U. of Iowa 67-20
Distribution of this document is unlimited

AD 654406

Acquisitioned Document
SQT

This document has been approved for public release and sale; its distribution is unlimited.

N67-36485
(ACCESSION NUMBER)
(THRU)
26
(PAGES)
(CODE)
AD-654406
(NASA CR OR TMX OR AD NUMBER)
TMX-60236
(CATEGORY)
FACILITY FORM 602

This work was supported in part by the office of Naval Research under Contract No. Nonr-1509(06)

Department of Physics and Astronomy
THE UNIVERSITY OF IOWA
Iowa City, Iowa

U. of Iowa 67-20

Simultaneous Satellite and Balloon Observations of the Same Auroral Zone Precipitation Event*

by

D. W. Milton
Space Sciences Laboratory
University of California, Berkeley

and

M. N. Oliven**
Department of Physics and Astronomy
University of Iowa, Iowa City

June 1967

* Work at the University of California supported by National Science Foundation Contract NSF-GP-5583 and at the University of Iowa by Office of Naval Research Contract 1509(06).

** NASA Graduate Trainee

ABSTRACT

On September 20, 1963 the Injun III satellite, at an altitude of 2350 km, passed within close proximity of a balloon x-ray detector at 35 km altitude. During a transit of the L-shell of the balloon, a marked correlation in the increases of flux of the satellite precipitating electron $E \geq 40$ keV detector and the balloon x-ray $E \geq 30$ keV detector is found. These results place a lower limit of 430 km east-west extent of the mutually observed pulsation event.

I. INTRODUCTION

On September 20, 1963 Injun III satellite, carrying a large complement of electron detectors, passed over North America near the L=5 magnetic shell. Under an unusual set of circumstances, a balloon-borne bremsstrahlung x-ray detector was operating for a portion of this pass, and furthermore, both units encountered a highly time-structured precipitating electron flux. Both detectors saw similar precipitation time structure during the one-minute period surrounding the transit of Injun III across L = 5.2 (the location of the balloon). These measurements made it possible to state a minimum spatial extent in longitude for which similar time structure exist in the events, since the satellite and balloon were separated longitudinally.

II. INSTRUMENTATION

The Injun III electron detector employed in these measurements described by O'Brien et al. [1964], was a type 213 Anton Geiger counter with 1.2 mg cm^{-2} window thickness. It was collimated to an 86° diameter field of view giving a geometric factor of 5×10^{-2} cm^2 ster. The Injun III satellite was magnetically oriented such that the collimator axis of this 180° detector was continuously anti-parallel to the local geomagnetic field line in the northern hemisphere, thus detecting precipitating electrons with energies $E \geq 40$ keV. There was also a detector oriented at 90° with respect to the magnetic field line, observing trapped electrons. The 90° detector was similar to the 180° detector but had a 26° diameter field of view and a geometric factor of 1.1×10^{-2} cm^2 ster. Data samples were telemetered at quarter second intervals.

The balloon-borne detector, more fully described by Anderson and Milton [1964], was a 1/2" x 5" NaI(Tl) scintillation detector with a 0.14 cm^{-2} Al entrance window. Pulse height energy discrimination provided integral energy channels above 30 keV and 60 keV as well as a window from 30

to 60 keV. The 30 keV integral channel was telemetered digitally, while rapid response logarithmic analog circuitry was employed for the other two channels. The balloon was measured to be at 6.5 g cm^{-2} atmospheric depth, or about 35 km above the earth during the period of the satellite transit discussed herein. The crystal was essentially uncollimated, and had a geometric factor of about 400 cm^2 ster. The atmosphere above the balloon provides a degree of energy dependent collimation; softer photons are restricted to more nearly vertical incidence due to increased photoelectric absorption at larger angles. For a typical photon energy of 40 keV, the angular field of view to achieve half of the vertical atmosphere transmission is about 45°. This field of view corresponds to a circle of 130 km diameter at the x-ray production layer, which is about 65 km above the balloon.

III. OBSERVATIONS

On September 20, 1963 at 1530 UT Injun III passed over the vicinity of Flin Flon, Manitoba, Canada (56° N. Lat., 102° W. Long.) from which a balloon-borne x-ray detector had been launced several hours previously. The position of the satellite was known to within ± 2 km, and that of the balloon to within ± 15 km. Figure 1 shows a map of the trajectory of the subsatellite point and of the balloon position (which did not change significantly during the satellite pass). The satellite was on a SW to NE course with a trajectory which, when projected to the same latitude and longitude at balloon altitude, passed within a horizontal distance of 210 km from the balloon at 1531 UT. Figure 2 presents the L-value of the satellite and balloon versus time, which was known for both to within 1 second. The satellite at 2350 km altitude crossed the L = 5.2 shell that the balloon was on at 1529:04 UT. At that time, the satellite was on a parallel of latitude 3.1° south of the balloon latitude. This difference in latitude is the value to be expected when the magnetic field line through the balloon is extrapolated to satellite altitude, as shown in Figure 1.

Examination of both satellite and balloon records during the period of closest approach reveals that both detectors observe microburst and pulsation time structure. These two components, which can be seen in Figure 3a, are characteristic of auroral zone x-rays and the causative precipitating electrons [Anderson et al., 1966; Oliven et al., 1967; and Oliven and Gurnett, 1967]. Microbursts are the 0.1 to 1 second long impulsive events which can occur separately or in groups. Pulsations have a longer time scale of 5 to 40 seconds duration or spacing. Microbursts are often organized into trains having the characteristic 5 to 40 second periodicities of the pulsation phenomena or can be superposed on the pulsations, as is the case in this data. The satellite-balloon correlations described in this paper concern the pulsation phenomena.

For the entire period of the closest approach, the quarter second samples of the Injun III 180° precipitating electron detector were compared with both the analog and digital records of the balloon x-ray detector, plotted on the same time scale. From 1528:40 to 1529:50 there were four pulsations in the flux of precipitating electrons which coincided with similar increases in the x-ray flux data from the balloon. Figure 3

shows a two minute sample of satellite and balloon data, including the above interval. The correlated segment contains the time 1529:04, which is the exact time of transit of the satellite past the L-shell of the balloon. No correlation was found between the balloon and satellite records, either before or after this period of time. No correlation was observed either at the time of geographic latitude transit or the closest spatial separation. The balloon instrument calibrator operated during longitudinal transit, making it impossible to search for any correlations at that time.

To substantiate the visually observed correlation, a cross correlation calculation was performed. Quarter second samples of the balloon digital data from 1528:40 to 1529:50 were moved along with respect to the satellite digital data in half-second steps out to 1 minute earlier and later. At each step the simple correlation coefficient, r, between corresponding values in the two sets of data was calculated, and the results are presented in Figure 4. The statistically significant peak near zero (which is exact time coincidence) corresponds to the visually observed pulsation correlation. The other signficant peak at minus 21 seconds is due to the approximate 20 second periodicity in both sets of data. This periodicity can be seen in the original data in Figure 3, and also appeared in autocorrelation calculations performed separately on each set of data.

Pulsation periodicities can vary greatly from episode to episode. The fact that both satellite and balloon instruments separately observe the same ~20 second periodicity further indicates that the same event is being observed by both.

The 90° detector records shown in Figure 3d reveal some of the pulsations indicated in the 180° detector and in the balloon data, although some of these are masked, as the peak flux in the 180° detector is often less than the background flux in the 90° detector. Thus, although these pulsations and/or microbursts may be present in the 90° direction, they are masked by the high background fluxes.

While microbursts are clearly seen in both detectors, it is not possible to demonstrate a one-to-one correspondence as was done for pulsations. However, as shown in Figure 3a and 3b, many microbursts appear to occur in similar precipitation patterns during the same time interval. Although the quarter second time resolution of the satellite data make comparisons with the analog record difficult, the width and percentage flux changes of many microbursts are also similar in the two records.

The absence of one-to-one microburst correspondence in the two records while the vehicles were separated by 6° in longitude, (or 430 km at balloon altitude) is to be expected according to other workers. Simultaneous balloon studies reported by Brown et al. [1965] and Trefall et al. [1965], using balloons separated by 150 and 300 km respectively in the east-west direction, place the microburst source region at about 200 km in extent. A single balloon instrument with multiple detectors pointing to separate 20 km regions of the production layer [Parks, 1967] places the microburst source region size at about 80 km.

IV. INTERPRETATIONS

Due to the guiding action of the field lines, only electrons traveling within one gyro-radius of the satellite-borne detector can be detected by it. For a 100 keV electron at satellite altitude, this gyro-radius is about 40 meters, making the satellite essentially a point detector on the distance scale of the satellite-balloon spacing. The balloon-borne x-ray detector can respond to x-rays originating within an approximately 130 km diameter circle above the balloon, the exact value being dependent upon the photon energy.

When the satellite made the transit past the L-value of the balloon, the two were separated 430 km in longitude. This value went from 510 to 370 km over the time interval of the observed correlation. On the basis of the limited region of visual correlation of the two sets of data (70 seconds) and the computed correlation coefficients during that time interval, it is concluded that the correlated pulsation time structure existed at least 400 km apart in longitude on the L=5.2 shell. Furthermore, since the correlation did not appear before 1528:40, nor after 1529:50, reference to Figures 1 and 2 shows that the latitudinal extent of the correlated precipitation was 250 km, or a range of 0.9 in L-value, for these observations.

There is only limited evidence available from other sources concerning the spatial extent of pulsation events. Post-midnight data from auroral observation, ionospheric absorption, and magnetic bay measurements indicate that electron precipitation generally is much more extended in the east-west than the north-south direction [Brown, 1966]. Time varying electron precipitation events with time scales of several minutes have been observed in time coincidence over east-west distances of 1000 km by comparing balloon-borne x-ray detector with ionospheric absorption data [Barcus and Rosenberg, 1965]. However, on the time scale of the 5 to 40 second pulsations being discussed in this article, Brown et al. [1965], using simultaneous balloons, failed to see correspondence at 150 km separation in the east-west direction, while on another occasion did see correlation at 100 km distance in the north-south direction.

The correlation presented in this article thus is a new result showing that it is possible to have coherence for the 5 to 40 second pulsation phenomena over east-west distances up to 400 km. The failure to observe this on the previous occasion with two simultaneous balloons could be due to one of the

balloons not being within the coherent region, as well as there not always being coherent behavior of this extent.

The balloon and satellite saw similar time structure in the precipitation event while separated by 400 km. If the assumption is made that the intensity of precipitating electrons was also comparable at the two locations, it is possible to check on the consistency of these data by comparing the observed and calculated electron to photon production ratios.

The electron flux values at each quarter second from 1528:40 to 1529:50 (the period of observed pulsation correlation) were compared to the x-ray flux values 1 second later. The 1 second lag corresponds to the peak correlation shown in Figure 4. The average ratio between the two fluxes was about $1.5 \pm 1.0 \times 10^5$ electrons $(cm^2 \text{ sec ster})^{-1}$ above 40 keV per photon $(cm^2 \text{ sec ster})^{-1}$ above 30 keV.

Theoretical work on the generation of x-rays from electrons in the atmosphere has been presented by Anderson and Enemark [1960] and Bhavsar [1961]. The two-step determination consists of first correcting the x-ray spectrum observed at balloon altitudes to that at the production layer, considering photoelectric absorption in the atmosphere, and the second of

selecting the electron spectrum which most nearly produces the corrected x-ray spectrum as determined by thick target bremsstrahlung theory. Further details and sample photon to electron conversion factors can be found in Anderson [1965]. These results can be applied only approximately to the present balloon data because two channels of energy information and an uncollimated crystal allow only an estimation of the photon spectrum and intensity. Carrying this estimate through, the result is 0.5×10^5 electrons $(cm^2 \text{ sec ster})^{-1}$ above 40 keV per photon $(cm^2 \text{ sec ster})^{-1}$ above 30 keV, in approximate agreement with the observed value.

ACKNOWLEDGMENTS

The authors wish to express their thanks for the advice and support offered in this project by Professor K. A. Anderson of the University of California and Professor J. A. Van Allen and Dr. D. A. Gurnett of the University of Iowa. This work was supported at the University of California by National Science Foundation Contract NSF-GP-5583 and at the University of Iowa by Office of Naval Research Contract 1509(06).

REFERENCES

Anderson, K. A. and D. E. Enemark, "Balloon Observations of X-rays in the Auroral Zone II," J. Geophys. Res. 65, 3521-3538 (1960).

Anderson, K. A. and D. W. Milton, "Balloon Observations of X-rays in the Auroral Zone, 3, High Time Resolution Studies," J. Geophys. Res. 69, 4457-4479 (1964).

Anderson, K. A., "Balloon Measurements of X-rays in the Auroral Zone," Auroral Phenomena, ed. M. Walt (Stanford Univ. Press, Stanford, California, 1965).

Anderson, K. A., L. M. Chase, H. S. Hudson, M. Lampton, D. W. Milton, and G. K. Parks, "Balloon and Rocket Observations of Auroral Zone Microbursts," J. Geophys. Res. 71, 4617-4629 (1966).

Barcus, J. R. and T. J. Rosenberg, "Observations on the Spatial Structure of Pulsating Electron Precipitation Accompanying Low Frequency Hydromagnetic Disturbances in the Auroral Zone," J. Geophys. Res. 70, 1707-1716 (1965).

Bhavsar, P. D., "Scintillation Counter Observations of Auroral X-rays During the Geomagnetic Storm of May 12, 1959," J. Geophys. Res. 66, 679-692 (1961).

Brown, R. R., J. R. Barcus, and N. R. Parsons, "Balloon Observations of Auroral Zone X-rays in Conjugate Regions, 2, Microbursts and Pulsations," J. Geophys. Res. 70, 2599-2612 (1965).

Brown, R. R., "Electron Precipitation in the Auroral Zone," Space Sci. Rev. 5, 311-387 (1966).

O'Brien, B. J., C. D. Laughlin, and D. A. Gurnett, "High Latitude Geophysical Studies with Satellite Injun 3, 1. Description of the Satellite," J. Geophys. Res. 69, 1-12 (1964).

Oliven, M. N. and D. A. Gurnett, "Statistical Studies Concerning the Connection between 40 keV Electron Microbursts and VLF Chorus Emissions," Trans. Am. Geophys. Union 48, 74 (1967).

Oliven, M. N., D. Venkatesan, K. G. McCracken, and M. Steinbock, "Microburst Phenomena 2. Auroral Zone Electrons," University of Iowa Report #67-19 (1967).

Parks, G. K., "Spatial Characteristics of Auroral-zone X-ray Microbursts," J. Geophys. Res. 72, 215-226 (1967).

Trefall, H. J. Bjordal, S. L. Ullaland, and J. Stadsnes, "On the Extension of Auroral-Zone X-ray Microbursts," J. Atmos. and Terr. Phys. 28, 225-233 (1966).

FIGURE CAPTIONS

Figure 1. Injun III trajectory at 2350 Km passing over a balloon launched from Flin Flon, Canada (L=6). Correlated pulsation time structure (5 to 40 second range) was seen between the precipitating electrons and the bremsstrahlung x-rays during the bracketed period.

Figure 2. L-value vs. time for the two vehicles. The pulsation correlations were seen during the L-value transit while there was about 400 km longitudinal separation.

Figure 3. Two minutes of satellite and balloon data containing the correlated segment from 1528:40 to 1529:50. Analog balloon data in Part a illustrate 1-second microbursts and 10-second pulsations. Part b, showing quarter second samples of precipitating electron flux, also has microbursts and pulsations. Only the pulsations are clearly correlated. Part c is the digitally accumulated x-ray flux. Part d shows quarter second samples of the trapped electron flux.

Figure 4. A cross correlation between the satellite and balloon data in Parts b and c of Figure 3. Positive lag time

Figure 4. (Cont'd.) represents shifting the balloon data later with respect to the satellite data. The statistically signficant peak near zero (time coincidence) substantiates the observed correlation, while the one near minus 20 seconds is due to periodicities in both data.

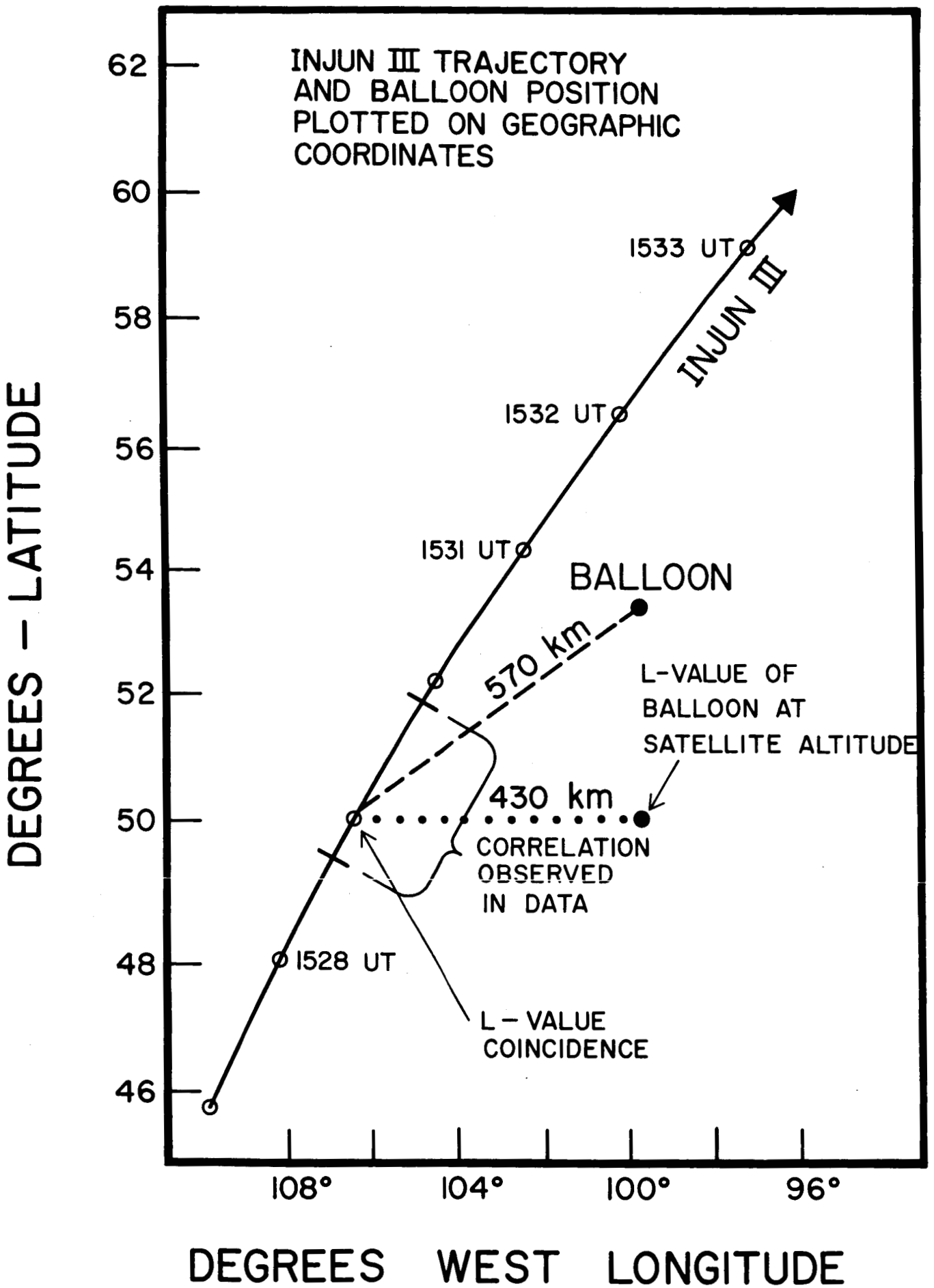
INJUN III TRAJECTORY
AND BALLOON POSITION
PLOTTED ON GEOGRAPHIC
COORDINATES
INJUN III
1533 UT
1532 UT
1531 UT
1528 UT
BALLOON
570 km
430 km
L-VALUE OF
BALLOON AT
SATELLITE ALTITUDE
CORRELATION
OBSERVED
IN DATA
L - VALUE
COINCIDENCE
62
60
58
56
54
52
50
48
46
DEGREES - LATITUDE
108°
104°
100°
96°
DEGREES WEST LONGITUDE

FIGURE 1

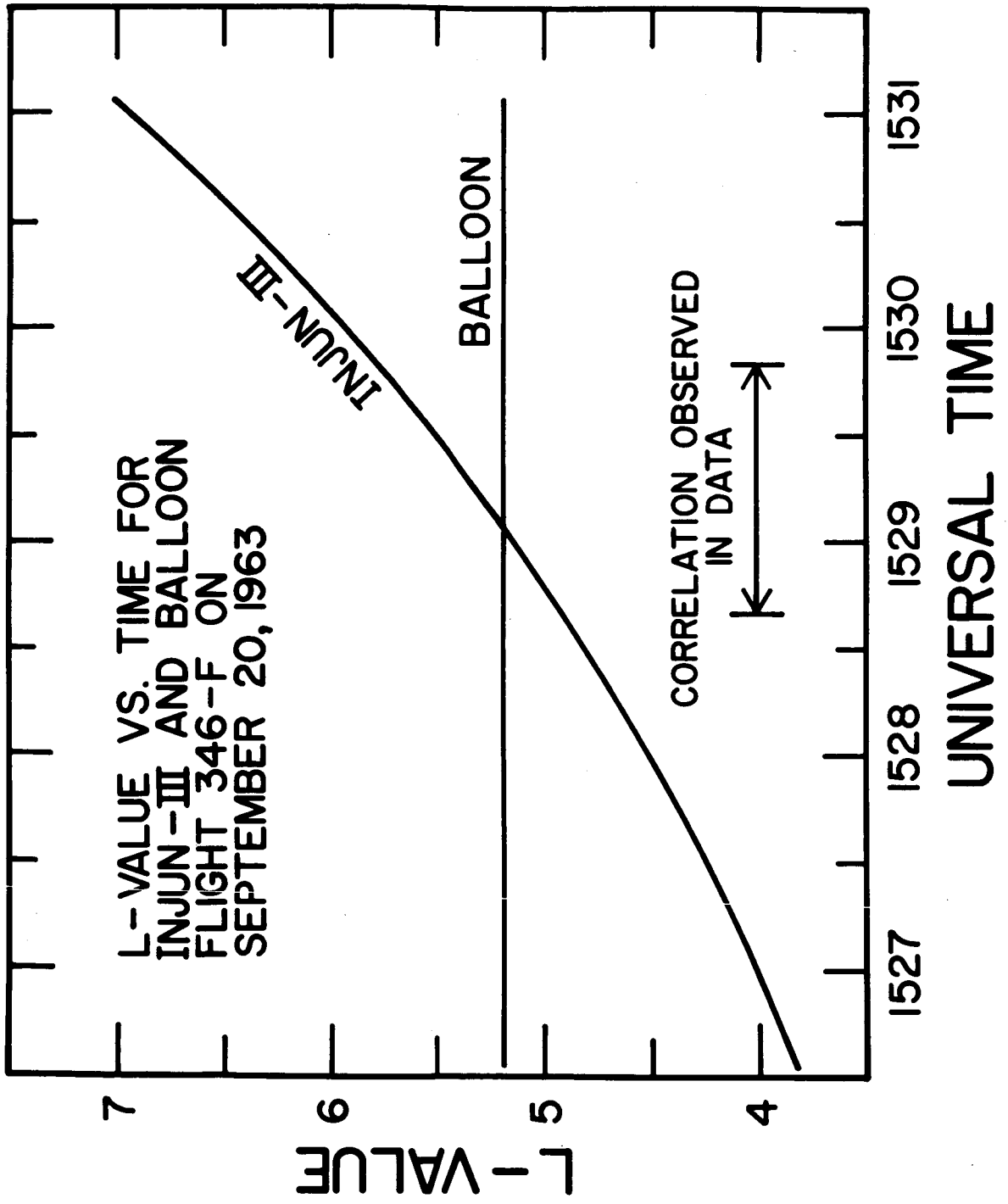
L-VALUE VS. TIME FOR
INJUN-III AND BALLOON
FLIGHT 346-F ON
SEPTEMBER 20, 1963
INJUN-III
BALLOON
CORRELATION OBSERVED
IN DATA
L-VALUE
7
6
5
4
1527
1528
1529
1530
1531
UNIVERSAL TIME

FIGURE 2

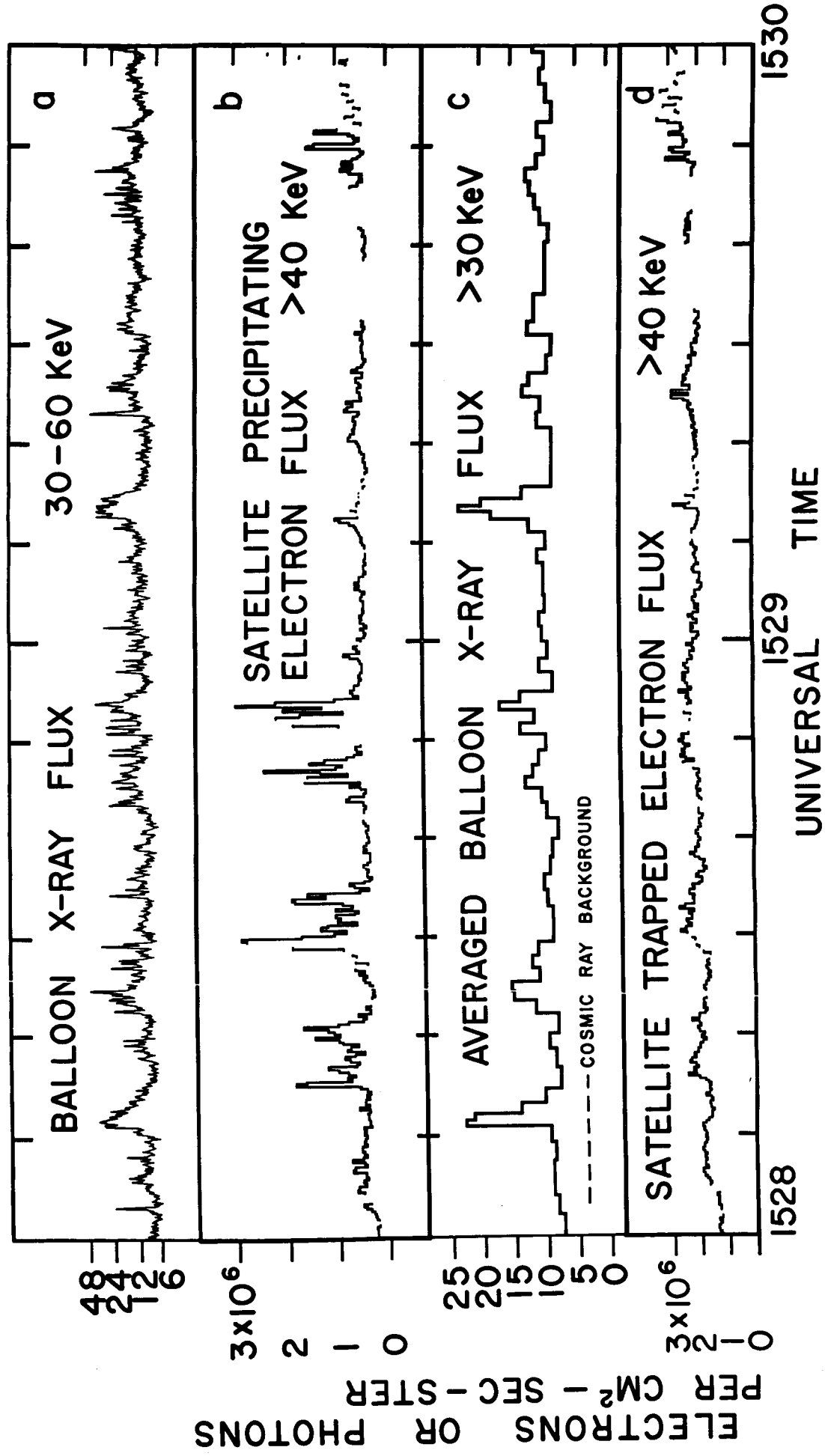
a
BALLOON X-RAY FLUX
30-60 KeV
48
24
12
6
b
SATELLITE PRECIPITATING
ELECTRON FLUX
>40 KeV
3x10^6
2
1
0
c
AVERAGED BALLOON X-RAY FLUX
>30 KeV
COSMIC RAY BACKGROUND
25
20
15
10
5
0
d
SATELLITE TRAPPED ELECTRON FLUX
>40 KeV
3x10^6
2
1
0
1528
1529
1530
UNIVERSAL TIME
ELECTRONS OR PHOTONS
PER CM² - SEC - STER

FIGURE 3

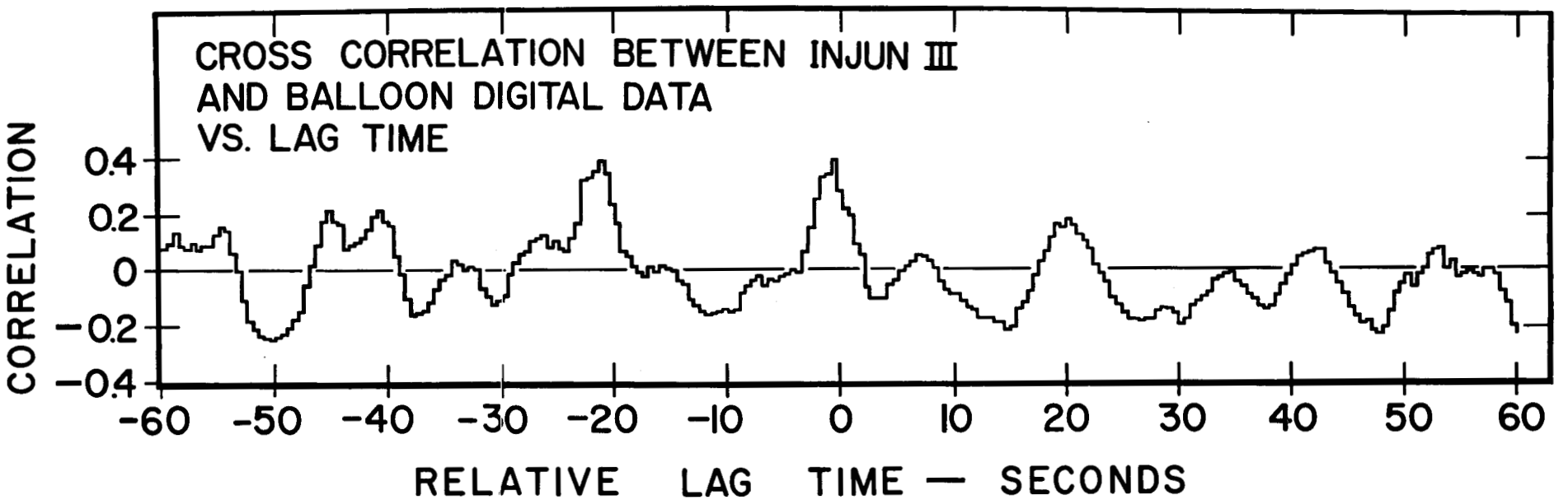
CROSS CORRELATION BETWEEN INJUN III
AND BALLOON DIGITAL DATA
VS. LAG TIME
CORRELATION
0.4
0.2
0
-0.2
-0.4
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
RELATIVE LAG TIME — SECONDS

FIGURE 4

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* University of Iowa Department of Physics and Astronomy	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

Simultaneous Satellite and Balloon Observations of the Same Auroral Zone Precipitation Event

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Progress June 1967

5. AUTHOR(S) *(Last name, first name, initial)*

Milton, D. W. and Oliven, M. N.

6. REPORT DATE June 1967	7a. TOTAL NO. OF PAGES 22	7b. NO. OF REFS 13
8a. CONTRACT OR GRANT NO. Nonr 1509(06) b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) U. of Iowa 67-20 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Naval Research

13. ABSTRACT

On September 20, 1963 the Injun III satellite, at an altitude of 2350 km, passed within close proximity of a balloon x-ray detector at 35 km altitude. During a transit of the L-shell of the balloon, a marked correlation in the increases of flux of the satellite precipitating electron $E \geq 40$ keV detector and the balloon x-ray $E \geq 30$ keV detector is found. These results place a lower limit of 430 km east-west separation of the mutually observed pulsation event.

DD FORM 1 JAN 64 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Auroral Zone Precipitation						
Simultaneous Satellite and Balloon Observations of the Same Auroral Zone Precipitation Event						
Satellite Observed Auroral Zone Precipitating Electrons -- Balloon Observed Bremsstrahlung X-rays						
Pulsation Events						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.