Letters to the Editor

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Atmospheric Absorption of Solar Infrared Radiation

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AS a result of some measurements of solar radiation taken with a KBr double monochromator in the infrared region 1.5 to 20 microns, the data collected were assessed and values of absorption coefficients for the continuous absorption spectrum in the region 8–20 microns were evaluated. The coefficients were obtained from the slopes of the lines shown in Fig. 1, which indicate adherence to the well-known Lambert's law. The resulting coefficients were compared with those of Adel[1] and Elsasser[2] in Fig. 2. The computed values indicated by Elsasser's curve were based on line width of 0.25 cm^{-1} and should be reduced in accordance with the more recent value of the line width in the water vapor rotation spectrum measured by Adel[3] to be 0.11 cm^{-1}. In the 8–13 microns region of the solar spectrum the absorption coefficient can be taken to be proportional to line width. When thus reduced, these values come to closer agreement with the smaller values of the coefficients.

In a recent paper presented at an American Physical Society meeting[4] it was pointed out that there appears approximately a factor of 2 difference in the experimental determination of the absorption coefficients by Adel and the author. Actually, in terms of percent transmission, there is agreement within 8 percent in the values obtained for this region of low absorption for, say, 1 cm of precipitable water in the optical path. Furthermore, we have found that the window in the region 17–20 microns recorded by Adel[5] has shown up quite well with a slit width four times that used in the region 8–14 microns. This region is highly sensitive to water vapor content.[6]

The observations were made from the top of Table Mountain, California, with the cooperation of the Smithsonian Institution group stationed there.

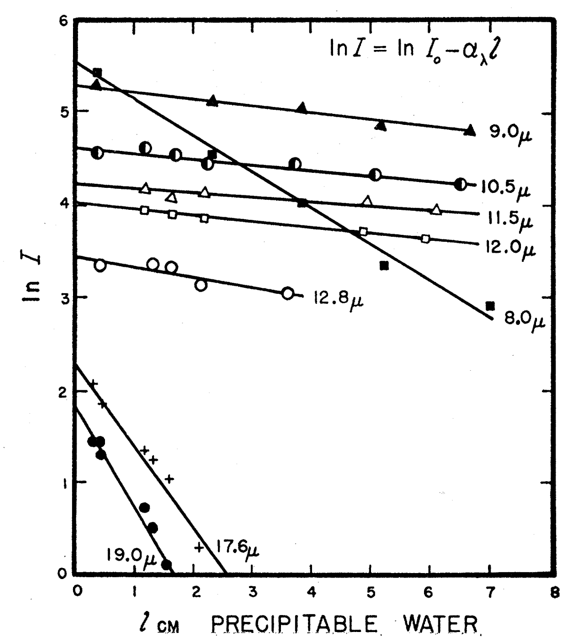

FIG. 1. Experimental curves for the logarithm of the solar intensity *versus* precipitable water with wavelength as parameter. Water vapor content determined spectroscopically using Fowles method (reference 6).

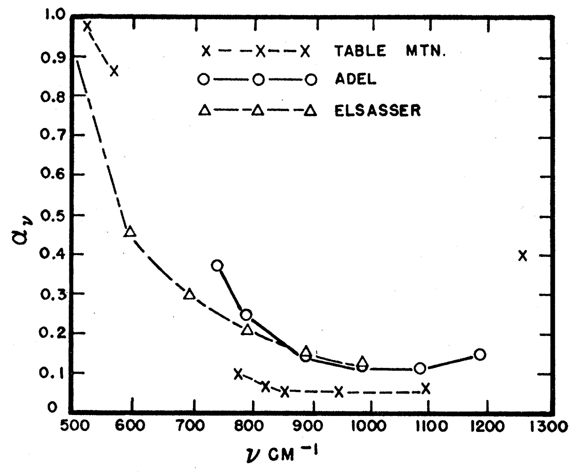

FIG. 2. Comparison of computed values with experimental values of absorption coefficient α_ν, as a function of ν cm^{-1}.

[1] Arthur Adel, Astrophys. J. **89**, 1 (1939).
[2] W. M. Elsasser, Phys. Rev. **53**, 768 (1938).
[3] Arthur Adel, Phys. Rev. **71**, 806 (1947).
[4] Romuald Anthony, American Physical Society Meeting, June 25, 1951, Vancouver, B. C. [Phys. Rev. **83**, 888 (1951)].
[5] Arthur Adel, Astrophys. J. **96**, 239 (1942).
[6] F. E. Fowle, Astrophys. J. **42**, 394 (1915).

Diurnal Variations in High Energy Cosmic-Ray Intensities*

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EXPERIMENTS were performed in a salt mine near Ithaca, New York, at a depth of 1600-meters water equivalent to investigate the properties of high energy cosmic rays. The apparatus consisted of five counter telescopes, each containing two trays of Geiger counters (30 in.×36 in.) separated by 4 in. of Pb and ½ in. Fe, and shielded above and below by 2 in. of Pb. From July 15, 1951 to October 9, 1951, 90,702 coincidences were recorded with an average rate per telescope of 10.46 hr^{-1}. The accidental coincidence rate was about 5 percent. The number of coincidences in each telescope was recorded every hour.

Other experiments, to be reported later, indicate that the particles observed are mu-mesons. In order to penetrate to this depth the meson must have an energy of at least 5×10^{11} ev. On the average, the mesons are created with 10^{12} electron volts by pi-mesons of 1.3×10^{12} ev energy, and these pi-mesons are created by nuclear interactions of primary nucleons having an average energy on the order of 5×10^{13} ev. Because of the zenith angle distribution of the mesons the angular resolution of the telescope is about 60 degrees, and therefore, only variations in the coincidence rate lasting for four hours or more should be considered significant.

The variation of intensity with solar time is shown in Fig. 1. The errors are standard errors. The mean square deviation of the observed coincidence rates from the average agrees with that expected from a normal distribution. These data indicate that

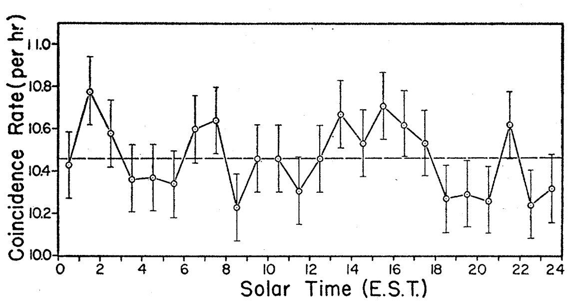

FIG. 1. Solar-time variation of cosmic rays at 1600-m water equivalent depth. Errors shown are standard errors. The horizontal line indicates the average coincidence rate per telescope.

within two standard errors the root-mean-square value of a solar diurnal effect is less than one percent for the particles observed.

In Fig. 2 the data are grouped in sidereal time intervals and plotted against local sidereal time. The local sidereal time at 0000 hours Eastern Standard Time on July 22, 1951, was taken as 19 hr 50 min. On the basis of these data the existence of a sidereal diurnal variation greater than two percent would seem highly improbable. However, the deviations of the hourly rates from the average are slightly larger than expected from a normal distribution, and the results are indecisive as to the probable existence of a sidereal diurnal effect of about one percent.

A sidereal diurnal effect of about ten percent has been reported by Sekido and collaborators[1] based on a total number of 1720 particles observed at a depth of 1400 meters H_2O equivalent. They show a peak in intensity coming at five hours and 20 minutes local sidereal time. Our data reveal no peak in intensity near this hour, and as our standard error is much smaller and our angular resolution is similar to theirs, such an effect should have been readily detectable.

Any observed anisotropy of cosmic rays depends not only on the anisotropy in the distribution of sources, but also on the deflections of the rays while crossing the space between the sources and the earth. Considerations of the energy density in cosmic rays[2] lead to the belief that they come from sources within our galaxy and are confined to the galaxy by magnetic fields. These magnetic fields would cause large and irregular changes in direction of the cosmic rays, resulting in a high degree of isotropy in the incident radiation, even if the sources are highly localized. In spite of this smearing, there should be a broad maximum in the intensity coming from the direction of any strong source. The width of the peak should be so great that the poor angular resolution of our apparatus would have little effect on it. But if curling due to magnetic fields is sufficiently strong, the departure from complete isotropy may not be observable. This has been discussed quantitatively by Cocconi,[3] who concluded from the observed isotropy of the cosmic rays of 10^{13}–10^{14} ev that the

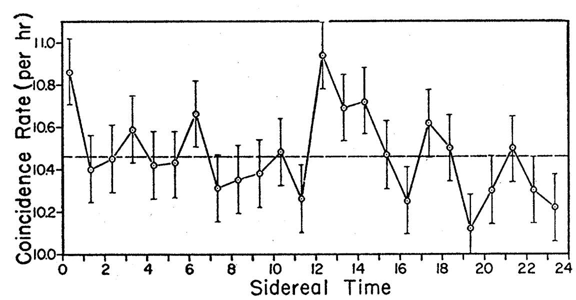

FIG. 2. Sidereal-time variation of cosmic rays at 1600-m water equivalent depth. Errors shown are standard errors. The horizontal line indicates the average coincidence rate per telescope.

galactic fields must have a strength of at least 10^{-9} gauss. Our data confirm his order of magnitude.

We are grateful to Professors G. Cocconi and K. I. Greisen for their helpful criticism and suggestions.

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[1] Sekido, Masuda, Yoshida, and Wada, Phys. Rev. **83**, 658 (1951).
[2] R. D. Richtmeyer and E. Teller, Phys. Rev. **75**, 1729 (1949).
[3] G. Cocconi, Phys. Rev. **83**, 1193 (1951). In a private communication from Dr. Cocconi he states that his accuracy of measurement should give $a \leq 6\times10^{-2}$ instead of $a \leq 3\times10^{-2}$, as stated in his article. Our results give $a \leq 4\times10^{-2}$.

The Scattering of 0.5-Mev Circularly Polarized Photons in Magnetized Iron*

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THE possibility of detecting circularly polarized photons by Compton scattering in magnetized ferromagnets has been both implied[1,2] and explicitly suggested[3] in several recent theoretical treatments. The dependence of the scattering cross section of circularly polarized (c.p.) photons upon both the sense of polarization and the polarization state of the scattering electrons is perhaps most clearly seen in the formalism adopted by Fano.[2] He describes the intensity and polarization state of an incident photon by means of a four-vector constructed from the Stoke's parameters and the scattering of this photon into another state

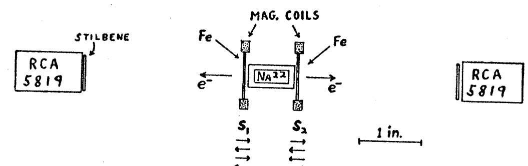

FIG. 1. Experimental arrangement.

by a 4×4 matrix which relates the Stoke's parameters of the incident and scattered radiation. In the case of unpolarized incident radiation this matrix transformation reduces to the well-known Klein-Nishina formula.

However, the intensity of c.p. incident radiation scattered at an angle θ by an electron with initial spin of direction **S** is of the form

$$\Phi(\theta)=C\{A(\theta)\pm(1-\cos\theta)(\mathbf{k}_0\cos\theta+\mathbf{k})\cdot\mathbf{S}\}, \quad (1)$$

$$\Phi(\theta)=C\{A\mp B\mathbf{n}_0\cdot\mathbf{S}\}, \quad \text{for} \quad \theta=\pi, \quad (2)$$

where $\mathbf{k}_0$ and $\mathbf{k}$ represent, respectively, the incident and scattered photon momenta in electron rest mass units, $\mathbf{k}_0=k_0\mathbf{n}_0$, and the upper or lower signs refer to right or left c.p. photons, respectively.

We have investigated this dependence of intensity upon **S** by observing in coincidence the forward direction Compton electrons ($\theta=\pi$) produced in magnetized Fe foils by annihilation quanta. Wheeler[4] was the first to point out that two-photon annihilation of positronium can proceed only from the singlet state (zero angular momentum). Hence, an experiment detecting coincidentally the polarization states of the annihilation photon pair must verify plane polarized photons with crossed planes or c.p. photons of opposite senses. The first possibility has been confirmed experimentally by several workers;[5,6] the second provides the c.p. photons employed in the experiment described here.

The experimental arrangement is depicted in Fig. 1. Forward direction Compton electrons from two magnetized Fe foils (0.1 g/cm^2) were detected by two thin (0.5 mm) stilbene crystals covered by 0.004 g/cm^2 Al foil. Scintillations were recorded by a fast coincidence circuit[7] (2×10^{-8} sec resolving time), and rates