# The Jansky VLA Sky Survey (VLASS)


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National Radio Astronomy Observatory

Socorro NM

for the VLASS Survey Team

and the Survey Science Group

Atacama Large Millimeter/submillimeter Array

Expanded Very Large Array

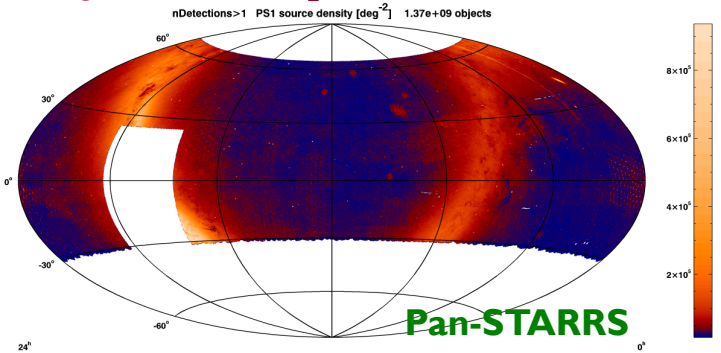
Robert C. Byrd Green Bank Telescope

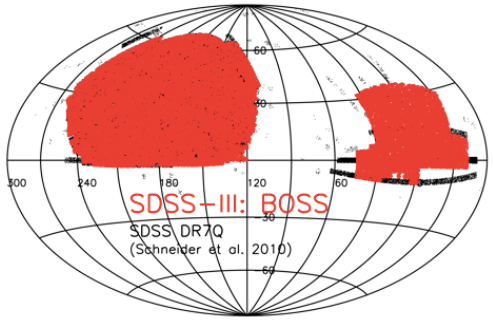
Very Long Baseline Array

NRAO

# Surveys and the VLA/Why Now?

- Science based on surveys comprise a steadily increasing fraction of VLA publications
- 20 years since NVSS and FIRST!
  - and ~10 years before SKA-1




- ***New capabilities on the VLA***
  - OTF mosaics, wide fractional bandwidths for increased continuum sensitivity, instantaneous spectral index determination, polarization
- ***New scientific opportunities***
  - especially in time domain, need to start now to build time series
  - multi-messenger surveys need radio counterpart *with comparable or better resolution* than in O/IR (sub-arcsecond)

NRAO

# The VLA Sky Survey (VLASS) Initiative

- Announced 11 July 2013 : Community-led Program to define a new radio sky survey using the upgraded Karl G. Jansky VLA
  - Previous centimeter-wave VLA Surveys: NVSS & FIRST 1993-2002
  - Open *international* participation, public data and products
  - VLASS data public from start (no proprietary period)
- Fall 2013: Issued a call for White Papers - **21 Papers!**
- AAS workshop 5 January 2014 (~50 attendees, see online)
- 2014: Survey Science Group (SSG), working groups formed
  - co-chairs: S. Baum (RIT/UManitoba), E. Murphy (IPAC)
  - technical implementation plan (TIP: Myers et al.)
- Jan 2015: Final Proposal posted ALL-SKY + DEEP
  - ~9000 hrs. over 7 years (6 config. cycles, A+B config.)

https://science.nrao.edu/science/surveys/vlass

# VLASS SSG and Proposal Contributors

**Table 8:** VLASS Proposal Contributors, Including VLASS White Paper Authors

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Note: Members of the SSG are listed in **bold**.

# The VLASS : community review

- Community Review: March 4-6 in Socorro, NM
  - recommended proceed with ALL-SKY only
  - key science: hidden explosions and polarization
  - DEEP had very strong case as a P.I. led Large Proposal
- The VLASS: post-review
  - ALL-SKY only (~5400 hrs.)
  - 3 epochs over 7 years (6 config. cycles, ~900hrs/cycle)
    - cadence: 32 months (alternating 16mos. half-survey)
- What about DEEP?
  - new multi-year Large Proposal category recommended
  - submitted in Aug 2015 (fate not yet known)

# VLASS: Post-Review Survey Definition

- Captures a set of snapshots of the radio sky unique in time & "space"
- Enables : focused radio, multi-λ, statistical, time domain studies
- S-Band (2 – 4 GHz), B/BnA configurations
  - Wide Bandwidth – spectral index, improved synthesized PSF
  - Full Polarization – Improved RM Synthesis Imaging
  - All-sky (~34Kdeg$^2$) – including Galactic plane and bulge
  - Synoptic – 3 epochs, 120μJy/beam per epoch, 32 month cadence
    - OTFM scanning at 3'/s (or 6'/s)
  - High Angular Resolution (2.5")
    - locate hosts **and location within hosts**
- ~5400 hr investment over ~7yr
  - ~15% impact on PI time

| Tier | Density (deg$^{-2}$) | Total Detections |
|---|---|---|
| **All-Sky** | **290** | **9,700,000** |

10x FIRST yield, ~5x NVSS

| Tier | Area (deg$^2$) | Resolution ('',robust) | Rms (μJy/bm) | Time (hr) | Epochs |
|---|---|---|---|---|---|
| All-Sky | 33,885 (δ > -40°) | 2.5 | 69 | 5436 | 3 |

# VLASS Basic Data Products (BDP)

- Deliverables by NRAO (with SSG collaboration where possible):

| Product | Timescale | Notes |
|---|---|---|
| Raw Data | immediate | no proprietary period |
| Calibrated Data | 1 week | same, served from archive |
| Quick-Look Images | 48 hrs. | continuum only, simple QA |
| Quick-Look Catalog | w/QLI | only basic image object finding |
| Single-Epoch Images | 6 mos. (12 mos. pol) | better quality assurance |
| Single-Epoch Catalog | w/SEI | more object parameters |
| Cumulative Images | 12 mos. (16 mos. pol) | produced after each epoch after first, increased depth |
| Cumulative Catalog | w/CI | more detailed |

- Also, Enhanced Data Products (EDP):
  - added value by community groups, e.g. RM synthesis maps, transient catalogs and alerts. Announcement of call soon…

# ALL-SKY images (tentative plan)

Fast Transient Search
Correlator dump time 0.45s (or 0.25s)
100Mpix x 1024ch x 4 pol / 0.45s ~ 1Tpix/s
(LSST ~ 1.6Gpix/s)

- 33885 deg$^2$ at 0.6" pixel size → 1.2Tpix (4.8TB) per plane
- QL images
  - 2 continuum images (I + σ) = 2.4Tpix (9.6TB)
- SE images (3 epochs)
  - 3 x 4 continuum images (Iα+σ) = 14.4Tpix (57.6TB)
  - 3 x 5 (IQU+σ) coarse cubes (14 planes, 128MHz) = 252Tpix (1008TB)
    - very large! considering compress/cutout/drop options
  - 3 x 5 full cubes (180 planes,10MHz) = 3.24Ppix (13PB) = NO WAY!
- CF images (best combined images after each new epoch)
  - 6 continuum images (Iαβ+σ) = 7.2Tpix (28.8TB)
  - 5 coarse cubes (14 planes) = 84Tpix (336TB) – compress 10:1 to 33.6TB
  - 5 fine cubes (180 planes) = 1.1Ppix (4.32PB) – compress 40:1 to 108TB
- Full spectral resolution (>100 PB) – Process on Demand (PoD), no storage
  - pursuing development of this as new workflow model

VLA NGAS storage plan 5.7PB in 2020

# VLASS Headline Science

- Large Area Survey for Transients
  - Radio Bursts on timescales from 1ms to >1 year
  - EM Counterparts to GW events (LIGO/VIRGO)
- Faraday Tomography of the Universe
  - Linear Polarimetry for B-field Studies

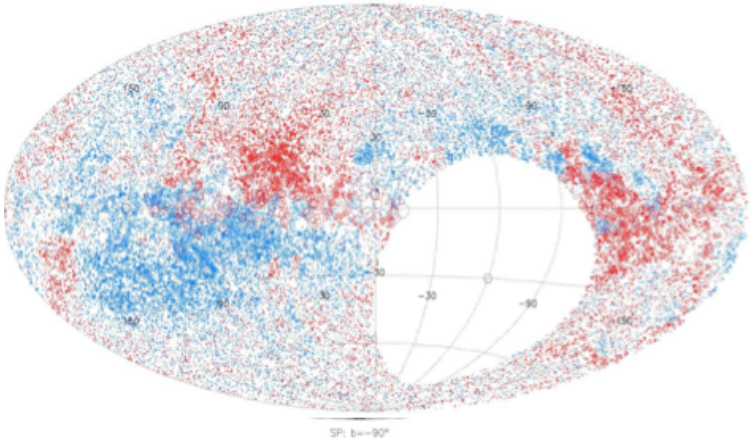
A Radio Astronomy Laboratory for Astrophysics & Cosmology

Clusters & Polarization: Clarke et al., Edge et al., Mao et al.

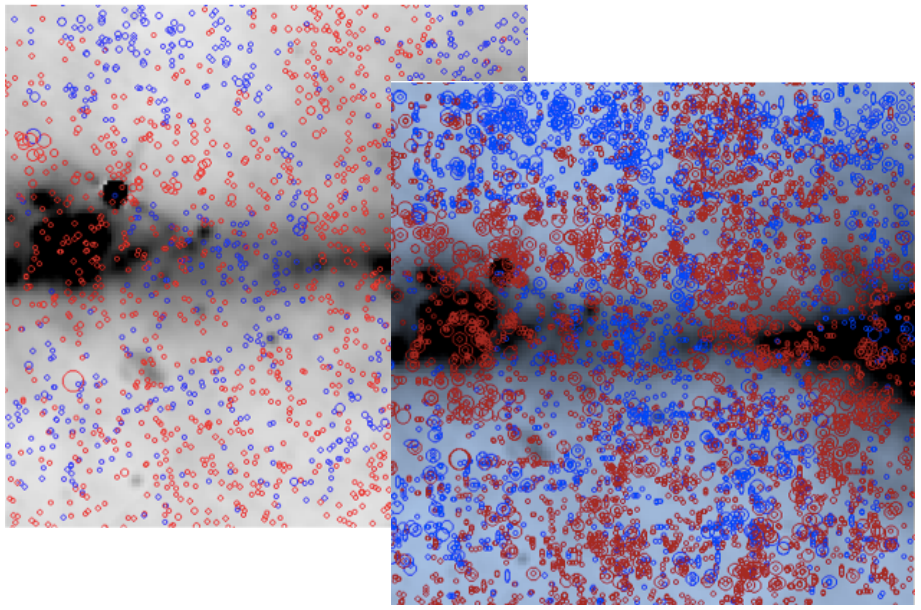
Transients: Chatterjee et al., Hallinan et al., Kamble et al., Law et al., Wilson et al.

# Headline Science: Faraday Tomography

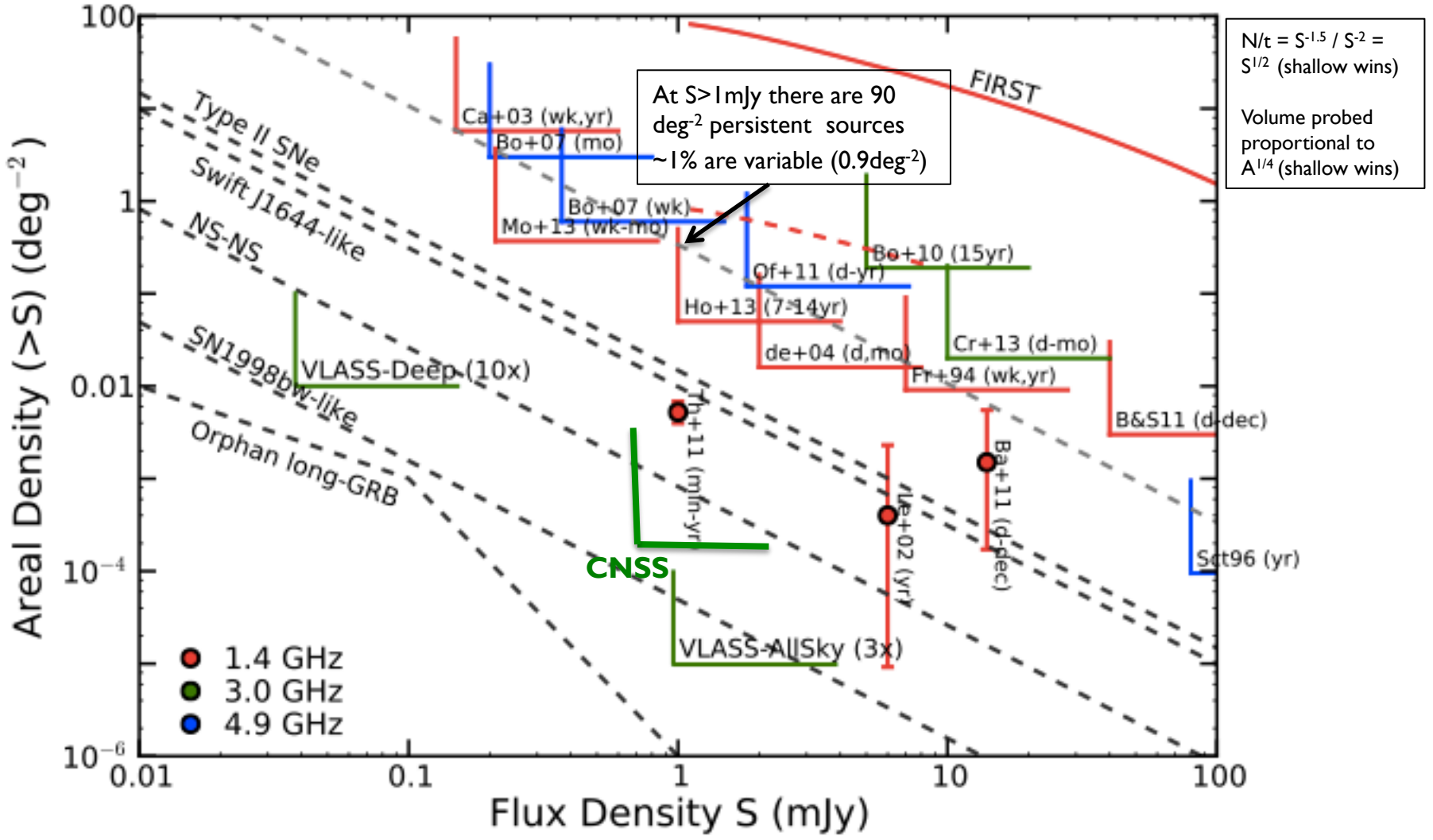
- NVSS+: Taylor, Stil, Sundstrom 2009
  - $3 \times 10^4$ sources, ~1/deg$^2$
- VLASS:
  - conservative estimate
  - $2 \times 10^5$ sources, ~ 6/deg$^2$
- Science:
  - map our Galactic B
  - B through the cosmic web
  - evolution with z



NVSS + Taylor, Stil, Sunstrum 2009



# Headline Science: Hidden Explosions




VLASS will find >20 of key slow transient classes
the best survey before SKA-1 (better than ASKAP)


RADIO DATA

Near-Real-Time Transient-Detection Pipeline

Courtesy Kunal Mooley (Caltech)

Generating too many candidates saturates the system - need arcsecond localization to find extra-nuclear candidates.


SDSS III

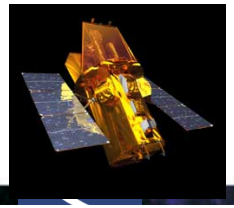
Transient Candidates

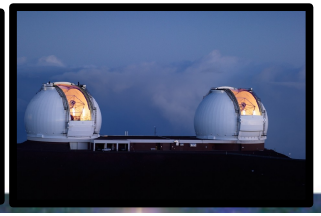
OPTICAL COUNTERPARTS

Generating transient candidates isn't enough - they aren't useful until you follow them up!

IN THE ERA OF TRANSIENT FACTORIES, FOLLOW-UP IS KING!!!

Interesting Transients





# Bomb Lab: A Multi-messenger Approach

- A multi-wavelength and/or multi-messenger approach is needed to identify and characterize the explosion sites, progenitors, and aftereffects of the bursts.
  - Classic example: Gamma-Ray Bursts and afterglows (localization & ID!)
  - Current example: properties of unusual Supernovae and TDEs
  - Now showing: VLA monitoring of SDSS Stripe 82!
  - Coming Attraction: JVLA and VLASS EM counterparts to A-LIGO

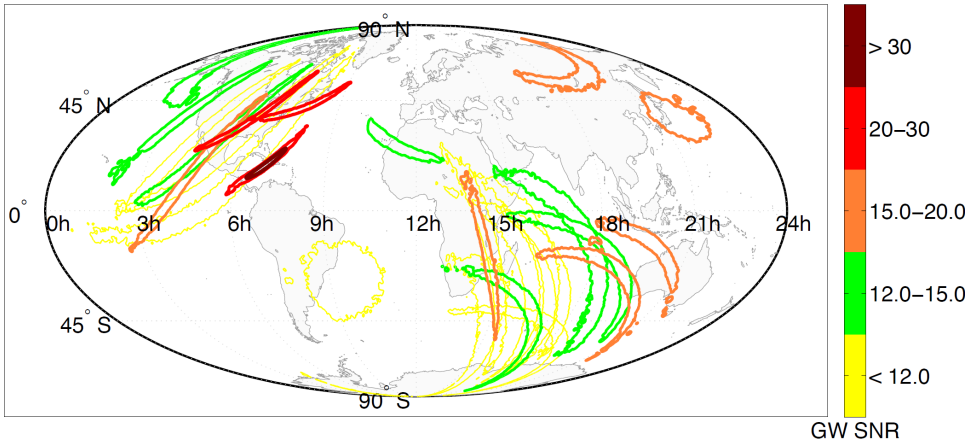



FIG. 2.— Sky location and localization arcs of mergers detected by LIGO-H and LIGO-L. Color represents expected network SNR. Note that the quadrupolar antenna pattern has a bias towards two sky quadrants. The rate of detected mergers is ≈40% of the rate of a three interferometer network. The EM observatory location dictates a time lag in response to GW trigger of up to to one day (Table 1).

# Status & Plans

- Establishment of the VLASS Survey Team underway
- Preparing for Preliminary Design Review (PDR)
  - current schedule for PDR in May 2016
- Carrying out Test & Development Program
  - test observations ongoing & available (TSKY0001)
    - B/A 16deg$^2$ M31, Taurus, Orion; A/D144deg$^2$ Stripe-82
  - benchmarking for processing needs
- Planning for VLASS Pilot Project
  - goal for 150+ hours in 16A B-configuration
  - scientifically viable observations, 3000+ deg$^2$

# VLASS Milestones

## Notional schedule (as of Nov 2015)

| Date | Activity |
|---|---|
| 2015 March 4–6 | External Community Review (Socorro) |
| 2015 March – 2015 Nov | Set up Project Office & Team, draft workplan, allocate resources |
| 2015 March – 2016 Oct | Test & Development Program carried out |
| 2016 May (TBD) | VLASS Preliminary Design Review (PDR), pilot go/no-go |
| 2016 May 27 | Start of 2016A B-config (VLASS pilot observations) |
| 2016 Sep 5 | End of 2016A B-config (includes 1 week extension for pilot) |
| 2016 Oct (TBD) | VLASS Critical Design Review (CDR), final go/no-go |
| 2016 Oct – 2017 Sep | Demonstration of Basic and Enhanced Data Products from pilot |
| 2017 Sep | VLASS epoch 1 observing begins (B-config) |
| 2018 March | Delivery of Epoch 1 BDP (6 months: Stokes I only) |
| 2018 Sep | Delivery of Epoch 1 BDP (12 months: Pol.) |
| 2020 Jan | VLASS epoch 2 observing begins (B-config) |

# Opportunities

- Participate in the VLASS Pilot Project!
  - students, post-docs can embed in small team
- Calling for Community interest in Enhanced Data Products & Services (EDPS)
  - transient alerts, polarization, catalogs & IDs, archives, …
  - community-led MSIP, international partners
- Do your science with VLASS data and data products!
  - data public when observed, can propose to NSF
  - participate in advising and conducting the survey
    - mechanism TBD, if interested contact: vlass@nrao.edu
- Developing VLASS EPO plan
  - local NM partnerships particularly welcome!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