rotationally symmetric around the instantaneous magnetic field direction, it is a function of a single variable, the pitch angle, and can be written as a Fourier series. It is shown here that there is a linear relation between its coefficients and the set of sector counting rates. It can therefore be expressed by a matrix. The matrix elements depend on the number of sectors, the opening cone of the detector telescope, the angle between spin axis and the magnetic field direction, and the angle between spin axis and detector axis. This algebraic approach allows to determine the maximum obtainable number of Fourier coefficients and their accuracy for any such experiment.
In the interplanetary medium the Compton Getting effect due to convection with the solar wind makes pitch angle distributions appear rotationally asymmetric. A reduction of this effect is also possible using matrix notation.

SC 17

PITCH ANGLE DISTRIBUTIONS OF CHARGED PARTICLES IN INTERPLANETARY SPACE MEASURED ON HELIOS DURING A SOLAR EVENT

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For a solar event of rather simple structure observed by HELIOS sectorized particle data of the University of Kiel Cosmic Ray Experiment were analysed by the method described by Green in this meeting using flux gate magnetic field data from the University of Braunschweig Magnetometer Experiment.
This event is an example for the advantages of this method: The pitch angle distributions are determined up to the fourth harmonic, the influence of the magnetic field elevation out of the ecliptic plane is revealed, field aligned anisotropies can be detected down to low values by applying a Compton Getting correction and by accumulating the data on the ground over sufficiently long time intervals to improve the statistics using a coordinate system which rotates together with the field azimuth.

SC 18

SOLAR PARTICLE OBSERVATIONS AT SOLAR MINIMUM

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Characteristics of 8 solar cosmic ray events observed during the minimum of the current solar cycle will be discussed. The events were observed during the period 1974-1976 by orthogonal solid state detector telescopes on ATS-6 in synchronous orbit. The telescopes determine a differential energy spectrum for protons from 300 KeV to 200 MeV and for alpha particles from 2 MeV to 220 MeV with North and East view directions. The observed proton intensity will be discussed as a function of energy, arrival direction, magnetic activity, local time and the interplanetary intensity.

SC 19

CORONAL CONTROL OF PLASMA AND ENERGETIC PARTICLE EMISSION FROM THE APRIL 10, 1969 SOLAR FLARE

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We have re-examined interplanetary solar wind and energetic particle data for the March-April 1969 period of solar activity from Pioneers 6-9 in deep space and Explorer 34 near Earth. The solar wind velocities are used to estimate the high coronal emission longitudes of the plasma, and these are also assumed to be the injection longitude onto interplanetary field lines for the energetic particles. The observations from the 5 spacecraft (nearly equi-spaced over 210°), reveals that the large solar wind disturbance from the April 10 east limb flare had a velocity emission profile on April 12 which peaked (>1100 km s^{-1}) near the flare site (85° heliographic) with a half-width ~ 60° at velocities ~ 600 km s^{-1}. The emission profile preserved its shape as it decayed on April 13 and 14. The initial injection of 7.5-45 MeV protons (measured by the UTD detectors on Pioneers 6-9 and the APL/JHU detector on Explorer 34), may also have peaked over the flare site on April 11 (00 h) but by April 12 (00 h) the peak of the proton injection profile had shifted to 90° to the west of the flare site and remained there through April 16. The injection profiles can be approximated by exponentials in longitude with e-folding angles of $\varphi_E \simeq 28°$ and $\varphi_W \simeq 20°$ for the east and west wings of the population April 12-13. By April 16, $\varphi_E \simeq 10°$ while φ_W remained nearly constant. This solar event demonstrates clearly that different coronal structures control the emission of flare plasma and energetic particles.

SC 20

THE INTERPLANETARY SHOCK WAVE EVENT OF NOV. 1975 OBSERVED BY HELIOS-A AND IMP-7,8

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In studying the interplanetary acceleration of energetic particles, i.e. shock-spikes and in particular ESP events, it is important to distinguish the short term (few minutes) intensive acceleration at shock fronts, which depends locally on the direction of the interplanetary magnetic field w.r.t. the short front, from a still unknown but occasionally assumed to exist long-lasting (days) acceleration of particles in the downstream shocked medium. Favorable arrangements of widely separated spacecraft in the interplanetary medium are needed in order to study these events. Presumably, under different local conditions of the upstream interplanetary magnetic field at the shock front the short term acceleration may be shut-off at one spacecraft whereas the long-lasting effects on the particle population may still persist.

Such a favorable geometry obtained during the Nov. 23, 1975 shock event between the HELIOS-A and IMP-7 and 8 spacecraft where HELIOS-A was ~ 0.1 AU inside of the Earth orbit and only 6° off the Sun-Earth line. Detailed directional and spectral information on the energetic particle event, which is associated with the shock wave passage by both HELIOS-A and the Earth, were obtained by the E 8 experiment on HELIOS-A (80 keV $\leq E_p \leq$ 6200 keV, 16 keV $\leq E_p \leq$2000 keV) and by the APL/JHU experiments on IMP-7 and 8 ($E_p \geq$ 290 keV, $E_e \geq$220 keV, $E_\alpha \geq$ 640 keV/nuc, E_u (Z $\geq$3)$\geq$ 770 keV/nuc). The measurements and their implications on the acceleration mechanism(s) are discussed.

SC 21

ACCELERATION OF ENERGETIC PARTICLES BY SHOCK WAVES

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The problem of acceleration of energetic particles by shock waves propagating in a scattering medium has been considered by Fisk in his discussion of energetic storm particle events and shock spikes. We will review this work and add some additional comments concerning steady state solutions and energy spectra of general form. In addition, we will discuss the situation in which the energetic particle pressure is sufficient to affect the background flow. The results are of interest with regard to the termination of the solar wind and to the acceleration of low energy cosmic rays in corotating interaction regions. In the latter case, the forward and reverse shock pairs which arise must be separated by a contact surface in the vicinity of which the medium undergoes a gross expansion. The observed signatures of the energetic particles associated with such interaction regions provides clear evidence for the adiabatic *deceleration* of particles which must result from such an expansion.

SC 22

A SIMILARITY THEORY FOR ENERGETIC PARTICLE ENHANCEMENTS ASSOCIATED WITH INTERPLANETARY SHOCKS

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It is assumed that a spherically symmetric forward-reverse shock pair sweeps radially through a quiet-day solar wind containing a spherically symmetric distribution of low energy cosmic rays. The cosmic rays are allowed to pass, without reflection, from the unshocked to the shocked solar wind. Using a solar wind velocity profile for strong shocks[1] a similarity solution for the differential cosmic ray number density, valid for a general ambient cosmic ray spectrum, $U_a(T)$, and an energy-dependent radial diffusion coefficient, KT^ℓ, is formulated. For the case in which $U_a(T)$ is a power law and ℓ = o, it is found that (1) similarity solutions exist only for a small range of U_a, (2) the cosmic ray amplification at the forward shock is large for ambient spectra near the critically steep U_a, (3) if the spectral index of U_a exceeds 2, the cosmic ray density falls off vehind the forward shock, becoming small in the vicinity of the contact surface, and (4) the cosmic ray density in the vicinity of the reverse shock is qualitatively similar, producing an overall double-humped profile across the shock pair.

1. Simon, M. and Axford, W. I., Shock Waves in the Interplanetary Medium, Planet. Space Sci., 14, 901, 1966.

SC 23

PERSISTENT SUNWARD FLOW OF ~1.6 MEV PROTONS AT 1 AU

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The anisotropy of 1.3 to 2.3 MeV protons has been measured with the Caltech Electron/Isotope Spectrometer aboard IMP-7 for periods between prompt solar particle events from 72/273 to 74/2. The diffusive anisotropy, which has been computed by subtracting the independently determined convective anisotropy from the observed anisotropy, is predominantly directed toward the sun with a typical radial component of 14%. This sunward diffusion is typical of intensities from 0.012 to 1.2 $(cm^2\text{-sec-sr-MeV})^{-1}$ and indicates that a positive radial gradient of 1.3 to 2.3 MeV protons is associated with these modestly enhanced fluxes. The direction of this flow is opposite to that produced by the continuous solar sources used to explain increases previously observed near 1 AU. The direction of the diffusive anisotropy strongly depends on the direction of the concurrently measured magnetic field, indicating that diffusion is preferentially along rather than across the magnetic field lines (i.e.,$\kappa_\perp < \kappa_\parallel$).

SC 24

A STEADY-STATE MODEL OF SUNWARD FLOW OF LOW ENERGY PROTONS

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The persistent sunward flow of ~1.6 MeV protons observed on IMP-7 has been modeled as steady-state injection of protons beyond 1 AU. The propagation of these particles is computed using a series solution to the Fokker-Planck equation, which includes diffusion, convection, and adiabatic energy loss. The equation has been simplified by assuming 1) azimuthal symmetry, 2) κ_{rr} independent of energy and radius, 3) no injection of particles inside r = L>1 AU, 4) a finite density at r = 0, and 5) the solar wind velocity V independent of radius. The calculated diffusive anisotropy is found to be strongly dependent on V but only weakly dependent on κ_{rr}. Using the mean observed spectral index γ of -3.15 and the mean solar wind speed of 440 km-sec^{-1}, the model produces a range of radial diffusive anisotropy from 10% to 17% for κ_{rr} from 10^{20} to 10^{21} cm^2-sec^{-1} (the observed anisotropy is 14%). This range of κ_{rr} is comparable to that previously reported using a similar, but time-dependent, model to best fit the temporal development of prompt solar particle events. A κ_{rr} of 10^{21}cm^2-sec^{-1} produces a modulation factor of 11 between 1 AU and 3 AU. Evidence for comparable modulation in corotating streams has been found by Pioneer XI. The approximately linear dependence of the diffusive anisotropy on the solar wind speed predicted by the model is found to be consistent with the observed dependence.

SC 25

EFFECTS OF PARTICLE DRIFT ON SOLAR MODULATION OF GALACTIC COSMIC RAYS

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Although gradient and curvature drifts are explicitly contained in the general equations of cosmic-ray transport, they have been almost universally neglected in applications of these equations. We evaluate the drifts explicitly for the Parker spiral magnetic field and show that, for particles with rigidities greater than ~0.3 GV in the solar wind, they are larger than the solar-wind velocity over much of the heliosphere. Hence most current models of solar modulation and solar-flare particle events neglect terms which in many cases are as important as those retained. Calculations are presented which demonstrate the importance of the effects for simple modulation models. We conclude that comparisons of presently available model calculations with observations do not provide a fair test of transport theory since they neglect drifts. Results of Monte Carlo simulations show that the heliocentric cosmic-ray gradient and mean energy change can be significantly reduced by the inclusion of drifts.

SC 26

METEORITE GRADIENTS AND THE MAUNDER MINIMUM

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A recent compilation of 48 measurements of the Argon-39 (269 year half-life) activity in the metallic phase of meteorites showed values of 22.5 ± 2.5 dpm/kg. This spread could be due to experimental errors alone, and the true variation is probably smaller. Since such a sample of meteorites can reasonably be expected from meteor data to have a spread of mean distances from the sun of 2.5 ± 1 AU, an upper limit of 10%/AU on the magnitude of the integral cosmic ray gradient between about 1.5 and 3.5 AU averaged over about the last 500 years was deduced. The mean Argon-39 activity of 22.5 dpm/kg is a little high compared to the value 19 ± 3 dpm/kg we infer for the last solar cycle at 1 AU from Argon-37 activities in meteorites which fell since 1959. Argon-39 and Argon-37 have essentially equal production cross sections in meteoritic nickel-iron. Unless all the solar-cycle change in modulation occurs within 3.5 AU, we may interpret this slight excess as a possible indication that there was higher cosmic ray flux, and less solar modulation averaged over the last several mean lives of Argon-39, than over solar cycles typified by the last cycle, i.e., cycles since 1715. This implies a higher cosmic ray flux for the few hundred years prior to 1715, during the Maunder and Sporer minima in solar activity. The importance of this possibility is that it would confirm that the DeVries Fluctuation in Carbon-14 activity around 1690 was due to changes in primary cosmic ray flux, as Eddy suggests, and not the effect of a climatic fluctuation.

Solar-Planetary Relationships: Magnetospheric Physics

SM 1

THE LARGE SCALE IONOSPHERIC ELECTRIC FIELD: ITS VARIATION WITH MAGNETIC ACTIVITY AND RELATION TO TERRESTRIAL KILOMETRIC RADIATION

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Four days of simultaneous auroral zone electric field measurements on balloons flown from six sites spaced 180° in magnetic longitude have been analyzed. The average electric field behavior during this magnetically very quiet epoch are consistent with earlier single point measurements. When these data are mapped to the equator, a steady dawn-to-dusk component is apparent only on the average, while instantaneously the field is quite variable. The ionospheric electric field during isolated substorms is shown to have differing signatures east and west of 2200 LT. A world wide positive correlation is shown to exist between the auroral zone electric field strength and the intensity of terrestrial kilometric radiation.

SM 2

RELATION BETWEEN BOUNCE-AVERAGED COLLISIONAL TRANSPORT COEFFICIENTS FOR GEOMAGNETICALLY TRAPPED ELECTRONS

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The unweighted bounce average $\langle N_j \rangle$ of the atmospheric density (N_j) along a field line and the weighted bounce average $\langle (B_0/B) N_j \cos^2\alpha \rangle$ are related (for each atmospheric constituent j) by an integral or derivative with respect to the sine (y) of the equatorial pitch angle (α_0), where B/B_0 (= $y^{-2}\sin^2\alpha$) is the ratio of local to equatorial magnetic-field intensity and α is the local pitch angle. The unweighted bounce average $\langle N_j \rangle$ is relevant to energy deposition by radiation-belt particles of all species, and the weighted bounce average $\langle (B_0/B) N_j \cos^2\alpha \rangle$ is relevant to the description of pitch-angle diffusion of radiation-belt electrons. The precise relationship between the two averages is given by

$$y(2\pi/\Omega_2)\langle N_j \rangle = -\frac{d}{dy}\left[(2\pi/\Omega_2)\langle (B_0/B) N_j \cos^2\alpha \rangle\right],$$

where $2\pi/\Omega_2$ is the full bounce period (a function of y).

SM 3

PLASMAPAUSE SIGNATURES IN THE IONOSPHERE AND MAGNETOSPHERE

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Latitude profiles of ionospheric composition, density, temperature, and H^+ vertical velocity, measured by the polar orbiting ISIS2 satellite at 1400 km, are compared with simultaneous equatorial electron density profiles determined by whistler analysis during a six day period of moderate to quiet magnetic activity. The low latitude boundary of the light ion trough does not exhibit a diurnal variation in latitude and lies ~ 2°- 5° equatorward of the whistler plasmapause at both dawn and dusk. Maxima in the electron temperature and H^+ upward velocity also lie equatorward of the plasmapause latitude. The data suggest that the low altitude troughs are associated with flux tubes on which the equatorial density is below its equilibrium value, and which are thus refilling from below. Trapped plasma sheet electrons are observed to extend inward to the plasmapause at both dawn and dusk and could be used to identify the equatorial plasmapause latitude in the absense of whistler measurements.

SM 4

EVIDENCE FOR DRIFT WAVES AT THE PLASMAPAUSE

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As the Hawkeye-1 spacecraft crosses the plasmapause at high altitudes (R > 3 R_e) a band of electric field noise is often detected in the frequency channels from 1.7 Hz to 178 Hz. No corresponding magnetic field noise is detected, indicating that the noise is electrostatic (or at least quasi-electrostatic), and the electric field is polarized perpendicular to the plasma density gradient. The noise is only detected when the scale length of the plasmapause is 0.1 R_e or less, indicating that a large density gradient is required to produce the noise. These characteristics are all consistent with the interpretation that this noise consists of electrostatic waves excited by the drift mode instability. Using reasonable assumptions concerning the wavelengths of these waves the observed frequency spectrum can be explained as being due to doppler shifts caused by the spacecraft motion through the plasma.

SM 5

RADIATION BELT PROTONS DURING GEOMAGNETICALLY QUIESCENT CONDITIONS

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The average steady state structure of energetic radiation belt protons can be explained as an equilibrium balance between radial diffusive transport from a proton source located just within the first closed field lines, losses due to Coulomb collisions and charge exchange with the ambient neutral hydrogen geocorona. The mode of transport is due to substorm associated fluctuations in the large scale electric and magnetic fields. Attention is restricted to equatorially mirroring protons and comparison is made between theoretical predictions of proton energy spectra at L-values between 2 and 6.6 and in situ radiation belt ion observation onboard the satellites Explorer 45 and ATS-6, both orbiting close to the equatorial plane. Good agreement between theory and observation suggests that the dominant ion population in the energy range 50 to 1000 keV in the inner magnetosphere is indeed a proton population. Beyond this interval the major ions may be different from protons.