The FES Scattered Light Anomaly:

A New Twist

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On February 20th, 1991, the scattered light in the FES was first noticed. Since that time, we have been working to understand the unusual behavior of this anomaly by monitoring the background counts in the FES. Recently, we have detected a significant enhancement of this background in the sunward direction in the FES field of view. This enhancement has become known as the FES Streak, and it has displayed some correlation with both β angles and the lunar phase, suggesting this anomaly may be the result of moonlight scattered into the telescope. However, it should be kept in mind that this is only one of many possible sources for this anomaly.

1 The Diffuse Background.

In Figure 1, we have plotted the data from before and after shadow season #30. The large daily variations observed in the scattered light since shadow season #29 make it difficult to accurately estimate the level of scattered light at a given β from this plot. Since shadow season #30, the scattered light has increased. Therefore, we have developed some rough guidelines to assist the operations staff and guest observers in estimating the amount of scattered light present at a particular β angle.

- $30° \leq \beta \leq 60°$: Estimate scattered light level from the graph (Figure 1).
- $60° \leq \beta \leq 125°$: 424 ± 100 S/O Counts

In order to asses the evolution of the diffuse scattered light background with time, we have been monitoring two stars at $\beta \sim 90$, near the North Ecliptic Pole. This data is presented in Figure 2. We see that after day 400, the scattered light background began to steadily rise. In addition, the background became enhanced during each of the shadow seasons we have encountered since the anomaly first appeared, but returned to pre-shadow levels after the shadow season was over. The exception to this is shadow season 30; we believe that the lack of an increase in the counts during shadow was the result of our deliberate attempts to pass through shadow each day at β angles ≤ 65, thus minimizing the thermal shock the end of the telescope tube experiences.

2 The Streak

On day 258 1992, the operations staff noted that the scattered light had increased dramatically in the FES, but this increase was confined to the lower right hand corner of the FES (See Figure 3). This anomalous streak in FES has been seen to come and go more or less regularly for the past three months, and except for one or two instances, it seems that the streak appears when the lunar phase is between first and third quarter. In addition, the streak seems to be getting worse with each lunar cycle that passes; during the previous full moon, the streak covered 2/3 of the FES field of view (Figure 4).

The first night the streak was noticed, several tests were performed to attempt to characterize the streak. The spacecraft was rolled out in both the positive and negative directions, to look for a roll dependance similar to that seen in the diffuse scattered light background. There was such a dependency seen, although it is in the opposite sense as that for the diffuse scattered light background. Figure 5 displays the results of this roll test; we see that the streak (the bright white region in the lower right-hand corner of these pictures) increases with positive spacecraft roll angles. The sunshutter was closed and an FES image was taken; the streak was not present in these images, confirming our suspicions that the streak is external to the aperture plate. Also, the spacecraft was maneuvered in pitch, and it was noticed that the streak decreases with decreasing β angle.

As it became obvious that this streak was returning with each lunar cycle, we began monitoring the counts at -300, -1400 in the FES in order to track its behavior. Figure 6 displays the counts at this position vs β (in the top panel) and vs time (in the bottom panel) for days 314-317. These dates were chosen because during this period of time, the spacecraft was almost exclusively observing the same 4 stars for the entire 4 days. We see a rough correlation with β, reminiscent of that which is seen with the diffuse scattered light background, although there is a lot of scatter at a given β. There does not seem to be any relationship between time of observation and background level over these four days.

We have also monitored the counts in this region of the FES during several spacecraft maneuvers, and we display two examples of this in Figure 7. These plots confirm the strong β dependance of this phenomena, and also show that the streak undergoes very rapid changes at or near the end on maneuvers.

Since it had been hypothesized that this streak may be due to the moon, we decided to calculate the angle between the moon and the normal to the sunshade, in order to see if there was a relationship between this angle and the intensity of the streak. Figure 8 displays a plot of the angle between the moon and the sunshade normal vs β and Figure 9 displays the angle between each of the spacecraft axis and the moon vs the FES counts at -300, -1400. There is no obvious relationship between the two quantities, making it difficult to definitively prove the moon is responsible for this streak.

The streak also poses problems for operations, since it is very bright, and at times can cover up to two thirds of the FES field of view. From our experience on shift, we have come up with several methods of continuing science operations in the presence of this streak:

• For bright ($m \leq 5.0$) targets, using the FESIMAGE procedure with a reconstruction option of 2 or 4 instead of zero eliminates the saturation of the FES in camera mode, and allows the identification of bright targets in FES images.

• For faint targets, blind offset techniques will have to be used, and in many cases double offsets may be necessary. By picking a bright star that meets the criteria outlined above, one can identify it even in the presence of the enhanced background due to the streak. This star can then be moved to a "new" reference point in the area uncontaminated by the streak. Then a short maneuver or pyslew can be performed to the second offset star. This star can then be identified and brought to the standard reference point, after which a pyslew to the target can be performed, followed by the traditional blind offset aquisition procedures. Note well that the slew to the standard reference point is blind, since the streak is too bright to use the FESLOCKR procedure to lock the second offset star to the reference point.

• The use of FESST(search and track mode) to find targets and/or bright guide stars is not recommended with the streak present, since the FES will most likely find the streak rather than the target or guide star.

• Guide stars will have to be chosen with care...only stars within the uncontaminated regions of the FES can be used for guiding, unless they are bright enough to sit well above the level of the streak. We have found the HST GSC to be an invaluable tool for finding other guide stars in the field.

• Long LWP low dispersion spectra may not be able to be obtained if the streak is filling the apertures. We have exposed as long as 3 hours in the SWP camera in low dispersion with the streak covering the apertures, and have seen no evidence of contamination in the SWP spectra. On the other hand, a two hour LWP exposure in the presence of the streak provided a strong detections of a solar-type spectrum filling the aperture(see below).

• If the streak is covering the apertures, one can attempt to reduce the extent of the streak in the FES by performing a straight pitch maneuver to $\beta \sim 105$, then maneuver back down to the target. In the past, this has dramatically reduced the level of the scattered light at $\beta \sim 90$. An example of this is displayed in Figures 10a-c. Figure 10a displays the level of the streak at $\beta \sim 90$ on day 318. After a maneuver to $\beta \sim 120$ and back, we found the streak noticeably reduced (Figure 10b-This is a default size image because we were using the VHF antenna rather than the standard S-Band antenna for these observations.). After a third maneuver up and down, the streak was reduced even further (Figure 10c). In each of these images, the apertures are roughly in the center of the picture.

• Another solution may be to roll the spacecraft in order to acquire targets and to obtain science data. As mentioned above, when the anomaly first appeared, a roll test was performed, which indicated that the streak intensity and position could be reduced by rolling the spacecraft. This option is currently under investigation by the Operations Control Center but can not be implemented at this time.

Recent observations have shown that the streak has become highly variable during the past few days. As an example, on day 319, a 32 degree pitch/-133 degree yaw maneuver was performed. Before leaving the target, the streak was covering approximately 1/2 the FES at $\beta \sim 96$. At the end of the maneuver at $\beta \sim 67$, the streak was covering 2/3 of the FES. This target was within the Lunar avoidance zone and these observations could not be obtained, so a maneuver back to the previous target was performed, at the end of which the streak had mysteriously disappeared! Another instance of this rapid variation occurred on day 321, when the streak was observed to be present at $\beta \sim 89$, filling 1/2 the FES field of view. After a subsequent 6 degree pitch maneuver to another target at $\beta \sim 95$, the streak had once again disappeared (Figure 11-Both are full field images with the apertures near the center of the images). Our observations also indicate that the level of the diffuse scattered light are $\sim$ doubled after the streak has disappeared.

On day 322 , we obtained a 120 minute LWP lo dispersion spectrum of the streak, which is displayed in Figure 12. In Figure 13, we display this spectrum along with a spectrum of G2 V star from the IUE Spectral Atlas and a spectrum of the moon, also from the IUE Spectral Atlas. It appears that we can say with a high degree of confidence that we are seeing a reflected solar spectrum.

Due to the highly variable nature of this streak, our predicative powers are extremely limited. Observations obtained near new moon are less likely to be affected by this streak, although there is some indication that the Earth can also be a source of illumination resulting in the appearance of this streak even during time of new moon. We are currently designing some specific tests which we hope will provide further insights into this phenomena.

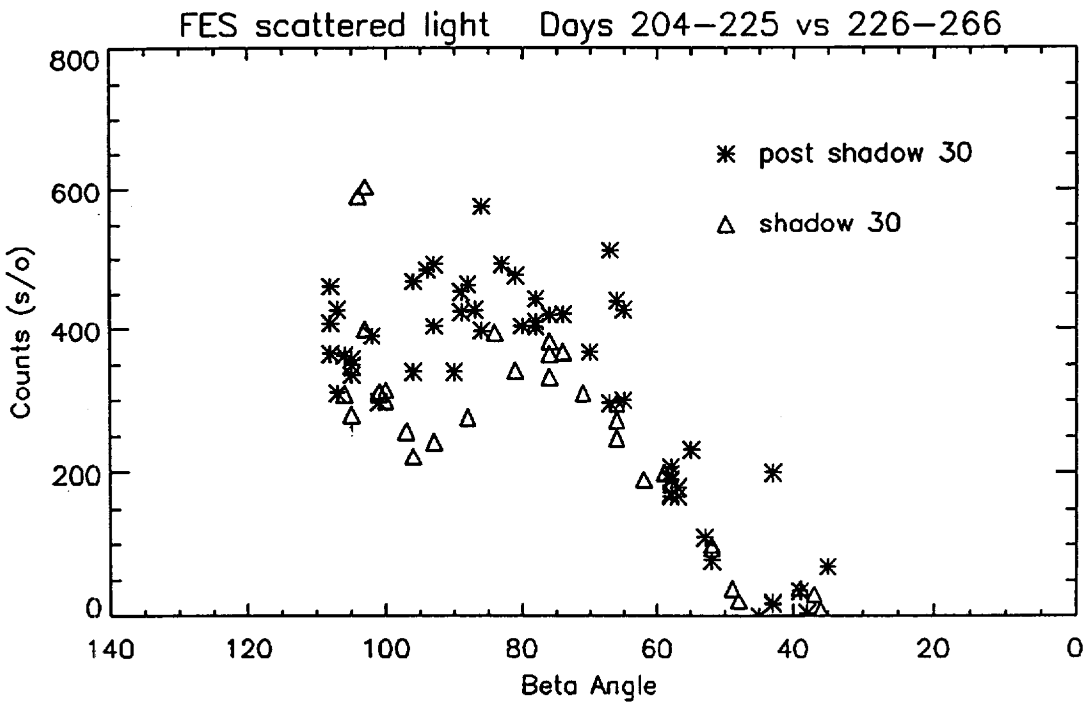


Figure 1. The FES Scattered Light before and after Shadow Season 30.

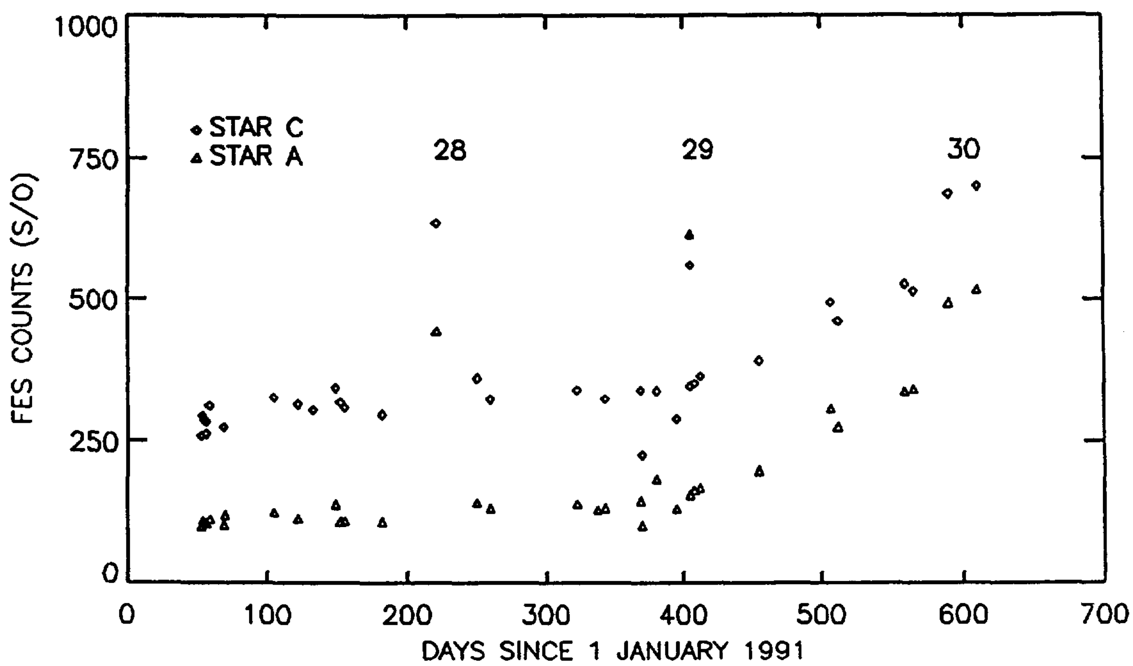


Figure 2. Observations of two stars at the North Ecliptic Pole displaying the change in the background with time at $\beta \sim 90$.

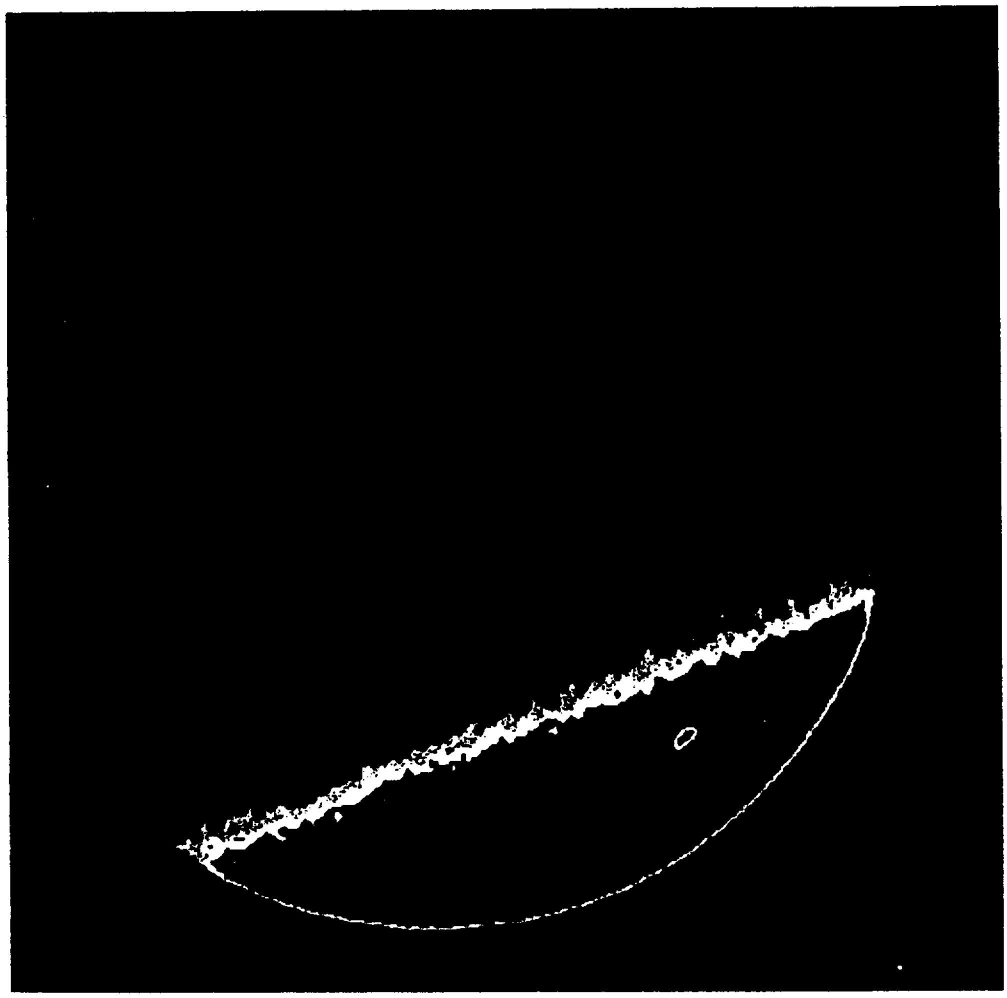


Figure 3. FES image of the first occurrence of the streak, Day 258, $\beta \sim 90$.

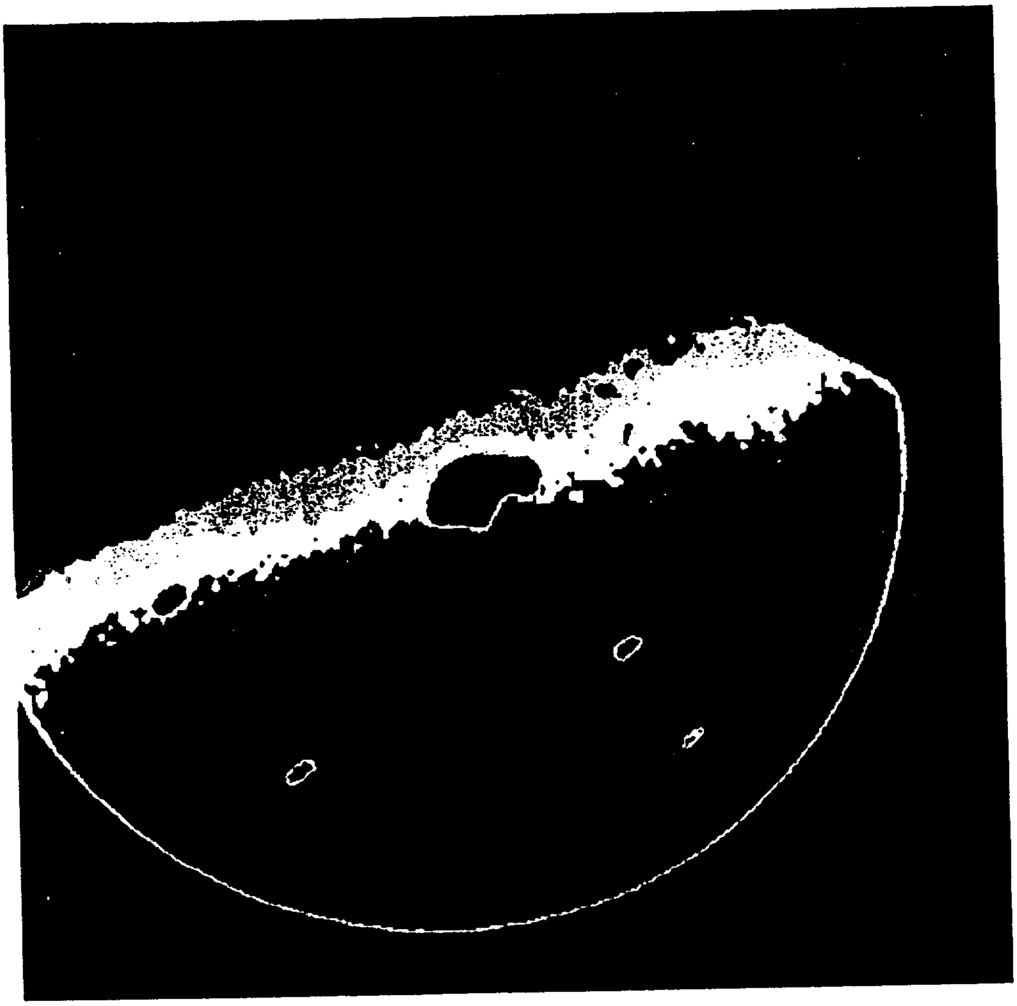


Figure 4. Worst occurrence of the FES streak, Day 317, $\beta \sim 67$.

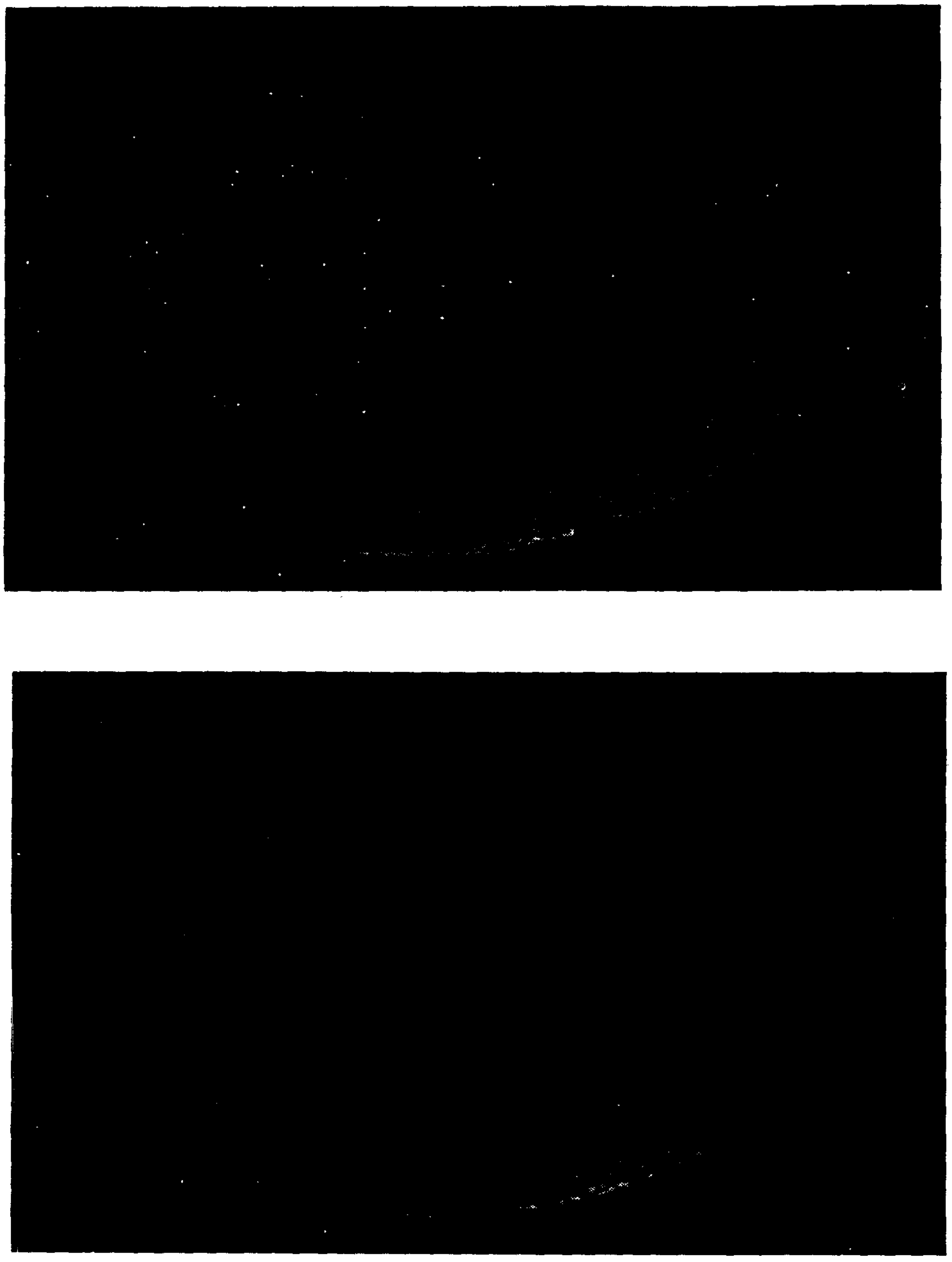


Figure 5. The level of the scattered light at two different spacecraft roll angles: +5 (top panel) and -7.5 (bottom panel.)

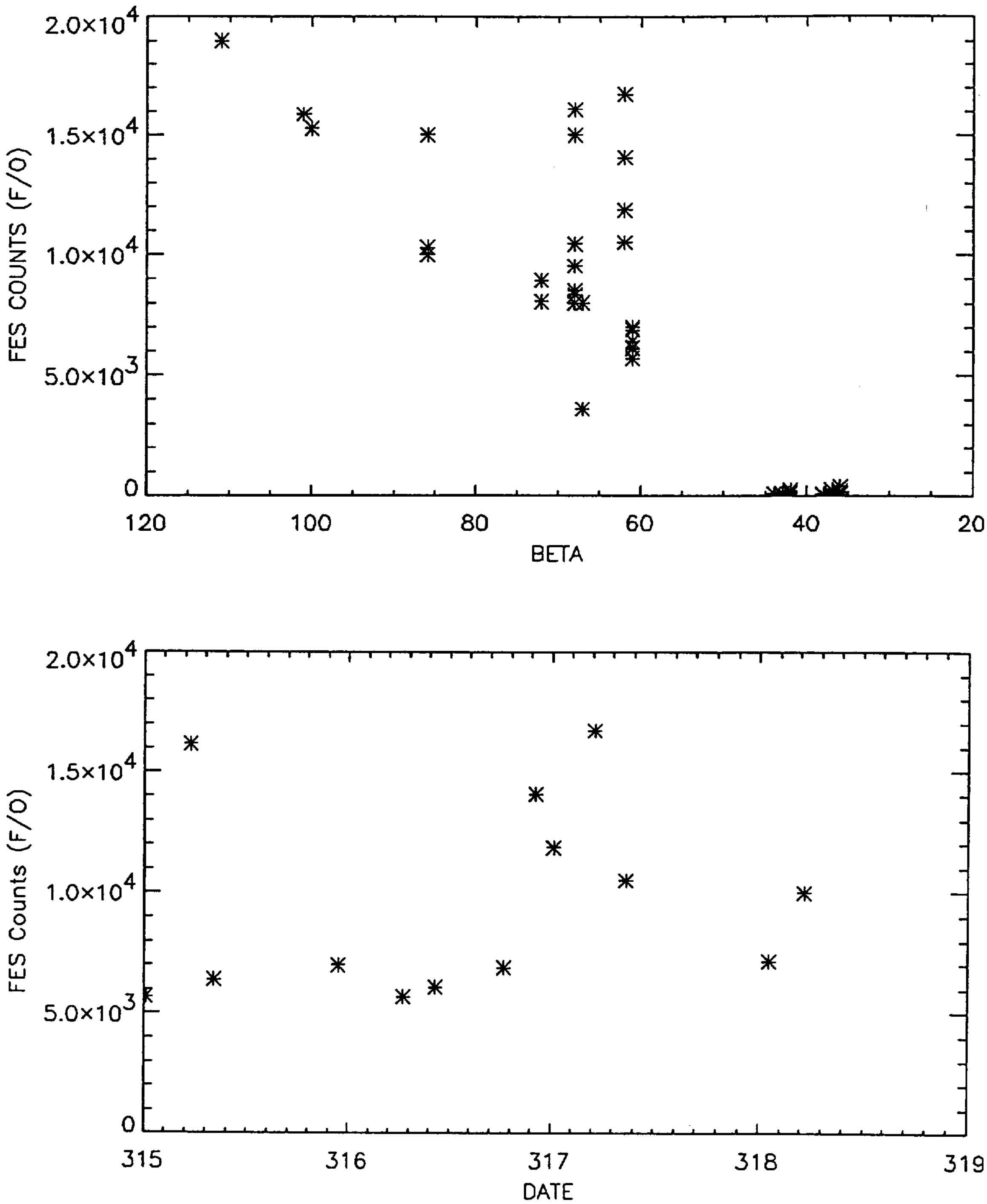
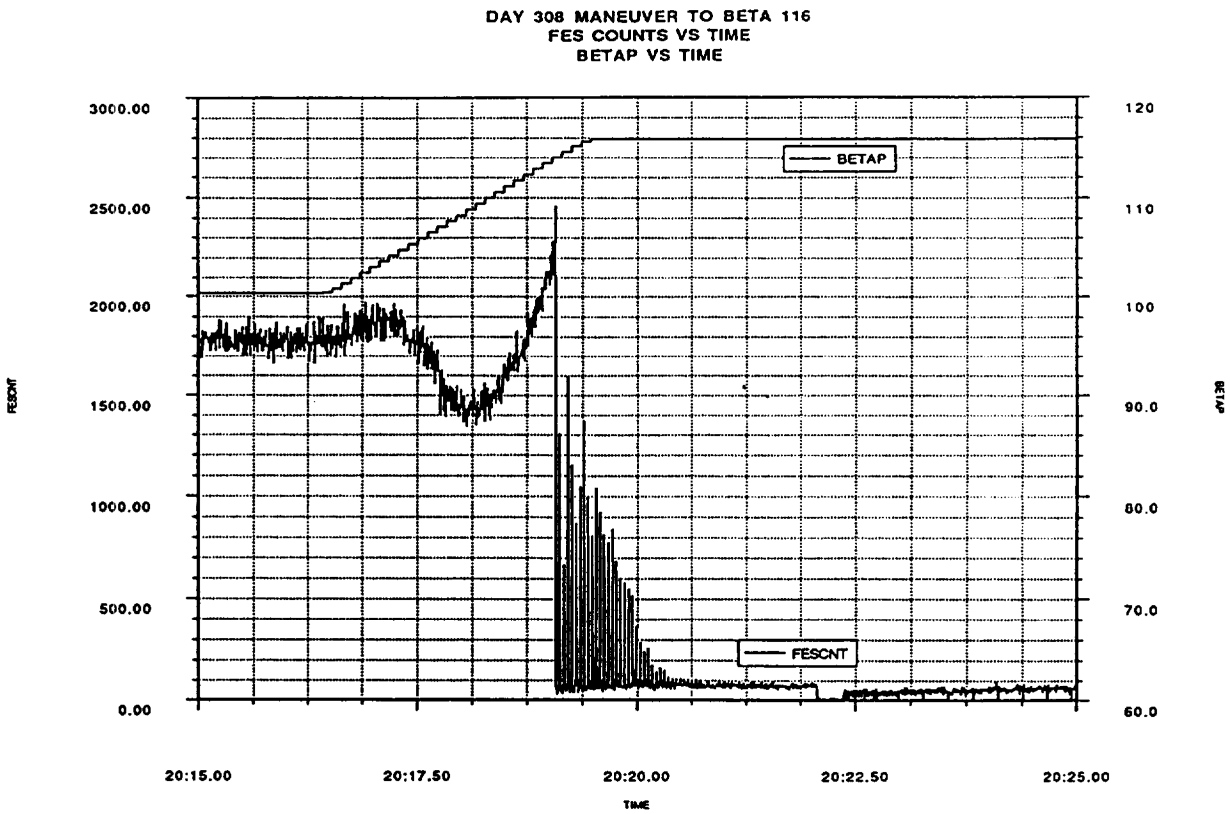


Figure 6. Top Panel: Fes counts at -300, -1400 vs β. Bottom Panel: Fes counts at -300, -1400 vs UT Date.



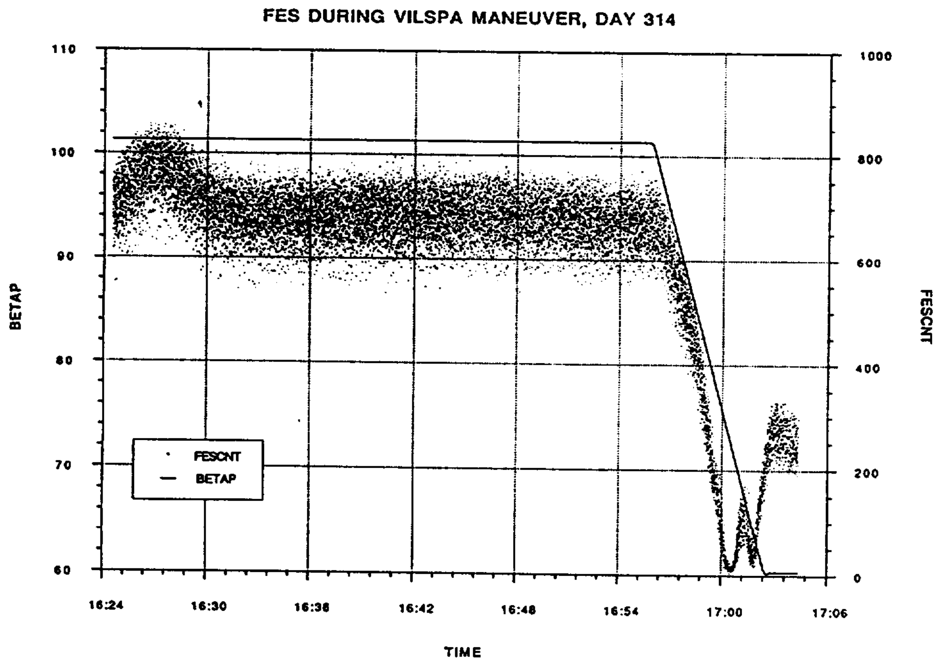


Figure 7. Plots of the counts in the FES at -300, -1400, during two separate maneuvers.

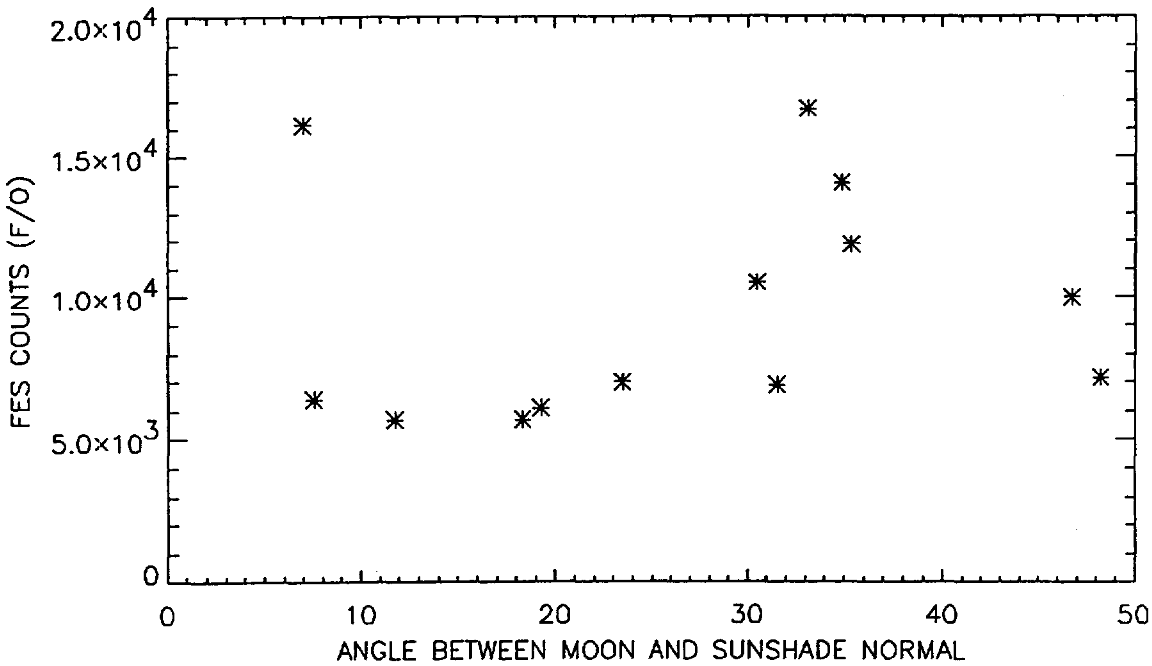


Figure 8. Plot of the angle between the sunshade normal and the moon during days 314-317.

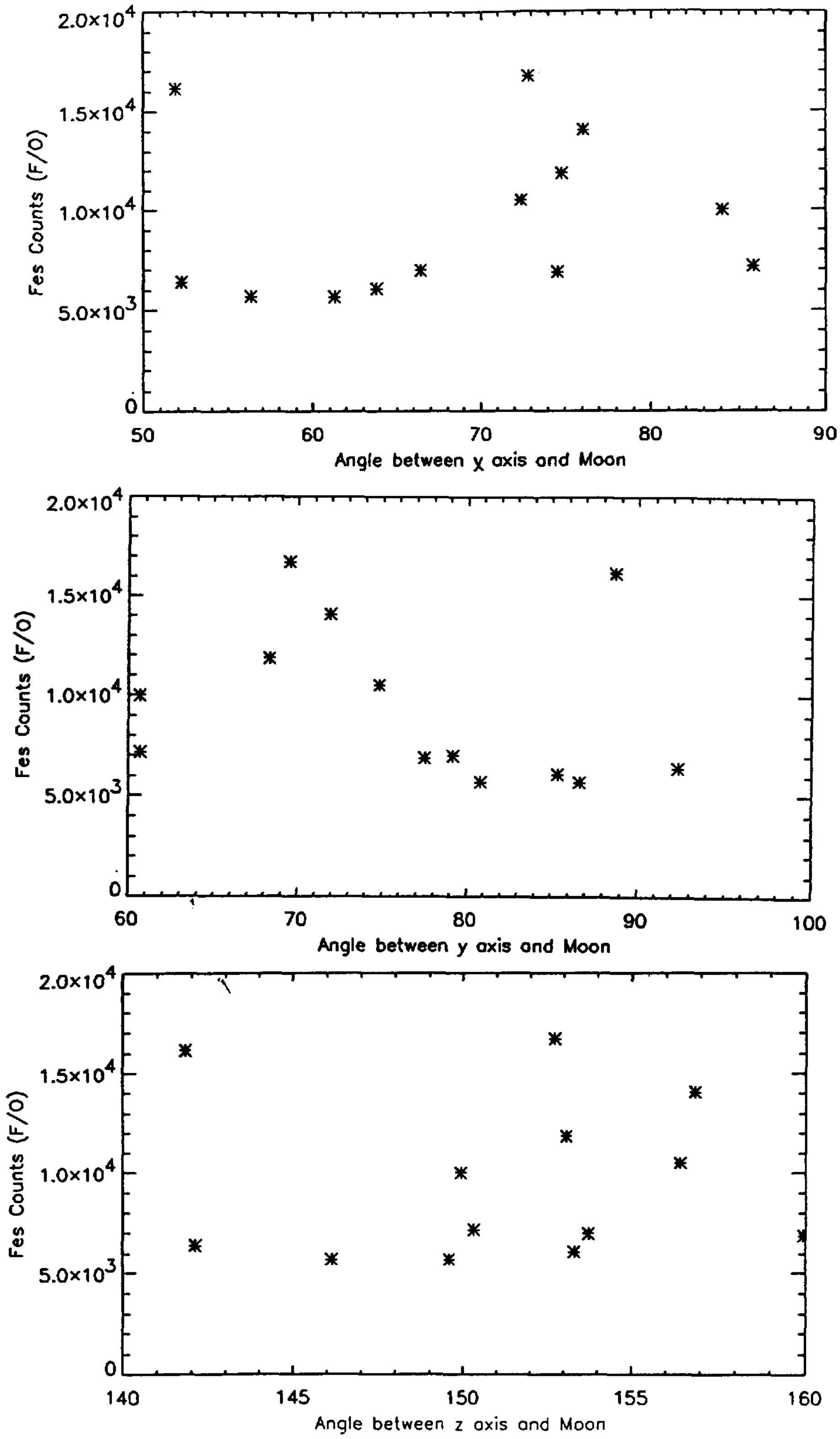


Figure 9. Plot of the angle between the x (top panel) y (middle panel) and z (bottom panel) spacecraft axis and the moon during days 314-317.

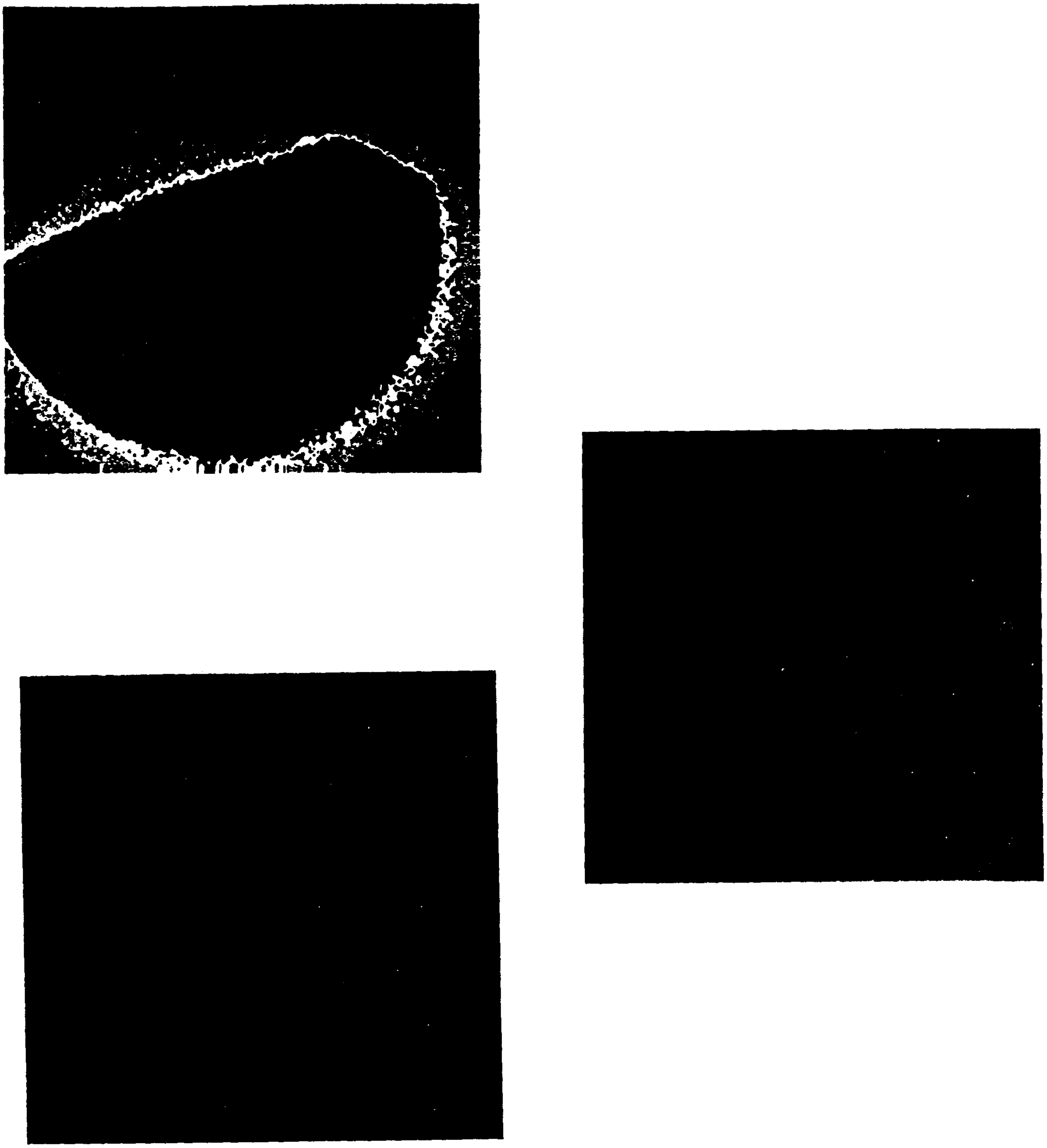
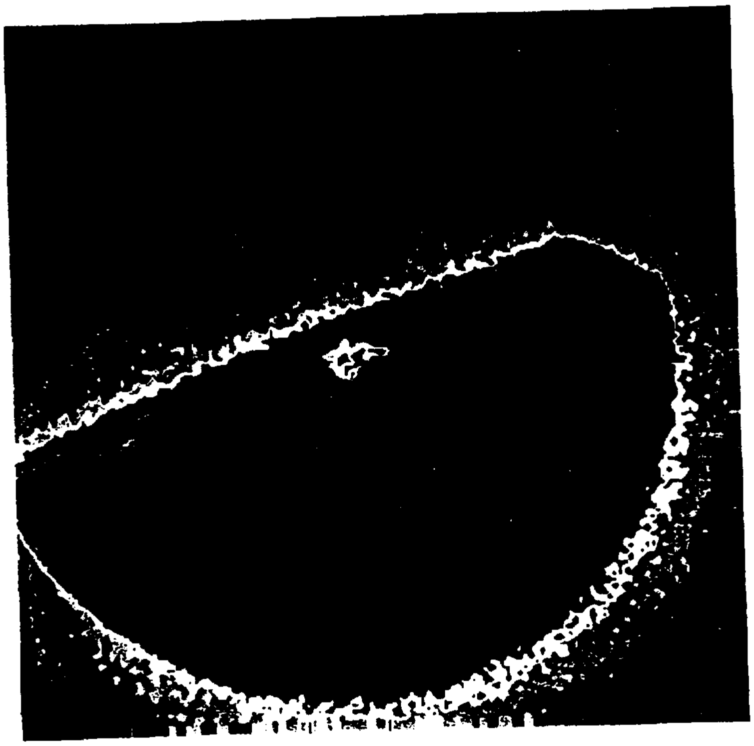


Figure 10a-c. A sequence of FES images at $\beta \sim 90$, after pitch maneuvers to $\beta \sim 120$ and back. 8a displays the field after arriving at $\beta \sim 90$, 8b is the field after one pitch maneuver up and back and 8c is after a second pitch maneuver up and back.



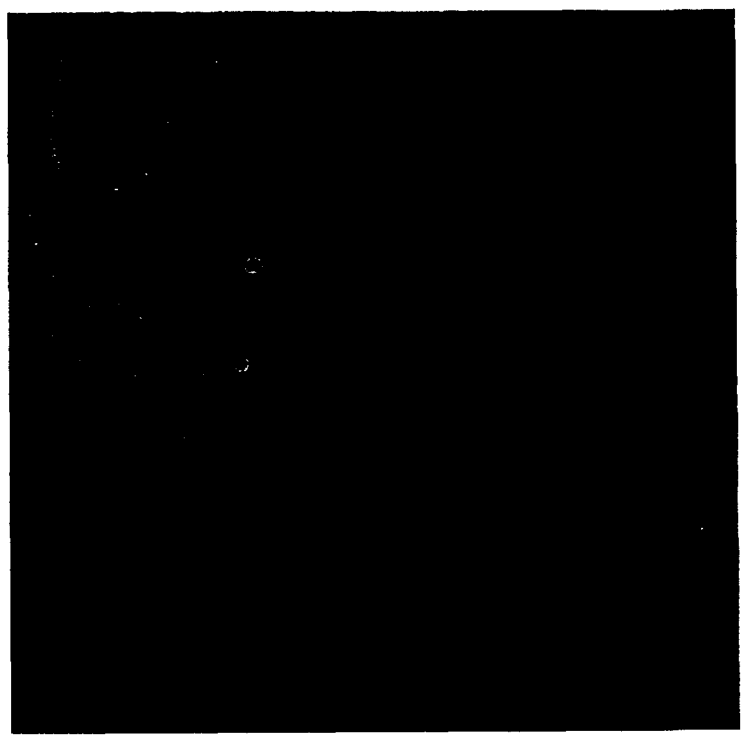


Figure 11. Top Panel: FES image at $\beta \sim 89$, Day 321, showing clear evidence of the streak. Bottom Panel: FES images after 6 degree pitch maneuver to $\beta \sim 95$ showing no evidence of the streak.

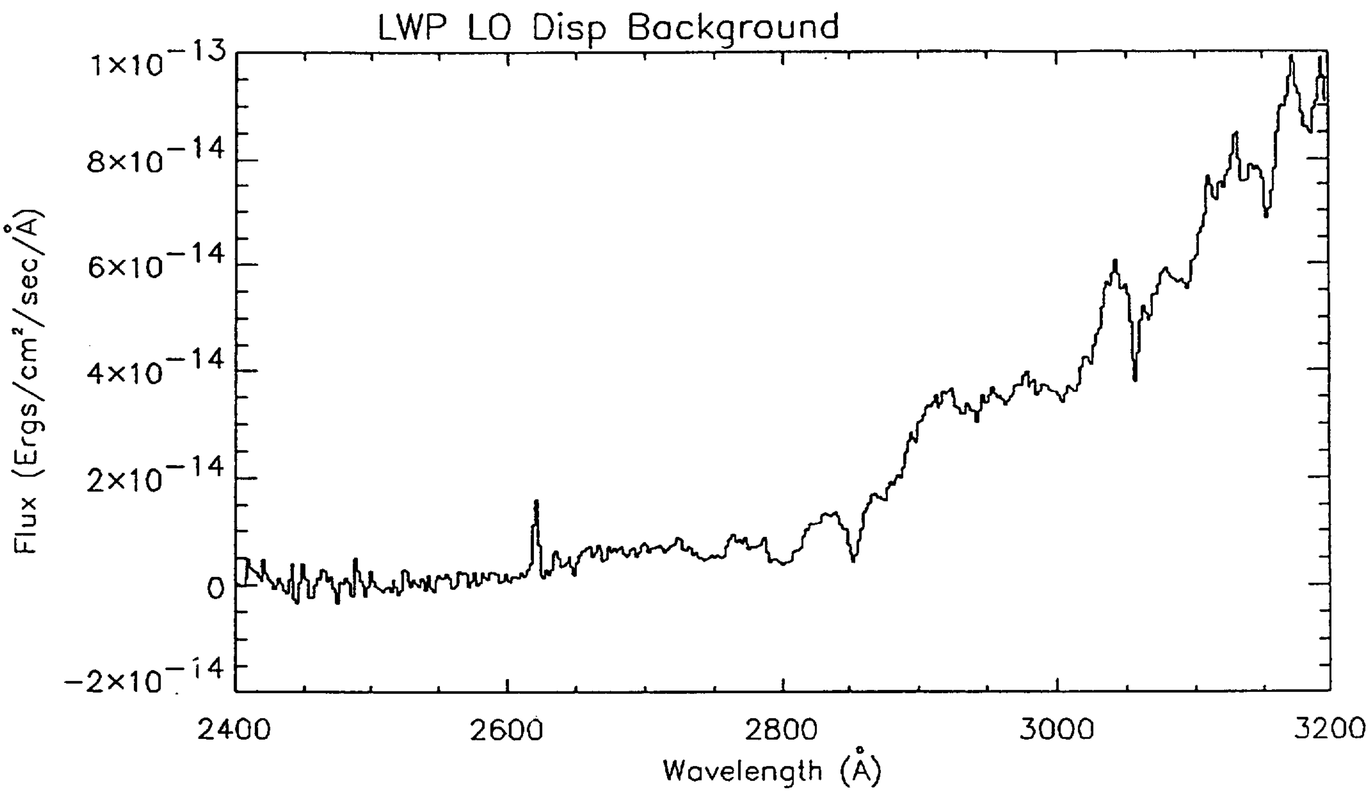


Figure 12. A spectrum of the FES Streak, obtained Day 322.

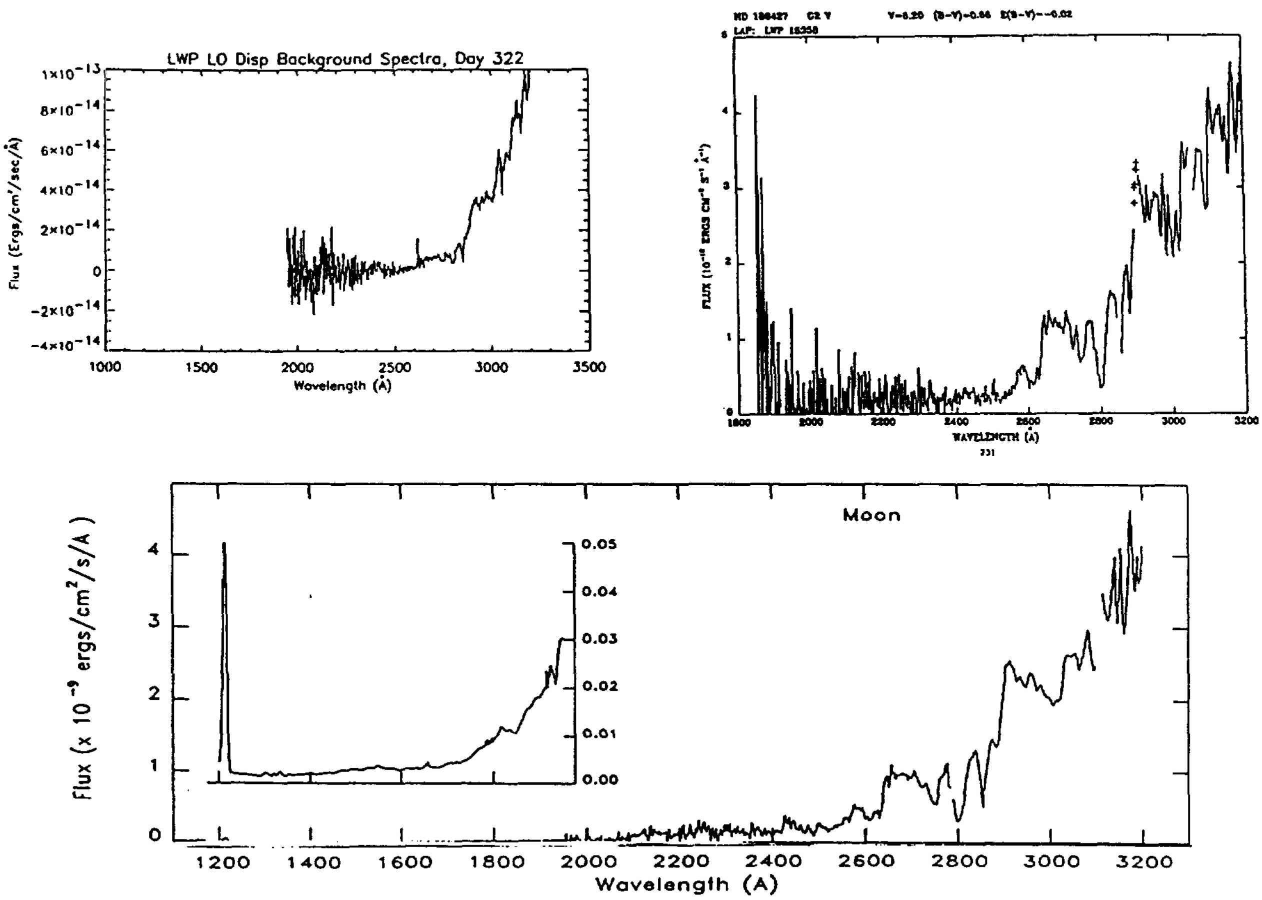


Figure 13. The spectra of the FES Streak, along with the spectra of a G2 V star and that of the moon.