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SOME RESULTS FROM THE IMP-1 GM COSMIC RAY DETECTOR

by

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The satellite IMP-1 (Explorer XVIII) was launched on Nov. 27, 1963 into a highly accentric orbit, with an initial apogee of ~198,000 km. and a perigee of ~192 km. The initial revolution period was ~3 days and 22 hours. Due to its high eccentric orbit, it spends an appreciable part of its lifetime above the magnetosphere and thus provides cosmic ray data for long continuous periods of over 3 days each without interruption due to the crossing of the radiation belts.

A schematic view of one of the cosmic rays experiments carried by this satellite is shown in Fig. 1. Four disc shaped GM counters are arranged to form 2 mutually perpendicular telescopes, one of which is parallel to the spin axis of the satellite. During 40 sec. for every 5 min., three outputs are telemetered back to the receiving stations: two coincidences between 2 pairs of counters, called the T_p and T_n rates, and the output due to any one of the 4 counters being discharged and called the SUM rate.

Fig. 2 shows the directions in the celestial sphere into which the 2 telescopes look. Since the satellite is spin stabilized and spins at a very large rate (20 rpm), the telescope along the spin axis (T_p) samples radiation from a relatively small region of the celestial sphere, not too far from the ecliptic poles, while the other telescope perpendicular to the spin axis (T_n) samples radiation from a broad band in the sky.

Fig. 3 shows the daily average counting rate of the

SUM detector. In the same figure we show for comparison the daily average counting rate of a large plastic scintillator used in another cosmic ray experiment on board of the same satellite, and the Deep River Super Neutron Monitor daily averages [1].

Fig. 4 shows the daily average counting rates of the 2 telescopes T_p and T_n. We can see that there is good agreement between the 2 curves in the short and long term charges.

In order to study the long term trend we submitted the data from both telescopes to a 15 day double moving average process in order to eliminate the short term fluctuations. The results are presented in Fig. 5.

We can see from this slide that both telescopes have a trend to increase, following the general trend of the 11 year cycle variation. There is a tendency however for the T_p telescope, which has more directional selectivity, to recover faster than T_n, which looks into a broader area in the sky and can therefore be considered as measuring an averaged background intensity.

In order to check this point more throughly, we plotted the ratio T_p/T_n against time and compared with similar curve for the SUM detector. The results are presented in Fig. 6.

It is clear from this slide that the ratio T_p/T_n follows very closely the SUM curve, indicating that as the cosmic ray intensity recovers following the 11 year cycle variation, the telescope along the spin axis which points close to the ecliptic poles, sees the greatest change. If we interpret the 11 year solar cycle variation of the cosmic ray intensity as due to the formation of a cavity in the inner solar system due to the blowing of the solar wind and its eventual slowing down and stopping, with the cosmic ray intensity inside this cavity being less than the galactic intensity that prevails outside, our observations support then the idea of a cavity lacking spherical symmetry. Some measurements of the solar corona density as a function of distance from the sun during the solar minimum and maximum are presented in Fig. 7. It is evident from these measurements that it is the polar corona that suffers the greatest change during the solar cycle. This fact is also brought about by direct photographs taken at times of total solar eclipses. This asymmetry in the visible solar corona should then also be present in the quiet day coronal expansion (the solar wind) and in the shape of the cavity that the solar wind produces when it blows away from the sun until it is stopped by the galactic environment. Such an asymmetric cavity as pictured by Ahluwalia and Escobar [2] during solar minimum is shown in Fig. 8. Taking the equatorial radius of this cavity to be 50 A.U., it is clear that at the position of the earth we are closer to the cavity boundary when looking at large angles from the ecliptic plane. Therefore, since the coronal changes during the solar cycle are more pronounced along this direction, we would expect the cosmic ray modulation to be larger in this direction, and this is what we indeed observe.

Another feature of the data I would like to discuss is the existence of periodic fluctuations in intensity. Fig. 9 shows the counting rate of the SUM during a few days after launch. We can see from this slide that there are some periodic fluctuations in intensity with period somewhat between 10 and 20 hours, and lasting for several periods.

In order to test whether these fluctuations are a more or less regular feature and to try to determine more accurately their periods, we submitted the data to a power spectrum analysis, the results of which are shown in Fig. 10. We can see that the power is maximum for a period close to 12 hours.

Since this period agrees with the period of the semi-diurnal component of the variation measured with ground detectors, we decided to subject the data from the SUM detector and from the Deep River Super Neutron Monitor to a Fourier Analysis. For this purpose we divided the data, starting on Nov. 29, 1963 into 4 groups of 30 days each, and for each group we calculated the amplitude and time of maximum of the 24 and 12 hours waves. The results are presented in Fig. 11. It is clear from this slide that whenever the amplitude of the 12 hours wave is statistically different from zero, the time of maximum is between 0615 and 0715 UT. This holds true for the IMP and Deep River data. The averaged results for the whole period under study are also presented in this slide. They agree remarkably well in amplitude and phase.

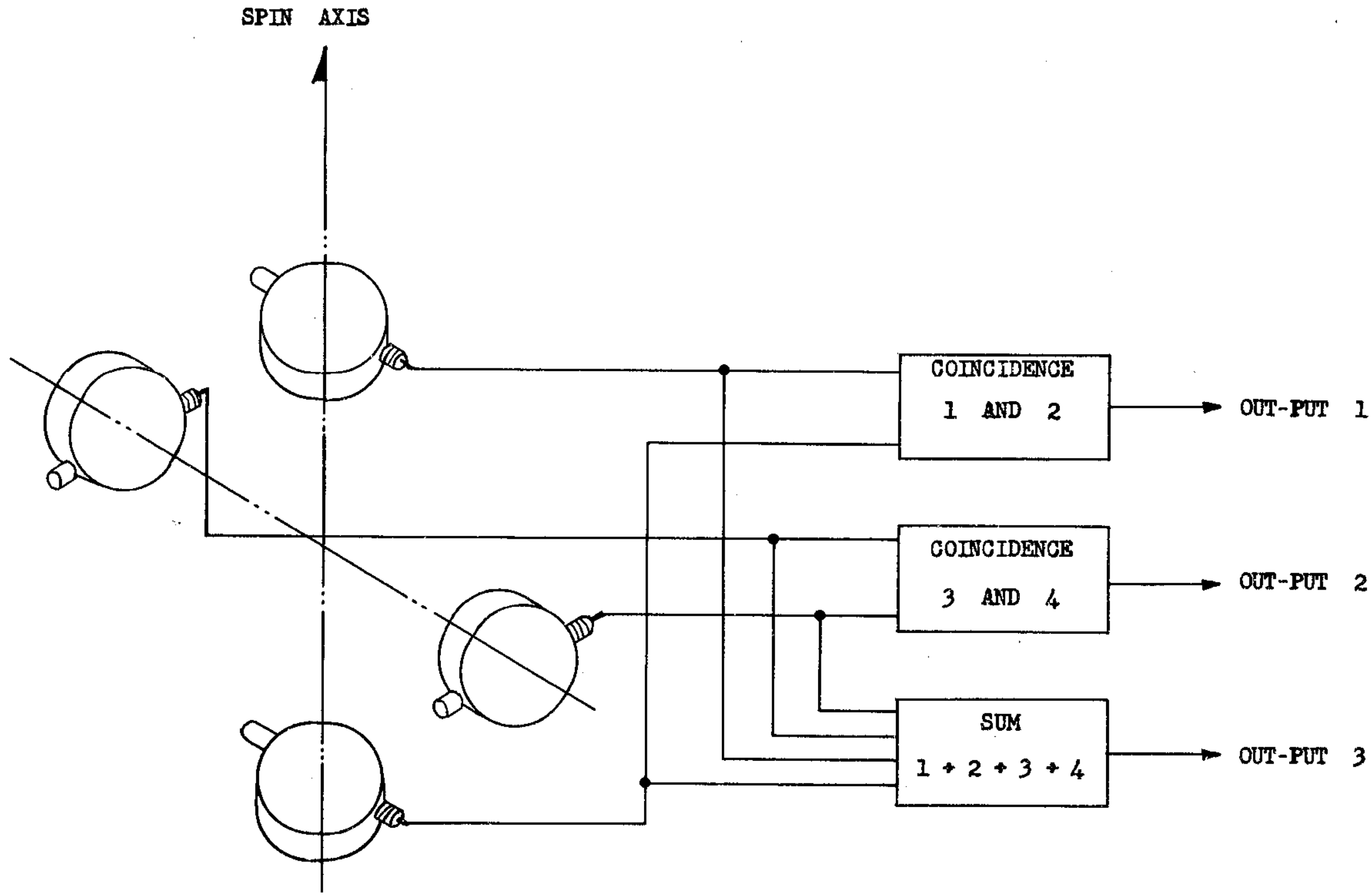
For comparison, we have also included the results of the Fourier analysis of the 24 hours wave. From this we can see that whereas the Deep River data show the usual diurnal variation, with time of maximum close to 2000 UT (1500LT), the IMP data show no statistically significant amplitude for each of the 4 periods considered. This also holds true for the average for the whole period.

Our data suggest then that there exists at some times a periodic fluctuation with period close to 12 hours, in the cosmic ray intensity of particles with energy greater than 40 MeV, and that this fluctuation is a true time variation phenomenon, since no other cause will explain its observation with the satellite borne detector. The fact that a similar fluctuation, for the same period of time was also observed with the Deep River Monitor indicates that such fluctuations extend into the BeV range of energies with a flat spectrum.

No explanation is offered for the origin of such variations, but the agreement with Deep River in amplitude and phase suggests that part or all of the semi-diurnal variation measured with ground detectors might be a true time variation and not a higher harmonic of the diurnal variation, or a variation of meteorological origin.

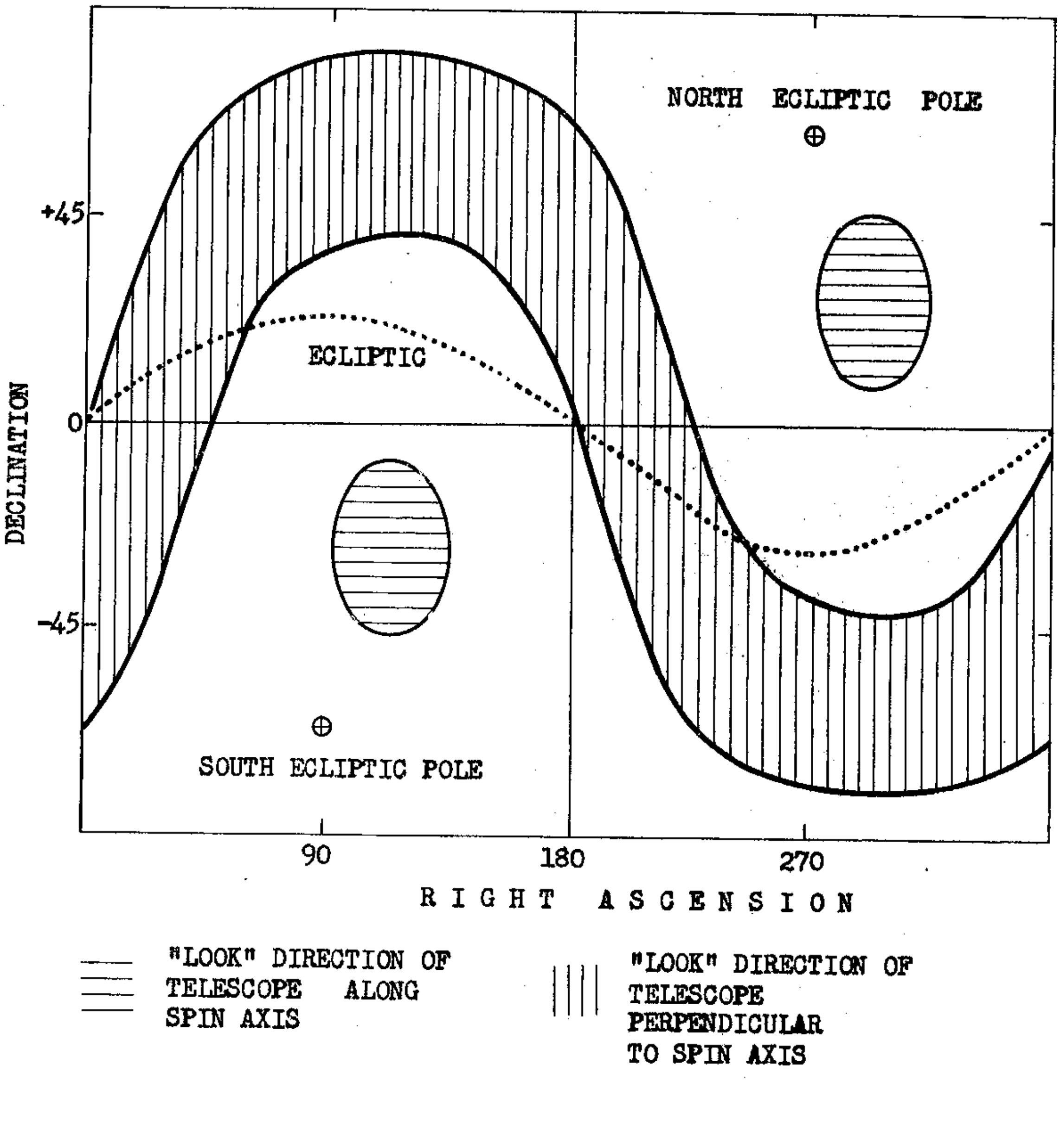
	IMP				DEEP RIVER NEUTRON MONITOR			
	24 HOUR		12 HOUR		24 HOUR		12 HOUR	
INTERVAL	R (%)	T (UT)	R (%)	T (UT)	R (%)	T (UT)	R (%)	T (UT)
NOV 29 - DEC 28, 1963	0.02±0.03	1251±0432	0.08±0.03	0709±0043	0.26±0.01	1956±0008	0.07±0.01	0716±0015
DEC 29 - JAN 27, 1963-64	0.01±0.03	1816±0701	0.01±0.03	0259±0507	0.30±0.01	2044±0007	0.08±0.01	0557±0012
JAN 28 - FEB 26, 1964	0.03±0.03	1343±0434	0.03±0.03	0712±0036	0.37±0.01	1985±0005	0.10±0.01	0651±0010
FEB 27 - MAR 27, 1964	0.04±0.03	0803±0303	0.12±0.03	0637±0024	0.38±0.01	2034±0005	0.08±0.01	0641±0010
NOV 29 - APR 6, 1963-64	0.02±0.01	1056±0312	0.07±0.01	0644±0021	0.33±0.005	2012±0003	0.08±0.005	0636±0005

AMPLITUDE AND TIME OF MAXIMUM OF 24 AND 12 HOUR WAVES



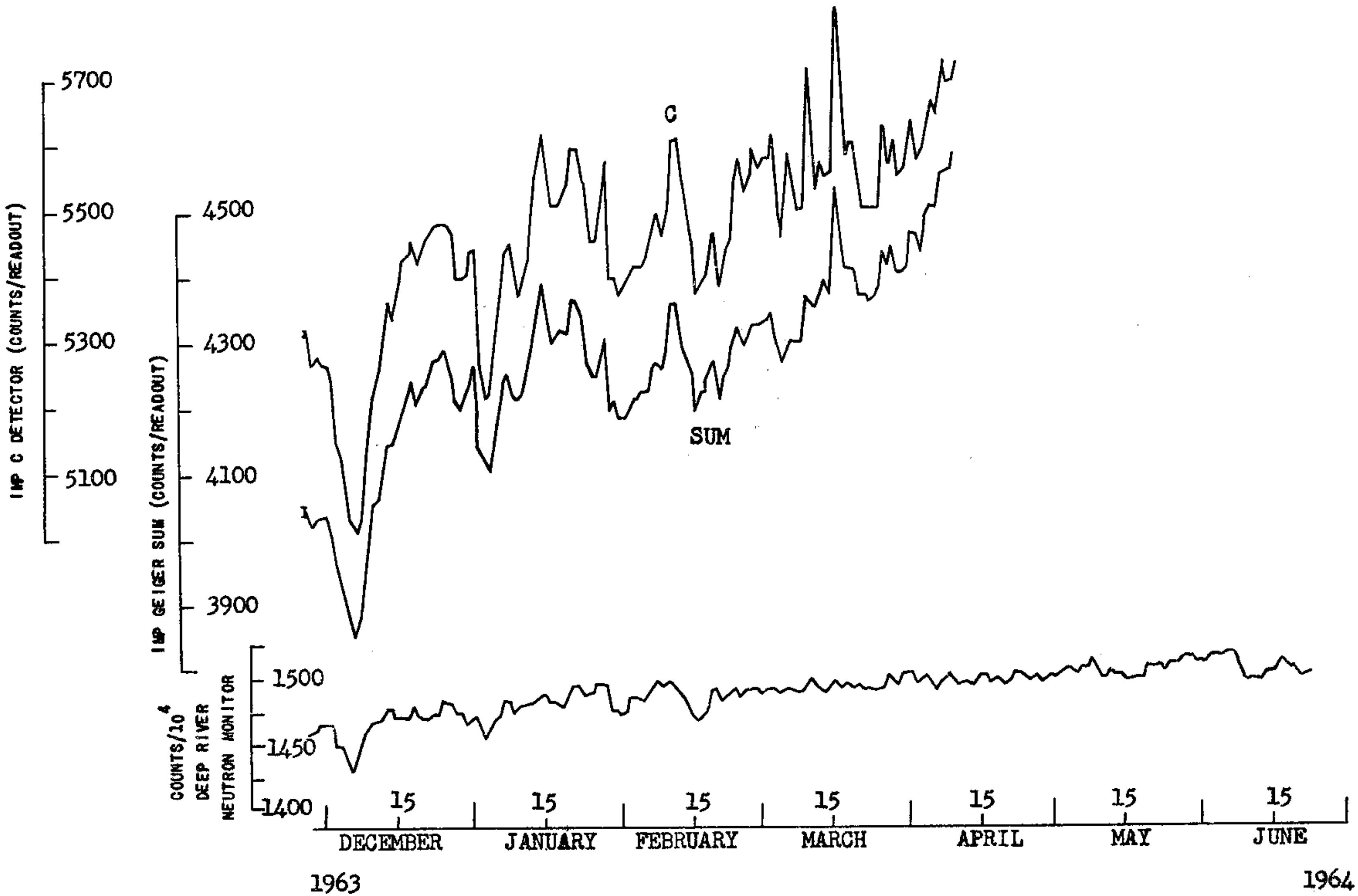
IMP GEIGER COUNTER TELESCOPE

FIG. 1



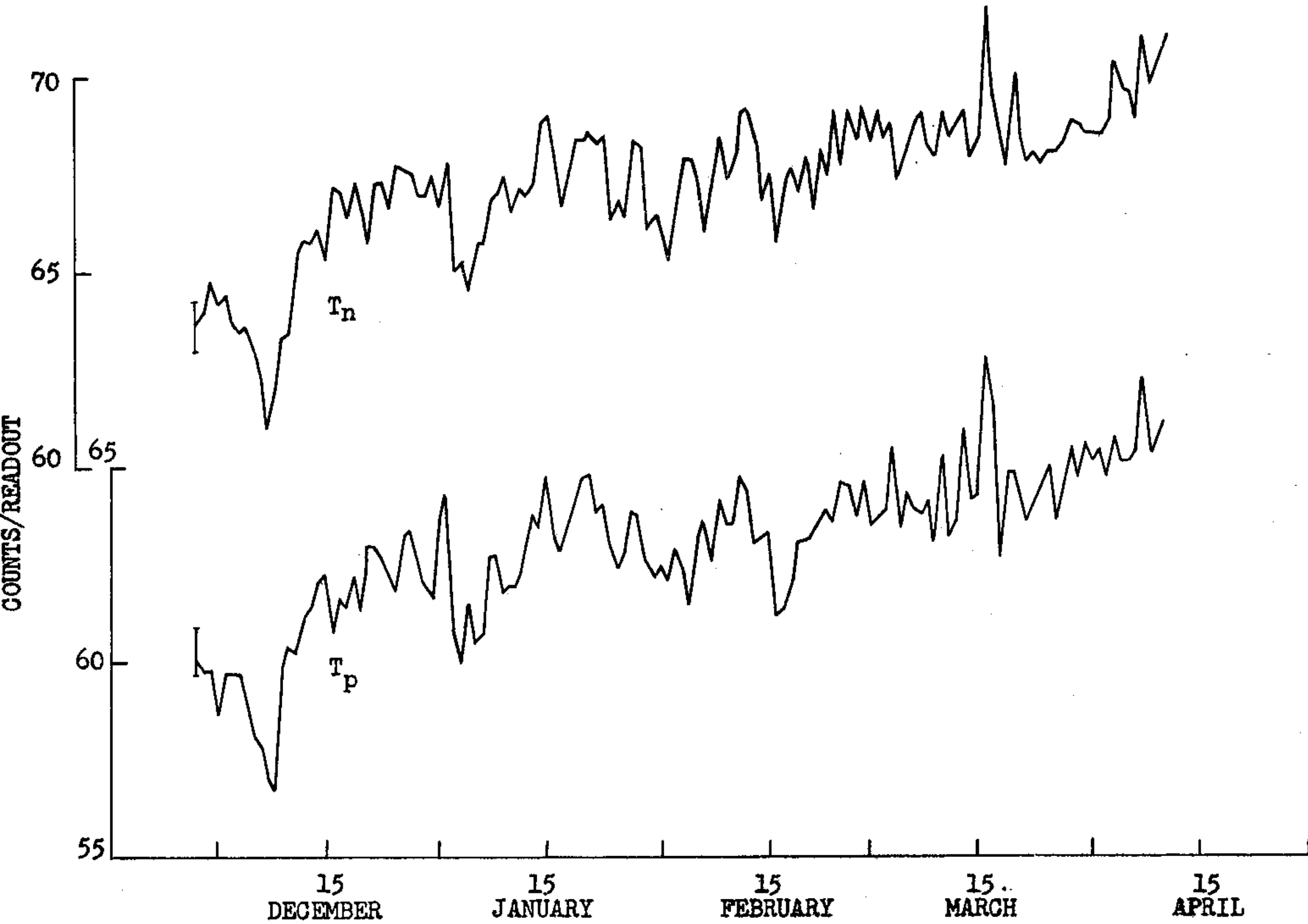
NORTH ECLIPTIC POLE
+45
ECLIPTIC
DECLINATION
0
-45
SOUTH ECLIPTIC POLE
90
180
270
RIGHT ASCENSION
"LOOK" DIRECTION OF TELESCOPE ALONG SPIN AXIS
"LOOK" DIRECTION OF TELESCOPE PERPENDICULAR TO SPIN AXIS

FIG. 2



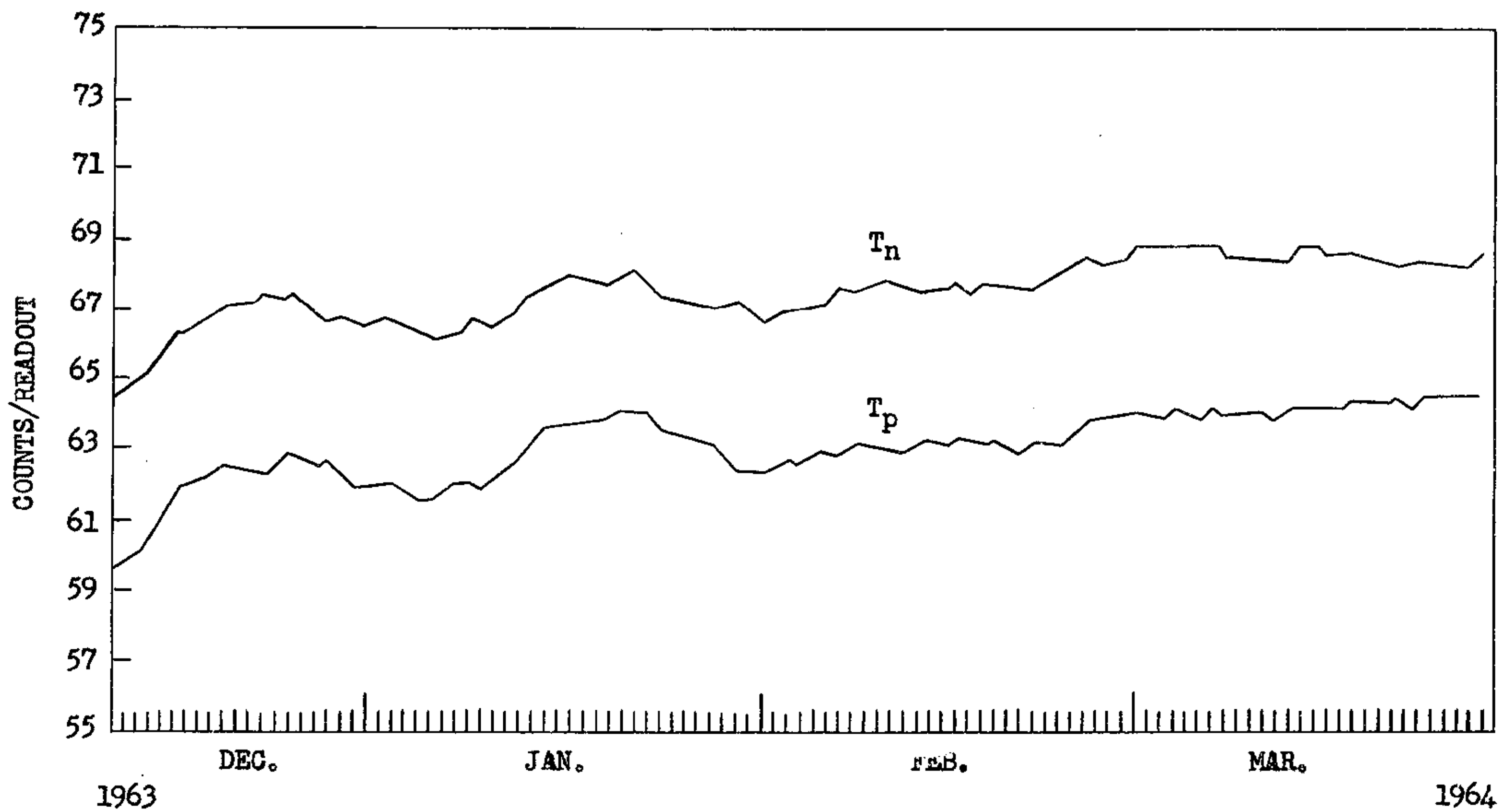
DAILY AVERAGES OF THE SUM, THE C DETECTOR AND DEEP RIVER NEUTRON MONITOR

FIG. 3



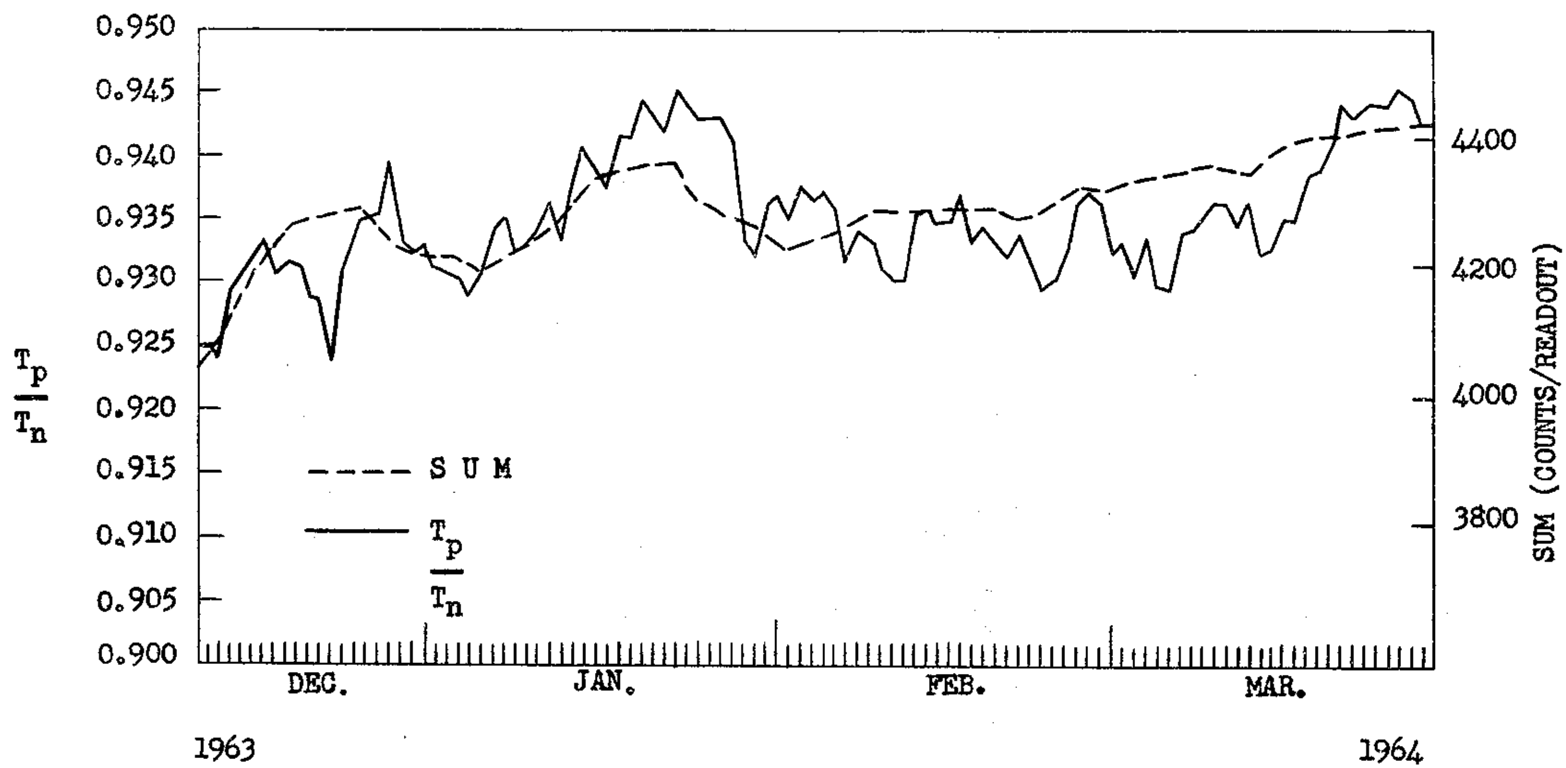
DAILY AVERAGES OF THE PARALLEL (T_p) AND PERPENDICULAR (T_n) TELESCOPES

FIG. 4



MOVING AVERAGES OF T_p AND T_n

FIG. 5



MOVING AVERAGES OF THE DAILY AVERAGES OF SUM AND $\frac{T_p}{T_n}$

FIG. 6

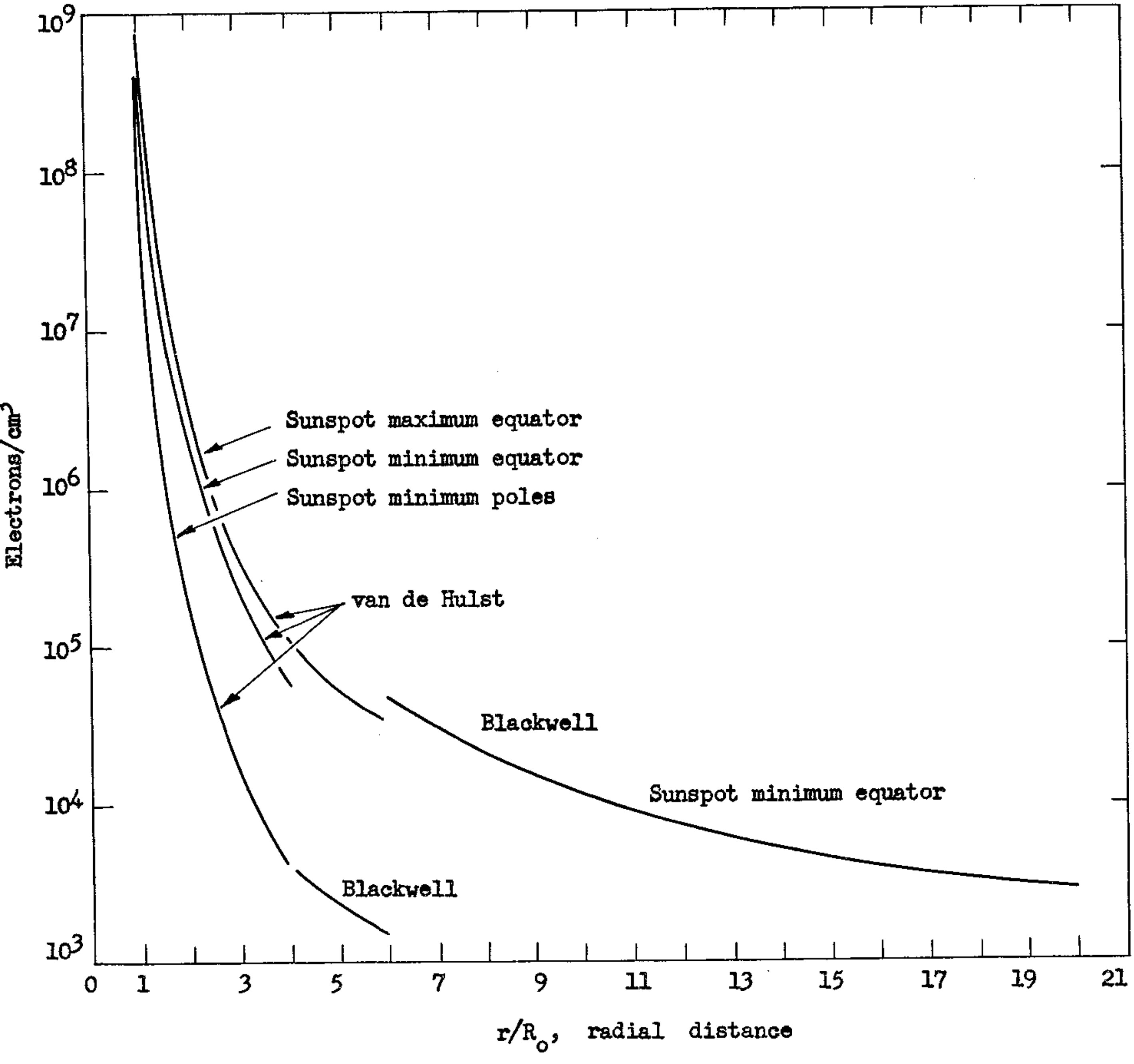
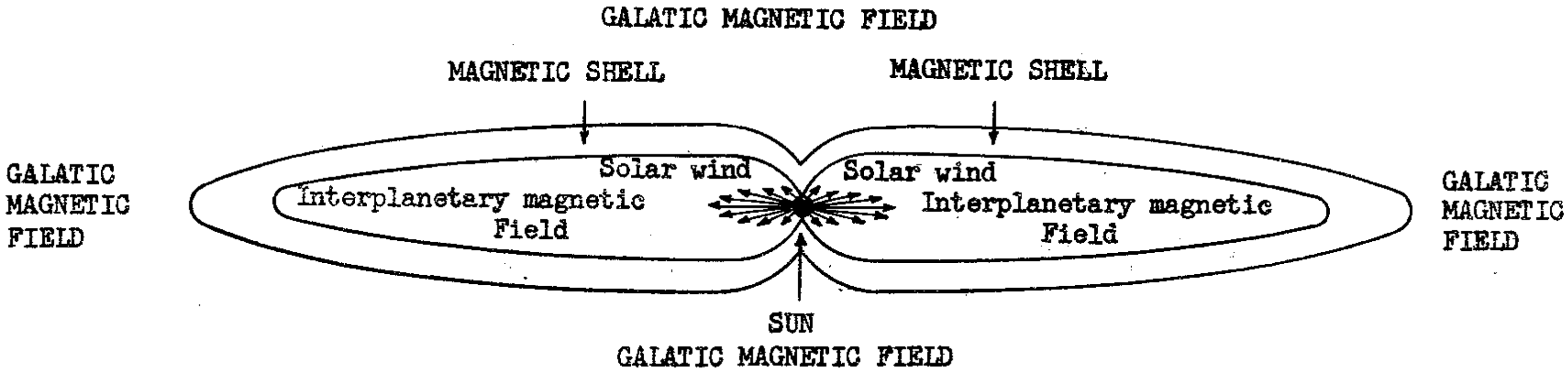

10^9
10^8
10^7
10^6
10^5
10^4
10^3
Electrons/cm^3
Sunspot maximum equator
Sunspot minimum equator
Sunspot minimum poles
van de Hulst
Blackwell
Sunspot minimum equator
Blackwell
0 1 3 5 7 9 11 13 15 17 19 21
r/R_o, radial distance

FIG. 7



SHAPE OF SOLAR CAVITY NEAR SOLAR MINIMUM

FIG. 8

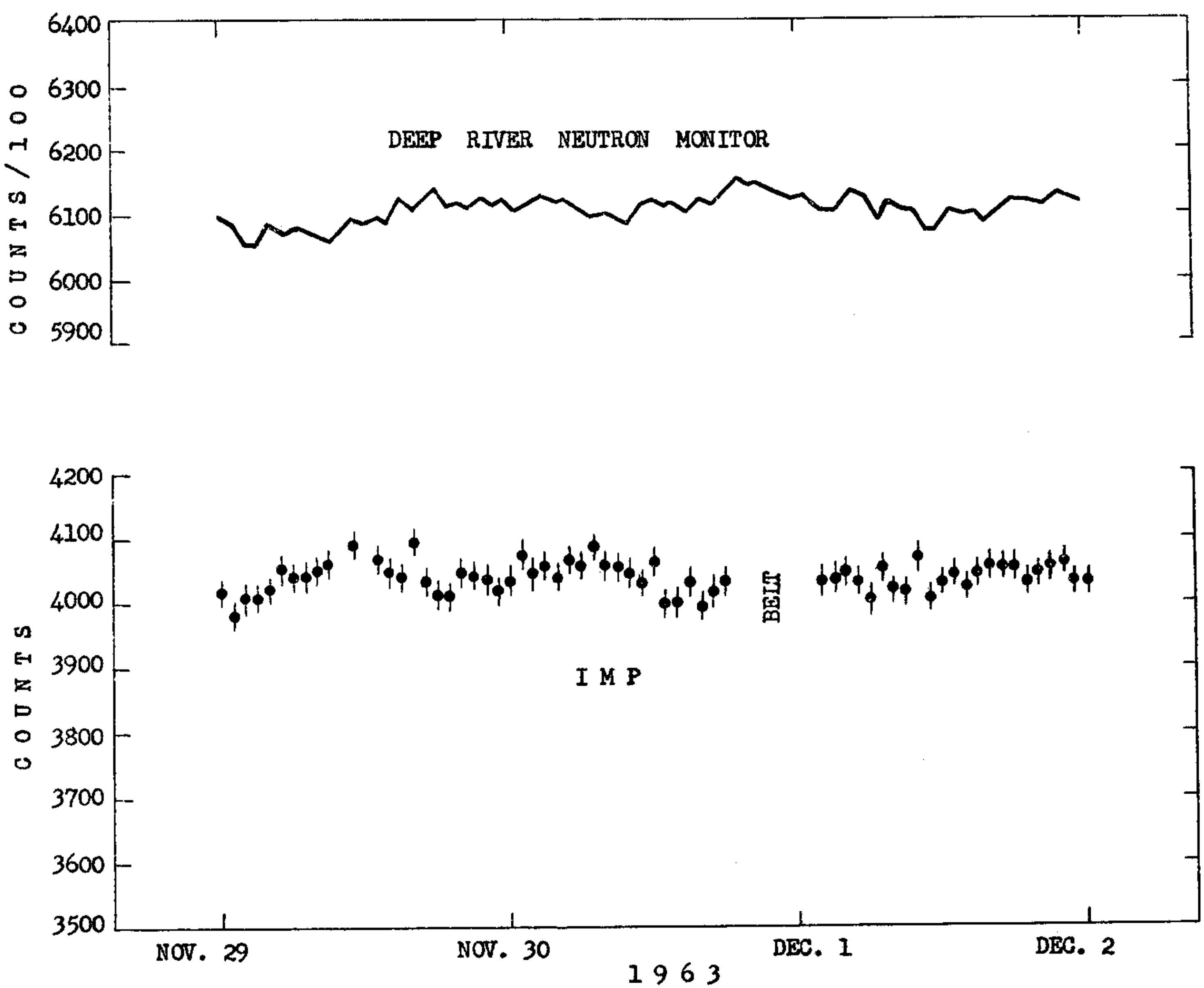
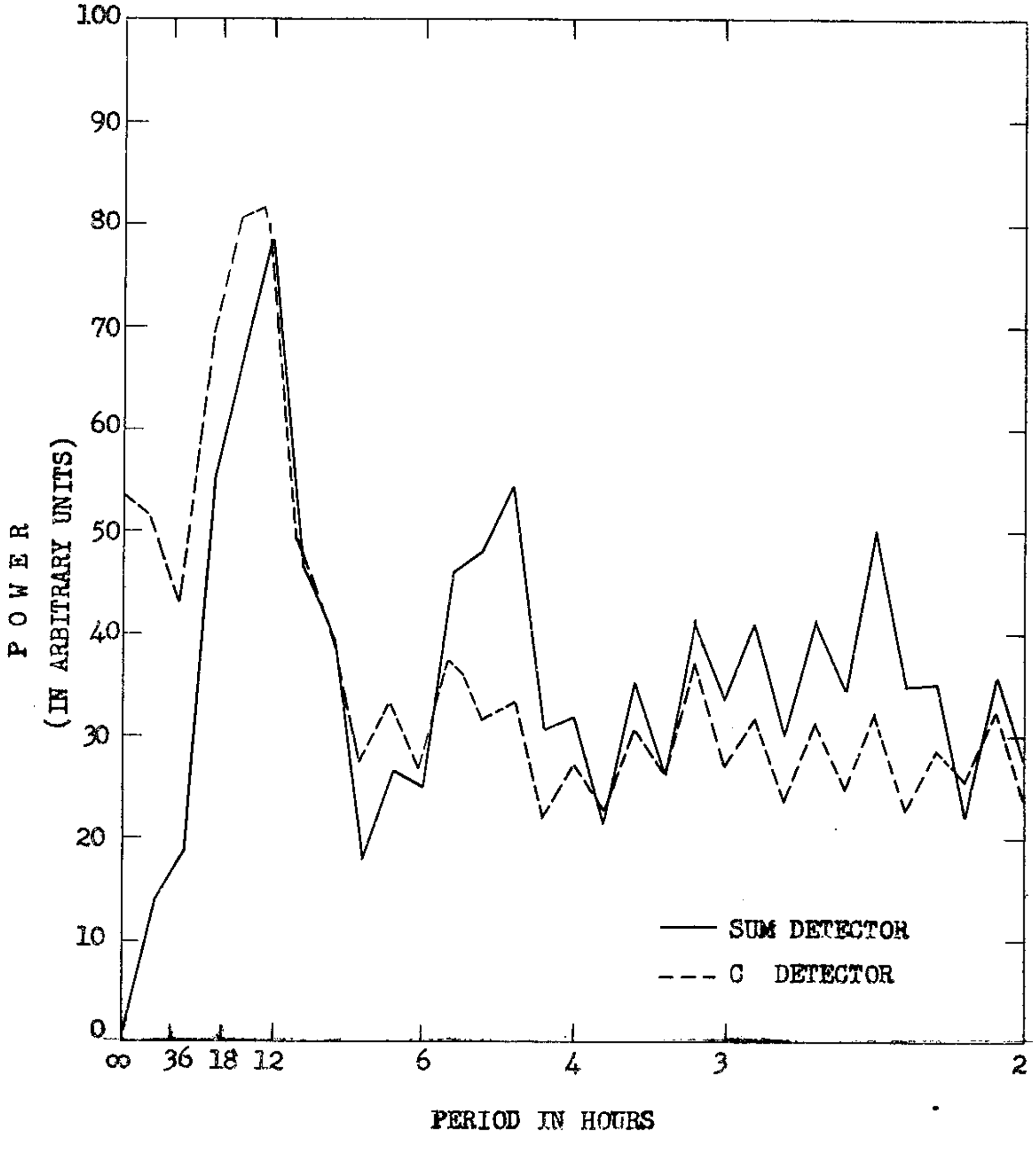

DEEP RIVER NEUTRON MONITOR
COUNTS/100
6400
6300
6200
6100
6000
5900
IMP
BELT
COUNTS
4200
4100
4000
3900
3800
3700
3600
3500
NOV. 29
NOV. 30
DEC. 1
DEC. 2
1963

FIG. 9



P O W E R   S P E C T R U M

FIG. 10