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Improvements in Filter Design for Removing Galactic "Cirrus" from IRAS Images

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Abstract. Design improvements continue to be made in the filter developed using mathematical morphology principles for the Infrared Astronomical Satellite (*IRAS*) images. The purpose of this filter is to eliminate Galactic cirrus emission from extragalactic fields. Current improvements are based on dividing the structure in the *IRAS* images into several classes, and then filtering the information in the image class by class. The current procedure gives significantly improved results compared to those of the first version of the filter.

1. Introduction

"Cirrus" emission in *IRAS* images at 60 μm and, especially, at 100 μm, has hampered the study of extended extragalactic structures. The problem is made more difficult by the fact that the cirrus emission can exhibit a wide spread in far-IR color temperatures, ranging from 20 K to 35 K. Our approach for reducing the IR cirrus in *IRAS* images is based upon an image processing procedure called *mathematical morphology* (Serra 1982). Results from the first version of our filter are discussed in Basart, Siqueira, & Appleton (1992), Appleton, Siqueira, & Basart (1993), and Pedelty, Appleton, & Basart (1994). Previous filtered results of the M81 group showed considerable improvement over the original image. Not all undesired features were filtered out, however, so filter design continued. The second version of the filter, presented here, produces significantly better results than the first filter.

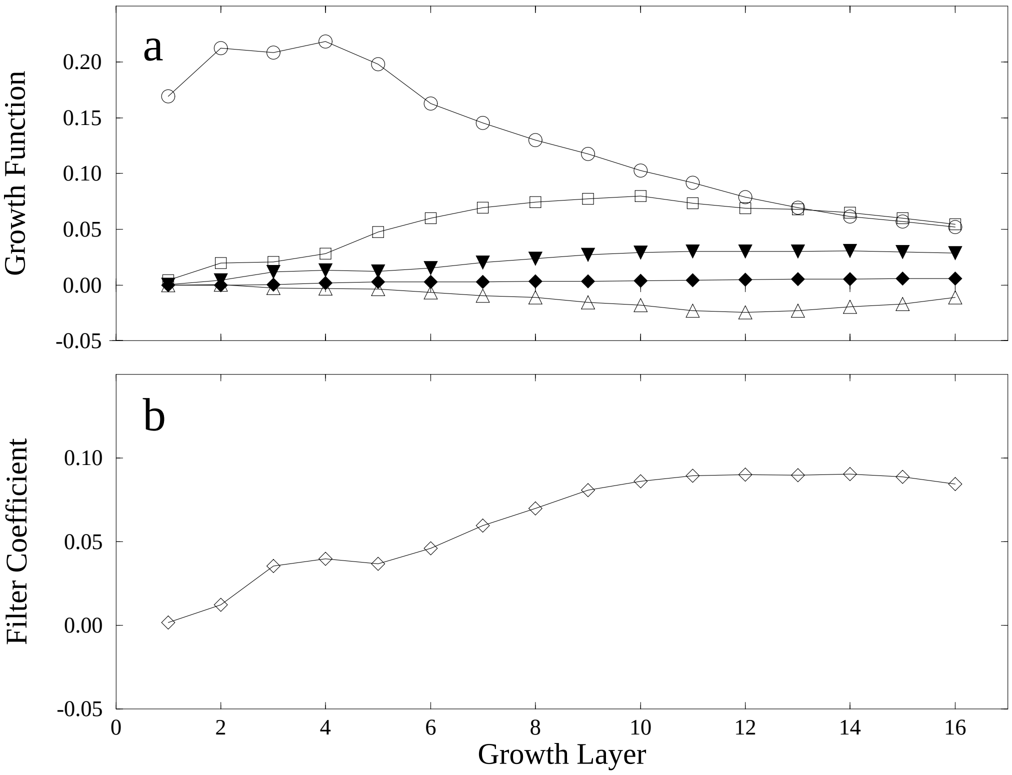


Figure 1. The top plot (a) shows an example of the growth functions for various structural types as explained in the text. The bottom plot (b) shows the filter coefficients created from the growth curve and used to filter the image shown in Figure 2b.

2. Filter Design

We briefly review the basic procedure underlying both filters. The process starts by performing an opening operation (Appleton et al. 1993) on the filter, with a Gaussian shaped structuring element. This opening operation eliminates all structural information smaller than the structuring element. We then open the original image again with a slightly larger structuring element, and subtract the first result from the second. This difference produces an image with a narrow range of structural sizes: those that lie between the sizes of the two structuring elements. We then open the original image with a third structuring element, whose size is a little larger than the second structuring element. We subtract this third opening from the second opening, giving another image with a different range of structural sizes—larger sizes than those of the first differenced image. We continue this process until we get a set of 16 images whose range of structural sizes varies from seven pixels to thirty nine pixels. We call the resulting plot of intensity vs. structural size at one pixel a "growth curve."

The growth curve contains information central to the filtering operation. In version one of the filter, the growth curves for many cirrus pixels not containing galaxies were averaged together, and the results used as the filter curve. With an appropriate normalization, the filter curve was applied to each pixel in the image to remove the Galactic cirrus. This filter had a high degree of success because the growth information of the galaxies differed from that of the cirrus. However, not all information averaged together to make the filter curve was homogeneous, causing artifacts to be introduced into the final image. This difficulty led to the development of version two of the filter. In this extended approach a classification procedure was introduced. The growth curve was treated as feature information in 16 dimensional space−one dimension for each difference in openings. After placing all opening differences into the feature space, a clustering operation was performed to determine groupings. Five clusters were allowed. The growth curves for each of the five structural types are shown in Figure 1a. Four of the curves are somewhat similar while the top curve is much different. Viewing the central portion of the graph, the identification of the structure from the top curve to the bottom curve is: (1) small bright objects, (2) regions around the small bright objects, (3) small cloud structure, (4) large cloud structure, and (5) corrupted structure caused by the boundaries of the image. It is apparent from the curve that filter performance could be improved over that of version one by selectively filtering by structure type.

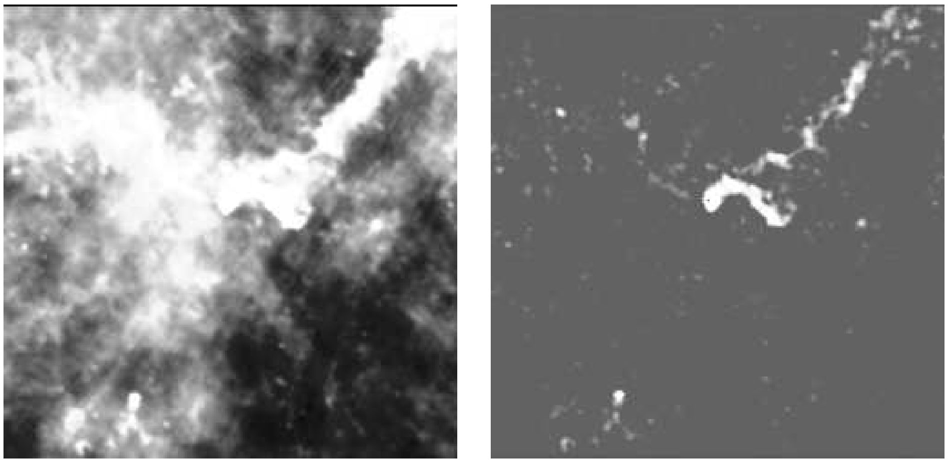
3. Results

Version two of the filter uses a filter curve based upon type 3 structure, as identified above. A filter curve was created by normalizing the growth curve by the area under this curve. The resulting filter curve is shown in Figure 1b. This curve, with appropriate re-normalization, was applied to all pixels in the image.

Figure 2a shows an example of *IRAS* field I363B4H0 before filtering, and Figure 2b shows the results after filtering. The original image (Figure 2a) is very heavily contaminated with $100\,\mu$m IR cirrus emission. The image shown is a portion of an *IRAS* field which contains a variety of non-cirrus structure ranging from Galactic nebulae to galaxies. Small objects, such as galaxies, are difficult, if not possible, to detect. Even more ambiguous is the tenuous structure on the periphery of galaxies. The purpose of the filter is to minimize the presence of Galactic IR cirrus in the image in order to make the extragalactic IR emission more visible.

The filtered image contains considerably less Galactic cirrus than the unfiltered image. The remaining structure in the filtered image is primarily from non-diffuse objects. About 30% of the point-like sources in the image are galaxies and the remaining objects are extended structures. Many of the extended structures appear to be highly correlated with unusually bright and sharply defined reflection nebulosity. The latter conclusion was drawn by comparing the filtered image with an optical image.

Preliminary testing for flux integrity during the filtering process has been completed. Throughout the image, flux retention is better than 1% in consistency. In absolute terms, the filtered flux is within a few percent of what is assumed to be a true flux of an object. Overall, the filter has been extremely effective at extracting unusual and interesting sources. We are currently following up our results with wide-field CCD observations of these objects.



(a) (b)

Figure 2. The left figure (a) is a portion of the *IRAS* field I363B4H0 observed at 100 μm. The right figure (b) is the result of filtering out much of the IR cirrus structure using a filter based upon mathematical morphology.

References

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