Data Reduction Workshop
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Wide-band Wide-field Imaging

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Why new algorithms?

- Instantaneous wide-band capability of the EVLA is the single dominant parameter that enables new scientific capabilities

$$Noise \propto \frac{T_{sys}}{A_{eff}\sqrt{\Delta\nu\,\Delta T}}$$

  - More instantaneous information about the emission
    - Spectral Index, RM,...

- $$V_{ij}(\nu) = G_{ij}^{DI}\; W_{ij} \int \underbrace{P_{ij}(\mathbf{s},\nu,t)\; I(\mathbf{s},\nu)\; e^{\iota\,\mathbf{s}.\mathbf{b}_{ij}}}_{\text{Direction Dependent (DD) terms}}\; d\mathbf{s}$$

  - Terms inside the integral cannot be accounted-for before imaging
    - Conventional imaging ignores DD terms
    - Also ignores time, frequency and polarization dependence
  - Solutions: Project-out the effects during imaging + model frequency dependence of the sky during deconvolution
  - Or resort to spectral cube imaging + image-plane corrections/averaging

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PB Effects (A-Projection)

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  Spectral Index effects (MT-MFS)

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Non co-planar baselines (W-term) (W-Projection)

Direction Dependent (DD) terms

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Plan

- Wide-band Imaging
  - Account for frequency dependent sky brightness distribution
  - Algorithm: Multi-term Multi-Frequency Synthesis (MT-MFS, MS-MFS)

[Rau & Cornwell, A&A, 2011]

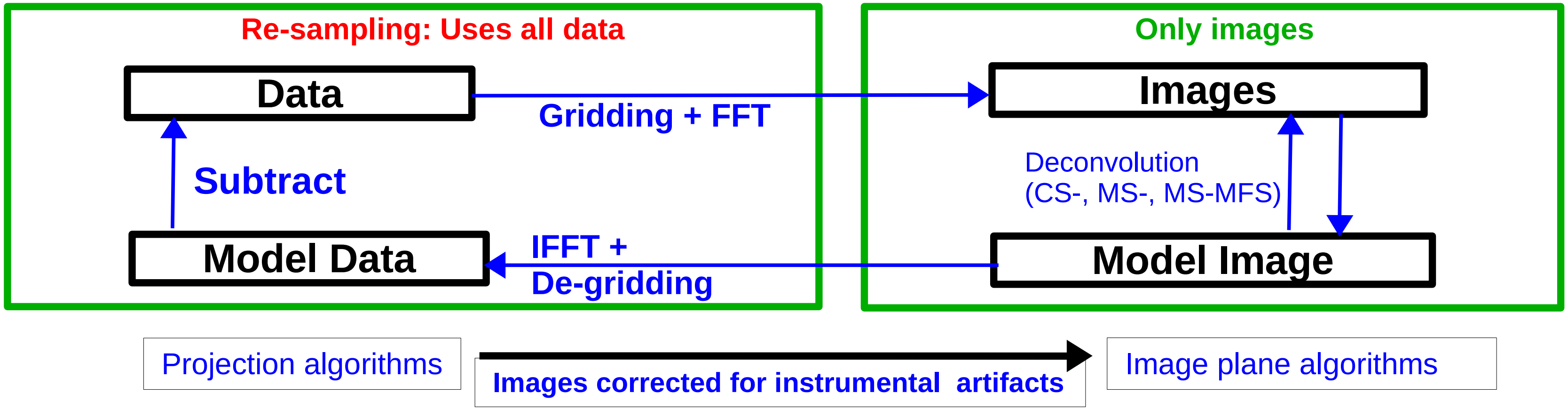
- Wide-field Imaging: Includes any effect that increases with R
  - Non co-planar baseline effect (W-term) **[Cornwell, Golap, Bhatnagar, Proc. IEEE, 2009]**
  - Effect of antenna PB: Time- and Poln.-dependence **[Bhatnagar et al., A&A, 2008]**
    - Includes mosaic imaging
  - Algorithm: W-Projection, (WB) A-Projection

[General review: Rau et al., Proc. IEEE, V. 97 (8) 2009]

- Wide-band Wide-field Imaging
  - All of the above + PB frequency dependence **[Bhatnagar et al., A&A, 2012]**
  - Algorithm: MT-MFS + (WB) AW-Projection (+ Mosaic) **[WB Mosaic: Rau, Bhatnagar, Golap, In prep.]**

Imaging & Deconvolution: A recap

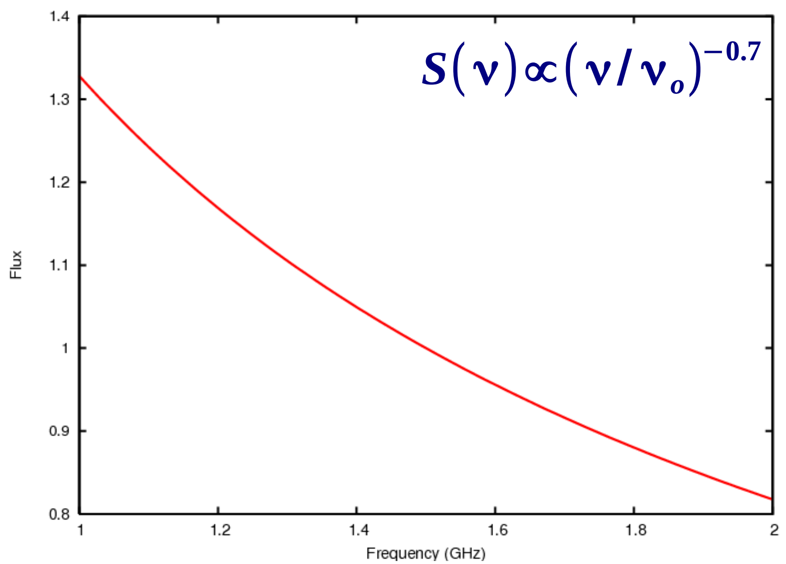
- Compute residuals using the original data
  - Needs Gridding and de-Gridding during major-cycle iterations

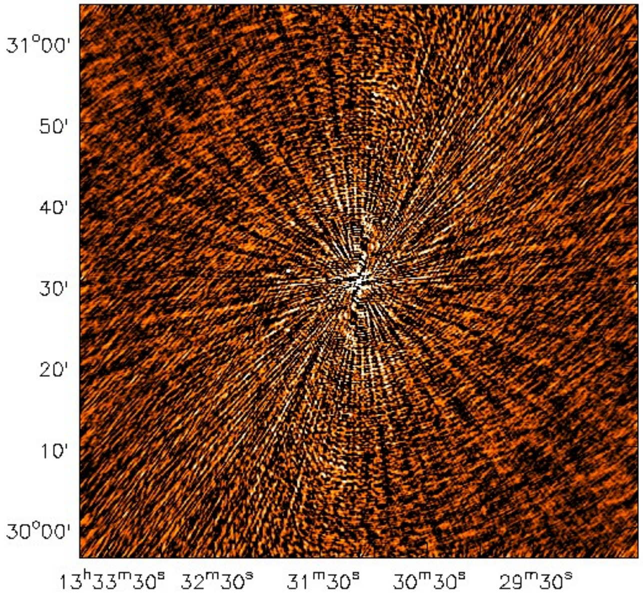


W-Projection	CS-Clean
A-Projection	MS-Clean
WB A-Projection	MT-MFS/MS-MFS

What do we call wide-band?

- When fractional signal bandwidth used for imaging > ~20%
  - Plus source spectral index >= -1.0
  - Plus target dynamic range > 1000
- Spectral effects for higher source spectral index will become significant at lower bandwidth ratios
  - Empirical Dynamic range : $\frac{I\alpha}{100}$
  - Spectral line imaging, by definition, does not require wide-band imaging algorithms





Wide-band Imaging Sensitivity

Frequency Range :	(1 – 2 GHz)	(4 – 8 GHz)	(8 – 12 GHz)
Bandwidth : $\nu_{max} - \nu_{min}$	1 GHz	4 GHz	4 GHz
Bandwidth Ratio : $\nu_{max} : \nu_{min}$	2 : 1	2 : 1	1.5 : 1
Fractional Bandwidth : $(\nu_{max} - \nu_{min}) / \nu_{mid}$	66%	66%	40%

Broad-band receivers increase the 'instantaneous' imaging sensitivity of an instrument

Continuum sensitivity : $\sigma_{cont} \propto \frac{T_{sys}}{\sqrt{N_{ant}(N_{ant}-1)\ \delta\tau\,\delta\nu}}$
(at field-center)

50 MHz → 2 GHz   Theoretical sensitivity improvement : $\sqrt{\frac{2\,GHz}{50\,MHz}} \approx 6$ times.

In practice, effective broadband sensitivity for imaging depends on bandpass shape, data weights, and regions of the spectrum flagged due to RFI (radio-frequency interference).

Use narrow-band channels – avoid bandwidth smearing

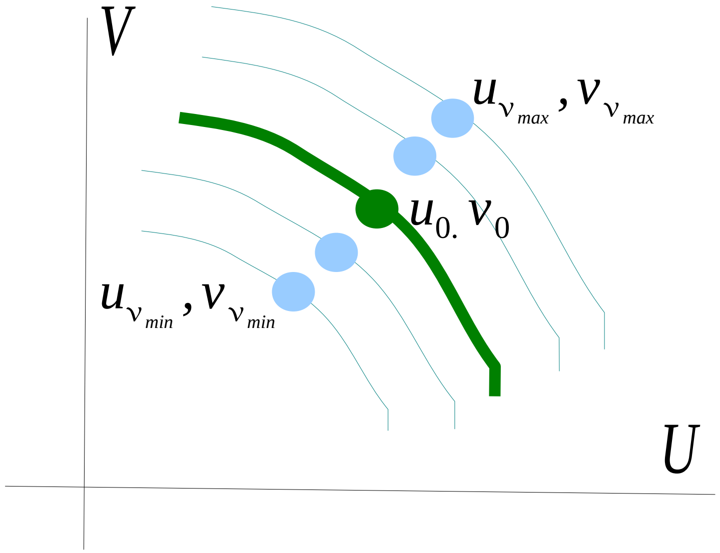
In the early days of continuum-observing, only one visibility was computed across the entire bandwidth of the receiver, and attributed to the reference (or middle) frequency ν_0. Delay-tracking was also done only at ν_0 .

The visibility $V(u_\nu)$ is mistakenly mapped to $u_0 = \frac{b\nu_0}{c} = \frac{\nu_0}{\nu} u_\nu$

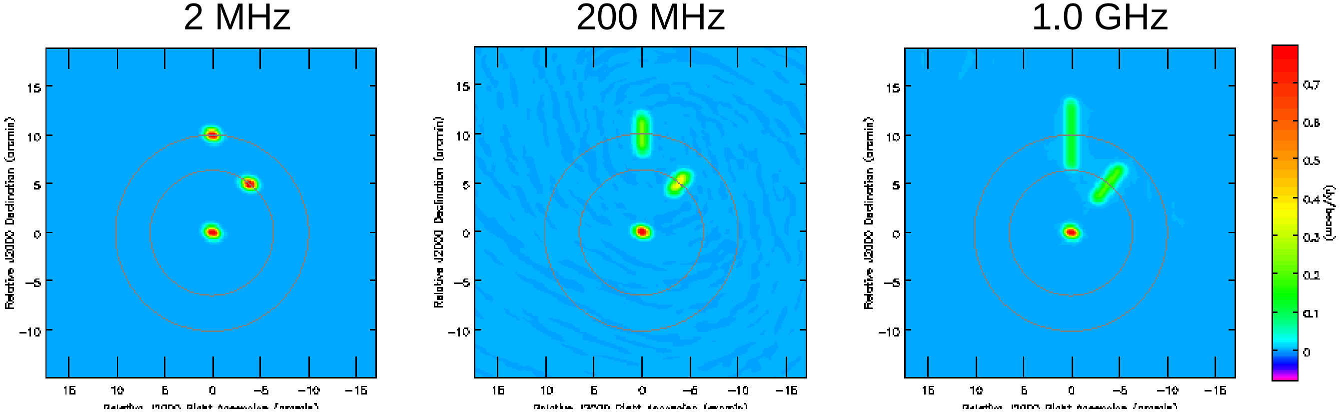
Similarity theorem of Fourier-transforms :

=> A radial shift in the source position, with frequency.
=> Radial smearing of the brightness-distribution

Note : Excessive channel-averaging has a similar effect.



An (exaggerated) example of bandwidth-smearing with a 1-2 GHz signal......



Bandwidth Smearing Limits at 1.4 GHz

33 MHz (VLA D-config),
10 MHz (VLA C-config),
3 MHz (VLA B-config),
1 MHz (VLA A-config)

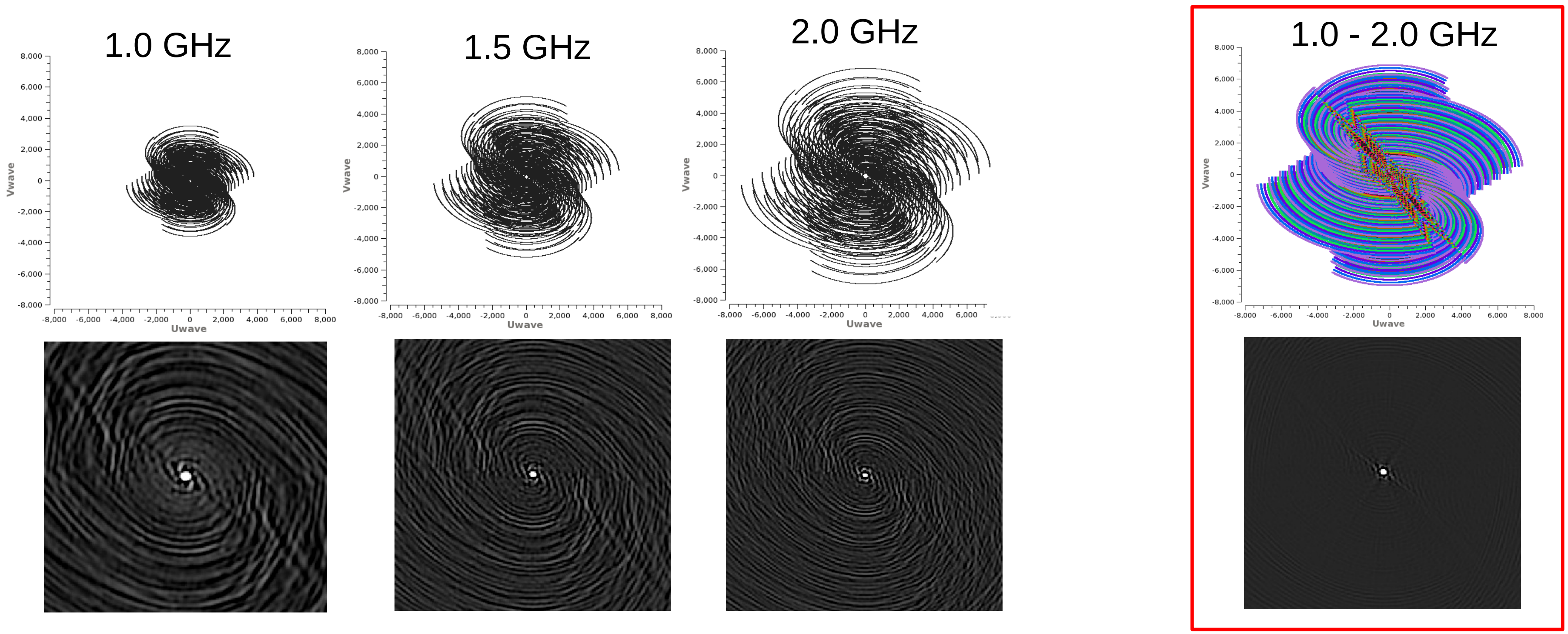
Contours represent 5 and 10 arcmin distances from the phase-center.

Frequency-dependent UV-coverages and PSFs

Spatial-frequency coverage and imaging properties change with frequency :

- Angular-resolution increases at higher frequencies
- Sensitivity to large scales decreases at higher frequencies
- Wideband UV-coverage has fewer gaps => lower Psf sidelobe levels

$$S(u,v)_{\nu} = \frac{\vec{b}}{\lambda} = \frac{\vec{b}\,\nu}{c}$$



But, when the source intensity varies with frequency, different channels measure the visibility function of different sky-brightness distributions

the $V(u_{\nu}, v_{\nu}) = \iint I(l,m,\nu)\, e^{2\pi i (u_{\nu} l + v_{\nu} m)}\, dl\, dm$

=> Need to model the spectrum as part of image reconstruction

Frequency-dependent UV-coverages and PSFs

Spatial-frequency coverage and imaging properties change with frequency:

- PSF structure scales with frequency

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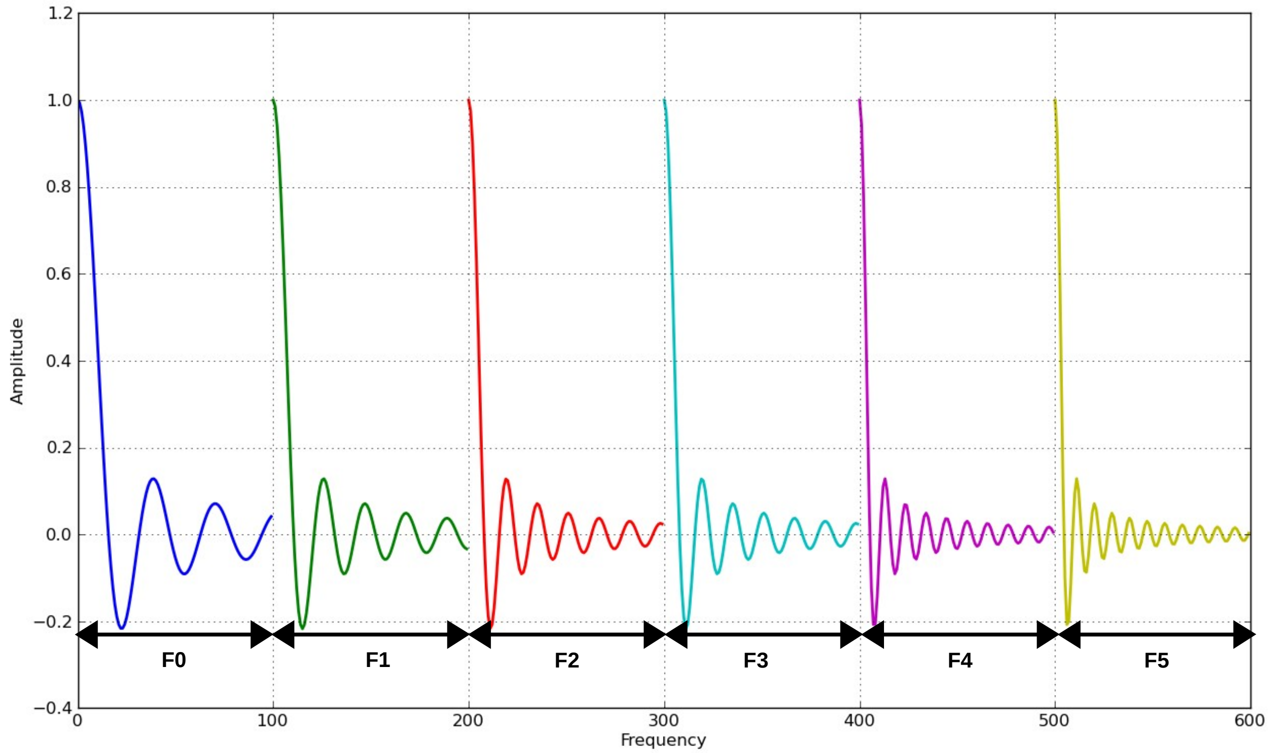

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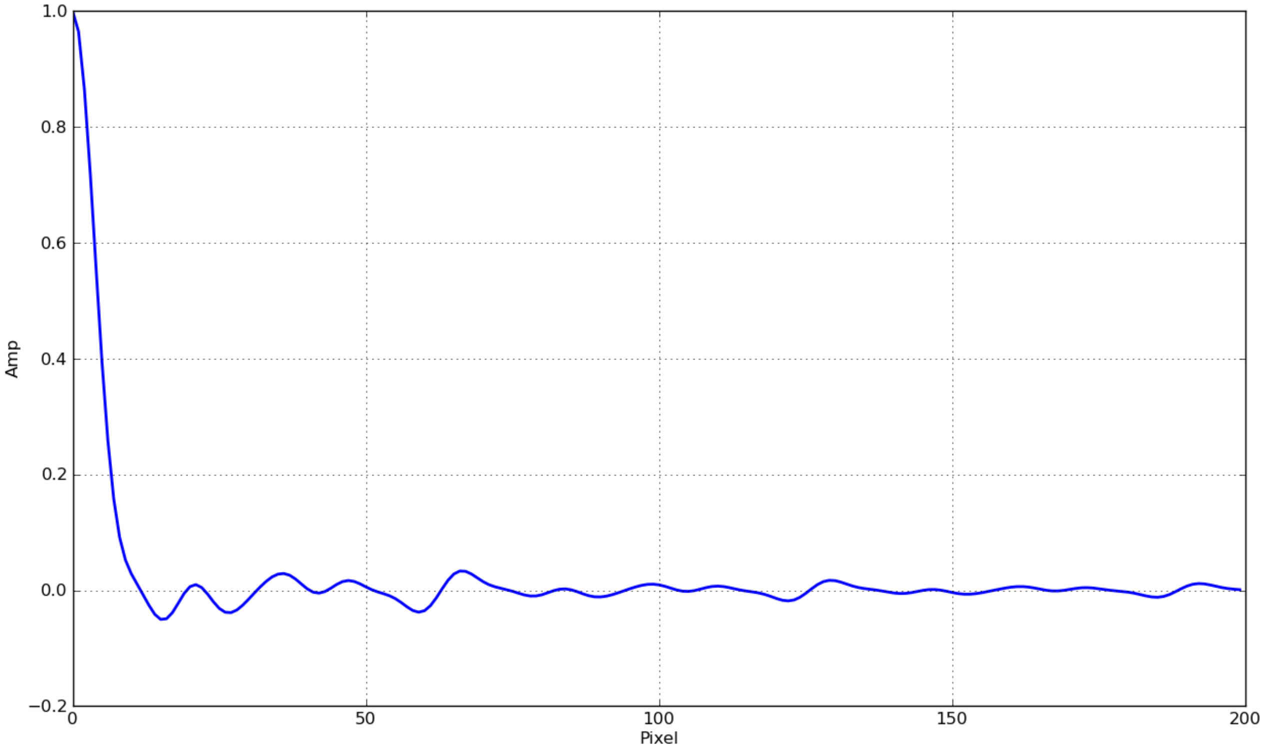
$$PSF_{Continuum} = \sum_\nu PSF(\nu)$$



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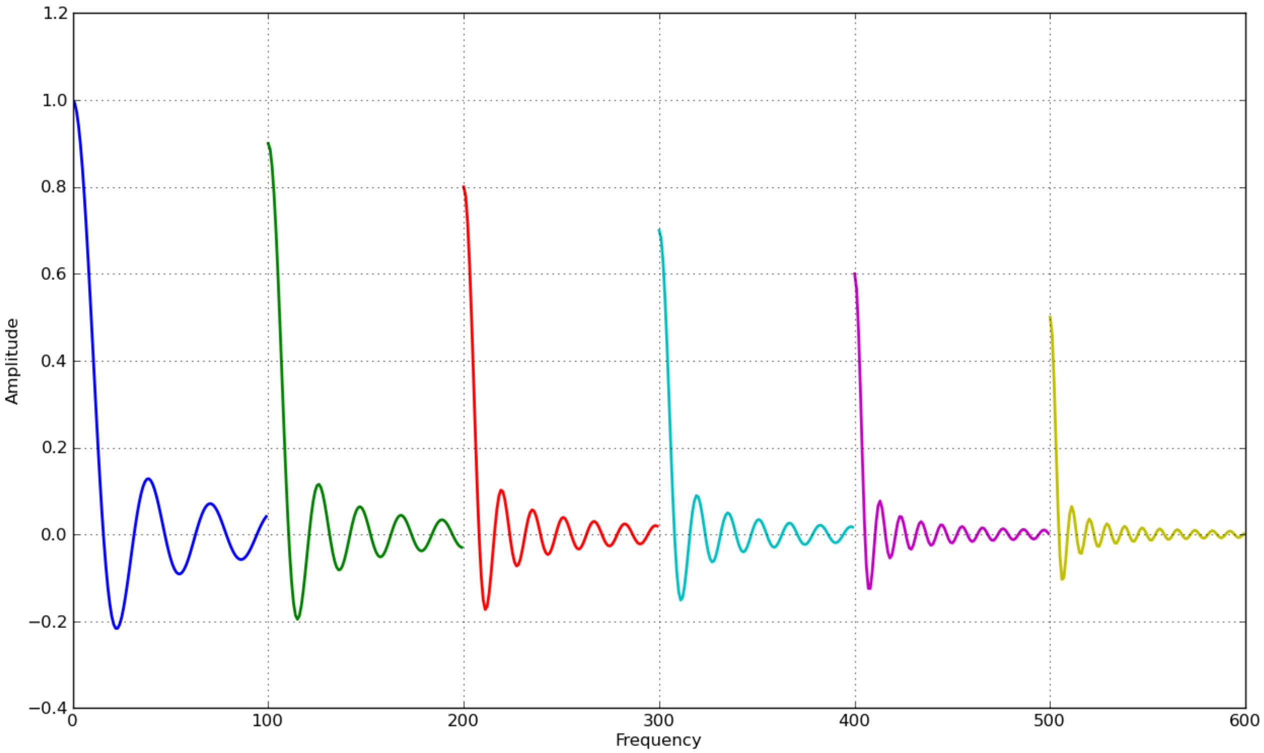
- Due to source Spectral Index, PSF amplitude also changes with frequency



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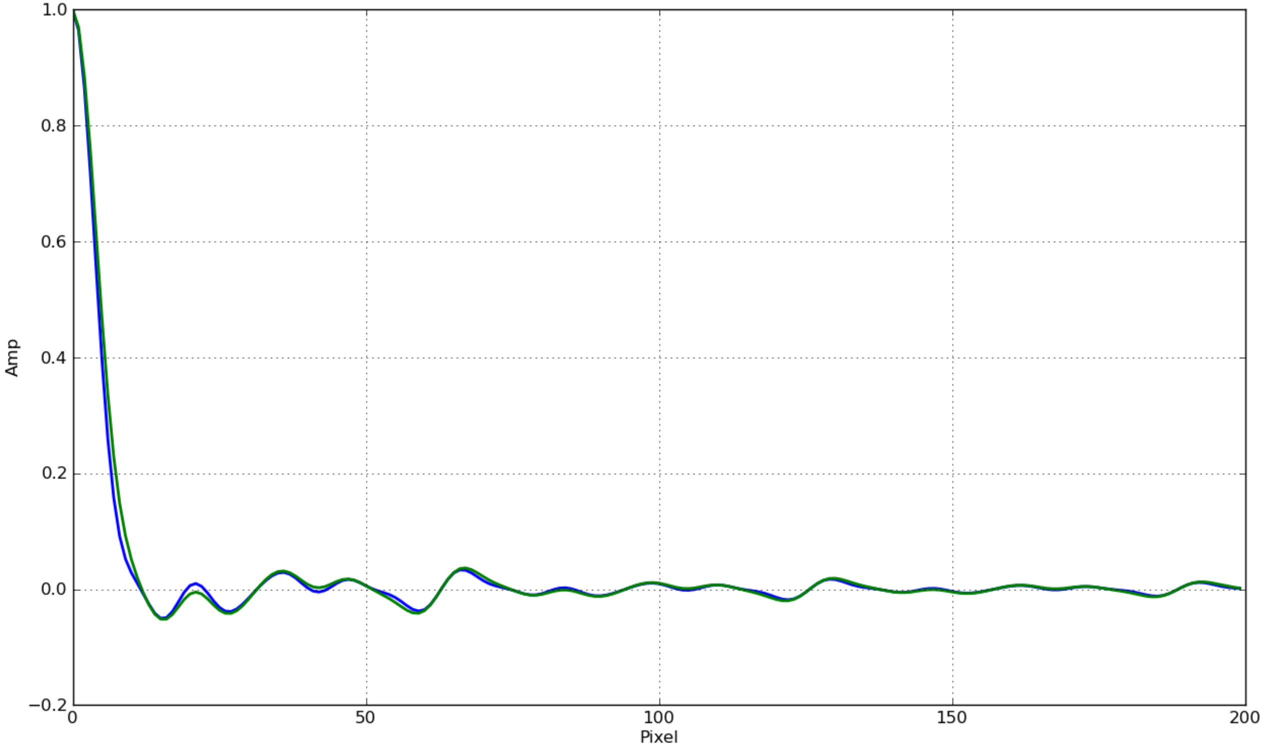
$$PSF(x_o)_{Continuum} = \sum_\nu I(x_o,\nu)\, PSF(x - x_o, \nu)$$



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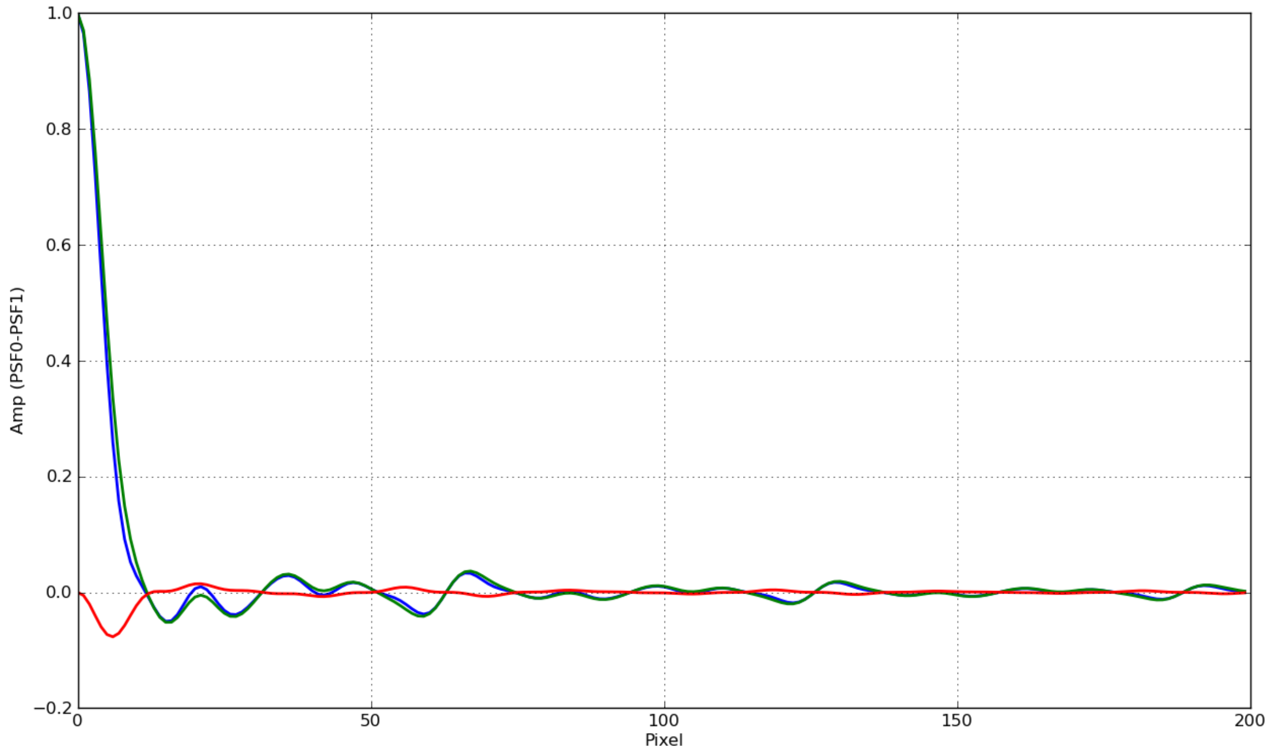
$$Res(x_o)_{Continuum} = \sum_\nu PSF(x-x_o,\nu) - \sum_\nu I(x_o,\nu) PSF(x-x_o\nu)$$



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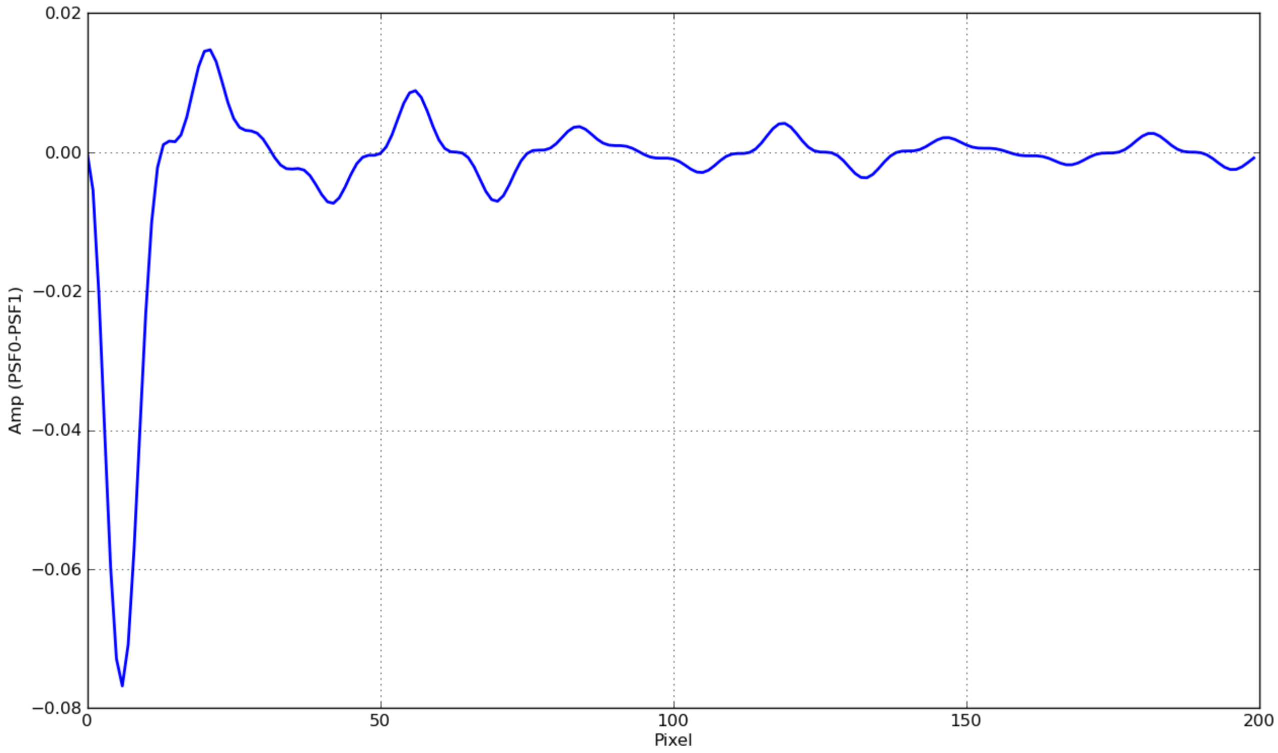


Wideband Imaging Options

(1) Make images for each channel / SPW separately.

- Signal-to-noise ratio : one SPW
- Angular resolution varies with SPW (smooth to lowest)
- Imaging fidelity may change across SPWs
- Primary beam correction can be done per SPW

Cube imaging will suffice for sources with simple spatial structures, and where the added uv-coverage, sensitivity and angular resolution is not required for the target science.

(2) Combine all frequencies during imaging (MFS : multi-frequency synthesis)

- Signal-to-noise ratio : all SPWs
- Angular resolution is given by the highest frequency
- Imaging fidelity is given by the combined uv-coverage
- Wideband PB correction is required (average gain and spectrum)

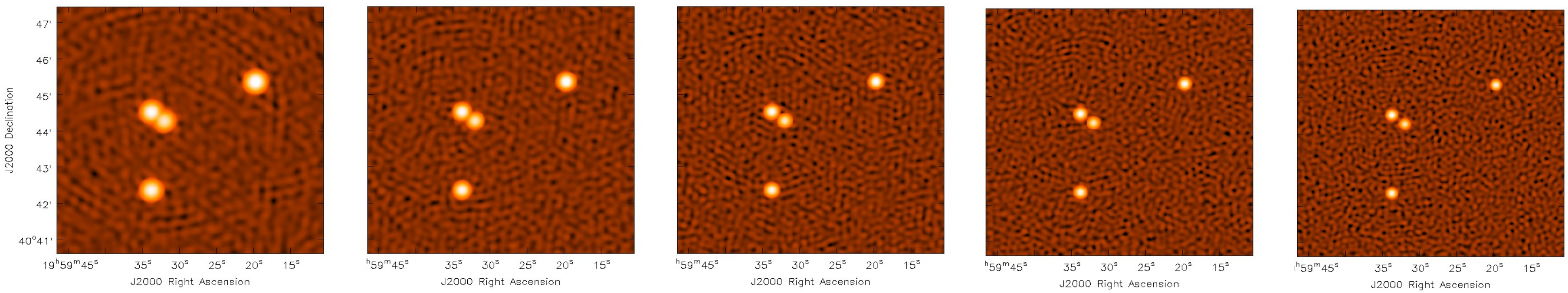
Multi-frequency-synthesis is needed to fully utilize the wideband uv-coverage and sensitivity during image reconstruction.

The frequency dependence of the sky and instrument must be taken into account

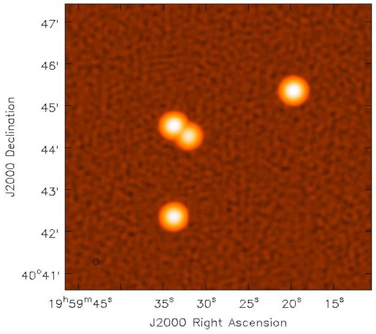
Single-channel vs MFS imaging – Angular Resolution

Simulated Example : 3 flat-spectrum sources + 1 steep-spectrum source (1-2 GHz)

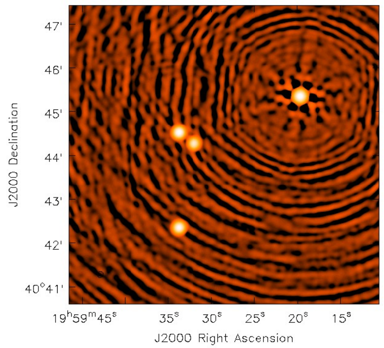
Images made separately at different frequencies between 1 and 2 GHz



Combine all single-frequency images (after smoothing)

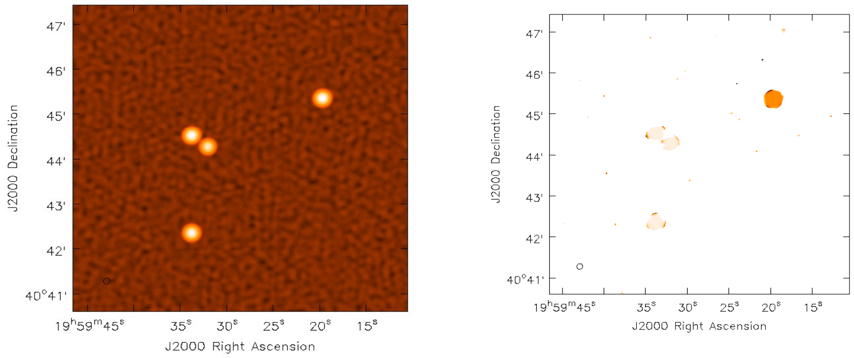


Use all UV-coverage together, but ignore spectra



Use all UV-coverage together + Model and fit for spectra too

Output : Intensity and Spectral-Index



=> Imaging with a spectrum model : higher angular resolution + continuum sensitivity.

Continuum Imaging : (multi-scale) multi-frequency-synthesis

Sky Model : Collection of multi-scale flux components whose amplitudes follow a polynomial in frequency

$$I_\nu^{sky} = \sum_t I_t \left(\frac{\nu - \nu_0}{\nu_0} \right)^t \quad \text{where } I_t = \sum_s [I_s^{shp} * I_{s,t}]$$

Algorithm : Linear least squares + deconvolution

Parameters : mode='mfs', nterms=2, reffreq='1.5GHz', multiscale=[0,6,10]

Data Products : Taylor-Coefficient images $I_{0,}^m I_{1,}^m I_{2,}^m \ldots$ that represent the observed spectrum

Interpretation :

- As a power-law (spectral index and curvature) $I_\nu = I_{\nu_0} \left(\frac{\nu}{\nu_0} \right)^{\alpha + \beta \log(\nu/\nu_0)}$

$$I_0^m = I_{\nu_0} \qquad I_1^m = I_{\nu_0} \alpha \qquad I_2^m = I_{\nu_0} \left(\frac{\alpha(\alpha-1)}{2} + \beta \right)$$

- PB-correction : Model the average PB-spectrum with a Tayor-polynomial, and do a post-deconvolution Polynomial-Division

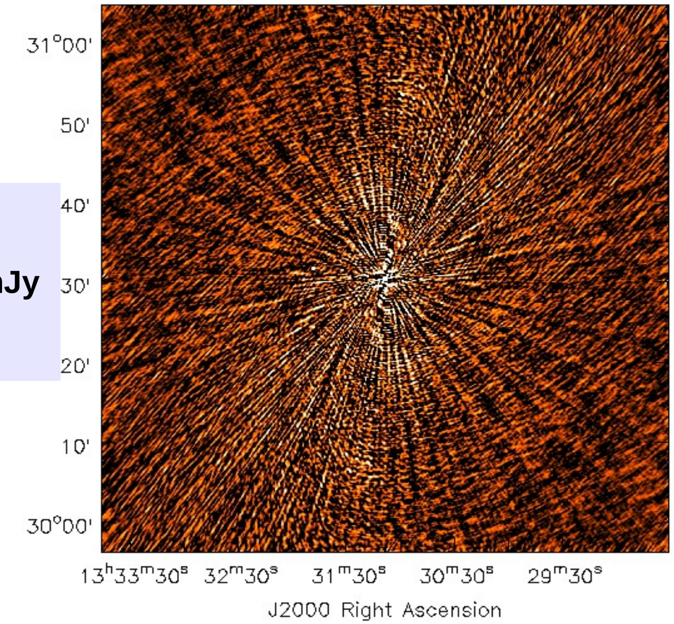
$$\frac{(I_{0,}^m I_{1,}^m I_{2,}^m \ldots)}{(P_{0,} P_{1,} P_{2,} \ldots)} = (I_{0,}^{sky} I_{1,}^{sky} I_2^{sky} \ldots)$$

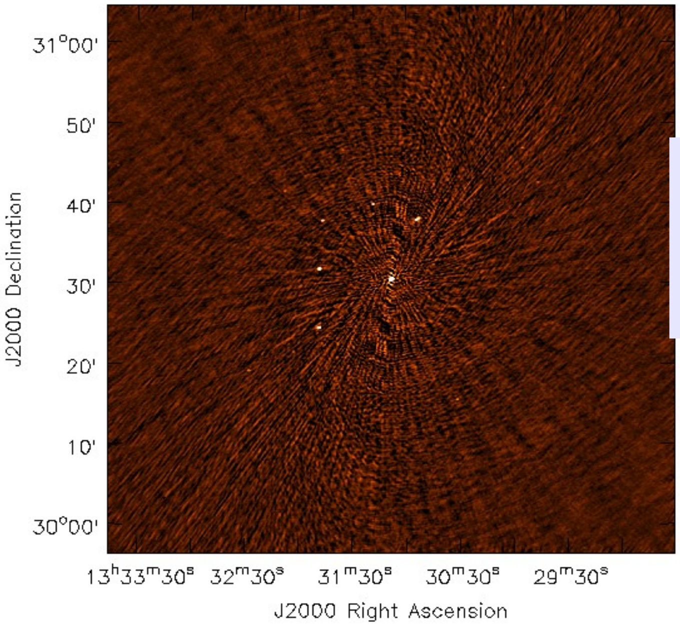
Dynamic-range with MS-MFS : 3C286 example : Nt=1,2,3,4

NTERMS = 1

Rms : 9 mJy -- 1 mJy

DR : 1600 -- 13000





NTERMS = 2

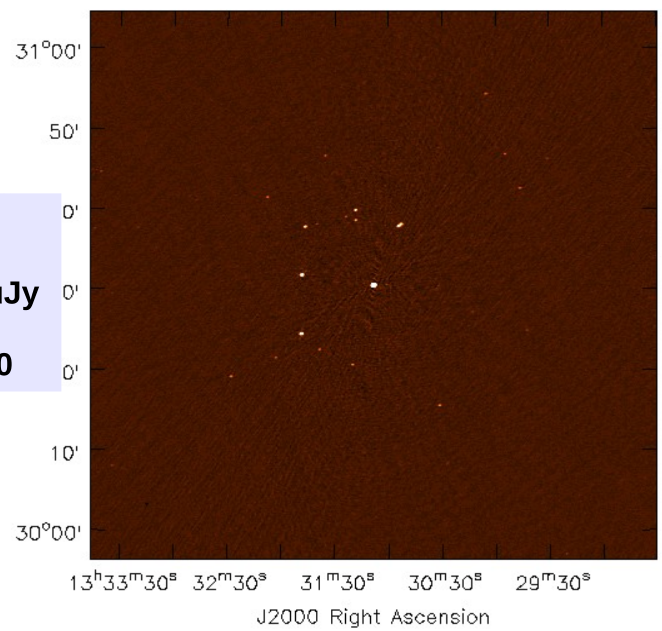
Rms :1 mJy -- 0.2 mJy

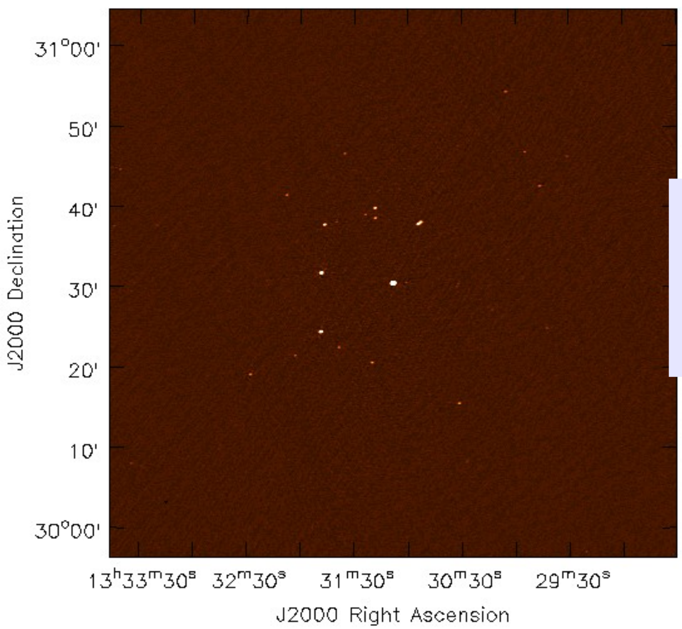
DR :10,000 -- 17,000

NTERMS = 3

Rms : 0.2 mJy -- 85 uJy

DR : 65,000 -- 170,000





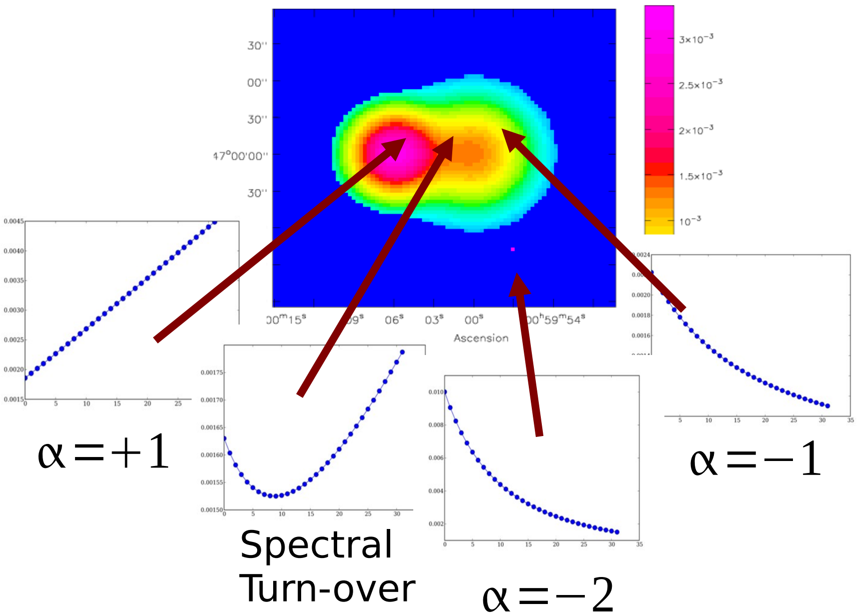
NTERMS = 4

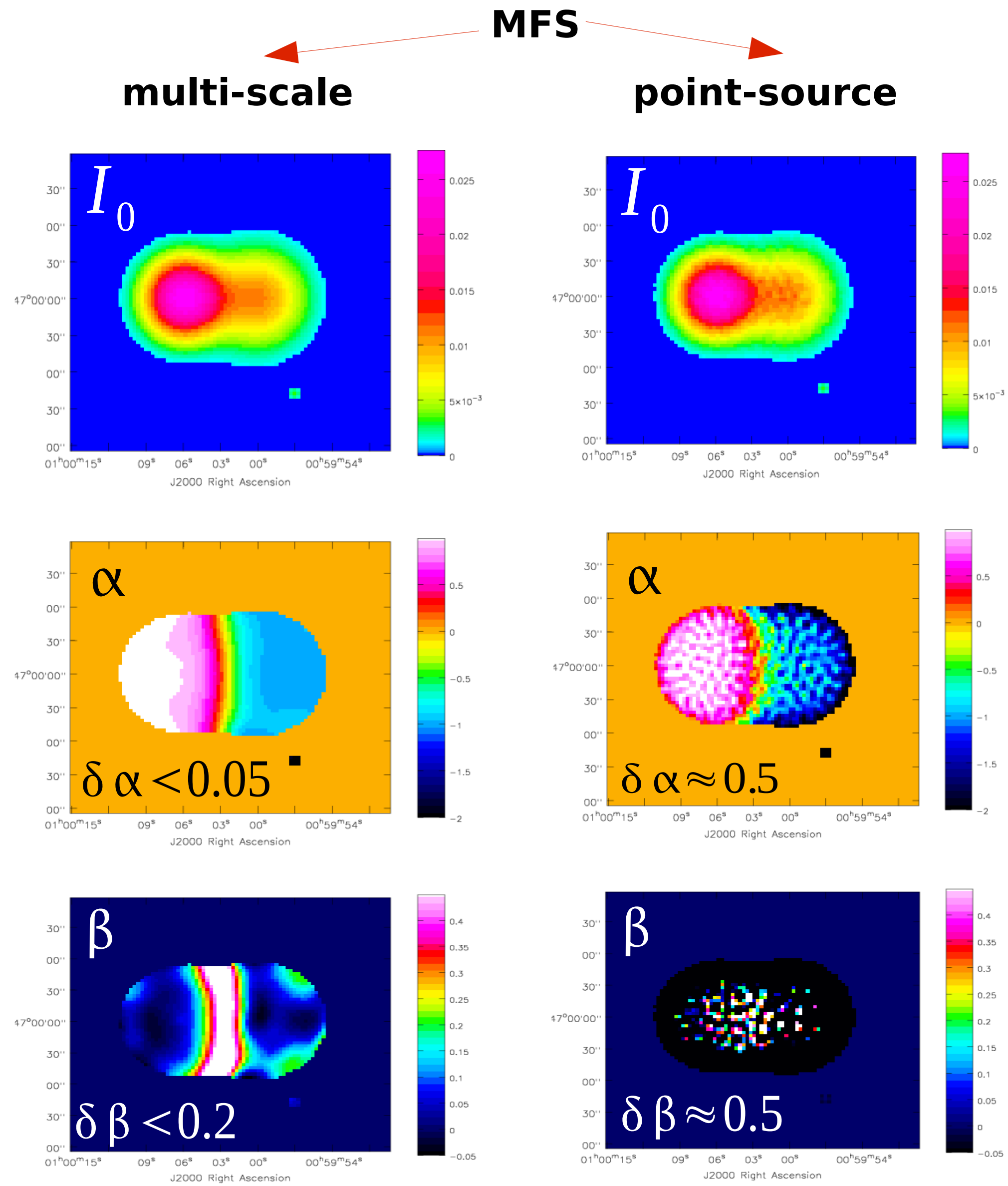
Rms 0.14 mJy -- 80 uJy

DR :>110,000 -- 180,000

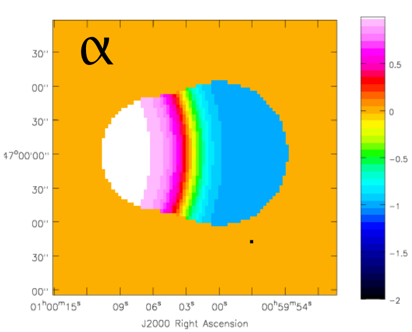
Example of wideband-imaging on extended-emission

Intensity Image

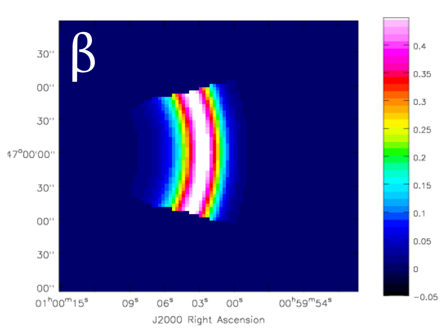




Average Spectral Index



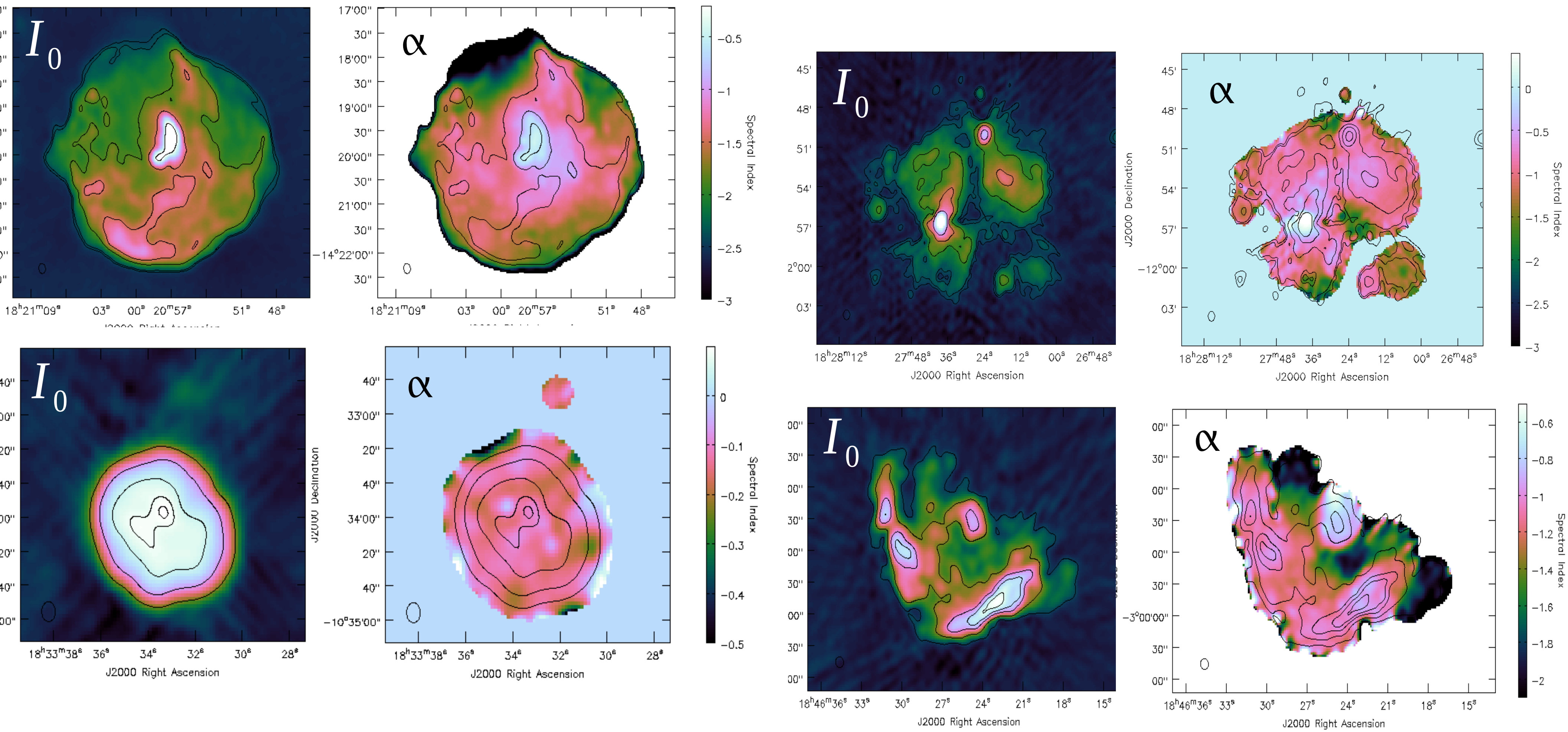
Gradient in Spectral Index



=> For extended emission - spectral-index error is dominated by 'division between noisy images'

– a multi-scale model gives better spectral index and curvature maps

Extended emission – SNR example (a realistic expectation)



These examples used nterms=2, and about 5 scales.

=> Within 1-2 Ghz and 4-8 GHz, can tell-apart regions by their spectral-index (+/- 0.2) if SNR>100.
(this accuracy will increase with wider bandwidths – 1-3 GHz CABB)

=> These images have a dynamic-range limit of few x 1000 ---> residuals are artifact-dominated

Errors in polynomial fitting + Imaging (empirical)

For a 1 Jy point source with spectral index of -1.0 ...

– If spectra are ignored during MFS imaging => Errors increase with bandwidth.

Dynamic-range limits for VLA uv-coverage (natural)

1-2 GHz => ~ 1000
1-3 GHz => few 100

– If spectra are modeled + High signal-to-noise => Need higher-order polynomials to fit a power-law

1 term (flat spectrum) => peak intensity error of 0.1 (on 1 Jy)
2 terms (linear spectrum) => peak intensity error of 0.02, spectral index error of 0.1
3 terms (quadratic spectrum) => intensity error of 0.0001, spectral index error of 0.05

– If spectra are modeled + Low signal-to-noise => Higher-order polynomials give more errors

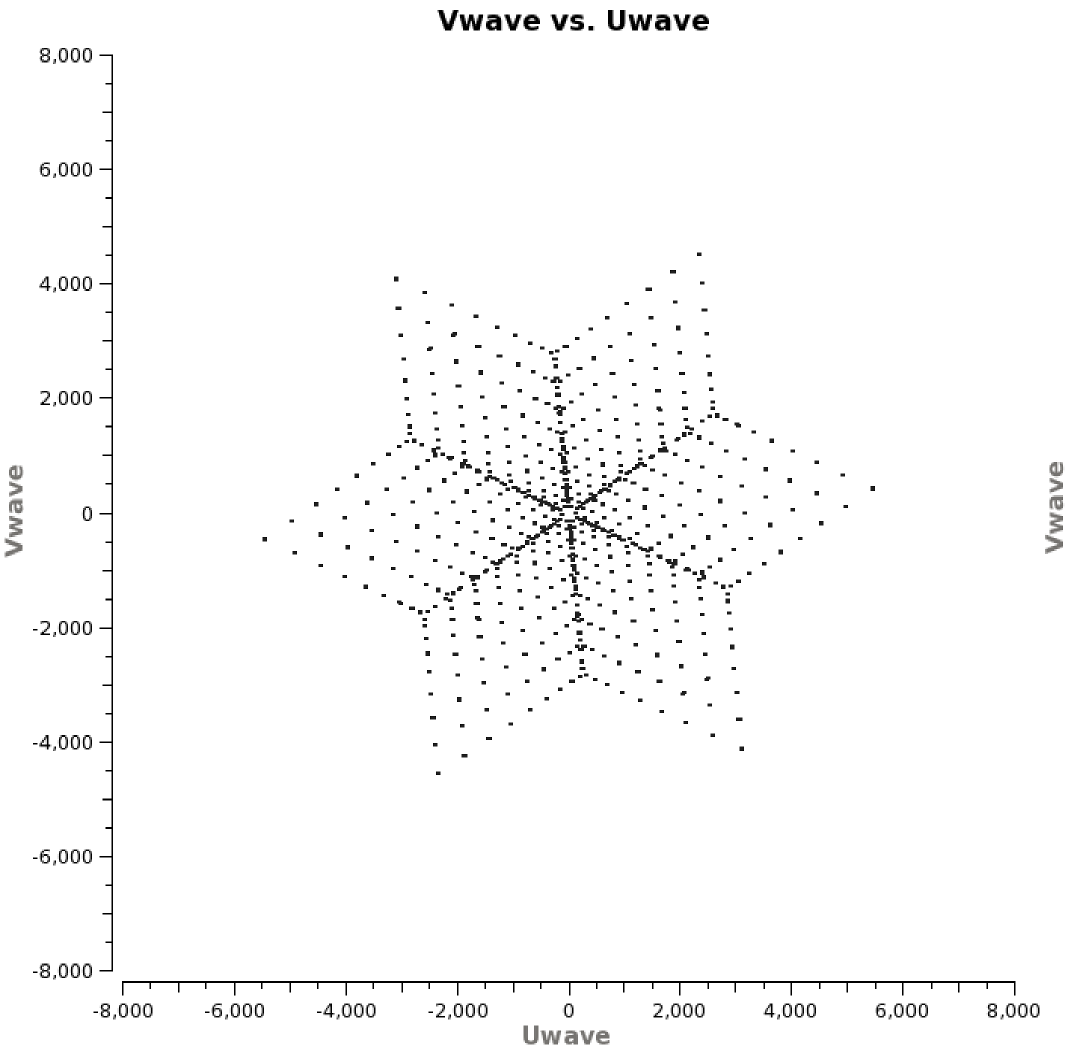
The following situations give similar error on spectral index (~ 0.1) for a point source....

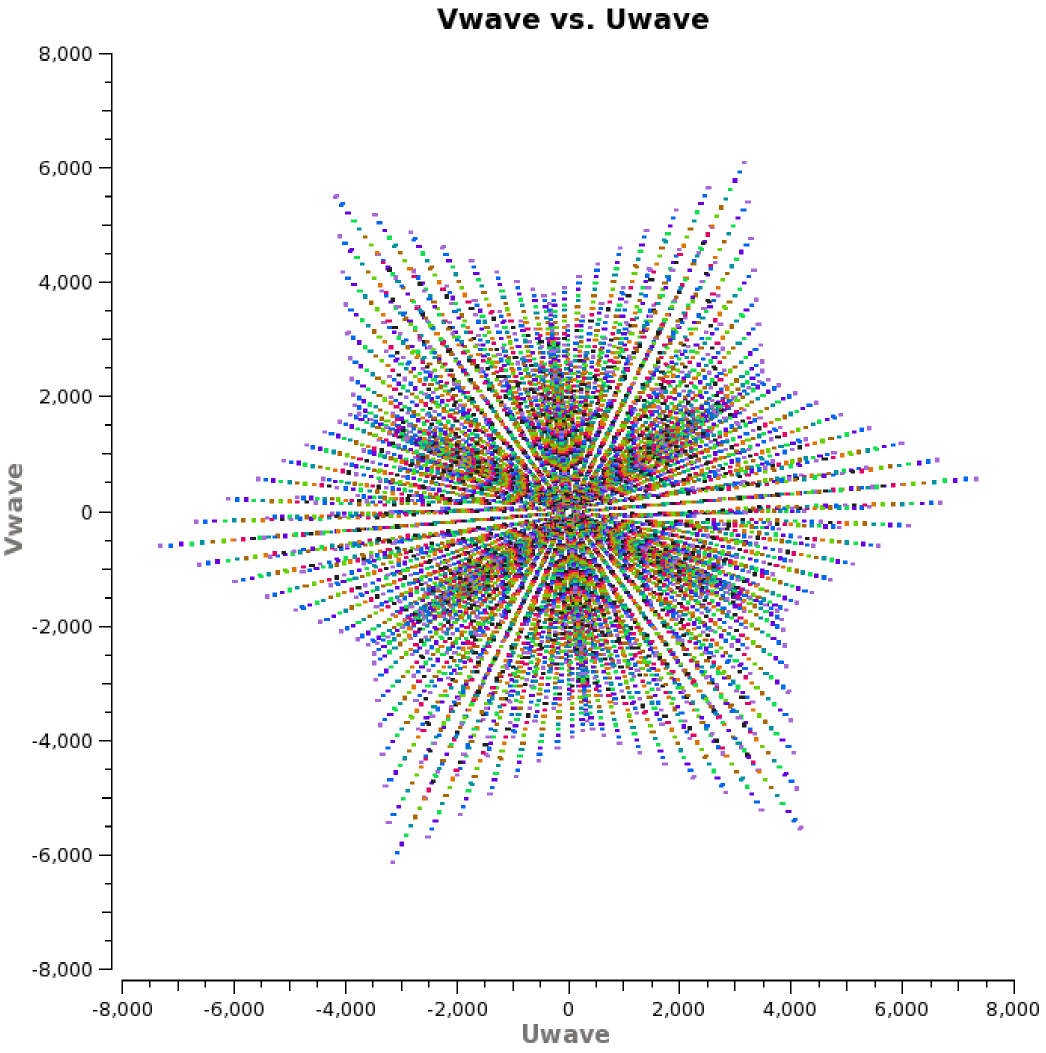
L-Band + C-Band : 1-8 GHz : Sources with signal-to-noise ratio of 10~20
L-Band only (1-2 GHz) or C-Band only (4-8 GHz) : Sources with SNR ~ 40

For extended emission, spectral index errors <= 0.2 only for SNR > 100......

Multi-Frequency-Synthesis : Snapshot

Observing tip.....

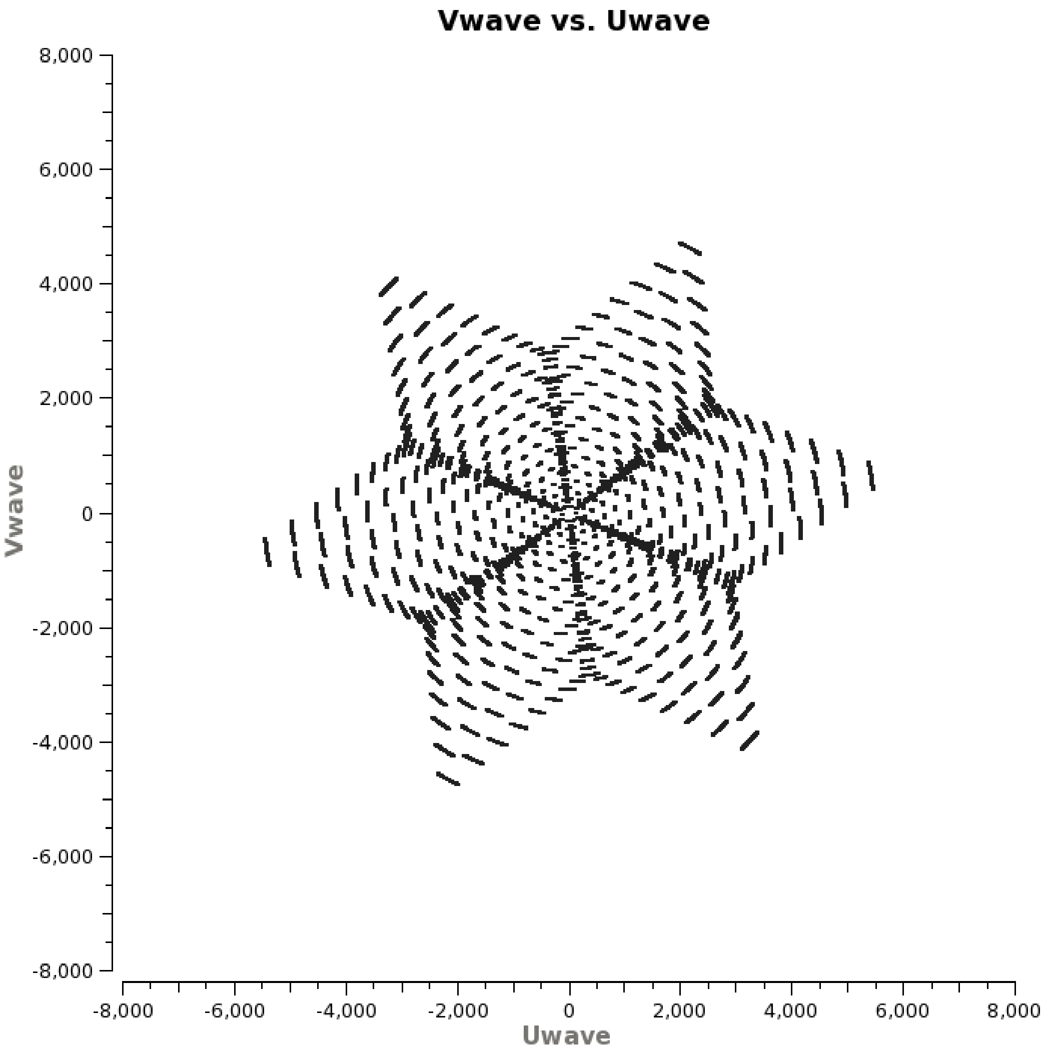


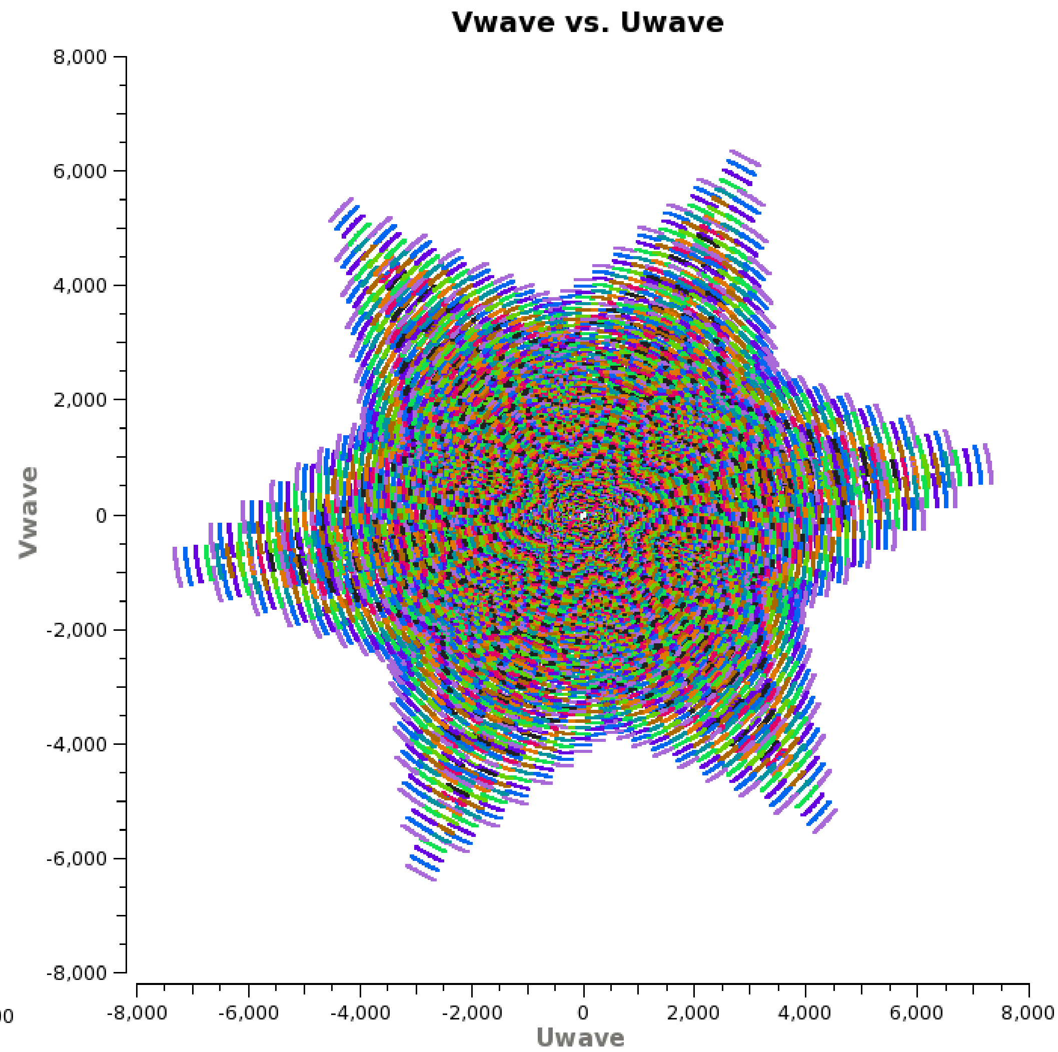


Wideband UV-coverage fills the UV-plane radially.....

Multi-Frequency-Synthesis : 30 min

Observing tip.....



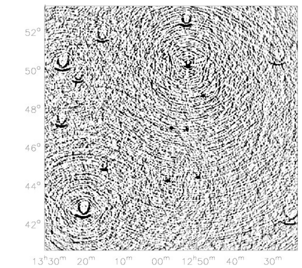


Small time-increments generate good uv-filling => Plan wideband observations in small time-chunks, spread out in time to cover more spatial-frequencies at-least once.

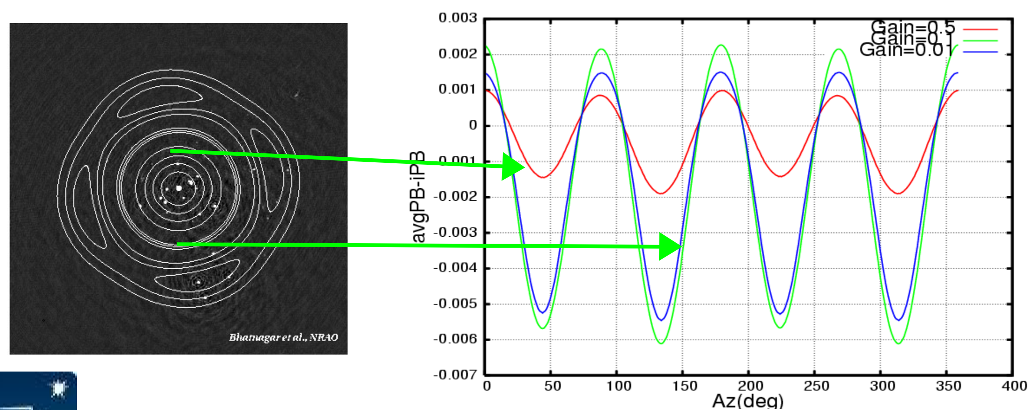
What do we call wide-field?

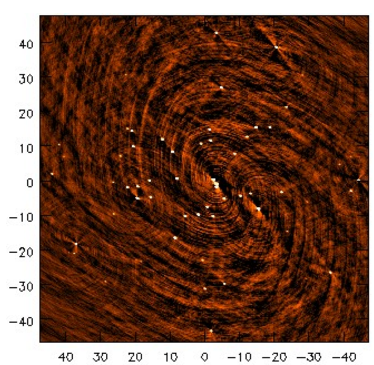
- Imaging that requires invoking any of the following:
  - Corrections for non co-planar baseline effects
  - Corrections for the rotational asymmetry of the PB
    - Imaging beyond 50% point, mosaicking
  - Corrections for the frequency or polarization dependent effects
  - Noise limited imaging at 4-,P-,L-, S- (and probably C-Band)
    - Because of the radio brightness distribution

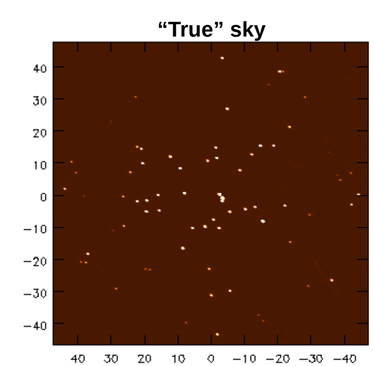
$$\frac{\lambda}{B_{max}} \le \theta_f^2$$



- Noise limited imaging of structure comparable to the PB beam-width
- Mosaicking: imaging on scales larger than the PB beam-width

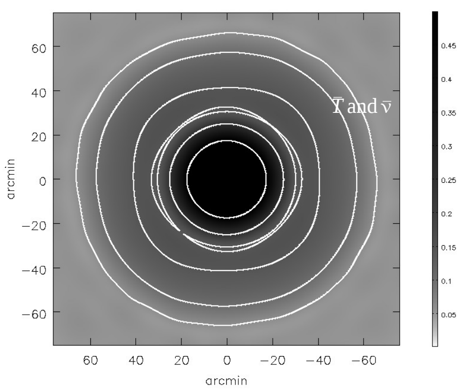


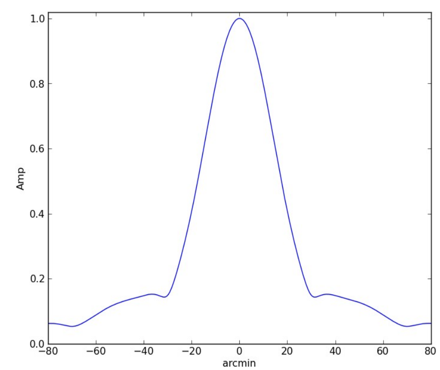




Why wide-field?

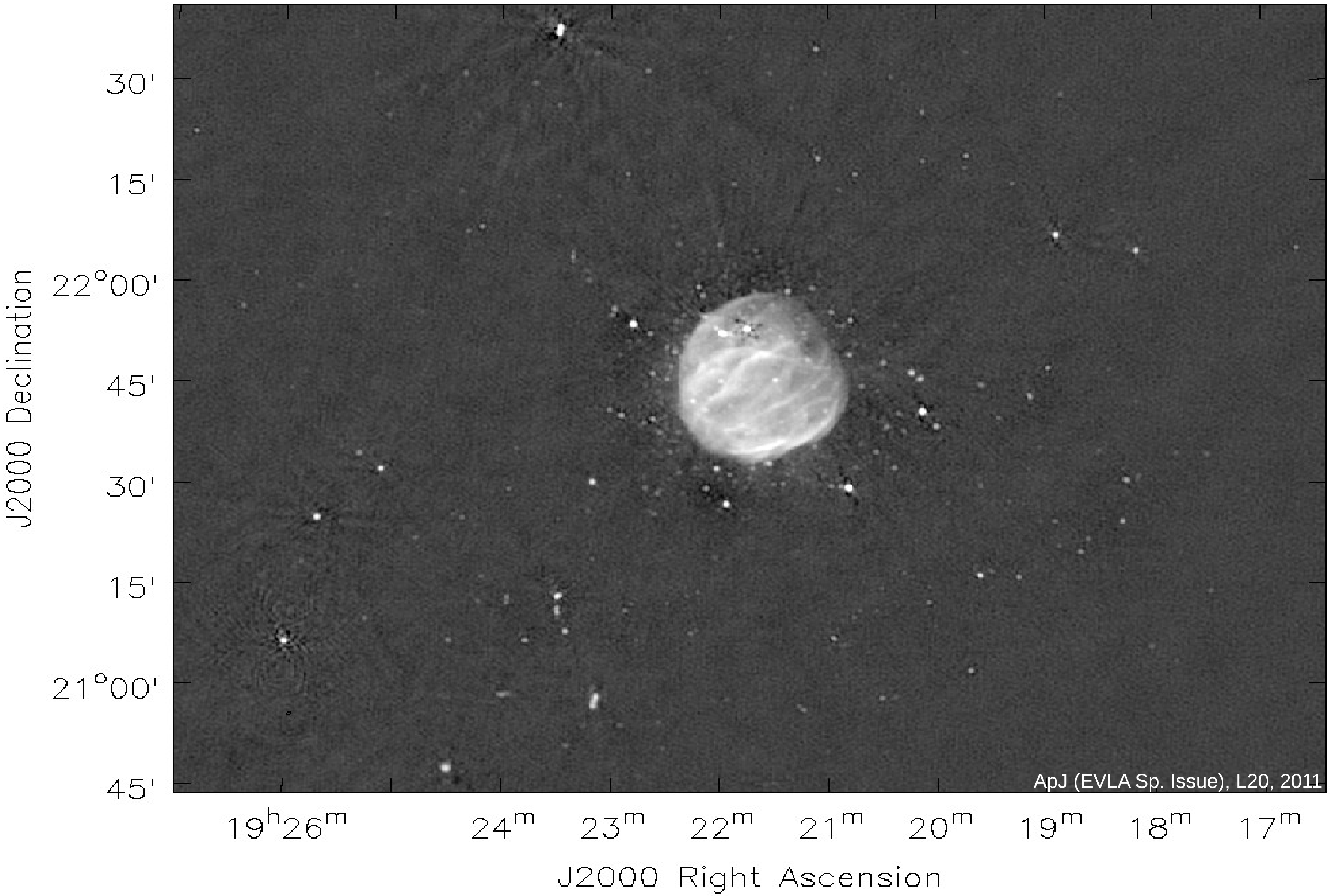
- Primarily due to improved continuum sensitivity
- @L-Band, PB gain ~1 deg. away can be up to 10%
  - In the EVLA sensitivity pattern, VLA sensitivity is achieved at the location of the VLA-null!
  - No null in the EVLA sensitivity pattern





- E.g. a 1% PSF side lobe due to a source away from the center is now significantly above continuum thermal noise limit
  - This is a largely independent of the total integration time

Wide-field Issues



Wide-field sensitivity because of wide-bandwidths

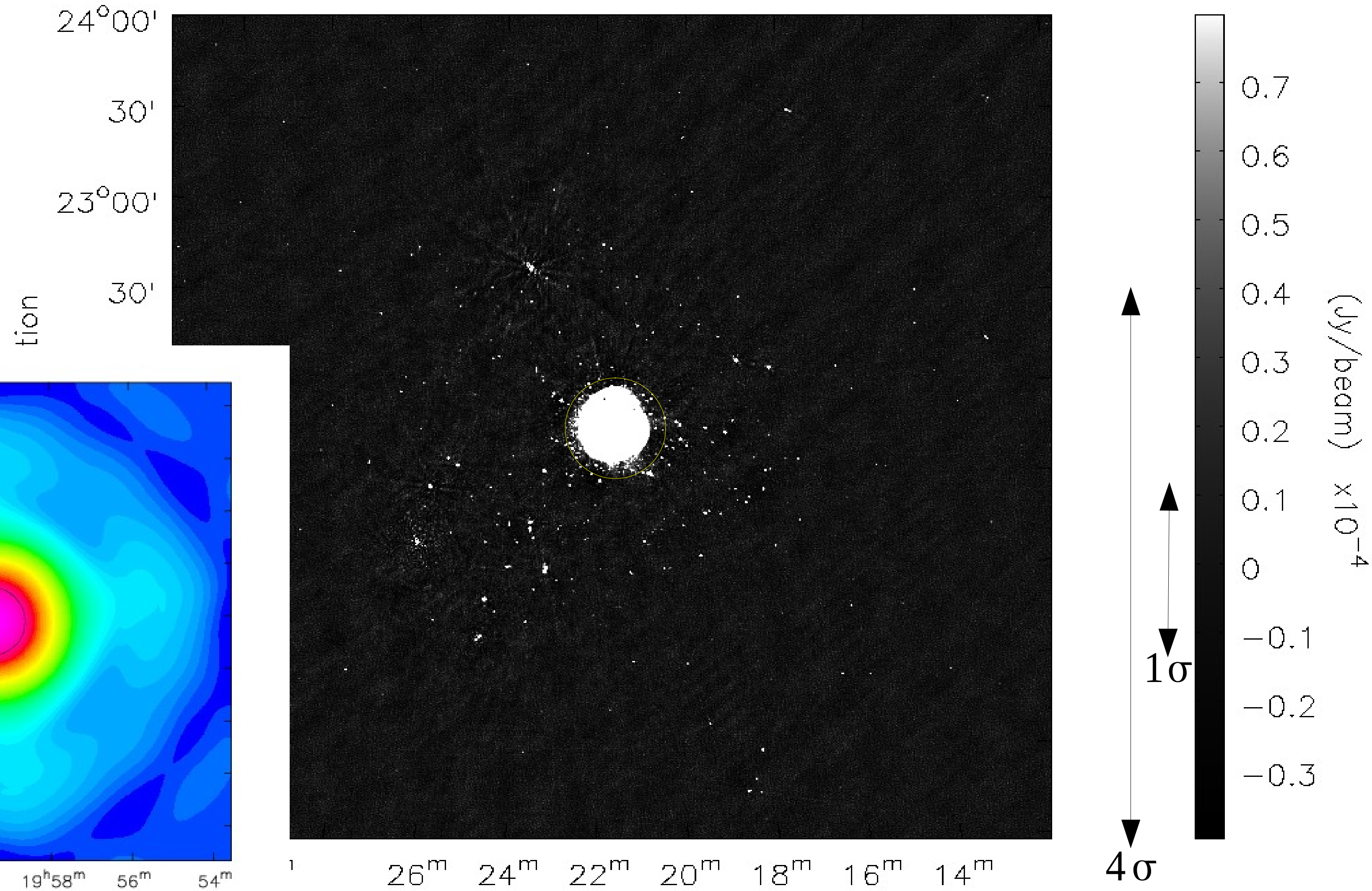
G55.7+3.4 : Galactic supernova remnant : 4 x 4 degree field-of-view from one EVLA pointing

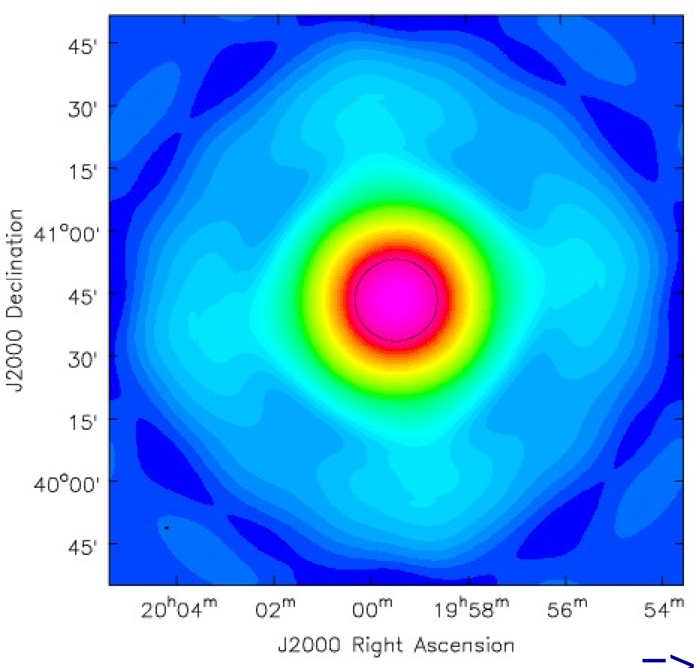
1 Jy total flux

24 arcmin

(PB: 30 arcmin)

10 micro Jy RMS

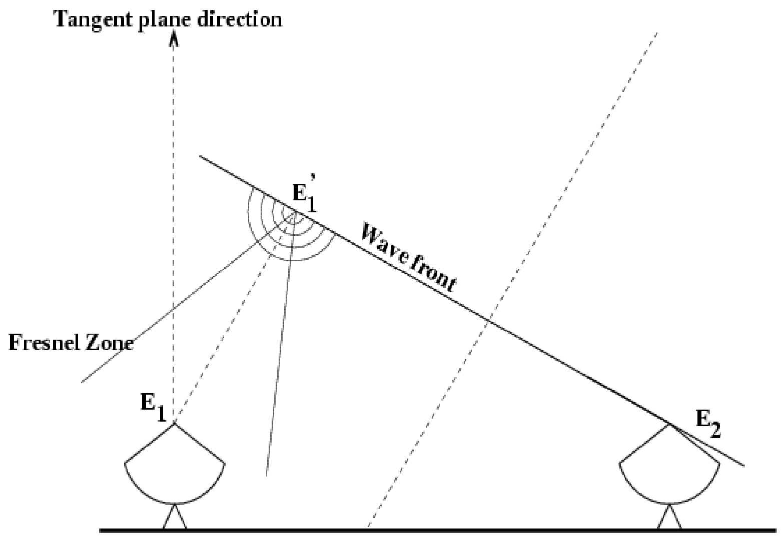


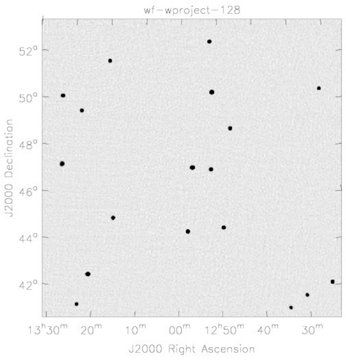


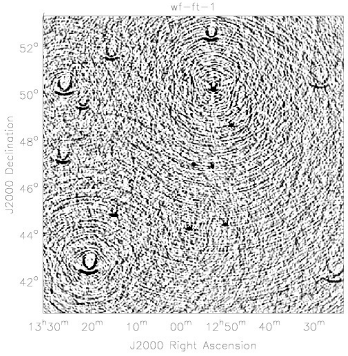
=> Need to combine wide-field imaging techniques with wideband..

Non co-planar baseline: The W-term

- 2D FT approximation of the Measurement Equation breaks down



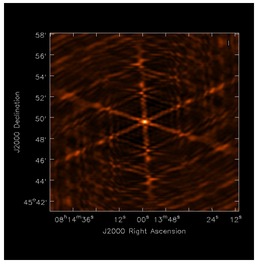




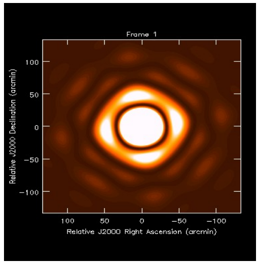
- We measure: $V_{12} = \langle \boldsymbol{E_1}(u, v, w=0) \boldsymbol{E_2}^*(0,0,0) \rangle$
- We interpret it as: $V^o_{12} = \langle \boldsymbol{E}_1'(u, v, w \neq 0) \boldsymbol{E_2}^*(0,0,0) \rangle$
- We should interpret E_1 as [E_1' x Fresnel Propagator]

PB Effects: Rotation asymmetry

- Only average quantities are available in the image domain
- Asymmetric PB rotation leads to time and direction dependent gains



$$\Delta I^R = \sum_{\psi} \left[PSF(\psi) - avgPSF \right] * \left[\left(PB(\psi) - avgPB \right) I^o \right]$$

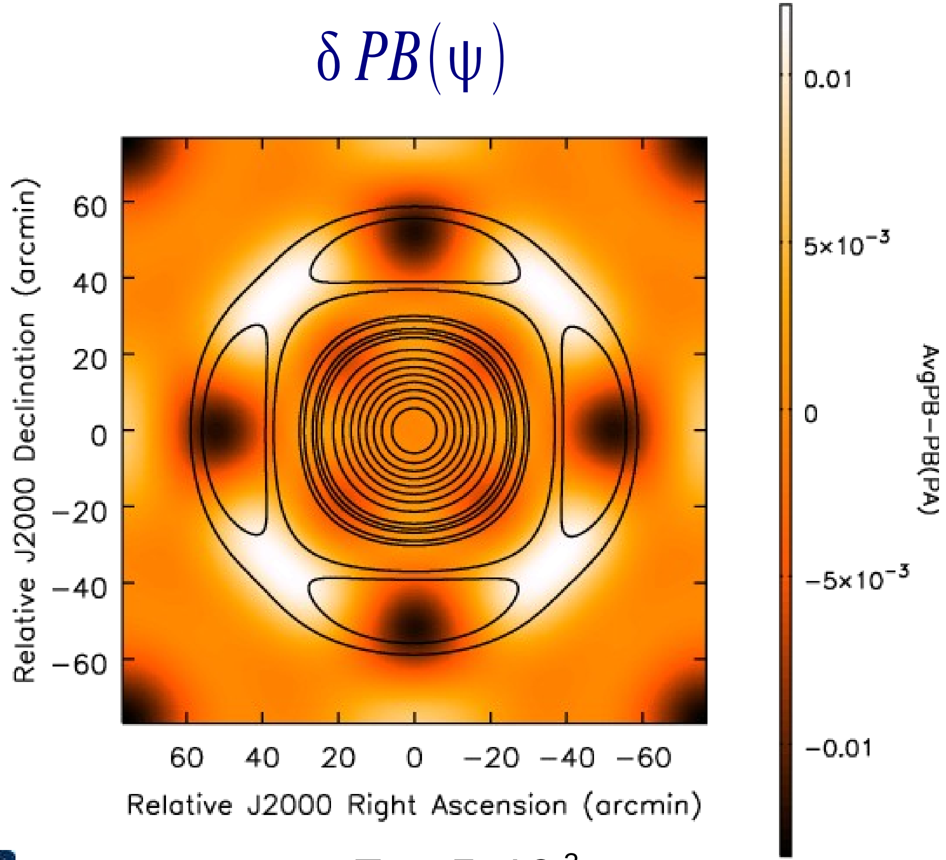


- Time-variability due to rotational asymmetry is stronger below ~10% point and in the side-lobes.
- Time-variability due to pointing errors is stronger ~50% point.

PB Effects: Error Propagation

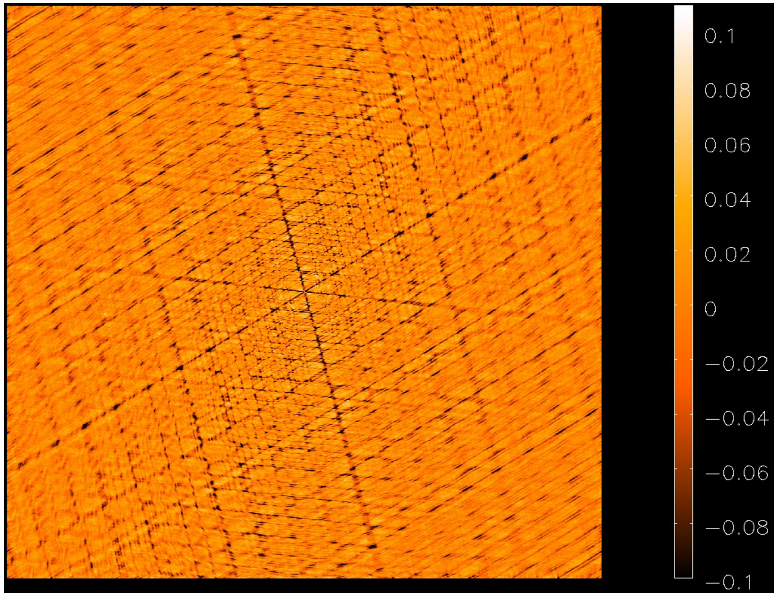
$$\Delta I^R = \sum_\psi \delta PSF(\psi) * [\delta PB(\psi) I^o]$$

$\delta PB(\psi)$



E.g. $5\mathrm{x}10^{-3}$

$\delta PSF(\psi)$



E.g. $2\mathrm{x}10^{-2}$

Projection algorithms

- Direction-dependent effects in the image domain are convolutional terms in the data domain

- Projection algorithms for DD corrections:
  - Project-out various DD effects as part of the gridding operator
    - ME:

$$V_{ij}^{Obs} = A_{ij} * V^o + N_{ij}$$

    - Construct D, such that

$$D_{ij}^T * A_{ij} \approx \text{Time/Freq./Pol.} \quad \text{indep.}$$

    - Imaging:

$$I = F^{-1} \sum_{ij} D_{ij}^T * V_{ij}^{Obs} = F^{-1} \frac{\sum_{ij} D_{ij}^T * A_{ij} * V_{ij}^o + D_{ij}^T N_{ij}}{Normalization}$$

DI Corrections: Standard Calibration

- DI ME entirely in the visibility domain:

$$V_{ij}^{Obs} = [J_i \otimes J_j^*].[V_{ij}^o] = [M_{ij}].[V_{ij}^o]$$

$$\begin{bmatrix} V_{pp}^{Obs} \\ V_{pq}^{Obs} \\ V_{qp}^{Obs} \\ V_{qq}^{Obs} \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} . \begin{bmatrix} V_{pp}^o \\ V_{pq}^o \\ V_{qp}^o \\ V_{qq}^0 \end{bmatrix}$$

- Diagonal: “pure” poln. products
- Off-diagonal: Include poln. leakage

$$SelfCal \quad model: \quad M_{ij} = g_i g_j^*$$

- Full-pol. DI Correction

$$V_{ij}^{Corr} = [M_{ij}^{M^{-1}}].[V_{ij}^{Obs}] = \frac{adj(M_{ij}^M)}{det(M_{ij}^M)}.[V_{ij}^{Obs}]$$ Equivalent Complex math.: $G_i^{-1} = \frac{G^*}{|G|^2}$

No pol. leakage case: $= \frac{G_{q,ij}^{M^*}}{G_{p,ij}^M G_{q,ij}^{M^*}}$

gaincal, bandpass, gencal, applycal, polcal,...

DD Corrections: Projection algorithms

- DD ME entirely in the visibility domain:

$$V_{ij}^{Obs} = \left[J_i \otimes J_j^*\right] * \left[V_{ij}^o\right] = \left[M_{ij}\right] * \left[V_{ij}^o\right]$$

J : Each elements is a function

$\otimes$ = Element-by-element convolution

$$\begin{bmatrix} V_{pp}^{Obs} \\ V_{pq}^{Obs} \\ V_{qp}^{Obs} \\ V_{qq}^{Obs} \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} * \begin{bmatrix} V_{pp}^{o} \\ V_{pq}^{o} \\ V_{qp}^{o} \\ V_{qq}^{o} \end{bmatrix}$$

- Diagonal: "pure" poln. PBs
- Off-diagonal: Include in-beam poln. leakage

$$M_{pq} = J_{p,i} * J_{q,j}^*$$

- Full-pol. DD corrections

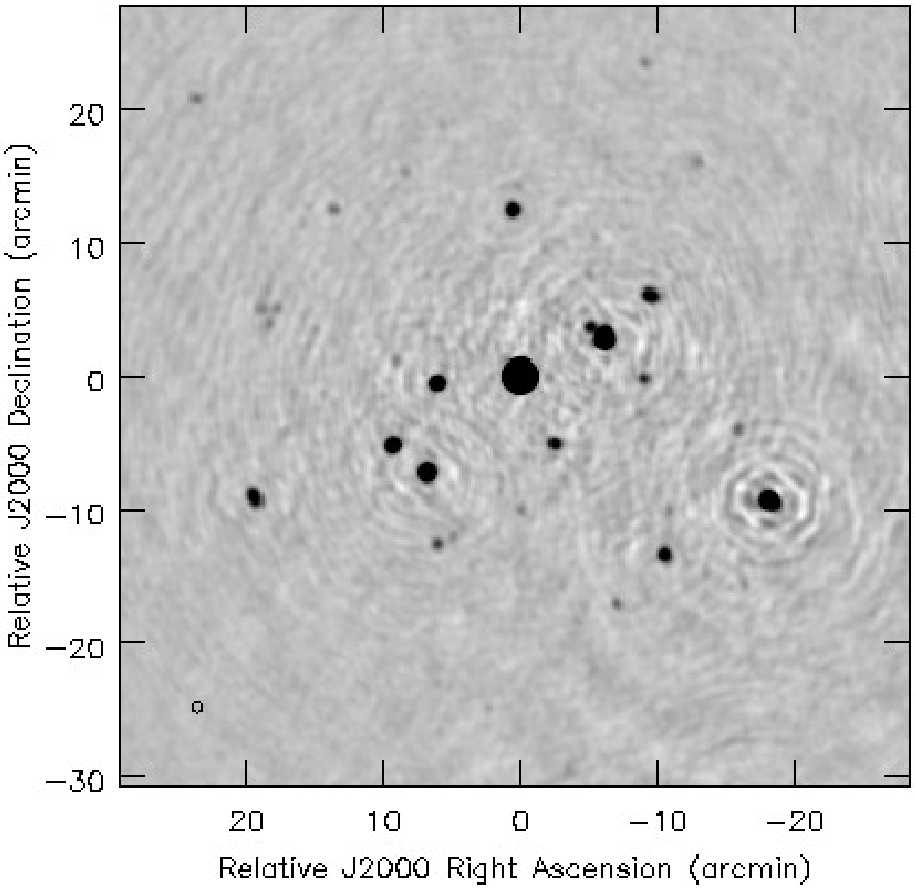
$$V_{ij}^{Corr} = \left[M_{ij}^{M^{-1}}\right] * \left[V_{ij}^{Obs}\right] = \frac{adj(M_{ij}^M)}{det(M_{ij}^M)} * \left[V_{ij}^{Obs}\right]$$

$$I_{ij}^{Corr} = \frac{F\left[adj(M_{ij}^{M^T})\right] * \left[V_{ij}^{Obs}\right]}{F\, det(M_{ij}^M)}$$

During gridding

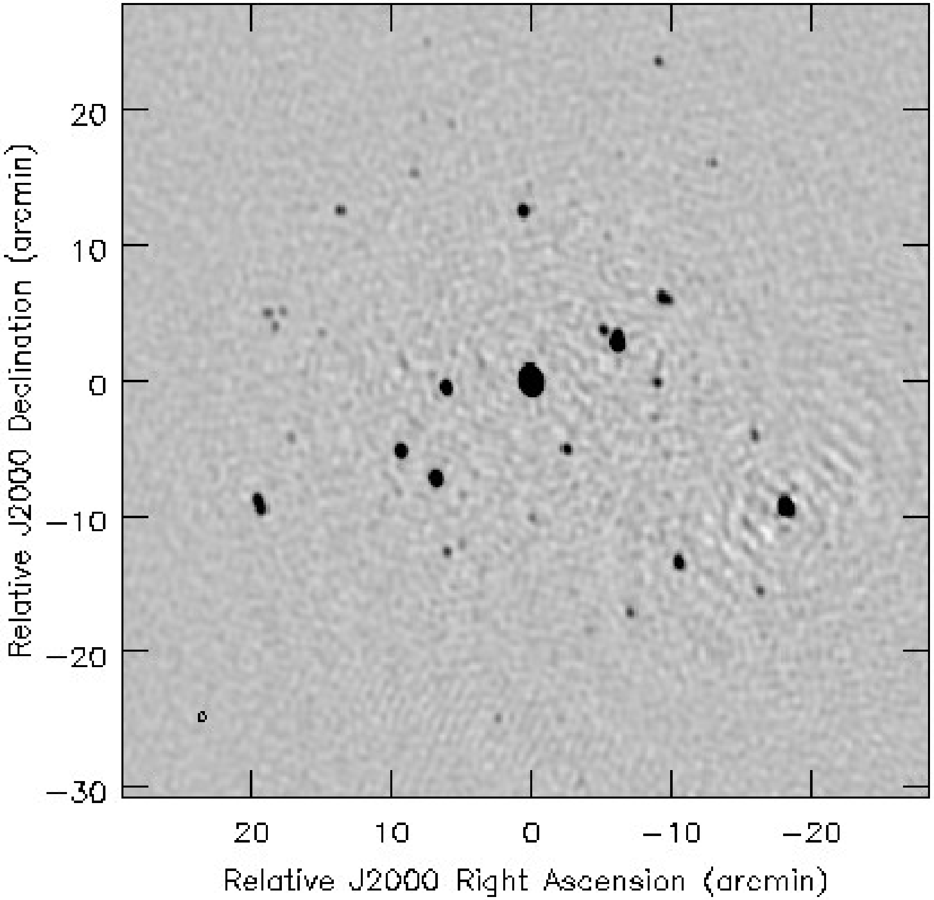
Image plane normalization

A-Projection: Stokes-I Before



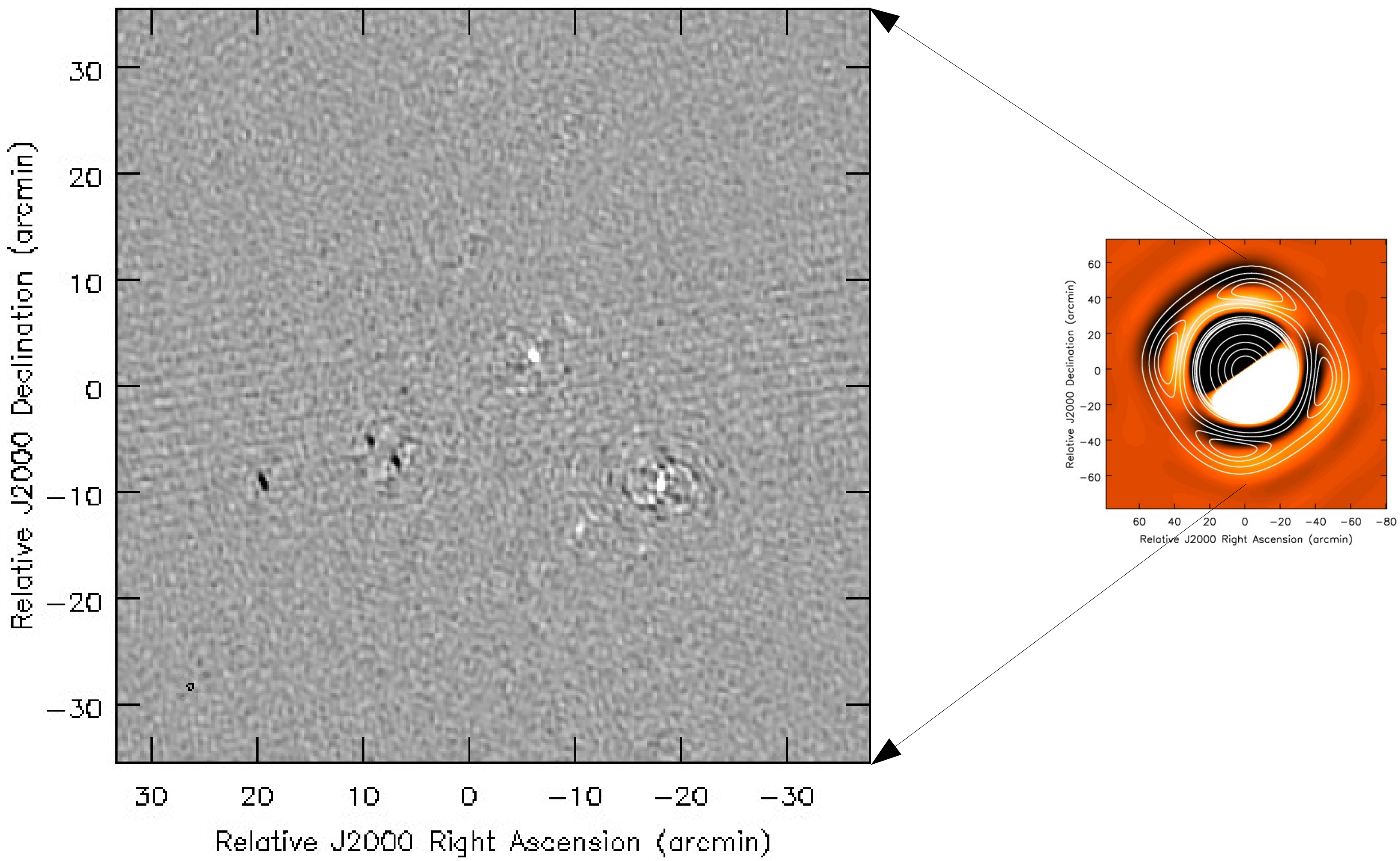
Effective PB is time-variant

A-Projection: Stokes-I After



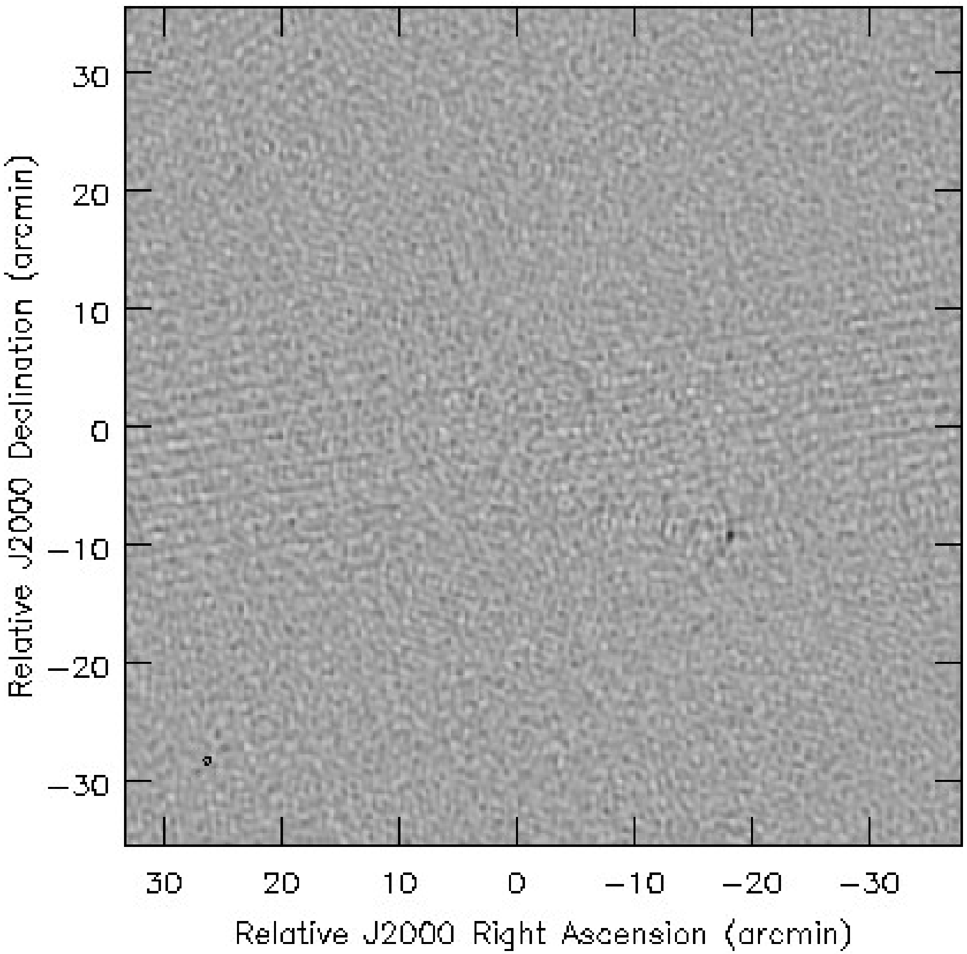
Effective PB is time-invariant

A-Projection: Stokes-V Before



Effective PB is polarization-variant

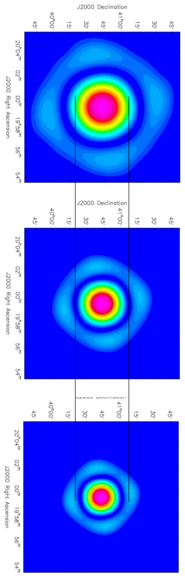
A-Projection: Stokes-V After

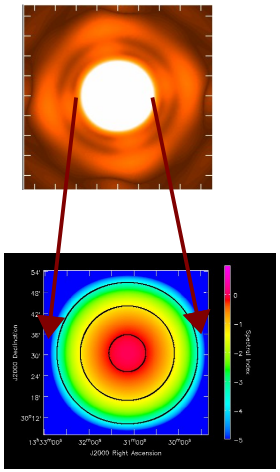


Effective PB is polarization-invariant

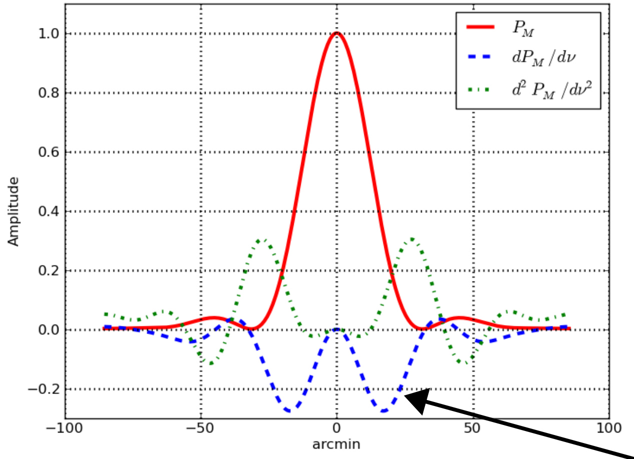
Wide-band Wide-field Imaging

- Wide band data to image beyond the ~50% point of the PB at a reference frequency
  - Bandwidth ratio > ~20%
  - FoV > ~HPBW @ reference frequency
  - Variable PB:
    - Long integration (rotation), Mosaicking (pointings at different PA), in-beam polarization is large (AA)



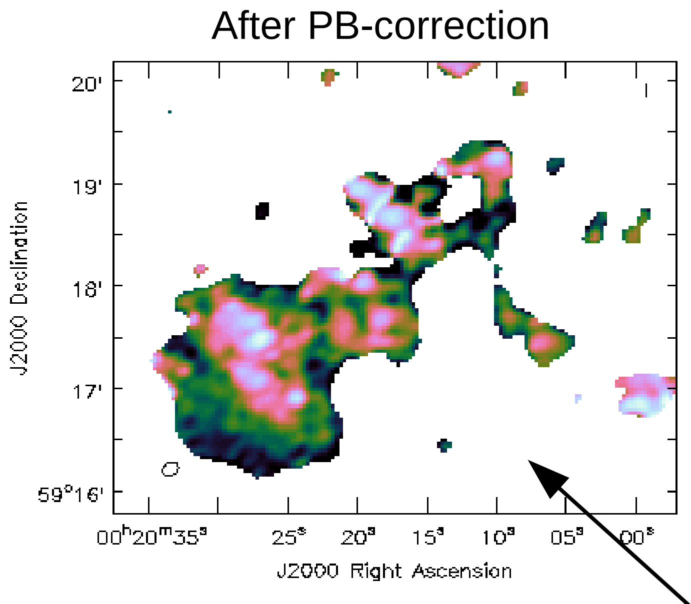


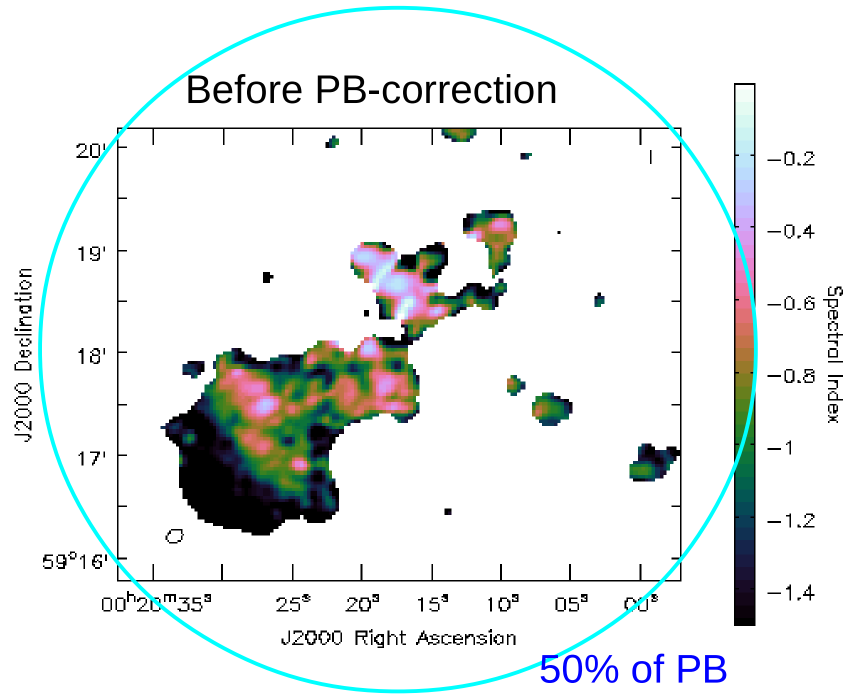
PB “Spectral Index”



PB Frequency dependence (blue curve)

Continuum (MS-MFS) vs Cube Imaging (with PB-correction)

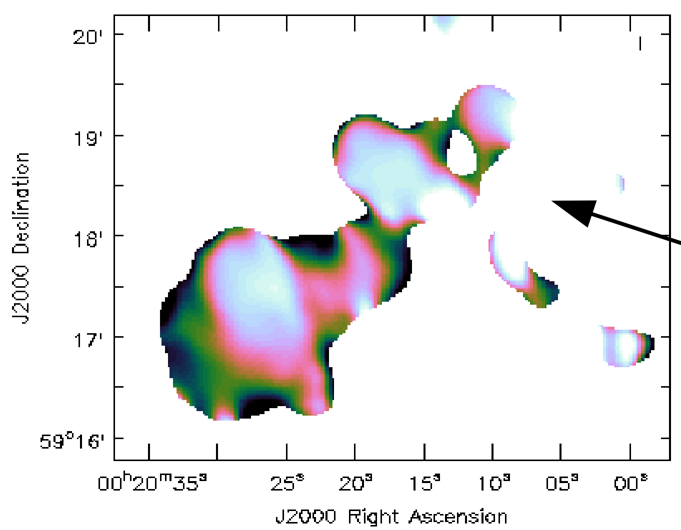




IC10 Dwarf Galaxy :

Spectral Index across C-Band.

Dynamic-range ~ 2000 (~ noise-limited image obtained)

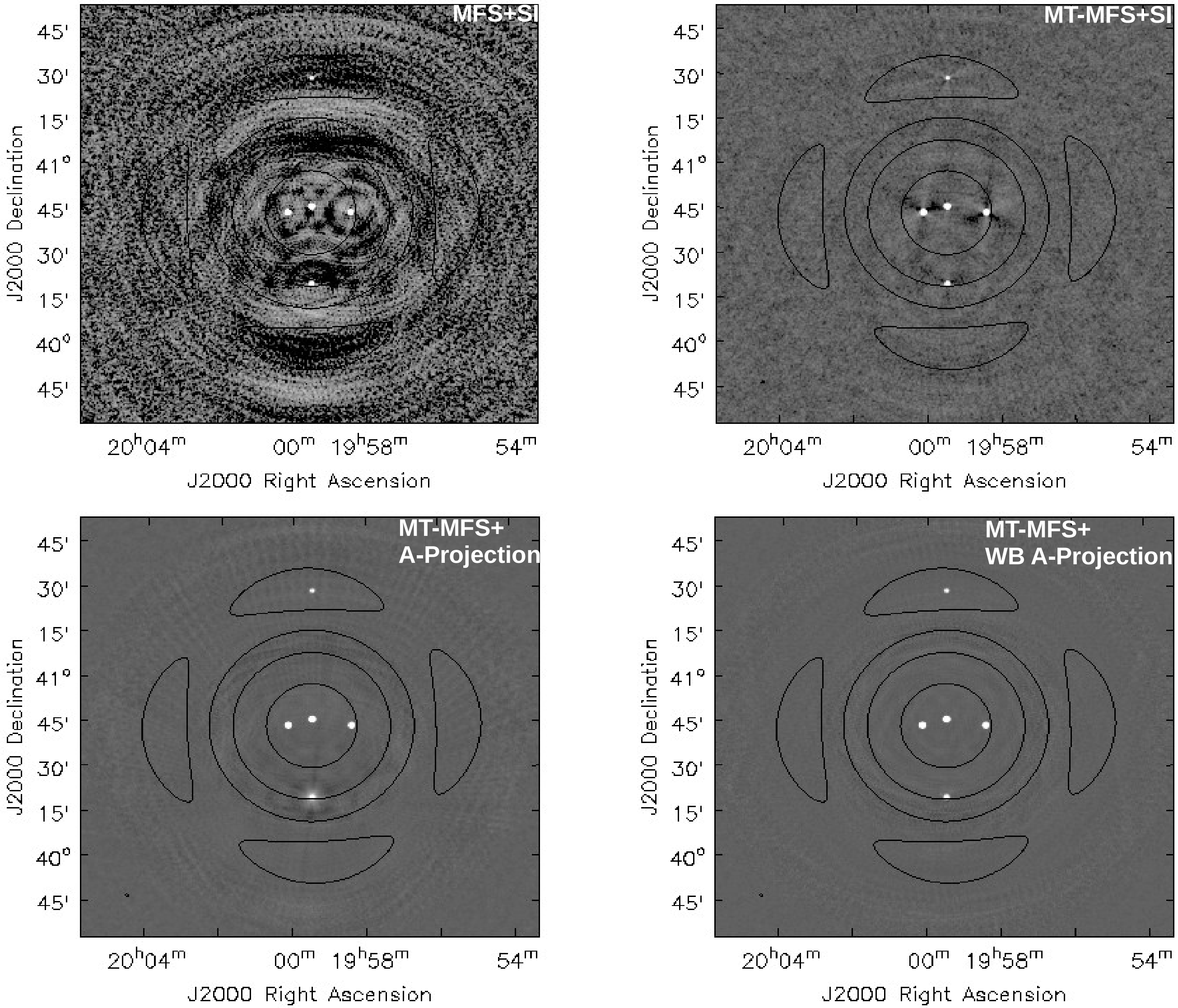


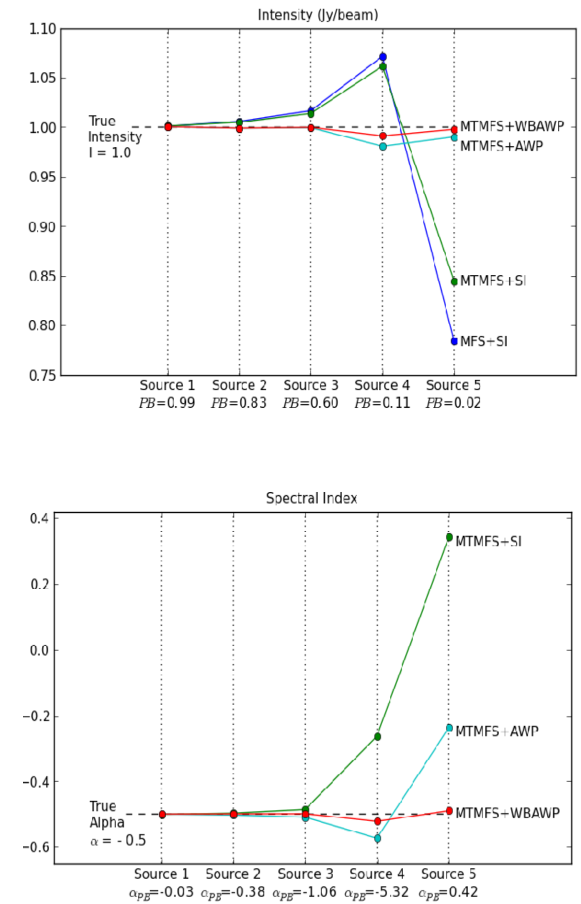
MS-MFS :
Result of wide-band PB-correction after MT-MS-MFS.

Cube :
Spectral-index map made by PB-correcting single-SPW images smoothed to the lowest resolution.

Wide-band Wide-field Imaging

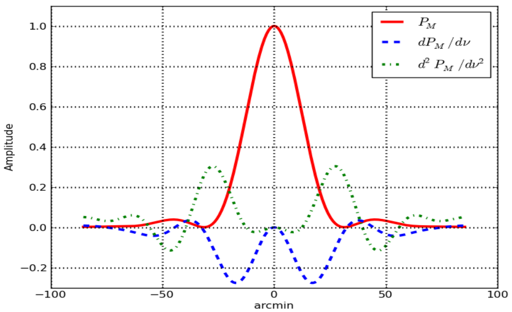
- Characterization of the (WB) A-Projection + MT-MFS

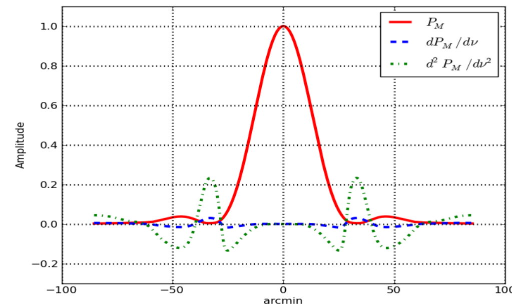




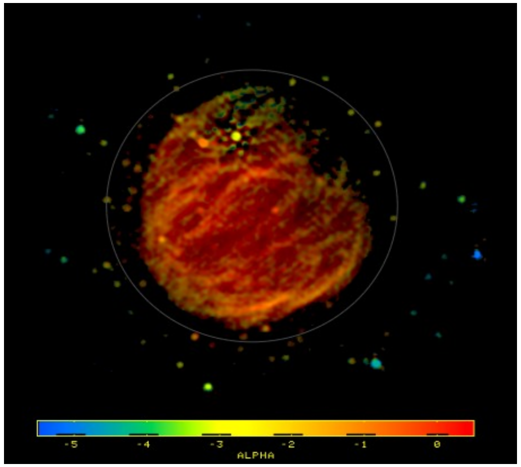
Wide-band Wide-field Imaging

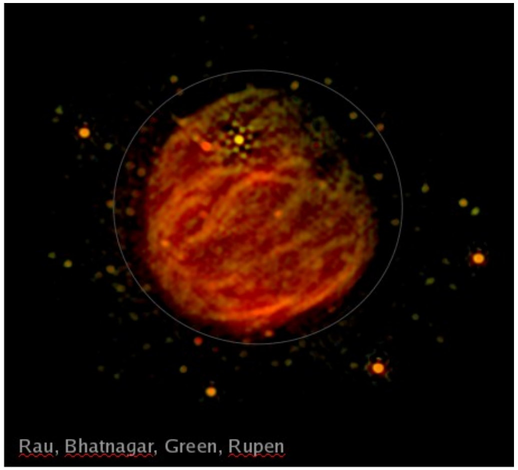
- WB A-Projection + MT-MFS
  - WB A-Projection for PB





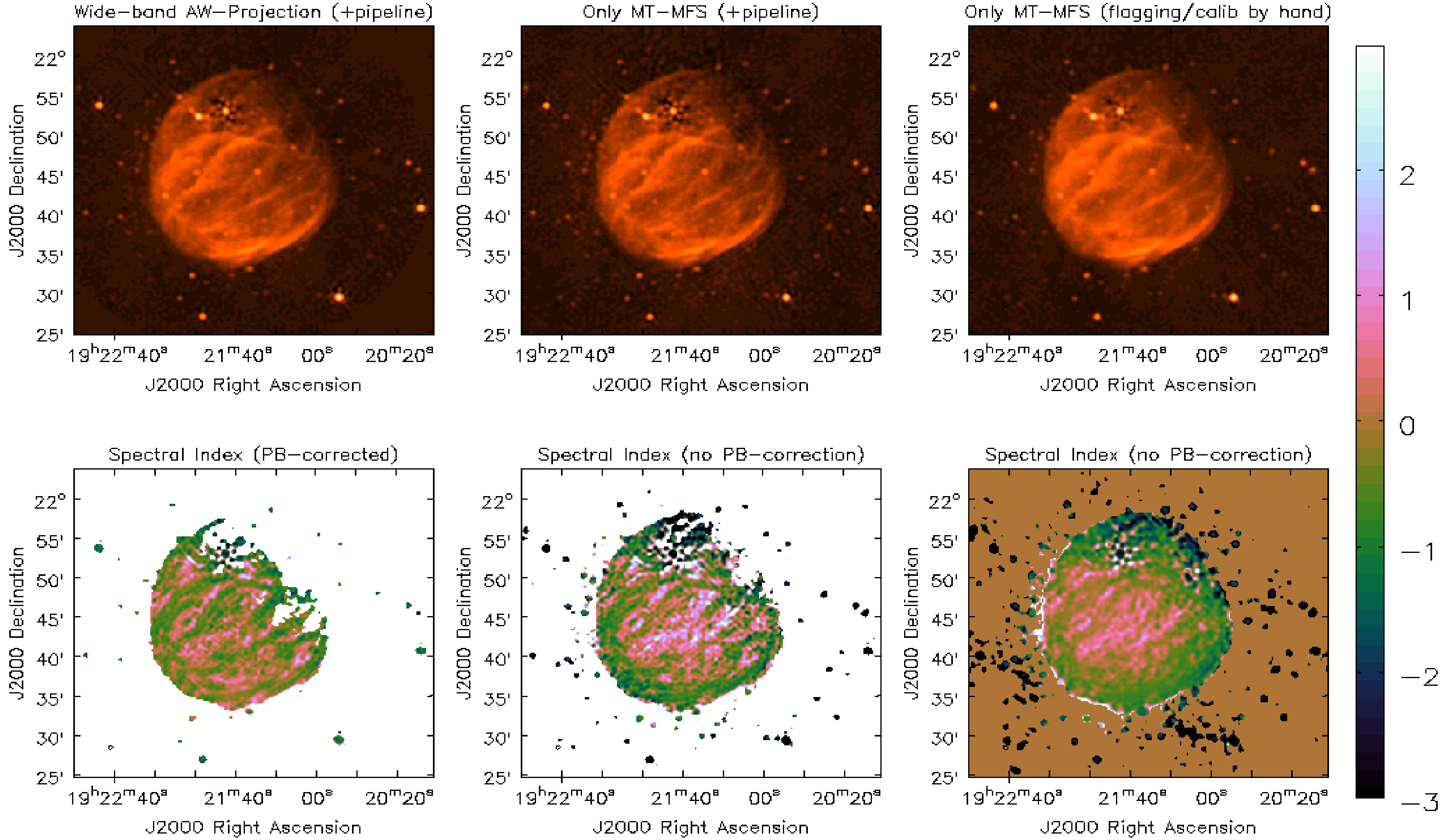
  - MT-MFS for sky





Wide-band Wide-field Imaging

- WB A-Projection + MT-MFS

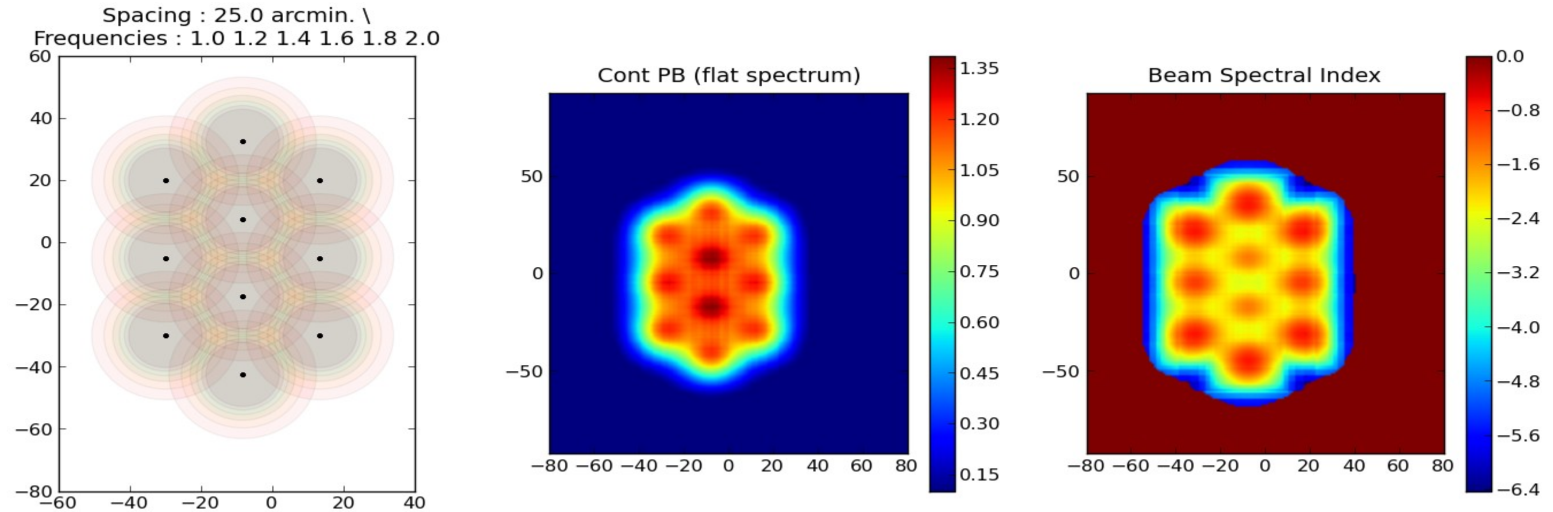


Wideband Primary Beams – Mosaic

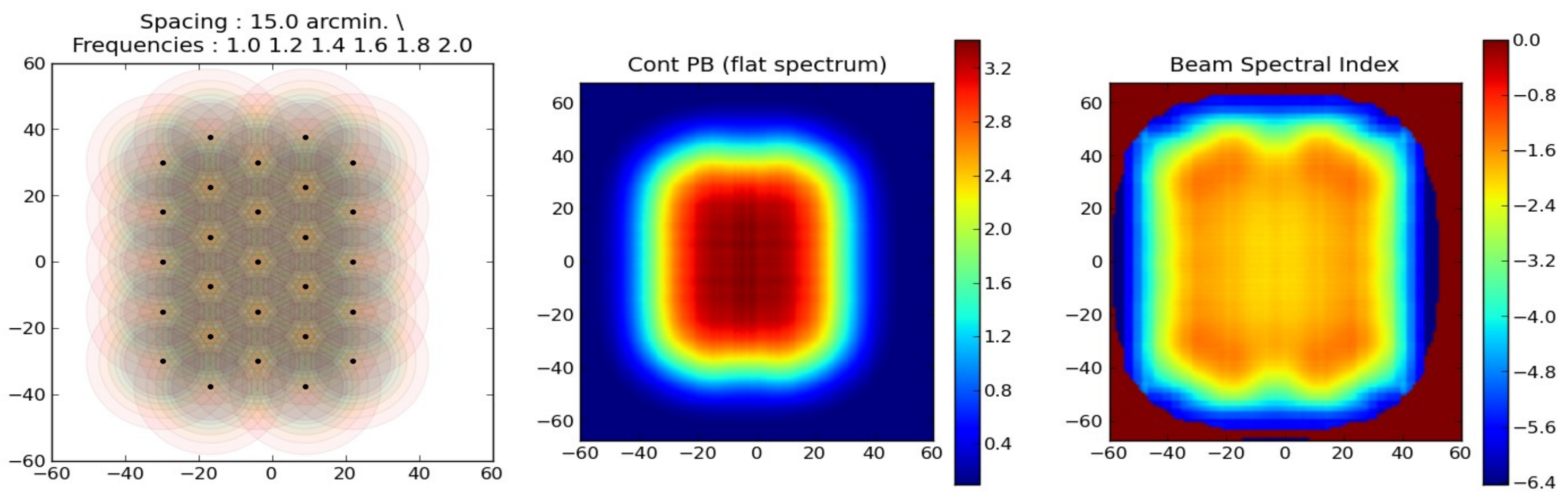
For single pointings, the wideband PB spectrum is relevant only away from the pointing center.

For mosaics, the wideband PB spectrum must be accounted-for <u>all over the mosaic field of view</u>

25 arcmin spacing (1-2 GHz)



15 arcmin spacing (1-2 GHz)



Wideband imaging capabilities in CASA – Now, and coming...

Cube Imaging :

- Per channel imaging with point source and multi-scale methods, and w-projection
- Post-deconvolution PB correction (divide final image by PB).
- Linear mosaics using the output of imaging
- Joint mosaic deconvolution within imaging (no w-projection)
- Tasks to smooth planes to a common resolution, and to collapse along frequency.

MFS Imaging :

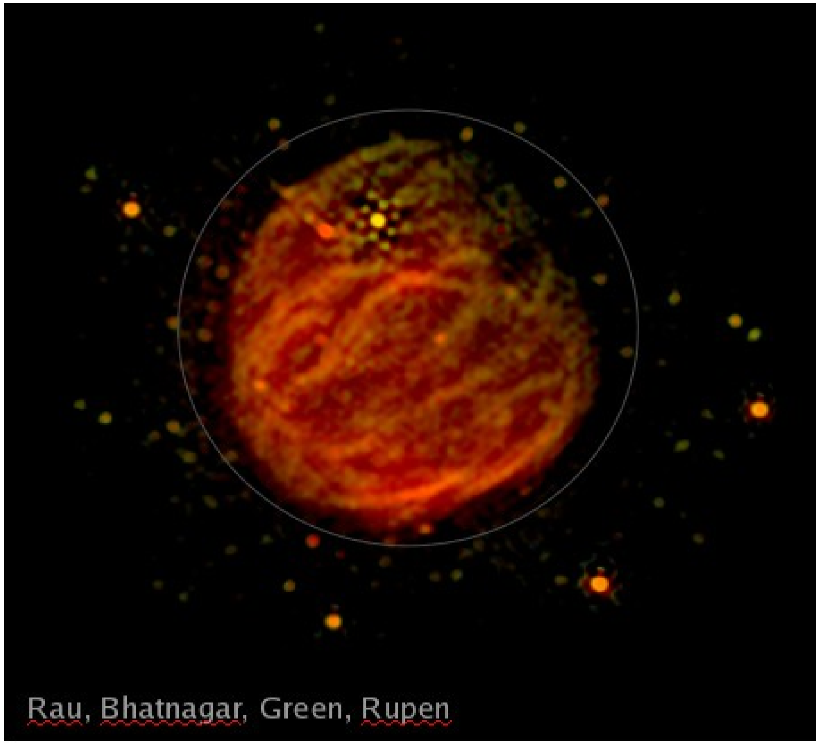
- Wideband imaging with point source and multi-scale methods
- Choice of the order of the polynomial used to model the spectrum
- Post-deconvolution wideband PB-correction with multi-term imaging
- Linear mosaics using the output of wideband imaging (single and multi-term)
- Joint mosaics with MFS gridding (not for multi-term)

Coming...... (needed mainly for high dynamic-range imaging)

- Time variable, full-polarization wide-band PB corrections with W-projection (DD-corrections)
- Combined application of DD-corrections for mosaics
- Joint mosaics for MFS multi-term imaging with pre- and post-deconvolution PB correction

Scales for Multi-Scale Deconvolution

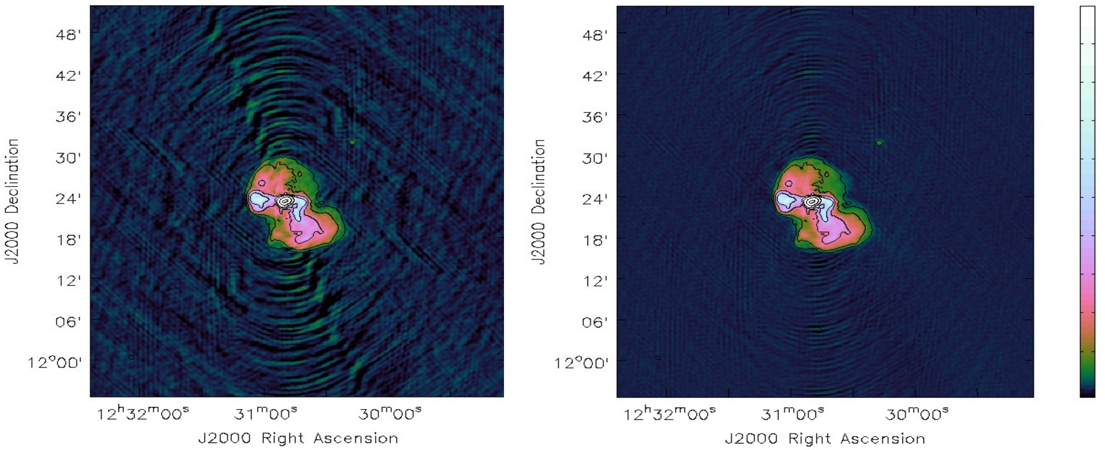
- Thumb rule for selection largest scale
  - Smallest dimension of the largest scale in the image



Using Wide-Band Models for other processing....

WideBand Model : $I^m_{0,} I^m_{1,} I^m_{2,} \ldots$

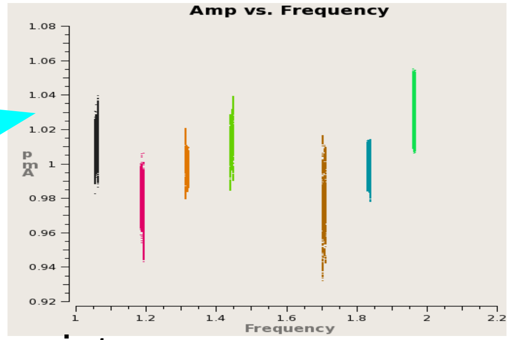
Evaluate spectrum $I^{sky}_{\nu} = \sum_t I_t \left(\frac{\nu - \nu_0}{\nu_0} \right)^t$



(1) Wide-Band Self-Calibration

- Can be used on target source, after initial calibration per spw.
- Can use it on the calibrator itself to bootstrap the model.

Amplitudes of bandpass gain solutions......

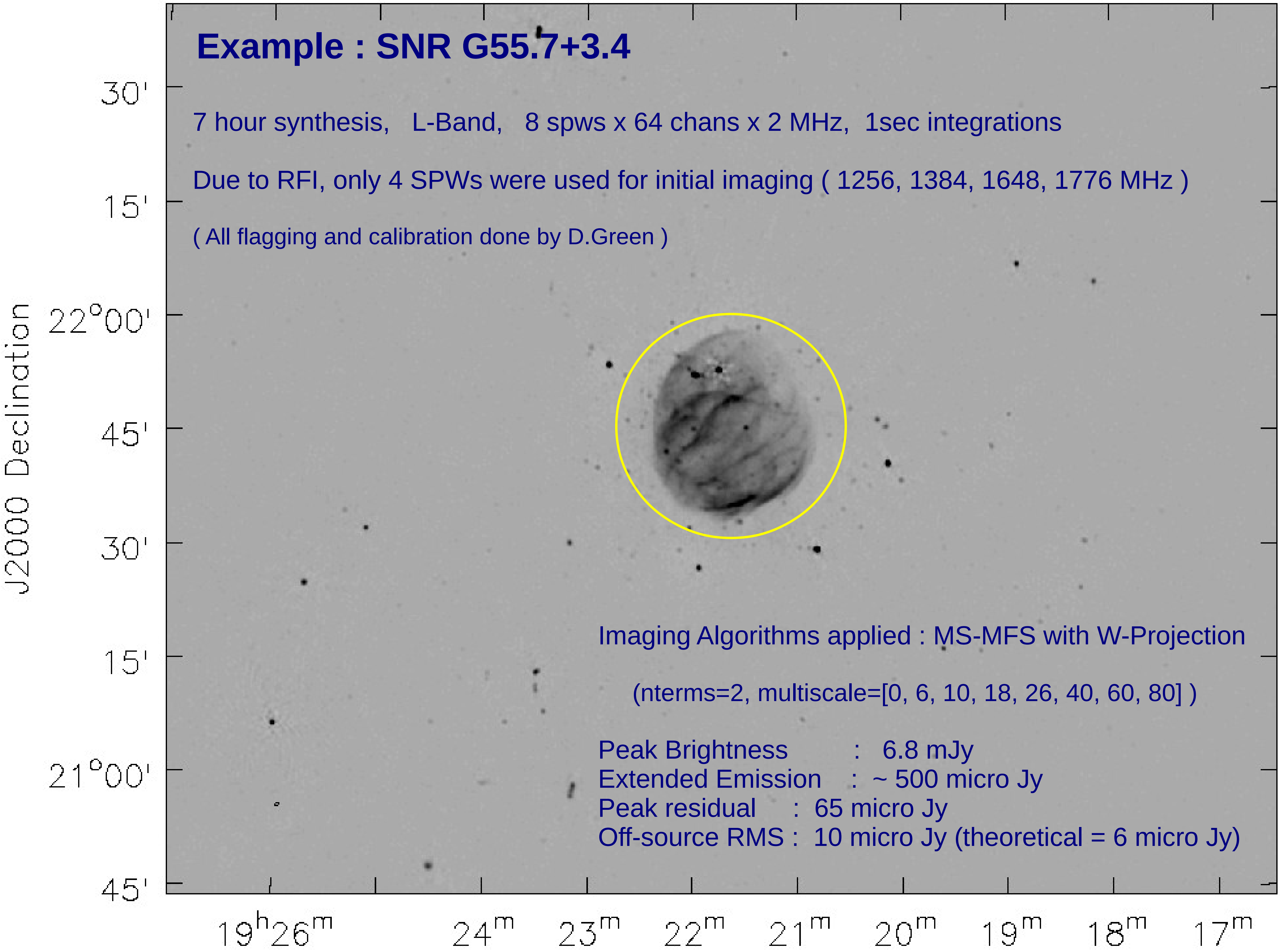


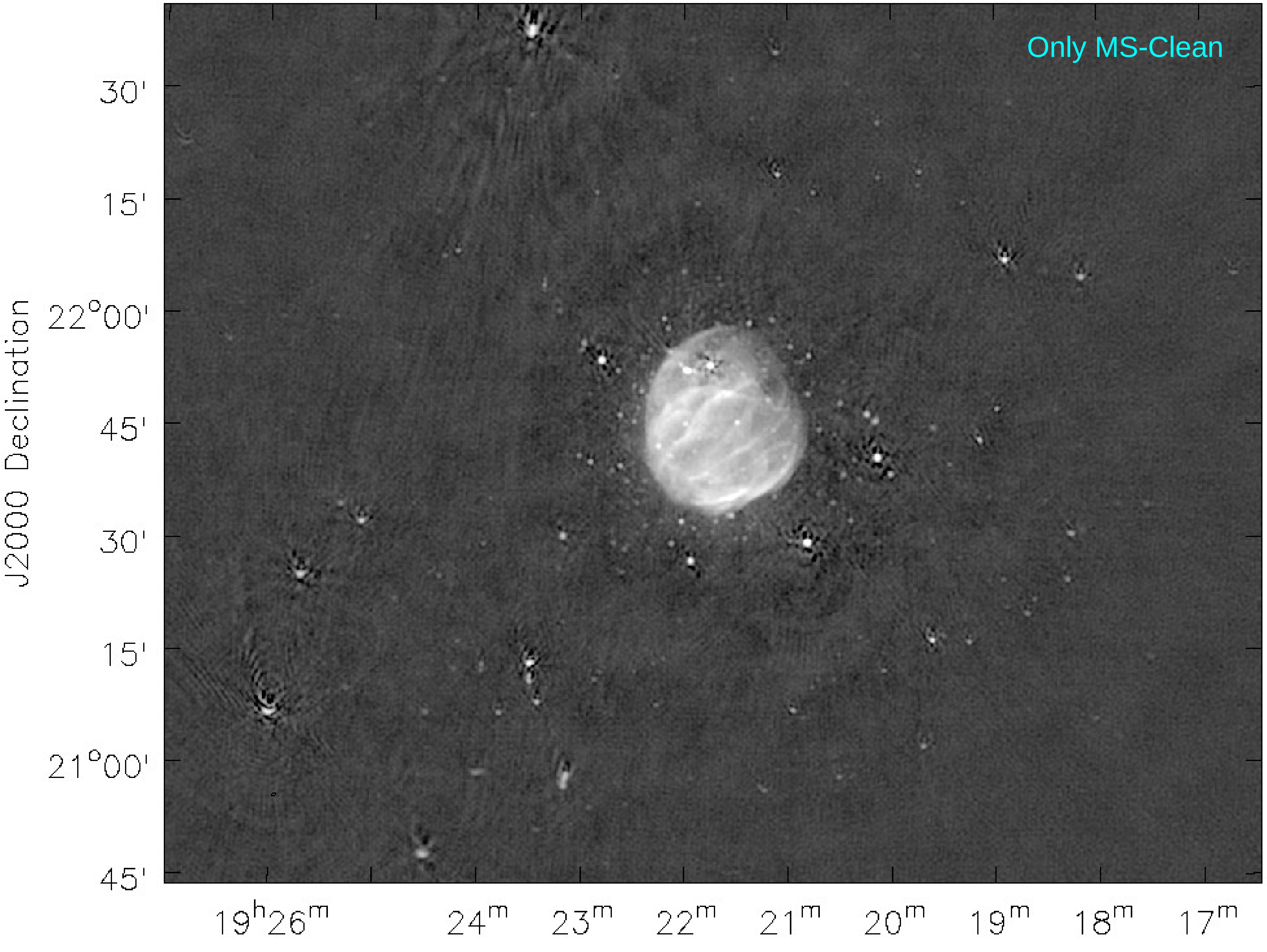
(2) Continuum Subtraction

-- De-select frequency channels in which your spectral-lines exist.
– Make a wide-band image model of the continuum intensity and spectra
– Predict model-visibilities over **all** channels (using WB A-Projection, if necessary)
-- Subtract these model visibilities from the data

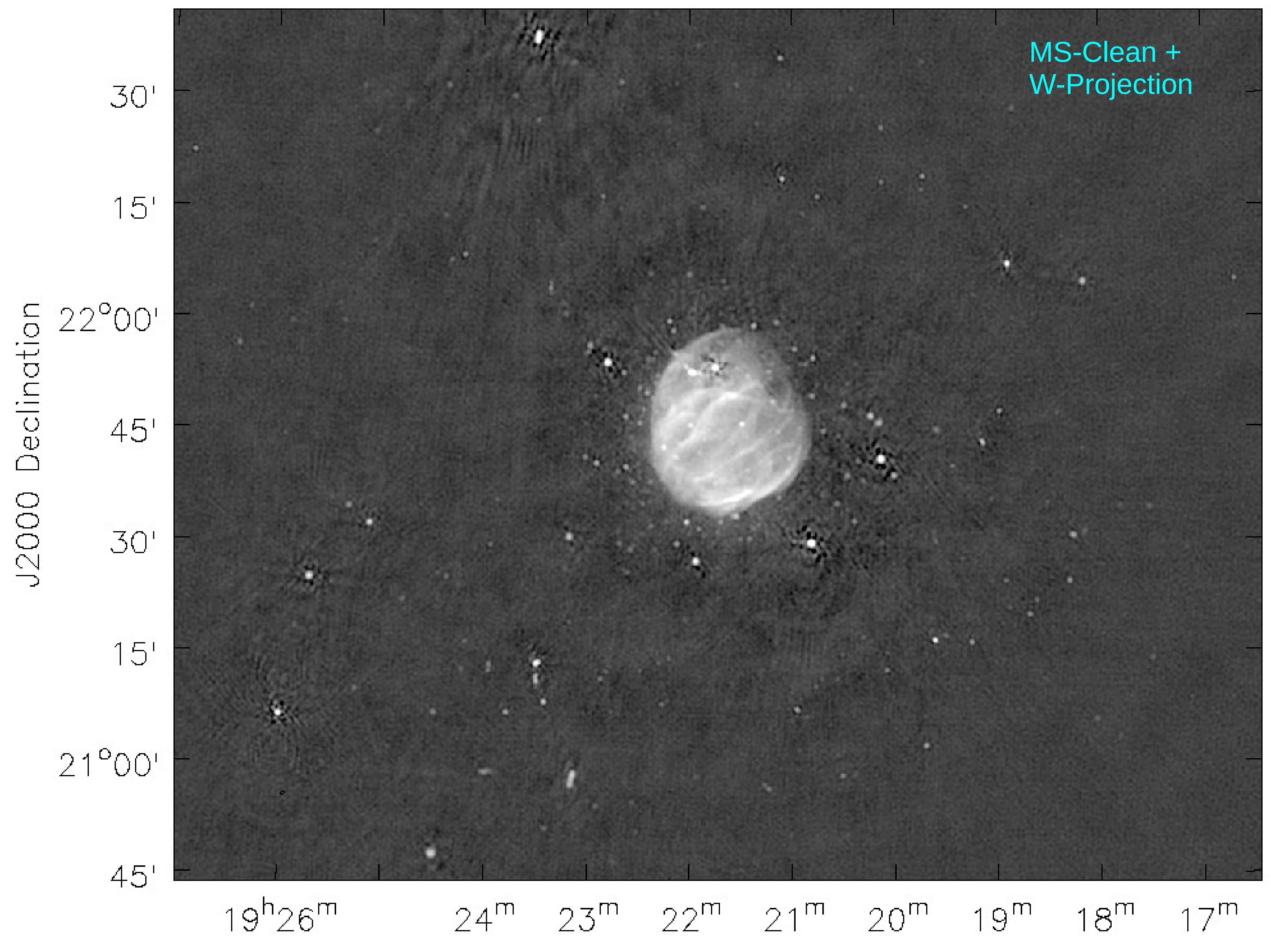
(3) Combination with single-dish data

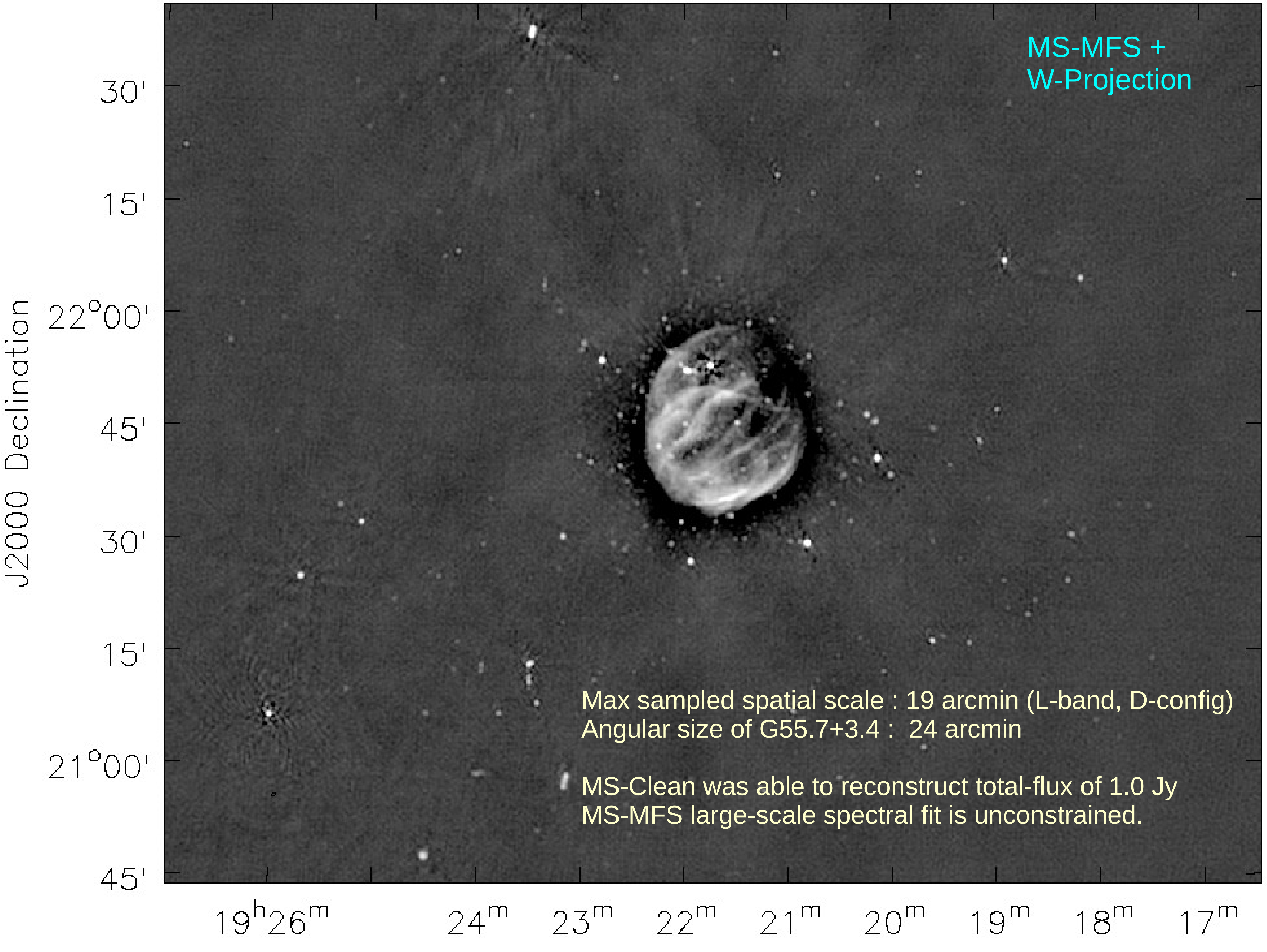
– Use Taylor-coefficient images made from single-dish images, as a starting model

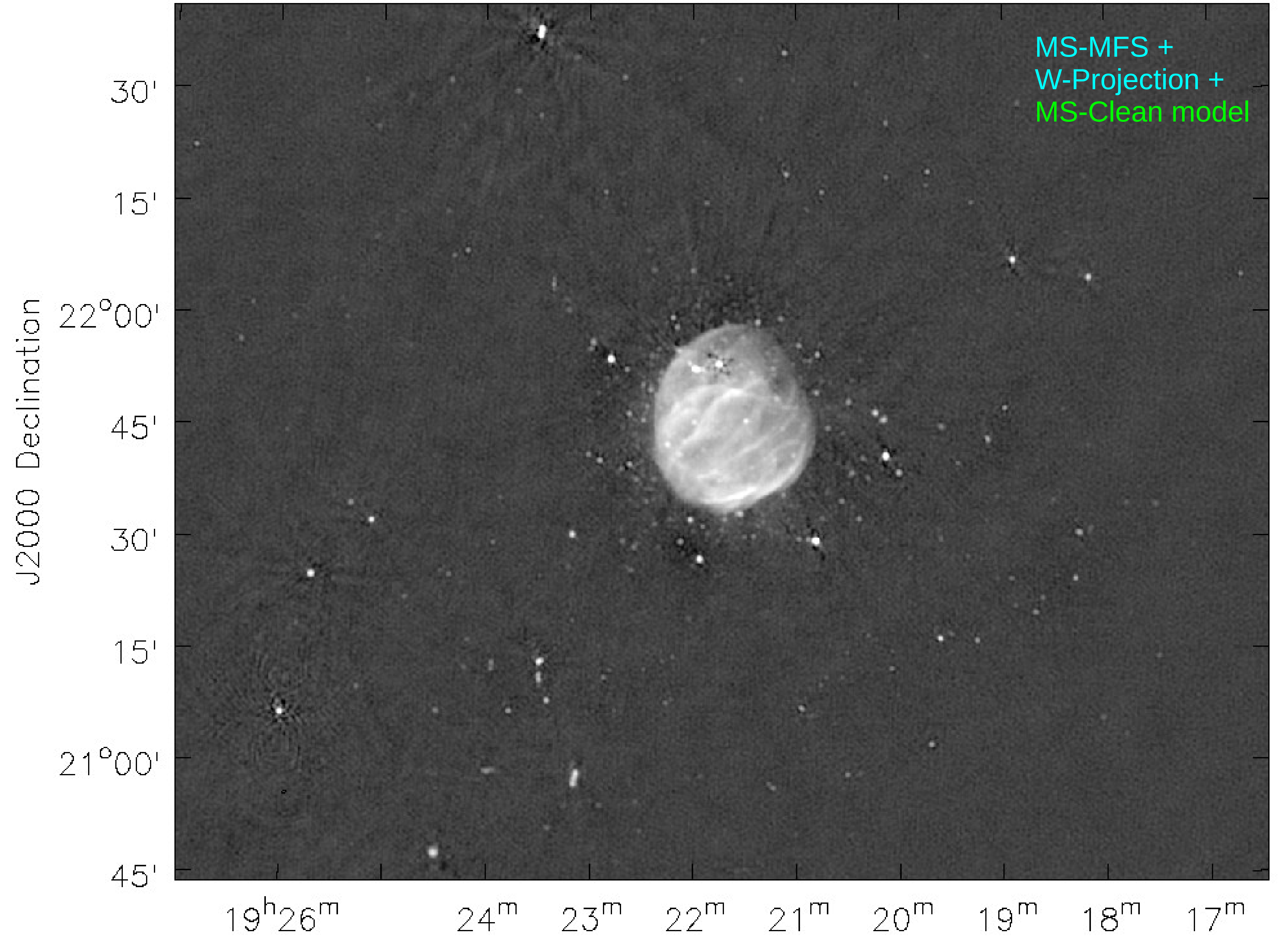

Example : SNR G55.7+3.4
7 hour synthesis, L-Band, 8 spws x 64 chans x 2 MHz, 1sec integrations
Due to RFI, only 4 SPWs were used for initial imaging (1256, 1384, 1648, 1776 MHz)
(All flagging and calibration done by D.Green)
Imaging Algorithms applied : MS-MFS with W-Projection
(nterms=2, multiscale=[0, 6, 10, 18, 26, 40, 60, 80])
Peak Brightness : 6.8 mJy
Extended Emission : ~ 500 micro Jy
Peak residual : 65 micro Jy
Off-source RMS : 10 micro Jy (theoretical = 6 micro Jy)
J2000 Declination
30'
15'
22°00'
45'
30'
15'
21°00'
45'
19h26m
24m
23m
22m
21m
20m
19m
18m
17m



Only MS-Clean
J2000 Declination
30'
15'
22°00'
45'
30'
15'
21°00'
45'
19h26m
24m
23m
22m
21m
20m
19m
18m
17m


MS-Clean +
W-Projection
J2000 Declination
30'
15'
22°00'
45'
30'
15'
21°00'
45'
19h26m
24m
23m
22m
21m
20m
19m
18m
17m


MS-MFS +
W-Projection
Max sampled spatial scale : 19 arcmin (L-band, D-config)
Angular size of G55.7+3.4 : 24 arcmin
MS-Clean was able to reconstruct total-flux of 1.0 Jy
MS-MFS large-scale spectral fit is unconstrained.
J2000 Declination
30'
15'
22°00'
45'
30'
15'
21°00'
45'
19h26m
24m
23m
22m
21m
20m
19m
18m
17m


MS-MFS +
W-Projection +
MS-Clean model
J2000 Declination
30'
15'
22°00'
45'
30'
15'
21°00'
45'
19h26m
24m
23m
22m
21m
20m
19m
18m
17m

Wide-field Issues