A joint deconvolution algorithm to combine single dish and interferometer data for wideband multi-term imaging

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Imaging in radio astronomy is done either using a single dish telescope to make raster scans of a region of the sky or by using an interferometer to measure a set of samples of the visibility function of the sky brightness from which an image is reconstructed. A radio interferometer offers excellent angular resolution but suffers from the short-spacing problem where sources with large angular size and low surface brightness may be completely missed by the interferometer's sampling function and therefore impossible to reconstruct accurately. On the other hand, single-dish radio telescopes offer a comparatively coarse angular resolution but respond very well to large angular scales.

Techniques to combine data from single dish telescopes and interferometers have existed for a long time. One technique is to first construct images separately from each telescope and then combine them using a variety of weighting schemes. This approach is error prone in cases where the interferometric imaging makes irrecoverable errors on scales close to or larger than the maximum measured. This is especially true with wideband multi-term imaging where the short spacing problem manifests itself by causing a dramatic over-steepening of extended emission that is burnt into the output images from the interferometer. Another method uses a single dish image as a starting model in an interferometric reconstruction, but this method is effective in preventing reconstruction errors only when there is significant overlap between the spatial frequency coverage of both instruments (at all observing frequencies).

In this paper we describe a joint reconstruction approach that iteratively builds a multiscale model based on constraints from both datasets at once and demonstrate the efficacy of the approach on wideband multi-term imaging where both older approaches fail. Our method computes a joint observed image as well as a joint point spread function before iterative deconvolution in a scheme that can be interpreted simply as a choice of data weighting, thus allowing the algorithm to be relatively immune to scale factors traditionally used to carefully align single dish and interferometer data in the spatial frequency domain. The algorithm can be applied to narrow-band (spectral line) imaging as well as wideband multi-term imaging that reconstructs the continuum spectrum of the sky at spatial scales probed primarily by the single dish while also preserving high resolution information from the interferometer data. Through this algorithm, wideband multi-term imaging can also be run on only the wideband single dish data to produce a reconstruction of spectral structure at an angular resolution better than that offered by the lowest frequency. Results for all of the above are demonstrated via VLA and GBT simulations between 1-2 GHz. The potential for using such methods for ALMA is also discussed.