# COSPAR Abstract for Warsaw, Poland, 2000

## NONLINEAR ALFVÉN WAVES IN INTERPLANETARY SPACE

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The properties of Alfvén waves detected in both high-speed and slow-speed streams as detected by Ulysses will be reviewed. The waves are nonlinear with $\Delta\vec{B}/B_0 \approx 1$ to 2 and are often arc-polarized and phase-steepened. Computer simulations will be used to investigate the phase-steepening and dissipation processes.

**Abstracts to be submitted on or before January 7, 2000 to Copernicus Office with copy to appropriate Main Scientific Organizer:**

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| TYPE OF DISCONTINUITY | MASS FLUX | CHANGE IN MAGNETIC FIELD | |
|---|---|---|---|
| | $\rho v_n$ | $[\vec{H}]$ | |
| ROTATIONAL DISCONTINUITY | $\neq 0$ | $[H_t] = 0$ | $H_n \neq 0$ |
| TANGENTIAL DISCONTINUITY | 0 | $[\vec{H}_t] \neq 0$ | $H_n = 0$ |
| SHOCK | $\neq 0$ | $[\vec{H}_t] \neq 0$<br>$[H_t] \neq 0$ | $H_n \neq 0$ |
| CONTACT DISCONTINUITY | 0 | $[\vec{H}_t] = 0$ | $H_n \neq 0$ |

# Discontinuity Selection Criterion

Tsurutani and Smith (TS) Criterion of Interplanetary Magnetic Field Discontinuity (JGR, 1979):

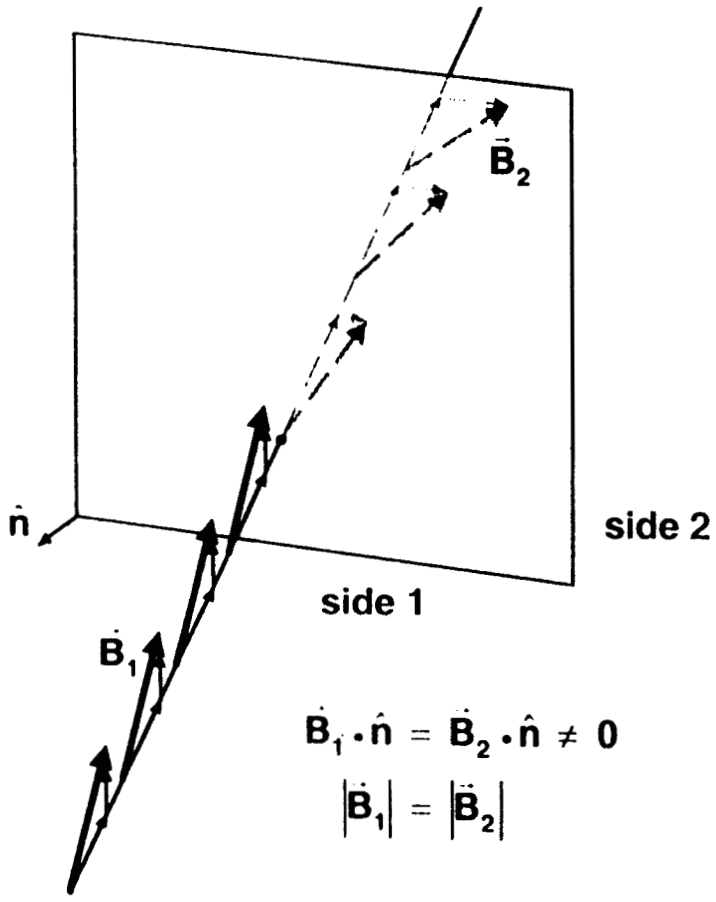
$$\frac{|\Delta B|}{B} \geq 0.5,$$

$$|\Delta B| \geq 2\delta = 2\sqrt{N^{-1}\sum_{i=1}^{N}\left|B_{i+1} - B_i\right|^2}$$

where N=14. Applied to one minute average data, where the two one-minute vectors that are compared are separated by three minutes.

The thickness of discontinuities varies with radial distance. An empirical factor of exp (r-1)/5 has been determined.

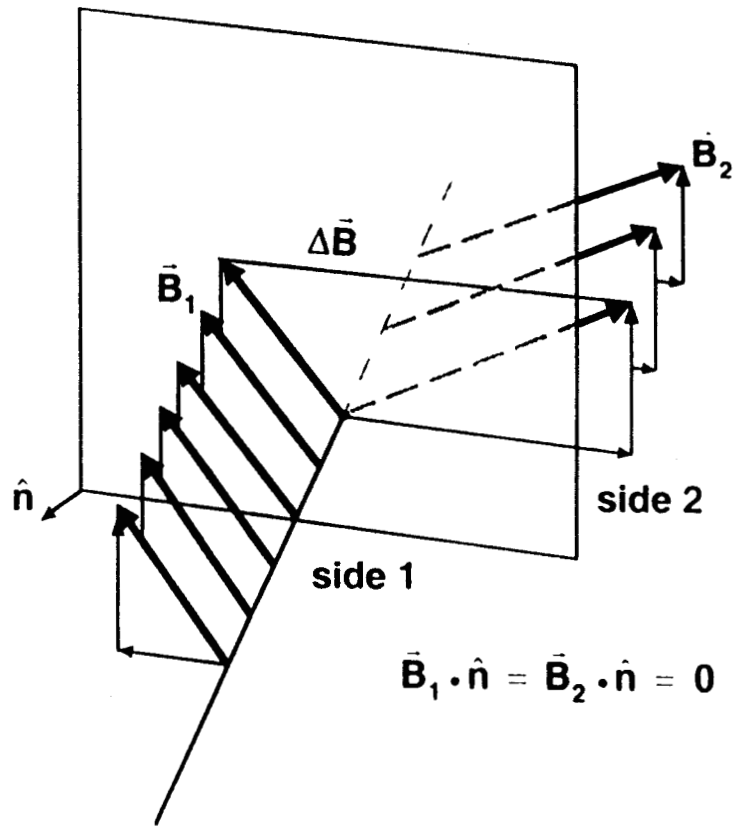
## Rotational Discontinuity



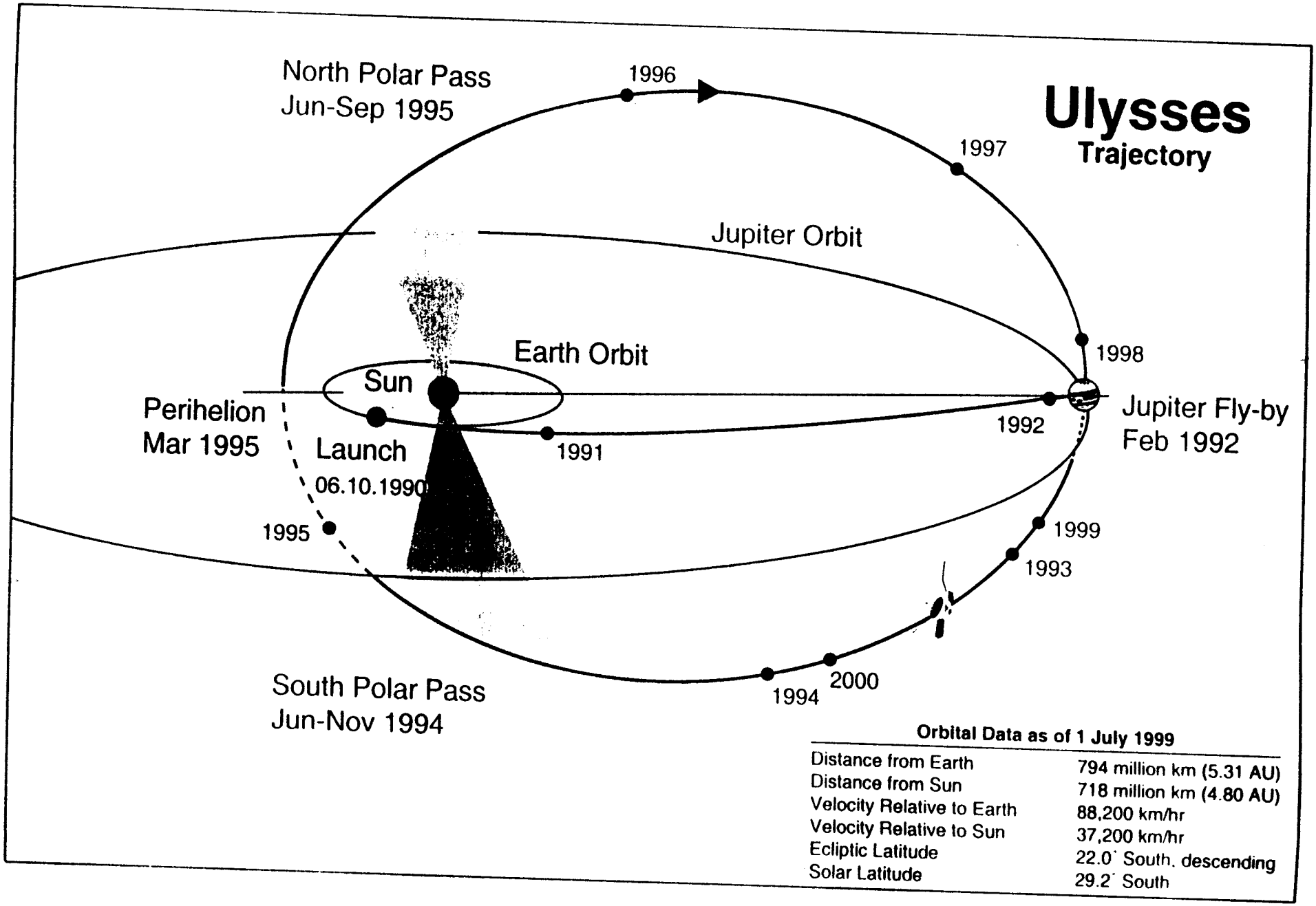

$$\vec{B}_1 \cdot \hat{n} = \vec{B}_2 \cdot \hat{n} \neq 0$$

$$|\vec{B}_1| = |\vec{B}_2|$$

## Tangential Discontinuity

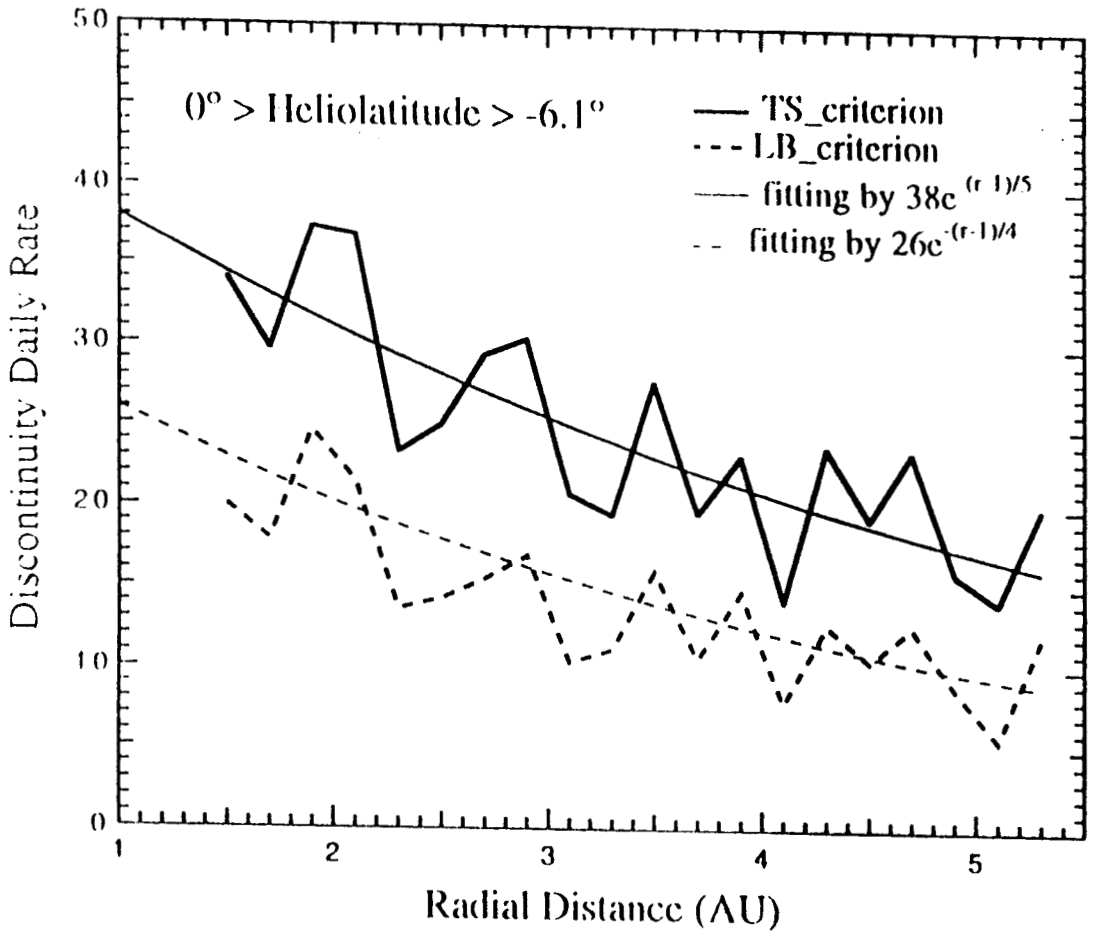



$$\vec{B}_1 \cdot \hat{n} = \vec{B}_2 \cdot \hat{n} = 0$$

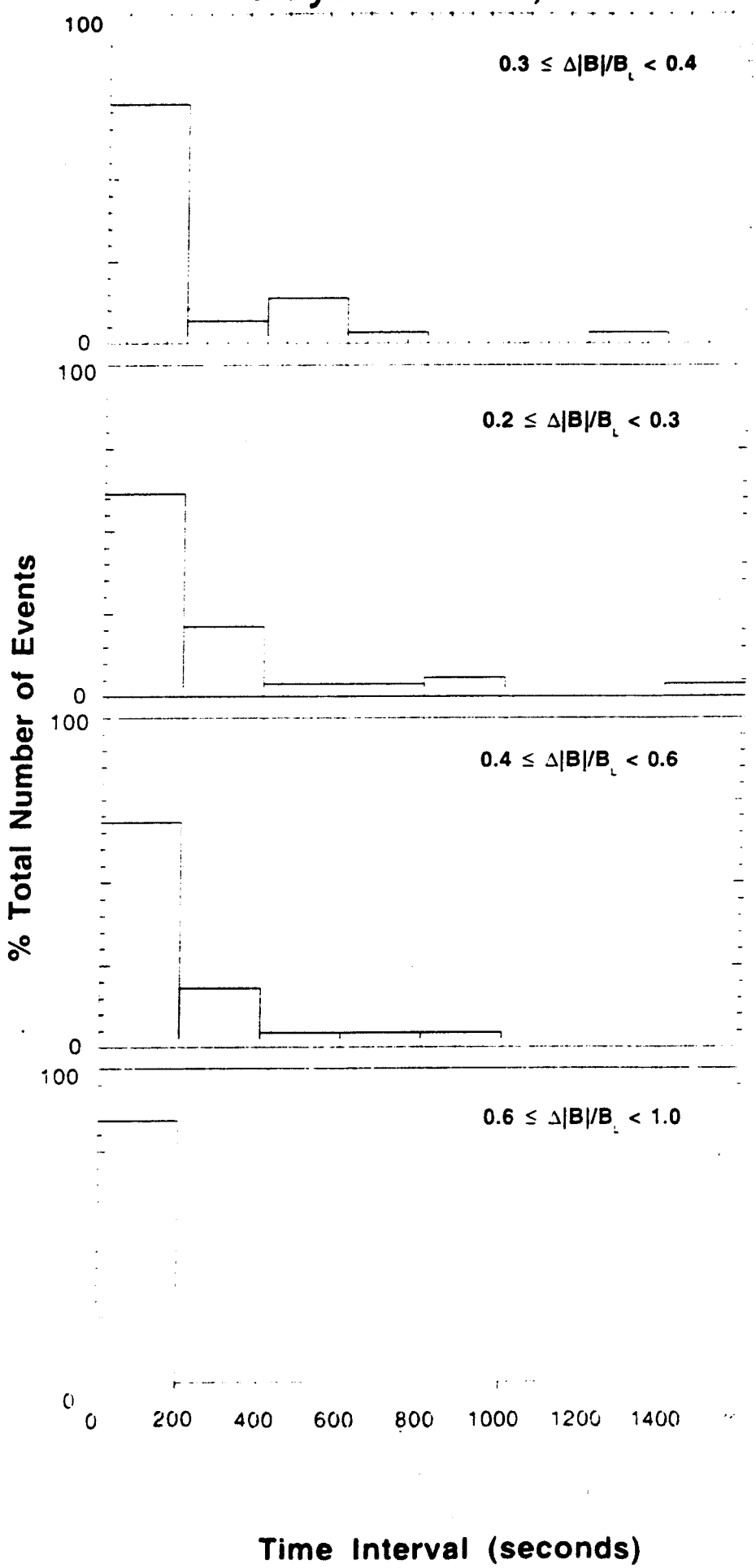



**Orbital Data as of 1 July 1999**

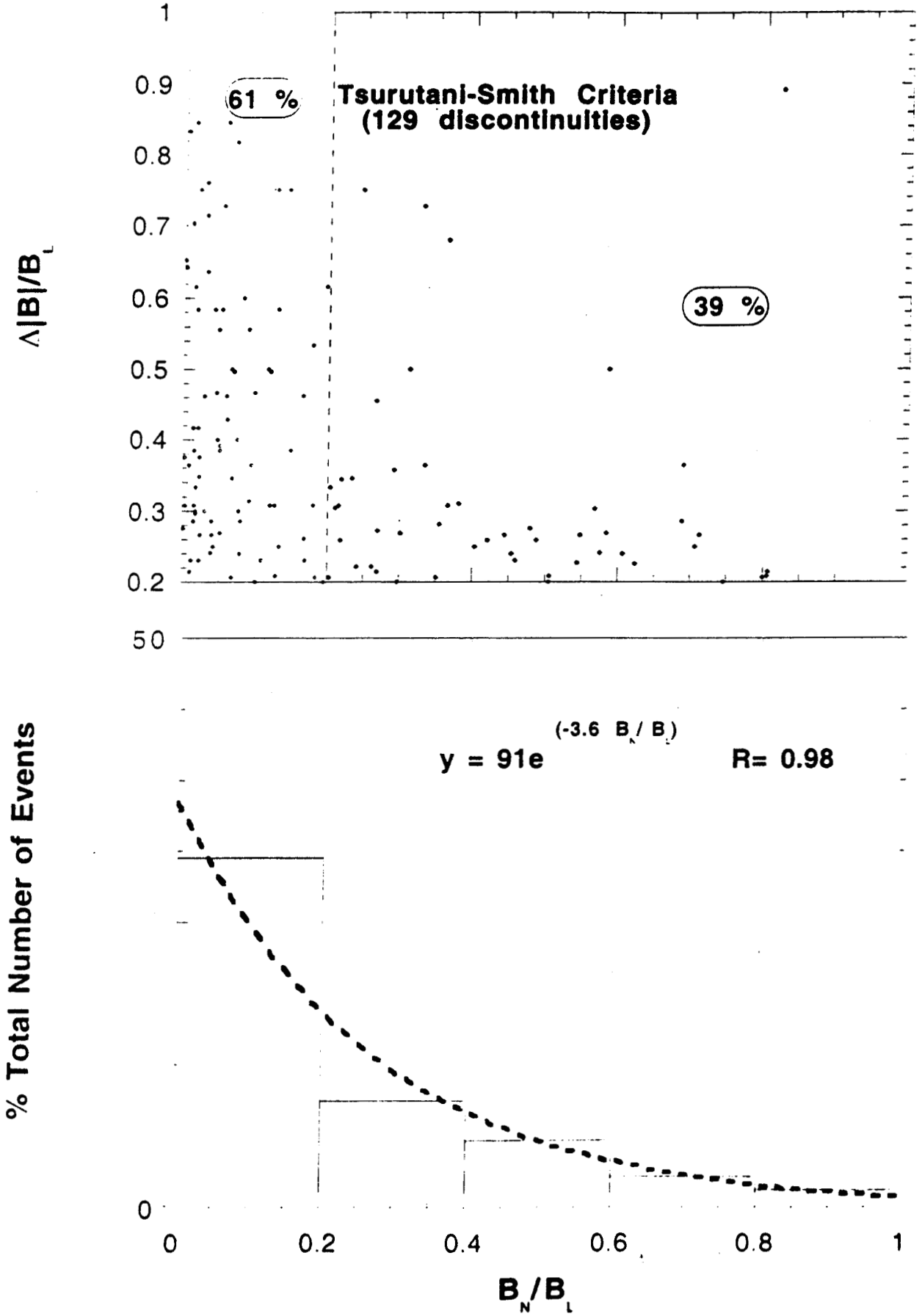
| | |
|---|---|
| Distance from Earth | 794 million km (5.31 AU) |
| Distance from Sun | 718 million km (4.80 AU) |
| Velocity Relative to Earth | 88,200 km/hr |
| Velocity Relative to Sun | 37,200 km/hr |
| Ecliptic Latitude | 22.0° South, descending |
| Solar Latitude | 29.2° South |

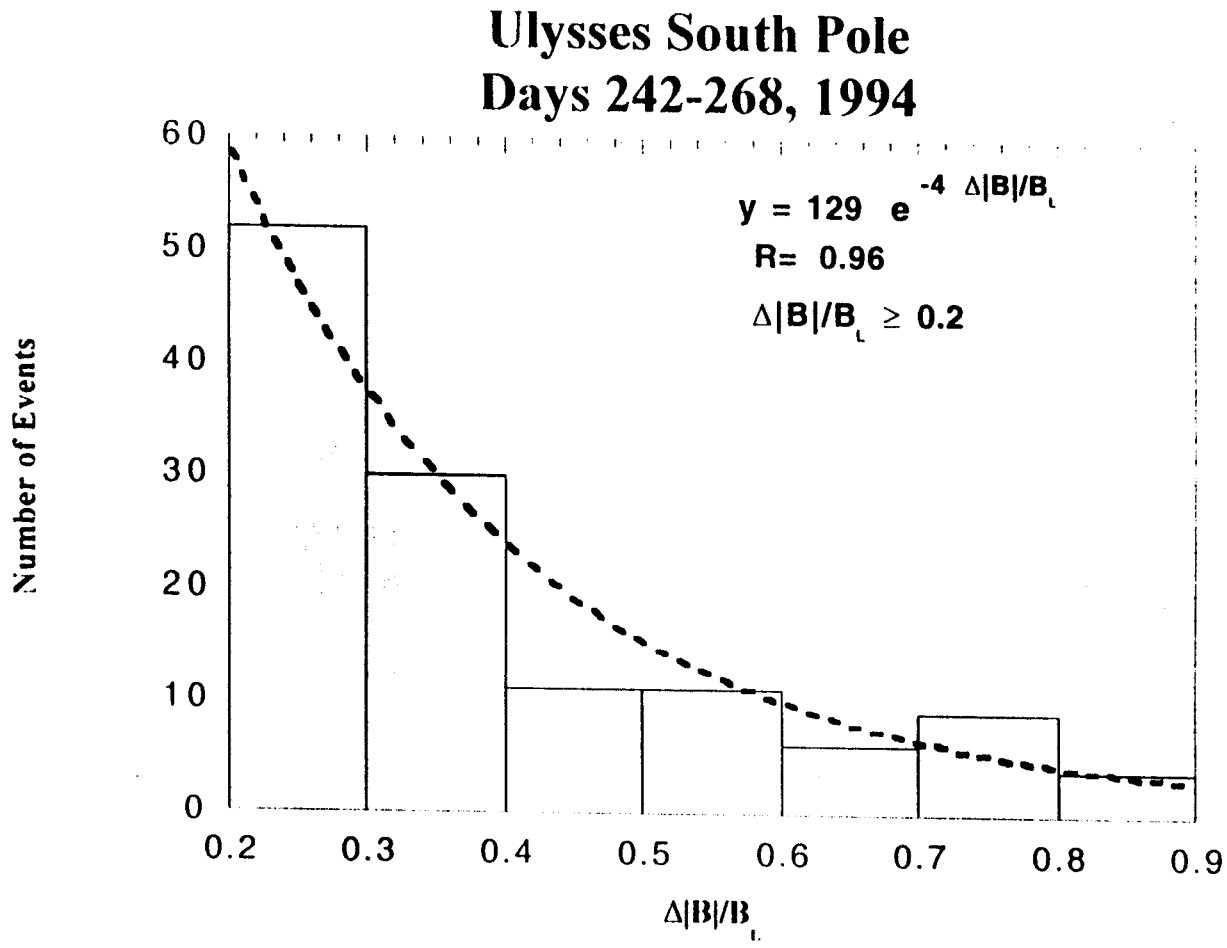

0° > Heliolatitude > -6.1°
TS_criterion
LB_criterion
fitting by 38e^(r-1)/5
fitting by 26e^-(r-1)/4
Discontinuity Daily Rate
Radial Distance (AU)
0
10
20
30
40
50
1
2
3
4
5

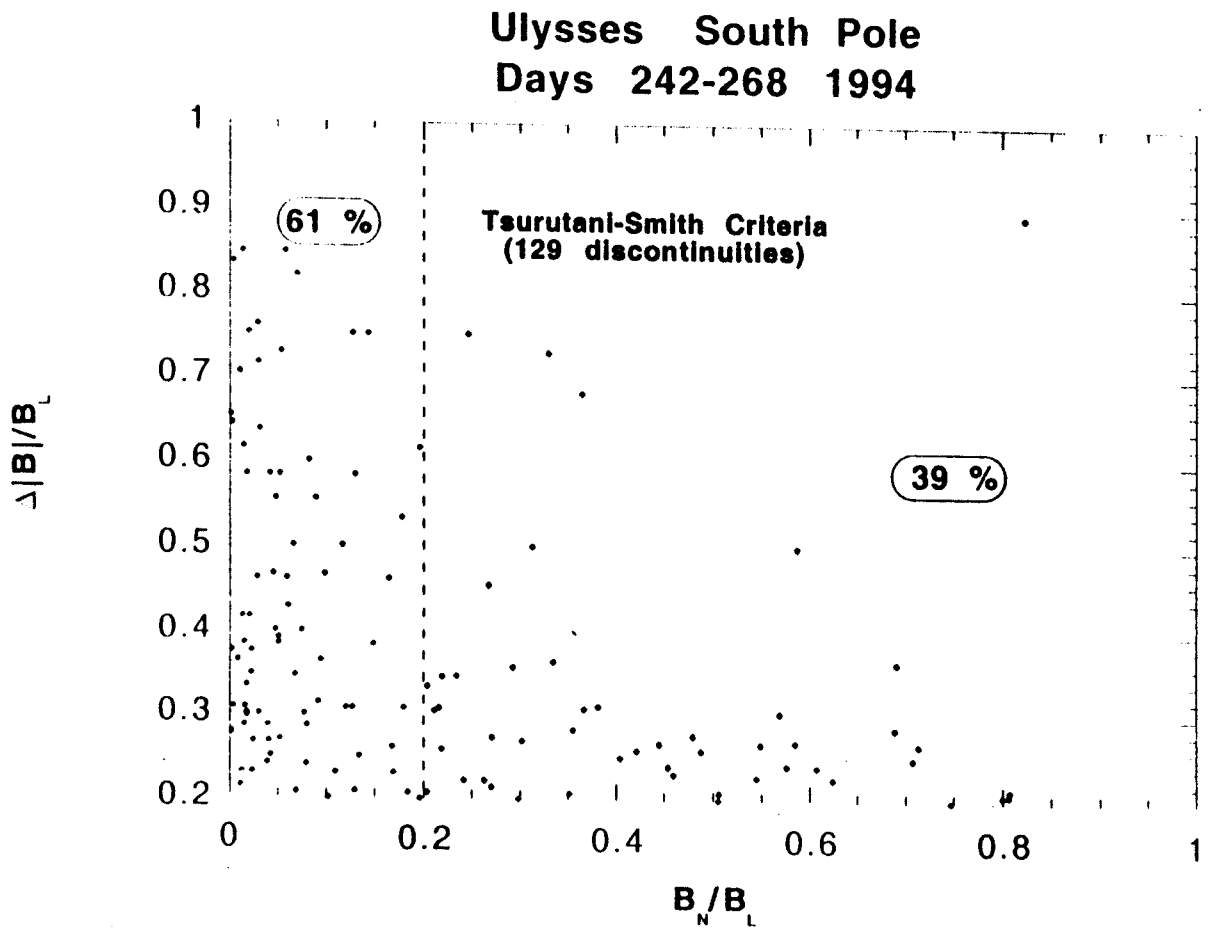
# Ulysses South Pole
# Days 242-268, 1994

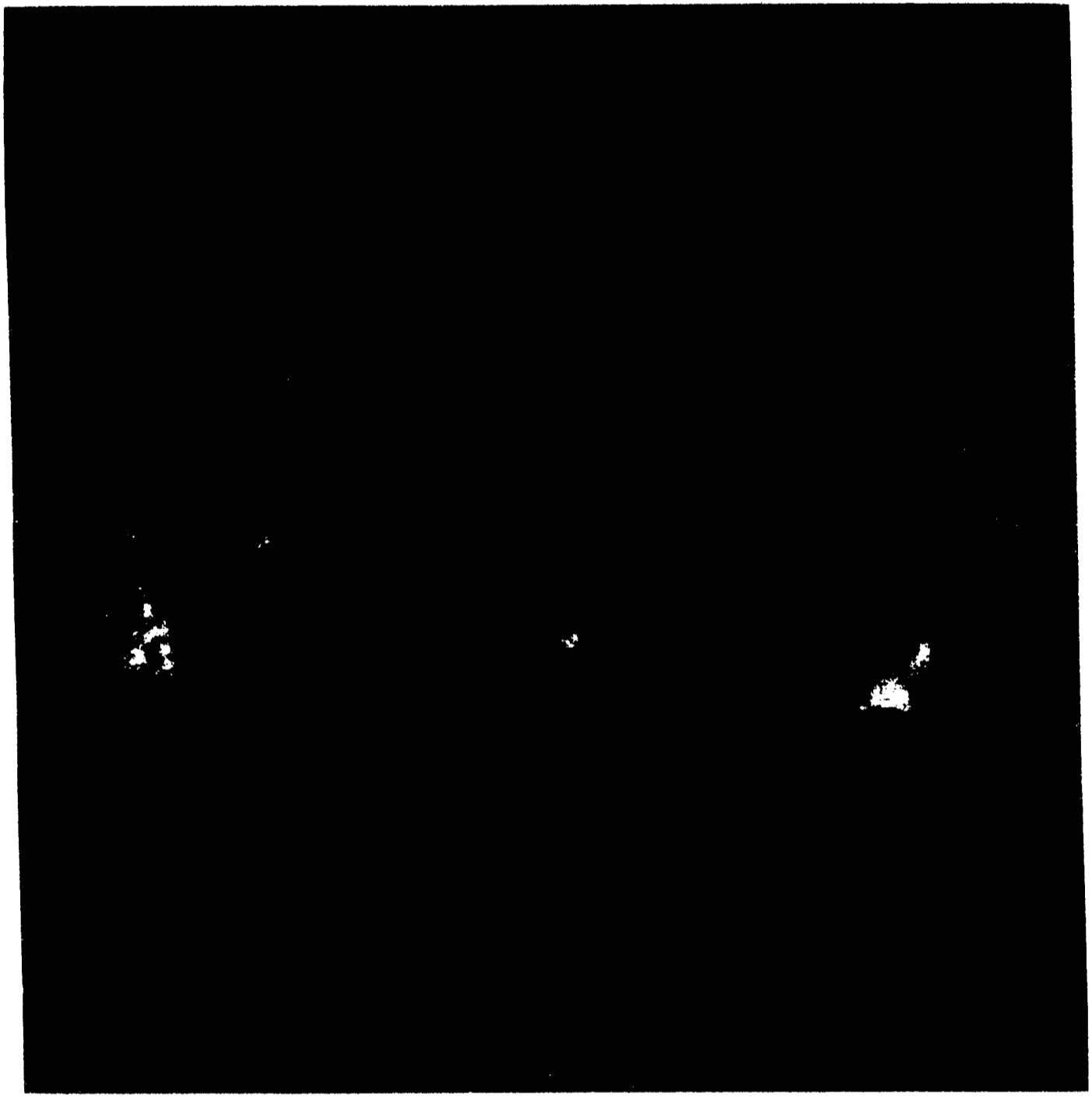


# Ulysses South Pole
# Days 242-268 1994

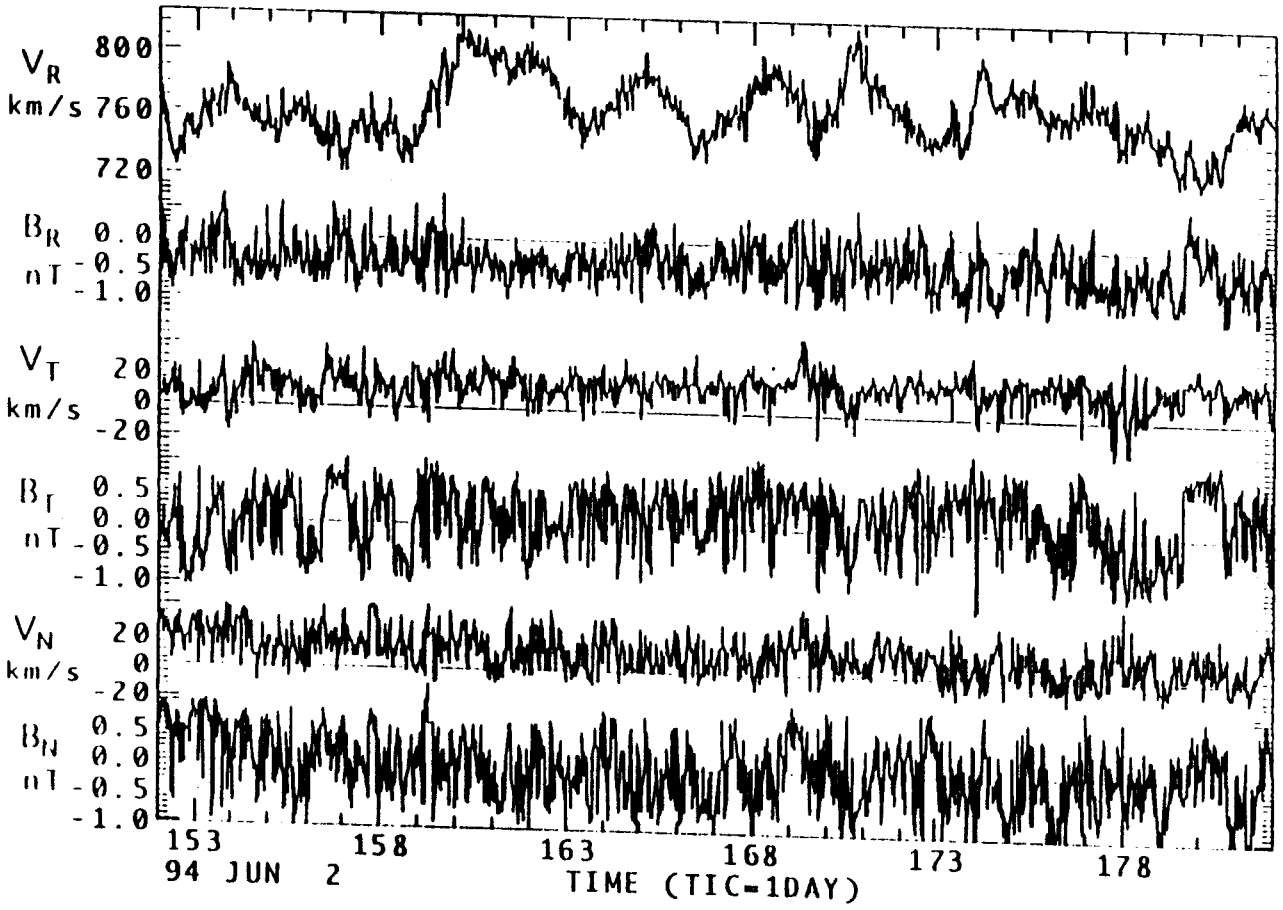


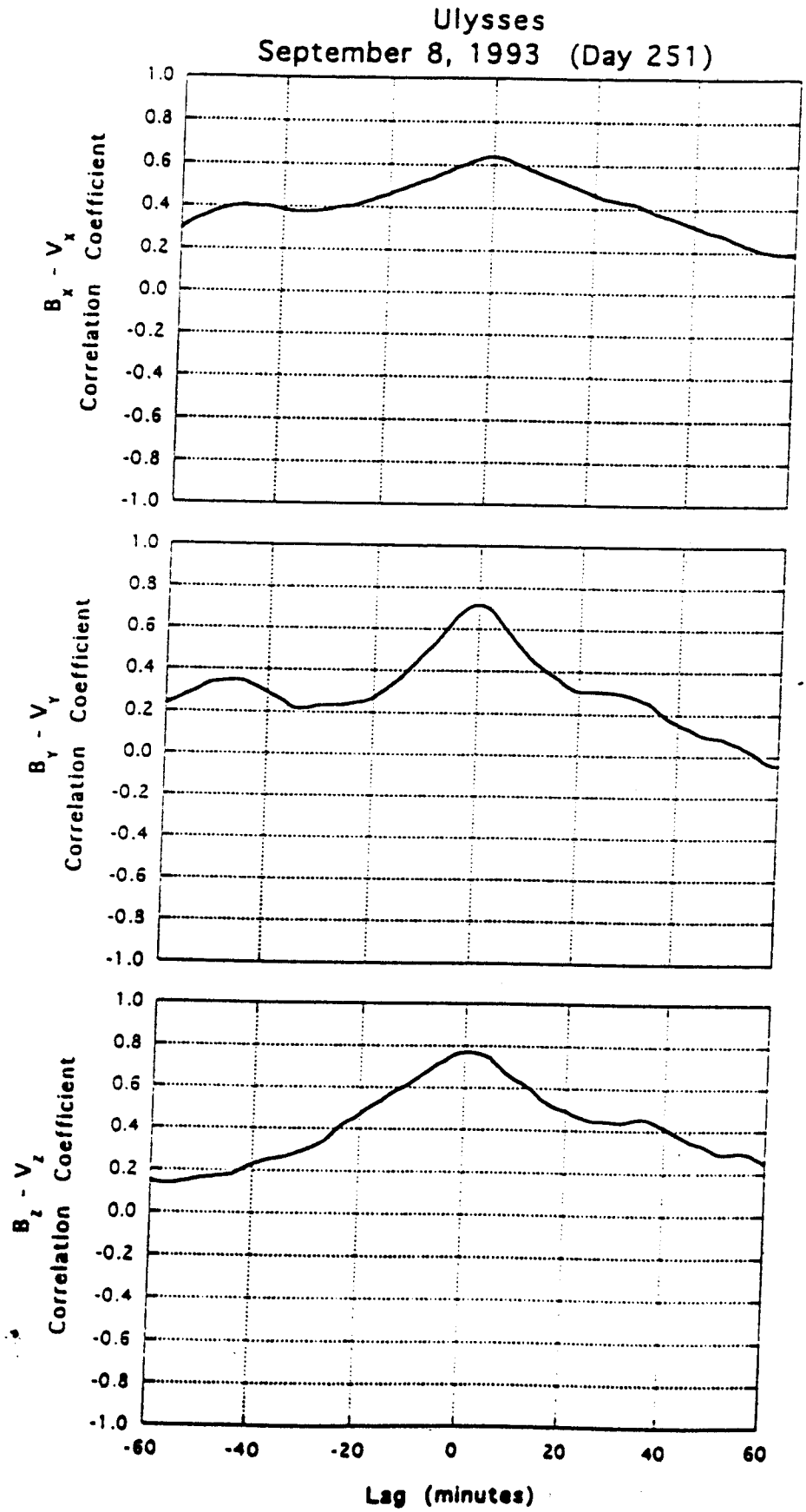

Ulysses South Pole
Days 242-268, 1994
y = 129 e^-4 Δ|B|/B_L
R= 0.96
Δ|B|/B_L ≥ 0.2
Number of Events
60
50
40
30
20
10
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Δ|B|/B_L

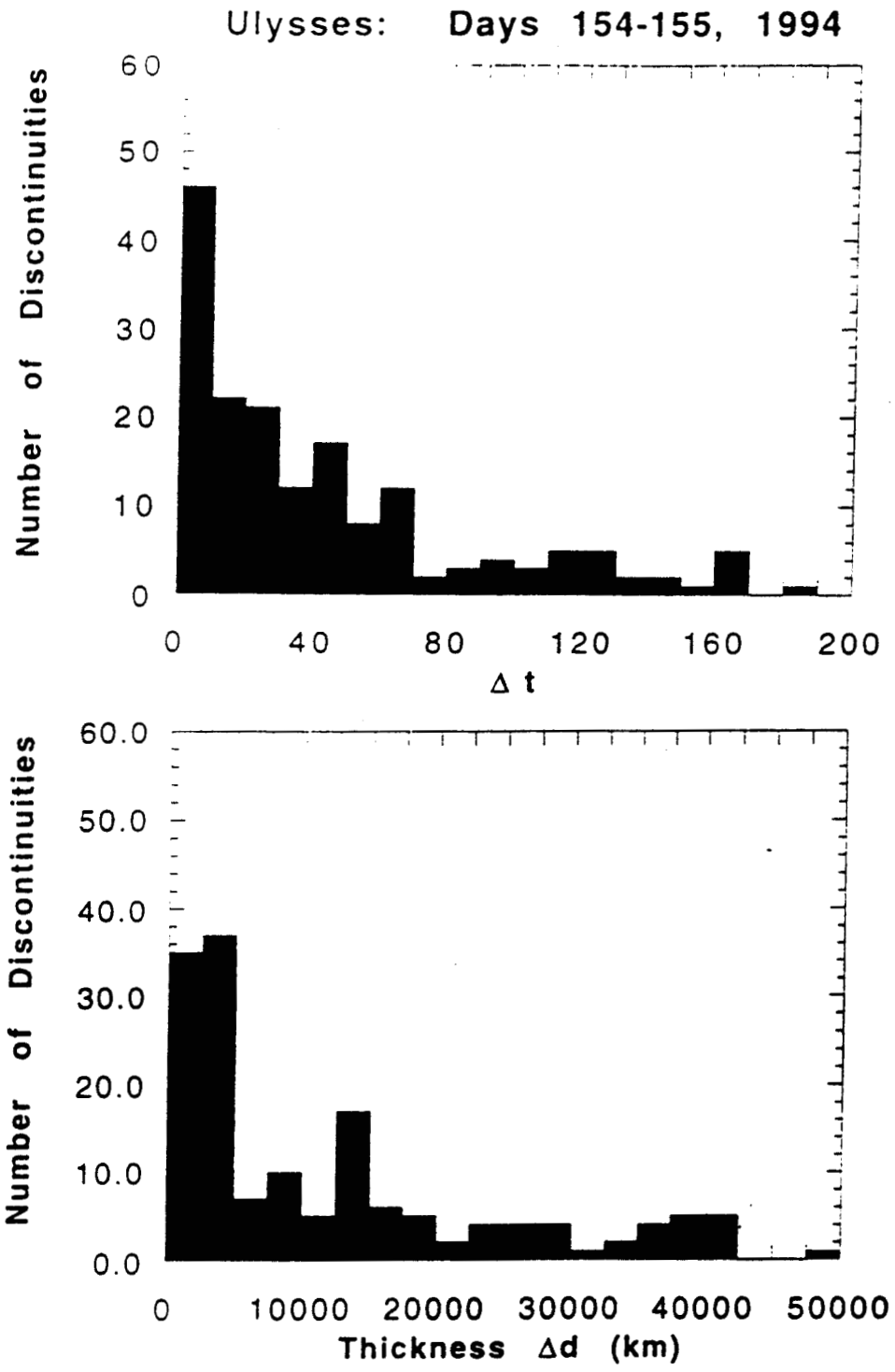

Ulysses South Pole
Days 242-268 1994
Tsurutani-Smith Criteria
(129 discontinuities)
61 %
39 %
Δ|B|/B_L
B_N/B_L
0
0.2
0.4
0.6
0.8
1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

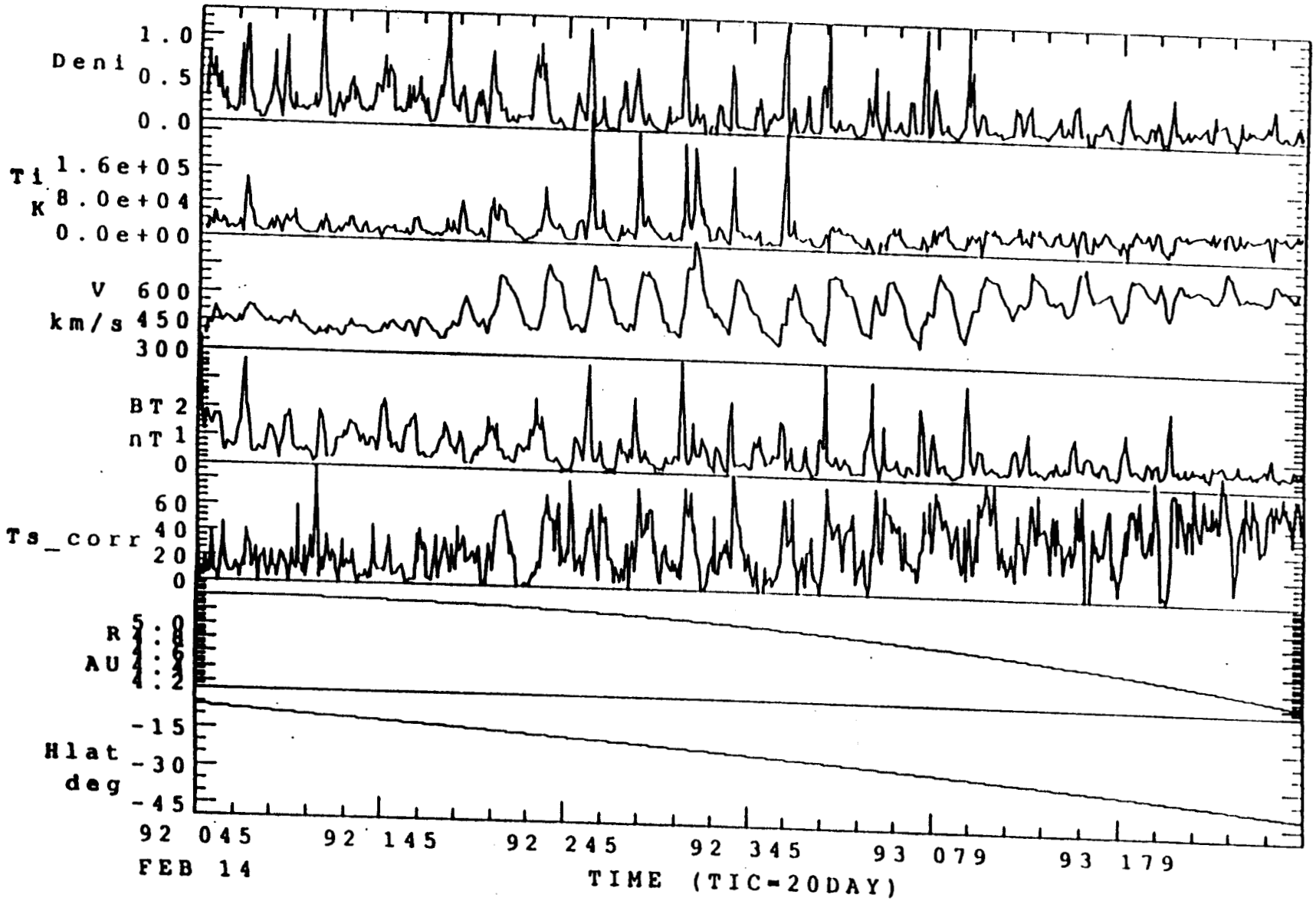


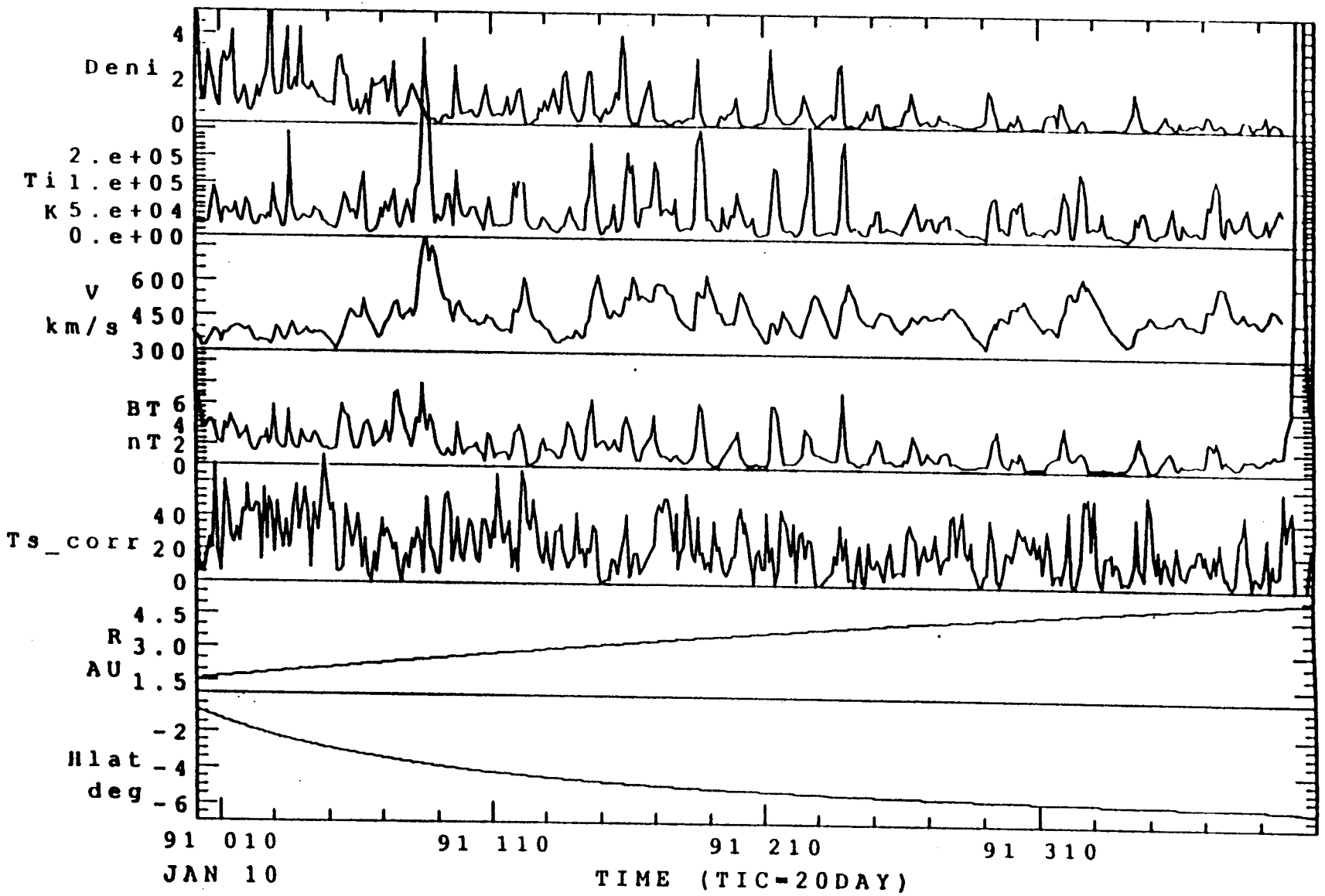
Yohkoh SXT 14 May 1992

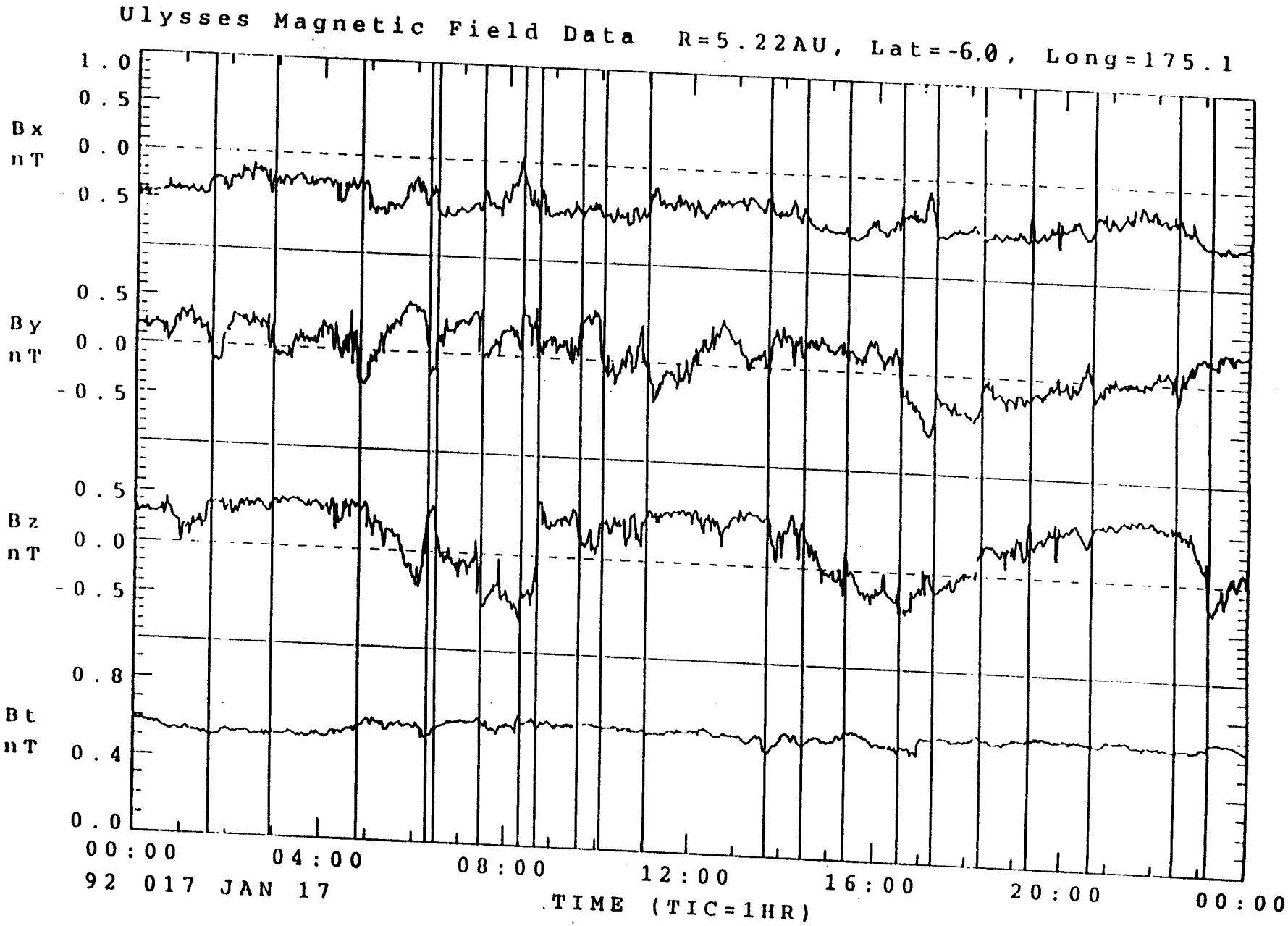

$V_R$
km/s
800
760
720
$B_R$
nT
0.0
-0.5
-1.0
$V_T$
km/s
20
0
-20
$B_T$
nT
0.5
0.0
-0.5
-1.0
$V_N$
km/s
20
0
-20
$B_N$
nT
0.5
0.0
-0.5
-1.0
153
94 JUN 2
158
163
168
173
178
TIME (TIC=1DAY)


Ulysses
September 8, 1993 (Day 251)
$B_x - V_x$ Correlation Coefficient
$B_Y - V_Y$ Correlation Coefficient
$B_z - V_z$ Correlation Coefficient
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-60
-40
-20
0
20
40
60
Lag (minutes)


Ulysses: Days 154-155, 1994
Number of Discontinuities
60
50
40
30
20
10
0
0
40
80
120
160
200
Δ t
Number of Discontinuities
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
10000
20000
30000
40000
50000
Thickness Δd (km)

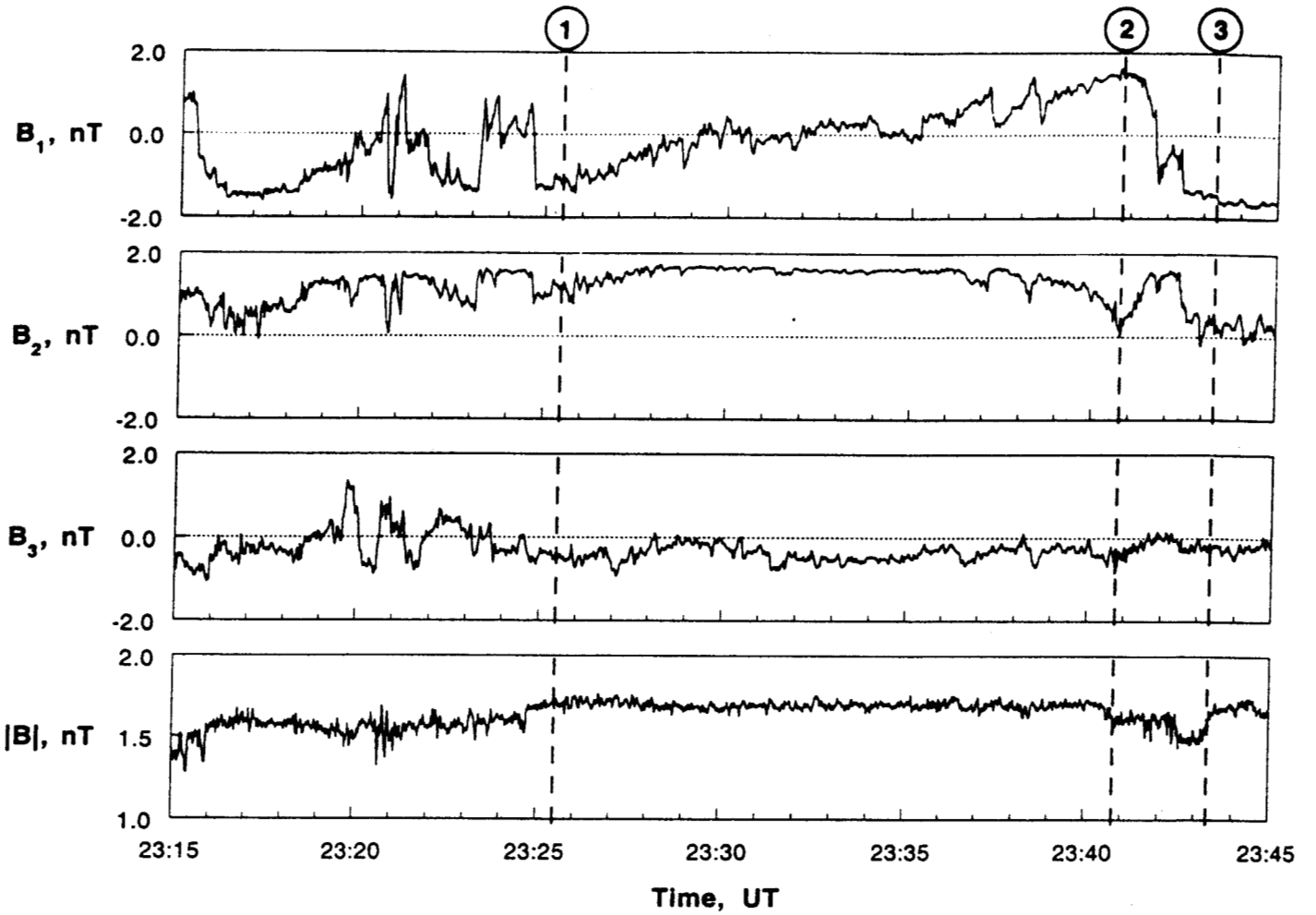

Deni
1.0
0.5
0.0
Ti
K
1.6e+05
8.0e+04
0.0e+00
V
km/s
600
450
300
BT
nT
2
1
0
Ts_corr
60
40
20
0
R
AU
5.0
4.8
4.6
4.4
4.2
Hlat
deg
-15
-30
-45
92 045
FEB 14
92 145
92 245
92 345
93 079
93 179
TIME (TIC=20DAY)


Deni
4
2
0
Ti
2.e+05
1.e+05
5.e+04
0.e+00
K
V
km/s
600
450
300
BT
nT
6
4
2
0
Ts_corr
40
20
0
R
AU
4.5
3.0
1.5
Hlat
deg
-2
-4
-6
91 010
JAN 10
91 110
91 210
91 310
TIME (TIC-20DAY)

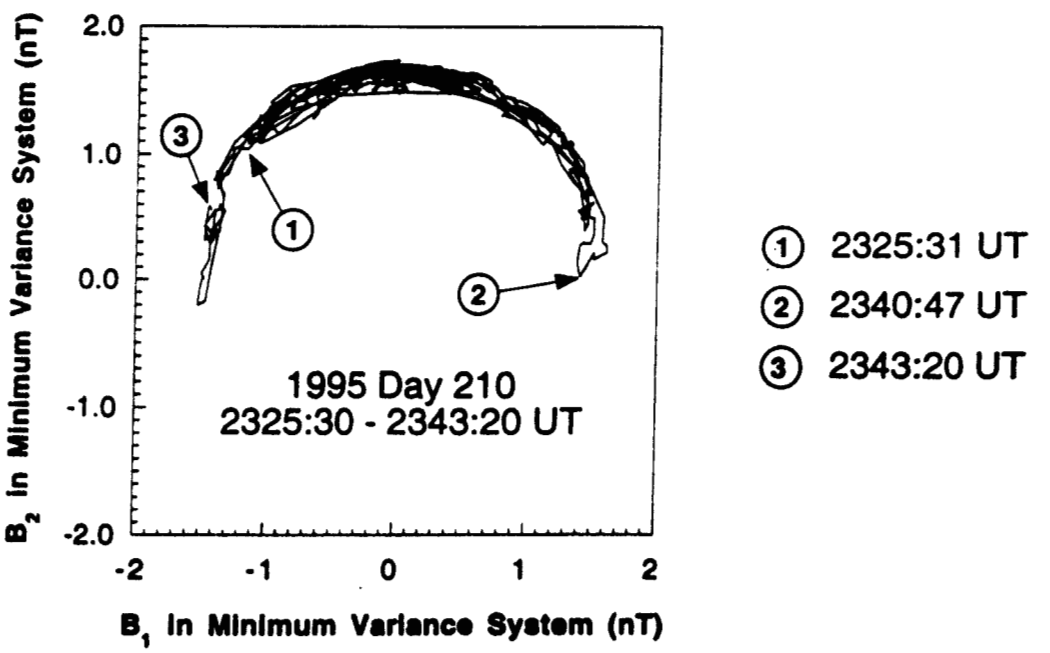

Ulysses Magnetic Field Data R=5.22AU, Lat=-6.0, Long=175.1
Bx nT
1.0
0.5
0.0
-0.5
By nT
0.5
0.0
-0.5
Bz nT
0.5
0.0
-0.5
Bt nT
0.8
0.4
0.0
00:00
04:00
08:00
12:00
16:00
20:00
00:00
92 017 JAN 17
TIME (TIC=1HR)

**Ulysses**

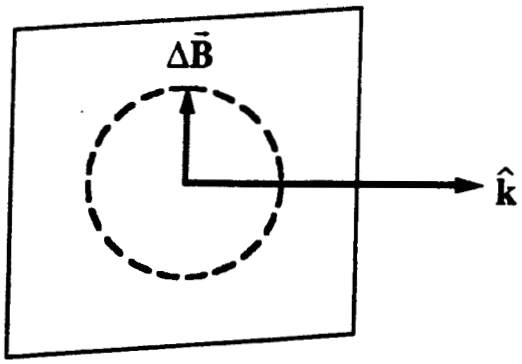
**July 29, 1995**
**Day 210**



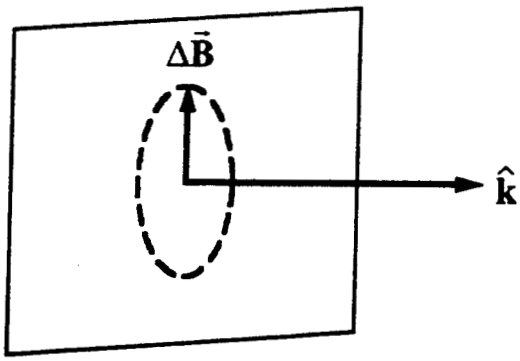

**Ulysses Heliographic Latitude = 80.2°**



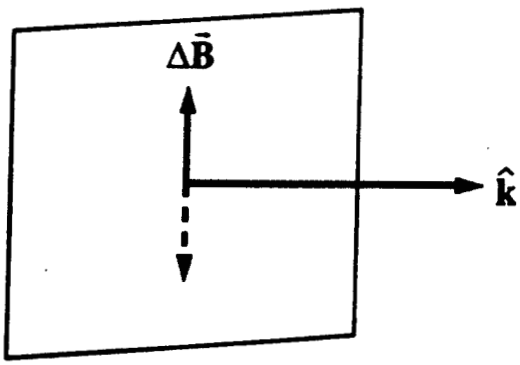
# Planar Waves




Circular Polarization

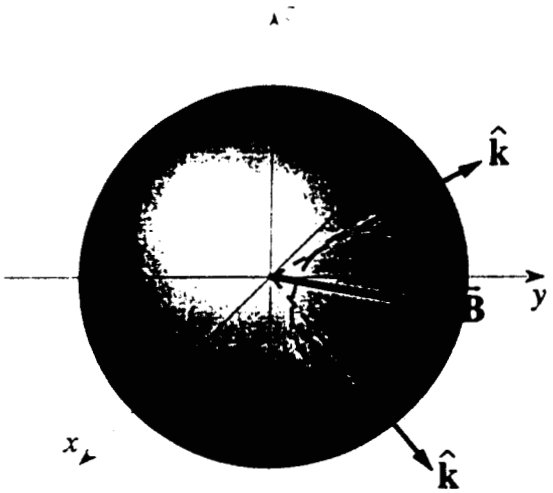



Elliptical Polarization

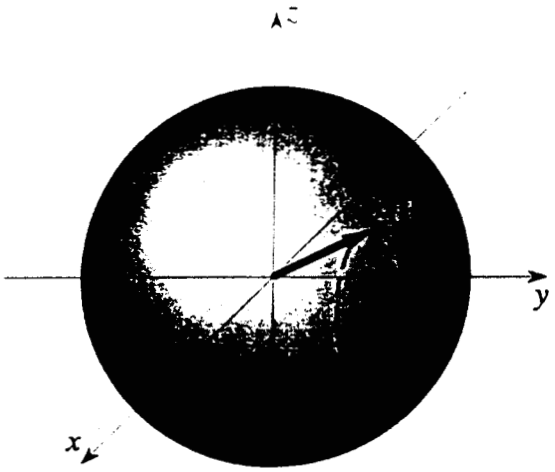



Linear Polarization

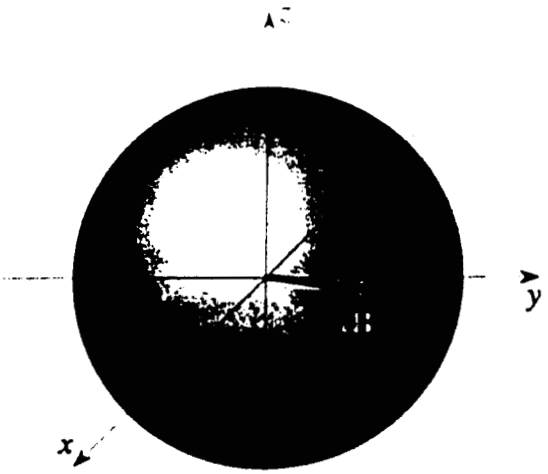
# Spherical Waves




**Circular Polarization**




**Elliptical Polarization**




**Arc Polarization**

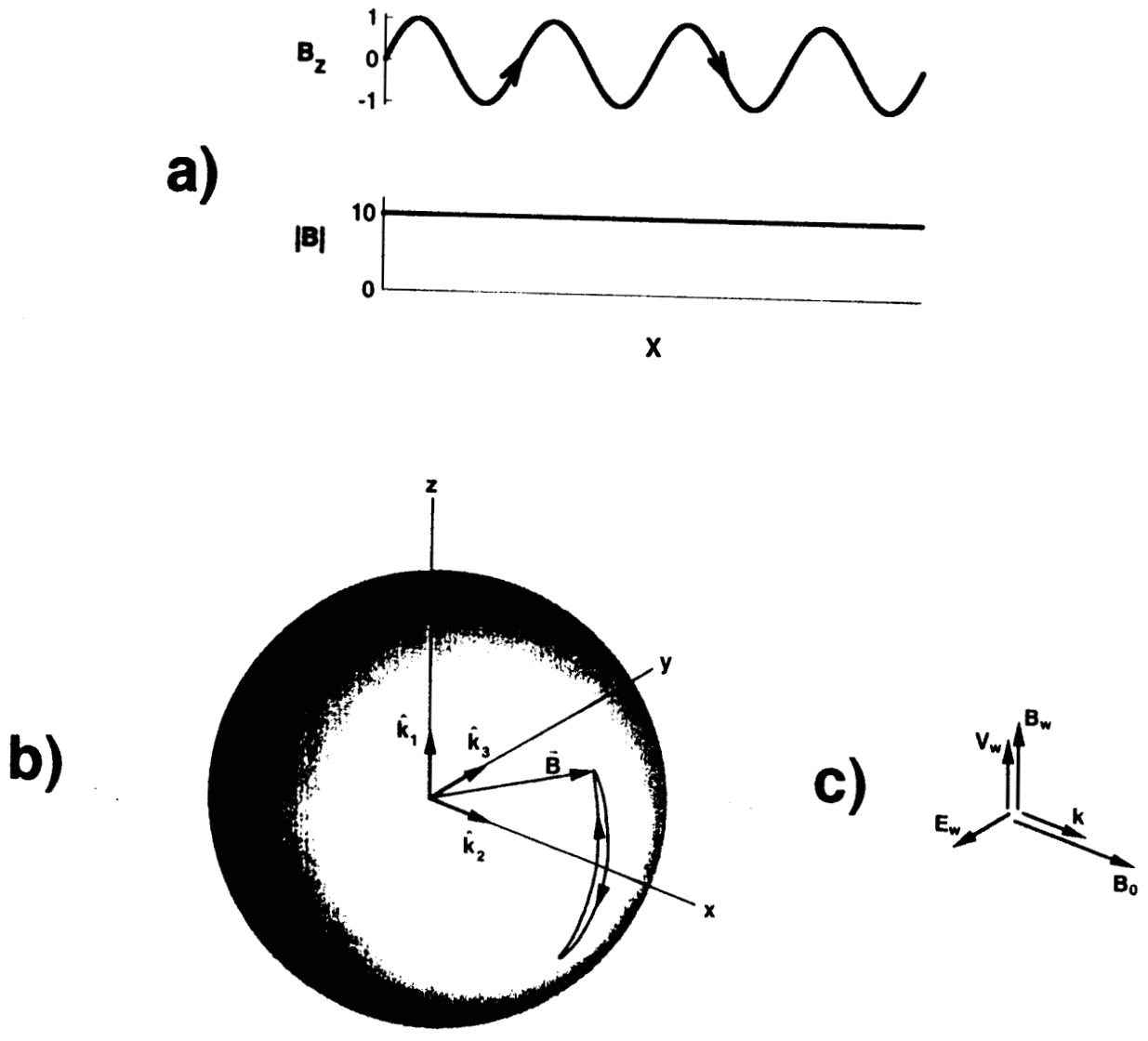
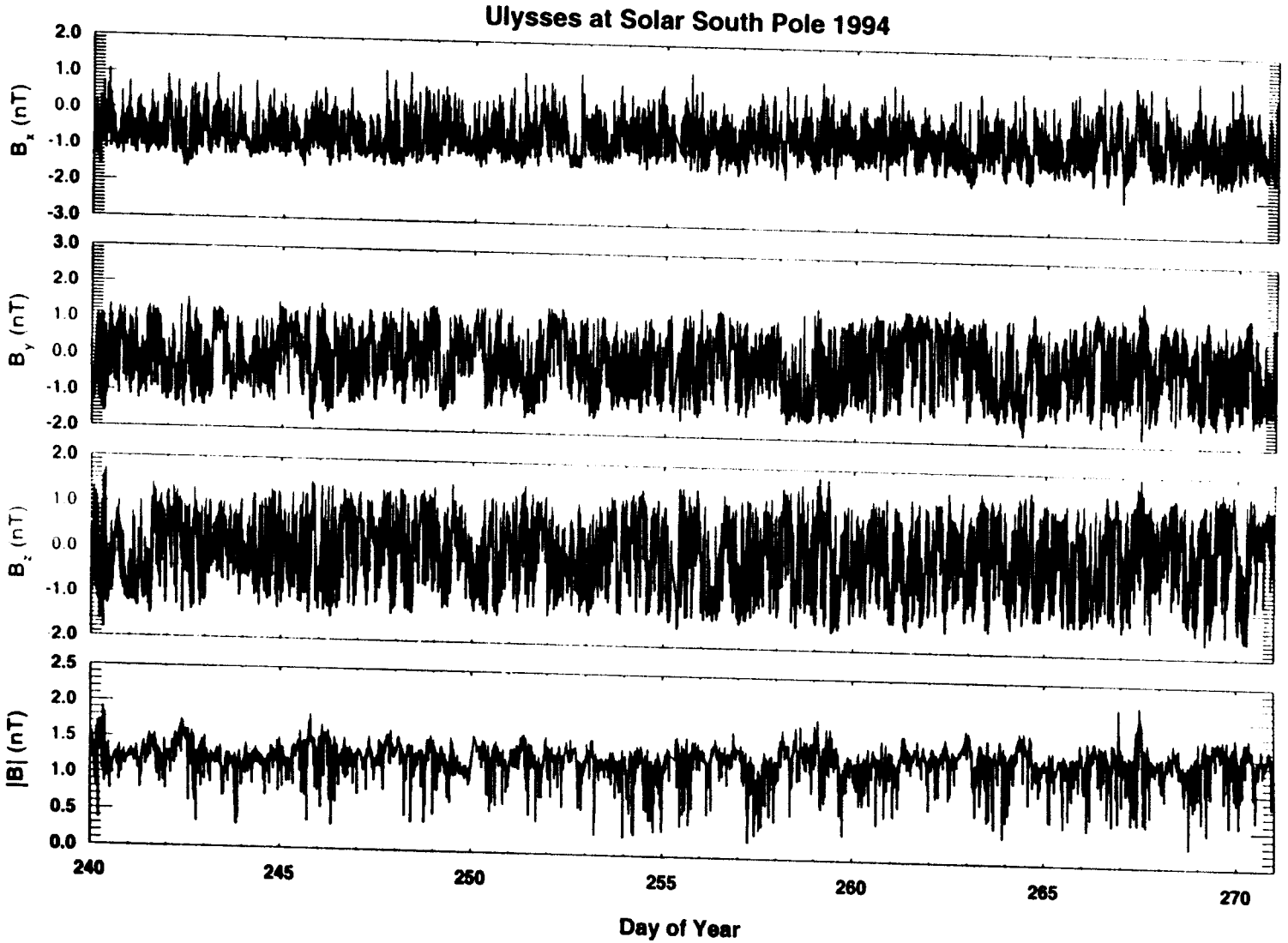
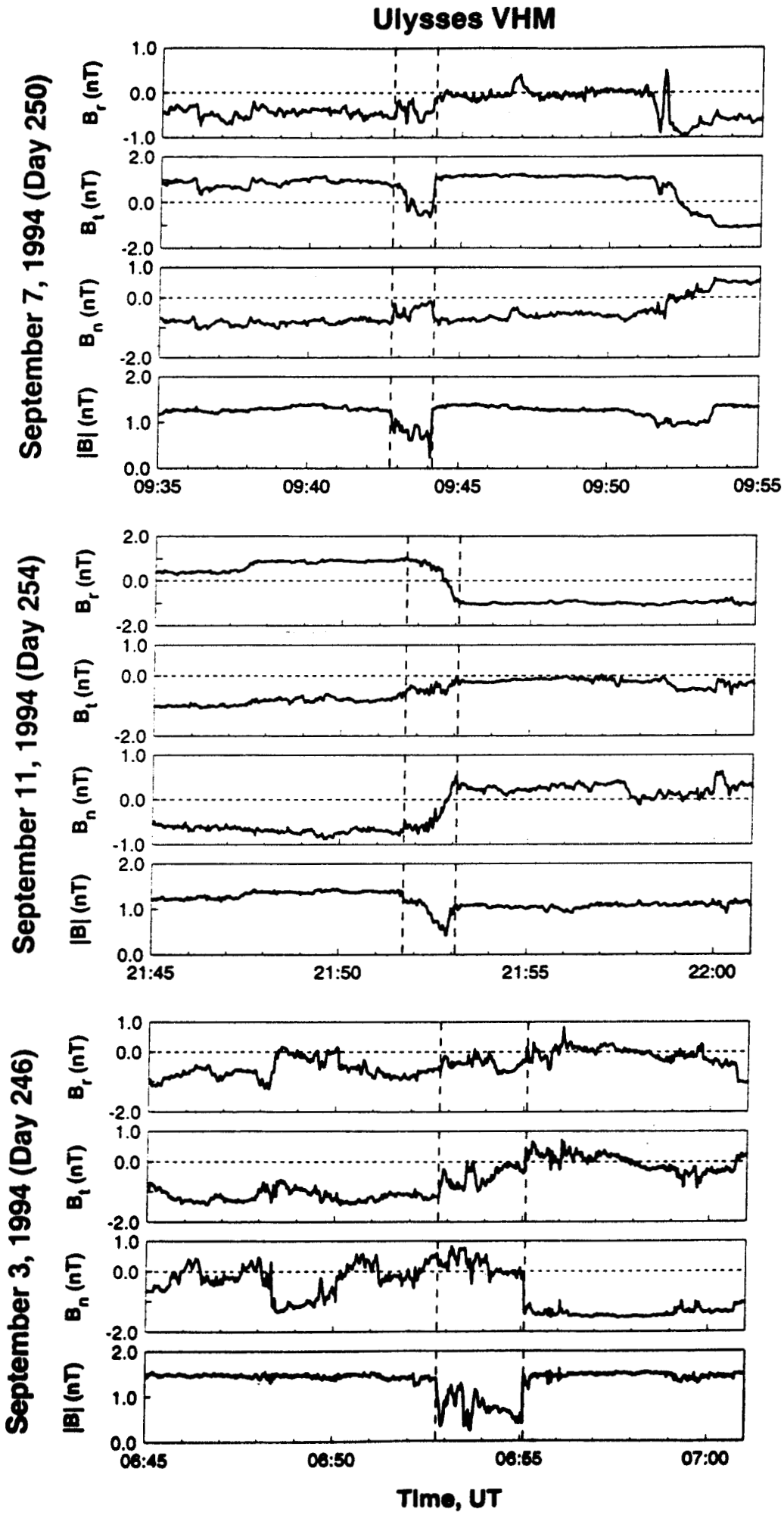
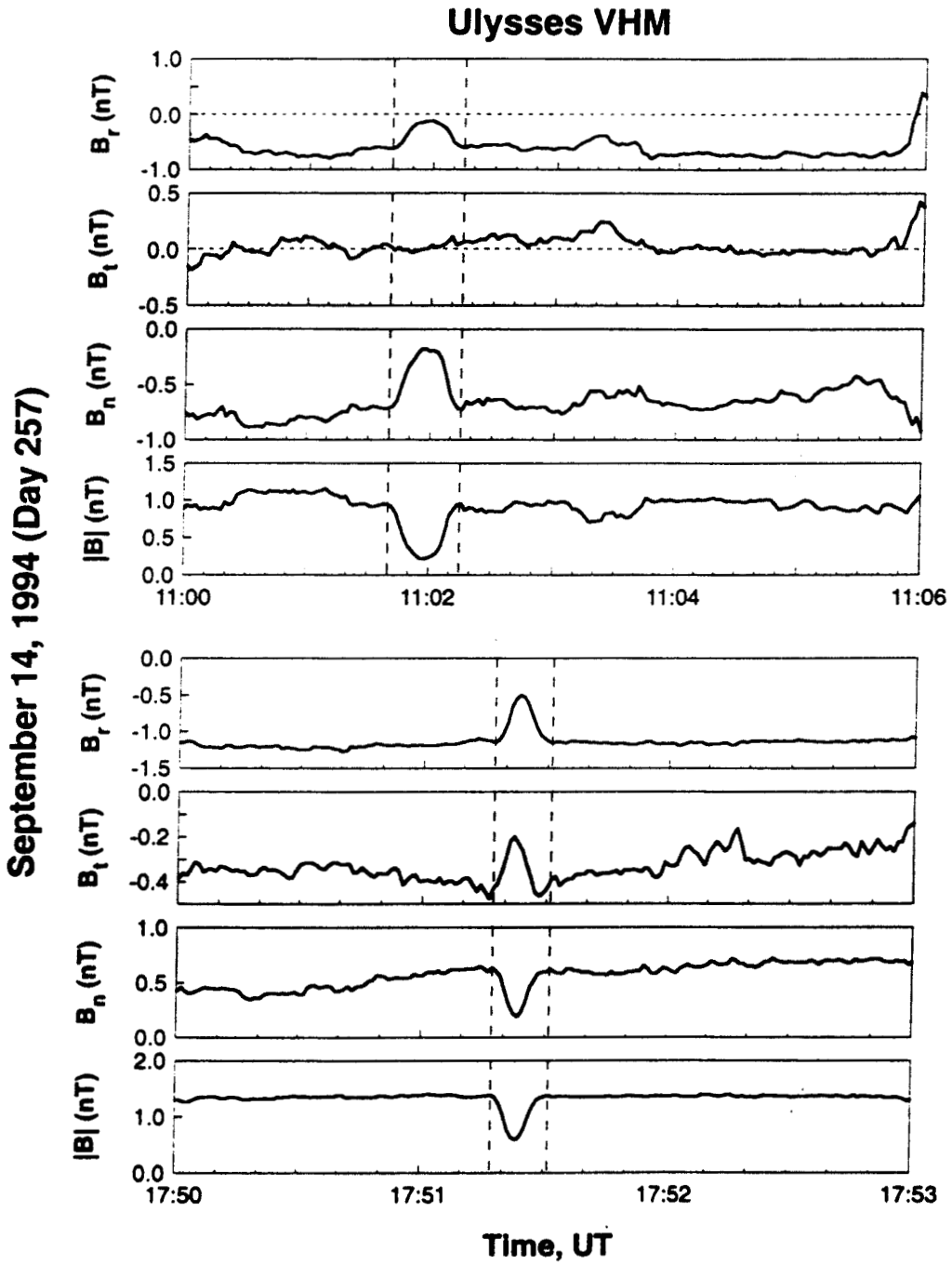
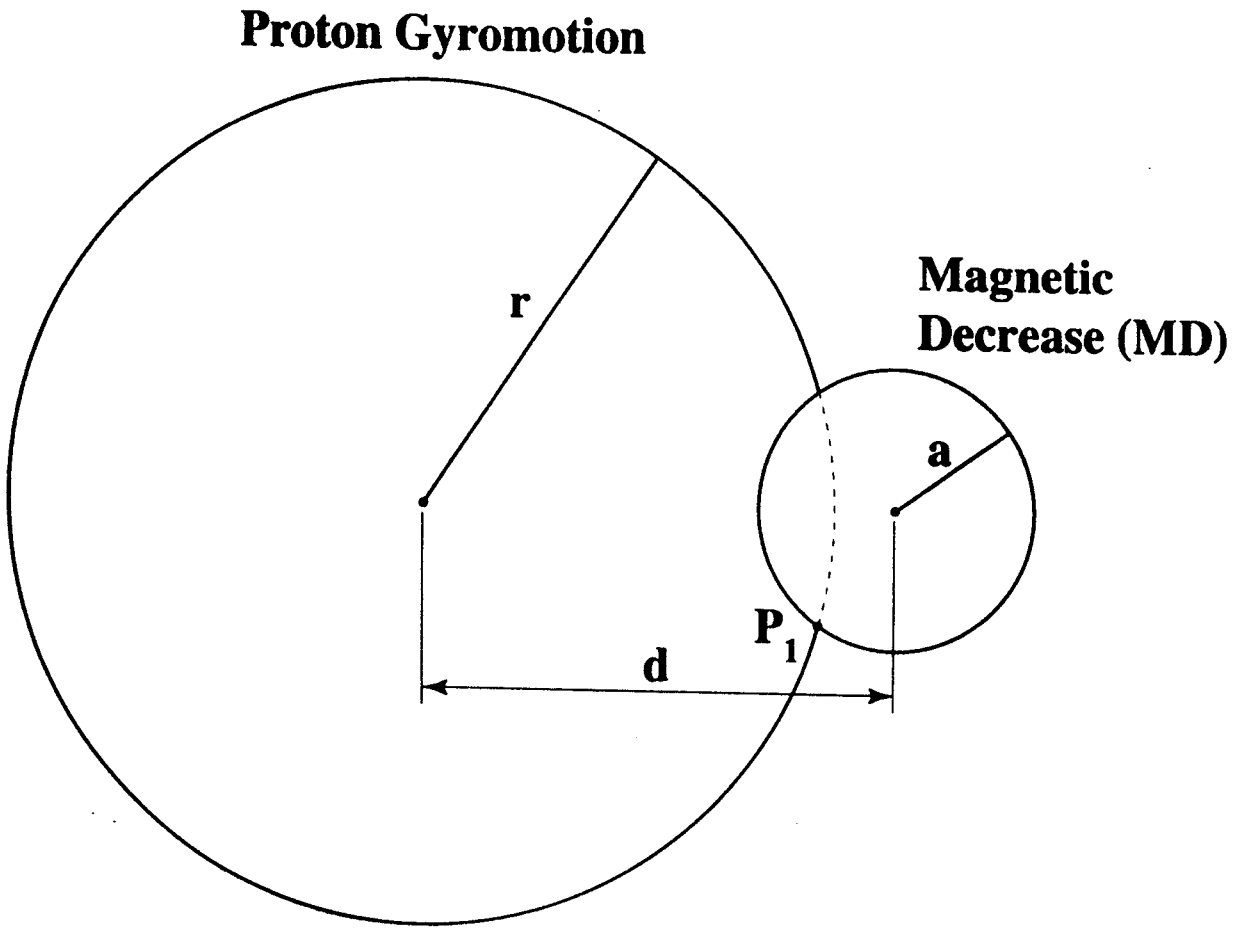



**Figure 4**

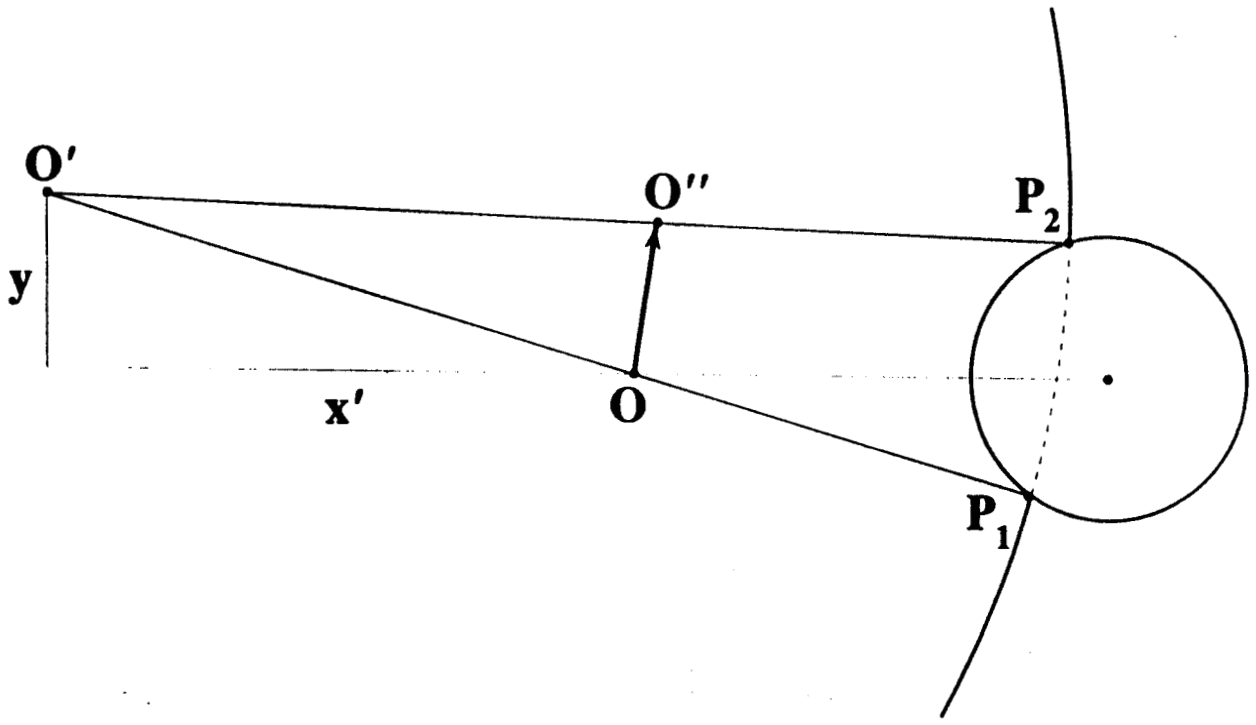

Ulysses at Solar South Pole 1994
$B_x$ (nT)
2.0
1.0
0.0
-1.0
-2.0
-3.0
$B_y$ (nT)
3.0
2.0
1.0
0.0
-1.0
-2.0
$B_z$ (nT)
2.0
1.0
0.0
-1.0
-2.0
|B| (nT)
2.5
2.0
1.5
1.0
0.5
0.0
240
245
250
255
260
265
270
Day of Year


Ulysses VHM
September 7, 1994 (Day 250)
September 11, 1994 (Day 254)
September 3, 1994 (Day 246)
$B_r$ (nT)
$B_t$ (nT)
$B_n$ (nT)
|B| (nT)
09:35
09:40
09:45
09:50
09:55
21:45
21:50
21:55
22:00
06:45
06:50
06:55
07:00
Time, UT


Ulysses VHM
September 14, 1994 (Day 257)
$B_r$ (nT)
$B_t$ (nT)
$B_n$ (nT)
|B| (nT)
1.0
0.0
-1.0
0.5
0.0
-0.5
0.0
-0.5
-1.0
1.5
1.0
0.5
0.0
11:00
11:02
11:04
11:06
0.0
-0.5
-1.0
-1.5
0.0
-0.2
-0.4
1.0
0.5
0.0
2.0
1.0
0.0
17:50
17:51
17:52
17:53
Time, UT

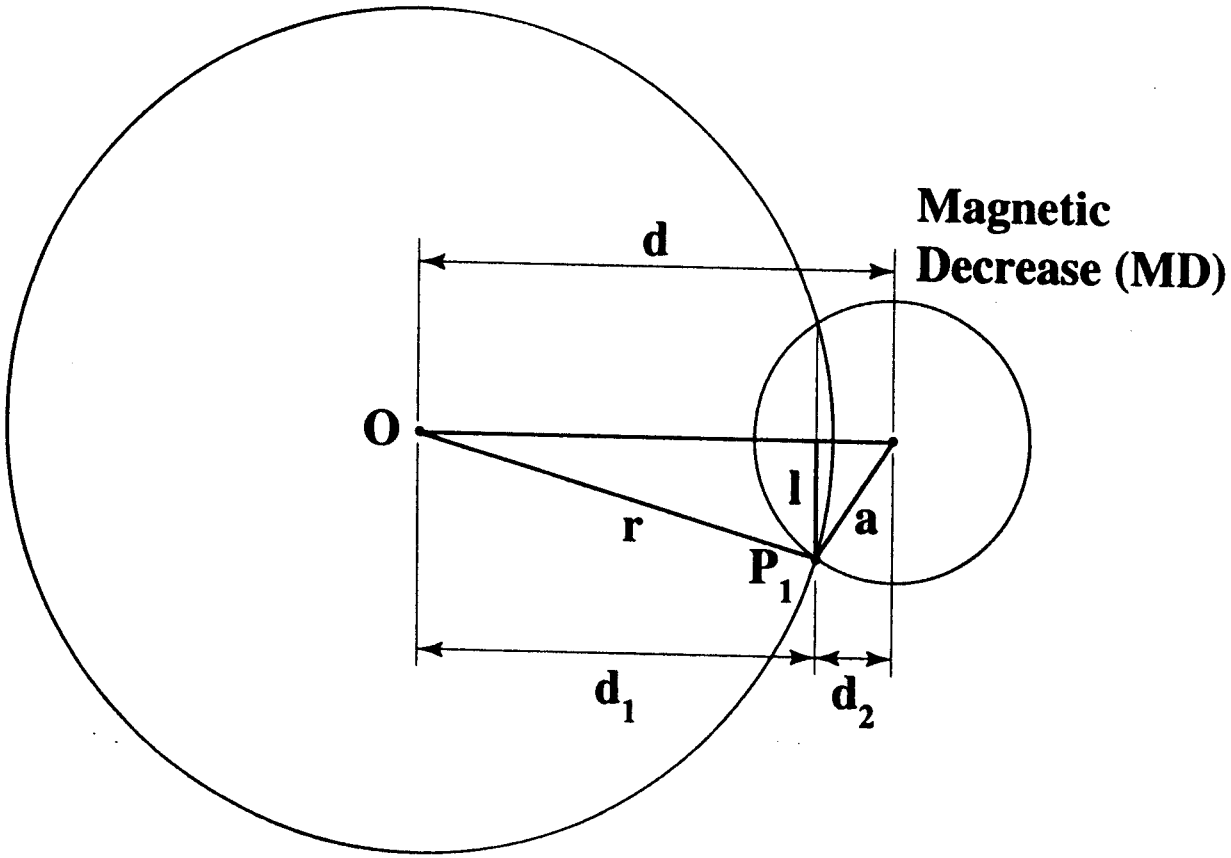



BTT/JKA
July 1999

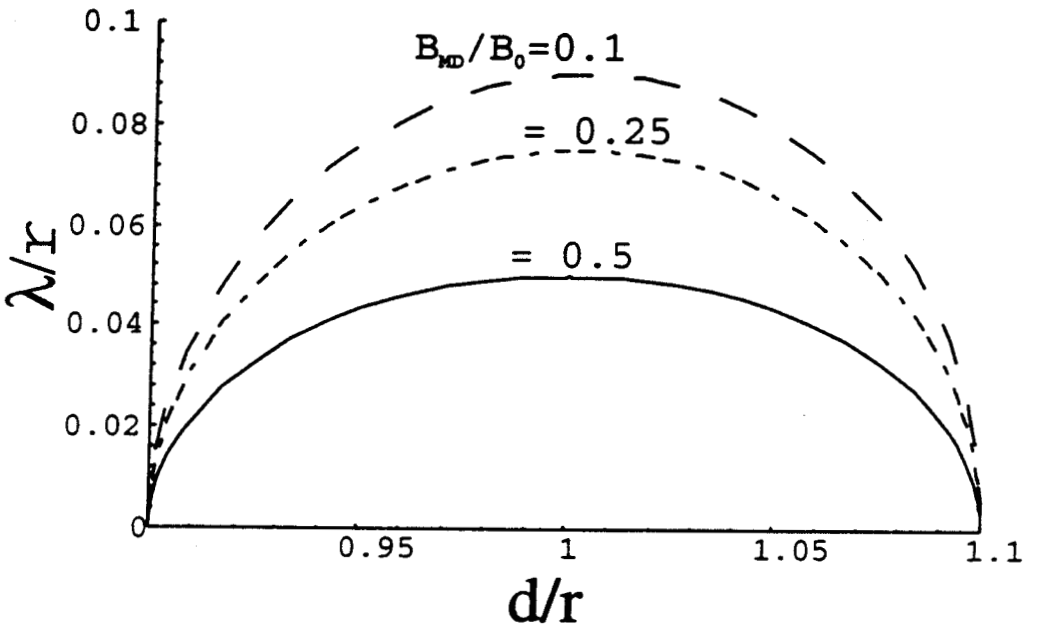


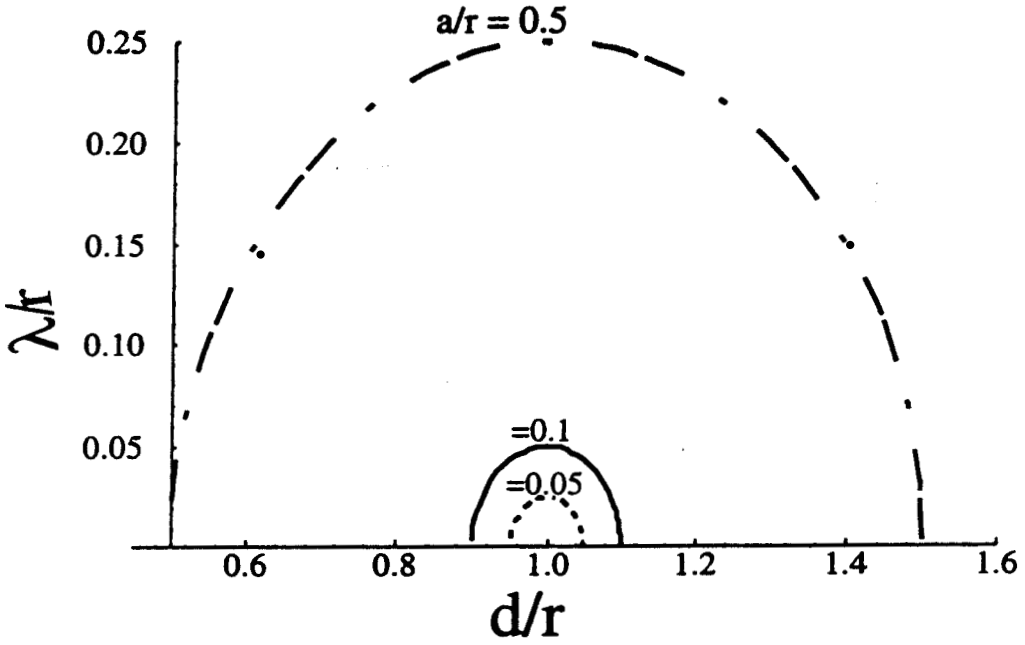

BTT/JKA
July 1999

# Proton Gyromotion




BTT/JKA
July 1999


0.1
0.08
0.06
0.04
0.02
0
λ/r
B_MD/B_0=0.1
= 0.25
= 0.5
0.95
1
1.05
1.1
d/r


a/r = 0.5
0.25
0.20
0.15
0.10
0.05
λ/r
=0.1
=0.05
0.6
0.8
1.0
1.2
1.4
1.6
d/r

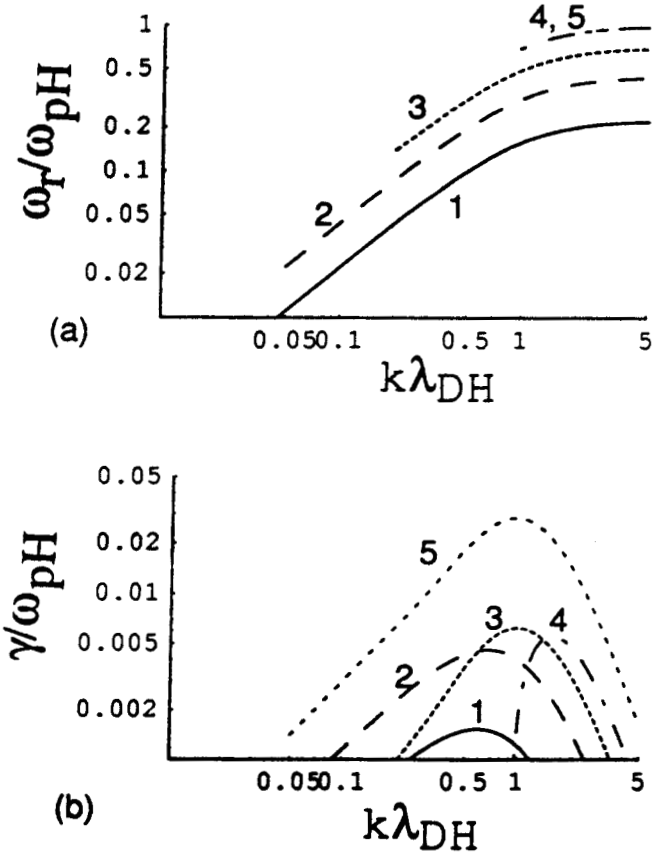

1
0.5
0.2
0.1
0.05
0.02
$\omega_r/\omega_{pH}$
4, 5
3
2
1
(a)
0.05 0.1
0.5 1
5
$k\lambda_{DH}$
0.05
0.02
0.01
0.005
0.002
$\gamma/\omega_{pH}$
5
3
4
2
1
(b)
0.05 0.1
0.5 1
5
$k\lambda_{DH}$

Fig. 3