

EVLA Algorithm Research & Development

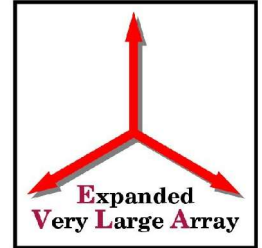
Progress & Plans

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AIPS++/EVLA



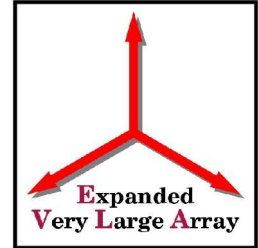
Requirements



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- Full beam, full bandwidth, full Stokes noise limited imaging!
 - From algorithms point of view, this requires
 - 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 $\sim 10^6$:
 - Scale & frequency sensitive deconvolution
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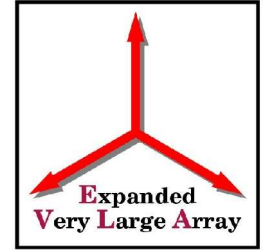
Requirements



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- Calibration: No serious algorithmic issues
 - Band pass calibration:
 - Per frequency channel solution
 - Polynomial/Spline solutions (overlaps with ALMA requirements)
 - Multiple spectral windows
 - Polarization leakage
 - Frequency dependant leakage
 - Beam polarization correction (done during imaging)
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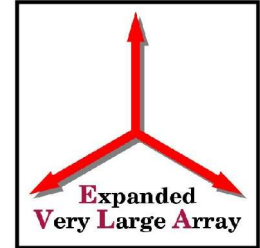
Imaging limits



- Limits due to asymmetric PB rotation at L-band
 - In-beam max. error @ ~10% point: $15\mu\text{Jy}/\text{beam}$
 - 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: $\sim 10\mu\text{Jy}/\text{beam}$
 - Similar error for mosaicking at higher frequencies



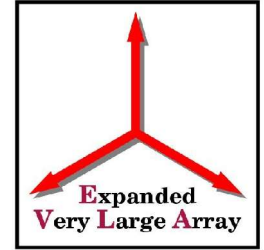
Imaging limits



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- 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 (NUMBERS)
 - Limits due to widebands (Spectral Index effects)
 - L-band: 10-15 μ Jy/beam (2:1 BWR)
 - Less of a problem at higher bands, except for mosaicking
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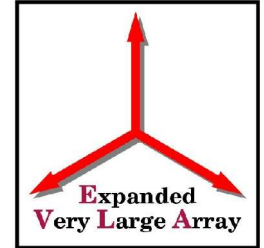
Algorithmic dependencies



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- 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)
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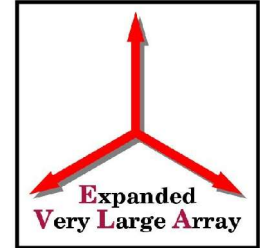
Challenges



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- 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
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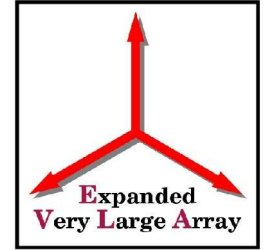
Plan (from last year)



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- Wide field imaging
 - W-projection algorithm: An improvement over the image-plane faceted algorithm: 10x faster
 - Implemented [Done/Testing] (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
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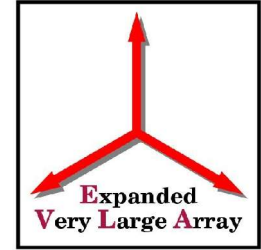
Plan (from last year)



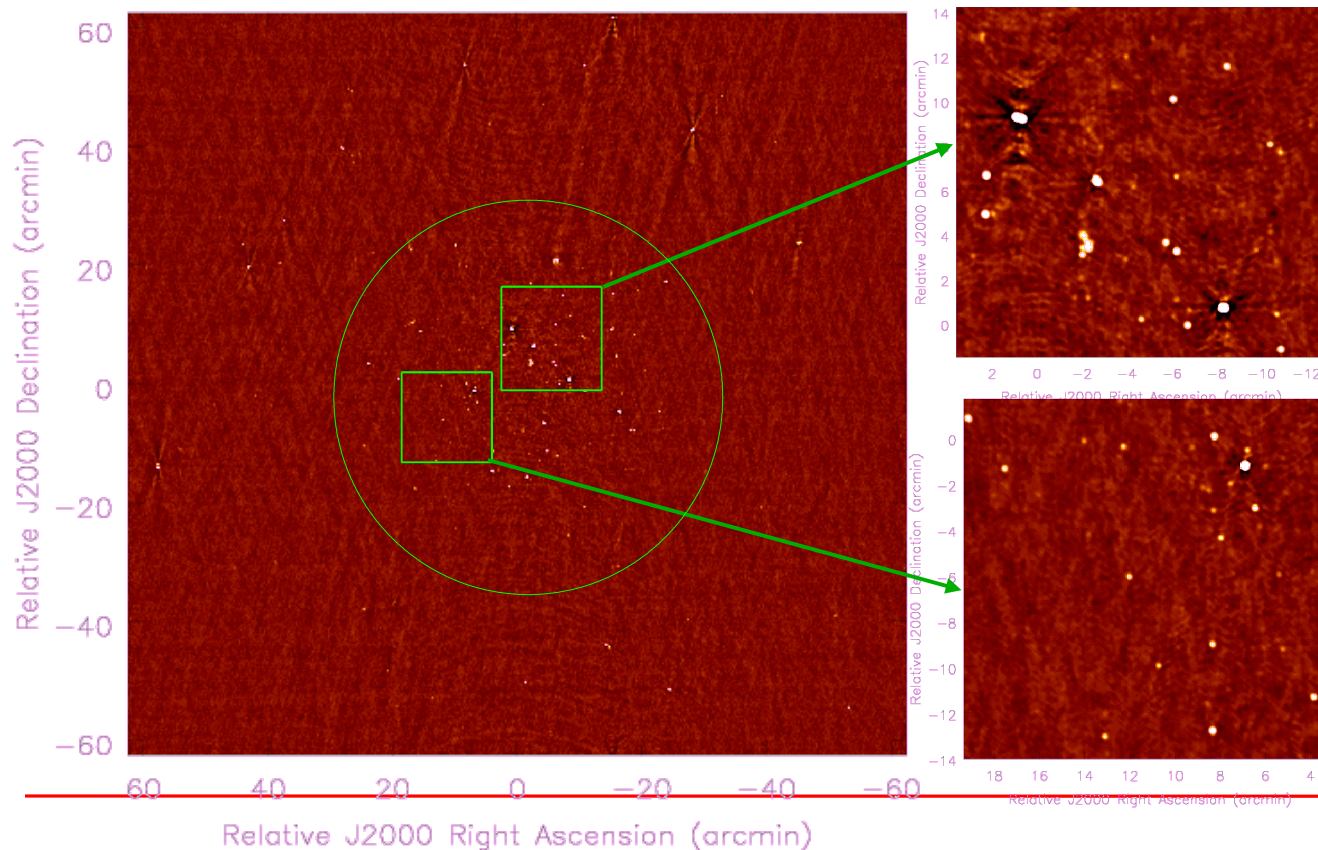
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- Initial investigation for deconvolution [Done] (EVLA Memo 101, Rao-Venkata & Cornwell)
 - Scale & frequency sensitive deconvolution [Work in progress]
 - The code in C++ works – but as a Glish client
 - Extend it for frequency dependent components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



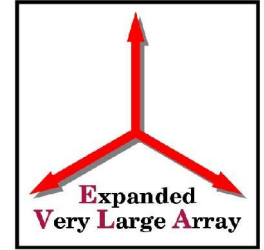
- W-projection: Adequate for EVLA imaging



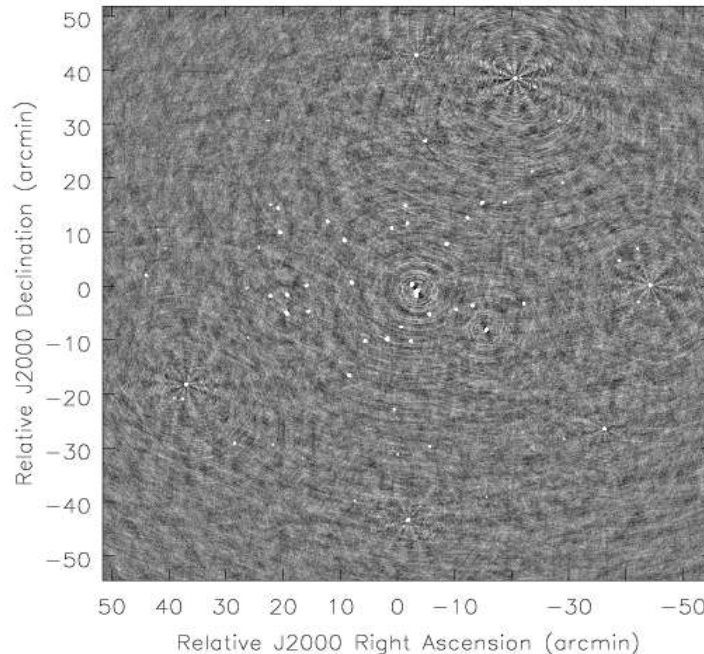
- Errors not due to w-term
- Limited by pointing errors/PB-rotation?
- Errors in the first sidelobe due to PB-rotation



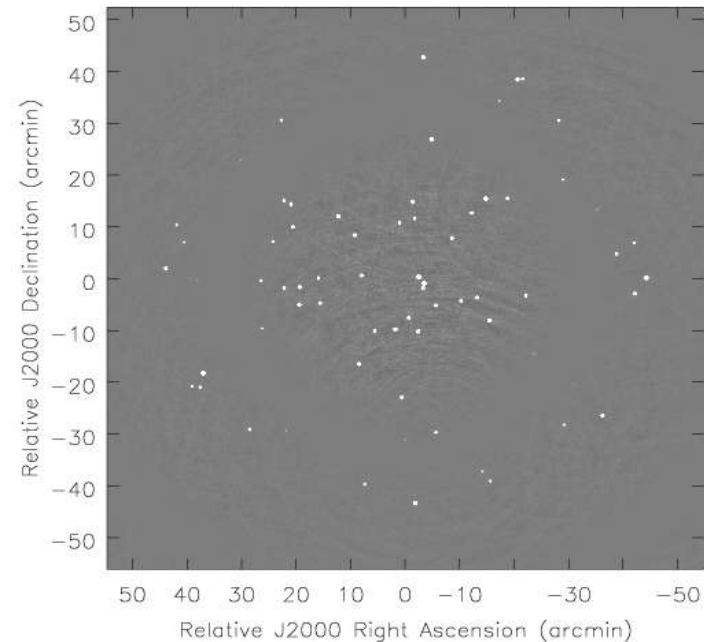
PB Corrections: Stokes-I



- Correction for PB rotation & polarization effects



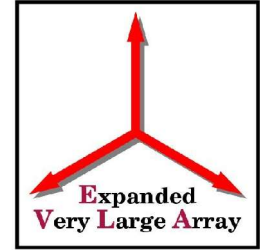
Before correction for pointing
and PB-rotation



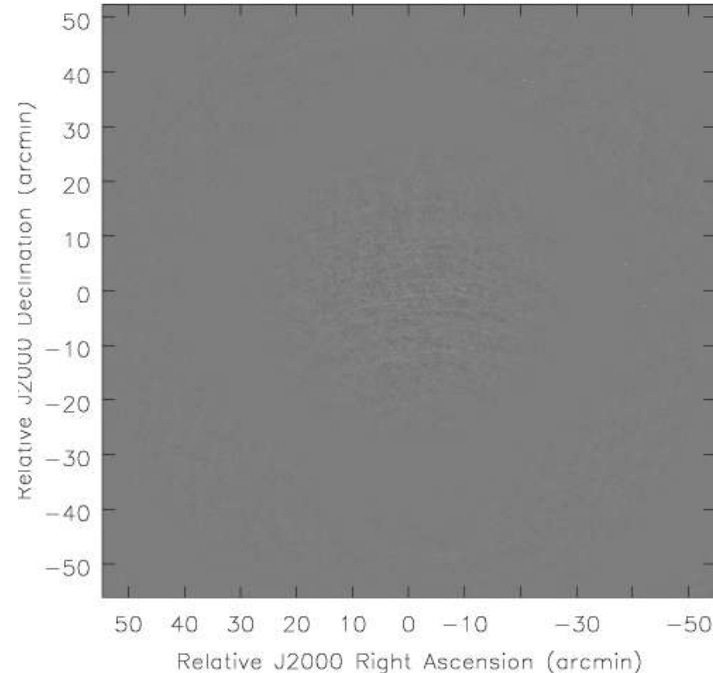
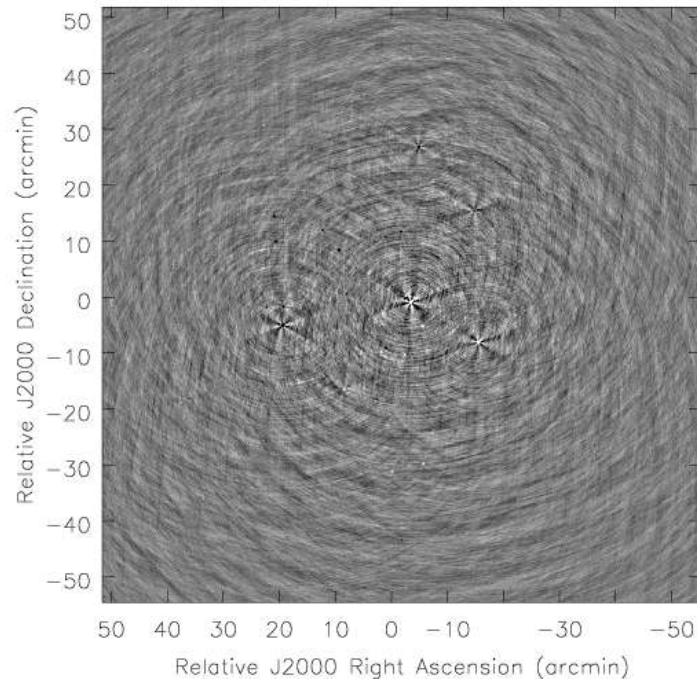
After correction for pointing
and PB-rotation



PB Corrections: Stokes-V



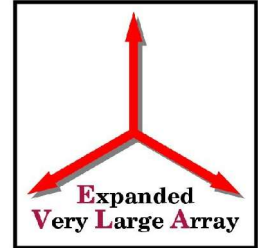
- Correction for PB rotation & polarization effects



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



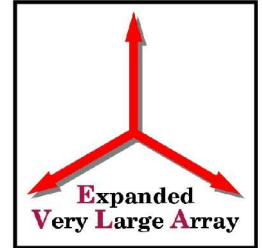
Wide band imaging



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- 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 $\sim 10 \mu\text{Jy}/\text{beam RMS}$
 - 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
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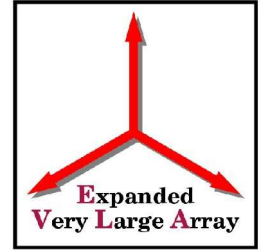
Computing & I/O load



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- 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.
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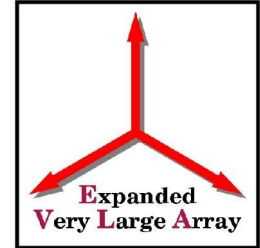
Parallel Computing & I/O



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- 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
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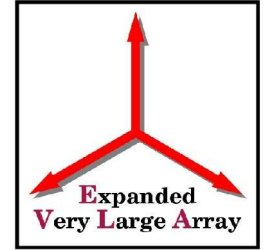
Resource requirements



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- Invest in a modest cluster now
 - In the process of acquiring a 8-node cluster
 - 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
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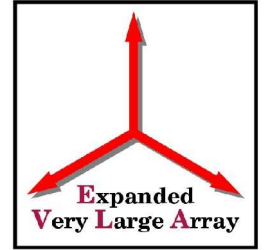
Algorithms Group



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- 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)
 - Eric Greisen
 - outside connections (e.g. LWA/UNM)
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Cooperation



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