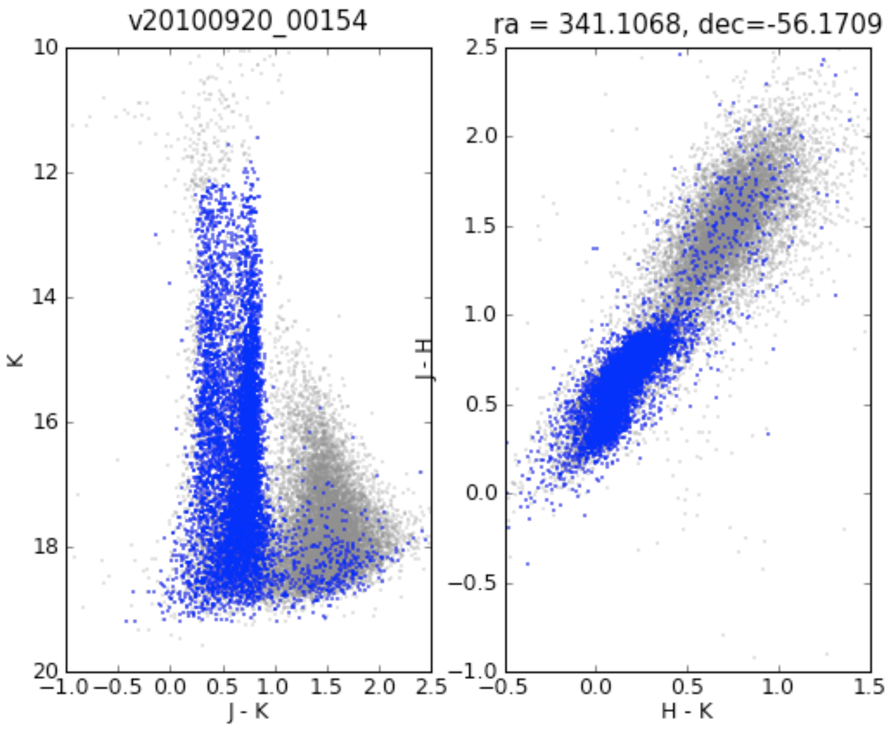

Figure 2(b): Recent VHS OB from Sep, 2010. Magnitudes are in Vega system. Blue points are starlike objects; Grey points are non-stellar objects

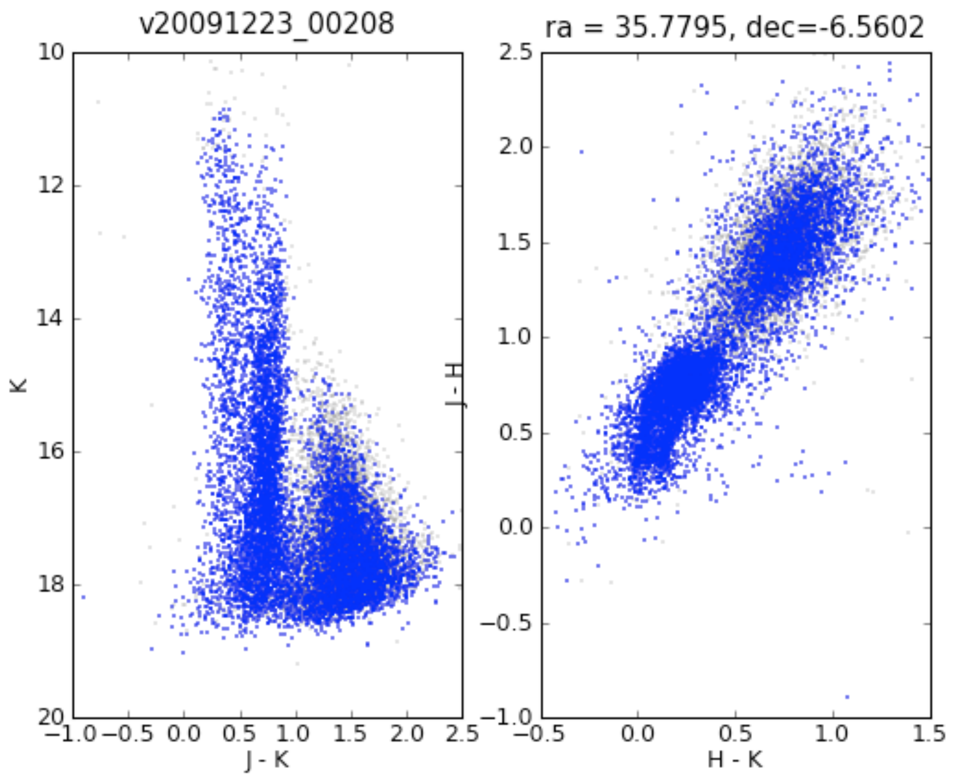

Figure 3(a): QC problem with star-galaxy separation. Blue points are starlike objects; Grey points are non-stellar objects

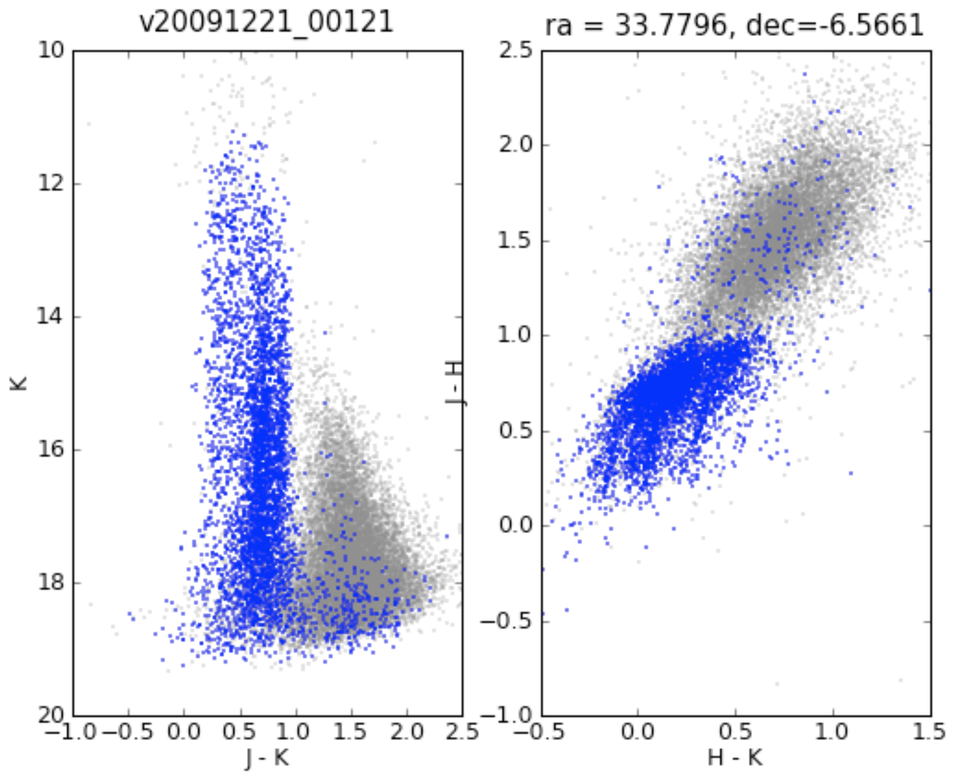

Figure 3(b): QC problem showing multiple offset stellar loci due to variable seeing causing spatially dependent aperture corrections in different pawprints.

3. Quality Control and Advanced Data Products. The advanced data product submission plan should be described here. In addition the PI should comment on Quality Control on the acquired data. In particular, do the acquired data meet the survey requirements including image quality, target limiting flux, sky subtraction filters?

Robust quantitative quality control processes for VHS are still under development and we are working closely with the VDFS pipeline team at CASU in Cambridge to develop routine automated machine learning based techniques such as decision tree based QC techniques. A wide range of diagnostic plots is being produced following the plan outlined in the VHS SMP.

Colour-magnitude and colour-colour plots as shown in Figure 2 and 3 are being produced for all paw-print and tile bandmerged catalogues. Figure 2 shows typical examples of data that passes our QC. Figure 3 shows two examples of data which have been identified as failing our QC procedures. In both case the pawprint level products pass QC and these are ready for delivery as advanced data products to ESO. However there are problems with the mosaiced tiles that most likely are caused by seeing variations between paw-prints. A pipeline improvement to attempt to robustly deal with this issue is under development at CASU.

Image quality

Figure 4 shows the distributions of the image quality in all wavebands for all VHS observations. This plots contain repeat OBs and hence although the median value will be robust, poor quality data will be over represented since some OBs have been repeated. Figure 4(a) shows the measured seeing(FWHM) for stellar objects and Figure 4(b) shows the image ellipticity distribution. Visual inspection of the images with ellipticity > 0.15 is in progress. Some have double images whereas some may still be useable. The medians of the seeing distributions show a wavelength dependence increasing from 1.03 arc seconds in K_S to 1.14 arc seconds in J. The ratio of 1.11 is consistent with a Kolmogorov $\lambda^{-1/5}$ wavelength dependence assuming a effective wavelengths of 2.149μm for K_S and 1.254μm for J.

The seeing distributions in Y and J are also significantly broader than H and K with ranges between the 10 and 90 percentiles of 0.79, 0.71, 0.59 and 0.60 arc seconds respectively. In the case of the Y band data 20% is outside our minimum requirement limit of 1.4”. In J, 15% are outside this seeing requirement limit whereas for H and K it is 10%.

The median airmass shown in Figure 5 for all wavebands is similar and in the range 1.27(K) to 1.35(Y) and hence this is should not be causing any trend with wavelength. Further analysis is required in order to determine whether a change in observational strategy is required; e.g. increasing the Y and J exposures since the poorer IQ will effect the limiting magnitudes. It is possible that increasing the AO priority would improve the seeing. This would increase observing overheads by ~10% but this would be balanced by better quality data.

Astrometry

Figure 6 shows the distribution of the World Cooordinate System (WCS) rms astrometric errors derived from 2MASS. The J and K bands have a tail to smaller values compared to Y and H since there are J and K observations in regions of higher stellar density at lower galactic latitude.

Sky brightness

Figure 7 shows the measured sky brightness on all VHS tiles for Period 85. Note the tail to bright magnitudes that effects 5% of observations. This is probably due to scattered moonlight when cirrus is present. The median measured values are 17.0, 15.8, 13.9 and 13.1 respectively. The values that were assumed based on the VISTA ETC in the VHS SMP were 17.2, 16.0, 14.1 and 13.0. Therefore the median measured sky is +0.2 magnitudes brighter in Y, J and H and 0.1 magnitudes fainter in K. The brighter values in Y, J and H may be due to observations taking place too close to evening twilight. This well know issue was discussed in the VHS SMP but at that time ESO observing procedures would not allow a twilight avoidance condition. This has now been added to P2PP and we use it in Period 86.

Zero-points and atmospheric transparency

Figure 8 shows the measured zero-point on tiles for all Period 85 VHS observations based on photometric calibration using 2MASS. There is a tail to bright magnitudes where 10% have relative attenuation >0.2magnitudes which is outside the ESO THIN constraint. The tail is worse in Y but this may be due to the known degradation in the VISTA system throughput since the primary mirror was coated in September 2009.

Limiting magnitudes

Figure 9 shows the computed 5sigma point source limiting magnitudes for the 3 VHS survey components. Note the VHS DES component has exposure times of 120 seconds per band compared to 60 seconds for the other two components (GPS and ATLAS). Despite the inclusion of some sub-standard data in these distributions, the K_s limiting magnitudes meet VHS survey goals. However, the Y and J band data has median limits that are ~0.5 brighter than our goals. This is a combination of poorer than expected IQ and brighter sky brightness. We will return to this issue in Section 4.

Status and delivery of advanced products

The astrometric and photometric calibrated VHS paw-print catalogues and images and ancillary calibration frames for observations obtained up-to the end of the Dry Run period are currently ready for delivery and we expect that we can start to formally deliver data products early in 2011. The details of the ESO delivery procedures will be presented by ESO at a workshop in Garching on Nov 30th, 2010. CASU already has 4 years of experience in the delivery of WFCAM data to ESO and we assume that similar internet based automated techniques can be used for VHS advanced data products.

4. Are any changes proposed with respect to the Survey Management Plan in P87 (e.g., in strategy, targets, exposure time and/or other settings)? If yes, please provide a clear and detailed justification.

The OPC ranked VHS as the highest ranked VISTA Public survey. We are concerned that our current VHS observations are not meeting our median limiting magnitude goals in the shorter wavelength bands, especially J in VHS-DES and in both Y and J in VHS-ATLAS as described in section 3. This is likely to be combination of poorer than expected IQ in these bands and the brighter median measured sky brightness particularly in Y and J. The use of the new twilight constraint in P2PP may improve the sky brightness situation since observations will be executed when the terrestrial OH has had time to de-excite. We could also experiment with the AO priority to see if this improves the delivered IQ in the bluer wavebands although it would increase our overheads by 10%.

Another option is that we redistribute observing time from the redder bands to the bluer wavebands. e.g. in VHS-DES we change from 120 seconds in J, H and K_S by reducing the K_S from 120 seconds to 60 seconds, leave H unchanged and increase J from 120seconds to 180 seconds so that the relative depths are closer to our goal. The J band is important for photometric redshifts at redshifts less than 1.5 since J is above the rest frame 4000Å break. It is also very important for the L dwarf and high redshift quasar science goals. An exposure time redistribution between the wavebands would not require any additional observing time or increase the overheads.

Another option as outlined in the VHS SMP in section 2.2.3 and 2.2.4 is to follow the UKIDSS survey implementation strategy where the default exposure times are doubled when there are specific combinations of seeing, sky brightness and sky transparency observing conditions which would result in data that does not meet the survey requirements (see section 5.2.1 in Dye et al, MNRAS, 372, 1227, 2006). This would only be needed in Y, J and H. Since some of the overheads remain the same, the increase in the execution time for these OBs would be around 50%.

This 'extra' OB execution time could result in a "zero-sum" game from an operational point of view since it could be cost neutral if more OBs would the pass the VHS magnitude limit threshold. This issue was discussed in the VHS SMP in section 2.2. We are not sure how to implement this strategy in the most efficient manner since ESO policies for Service Mode Observations mean that exposure times cannot be adjusted at the telescope. One approach would be to for VHS to provide extra RA stripes of OBs that have double the nominal YJH exposure times and this would be executed ONLY when the seeing at the start of an OB was between 1.2 arc seconds and 1.4 arc seconds and the sky conditions were not CLEAR. This form of logic is not supported in the current operational model. OB selection logic based the measured sky brightness would also be useful.

Since there are a number of different options and we assume ESO is also evaluating these issues a dialogue could be timely especially bearing in the mind the legacy value of the VHS survey data. Even if ESO cannot support UKIDSS type of OB implemenation at the moment it would be useful to know whether such a capability might become available in the next year or two.

5. Observing Plan for Period 87.

Specify which part of the Survey Management Plan (SMP) the survey will focus on in P87 in the 1st column. If changes are foreseen in P87, please specify details of the observing strategy in the table and provide a full justification in Section 4 above.

SMP Period	Field name/ mean RA	Filter	Time (h)	Seeing	Moon	Transparency	Comments / strategy (e.g., no. of epochs)
P87	18hr	Y, J, H, K	311	<1.4	any	thin	

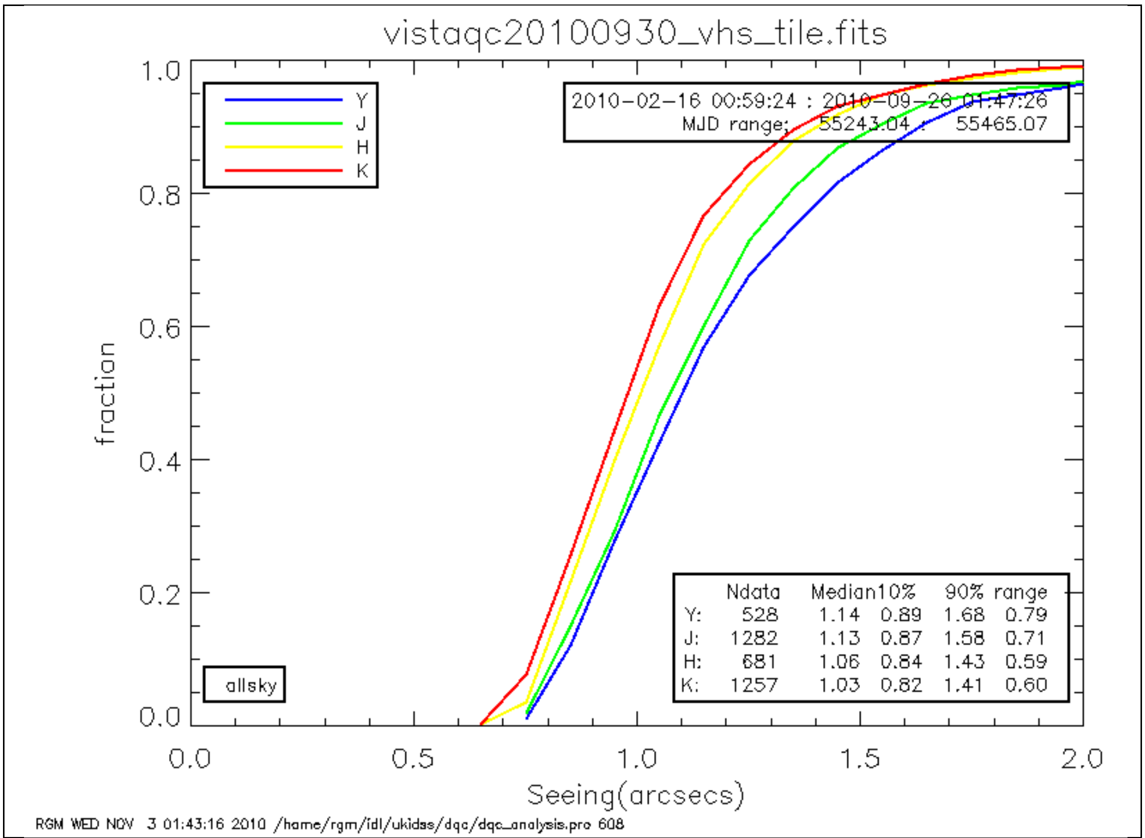

Figure 4(a): Measured image seeing (stellar FWHM) on tiles for all Period 85 VHS observations including rejected and repeated OBs.

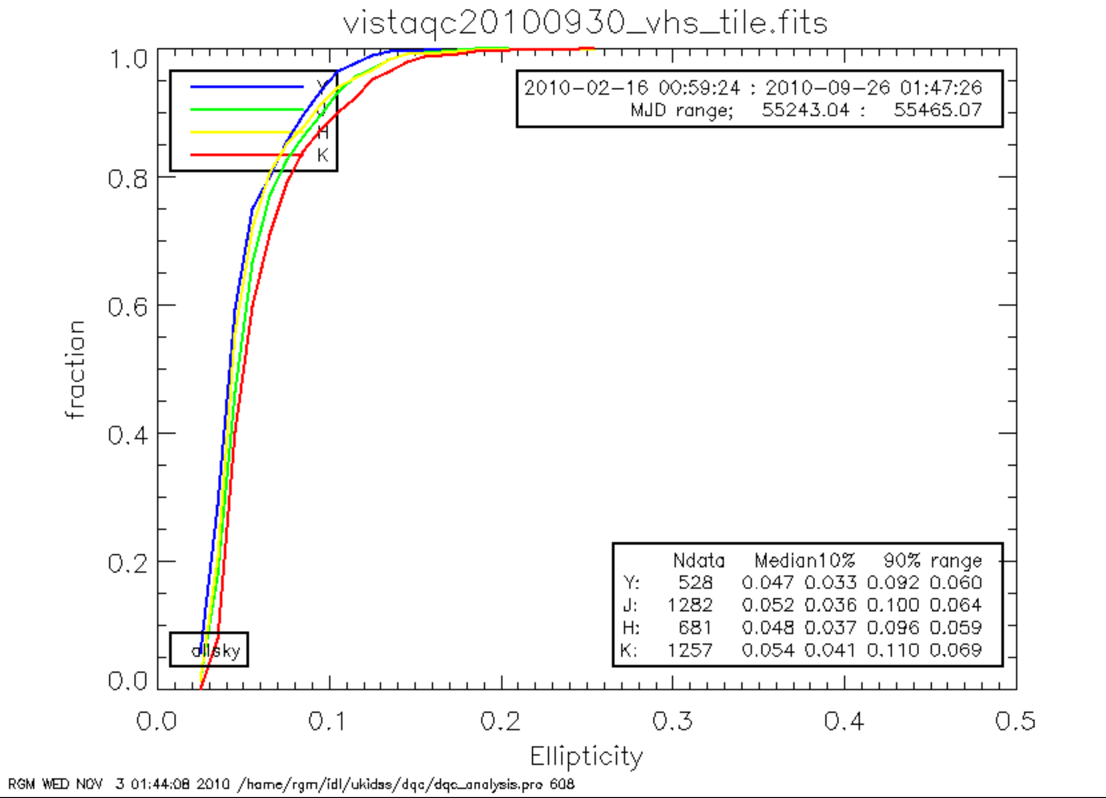

Figure 4(b): Measured image ellipticity on all tiles for Period 85 VHS observations including rejected and repeated OBs

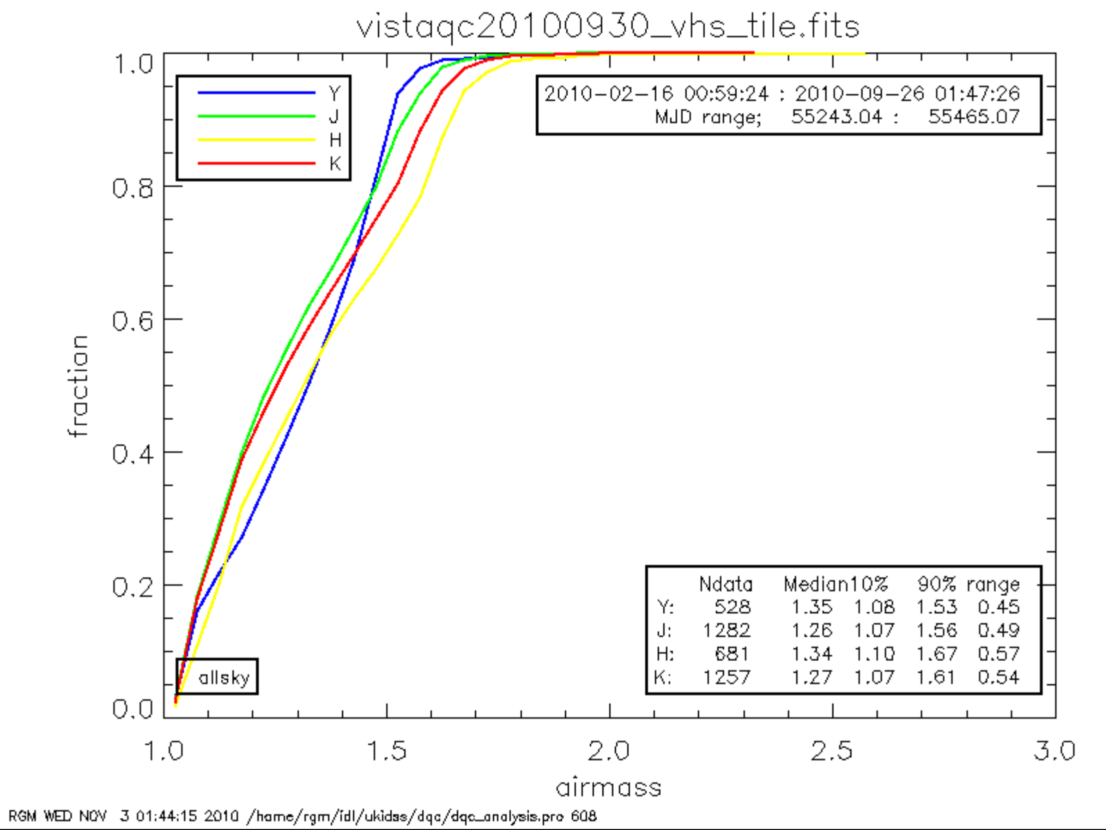

Figure 5: Airmass distribution for all Period 85 VHS observations i.e. includes rejected and repeated OBs.

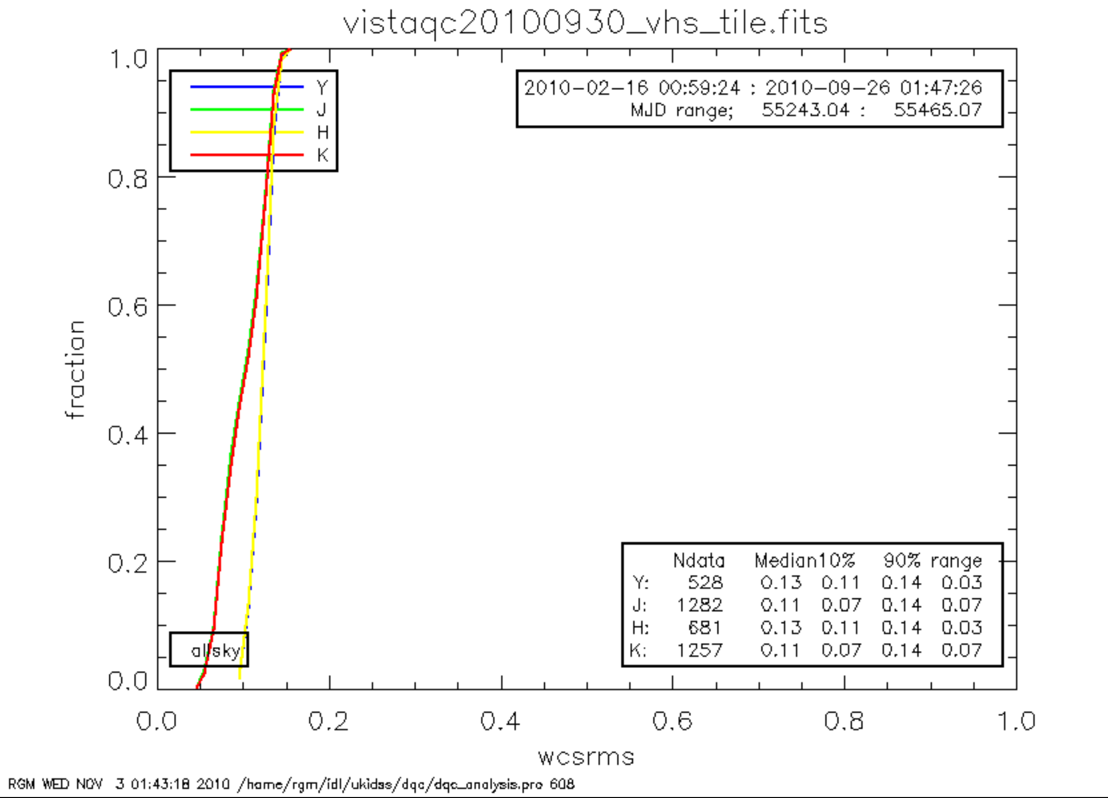

Figure 6: Distribution of the World Cooordinate System(WCS) rms astrometric errors for tiles. The J and K bands have a tail to smaller values compared to Y and H [see text]

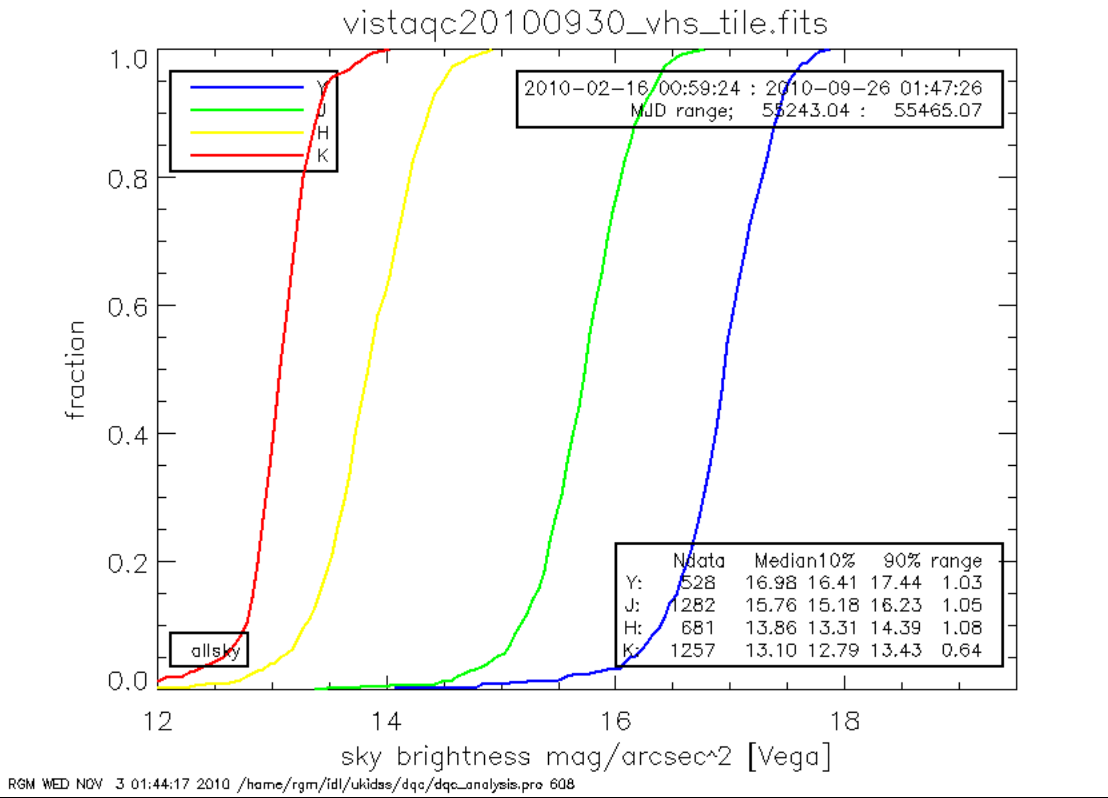

Figure 7: Measured sky brightness seeing on all VHS tiles for Period 85 observations. Note the tail to bright magnitudes that effects 5-10% of observations.

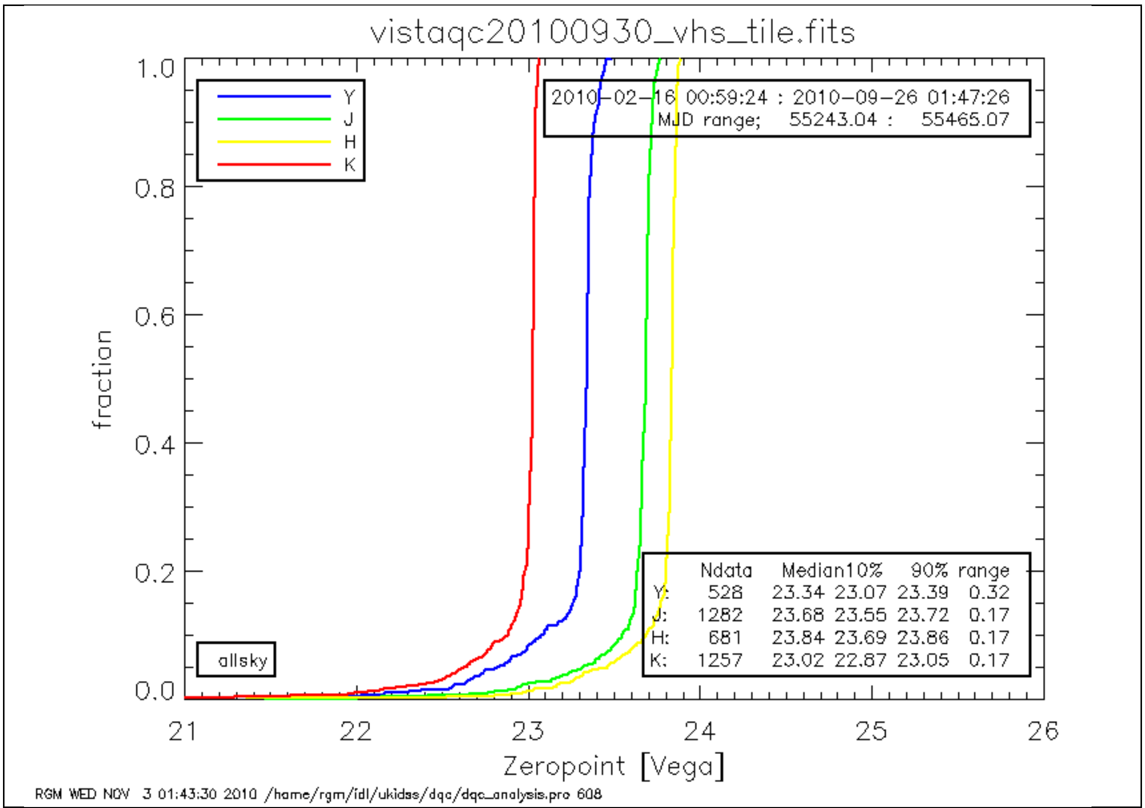

Figure 8: Measured zeropoint on tiles for all Period 85 VHS observations. Note the tail to bright magnitude. Around 10% have attenuation >0.2magnitudes.

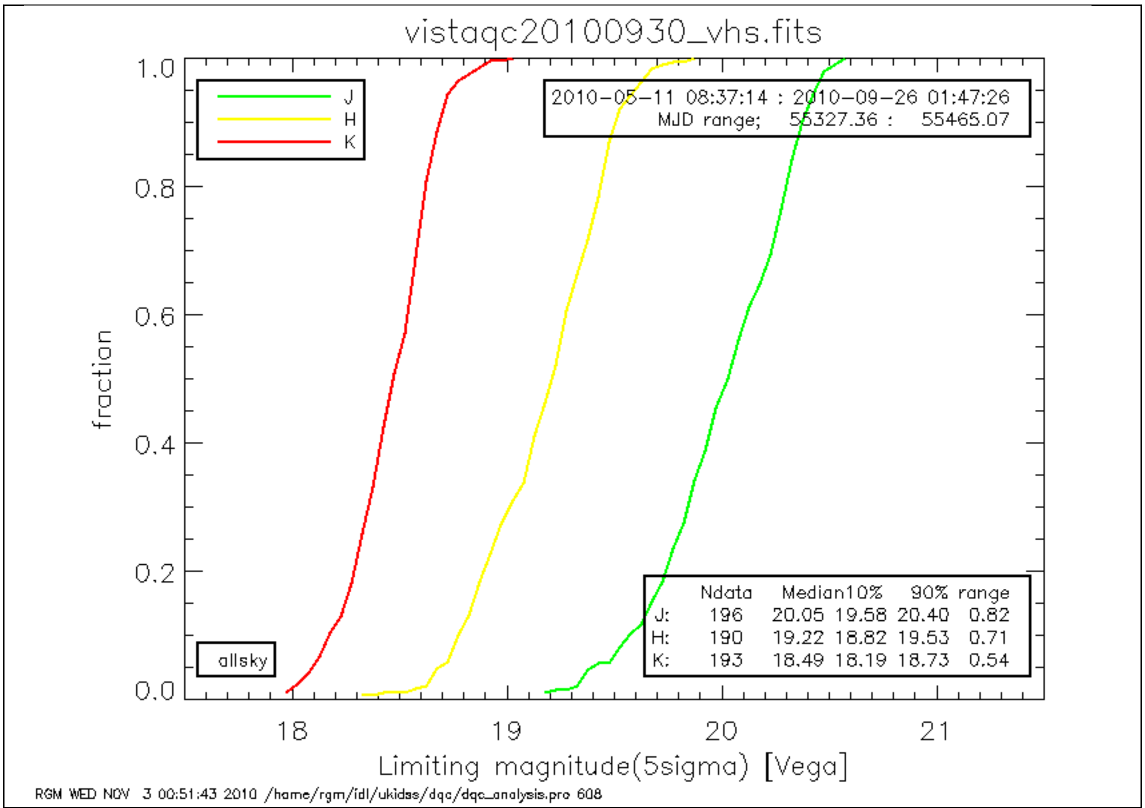

Figure 9(a): Limiting magnitudes for VHS DES component

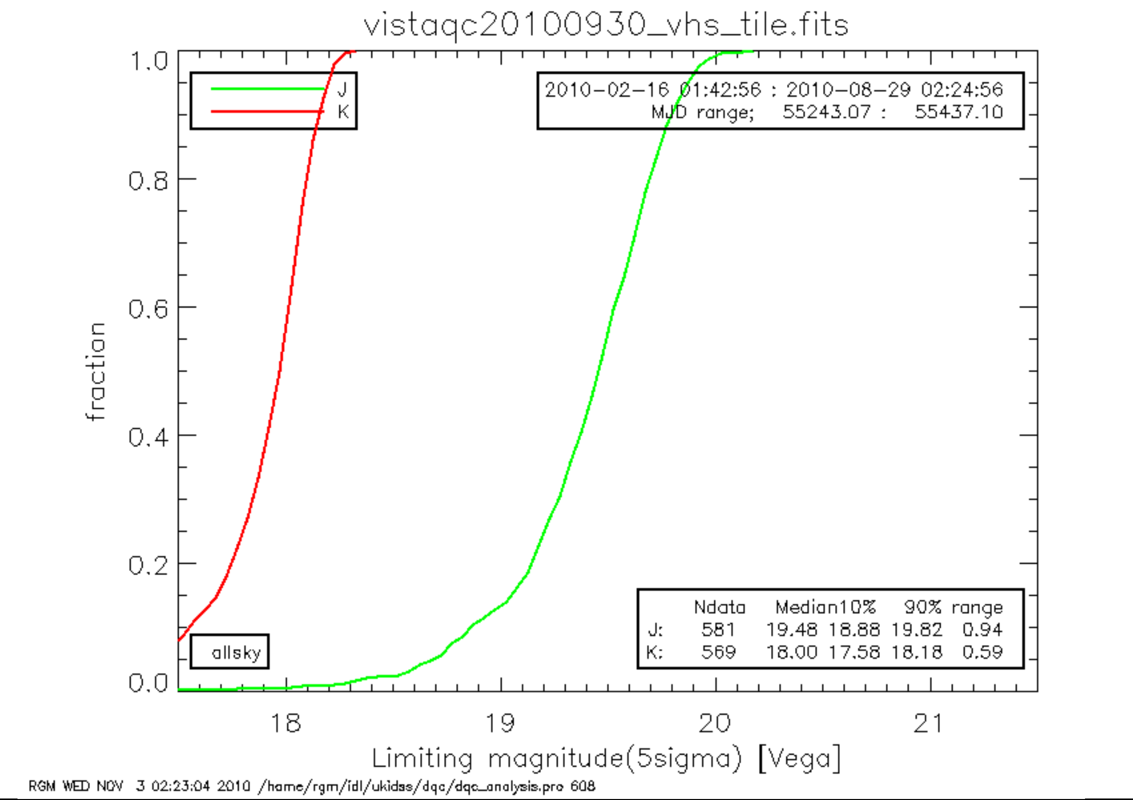

Figure 9(b): Limiting magnitude for VHS GPS component

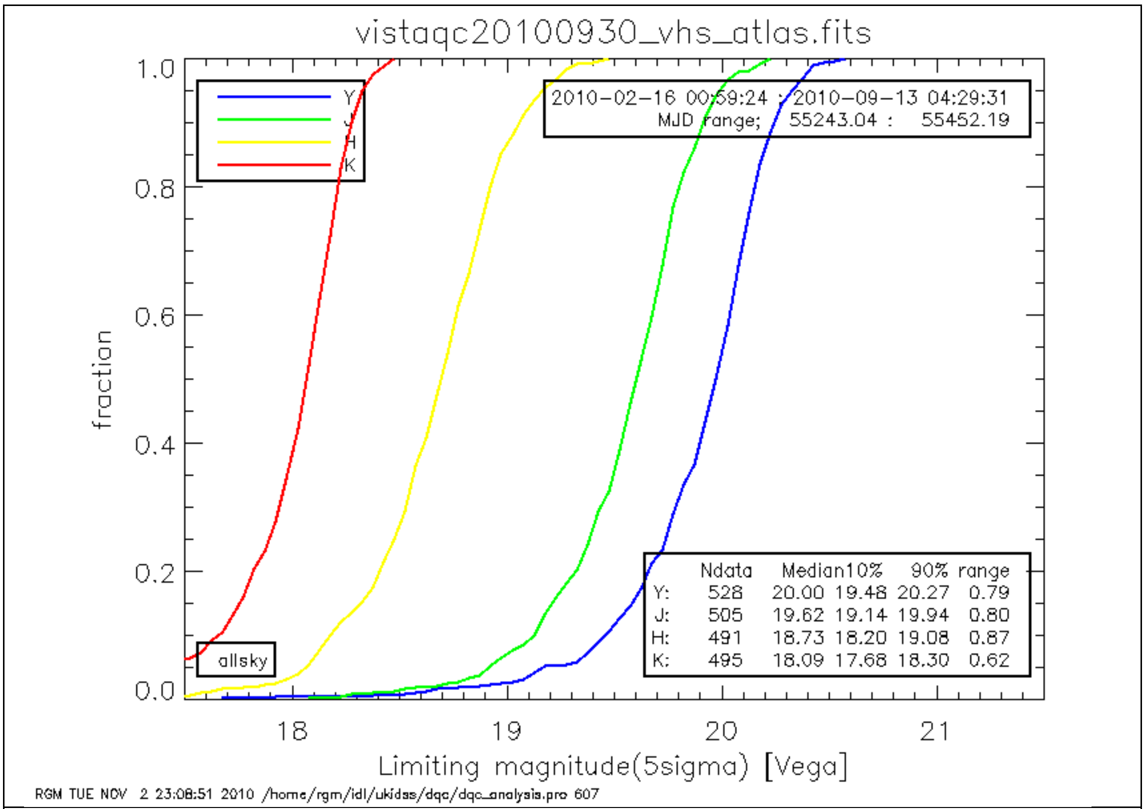

Figure 9(c): Limiting magnitude for VHS ATLAS component