How accurately do our imaging algorithms reconstruct intensities and spectral indices of weak sources ?

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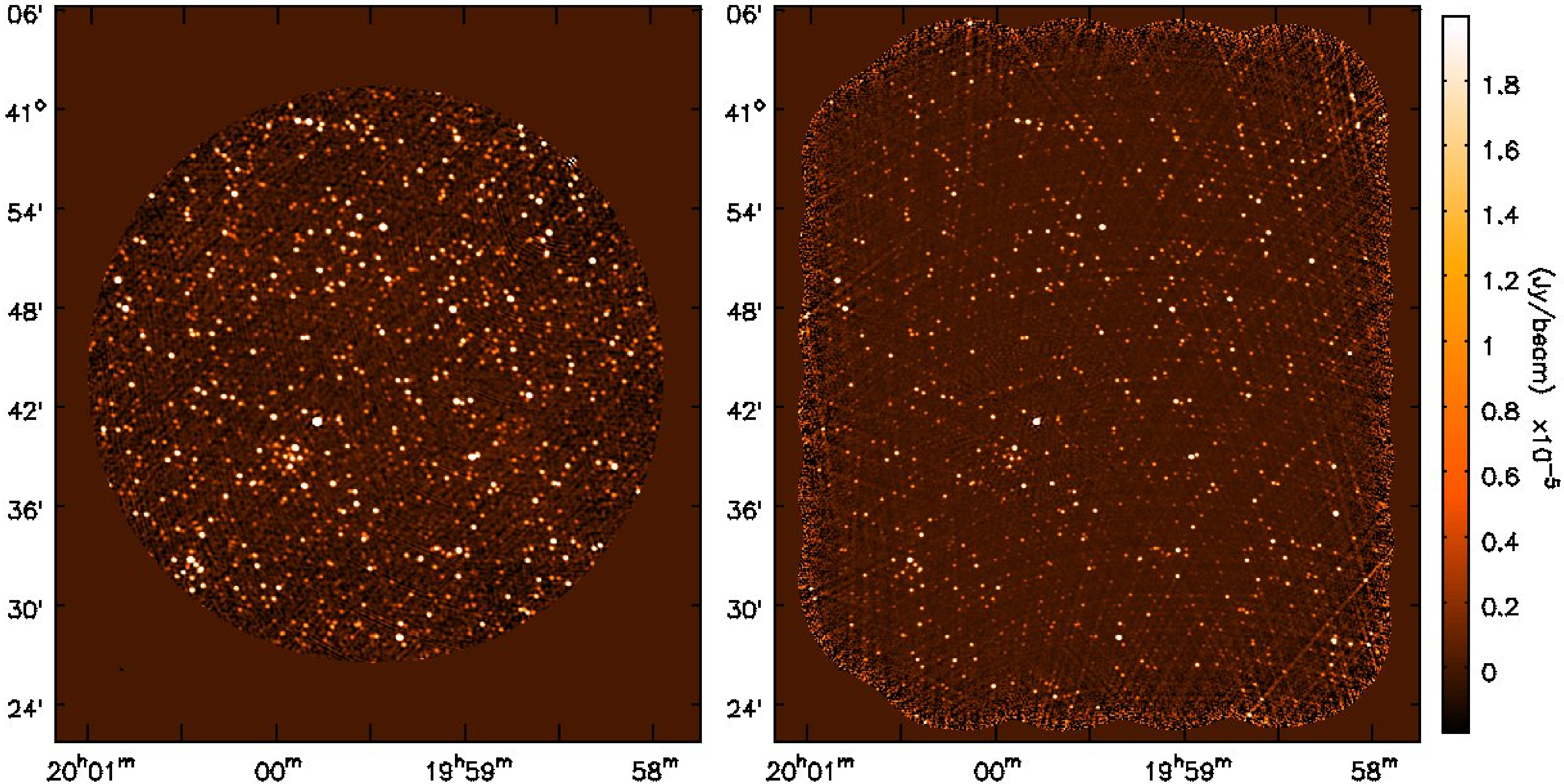
29th Annual New Mexico Symposium, NRAO, Socorro, 17 January 2014



VLA Wide-band wide-field simulations : (LEFT) L-Band, C-config, 1-pointing , (RIGHT) C-band, D-config, 46 pointings

Simulation Parameters : One Pointing, L-Band (1-2 GHz), C-config

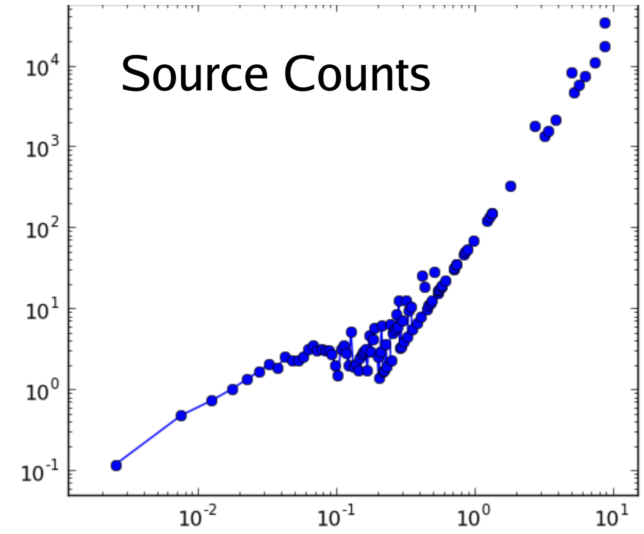
Sky : ~8000 point sources within one deg^2 (SCube)
Sources at pixel centers (+ compared with not)

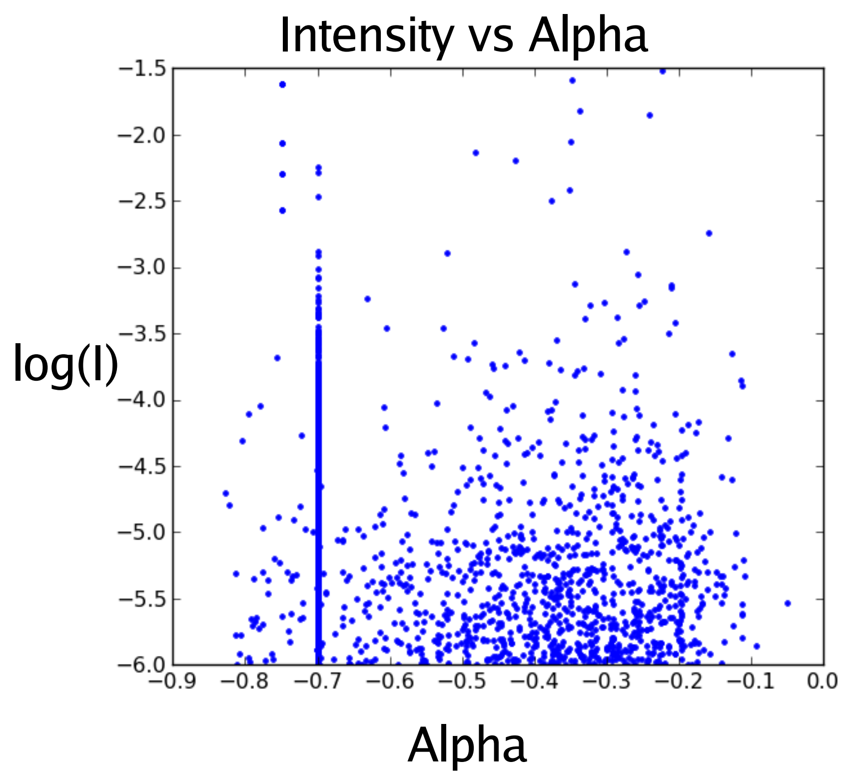
Intensity : between 1 micro Jy and 7 mJy.
(+ one 100 mJy source for HDR test)

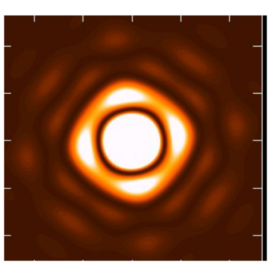
Spectral indices : between 0.0 and -0.8.

Observation : 16 channels/spws across 1-2 GHz
One snapshot every 20 minutes, for 4 hrs
(compare with one snapshot
every 2 minutes, for 4 hrs)

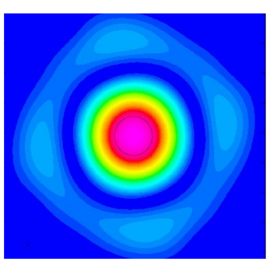
Data Prediction : Visibilities were calculated using the Wideband A-Projection de-gridder. No noise.



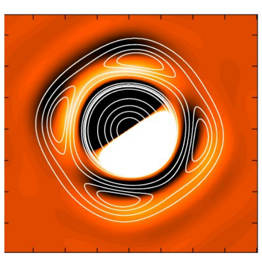



PB (time)

+


PB (freq)

+


PB (pol)

Imaging Options : Wideband MFS [yes/no], A-Projection [yes/no]

MT-MFS (nterms>1)

Multi-term MFS (wideband) Imaging
+
Absorb PB spectrum into sky model
+
Post-deconvolution Wideband PBcor for intensity and alpha

Rau & Cornwell, 2011, Sault &Wieringa 1994

MT-MFS + WB-A-Projection

Multi-term MFS with wideband A-Projection to remove PB spectrum during gridding
+
Minor cycle sees only sky spectrum
+
Post-deconvolution PBcor of intensity only.

Bhatnagar & Rau, 2012

Cube

Per channel Hogbom/Clark/CS Clean
+
Per channel post-deconvolution Pbcor
+
Smooth to lowest resolution
+
Fit spectrum per pixel, Collapse channels

Hogbom 1974, Clark 1980, Schwab & Cotton 1983, Schwarz, 1978

Cube + A-Projection

Same as Cube,
- with narrow-band A-Projection per channel

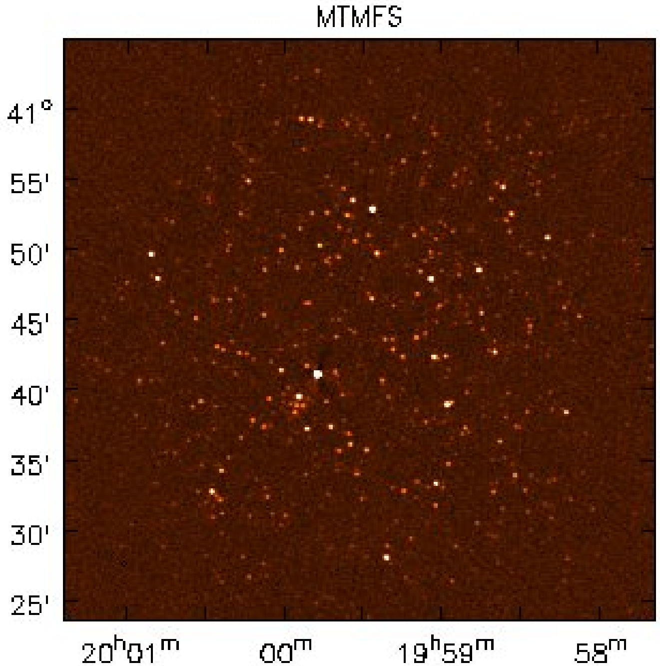
(A-Projection : Construct gridding convolution operators from antenna aperture illumination models. Removes beam squint and accounts for aperture rotation)

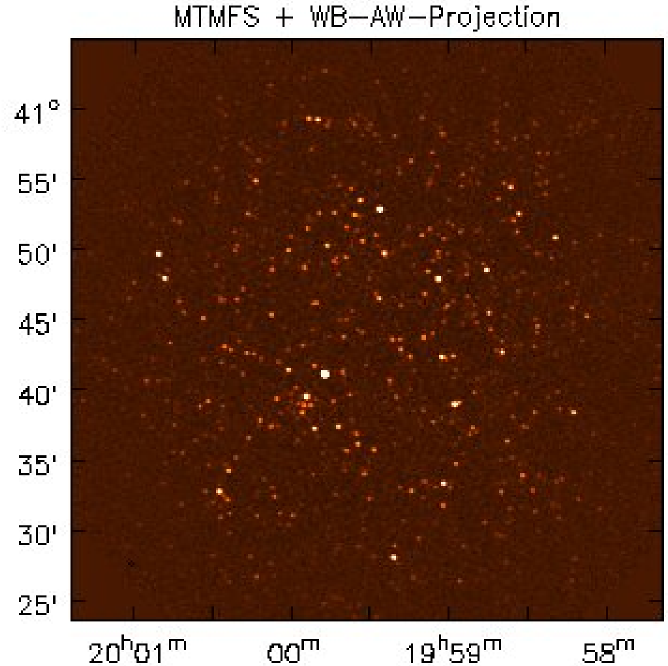
Bhatnagar, Cornwell, Golap, Uson, 2004

Low dynamic range test (< 10^4) – compare four methods

MT-MFS

2 uJy rms





MT-MFS
+
WB-AWP

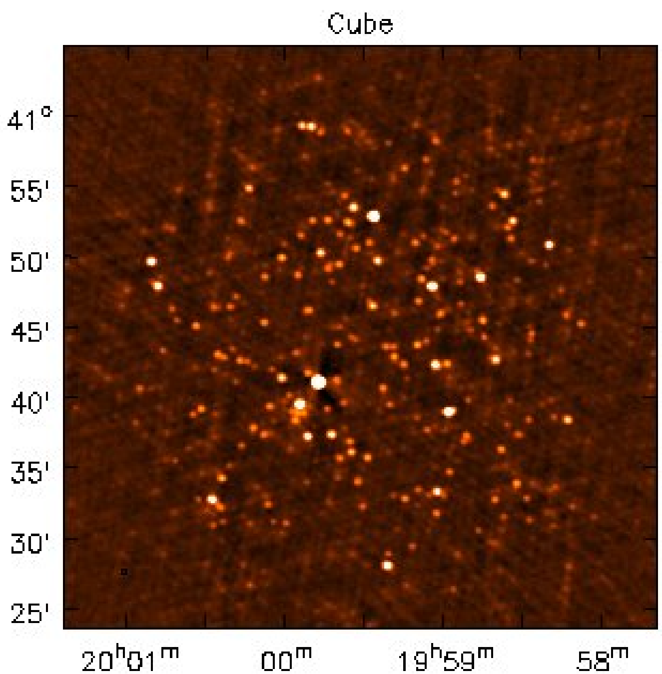
2 uJy rms

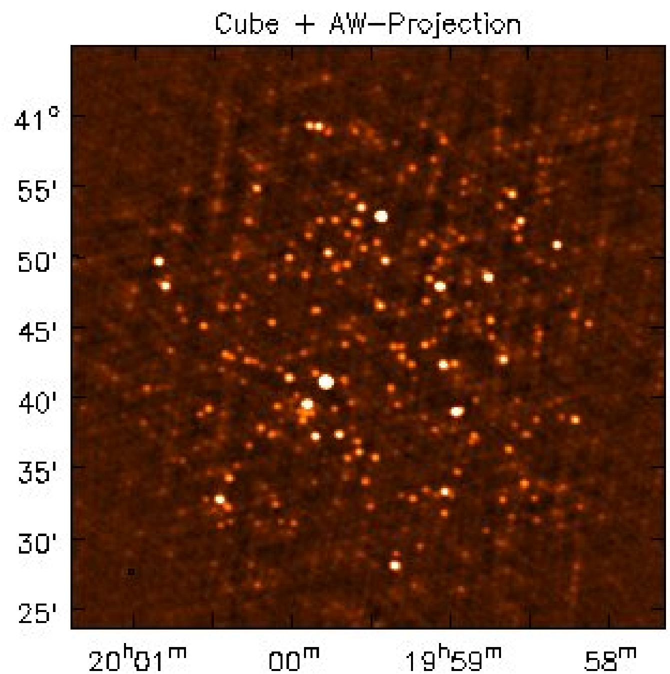
Brightest
Source :
7 mJy

Cube

3 uJy rms

peak res :
9 uJy



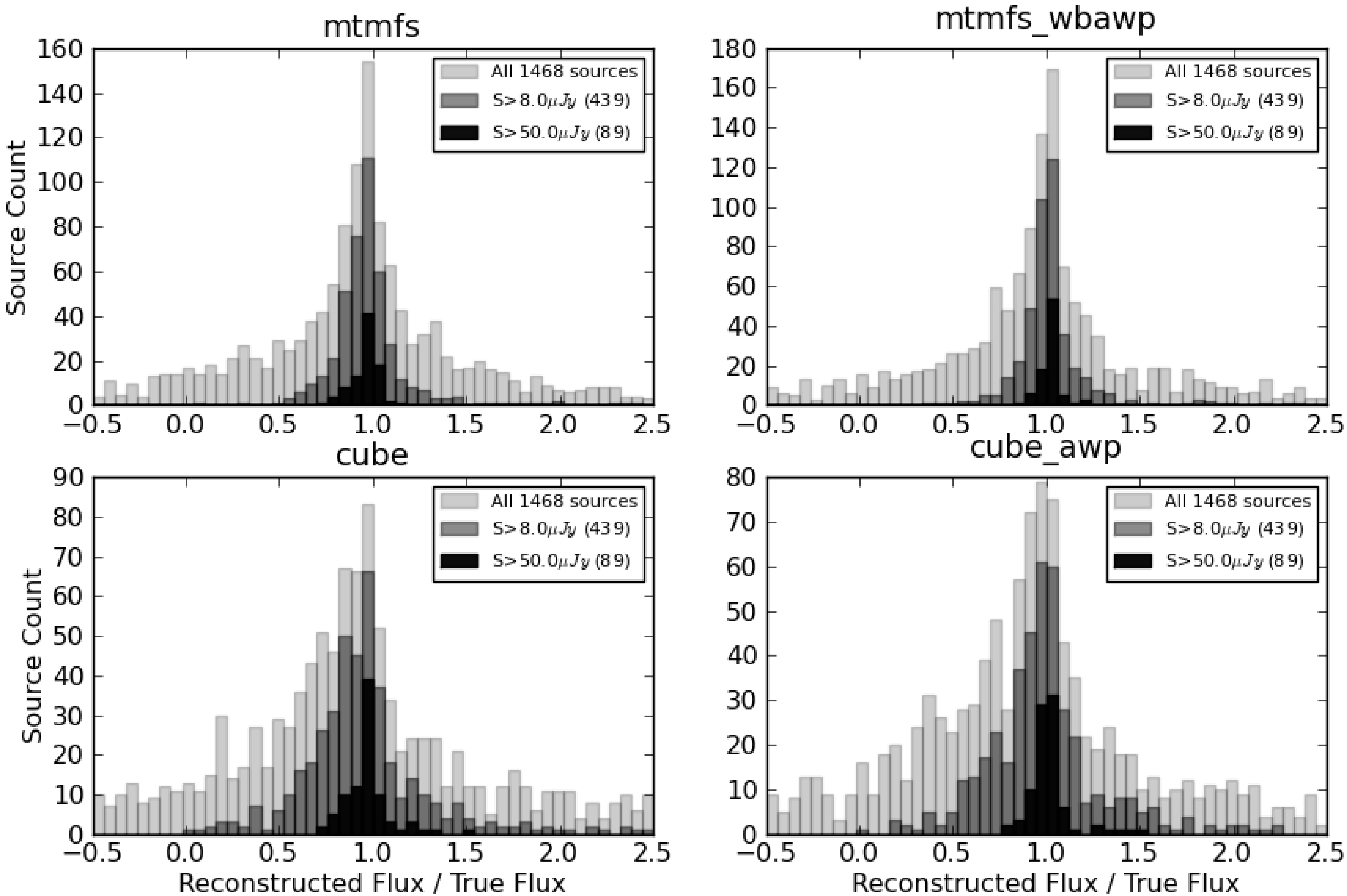


Cube
+
AWP

3 u Jy rms

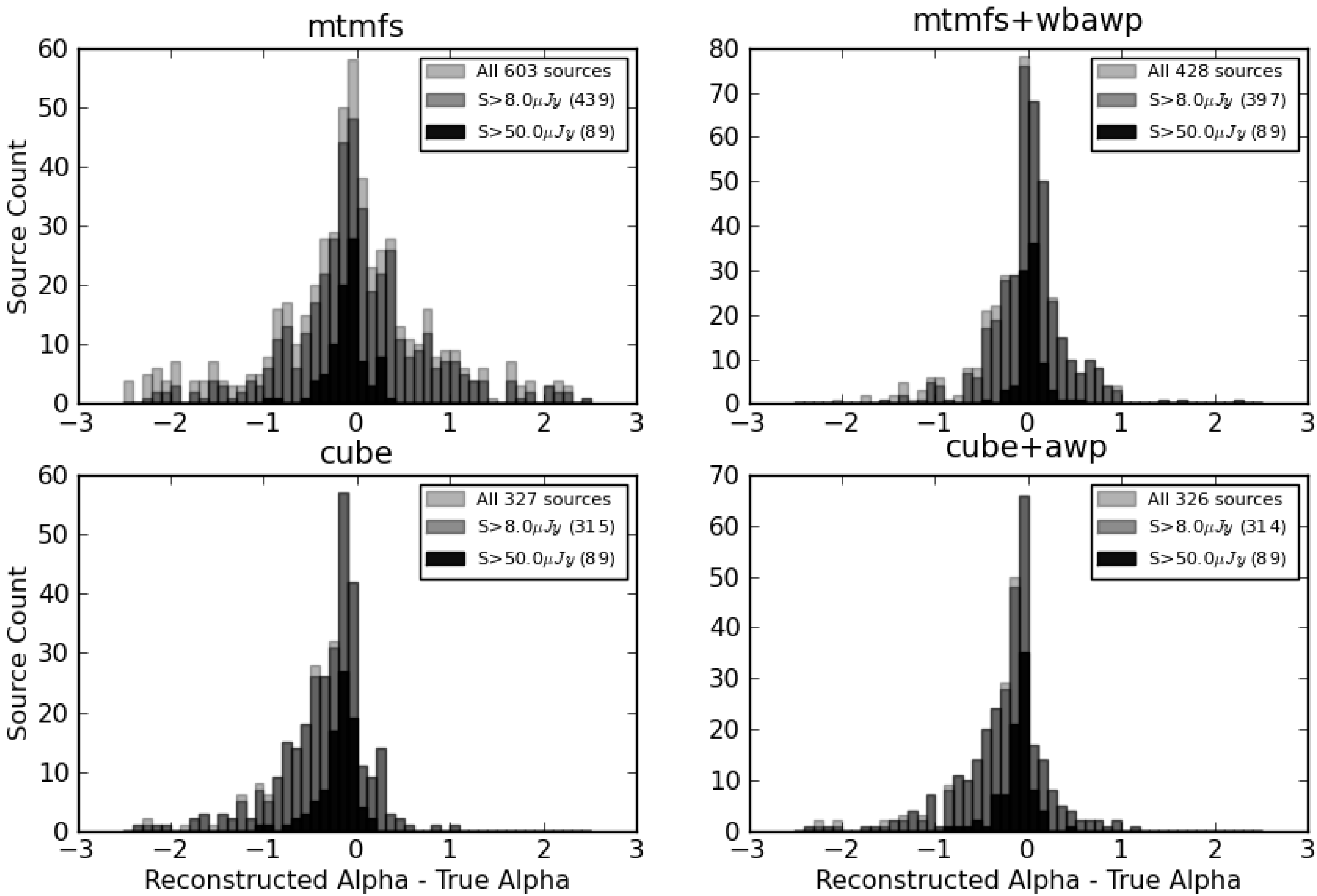
(Reconstructed / True) Intensity for different intensity ranges

Locate sources in true image. Plot all sources >1 micro Jy. (Brighter sources are more accurate)
No source-finding uncertainty.



(Reconstructed – True) Alpha for different intensity ranges

Spectral index for brighter sources are more accurate. Degrades quickly with lower intensity.
(note different numbers of sources with alpha detections)



High dynamic range test (>10^4) - compare four methods

MT-MFS

6 uJy rms*

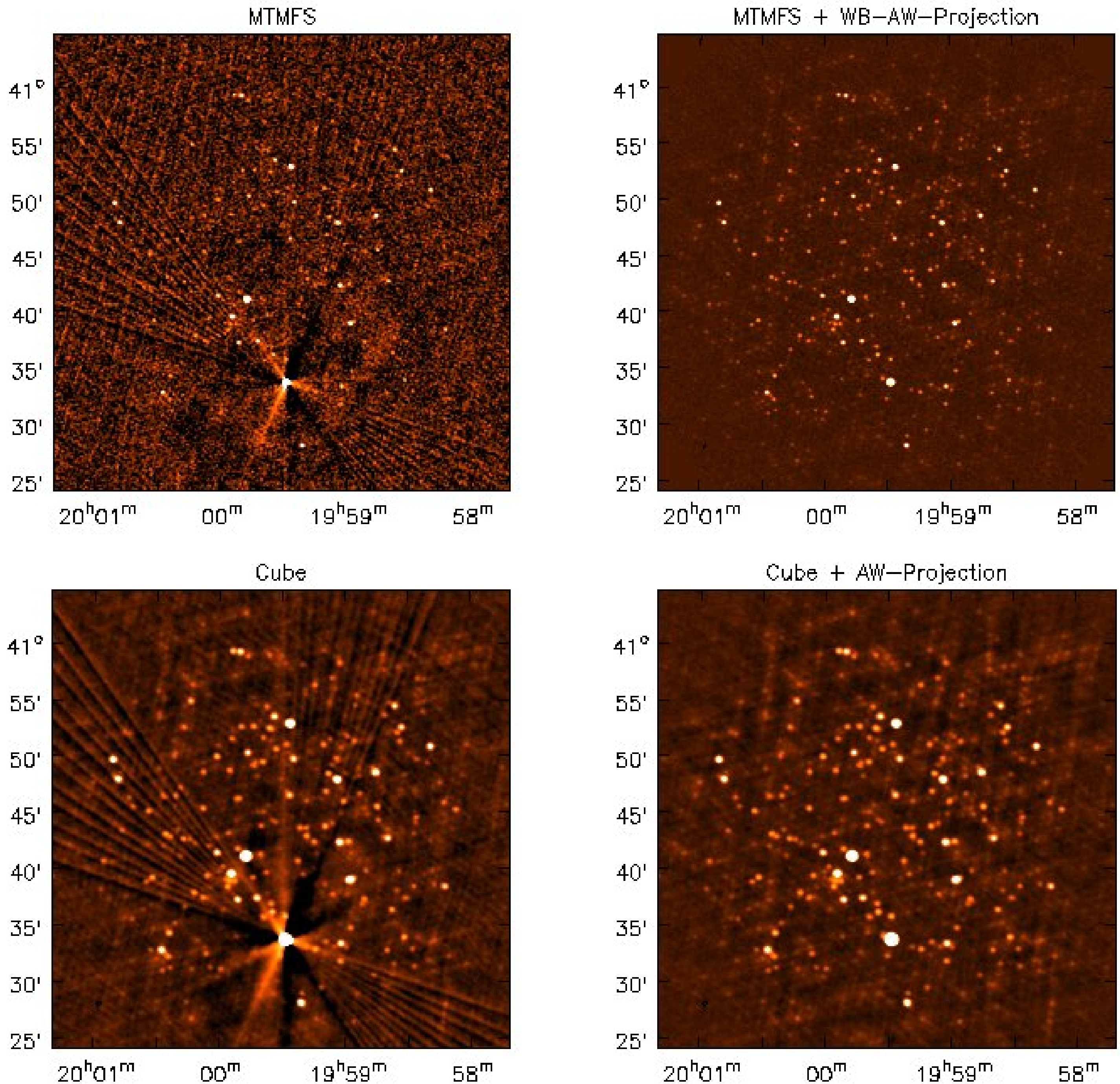
peak res : 15 uJy

Brightest Source : 100 mJy

Cube

4 uJy rms

peak res : 20 uJy



MT-MFS + WB-AWP

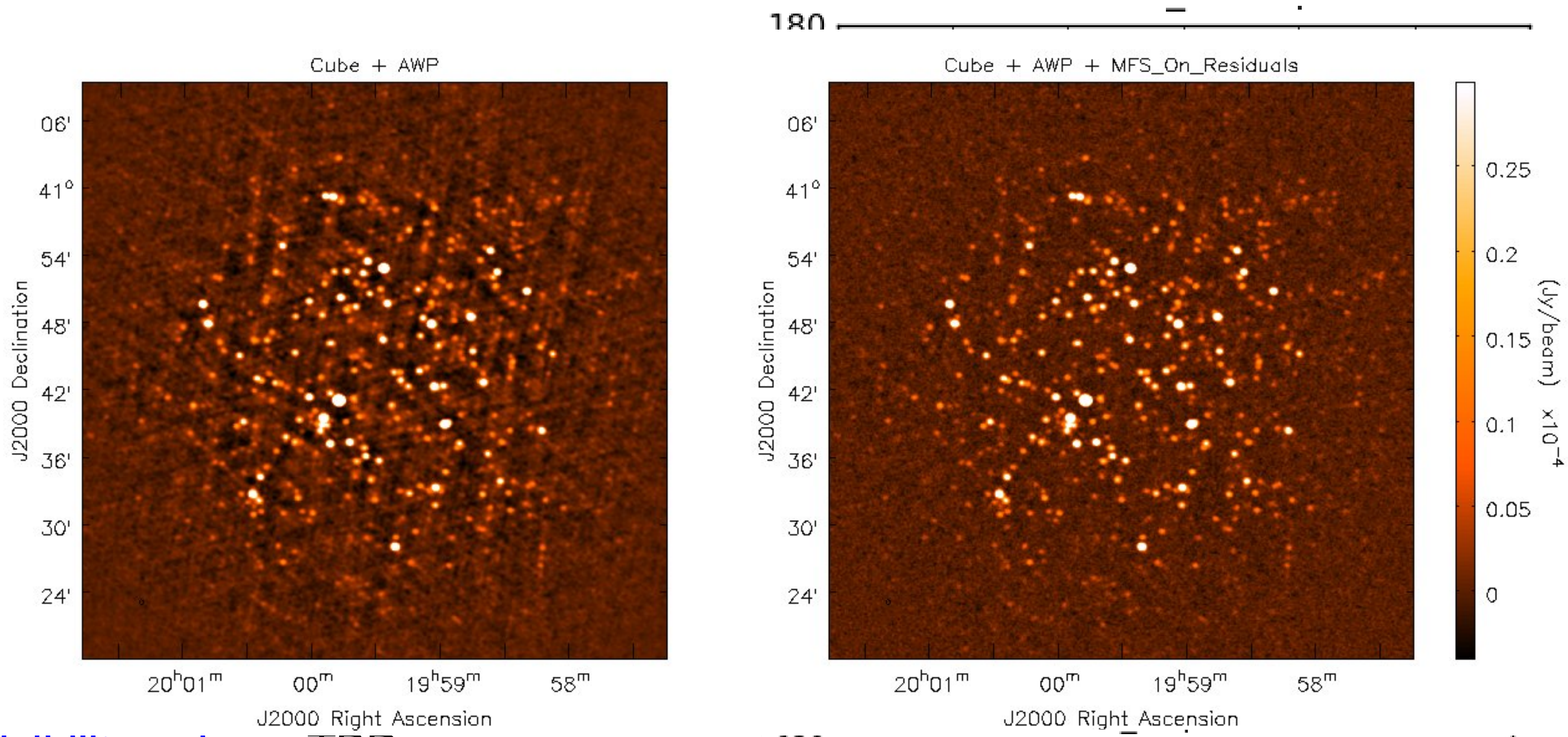
2 uJy rms

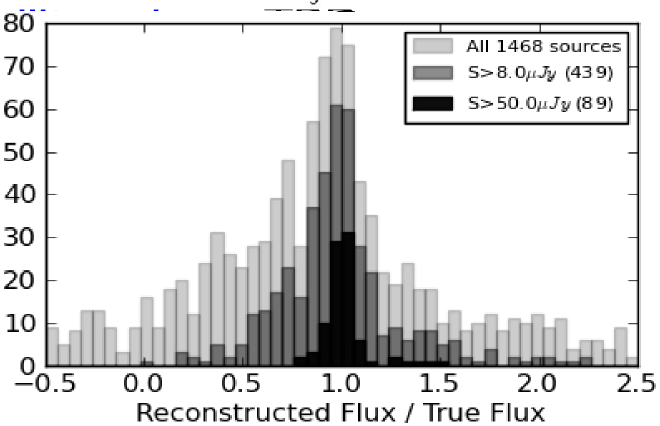
Cube + AW-Proj

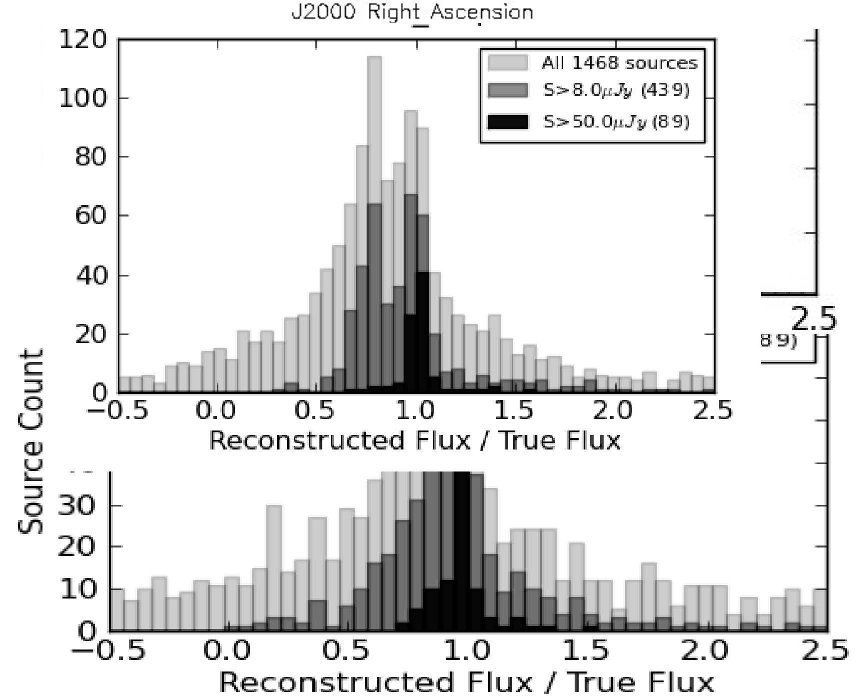
3 uJy rms

Details : validating simulations and testing algorithm limits

- Clean bias and
- Effect of PSF q
- Un-deconvolve
- Instrumental po
- Effect of source
- Effect of baseli
- Effect of adding vis
- Reconstruction acc
- Numerical / implem
  - Differences due to
  - Some uv-coverage
  - Algorithms react differently to bright outlier sources, deper
  - Different achieved noise levels with MosaicFT / FT / A-Prc
  - Non identical results between FT and the equivalent of FT





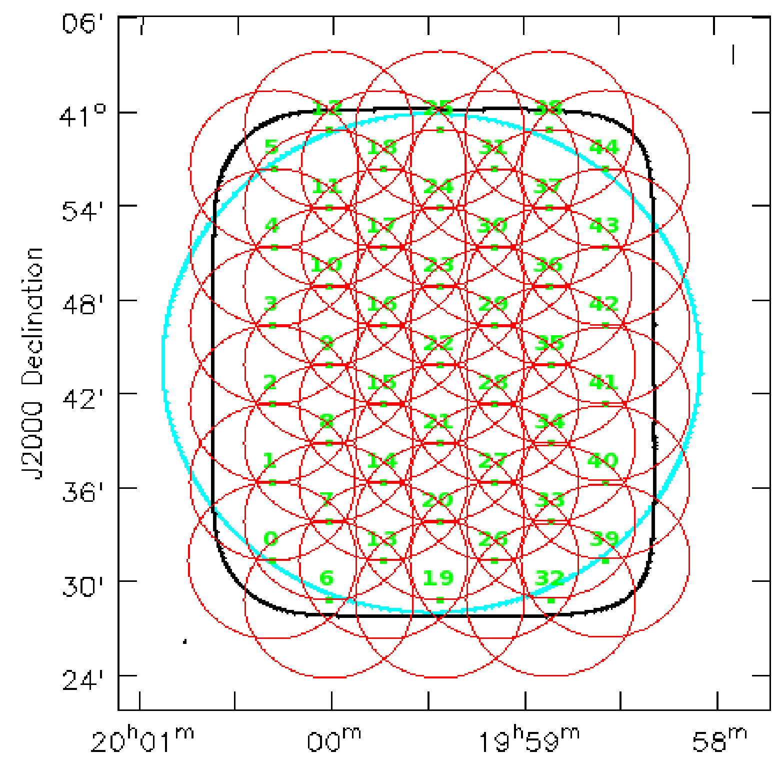


Wideband Mosaics – Simulation and Algorithms

EVLA D-config, C-band (4-8 GHz), 16 spws/chans

[Same field as with C-config L-band single pointing]

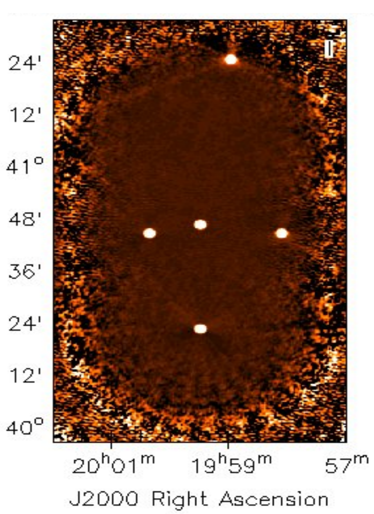
– 46 pointings at 5 arcmin spacing, 2 loops
– One snapshot every 6 min => 8.8 hr synthesis



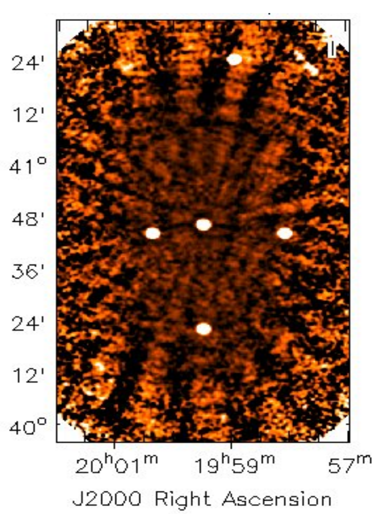
Algorithms :

- Deconvolve Pointings separately or together
- Deconvolve Channels separately or together
- Use A-Projection or not

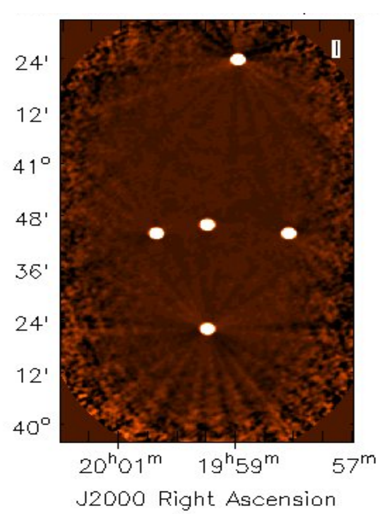
Joint Mosaic Wideband-AP



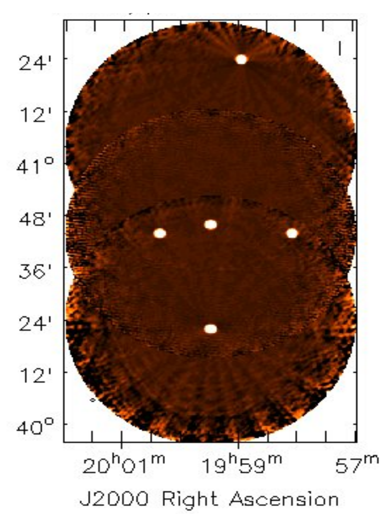
Joint Mosaic Cube



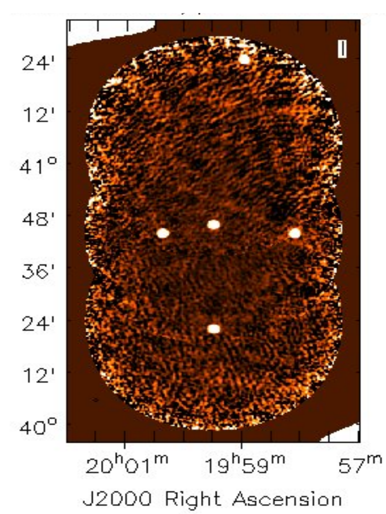
Joint Mosaic Cube-AP



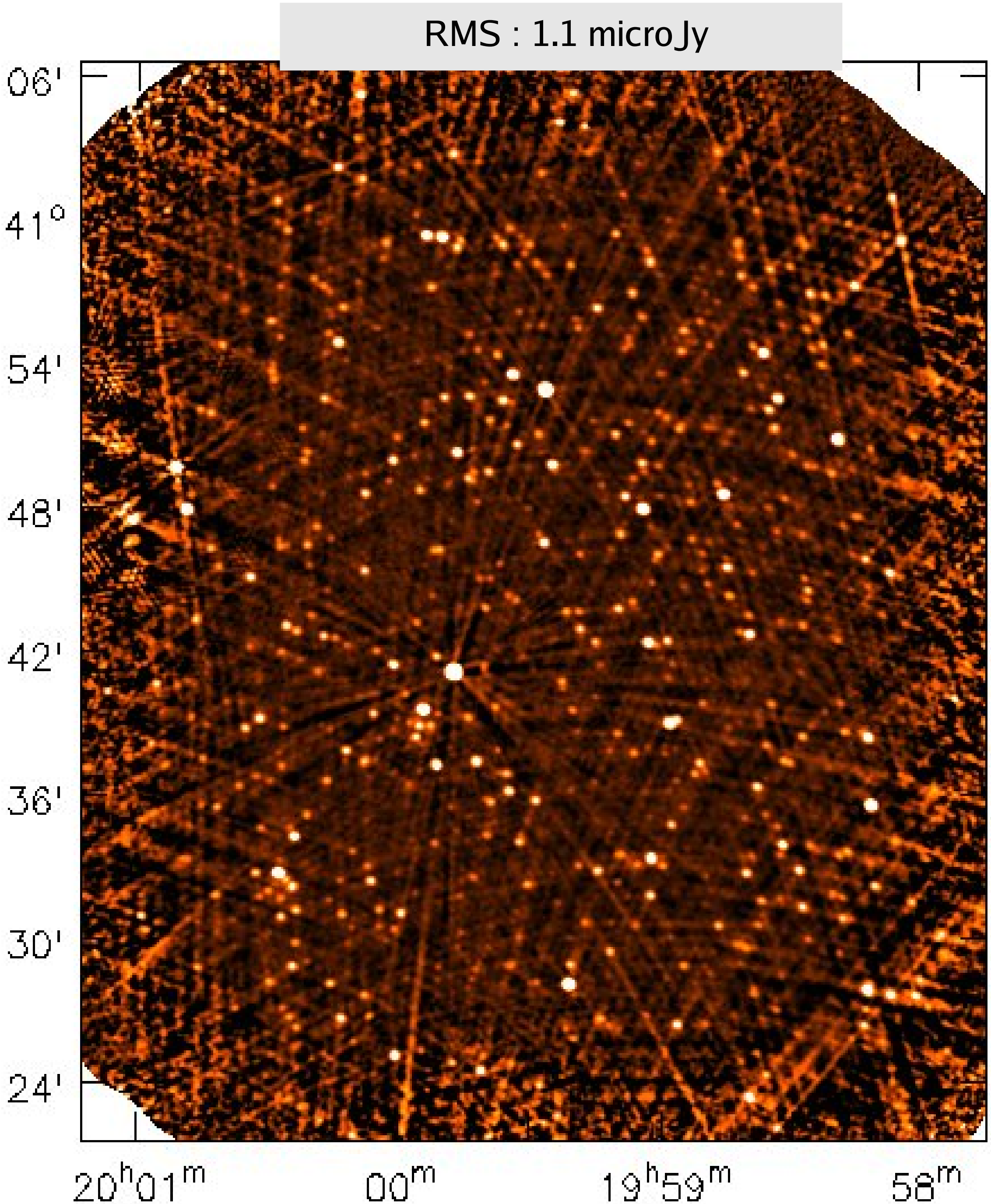
Linear Mosaic Wideband

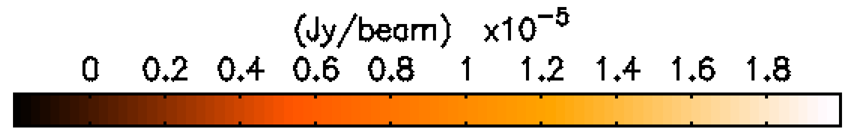


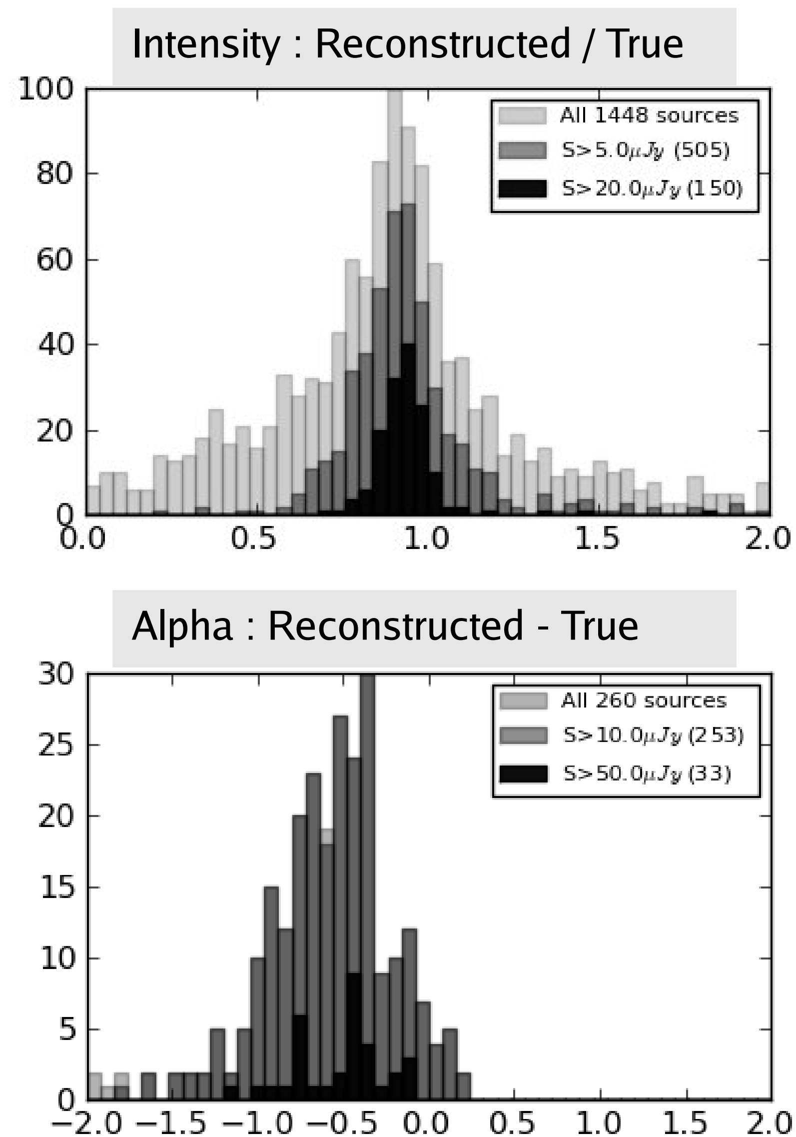
Linear Mosaic Wideband-AP



Cube Imaging with a Joint Mosaic (Ap=F) and PBCOR per SPW

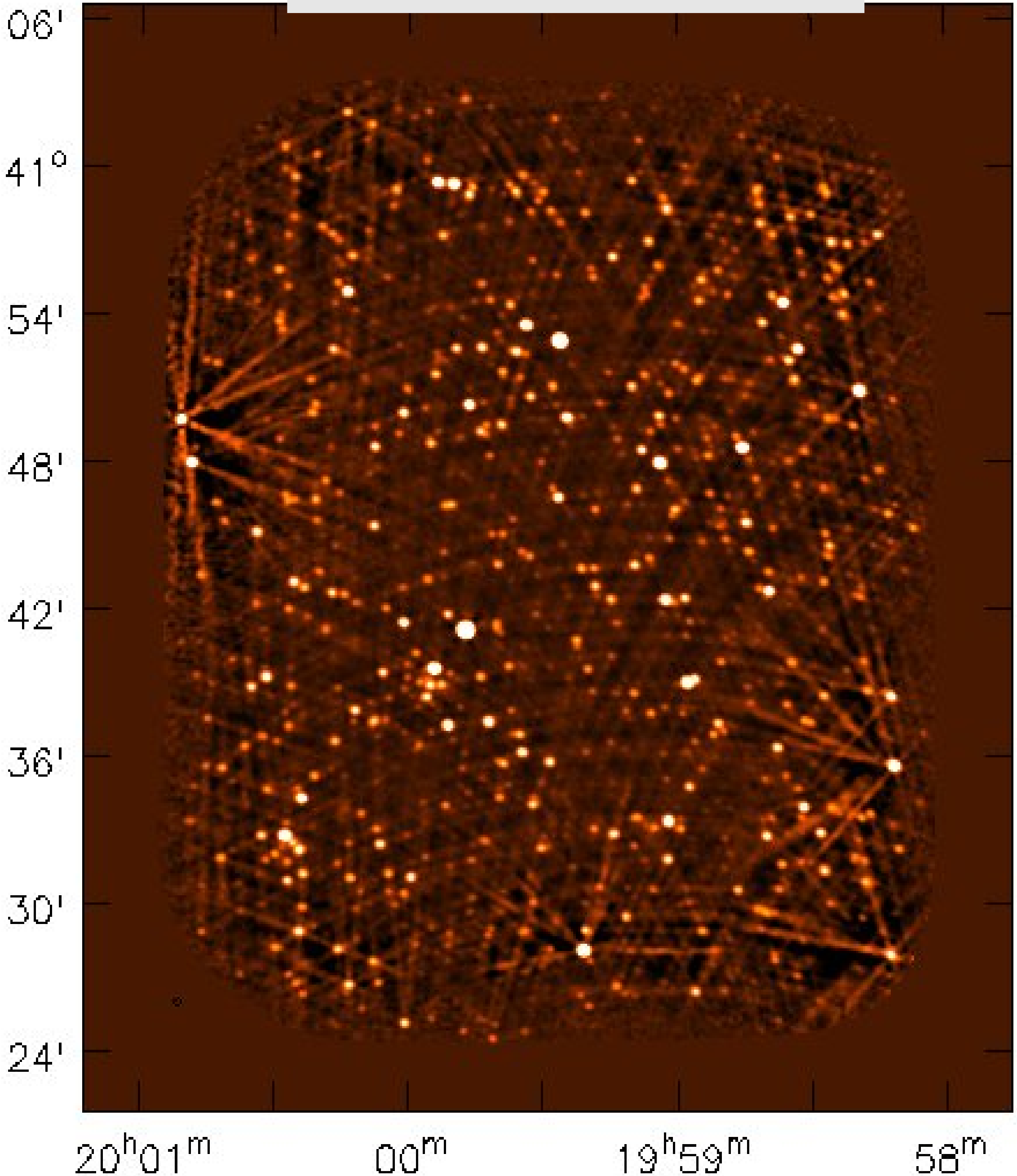


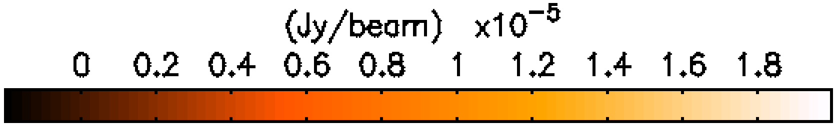




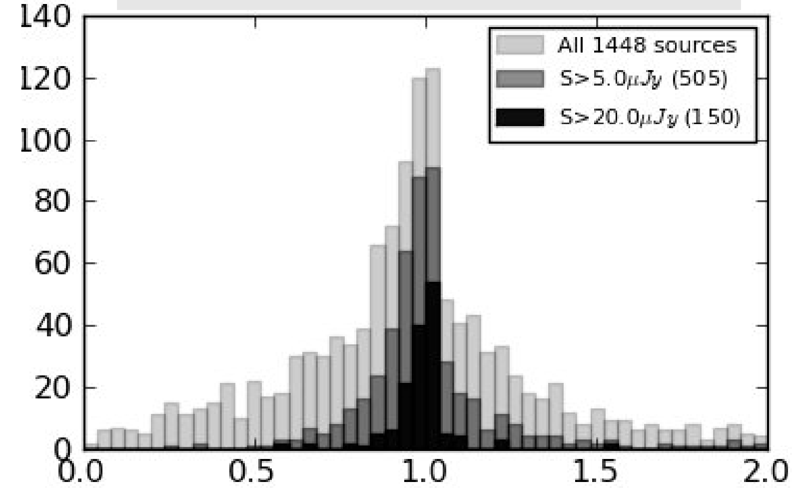
Cube Imaging with a Joint Mosaic (Ap=T) and PBCOR per SPW

RMS : 0.7 microJy

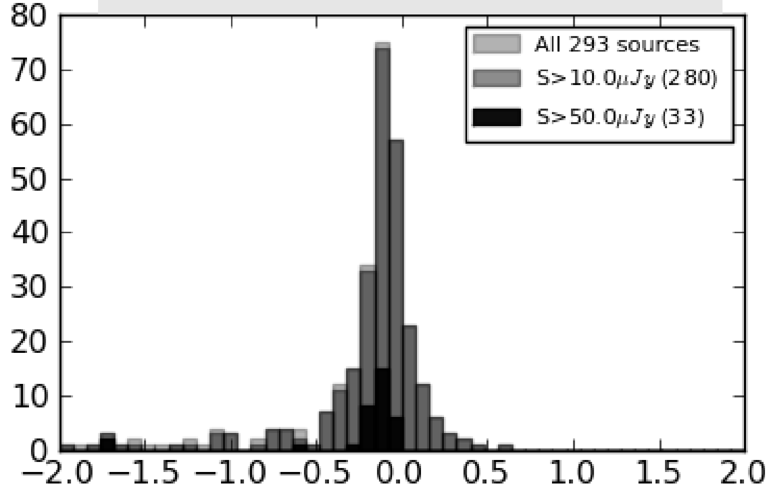




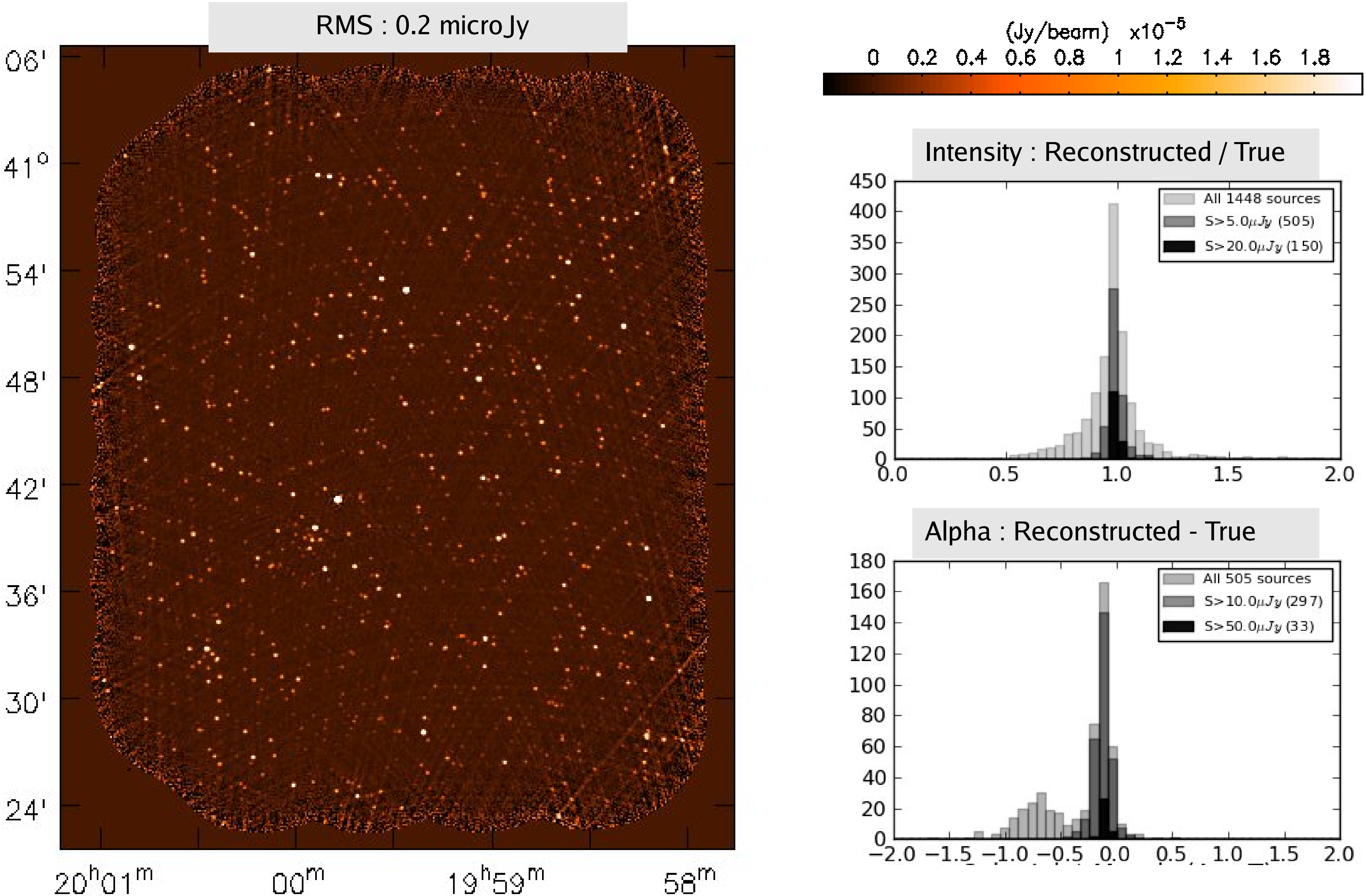
Intensity : Reconstructed / True



Alpha : Reconstructed - True



Joint Mosaic with Wideband AW-Projection and MT-MFS (nt=2)



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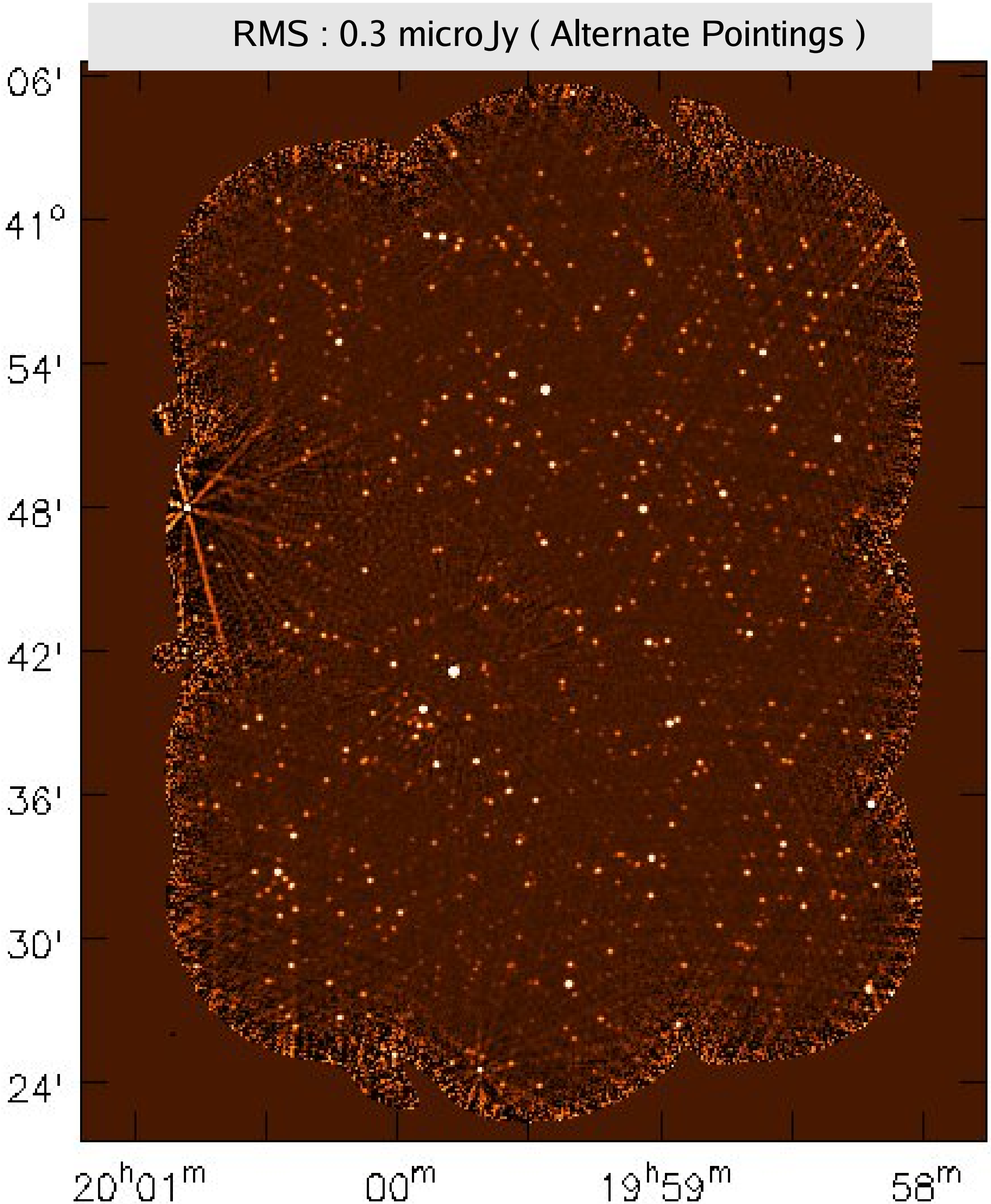

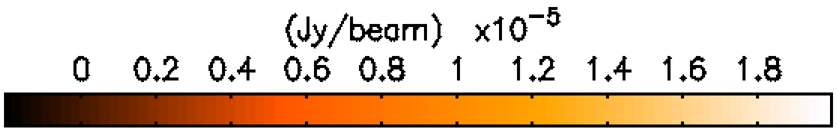

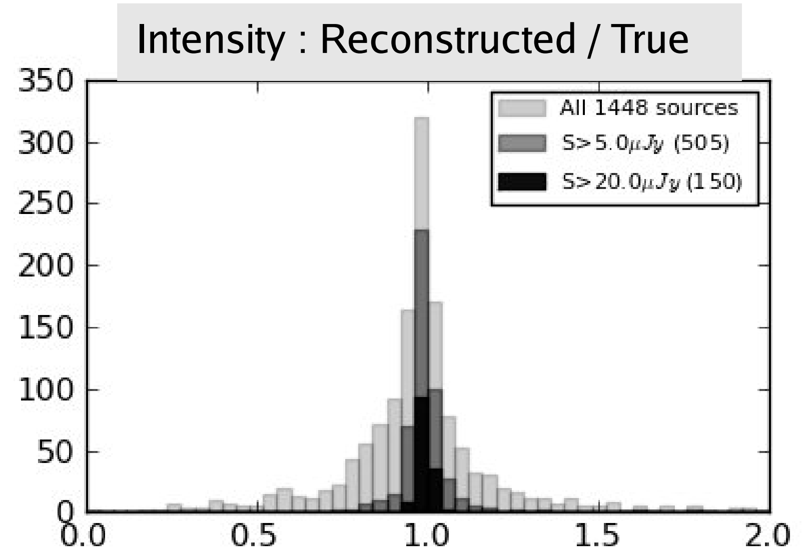

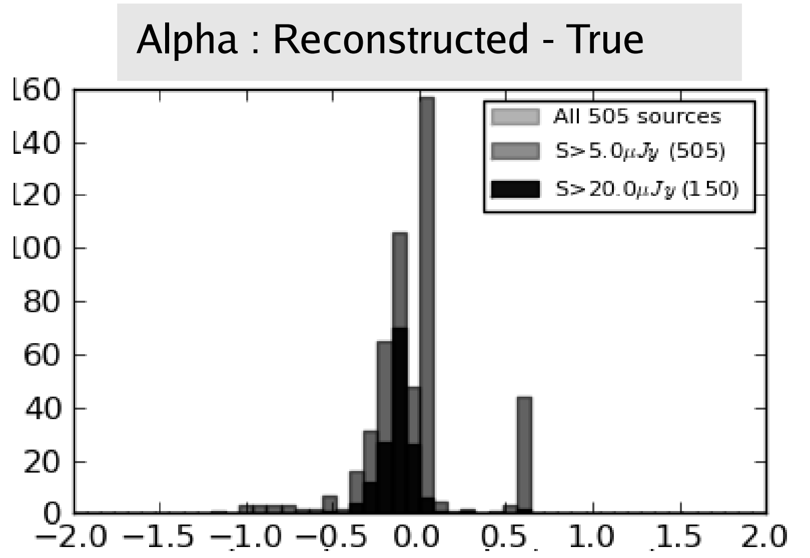

Summary + Future Work

- Work in progress to com

  - Wideband wide-field i

  - Even in perfectly cont
    the astrophysical inte

- Demonstrations on wide

  - Single pointings : A22
    Pla

  - Mosaics : CTB80 fiel
    Centaurus-

- More simulations

  - Add calibration error
    (Kara Kundert / undergr

  - Add source polarizat
    (Preshanth Jagannatha