

Ur
SEC

AD-A235 707



INFORMATION PAGE

Form Approved
OMB No. 0704-0188

1a Unclassified		1b RESTRICTIVE MARKINGS	
2a. SECURITY CLASSIFICATION AUTHORITY		3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; Distribution unlimited	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		5 MONITORING ORGANIZATION REPORT NUMBER(S)	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) PL-TR-91-3000		7a. NAME OF MONITORING ORGANIZATION	
6a. NAME OF PERFORMING ORGANIZATION Phillips Lab, Geophysics Directorate	6b. OFFICE SYMBOL (if applicable) PHG	7b. ADDRESS (City, State, and ZIP Code)	
6c. ADDRESS (City, State, and ZIP Code) Hanscom AFB Massachusetts 01731-5000		9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (if applicable)	10 SOURCE OF FUNDING NUMBERS	
8c. ADDRESS (City, State, and ZIP Code)		PROGRAM ELEMENT NO 61102F	PROJECT NO 2311
		TASK NO G4	WORK UNIT ACCESSION NO 01
11. TITLE (Include Security Classification) Latitudinal Cosmic Ray Gradients and Their Relation to Solar Activity Asymmetries			
12. PERSONAL AUTHOR(S) D.B. Swinson*, J.E. Humble#, M.A. Shea, D.F. Smart			
13a. TYPE OF REPORT Reprint	13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) 1991 May 3	15. PAGE COUNT 4
16. SUPPLEMENTARY NOTATION *Dept of Physics & Astronomy, University of New Mexico, 800 Yale NE, Albuquerque, NM 87131 #Physics Dept, University of Tasmania, Hobart, Tasmania, Australia 2001 - Reprint from 21st International Cosmic Ray Conference, Conference Papers, 6, 79-82, 1990			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	
		Cosmic rays, Solar activity, Neutral sheet, Heliospheric studies, Muon detectors	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
Data from underground cosmic ray muon telescopes in New Mexico, Bolivia and Tasmania are shown to be consistent with a latitudinal cosmic ray density gradient where the cosmic ray density initially decreases with distance from the neutral sheet and then, farther from the neutral sheet increases with increasing distance from the sheet on both sides of the sheet.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ OTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL M.A. Shea		22b. TELEPHONE (Include Area Code) (617) 377-3977	22c. OFFICE SYMBOL PHG

DD Form 1473, JUN 86

Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

Reprint from 21st International Cosmic Ray Conference, Conference Papers, 6, 79-82, 1990.

LATITUDINAL COSMIC RAY GRADIENTS AND
THEIR RELATION TO SOLAR ACTIVITY ASYMMETRIES

D. B. Swinson, J. E. Humble+, M. A. Shea* and D. F. Smart*

Department of Physics & Astronomy, University of New Mexico,
800 Yale NE, Albuquerque, NM 87131, USA

+ Physics Dept., University of Tasmania, Hobart, Tasmania, Australia 7001

*Geophysics Laboratory, Hanscom AFB, Bedford, MA 01731, USA

Abstract

Data from underground cosmic ray muon telescopes in New Mexico, Bolivia and Tasmania are shown to be consistent with a latitudinal cosmic ray density gradient where the cosmic ray density initially decreases with distance from the neutral sheet and then, farther from the neutral sheet increases with increasing distance from the sheet on both sides of the sheet.

Introduction. The neutral sheet separates regions of opposite magnetic polarity in the heliosphere. For much of each solar cycle these regions are somewhat mis-shapen hemispheres. The sheet is warped, with the amplitude of the warp varying through a solar cycle, and acts as if it has its source just above the solar photosphere. Hoeksema et al. (1983) suggested that 2.5 solar radii is an appropriate altitude.

In a companion paper (Swinson et al., 1990, paper SH 6.2-2, this conference) we have tried to demonstrate that hemispheric asymmetries in solar activity, as represented by sunspot numbers, result in the displacement of the source of the neutral sheet away from the more active solar hemisphere, thus moving the average position of the neutral sheet in interplanetary space away from the solar equatorial plane. This in turn results in the near-earth environment experiencing more days during which the interplanetary magnetic field (IMF) is directed, for example, towards the sun (T days) than days during which it is directed away from the sun (A days). The four possible combinations of solar magnetic polarity and dominant hemisphere were examined and, for the period 1965 to 1983, our model correctly predicts the average near-earth IMF polarity. In this paper we relate this situation to high energy cosmic ray measurements.

Cosmic Ray Density Relative to the Neutral Sheet. Saito and Swinson (1985, 1986), Smith and Thomas (1986) and Webber and Lockwood (1988) have shown that as the warp of the neutral sheet increases the cosmic ray intensity at the earth decreases. This can be interpreted to mean that the average cosmic ray intensity is reduced in periods when the earth is spending more time well removed from the neutral sheet. A similar conclusion may be reached from analyses by Newkirk and Fisk (1985) and Badruddin et al. (1985), who showed that the cosmic ray intensity at the earth is higher at the time a sector boundary passes the earth than it is on days on either side. These investigations all utilized neutron monitor data sampling the cosmic ray regime within 0.1 AU of the earth, and are consistent with a cosmic ray density or intensity gradient perpendicular to the neutral sheet

with intensity decreasing with distance away from the sheet on both sides in regions relatively close to the sheet.

Cosmic ray detectors having different geomagnetic and detector cutoffs, and looking in various asymptotic directions, permit assessment of the latitudinal gradient at various distances from the earth. Underground muon telescopes have much higher median rigidities than do neutron monitors, and sample the cosmic ray regime considerably further from the earth. If, in addition, their asymptotic directions of viewing are well away from the equator, such telescopes will sample regions of space well removed from the ecliptic and are thus capable of providing information on the latitudinal gradient at distances up to 1 AU.

The latitudinal cosmic ray gradient contributes to the cosmic ray solar diurnal variation. It can be extracted by sorting daily cosmic ray data according to the direction of the IMF, and then obtaining annual average solar diurnal variations for the Toward (T) and Away (A) days separately (Swinson, 1970, 1976; Swinson, Shea and Humble, 1986). The vector difference between the solar diurnal variations for the T and A subsets is an indicator of the resultant perpendicular gradient relative to the earth.

Data. In Figure 1 we show data from the Embudo vertical underground detector in New Mexico (top picture) and solar activity data from the sun's northern and southern hemispheres (bottom picture) from 1965 to 1983 (Koyama, 1985). In the top diagram shading occurs when the A amplitude for the cosmic ray solar diurnal variation exceeds the T amplitude, indicating

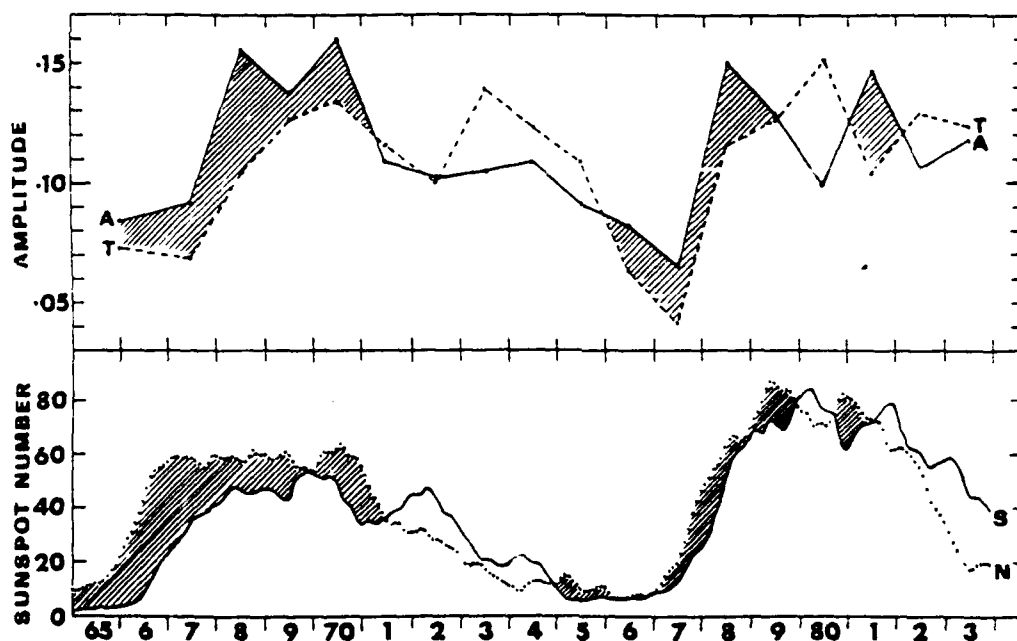


Fig. 1 (Top) Embudo Vertical Telescope: annual amplitudes of the solar diurnal cosmic ray variation for IMF toward (T) and away from (A) the sun; shading occurs when the away amplitude exceeds the toward amplitude. (Bottom) Relative frequency of sunspots on the sun's northern (N) and southern (S) hemispheres; shading occurs when northern sunspots predominate over southern sunspots. The sunspot data are from Koyama [1985].

that the latitudinal cosmic ray gradient seen from the earth points southward (Swinson, 1970, 1976; Swinson and Kananen, 1982; Swinson, Shea and Humble, 1986). The shading (inferring southward gradient) tends to occur at times when excess northern hemisphere solar activity (shown by shading in the bottom picture in Figure 1) occurs.

The Embudo vertical telescope has asymptotic viewing directions close the earth's equator (Regener and Swinson, 1968) and so the cosmic ray data in Figure 1 are representative of conditions closer to the earth. To investigate the cosmic ray regime further above and below the earth we have performed the same analysis on the north, south and vertical telescopes at Embudo and Bolivia and the vertical telescope at Hobart (the data are not shown here due to lack of space). These seven telescopes cover a range of latitudes from about 60°N to 50°S and are therefore sensitive to cosmic ray conditions well above and below the earth's location.

Alternating shaded (inferring southward gradient) and unshaded (inferring northward gradient) regions are present to varying extents in the plots for these seven inclined telescopes in a similar manner to the shaded/unshaded regions shown in Figure 1 for the Embudo Vertical Telescope. In addition to this alternation, it is apparent that there is a greater prevalence of unshaded regions in the results from the more northerly detectors and a greater prevalence of shaded regions in the more southerly data. These observations imply that at significant distances from the neutral sheet the cosmic ray intensity increases again with greater distance from the sheet both north and south of the sheet.

Explanation. Figure 2 shows hypothetical cosmic ray density distributions relative to the neutral sheet for the situations in which the earth is below (left picture) or above (right picture) the neutral sheet. In both pictures the cosmic ray density at the neutral sheet is represented by the number 100, decreasing intensity both above and below the sheet being represented by a purely arbitrary set of numbers which decrease uniformly with distance on each side of the sheet. An indication of the relative density above and below the earth can be obtained by adding together separately the four closest numbers above and below the earth. Doing this reveals that when the earth is below the neutral sheet the average cosmic ray density above the earth is higher than it is below the earth. The reverse situation also applies. A consequence is that a symmetrical gradient perpendicular to the neutral sheet becomes an asymmetrical gradient relative to the earth when the neutral sheet is displaced, on average, away from the solar equatorial plane.

This would account for the alternating occurrence of shaded regions and unshaded regions in the top picture of Figure 1, and would apply to a region closer to the earth. However, the predominance of unshaded regions in the results from more northerly detectors and shaded regions in the more southerly data imply that after cosmic ray densities decrease to a minimum at some intermediate distance from the neutral sheet, they start to increase again with distance from the neutral sheet on both sides of the sheet. Detectors whose viewing directions are closer to the earth's equator are more sensitive to the gradients close the neutral sheet, but detectors with viewing directions at higher latitudes also see lateral gradients where density increases with distance from the sheet beyond the intermediate minimum.

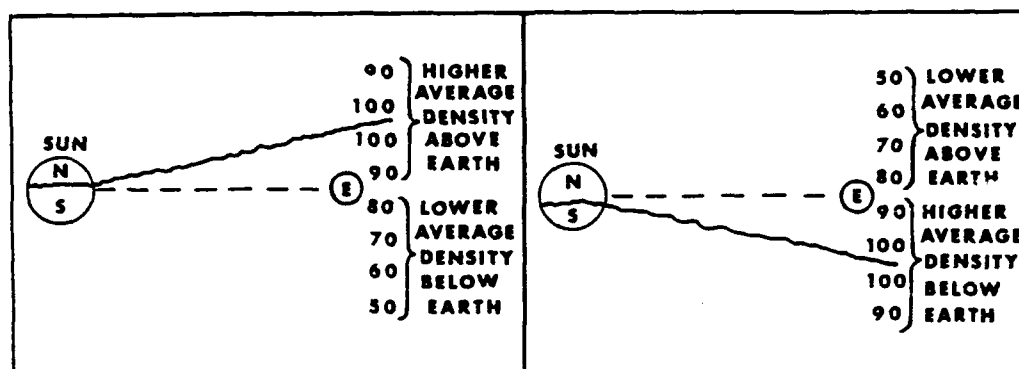


Figure 2. Hypothetical cosmic ray intensities in the region of the earth.

Conclusion. Previously it has been necessary to invoke more complicated mechanisms (Swinson, Shea and Humble, 1986) to account for apparent gradients derived from observations by high energy cosmic ray detectors. From the results presented here it becomes evident that the cosmic ray results are easily accounted for by a symmetrical gradient relative to a neutral sheet whose average location, relative to the earth, changes throughout the solar cycle as solar activity asymmetry changes.

Kota and Jokipii (1983) have calculated that at neutron monitor rigidities the cosmic ray density should decrease away from the neutral sheet on both sides, reach a minimum around 0.25 AU, and then commence to increase with increasing distance from the sheet. Our results, which we note refer to a significantly higher rigidity, and also the neutron monitor results discussed above, are consistent with their prediction.

Acknowledgements. The work of DBS was supported by the Atmospheric Sciences Section, National Science Foundation, under grants ATM-8606885 and ATM-8910840.

References.

- Badruddin, Yadev, R.S. and Yadev, N.R.: 1985, *Planet Space Sci* **33**, 191-201
 Hoeksema, J.T., Wilcox, J.M. and Scherrer, P.H.: 1983, *J. Geophys. Res.*, **88**, 9910-9918
 Kota, J. and Jokipii, J.R.: 1983, *Astrophys J*, **265**, 573-581
 Koyama, H.: 1985, *Observations of Sunspots 1947-1984*, Kawadeshoboshinsha, Tokyo.
 Newkirk, G. and Fisk, L.A.: 1985, *J. Geophys. Res.*, **90**, 3391-3414.
 Regener, V.H., and Swinson, D.B.: 1968, *Can. J. Phys*, **46**, S784-S787.
 Saito, T. and Swinson, D.B.: 1985, *Proc 19th Int.Cos.Ray Conf*, **4**, 441-444
 Saito, T. and Swinson, D.B.: 1986, *J. Geophys. Res.*, **91**, 4536-4542
 Smith, E.J. and Thomas B.: 1986, *J. Geophys. Res.*, **91**, 2933-2942
 Swinson, D.B.: 1970, *J. Geophys. Res.*, **75**, 7303-7306
 Swinson, D.B.: 1976, *J. Geophys. Res.*, **81**, 2075-2081
 Swinson, D.B. and Kananen, H.: 1982, *J. Geophys. Res.*, **87**, 1005-1087
 Swinson, D.B., Shea, M.A., and Humble, J. E.: 1986, *J. Geophys. Res.*, **91**, 2943-2949.
 Webber, W.R. and Lockwood, J.A.: 1988, *J. Geophys. Res.*, **93**, 8735-8740.