PUBLIC SURVEY STATUS REPORT
(99th OPC MEETING)

This report should be returned to the Observing Programmes Office of the European Southern Observatory (opo@eso.org) by Oct. 20, 2016. This report will be reviewed by the OPC and Joint VISTA/VST Public Survey Panel.

PROPOSAL ESO No.: 177.A-3011
TITLE: VST ATLAS
PRINCIPAL INVESTIGATOR: T. Shanks

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1. Scientific Aims (brief description)

The main aim of the VST ATLAS is to make a survey of ~4700deg^2 in the Southern Hemisphere in the *ugriz* bands to the depth of SDSS. The ATLAS will cover ~2200deg^2 in the North Galactic Cap between 10h<RA<15h30 and ~2500deg^2 in the South Galactic Cap between 21h30<RA<04h00. The main motivation for the survey is for cosmology. For example, there is the possibility of using the VST ATLAS UV coverage as the base for spectroscopic QSO redshift surveys out to z=2.2 in order to use QSO clustering to investigate primordial non-Gaussianity, the power-spectrum turnover and BAO measurements of the Dark Energy equation of state at z~1.5. 17 nights of pilot survey observations based on ATLAS data have already been carried out on the AAT 2-degree Field (2dF) facility and future AGN surveys from e-ROSITA and 4MOST will greatly benefit from these data. This quasar redshift survey has further demonstrated the power of combining ATLAS with WISE satellite data in the L(3.4micron) and M(4.6 micron) bands to increase the quasar selection density. ATLAS data can also be further combined with the VISTA Hemisphere Survey to produce *ugrizYJKLM* photo-z for galaxies out to z~1. Then cross-correlation of Luminous Red Galaxies with the Cosmic Microwave Background fluctuations will test the evidence for an accelerating Universe via the Integrated Sachs Wolfe effect. Many other non-cosmological projects are clearly also feasible including the search for high redshift z>6 QSOs via optical dropout, the search for stellar streams and the search for local large scale structure including the Great Attractor. Indeed, our aim is that ATLAS becomes the equivalent of a Southern Sloan with similar scientific impact. ATLAS Data Release 2 (DR2) covering the period from 1/8/2011 - 30/9/2013 is available from the ESO archive and the release of DR3 (1/8/2011 -30/9/2014) is imminent.

All OBs have been submitted in P87 through P94 for *ugriz* coverage of the ~4000 deg^2 of ATLAS that were originally approved by the PSP. However, it was always envisaged that ATLAS would cover ~4700deg^2 by including the area at b>29deg and Dec<-20 in the NGC and the science case in the revised Survey Management Plan assumed this increased area. At its April 2014 meeting, the PSP gave approval to observe this extra area in the *iz* bands to take ATLAS to its full 4700deg^2 area. A Chilean VST proposal (PI L Infante) was accepted by the ESO OPC for P95, P96 and P97 (but unfortunately not P98) to survey this extended area in the *ugr* bands.

2. Detailed progress report with respect to initial estimate from the Survey Management Plan.

2.1 Scientific Progress and Outlook

The VST ATLAS now has covered the equivalent of ~3900 deg^2 in *ugr* and ~4600deg^2 in *iz* between mid-August 2011 and October 2016 in Periods 87 - 97 (see status maps at http://astro.dur.ac.uk/Cosmology/vstatlas/). All OBs for the originally approved ATLAS area of 4000deg^2 (and the additional ~700deg^2 in the NGC) are already submitted, there is a steadily decreasing backlog of OBs rolled over from previous Periods. The original 4000deg^2 in *iz* is virtually complete and the *iz* NGC survey extension should be complete before the end of P98(1/4/17). The *ugr* bands will also take until the end of P98 to be complete in the original survey area.

Meanwhile CASU are up-to-date in their reduction of the ATLAS data.
The total number of tiles to cover the original ~4000deg^2 ATLAS area is 4276 (x5 bands). The extra NGC area in *iz* corresponds to 797 tiles taking the *iz* totals to 5073. Table 1 shows how many of these have been completed by passband. It can be seen that *i* and *z* which are done in gray/bright time have the highest completeness (taking account of their extra area) followed by *r* and *g* then *u*.

Band	Completed	Failed	Scheduled
U	4157 (947)	0	119
G	4208 (491)	34	34
R	4242 (306)	34	0
I	4907 (417)	47	119
Z	4922 (313)	50	101

Table 1. Total number of VST ATLAS pointings so far completed up to October 2016. Scheduled means OB submitted. Number in brackets in the Completed column shows tiles completed in the last year.

As noted above, PSP at its 28-29/4/14 meeting recommended that we be allowed to extend the survey to its originally envisaged ~4700deg^2 by allowing us to survey the NGC area above galactic latitude b>29 and Dec<-20 in *iz*. A Chilean proposal (PI L. Infante) to complete the survey of this extended area in *ugr* has been accepted by the ESO TAC for P95, P96 and P97 but unfortunately not P98. Chilean OBs not completed in previous Periods and not carried over are being reapplied for in P99 and subsequent Periods. This *ugr* extension is going too slowly and needs higher priority time.

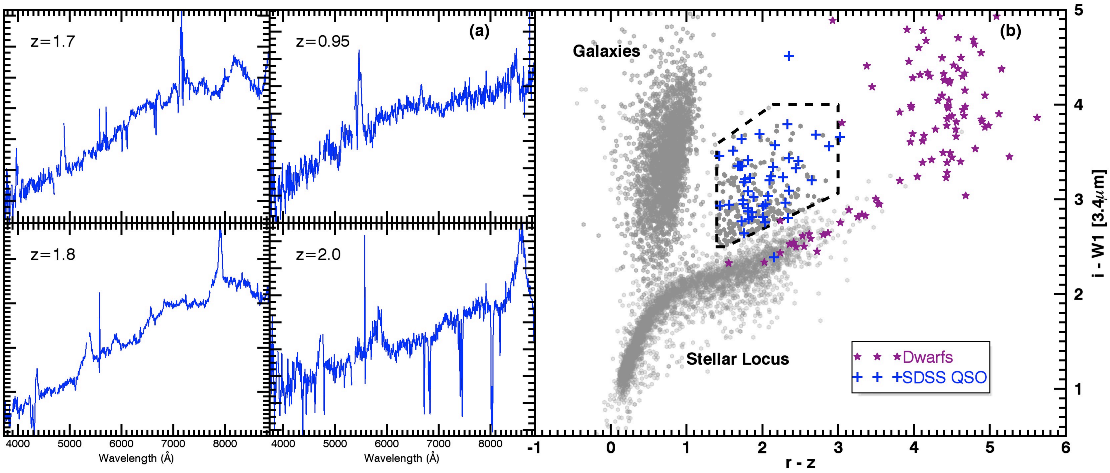

Fig. 1a. *4 examples of a new population of dust absorbed red quasars at z<2.5 selected from g-i:i-W1 by a combination of WISE and ATLAS. Spectra from AAT 2dF AAOmega (Chehade et al 2016).* **Fig. 1b.** *WISE and ATLAS r-z:i-W1 colour-colour plot shows high efficiency in isolating previously discovered SDSS 5<z<6 quasars (Findlay et al 2015 in prep.).*

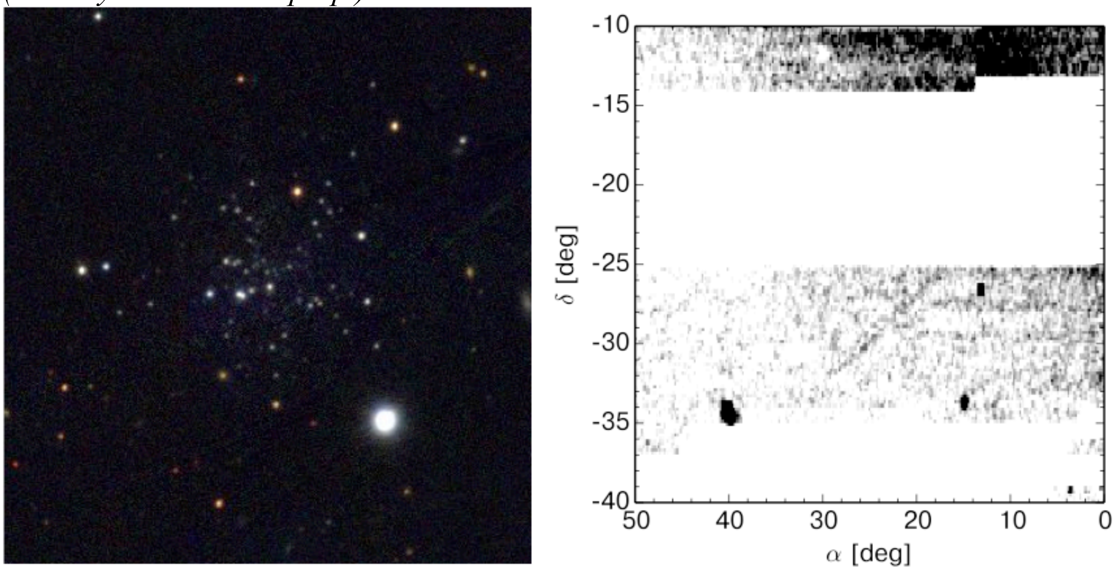

Fig. 2a *Discovery of the Crater Milky Way satellite in VST ATLAS survey data as shown here in a ~3x3arcmin true colour gri image (Belokurov et al, 2014).* **Fig. 2b** *The spatial density variation of stellar sources in the g- and r-bands which track the stellar locus of the stream colour magnitude diagram (Koposov et al, 2014).*

As examples of science highlights, in Fig 1a we show results from the 2QDES pilot survey where 10000 0.5<z<3.5 quasar redshifts were observed using the combination of ATLAS and WISE photometry (Chehade et al 2016). A population of obscured dusty quasars were also found, some examples of whose very red spectra are shown here. In Fig 1b a redder combination of ATLAS and WISE bands is used to select higher redshift 5<z<6 quasars and follow-up of these candidates is ongoing.

Another science highlight is that ATLAS is also proving ideal for searching for Milky Way satellites and stellar streams as shown by the discovery by Belokurov et al (2014) of the Crater dwarf galaxy, a new Milky Way satellite (see Fig. 2a) and a new stellar stream Koposov et al (2014) (see Fig. 2b). Torrealba et al (2016a,b) have found a further 3 dwarf satellite galaxies using ATLAS data.

A further science highlight is the discovery of four z>6 quasars by combining ATLAS and WISE photometry (Carnall et al 2015, Chehade et al 2016 in prep.). The quasars shown in Fig. 3 have been confirmed by observations using Magellan LDSS-3 (top 2) and the third has been confirmed by Keck LRIS observations. The fourth quasar was confirmed by NTT EFOSC2.

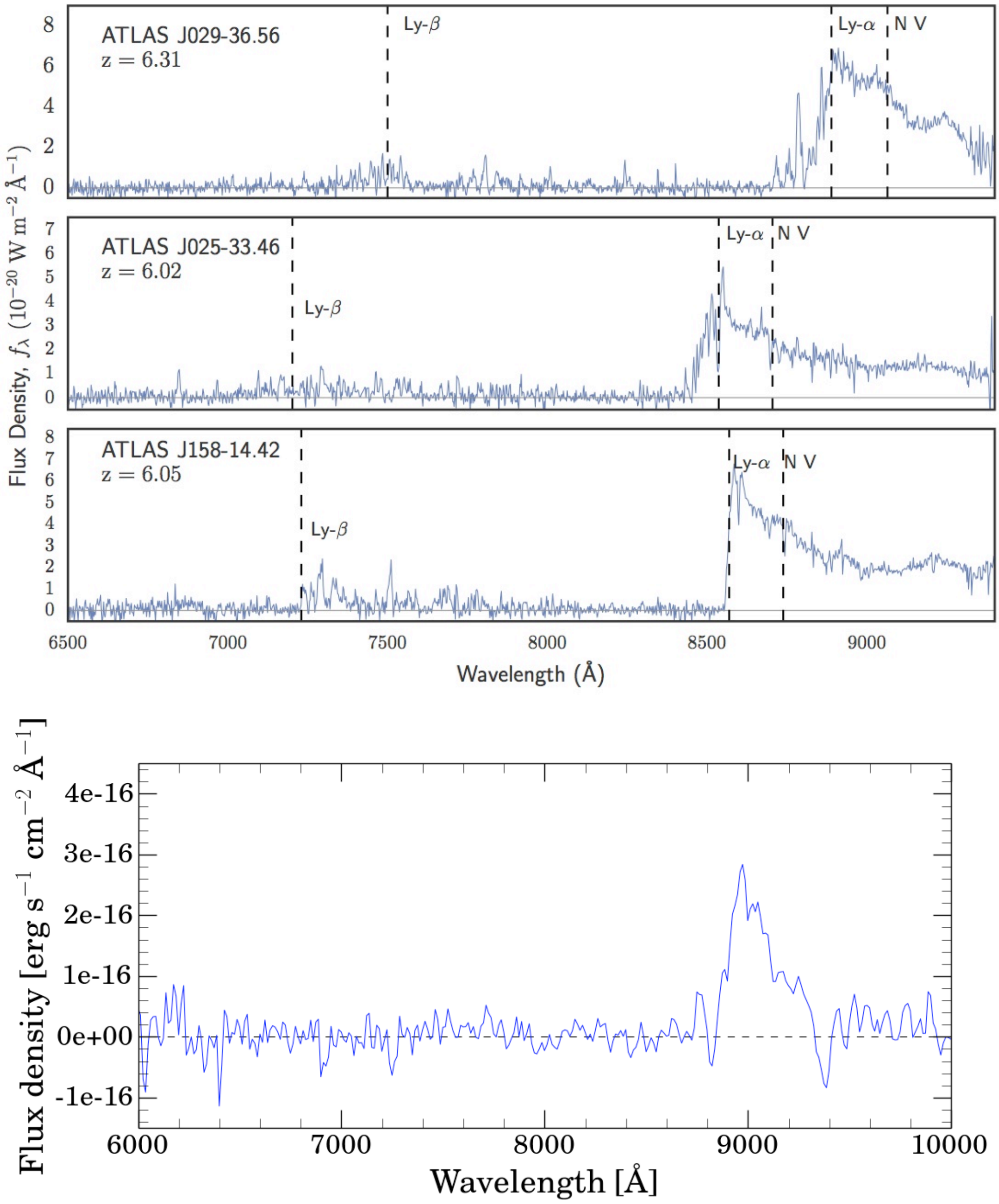

Fig. 3 Four z>6 quasars spectroscopically confirmed at Magellan(x2), Keck and NTT. The discovery of these quasars is described by Carnall et al (2015) and Chehade et al (2016 in prep.)

We note that the GAMA, OzDES and 2dFLENS collaborations are also using imaging data from VST ATLAS. The 2dF galaxy redshift survey of the Cold Spot void (Mackenzie et al 2016) is also based on VST ATLAS imaging data.

The excellent seeing and wide area of VST ATLAS can be exploited by studies of galaxy-galaxy lensing. SDSS claimed significant results in this area and ATLAS seeing is some 50% better than theirs. The Bonn group (D Klaes et al) is re-reducing the ATLAS data for such lensing purposes.

2.2 Refereed Publications (accepted or in press)

”ATLAS lifts the Cup: Discovery of a New Milky Way satellite in Crater”, Belokurov, V.; Irwin, M. J.; Koposov, S. E.; Evans, N. W.; Gonzalez-Solares, E.; Metcalfe, N.; Shanks, T., 2014 MNRAS, 441, 2124.

“Discovery of a cold stellar stream in the ATLAS DR1 data”, Koposov, S. E.; Irwin, M. J.; Belokurov, V.; Gonzalez-Solares, E.; Kupcu Yoldas, A., Lewis, A., Metcalfe, N.; Shanks, T. 2014, MNRAS, 442, L85.

“The SAMI Galaxy Survey: instrument specification and target selection”, Bryant, J.J; Owers, M.S.; Robotham A.S.G.; Croom, S.M. et al 2015, MNRAS, 447, 2857.

“The VLT Survey Telescope ATLAS”, Shanks, T., Metcalfe, N., Chehade, B., Findlay, J. R., Irwin, M. J., Gonzalez-Solares, E., Lewis, J. R., Yoldas, A. K., Mann, R. G., Read, M.A., Sutorius, E. T. W., Voutsinas, S., 2015, MNRAS 451, 4238.

“Two bright z > 6 quasars from VST ATLAS and a new method of optical plus mid-infrared colour selection”, Carnall, A. C., Shanks, T., Chehade, B., Fumagalli, M., Rauch, M., Irwin, M. J., Gonzalez-Solares, E., Findlay, J. R., Metcalfe, N., 2015, MNRAS, 451, L16.

“The shell game: a panoramic view of Fornax”, Bate, N. F., McMonigal, B., Lewis, G. F., Irwin, M. J., Gonzalez-Solares, E., Shanks, T., Metcalfe, N., 2015, Monthly Notices of the Royal Astronomical Society, 453, 690.

“The 2dF Quasar Dark Energy Survey – Small-Scale Quasar Clustering”, Chehade, B., Shanks, T., Findlay, J., Metcalfe, N., Sawangwit, U., Irwin, M. J., Gonzalez-Solares, E, 2016 MNRAS 460, 590.

“The feeble giant. Discovery of a large and diffuse Milky Way dwarf galaxy in the constellation of Crater”, Torrealba, G., Koposov, S. E., Belokurov, V., Irwin, M., 2016a, MNRAS, 459, 2370

“At the survey limits: discovery of the Aquarius 2 dwarf galaxy in the VST ATLAS and the SDSS data”, Torrealba, G.; Koposov, S. E.; Belokurov, V.; Irwin, M.; Collins, M.; Spencer, M.; Ibata, R.; Mateo, M.; Bonaca, A.; Jethwa, P. 2016b MNRAS, 463, 712

“First lensed quasar system(s) from the VST-ATLAS survey: one quad and three nearly identical pairs”, Schechter, P.L., Morgan, N.D, Chehade, B., Mecalfe, N., Shanks, T. and McDonald, M. , 2016, Astr. J. accepted, arXiv:1607.07476

"Evidence of a primordial origin for the CMB Cold Spot", Mackenzie, R, Shanks, T., Bremer, M.N., Cai, Y-C, Gunawardhana, M..L.P., Kovacs, A., Norberg, P., Szapudi, I., MNRAS, 2016, submitted.

2.3. Other Publications (e.g. conference proceedings)

"VST ATLAS First Science Results", T Shanks, V Belokurov, B Chehade, SM Croom, JR Findlay, E Gonzalez-Solares, MJ Irwin, S Koposov, RG Mann, N Metcalfe, D Murphy, PR Norberg, MA Read, E Sutorius, G. Worseck, 2013, *ESO Messenger*, 154, 38.

"Digital Sky Surveys from the ground: Status and Perspectives", Shanks, T., 2015, arXiv:1507.07694

We have also published online the presentations of the 3-day workshop "Exploiting the VST ATLAS… and its sister surveys" held at Durham University on 14-16 April, 2014. (see http://astro.dur.ac.uk/VSTWorkshop/programme.php)

2.4 Overall survey status: where does the survey stand scientifically compared to other survey projects, either ongoing or to be started in the near future?

`VST ATLAS main competitors are PanSTARRS, DES and DECaLS. None of these surveys observe in the *u* band so ATLAS is unique in this respect. None of these surveys have or will have as good seeing as VST ATLAS (Shanks 2015) so ATLAS is also unique in this respect. The combination of excellent seeing and UV sensitivity means that ATLAS is ideal for UVX quasar surveys. This is particularly the case if the Chilean *u* extension is included which means, in the combined survey (4x60s in *u*), we can reach quasars down to a limit of $g=22.5$ where the sky density is ~130deg^{-2}. We are therefore currently exploring the possibility of complementing the eROSITA X-ray AGN survey with 4MOST spectroscopic follow-up using ATLAS optical identifications. T Shanks is now an eROSITA external collaborator to promote eROSITA–ATLAS collaboration. In P99 we have applied for DEUCE (PI T Shanks), a further ATLAS *u* extension as a VST "filler" programme to cover 2800 deg^2 of the DES survey area to support eROSITA AGN follow-up.

2.5 Survey completion reached after five years of operations (starting date: Oct 2011). What has been achieved? How much of the survey has been completed?

Since all the ATLAS OBs have now been submitted covering ~4000deg^2 in *ugr* and ~4700deg^2 in *iz*, it only remains to finish off the backlog. Table 2 shows how the ATLAS OBs have been completed as a function of Period between P87 and P95. It can be seen that OBs submitted before P93 have mostly been completed but there remains a backlog of OBs from P94-P95. The completion of the 5 bands of the main survey is depicted graphically in Fig. 4. We see that *iz* is virtually complete in the original 4000deg^2 area and will be complete over 4700deg^2 in another 6 months. *ugr* should also be complete over the original 400deg^2 area in the same period. The whole survey should therefore be complete by April 2017 ie the end of P98.

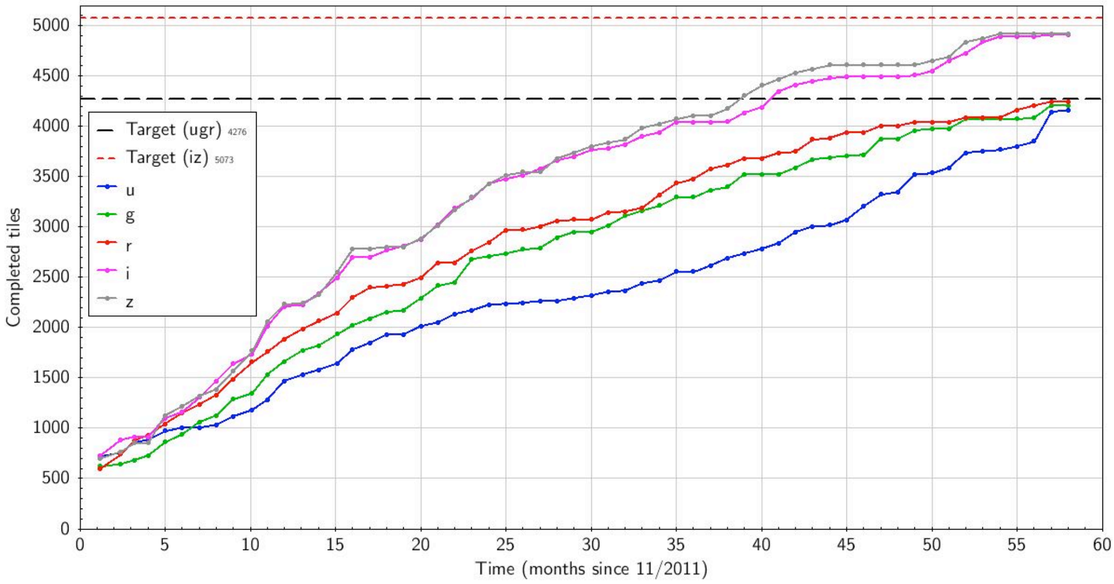

Fig. 4 Completed ATLAS tiles versus Months since the ATLAS survey started. 4276 represents the target number of tiles in the original survey and is the ugr target. 5073 represents the target number of tiles including the NGC extension and therefore represents the iz target.

Band	**P87 (A,B)**			**P88 (C)**			**P89 (D)**			**P90 (E)**		
	√	**X**	**?**	**√**	**X**	**?**	**√**	**X**	**?**	**√**	**X**	**?**
u	**442**	**0**	**0**	**1453**	**0**	**0**	**1038**	**0**	**119**	**73**	**0**	**0**
g	**442**	**0**	**0**	**1453**	**0**	**0**	**1089**	**34**	**34**	**73**	**0**	**0**
r	**442**	**0**	**0**	**1453**	**0**	**0**	**1123**	**34**	**0**	**73**	**0**	**0**
i	**425**	**0**	**0**	**1453**	**0**	**0**	**1157**	**0**	**0**	**73**	**0**	**0**
z	**425**	**0**	**0**	**1453**	**0**	**0**	**1157**	**0**	**0**	**73**	**0**	**0**
Band	**P91 (F,G)**			**P92 (H)**			**P93 (I,J)**			**P94 (K)**		
	√	**X**	**?**	**√**	**X**	**?**	**√**	**X**	**?**	**√**	**X**	**?**
u	**181**	**0**	**0**	**524**	**0**	**0**	**446**	**0**	**0**	**0**	**0**	**0**
g	**181**	**0**	**0**	**524**	**0**	**0**	**446**	**0**	**0**	**0**	**0**	**0**
r	**181**	**0**	**0**	**524**	**0**	**0**	**446**	**0**	**0**	**0**	**0**	**0**
i	**930**	**0**	**0**	**102**	**0**	**0**	**238**	**0**	**0**	**529**	**47**	**119**
z	**930**	**0**	**0**	**102**	**0**	**0**	**238**	**0**	**0**	**544**	**50**	**101**
Band	**P95 (L)**			**P97 (M)**								
	√	**X**	**?**	**√**	**X**	**?**						
u	**(24)**	**0**	**0**	**(11)**	**0**	**1**						
g	**(5)**	**0**	**0**	**(7)**	**0**	**1**						
r	**(17)**	**0**	**0**	**0**	**0**	**0**						
i	**(10)**	**0**	**0**	**(8)**	**0**	**0**						
z	**(24)**	**0**	**0**	**(10)**	**0**	**0**						

Table 2. VST ATLAS pointings by Period and bandpass. √ means completed, X means failed/rescheduled and ? means OB submitted but not completed. ( ) in P95 means category D tiles submitted for re-observing,

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.

Quality control is ongoing at Cambridge, Durham and Edinburgh. Generally data quality is excellent. The most important way to validate the data is by using it for science projects and we have now carried out 17 nights of pilot observations for a proposed AAT 2dF quasar redshift survey called the 2dF QSO Dark Energy Survey (2QDES). VST ATLAS provided the imaging data base for these pilot observations between December 2011 and July 2013. We prepared ~200 sq deg of ATLAS imaging data using *u-g:g-r* and *g-r:r-i* colour-colour diagrams to select QSO candidates which were then observed ~330 at a time using 2dF. The observations realized ~10000 QSO redshifts. 2dF fibre observations are clearly quite demanding, even more so since we were pushing to a limit of g~22.5 for QSO identifications. The success of the observations confirm that the positions for faint stellar objects are good enough for them to be observed in 2.1 arcsecond diameter fibres over a 3 sq deg field simultaneously. It also confirms that the CASU photometry reaches the equivalent of *g*~22 in the *u*-band. The best rates we have achieved from ATLAS are QSO sky densities of 95deg^{-2} or about 300 per 2dF field (Chehade et al 2016). This is even before the inclusion of the ongoing Chilean *u* band extension (PI L. Infante) which doubles the *u* band exposure to 240s.

CASU have implemented an illumination correction that reduces centre to edge photometric offsets from ~0.25mag to ~0.01mag. This is now within the tolerance needed for projected galaxy and quasar clustering analyses.

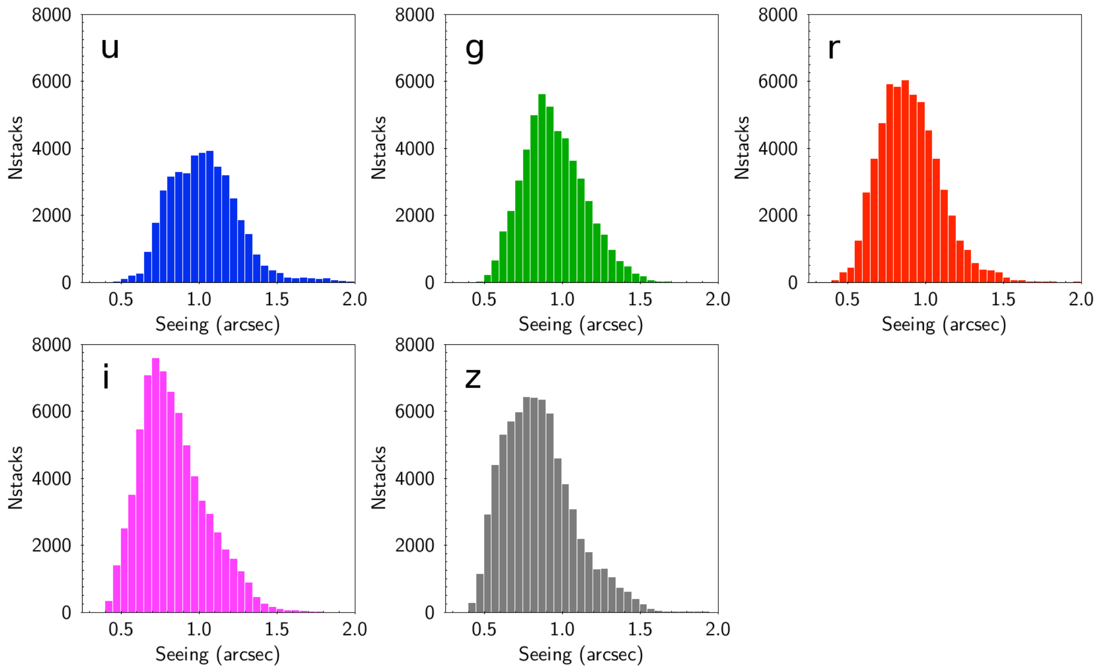

Fig. 5. Seeing (FWHM) distributions from ATLAS A, B grade stacks.

We also note that the ATLAS median seeings (see Fig. 5) in the *riz* bands are 0.90, 0.81 and 0.84 arcsec FWHM. In *u* and *g* the median seeings are 1.0 and 0.95 arcsec FWHM. These distributions are well within our <1.4arcsec specification and are significantly better than the SDSS equivalents. ATLAS median 5σ stellar AB magnitude limits are 22.0 in *u*, 23.1 in *g*, 22.67 in *r*, 22.0 in *i* and 20.87 in *z*, again well within specification. Full details of these and other survey characteristics are given in our DR3 release descriptions that accompany the data on the ESO SAF (or see `http://astro.dur.ac.uk/Cosmology/vstatlas`).

Currently we have calibrated magnitude zeropoints using APASS star magnitudes and these still show problems due to the need to extrapolate to *u* and *z* from APASS *gri* and due to some residual issues in the APASS *gri* photometry. As ATLAS gets more complete we shall be in a better position to use the 2 arcmin overlaps between tiles to produce an improved calibration, because this method requires large contiguous areas.

3.2 The PI should describe here the current status of the Phase 3 submission for her/his survey project and specify how s/he wishes to structure the submission of data products during the year 2017. These plans will be reviewed and iterated with ESO to reach agreement. PIs should also include any relevant information for the scientific validation of the data products.

The Phase 3 submission plan remains the one described in Section 5 of the Revised ATLAS SMP. ATLAS Data Release 1 was rolled out in October 2013 based on the first year of data taken to 1/10/12. DR3 is currently being released (October 2016) based on data taken in the period 1/8/11-1/10/14. Data releases will continue at yearly intervals till the survey ends. DR1, DR2 and DR3 are only flux calibrated on a nightly basis, whereas the aim for the final release 6 months after the survey ends is to place the entire survey on a uniform photometric scale.

In addition to the DR1, DR2 DR3 catalogue releases indicated above, the ATLAS team also delivers the following core data products to the ESO SAF:

- astrometrically and photometrically calibrated images, along with their respective weight maps, in all of the project-relevant filters are provided on a per pointing basis.
- source catalogues based on individual bands. Associated source catalogues linking the parameters of individual objects across all of the observed filter bands are provided on a pointing by pointing basis.
- these survey products are supported and characterized by additional “meta” information providing a full description sufficient for their full scientific exploitation.
- For DR2 and DR3 we are also providing *ugriz* bandmerged catalogues sourced from WFAU.

Further access to the ATLAS data is available at the Cambridge Astronomical Surveys Unit database (http://casu.ast.cam.ac.uk/surveys-projects/vst) and at the Edinburgh Wide Field Astronomy Unit archive at http://surveys.roe.ac.k/osa.

Year(*)	Year/ Data volume acquired (since 01.10. 2013)	Percentage reduced data/year (since 01.10.2013)	Percentage of data (images/source lists) submitted /year (since 01.10.2013)	Percentage of catalogs submitted / year (since 01.10.2013)
10.2013-10.2014	3.7Tb	100%	100%	100%
10.2014-10.2015	3.3Tb	100%	0%	0%
10.2015-10.2016	2.7Tb	80%	0%	0%

(*) add any number of rows needed to describe the Survey Phase3 submission status. The time interval is only indicative.

4. Are any changes in the OVERALL observing strategy required for the completion of the survey? If yes, please provide a clear and detailed justification. For VPHAS+: please detail extension approved by the PSP in May 2016.

As part of the efforts to provide a global ATLAS calibration, we have found several concatenations of 17 fields affected by cloud as indicated by an erroneous zeropoint. This means that the magnitude limit on these fields is too bright and frequently out of specification. We therefore propose that these fields should be re-observed. We estimate that 10 concatenations are in this category. We therefore ask for a further 10hrs of VST time to re-observe these fields. The time should be split equally between dark and grey/bright conditions,

Please specify which part of the Survey Management Plan (SMP) the survey will focus on in P99 in the 1st column and provide the corresponding details in the table below. In particular, highlight any changes with respect to the SMP for P99.

Not applicable.

5. The PIs of the VST public surveys are requested to review the observations that were assigned a Quality Control grade "D". Please report what fraction of the D-classified OBs must be repeated to attain their scientific goals and include an assessment of the time required to repeat these OBs.

We have assessed the 37 D grade OBs observed since October 2015 and 20 need to be re-done to satisfy our survey's scientific goals, because the Image Quality, ellipticity or seeing was usually outside specification. There are a further 17 D grades (one concatenation) that were only flagged as such because no standard star fields were taken on that night. So we do not need to repeat this. We therefore request 3hrs in total to take into account the increased overhead in observing 20 single fields. The total extra time requested is therefore 13hrs dark+gray/bright time for re-observing both the D grade OBs and the cloud affected concatenations.