# THE INTERACTIVE ASTRONOMICAL DATA ANALYSIS FACILITY – IMAGE ENHANCEMENT TECHNIQUES APPLIED TO COMET HALLEY

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I want to thank Dr. Whipple for providing me with a perfect lead in for the description of the Interactive Astronomical Data Analysis Facility, IADAF. His discussion of nuclear rotation makes my choice of slides most appropriate since I had selected a series of slides based on analysis that Dr. Rahe and I had done with imagery of Comet Halley. This sequence will show some of the features that our IADAF is capable of performing and the usefulness of an interactive analysis system. Also I will clearly show evidence for eruptions from the nucleus of Comet Halley.

The IADAF is a general purpose interactive data analysis facility designed to permit the scientist easy access to his data in both visual imagery and graphic representations. The IADAF has at its heart a PDP 11/40 computer. The major components consist of: the 11/40 CPU and 256K bytes of 16-bit memory; two TU10 tape drives; 20 million bytes of disk storage; three user terminals; and the COMTAL image processing display system.

The disk storage is on eight platters of 2.5 million bytes each. Five of the drives are removable and three are fixed. The software system resides on the first two disk drives, two disks are reserved for image data and four are reserved for other user data disks. Thus with two platters of image storage it is possible to have in the system 9 images with 512 by 512 pixels of 16-bit data or any combination of image sizes such that the total number of pixels is less than 2.5 million. If the images are byte data (0-255) twice the number of images could be stored. A 9 track 800 BPI tape can hold approximately forty 512 by 512 images or two 2000 by 2000 images.

The COMTAL display system contains memory sufficient to store three 8-bit images of 512 by 512 pixels. This storage is used as the refresh memory for the TV display. Each image plane in the COMTAL has its own function table and associated overlay plane. There is a pseudo-color table preceeding the CONRAC color monitor. Thus it is possible to obtain either a psuedo-color or B/W display of each image stored in the COMTAL or to combine the three images into a single "truecolor" display. The image display works in the following manner for single frame display: each 8-bit pixel is sent from the image memory through the function table and then to the color table to provide 3 four-bit numbers one for each of the color guns which are aimed at the correct pixel location on the screen. All of this is done at standard TV display rates. For "truecolor" all three images are used and the 8-bit image data from each image goes through its own function table and then directly to one of the three color guns. Any image can be assigned to any gun.

The overlay plane for each image is a 1-bit 512 by 512 pixel memory and permits the drawings of lines, boxes and circles on top of the displayed image as well as textual information. There are eight colors possible for each of the overlay planes.

There is also a PDS 1010A microdensitometer with a 0-5D photomultiplier that has a series of square apertures ranging in size from 1 to 100 microns. There are also several long slits ranging in size from 1 by 100 to 40 by 1000 microns.

The IADAF computer is currently running under the control of the DEC standard operating system RSX11M. This software supports not only FORTRAN IV, BASIC and the standard utilities but also FORTH and IDL. The image processing software is written in FORTH, mostly in high level colon words, except that CODE words are used where speed is of the utmost importance. We have attempted to adhere to the FORTH 79 standards except for specialized display drivers. This software should be transportable to other FORTH installations.

Figure 1. Reproduction of one of the original plates of Comet Halley taken on May 25, 1910 at Helwan, Egypt.

The data that I wish to show today consists of two sequences of photographs obtained on May 25 and 26, 1910 of Comet Halley in Helwan, Egypt. Figure 1 shows one of the exposures taken on May 25, 1910. On the original plate it is just barely possible to see that there is a feature heading straight back from the nucleus and a hint of two arcs coming from the front of the nucleus. We have digitized 9 plates (4 from May 25 and 5 from May 26) around the coma of Comet Halley. In order to improve the signal/noise ratio of the digitized images we have added together all of the images for each night. This was done in density units since we had no information on the relationship between density and intensity for these photographs. In order to do this addition we had to be able to shift each image with respect to one another and place the nuclear peak at the same pixel in each image.

Thus in Figure 2 we see a psuedo-color rendition of the sun of the four images obtained on May 25. The color scale across the bottom of the image shows the relationship between the digital counts of 0 to 255 and the chosen color scale, with black being equal to 0 density and red equal to maximum density. The digital counts are in arbitrary units of density. The sets of streaks that are seen are the star trails left by tracking on the comet nucleus. In this image there is little, if any, indication of features within the coma that could show any nuclear rotation. The psuedo color scale gives the overall impression that the coma region is smooth.

In order to learn if this is really the case we tried to draw contours in the image. This was done by setting every 10th count equal to 255. Thus all the values of 0, 10, 20 ...250 were set to 255. Figure 3 shows the result of this contouring, which is that the data is still too noisy to attempt contouring. However, after doing a 5 by 5 low pass filter on the image, we see in Figure 4 that the contour lines are well defined and give a clear indication of the jet or stream that is going back along the tail of the comet and some indication that there is an arc-like feature that goes down and to the left from the nucleus.

The final step in this process was to take the derivative of the unsmoothed image. This was done by shifting the image with respect to itself and subtracting it from its unshifted self, thusly:

$$(\text{new image})_{i,j} = (\text{old image})_{i,j} - (\text{old image})_{i+n,j+m} + 128$$

Depending on the values choosen for n or m a vertical, horizontal or diagonal derivative may be obtained. This process has the effect of enchancing edges and removing slowly varying backgrounds like the brightness gradient within the coma. Figure 5 shows the result of this operation with n and m set to 3, ie a diagonal derivative. Since it is impossible to show negative intensities, 128 counts were added so that a difference of zero would be half way up the intensity scale and negative derivatives would tend toward black while positive derivatives would tend toward white. Thus the star trails stand out as black and white lines and the two arc-like features are clearly seen emerging from the nucleus. In this presentation the jet-like feature heading back along the tail is not too clear. However, in Figure 6 which has had the contrast reversed, that is, negative slopes are white and positive slopes are black, the jet becomes visible.

Thus on May 25, 1910, there is clear evidence for jets of material being expelled from the nucleus. However, on the following night, May 26, as seen in Figure 7, there is no evidence for the presence of any jet-like material.

I hope that I have been able to show not only that Comet Halley had, on at least one occasion, jet like streamers emitted from the nucleus, but also that an interactive analysis facility like the IADAF is capable of providing the tools needed to extract the ultimate amount of information from astronomical imagery. We have seen that the existing hardware/software system is capable of many things: registration of images, simple algebraic operations between images (+,-,*,-), contour plots, two dimensional filtering, contrast and psuedo-color enhancement, edge enhancement and slide preparation. The ability to sit at a display and manipulate one's data and see the results in near real time (less than 5 minutes) lets the astronomer explore many different approaches to his data that are otherwise just too tedious.
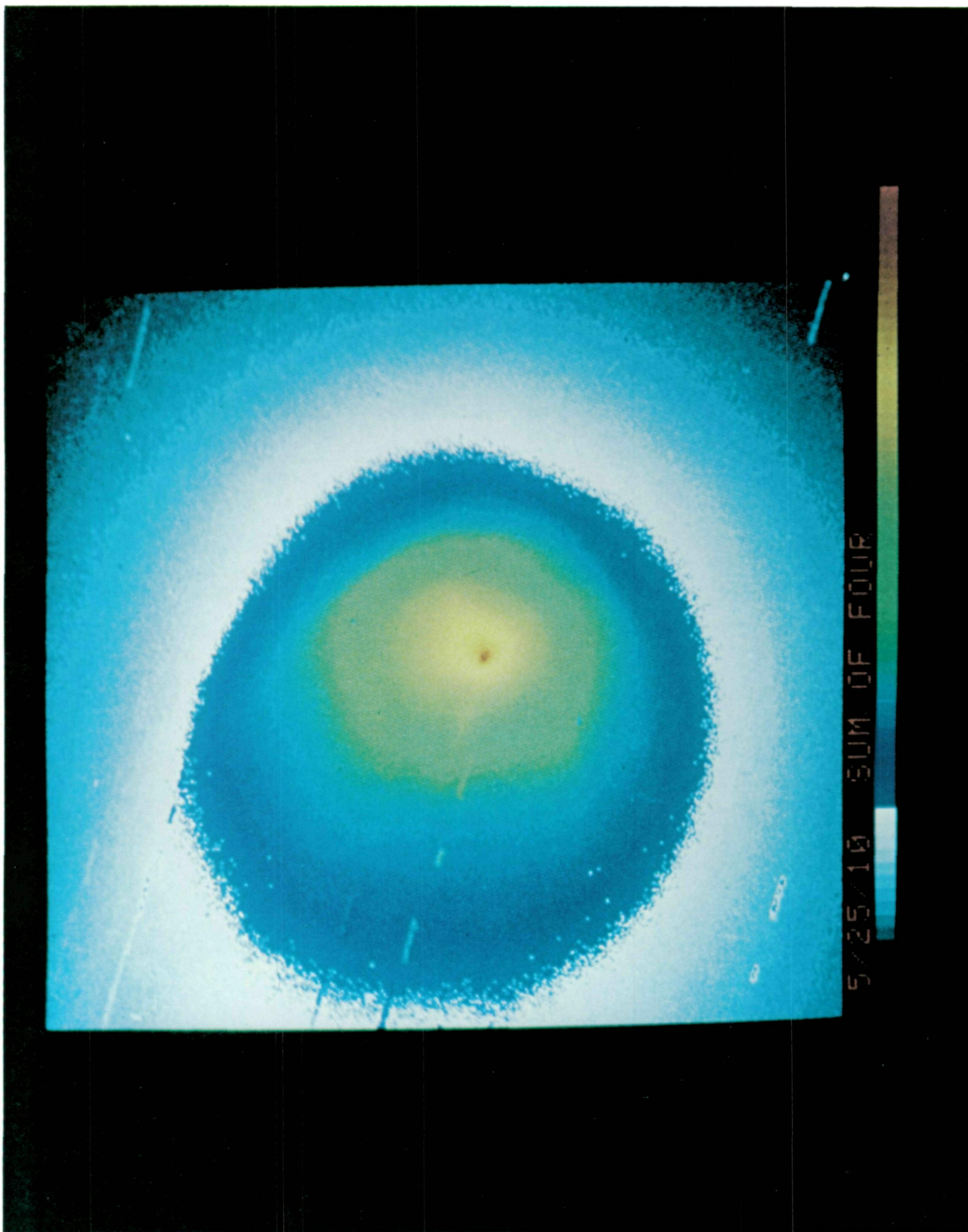
Figure 2. Psuedo-color representation of the sum of the four images of comet
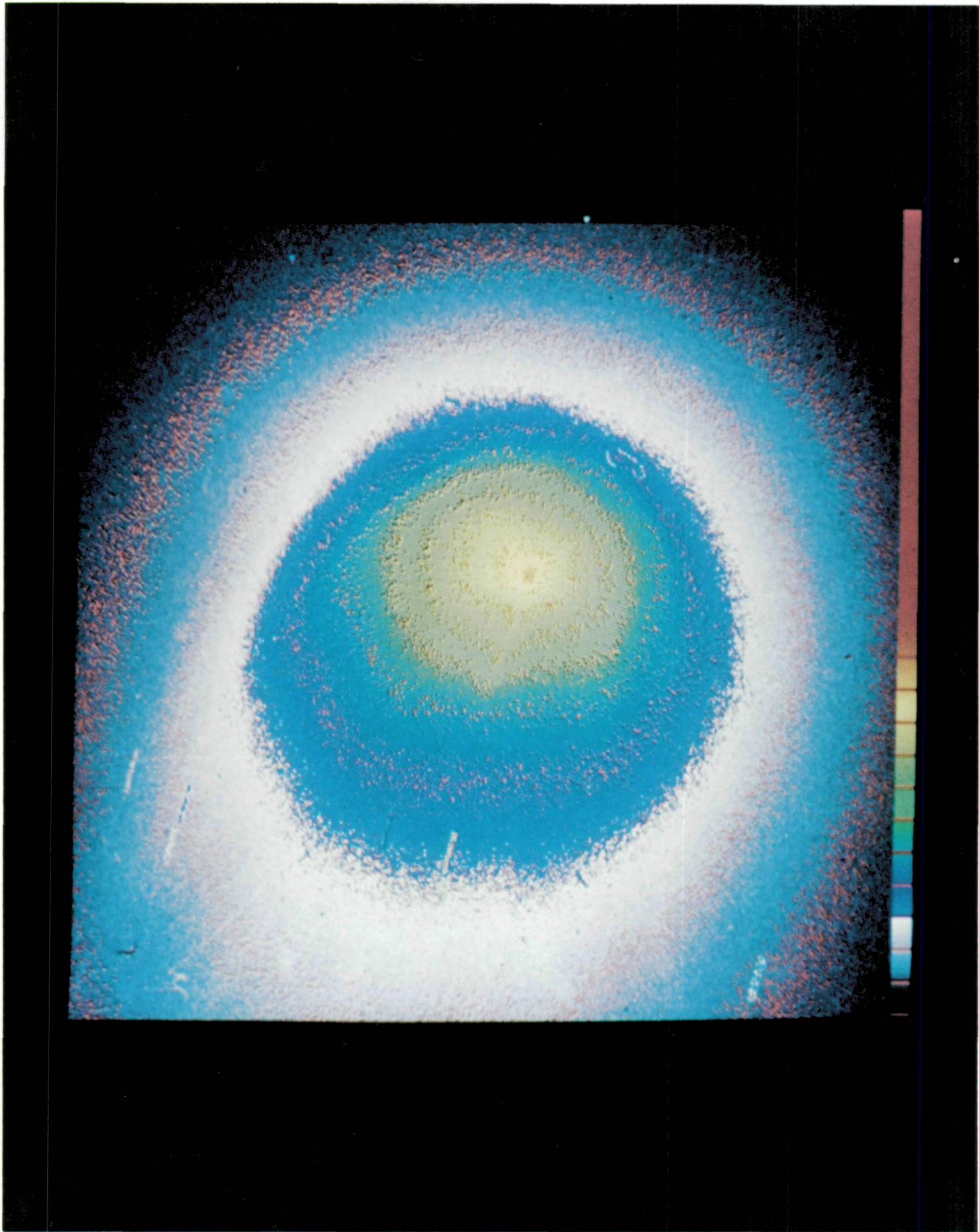Halley obtained on May 25, 1910 at Helwan, Egypt.

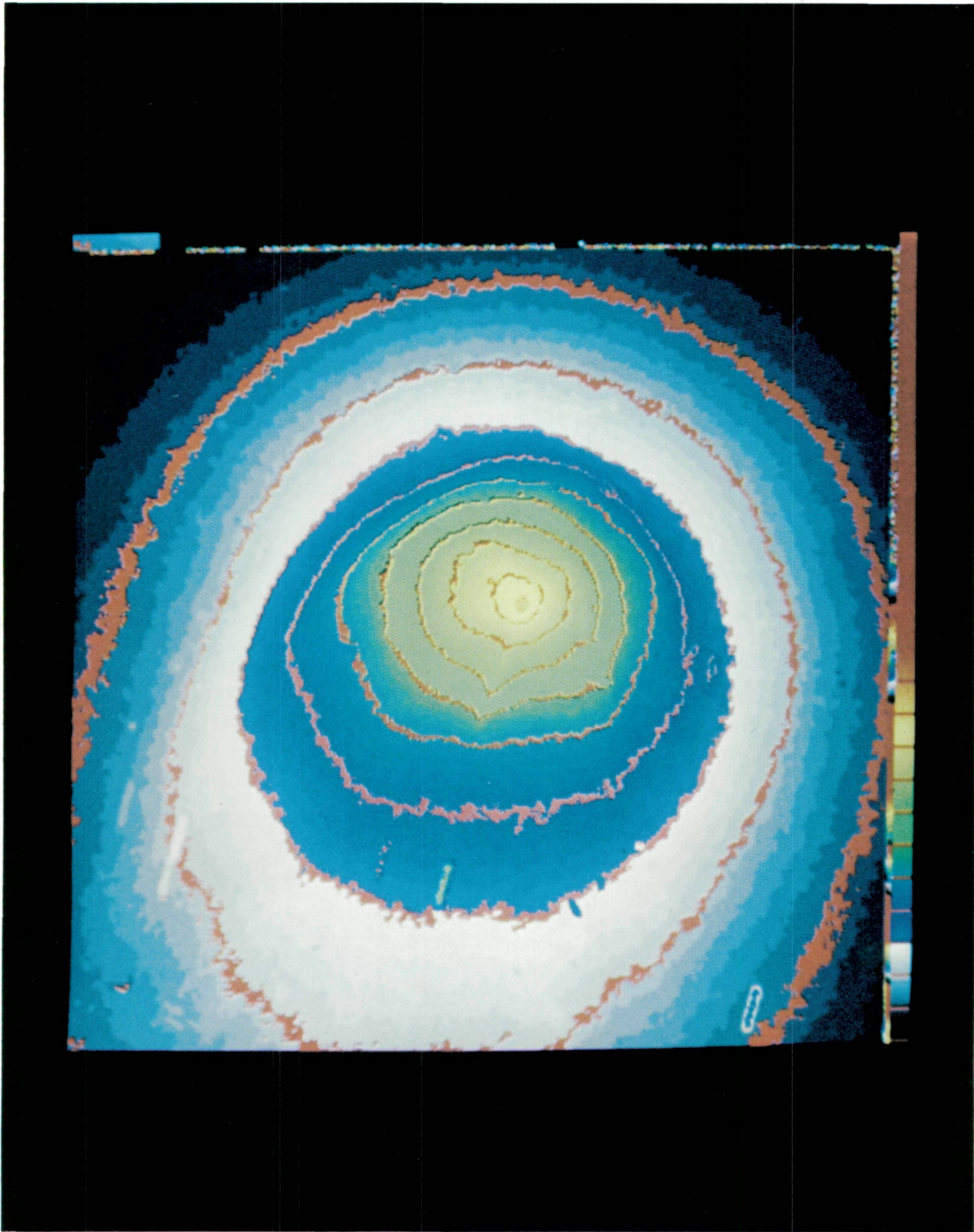Figure 3.   Contour levels set at every 10th count for the unsmoothed image.

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Figure 4.   Contour levels set at every 10th count for the smoothed image.
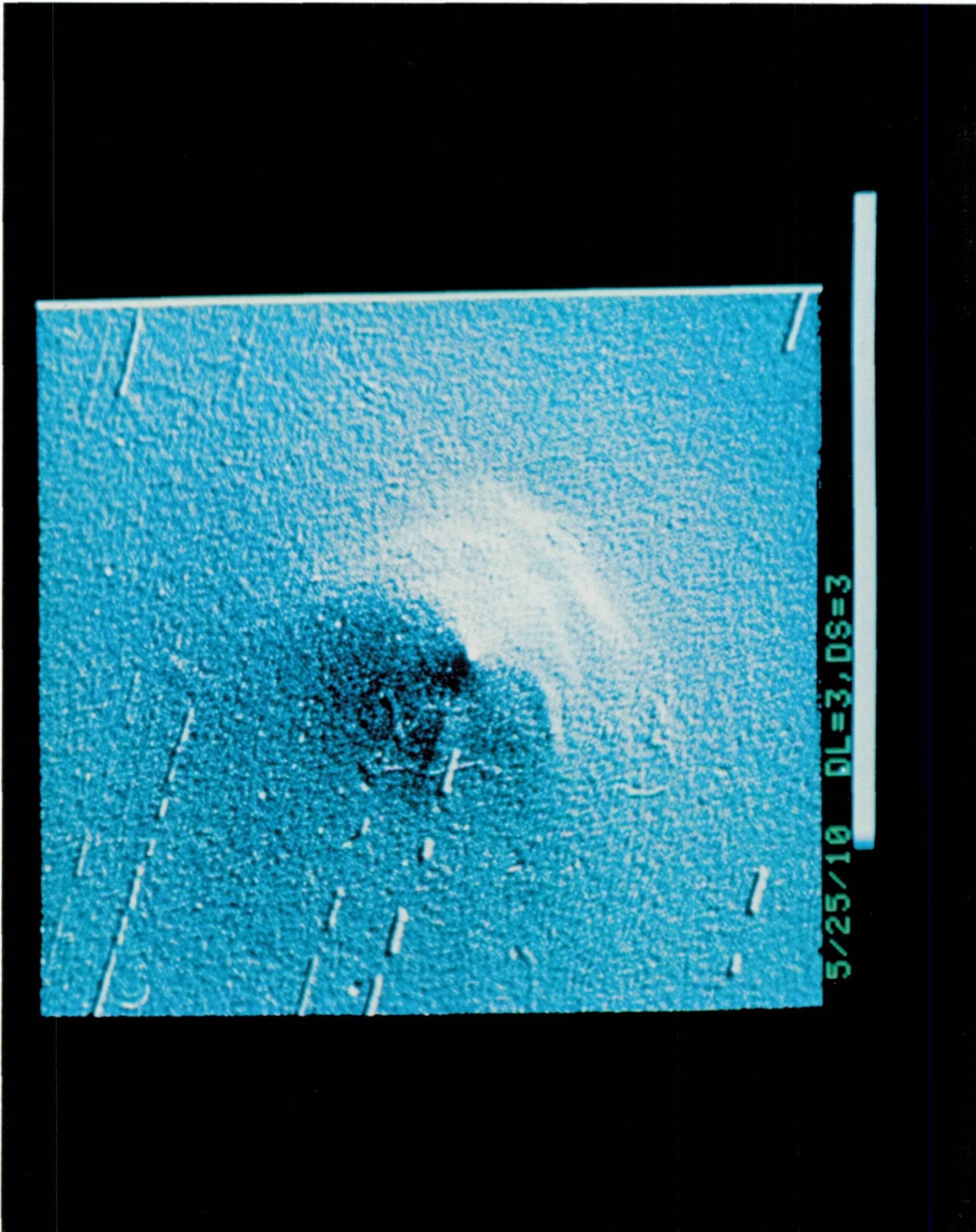Smoothing by a 5 x 5 box filter.

Figure 5. The shifted difference image. Negative slopes appear dark and positive slopes appear bright.
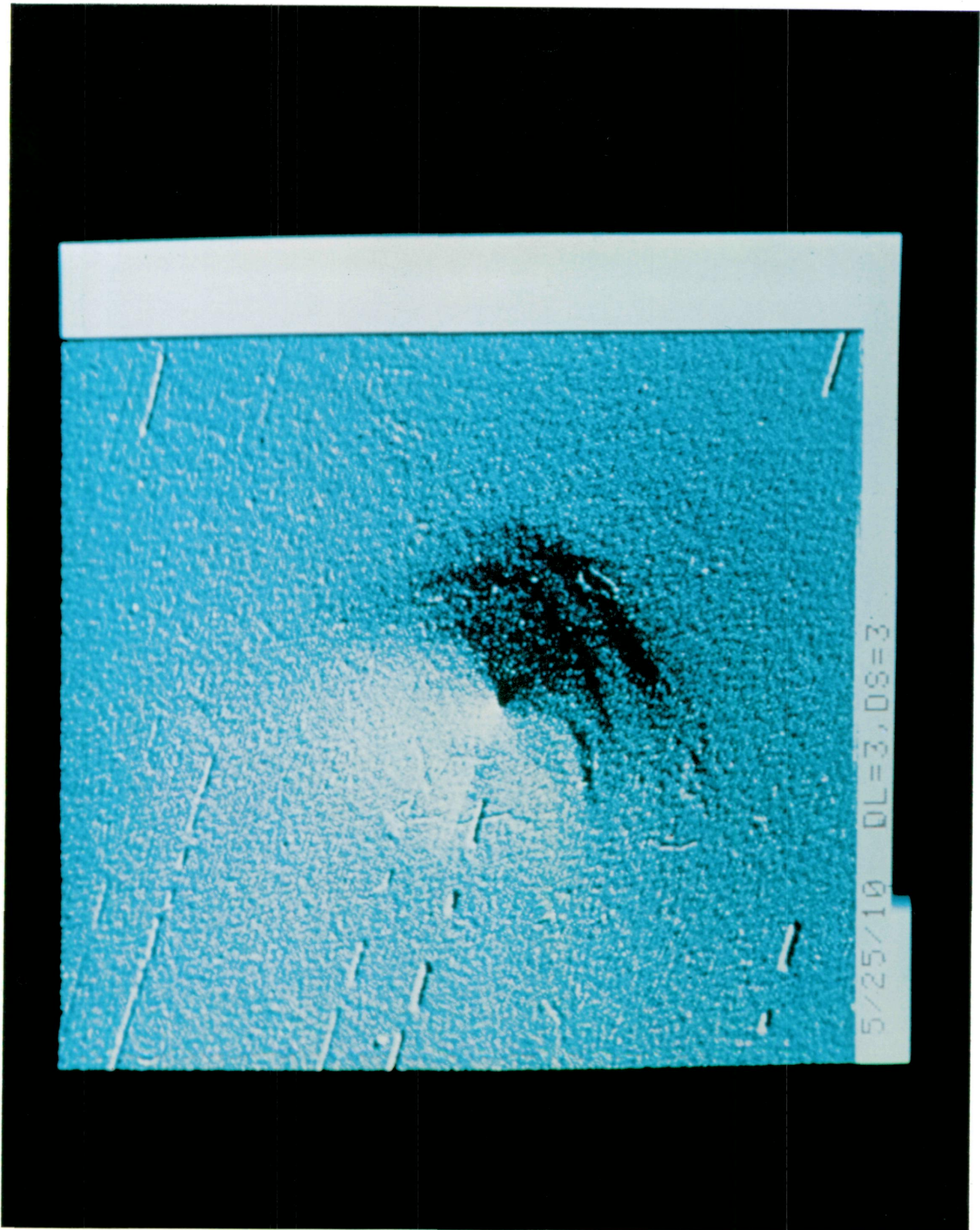
Figure 6. Same as Figure 5 with the contrast reversed. That is the negative slopes appear bright and the positive slopes appear dark.
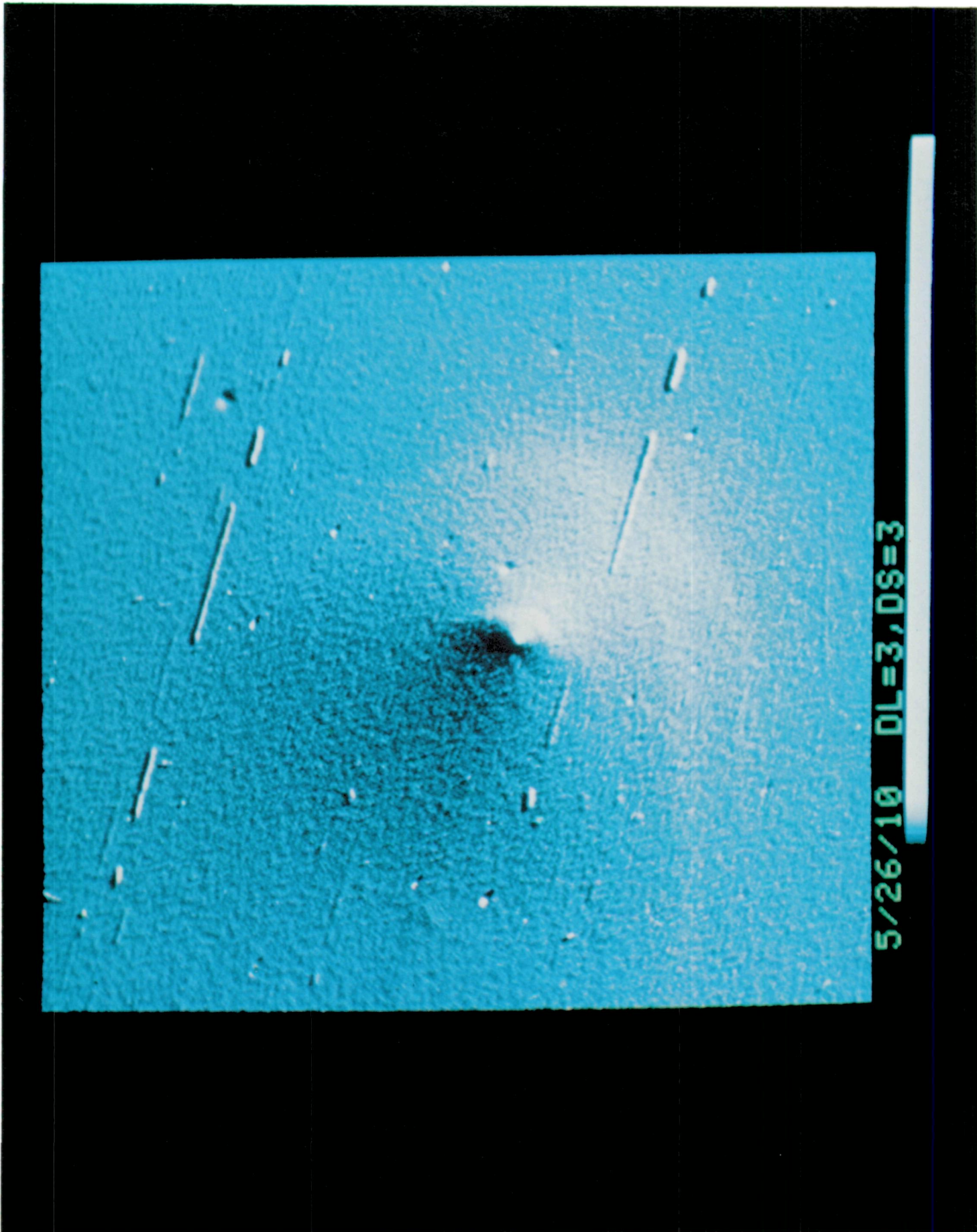
Figure 7. The shifted difference image for the sum of 5 images taken on
May 26, 1910. Note the lack of arc structure and the lack of a jet going
back along the tail.