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A Method to Filter Fringe Patterns in CCD Images

Pablo G. Ostrov[1]
Facultad de Ciencias Astronómicas y Geofísicas, Paseo del Bosque S/N (1900), La Plata, Argentina
Electronic mail: ostrov@fcaglp.edu.ar

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ABSTRACT. A technique to remove fringe pattern noise is presented. The method consists of the application of a median filtering technique within a moving window which is "aligned" with fringes at every point of the pattern. This procedure allows one to remove the bulk of noise in fringe patterns without destroying them and, hence, diminishing the final noise in the reduced program images.

1. INTRODUCTION

The old thinned back-illuminated RCA CCDs have a thickness of about 10 μm and are cemented by its back to a glass plate by means of an about 1 μm thick glue layer. Such a structure produces noticeable interference patterns when illuminated by monochromatic light, as that generated by atmospheric emission lines.

Instead, more modern CCDs are bonded to a silicon substrate by the front and are antireflection coated, so that fringe patterns are substantially reduced. Fringes usually vanish at the shortest wavelengths since absorption inside the CCD is frequency dependent. Nonthinned CCDs are virtually free from fringing.

Fringing is especially troublesome either when one is observing through a narrow-band filter, or strong atmospheric emission lines are present. In both cases, a fringe frame must be derived (usually by means of the so-called shift-and-star technique, Tyson 1989) to be subtracted afterward from the images. A more problematic case would be that of the fringes being produced by emission lines in the target object to be observed (Gullixson 1992). The drawback of this procedure is that when subtracting the derived fringe pattern, additional noise is added, namely, the readout noise and the photon-shot noise of the images used for constructing the fringe frame.

It has been argued frequently that any attempt to apply some kind of filtering technique to the fringe frame would destroy the fringe pattern. As P. Massey points out in the IRAF User's Manual, "prevention is the best cure for fringes: avoid using chips that fringe a lot... ."

Nevertheless, one could imagine that a draftsman would be able to reproduce the fringe pattern without adding the noise. It follows then that there must be some way to remove the noise of fringe frames without destroying the pattern.

2. DESCRIPTION OF THE METHOD

The basic idea of the method is rather simple: It consists of the use of a median filter into a one pixel wide rotating window. The window is aligned parallel with the fringes at each point of the frame. The window length is chosen short enough to follow the curvature of the fringes.

The procedure to align window and fringes can be sketched as follows. Let us consider a typical pixel of the fringe frame. If one centers the rotating window at this pixel and rotates it around its center, then the angle at which the minimum value of the dispersion inside the window occurs will correspond to the inclination of fringes. Unfortunately, this procedure turns out to be unsuitable—in some frames—because of the low signal-to-noise ratio of the fringes.

To overcome this problem, a slightly different procedure has been adopted: The frame is scanned with a grid similar to the one shown in Fig. 1. For each value of the inclination angle, the median value is calculated for every w_k grid column. Then, the dispersion of the distribution of median values is calculated. Such a dispersion is maximum when grid and fringes are aligned. The values of the flux in the "pseudo-pixels" of the rotated grid can be computed easily by linear interpolation of the flux of the three nearest pixels of the frame. Notice that, because of the use of medians at the first step, this process is immune to bad pixels.

As a result of this stage an image equal in size to the original fringe frame is obtained, which contains, in each pixel, a value proportional to the inclination angle of fringes at the corresponding point of the image. An example of this inclination map is shown in Fig. 2.

The final stage of the process is to filter the original fringe frame with the aid of the information contained in the inclination map. This is easily done by inverting the procedure described above. The inclination map is read and a single 1 pixel wide window is properly orientated on the original fringe frame. Then, the median of the intensity distribution over this window is adopted as the final pixel intensity at the given position.

The software is available to interested readers upon request.

3. RESULTS

This technique was originally developed to improve the quality of the NGC 1399 images analyzed in Geisler and Forte (1990) and Ostrov et al. (1993). These images were acquired with the RCA No. 1 CCD at CTIO in 1987. The C,

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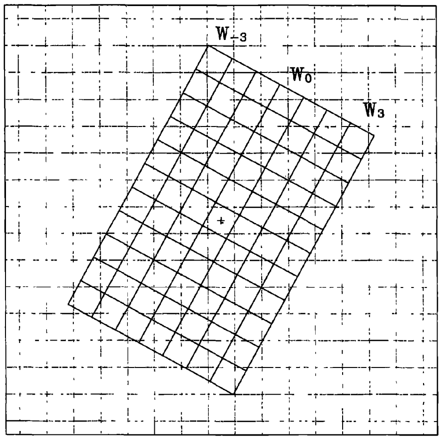

FIG. 1—The rotating grid used to scan the fringe frame.

M and T_1 Washington system filters were used. The RCA No. 1 CCD is a SID52501 back-illuminated device, antireflection coated, with a size of 320×520 pixels. After bias trimming, the frames have a size of 300×508 pixels.

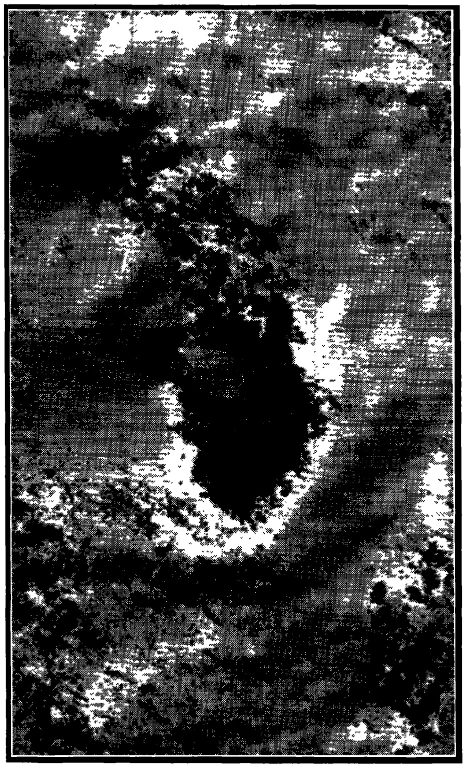

FIG. 2—An inclination map constructed with a window of 11 pixels long and 16 different inclinations.

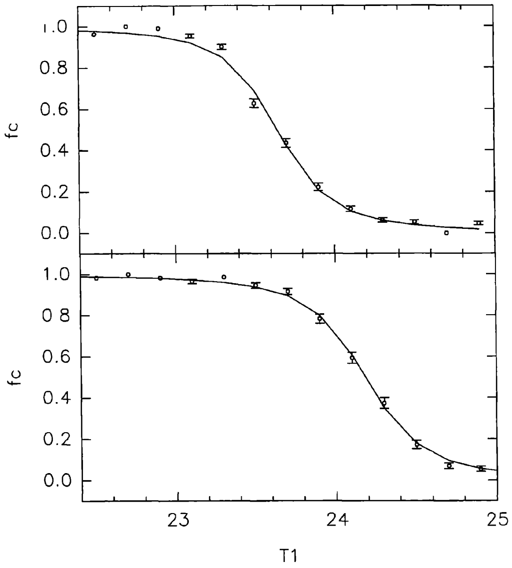

FIG. 3—Completeness factors. Top: for the original galaxy image, which was fringe substracted using the unfiltered fringe frame. Bottom: for the new galaxy image, fringe substracted with the filtered fringe frame.

In Ostrov (1995) an exhaustive analysis of the completeness of these frames was carried out. The 50% of completeness magnitude reaches $T_1 = 23.63$ in the frame centered in NGC 1399 (the deepest of the galaxy area frames). Fringing is noticeable in the T_1 band images, and rather strong in the M band images. It was removed using a fringe frame derived from dithered observations of a comparison field, about 2 degrees to the north of the center of NGC 1399.

A substantial contribution to the total noise in the fringe corrected images, which I intended to remove, comes from this derived fringe frame. Since noise in the galaxy frames depends on the position due to the photon shot contribution of the halo light, several small regions were chosen at different fixed positions to measure the total noise. These regions were selected free of evident visible objects. The total noise was about 11.3 ADUs in the old original frame, which was fringe subtracted using the standard technique.

A filtered fringe frame was obtained by means of the procedure sketched above. Since fringing was much stronger in the M band, the M fringe frame was first used to make the inclination map, and this map was used to do the filtering on the T_1 original fringe frame. This swindle allows us to avoid the difficulty of deriving an inclination map for a too noisy fringe frame. This does not spoil the final result since the inclinations of the fringes do not depend on wavelength.

A new galaxy frame was constructed by subtracting this filtered fringe frame. Its noise (in the same above-mentioned regions) was about 7.3 ADUs. This substantial noise reduction allowed us to reach about one half magnitude deeper than the old frame did.

Figure 3 shows the results of the completeness experiments for the old and new galaxy frames. The curve represents the fitting of a Pritchet function:

$$fc = \frac{1}{2}\left\{1-\frac{\alpha(m-m_{\mathrm{lim}})}{\sqrt{1+\alpha^2(m-m_{\mathrm{lim}})^2}}\right\}.$$

These experiments were carried out using the DAOPHOT routines (Stetson 1987). The 50% of completeness magnitude reached 24.18 mag in the T_1 band when the filtered fringe frame was used.

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