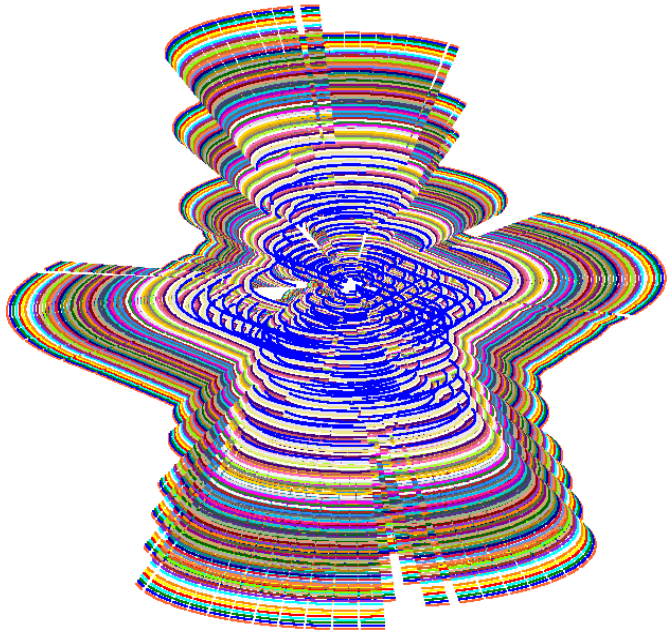
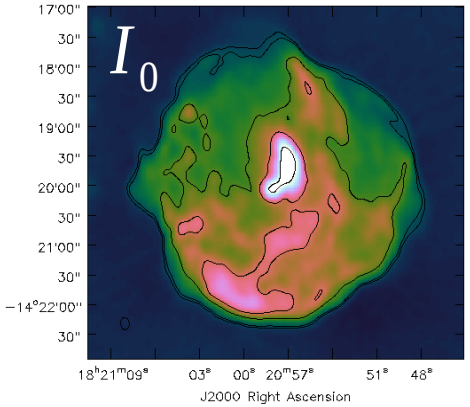
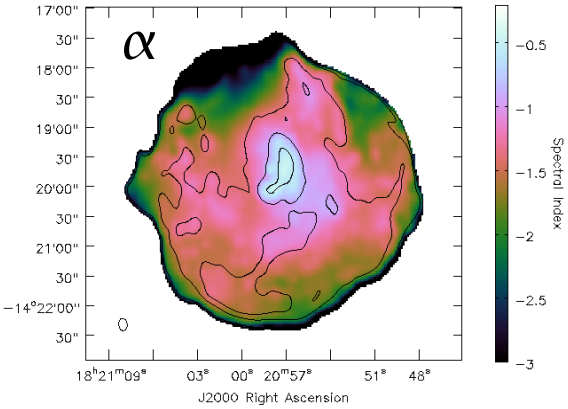
Pilot Project For an EVLA Wide-band Galactic-Plane Survey - First Results : Technical Feasibility







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Sanjay Bhatnagar, David Green, Michael Rupen, Rick Perley, Kumar Golap

5 Nov 2010

26th Annual New Mexico Symposium, Socorro, NM

Missing Supernova-Remnants in the Galaxy

The number of observed Galactic supernova remnants is much less than that predicted from supernova rates and lifetimes.

Statistical studies using cataloged SNRs show a dearth of young and small remnants.

(D.A.Green, 2005) (D.A.Green, 2009)

Selection effects : compact, weak remnants are easily confused with

- diffuse non-thermal emission
- thermal emission from HII regions

But, the nature of the emission is also imprinted on the continuum spectra.....

- Spectral Index : -0.3 to -0.6 for SNRs, +0.1 in HII regions
- Compact, young SNRs may be spectrally separable from compact thermal emission

A systematic unbiased search for compact SNRs will require a high resolution wide-band Galactic-plane survey.

The large instantaneous bandwidth of the EVLA will allow imaging of Stokes-I intensity as well as spectral index (across a 2:1 bandwidth) from a single observation.

=> We are conducting a pilot project to assess technical feasibility of such a survey.

Technical Goals of the Pilot project

(1) Wide-Band Imaging : Reconstruct both spatial and spectral structure *Urvashi R.V. , 2010 (PhD Thesis)*

Question : Sufficient imaging fidelity and error bars on spectral index maps ?

(2) Wide-field imaging : Apply direction-dependent instrumental corrections *S. Bhatnagar et al, 2008* *S.Bhatnagar et al, 2006*

Question : How far out from the field/pointing center can we go ?

(3) Auto-flagging : Automatic RFI identification and flagging *Offringa, 2010,* *Urvashi R.V. , 2003, Tech.Rep.*

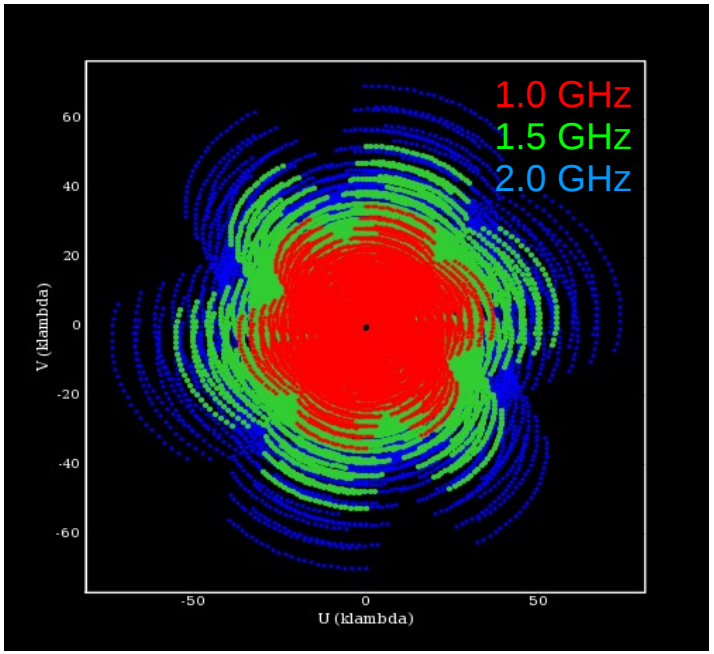
Question : Sufficient imaging accuracy with only automatic flagging ?

(4) High-performance computing *K.Golap, J.Robnett, H.Ye (ongoing in CASA)*

Question : Can we handle automated post-processing of large datasets ?
(~ 100 GB for a full-synthesis run)

Wide-band Imaging - Multi-Frequency-Synthesis

Multi-frequency UV-coverage



MFS : Combine all channels during imaging

- Better imaging fidelity
- Increased signal-to-noise ratio
- Higher angular resolution

Sky brightness changes with frequency

$$I_{\nu}^{sky} = I_{\nu_0}^{sky} \left(\frac{\nu}{\nu_0} \right)^{\alpha + \beta \log(\nu/\nu_0)}$$

MS-MFS algorithm :

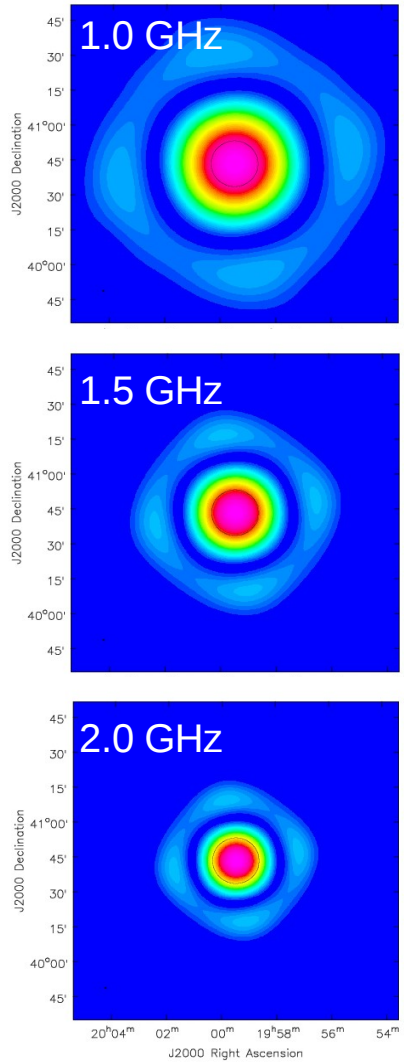
Sky Model : Collection of multi-scale flux components whose amplitudes follow a polynomial in frequency

Image Reconstruction : Linear least squares + Deconvolution + W-Projection

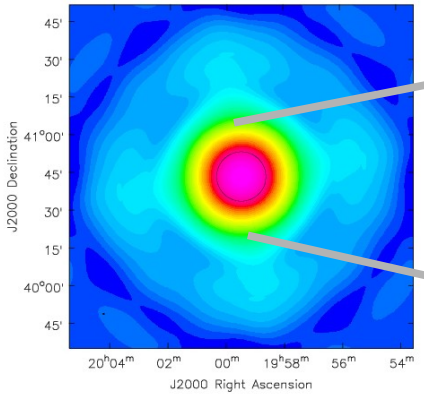
Data Products : Taylor-Coefficient images
Interpret in terms of a power-law : spectral index and curvature

Wide-field Wide-band Imaging

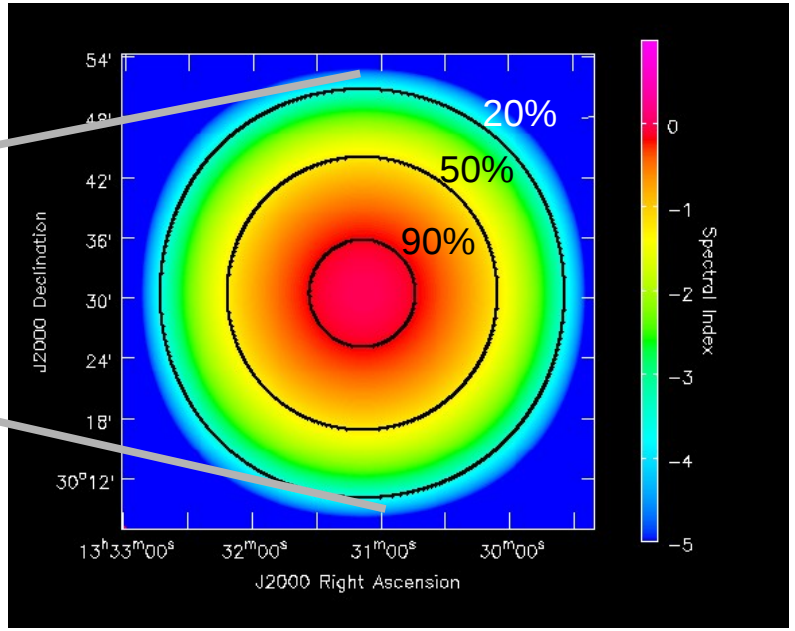
Multi-Frequency Primary Beams



Average Primary Beam



Spectral Index of Primary Beam



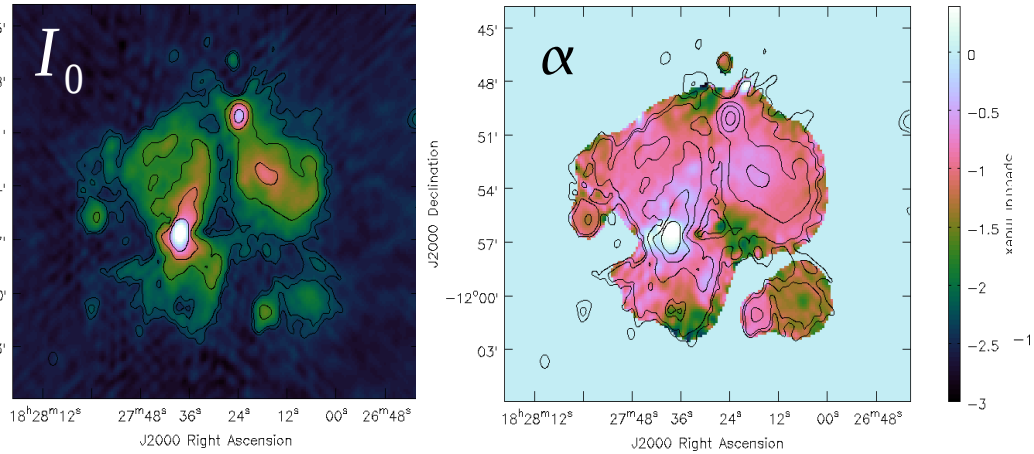
Frequency-dependent and direction-dependent corrections for instrumental effects

- Primary-beam : A-Projection algorithm
- Non-coplanar-baseline effect : W-Projection algorithm
- Mosaic imaging : Projection-based mosaicing *K.Golap (CASA)*

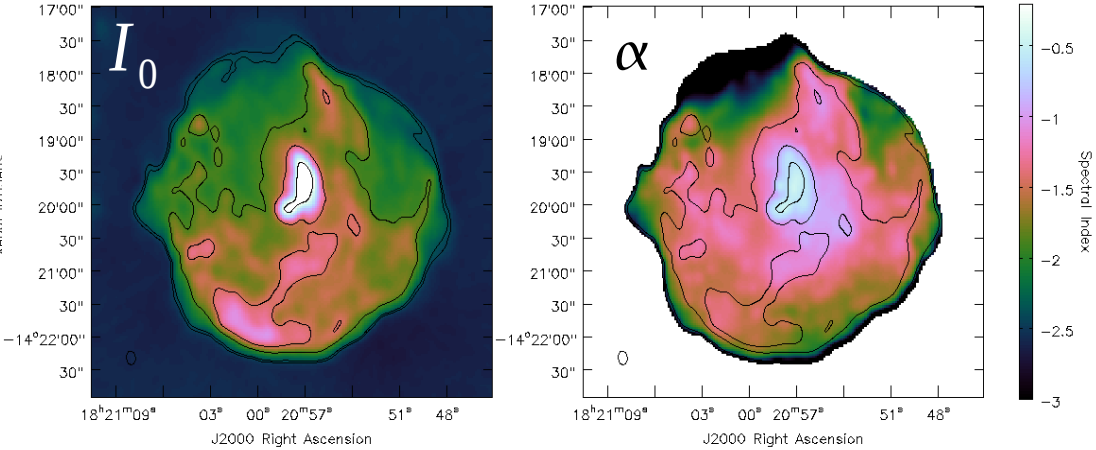
- MS-MFS must work with all of the above...

Supernova-remnants in/near Galactic Plane – thermal vs non-thermal

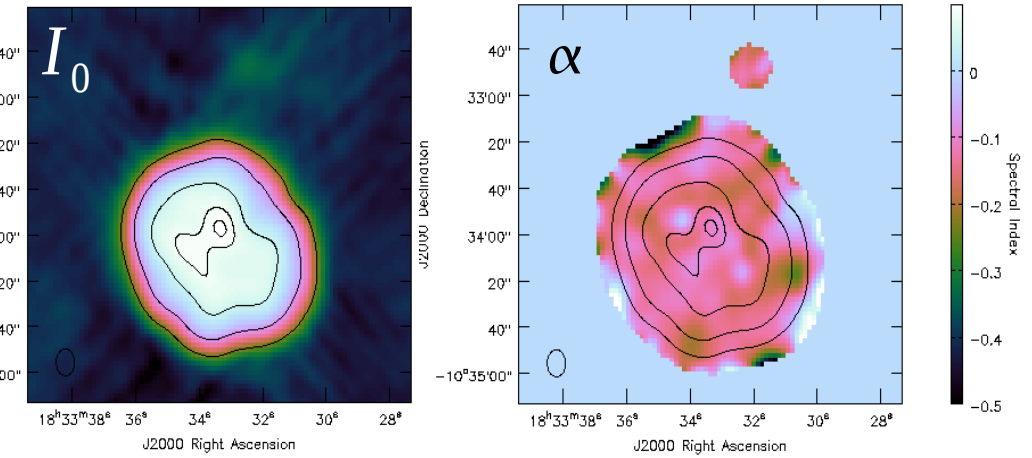
G19.6-0.2



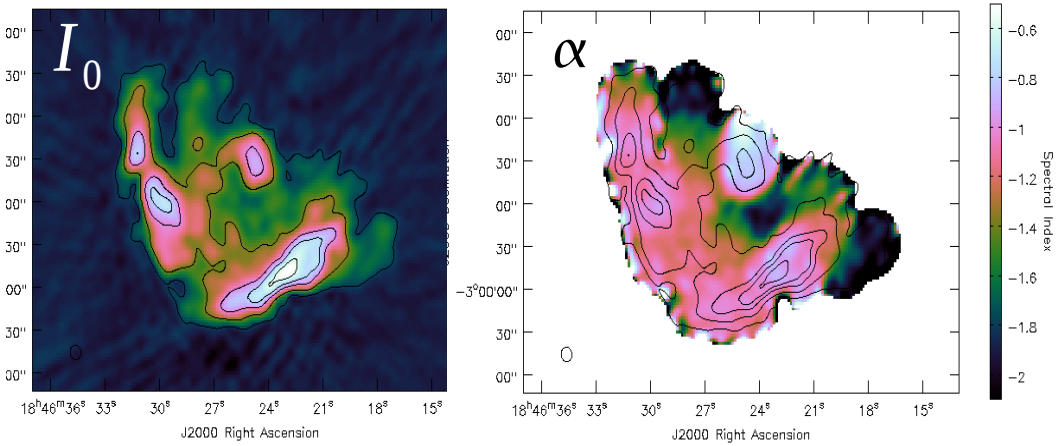
G16.7+0.1



G21.5-0.9



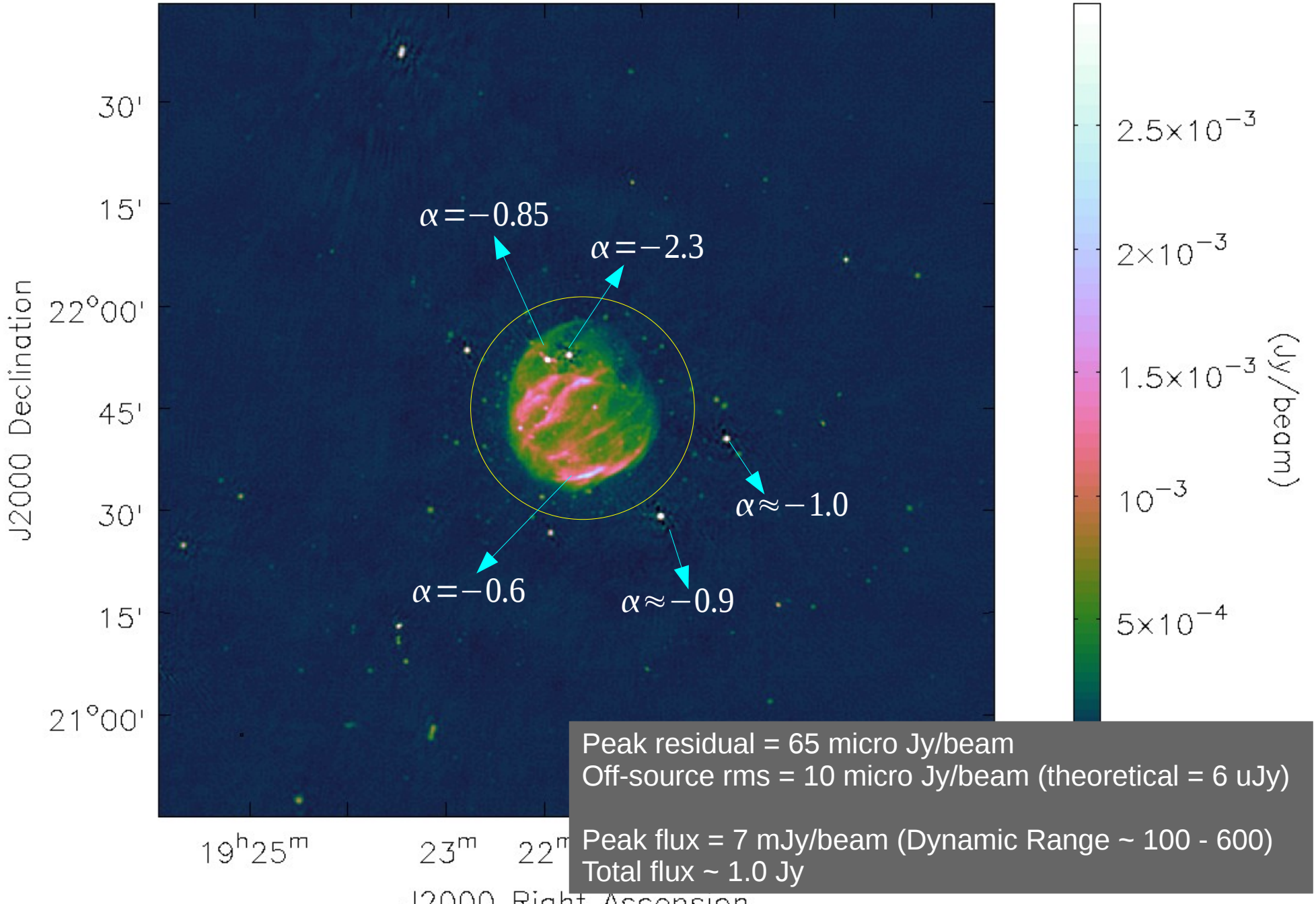
G29.7-0.3



Calibration and manual-flagging done by Dave Green during his RSRO stay in Socorro

Raw Data Sizes : ~ 7 hour run and 1-sec integration, and 2 MHz channel-width : 300 GB.
Target source data size after calibration and 10-sec averaging ~ 10 to 20 GB.
Image-reconstruction time (single node) ~ 3 hours

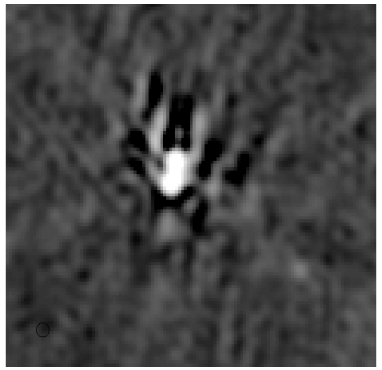
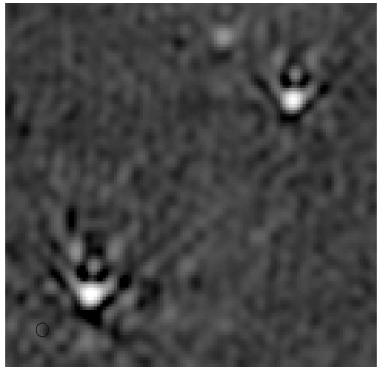
SNR G55.7+3.4



Peak residual = 65 micro Jy/beam
Off-source rms = 10 micro Jy/beam (theoretical = 6 uJy)

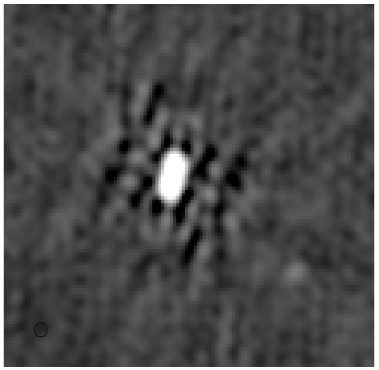
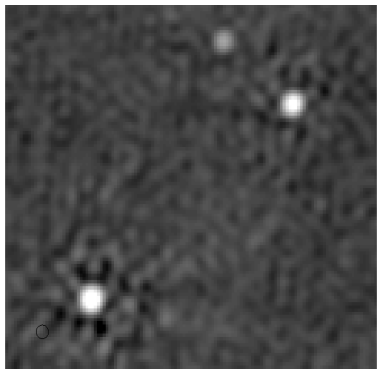
Peak flux = 7 mJy/beam (Dynamic Range ~ 100 - 600)
Total flux ~ 1.0 Jy

Algorithm comparison on G55.7+0.4

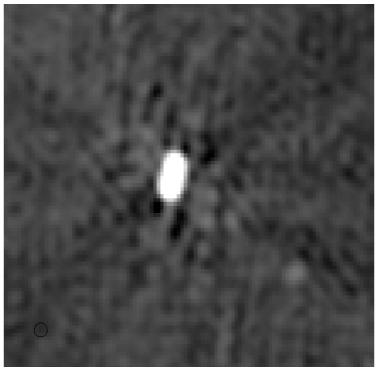
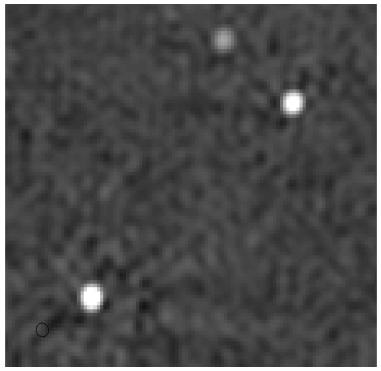
MS-Clean +
Flat-spectrum MFS

- w-term errors dominate for far-out sources.
- spectral errors dominate for sources near the center

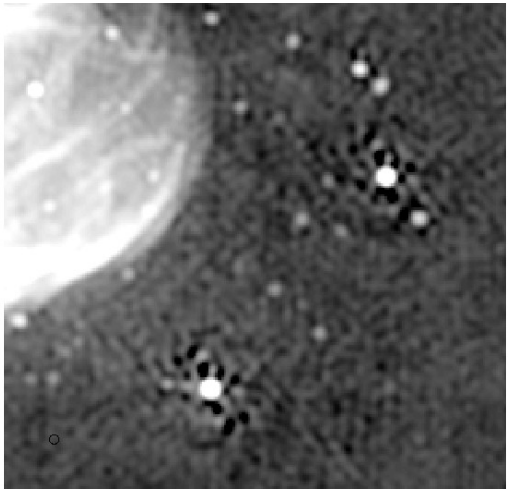
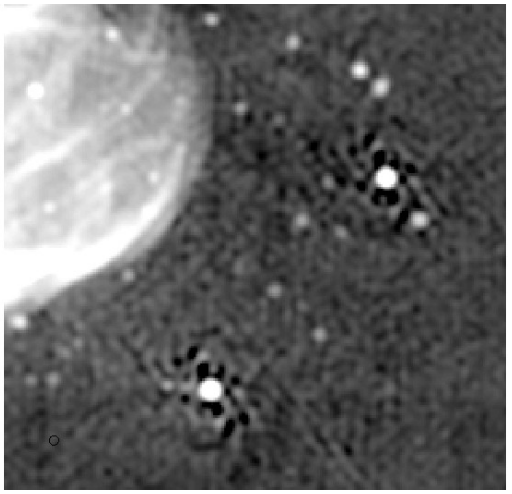
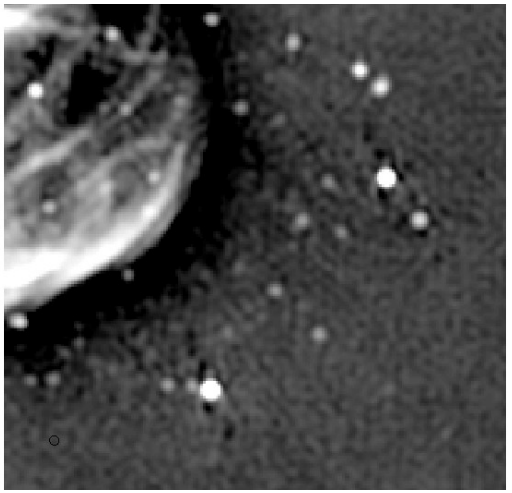
MS-Clean + W-Projection +
Flat-spectrum MFS

- w-term errors are gone.
- spectral errors dominate

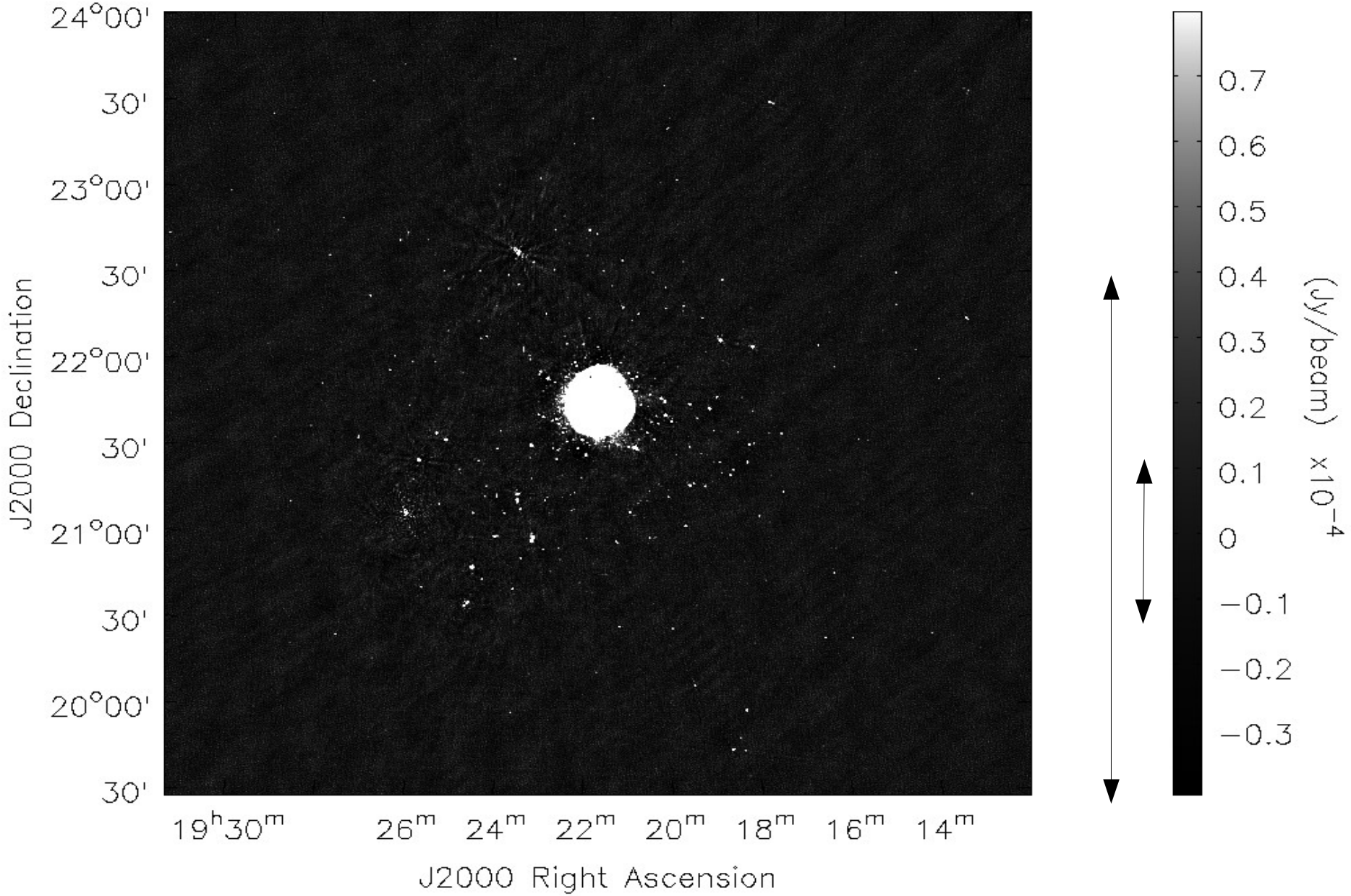



MS-MFS with 2-Taylor terms
+ W-Projection

- w-term errors are gone.
- spectral errors are lower
- artificially-steep spectrum on the largest scales
(requires short-spacing model)

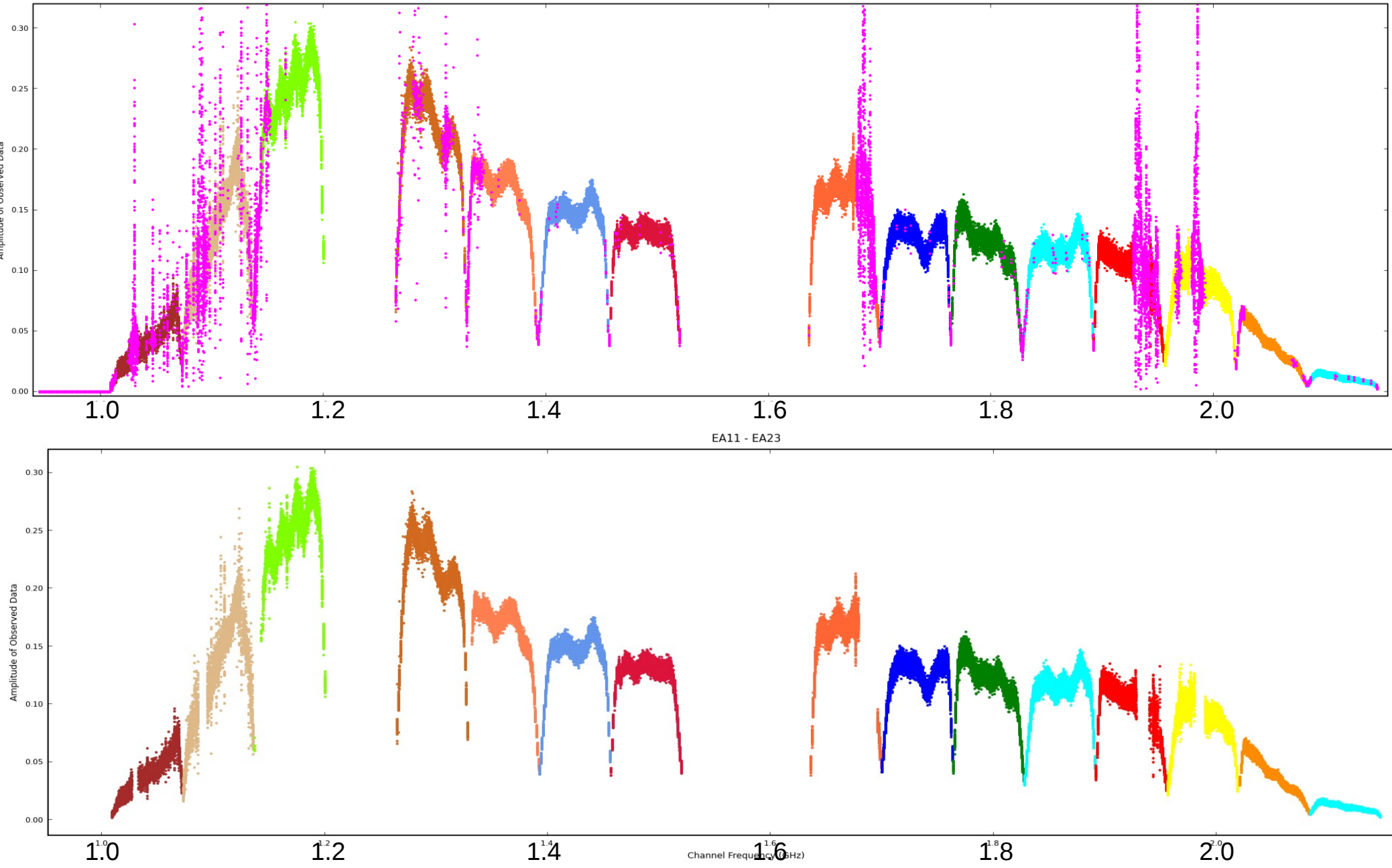




G55.7+3.4 : one pointing, 4 deg x 4 deg field-of-view, 7 hr synthesis



RFI : Automatic flagging example (using un-calibrated 3C286 data)

EA11 – EA23 : 1 scan = 90 x 1sec, 16 spws x 64 chans x 1 MHz ---> Flagged 17% of the data



Technical conclusions about feasibility.... so far....

(1) Spectral index mapping using MSMFS

- Can spectrally differentiate between thermal and non-thermal regions
- Imaging fidelity
  - point sources : OK
  - extended emission : OK only if spectrum is sampled at largest spatial scales
    (error-bars between 0.1 and 0.3 due to multi-scale deconvolution errors)

(2) Wide-field imaging :

- w-term correction : OK, works with MS-MFS
- wide-band primary-beam correction : In-principle demonstration on 3C286 data.
  Not yet tested on extended emission.

(3) Automatic flagging : Promising results on test 3C286 data, but still experimental.

(4) Computation : Parallel Imaging available in CASA for standard imaging
(not yet MSMFS).