Lessons Learned from Jansky VLA Science Operations

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The Karl G. Jansky Very Large Array

Reconfigurable array located in central New Mexico

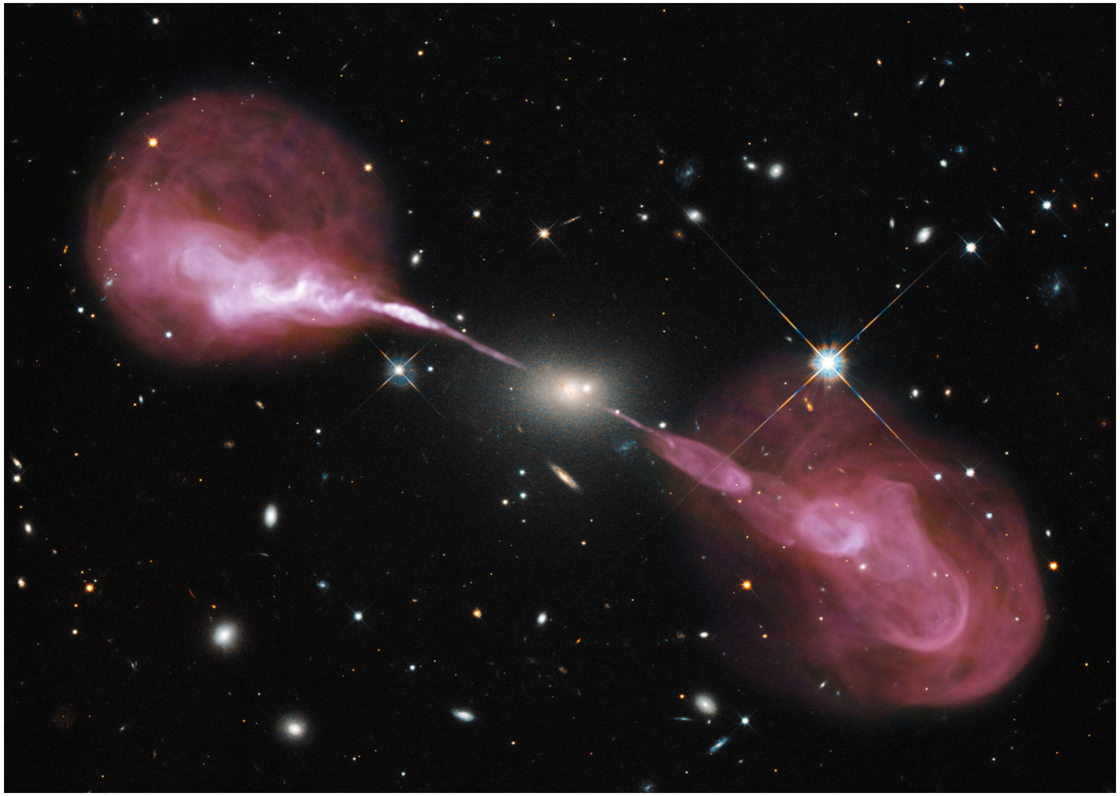
- 27x25m antennas in the shape of a Y, can be in one of four configurations, D (most compact, B_{max}~1km) to A (most extended, B_{max}~36km)
- Collecting area equivalent to a 130m aperture
- Field of view 45'/ν(GHz)
- Frequency range 350 MHz to 50 GHz
- Spatial resolution as high as 40mas (depends on ν and array configuration)

Capability improvements with the EVLA project

- Original VLA constructed in 1970's, fully operational 1980
- Jansky VLA → culmination of the decade-long Expanded Very Large Array construction project funded by the NSF, Canada, Mexico
- Multiplied by orders of magnitude the observational capabilities of the VLA
  - Full frequency coverage from 1 to 50 GHz
  - Up to 8 GHz/pol instantaneous bandwidth
  - New correlator with unprecedented spectral capabilities
- In full operation since Jan 2013, with new operational model:
  - Full dynamic scheduling including fast response for time domain science
  - New data reduction software (CASA)
  - Pipeline-calibrated visibility data
- New capabilities come with new challenges:
  - Continuum sensitivity improved by factor of 5-10 through increased bandwidth, requires new algorithms to correct for frequency-dependent primary beam, source spectral indices
  - Data volume!

New science enabled!

Hercules A: instantaneous spectral index information from wide fractional bandwidth



Credit: NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA)

SS433: high instantaneous sensitivity → movies of time variable sources

- 26 GHz emission from microquasar SS433, 0.095” (520 AU) resolution

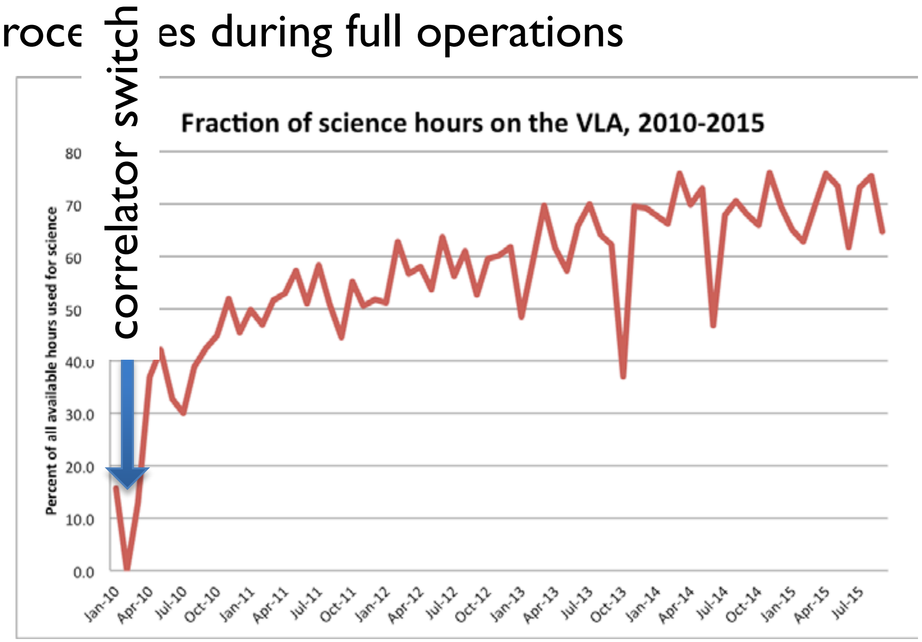
Credit: Mioduszewski & Miller-Jones, EVLA demonstration science

Challenges: length of EVLA construction

- Need to keep an engaged user community: NRAO Users Committee supported (demanded) continued access throughout EVLA construction project
  - Several years of operation with a mix of old VLA and new EVLA
    - Increased cost to the construction project (need to build special hardware to convert digital EVLA signals into analog signals needed by old VLA correlator)
    - "Challenging" data delivered to users (aliasing at band edges, limitations on Doppler tracking)
  - Minimum downtime
    - Only 7 weeks "official" downtime for correlator transition in 2010
    - Several weeks' worth of observations needed to be repeated (or have the data corrected) due to data quality issues at various times
      - Switch from MODCOMPs to linux-based online system
      - Bugs in the correlator software

Challenges: construction + commissioning + operations

- Need to maintain an operating instrument alongside construction and commissioning
  - Need to return to a functional astronomical system at the end of every work day
    - Handover procedures from Construction to Operations
    - System tests to verify functioning system
    - Continue to implement these proce es during full operations
  - Fraction of science hours lower during EVLA construction (60% prior to WIDAR) compared with old VLA (70%)
    - Back up to 70% now



Observing Programs during EVLA construction

- Goal: provide user access to new capabilities as soon as possible
  - New observing programs defined to go with new correlator (2010):
    - *Open Shared Risk Observing*
      - Well tested capabilities, steadily increasing throughout commissioning phase
    - *Resident Shared Risk Observing*
      - Early access to capabilities that are not robust or require extensive testing/development; required residency and commissioning effort
      - Helped to grow expertise in the user community
      - Injected energy into NRAO commissioning staff
      - RSRO program continues into full operations, per request from user community
    - *EVLA Commissioning Staff Observing*
      - Ensure NRAO staff working on EVLA commissioning have same access to RSRO capabilities as community
      - Reward for a decade of commissioning effort

Development of new capabilities continues…

- Observing programs for full operations:
  - *General Observing* (well-tested capabilities, available for all observers)
  - *Shared Risk Observing* (access to more flexible/advanced capabilities that can be set up and executed with existing obs prep/scheduling software but not well tested; test time provided to validate set-ups)
  - *RSRO* (but with relaxed residency requirements compared with EVLA construction)
- Using RSRO program to inform us what the community would most like to see next on the VLA; currently available through RSRO program:

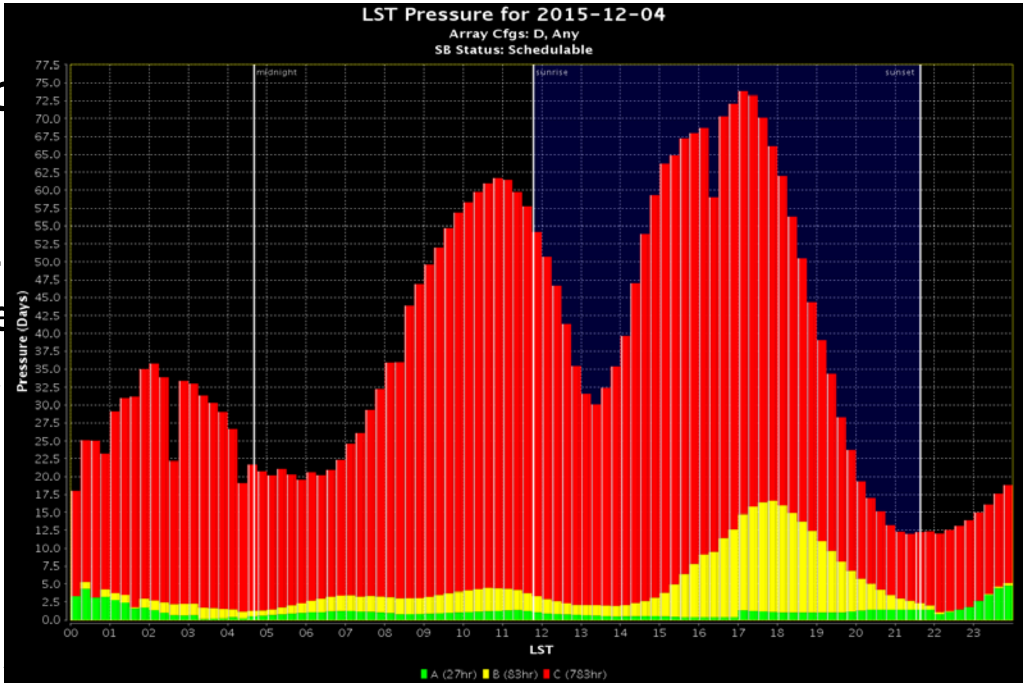
RSRO capabilities to be offered for semester 2016B	
Fast correlator dumps	Data rates >60MB/s
Phased array for pulsars	>1M channels
New 4-band system	Frequency averaging in CBE

New operational model for the VLA

Function	Old (→Dec 2012)	New (Jan 2013 →)
User support	Staff "friend", visits to Socorro	NRAO Helpdesk, visits to Socorro
Observation preparation	Stand-alone (J)Observe	Web-based Obs Prep Tool (OPT)
Scheduling	Mostly fixed-date	Fully dynamic
Data product	Raw visibilities	Raw+pipeline-calibrated visibilities
Data access	FTP	FTP/disk shipment
Post-process software	AIPS	CASA
Computing facilities	Home institution	50-node cluster in Socorro

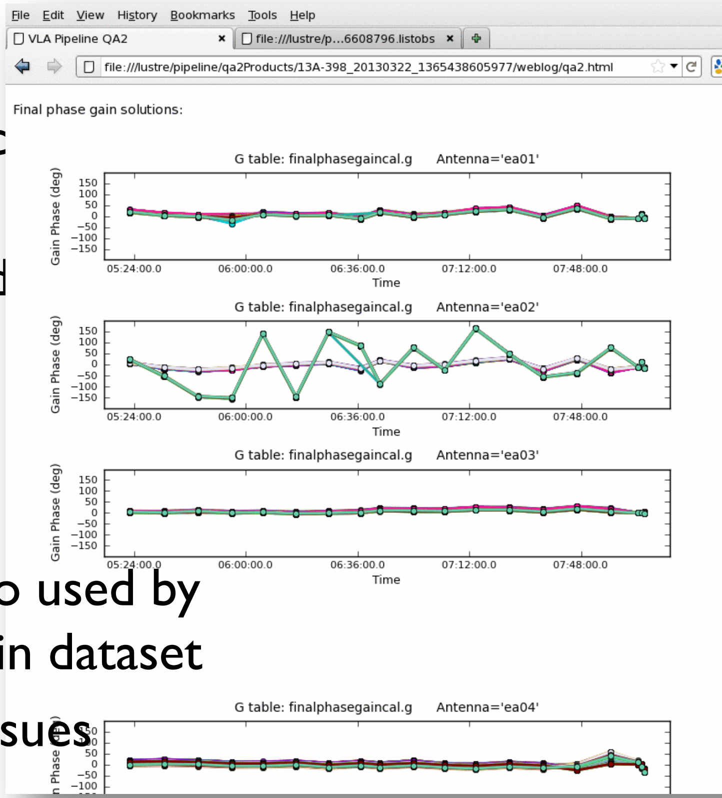
Operational model

- Full dynamic scheduling
  - Matches weather, phase stability, and other criteria to queue of Scheduling Blocks to improve observing efficiency
  - Enables time critical observations to be made within a few hours of triggering, if needed
- Pipeline-calibrated visib
  - Optimized for Stokes I
  - Excellent starting point
    experts to identify pote
  - Used by operations for
- Data access
  - Dataset sizes increased
    - Typical VLA ~1GB →
  - Disk shipment available for users with slow FTP connections



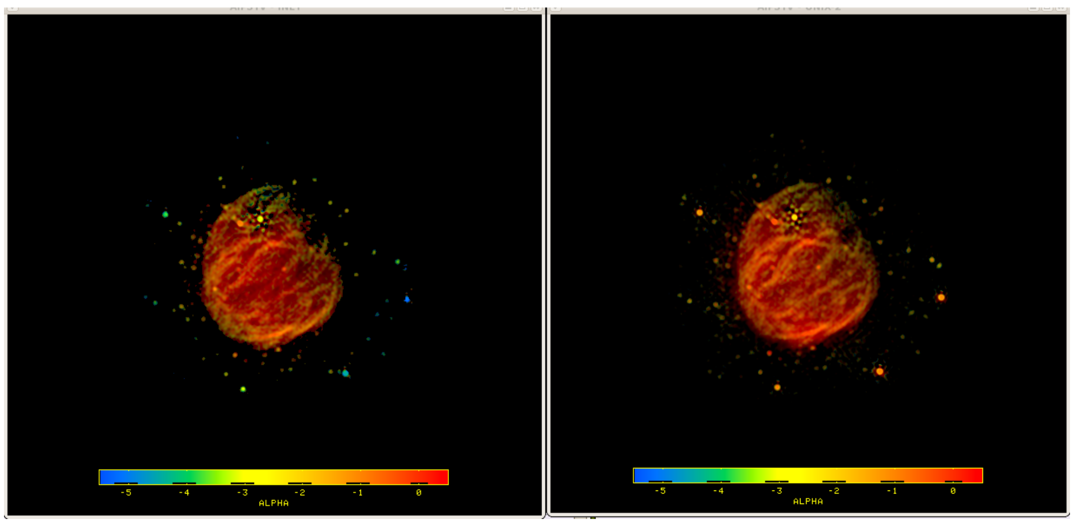
Operational model

- Full dynamic scheduling
  - Matches weather, phase stability, and other c Blocks to improve observing efficiency
  - Enables time critical observations to be mad triggering, if needed
- Pipeline-calibrated visibilities
  - Optimized for Stokes I continuum
  - Excellent starting point for novice users, also used by experts to identify potential problem areas in dataset
  - Used by operations for identifying system issues
- Data access
  - Dataset sizes increased by 1-3 orders of magnitude
    - Typical VLA ~1GB → JVLA ~10GB to ~1TB
  - Disk shipment available for users with slow FTP connections



Post processing challenges

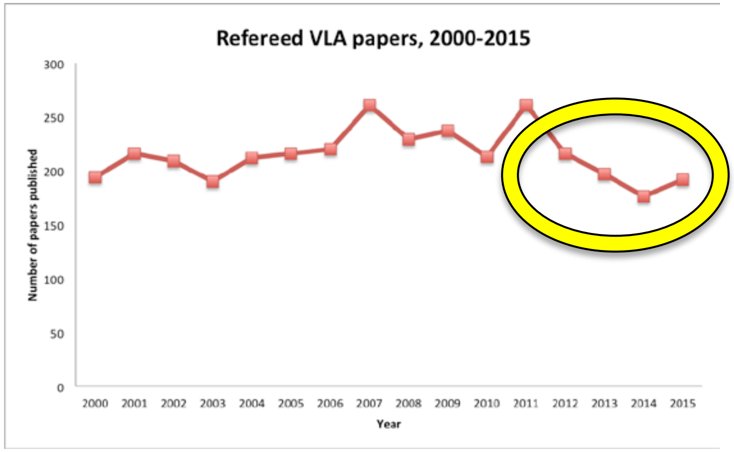
- Spectral indices of *all* sources need to be modeled to achieve expected sensitivity
  - "All" sources includes those outside primary beam, varying in time and frequency
- Primary beam varies across wide fractional bandwidths, impacts spectral index determination



Spectral index of 1–2 GHz emission from SNR G55.7+3.4, before correction for the frequency-dependence of the primary beam (left), and after correction (right) (Bhatnagar et al. 2011)

- Data volumes → imaging/self-cal for A-config can take weeks

The new challenge: how to avoid user community overwhelmed by JVLA data?



- Signal in last few years of decline in publication rates for VLA data
- User surveys indicate issues with data processing at their home institutions
- Solutions:
  - Provide remote access to our 50-node post-processing cluster and Lustre filesystem for data processing (a hint from 2015 stats that this is helping!)
  - Pipelined imaging along with a web-based interface for user-specified pipeline reprocessing on NRAO computing facilities
  - Ultimately: provide users with "Science Ready Data Products"
- The VLA Sky Survey: https://science.nrao.edu/science/surveys/vlass
  - Provide high-level data products for a multi-epoch, All-Sky, S-band (2–4GHz), full Stokes continuum survey
  - PDR/CDR and pilot in 2016
  - Survey to begin mid-2017, first data products mid-2018

Considerations for ngVLA

- JVLA→ngVLA transition: maintain engaged community
- Science program: "PI-led" vs. "survey mode"

PI-led	Survey mode
Innovation, ability to adapt to new fields of science	Limited number of well-defined modes
Increased complexity for SRDPs, increased burden on observatory science operations	Easier to provide SRDPs
Technically-engaged community, train next generation (e.g., RSRO)	Potentially reaches wider userbase

Must be driven by scientific impact!

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