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Further Remarks on the Absence of a Very Extended Magnetospheric Tail

by

J. A. Van Allen
University of Iowa
Iowa City, Iowa 52240

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Any worthy theory of the structure and length of the magnetospheric tail must be prepared to deal with questions of quantitative physical significance. That is to say, it must be subject to one or more observational tests which can, at least in principle, determine the presence or absence of the tail at specified points in space. Dessler and collaborators [Dessler, 1964] [Michel and Dessler, 1965] [Dessler and Juday, 1965] [Michel, 1965] have hypothesized that the magnetospheric tail of the earth extends to some 20 to 50 astronomical units ($\sim 10^6$ earth radii) in the anti-solar direction. Dungey [1965] has contested this hypothesis on grounds of semi-empirical implausibility. Nonetheless, it is of interest to subject the hypothesis of Dessler to further observational tests. Dessler et al. have suggested three test questions of an observational nature:

<u>Test Question I</u>: Is the vector magnetic field due to the tail observable in the presence of the interplanetary magnetic field of the solar wind, the latter being the physical agent for the production of the tail? [Dessler, 1964]

<u>Test Question II</u>: Is the arrival of low energy ($\lesssim 5$ MeV) solar protons at the top of earth's atmosphere during the early phase of a PCA event preferentially in the auroral zones (geomagnetic latitude $\sim 68°$) and <u>not</u> within the polar caps? [Michel and Dessler, 1965]

<u>Test Question III</u>: Does the effective geomagnetic cut-off for solar protons vanish at the same latitude for all energies less than ~ 40 MeV and with a "sharpness" in latitude corresponding to a gyro-radius?

Inasmuch as the generation of super-thermal electrons in agitated plasmas is a well-known, though poorly understood, phenomenon in the laboratory, in astrophysical systems [Parker, 1965] and more specifically in the magnetospheric tail itself out to anti-solar distances at least as great as 32 earth radii [Frank, 1965] [Anderson, 1965], I have proposed a fourth test question:

<u>Test Question IV</u>: To what anti-solar distance in the earth's magnetospheric tail are there detectable intensities of super-thermal electrons? [Van Allen, 1965]

As described in the immediately foregoing reference, I have used Mariner IV data during late January--early February 1965 to provide a limited answer to T. Q. IV. The answer was a negative one at an anti-solar distance of 3300 earth radii (0.14 astronomical unit) to within the carefully specified conditions of the observations and characteristics of the equipment. I have no delusions about the comprehensive significance of these measurements but I do consider that they contribute to a rational consideration of the basic hypothesis. Thus I do not disagree with the strict substance of Michel's [1966] remarks in the accompanying letter but I do continue to believe that the Mariner IV particle measurements favor the belief that the earth's magnetospheric tail is physically insignificant at 3300 earth radii, in the spirit of T. Q. IV.

With respect to T. Q. I, Heppner et al. [1963] and Ness [1965] have shown the clear detectability of the magnetic field of the earth's tail out to distances of about 43 earth radii, but Coleman et al. [1965] found no detectable effect with the Mariner IV magnetometer at 3300 earth radii. The latter result is ignored by Michel, possibly again on the grounds that Mariner IV came no closer than a geocentric angle of 1° to the idealized center line of the earth's tail. Such a point-of-view may be valid but I find it difficult to believe that a weak and extended magnetospheric tail could be attached to the earth as rigidly and ideally as Michel maintains.

Turning to T. Q. II, Michel and Dessler [1965] cite the study of Hakura [1964] on the 9-12 February 1958 solar cosmic ray event as providing specific support to their hypothesis. The papers of Hakura [1964] and Hakura and Nagai [1964] do indeed provide a beautifully detailed study of the complex ionospheric phenomena associated with the aforementioned event. But these effects are almost certainly due to a complex admixture of causes--solar protons, "auroral zone electrons", and electrons and protons precipitated from the outer radiation belt. The portion of the ionospheric effects which is most reasonably attributable to solar protons is that designated as (PCA)p by Hakura and Nagai. The growth of the (PCA)p precipitation pattern is exactly contrary to that anticipated by Michel and Dessler, since it appears first near the pole and subsequently expands toward lower latitudes.

A much more clear-cut response to T. Q. II and to T. Q. III is provided by study of the September 1963 solar proton data of the magnetically oriented satellite Injun III using a combination of particle detectors, especially the solid state detector of Bostrom for the direct and specific detection of protons in the narrow energy range 1 to 2 MeV and within a narrow angular range. A time sequence of passes shows without exception a monotonically increasing (or constant) intensity of such protons with increasing latitude over the range $4 < L < 30$, again contrary to the expectation of Michel and Dessler (T. Q. II). Also contrary to the expectation of Michel (T. Q. III), the principal increase in intensity with increasing latitude occurs rather gradually over about 4° in latitude--that is, over a latitudinal distance of some 450 km or about 100 gyro-radii. A detailed paper on these results is in preparation by Bostrom of the Applied Physics Laboratory of Johns Hopkins University and by Harding and Van Allen of the University of Iowa.

On the strength of the foregoing discussion, I conclude (a) that there is no observational evidence whatever in favor of the hypothesis of Dessler et al. and (b) that there is indeed substantial observational evidence to the contrary.

It is planned to continue the observational exploration of the magnetospheric tail out to 60 earth radii with the "lunar-anchored" spacecraft, IMP's D and E.

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Comments on Paper by J. A. Van Allen,
'Absence of 40 keV Electrons in the Earth's
Magnetospheric Tail at 3300 Earth Radii'

F. C. Michel
Department of Space Science
Rice University, Houston, Texas
and
NASA Manned Spacecraft Center
Houston, Texas

In examining the above paper [Van Allen, 1965], it is possible one might get the impression that the absence of detectable 40 keV electron fluxes has somehow been interpreted as indicating the absence of a geomagnetic tail extending to 3300 earth radii (R_E). However, such is evidently not Van Allen's interpretation, for he emphasizes in conclusion that ' ... the magnetospheric tail of the earth becomes unobservable by the means used in this investigation between 32 and 3300 R_E ... ' Furthermore, he points out that the available data on electrons in the tail out to 32 R_E [Anderson, 1965] would not support an expectation of seeing detectable fluxes ($j \geq 2$ electrons/cm^2 sec ster) of 40 keV electrons.

Anderson observes the flux of magnetosheath electrons in the geomagnetic tail dropping very rapidly into the background (e-folding distances no larger than 1 R_E) in distances less than 32 R_E, while the "islands" of high ($2 \geq 10^5$/cm^2 sec ster) electron fluxes are observed with rapidly decreasing frequency at increasing radial distances [Anderson, 1965, Figs. 19A and 19B].

Unfortunately a few comments in the paper could be misinterpreted, such as the one immediately preceding the conclusion quoted above, which reads, ' ... it seems quite unlikely that the tail, if indeed significant at this distance, would not have "waggled" past the spacecraft close enough to produce an effect equivalent to an average intensity $j \geq 2/cm^2$ sec ster for 4 hours.' One must conclude this to be some sort of error that has slipped by unnoticed: Van Allen has indicated in this same paper, that there is no reason to expect $j \geq 2/cm^2$ sec ster at large distances even if the spacecraft were continuously in the tail. Furthermore, Van Allen is undoubtedly aware that (1) no experimental evidence exists that can be uniquely interpreted as waggling of the tail and (2) the only pertinent theoretical work indicates either motion essentially in the ecliptic plane (hence, almost parallel to the Mariner 4 trajectory) [Dessler and Fejer, 1963], or motion in the immediate vicinity of the earth where the bow shock is strong [Dessler and Walters, 1964]. Thus there is no reason to expect a vehicle 52 R_E above the ecliptic plane to necessarily intersect the tail.

Similarly two discussions on detector sensitivity [items (g) and (h) of page 4736, Van Allen, 1965], in which it is argued that rather large ($j = 10^2/cm^2$ sec ster) fluxes are unlikely to escape detection, could be misinterpreted by the casual reader as indicating that Van Allen somehow expects such fluxes in the vicinity of the magnetospheric tail, even at 3300 R_E. Such an interpretation again seems inconsistent with Van Allen's assessment of Anderson's data.

From the data presented in the above paper it is evident that no conclusion can be drawn regarding the length of the magnetospheric tail.

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Absence of 40-kev Electrons in the Earth's Magnetospheric Tail at 3300 Earth Radii

J. A. VAN ALLEN

Department of Physics and Astronomy
University of Iowa, Iowa City

Abstract. The Mars-bound spacecraft Mariner 4 drifted westward through the presumed region of an extended magnetospheric tail of the earth during late January and early February 1965 at a geocentric radial distance of $\sim 3300 R_E$ (earth radii). A pair of thin-window Geiger tubes with wide-angle collimators, which had shown the presence of electrons $E_e > 40$ kev out to $23R_E$ in the morning fringe of the magnetosphere during the early phase of the flight, failed to detect any effects of a magnetospheric tail during 7 days of flight within a geocentric angle between 1° and 5° from its presumed center line.

INTRODUCTION

The interaction between the solar wind and the earth's magnetic field results in the partial conversion of the directed kinetic energy of the solar wind into quasi-thermal energy of the constituent particles. The most direct evidence for this aspect of the interaction phenomena comes from the observation of electrons having kinetic energies E_e in the range from about 1 kev to some tens of kev in the transition region on the sunward side of the magnetopause [*Freeman et al.*, 1963; *Freeman*, 1964; *Fan et al.*, 1964; *Frank and Van Allen*, 1964*a*; *Anderson et al.*, 1965] (see theoretical discussion by *Scharf et al.* [1965]), in the evening and morning wings of the transition region, and in the magnetospheric tail [*Van Allen and Frank*, 1959; *Gringauz*, 1961; *Frank et al.*, 1963; *Frank and Van Allen*, 1964*b*; *Anderson et al.*, 1965; *Frank*, 1965]. Directional intensities of electrons $E_e > 40$ kev exceeding 10^4 (cm^2 sec ster)$^{-1}$ are commonly observed. These electrons usually occur in spatial or temporal patches, or both, in the above-mentioned regions. *Anderson and Harris* [1965] have found (*a*) that such patches exist in the magnetospheric tail out to the maximum antisolar distance of their observations, $32R_E$ (earth radii) from the earth's center; (*b*) that they have a transient existence for times of the order of minutes to hours; (*c*) that the time duration of a given patch, typically an hour, is more or less independent of radial distance; (*d*) that the apparent spatial dimension of patches, typically $1R_E$ at $25R_E$ radial distance, decreases with increasing radial distance; and (*e*) that the frequency of occurrence of patches (number of patches per unit time of observation) increases with increasing geomagnetic activity but decreases with increasing distance in such a way that the effect might be thought to have vanished beyond, perhaps, $100R_E$.

Dessler [1964] and *Michel* [1965] have given theoretical arguments which suggest that the magnetospheric tail may be detectable by its influence on the configuration of the interplanetary magnetic field to antisolar distances as great as 20 to 50 astronomical units ($\sim 10^6 R_E$). The physical plausibility of such a suggestion has been contested by *Dungey* [1965] on detailed grounds; he regards $10^3 R_E$ as a reasonable outer bound. Other recent theoretical papers relevant to this subject are by *Piddington* [1965] and by *Axford et al.* [1965].

Interest in this matter is heightened by several other observational investigations:

(*a*) Diverse statistical evidence has been presented both for and against a significant geomagnetic effect due to the moon and to the inner planets Mercury and Venus, and for and against the influence of the earth on Mars. (See *Bowen* [1964]; *Bigg* [1964]; *Davidson and Martyn* [1964]; *Six et al.* [1965]; and *Michel et al.* [1964] for recent brief reviews).

(*b*) *Ness* [1965] has reported one or perhaps two examples of disturbances in the interplanetary magnetic field as measured by a satellite-borne magnetometer at $30R_E$ from the earth's center on its sunward side and near the sun-moon line at ~140 lunar radii or 243,000 km 'downstream' from the moon. The apparent diameter of the disturbed region was some 70 lunar radii at this distance. Ness interprets this effect as evidence for a magnetic wake of the moon caused by perturbation of the solar-wind flow by the body of the moon (cf. *Michel* [1965]).

The present paper reports observations of electrons $E_e > 40$ kev with equipment on the Mars flyby spacecraft Mariner 4 during its incidental passage through the region presumably occupied by an extended magnetospheric tail of the earth at an antisolar geocentric distance of $\sim 3300R_E$.

Trajectory of Mariner 4

The spacecraft Mariner 4 of the National Aeronautics and Space Administration and its Jet Propulsion Laboratory were launched successfully at 1422 UT on November 28, 1964. For the purposes of this paper it is convenient to describe the trajectory of the spacecraft in an earth-centered system of Cartesian coordinates X, Y, Z with $\hat{x}$ inward toward the sun along the earth-sun line, $\hat{y}$ in the plane of the ecliptic, and $\hat{z}$ northward, perpendicular to the plane of the ecliptic. The position of the spacecraft is specified by its Cartesian coordinates (x, y, z) or by spherical polar coordinates (r, θ, ϕ), where r is the geocentric radial distance; θ is the geocentric ecliptic latitude, positive north of the X-Y plane; and ϕ is the azimuthal angle in the X-Y plane measured eastward from the X axis. This system of coordinates is sometimes called a geocentric solar ecliptic coordinate system. The wobble (due to the moon) of the center of the earth by a few hundred kilometers about its mean position along the ecliptic is taken as negligible for most of the considerations of this paper. Numerical values of trajectory quantities are taken directly or derived from the post-mid-course-maneuver ephemeris computed by the Jet Propulsion Laboratory on December 15, 1964, and designated IBSYS-JPTRAJ-SFPRO 111464.

Figure 1 shows the time-labeled trace of the trajectory projected on the X-Y plane; the central portion of Figure 3 shows r, z, and (ϕ − 180°) as functions of time. These plots show the slow westward drift of the spacecraft through the region presumably occupied by an extended magnetospheric tail. Sets of data at two times of special interest are given to greater accuracy than is available on the figures:

(*a*) On January 28, 1965, at 2000 UT (spacecraft time):

$x = -19{,}230{,}300$ km ($3018R_E$).
$y = +16{,}500$ km ($2.6R_E$).
$z = +323{,}000$ km ($50.7R_E$).
$r = 19{,}233{,}000$ km ($3019R_E$).
$\theta = +0.96°$.
$(\phi - 180°) = -0.05°$.

(*b*) On February 1, 1965, at 0800 UT (spacecraft time):

$x = -20{,}889{,}900$ km ($3279R_E$).
$y = +1{,}560{,}400$ km ($245R_E$).
$z = +335{,}400$ km ($52.6R_E$).
$r = 20{,}949{,}800$ km ($3288R_E$).
$\theta = +0.92°$.
$(\phi - 180°) = -4.3°$.

Apparatus

The University of Iowa package of low-energy particle detectors on Mariner 4 comprises three end-window Geiger-Müller tubes (EON type 6213), designated A, B, and C, respectively; and one thin (35 micron) surface barrier solid-state detector (Nuclear Diodes, Inc.) having two discrimination levels, designated D_1 and D_2. Each of the four detectors has a conical collimator with a full vertex angle of 60° (nominal). The axes of the collimators of B, C, and D are parallel to each other at an angle of 70° to the roll axis of the spacecraft, and the axis of the collimator of A is at an angle

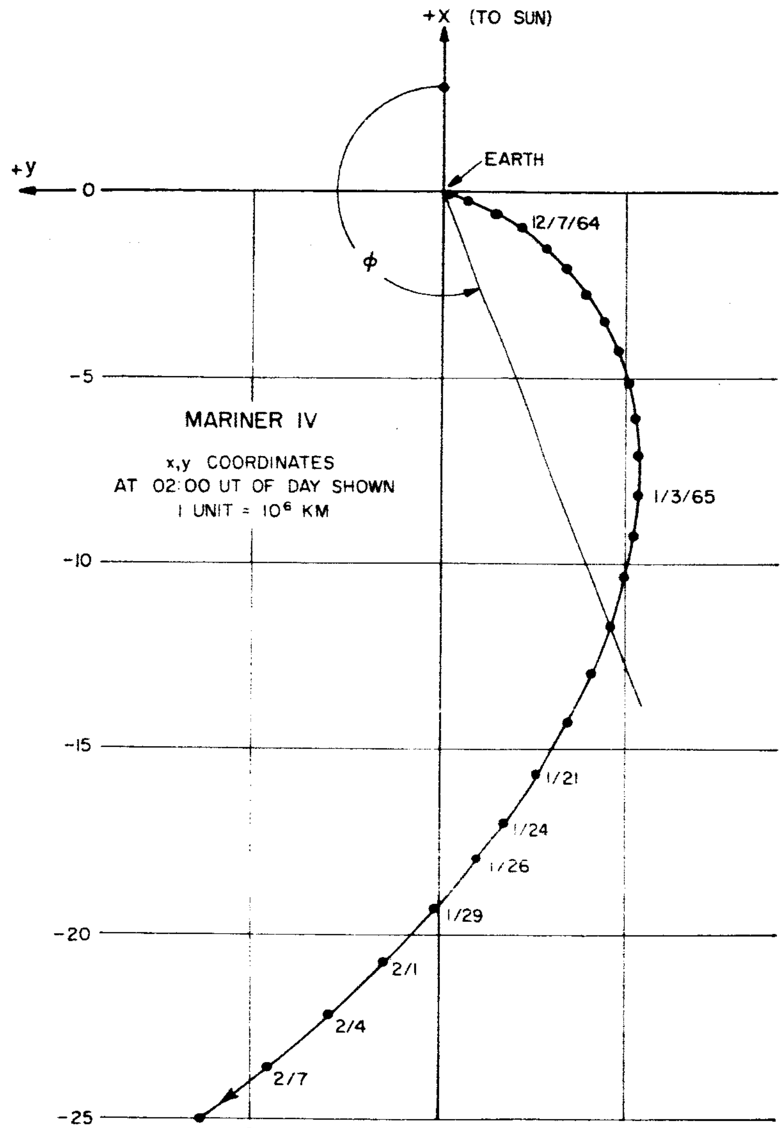

Fig. 1. Time-labeled projection of the trajectory of Mariner 4 on the ecliptic plane as referred to geocentric solar ecliptic coordinates.

of 135°. The roll axis of the spacecraft is directed continuously at the sun with an error of less than 1°; rotation of the spacecraft about this axis is controlled in such a way as to point the axis of a spacecraft-fixed, directional antenna approximately toward the earth. Thus, detectors *B*, *C*, and *D* receive particles moving generally outward from the sun and at angles to the sun-to-probe vector of 70° ± 30°. The detectors themselves and the complete inner walls of their collimators are shielded from direct light and X rays from the sun. Detector *A* receives particles moving generally inward toward the sun at angles to the sun-to-probe vector of 135° ± 30°. The sidewall shielding of all detectors has a minimum thickness corresponding to the range of ~50 Mev protons. Both channels of the solid-state detector *D* are quite insensitive to electrons of any energy. It is equipped with an $_{95}Am^{241}$ source of ~5.4

TABLE 1. Characteristics of Detectors

Detector	Unidirectional Geometric Factor, cm^2 ster	Omnidirectional Geometric Factor, cm^2	Particles to Which Sensitive	Dynamic Range, counts/sec
A	0.044 ± 0.005	~ 0.15	Electrons: $E_e \gtrsim 45$ kev Protons: $E_p > 670 \pm 30$ kev	From galactic cosmic ray rate of 0.6 to 10^7
B	0.055 ± 0.005	~ 0.15	Electrons: $E_e \gtrsim 40$ kev Protons: $E_p > 550 \pm 20$ kev	From galactic cosmic ray rate of 0.6 to 10^7
C	0.050 ± 0.005	~ 0.15	Electrons: $E_e \gtrsim 150$ kev Protons: $E_p > 3.1$ Mev	From galactic cosmic ray rate of 0.6to10^7
D_1	0.065 ± 0.003	...	Electrons: None Protons: $0.50 \leq E_p \leq 11$ Mev	From in-flight source rate to 10^6
D_2	0.065 ± 0.003	...	Electrons: None Protons: $0.88 \leq E_p \leq 4.0$ Mev	From in-flight source rate to 10^6

Mev α particles which provides in-flight background rates of 0.071 and 0.059 $(sec)^{-1}$ on D_1 and D_2, respectively.

Further details about the detectors are given in Table 1.

The five University of Iowa data channels are part of a commutated sequence of eight: *E*, *B*, D_1, D_2, *E*, *B*, *A*, *C* (where *E* represents the data channel from another experiment). The basic frame of telemetry during the 'cruise mode' (8⅓ bits/sec for entire spacecraft), which was employed throughout the period of the present study, is of 50.4-second duration. Unscaled counts from each of the detectors corresponding to the above eight channels are gated in turn into a shift register of 19 bits plus 2 overflow bits for a 45.0-second period and are read out through the spacecraft telemetry system during the subsequent 5.4 seconds. A complete cycle of eight detectors is completed each $8 \times 50.4 = 403.2$ seconds. Thus the 'duty cycle' of each of the four channels *A*, *C*, D_1, and D_2 is 11.2%, and that of channel *B* is 22.3%.

Charged-Particle Observations January 20 to February 5, 1965

As has previously been reported [*Van Allen*, 1965], the interplanetary intensity of low-energy particles (electrons $E_e \gtrsim 40$ kev and protons $E_p \gtrsim 0.5$ Mev) is strikingly less during early 1965 than during the period of Mariner 2 observations, August 1962 to January 1963 [*Van Allen et al.*, 1964]. This fact aids the search for small effects attributable to the earth.

Of the four detectors in the University of Iowa equipment, the low-energy electron detectors *A* and *B* are the most sensitive for the detection of a magnetospheric tail. A specific demonstration is provided by the data from Mariner 4 itself during its outbound traversal of the morning fringe of the magnetosphere on November 28–29, 1964. The responses of detectors *A*, *B*, and *C* during this period are shown in Figure 2. The intensity of protons $0.5 \leq E_p \leq 11$ Mev (D_1) drops to an undetectable level at a radial distance of $10.5 R_E$ [*Krimigis and Armstrong*, 1965] (not shown in Figure 2), but electrons $E_e > 40$ kev are clearly detectable out to $23 R_E$, with an apparently significant spike at $25.7 R_E$. The unidirectional geometric factors of detectors *A* and *B* on Mariner 4 (Table 1) are more than 20 times as great as those of similar low-energy electron detectors used by this laboratory in Explorer 14 and Ogo 1 and by Anderson et al. in Imp 1, Imp 2, and Imp 3. Their omnidirectional geometric factors, how-

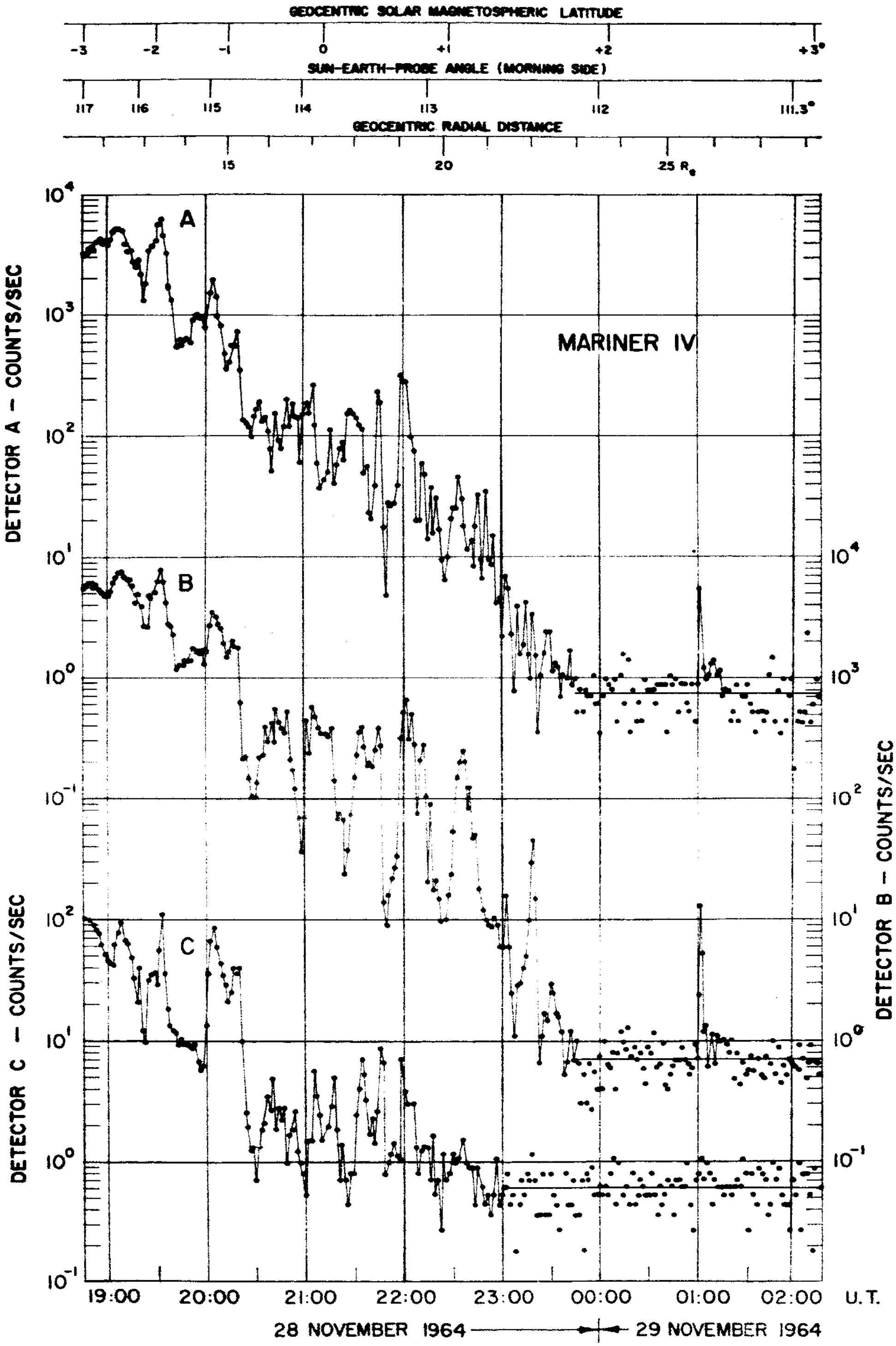

Fig. 2. Counting rates of detectors *A*, *B*, and *C* on Mariner 4 during traversal of the morning fringe of the earth's magnetosphere.

ever, are about the same. Hence the detectors on Mariner 4 have a 20-fold increase in signal-to-noise ratio for the detection of electrons having energies of the order of some tens of kev.

Four-hour averaged counting rates of detectors A and B during the period January 20 to February 5, 1965, are shown in Figure 3, together with relevant trajectory parameters.

Both sets of counting rates show a noteworthy absence of any effect due to a presumed magnetospheric tail.

A similar result is found for detectors C and D_1 and D_2, though the sensitivity of these detectors for the detection of a magnetospheric influence is much less than that of A and B, and their counting rates are not discussed in detail.

The foregoing impression is made more quantitative as follows:

(*a*) The mean rates of A and B with their statistical standard deviations during the entire period shown are 0.689 ± 0.002 and 0.585 ± 0.0015 count/sec, respectively.

(*b*) Similar rates are observed along segments of the trajectory quite remote from any conceivable terrestrial effects.

(*c*) The omnidirectional geometric factors of detectors A and B for penetrating particles are not known with precision, but the rates quoted in (*a*) are attributable in a reasonable way to the interplanetary galactic cosmic ray intensity of 4.0 $(\text{cm}^2 \text{ sec})^{-1}$ as found by *Neher and Anderson* [1965] with a large Geiger tube, also on Mariner 4.

(*d*) The empirical and statistically expected standard deviations of 4-hour averages (about one-third of which suffer some loss of telemetry data) are, respectively, for A, 0.025 and 0.024, and for B, 0.016 and 0.016 count/sec.

(*e*) Of 94 four-hour averages of the counting rate of A during the period under study, 5 depart from the mean (2 high and 3 low) by more than 2 standard deviations and none by as much as 3. The corresponding departures for B are 4 (2 high and 2 low) by more than 2 standard deviations and none by as much as 3.

(*f*) The sensitivity of detectors A and B is as follows: An added unidirectional intensity $j = 2$ $(\text{cm}^2 \text{ sec ster})^{-1}$ of electrons $E_e \gtrsim 40$ kev throughout any 4-hour period would produce a departure of more than 3 standard deviations from the long-term 4-hour average. No such departures are observed.

(*g*) The above-quoted intensity is less by a factor of the order of 10^4 than that often observed in the magnetospheric tail out to $30R_E$. An added unidirectional intensity $j = 10^2$ $(\text{cm}^2 \text{ sec ster})^{-1}$ for an isolated period as brief as 200 seconds would cause an individual 45-second sample rate of either A or B or both to be increased by a factor of ~10 over its mean value and would cause the 4-hour average which included such a burst to depart by more than 3 standard deviations from the long-term 4-hour average. Again, no such event is observed throughout the 17-day period under discussion. It is not possible, of course, to exclude the occurrence of one or more bursts of duration less than 150 seconds, accurately and diabolically located between sampling intervals of both A and B.

(*h*) If electrons in the magnetospheric tail are streaming outward from the earth at angles less than 40° or inward at angles greater than 165° to the sun-probe line they will not enter the collimators of A or B. These possibilities constitute a qualification to the failure to observe an effect, but such neat directionality seems quite unlikely, in view of the 'roughness' in direction and magnitude of the **B** vector as reported by the magnetometer measurements on Mariner 4 during the same period [*Coleman et al.*, 1965].

Remarks and Conclusions

The value of $(\phi - 180°)$ varies from $+11°$ to $-9°$ during the period January 20 to February 5. The presumed angle of observation of the center line of the magnetospheric tail is the aberration angle $(\phi - 180°) = -\text{arc tan}$ (earth's orbital velocity/solar-wind velocity) $\approx -\text{arc tan } (30/400) = -4.3°$. Mariner 4 passed slowly through this value of $(\phi - 180°)$ at 0800 on February 1, 1965, at a distance of $52.6R_E$ above (north of) the plane of the ecliptic at a radial distance from the earth of $3288R_E$. The useful observational period extends to 1840 on February 5, when a solar cosmic ray event is encountered. At this time $(\phi - 180°)$ is $-9°$, the aberration angle corresponding to a solar-wind velocity of 200 km/sec, a value considerably lower than has been observed. A slightly positive effect is suggested by the upward march of the counting rate of detector A on February 1, but it is not significant statis-

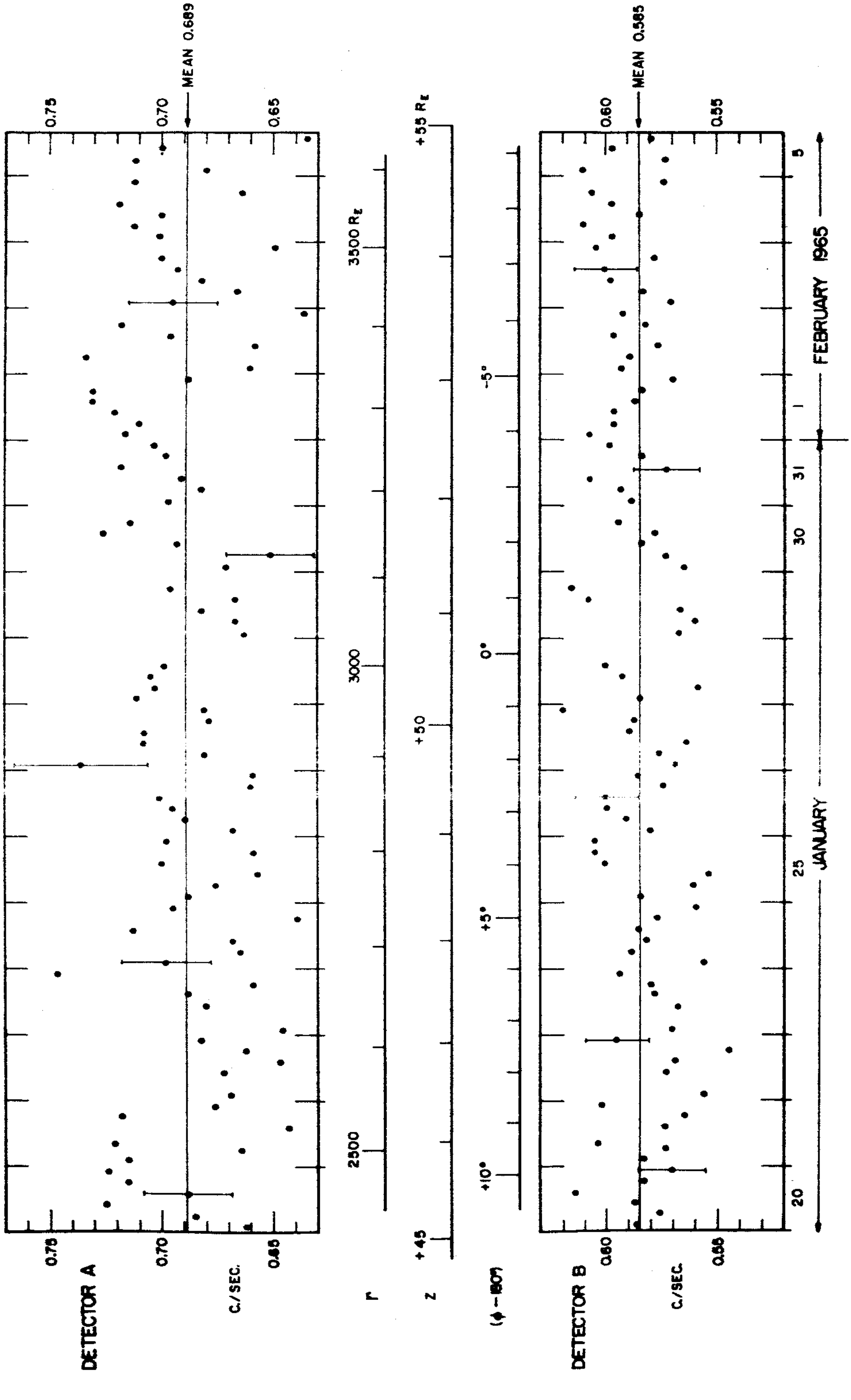

Fig. 3. Four-hour averaged counting rates of detectors *A* and *B* and relevant parameters of the trajectory of the spacecraft for the flight period January 20 to February 5, 1965.

tically; also, no such trend appears in the data from B.

It may be noted that the 3-hour planetary values of the magnetic index K_p are not greater than 3 during the period January 29 through February 5 (*Compilations of Solar-Geophysical Data,* May 1965, National Bureau of Standards). Hence solar-wind conditions may be presumed to be relatively quite during this period.

The radius of the outer fringe of the magnetosphere is about $20R_E$ in a plane through the earth perpendicular to the sun-earth line ($\phi = 90°, 270°$) and increases in the downstream direction. The 'downstream ratio' $3300R_E/20R_E = 165$ may be compared with the corresponding value of 140 for the lunar wake observations of Ness.

Since Mariner 4 made only a single pass along a somewhat off-center line through the presumed region of the magnetospheric tail, it may be argued that the previously described negative results do not establish the absence of a detectable tail at $3300R_E$. But, since the spacecraft spends some 7 days within a geocentric angle between 1° and 5° of the presumed center line of the tail (Figure 3), it seems quite unlikely that the tail, if indeed significant at this distance, would not have 'waggled' past the spacecraft close enough to produce an effect equivalent to an average intensity $j \geq 2$ (cm^2 sec ster)$^{-1}$ for 4 hours.

Hence, I conclude that the magnetospheric tail of the earth becomes unobservable by the means used in this investigation between 32 and $3300R_E$ (at least during conditions of mild geomagnetic activity). In view of the great interplanetary melee of lower-energy particles and turbulent magnetic fields this conclusion seems palatable.

The corresponding failure of the magnetometer on Mariner 4 to detect a magnetospheric tail at $\sim 3300R_E$ has been reported in a preliminary way by *Coleman et al.* [1965].

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