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TWO-SATELLITE STUDY OF PROTON DRIFT ON QUIET DAYS.(U)

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Two-Satellite Study of Proton Drift on Quiet Days

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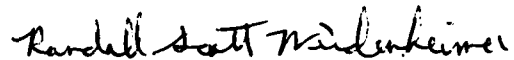
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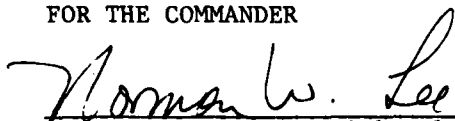
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PREFACE

This work was supported by the Max-Planck-Gesellschaft zur Förderung der Wissenschaften and by the Ministerium für Forschung und Technologie through the DFVLR-PT under contract No. RV 14-B12/73 (WRK 243)-SF21 and by the US Air Force under contract No. F-04701-80-C-0081.

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INTRODUCTION

Drift-shell splitting has been universally recognized as an explanation for the changes in quiet time pitch angle distributions observed as a function of local time in the outer magnetosphere [1]. The effect is dominant for particles with energies high enough (usually greater than 30 keV) that the electrostatic potential can be ignored [2,3,4]. The magnetic shell splitting is a direct result of the azimuthal asymmetries of the magnetospheric magnetic field. In order to conserve the first and the second adiabatic invariant, a particle having $\alpha_0 \approx 90^\circ$ (α_0 equatorial pitch angle) will trace a drift shell defined by field lines that have almost the same equatorial magnitude as the magnetic field induction B_0 . A particle having $\alpha_0 \approx 0^\circ$ will trace a drift shell defined by field lines that have almost the same arc length.

Several authors have traced particle drift shells in various models of the field [2,4]. This is a laborious process and is rarely done for comparison with observations [5,6]. Recently a simplified prescription for tracing magnetic drift shells has been described by Luhmann and Schulz [7]. The procedure involves the use of a three term Mead model [8] of the magnetic field in which the nondipolar contributions are obtained by fitting the diurnal variation of the magnetic field observed

at synchronous orbit. Since the magnetic field is a function of radial distance the observed equatorial particle flux variation can be used to generate an equatorial "radial" flux profile. The particle drift shells are then specified analytically as a function of pitch angle at local noon. We have utilized this procedure to calculate the expected magnetic shell splitting for the GEOS-2 ion data. To obtain a "radial" flux profile over a wide range of spatial parameters (B and L) we have taken also data from the P78-2 (SCATHA) spacecraft. This allows us to cover the complete "radial" range of the particle drift shells that have access to synchronous orbit at some point in their motion.

INSTRUMENTS AND OBSERVATIONS

The instruments on both spacecraft measure ions with two-element telescopes in similar energy ranges and provide good pitch angle distributions. Ions are measured with the GEOS-2 MPAE instrument from 35 to 400 keV in 9 differential energy channels and with the SCATHA-Aerospace instrument from 14 to 700 keV in 6 differential energy channels. The various energy pass bands are given in Table 1.

TABLE 1 Ion Energy Channels of the Two Instruments

Energy Channel	GEOS-2 MPAE	SCATHA-Aerospace
1	35 - 45 keV	14 - 24 keV
2	45 - 59 keV	24 - 48 keV
3	59 - 75 keV	48 - 94 keV
4	75 - 98 keV	94 - 172 keV
5	98 - 129 keV	172 - 352 keV
6	129 - 169 keV	352 - 700 keV
7	169 - 225 keV	
8	225 - 301 keV	
9	301 - 403 keV	

For our initial study we have chosen two relatively quiet periods, 13-14 February, 1979 and 18-19 March, 1979. The February period is very quiet, but the satellites are separated by about ten hours in local time. On March 18 the satellites are separated by about one hour of local time from each other, but the geomagnetic field was mildly disturbed. Figure 1 shows the ion energy spectra for the two instruments on February 13, 1979 at about 2:30 local time and on March 18, 1979 at about 23:30 local time. Both spacecraft are at this time almost on the same

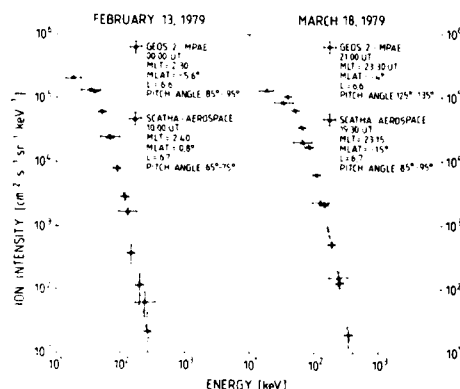


Fig. 1 Ion energy spectra from the GEOS-2 MPAE and the SCATHA-Aerospace instruments at $L \approx 6.6$ on February 13, 1979 and on March 18, 1979.

L-shell, but the magnetic latitudes differ slightly. Therefore the spectra are shown for equivalent pitch angles which are calculated from the magnetic field values at the two spacecraft. There is a good agreement of the spectra on February 13 and a slight deviation of the spectra at low energies on March 18.

Figure 2 shows a series of ion pitch angle distributions measured on GEOS-2 in various energy channels from 20:00 UT on February 13 to 10:00 UT on February 14 every two hours. The data are averaged over 15 min. The position of GEOS-2 is at 37° east longitude. This means that local time is universal time plus 2.5 hours. The selected time interval shows the variation of the pitch angle distribution from midnight to noon. The distribution changes from one with a minimum at pitch angle, $\alpha_0 = 90^\circ$ during midnight to one with a maximum at $\alpha_0 = 90^\circ$ near noon up to energies of 75 keV. Above 75 keV the minima at $\alpha_0 = 90^\circ$ are observed over the entire day. They only vary in intensity.

GEOS 2 - MP Ae
Feb 13/14, 1979

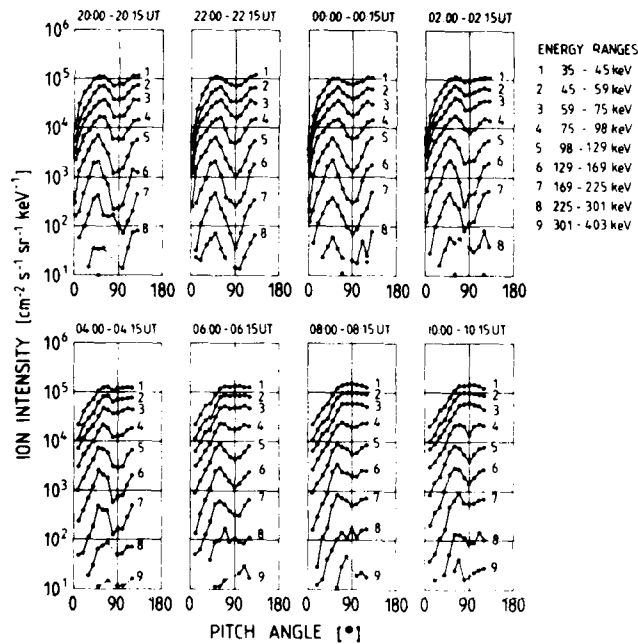


Fig. 2 Ion pitch angle distributions in various energy channels measured with the GEOS-2 MP Ae instrument from 20:00 UT on February 13 to 10:00 UT on February 14, 1979.

In Figure 3 we have plotted the diurnal variation of the ion intensity at $\alpha_0 = 90^\circ$ against the diurnal variation of the magnetic field B_0 for various energy channels. This observed particle flux variation was used to generate an equatorial "radial" flux profile on 13-14 February, 1979. The data were fit to function of the form

$$j = a \exp (c \cdot B_0)$$

The radial dependence of the flux is implicit in the dependence of B_0 by

$$L_0 \equiv (-g_1^0 / B_0)^{1/3}$$

For February 13-14 it takes two such functions to cover the full range of B_0 . The best fits for the GEOS instrument are given for the various energy pass bands by

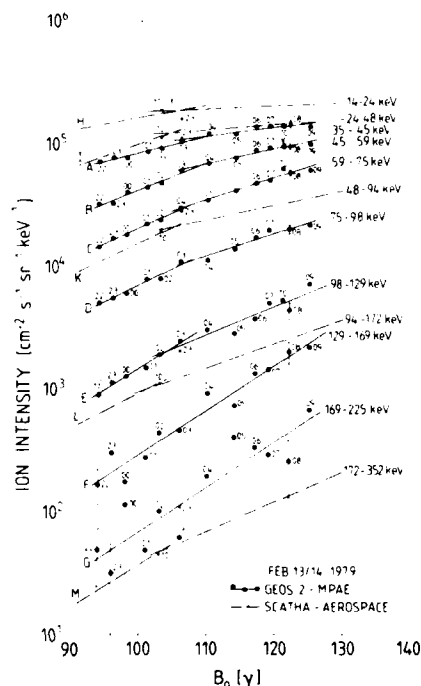


Fig. 3 Observed variation of ion intensity (pitch angle $\alpha_0 = 85^\circ$ - 95°) with magnetic field B_0 in various energy channels on GEOS 2 (—○—) at indicated hours of universal time UT and on SCATHA (---○---).

adjusted to fit the diurnal variation of B_0 observed at GEOS-2 ($r = 6.6 a$; a is the earth radius = 6371 km). The results are $\bar{g}_1^0 = -1.32$ gamma and $\bar{g}_2^1 = 1.30$ gamma. The good fit of B_0 supports our assumption that the magnetic field was static between 22:00 hrs February 13 and 12:00 hrs February 14 local time. In the upper part of Figure 4 we plotted for the four lowest energy channels on GEOS-2 the intensity for $\alpha_0 = 60^\circ$ and $\alpha_0 = 90^\circ$ versus local time. The drift shell splitting is very clearly seen near midnight. The 60° pitch angle intensity becomes larger than the 90° intensity at about 07:00 local time for the 35-45 keV energy channel. The point of intersection is energy dependent and shifts to local noon for higher

a solid line and for the SCATHA instrument by a dashed line. The data indicate that the radial profile of both spacecraft show very similar values although the spatial range of the SCATHA satellite is much larger.

The lower part of Figure 4 shows the magnetic field variation on February 13-14, 1979 measured by the magnetometer on GEOS versus local time (local time = UT + 2.5 hrs) and Kp-index. The dashed line is the best fit curve from the Mead model

$$B_0 = -(a/r)^3 \bar{g}_1^0 - \bar{g}_1^0 - \sqrt{3} \bar{g}_2^1 (r/a) \cos \phi_0$$

for the period 20:00 UT February 13 to 16:00 UT February 14, 1979. The parameter $\bar{g}_1^0 = -30900$ gamma is fixed by the magnitude of the earth's dipole moment.

but the parameters $\bar{g}_1^0$ and $\bar{g}_2^1$ are to be

energies. Above an ion energy of 75 keV we find at all local times a minimum at 90° pitch angle.

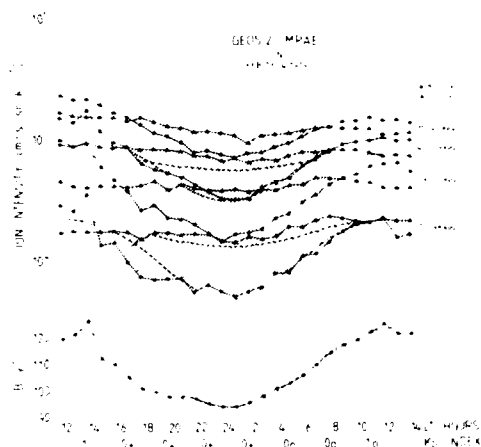


Fig. 4 (Lower): Comparison of the magnetic field on February 13/14, 1979 as measured by the magnetometer on GEOS-2 and the best-fit curve from the Mead model (dashed line). (Upper): The comparison between the measured intensities in various energy channels at pitch angles $\alpha_0 = 55^\circ$ - 65° and $\alpha_0 = 85^\circ$ - 95° with the calculated intensities obtained from the radial gradient and drift shells based on the Mead model.

To calculate the pitch angle distribution at all local times we follow the procedure of Luhmann and Schulz [7] and Pfitzer et al. [5] in assuming that the normalized equatorial pitch angle distribution $g(\alpha_0^*)$ on the noon meridian is independent of geocentric distance for drift shells accessible to the synchronous orbit. Thus we express the intensity $j(\alpha_0, B_0(L), \omega_0)$ as

$$j(\alpha_0, B_0(L), \omega_0) = g(\alpha_0^*) h(B_0^*(L))$$

where $h(B_0^*(L))$ represents the "radial" dependence of the particle flux at the equator in the noon meridian ($\omega_0 = \omega_0^* \equiv \tau$ reference longitude at noon) where the equatorial field is B_0^* .

Calculations at pitch angles $\alpha_0 = 60^\circ$ and $\alpha_0 = 90^\circ$ for two energy channels are given as dashed lines in the upper part of Figure 4. They are in fairly good agreement with the measured values and show also the energy dependence of the intersection point for 60° and 90° pitch angle.

RESULTS

Our measurements with high energy and pitch angle resolution clearly show the effects of drift shell splitting, on the distribution of energetic ions. This is most obvious for the diurnal variation of the pitch angle distributions. At midnight maximum intensities are encountered at pitch angles of 60° (120°). The ratio $j(60^\circ)/j(90^\circ)$ of the intensities at pitch angles of 60° and 90° is larger than 1 between midnight and 0700 LT for the lowest energy channel. The cross over time for $j(60^\circ)$ and $j(90^\circ)$ depends on the ion energy. It is shifted towards local noon with increasing ion energy. Above 75 keV the intensity at 60° is larger than at 90° for all local times. For mildly disturbed days like March 18/19, 1979 the minimum for the 90° ions disappears for low energies at midnight.

Our observations are in good agreement with the simplified method of magnetic drift shell tracing by Luhmann and Schulz [7]. The 90° ion intensities at about 50 keV are predicted to vary by a factor of 3.4 in intensity with local time the 60° ion intensities by a factor of 1.4. The deviation from the observation are less than 15 %.

It should be noted that the procedure of determining the quiet time distribution automatically warns us against trying to fit genuine temporal variations with a static model of the magnetosphere. In a static magnetosphere the intensity of $x_j = 90^\circ$ ions must be a single valued function of x_j plotted with universal time (UT) as a parameter.

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