The VLA Sky Survey

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Sixteenth Synthesis Imaging Workshop

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NRAO ALMA AUI NSF New Mexico Tech SCIENCE · ENGINEERING · RESEARCH · UNIVERSITY The University of New Mexico New Mexico CONSORTIUM

Design

- Highest spatial resolution, all-sky radio survey to date
  - All-sky (33,885 deg^2 above declination –40°)
  - Frequency: 3 GHz (2–4 GHz, less RFI affected regions) "S-band"
  - 64 x 2-MHz channels per spectral window, 16 spectral windows
  - Stokes I wideband and Stokes IQU cubes
  - High angular resolution: 2.5" (VLA B/BnA-configurations)
  - Synoptic: 3 epochs separated by 32 months
  - Observing time: 920 hours per configuration cycle x 6 cycles (13% of VLA science time)
    - Full survey, 7 years: September 2017 – October 2024

Area (deg^2)	Resolution (robust)	RMS goal (μJy/bm) epoch/full	Density (deg^{-2})	Total Detections
33,885 (δ > –40°)	2.5"	120 /69	~290	9,700,000

Science Goals

- Provide a reference radio sky at high angular resolution for multi-wavelength studies
- Image galaxies through time and space
  - AGN feedback, flares, BH merger events; synergies with surveys at other wavelengths (resolution is key!)
- Reveal hidden explosions
  - VLASS will open new parameter space for finding dusty/unbeamed GRBs, SNe, compact object mergers
- Faraday tomography of the magnetic sky
  - Studies of magnetic fields throughout the universe: hot gas in galaxy clusters, magnetic fields within other galaxies, magnetic field in the Milky Way
- Peer through our dusty galaxy
  - Extreme pulsars, cool stars with active coronae, planetary nebulae, HII regions
- Missing Physics
  - Serendipitous discoveries that come from opening up new parts of observational parameter space

Basic Data Products (NRAO)

Product	Timescale for production	Notes
Raw visibility data	Immediate	In standard archive
Calibrated data (initial)	4 days*	From standard archive
Quick Look Images	1 week*	Stokes I wide-band continuum only
Single Epoch Images	12 months*	Stokes I wide-band continuum and tapered
Single Epoch Images	16 months*	Stokes IQU cubes
Single Epoch Catalogs	w/Single Epoch Images	By product
Cumulative Images	12 months	Stokes I wide-band continuum and tapered
Cumulative Images	16 months	Stokes IQU cubes
Cumulative Catalogs	w/Cumulative Images	By product

- Uses CASA ALMA/VLA data calibration pipeline with special VLASS "recipe"
- New imaging pipeline

* May be a delay for the first half of first epoch (VLASS1.1)

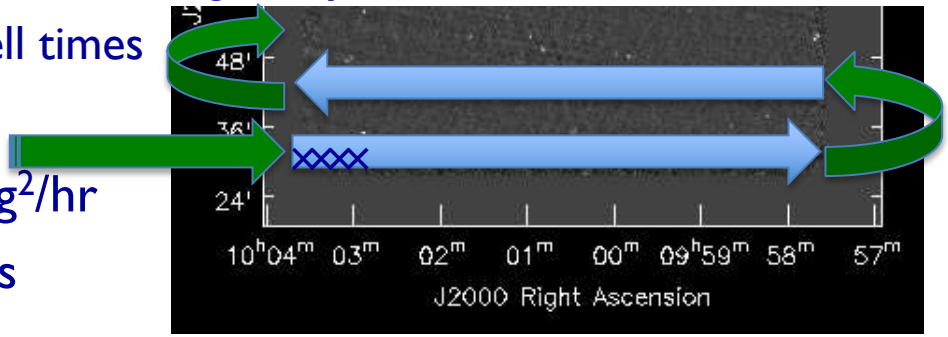
Enhanced Data Products (community)

- Canadian Initiative for Radio Astronomy Data Analysis (CIRADA) proposal approved for funding by the Canada Foundation for Innovation, covers various projects (VLASS, CHIME, ASKAP), total value ~CAD$9.4M, PI Bryan Gaensler (U. Toronto)
- For VLASS, this covers:
  - Source catalogs, including radio polarimetry and multi-wavelength info
  - Cubes of Faraday depth for bright sources
  - Transient identification, quality assurance, and announcements based on QL images and *realfast*
  - Accessible archive of above products
- Shea Brown (U. Iowa) also working on machine learning algorithms for source classification:

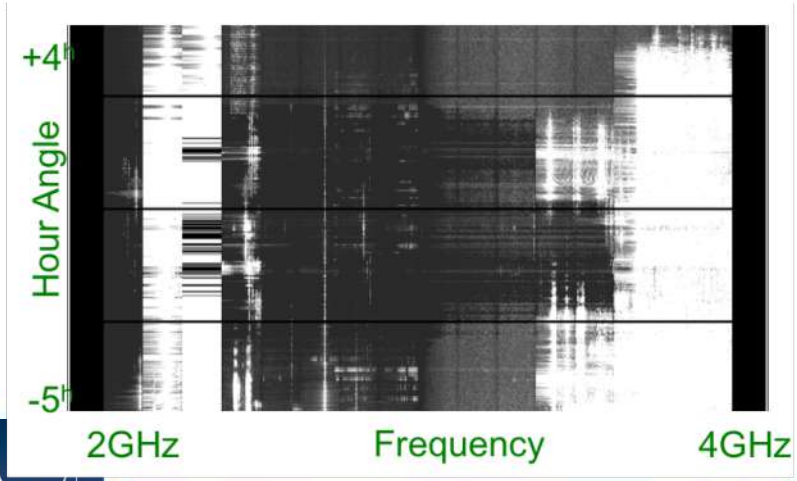
https://bablai.com/vlass/

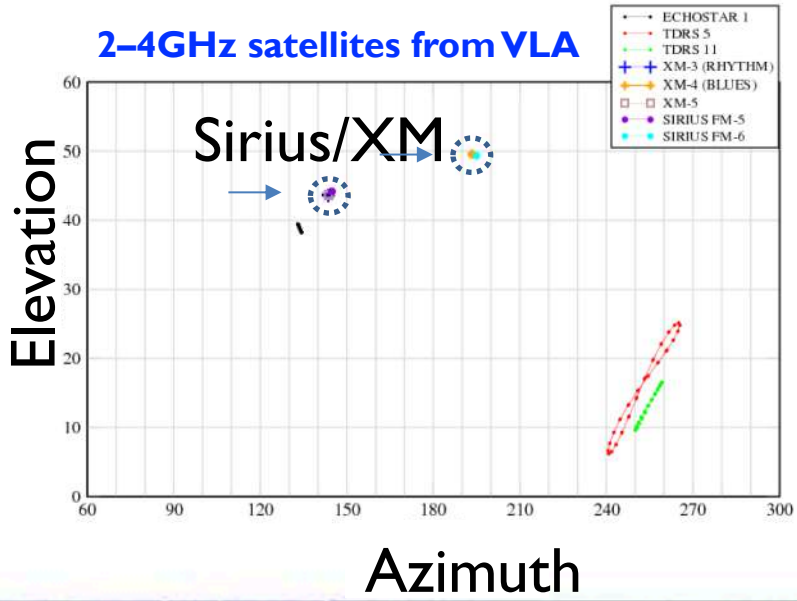
Technical I

- Multi-epoch sky coverage enabled by On-The-Fly mosaicking
  - Scan telescopes across sky while taking array data
    - Very efficient for short dwell times
  - Scan rate 3.3'/s, row sep 7.2'
  - VLASS survey speed: ~20 deg^2/hr
  - Equivalent time-on-source: 5s



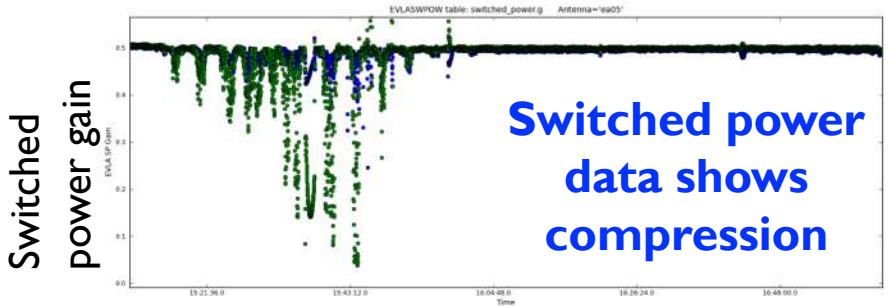
- RFI

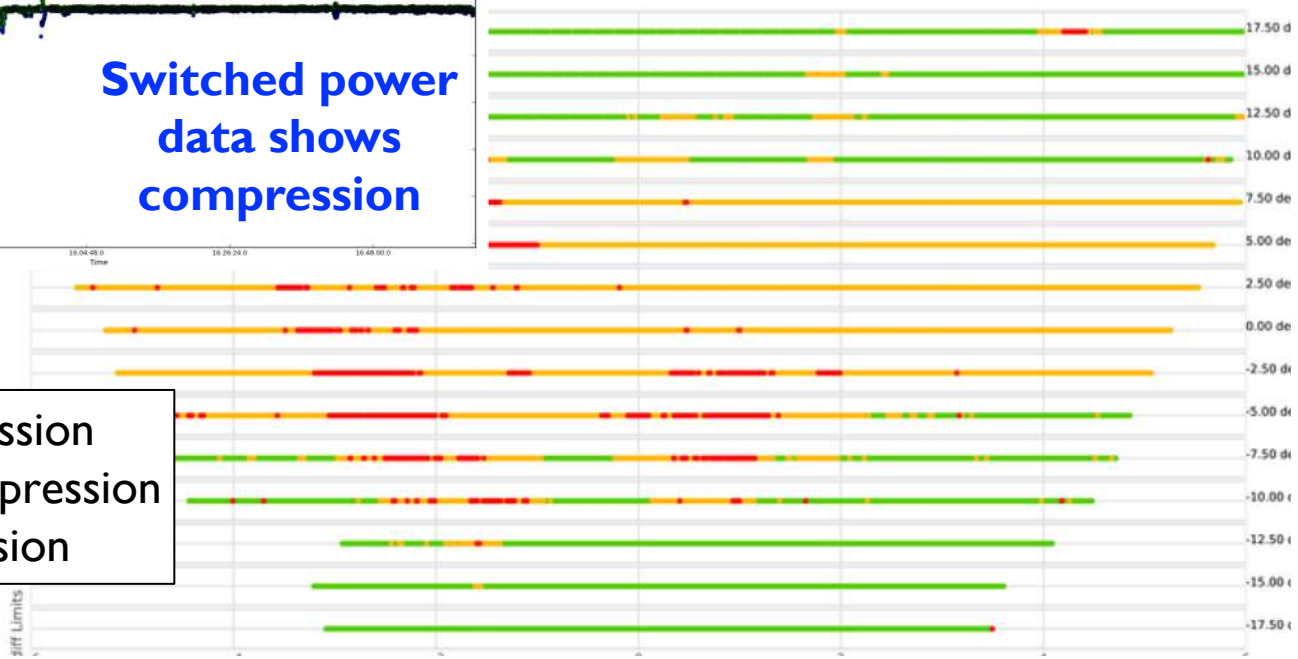




Technical II

- Compression (identified in pilot data)
  - Affects entire baseband, not just spws containing RFI
  - Problem for much larger fraction of sky than originally thought
  - Special algorithm developed that can correct for moderate compression





Green: <5% compression
Yellow: 5–20 % compression
Red: >20% compression

Technical III

- Mosaic imaging algorithms
  - 'mosaic' gridder
    - Used for Quick Look Imaging
    - Uses fit to azimuthally averaged PB
    - Issues with bright sources outside primary beam that are not subtracted in major cycle
  - 'awproject' gridder
    - Will probably use for Single Epoch Imaging
    - Uses 2D PB derived from ray tracing
    - Less well-exercised than 'mosaic' gridder, still debugging code
  - Both algorithms have issues with use of single PSF in minor cycle
  - Ongoing development → algorithms are converging!

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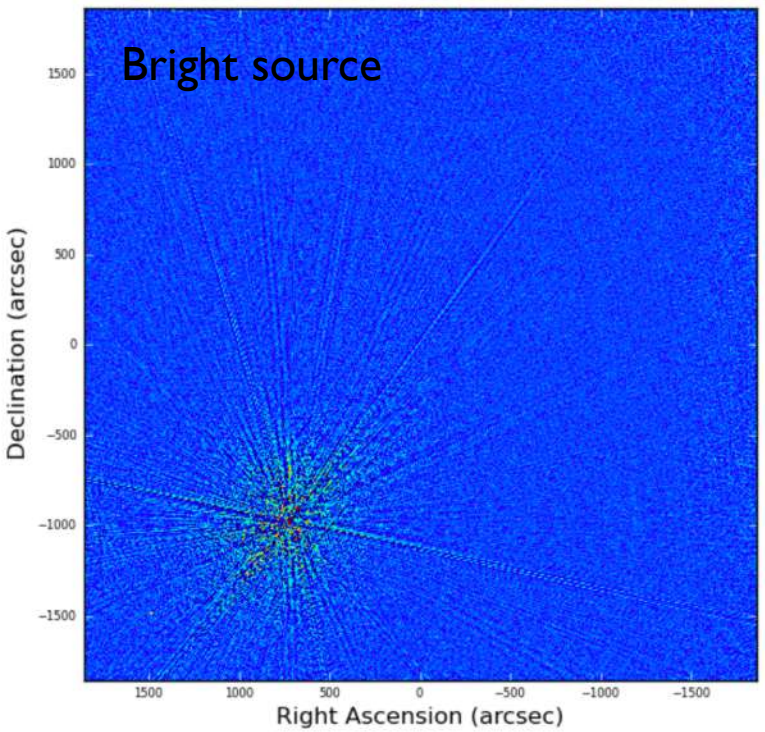

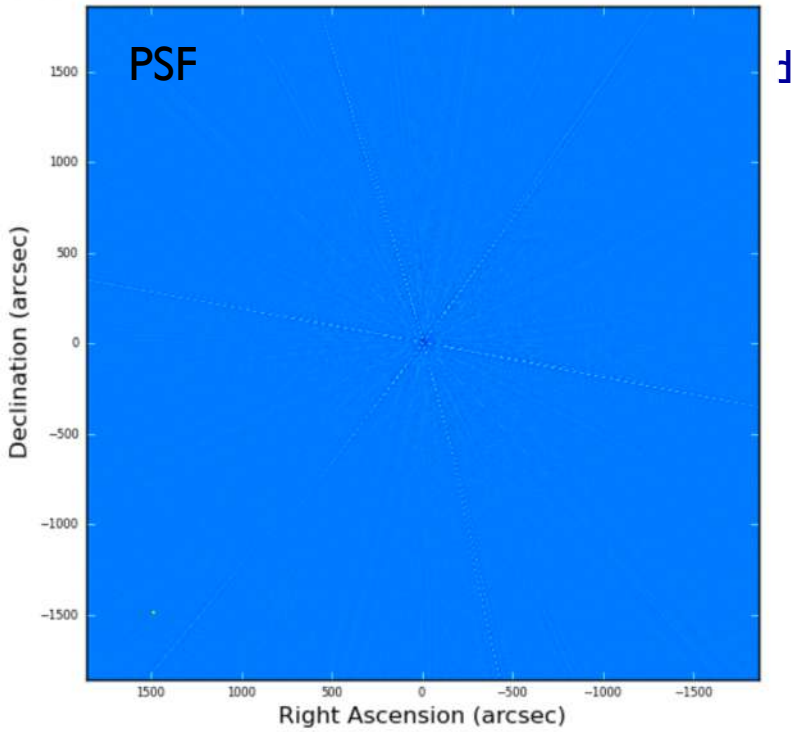

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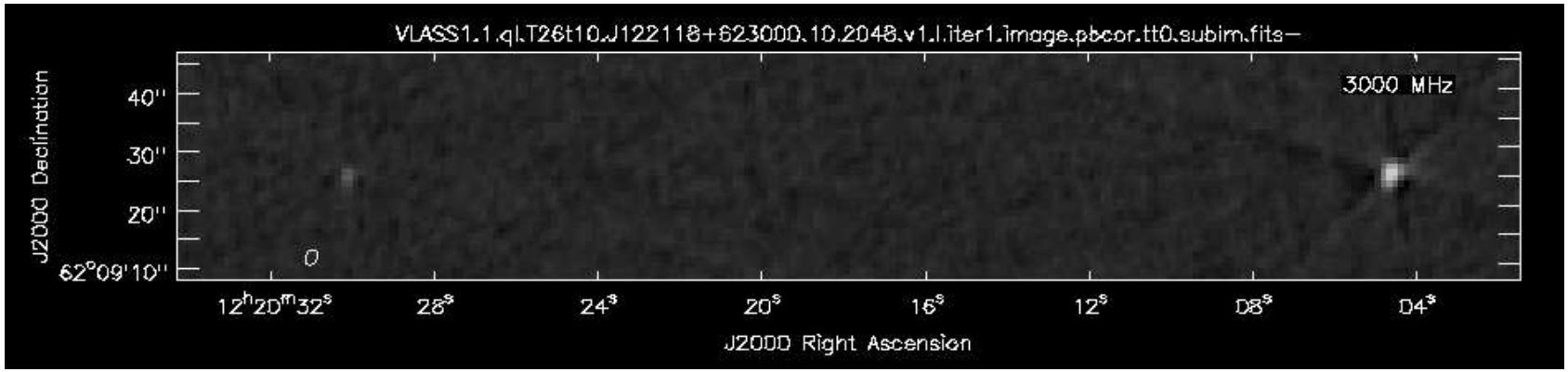
Technical IV

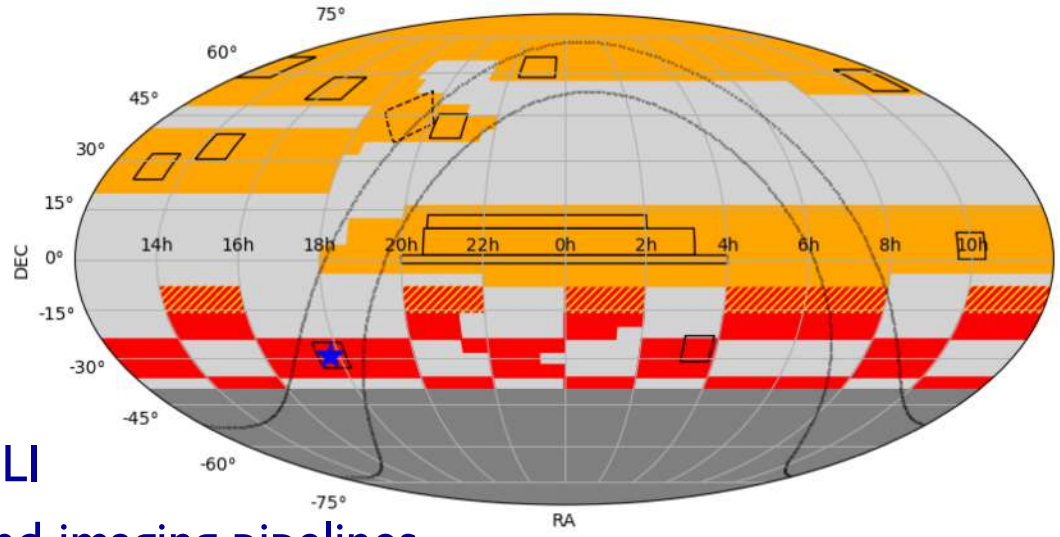
- Ghost sources!
  - The VLASS observing mode revealed an issue with the online system, whereby the delay model was occasionally delivered late to the correlator, resulting in data being correlated at a different position from that recorded in the SDM
  - Minimal effect in regular observing
  - 0.9s scans used by VLASS → presence of "ghosts" of bright sources offset in OTF scan direction (RA) by ~3 arcmin (separation of phase centers)



  - Online system modified
    - Added ability to send up to 5s-worth of future delay models to correlator
    - Added code to detect problem and trigger alerts

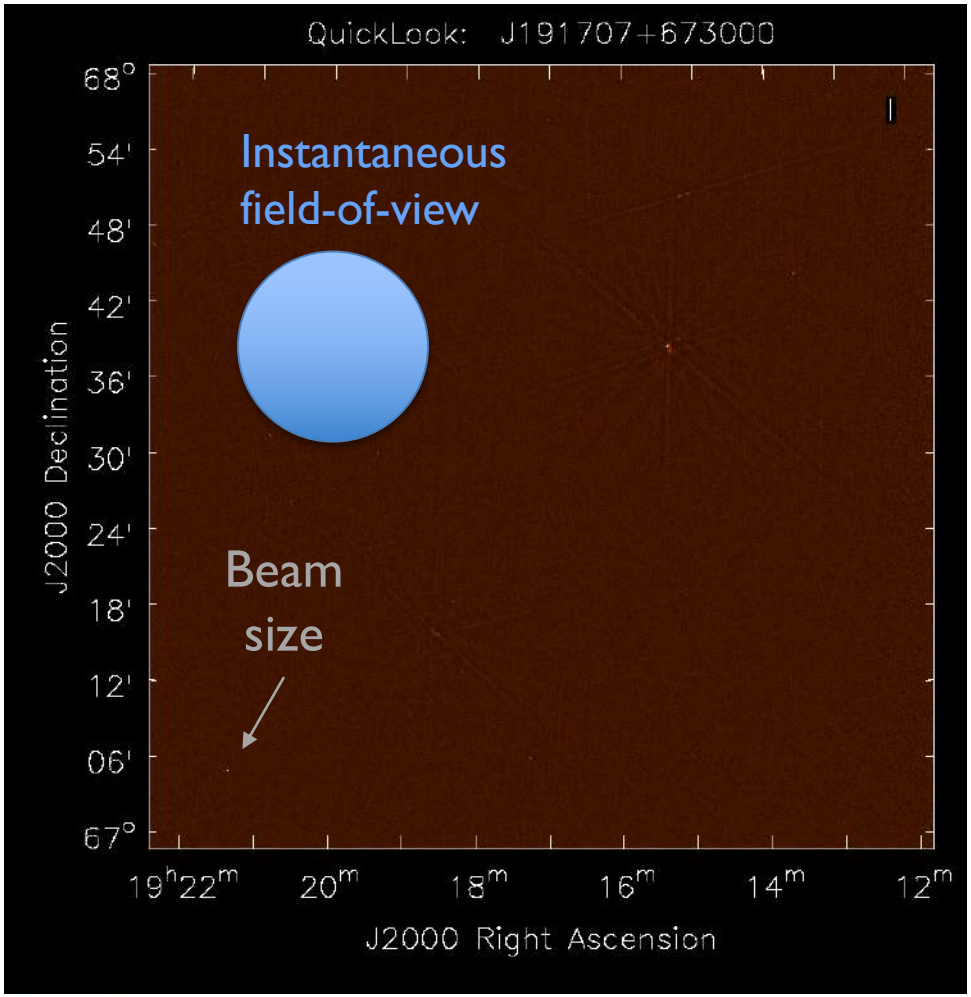
Status and Results

- Design calls for half of sky visible to VLA (~16,940 sq. deg.) to be covered per 16-month VLA configuration cycle
- VLASS1.1 observing started Sep 7, 2017, completed Feb 20, 2018
  - Covered ~16,830 sq. deg. (~109 sq. deg. failed because of wind)
  - Delivered ~16,760 sq. deg. Quick Look Images (5/16/18)
  - Fraction of "QA rejected" Quick Look Images <1%



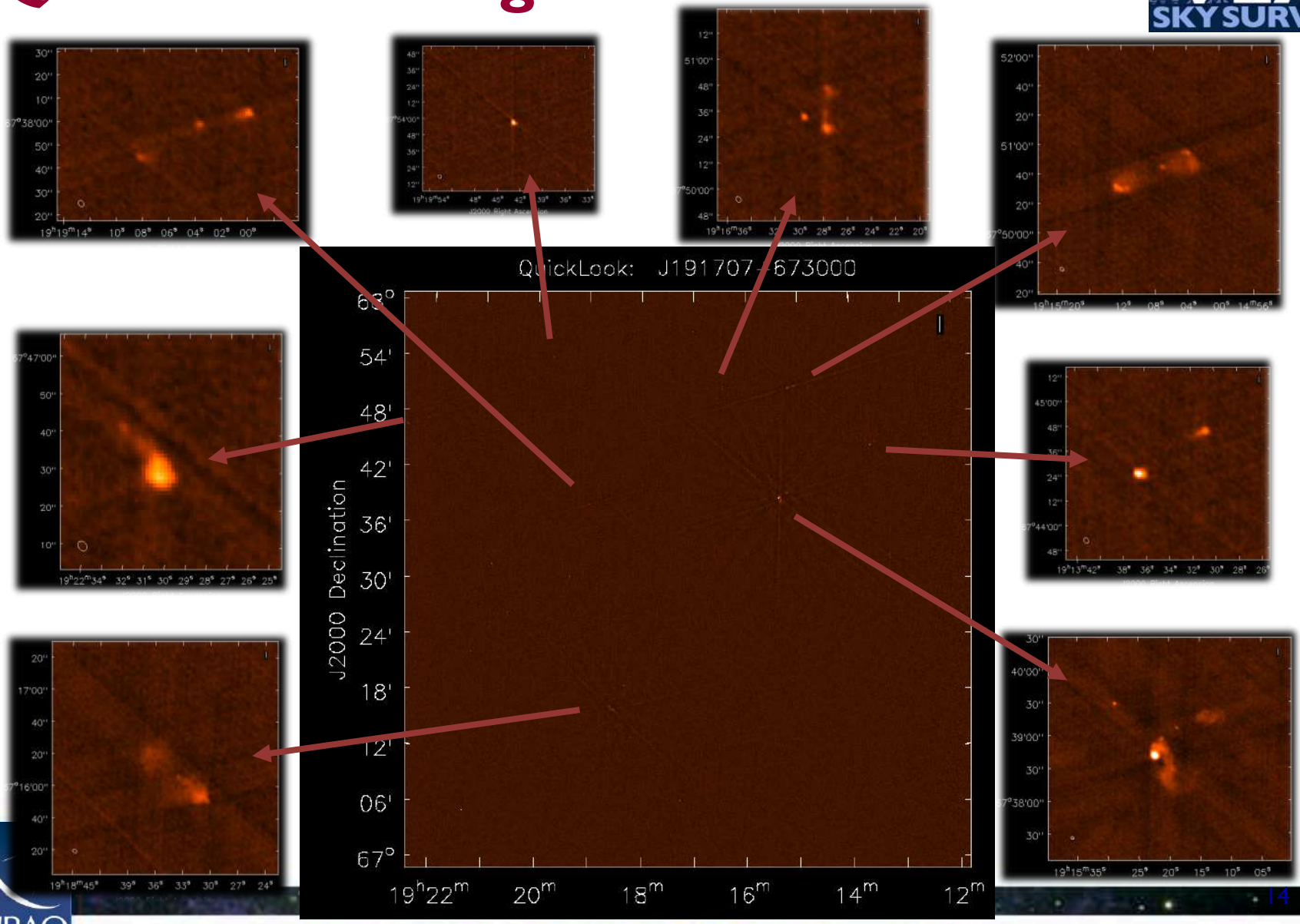
- Still dealing with ghosts in QLI
- Working on SE calibration and imaging pipelines

Quick Look Images



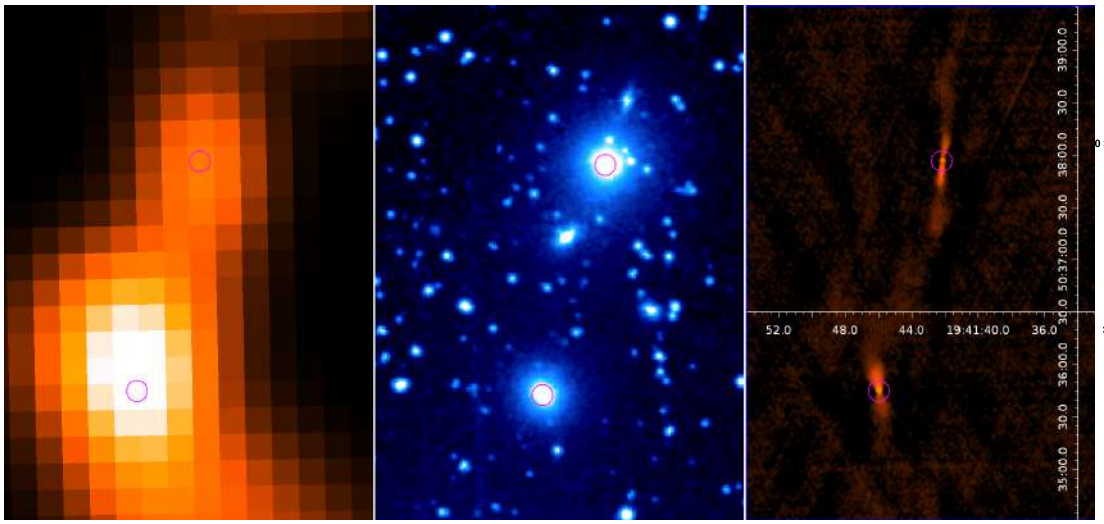
1°x1° subimage (full 2°x2°)
1" pixel size (13Mpix)
416 phase-centers (2 x 0.45s integ.)
~10GB visibility data
multi -term, -frequency image
σ_I = 120μJy/beam

Quick Look Images

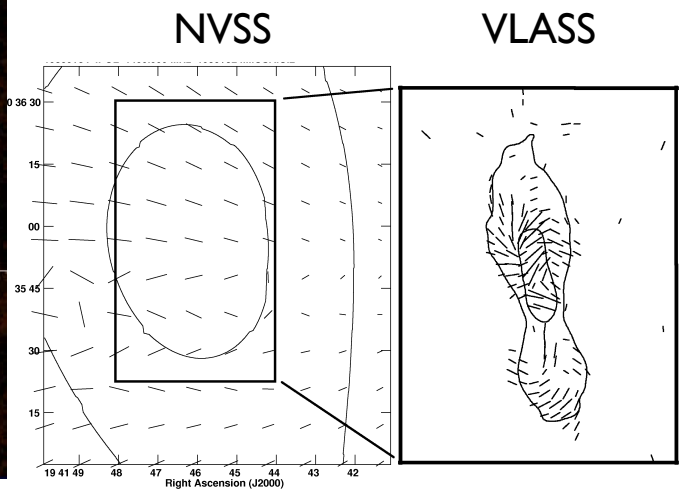


Status and Results III

- Initial calibration already good enough for community to produce advanced polarimetric data products for some objects: radio source 3C402



Polarization of 3C402S (courtesy Larry Rudnick, U. Minnesota):



Data Access

- Data access:
  - Visibility data, calibrations, and flags are available through the new archive interface:
    - https://archive-new.nrao.edu/archivelface/#/
  - Quick Look Images are available from:
    - https://archive-new.nrao.edu/vlass/
    - Also: tile definitions, pipeline weblogs, and HiPS image
  - Working on ingesting images into new archive and enabling multi-product downloads; expected late summer
    - Will also support thumbnail images
    - Will also support cutouts in future

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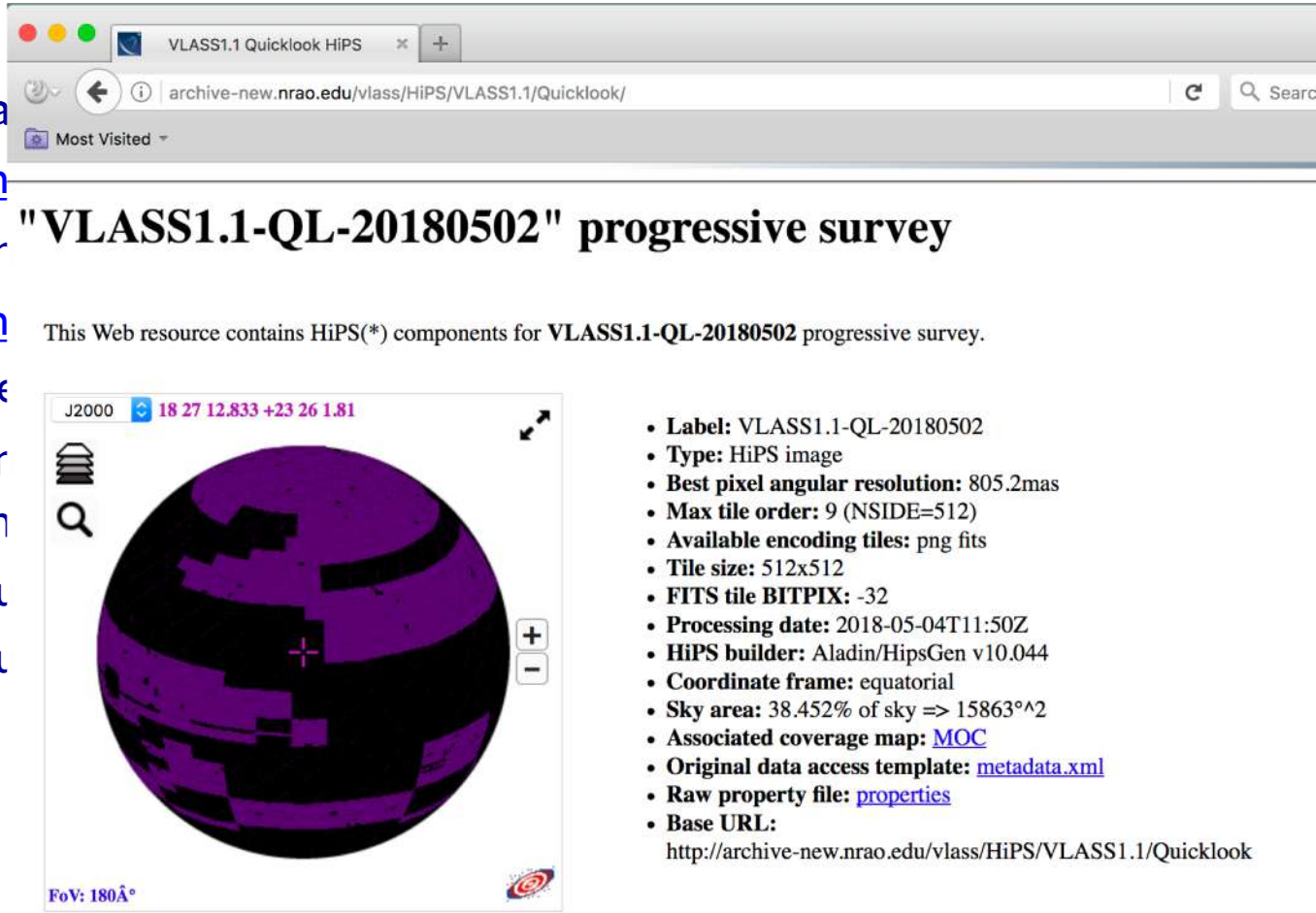
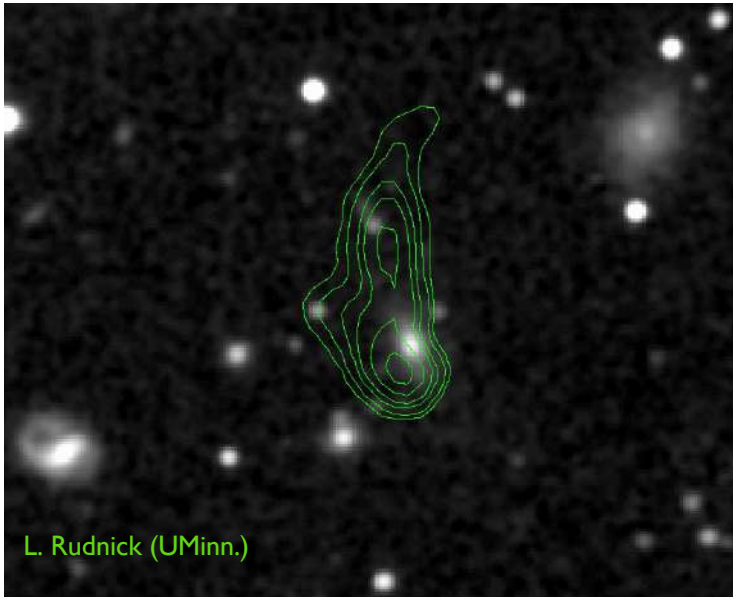
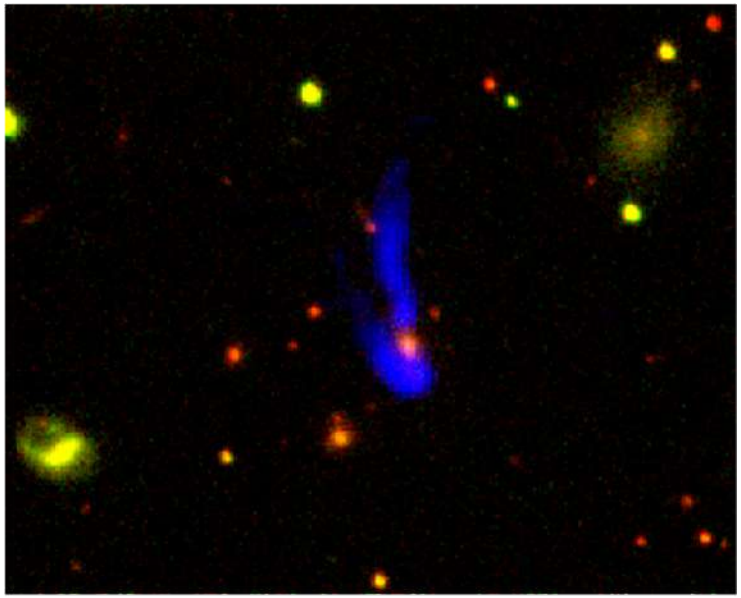


Finally…

- Observing for VLASS1.1 is completed, Quick Look Images available
  - Investigating ghost sources and will remake affected images
- Higher quality calibration, imaging, catalogs coming later this summer
- Think about how to use VLASS data for YOUR science!



FIRST contours on SDSS



SDSS (red/green) image overlay on VLASS (blue). Improved VLASS resolution allows us to classify the radio source as a galaxy at z=0.25, possibly in a cluster.