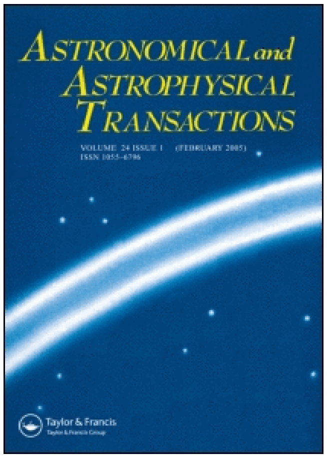

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TWO-CHANNEL RESTORATION VIA AUTOMATIC POINT-SOURCE DETECTION

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An image restoration technique is described which is based on a two-channel decomposition of astronomical images. The first channel consists of point sources which are automatically detected and extracted from the image. The second channel contains the remaining smooth objects which are processed by standard restoration methods. The positions of the point sources have to be determined with subpixel accuracy. With this method both the photometric accuracy for point sources as well as extended objects and the astrometric accuracy can be improved. Examples of the use of this technique on simulated HST data frames are given.

KEY WORDS Image processing, data analysis

1 INTRODUCTION

Many astronomical images consist of point sources (e.g. QSOs, stars) and a smoother intensity distribution as background. Often situations arise where bright point sources (sharp intensity transitions) are located atop extended objects. When a bright point source is deconvolved by standard restoration methods, it is represented by an extended intensity distribution producing some artefacts in the restored image (ringing). A non-negativity constraint is of little help against ringing if the star stands atop of extended emission. Objects which vary on different spatial extensions should be treated differently in the context of image restoration. Therefore we adopt a restoration technique where the image is decomposed into two channels. The first channel consists of point sources which are automatically detected and extracted from the image. The second channel contains the remaining smooth objects which are processed by standard restoration methods.

2 AUTOMATIC POINT-SOURCE EXTRACTION

In order to decompose the image, an automatic point-source detection and extraction method as a preprocessing tool is chosen.

The task of finding point sources involves:

(1) detecting and locating small, positive brightness enhancements within an image;

(2) distinguishing legitimate stellar images from (a) random noise peaks in the data and (b) images of galaxies or other extended astronomical objects;

(3) recognizing when an apparently extended object consists of two or more overlapping stellar images.

In a first step local maxima are searched for. Only those maxima above a given threshold are considered as possible candidates. The threshold is a user-defined multiple of the standard deviation of the data. The standard deviation is estimated by approximating the data with low-order polynomials in regions without local maxima with an extension larger than two pixels.

The local background is modelled by bivariate polynomials of degree n. The brightness and the position of the point source are calculated by fitting the point-spread function (PSF) and the local background to the observed stellar profile. If an object has been detected above the threshold level it may consist of a number of blended point sources. Therefore, we allow the fit of up to m point sources in a small array simultaneously. The parameters for the fit are the brightness of point sources, the coordinates of the centroids of the point sources, and the coefficients of the polynomials for the background. The fitting area is chosen so as to get reasonable estimates for the background. If the PSF is not well sampled or undersampled it is necessary to determine the position of the point source relative to the centre of the pixel it is located in. Otherwise artefacts are introduced in the restored image.

The detected point sources are stored in a scratch file and are subtracted from the data. The remaining image is then deconvolved with standard techniques. Afterwards the point sources are added to the deconvolved image to obtain the final result.

For the non-linear optimization a damped Gauss–Newton method (Golub and Van Loan, 1990; Deuflhard, 1974) is used, which works quite well. We tested polynomial approximations up to third degree in each coordinate and achieved best results with second-order polynomials (see Figures 1–6). Please note that point sources have been truncated in the perspective plots.

3 IMPLEMENTATION AND FIRST RESULTS

The test images were constructed using a pixel size which is 1/10 the size of the actual pixel size of the real CCD chip. This method allows us to simulate stars with

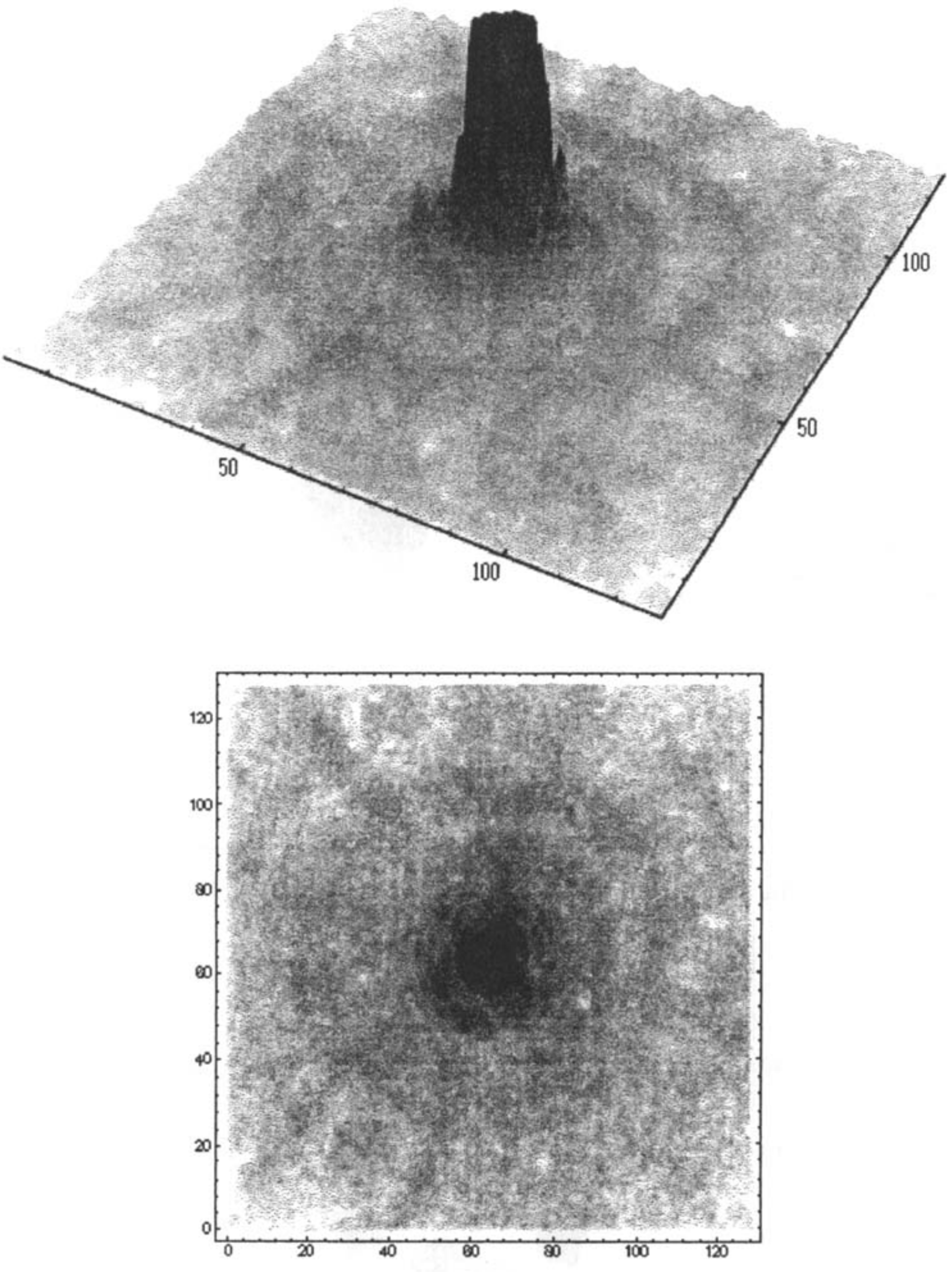

Figure 1 Simulated PSF of the Faint Object Camera of the Hubble Space Telescope.

positions that are not required to be at the centre of the real pixel. We have performed simulations where we blurred (Figure 3) the original brightness distribution (Figure 2) with a simulated Faint Object Camera (FOC) PSF (Figure 1). The true

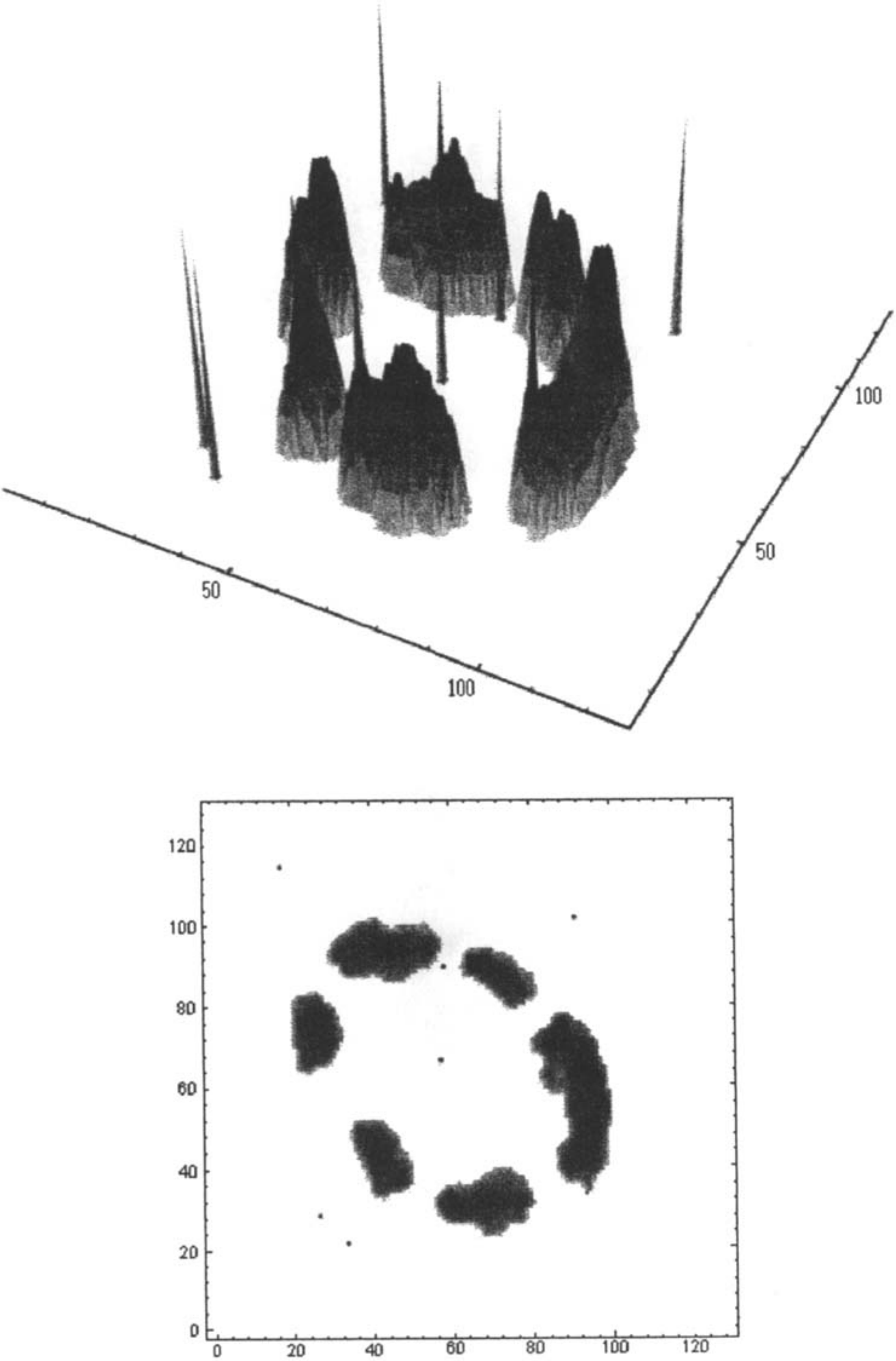

Figure 2 True 128 x 128 simulated data.

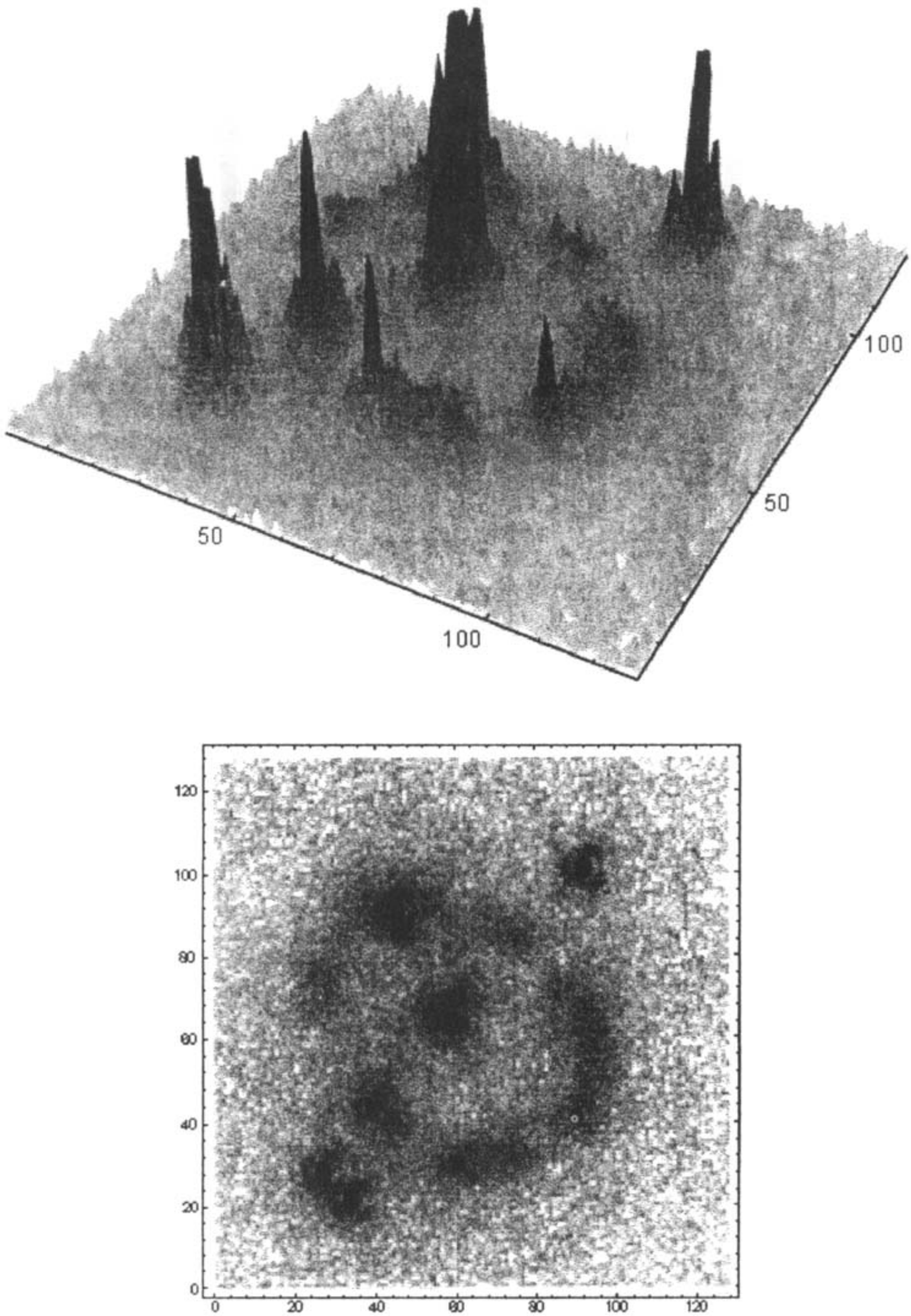

Figure 3 True data blurred with the FOC psf and noise added.

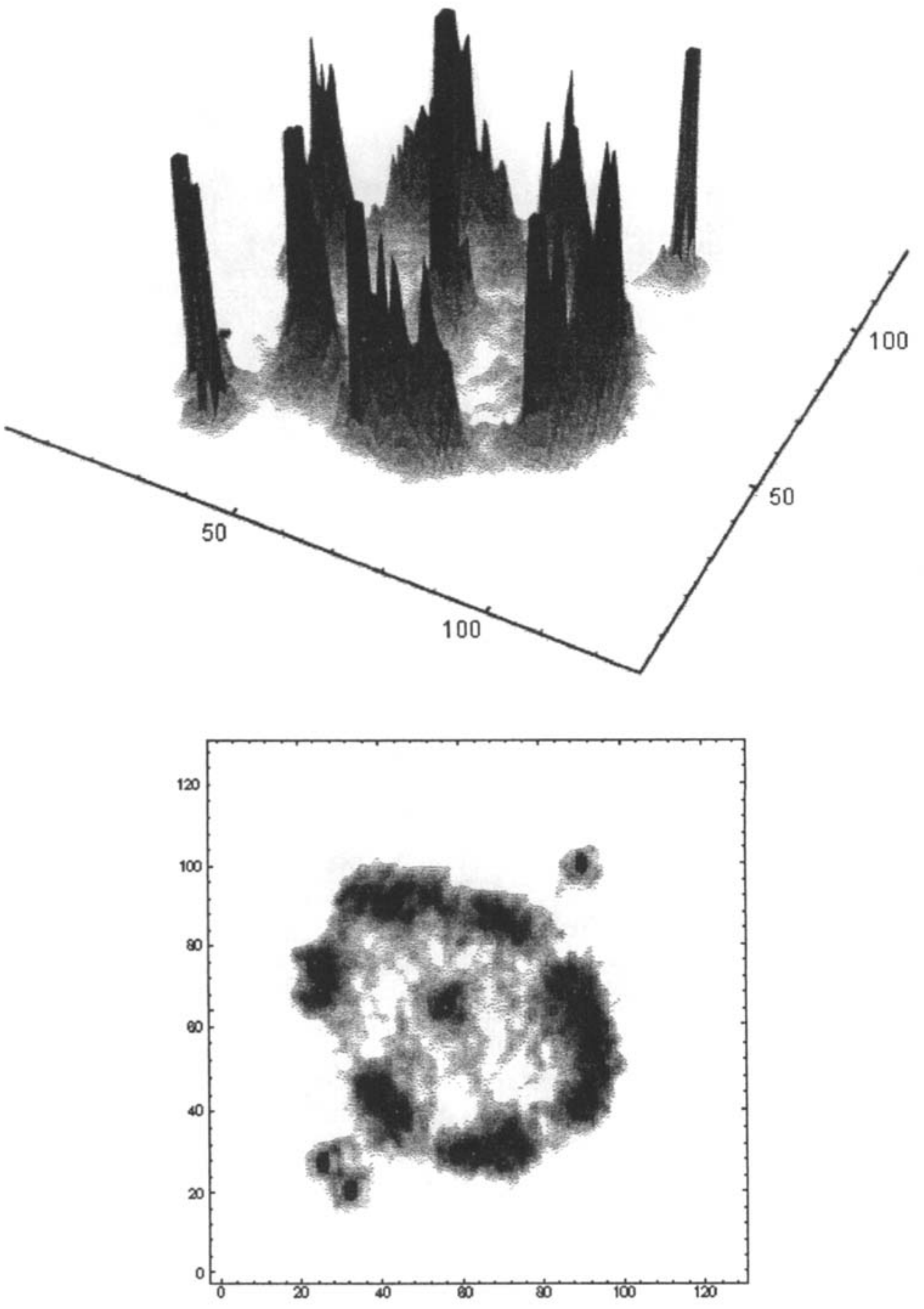

Figure 4 RL restored image without point-source extraction after 30 iterations.

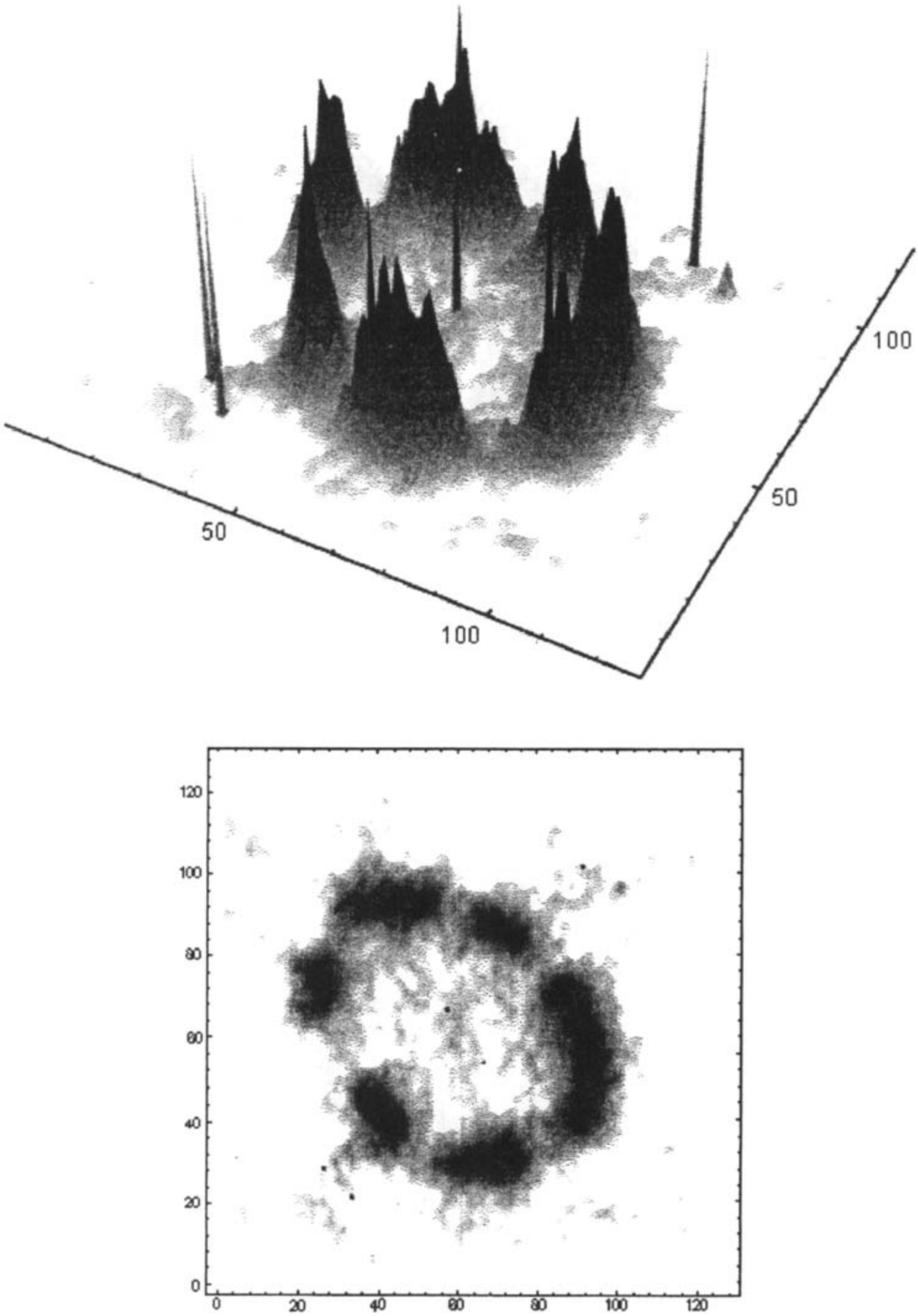

Figure 5 RL restored image with point-source extraction after 10 iterations.

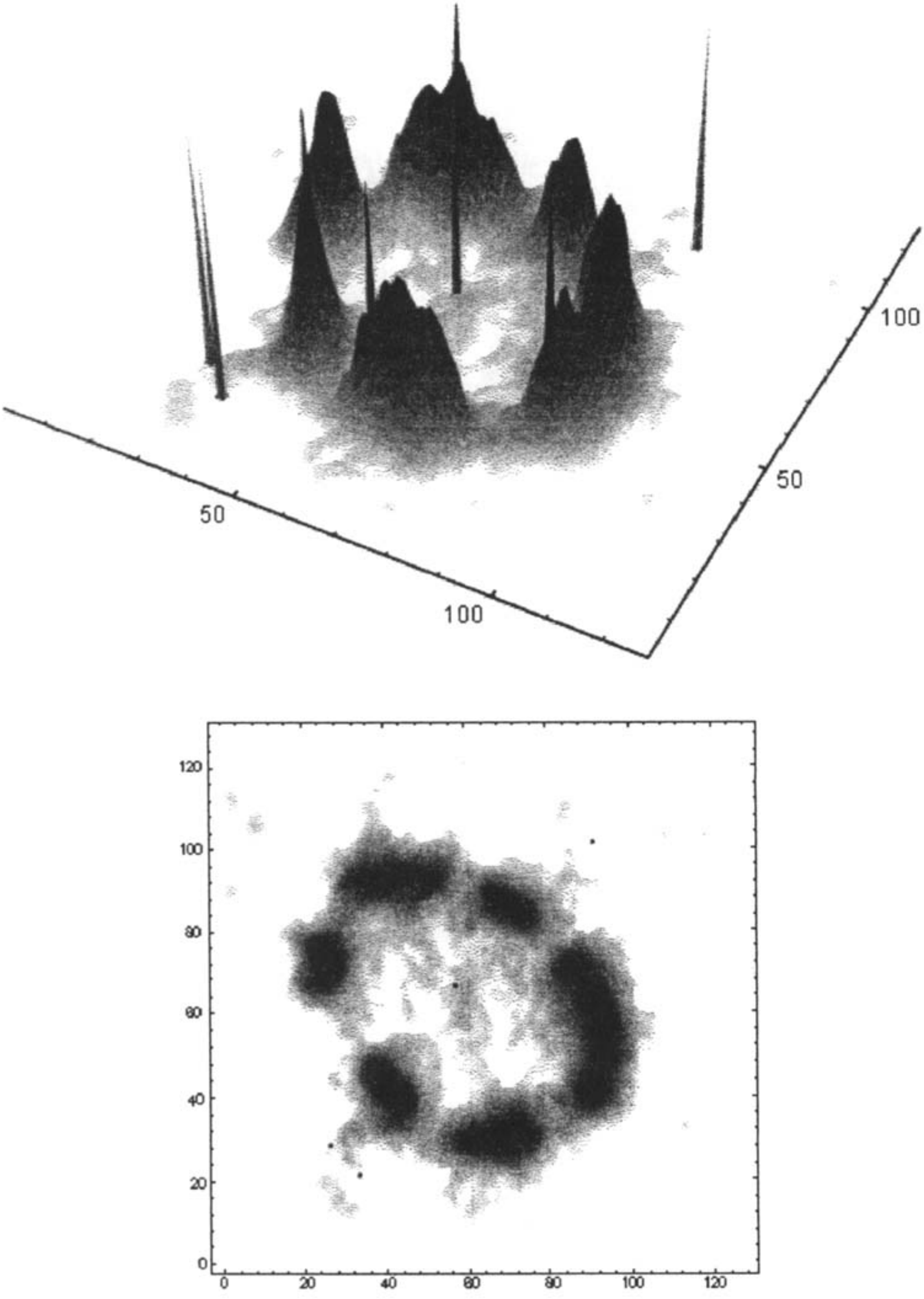

Figure 6 MIM restored image with point-source extraction.

image contains 10 point sources and six faint extended objects. Four of the point sources are superimposed on the faint objects.

Figure 4 shows the results of one-channel Richardson–Lucy (RL) (Lucy, 1974; Hook and Lucy 1992, 1994) restoration after 30 iterations. The accuracy of integrated photometry agrees well with the true values for the brightest stars. Fainter stars are too weak with respect to the true values. The maximum deviation from the true integrated flux is no larger than 10%. Considering the morphology of the faint objects, it can be seen that they are too lumpy and structured. In particular, they show a lot of small peaks. The maximum deviation for the flux lies within 20%.

We compared the results with a preprocessed RL restoration. In particular, first we looked for stars, subtracted them, and performed 10 (one-channel) RL iterations. As can be seen in Figure 5 the extended objects are not so structured and show not as many small peaks as Figure 4. They are still too faint but the maximum error has been reduced to 10%. The appearance of the preprocessed Minimum–Information Method (MIM) (Pfleiderer, 1990) result is very smooth. Photometry results are comparable with the RL restoration.

4 CONCLUSION AND PLANS FOR FUTURE WORK

We have investigated the effects of deconvolution on FOC images quantitatively. As a result we found that preprocessing the blurred image before deconvolution could be very useful, if the image contains extended sources as well as bright point sources and if the signal-to-noise ratio (SNR) is large enough.

Our preprocessing method is not able to compute the amplitudes for weak point sources in the case of low SNR. Therefore we plan to use an adaptive filtering technique to remove some noise before the point source detection is started.

Currently we are implementing the possibility of spatially variant point spread functions (SV-PSF) into our algorithms.

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