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## VISTA PUBLIC SURVEY STATUS REPORT (90th OPC MEETING)

This report has to be returned to the Observing Programmes Office of the European Southern Observatory ([opo@eso.org](mailto:opo@eso.org)).

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**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-Redsurvey, which when combined with other VISTA Public Surveys will result in coverage of the whole southern celestial hemisphere ( $\sim 20,000 \text{ deg}^2$ ) 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  $5\sigma$  point source (Vega) limits of  $J = 20.2$  and  $K_s = 18.1$ . In the South Galactic Cap,  $\sim 5000 \text{ deg}^2$  will be imaged deeper with an exposure time of 120 seconds and also including the H band producing median  $5\sigma$  point limits of:  $J = 20.6$ ;  $H = 19.8$ ;  $K_s = 18.5$ . In this  $5000 \text{ deg}^2$  region of sky the Dark Energy Survey (DES) will provide deep multi-band optical (grizY) imaging data. The remainder of the high galactic latitude ( $|b| > 30^\circ$ ) 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  $z \sim 1$  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).

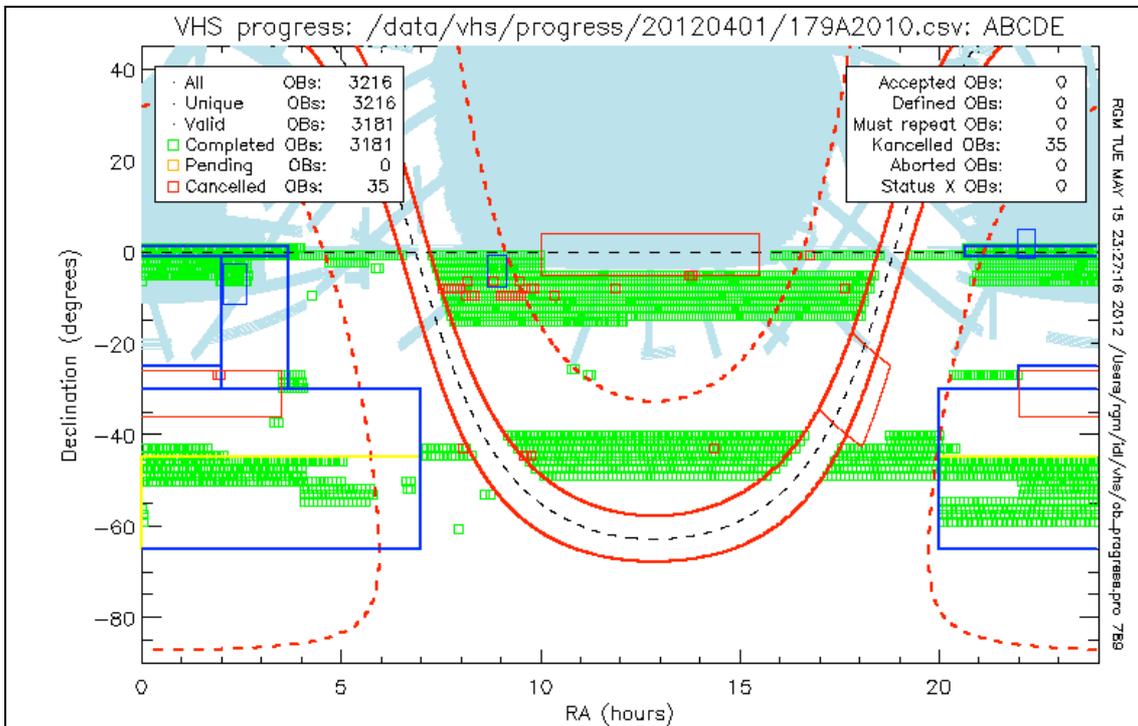
#### 2.1. Progress report

In Figure 1 we show the RA, Dec distribution of OBs for Period 84-88 (including Dry Run observations in Period 84; runs A-E) that have been submitted and executed up to the end of Period 88 on Mar 30<sup>th</sup> 2012.

Figure 1 is generated automatically from the csv files available via the ESO Portal. Table 1 reports the OBs execution status for each period. Note incomplete OBs submitted in each observing period except for the Dry Run period are carried over into the next period and hence the observing efficiency in each Period cannot be derived from the Table 1.

A total of 2903 OBs including 230 during the Dry Run period in Period 84 have been submitted. All the 230 DryRun OBs were completed although some may have to be repeated. Of the 2673 Period 85-87 OBs, 2509 (94%) are reported by ESO as completed and 164 (6%) are incomplete. This is a significant improvement on the status reported in our last report at the end of Period 86 where 451 submitted OBs were incomplete.

At least 2 submitted OBs have been cancelled since they were submitted in error. Our progress analysis software counts these as incomplete OBs. The progress software will be modified to take this into account.



**Figure 1:** Sky coverage of the VHS survey in equatorial coordinates based on ESO Portal report tables. These are copied each day via a script. The green and orange rectangle symbols show complete and incomplete OBs respectively. The light blue shading is the SDSS footprint. The thick blue lines show the Dark Energy Survey footprint. The red solid lines indicate regions that VHS is not covering such as the VIKING and VVV footprints and the inner galactic plane ( $|b| < 5$ degrees).

All data taken up to the end of Feb, 2011 has been processed through the VDFS pipeline at CASU, Cambridge and this data is available to the VHS team for quality control as single band FITS format images and binary table source catalogues. Band merged tables are also available for QC.

*Table 1 VHS OB progress on 2012-04-01*

<b>Period</b>	<b>Submitted OBs</b>	<b>Completed OBs</b>	<b>Incomplete OBs</b>
P84 (A); Dry Run	230	230	0
P85 (B)	1088	1088	0
P86 (C)	850	850	0
P87 (D)	700	700	0
P88 (E)	313	313	0
<b>Total</b>	<b>3183</b>	<b>3183</b>	

CASU processing of VISTA data has reached a stable state and is released in month quanta two to three months after the data is acquired by ESO. 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 QC plots in this report.

In our report to the 87<sup>th</sup> OPC meeting we reported that the photometric and astrometric calibrated paw-print level image and catalogue products had reached a stable state but that mosaiced tile products were still under going QC evaluation by CASU and VHS. This QC process indentified a problem with the aperture corrections that applied to photometry obtained from mosaics taken in conditions where the seeing varied significantly between pawprints in a tile. Version 1.0 of the Tile catalogues suffered from this problem. This was a known feature of VISTA data and was corrected for in version 1.1 of the Tile catalogues. The version 1.1 products for Period 84 and 85 were released by CASU on 2011 March 1<sup>st</sup>. These products have all been transferred to the ESO Phase 3 ftp site. The decision to deliver the version 1.1 products for Phase 3 rather than version 1.0 has caused some medium term delays in meeting the Phase 3 schedule. The alternative would have been to deliver version 1.0 products which may have been unsuitable for some science exploitation and would also have been superseded within a few months.

CASU made some minor upgrades to the pipeline at the start of Period 87 and the pipeline moved to v1.2.

### **Observing overhead concerns**

We repeat the concerns we raised in previous reports to the OPC about the observing overheads which have increased significantly since we submitted our SMP. In Table 2 we summarize the OB execution times compared with the OB time on sky.

*Table 2: OB overheads*

VHS component	OB time on sky (seconds)	SMP	P85	P87	P88
VHS-ATLAS	720	1199	1510	1910	1910
VHS-DES	1080	1491	1809	2129	2129
VHS-GPS	360	600	829	1005	1005

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The current charging for observing overheads is significantly 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 we used information provided by ESO and the VISTA project to estimate total execution times per OB including overheads of 600, 1199 and 1491 seconds respectively. The execution time charged within P2PP for Period 85 was 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.

In Period 87 and Period 88, the total execution time for the three types OB described above is 1005, 1910 and 2129 seconds respectively. Some of this is due to our decision in Period 87 to use AO Priority high to see if this will improve the median seeing that is delivered. This will hopefully improve our point source sensitivity although at the expense of increased overheads. We hope that the VISTA observing overheads will become lower in future.

### **Example colour-magnitude and colour-colour diagrams**

Figures 2-4 show 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 2 [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  $J-K > 1.0$ .

## **2.2. Publications**

A publication in a refereed journal associated with the next public data release is planned. This publication was delayed until receipt of the version 1.1 data products.

Much of the planned science program for VHS as described in the proposal requires optical data from VST or the Dark Energy Survey. VST ATLAS observations have only started in the last few months and the Dark Energy Survey is currently expected to start on the CTIO Blanco telescope in November 2012.

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We also note that VHS data is being used by the ESO Public Spectroscopic survey project: The Gaia-ESO Survey; PIs: Gerry Gilmore (IoA Cambridge, UK), Sofia Randich (INAF, Obs. Arcetri, Italy) for target selection.

A number of papers based on follow-up spectroscopic observations are in preparation.

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### **3. Quality Control and Phase 3. The Phase 3 submission plan should be described here.**

#### **3.1 The PI should comment on the quality control and the science validation of the acquired data.**

Robust, objective and 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 are being produced following the plan outlined in the VHS SMP.

Colour-magnitude and colour-colour plots as shown in Figure 2-4 are produced for all paw-print and tile band-merged catalogues. These are made available to the VHS QC team via the WWW. Figure 2 shows examples of version 1.0 VDFS data products that failed our QC. This is the same data presented in Figure 3 of our status report to the 87<sup>th</sup> OPC meeting. Figure 3 shows the VDFS version 1.1 data products for the same raw data and shows that the version 1.1 products now pass our image classification and photometric QC. Figure 4 shows data from the final night of Period 85 and the end of December, 2011 respectively.

#### **Image quality**

Figure 5 shows the distributions of the image quality in all wavebands for all VHS observations obtained in Period 86 and the first few months of Period 87. Figure 5(a) and 5(b) shows the FWHM distributions for the stacked tiles for Period 86 and 87 respectively. Figure 5(c) and 5(d) shows the FWHM distributions for the individual chips in each pawprint that is used for the tiles for Period 86 and 87 respectively. The pawprints have FWHM that are around 0.1'' better than the final stacked tiles. It is possible that this is due to the resampling technique that is used for the tiling and will be investigated with CASU to see if the mosaiced Tile image quality can be improved.

Figure 5 shows the measured seeing (FWHM) for stellar objects and Figure 6 shows the image ellipticity distribution. Visual inspection of the images with ellipticity > 0.15 is carried out. Some have double images whereas some may still be useable. In Period 86 the ellipticity distribution improved compared with Period 85.

In period 86, the medians of the seeing distributions show a wavelength dependence increasing from 1.03 arc seconds in K<sub>S</sub> to 1.11 arc seconds in J. The ratio of 1.08 is consistent with a Kolmogorov  $\lambda^{-1/5}$  wavelength dependence assuming a effective wavelengths of 2.149 $\mu$ m for K<sub>S</sub> and 1.254 $\mu$ m for J. The Y band images have median seeing of 1.07 arc seconds. Overall the median measured seeing is similar to the values obtained in Period 85.

The seeing distributions in J has a significant tail to value that exceed out seeing limit of 1.4''. In Period 85, Y band also had a large tail but in period 86 this is reduced. 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. In Period 87, we observed with AO Priority high to

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determine whether increasing the AO priority will improve the median seeing. This increases observing overheads by ~10% but could be balanced by better quality data. The data that has been analyzed during period 87 does not show a significant improvement.

### **Astrometry**

Figure 8 shows the distribution of the World Coordinate 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. These distribution meet our science requirements. We plan to carry out independent tests by comparing with SDSS and UKIDSS data to check for systematics by comparing galactic and extragalactic reference frames using known quasars, galaxies and galactic stars.

### **Sky brightness**

Figure 9 shows the measured sky brightness on all VHS tiles for Period 86. 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 16.85, 15.64, 13.67 and 12.91 respectively. The Period 85 measured median values were 16.98, 15.76, 13.86 and 13.10 respectively. i.e. the median measured sky brightness is brighter during Period 86 compared with Period 85 by 0.1 to 0.2 magnitudes.

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 during Period 86 is +0.3 magnitudes brighter in Y, J and 0.2 magnitudes brighter H and K.

In our last report we noted that the brighter values in Y, J and H may be due to observations taking place too close to evening twilight. During Period 86 and 87 we used the twilight constraint. Table 3 shows how the measured sky brightness has varied in the last three periods compared with the values assumed in the SMP.

*Table 3: Median Sky Brightness*

VHS component	SMP	P85	P86	P87
Y	17.2	16.98	16.85	16.94
J	16.0	15.76	15.64	15.57
H	14.1	13.86	13.67	13.73
Ks	13.0	13.10	12.91	12.80

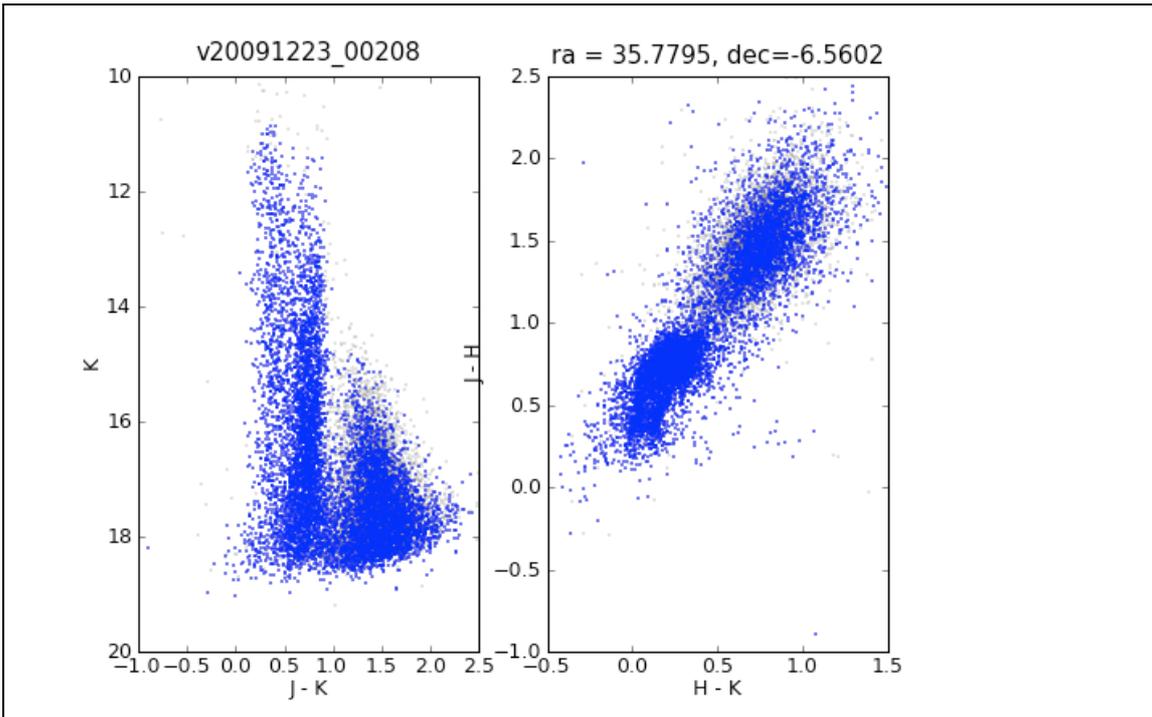
### **Zero-points and atmospheric transparency**

Figure 10 shows the measured zero-point on tiles for all Period 86 VHS observations based on photometric calibration using 2MASS. There is a tail to bright magnitudes and ~10% have relative attenuation >0.2 magnitudes which is outside the ESO THIN constraint. Some of this may be due to the known degradation in the VISTA system throughput due to the degradation of the primary mirror reflectivity since the primary mirror was coated in September 2009.

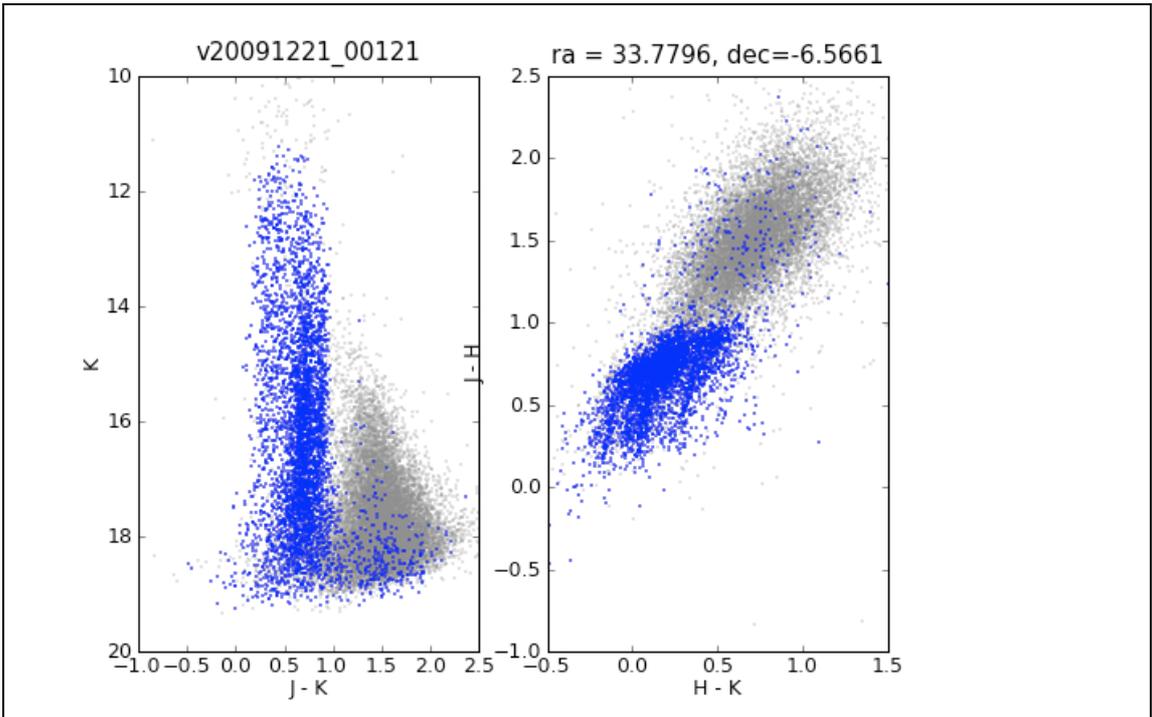
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### **Limiting magnitudes**

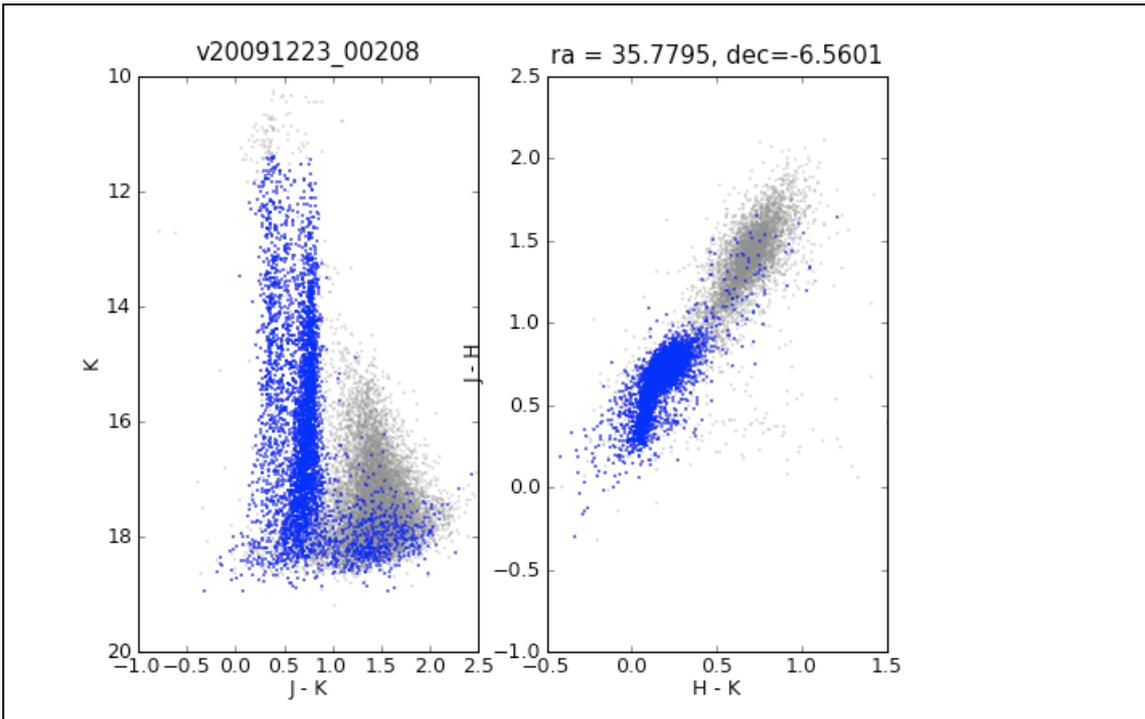
Figure 11(a,b,c) shows the computed 5sigma point source limiting magnitudes for the 3 VHS survey components for all observations obtained in Period 87. Note the VHS DES component has exposure times of 120 seconds per band compared to 60 seconds for the other two components (GPS and ATLAS). Despite the 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  $\sim 0.5$  brighter than our goals. This is a combination of poorer than expected IQ and brighter sky brightness.



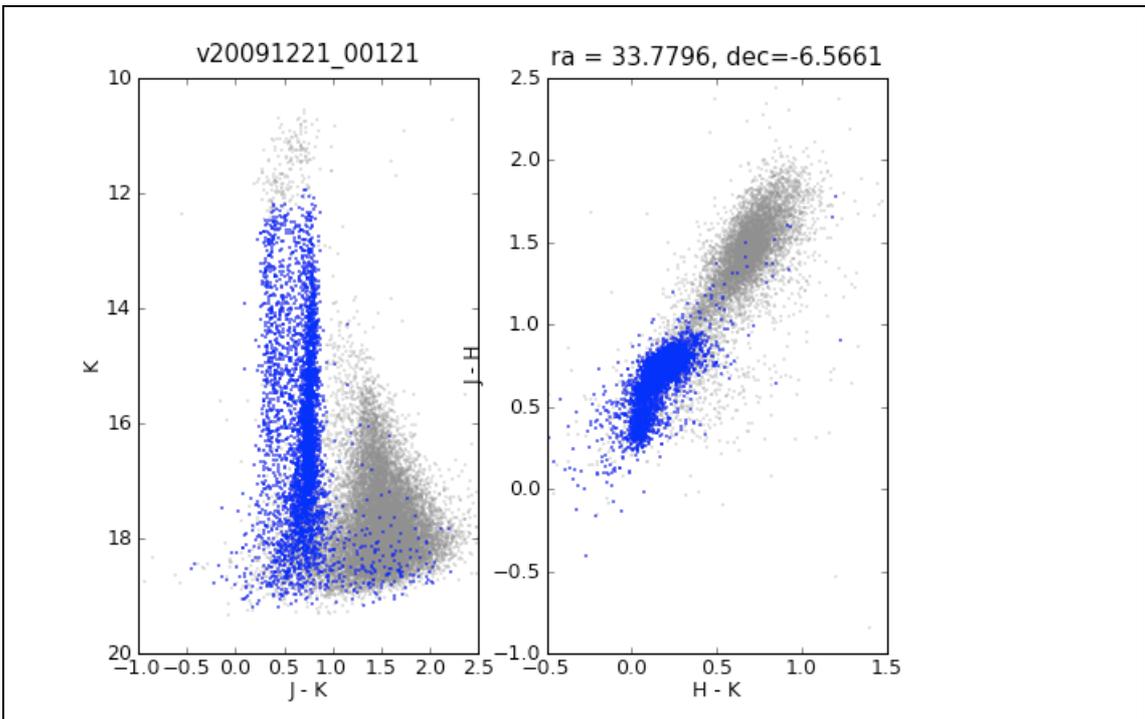
**Figure 2(a):** Version 1.0 data products showing QC problem with star-galaxy separation. Blue points are starlike objects; Grey points are non-stellar objects



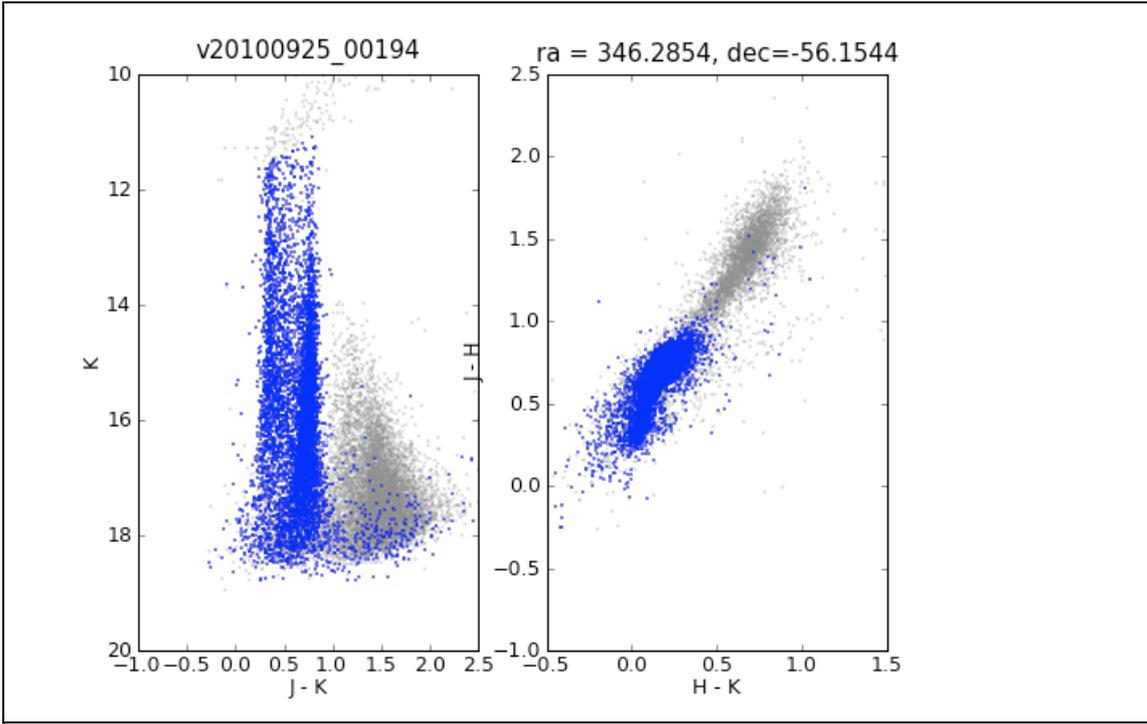
**Figure 2(b):** Version 1.0 data products showing QC problem with multiple offset stellar loci due to variable seeing causing spatially dependent aperture corrections in different pawprints.



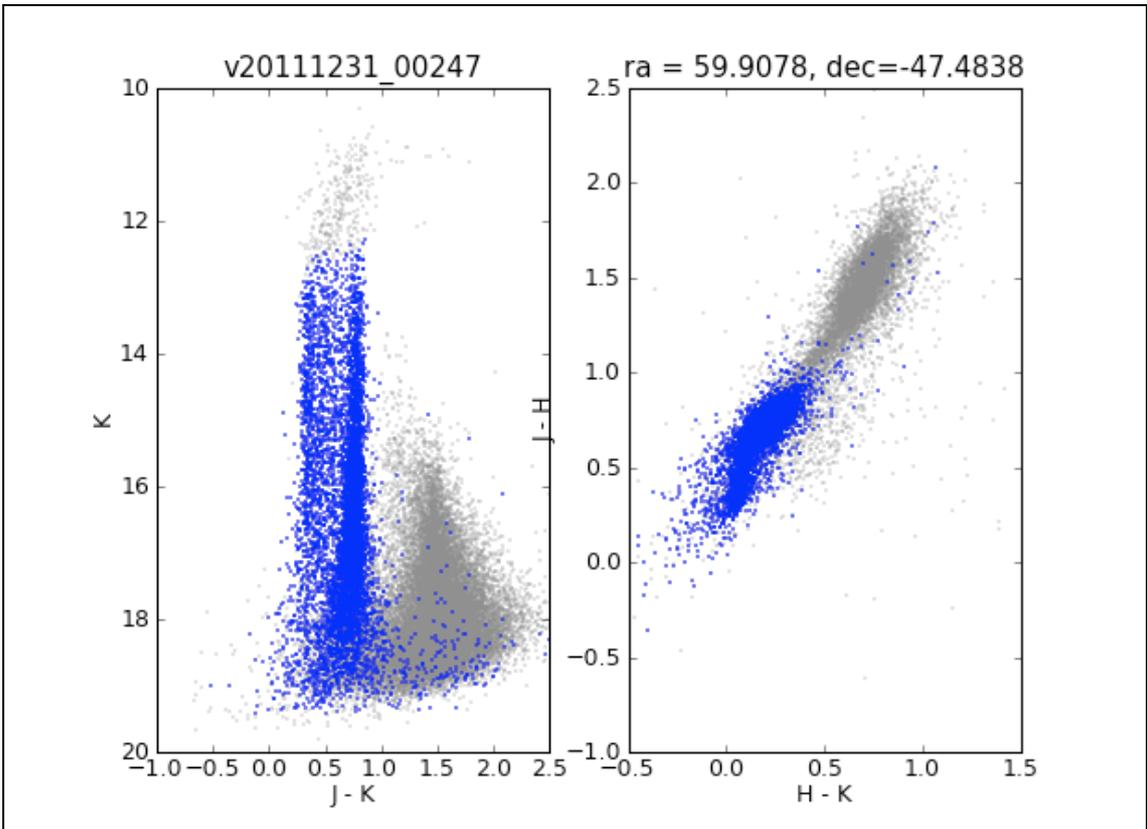
**Figure 3(a):** Version 1.1 data products for same observations as Figure 2(a) showing the improvement in star-galaxy separation for this OB. Blue points are starlike objects; Grey points are non-stellar objects



**Figure 3(b):** Version 1.1 data products for same observations as Figure 2(a) showing the improvement in photometry. Blue points are starlike objects; Grey points are non-stellar objects. The QC problem showing multiple offset stellar loci due to variable seeing causing spatially dependent aperture corrections in different pawprints has been removed. The same raw data has been used in both Figure 2 and 3.



**Figure 4(a):** Version 1.1 data products for VHS final Period 85 OB acquired on 2010 Sep, 25<sup>th</sup>. Blue points are starlike objects; Grey points are non-stellar objects



**Figure 4(b):** Version 1.2 data products for a VHS-DES Period 87 OB acquired on 2011 Dec, 31<sup>st</sup>

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**3.2 The PI should describe the current status of the Phase 3 submission. Any feedback or requested modifications of data products or timeline for survey releases should be described here. PIs should also include any relevant information for the scientific validation of the data products.**

The astrometric and photometric calibrated VHS paw-print and tile catalogues and images and ancillary calibration frames for observations obtained up-to the end of period 86 were planned to ready for delivery in December, 2010 based on the CASU version 1.0 pipeline products. The details of the ESO delivery procedures were presented by ESO at a workshop in Garching on Nov 30<sup>th</sup>, 2010. After this meeting ESO announced a delay in the availability of the Phase 3 system. The system was eventually opened in mid-March.

The version 1.1 products for Period 84 and 85 data were released by CASU to the VHS team on March 1<sup>st</sup>, 2011. This data has been transferred to the ESO Phase 3 ftp site. The data has been validated by ESO and a number of changes made. Due to the fact that the new CASU version was released quite close to the Phase 3 deadline there were some logistic problems within VHS since QC was well advanced on the version 1.0 products.

The decision to deliver the version 1.1 products for Phase 3 rather than version 1.0 has caused some medium term delays in meeting the Phase 3 schedule. The alternative would have been to deliver version 1.0 products which may have been unsuitable for some science exploitation and would also have been superseded within a few months.

The first release of VHS data was released to the community on 17<sup>th</sup> Oct, 2011.

The next Phase 3 stage delivery will occur after the ESO Phase 3 infrastructure is has been upgraded and released.

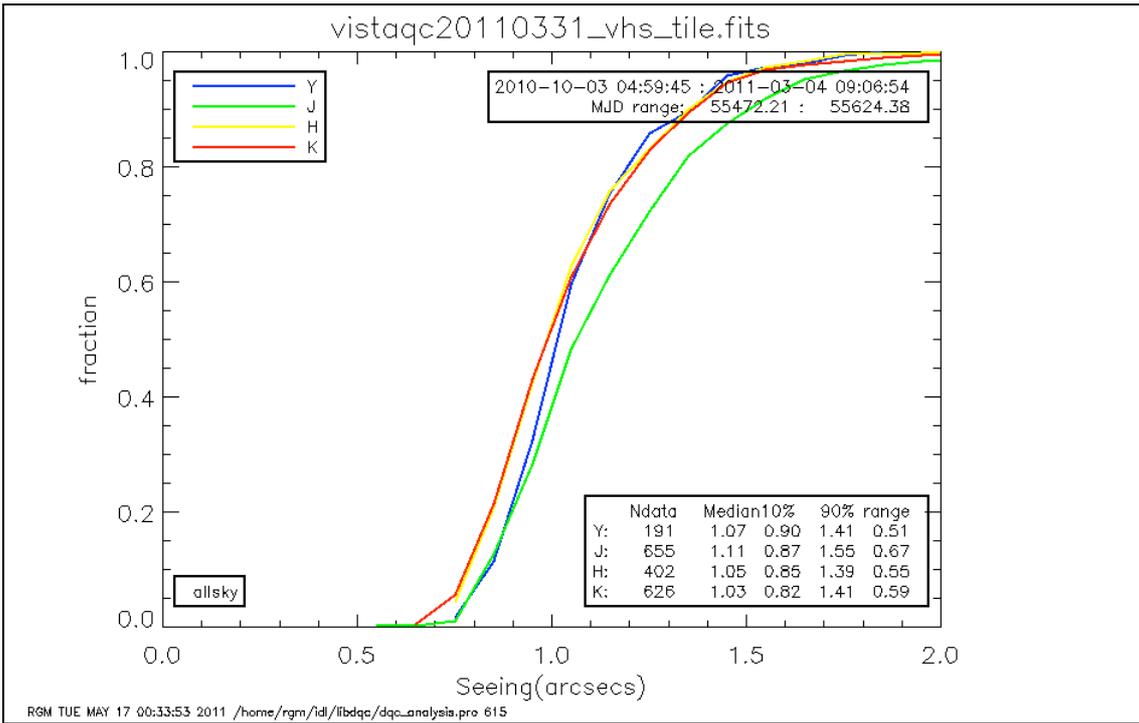
**4. Are any changes proposed with respect to the Survey Management Plan in P90 (e.g., in strategy, field coordinates, exposure time and/or other settings)? If yes, please provide a clear and detailed justification.**

As proposed in our last report we have moved the H band exposure time to the bluest band in VHS-DES and VHS ATLAS so that the J and Y band observations are closer to the SMP depth requirements.

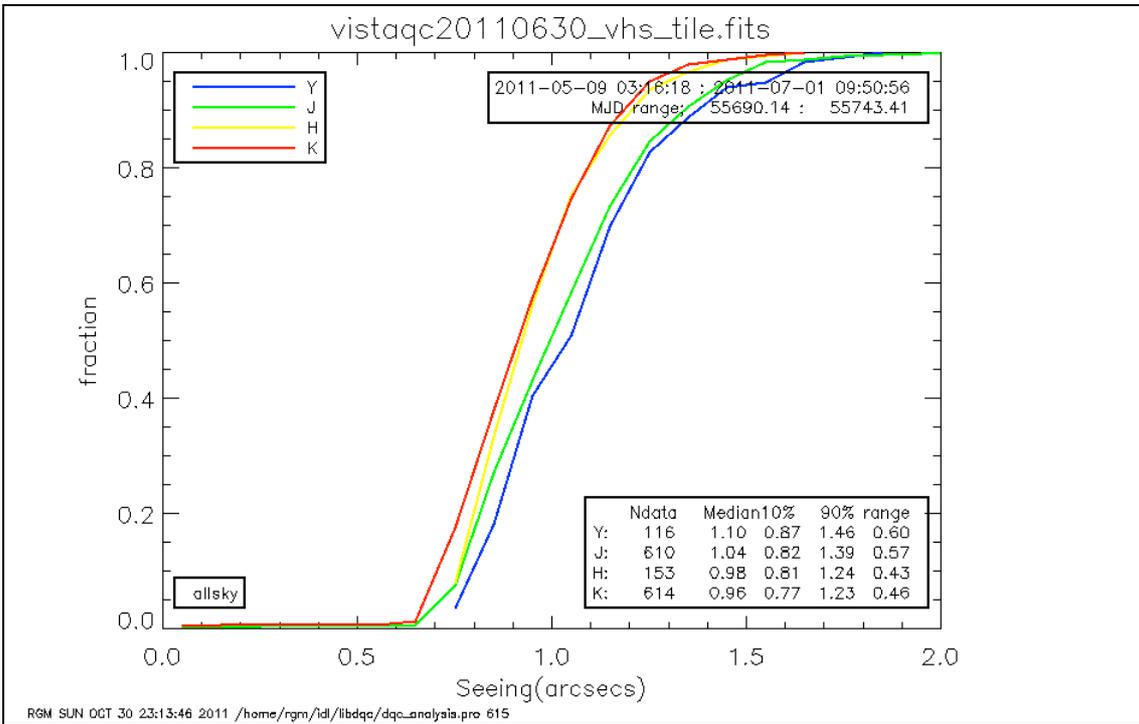
**5. Observing Plan for Period 90.**

**Specify which part of the Survey Management Plan (SMP) the survey will focus on in P90 in the 1<sup>st</sup> column and provide the corresponding details in the table below. In particular please highlight any changes with respect to the SMP for P90, and provide a full justification for these changes in Section 4 above.**

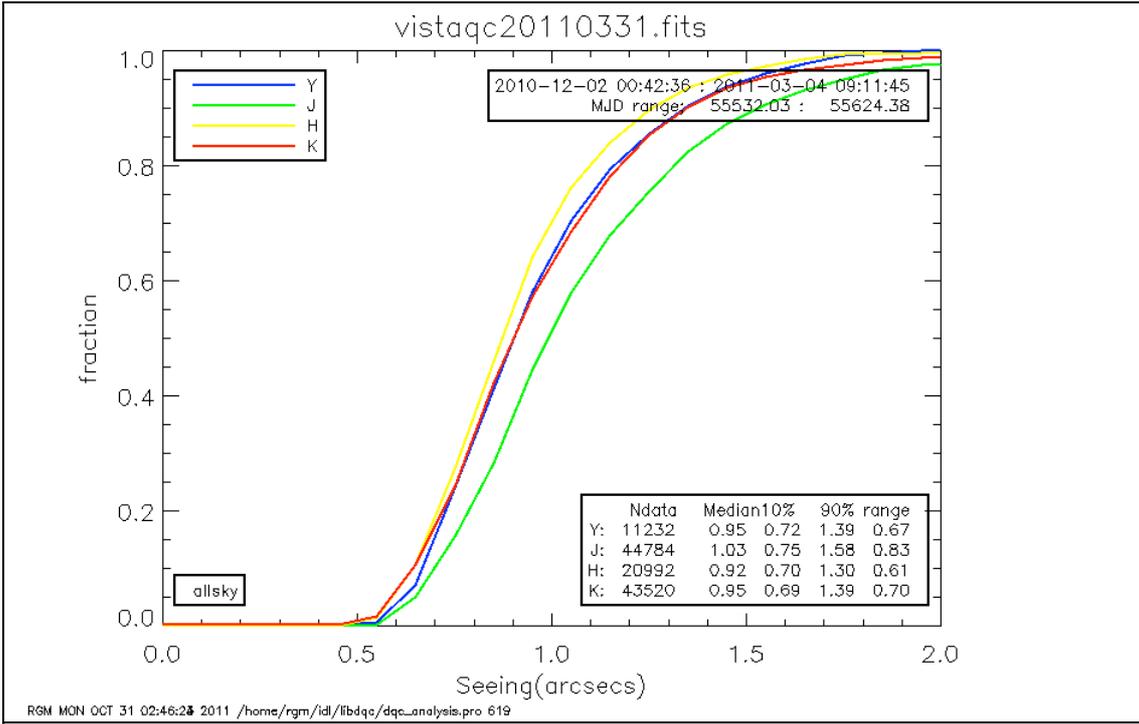
SMP Period	Field name/ mean RA	Filter	Time (h)	Seeing	Moon	Transparency	Comments / strategy (e.g., no. of epochs)
90	12hr	Y,J, H,K	311	<1.4	any	thin	



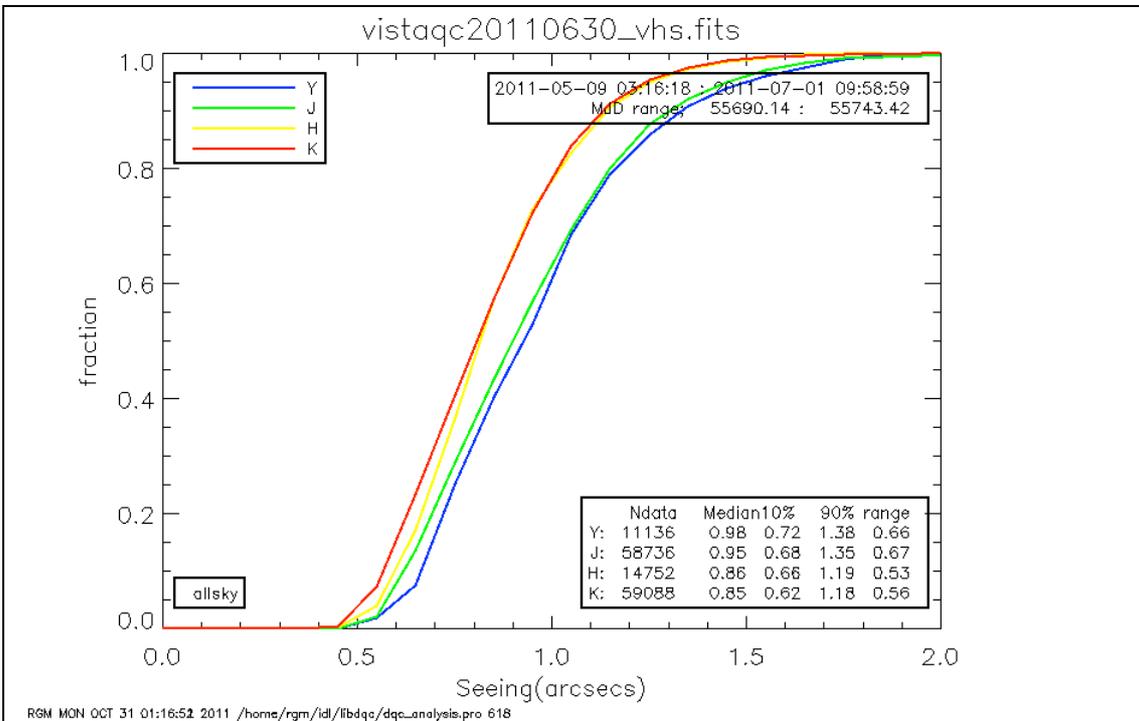
**Figure 5 (a):** Measured image seeing (stellar FWHM) on tiles for all Period 86 VHS observations including rejected and repeated OBs.



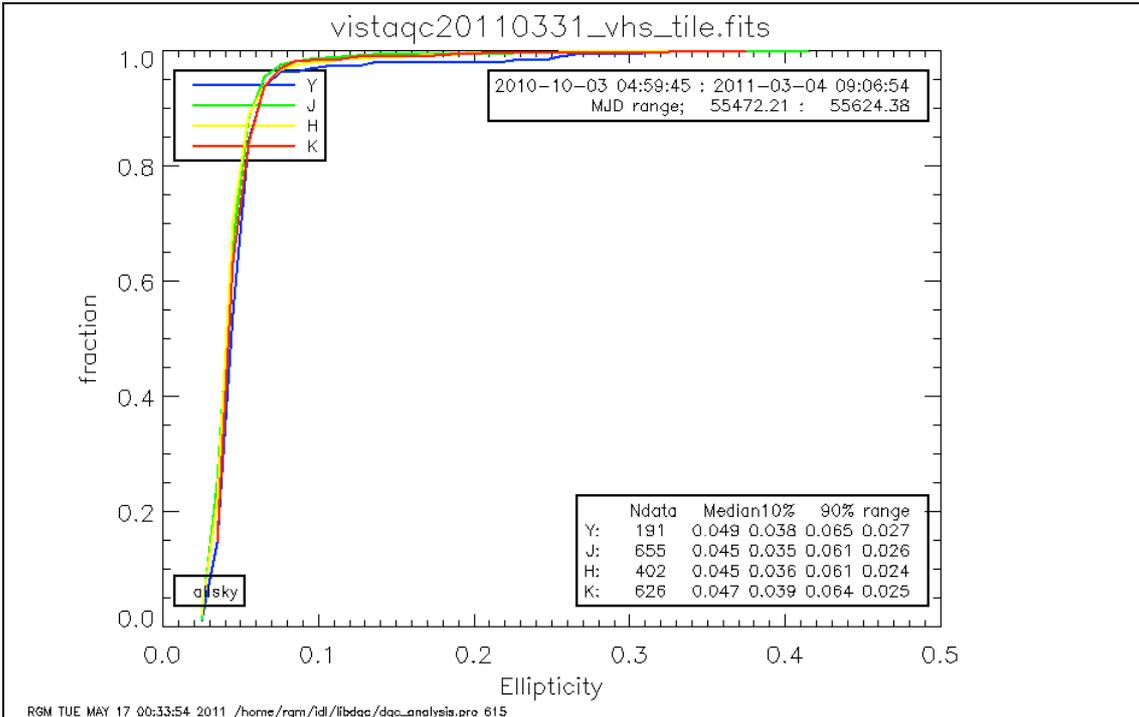
**Figure 5 (b):** Measured image seeing (stellar FWHM) on tiles for Period 87 VHS observations including rejected and repeated OBs.



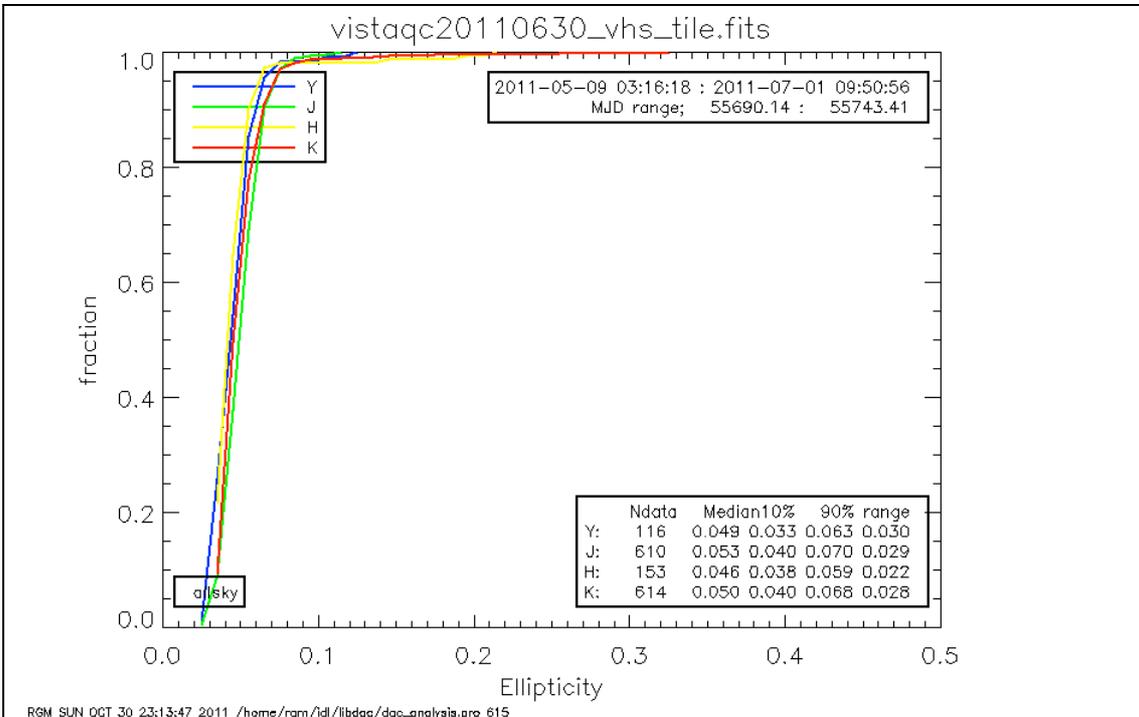
**Figure 5 (c):** Measured image seeing (stellar FWHM) on pawprints for Period 86 VHS observations including rejected and repeated OBs.



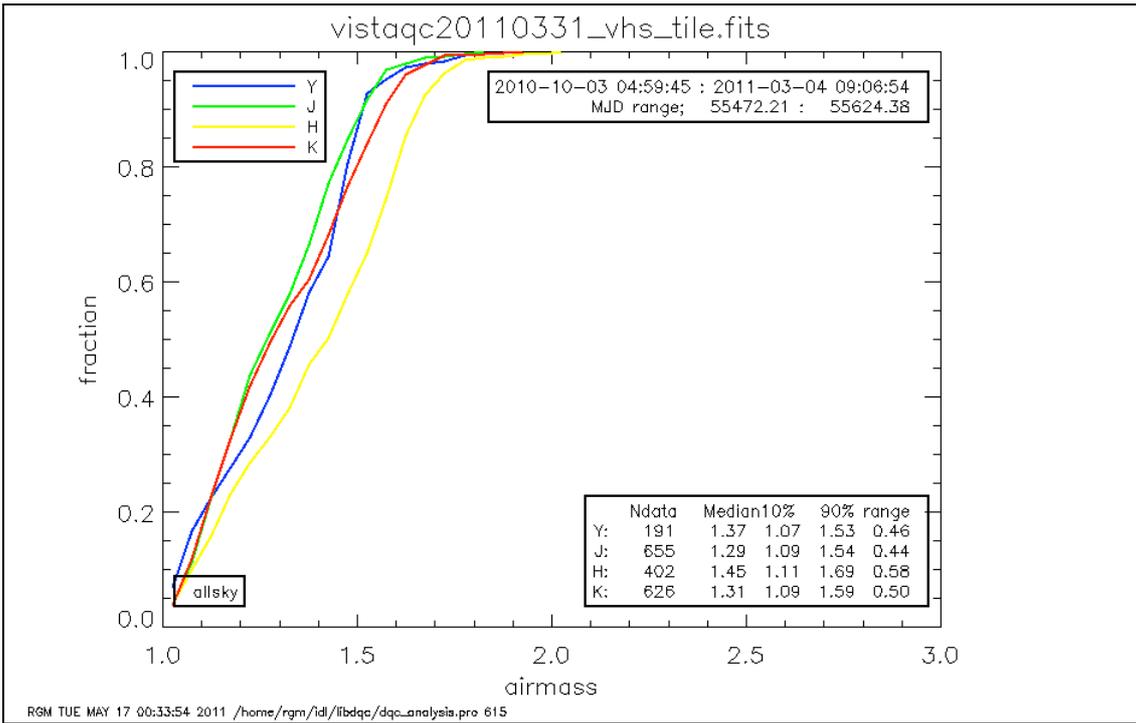
**Figure 5 (d):** Measured image seeing (stellar FWHM) on pawprints for Period 87 VHS observations upto the end of June, 2011 including rejected and repeated OBs.



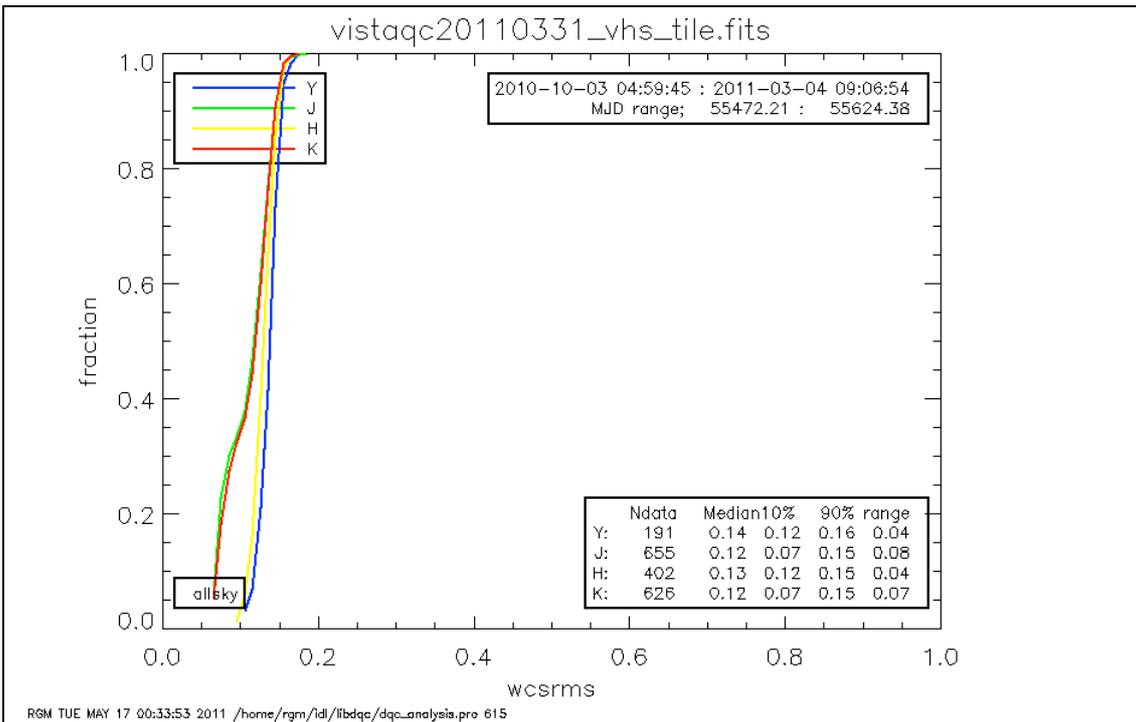
**Figure 6 (a):** Measured image ellipticity on all tiles for Period 86 VHS observations including rejected and repeated OBs



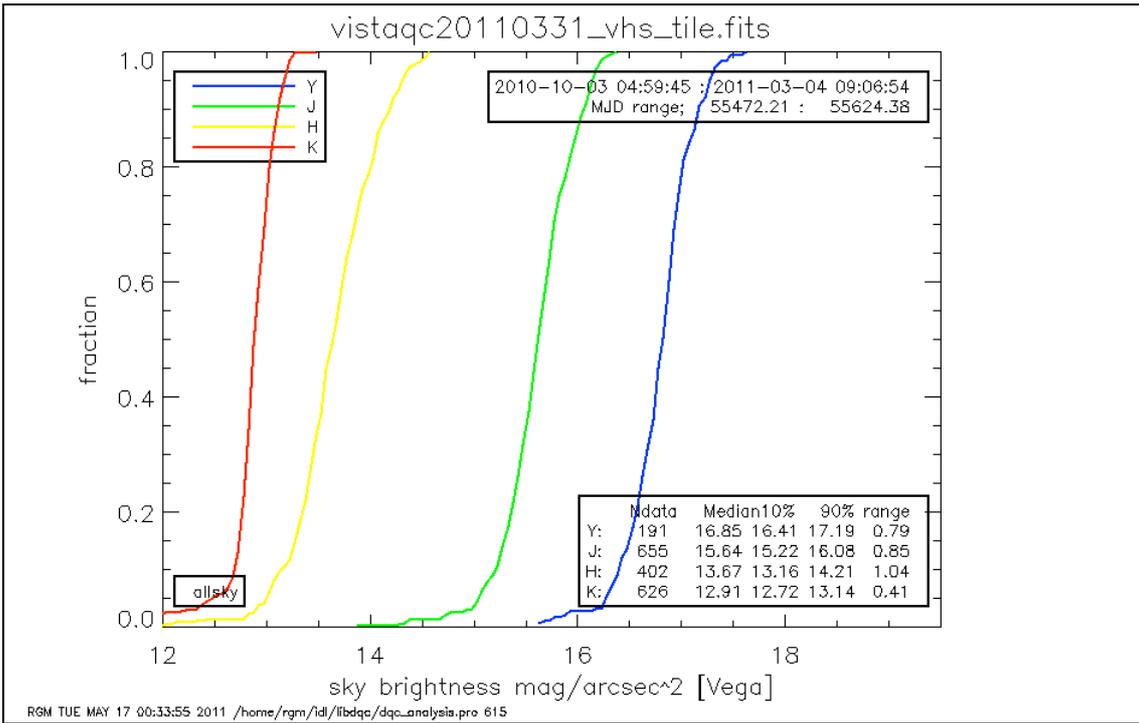
**Figure 6 (b):** Measured image ellipticity on all tiles for Period 87 VHS observations up to the end of June, 2011 including rejected and repeated OBs.



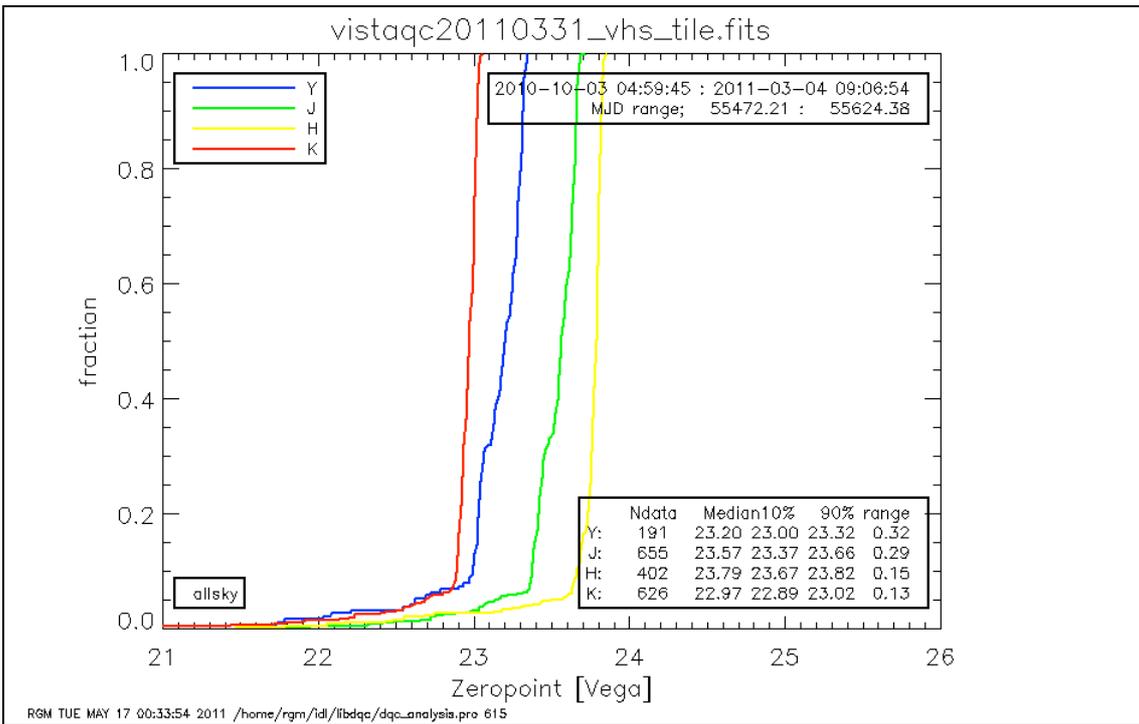
**Figure 7:** Airmass distribution for all Period 86 VHS observations i.e. includes rejected and repeated OBs.



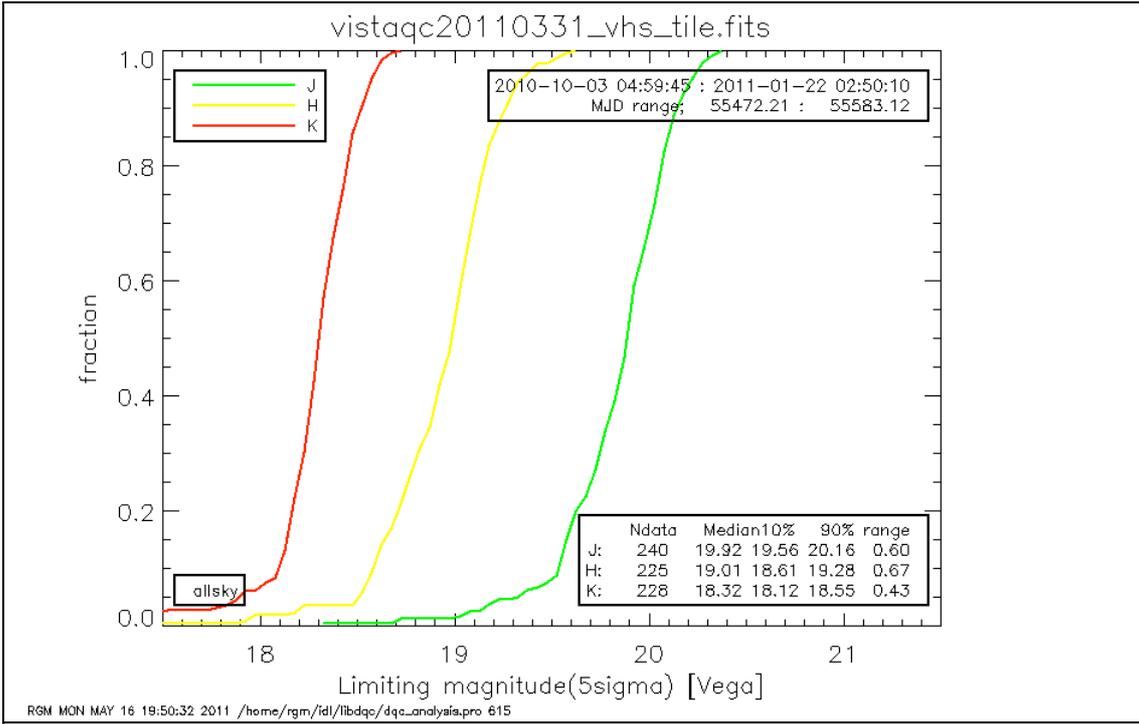
**Figure 8:** Distribution of the World Coordinate System (WCS) rms astrometric errors for tiles. The J and K bands have a tail to smaller values compared to Y and H due to larger fraction of fields at low galactic latitude and hence more WCS 2MASS astrometric calibration stars.



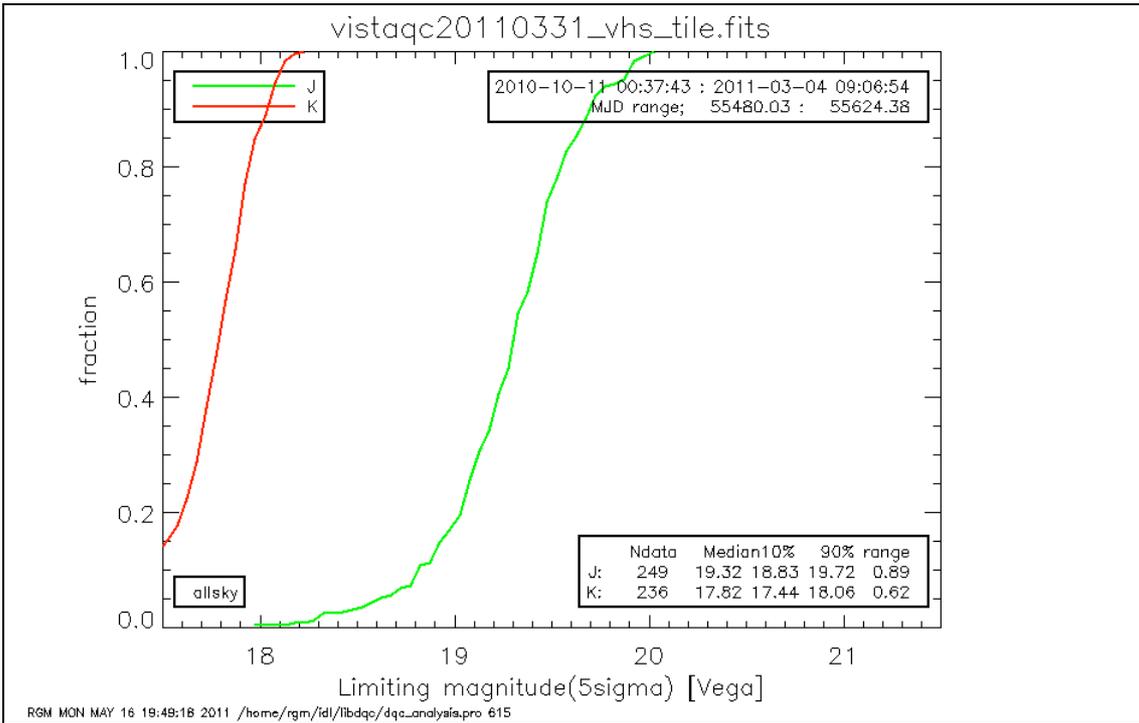
**Figure 9:** Measured sky brightness seeing on all VHS tiles for Period 86 observations. Note the tail to bright magnitudes that effects ~5% of observations.



**Figure 10:** Measured zeropoint on tiles for all Period 86 VHS observations. Note the tail to bright magnitude. 5-10% have attenuation >0.2magnitudes.



**Figure 11(a):** Limiting magnitudes for VHS DES component P86 observations



**Figure 11(b):** Limiting magnitudes for VHS GPS component P86 observations

