EVLA Algorithm Research & Development

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Outline

- What EVLA needs (and when, and why)
- What we can do now – current limitations
- What will need to be researched – prognosis
- What people are doing now – highlights

- Next talk (Ed) – How we will organize and implement algorithm R&D

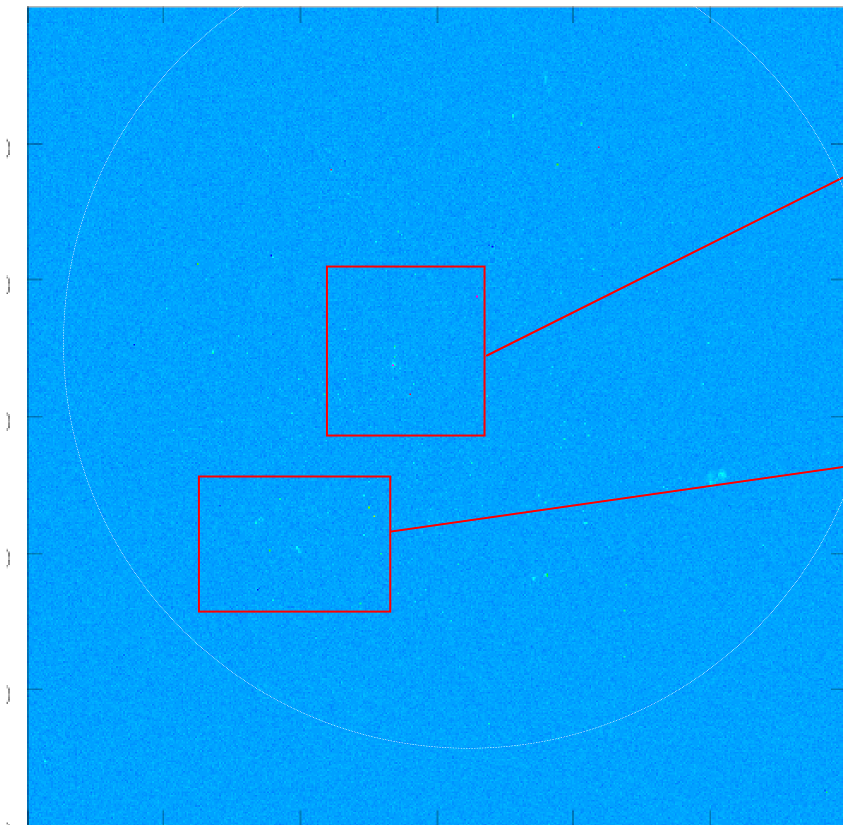
Focus

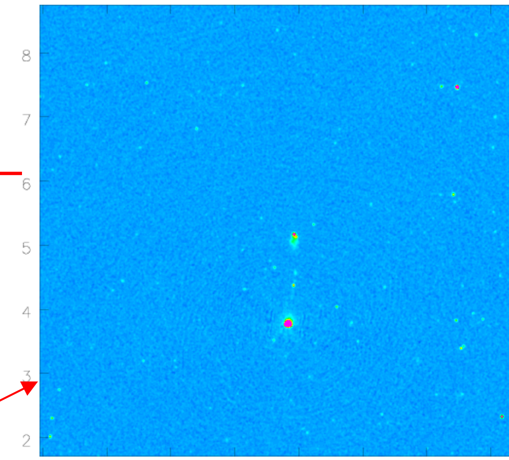
- Assess what our current limitations are
- Develop the algorithms for the things we do not yet know how to do
- Improve efficiency of existing algorithms, refactoring if necessary (parallelization)
- Implementation of algorithms is a separate responsibility (e.g. of CASA and AIPS)

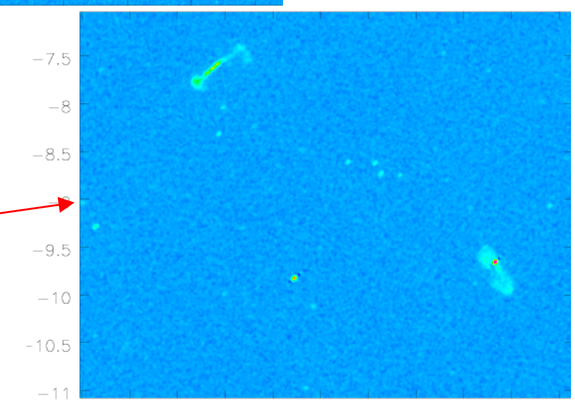
The Users Need to

- Use the full bandwidth of the EVLA for continuum sensitivity (1 μJy or better)
  - also image lots of spectral channels
- Image complicated emission in the entire field-of-view and beyond
- Deal with bright sources
  - want high dynamic range and fidelity ($>10^4$)

Example: Deep VLA Image (3μJy)







120h integration with Very Large Array

EVLA 3-10 times deeper in a couple hours!

SKA will go 10 times deeper in a few hours

Already limited by pointing errors?

The EVLA will provide

- High Data rates
  - 2008 spec 25 MB/s max (cf. VLA 0.1 MB/s)
  - sustained rate spec ramps up with time
  - WIDAR can produce much higher rates!
- Large Data Volumes
  - TeraByte datasets (25 MB/s = 2 TB/day)
  - thousands to millions of channels (16k – 4M)
  - will eventually need high-performance computing

How Much When?

- Near Term (2008)
  - 10 ant @ 1.5 GHz, commissioning, handle data
- Ramp Up (2009-2010)
  - implement and use current best algorithms
- Routine Use (2010-2012)
  - handle high-sensitivity wide-band continuum
- Full Operation (2012+)
  - improve efficiency to handle maximum data rates

Status Assessment

- High frequencies (above 18 GHz)
  - can handle modest bandwidth ratios (<1.45:1)
  - mostly will be calibration issues (atmosphere, pointing) with current methods ok
- Low frequencies (below 8 GHz)
  - need algorithms for bandwidth ratios up to 2:1
    - current limit ~ 10^5 dynamic range (100 mJy/1 μJy)
  - will require direction dependent calibration
    - current limit also ~ 10^5 dynamic range

How to Do It

- Full bandwidth continuum imaging
  - Multi-frequency Synthesis (MFS) at 2:1 BWR
- Full beam imaging
  - Wide field imaging problem at L-band
  - "peeling" of interfering sources
- Direction-dependent image-plane corrections
  - e.g. pointing offsets, polarization beam

all with high fidelity & dynamic range!

Who Is Doing It?

- wide-band high-fidelity imaging
  - Urvashi Rao-Venkata (PhD), with Cornwell, Bhatnagar, Golap, Myers
- wide-field full polarization imaging
  - Bhatnagar, Golap, Moellenbrock, also Cotton and Uson
- ionosphere
  - Abhirup Datta (PhD), with Bhatnagar, Myers
  - also LWA and Cotton, as well as LOFAR
- multi-scale deconvolution
  - various (Urvashi, Bhatnagar, Golap, Myers), also Greisen, Uson

Highlight: Wide-band imaging

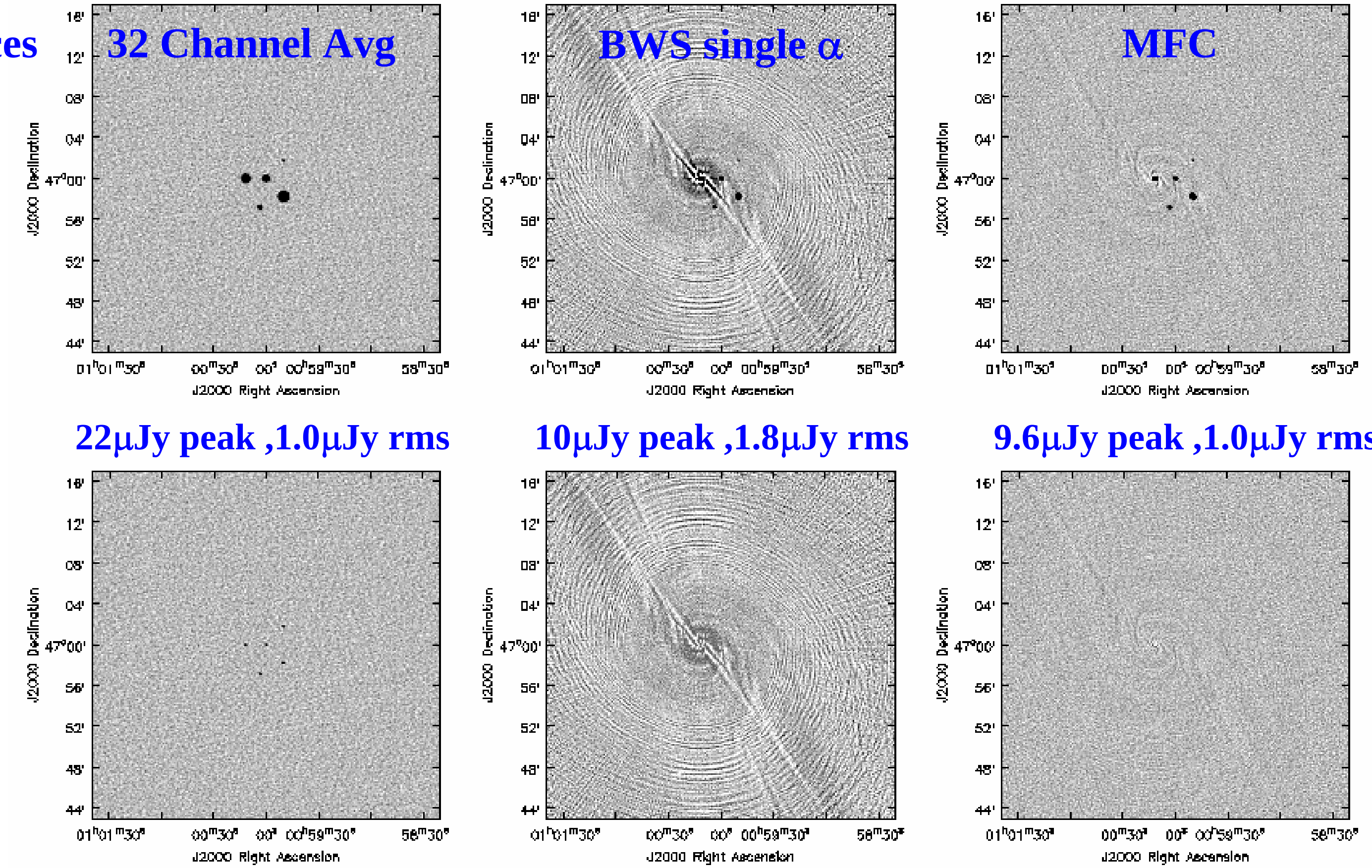
- Urvashi Rao-Venkata (NMT) PhD
  - with Cornwell, Bhatnagar, Golap & Myers
- The goals:
  - wide bandwidth continuum (1.3:1 – 2:1)
  - high dynamic range (1μJy with 100mJy peak)
  - varying spectral indices
  - extended emission
  - incorporate into CASA

Multi-Frequency Synthesis (MFS)

- Current State-of-the-Art:
  - see EVLA Memo 101
  - "channel-average" methods too limiting in sensitivity
  - Conway/Cornell/Sault MFClean (Miriad) works OK to 30% bandwidth for power-law spectra
  - "Hybrid" methods (chan-avg + MFC) promising (focus of current work), probably "good enough"
  - BUT: need to combine with multi-scale

Wide-band Now: EVLA Memo 101

Point Sources
α = 0.5-1.6

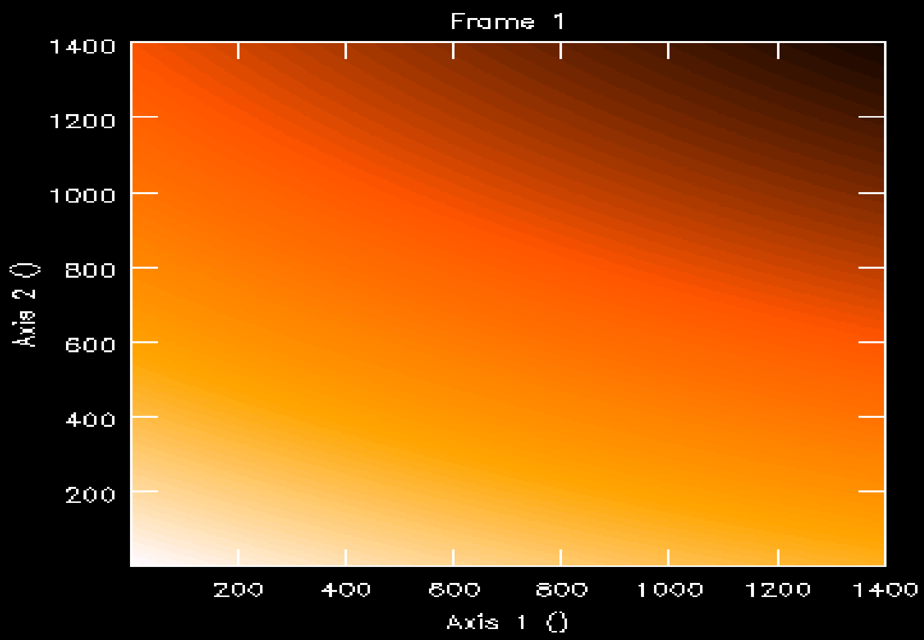


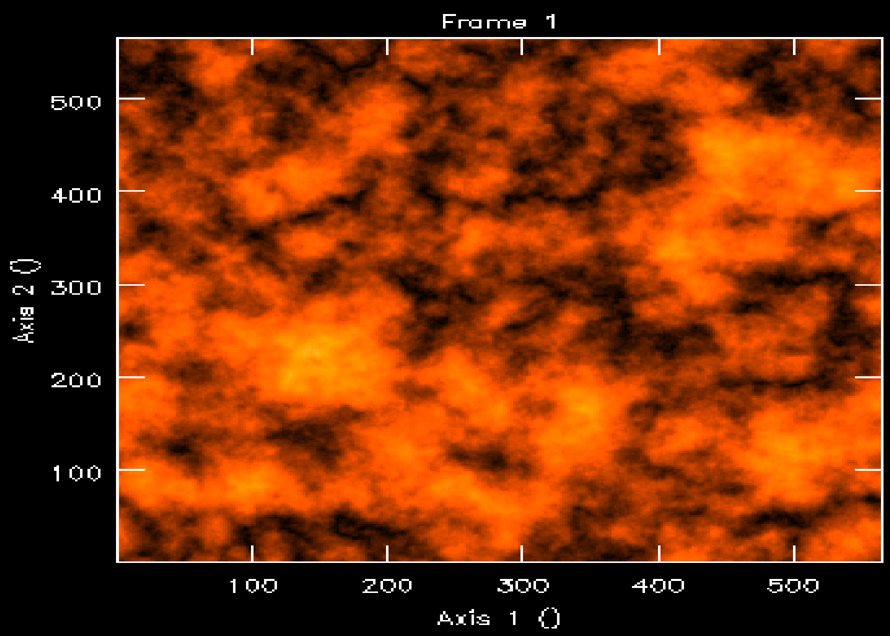
dyn range ~ 10^5

Highlight: Ionosphere

- Abhirup Datta (NMT) PhD thesis
  - with Bhatnagar and Myers (& LWA)
  - also previous work by Cotton & others
- Goals:
  - simulation of ionosphere
  - reconstruction of "phase screen"
  - determine current limitations for EVLA above 1 GHz
  - reconstruction of ionosphere volume
  - collaborate with LOFAR and ionosphere community

Simulated Phase Screen





Present:

- Single (time-variable) Gradient (dominant) & Curvature – good enough above 1 GHz?

Future:

- Typical turbulent screen
- Needed for A-config below 1GHz

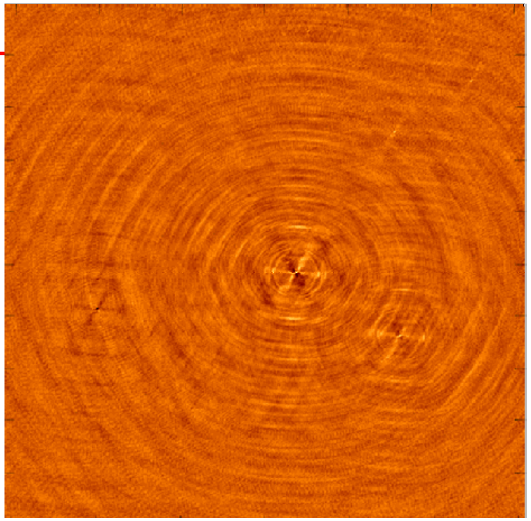
Wide-field High-fidelity imaging

- Sanjay Bhatnagar and Kumar Golap
  - also George Moellenbrock for calibration issues
- Goals:
  - w-term for low-frequency wide fields
  - mosaicing for higher frequencies
  - direction-dependent polarization and beam effects
  - “peeling” out of bright sources in sidelobes
  - incorporate into both calibration and imaging

W-f H-f progress

- Basic W-projection implemented
  - see EVLA Memo 67 (Cornwell, Golap & Bhatnagar)
  - measured speed-up for VLA-A, L-Band: up to x10
- Implement direction-dependent calibration
  - pointing self-cal implemented (EVLA Memos 100, 84)
  - need more trials on real data (vs. simulations)
- Polarized primary beam in imaging
  - investigated in EVLA Memo 62 (Cornwell)
  - PB application during gridding done (pointing selfcal)
  - Next: extend to frequency-dependent polarization beam

Pointing Self-cal: Expected performance



- See EVLA Memos 100 & 84
- Simulation of EVLA observations at 1.4GHz
- Residual images
  - Before correction: Peak 250µJy, RMS 15µJy
  - After correction: Peak 5µJy, RMS 1µJy
- Can incorporate into standard self-calibration procedures
- Computational cost ok for now
- Implementing in CASA by Bhatnagar
  - testing underway

EVLA & ALMA

- Some of the issues are in common
  - wide-field mosaicing (but not w-projection)
  - multi-scale deconvolution
  - direction-dependent effects (e.g. pointing, pol beam)
  - "advanced" polarization calibration issues
- Multi-use development
  - CASA development is by same integrated team

Summary

- Have good algorithm research group
  - just need their time & effort
- Key goal – enable use of full EVLA sensitivity
  - wide continuum bandwidth, lots of spectral channels
  - high dynamic range & fidelity calibration and imaging
- Deal with high data rates & volumes
- Other issues: RFI, Data Mining, pipelines