# PUBLIC SURVEY PANEL REVIEW 2014:
# VST PUBLIC SURVEY STATUS REPORT

This report must be returned to the Observing Programmes Office of the European Southern Observatory (opo@eso.org) before **April 07, 2014**.

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**ESO PROPOSAL 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 >4000deg$^2$ in the Southern Hemisphere in the *ugriz* bands to the depth of SDSS. The ATLAS will comprise ~2000deg$^2$ in the North Galactic Cap between 10h<RA<15h30 and ~2000deg$^2$ 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 investigate via QSO clustering primordial non-Gaussianity, the power-spectrum turnover and Baryon Acoustic Oscillation 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-BOSS and e-Rosita 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. In this way, ATLAS has already uncovered a new population of dust-reddened quasars. ATLAS data can also be further combined with the VISTA Hemisphere Survey to produce *ugrizYJHKLM* 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~7 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 1 (DR1) covering the period from 1/8/2011 to 30/9/2012 is available from the ESO archive.

All OBs have been submitted in P87 through P93 for *ugriz* coverage of the ~4000 deg$^2$ of ATLAS that were approved by the PSP. However, it was always envisaged that ATLAS would cover ~4700deg$^2$ by including the area at b>30deg and -30<Dec<-20 in the NGC and the science case in the revised Survey Management Plan assumed this increased area. Note that this NGC area is not a target for any other optical survey and that it has already been surveyed by VHS in J and K (see http://casu.ast.cam.ac.uk/vistasp/overview). We are therefore here requesting PSP approval to observe this ~700deg$^2$ to take ATLAS to its full 4700deg$^2$ area.

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

**2.1 Scientific Progress and Outlook** The VST ATLAS now has covered the equivalent of ~2900 deg$^2$ in *ugriz* so far between mid-August 2011 and March 2014 in Periods 87, 88, 89, 90, 91 and 92 (see status maps at http://astro.dur.ac.uk/Cosmology/vstatlas/). Although all OBs for the currently approved ATLAS area of 4030deg$^2$ are already submitted, *there is a significant backlog of OBs rolled over from previous Periods*. Currently we are predicting that the survey will take to the end of P93 to finish in *i,z* but the *ugr* survey will take to the end of P95 (30/9/15 – see below). Meanwhile CASU are up-to-date in their reduction of the ATLAS data.

The total number of tiles to cover the approved ATLAS area is 4286 (x5 bands). 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 followed by *r* then *g* then *u*. The 93 *u* tiles in the past 5 months is reduced from the 389 in the previous 7 months. *r* is similarly reduced from 462 to 297 while *g* is down from 656 to 217. *i* and *z* have also shown significant decreases.

| Band | Complete | Failed | Scheduled | Unscheduled |
|---|---|---|---|---|
| **u** | **2262 (93)** | **93** | **1931** | **(792)** |
| **g** | **2894 (217)** | **48** | **1344** | **(792)** |
| **r** | **3057 (297)** | **66** | **1163** | **(792)** |
| **i** | **3664 (379)** | **102** | **622** | **(792)** |
| **z** | **3681 (385)** | **136** | **571** | **(792)** |

*Table 1. Total number of VST ATLAS pointings so far completed up to March 2014. Scheduled means OB submitted and Unscheduled means OB to be submitted. Number in brackets in the Complete column shows tiles completed in last 5 months. Number in brackets in Unscheduled column show the number of tiles needed to cover the new NGC area at -30<Dec<-20 for which PSP approval is being sought.*

In terms of estimating the time taken to complete the survey, *i* and *z* are going at a rate of about 140 tiles in each band a month and so should take 6 months from the time of writing to complete. The full ~4030deg$^2$ *iz* survey should therefore be completed by the end of P93. The *ugr* survey is going at a rate of ~90 per band per month and so will take another 16 months to complete. At that rate the survey will be completed by the end of P95.

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. A population of obscured dusty quasars were found, some examples of whose very red spectra are shown here. In Fig 1b a redder combination of ATLAS and WISE bands are used to select higher redshift 5<z<6 quasars and follow-up of these candidates is now ongoing.

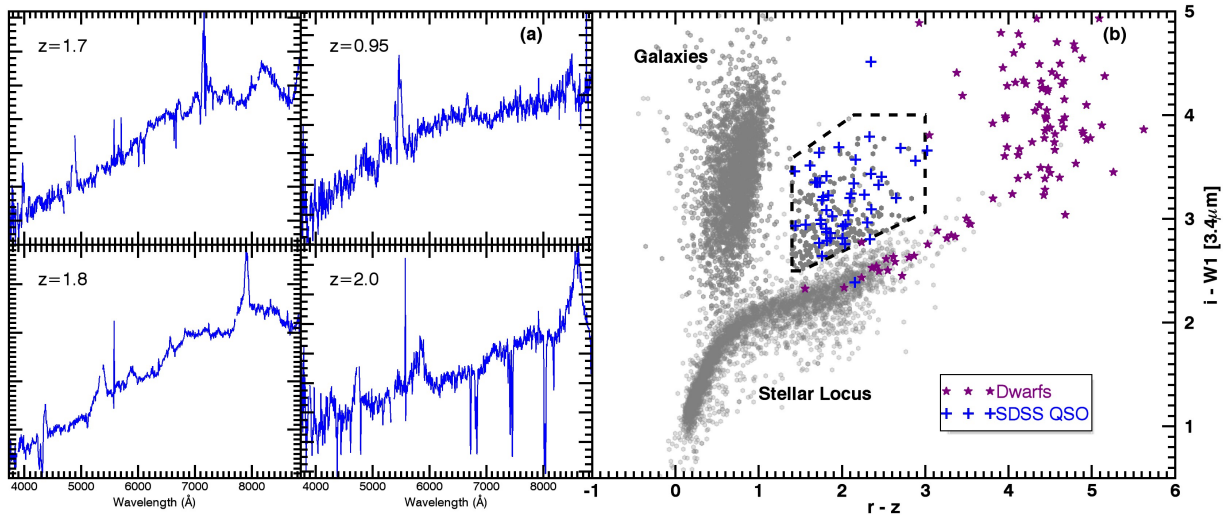


**Fig. 1a.** *4 examples of a new population of dust absorbed red quasars at z<2.5 selected from g-i:i-W1 by a combination of WISE and ATLAS. Spectra from AAT 2dF AAOmega.* **Fig. 1b.** *WISE and ATLAS r-z:i-W1 colour-colour plot shows high efficiency in isolating previously discovered SDSS 5<z<6 quasars.*

Another science highlight is that ATLAS is also proving ideal for searching for Milky Way satellites 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 (see Fig 2b).

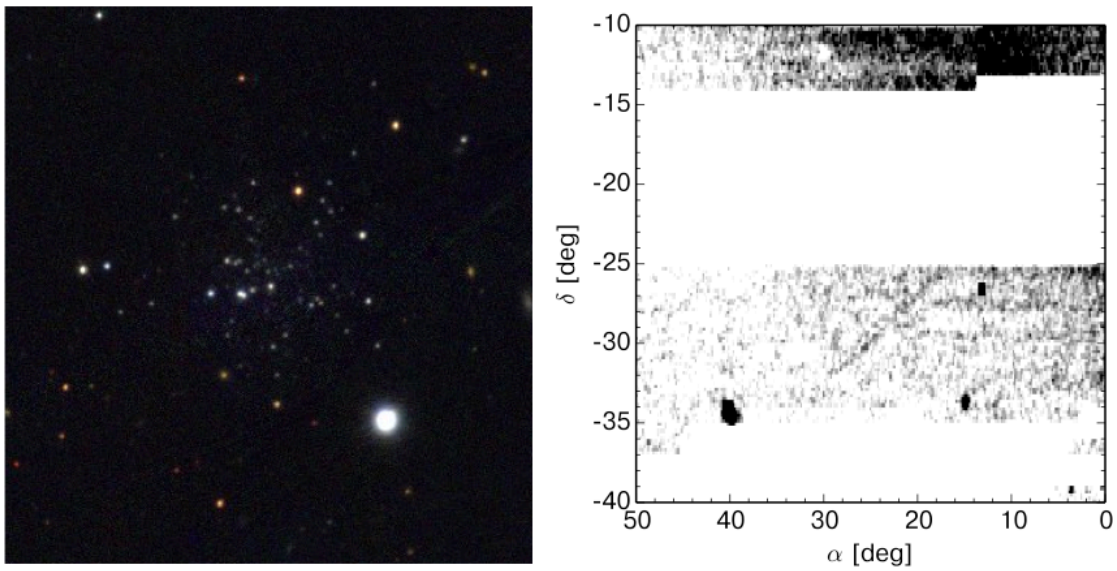


**Fig. 2a** *Discovery of the Crater Milky Way satellite in VST ATLAS survey data as shown here in a ~3x3arcmin true colour gri image (Belokurov et al, 2014, arXiV:1403:3406).* **Fig. 2b** *The spatial density variation of stellar sources in the g- and r-bands which track the stellar locus of the stream colour magnitude diagram (Koposov et al, 2014 arXiV:1403.3409).*

Many other science results are in preparation (see Shanks et al, 2013, ESO Messenger, 154, 38).

## 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, accepted, arXiv1403.3406B.

“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 accepted, arXiv1403.3409.

As indicated in the ATLAS ESO Messenger article there are many further science papers in preparation based on VST ATLAS data including the basic VST ATLAS description, (Shanks et al) , 2QDES redshift survey of 10000 quasars (Chehade et al), Survey of high-z quasars (Findlay et al), A UV bright quasar survey (Worseck et al), Luminous Red Galaxy surveys out to z~1 (Chehade et al), GAMA (Norberg et al), SAMI Galaxy survey (Croom et al), Galaxy Groups and Clusters (Murphy et al). Now that the illumination corrected and photometrically calibrated data is available most of these papers should proceed quite quickly to submission in refereed journals. However, others will require the full ATLAS area in at least some bands before they can be completed.

## 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.

We shall also be publishing online the presentations of the 3-day workshop “Exploiting the VST ATLAS… and its sister surveys” to be held at Durham University on 14-16 April, 2014.

## 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 carried out by the survey team.

Quality control is ongoing at Cambridge, Durham and Edinburgh. Generally data quality looks 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*~22.5 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. 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 range needed for projected galaxy and quasar clustering analyses.

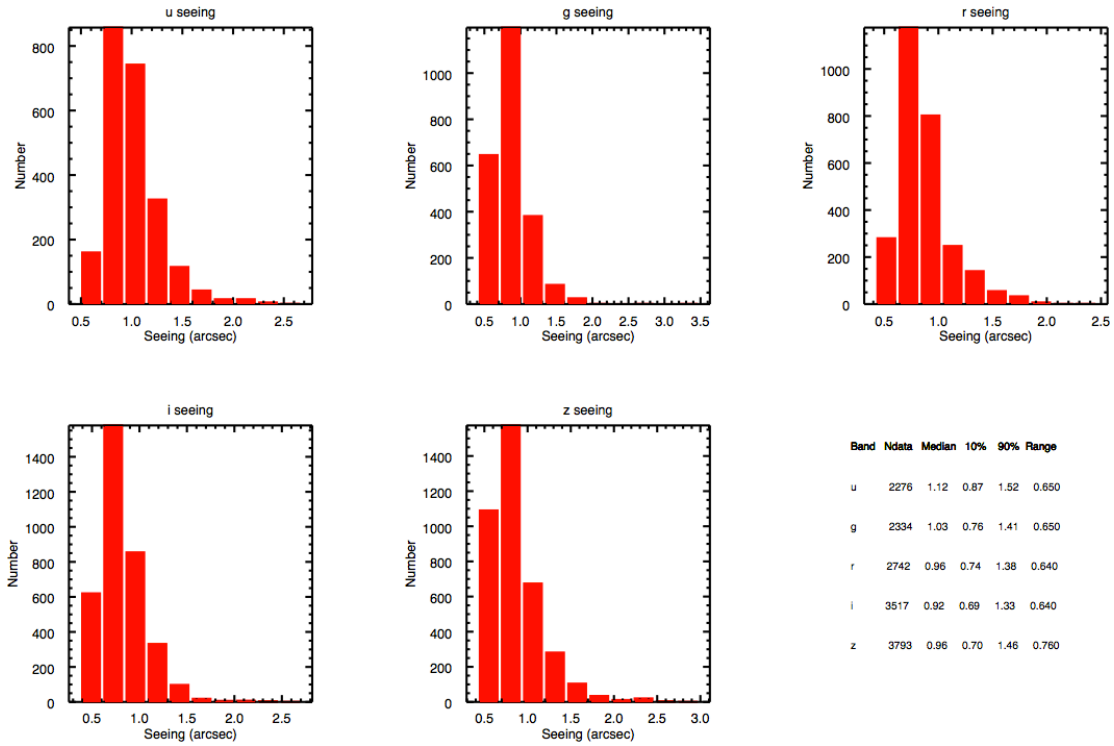


*Fig. 3. Seeing (FWHM) distributions from ATLAS data release DR1.*

We also note that the DR1 median seeing (see Fig. 3) in the *riz* bands is sub-arcsecond with modes at 0.7arcsec. In *u* and *g* the median seeing is 1.0 arcsec FWHM. These distributions are well within our <1.4arcsec specification and are significantly better than the SDSS equivalents. DR1 median 5$\sigma$ stellar magnitude limits are 21.08 in *u*, 23.2 in *g*, 22.56 in *r*, 21.58 in *i* and 20.32 in *z*, again well within specification. Full details of these and other survey characteristics are given in our DR1 release description that accompanies the data on the ESO SAF (or see `http://astro.dur.ac.uk/Cosmology/vstatlas`).

CASU have also implemented a global calibration in *gri* using the APASS survey stellar photometry. Meanwhile Durham are implementing an alternative global calibration based on the 2 arcmin overlaps between the ATLAS tiles.

**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 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. The DR2 data release will occur in 6 months time and data releases will continue at yearly intervals till the survey ends. DR1 is only flux calibrated at the individual pointing level, whereas the aim for the final release 6 months after the survey ends in P95 is to place the entire survey on a uniform photometric scale.

In addition to the DR1, DR2 etc catalogue release 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

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.

**4. Are any changes proposed with respect to the Survey Management Plan in P94 (e.g., in strategy, field coordinates, exposure time and/or other settings)? If yes, please provide a clear and detailed justification (please see also Sec. 8).**

The ATLAS survey was supposed to finish in P91. As described above, we need to roll over already submitted OBs to P93 to finish the survey in *i*, *z* and to P95 in *u, g, r.* Remembering that the PSP recommended that ATLAS be accelerated and completed by the end of P91 because of competition from DES, we therefore urge PSP to ask ESO to prioritise ATLAS *ugr* OBs in P93 and P94. Otherwise the danger is that even at the 500 per band per 6 month rate of a year ago the *u* survey could take 2 more years to complete! And in the last 5 months only 93 *u*-band OBs were completed!!

The situation in the *iz* bands is the reverse in that the survey backlog should be completed by the end of P93. Therefore while *ugr* will continue in dark time there will be no ATLAS targets designed for grey/bright time in P94.

We therefore request that an extra 792 OBs to cover the 680deg$^2$ NGC area in the range at 10h<RA<15h, -30< Dec<-20 be scheduled in *ugriz* for P94. In fact we have adjusted this area to cut the RA range to 10h20<RA<15h at -30<Dec<-20 and

have further cut out the area at b<30deg with 10h20<RA<12h (see updated ATLAS map in Fig. 4). We then add the equivalent area at 12h<RA<14h and -35<Dec<-30 to maintain the new area covered at ~680deg$^2$ (see Fig. 4). The total time to cover this area is estimated to be 140hrs of dark time in *ugr* and 85hrs of grey/bright in *iz*. Because we can only observe Jan-Mar we only request half this time 70hrs for *ugr* in P94 and we shall ask for a similar allocation to complete this area in P95.

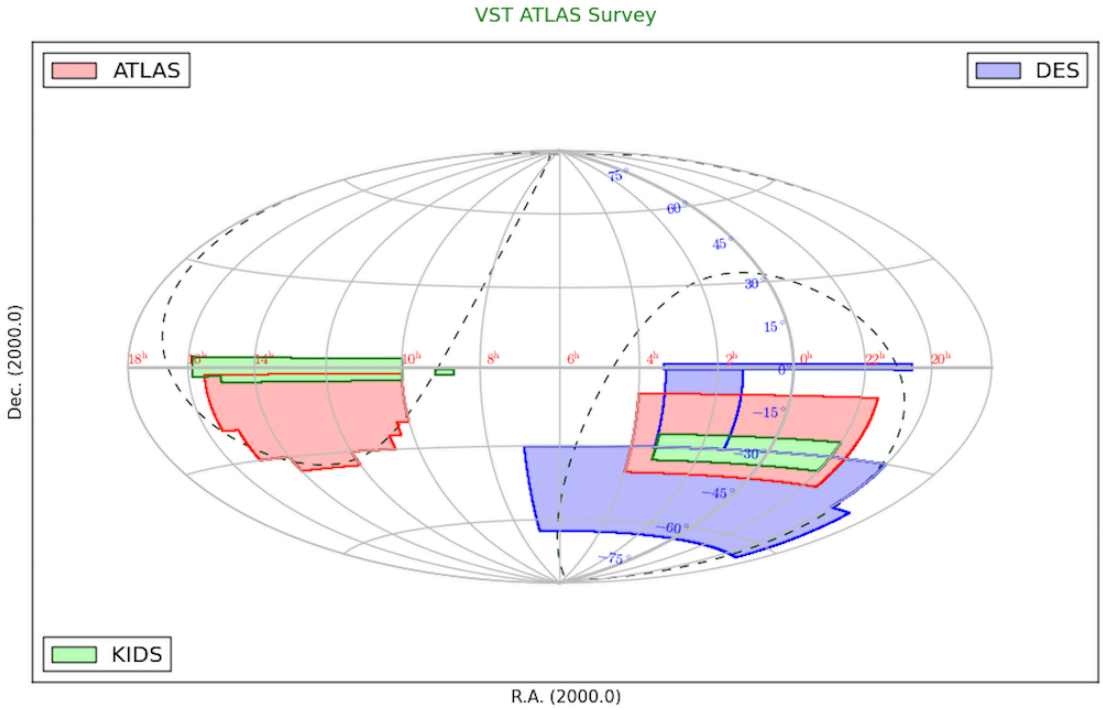


*Fig. 4. The footprint of the DES survey compared to the adjusted ATLAS and KiDS footprints The dashed lines indicate galactic latitudes b=29deg and b=-30deg.*

The scientific case for the extension in the NGC is strong since this area probes down to galactic latitude b~30deg which is expected to be a rich area for detections of new Milky Way satellites and for stellar streams. The area also covers our direction of motion with respect to the CMB and also the line of sight of the Great Attractor and the Shapley supercluster at RA~13h25, Dec~-30; including this cosmologically important region was the motivation for the slight adjustment to the new NGC area made above. The extra area is also at high enough galactic latitudes to be a significant help for observational cosmology projects such as the search for the Integrated Sach-Wolfe Effect by cross-correlating Planck CMB data with the sky positions of Luminous Red Galaxies.

## 5. Observing Plan

**Please include the specific request for P94 observing time in the table below.**

| Period | Field name/ mean RA | Filter | Time (h) | Seeing | Moon | Transparency | Comments / strategy (e.g., no. of epochs) |
|---|---|---|---|---|---|---|---|
| P94 Jan-Mar | NGC -30<Dec<-20 RA~12h | *ugr* | 70 | <1.4 | dark/gray | clear + some phot. | Nominal exposure in line with revised SMP |
| P94 Jan-Mar | NGC -30<Dec<-20 RA~12h | *iz* | 85 | <1.4 | gray/ bright | clear +some phot. | Nominal exposure in line with revised SMP |

*Table 2. Observing Plan for Period 94. The total number of hours requested is 155 hrs, significantly lower than the usual total of 331 hrs envisaged for each Period in the revised SMP. 85hrs is enough to complete the new 680deg$^2$ NGC area in i,z and 70 hrs represents half the time needed to cover the new area in ugr.*

## 6. Overall survey completion

**Specify the overall survey completion after two and a half years of operations. What has been achieved? How much of the survey has been completed? Please provide total estimate of the time necessary to complete the survey using the current survey observation overheads. In case this differs from the request in the approved SMP, provide a rationale for the difference.**

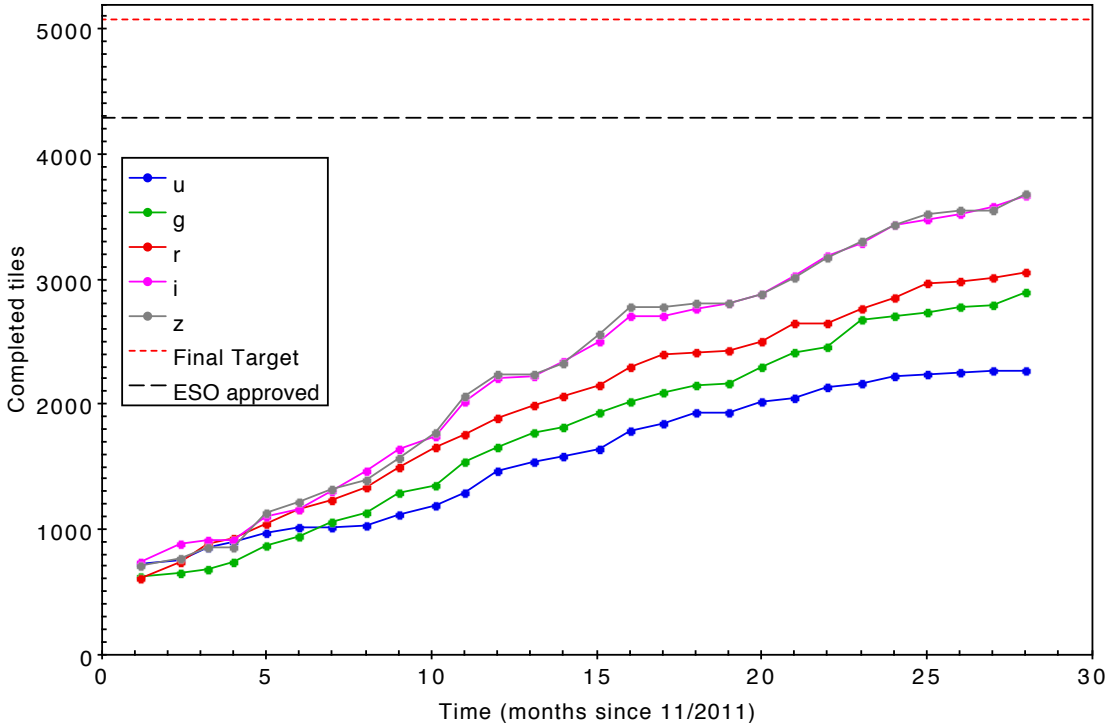


*Fig. 5. Cumulative ATLAS completeness plot split by filter versus months since start of ATLAS survey.*

Fig. 5 shows the cumulative ATLAS completeness plot split by filter. The black dashed line show the number of tiles needed to cover the currently approved survey area of 4030deg$^2$ and the red dotted line shows the number of tiles needed to cover the presently requested full survey of 4710deg$^2$. The plot shows that the *u* band has almost ground to a halt in the past few months, whereas the *i,z* bands seem to be within 6 months of completion. The *g,r* bands lie somewhere between these two.

| **Band** | **P87 (A,B)** | | | **P88 (C)** | | | **P89(D)** | | | **P90(E)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | √ | X | ? | √ | X | ? | √ | X | ? | √ | X | ? |
| **u** | **442** | **0** | **0** | **1285** | **0** | **151** | **277** | **80** | **800** | **12** | **13** | **48** |
| **g** | **442** | **0** | **0** | **1402** | **17** | **17** | **584** | **17** | **556** | **42** | **14** | **17** |
| **r** | **442** | **0** | **0** | **1436** | **0** | **0** | **681** | **34** | **442** | **59** | **14** | **0** |
| **i** | **425** | **0** | **0** | **1436** | **0** | **0** | **851** | **51** | **255** | **73** | **0** | **0** |
| **z** | **425** | **0** | **0** | **1419** | **17** | **0** | **868** | **185** | **204** | **73** | **0** | **0** |
| | | | | | | | | | | | | |
| **Band** | **P91 (F,G)** | | | **P92 (H)** | | | **P93(I, J)** | | | | | |
| | √ | X | ? | √ | X | ? | √ | X | ? | | | |
| **u** | **136** | **0** | **45** | **110** | **0** | **516** | **0** | **0** | **446** | | | |
| **g** | **166** | **0** | **15** | **258** | **0** | **266** | **0** | **0** | **448** | | | |
| **r** | **181** | **0** | **0** | **258** | **18** | **248** | **0** | **0** | **454** | | | |
| **I** | **879** | **51** | **0** | **0** | **0** | **102** | **0** | **0** | **241** | | | |
| **Z** | **896** | **34** | **0** | **0** | **0** | **102** | **0** | **0** | **241** | | | |

*Table 3. VST ATLAS pointings by Period and bandpass. √ means completed, X means failed/rescheduled and ? means OB submitted but not completed.*

Table 3 records the Periods where the backlog arises. All OBs submitted for P87 have now been completed. The OBs scheduled in P88, P90 and P91 are mostly complete, leaving the P89, P92 (and P93 just started) as the most incomplete. Note again that the *ugr* backlog is more than in *riz*. There has also been a slowing down of the rate at which *u* tiles are being observed. This is unwelcome given the emphasis of the science case for ATLAS on the bluer bands (see also Fig. 5).

**7. The survey teams' response to the VST PSP realignment review in September 2010. Where does the survey stand scientifically compared to other survey projects, either on-going or to be started in the near future? What would the PI like to change in the survey observing strategy to make it more scientifically productive and to complete it in a shorter amount of time?**

The main competing optical survey in the South is the Dark Energy Survey (DES) that has the footprint shown in Fig. 4 above. This is a *grizy* survey based on the CTIO Blanco 4-m that ultimately will reach depths comparable to KiDs. DES only observes in the SGC and so there is no competition in the NGC. It also has no *u* band and its *g*-band is redder than SDSS or ATLAS. Therefore ATLAS is in a good position with respect to DES in that its *iz* survey in the SGC (and NGC) should be completed by the end of P93 ie by 30/9/14. At that point the main outstanding band will be the *u* band where there is no competition from DES in the overlap area in the SGC. The DES

survey started on 1/9/13 and it should have one season of data in their SGC area by the present date.

For ATLAS, the main change is that in the newly requested NGC area we shall allow gray time also to be used for the *r*-band. This means that more dark time will be available to complete the *u* and *g*-bands.

**8. Does the PS team have additional comments to discuss with the VISTA/VST PSP?**

In summary we are asking that:

1) ATLAS *iz* OBs are prioritized to complete the approved 4030deg$^2$ area in P93.
2) ATLAS *ugr* OBs are prioritized to complete the approved 4030deg$^2$ area as soon as possible and hopefully by the end of P95.
3) PSP approve the extra 680deg$^2$ area in the NGC at -30<Dec<-20 (including the small adjustments made in Section 4) with OBs to be submitted in P94 and P95. In this area, *r* band OBs can be done in gray time.

**This input will be reviewed by the VISTA/VST Public Survey Panel and will be taken together with the section on the survey progress report (section 2) and Phase 3 submission report (section 3) into account to assess your survey together with the other VISTA/VST surveys and to make recommendations regarding the time allocation for Period 94 and beyond.**