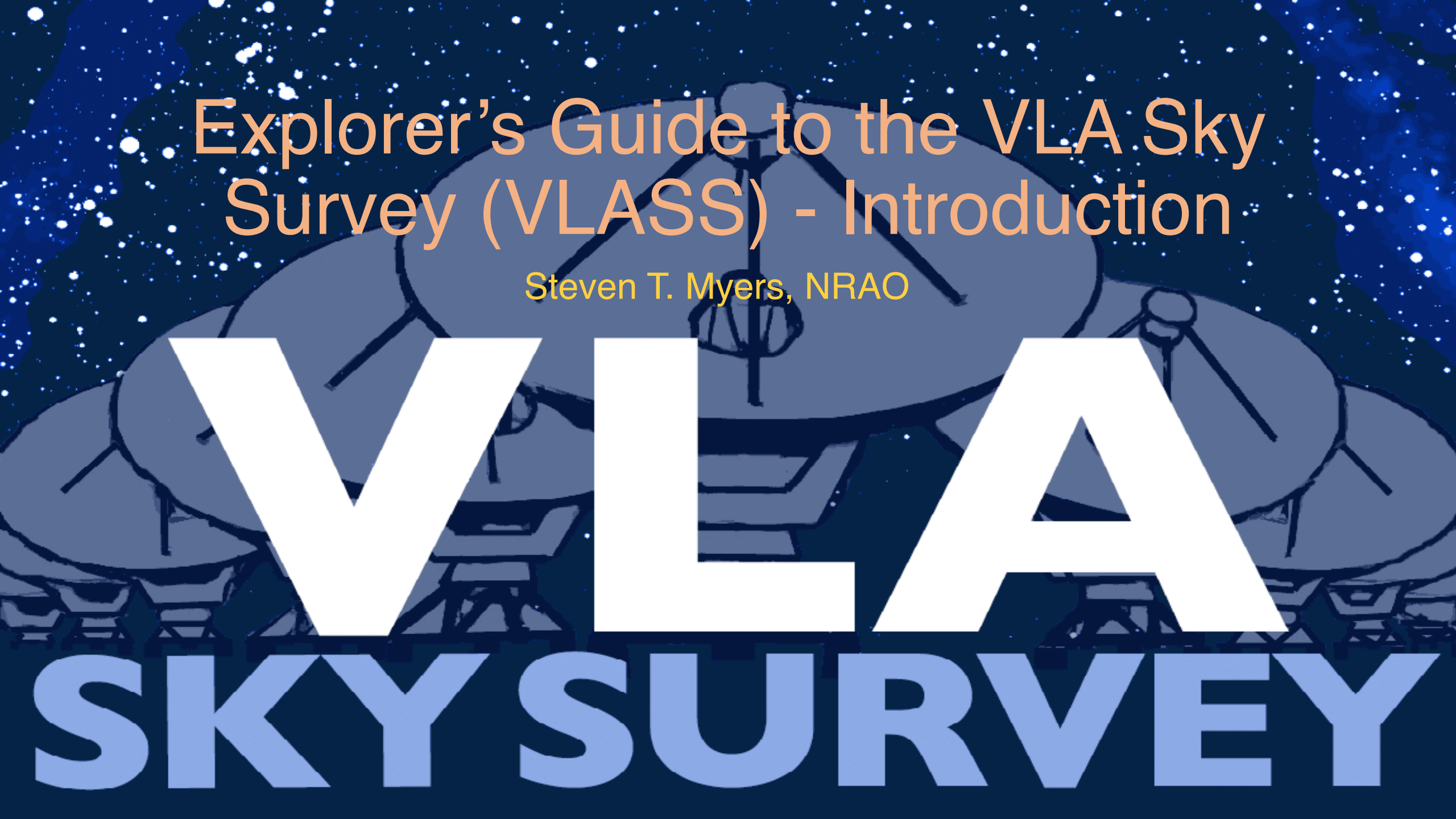
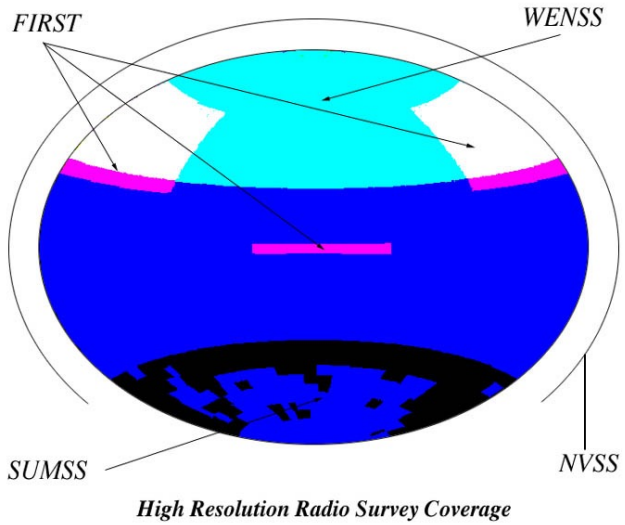
Explorer's Guide to the VLA Sky Survey (VLASS) - Introduction

Steven T. Myers, NRAO



The VLA Sky Survey (VLASS)

- Survey science is of increasing interest
- Multi-λ multi-messenger (GW, ZTF, Rubin/LSST)
- 20+ years since VLA surveys **FIRST** and **NVSS**
- **VLA Upgraded in 2010**, on-the-fly mosaicking
- Bridge to ASKAP, ngVLA, SKA, DSA2000 surveys

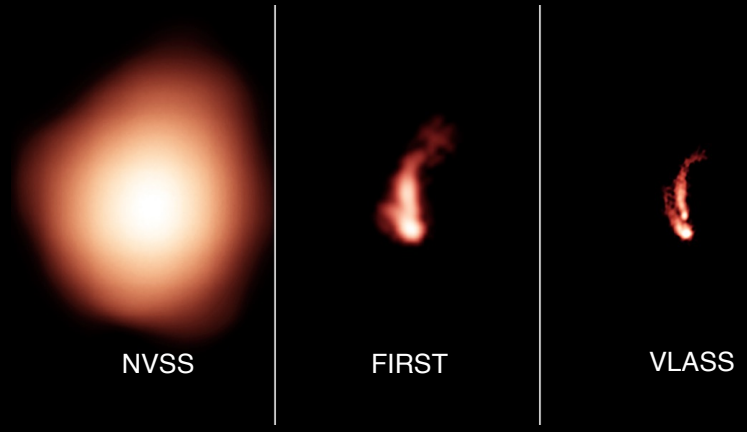


High Resolution Radio Survey Coverage

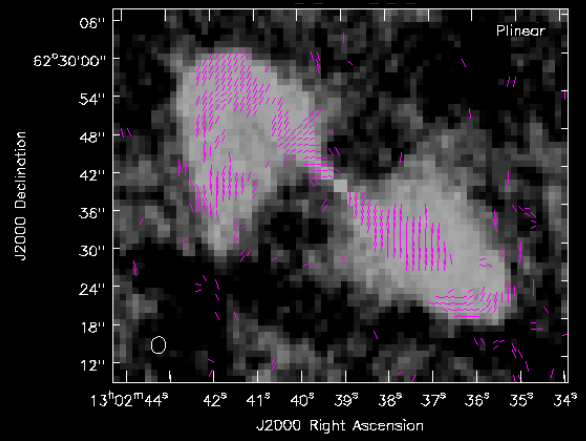
- ***New scientific opportunities***
  - build time series for time domain studies
  - multi-messenger surveys need radio counterpart *with comparable or better resolution*
- ***Community driven survey***
  - Astronomy community proposed new survey taking advantage of VLA's upgraded capabilities
  - Reviewed by independent panel, approved by NRAO Director in 2015

VLA Sky Survey Key Science Themes

Galaxy Evolution Through Space and Time



Magnetic Universe



Transient Universe aka Hidden Explosions

Peering Through Our Dusty Galaxy

Image Credits NRAO/AU,GOODS North, CGPS, NRAO press release

Slide credit: Dale Frail

VLASS Survey Definition

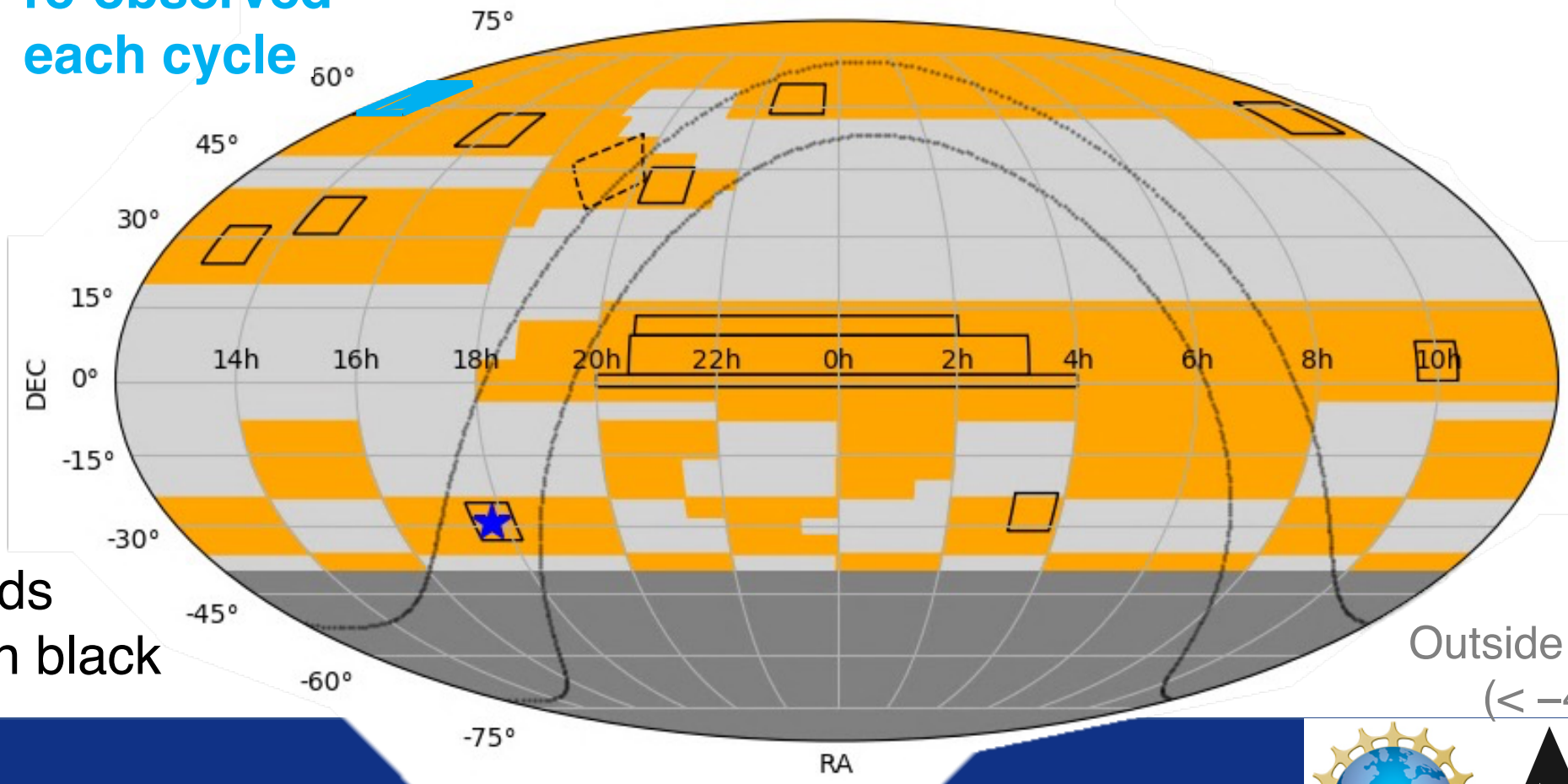
- **Highest spatial resolution, all-sky radio survey to date**
  - Sky visible to the VLA: decl. > -40°
  - Frequency: 3 GHz (**2-4 GHz**) “S-band”
  - High **angular resolution: ~2.5"** (VLA B/BnA-configurations)
  - 1024 x **2-MHz channels**
  - **Full polarization (Stokes IQUV)**
  - Synoptic: **3 epochs** separated by 32 months
    - Alternating halves of sky each 16 month configuration cycle
  - Observing time: ~920 hours per configuration cycle X 6 cycles (over 7 years)

Area (deg^2)	Resolution (robust)	Rms (μJy/bm)	Density (deg^{-2})	Expected Total Detections
33,885 (δ > -40°)	2.5”	~140 / ~80	~150	5,000,000

VLASS Sky Coverage

GOODS-N: re-observed each cycle

1st half of sky (Epoch X.1)



2nd half of sky (X.2)

BnA config

Pilot fields shown in black

Outside VLA visibility (< –40° decl.)

VLASS Observing 2016-2024

(all raw data available in archive, most calibrations)

- Pilot – Jun 2016 to Sep 2016 (observed)
  - Quick-Look processing only
- VLASS1.1 – Sep 2017 to Feb 2018 (observed)
  - QL calibrated, reimaging underway
- VLASS1.2 – Mar 2019 to Jul 2019 (observed)
  - QL calibrated, reimaging complete
- VLASS2.1 – Jun 2020 to Oct 2020 (observed)
  - QL complete & corrected; Single-Epoch calibration & imaging started
- VLASS2.2 – Oct 2021 to Mar 2022 (observed)
- VLASS3.1 – Jan 2023 to Jun 2023 (underway)
- VLASS3.2 – approximate May 2024 to Oct 2024

VLASS Data Products (served from NRAO data archive)

– Raw visibility data

✅ • *timescale: immediate ingestion into archive*

Sensitivity:
~140 uJy/bm (per epoch)
~80 uJy/bm (combined)

– Calibrated data: from VLA calibration pipeline, with VLASS recipe

✅ • *timescale: days*

– "QuickLook" images: for identification of long transients

- Image 2x2deg^2; take central quarter (1x1deg^2)
- multi-frequency synthesis with CASA's mosaic gridder

✅ • *timescale: days to weeks*

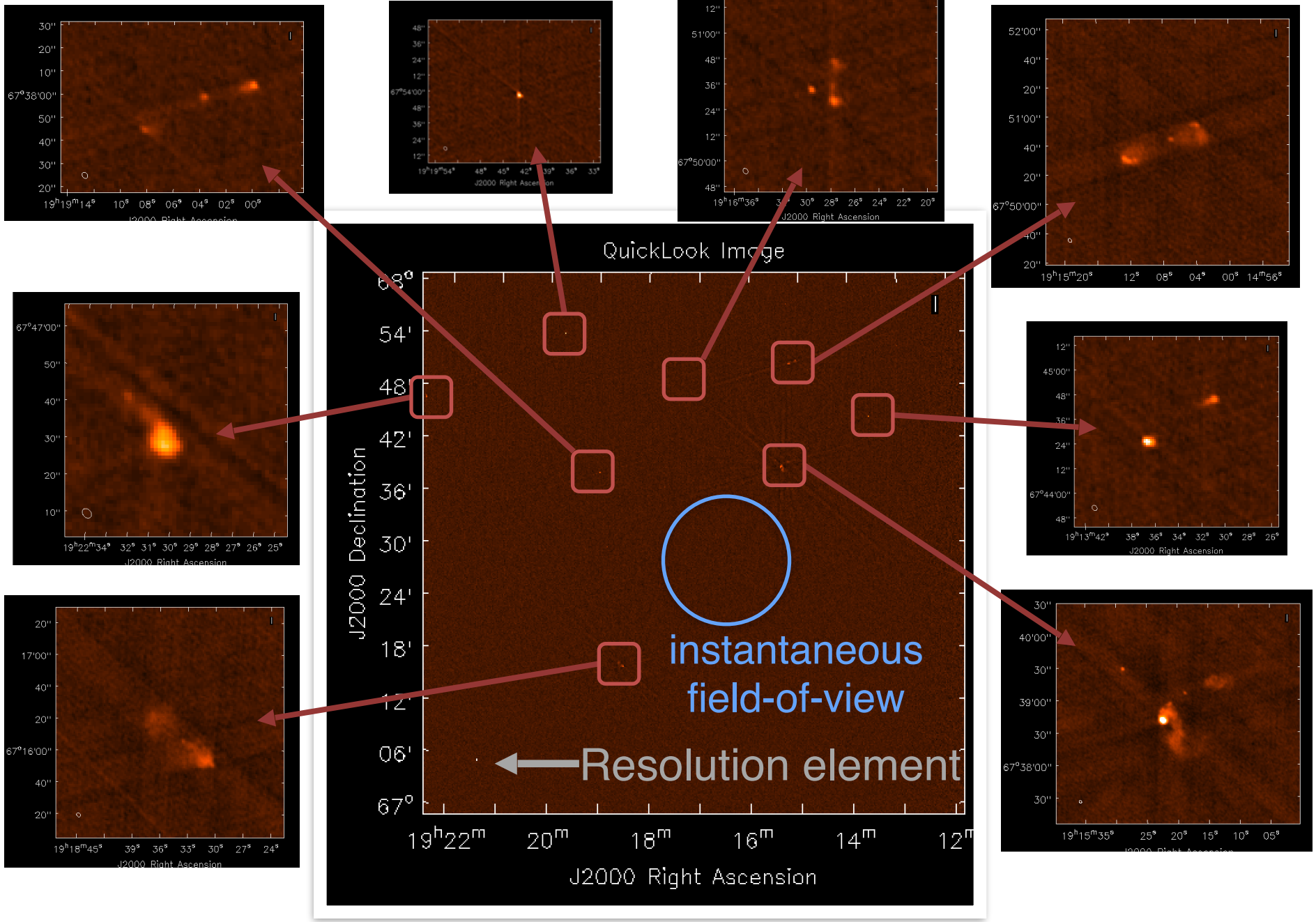
Data processing will continue through 2032, e.g. for final "cumulative" images

– "Single Epoch" products: higher-fidelity images and cubes

- Multi-freq. Stokes-IQU cubes, spectral index images, preliminary catalogs
- mosaic gridder for most of sky; nterms=2

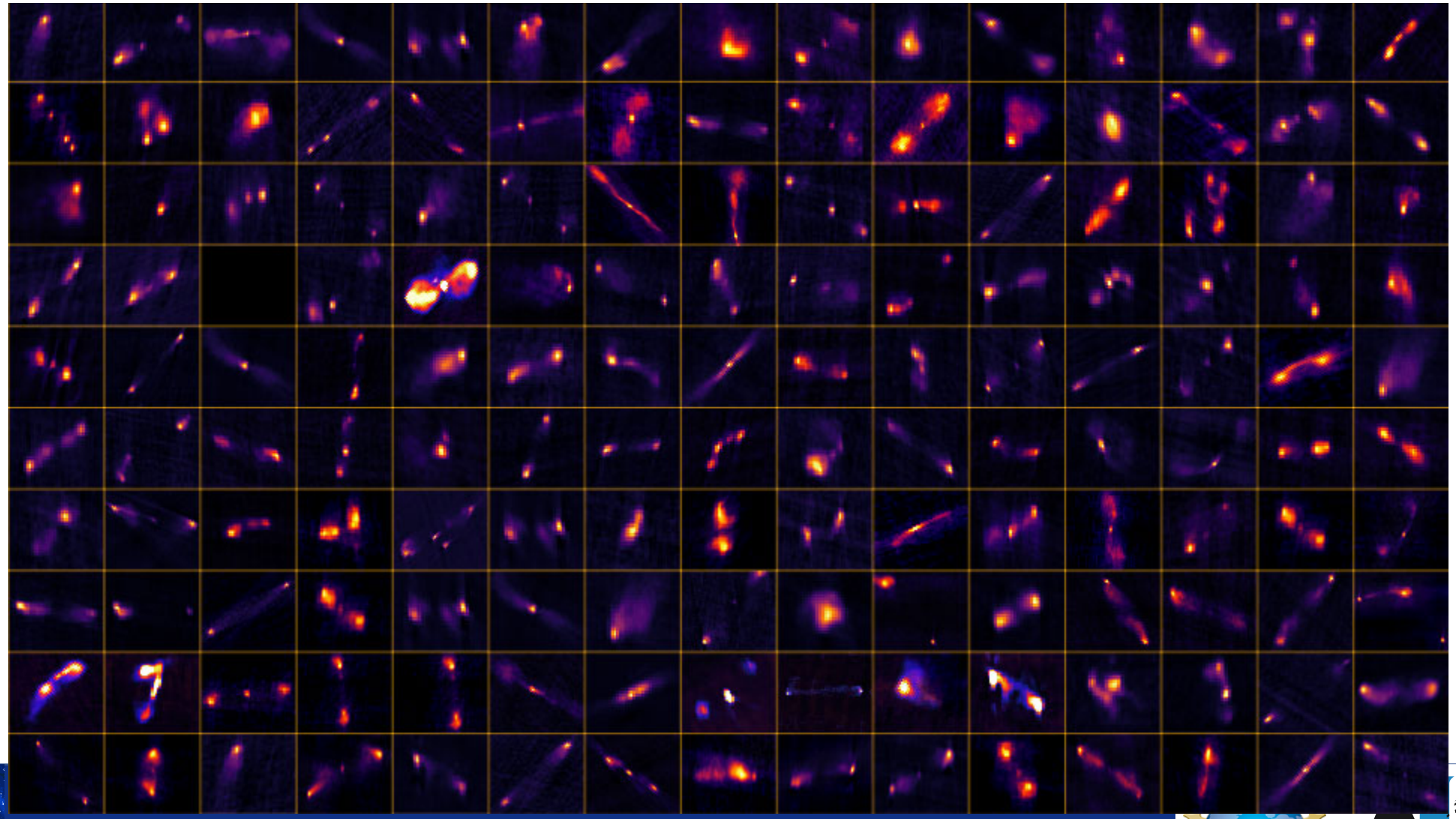
⚠️ • *timescale: ~~months to a year~~ (producing as quickly as we can)*

Data Quality Assurance by VLASS-Ops team


QuickLook Image
J2000 Declination
J2000 Right Ascension
instantaneous
field-of-view
Resolution element

VLASS Radio-Jet Menagerie!

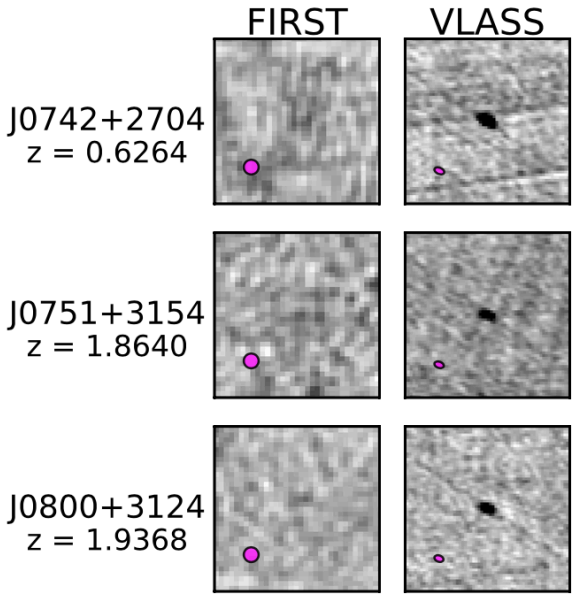
Credit: NRAO/AUI/NSF



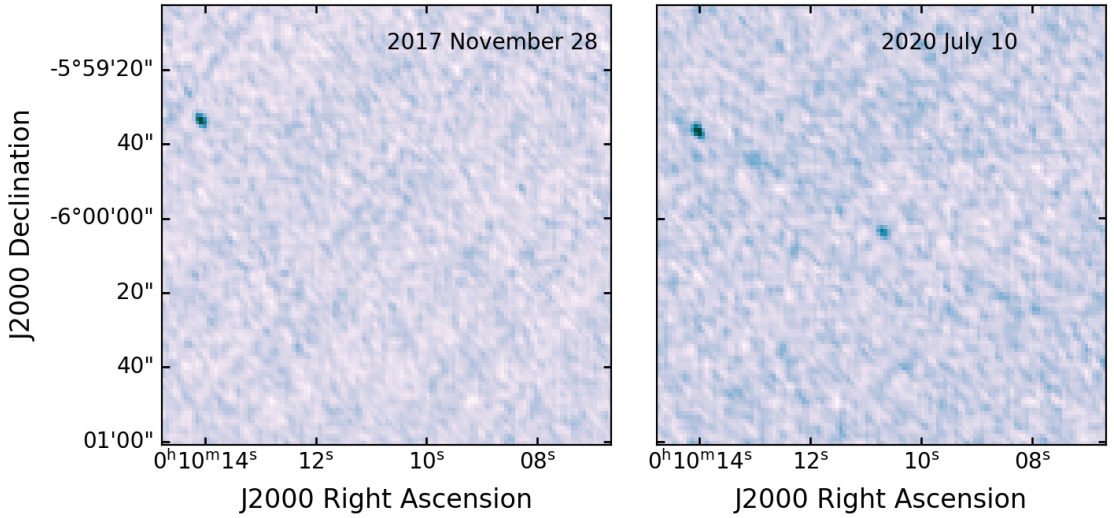
Science highlights: Time domain universe

- Quasars can transition from radio-quiet to radio-loud on decade timescales, based on VLASS Epoch1+ FIRST comparison *(Nyland+20, ApJ,905,74)*

- Supernova 2019xhb (Type 1b/c) found in the first 1000 deg^2 of comparison between VLASS Epoch1 and Epoch 2 *(Hallinan+ 2020, ATel, 14020)*.



See talks later in session by Dillon Dong and Pallavi Patil



More Data!

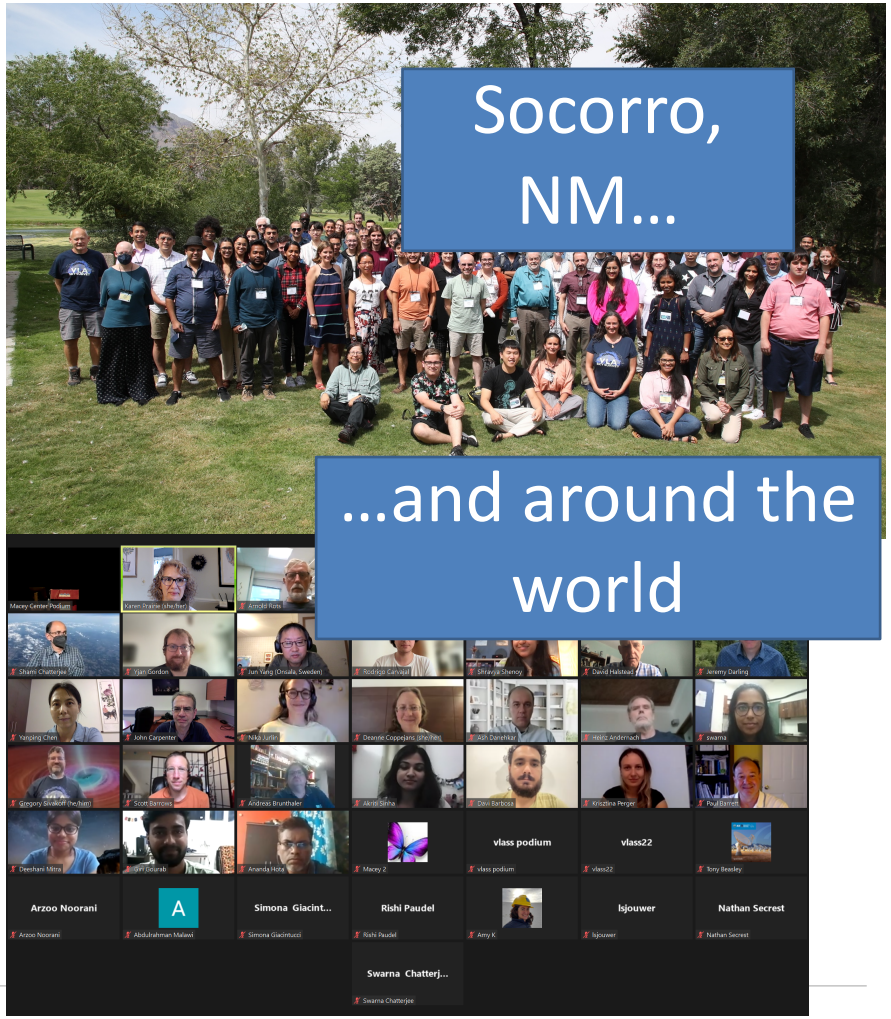
- Future: Cumulative Images
  - Combined all epochs, continuum depth 70-80 uJy/bm
- Commensal Data Products
  - VCSS (NRL) 350MHz using VLITE on VLA
  - Realfast (NRAO) - FRB search on VLA
  - Soon: COSMIC SETI
- Enhanced Data Products: CIRADA (Canada)
  - catalogs, cutout server, more
  - https://cirada.ca

CIRADA
CANADIAN INITIATIVE FOR RADIO ASTRONOMY DATA ANALYSI

VLA SKY SURVEY

NSF AUI NRAO

VLASS Science Meeting 2022



http://go.nrao.edu/vlass22

7-9 September 2022

Science with VLASS

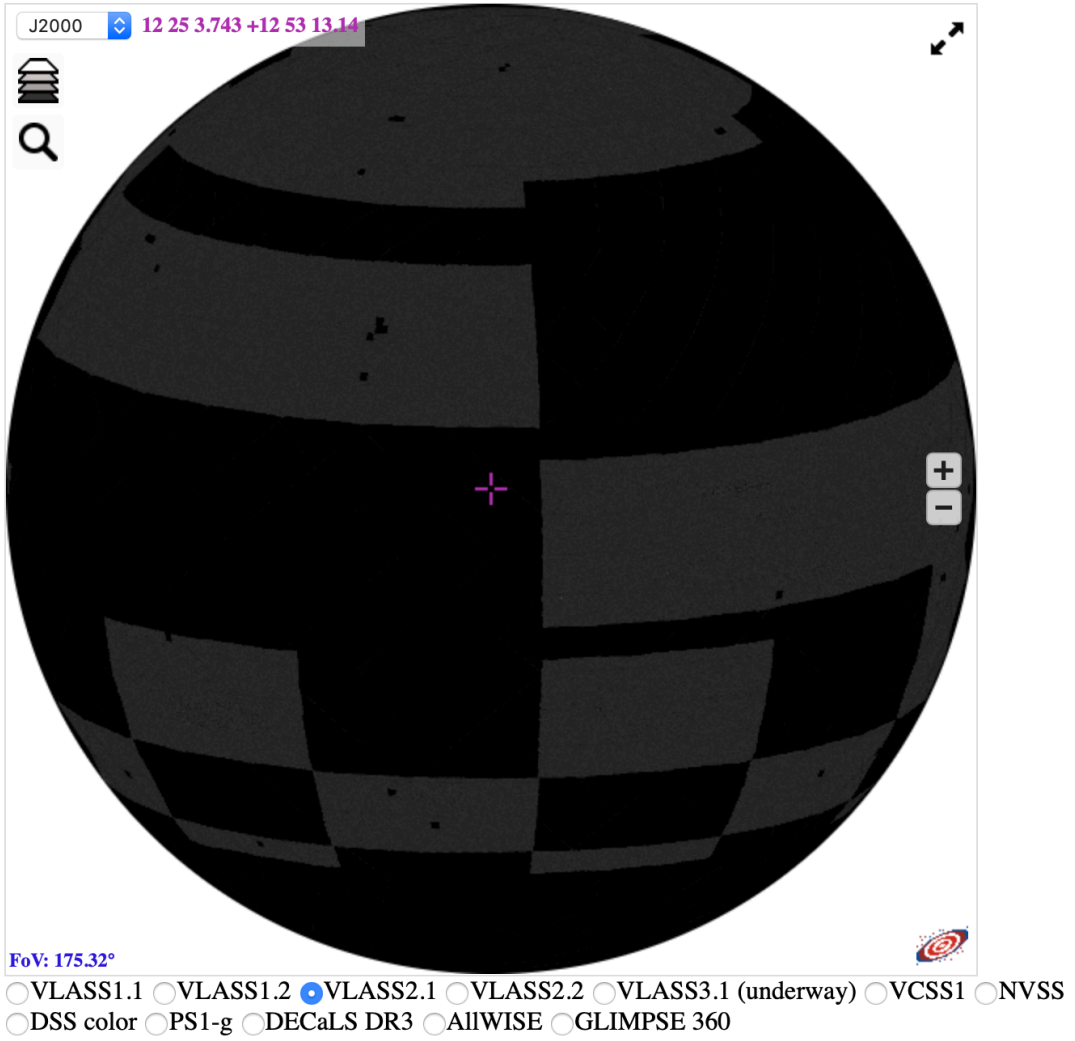
Broadening Participation in Astronomy

First Exploration: HiPS Images

- Interactive images (Aladin and AladinLite)
- Individual Epoch HiPS contain full FITS images (use these in Aladin desktop)
- “All Epochs” HiPS just points to these
- Plans to register these with CDS
- https://science.nrao.edu/vlass

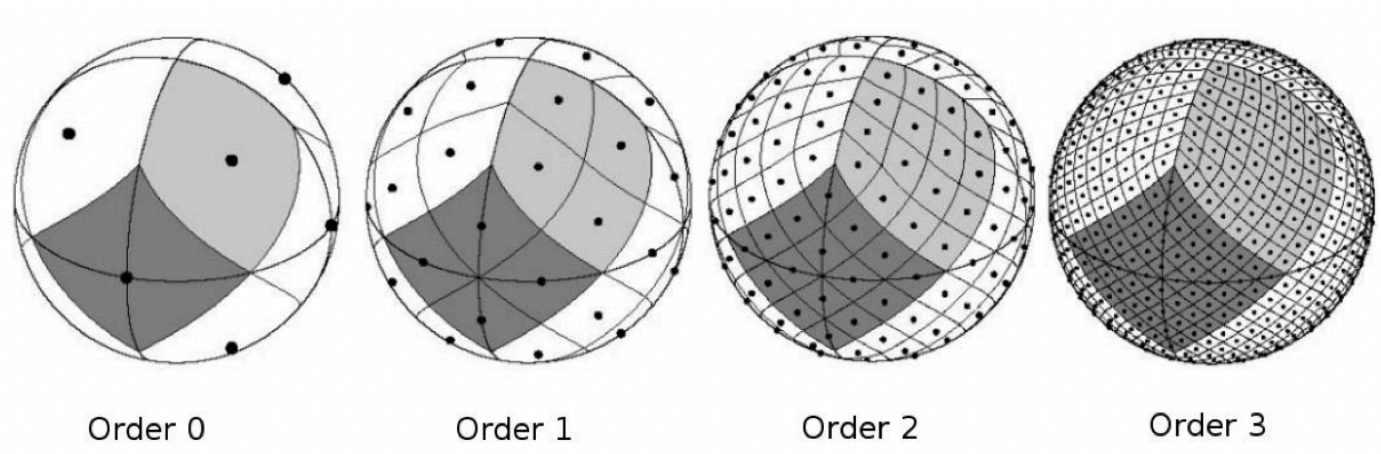
http://archive-new.nrao.edu/vlass/HiPS/All_VLASS/Quicklook/

VLASS Quicklook All Epochs interactive map



Aladin & HiPS

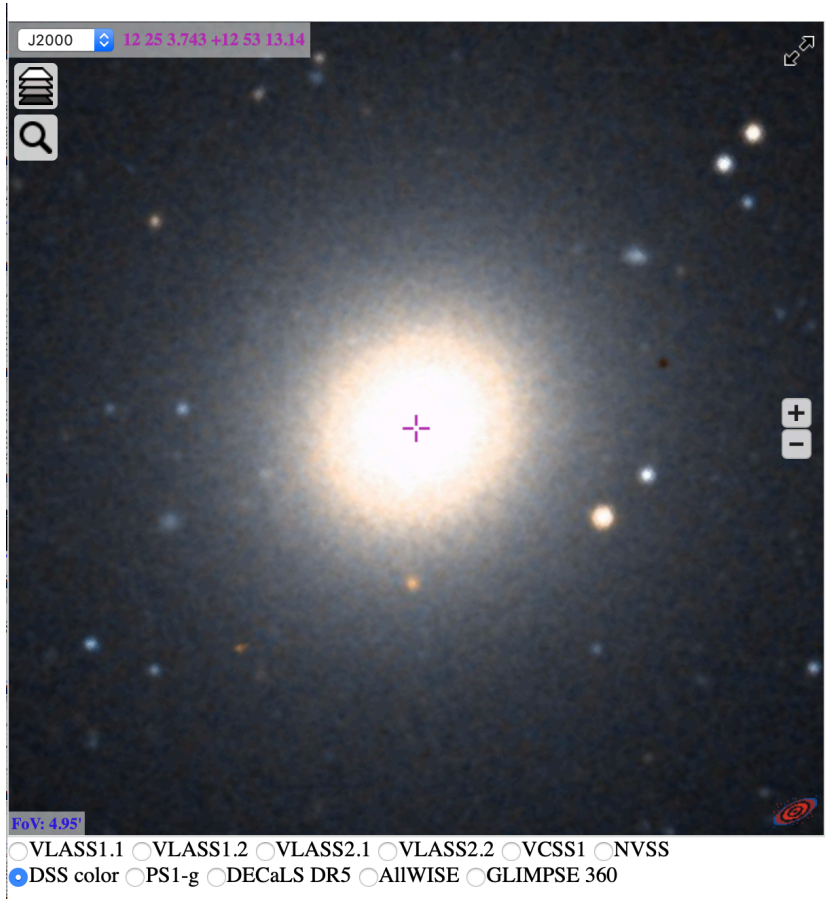
- Aladin (https://aladin.u-strasbg.fr) – generalized data visualization tool using VO standards
  - Desktop or browser-based (Aladin Lite)
- HIPS (Hierarchical Progressive Survey) – tiling of the sky based on Healpix
  - Images created at progressively higher “zoom” levels as in Google maps
  - VLASS implementation by Steve Myers (http://archive-new.nrao.edu/vlass/HiPS/)
- MOC – multi-order coverage map – like HIPS, but for survey footprints.

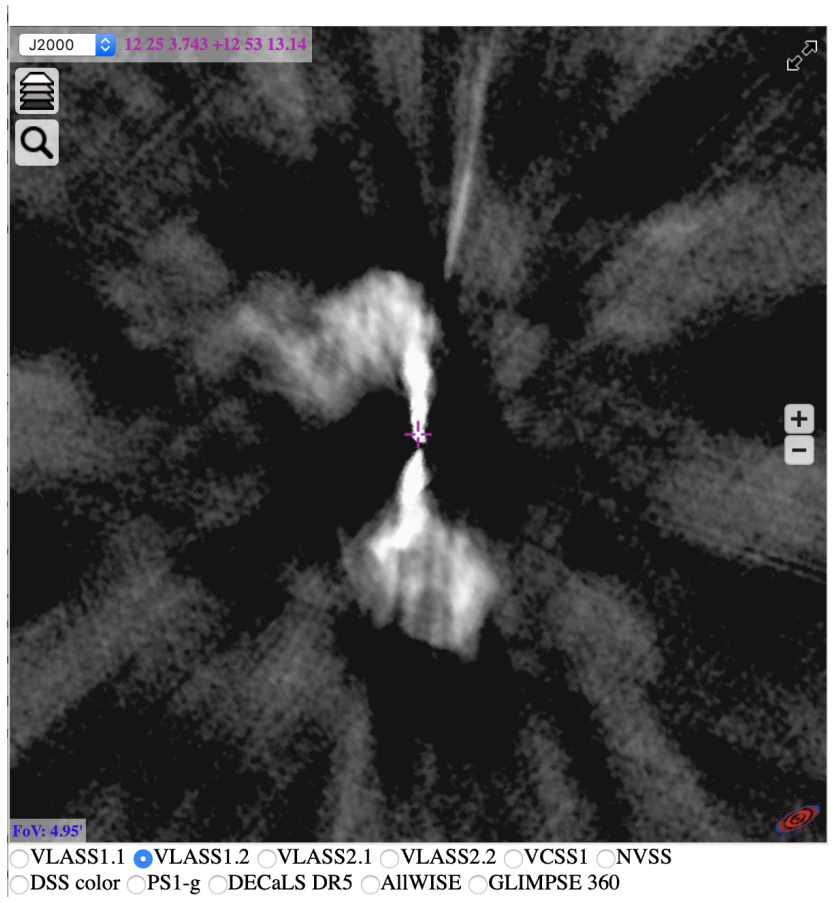


Explore: HiPS Images

- Zoom in to galaxy M84

High Resolution Survey!
Must Zoom far in to HiPS to see anything!



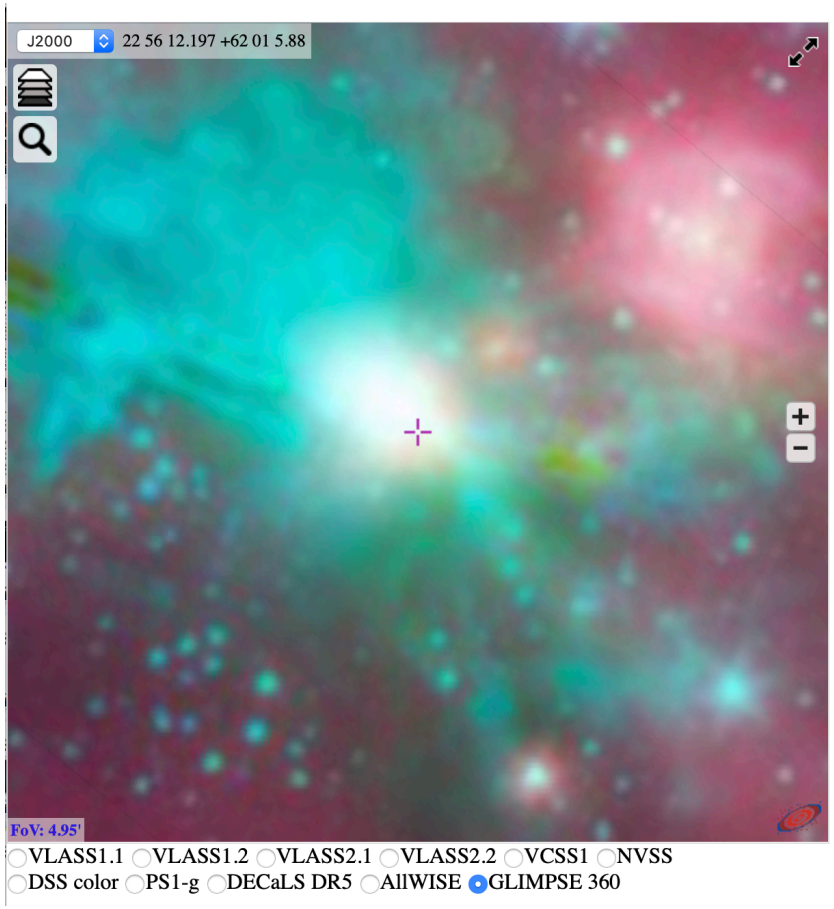


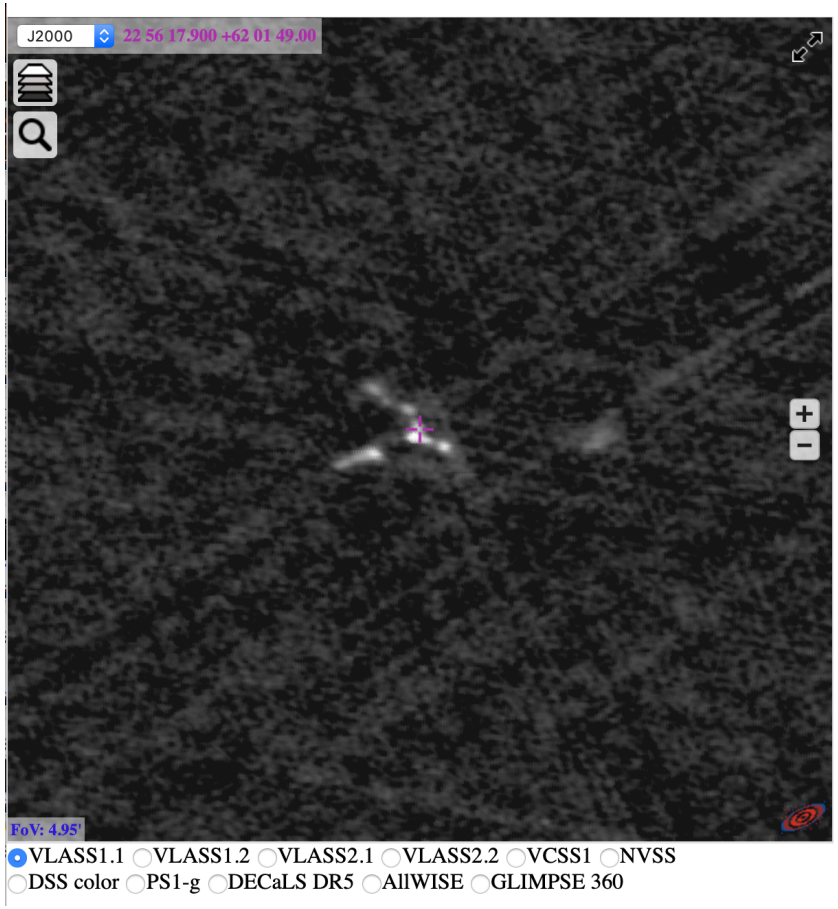
http://archive-new.nrao.edu/vlass/HiPS/All_VLASS/Quicklook/

Explore: HiPS Images

- Cepheus A (galactic star forming region)

B-configuration snapshot resolves out emission with size >30” (LAS)

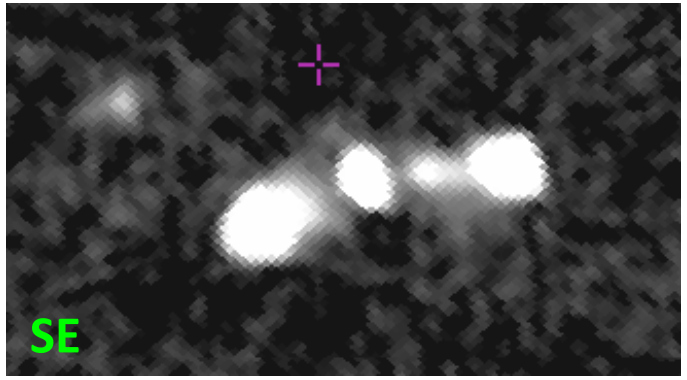


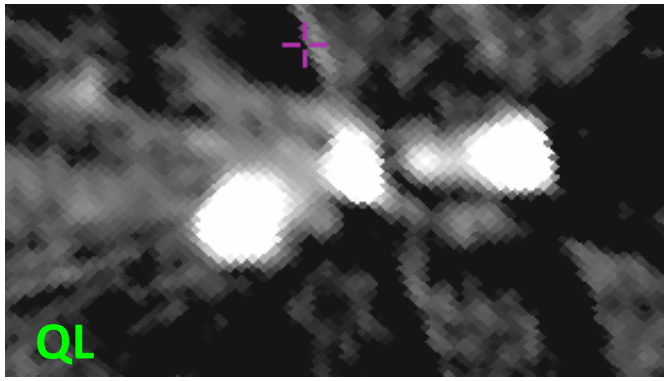


http://archive-new.nrao.edu/vlass/HiPS/All_VLASS/Quicklook/

New Exploration: SE HiPS Images

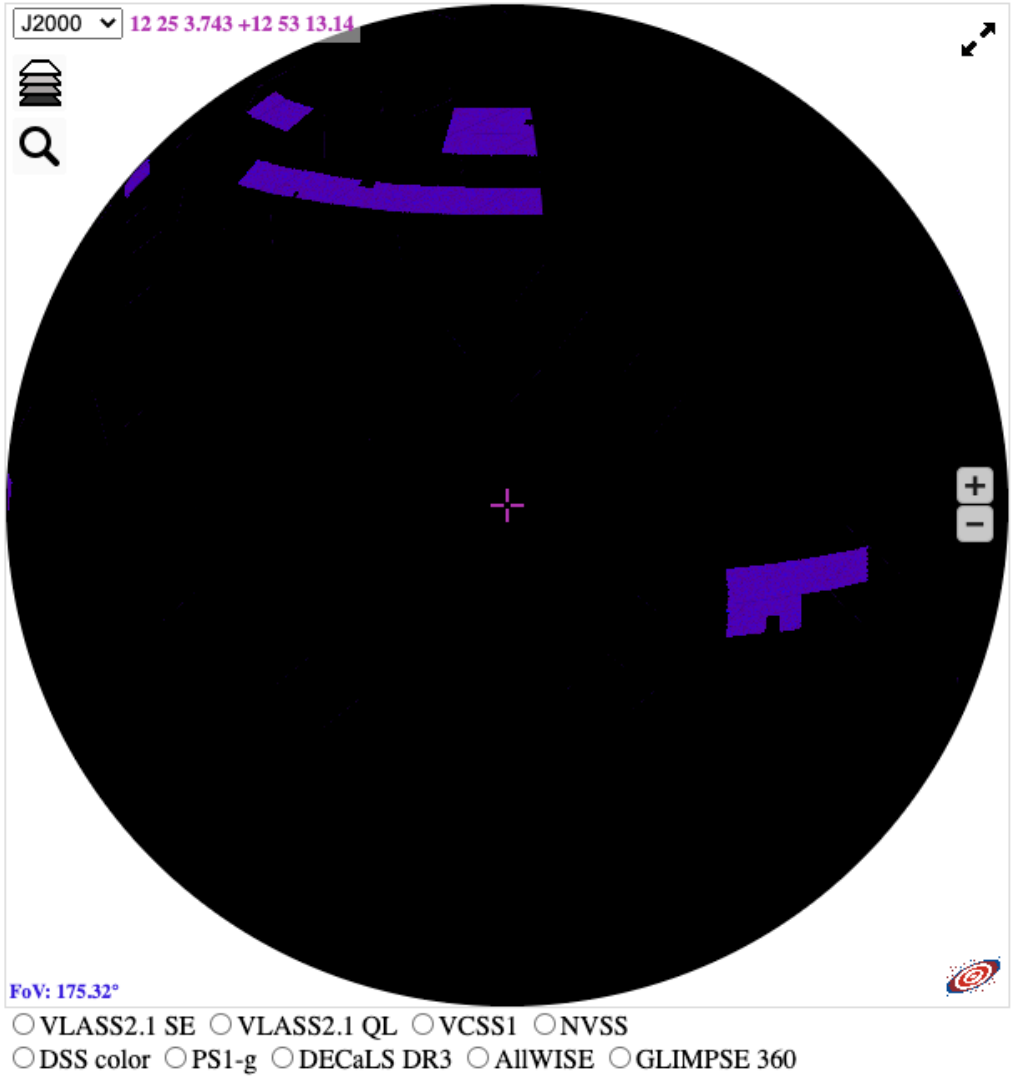
- Includes “demonstration release” of SE images made with special pipeline
- Allows SE and QL comparison





http://archive-new.nrao.edu/vlass/HiPS/All_VLASS/SingleEpoch/

VLASS SingleEpoch All Epochs interactive map



Summary

- Highest spatial resolution all-sky radio survey yet undertaken
  - Resolution critical for cross-identification with other wavelengths
  - Multi-epoch for transient & variability identification
  - Full polarimetry to reveal the magnetic universe

- First 2 observing epochs completed *(3rd epoch underway!)*
  - Raw data, calibrations, “QuickLook” images now available
  - Single Epoch Continuum & Cube Images in production “soon”
  - Combined Cumulative products: development underway

- Resources:
  - Survey science Paper: Lacy et al. (2020, PASP, 132, 5001)
  - Survey science website: https://science.nrao.edu/vlass
  - HiPS images: http://archive-new.nrao.edu/vlass/HiPS/
  - Technical memos: https://library.nrao.edu/vlass.shtml

VLASS At AAS242

https://science.nrao.edu/vlass/vlass-at-aas242

Splinter "An Explorer's Guide to the VLA Sky Survey (VLASS)"
Tuesday, June 6, 2023 | 9:00 AM - 3:00 PM MT
Meeting Rooms 15/16/32

329.07 Dillon Dong (NRAO) "Powerful young pulsar wind nebulae as extragalactic radio transients: the case of VLASS Transient J1137-0337"
Session 329. Neutron Stars
Wednesday, June 7, 2023 | 2:00 PM - 3:30 PM MT
Meeting Room 235

338.02 Trent Seelig (NRAO) "Automation of VLASS Quick Look Image Quality Assurance"
iPoster
Session 338. Large Surveys, Programs and Catalogs
Wednesday, June 7, 2023 | 5:30 PM MT - 6:30 PM MT
Exhibit Hall 3, Terminal Number: 16

VLA Sky Survey (VLASS)
Development and Operations at NRAO

Current VLASS Management Team

Project Director: Mark Lacy

Operations Lead: Amy Kimball

Project Scientist: **Steve Myers**

Technical Lead: Juergen Ott *(formerly John Tobin)*

Contributing Teams/Groups at NRAO

- VLA Operators
- VLA Data Analysts
- Algorithm Research and Development Group
- CASA Development Team
- Scientific Computing Group
- Pipeline Development Team
- Computing Information Services
- Education and Public Outreach Team
- VLA Schedulers
- New Mexico Systems Team
- Scientific Support & Archive Team
- VLA Science Support Group
- VLA User Support Group
- VLA Pipeline Operations Group
- Electronics Engineering Division
- Engineering Services Division