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THE ARTIFICIAL ELECTRON BELT, OCTOBER 1963 TO OCTOBER 1966

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INTRODUCTION

Satellite 1963 38C, launched September 28, 1963 into a polar orbit at 1100 km, continues to operate normally as of July 1967. This paper deals with the measured decay of the Starfish electron radiation belt over a 36 month period commencing 15 months after the Starfish high altitude nuclear detonation of July 9, 1962. The present work summarized the main results of a 27 month study (BEALL et al, 1967) and extends the time coverage to a full 3 years. The latest data collection interval occurs in October 1966. Table I lists all the intervals for which data is presented. The list of references given in the previous publication will not be repeated here.

INSTRUMENTATION

The satellite z-axis is aligned to within $\pm 6^\circ$ of the local magnetic field direction by means of a permanent magnet. A 5-channel electron spectrometer is oriented to "look" perpendicular to the z-axis, and hence, perpendicular to the field line. Each detector is shielded by a narrow angle collimator, so that the spectrometer is designed to measure $j_\perp$, the flux of mirroring electrons. Each detector is also sensitive to low energy mirroring protons as well as high energy omnidirectional protons. The geometric factor and particle sensitivities of each detector are given in Table II. Channel 5 is identical to Channel 1 except for geometric factor and is used to support conclusions concerning Channel 1. Channel 4 is useful mainly as a proton background detector.

The stable high energy proton population in the inner zone contributes substantially to the total counting rates of Channels 2, 3, and 4, especially for T ≥ 32 months. It is possible, however, to isolate this component with a fair degree of precision, so that fluxes, spectral parameters, and decay constants given here are corrected for proton background. Even though it is felt that the proton background contribution is known to within 20%, the uncertainty in the remaining electron component can be considerably greater where the proton background is a large fraction of the total count rate, such as occurs at high L and at late times. At the other extreme, an accurate choice of proton background is of negligible importance in the case of Channel 1 at early times, when the total rate is many times background. A detailed treatment of this problem and others can be found in the above mentioned reference.

RESULTS

Counting rates at L = 1.25, 1.40, and 1.55 are shown in Figure 1 for all 6 time periods. The points are individually corrected for deadtime, and the curves are least-squares 4th degree polynomial fits calculated and plotted by computer. The background levels shown are the same for Channels 2, 3, and 4, and are somewhat higher for Channel 1. These levels were chosen before the T = 52 data became available. A small downward revision at L = 1.25 would seem required, but for the most part, the new data is consistent with the old background choice. The decay at L = 1.25 is fairly orderly for all channels. Channels 3 and 4 are at or very near background at T = 52, and this same level is being approached by Channel 2. Channel 1 decays steadily throughout the 3 years at L = 1.25, but at L = 1.40 and 1.55, the rate is anything but constant. At L = 1.40 there is only a small net decay between T = 15 and T = 20, and there is a small B-dependent increase between T = 42 and T = 52. There are corresponding increases during both times at L = 1.55, the last being quite large. Channel 5 confirms in every detail the behavior of Channel 1. It is felt that these increases are due to low energy (< 1.2 Mev) electrons, and preliminary results of a more complete time history indicate that the last increase may be associated with the September 2, 1966 solar flare and subsequent magnetic storm. The irregular decay of Channel 1 is emphasized in Figure 2, and the B-dependence of the last increase shows clearly here.

The average efficiency of each detector varies with the electron spectrum and is calculated from actual electron counting rate ratios. Fluxes are shown in Figure 3 for the two epochs T = 15 and T = 42. The spectrum softens with increasing L, and the decay is a factor of approximately 10 over the 27 month period. Characteristic e-fold energies are shown in Figure 4, along with shaded areas representing the effect of varying the proton background by +5% and -20%. There is a definite spectral softening with increasing L. Figure 5 shows the (1/e) decay constants for Channels 1, 2, and 3, and again the shaded area represents a +5%, -20% background adjustment. The higher energy electrons appear to decay faster than the lower energies, and the L shells at which the decay constants peak vary with energy. Although not shown here, there is also a tendency for the τ's to grow with time and decrease with increasing B ($L \lesssim 1.35$).

The latest data is significant in two respects:

(1) It is consistent with the earlier data, so that no revisions of previous conclusions need be made at this time. A small downward adjustment in proton background will have the effect of increasing τ_2 and τ_3 somewhat at low L.

(2) The increase in Channel 1 for $L > 1.4$ appears quite real. The effect likely extends down to $L \approx 1.3$ or lower, since it is superimposed on a long-term decay. The percentage increase rises steadily with increasing L to at least $L = 2.0$. The increase also favors the low B region, and appears to be associated with the September 2, 1966 solar flare. At $L = 1.8$, $B \approx .20$ (Figure 6), a growth of factor 5 occurred, peaking between 10 and 25 days after the flare. This was followed by a rather fast decay ($\tau_1 \approx 130$ days). Such behavior makes it clear why certain decay constants may be at such variance and emphasizes the need for detailed time histories of the inner zone, especially in the approaching period of solar maximum.

TABLE I. DATA COLLECTION INTERVALS

Collection Interval	Days after 9 July 1962	Month Code
Days 275 - 290, 1963	450 - 465	T = 15
060 - 075, 1964	600 - 615	20
210 - 225, 1964	750 - 765	25
052 - 067, 1965	958 - 973	32
350 - 365, 1965	1256 - 1271	42
285 - 300, 1966	1541 - 1556	52

TABLE II. ELECTRON SPECTROMETER CHARACTERISTICS, NORMAL INCIDENCE

Detector	Half Angle, deg.	Geometric Factor, cm^2-ster	Foil Thickness, mg/cm^2	Lower Level Response	
				Electrons, Mev	Protons, Mev
1	6.4	$2.8(10)^{-3}$	10.3 Al	≥ 0.28	1.93-2.28; ≥ 153
2	6.4	$2.8(10)^{-3}$	412 Cu	≥ 1.2	14.4-14.5; ≥ 154
3	6.4	$2.8(10)^{-3}$	946 Cu	≥ 2.4	23.3-23.4; ≥ 156
4	6.4	$2.8(10)^{-3}$	1470 Cu	≥ 3.6	30.0-30.1; ≥ 158
5	3.2*	$4.9(10)^{-4}$*	10.3 Al	≥ 0.28	1.93-2.28; ≥ 153

*These numbers refer to the calculated geometric factor. Comparison of the actual in-orbit counting rates from channels 1 and 5 yields an effective geometric factor of $1.0(10)^{-3}$ cm^2-ster.

FIGURE CAPTIONS

Figure 1. Total counting rates, sec^{-1}, observed over 36 months at three L values. The proton levels shown were selected before the T = 52 data became available. A slight adjustment seems required at L = 1.25.

Figure 2. Total counting rates, plotted versus time. The increases of C_1 (L = 1.55) are due to low energy (< 1.2 Mev) electrons. C_2 is expected to decay eventually to the same background level shown for C_3.

Figure 3. Electron fluxes, showing all data taken at 15 and 42 months after the Starfish event. A decrease of approximately a factor of 10 occurs during the 27 months. The dotted curves locate the peak fluxes at constant B.

Figure 4. Electron e-fold energies, Mev. The curves are corrected for proton background. The top borders of the shaded portions correspond to decreasing this background by 20%. The bottom borders correspond to an increase of 5%.

Figure 5. Electron mean-life decay constants, measured from T = 15 to T = 42 months after Starfish. τ_i is the time in days that is required for N_i to decay to (1/e) of its previous value. The shaded portions are analogous to those seen in Figure 4.

Figure 6. C_1 (L = 1.8, 0.18 < B < 0.21) as a detailed function of time, 1966. This preliminary figure, using only part of all available data, indicates a large, rapid increase subsequent to

September 2, 1966. This is then followed by a relatively rapid decay. The decay rate in the first 6 months is the same as occurred between T = 32 and T = 42.

REFERENCES

BEALL, D. S., BOSTROM, C. O., and WILLIAMS, D. J.: 1967, J. Geophys. Res. 72, 3403.

1963 38C ELECTRON SPECTROMETER TOTAL COUNTS, SEC^{-1}

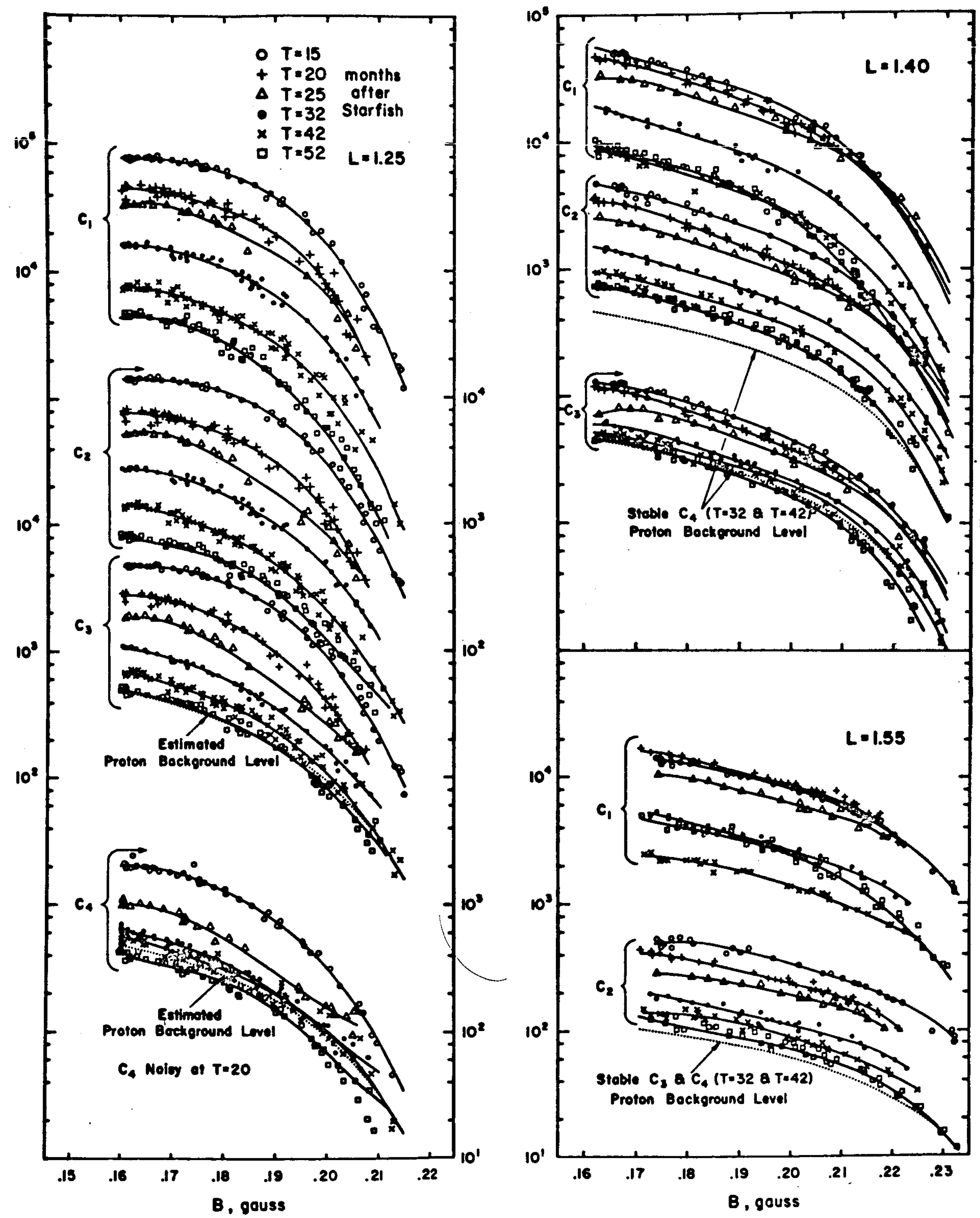

FIGURE 1

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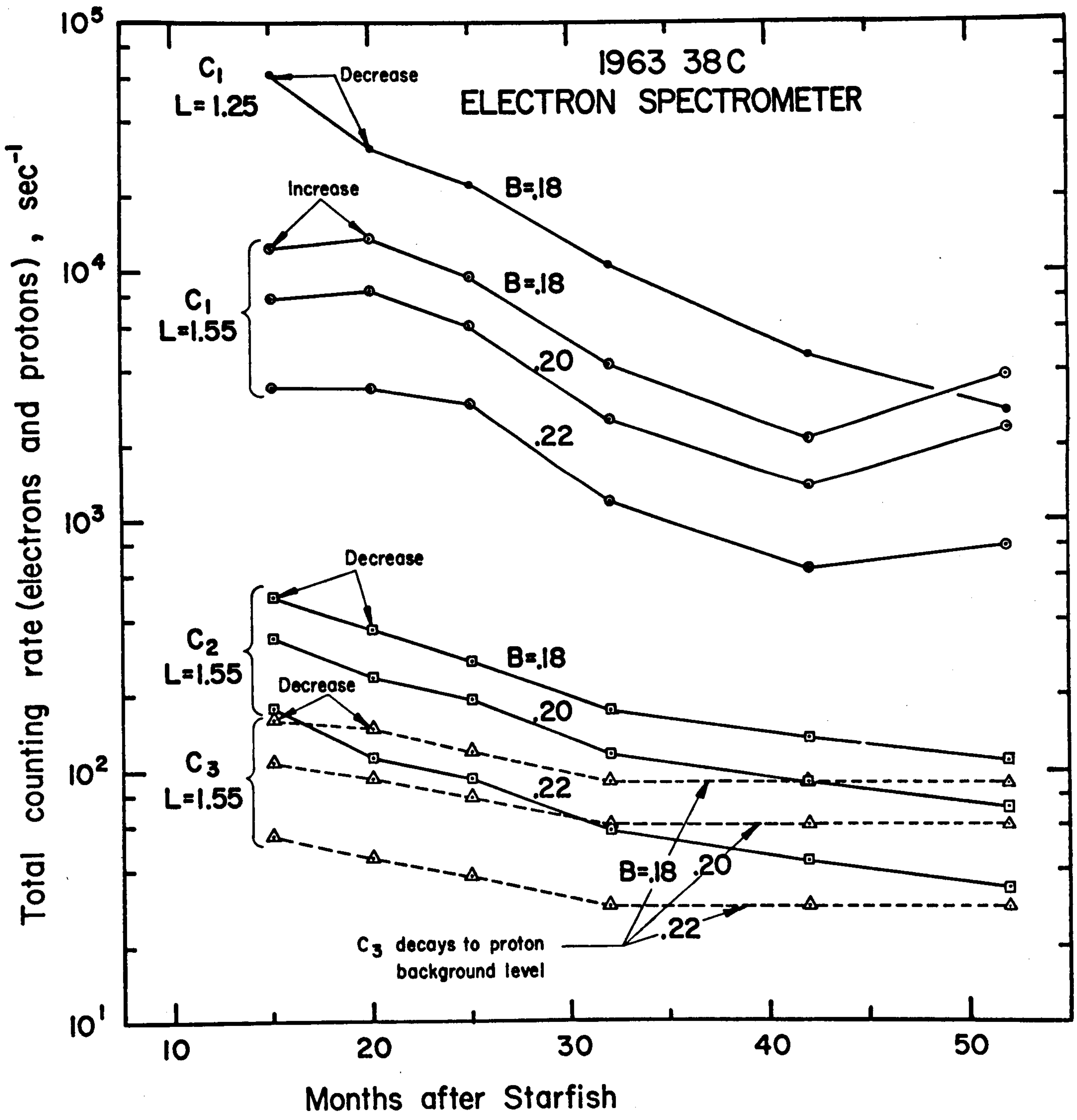
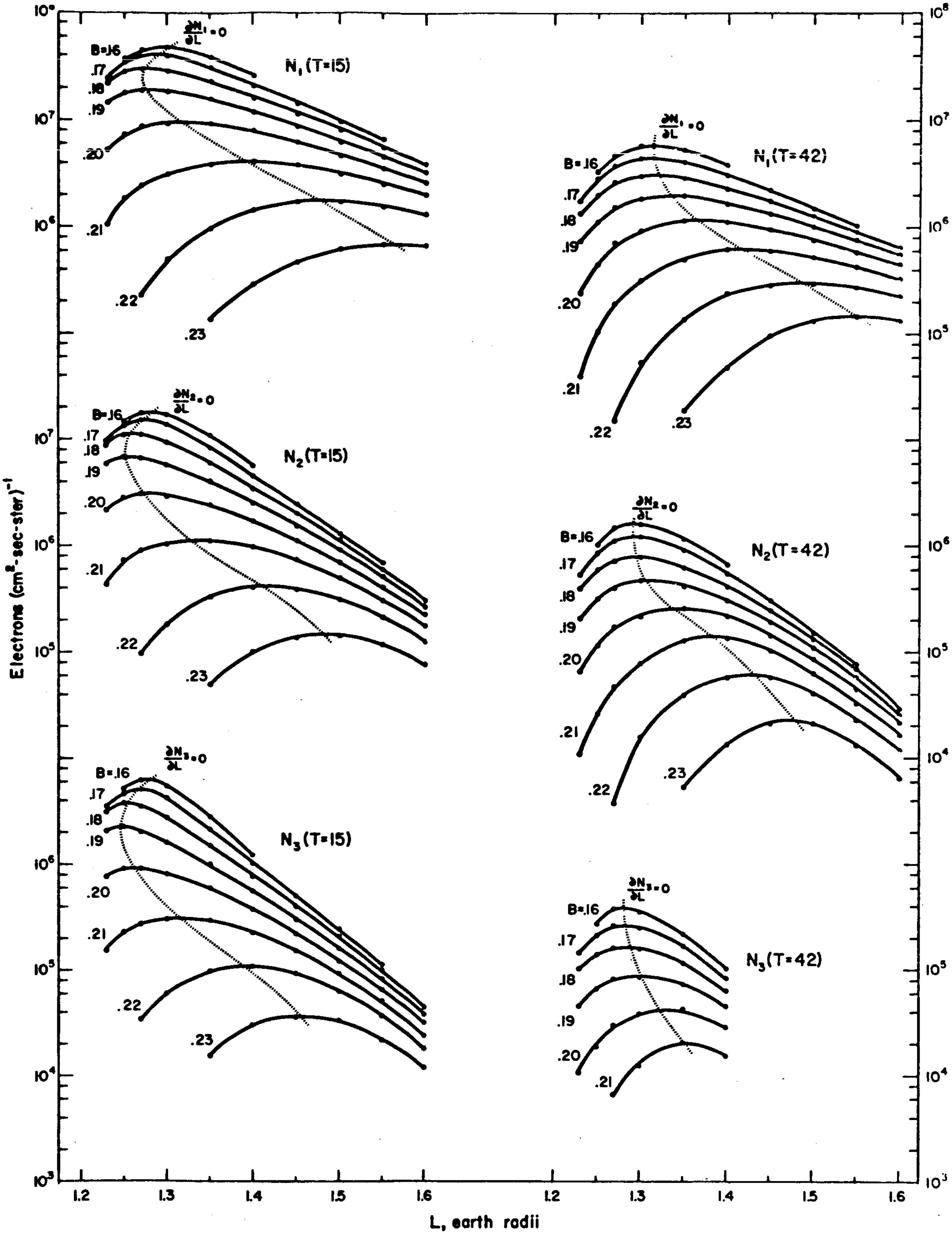
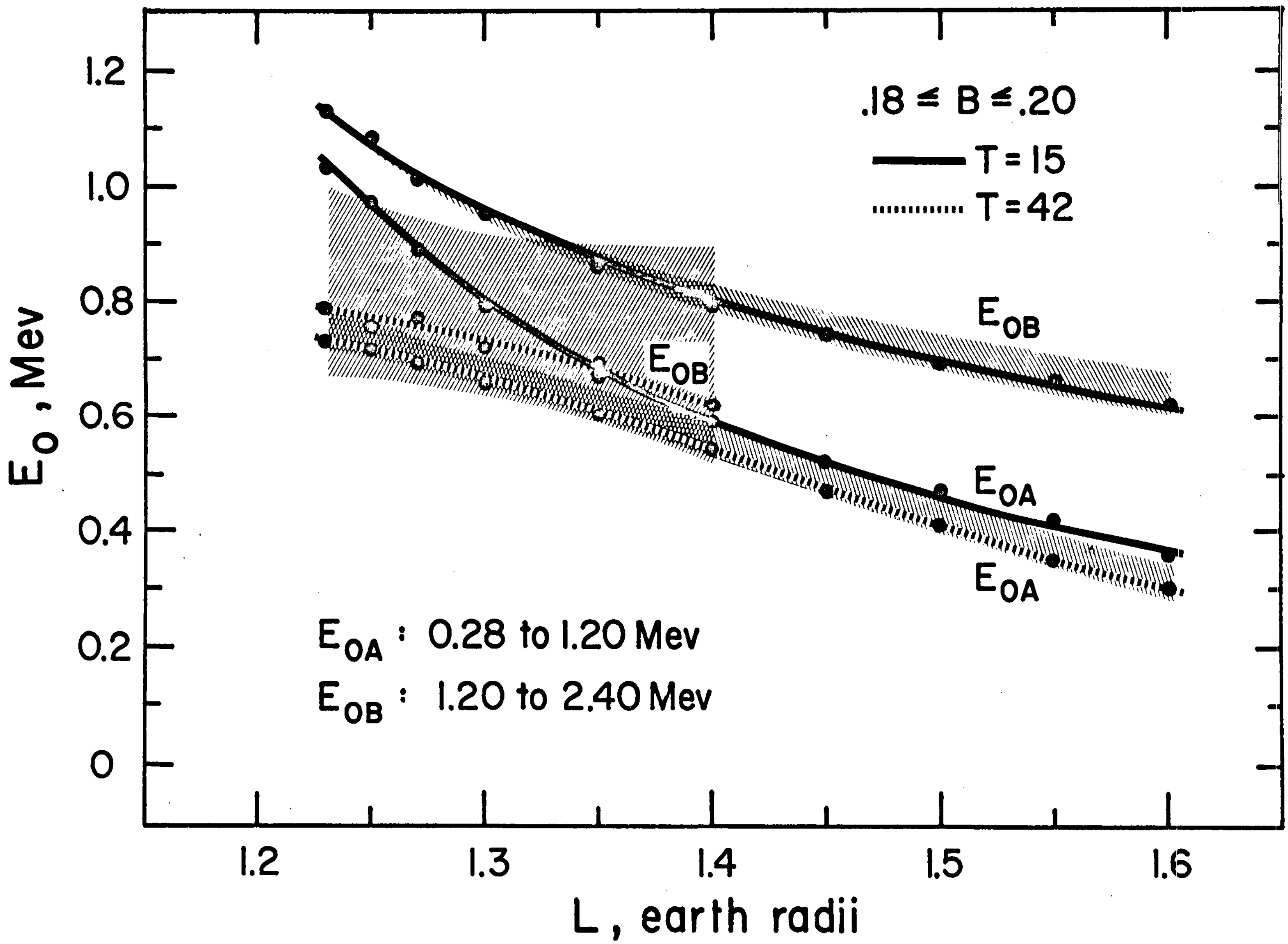

1963 38C
ELECTRON SPECTROMETER
C_1 L=1.25
Decrease
B=.18
Increase
C_1 L=1.55
B=.18
.20
.22
Decrease
C_2 L=1.55
B=.18
.20
Decrease
C_3 L=1.55
.22
B=.18
.20
.22
C_3 decays to proton background level
10^5
10^4
10^3
10^2
10^1
Total counting rate (electrons and protons), sec^{-1}
10
20
30
40
50
Months after Starfish

FIGURE 2.



N₁(T=15)
N₁(T=42)
N₂(T=15)
N₂(T=42)
N₃(T=15)
N₃(T=42)
Electrons (cm²-sec-ster)⁻¹
L, earth radii

FIGURE 3



.18 ≤ B ≤ .20
T = 15
T = 42
E_{OB}
E_{OB}
E_{OA}
E_{OA}
E_{OA} : 0.28 to 1.20 Mev
E_{OB} : 1.20 to 2.40 Mev
E_O , Mev
1.2
1.0
0.8
0.6
0.4
0.2
0
1.2
1.3
1.4
1.5
1.6
L , earth radii

FIGURE 4

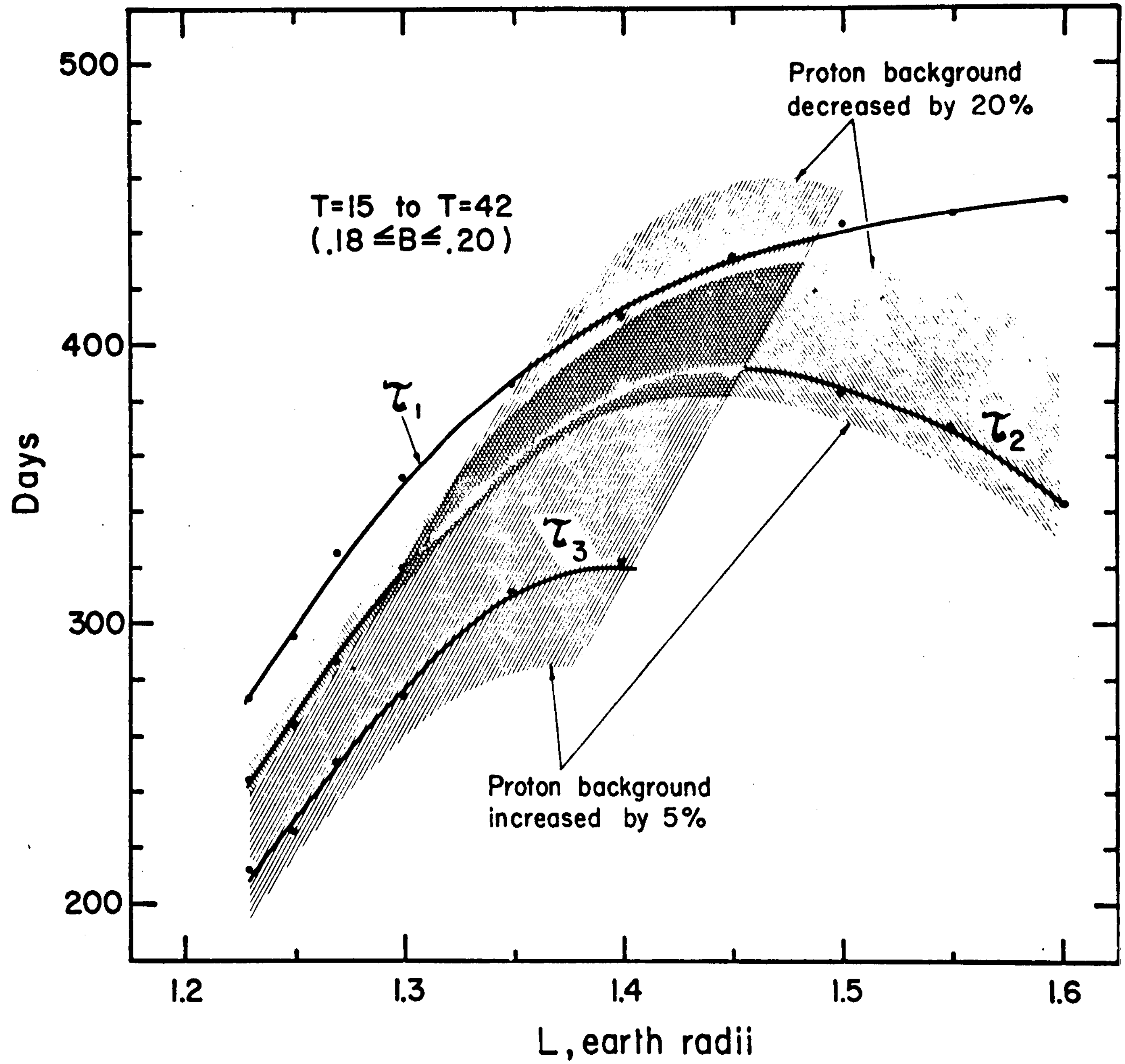

Proton background
decreased by 20%
T=15 to T=42
(.18 ≤ B ≤ .20)
τ_1
τ_2
τ_3
Proton background
increased by 5%
Days
500
400
300
200
1.2
1.3
1.4
1.5
1.6
L, earth radii

FIGURE 5

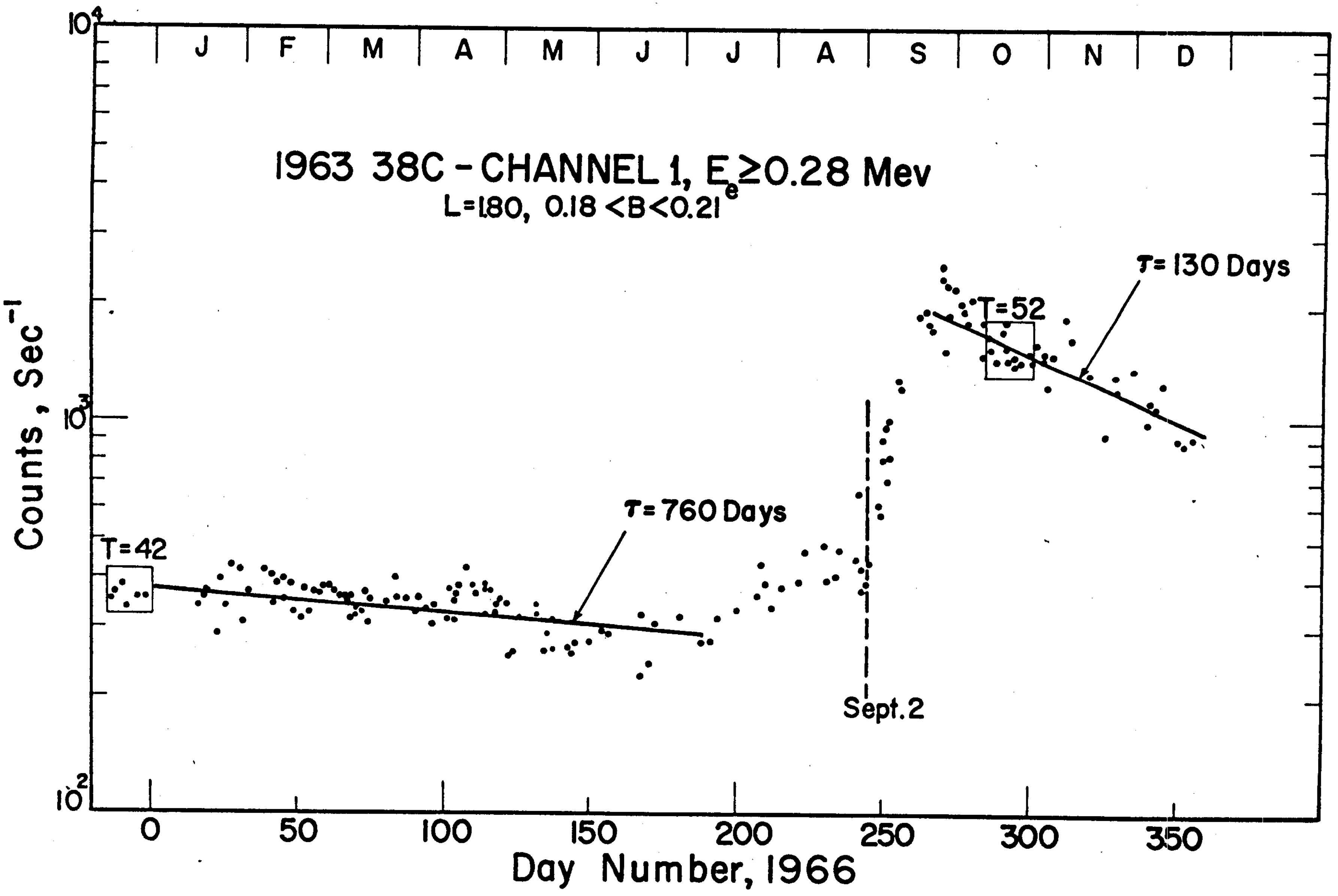

1963 38C - CHANNEL 1, E_e≥0.28 Mev
L=1.80, 0.18<B<0.21
T=42
T=52
τ= 760 Days
τ= 130 Days
Sept. 2
J F M A M J J A S O N D
Counts, Sec⁻¹
Day Number, 1966
10^4
10^3
10^2
0 50 100 150 200 250 300 350

FIGURE 6