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Filter CLEAN — An Improved Method for CLEANing Images

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Abstract. The Filter CLEAN algorithm has been developed for CLEANing images containing a mixture of extended and fine-scale sources. Filter CLEAN requires fewer iterations and the residual rms is much lower than results from Högbom CLEAN. Filter CLEAN is particularly good at recovering extended sources while maintaining good resolution on fine-scale sources. The Filter CLEAN algorithm is described and results presented.

1. Outline of Method and Example of Application

A method of implementation of a deconvolution algorithm for improving the quality of the restoration of radio astronomy images containing both fine-scale and extended sources is outlined. The algorithm, which we originally called Filter CLEAN, applies spatial filters to observations to produce images of different resolutions, progressively deconvolves these separate images using CLEAN [Högbom, 1974] and then sums the results of these deconvolutions to produce a final restored image. The method has recently be renamed Progressive Filter CLEAN because it better describes the algorithm.

The method has its origins in an algorithm, initially called Pyramid CLEAN, then Filter CLEAN [Skellern, 1984] that was demonstrated in principle but was reported to yield unreliable results. Progressive Filter CLEAN is similar in character and intent to Multi-resolution CLEAN (MRC) [Wakker and Schwartz, 1988], which separately CLEANs then combines the results from a smoothed and difference image. However, Progressive Filter CLEAN differs from MRC in three important respects. Firstly, MRC considers only smoothed and difference images, whereas Progressive Filter CLEAN accommodates multiple images. Secondly, Progressive Filter CLEAN at each step processes the high-resolution image before the low resolution image and, moreover, removes the the high-resolution CLEAN components from the low-resolution image before CLEANing it.

Suitable visibility data for the application of Progressive Filter CLEAN will have a relatively constant magnitiude for most *uv* radii and a narrow peak around zero *uv* radius. A graph of visibility data averaged in annuli is produced as a function of *uv* distance. A rectangular filter cutoff is then selected to be at least four times the FWHM of the peak in the visibility data. An image and beam are then produced from the visibility data at *uv* radii above the filter cutoff. This fine-scale image is then CLEANed and the resulting CLEAN components

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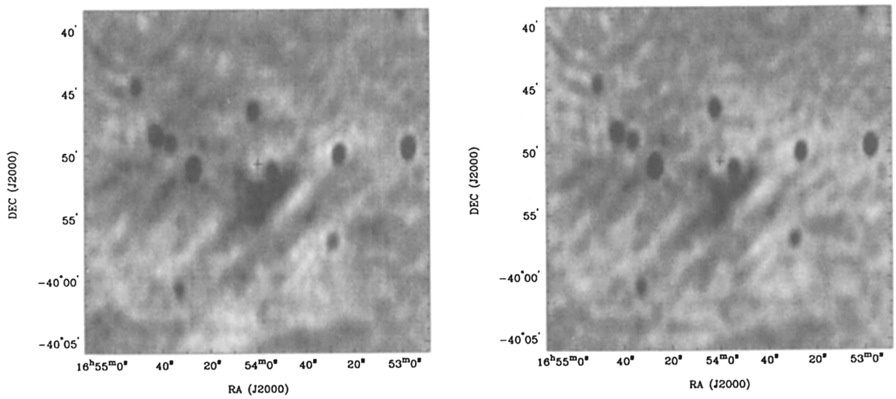

Figure 1. A Högbom CLEAN restoration(left-hand figure) and a Progressive Filter CLEAN restoration of GRO1655-40.

removed from the visiblity data at *uv* radii below cutoff. This shorter spacing data is then separated into high- and low-resolution data with a Gaussian filter. The high-resolution data is CLEANed and the resulting CLEAN components removed from the low-resolution data which is then CLEANed. The final step is to restore each image with the appropriate CLEAN beam and sum the results.

The results of an observation of GRO1655-40, an x-ray binary, are shown in Figures 1 and 2. As the region of interest in on the galactic plane, there is a high level of extended emission. After inspection of of the visibility data, the rectangular filter was set at 1000 wavelengths and the fine-scale image CLEANed. After removing the resulting CLEAN components from the visibility data at *uv* radii below the filter cutoff, the process was repeated using a Gaussian filter on the remaining visibility data. The Gaussian filter had a FWHM of three times the beam FWHM. Finally, the lowest resolution image was CLEANed and the results of the three separately restored images were then scaled and added.

Progressive Filter CLEAN does not have the artefacts of the Högbom restoration, requires only a tenth of the effective number of iterations, and the rms of the residuals is considerably less, 2.4 compared with 3.5 (values normalized to the rms of the data). Inspection of the individual images before final summing separately shows the fine-scale and extended emissions. Comparison of these images with the Högbom restoration clearly shows that the Högbom restoration contains artefacts.

Progressive Filter CLEAN is an effective method the the intended application and will now be implemented for users.

References

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