EVLA Algorithm Research & Development

Progress & Plans

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Requirements

- Full beam, full bandwidth, full Stokes noise limited imaging!
- What will it take to do the above (algorithmic requirements):
  - Wide field imaging problem at L-band (the W-term)
  - Multi-frequency Synthesis at 2:1 BWR
  - PB corrections: Time varying pointing offsets & PB rotation, Polarization
  - High DR ~10^6:
    - Scale & frequency sensitive deconvolution

Requirements

- Calibration: Algorithm development for Pointing SelfCal
- Band pass calibration:
  - Per frequency channel solution
  - Polynomial/Spline solutions (ALMA requirements)
  - Multiple spectral windows
- Polarization leakage
  - Frequency dependant leakage (time dependant?)
  - Beam polarization correction (done during imaging)
- RFI
  - Strong: Auto-, Semi-auto Flagging
  - Weak: Research problem

Imaging limits

- Limits due to asymmetric PB rotation at L-band
  - In-beam max. error @~10% point: 15μJy/beam (few x1000:1)
  - First sidelobe: ~3-4x higher
  - Less of a problem for single pointing observations at higher frequency (>C-band)
    - But similar problem for mosaicking at higher frequencies
- Limits due to antenna pointing errors
  - In-beam and first sidelobe max. error: ~10μJy/beam (few x1000:1)
  - Similar error for mosaicking at higher frequencies

Imaging limits

- Frequency dependence of the sky and the primary beam
  - PB dependence can be modelled or measured
  - Sky dependence needs to be solved for during imaging
- Limits due to PB-scaling across the band
  - Dominant error for wideband imaging
- Limits due to widebands (Spectral Index effects)
  - L-band: 10-15μJy/beam (2:1 BWR)
  - Less of a problem at higher bands, except for mosaicking

Algorithmic dependencies

- Problems of wide-band, full-beam, full-Stokes imaging related
  - Full wide-band high dynamic range imaging requires Scale & frequency sensitive deconvolution + PB-corrections
  - Techniques for full Stokes imaging are same as those required for PB-corrections/PB rotation
  - Mosaicking requires pointing and PB-rotation corrections (overlaps with ALMA)

Challenges

- Significant increase in compute load due to more sophisticated parametrization
  - Incorporate direction dependent effects
  - Scale sensitive deconvolution
- Typical data size (10x by 2014):
  - Peak 25 MB/s (~700GB in 8h)
  - Average 3MB/s (~85GB in 8h)
- Data volume increase => I/O load
  - Deconvolution typically requires ~20 accesses of the entire data (typical disk I/O rate: 30-100MB/s)
  - Each trial step in the solvers => full access

Plan (from last year)

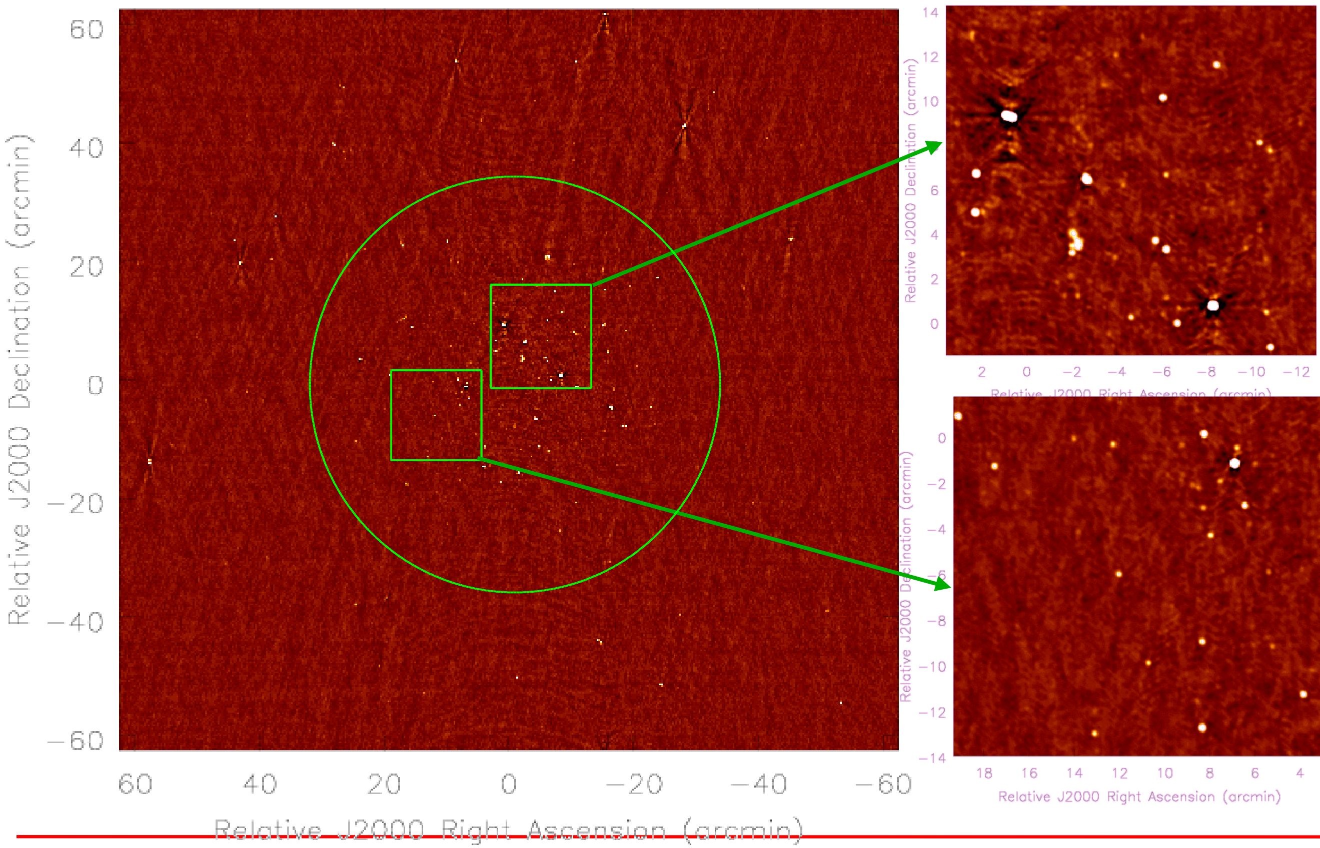
- Wide field imaging
  - W-projection algorithm: An improvement over the image-plane faceted algorithm: 3-10x faster
  - Implemented [Done/Tested](EVLA Memo 67; Cornwell, Golap, Bhatnagar)
- PB corrections
  - PB-projection algorithm [Done/Testing]
    - PB/In-beam polarization correction (EVLA Memo 100; Bhatnagar, Cornwell, Golap)
    - Pointing SelfCal [Testing] (EVLA Memo 84; Bhatnagar, Cornwell, Golap)
    - Extend it for frequency dependent PB/Sky

Plan (from last year)

- Initial investigation for deconvolution [Done] (EVLA Memo 101, Rao-Venkata & Cornwell]
- Scale & frequency sensitive deconvolution [Work in progress]
  - The code in C++ works – but as a Glish client
  - Extend it for frequency dependent components

Wide field imaging

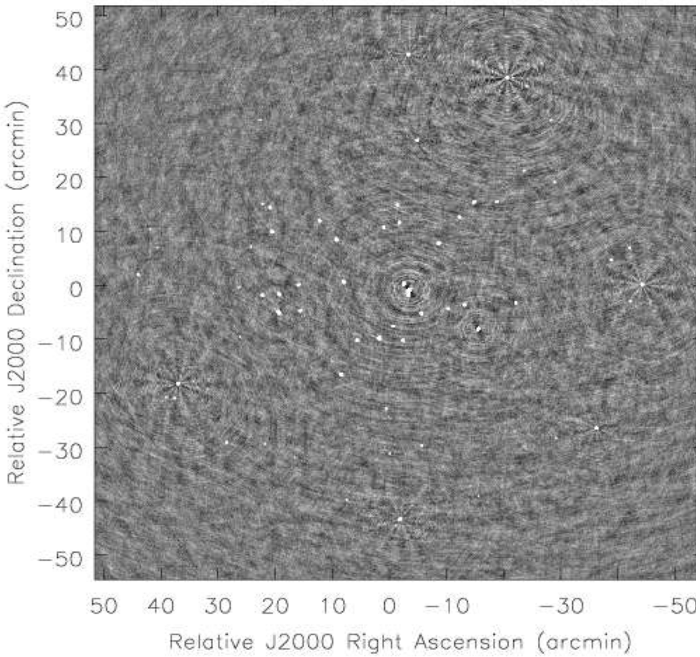
- W-projection: Adequate for EVLA imaging



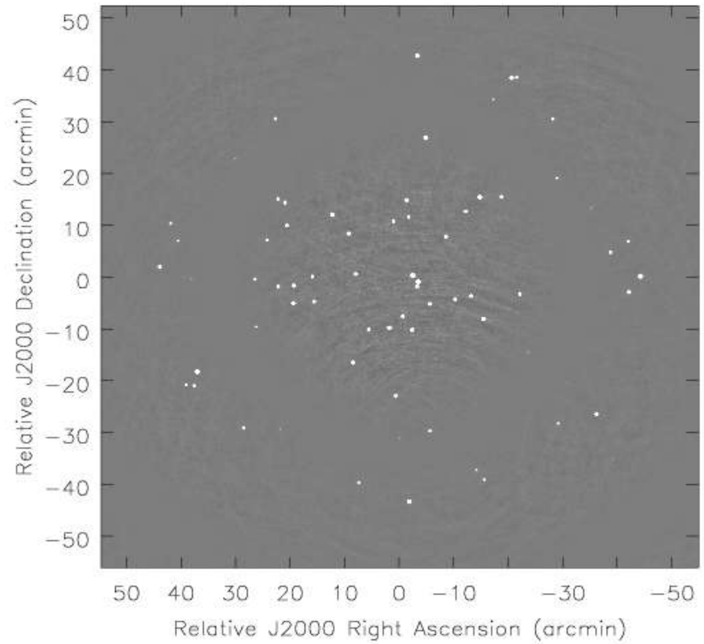
- Errors not due to w-term
- Limited by pointing errors/PB-rotation?
- Errors in the first sidelobe due to PB-rotation

PB Corrections: Stokes-I

- Correction for PB rotation & polarization effects



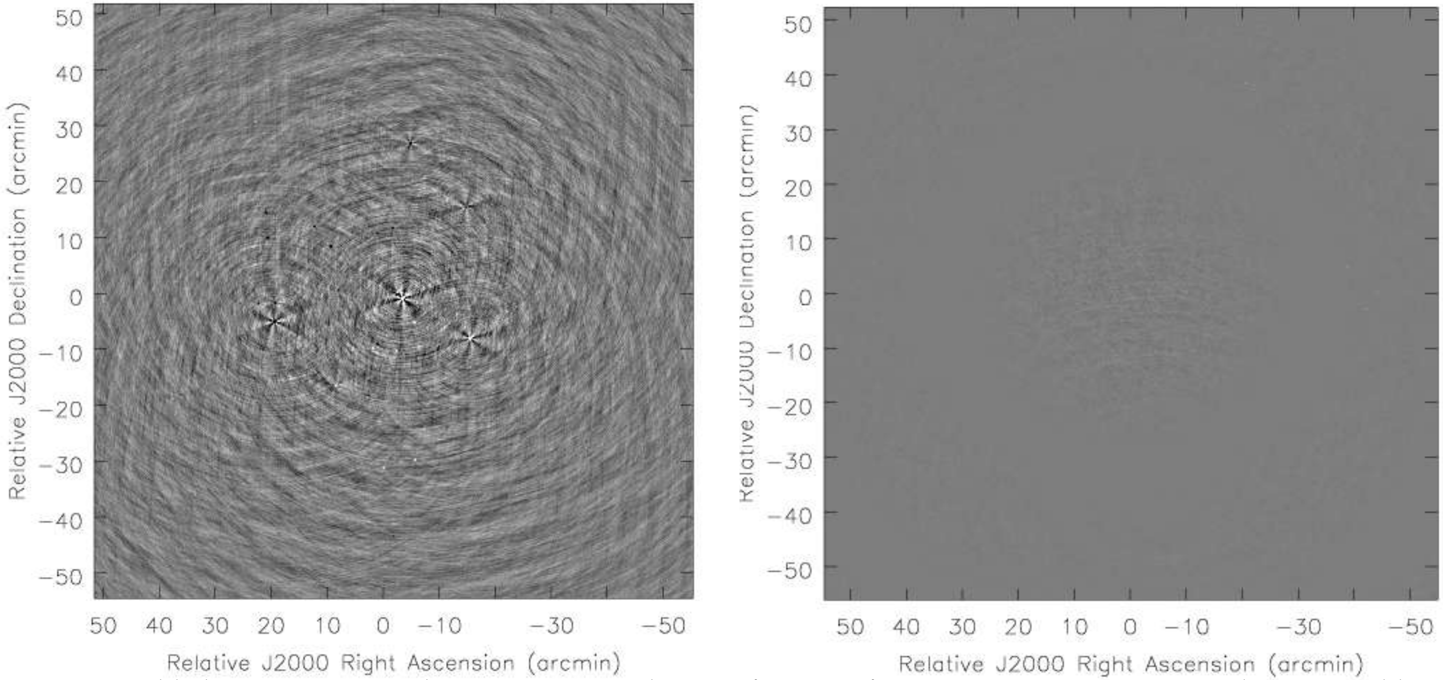
Before correction for pointing and PB-rotation



After correction for pointing and PB-rotation

PB Corrections: Stokes-V

- Correction for PB rotation & polarization effects



- Full beam Stokes-Q and -U imaging: Errors much smaller
- Corrections can be similarly done

Wide band imaging

- Requires use of PB-projection and scale sensitive deconvolution ideas
  - Dominant error due to PB scaling
  - Simulations show that frequency dependence of the sky alone limits to few x1000:1 imaging dynamic range
- Initial investigation for deconvolution (EVLA Memo 101)
  - Multi-frequency Synthesis (MSF)/Bandwidth synthesis/Chan. Avg. inadequate for EVLA 2:1 BWR
  - Hybrid approach promising for DR ~ 10000

Computing & I/O load

- Wide field imaging
  - 8h, VLA-A, L-Band data processed in ~10h.
  - Freq. + PB-corrections significantly increase the load
- Major cycle: data prediction
  - For normal Clean, this is the most expensive step.
  - PB- & W-projection is limited by the I/O speeds.
- Minor cycle: component search
  - Compute limited for component based imaging.

Parallel Computing& I/O

- Start work on parallelization along with current algorithm development
- Parallel I/O
  - Parallelizing gridding by data partitioning
  - Use parallel file system to access data for other applications (viewer, etc.)
- Need to develop portable imaging and calibration software for clusters.
  - Implement imaging/calibration algorithms on cluster machine

Resource requirements

- Invest in a modest cluster now
  - In the process of acquiring a 8-node cluster
- Build collaborations with other groups (UIUC/UNM/etc.)
- Develop local expertise
  - Parallel algorithms are significantly more complex
  - Significant increase in code complexity=> increase in development time
- More human-resources for [1-2FTE]
  - Parallel computing development
  - RFI Removal, simulations/tests for other bands
  - Data Visualization

Algorithms Group

- Algorithms working group
  - formerly led by Tim Cornwell (now at ATNF)
  - currently led by Sanjay Bhatnagar & Steve Myers
  - includes aips++/casa developers, students
    - Kumar Golap, George Moellenbrock, Urvashi Rao-Venkata
  - also NRAO-wide staff participation (e.g. AIPS group, NAWG)
    - E. Greisen, J. Uson
  - outside connections (e.g. LWA/UNM)

Cooperation

- ALMA – co-development of AIPS++ & pipeline
- LWA/UNM – research & algorithm development
- GBT – EVLA+GBT combination
- ATNF – Visualization, AIPS++ core code
- NFRA – Table system, Measures
- In the near future: NTD/xNTD/MWA