Kodaikanal Obs. Bull. (1997) 13, 95-98

# Reconstruction of Solar Features from an Image of Partially Eclipsed Sun

**V. Krishnakumar and P. Venkatakrishnan**
Indian Institute of Astrophysics, Bangalore 560 034, India

## Abstract

The photoheliograms obtained at Kodaikanal during the partial eclipse of the Sun on October 24, 1995 were digitised on a PDS microdensitometer. The lunar limb was used as a standard source for the digital reconstruction of a sunspot image. The details on the reconstruction are provided along with an example of a reconstructed image.

**Key Words :** Partial solar eclipse, Image reconstruction, Wiener filtering

## Introduction

The image we see is the result of the true object spectrum convolved with the point spread function (psf) of the atmosphere and also the telescope. This convolution blurs the true object intensity distribution. In general we do not have apriori information about the true object. During events like eclipse we can characterise the atmospheric psf using the limb of the moon against the sun's disk.

In this paper we discuss the reconstruction of images recorded during the partial solar eclipse of October 24, 1995 at Kodaikanal Observatory.

## Image degradation

The object we observe is blurred by the atmospheric psf and hence the spatial information is lost. To recover the true object intensity distribution we need to deconvolve the atmospheric psf and filter the additive noise. Once the atmospheric psf is determined the image can be reconstructed. Noise filteration is done using Weiner filtering and image is reconstructed.

The image degradation can be written as,

$$i\,(x,y) = \int o\,(\alpha, \beta)\, \phi\,(x - \alpha, y - \beta)\, d\alpha\, d\beta + n\,(x, y)$$

and in the Fourier domain,

$$I\,(u, v) = O\,(u, v)\, \Phi\,(u, v) + N\,(u, v)$$

where i (x,y) is the observed intensity distribution, o (x, y) is the true object intensity distribution, $\phi$ (x, y) is the atmospheric psf and n (x, y) is the noise added to the blurred image. I (u, v), O (u, v) and $\Phi$ (u, v) are the respective Fourier transforms. x, y are the spatial coordinates $\alpha, \beta$ are dummy coordinates in x, y space, and u,v are the spatial frequencies.

## Estimation of seeing

To reconstruct the object we need to deconvolve $\phi$ (x, y) from i (x, y) and supress the noise. Imaging during partial eclipse helps us to estimate the seeing (M. Collados and M. Vazquez, 1987).

To a very good approximation we can assume the limb of the moon eclipsing the sun to be a sharp edge. Hence when we image a partial eclipsed sun, ideally we expect the intensity profile to have a sharp fall off in intensity at the limb. The departure of the sharp fall off of this intensity profile gives an indirect estimate of the atmospheric psf.

The psf is estimated the following way, (R.N. Bracewell, 1986)

Let $\delta$ (x) be the true intensity profile. In the absence of atmospheric psf $\delta$ (x) is defined as,

$$\begin{aligned} & = && 0 \text{ for } x < 0 \\ \delta\,(x) & = && \tfrac{1}{2} \text{ for } x = 0 \\ & = && 0 \text{ for } x > 0 \\ \phi\,(x) & = && \frac{d}{dx}\,\delta\,(x) \end{aligned}$$

We assume an azimuthal symmetry for the psf and hence from the estimation of the width of the gradient of the intensity profile we construct a 2 dimensional atmospheric psf, where d(x) is the observed intensity profile of the limb.

## Observations

The Sun was observed using a broad band filter with a central wavelength of 5500Å, using the 15cm telescope at the Kodaikanal Observatory. The exposure time used for recording the images was 100ms. The photoheliograms were digitised using the photodensitometer. The images were digitized with 50μ sampling.

## Reconstruction

The width of the best fit gaussian is to be an estimate of the seeing. The seeing was estimated to be around 2.7". From this one dimensional profile of the psf a two dimensional atmospheric psf was constructed assuming azimuthal symmetry for the psf. The psf was constructed with a width of 2.7" and was deconvolved from the observed image using Weiner filtering.

Along with the finer features of the sunspot there are artifacts due to the reconstruction. It remains to establish a criterion to decide between artifacts and true features belonging to the object.

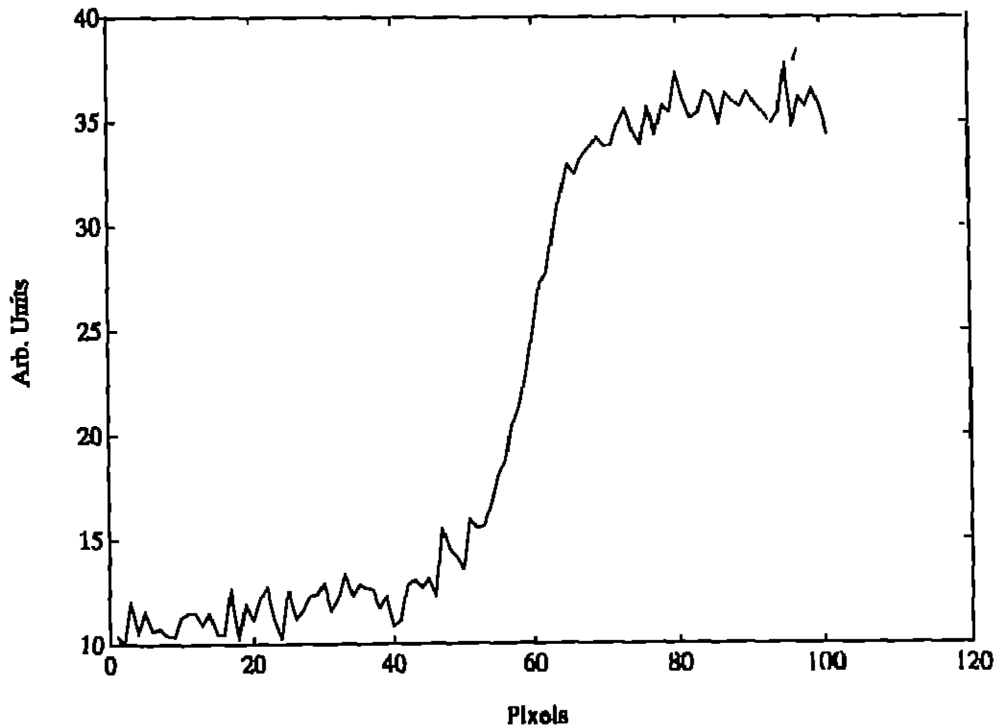


**Figure 1 :** The one dimensional intensity profile across the face of the Sun. Decrease in intensity can be seen towards the limb of the moon.

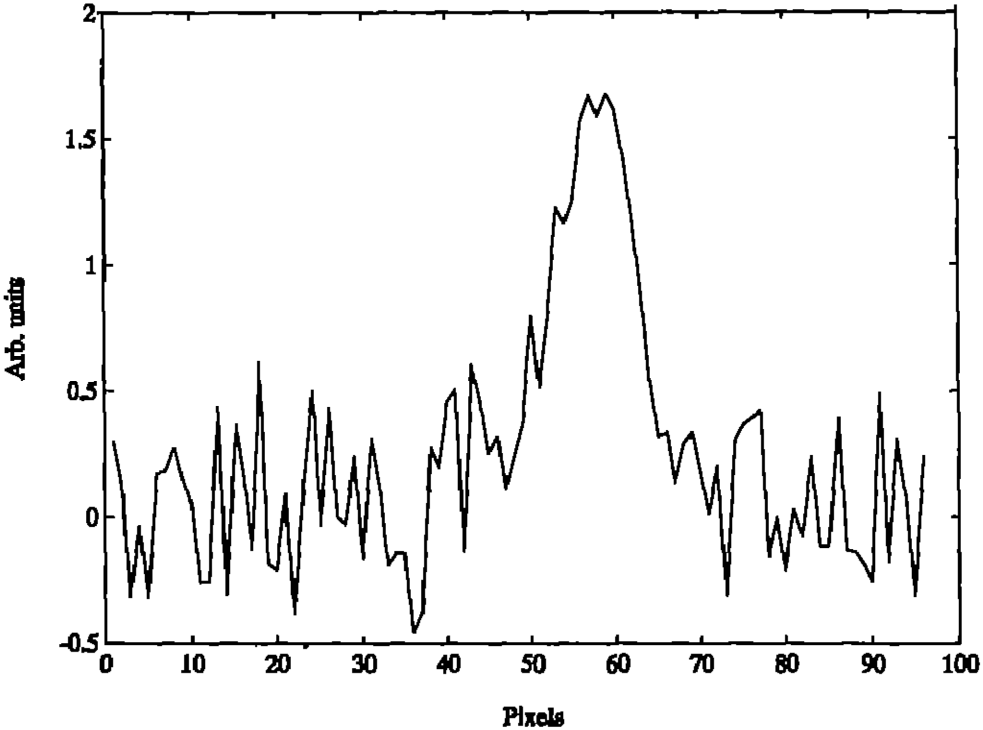


**Figure 2 :** The gradient of the intensity profile. A gaussian is fitted to this gradient profile.

## Acknowledgements

We would like to thank the observers at Kodaikanal, Mr. Paramasivam, Mr. Md. Khan, Mr. Muniyandi and Mr. P. Devendran.

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