DETERMINING POINT SPREAD FUNCTION OF SPACE OBSERVATIONS USING BID ALGORITHM

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Abstract

With the advent of improved data analysis tools and the superior image restoration capabilities of the newly developed Blind Iterative Deconvolution algorithm, the scientific return from the observations from space can be significantly improved. We present the results of the application of this algorithm to the EUV/Skylab images and to a sample of YOHKOH data.

1. Introduction

Solar observations from space have recorded images at the limb and on the disk that cover a wide variety of structures in active regions, quiet regions and coronal holes. The images usually contain many complex structures at different spatial scales, and the dynamic range between various features is often very high. The characteristics and distribution of the smallest spatial scale structures cannot readily be determined directly from these images, either because of limited resolution and noise in the images, or because of the high dynamic range between small-scale and large-scale structures.

Image reconstruction and enhancement algorithms can substantially increase the yield from the space observations. We present here, the results of the application of a recently developed image restoration algorithm, Blind Iterative Deconvolution (BID) (Ayers and Dainty 1988; Karovska et al. 1991 and references therein), to two different samples of Solar observations from space obtained with Skylab and YOHKOH.

2. The Blind Iterative Deconvolution Algorithm

The main advantage of the BID algorithm is that it allows both a high resolution image and the degrading point spread function (PSF) to be recovered from a high signal-to-noise image. When applied to high signal-to-noise images, degraded by an unknown linear and stationary function, the BID algorithm finds a pair of functions corresponding to the degrading function and the undegraded image, which when convolved reproduce the input image within given physical constraints. The first step in the iterative process is to deconvolve the degraded image with an estimate of the PSF using signal-to-noise ratio constraints. The result of the deconvolution is transformed back to the image space, and several physical constraints, including positivity of the image, are applied. The new estimate of the PSF is used to deconvolve the input image in the next iteration and the iteration continues until some concluding criterion is reached, such as image quality criterion or a limit to the number of cycles.

We performed a number of numerical and experimental tests of this algorithm. We found that it converges rapidly, after a few iterations, to a stable solution independently of the starting PSF (including a random gaussian). The relative brightness between the sources in the original data is preserved in the reconstructed image.

3. Results of Application of BID to the EUV/Skylab and YOHKOH Data

Data Base

Skylab Data: Simultaneous multiwavelength observations of the solar corona were carried out using the Harvard EUV spectroheliometer on Skylab, 1973-74. The data were recorded through the same instrumental slit thus removing any ambiguity regarding spatial correspondence between the different wavelengths. The instrumental resolution is 5"x 5" and the temporal resolution is 5.5 min. The data cover a wavelength range that spans the chromosphere into the corona. The Skylab data used in this study consist of solar disk observations of the quiet Sun in a coronal hole and of an active region carried out on 1974 August 21.

YOHKOH Data: A series of SXT images were recorded on 1993 April 17 of a compact bright source on the limb. The set of images used in this study consist of a time sequence of 12 128x128 pixel frames. Each image consist of a pair of separate exposures, 128x64 pixels each, which may be spatially offset from each other by up to 1-2". The pixel size is 2.46".

4. Reconstructed Images

The starting guess for the PSF was a gaussian with random noise and half power width radius of 5 pixels. Substantial sharpening of the structures in the images occurred after 20-30 iterations, and the iterative process was stopped when the reconstructed image remained effectively unchanged in further cycles of BID (not more than 100 iterations). As an example we show the starting and the final PSF corresponding to one of the Skylab images (Fig. 1).

Skylab Images

Figure 2 shows contours of the original and the reconstructed image in C II of a region in a coronal hole. The reconstructed image shows some sources within the bright points (labeled as 1, 2, and 3 in the original images) that are distinctly separated on a scale of 5".

The reconstructed images in Mg X of a small active region contain a series of discrete emission knots as small as 5" in size (Fig. 3). The Mg X emission is concentrated between sources emitting at lower temperatures. Although the unprocessed images show some evidence of this, the BID images give clearly defined boundaries of the emission at different temperatures.

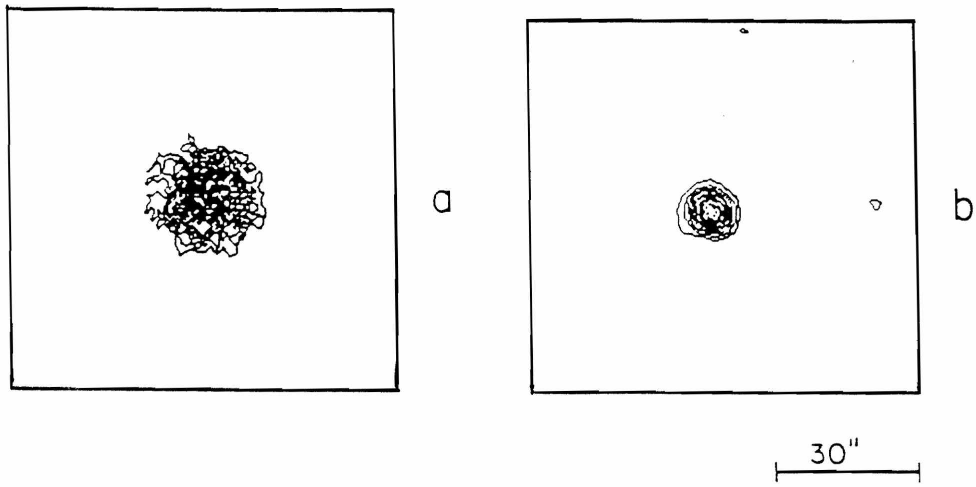

Fig. 1. The starting PSF (a) and the reconstructed PSF (b) for one of the Skylab images.

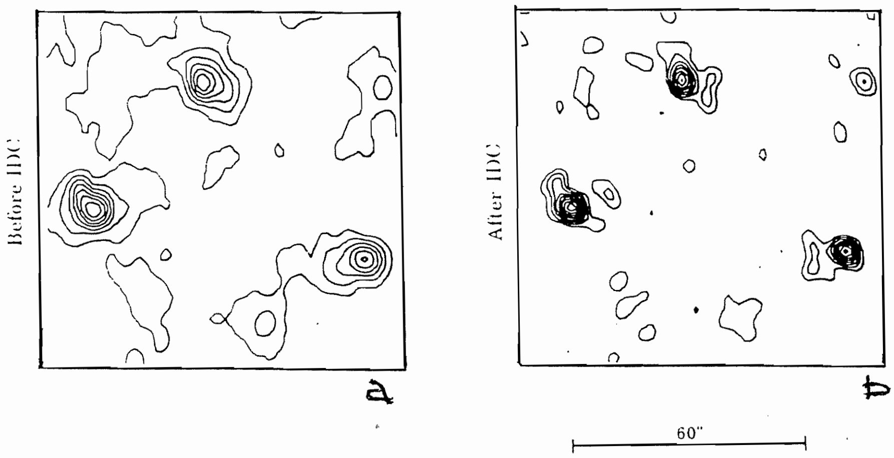

Fig. 2. Intensity contours of a region in a coronal hole showing several bright points in C II, before (a) and after the BID (b).

The improved resolution in the EUV Skylab images achieved with BID provides a more detailed view of the spatial structure of bright points and of active regions.

YOHKOH Images

The application of BID to the YOHKOH limb observations on 1993 April 17 sharpened substantially the original images. The improvement of the resolution can be seen by the emergence of distinct structures in the processed images. As an example, Figure 4 b shows the image reconstructed from the original image shown on Figure 4 a. Similar results were obtained for 10 of the 12 images (two of the images did not converge as rapidly as the others). The temporal evolution of the fine-scale structures shows substantial brightness variations and morphology changes.

The PSFs recovered from this series of YOHKOH images (nine of the twelve PSFs) are elongated and show core/halo structure (at approximately 10 percent from the max). The elongation in the PSFs could be result of contamination by the effects of the sharp solar

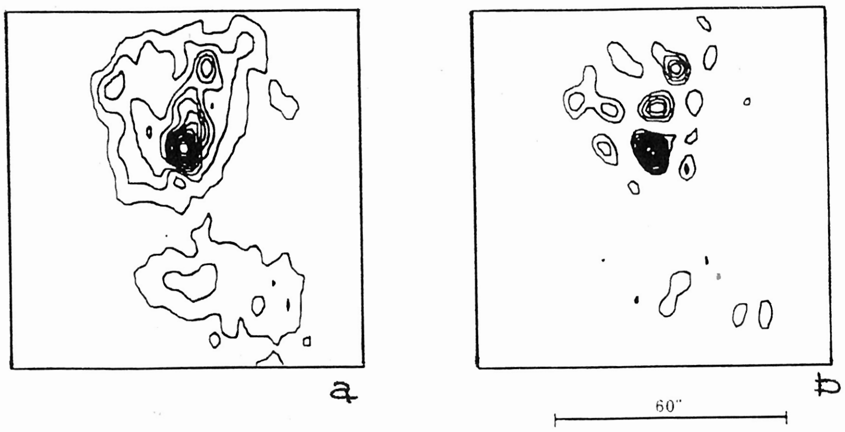

Fig. 3. Intensity contours of a small active region in Mg X, before (a) and after the BID (b).

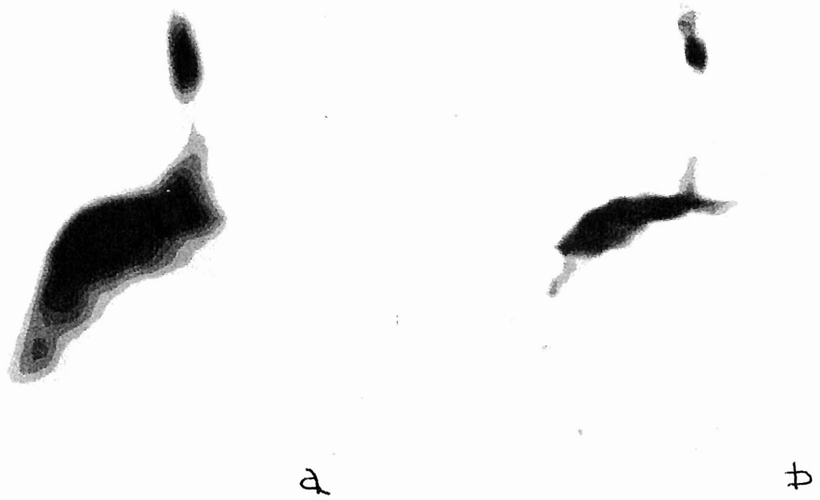

Fig. 4. (a) SXT image of the compact bright source on the limb. (b) Reconstructed image.

limb, or it could be due to the off-axis response of the mirror. To determine the cause of the elongation it is necessary to compare this PSF with the PSFs derived from data on the disk.

This exploratory work shows that the BID algorithm is a powerful tool for probing the fine scale structure and temporal variability in YOHKOH images. BID therefore presents a very promising avenue for improving the scientific yield of the existing data, and data to be acquired in the future.

References

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