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## PUBLIC SURVEY STATUS REPORT (105th OPC MEETING)

This report should be returned to the Observing Programmes Office of the European Southern Observatory ([opo@eso.org](mailto:opo@eso.org)) by Nov. 1st, 2019. This report will be reviewed by the EST, OPC and Public Survey Panel.

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**PROPOSAL ESO No.: 177.A-3011**

**TITLE: VST ATLAS**

**PRINCIPAL INVESTIGATOR: T. Shanks**

### 1. Scientific Aims (brief description)

The main aim of the VST ATLAS is to make a survey of  $\sim 4700\text{deg}^2$  in the Southern Hemisphere in the *ugriz* bands to the depth of SDSS. The ATLAS covers  $\sim 2200\text{deg}^2$  in the North Galactic Cap between  $10\text{h} < \text{RA} < 15\text{h}30$  and  $\sim 2500\text{deg}^2$  in the South Galactic Cap between  $21\text{h}30 < \text{RA} < 04\text{h}00$ . 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 4MOST 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  $z\sim 1.5$ . 17 nights of pilot survey observations based on ATLAS data have been made 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 NEOWISE satellite data in the W1(3.4micron) and W2(4.6 micron) bands to increase the quasar sky density. ATLAS data can also be further combined with the VISTA Hemisphere Survey to produce *ugrizYJKW1W2* photo-*z* for galaxies out to  $z\sim 1$ . Cross-correlation of ATLAS Luminous Red Galaxies with CMB fluctuations has now tested 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 4 (DR4) covering the period from 1/8/2011 - 30/6/2017 is now available from the ESO archive, with all photometry now globally calibrated.

The ATLAS area originally approved by the PSP is now complete. However, it was always envisaged that ATLAS would cover  $\sim 4700\text{deg}^2$  by including the area at  $b>29\text{deg}$  and  $\text{Dec}<-20$  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  $4700\text{deg}^2$  area. Chilean VST proposals (PI L Infante) were accepted by ESO in P95 +P96 to survey this extended area in the *ugr* bands. However, progress was slow and in P101 and P102,  $2\times 78\text{hrs}$  of public survey time was allocated to complete *ugr* in this  $745\text{deg}^2$  area. These 156hrs were carried over to P103 and P104 and now the *r* extension is complete and the *ug* extension should be completed in P104. So for P105 we request carryover of any time already allocated but unused in P104 plus a further 6h of dark time in P105 to ensure that 37 D grade tiles can be re-observed.

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

### 2.1 Scientific Progress and Outlook

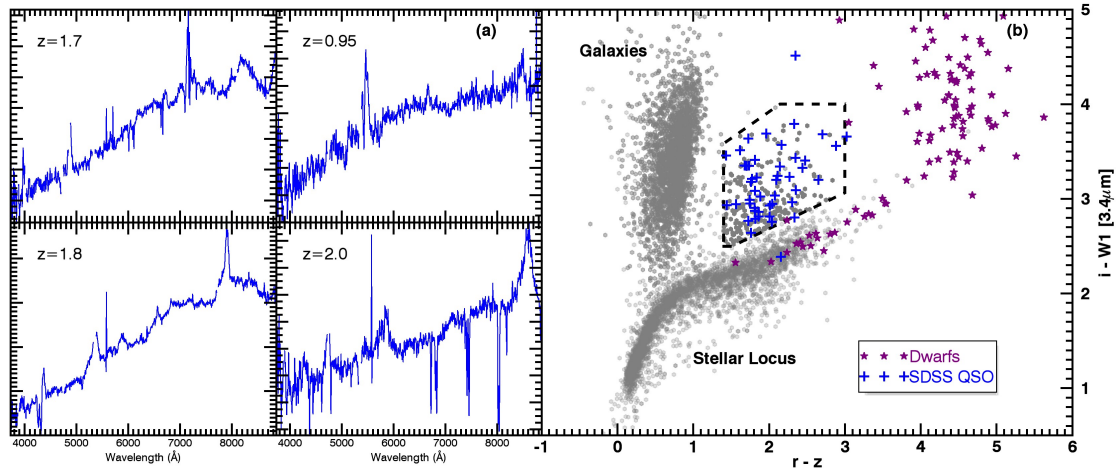
The VST ATLAS now has covered the equivalent of  $\sim 4000 \text{ deg}^2$  in *ugr* and  $\sim 4740 \text{ deg}^2$  in *iz* between mid-August 2011 and June 2017 in Periods 87 - 99 (see status maps at <http://astro.dur.ac.uk/Cosmology/vstatlas/>). Apart from a handful of tiles being re-observed, all *ugr* tiles in the original ATLAS area of  $4000 \text{ deg}^2$  and all *iz* tiles in the full ATLAS area of  $\sim 4700 \text{ deg}^2$  have been completed. Still to be completed is the NGC ATLAS “extension” at  $\text{Dec} < -20$  in *ugr*, It was already complete in *iz*. The extra NGC area in *ugr* corresponds to 797 tiles. Table 1 shows how many of these these have been observed up to 1/11/19 by passband.

Band	Completed	Failed	Scheduled
<b>u</b>	<b>627 (197)</b>	<b>11</b>	<b>170</b>
<b>g</b>	<b>663 (150)</b>	<b>35</b>	<b>134</b>
<b>r</b>	<b>797 (507)</b>	<b>0</b>	<b>0</b>

*Table 1. Total number of VST ATLAS NGC Dec < -20deg pointings completed up to October 2019. Scheduled means OB submitted. Number in brackets in the Completed column shows tiles observed in the last year. The r-band survey is now complete.*

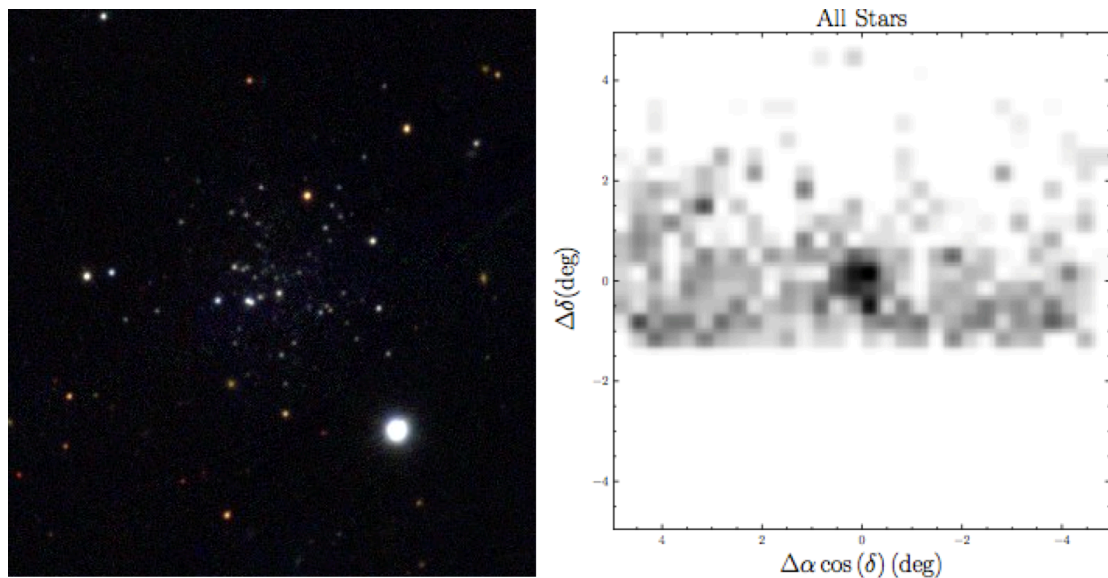
As noted above, PSP at its 28-29/4/14 meeting recommended that we be allowed to extend the survey to its originally envisaged  $\sim 4700 \text{ deg}^2$  by allowing us to survey the NGC area above galactic latitude  $b > 29$  and  $\text{Dec} < -20$  in *iz*. Chilean proposals (PI L. Infante) to complete the survey of this extended area in *ugr* were accepted by the ESO TAC for P95 (095A-0561) and P96 (096.A-0921) but only 28 (*u*), 35 (*g*) and 55 (*r*) tiles out of 797 in each band were completed, with the *u* data in particular being taken in too poor seeing to be useful (see Section 4 below). In our report 2 years ago we made the case that a total of 156h of time should be completed as a public survey and this was approved by the OPC.

**Science Highlights** As examples of science highlights, in Fig 1a we show results from the 2QDES pilot survey where  $\sim 10000$   $0.5 < z < 3.5$  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.



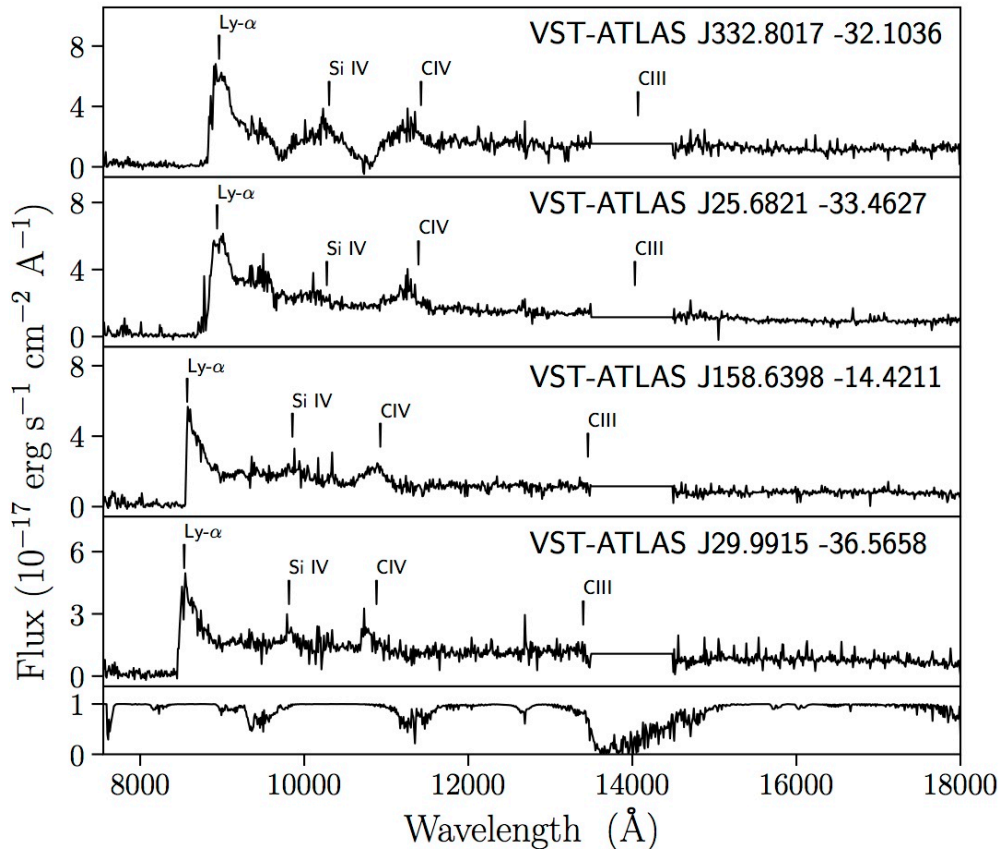
**Fig. 1a.** 4 examples of a new population of dust absorbed red quasars at  $z < 2.5$  selected from  $g-i:i-W1$  by a combination of WISE and ATLAS. Spectra from AAT 2dF AAOmega (Chehade et al 2016). **Fig. 1b.** WISE and ATLAS  $r-z:i-W1$  colour-colour plot shows high efficiency in isolating previously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

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



**Fig. 2a** Discovery of the Crater Milky Way satellite in VST ATLAS survey data as shown here in a  $\sim 3 \times 3$  arcmin true colour gri image (Belokurov et al, 2014). **Fig. 2b** The Crater 2 satellite galaxy is similar in size to LMC but with a very low velocity dispersion (Torrealba et al, 2016).

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 2018). The quasars' VLT X-shooter spectra are shown in Fig. 3 were initially confirmed by observations using Magellan LDSS-3 (top 2), Keck LRIS and 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 (2018). Here, their VLT X-shooter spectra are shown plus the atmospheric transmission in the lowest panel.*

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 2017) 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.

The excellent seeing also means that ATLAS (+WISE) data can be used to detect “quad” gravitational lenses like those whose HST images are shown in Fig. 4 (Schechter et al 2017).

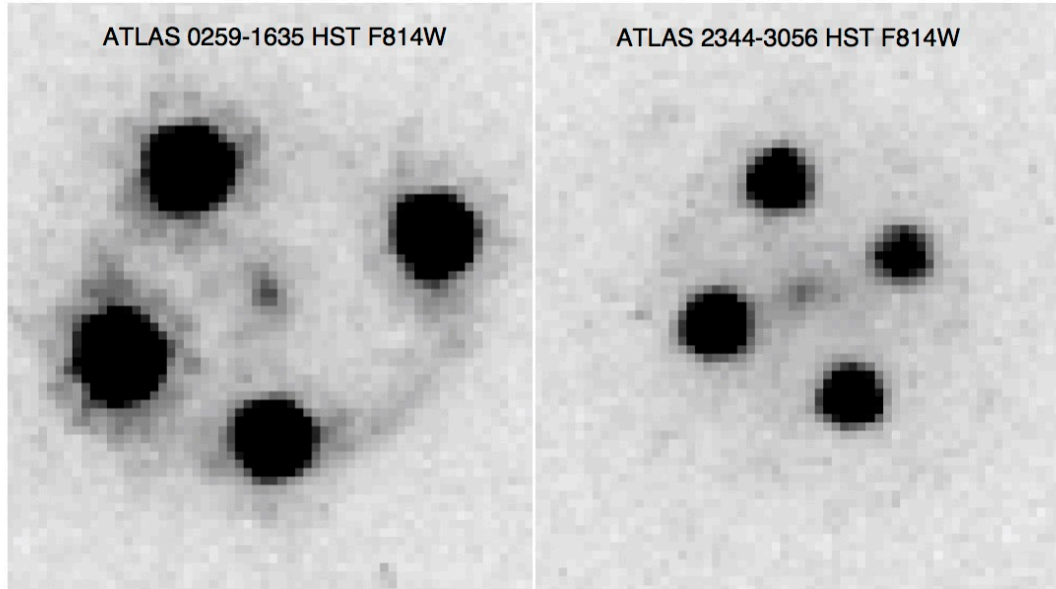


Fig. 4 HST WFC3 images of two quad lensed quasars found from analysis of WISE and ATLAS data (Schechter et al 2017).

Finally, Ansarinejad et al (2019) have recently completed one of the original long-term aims of VST ATLAS, to measure the Integrated Sachs-Wolfe effect in the Southern Hemisphere by cross-correlating ATLAS Luminous Red Galaxies with Planck CMB maps and to combine these data with those from SDSS in the North. In Fig. 5a we see that the ATLAS data has confirmed the SDSS detection at  $z=0.35$  and  $z=0.55$  where the results are consistent with  $\Lambda$ CDM predictions. In Fig 5b ATLAS again confirms the SDSS result but here both surveys find a much lower result than predicted by  $\Lambda$ CDM. These results are intriguing and if confirmed might suggest evidence for modified gravity models, representing a further highlight for ATLAS.

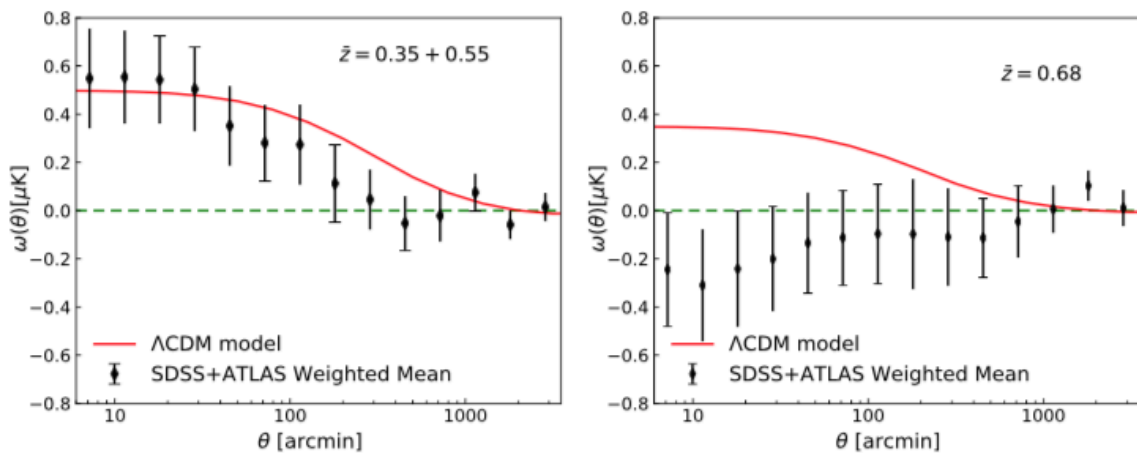


Fig. 5 (a) Mean ATLAS and SDSS ISW measurements at  $z=0.35$  and  $z=0.55$  from combined samples showing good agreement with  $\Lambda$ CDM. However at  $z=0.68$  the combined ATLAS and SDSS measurements are close to zero and deviate from the  $\Lambda$ CDM prediction.



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## 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.

“Digital Sky Surveys from the ground: Status and Perspectives”, Shanks, T., 2016, In “The Universe of Digital Sky Surveys”, Astrophysics and Space Science Proceedings, Vol. 42. Springer: Switzerland, p. 9

“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

“The 2dF Quasar Dark Energy Survey Pilot – 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 2-degree Field Lensing Survey: design and clustering measurements”, Blake, C.; Amon, A.; Childress, M.; Erben, T; Glazebrook, K.; Harnois-Deraps, J.; Heymans, C., et al. 2017, MNRAS, **462**, 4240.

“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

”The 2-degree Field Lensing Survey: photometric redshifts from a large new training sample to  $r < 19.5$ ”, Wolf, C.; Johnson, A. S.; Bilicki, M.; Blake, C.; Amon, A.;

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Erben, T.; Glazebrook, K.; Heymans, C.; Hildebrandt, H.; Joudaki, S. et al 2017, MNRAS, **466**, 1582.

“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. , 2017, Astr. J. , **153**, 219.

“A fork in the Sagittarius trailing debris”, Navarrete, C.; Belokurov, V.; Koposov, S. E.; Irwin, M.; Catelan, M.; Duffau, S.; Drake, A. J., 2017, MNRAS, **467**,1329.

“The SAMI Galaxy Survey: the cluster redshift survey, target selection and cluster properties”, Owers, M. S.; Allen, J. T.; Baldry, I.; Bryant, J. J.; Cecil, G. N.; Cortese, L.; Croom, S. M.; Driver, S. P.; Fogarty, L. M. R.; Green, A. W.; et al 2017, MNRAS, **468**, 1824.

“A catalogue of white dwarf candidates in VST ATLAS”, Fusillo, G. Pietro, N. Raddi, R., Gänsicke, B. T., Hermes, J. J., Pala, A.F., Fuchs, J. T., Chehade, B, Metcalfe, N., Shanks, T., 2017, MNRAS, **469**, 621

“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, 2017, **470**, 2328.

"Quasar lenses and pairs in the VST-ATLAS and Gaia",Agnello A., Schechter P.~L., Morgan N.~D., et al., 2018, MNRAS, **475**, 2086

"Quasars Probing Quasars. X. The Quasar Pair Spectral Database",Findlay J.~R., Prochaska J.~X., Hennawi J.~F., et al., 2018, ApJS, **236**, 44

"Two more, bright,  $z>6$  quasars from VST ATLAS and WISE", Chehade B., Carnall A.~C., Shanks T., et al., 2018, MNRAS, **478**, 1649

“catsHTM: A Tool for Fast Accessing and Cross-matching Large Astronomical Catalogs”, Soumagnac, M.T. & Ofek, E.O., 2018, PASP, **130**, 075002

"The first sample of spectroscopically confirmed ultra-compact massive galaxies in the Kilo Degree Survey",Tortora C., Napolitano N.~R., Spavone M., et al., 2018, MNRAS, **481**, 4728

"Another Quadruply Lensed Quasar from the VST-ATLAS Survey",Schechter P.~L., Anguita T., Morgan N.~D., Read M., Shanks T., 2018, RNAAS, **2**, 21

"Is every strong lens model unhappy in its own way? Uniform modelling of a sample of 12 quadruply+ imaged quasars", Shajib A.J., Birrer S., Treu T., et al., 2019, MNRAS, **483**, 5649

“Cross-correlating Planck with VST ATLAS LRGs: a new test for the ISW effect in the Southern Hemisphere”, Ansarinejad, B, Mackenzie, R., Shanks, T. & Metcalfe, N 2019, arXiv:1909.11095

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### 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.

"VST ATLAS - Past, Present and Future Highlights", Shanks T., 2018, vels.conf, 8

"QSOs from Large Imaging Surveys UVAS/ATLAS", Barrientos F., Pichara K., Troncoso P., Santander C., Ahumada T., Moya C., San Martin A., UVAS Team, 2018, vels.conf, 9

“4MOST Consortium Survey 8: Cosmology Redshift Survey (CRS)”, Richard, J., Kneib, J. -P. Blake, C., Raichoor, A., Comparat, J., Shanks, T. et al. 2019, *ESO Messenger*, 175, 50.

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 ( $4 \times 60$ s in  $u$ ), we can reach quasars down to a limit of  $g=22.5$  where the sky density is  $\sim 130 \text{ deg}^{-2}$ . 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 has been nominated an eROSITA external collaborator to promote eROSITA–ATLAS collaboration. In P100-P105 we applied for DEUCE (PI T Shanks), a further ATLAS  $u$  extension as a VST “filler” programme to cover  $2800 \text{ deg}^2$  of the DES survey area to support eROSITA AGN follow-up. DEUCE now covers  $\sim 1600 \text{ deg}^2$  of the DES area in the  $u$  band and is continuing.

#### **2.5 About survey completion: what has been achieved? How much of the survey has been completed?**

All of the original ATLAS OBs have now been observed covering  $\sim 4000 \text{ deg}^2$  in  $ugr$  and  $\sim 4700 \text{ deg}^2$  in  $iz$ . What remains is the  $ugr$  extension in the NGC at  $\text{Dec} < -20 \text{ deg}$ . Table 2 shows how the ATLAS NGC  $\text{Dec} < -20 \text{ deg}$  extension OBs have been completed in P103 and to date in P104.

**Public survey of NGC area at  $\text{Dec} < -20$  in  $ugr$ .** As noted in Section 2.1 the NGC area at  $\text{Dec} < -20 \text{ deg}$  although complete in  $iz$ , is still to be completed in  $ugr$  (see Figs. 5(u), 6(g), 7(r)). The original plan was that this area be done in Chilean time with PI



L. Infante. But in P95+P96 (095A-0561 and 096.A-0921) only ~8h out of 160h allocated was observed. In subsequent periods we therefore focused on completing the doubling of the ATLAS  $u$  exposure in the original  $4000\text{deg}^2$  ATLAS  $ugr$  area. This latter project is still ongoing. To speed progress, a year ago the OPC therefore reinstated the NGC Dec<-20  $ugr$  survey as a public survey, as was originally envisaged. The motivation to complete the optical survey remains high given particularly the uniqueness of the ATLAS  $u$  coverage, combined with ATLAS excellent seeing, especially advantageous for point sources such as quasars. This makes ATLAS  $u$  a natural complement to the follow-up of the eROSITA-DE X-ray AGN survey and the targeting of the 4MOST quasar cosmology survey. We have maintained the  $2 \times 120\text{s}$   $u$  band exposures over this area, which is the combined  $u$  exposure from the ATLAS+Chilean  $u$  surveys over the  $4000\text{deg}^2$  area. We have also maintained the  $2 \times 50\text{s}$   $g$ -band and  $2 \times 45\text{s}$   $r$ -band exposures, consistent with the rest of ATLAS. The usual ATLAS seeing and airmass constraints are still be applied. Including overheads, we requested 156 h of VST dark time for this purpose. Table 2 summarises the progress in P103 and P104. We therefore request any time allocated but unused in P104 to be carried over to P105 (and then P106) to complete  $ugr$  in the NGC at Dec<-20deg. We require seeing of 1.4 arcsec FWHM in  $u$  and airmass<1.4 as usual.

Band	P101 (P)			P102 (R)			P103 (S)			P104 (T)		
	√	X	?	√	X	?	√	X	?	√	X	?
<b>u</b>	47	11	313	336	0	398	244	0	170	0	0	170
<b>g</b>	153	0	217	152	18	343	358	17	134	0	0	134
<b>r</b>	255	0	115	289	0	343	253	0	0	0	0	0

Table 2. VST ATLAS NGC extension at Dec<-20deg pointings summarised by Period and bandpass. √ means completed, X means failed/rescheduled and ? means OB submitted but not completed. The r-band data are now complete.

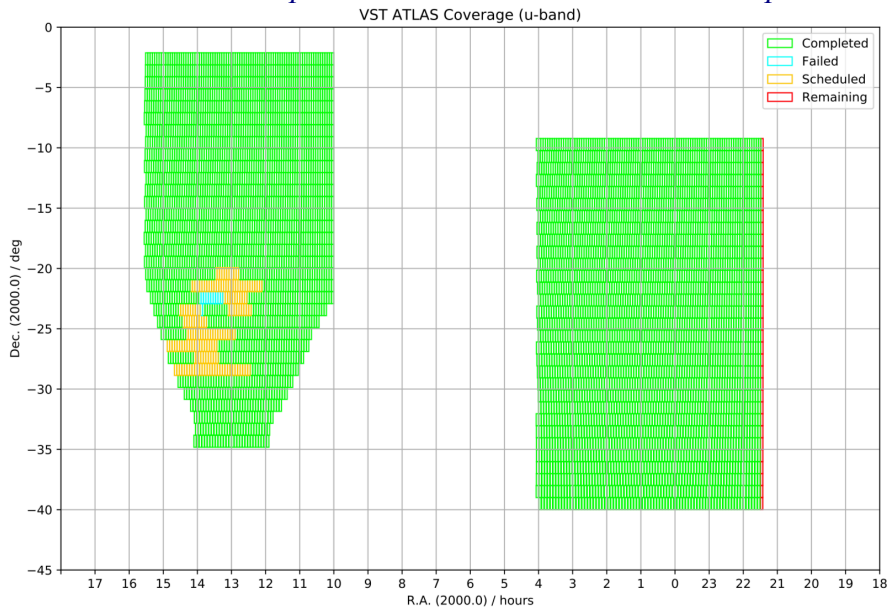
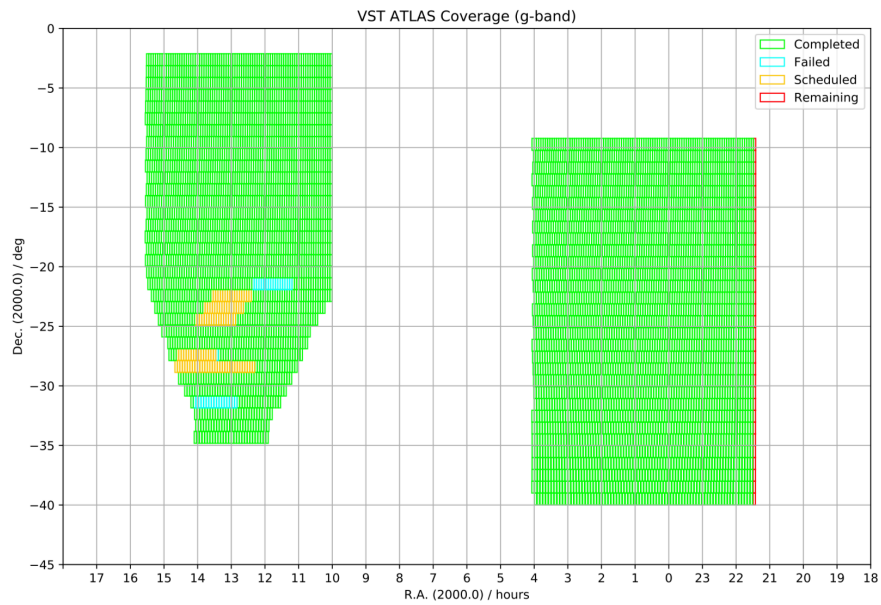
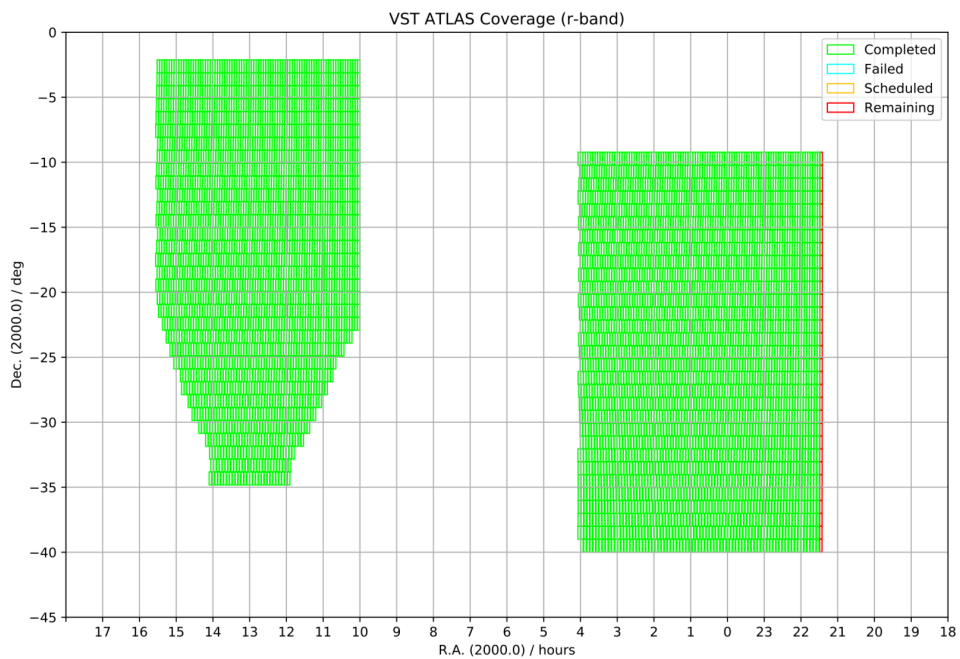


Fig. 5. The ATLAS survey areas marked in green are completed in  $u$ . The NGC area below Dec<-20deg is currently progressing as an extension, although it is already complete in  $riz$ .



*Fig. 6. The ATLAS survey areas marked in green are completed in  $u$ . The NGC area below  $Dec < -20deg$  is currently progressing as an extension, although it is already complete in  $riz$ .*



*Fig. 7. The ATLAS survey areas marked in green are completed in  $r$ . The NGC area below  $Dec < -20deg$  is therefore complete and so the whole survey is now complete in  $riz$ .*

### **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 originally 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. The observations realized  $\sim 10000$  QSO redshifts. 2dF fibre observations are clearly quite demanding, even more so since we were pushing to a limit of  $g \sim 22.5$  for QSO identifications. The success of such observations confirm that the positions for faint stellar objects are good enough for them to be observed in  $2.''1$  diameter fibres over a  $3 \text{ sq deg}$  field simultaneously. It also confirms that the CASU photometry reaches the equivalent of  $g \sim 22$  in the  $u$ -band. 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  $\sim 0.25 \text{ mag}$  to  $\sim 0.01 \text{ mag}$ . This is now within the tolerance needed for projected galaxy and quasar clustering analyses.

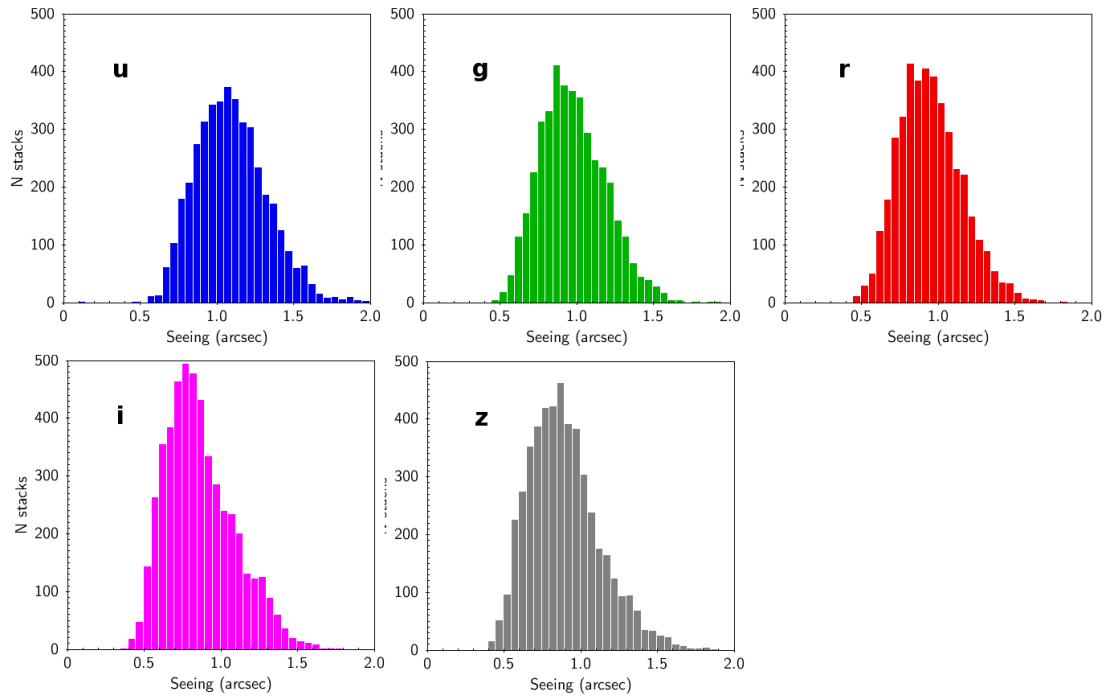


Fig. 8. Seeing (FWHM) distributions from ATLAS A, B grade stacks.

We also note that the ATLAS median seeings (see Fig. 8) 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  $<1.4 \text{ arcsec}$  specification and are significantly better than the SDSS equivalents. ATLAS median  $5\sigma$  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>).

Until recently we calibrated magnitude zeropoints using APASS star magnitudes but these still showed 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. With the completion of ATLAS, in DR4 we were able to use the 2 arcmin overlaps between tiles to produce an improved calibration in  $u$ . We also used the Gaia DR2  $G$ ,  $B_p$  and  $R_p$  photometry to finalise our global photometry scales in  $griz$ . This global photometric calibration is now available in ATLAS DR4.

**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 2019. 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 essentially the one described in Section 5 of the Revised ATLAS SMP. ATLAS DR4 was released in April 2019 based on all data taken up to 1/6/17. DR4 was envisaged to be the final release for the original ATLAS areas. We now envisage a further data release, DR5, to include the NGC Dec<-20deg extension, and all other ATLAS data ie 4700deg<sup>2</sup> of sky in  $ugriz$ .

In addition to the DR4 etc 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, DR3 and DR4 we also provided  $ugriz$  bandmerged catalogues sourced from WFAU. This will be continued in DR5.

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(*)	Data volume acquired per year (since 01.10.2015)	Percentage reduced data/year (since 01.10.2015)	Percentage of data (images/source lists) submitted / year (since 01.10.2015)	Percentage of catalogs submitted / year (since 01.10.2015)
10.2015-10.2016	2.7Tb	100%	100%	100%
10.2016-10.2017	~1Tb	100%	100%	100%

10.2017-10.2018	~0.25 Tb	100%	0%	0%
10.2018-10.2019	~1Tb	100%	0%	0%

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

**4. 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 D grade OBs observed since October 2018 and 37 need to be re-done to satisfy our survey’s scientific goals, because the Image Quality, ellipticity or seeing was usually outside specification. We therefore request 6h in P105 to take into account the increased overhead in observing a single field.

Period	Field name/ mean RA	Filter	Time (h)	Seeing	Moon	Transparency
105	10h-15h30	ugr	6	<1.”4	Dark	THN