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Department of Physics

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Frequency Dependence of ATS-1 Observed Micropulsations on Some Geophysical Parameters

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May, 1972

Frequency Dependence of ATS-1 Observed Micropulsations

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Abstract

Frequency Dependence of ATS-1 Observed Micropulsations on Some Geophysical Parameters. Low frequency oscillations in the earth's magnetic field at the synchronous orbit have been observed with the UCLA magnetometer experiment on board the ATS-1 satellite since Dec. 1966. Some general characteristics of oscillations in the range $2 \times 10^{-3} < f < 20 \times 10^{-3}$ Hz have been previously reported by these authors. A further analysis of oscillations in the above mentioned range for the two year interval Dec. 1966 through Dec. 1968 is reported here. It was found that the frequency of an event increases with the sum of Kp for 24 hours prior to the event midpoint. For events with duration greater than 6 hours, the product moment correlation coefficient for frequency, f, and $\sum Kp$ was $R = 0.87$. The best least squares linear fit to the data for these events was $f = (0.32)\sum Kp + 5.1$. For the same events the correlation coefficient for frequency and Dst was $R = -0.83$.

In this paper we will discuss the correlation between the frequency of magnetic oscillations observed at ATS-1 and two indices of geomagnetic disturbance. The indices are $\sum Kp$ and $<Dst>$. In tabulating $\sum Kp$ we summed the Kp index for 24 hours prior to the midpoint of the event as observed at ATS-1. In tabulating $< Dst >$ for an event we also computed the average over 24 hours prior to the event midpoint.

We found that the frequency of oscillations is negatively correlated with $<\mathrm{Dst}>$, i.e., when $<\mathrm{Dst}>$ is large negative, the event frequency is high. We also found that the frequency of oscillations is well correlated with $\sum Kp$, i.e., when $\sum Kp$ is high, the event frequency is also high. When the event frequencies are plotted against $\sum Kp$, it appears that the oscillations can be divided into two groups; those that occur when the plasmapause is beyond the orbit of the satellite, and those that occur when the plasmapause is within the orbit of the satellite.

Slide 1. This slide shows equatorial Dst, taken from the compilation of Sugiura and Poras for the magnetic storm that began on September 20, 1967. On the same plot we have placed the low-frequency oscillations that occurred at ATS-1 during this storm. The occurrence of low-frequency oscillations is marked with a cross on this plot. The horizontal bar shows the duration of the event. The vertical bar is one standard deviation on either side of the average of the measured frequencies for the event. This plot further illustrates the tendency of an event frequency to be high during magnetically disturbed conditions and to decline as the magnetosphere grows progressively quieter during the recovery phase of the storm.

Slide 2. Noting the tendency illustrated in the previous slide, we decided to quantitatively compare the event frequency with $<\mathrm{Dst}>$ for 24 hours prior to the event midpoint. This slide represents the results of such a comparison. In this plot only those events with duration greater than or equal to 5 hours were selected. The ordinate of the plot gives the event frequency in milli-hertz and the abscissa gives the average value of $<\mathrm{Dst}>$ for 24 hours prior to a given event. The error bars give one standard deviation on either side of the average frequency of the event. The solid line is the least squares linear fit to the data. The product moment correlation coefficient for this data was -0.84. We then computed correlation coefficients for frequency and $\langle$Dst$\rangle$ over 12 hours.

Slide 3. In this plot we have included only those events that had duration greater than or equal to 6 hours. The absolute value of the correlation coefficient was -0.694. As events with shorter duration were included, we found that the correlation coefficient was reduced in absolute value from the value just mentioned.

Realizing that both Dst and Kp decrease together, we decided to quantatively compare the event frequencies with the sum of Kp for 24 hours prior to the event midpoint. The next slide shows the result of one such comparison.

Slide 4. The ordinate of the plot gives the event frequency in milli-hertz and the abscissa is the sum of Kp for 24 hours prior to the event midpoint. In this plot we have included those events greater than or equal to 6 hours. The error bars are of the same nature as those in previous slides. The correlation coefficient was 0.87.

Even though the linear fit to the data had a relatively high correlation coefficient, it appears that the oscillations occurred in two groups; this could be interpretated alternatively. One group occurs when ΣKp was approximately above 17. The next slide shows our interpretation of this result.

Slide 5. In this plot we have included all events with duration greater than or equal to 5 hours. We calculated linear fits and correlation coefficients for the two groups of data points. The linear fit for the points with $\Sigma Kp < 17$ had an associated correlation coefficient 0.79. The correlation coefficient for the points with $\Sigma Kp > 17$ was only 0.26, therefore the slope of this line is perhaps not very significant.

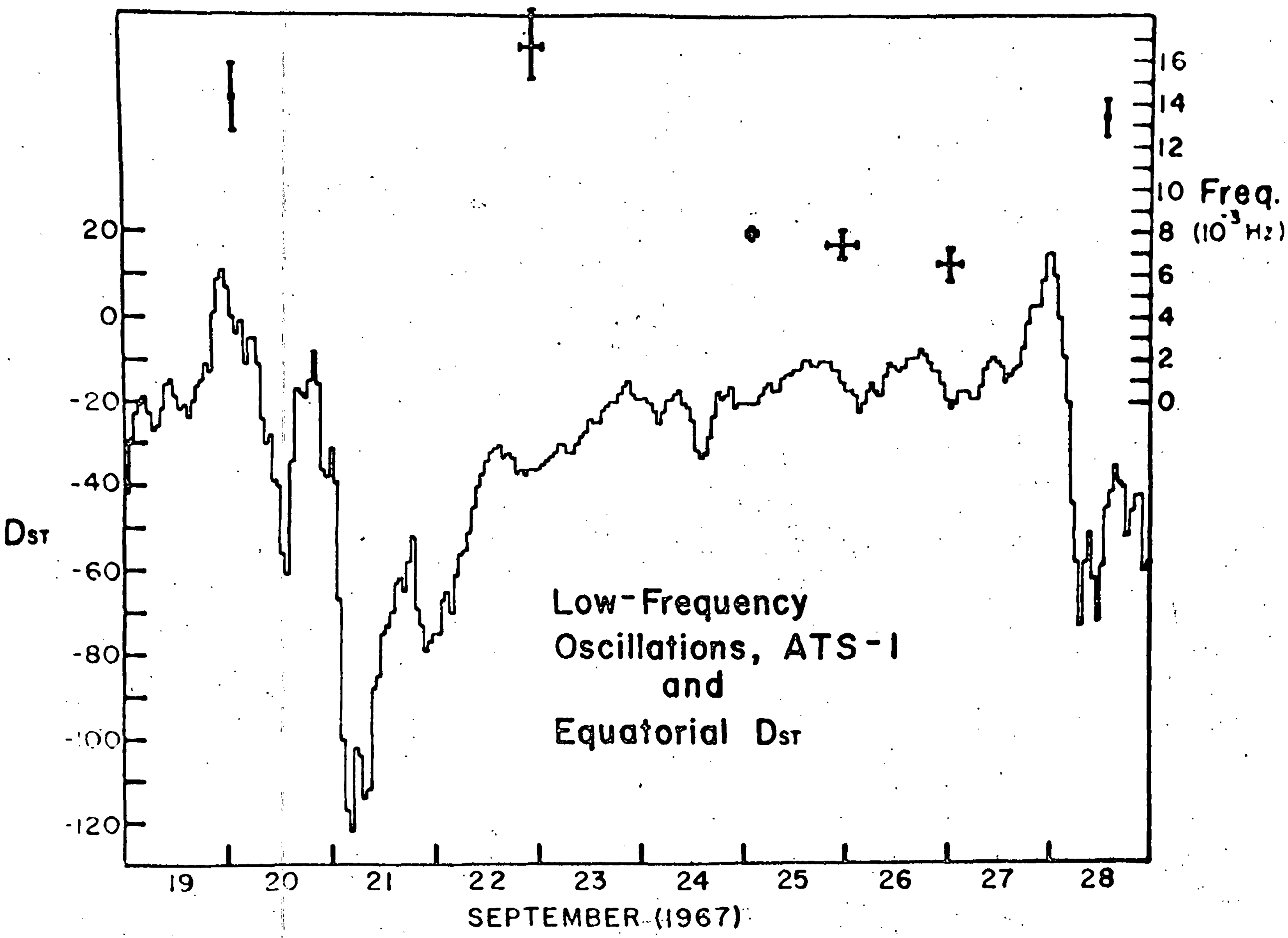
We suggest that the dividing line represents the plasmapause; i.e., when $\Sigma Kp < 17$ (or average $Kp < 2$) the plasmapause is beyond $L = 6.5$ on the day side of the magnetosphere, when $\Sigma Kp > 17$ (or average $Kp > 2$) the plasmapause is within $L = 6.5$. We believe this interpretation is consistent with direct satellite measurements of the plasmapause position (particularly the measurements reported by Taylor, Brinton, and Pharo).

In summary: We find that the frequency of magnetic oscillations observed at ATS-1 are well correlated with the two indices of geomagnetic disturbance, $\langle Dst \rangle$ and ΣKp. Also it appears that the Kp for 24 hours prior to the midpoint ordered the data in such a way that the events occurred in two distinct groups. For $\Sigma Kp <$ about 17 the oscillations occur at about 7 milli-Hz and for $\Sigma Kp >$ about 17 the oscillations occur at about 14 milli-hertz.

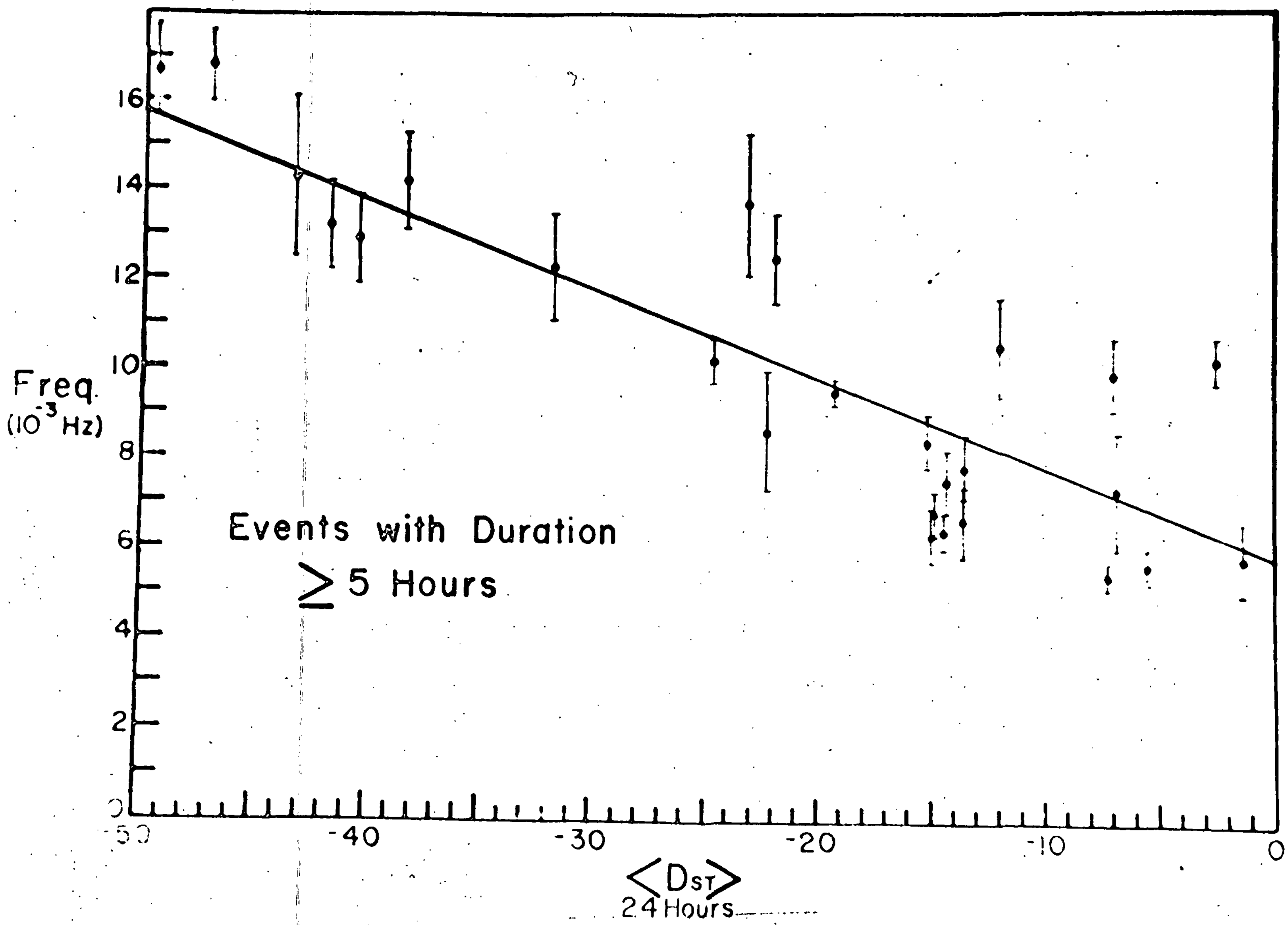
We believe that the lower frequency oscillation occur whenever the satellite is within the plasmapause and the higher frequency oscillation occur whenever the satellite is outside the plasmapause.

Acknowledgements

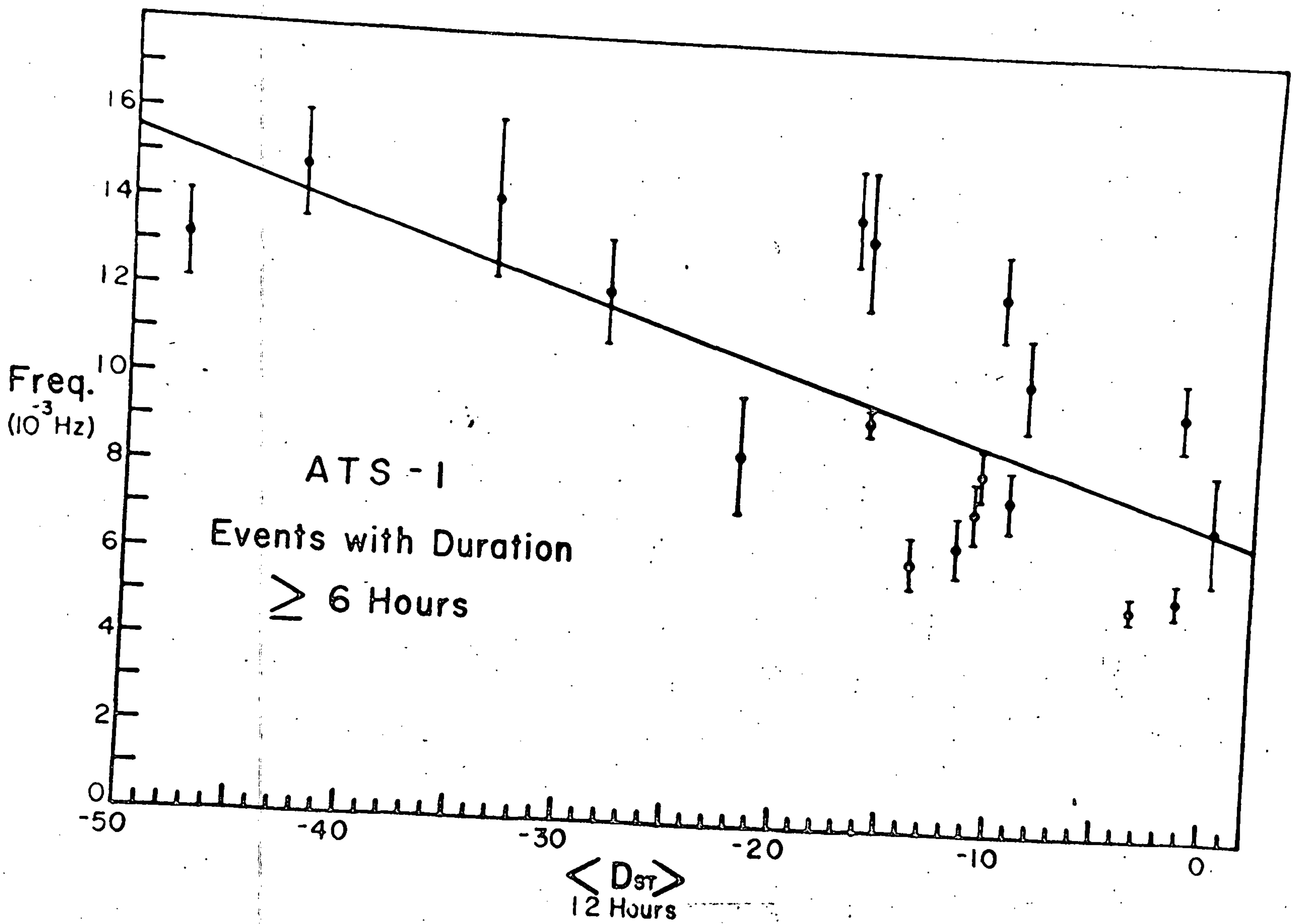
The work done at Grambling College was supported by the National Aeronautics and Space Administration grant NGR-19-011-007. The work done at UCLA was supported by the National Aeronautics and Space Administration grant NGL-05-007-004.


Low-Frequency Oscillations, ATS-1 and Equatorial Dst
Dst
20
0
-20
-40
-60
-80
-100
-120
16
14
12
10 Freq.
8 (10^{-3} Hz)
6
4
2
0
19 20 21 22 23 24 25 26 27 28
SEPTEMBER (1967)

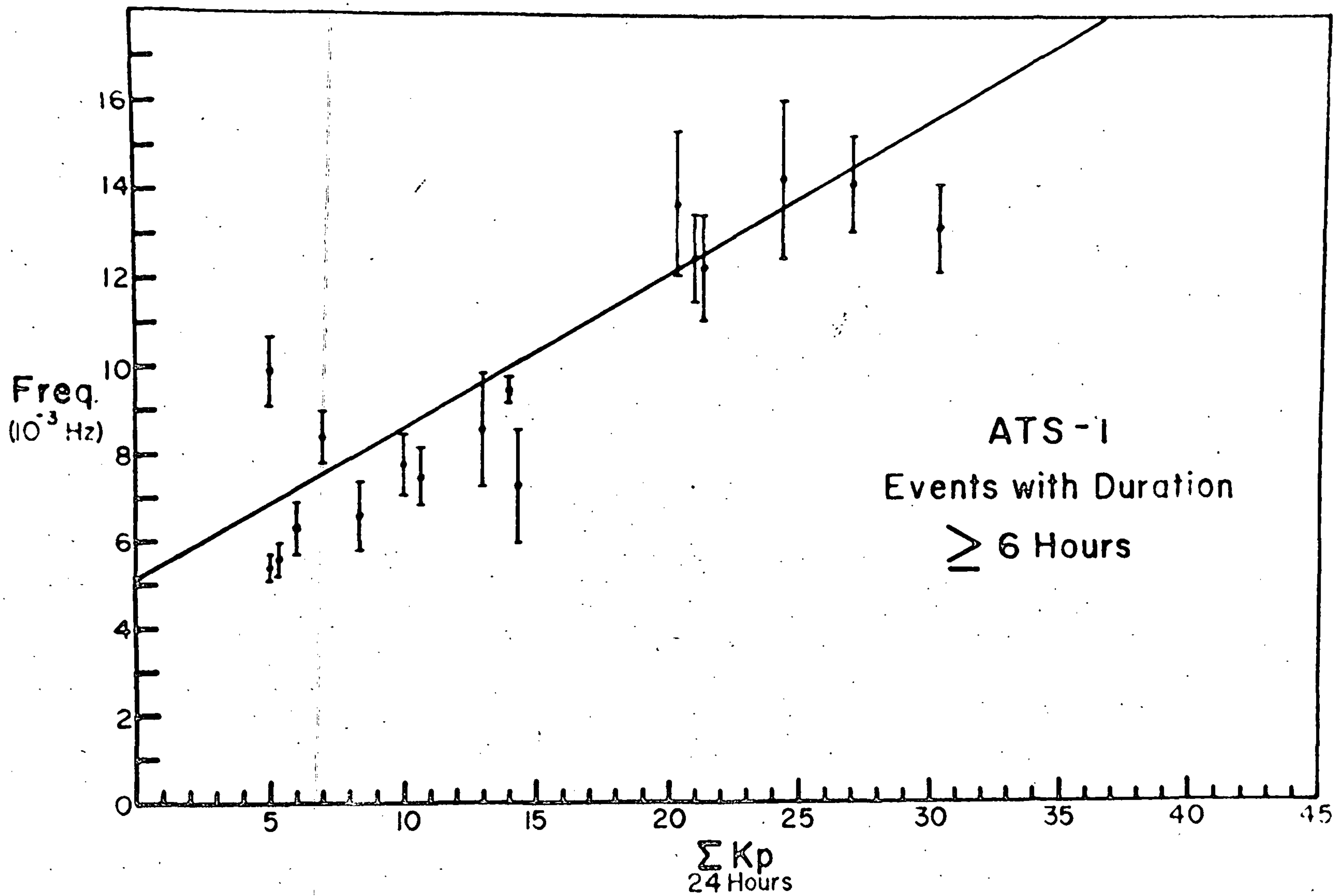
Slide 1


16
14
12
10
8
6
4
2
0
Freq.
(10^-3 Hz)
Events with Duration
≥ 5 Hours
-50
-40
-30
-20
-10
0
<Dst>
24 Hours

Slide 2

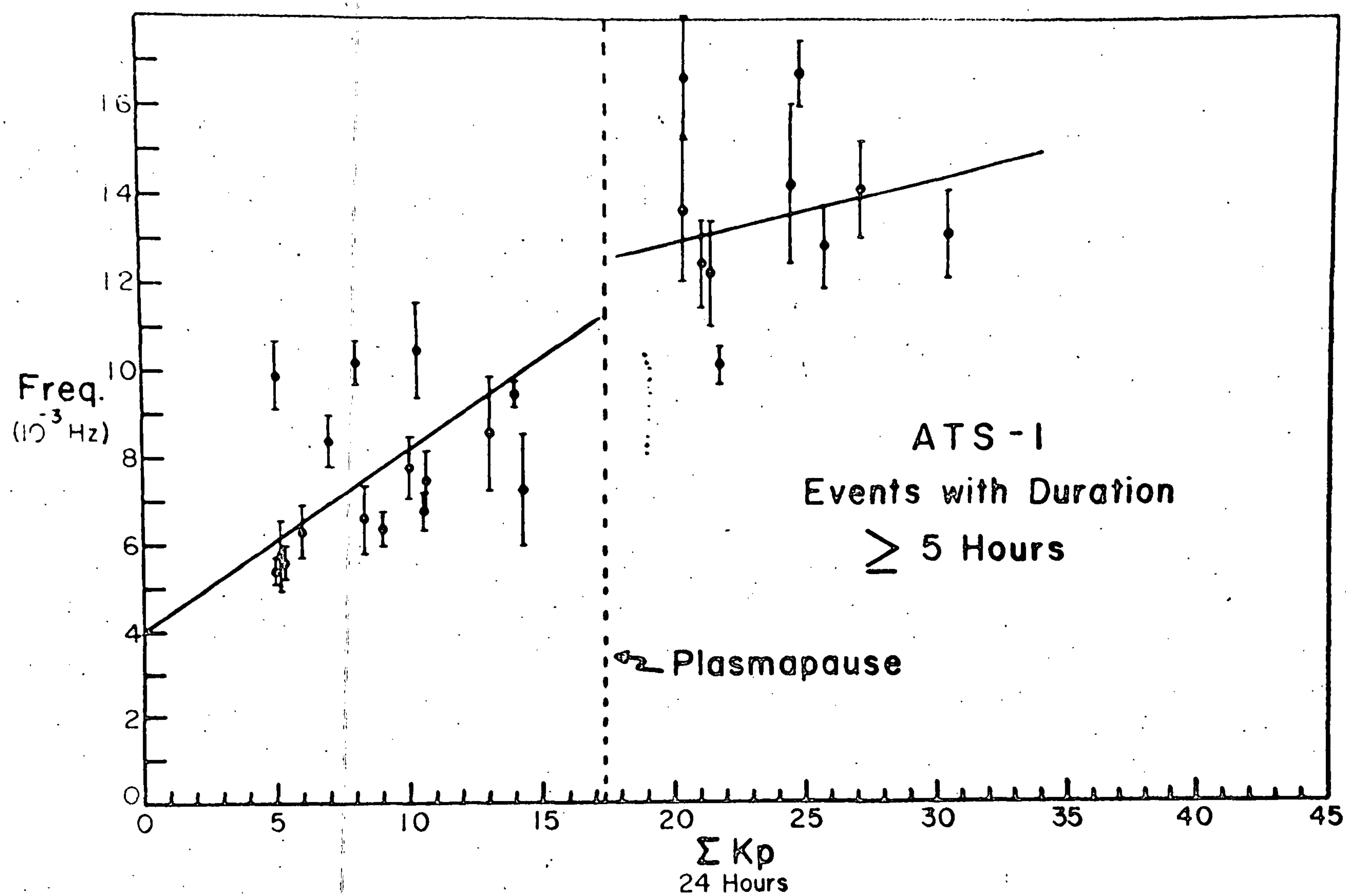

ATS - I
Events with Duration
≥ 6 Hours
Freq.
(10^{-3} Hz)
16
14
12
10
8
6
4
2
0
-50
-40
-30
-20
-10
0
$\langle D_{ST} \rangle$
12 Hours

Slide 3



16
14
12
10
8
6
4
2
0
Freq.
(10^{-3} Hz)
5
10
15
20
25
30
35
40
45
Σ Kp
24 Hours
ATS - 1
Events with Duration
$\geq$ 6 Hours

Slide 4



Freq.
(10^{-3} Hz)
16
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
40
45
ΣKp
24 Hours
ATS-1
Events with Duration
≥ 5 Hours
Plasmapause

Slide 5

Spectral and Polarization Analysis of Micropulsations Observed at ATS-1

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May, 1972

Spectral and Polarization Analysis of

Micropulsations Observed at ATS-1

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Abstract

Spectral and Polarization Analysis of Micropulsations Observed at ATS-1. This paper reports the results of an analysis of low-frequency oscillations in the earth's magnetic field as observed at the synchronous orbit by the UCLA magnetometer experiment on board ATS-1. Oscillations in the range $2 \times 10^{-3} < f < 20 \times 10^{-3}$ Hz for the one year period Dec. 1966 through Dec. 1967 were studied. The analysis combines a detailed, computer processed, spectral analysis of selected events with a less detailed manual analysis of all events in the two year time interval. The computer analysis revealed that a given event is often characterized by a dominant, narrow, spectral peak whose associated oscillations are almost entirely limited to a plane, together with several minor peaks. Dynamic spectral analyses reveal that the minor spectral peaks appear as short isolated bursts. The sense of rotation of the perturbation vector tends to change from right-handed elliptical at the beginning of a burst to left-handed elliptical at the end. The major axis of the polarization ellipse is inclined by typically 30° east of radial.

In this paper we report on some characteristics of the magnetic oscillations in the Pc4 range that occur at the geosynchronous satellite ATS-1. The events chosen were those in 1966 and 1967 that had durations greater than six (6) hours. The principal conclusions at this point in the analysis are:

(1) The oscillations appear to occur in bursts of approximately one hour duration.

(2) There appears to be a trend in the sense of rotation of the perturbation vector during a burst. The sense of rotation changes from right-handed elliptical at the beginning of the burst to left-handed elliptical at the end.

(3) The azimuth of the major axis of the polarization ellipse is inclined by typically 30° east of radial.

Slide 1. The first slide shows the result of an eigen-analysis of the real part of the spectral matrix for a typical quiet time event. The procedure of the analysis is equivalent to creating the variance ellipsoid of the perturbation at a given frequency interval and determining the length and orientation of its eigenvectors. The important point of the slide is the sharp peak in the power density at about 5 milli-hertz (or a period of about 200 seconds) with a rms power of 1 γ.

The bottom portion of the slide indicates that the average polarization was 80% and almost completely linear. However, as we shall show later, the ellipticity varies systematically throughout each of the bursts making up an event. The variation is such that the sense of rotation is right handed as often as it is left handed. This accounts for the average polarization being linear.

Slide 2. The next slide shows the dynamic power spectrum for oscillations in the plane transverse to the dipole axis. There were three bursts centered at 1811, 1931, and 2248 U.T. The first two bursts are of 171 second period and the third burst is of 213 second period. The time derivative of the signal is plotted above the dynamic power spectrum. The contour map is a dynamic spectrum of the derivative of the transverse signal.

Slide 3. The next slide shows the log of the power, the ellipticity, and the azimuth of the major axis of the polarization ellipse for the component of the signal at the frequency of peak power. The significant point of the slide is that at at each point when the signal power was maximum the ellipticity changed from positive, or right handed, to negative or left handed.

We have found no such systematic variation of the orientation of the major axis of the polarization ellipse in the events analysed to date.

Slide 4. The next slide shows in more detail the change in the sense of rotation of the perturbation vector at peak power. We have plotted the transverse components of the magnetic field during a typical short duration burst. On the same time scale we indicated the polarization ellipses as determined from an eigen value analysis of the transverse data. The ellipticities before and after the peak power point are typically .3. The sense of rotation is right handed before the point of peak power and left handed afterwards.

The major axis of the polarization ellipse is inclined to the radial by 30-40° throughout the burst.

Slide 5. To date we have yet to find a significant dependence of the orientation of the major axis of the polarization ellipse on any of the usual magnetic indices. However, we have found that the major axis of the polarization ellipse is generally inclined east of radial. This slide shows the results of several determinations of the azimuth of the polarization ellipse for each of the long duration events of 1966 and 1967. The most frequently measured azimuth angles are in the range 20-40°.

In summary we have found that the Pc4 events observed at ATS-1 occur in bursts of typically 1 hour duration. The sense of rotation of the perturbation vector usually changes from right handed to left handed at the peak power point. And finally the major axis of the polarization ellipse is usually inclined by about 30° east of radial.

Acknowledgements

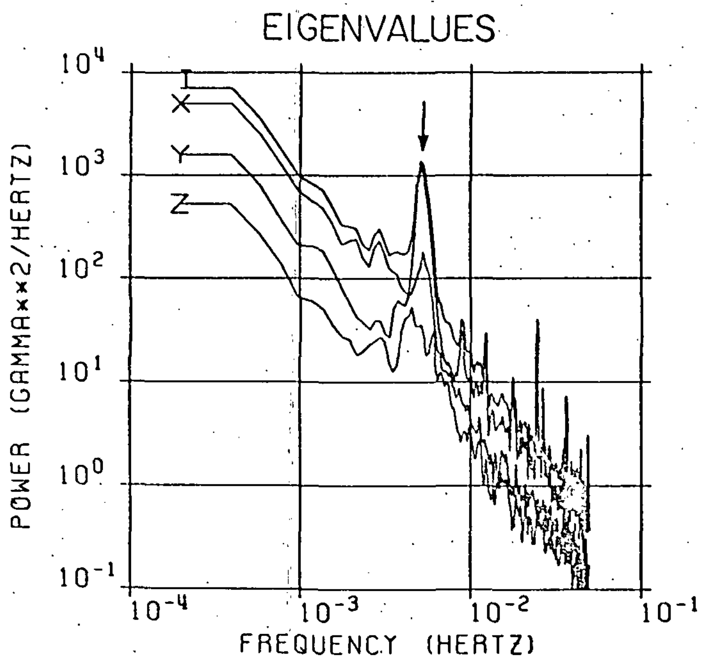
The work done at Grambling College was supported by The National Aeronautics and Space Administration grant NGR-19-011-007. The work done at UCLA was supported by The National Aeronautics and Space Administration grant NGL-05-007-004.

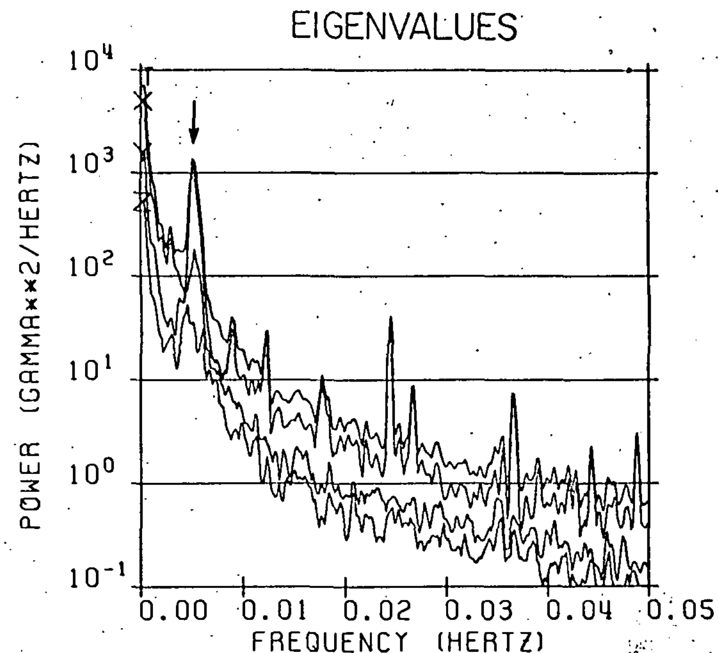
Pc4-5 MICROPULSATIONS

UCLA Fluxgate Magnetometer

ATS-1

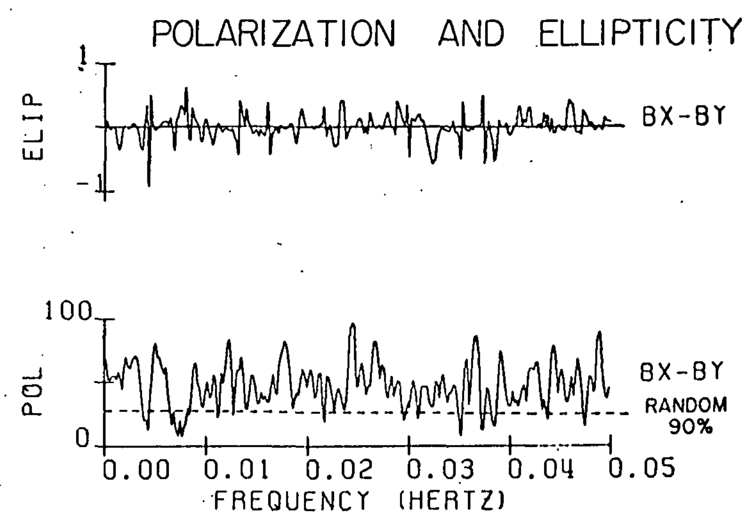
1400-0122, 5-6 JAN. 1967





SPECTRAL ANALYSIS PARAMETERS

- SAMPLE INTERVAL = 10.0 SEC
- DEGREES OF FREEDOM = 26
- NUMBER OF POINTS = 4096
- BAND WIDTH = 0.32×10^{-3} HZ
- BAND SEPARATION = 0.20×10^{-3} HZ

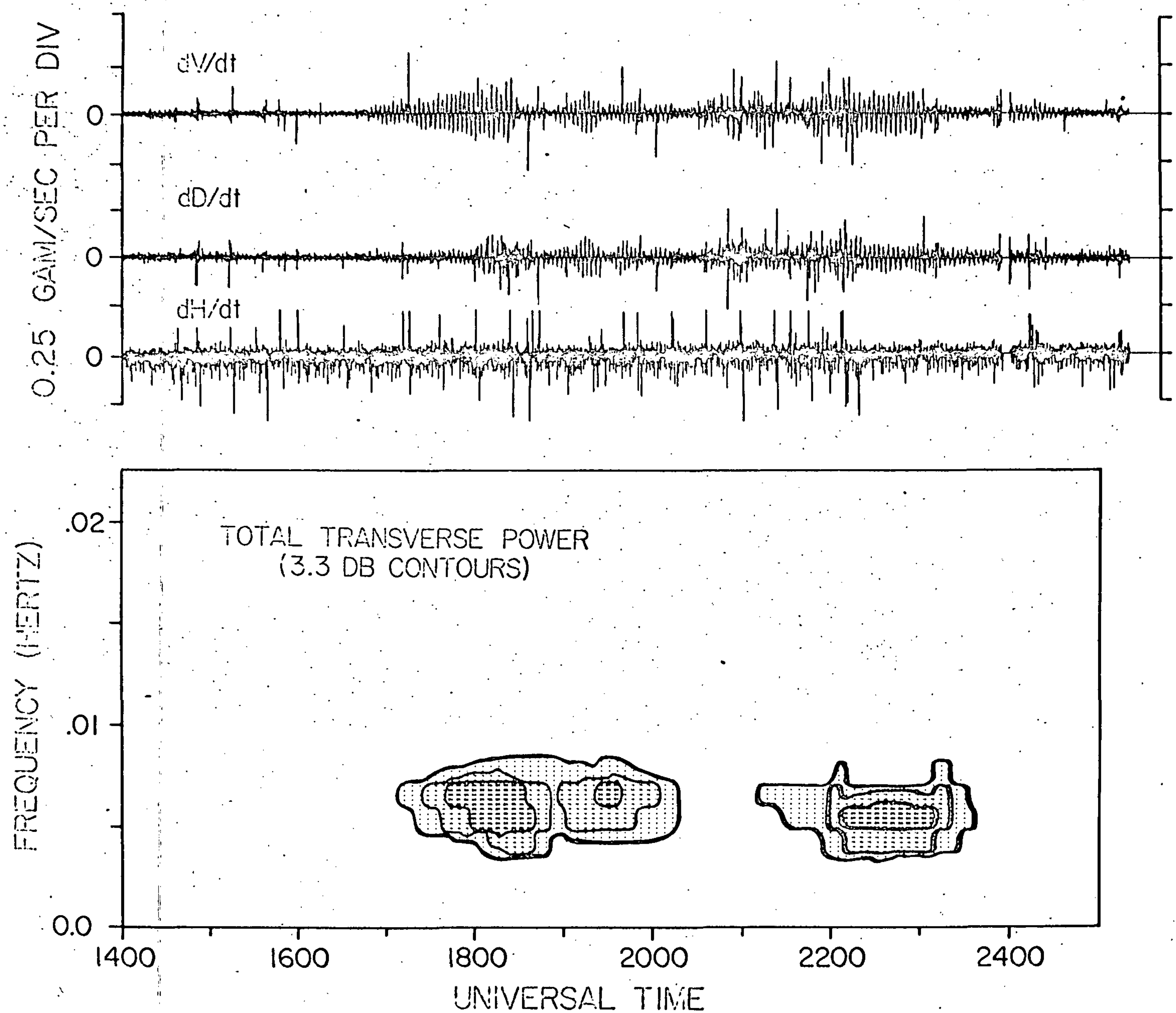


Pc4-5 MICROPULSATIONS

UCLA Fluxgate Magnetometer

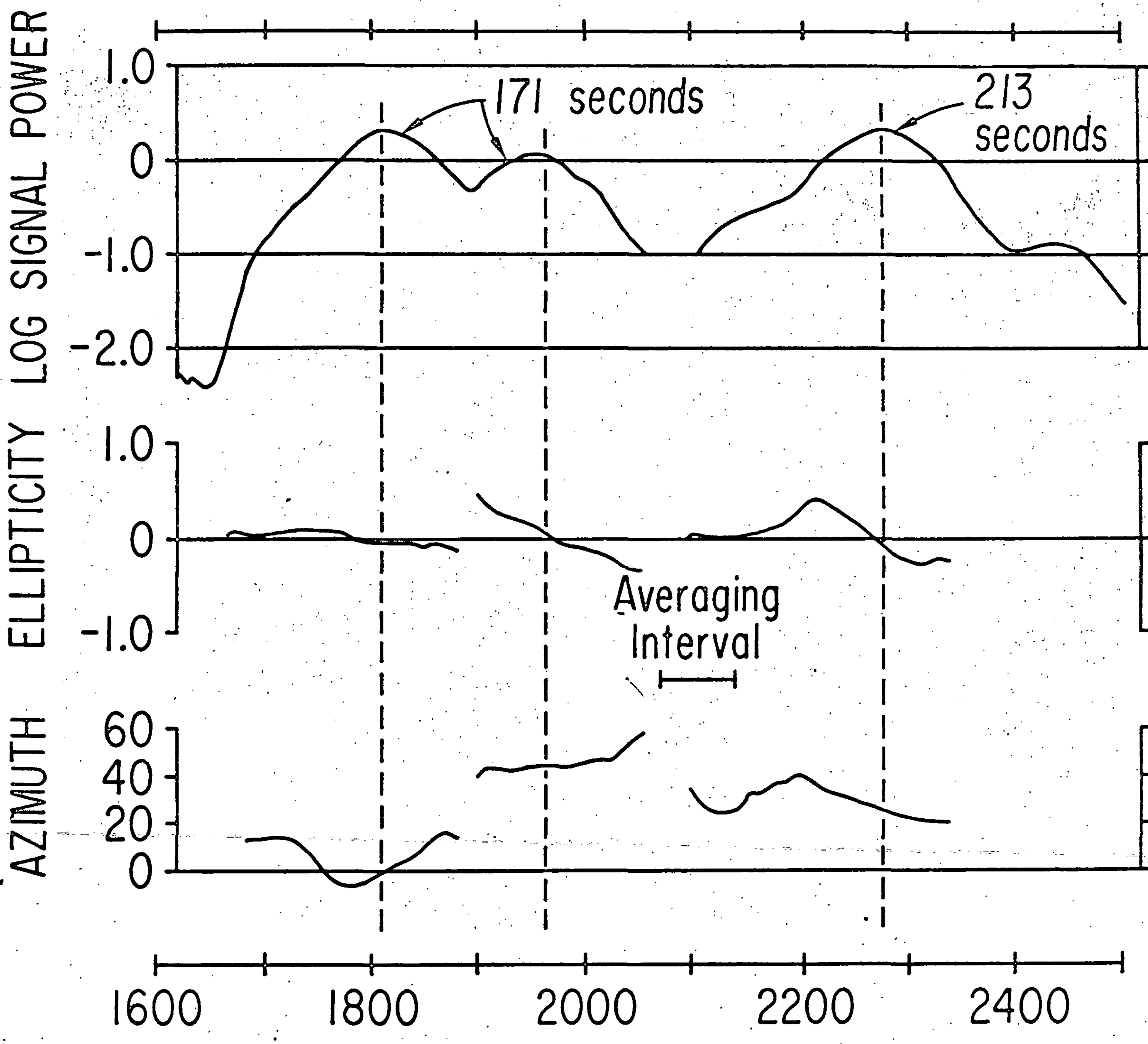
ATS-1

JANUARY 5, 1967

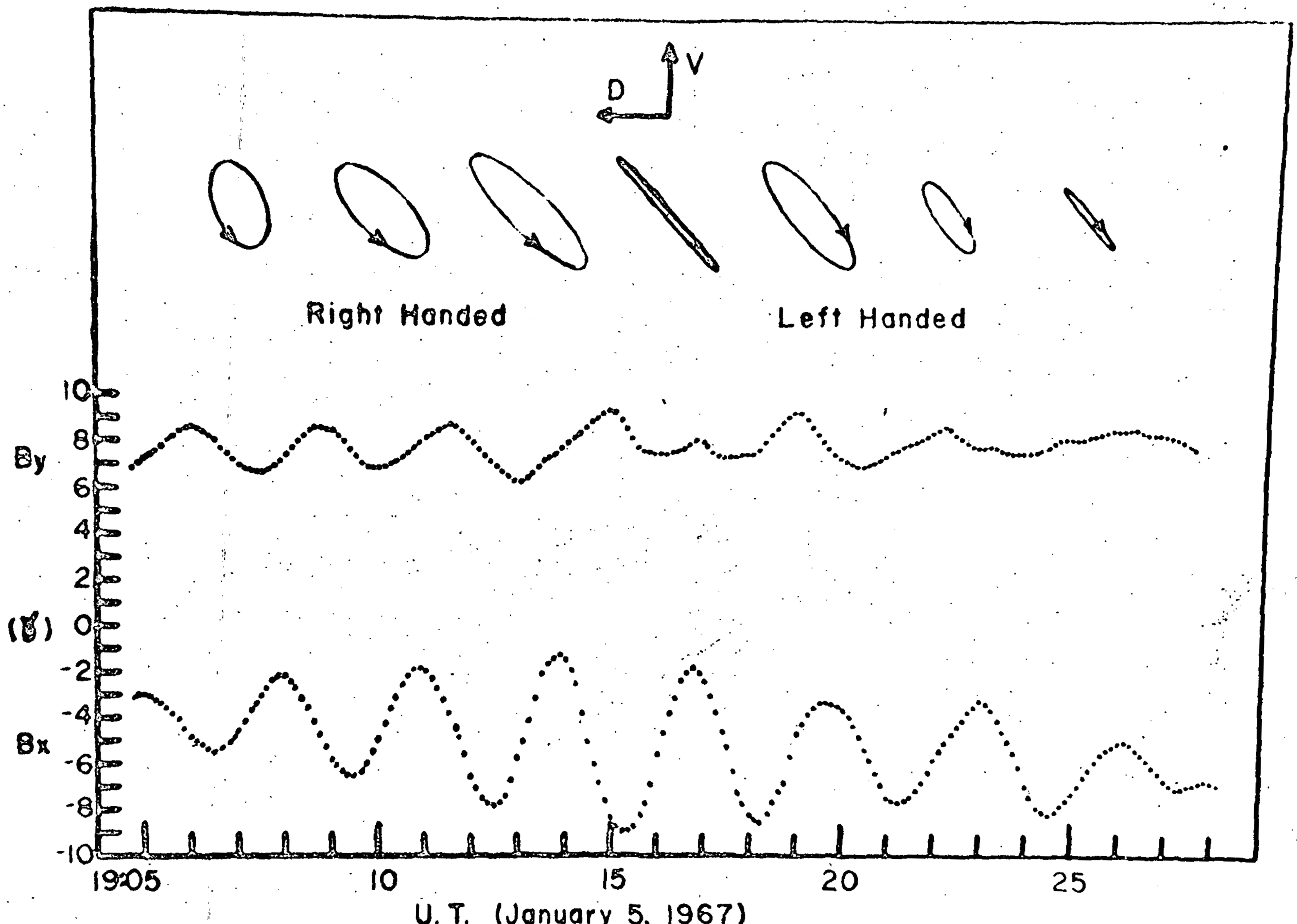


Slide 2

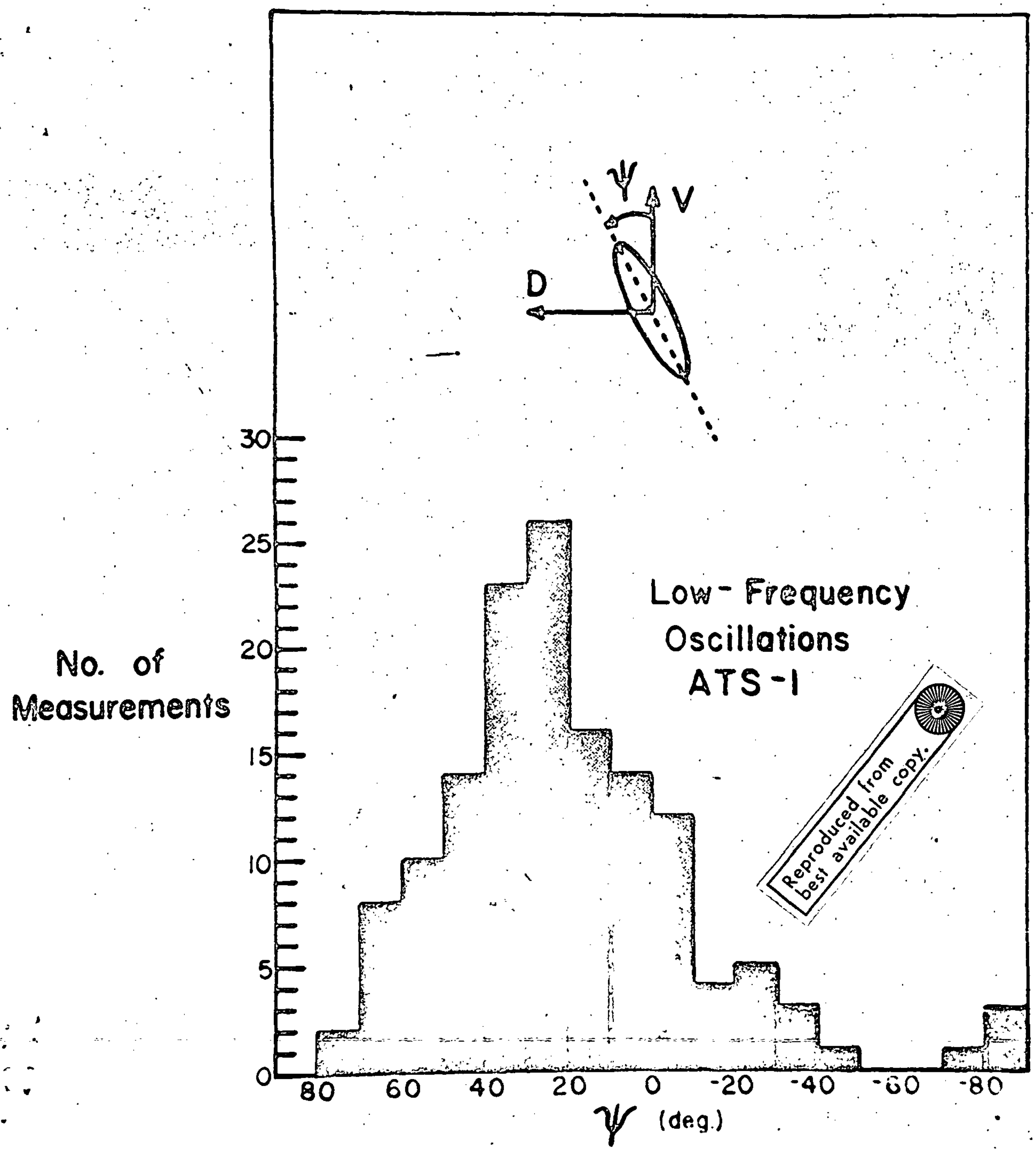
Pc 4-5 MICROPULSATIONS
UCLA FLUXGATE MAGNETOMETER
ATS-1
JANUARY 5, 1967



Slide 3


D
V
Right Handed
Left Handed
By
(γ)
Bx
10
8
6
4
2
0
-2
-4
-6
-8
-10
1905
10
15
20
25
U.T. (January 5, 1967)

Slide 4



ψ
V
D
Low-Frequency
Oscillations
ATS-1
No. of
Measurements
30
25
20
15
10
5
0
80
60
40
20
0
-20
-40
-60
-80
ψ (deg.)
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Slide 5