THE TEMPORAL CHARACTERISTICS OF THE TERRESTRIAL RADIATION BELT

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I. INTRODUCTION

In considering the terrestrial radiation belt and its measurement, one must first note the effect of this radiation on the detectors in the Wisconsin equipment. The lowest dark count rate observed in orbit, compared with that measured in the Thermal Vacuum test on the ground, shows no measurable difference for the solar blind ASCOP 541-F photomultiplier tubes while the EMI-6256B tubes show an increase in minimum dark count of a factor of from 20 to 150 times that observed on the ground. All instruments are perturbed when in the South Atlantic Anomaly, but the EMI tubes are by far the most sensitive to it. Indeed, the effect never goes away. Stellar 1 is the most sensitive so its data will be used for this first analysis.

II. THE OBSERVATIONS

When we plot the raw observed counts per second versus time for Stellar 1, in its dark configuration, at night, and outside of the South Atlantic Radiation Anomaly, we obtain Figure 1. Two gross features are visible at once; first, that from time to time there are large increases in the observed count rate, and second, that there is a quiescent or "normal" count rate between 10 and 30 counts per second. We shall examine the large variations first.

It can be argued that the peaks could be accounted for if the spacecraft happened to be closer to the South Atlantic Anomaly when the high count rates occur. This is not the case since a detailed investigation shows that high count rates occur at the same sub-satellite points as low count rates.

If we expand the time scale in the vicinity of a particularly sharp increase in counts, say, the area near day 320 on Figure 1 (21 November 1969), we get the result shown in Figure

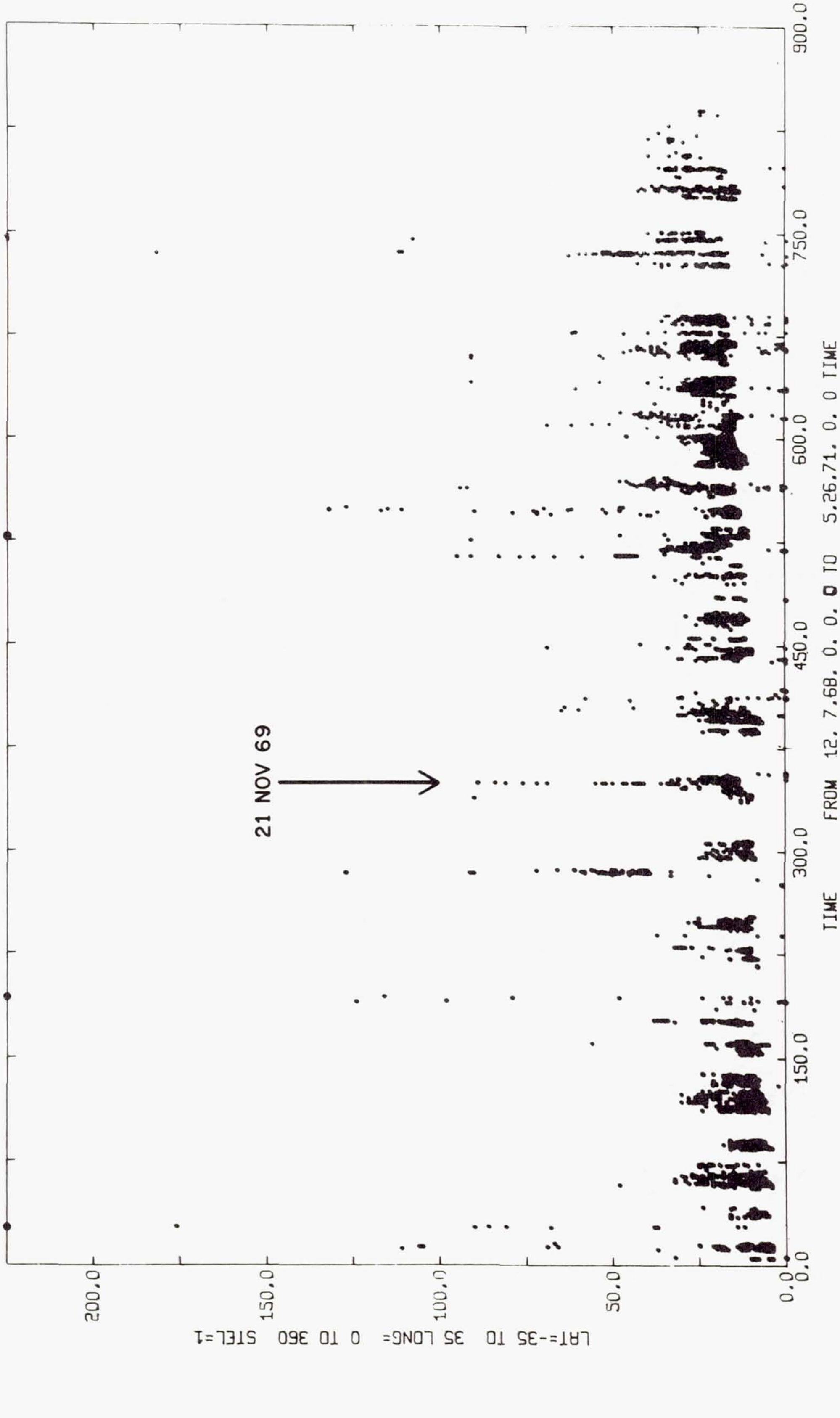

Figure 1.—Photometer dark counts for Stellar 1 at night, outside the anomaly, versus time in days after launch.

2. We observe a sharp increase of counts followed by a fairly rapid decay with, perhaps, a long tail. At 0900 GMT on the 21st of November 1969 the background seemed normal, while at 1021 GMT on the 21st an increase of counts of a factor of 3 to 4 was observed. The sawtooth structure at low count rates is typical of "normal" background data reflecting a one-day periodicity and a slope depending upon how recently the spacecraft has been in the South Atlantic Anomaly. Each point on the curve represents the data obtained from one orbit.

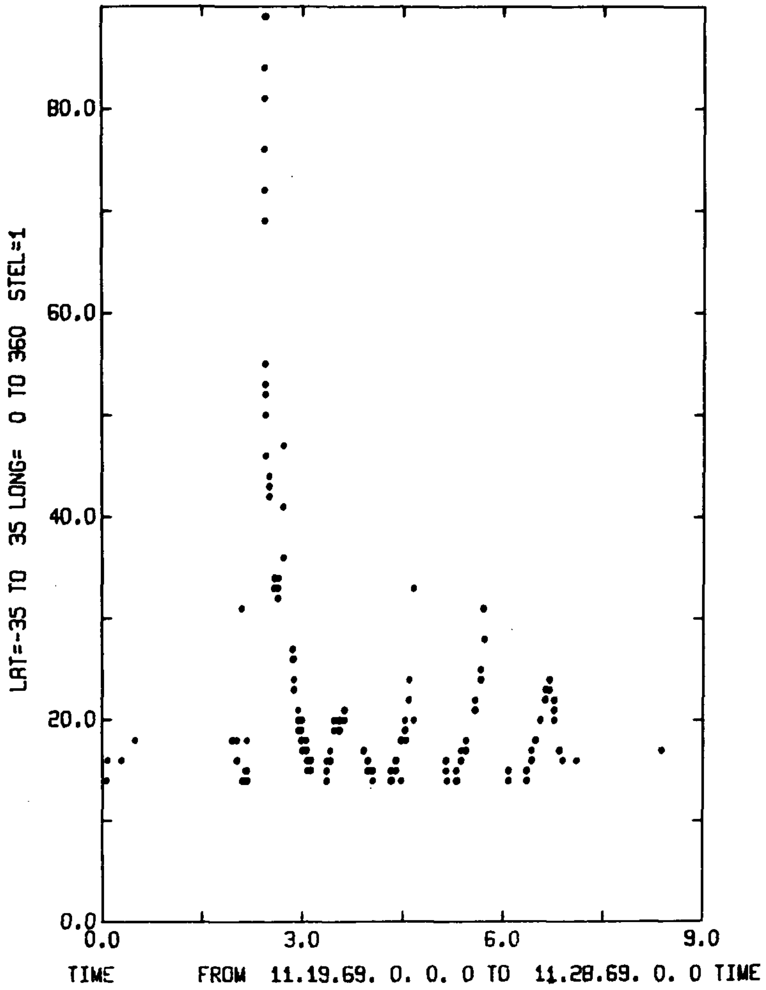

Figure 2.—Expansion of Figure 1 for the period 19 November to 29 November 1969.

To ensure that this increase in counts is due to something real we may place the count rate for the nine-day period of Figure 2 on a Latitude-Longitude plot shown as Figure 3. The South Atlantic Anomaly is in the lower half of the plot near 0°

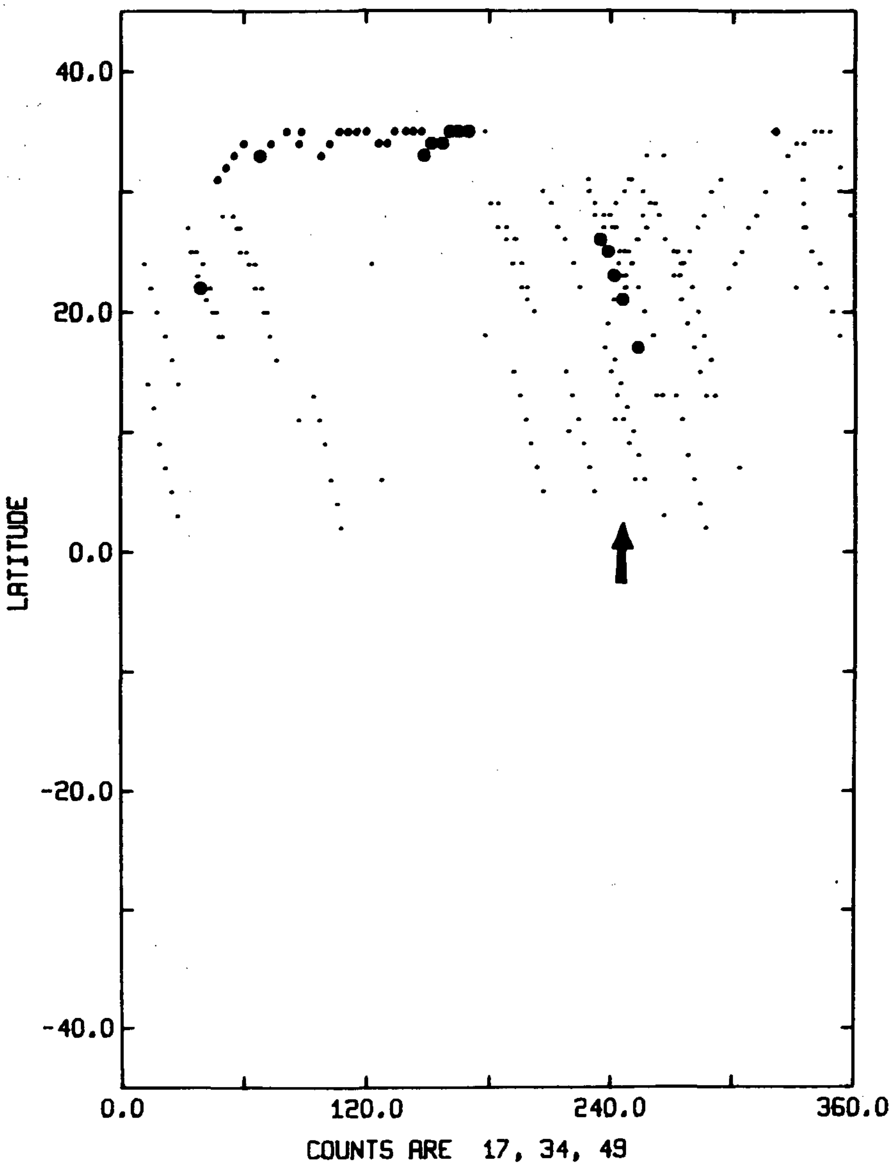

Figure 3.—Dark counts from Figure 2 plotted on a Latitude-Longitude plot, showing increase due to solar activity.

and 360° with its center at Long. 320° Lat. -30°. Orbital motion is left to right and upwards or downward depending upon daily phase. Of particular interest is the area near Long. 240° and Lat. +20°. This area will have the lowest "normal" count rate since the spacecraft has not been in the anomaly for a long time or is skirting around it. The normal count rate for this area is on the order of 20 counts per second. However, it is seen that there are some data points that show a count rate in the range of 50 per second and more. These points are the peak data points shown on Figure 2.

We now have the picture that each peak time represents a real increase in background count rate due most likely to trapped radiation. It is noted that in this particular case there was a proton flare on the 19th of November allowing for particle transit time—the 21st for this event is reasonable. Indeed, all increased count periods correlate with solar activity (particularly proton flares), and all quiet times are during no flare activity.

Let us now consider the "normal" or low count rate periods. One feature is that there is a net increase in the normal background with time. This amounts to about ten counts per second per year. The second thing that is evident after detailed plots have been examined is that there is an increase in the normal background when the spacecraft has been in the Anomaly recently over times when the orbits skirt around it. If we look at an area near Long. 150° and Lat. +20° (near the anti-anomaly) we see a difference of a factor of two between going south (about 30 counts per second, having been in the Anomaly) and going north (about 15 counts per second skirting the Anomaly). This difference accounts for the spread in observed low count rates. The minimum count rates are seen for orbits that cross Long. 0° and Lat. 35° since the spacecraft has not been near the anomaly in several orbits. The orbital period results in approximately 23° of earth motion per orbit. Therefore, the spacecraft must be in the Anomaly twice a day which accounts for the sawtooth curve seen in Figure 2.

III. DISCUSSION

One can see then that there are two decay mechanisms in the data: first, the actual decay of the radiation belt from high levels due to solar flare activity down to equilibrium levels, and second, the noise decay time of each photomultiplier detector after having been exposed to extreme radiation levels in the South Atlantic Anomaly. The 10 count per second upward trend may be explained by a net increase in tube noise due to a decay time of the order of 1/2 day so that the detectors never get a chance to recover before being subjected to intense radiation again. The multiplier tube decay must be removed before a correct interpretation of the actual spatial contribution of the radiation belt can be made. At present, it is felt that there is enough data to allow a determination of these two decay times but more work remains to be done.

Regardless of the decay mechanisms, it is seen that our most sensitive EMI tube has variations of ±10 counts where the radiation belt is quiet and may increase by a factor of 10 or more during solar storms. In order to obtain real dark count rates one must multiply the above numbers by 64 since the Wisconsin pulse counters have a precounter of length 6 bits. This gives a "normal dark" count of about 1200 counts per second for Stellar 1 and about 200 counts per second for Stellar 2 (a less sensitive instrument).

IV. CONCLUSION

It is felt that most of the low background observed is inherent tube dark count from having been in the radiation anomaly and not a measure of the real radiation away from the anomaly. If one argues that the noise is due to protons with energy levels on the order of 5 to 10 MEV then it is difficult to explain the background count rate on the basis of these particles at the place observed, since Stassinopoulos (1970) reports fewer than 10 such protons per second per square centimeter. One might suggest that the EMI tubes (sensitive to visible light) are seeing fluorescence of their envelopes due to cosmic rays. There appears to be enough cosmic ray flux to cause this background. However, this does not explain the large count during periods of increased solar activity.

Increased count rates are correlated well with solar activity in all cases. The long term upward drift is probably due to the instrument decay parameter and not a real increase in background.

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