If the expectation values $\langle a_n \rangle$ vanish for laser light, as they do for light from thermal sources, interference effects between two independent laser beams could be explained only in terms of the correlation of the intensity at different points in space and time.[3] The interference phenomena would be transient. Both the position and the visibility of the interference fringes would vary randomly. This is observed in the experiments with ruby lasers.[1] But these observed random variations of the position and visibility of the interference fringes are consistent also with the explanation based on the average intensity and the hypothesis that the expectation values $\langle a_n \rangle$ are significantly different from zero. The random spiking of ruby lasers allows only one picture of the interference fringes to be taken for each pair of simultaneous spikes from the two lasers.[1] A random variation of the position of the interference fringes from picture to picture can be explained by a random variation of the phases of the expectation values $\langle a_n \rangle$ from spike to spike. A variation in the visibility of the interference fringes can be explained by a variation in the magnitude of the expectation values $\langle a_n \rangle$ for different spikes and by the possibility of a variable number of modes per spike and a variable frequency difference between the modes of the two lasers as different modes are excited for each different spike.[1] These complications can be eliminated with gas lasers operating continously at a single well-stabilized frequency. The observation of stable interference fringes produced by the superposition of two such laser beams could be explained only according to our suggestions in terms of the average intensity with expectation values $\langle a_n \rangle$ significantly different from zero. The possibility of such an experimental test is suggested by the fact that beats between two gas lasers have already been observed.[13] The sensitivity of such a test would be enhanced by the fact that the explanation based on intensity correlation depends critically on the number of photons per mode in the radiation field.[3] According to that explanation, the fringe visibility of a semistable interference pattern should decrease as the intensity is cut. Our explanation based on the average intensity predicts no such decrease of the fringe visibility.

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ANOMALOUS ENERGY SPECTRUM OF PROTONS IN THE EARTH'S RADIATION BELT*

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The spatial distribution and energy spectrum of trapped protons have been measured over a broad region of space from 2500 to 7500 km in altitude. The early results confirm and extend certain important earlier measurements, and make dilemmas for theories offered to explain them.

The communications satellite Relay I carries the instrumentation for this survey. Still operating, Relay I was launched 14 December 1962, into a medium inclination orbit extending from 1.2 to 2.2 earth radii. Four detectors produce the eight data channels used in this paper. Their characteristics are listed in Table I. Data re-

Table I. Relay-I proton detectors used in this survey.

Label	Sensor	Shielding	Geometric factor	Proton energy ranges (MeV)
B	Thin silicon surface-barrier diode. 0.025-g/cm^2 depletion depth	0.0011 g/cm^2 Al	0.0136 cm^2-sr directional[a]	1.1 to 14 1.6 to 7.1 2.25 to 4.7
D	0.25-cm cylinder of plastic scintillator	0.049 g/cm^2 Al	0.0027 cm^2-sr directional[a]	>5.2
C	Telescope of two silicon lithium drift diodes of 0.090-g/cm^2 depletion depth		0.22 cm^2-sr directional[a]	18.2 to 25 25 to 35 35 to 63
A	0.9-cm sphere of plastic scintillator	1.3 g/cm^2 Al over 2π sr	0.33 cm^2 omnidirectional	>33.5

[a]The directional detectors are mounted perpendicular to the satellite spin axis and are gated by a magnetometer to record data only when they point within ±10° of the plane perpendicular to the local magnetic field vector. Thus, they measure $j_\perp$, the flux of locally mirroring particles.

duction is performed by computer and organized according to the B-L coordinate system.[1] The data are interpolated to selected magnetic shells (L = 2.0, 2.05, 2.1, etc.) wherever the satellite orbit crosses them, and ordered along these shells. With adequate data coverage, one thus obtains a graph of the intensity everywhere on a given L shell. From this, one can derive the angular and spatial distribution on any line of force in that shell. The time period covered by this paper extends from launch day until September 1963, when the distributions were perturbed by a magnetic storm.

Figure 1 presents the spatial distribution of low-energy protons (1.1 to 14 MeV) in a plot of $j_\perp$ vs B as measured on many separate L shells. Protons in this energy range have been observed before by Bame, Conner, Hill, and Holly[2] and by Naugle and Kniffen[3] with rocket flights, and by Davis and Williamson[4] with satellite instruments. Interpretation of the rocket measurements was handicapped by their limited spatial

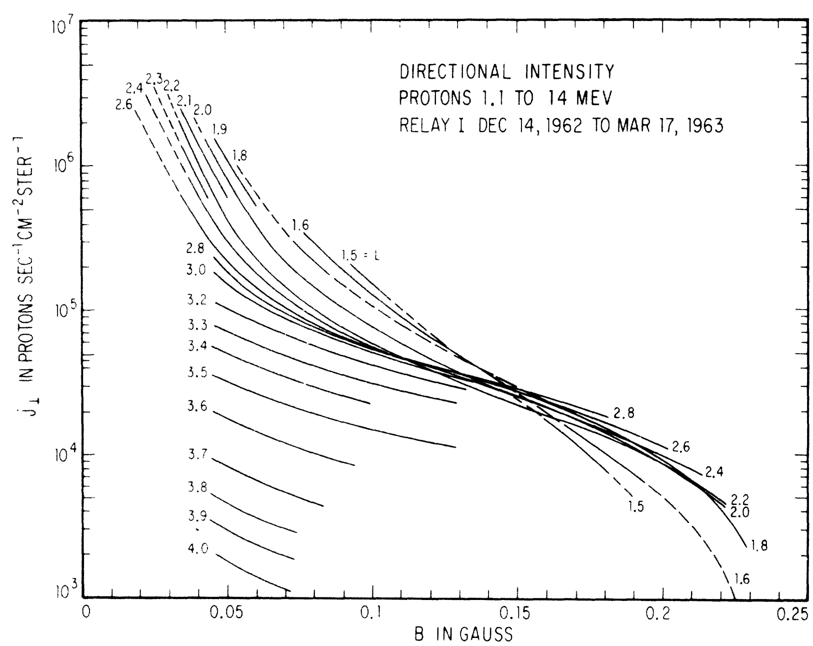

FIG. 1. The intensities of low-energy protons. Dashed lines represent extrapolated or interpolated data. The fluxes for L = 2.1 and 1.9 are not extended farther up the line of force because of crowding on the graph.

coverage. Thus the low-energy component seen at low altitudes by Naugle and Kniffen was attributed to the decay of albedo neutrons generated by low-energy solar cosmic rays at the earth's polar caps. At higher altitudes, the flux increases by a factor of 10^3 or 10^4, and the absolute intensity is far greater than the neutron albedo theory can explain. In addition to this discrepancy in intensity, the spatial distribution is not as predicted. The intense peaking of the directional flux at the equator is one of the most striking features of Fig. 1. (The equator is the minimum value of B for each line of force.) However, Lenchek[5] predicted a dearth of protons here because, by a simple geometry, neutrons produced in the polar regions cannot inject protons which mirror at the equator. New source and/or redistribution mechanisms are evidently needed.

Relay-I observations confirm the anomalous spatial distribution of 40- to 110-MeV protons previously found by Explorer XV.[6] This part of the proton energy spectrum is supposed to be controlled by nonadiabatic losses, and, although there is some disagreement among theories, they all expect the high-energy spectrum to get rapidly softer toward high L values because the critical trapping energy decreases. The Explorer-XV data showed a complicated spatial distribution exhibiting two unaccountable peaks at different radial distances. Figure 2 shows the equatorial

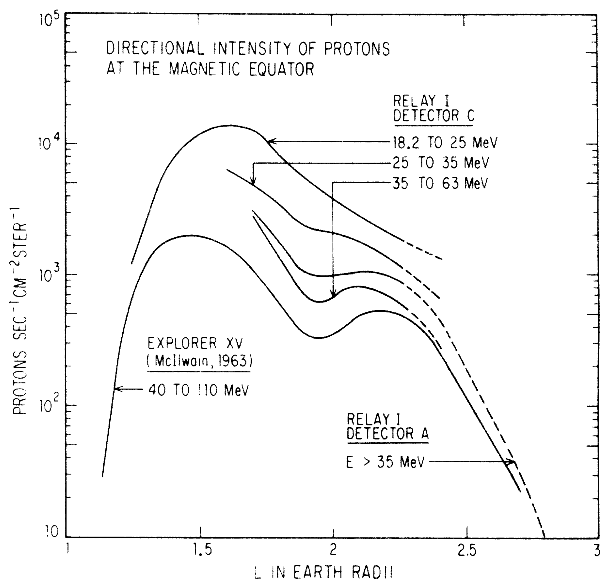

FIG. 2. Fluxes of protons mirroring at the equator.

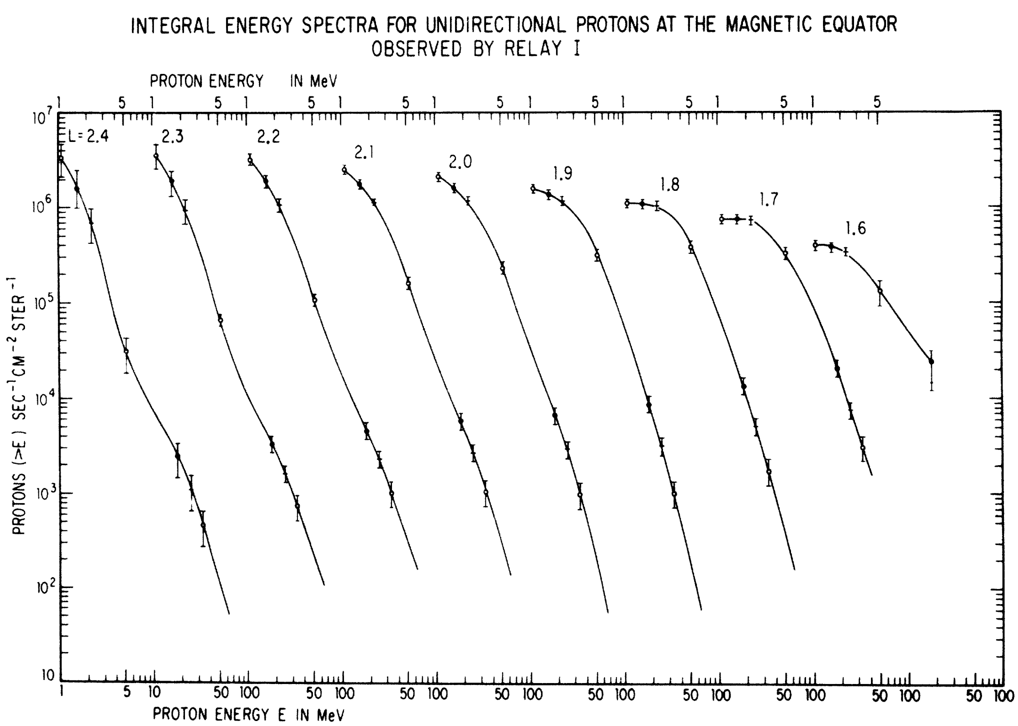

FIG. 3. Proton-energy spectra at the magnetic equator. Each spectrum extends from 1 to 60 MeV, but in order to compress the graph, their starting points have been shifted by only one decade.

profile of the directional proton flux as measured by the two satellites. The detector *A* fluxes have been converted from omnidirectional to directional for this comparison. The energy resolution of detector *C* makes it clear that the secondary peak is a phenomenon of the high-energy protons and disappears at lower energies. The first glance shows that the high-energy spectrum does not get noticeably softer as one goes to higher altitudes, in contradiction to the proposed loss mechanisms. Detailed comparison of the counting rates proves that the spectrum is softest at $L = 1.9$, where the high-energy protons go through a minimum, and actually gets harder toward higher L values.

Using all eight channels listed above, one can make a broad spatial survey of the proton spectrum. The spectrum of 1- to 60-MeV protons is shown in Fig. 3 using data taken on or extrapolated to the magnetic equator. The error brackets allow for time variations, counter statistics, calibration uncertainties, and reasonable extrapolation errors. As observed by Naugle and Kniffen, a soft component appears at L values greater than 1.6 earth radii. However, the same explanation cannot be offered since the new measurements are in the polar shadow. A power-law fit of the form $N(>E) = KE^{-n}$ at the high-energy end of the spectrum yields an exponent of 3 or 4. It is clear, though, that no single power law will fit the entire spectrum, and indeed, neither will any obvious relationship such as an exponential, Gaussian, etc.

It must be concluded that the theory of geomagnetically trapped protons is incomplete. One rather old idea which appears to be worth developing is that some of the low-energy solar cosmic rays are perturbed into trapped orbits by the time-varying magnetic fields near the outer limits of the magnetosphere and that the subsequent diffusion (and acceleration) caused by magnetic field fluctuations brings some of these protons into the inner part of the earth's magnetic field. Observations of particle motions during magnetic storms may be of great help in identifying the important mechanisms, but much more work appears necessary before the complete problem will be solved.

The authors gratefully ackowledge the contributions to the construction and calibration of these detectors made by D. C. Enemark and J. Valerio, and the aid in data reduction given by T. Hassitt and A. Davé.

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*This work was supported in part by NASA Contracts Nos. NAS5-1683, NASr-116, and NSG-538.

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THREE-PHOTON ABSORPTION IN NAPTHALENE CRYSTALS BY LASER EXCITATION

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(Received 23 March 1964)

The intense monochromatic radiation from pulsed ruby lasers has been successfully used for demonstrating two-photon processes[1-3] in solids. We have detected three-photon absorption in single crystals of naphthalene excited by the 14 400 cm^{-1} line of a ruby laser by observing the generation of uv fluorescent light between 25 000 and 31 000 cm^{-1}. Crystalline naphthalene is a suitable material for observing a three-photon process because it has no absorption band system at either the laser frequency or twice the laser frequency (28 800 cm^{-1}). The 0-0 transitions of the lowest triplet and singlet excited states are situated at 21 300 and 31 700 cm^{-1}, respectively. However, there is a relatively strong absorption system[4] ($f = 0.132$) between 40 000 and 45 000 cm^{-1} to which three-photon absorption from the laser can take place.

Single crystals of naphthalene were grown from zone-refined material from the melt as well as from solution in normal hexane. The unfocused red beam from a giant-pulse (0.07-joule output) ruby laser Q switched by a 24 000-rpm rotating prism was incident normal to the *ab* plane of the naphthalene crystal. The emitting end of the laser cavity was formed by a Corning 2-58 red-pass filter to eliminate the possibility of stray uv light from the xenon flash lamp reaching the sam-