Experiences With EVLA Data

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NRAO, Socorro

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

Imaging issues

- Full beam, full bandwidth, full Stokes noise limited imaging

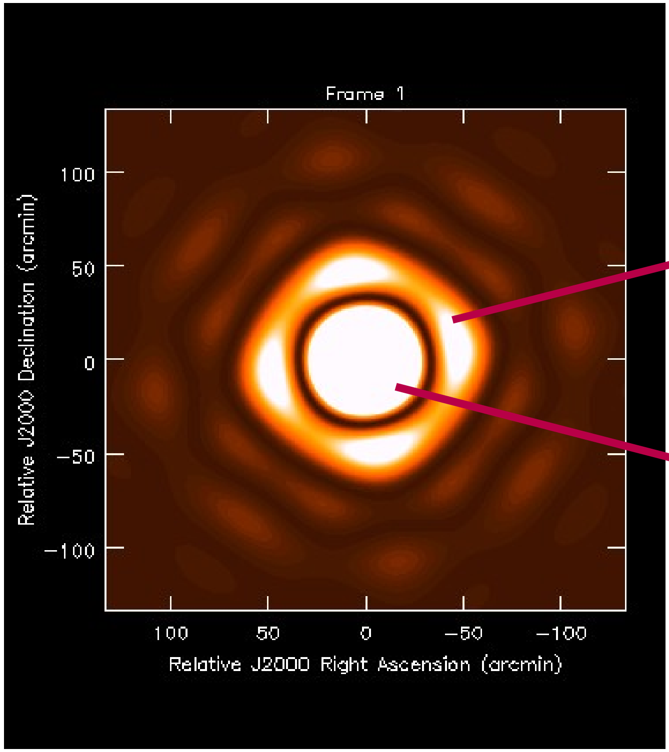
- Algorithmic Requirements:
  - PB corrections:
    - Rotation, Freq. & Poln. dependence, W-term (L-band)

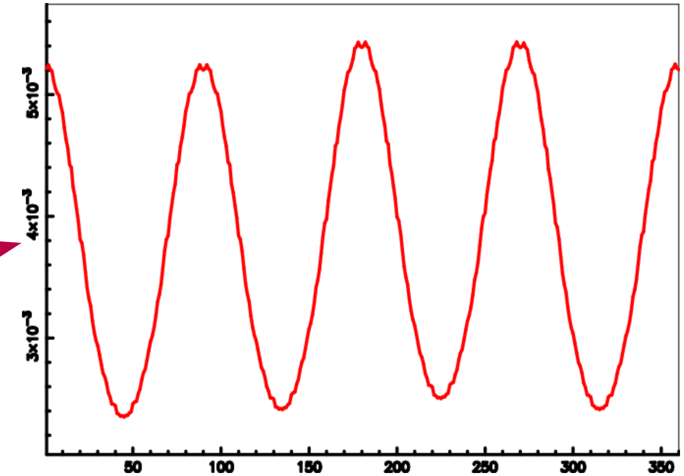
  - Multi-frequency Synthesis at 2:1 BWR
    - PB scaling with frequency, Spectral Index variations
    - Scale and frequency sensitive deconvolution

  - Direction dependent corrections
    - Time varying PB, pointing offsets, polarization

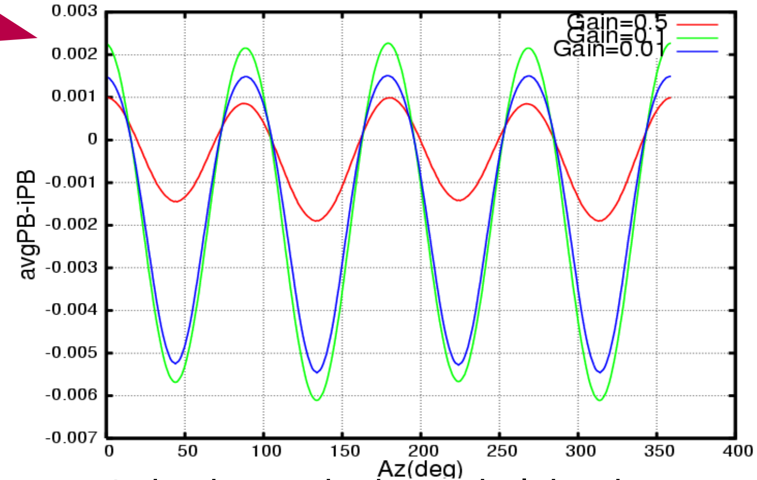
Time varying gains: PB rotation

(Brisken, EVLA Memo #58)





Gain change at first side lobe due to rotation



Gain change in the main-lobe due to rotation

Sources of time variability

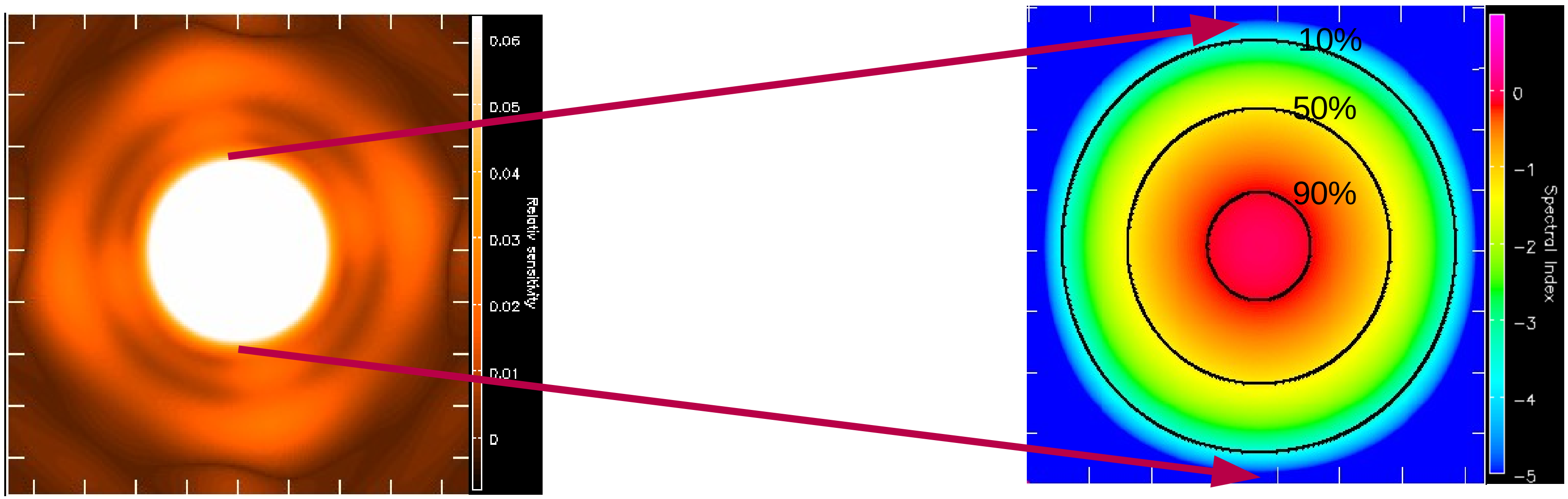
- PB rotationally asymmetric
- PB rotation with PA
- PB scaling with frequency
- Antenna pointing errors

Imaging limits: Due to PB rotation

- Limits due to asymmetric PB
  - In-beam max. error @ 10% point: ~10000:1
  - Errors due to sources in the first side-lobe: 3x-5x higher
  - Less of a problem for non-mosaicking observation at higher frequencies (>C-band)
    - But similar problems for mosaicking at higher frequencies

- Limits due to antenna pointing errors
  - In-beam and first side-lobe errors: ~10000:1
  - Similar limits for mosaicking at higher frequencies

Wide-band static PB



Wide-band power pattern
(3 Channels spanning
1 GHz of bandwidth)

Avg. PB Spectral Index
(1-2GHz)

Imaging limits: Due to bandwidth

- Frequency dependence
  - Instrumental: PB scales by 2X is strongest error term
  - Sky: Varying across the band – needs to be solved for during imaging (MFS)

- Limits due to sky spectral index variations:
  - A source with Sp. Index ~1 can limit the imaging dynamic range to $\sim 10^{3-4}$

Measurement Equation

- Generalized Measurement Equation

$$V_{ij}^{Obs}(\nu)=J_{ij}(\nu,t)\int J_{ij}^{S}(\mathbf{S},\nu,t)\,I^{o}(\mathbf{S},\nu)\,e^{\iota\,\mathbf{S}.\mathbf{B}_{ij}}\,d\mathbf{S}$$

Data   Corruptions   Sky

- J_{ij} are <u>Direction Independent</u> Mueller Matrix
- J^{s}_{ij} are <u>Direction Dependent</u> Mueller Matrix

- Unknowns in the above equation: $\mathbf{J}_{ij}$, $\mathbf{J}^{s}_{ij}$ and I^{o}

Projection methods: General approach

- Construct a K_{ij} *which models the desired DD effect*
- For an iterative deconvolution, compute update direction (Dirty Image) as

$$V_{ij}^{Obs} = E_{ij} * V^{M} \qquad if\ K_{ij}^{T} E_{ij} \approx Unity$$

$$FT\left[K_{ij}^{T} * V_{ij}^{Res}\right] \longrightarrow I^{Dirty} = I^{o} * PSF$$

- Accurate residual computation (Chisq) as

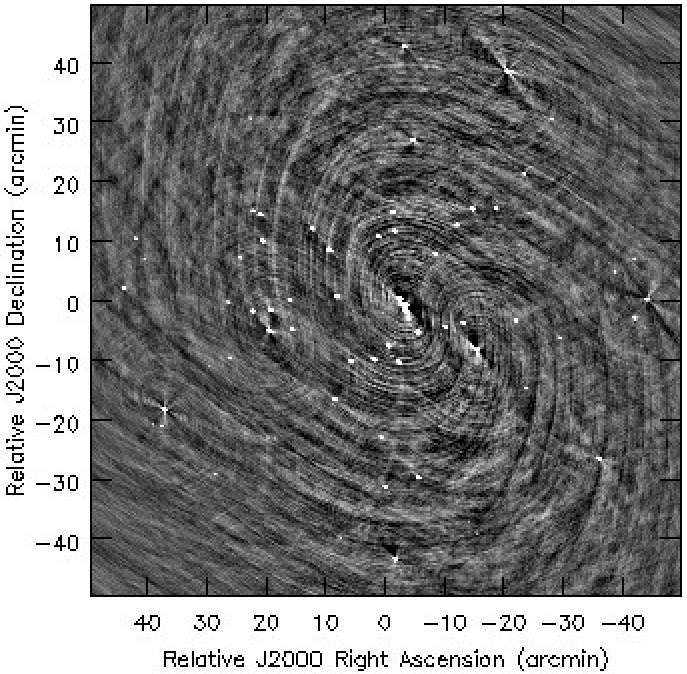
$$V^{Res} = K_{ij} * FT^{-1}\left[I^{M}\right] - V^{Obs}$$

- If the operator is approximately unitary, the iterations will converge

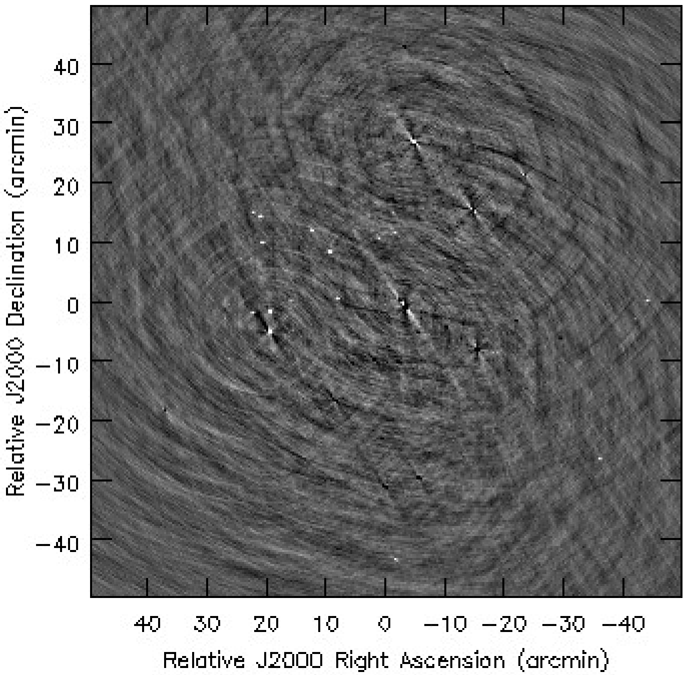
Correction for PB rotation

Before correction

Stokes-I



Stokes-V



(Bhatnagar et al., EVLA Memo 100 (2006), A&A (2008))

Correction for PB rotation

After correction

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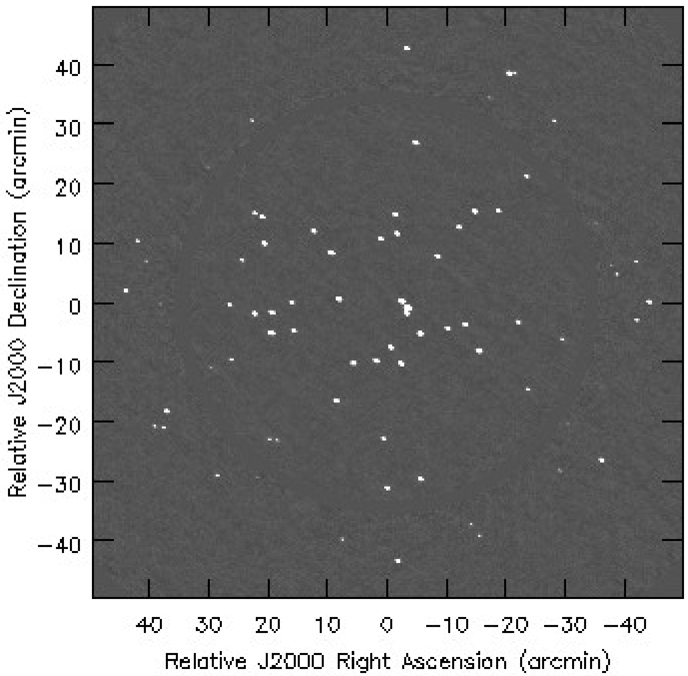
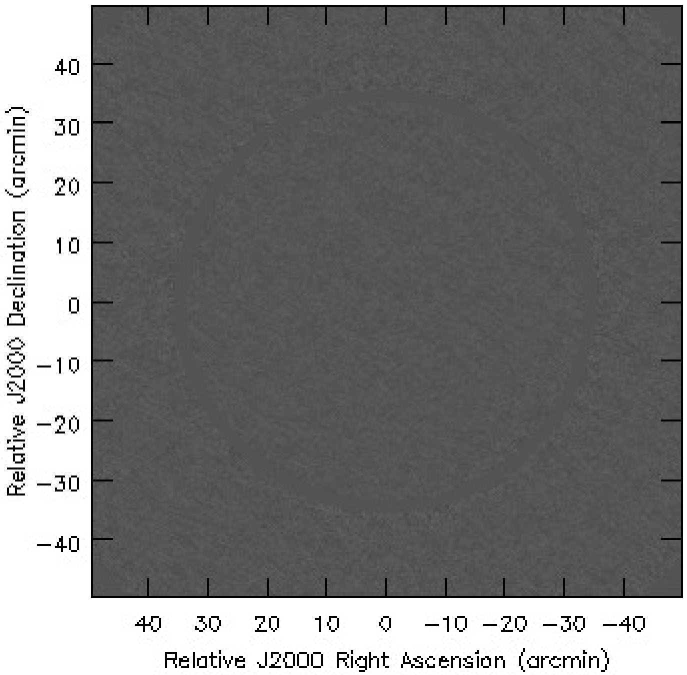


Stokes-V



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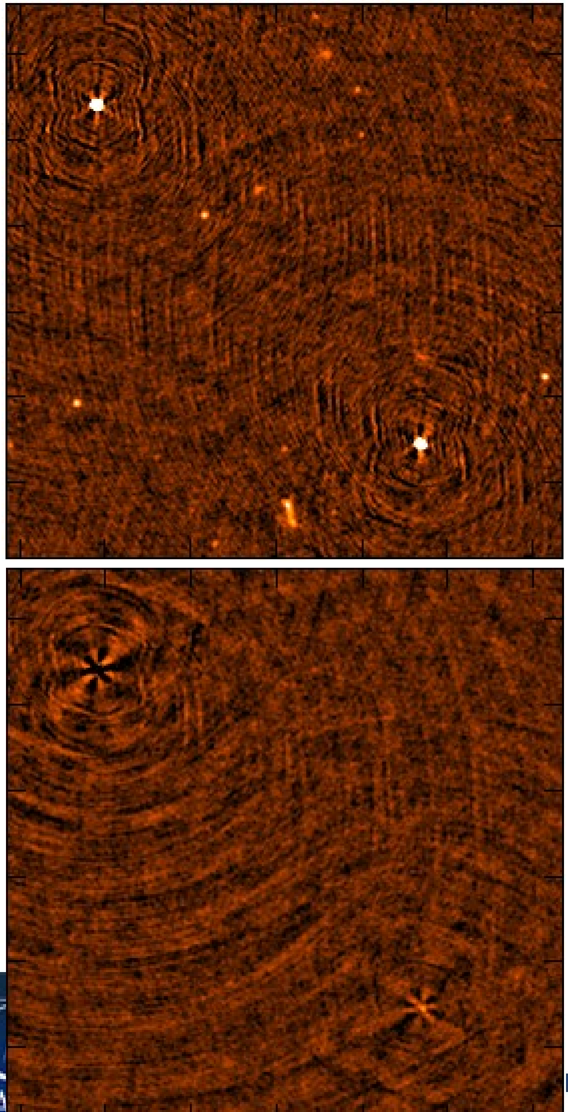
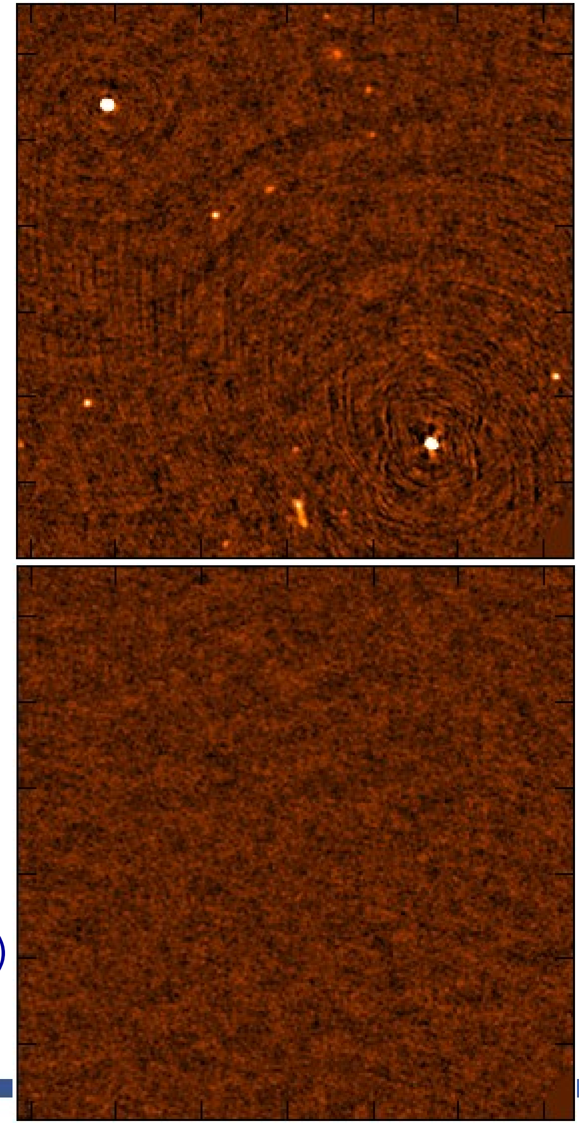
A-Projection: EVLA Squint correction



Stokes-I

Stokes-V

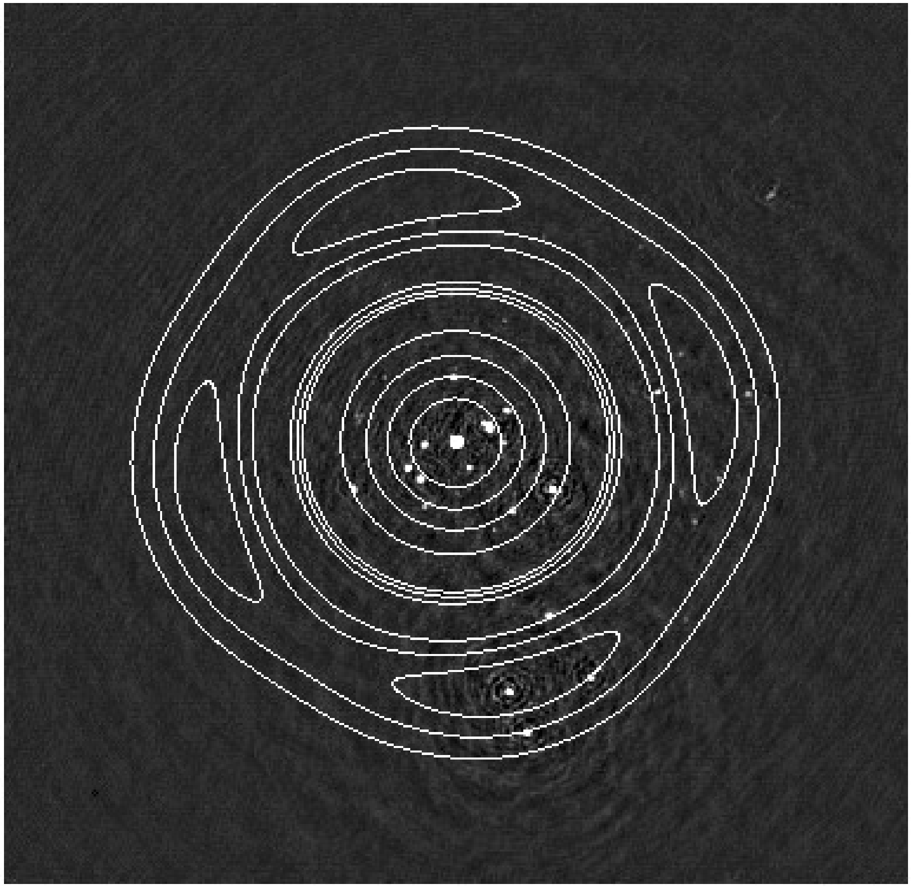
(10x improvement)



EVLA L-Band

- Field: 3C147
- 11 Antennas, BW=110 MHz
- Integration = 7hrs
- Gain + BandPass Calibration
- Single Baseline based correction
- DR: Peak/OffSource RMS
  - ~700,000 : 1

- Limited by DD errors
  - Due to PB rotation?
  - Errors in the sidelobe



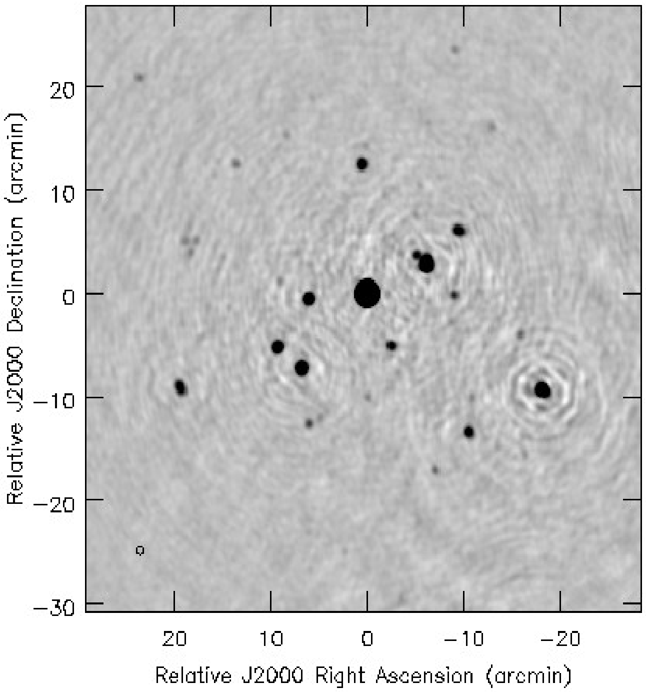
Data courtesy R. Perley

Work in progress

- Work in progress to eliminate “numerical noise”

- Possible source of errors
  - Interpolation errors in PA rotation?
  - Aliasing errors
  - Off-by-one pixel error
  - Model not good enough

- Current pace of progress limited by excessive run-time (not using parallel processing yet)



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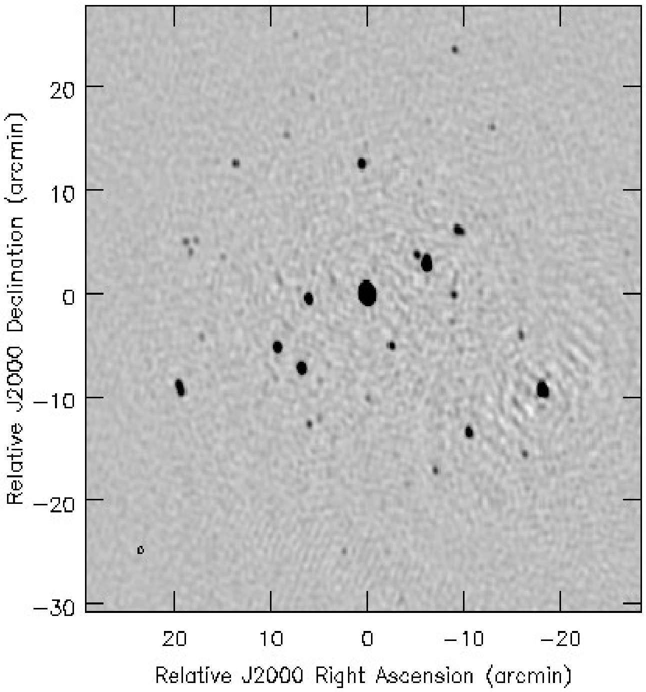
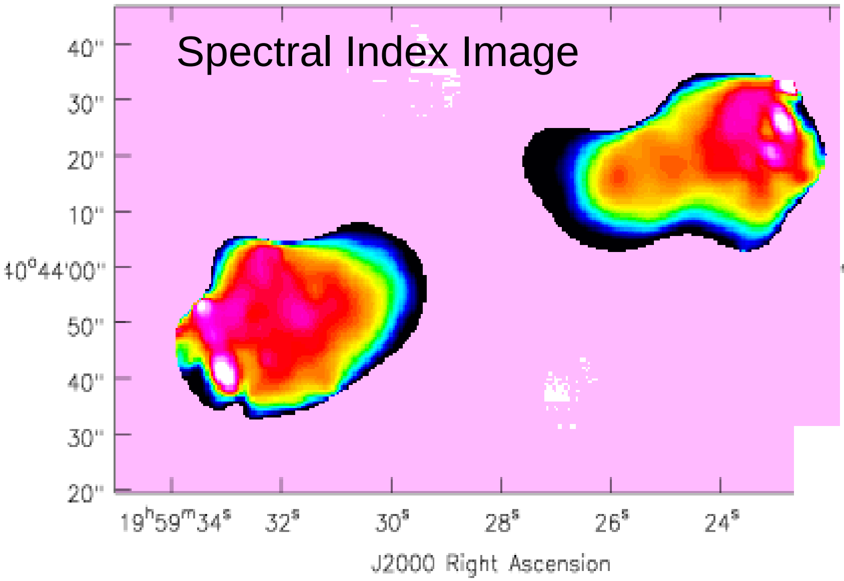
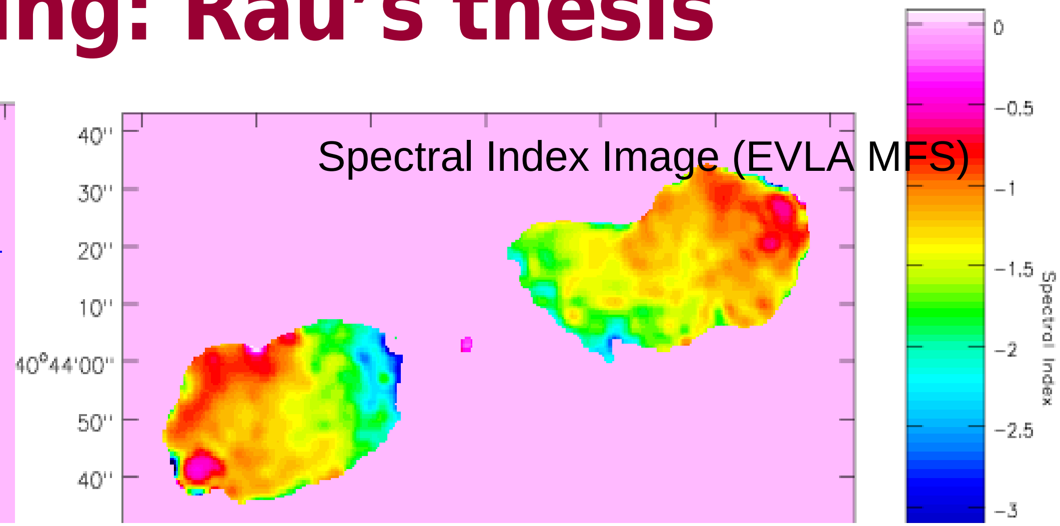
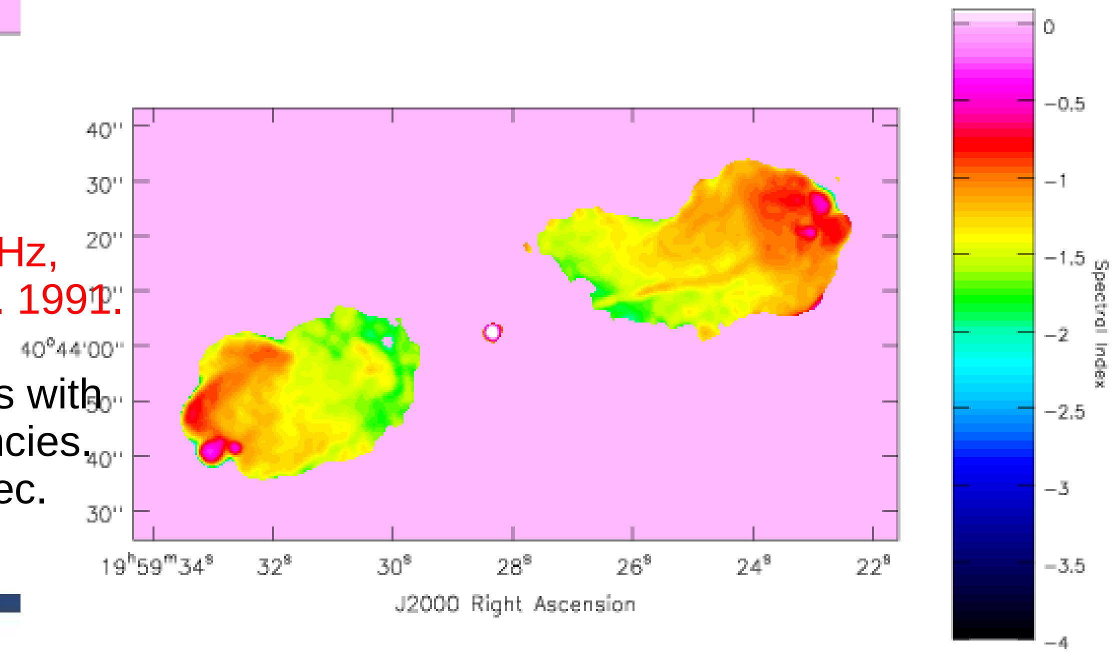


Wide-band imaging: Rau's thesis



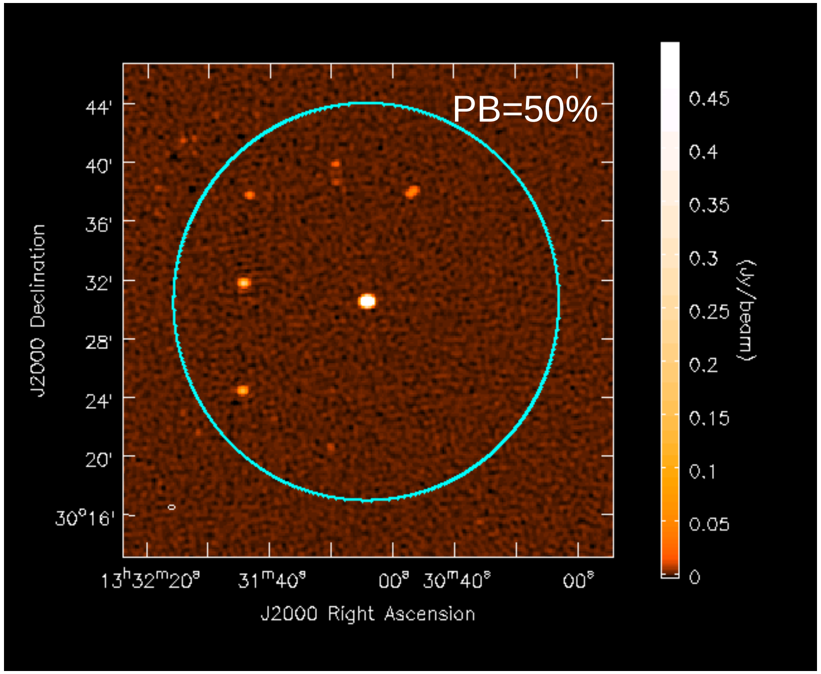




Spectral Index Map constructed from images at 1.4GHz and 4.8GHz, obtained from C.Carilli et al, Ap.J. 1991.

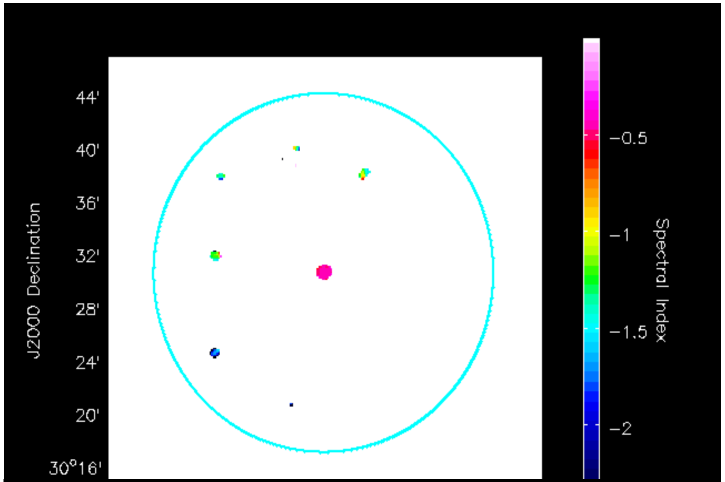
These data included synthesis runs with VLA A,B,C,D Array at both frequencies. Map has been smoothed to 1 arcsec.

Wideband PB correction

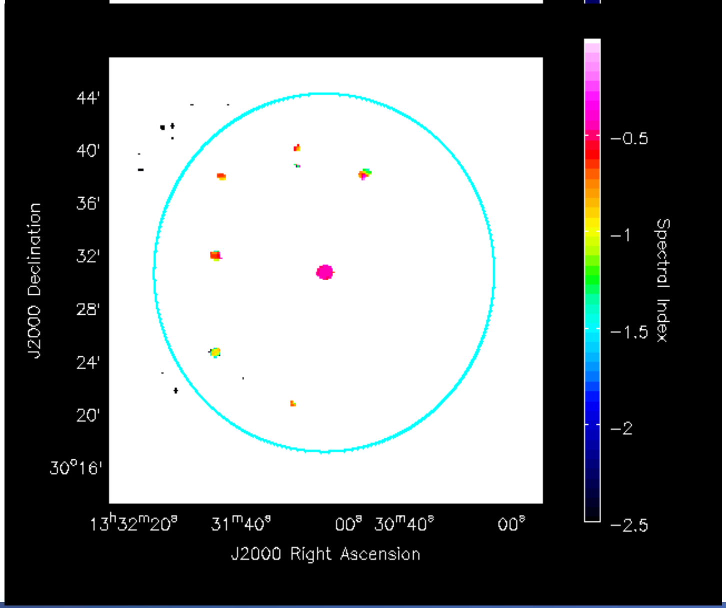


3C286 Stokes-I

Before PB correction

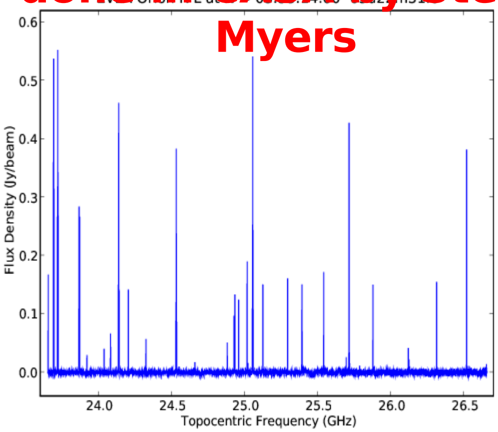


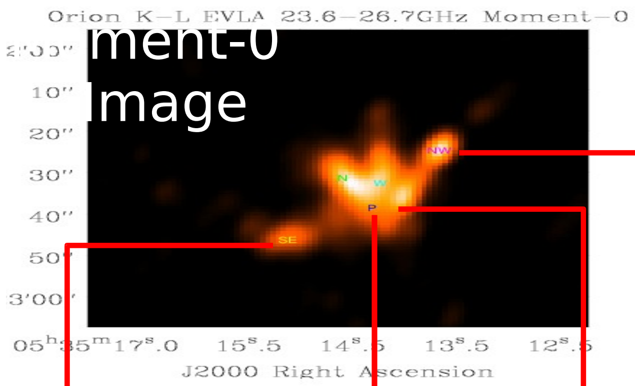
After PB correction

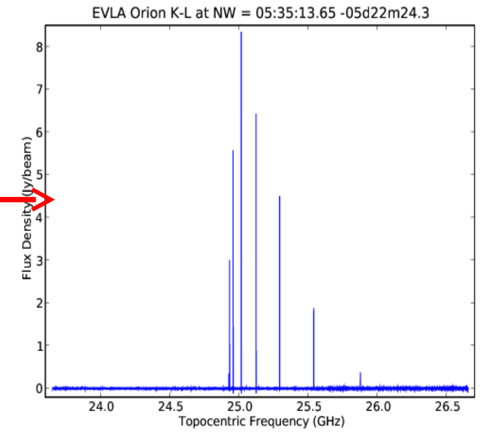


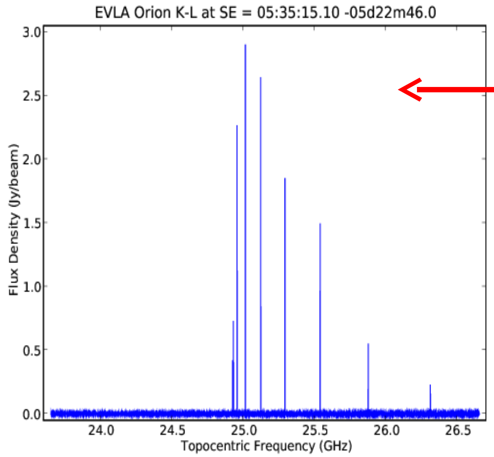
Wideband Spectra

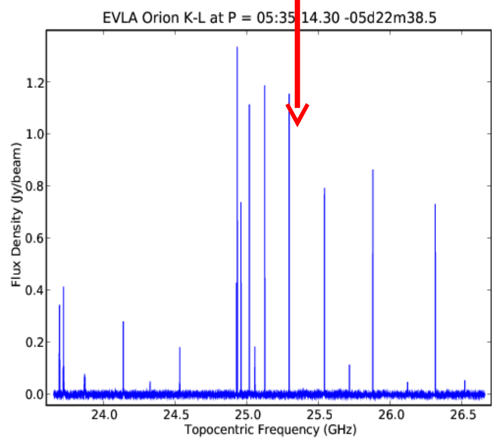
End to end processing done in CASA by Steve Myers

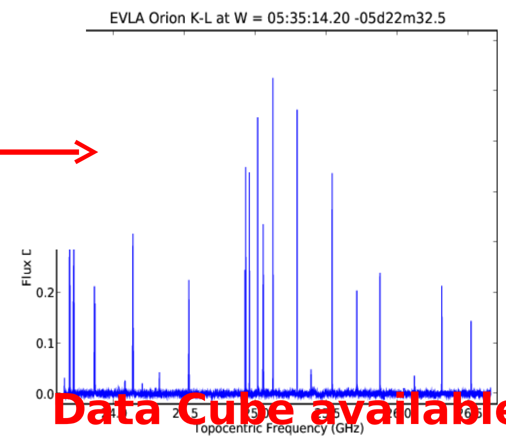












Data Cube available at: http://science.nrao.edu/evla/projectstatus/index.shtml

Early Science Programs

- Two early science programs: March 2010 through December 2011.
- Open Shared Risk Observing (OSRO):
  - A ‘business as usual’ observing protocol.
  - Observers will access EVLA in same manner as current for VLA.
  - Initial configuration provides 512 spectral channels with one or two spectral windows of 128 MHz (maximum) each.
- Resident Shared Risk Observing (RSRO):
  - Must be resident in Socorro for at least 3 months.
  - Participants will have access to more extensive observing capabilities.
  - Participants will assist NRAO staff in expanding capabilities
  - Observing time proportional to length of residency.
  - 27 proposals received on first call, 13 have been accepted.

For details, see: http://science.nrao.edu/evla/earlyscience/osro.shtml