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Multi-frequency Imaging in VLBI

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Multi-frequency imaging (MFI) consists of:

 <u>multi-frequency synthesis (MFS)</u>: image synthesis and deconvolution procedures (CLEAN, etc);

 <u>multi-frequency</u> analysis (MFA): estimates of the image spectral parameters (spectral indexes, etc).





Linear Multi-frequency Deconvolution Algorithm

If brightness
$$I_{kpq}$$
 in a point (x_p, y_q) can be presented as
 $I_{kpq} = (I_0)_{pq} \left(\frac{\mathbf{v}_k}{\mathbf{v}_0}\right)^{\alpha_{pq}}$
 $\alpha_{pq} = \alpha \left(x_p, y_q\right)$ is a spectral index
Let us minimize a metrics $\rho = \sum_{k=1}^{K} \sum_{n=0}^{M-1} \sum_{m=0}^{M-1} w_{knm} \left|V_{knm} - \hat{V}_{knm}\right|^2$

then a dirty map and the spectral index in a point (pq) can be presented as

$$(\mathbf{D}_{m})_{pq} = \sum_{k=1}^{K} D_{kpq} (\beta_{k})^{m} - \sum_{k=1}^{K} \sum_{i=0}^{M-1} \sum_{l=0}^{M-1} B_{k,p-i,q-l} (\beta_{k})^{m} \left(\left(\widehat{I}_{0} \right)_{il} + \ldots + \left(\widehat{I}_{N-1} \right)_{il} (\beta_{k})^{N-1} \right),$$

$$\alpha_{pq} = \left(I_{0} \right)_{pq} \cdot \left(I_{1} \right)_{pq}^{-1}.$$





The developed Linear Multi-frequency Deconvolution Algorithm (LMFDA) allows:

- to synthesize and analyze of high-quality VLBI images directly from the visibility data measured on a few frequencies, without analyses of the images itself;
- to synthesize an image of a radio source at any intermediate frequency *inside* any given frequency band. Thus, *spectral interpolation* of the image is feasible;
- it is possible to obtain an estimate of the *spectral index* for a given radio source;
- to provide the highest angular resolution possible for any VLBI project due to its improved (*u*,*v*) -coverage.



MFI Simulations













12 frequencies [MHz]: 4418, 4451, 4562, 4637, 4706, 4815, 5072, 5223, 5308, 5393, 5478, 5804.









_1733-56, I-POL, 5258.5MHz Max. value: 0.4157 Center at RA 17:37:31.4, DEC -56:34:47.3(2000) 1.889 x 1.704[as] at -10.25°













Courtesy of Jon Romney (NRAO)





3C84. VLBA. 8GHz&15GHz



0316+413, RR-POL, 15360.99MHz Max. value: 2.6358 Center at RA 3:19:48.2, DEC 41:30:42.1(2000) 0.000723 x 0.000462[as] at 1.07°



MF Synthesis. 3C84. 11GHz





MF Analysis. 3C84







<u>Jet</u>



W49B. MFI Analysis 327, 1452, 4885 MHz

-0.01

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W49B, RR-POL, 460MHz Max. value: 0.66186



W49B. MFI Analysis







- The problem is completely solved in the case of linear subtractive deconvoltion (MF CLEAN).
- Developed algorithms are implemented in the ASL for Windows and tested on the various VLBI data sets.
- Future plans: MF MEM, MF Self calibration.