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The VLA Low-band Ionosphere and Transient Experiment (VLITE)

T. E. Clarke

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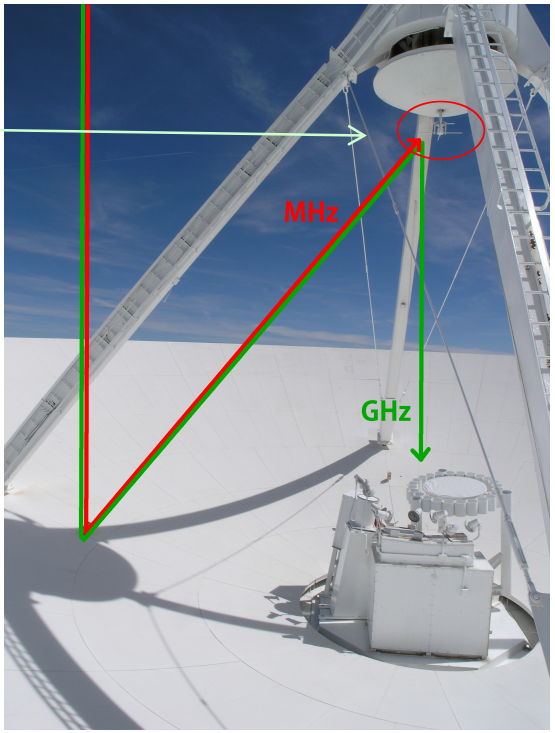
Jansky Very Large Array
Prime Focus Low-band System

Paul Harden (NRAO) holding P band (330 MHz) dipole feed.

- Feeds > 1GHz are Cassegrain, < 1 GHz prime focus
- Prime focus 330 MHz and 74 MHz feeds



Right: View of Cassegrain feed ring and P band dipole on NRAO VLA antenna.

TEC showing the new MJP 4 band feed.

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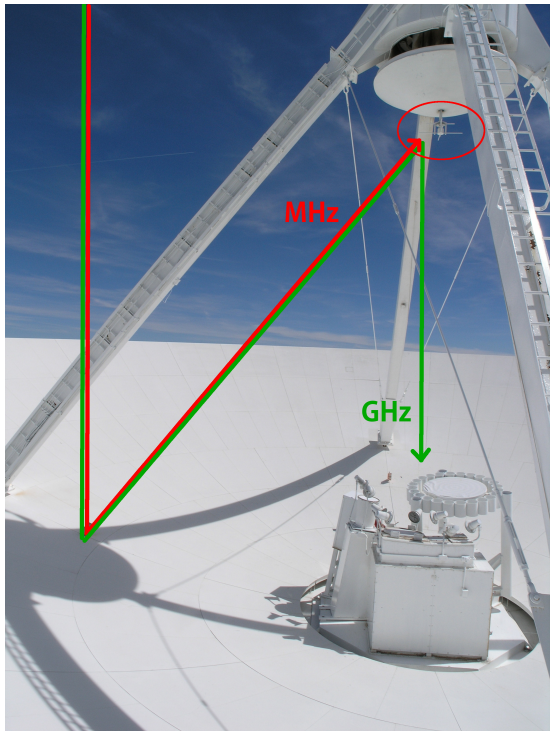
The Birth of a Commensal Low-band System



- **Opportunity:** simultaneous prime focus and Cassegrain with a new low band correlator
- 05/13 NRL proposed a commensal system with Navy funding ($1.1M + $0.5M 2017 upgrade)
- Dedicated samplers, fibers, and a custom DiFX software correlator running real-time

+2 years,
2017 upgrade

2013 2014 2015

May Nov Dec Apr Jun Sep Nov Feb

NRL proposed VLITE $$

SRR

PDR

CDR

Commissioning begins

10 antennas

Commissioning passed: Science operations begin

Final image fidelity tests

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VLA Low-band Ionosphere and Transient Experiment (VLITE)

- Correlates 330 MHz band for 10* VLA antennas

320<ν<384 MHz | $\Delta\nu_{chan}$ = 100 kHz | Δt = 2s

FoV ~ 12 square deg | 5” < θ < 3’ | 0.3 < σ < 10 mJy/bm | LAS ~ 1°

Data rate: 2 GB/hr -> 5 GB/hr | On-sky wall time: ~70% (actual)

Clarke et al. (2016)

*Upgrade: 1.5 years to on-the-fly correlator capability

2.5 years to 16 antennas

VLITE-16 became operational in 07/22/2017

- Minimal impact on VLA infrastructure & operations
- No impact on primary observer program resources

vlite.nrao.edu

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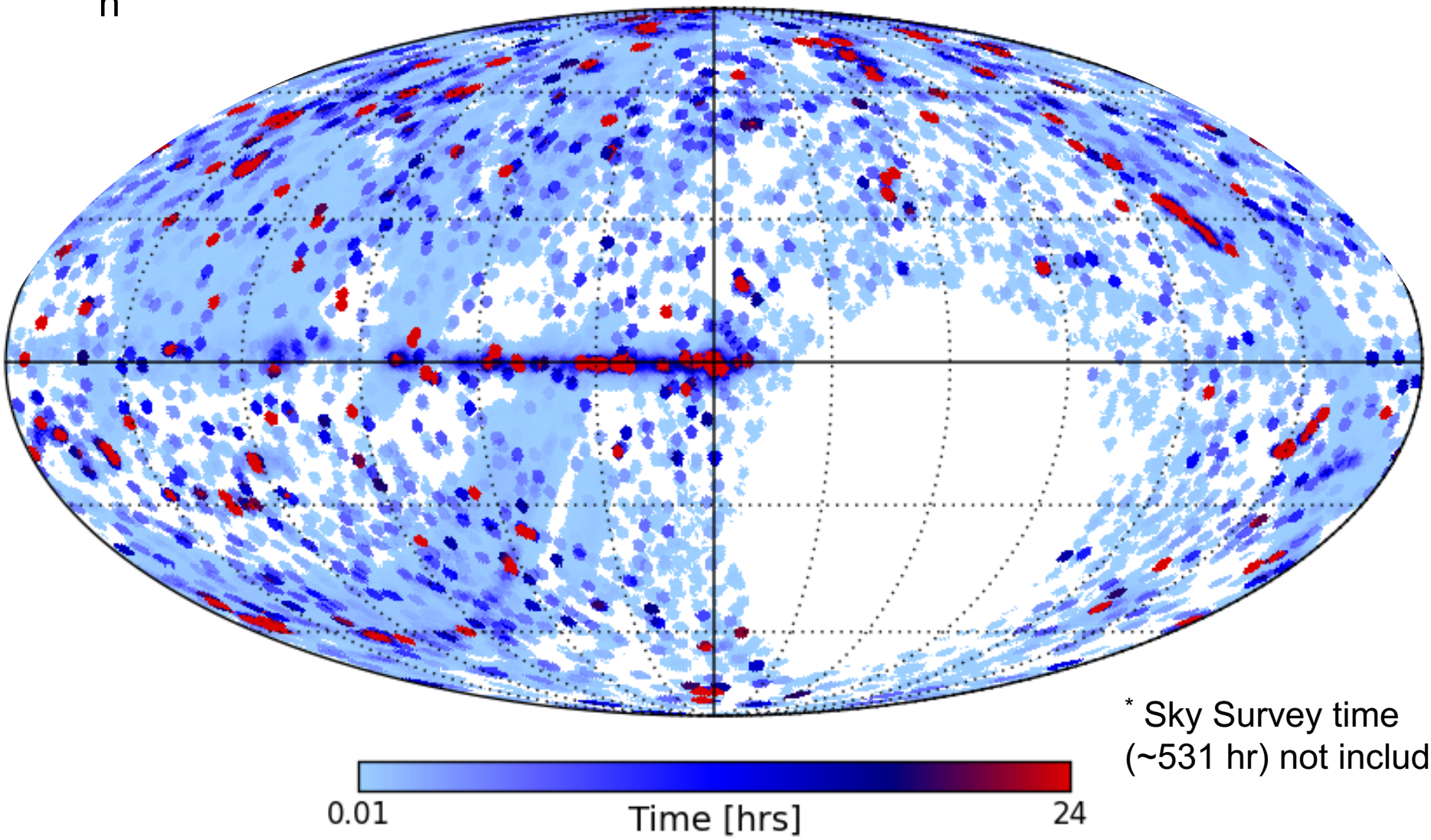
The Power of a Low Frequency Commensal System: Sky Coverage

3.1 years: 1,162,616 scans (19,525 hr), 71,797 images (~12,330 hr)*

VLITE 36 month δ>-40° : ~90% to > 30 s, ~50% to > 24 m, ~25% to > 2 h



* Sky Survey time (~531 hr) not included

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Why Build a Low Frequency Commensal System?

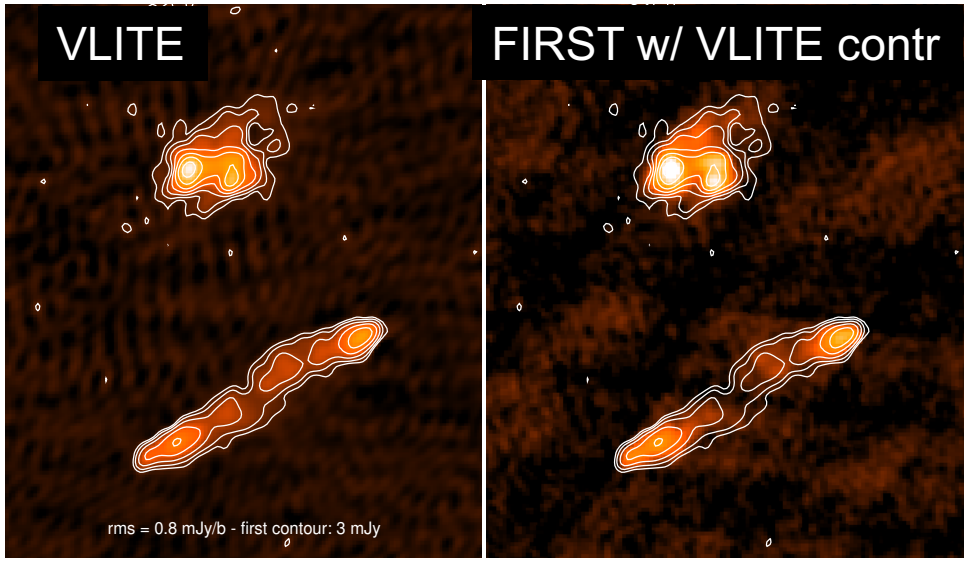
Experiment designed to demonstrate:

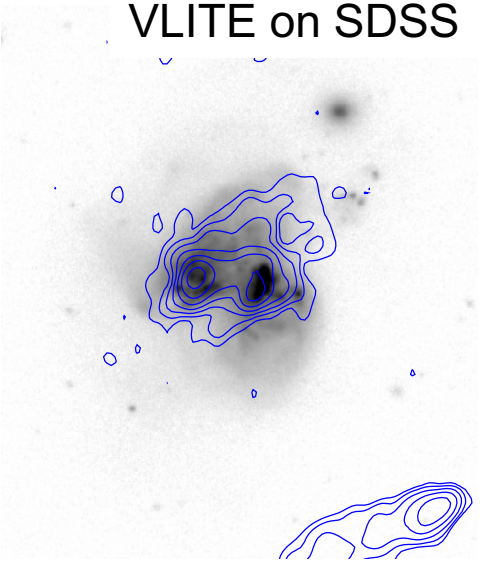
1)ionospheric monitoring – funds VLITE! (Helmboldt et al. 2017)

2)open phase space for slow and fast transients (Polisensky et al. 2016)

3)broad payoff: expanded PI science (e.g. morphology, spectral index), stand-alone science, serendipity, sky catalog (e.g. Giacintucci et al. 2018, Ogrean et al. 2015, Straal et al. 2016, Helmboldt et al. 2015)

Ultimate goal is broadband capabilities on the full 27 VLA antennas – the LOw Band Observatory (LOBO).





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A *Few* Complexities of a Low Frequency Commensal System

VLITE piggybacks under the strict requirement of non interference with JVLA

- No targeted VLITE observing beyond commissioning activities
- Calibrators supplied only by primary observer programs
- uv-coverage, time on source, observing location are all tied directly to higher frequency science program goals

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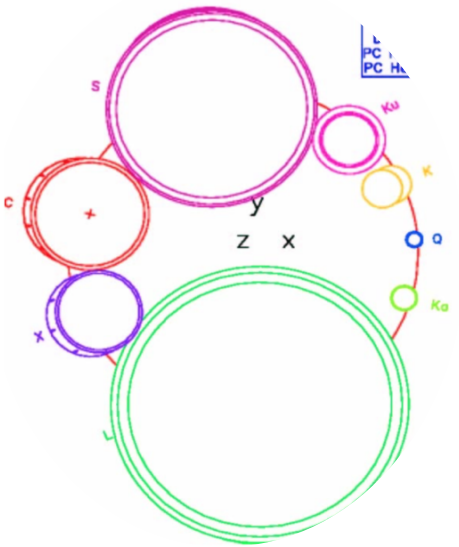
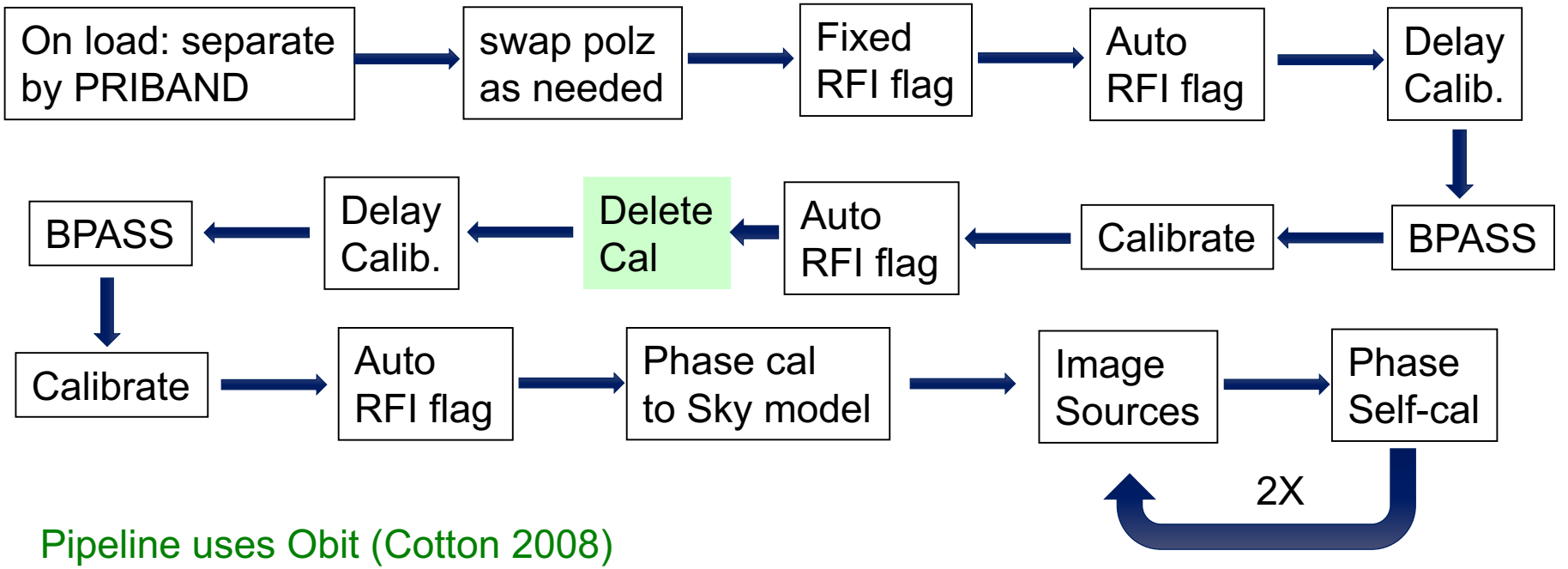
Pipeline Processing VLITE



- Processing is non-standard: pipeline must be functional over a wide range of operational cases
- Calibration relies on choices of higher frequency observer + subreflector focus and rotation

Overly simplified Pipeline flow



Pipeline uses Obit (Cotton 2008)

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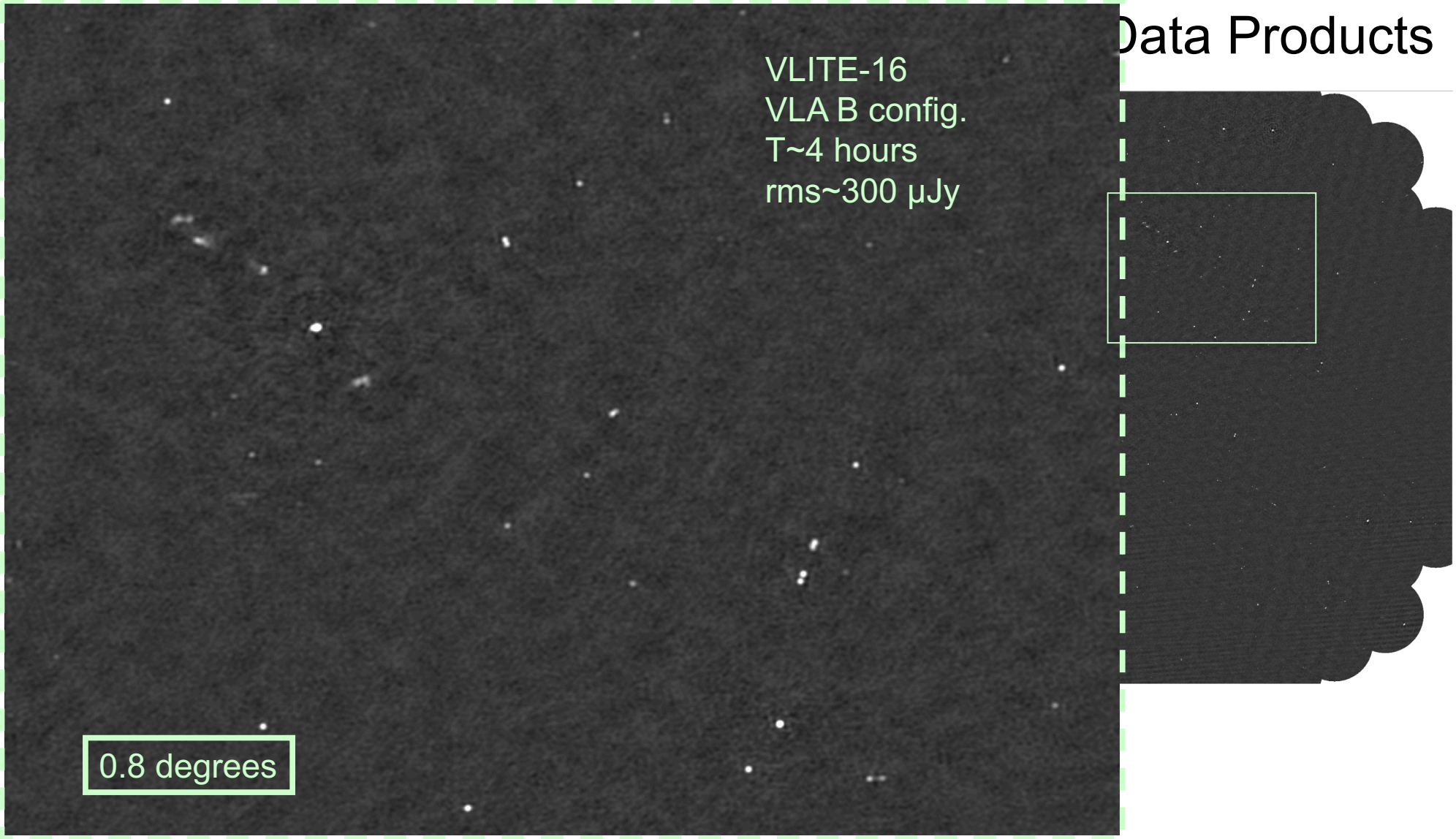
Commensal Complexities: Blind Imaging

Data Products



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On-The-Fly Observing with VLITE

NRAO is undertaking the next generation Sky Survey.

•VLA Sky Survey (VLASS): > 5400 hours for community-led multi-epoch (8 year span) 3 GHz on-the-fly (OTF) survey

- ✓ "Hidden explosions" and other radio transients
- ✓ Faraday tomography of the magnetic sky
- ✓ AGN and galaxy evolution in concert with new optical/IR surveys
- ✓ Peering through our dusty Galaxy
- ✓ "Missing physics"

•Initial Pilot testing in B configuration 2016

- ➢ VLITE was enhanced in 2016 to record VLASS Pilot data taken in OTF mode

✓Survey commenced in 09/2017 with full VLITE-16 operational

New VLITE processing pipeline developed specifically for sky survey.

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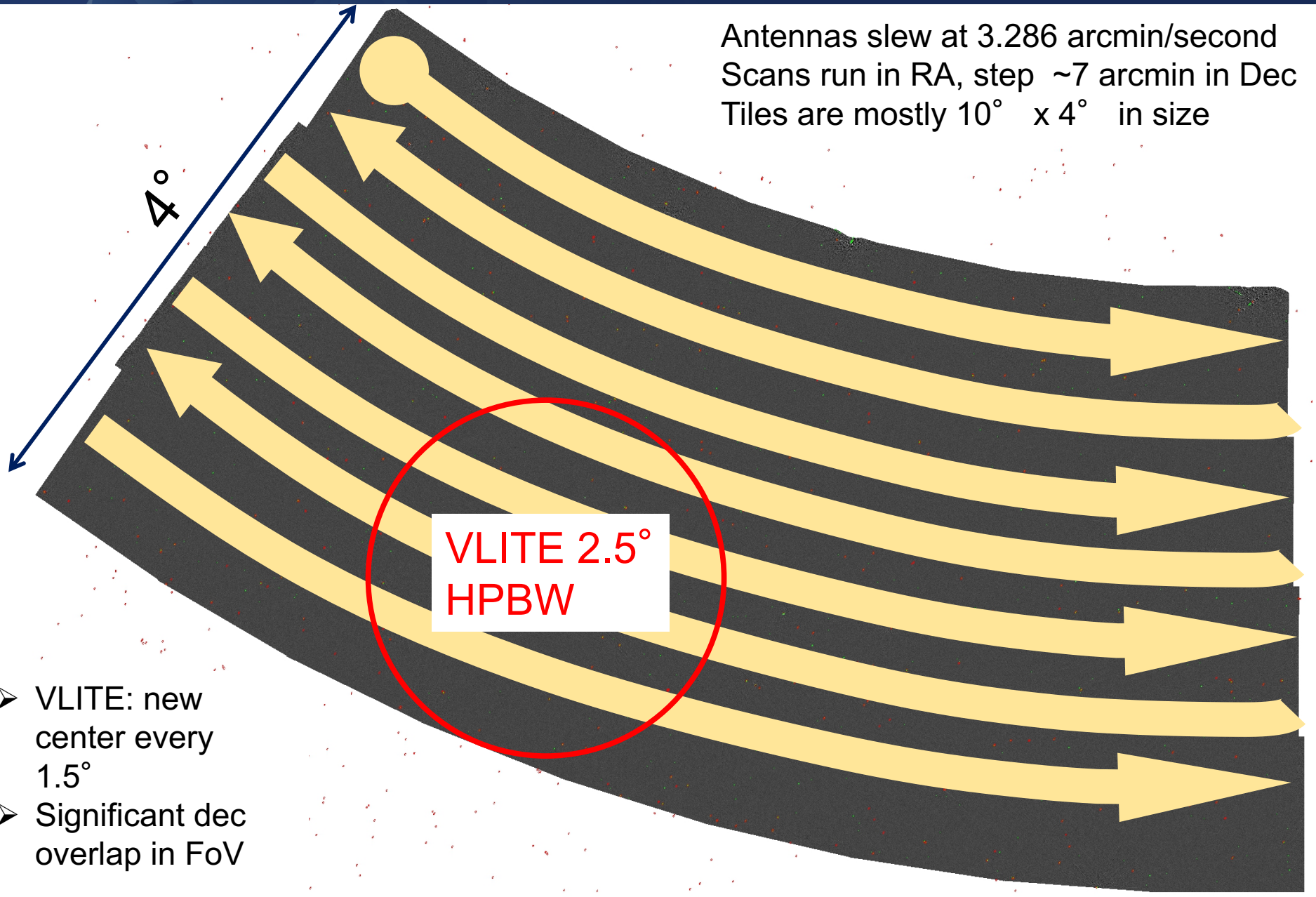
VLASS and the VLITE Commensal Sky Survey (VCSS)

Antennas slew at 3.286 arcmin/second
Scans run in RA, step ~7 arcmin in Dec
Tiles are mostly 10° x 4° in size



- VLITE: new center every 1.5°
- Significant dec overlap in FoV

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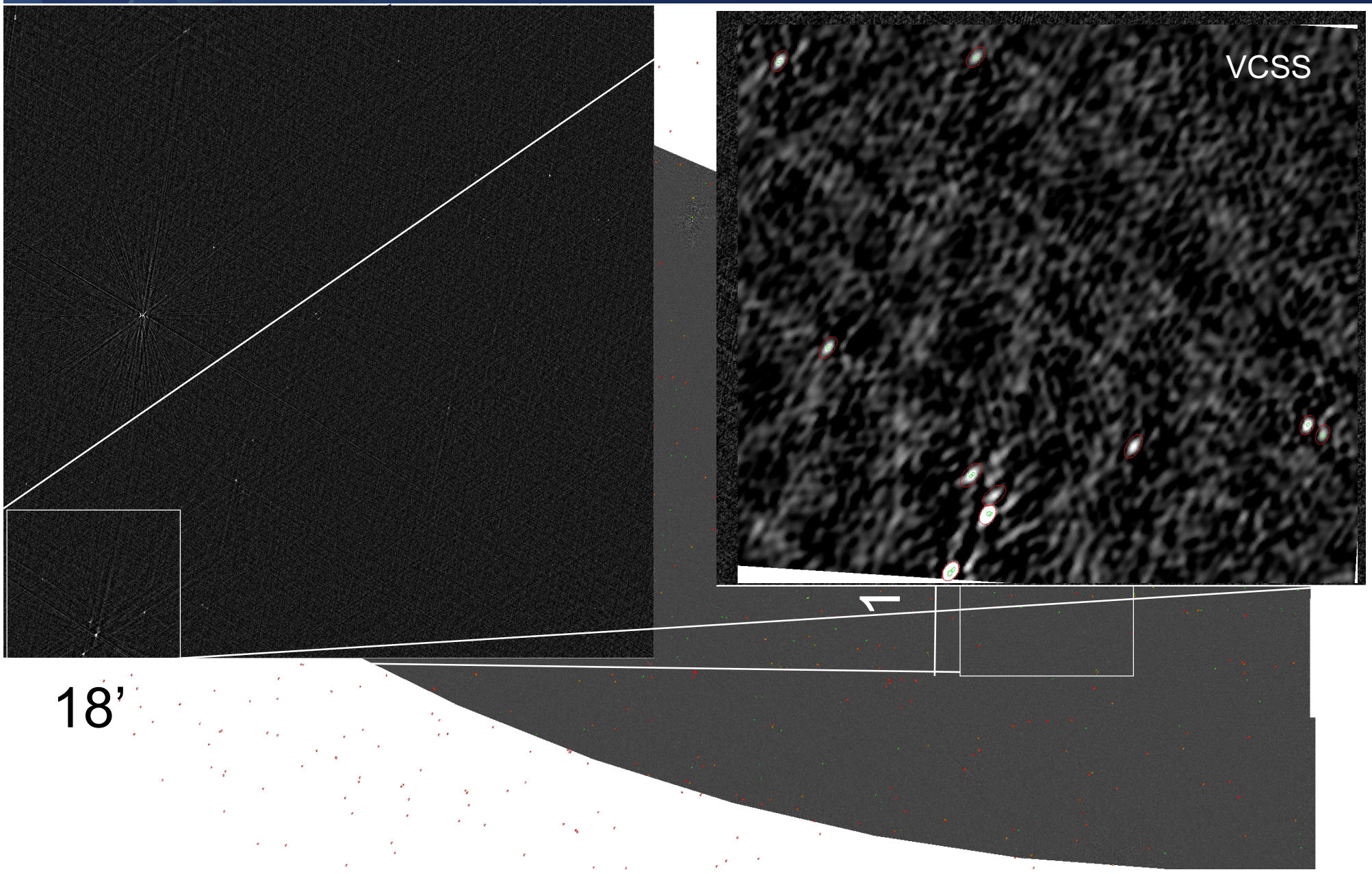
On-The-Fly Observing with VLITE: VLITE Commensal Sky Survey (VCSS)



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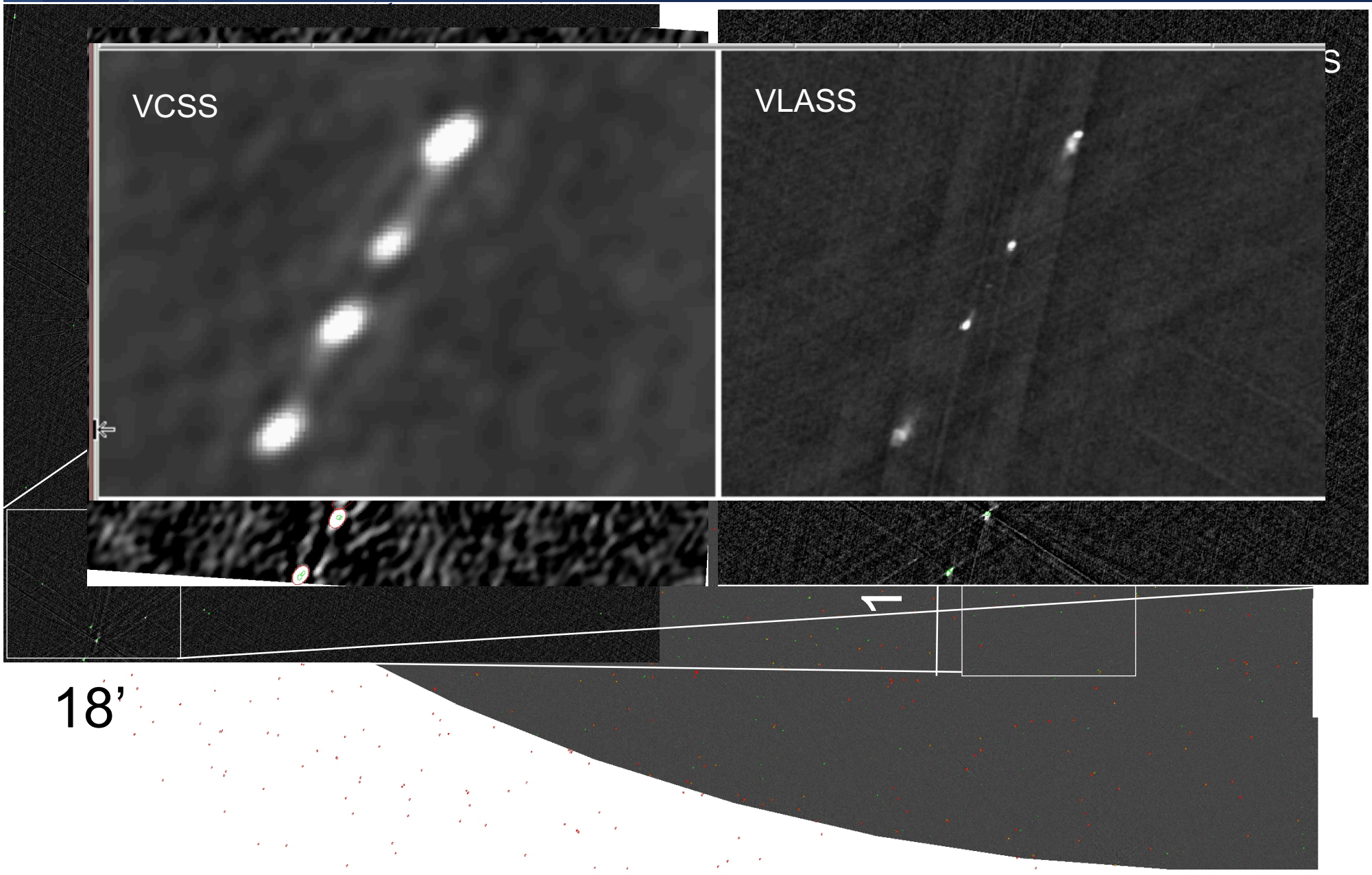

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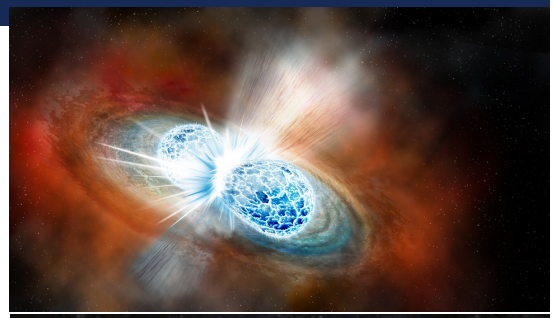
VLITE Transients: Fast and Slow

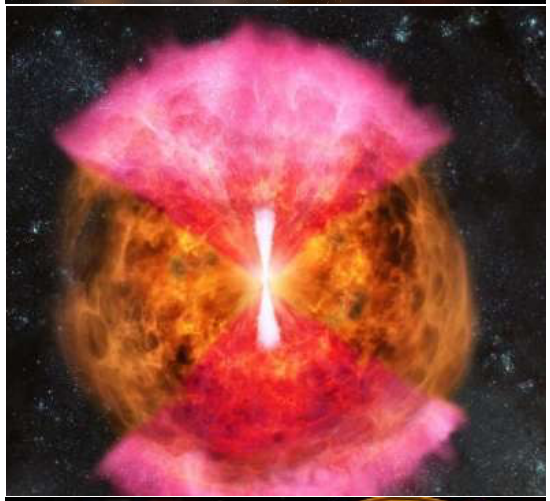
VLITE Slow: transients on scales of sec to yrs

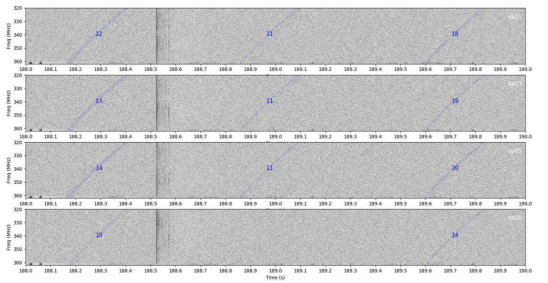
- initial search found known transients (SS443, V404 Cyg) but no new transients
- 3 year limits (Polisensky et al. 2018), no new detections, limits approaching predictions for several populations
- exploring exoplanet host systems (>70% of known systems are in VLITE images)

VLITE-Fast: parallel GPU-based pipeline capturing raw voltages on each VLITE-equipped antenna

- transients on 1-32 ms scales and dispersion to 1000 pc cm^{-3}
- running 24/7, buffer 60 sec of data and feed to heimdall for pulse searches. Trigger dumps buffer for off-line verification.







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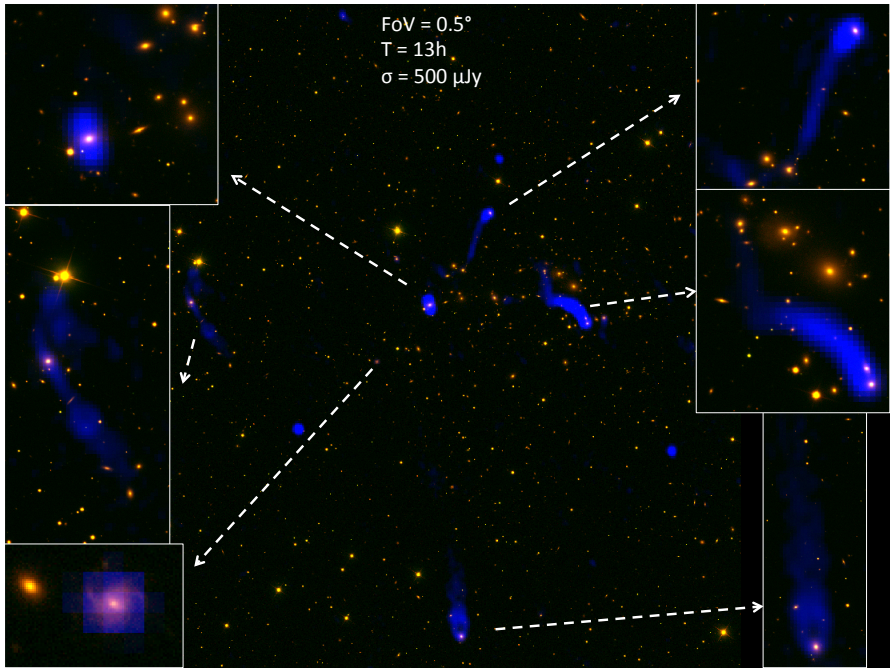
VLITE Operations, Archive & Products

- Astrophysics Pipeline: 1 day in 3-15 h, depends on config. + number of targets
- VCSS Pipeline in place, verification



Science Ready Data Products:

- Self-calibrated UV data for targets
- Multi-frequency image cube for target
- Single-frequency image for target
- 8-sigma source catalog

Current Status:

Data provided to all users on request. Manual processing as necessary to meet science goals. SQL database nearing completion (Emily Richards, NRC). Initial catalog release pending.

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What's Next?

- Increased automation of health diagnostics
- Global bandpass solutions
- Expand to 27 antennas (LOBO)

See Kassim talk

Postdoc Opportunities

- NRL has NRC postdoc opportunities for wide range of interested. Next deadline is Feb 1, contact myself (tracy.clarke@nrl.navy.mil) or Namir Kassim (namir.kassim@nrl.navy.mil).