Reports

West Ford Dipole Belt: Optical Detection at Palomar

Abstract. *Optical detection of the West Ford orbiting dipole belt was accomplished on at least four occasions during the second week in May 1963. The maximum surface brightness was about 4 percent of the night sky radiation at an effective wavelength of $\bar{\lambda} = 4400$ Å. The density of the belt has evidently decreased because it was not detected in a second observation period during the third week in June.*

Optical observations of the West Ford orbiting dipoles were begun at the Palomar Observatory as soon as the orbital parameters of the belt were available. Calculations of the altitude and azimuth of the satellite carrier at selected times for the Palomar site were rapidly and effectively made by the Lincoln Laboratory of Massachusetts Institute of Technology. These data were transmitted to Palomar by W. Liller who was the liaison contact between the Lincoln Laboratory and the West Ford committee of the National Academy of Sciences.

We obtained positive photoelectric observations of the belt on at least four occasions, starting at 07^{hr} 11^{min} U.T., 14 May 1963. The observations were made with a 51-cm (20-inch) Cassegrain reflector, with a refrigerated 1P21 photomultiplier working through an electrometer amplifier and a strip-chart recorder.

The telescope was set at the predicted right ascension and declination of the belt passage some 5 to 10 minutes early, the sky-blocking diaphragm of the photoelectric equipment was opened to its largest size, the star field was inspected to see that all visible stars were excluded from the photometer field of view, and the sky brightness was monitored at a high amplifier gain. As the belt was expected to be only a few percent of the night-sky brightness (*1, 2*), we were looking for a small signal which should occur near the predicted time of the passage of the carrier satellite. This signal would be superposed on the more intense night-sky radiation. During the monitoring period, which lasted from 10 to 20 minutes, the telescope was tracking at the sidereal rate to avoid passage of stars through the field.

The effective diameter of our field diaphragm was 6.4 minutes of arc on the plane of the sky. The observations were made behind a blue filter consisting of Schott BG12 glass, 0.7-mm thick, cemented to Schott GG13 filter, 2.0-mm thick. This combination transmits from $\lambda \simeq 3900$ Å to $\lambda \simeq 4800$ Å between half power points with an effective wavelength of $\bar{\lambda} \simeq 4400$ Å.

Figure 1 shows the record of the first two observed passes of the belt. Time increases from right to left in each of the tracings. The observation on 13 May at 23^{hr} 11.0^{min} P.S.T. (07^{hr} 11.0^{min} U.T., 14 May) was made as the moon was just below the horizon and rising in the east, which accounts for the slope of the sky signal. The observation was started with a 1-second time constant, after which it was continued with a 10-second time constant. This explains why the first 20 seconds of the sky signal has higher than normal fluctuations. The predicted time of passage of the satellite carrier on 13 May was 23^{hr} 11^{min} P.S.T. which agrees exactly with the observed time of the increase in signal seen on the record. From this and later observations we believe this signal was due to the West Ford belt. The observation on 16 May was made in a moonless sky. The increase in signal occurred at 23^{hr} 17.2^{min} P.S.T. which was 2.2 minutes later than the predicted carrier passage. Evidently the part of the needles belt which we detected was lagging behind the carrier on this date. Similar lags were observed on all subsequent positive observations of the belt.

It should be mentioned that on three occasions (05^{hr} 30^{min} U.T., 18 May; 04^{hr} 25^{min} U.T., 23 June; and 04^{hr} 30^{min} U.T., 26 June) the satellite carrier passed through the photometer field, causing a large and sudden increase in the signal which decayed with the 10-second time constant of our equip-

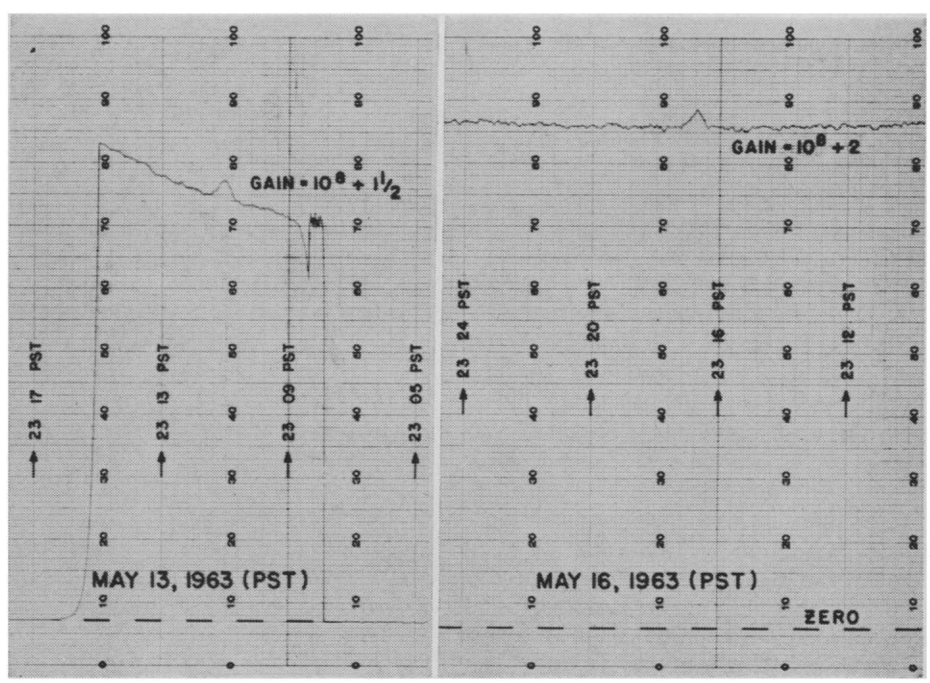

Fig. 1. The original record of the sky brightness with the superposed West Ford belt signal for 13 May and 16 May 1963. The gains represent values of the amplifier setting.

Table 1. Signals from West Ford dipoles. The figures in parentheses refer to observations that may not have been of the dipole belt.

Date (May 1963)	U.T. (hr min)	Sky brightness mag/□″	Belt brightness mag/□″	Belt % of sky	Duration of signal (sec)	Belt passage deviation (min)
14	07 11.0	22.4	25.8	4.5	52	on time
16	06 17.2	22.4	26.5	2.4	82	2.2 late
17	07 16.7	22.6	26.2	3.5	48	1.7 late
18	05 29.5	22.2	(26.3)	(2.2)	(105)	(0.5 early)
18	08 17.4	22.5	26.4	2.6	77	2.4 late
30*	08 51.5	21.8	(26.4)	(1.6)	(54)	(1.5 late)

* Observation on this date by S. Chandra.

ment. We estimate that the magnitude of the carrier is approximately between seventh and eighth blue magnitude. In each case, the passage was at the predicted time, to within the accuracy of our measurements.

Table 1 lists the data for the four definite observations of the belt, together with two uncertain observations on 18 May and 30 May U.T. The photometric records were reduced to the unit of equivalent B magnitude per square second of arc (mag/□″) by observing standard stars on each night.

The surface brightnesses were further converted to absolute units by noting that a star of blue magnitude $B = 0$ has a flux of 4.3×10^{-23} watts meter^{-2} per cycle per sec bandwidth, or 6.6×10^{-9} erg sec^{-1} cm^{-2} per Å bandwidth. Table 2 lists the data for the belt intensity expressed in these units.

These are probably minimum brightness values of the belt because we did not sweep the area to get the point of maximum signal. Since the belt was wider than our 6.4 minutes of arc diameter diaphragm we may have been observing on the fringes for some or for all of the time. It is, therefore, fair to state that the brightness was at least 4 percent of the night-sky surface brightness near the beginning of the observation period and that the densest part of the belt may have been brighter.

Evidently the surface brightness of the belt decreased with time. This may be suggested by column 4 of Table 1, but is more strongly suspected by attempts to observe the belt on 23, 26, and 27 June 1963. T. Greenfield, an observer from Rhodesia, had use of the telescope on these dates and we are indebted to him for his data. In these trials, no signal greater than 1 percent of the moonless night sky was found, which puts an upper limit of about 27.3 mag/□″ or 0.8×10^{-19} erg sec^{-1} cm^{-2} Å^{-1} (arcsec)$^{-2}$ for the belt brightness in the third week of June.

Our observations appear to be in agreement with the careful predictions of the optical surface brightness, made more than 2 years before launch by van de Hulst and Volders, by Liller as a check (*1*), and by Morrow and MacLellan (*2*). From the engineering standpoint we believe that the present belt does not constitute a serious interference to ground-based optical observation at the faintest light levels because the belt is highly localized in time and space and because it has become, and will continue to become, fainter as time goes on. Before the experiment was authorized, this aspect was discussed fully, first by the West Ford subcommittee of the Space Science Board, and later by a scientific committee, of which J. Tukey was chairman, accountable directly to J. Wiesner, the President's science advisor.

However, in our opinion, the broader aspects of the experiment must be questioned because no nation has the right to contaminate space unilaterally in an irreversible way. (The present experiment may be reversible if the lifetime of the dipoles is finite.) Although the data presented here suggest that the present West Ford test belt has been harmless to ground-based astronomy, future experiments of a similar nature with a larger payload may not be so lucky. If, for example, a West Ford operational belt is established with, say, 100 times the present payload, the belt would be four times brighter (shortly after launch) than the natural night-sky radiation, a level which would begin to be serious for certain types of astronomical observations. Once the principle of unilateral contamination is accepted, the doors are opened for disastrous future possibilities and man may well succeed in changing his environment (albeit astronomical) beyond repair.

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Table 2. Data for belt intensity in absolute units.

Date (May 1963)	Flux [10^{-33} wm^{-2} × (cy/sec)$^{-1}$ × (arcsec)$^{-2}$]	Flux [10^{-19} Erg × sec^{-1} cm^{-2} × Å^{-1}(arcsec)$^{-2}$]
14	2.2	3.3
16	1.1	1.7
17	1.4	2.1
18	1.3	2.0
18	1.1	1.7

References

1. W. Liller, *Astron. J.* **66**, 114 (1961).
2. W. E. Morrow and D. C. MacLellan, *ibid.*, p. 107.

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West Ford Dipole Belt: Photometric Observations

Abstract. *Photoelectric observations of the West Ford belt of copper dipoles covering the period from 1 week to 1 month after the launching show a feature considerably wider than the announced belt width. The present belt is not injurious to astronomical observations from the ground but it could seriously affect observations made from low-orbiting satellite systems. Much stronger belts would seriously interfere with astronomical observations.*

Photoelectric observations of the West Ford belt of copper dipoles were obtained on 13 occasions after the announcement of launch on 12 May 1963. The observations were obtained between 20 May and 21 June with five different telescopes and photometers (Perkins Observatory 69-inch reflector, United States Naval Observatory 40-inch reflector, and Lowell Observatory 42-inch, 24-inch, and 21-inch reflectors). The focal plane apertures ranged between 77 and 350 seconds of arc; the most frequently used diaphragms were in the neighborhood of 250 seconds. The spectral regions were isolated by glass or interference filters; the bands were relatively narrow and fell in the interval between 5000 and 6000 Å.

The observed sky fields were chosen, free of bright stars, and were monitored for some time before and after the passage time on each field. The parallactic motion caused by the earth's rotation