VLASS Project Memo 2

Requirements for a VLASS pilot survey and a proposal for the pilot survey definition

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1. Pilot survey properties

The basic pilot survey properties are as follows:

- Frequency: S-band (2-4 GHz), 1024 2MHz channels.
- Observing mode: On-the-Fly (OTF) mosaics scanning in RA and constant Dec.
- Mapping speed: ~20 sq. deg. per hour (net, including overhead)

The time available for VLASS tests and pilot observations in the VLA B-configuration, semester 2016A, is shown in Fig. 1, and arises from 168 hours approved by the TAC along with a further 120 hours from a one-week extension of the B-configuration approved by Mark McKinnon. We assume here that this time will comprise up to 200 hours for the pilot, with the rest being used for tests in support of the VLASS preliminary and critical design reviews. The pilot can therefore potentially cover ~4000 sq. deg. The rest of this document addresses what fields the pilot should observe in order to inform most usefully the final design of the full survey.

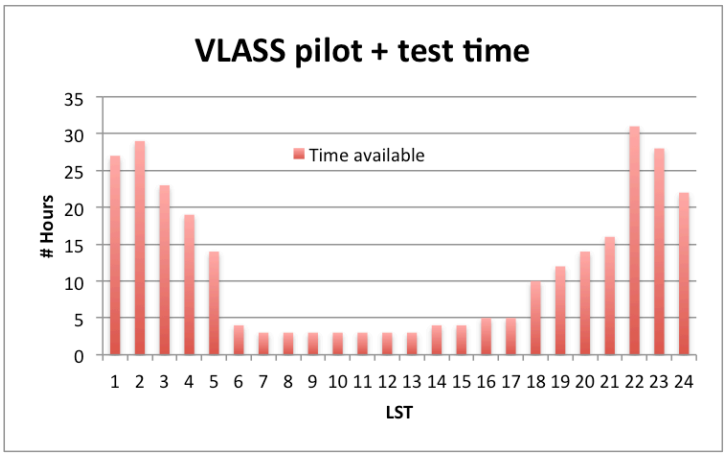

Figure 1: Number of hours per LST hour available for VLASS tests and pilot observations.

[1]Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

2. Technical requirements and implications for field selection

The following are the key areas for which information is needed to inform the full survey design, as identified by NRAO staff, that will affect exactly which fields are observed during the pilot:

1) Imaging of time-variable sources
2) Noise improvement with integration time
3) Transient detection algorithms
4) Imaging of compact sources
5) Imaging of extended sources
6) Completeness and reliability for compact sources
7) Completeness and reliability for extended sources
8) Systematics associated with data taking methods
9) Observation failure rate
10) Issues with southern declinations
11) Issues with very bright sources
12) Issues with fields transiting close to zenith
13) Operational and post-processing workflow issues
14) Polarimetry

The above key areas lead to the following requirements for the field selection:

(1,2,3)	⇒	3 epochs of one or more fields
(4,5,6,7)	⇒	Need to be evaluated using known fields that already have deeper observations than VLASS (COSMOS, other?)
(8)*	⇒	10 repeats of a single field
(9)	⇒	All observations in typical VLASS OTF mode will provide statistics for this
(10)	⇒	Simulations already tell us about beam elongation, this is more about Tsys degradation in and out of Galactic Plane, RFI, ionospheric effects at low elevation; a deep field would be useful
(11)	⇒	3C84 would be a good example for pilot LSTs
(12)*	⇒	Field(s) with dec ~35 deg. needed
(13)	⇒	Significant amount of time should be spent in typical VLASS OTF mode
(14)	⇒	Observations of a field with well-studied polarization near S-band

*Here, items that need to be done to evaluate system behavior but which will not be carried out in exactly the mode expected for the full survey will be carried out under test program TSKY0001.

3. Science requirements

A primary goal of the Pilot Survey is to prove the science goals of the VLASS and to provide Early Science opportunities for the community. The following are the pilot science goals based upon discussions held at a 1-day VLASS Early Science Workshop at Caltech on 7 April 2016, which included members of the NRAO, Caltech, IPAC/Spitzer, and JPL community. This meeting focused on the potential science return from the "Hidden Explosions" and AGN science cases, providing the following requirements:

1. Maximal areal coverage for a single epoch depth of 120μJy/beam in the FIRST/SDSS footprint, allowing prompt transient detection versus FIRST, and providing a reference epoch for this area for the first full epoch of the VLASS.

2. A modest area repeated 3x during the pilot to assess repeatability, which we confine to Stripe-82 (which has been previously surveyed to similar or deeper depth), a deep-field region in the South (CDFS), and a Galactic region.
3. A modest area in the Galactic Plane for Galactic transient studies, providing a reference epoch for the first epoch of VLASS.
4. A significant area that has good optical/IR coverage for extragalactic and AGN studies, such as identification of binary SMBH candidates. The Stripe-82 region and other deep fields are useful for this, as are the SDSS DR12 imaging and spectroscopic regions.
5. A significant area suitable for extragalactic and galactic polarimetry studies. This can be in any region of the sky, since the main comparison is versus NVSS, but should include a wide variety of regions (galactic longitudes and latitudes) if possible.

The footprint of the FIRST survey is shown in Figure 2, and that of the SDSS is shown in Figure 3. The FIRST survey, by design, covers the SDSS area.

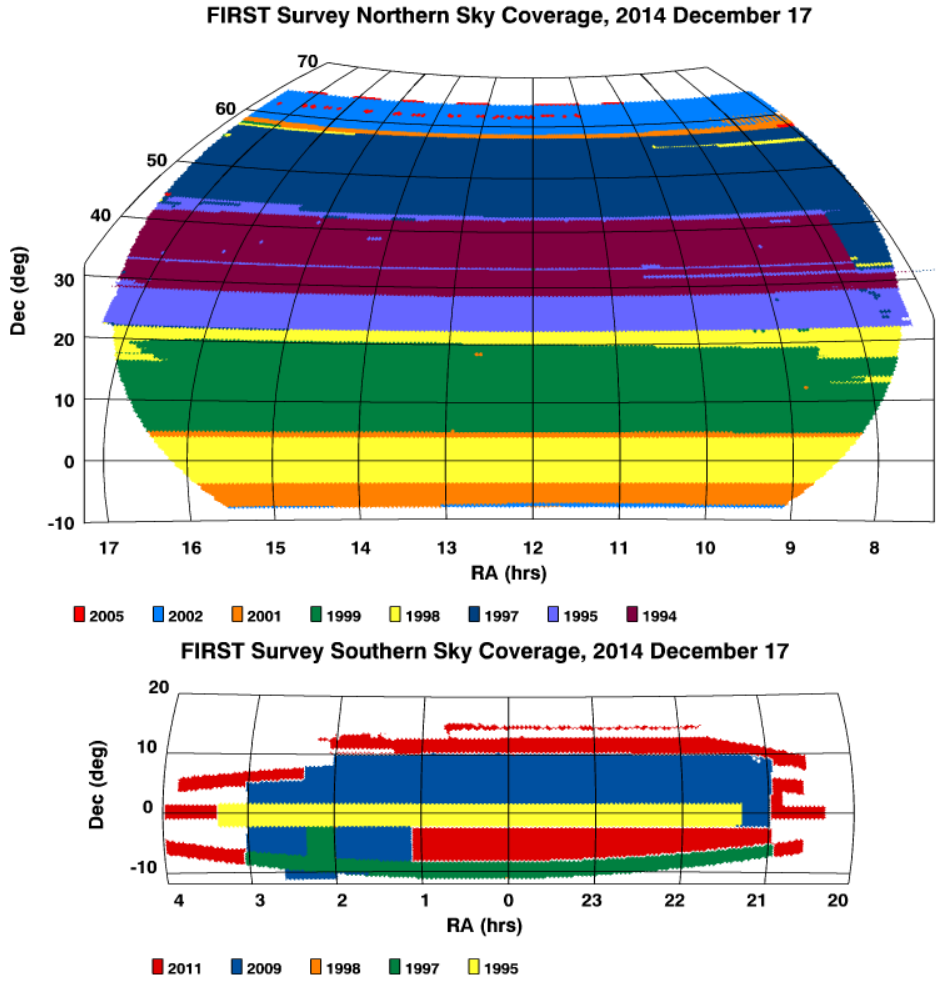

Figure 2: Coverage of the FIRST survey in the northern sky (top) and southern sky (bottom).

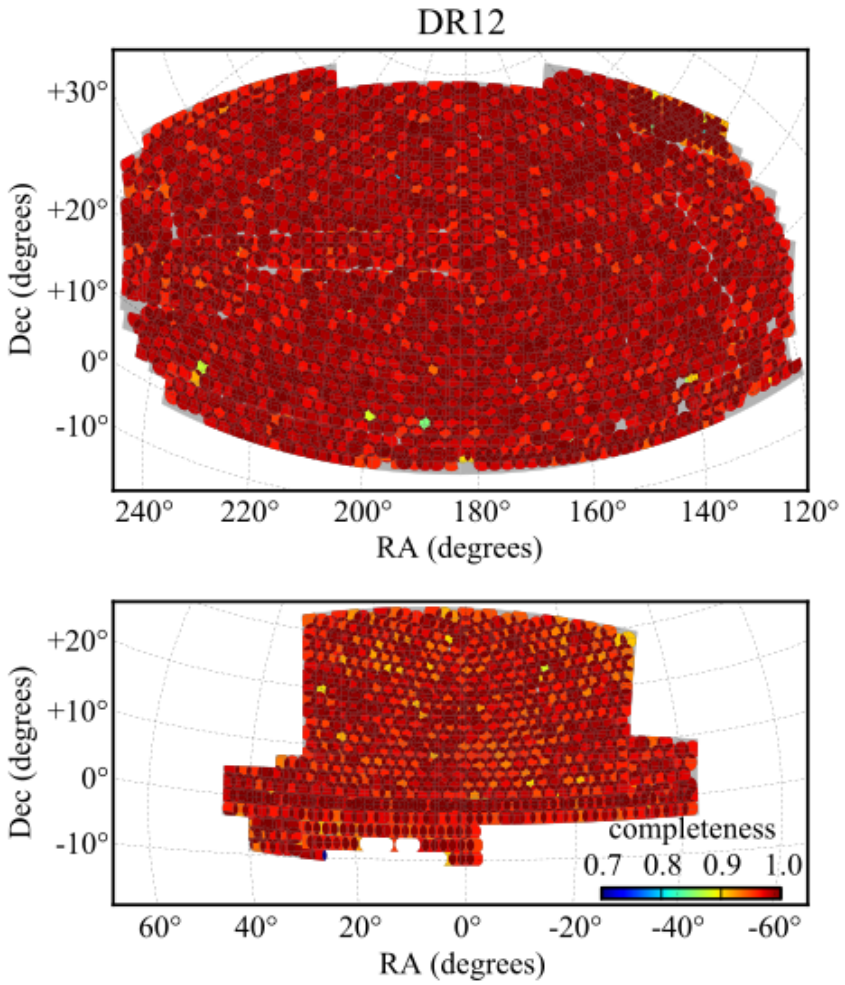

Figure 3: Spectroscopic sky coverage in the northern Galactic Cap (top) and southern Galactic Cap (bottom) from DR12 of the SDSS BOSS survey.

In addition to the transient science described above, the pilot should provide data products that illustrate the power of the full VLASS for both the Galactic and extragalactic communities in key areas of the sky that fit within the available LST range. For this, we require 3x repeats of each OTF observation in order to reach the 70μJy/beam expected in the cumulative images of the full survey. The areas in which we focus are those with good ancillary data and good community engagement. For the Galactic fields we propose to observe the Galactic Center region (which can also include the bulge and some of the plane), and the Cygnus and Cepheus regions of the Galactic Plane in the north. For the extragalactic fields we propose areas centered on the COSMOS and CDFS fields.

4. A proposed pilot survey definition

A proposal for a 196-hr pilot that will address the technical and scientific requirements described above is shown in Table 1. The size of the field covered by an individual observation depends on SB length. Here we assume 4-hr SBs, which is about as long as one wants to go with dynamic scheduling without requiring that the SBs be interruptible to support triggered and ToO observations. Where "Observation type" is

listed as multiple epochs observations are separated by as much as possible within the B configuration, with the goal of informing on how to detect and handle source variability, and evaluate calibration consistency and stability on the maximum timescale available within the scope of the pilot. Where "Observation type" is listed as multiple repeats observations may be close in time but are intended to be co-added to deliver a sensitivity equivalent to the full VLASS. The area covered by the proposed pilot survey is 1760 sq. deg. at 120μJy/beam, plus 720 sq. deg. at 70μJy/beam, for a total of 2480 sq. deg.

Table 1: A proposal for a 196-hr VLASS pilot that will address the key requirements at the same time as fitting within the time available in the B-configuration, semester 2016A.

Field	RA	Dec	Observation type	Area (sq. deg.)	# hrs	Key area #													
						(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
COSMOS	10.0h	+2°	3 epoch OTF (3x4hr)	80	12	x	x	x	x		x			x					x
Cygnus	20.5h	+40°	3 epoch OTF (3x4hr)	80	12	x	x	x		x		x		x					
Cepheus	23.0h	+62°	3 repeat OTF (3x4hr)	80	12		x			x				x					
CDFS	3.5h	–27°	3 repeat OTF (3x4hr)	80	12		x		x					x	x				
Galactic Center	17.8h	–29°	3 repeat OTF (3x4hr)	80	12		x	x						x	x	x			x
Stripe 82	21h–03h	0°	3 epoch OTF (12x4hr)	320	48		x		x					x				x	x
SDSS SGC	21h–03h	0° to 15°	1 repeat OTF (17x4hr)	1360	68				x					x				x	
SDSS NGC	10h–17h	50° to 60°	1 repeat OTF (5x4hr)	400	20				x					x				x	x

Comments on individual fields:

COSMOS: Unique: already have deep S-band observations for the completeness evaluation.

Cygnus: Unique: Galactic Plane at good RA for imaging extended structures. Needs an additional deep observation under TSKY0001 for completeness evaluation.

Cepheus: Not unique but at a good RA for the 10x systematics test, high declination. Seven of the 10 repeats should be done under TSKY0001.

CDFS: Unique: southern declination, empty field, good community engagement.

Galactic Center: Unique: southern declination, can evaluate impact of Galactic emission on Tsys, and strong variable sources such as SgrA*.

Stripe 82: Unique: already have 270 sq. deg. of SDSS Stripe 82 covered previously for validating results.

SDSS SGC: Not unique, but at a good RA given available LSTs, with good ancillary data. Overlap with FIRST/SDSS in southern Galactic Cap region; extends northward in declination from Stripe 82. Avoid declinations below zero for pilot because of Clarke Belt.

SDSS NGC: Not unique, but overlaps with FIRST/SDSS in northern Galactic Cap region, and can include Lonsdale SWIRE field region (14.7h +59°), Elais-N1 (16h +55°), and Lockman Hole (10.75h +58°).

In addition to the pilot summarized in Table 1, the tests in Table 2 are needed to support other technical aspects of the survey not covered directly by the pilot. These tests are separated from the pilot because they will not be carried out in the same observing mode as the VLASS. They include the following:

Cygnus pointed mosaic: Needed for completeness evaluation of Cygnus OTF field.

Cepheus 7x OTF: Completes the 10x observation of a single field in OTF mode to evaluate survey systematics.

Perseus: Unique: transits close to zenith for evaluation of high elevations on OTF tracking, excellent for evaluating dynamic range limitations due to very bright sources (3C84). Cover both the Perseus molecular cloud and the Perseus cluster of galaxies for potential science return in addition to the technical aspects of this test.

Table 2: Test observations to be carried out under TSKY0001 to support technical aspects of the survey not covered directly by the pilot.

Field	RA	Dec	Observation type	Area (sq. deg.)	# hrs	Technical area #													
						(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Cygnus	20.5h	+40°	Pointed mosaic ~1 sq. deg.	1	4							x							
Cepheus	23.0h	+62°	7 repeat OTF (7x4hr)	80	28		x			x			x	x					
Perseus	3.5h	+40°	1 repeat OTF (1x4hr)	80	4				x					x		x	x	x	x

The model for the pilot and test observations summarized in Tables 1 and 2 is a good match to the available time, and allows for time in the LST range 22 to 05 hr for additional tests, as shown in Fig. 4.

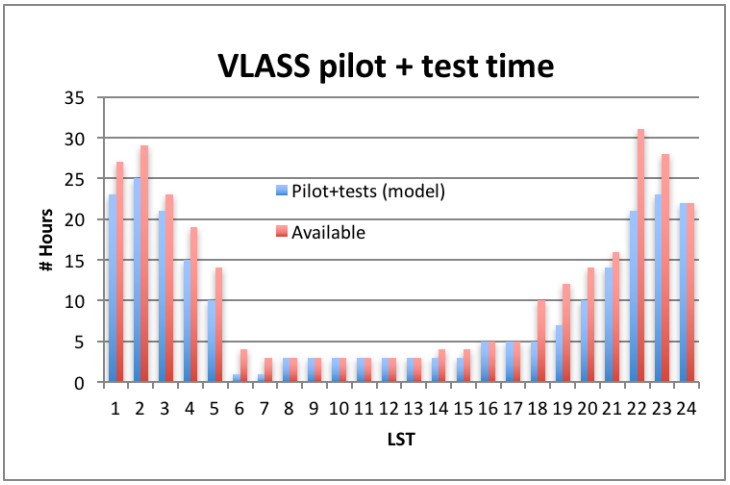

Figure 4: Pilot model plus tests (blue histogram) compared with available time in B-configuration, semester 2016A (red histogram).