two minutes. The intensity increase was again approximately 30%. The average coincidence rate was about 1000 counts per second.

Reports of solar and other geophysical activity were obtained for the two days the flights were made. No solar flares were observed on the 8th of August during the time measurements were made. On August 9th, a solar flare of importance 1 was observed on the west limb of the sun at 1330 UT; the activity lasted for about one hour (High Altitude Observatory, Boulder). Thus the onset of the flare preceded the first cosmic-ray event by about 20 minutes. Other geophysical events were observed during the same period. A radio noise storm on 200 Mc was in progress when the flare started and during the first cosmic-ray increase (reported by National Bureau of Standards, Boulder). A sudden ionospheric disturbance with shortwave fadeout (importance +3) followed the flare (reported by Central Radio Propagation Laboratory of the National Bureau of Standards, Boulder). A distinctive magnetic event was observed (at Fredericksburg, Virginia, Station) just at the time of the first cosmic-ray increase.

Several conclusions can be drawn from the results of these flights. The results offer the first direct experimental evidence for a time correlation between a small solar flare and cosmic-ray intensity increases of short duration. The increases followed the appearance of the flare by 20 minutes. The same time interval has been found between large solar flares and large cosmic-ray increases. But the increases reported here were in the form of a hump instead of a sharp rise and exponential decrease to normal.[2] The absence of similar increases at other cosmic-ray stations is indicative of the association of low-energy cosmic-ray particles with small solar flares. Evidently most of the particles causing the intensity increases have low energies and could not have reached sea level.

It seems probable therefore that many, perhaps most, solar flares can accelerate particles to energies which may however be quite low.[3] Provisionally we would assume that the low-energy cutoff ("knee") observed for the general cosmic radiation does not exist for the solar-flare cosmic rays. No statement can as yet be made about their charge spectrum.

The present experiment clearly shows the need for operating high counting rate cosmic-ray detectors in conjunction with short resolving time count ratemeters at high altitudes and at auroral latitudes to detect low-energy cosmic-ray particles associated with small solar flares. Failure of other cosmic-ray experiments to meet these two conditions may be the reason why such events have not been detected in the past.

Equipments similar to the one flown at high altitudes are at present in operation at mountain altitudes at Climax, Colorado (altitude 3400 meters), and at Banff, Canada (altitude 2283 meters) as part of the International Geophysical Year effort. Balloon flights are planned for the near future.

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*Supported by the Air Force Office of Scientific Research. We are particularly indebted to Mr. Ray Heer for his continued interest in this program and for making the difficult arrangements for the airplane flights.

[1] Dolbear, Elliot, and Dawton, J. Atm. and Terrest. Phys. 1, 187 (1950); J. Firor, Phys. Rev. 94, 1017 (1954).

[2] See, e.g., S. F. Singer, in Progress in Elementary Particle and Cosmic-Ray Physics (Interscience Publishers, New York, 1958).

[3] S. F. Singer, International Union of Pure and Applied Physics Cosmic-Ray Congress, Varenna, June, 1957, Suppl. Nuovo cimento (to be published).

FREQUENCY OF CESIUM IN TERMS OF EPHEMERIS TIME

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The National Physical Laboratory, Teddington, and the U. S. Naval Observatory, Washington, have been cooperating in a joint program since June 1955 to determine ν_E, the frequency of cesium in terms of the second of Ephemeris Time.[1] In 1955 the International Astronomical Union recommended that the second of Ephemeris Time be adopted as the fundamental unit of time, and in 1956 the International Committee of Weights and Measures redefined the second so as to make it identical with the second of Ephemeris Time (E.T.), which is considered to be a constant unit of time. The second of Universal Time is thus no longer the fundamental unit of time.

Ephemeris Time is defined by the orbital mo-

Table I. Results for ν_E obtained from four different sets of data.

		Means	ΔH (sec)	$\nu_E - \bar{\nu}_U$	ν_E	$\Delta T''$ (sec/yr^2)
1.	ΔT_0,	1954.25-1958.25	+1.146	-121	9 192 631 761	+ 0.17
2.	ΔT_0,	1955.25-1958.25	1.085	-115	767	+ 0.10
3.	ΔT_C,	1954.25-1958.25	1.035	-110	772	+ 0.12
4.	ΔT_C,	1955.25-1958.25	0.966	-102	780	+ 0.17

tion of the earth about the sun, but is obtained in practice from the orbital motion of the moon about the earth. The dual-rate moon position camera has been used at the U.S. Naval Observatory since June, 1952, to determine Ephemeris Time.[2] Photographs of the moon and surrounding stars are taken to determine the position of the moon at a known Universal Time. The Improved Lunar Ephemeris 1952-1959 tabulates the position of the moon as a function of E. T. The Lunar Ephemeris is entered with the observed position of the moon and E. T. is taken out. There is thus obtained the quantity ΔT = E.T.-U.T.

Semiannual means have been determined for the epochs 1952.75 to 1958.25, in two forms. ΔT_0 is the mean obtained initially and ΔT_C is the mean obtained by correcting for terms which depend upon the mean anomaly of the moon.

In a previous note[1] we have described an intermediate step, namely, the determination of ν_U, the frequency of cesium in terms of the second of UT2. In this note we describe how the observations of the moon are used to convert from ν_U to ν_E .

It may be shown that

$$\nu_E = \bar{\nu}_U - \nu_E(\Delta H/H),$$

where $\bar{\nu}_U$ is the mean value of ν_U in an interval of time H, and ΔH is the total change in ΔT during the interval.

The interval of comparison used is 1955.50 to 1958.25. For this interval $H = 8.68 \times 10^7$ sec, and $\bar{\nu}_U$ = 9 192 631 822 cps of UT2. ΔH was obtained by passing a parabola through the means, by least squares, and evaluating ΔT for the ends of the interval. Four solutions were made in order to determine the effect of using different data. The results are shown in Table I.

The last column gives the deceleration in the rotation of the earth as determined with the moon camera. The deceleration previously determined with the cesium standard was 50 parts in 10^{10} per year, which is equivalent to 0.16 sec/yr^2. The agreement between the moon camera and cesium is satisfactory.

The value of ν_E adopted is the mean of the four solutions, that is, 9 192 631 770 cps.

With this value of ν_E we may obtain ΔA = A.T. -U. T., where A.T. denotes atomic time, by integrating the values of ν_U previously obtained and by assigning an initial value of ΔA. The value adopted is ΔA=30.580 sec at 1957.0. Figure 1 shows ΔA, ΔT_0, ΔT_C, and ΔT_{C3}, the parabola obtained from solution No. 3. Its equation is

$$\Delta T_{C3} = [30.853 - 0.469\,(t - 1950.0) + 0.0615\,(t - 1950.0)^2]\ \text{sec}.$$

It is believed that the dispersion in the values of ΔT will be reduced by the application, in the future, of corrections for the figure of the moon which are now being completed by Dr. C. B. Watts of the Naval Observatory.

The probable error of ν_E is estimated to be ± 10 cps from internal considerations. The result, however, may be affected by possible systematic errors, especially in the determination of ΔH. There is also the possibility that a systematic error may be present in the chain of

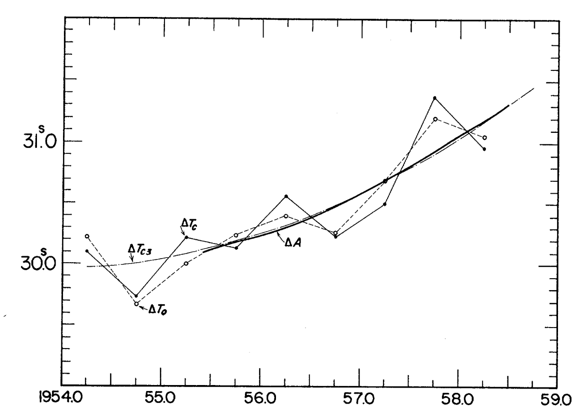

FIG. 1. Comparisons of Ephemeris Time and Atomic Time with Universal Time.

comparison between the cesium beam at Teddington and the moon camera at Washington. From an analysis of the various factors involved we have adopted a probable error of ±20 cps.

We find, thus, the transition frequency of cesium (4,0) → (3,0) at zero magnetic field is

$$\nu_E = 9\,192\,631\,770 \pm 20 \text{ cycles per second (of E.T.) at 1957.0.}$$

The mean epoch is specified because there is a possibility that the gravitational and atomic time scales may not be the same, and may change secularly. Future determinations of ν_E will decide this question.

[1] Essen, Parry, Markowitz, and R. G. Hall, Nature 181, 1054 (1958).
[2] Wm. Markowitz, Astron. J. 59, 69 (1954).

FURTHER OBSERVATIONS ON THE NATURE OF THE CURRENT REDUCTION IN THE PRIMARY COSMIC-RAY INTENSITY*

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It has been established recently that a sharp cutoff mechanism, operative now but not in 1949-50, has reduced the primary cosmic-ray intensity.[1] Although the experimental results which led to this conclusion were entirely consistent with the possibility that the 1958 and 1950 magnetic ridigity spectra differ only with respect to the lower limit, it was not possible on the basis of the available data to determine whether the form of the spectrum, *i.e.*, the exponent γ in the power law representation $J(>pc/Ze)=K(pc/Ze)^{-\gamma}$, had also changed.

This is a preliminary report upon the results of experiments with balloon-borne pulsed ionization chambers, which not only relate to this matter, but which also provide information regarding the flux of heavy nuclei.

An appropriately biased pulsed ionization chamber instrument responds principally to (1) nuclear disintegrations produced in the walls by fast protons and neutrons, and (2) heavy nuclei of atomic number $Z>8$. A detailed description of the experimental arrangement utilized in the present investigations, and a discussion of the interpretation of the measurements, has been presented previously.[2]

At balloon altitudes, events of Type (1) are produced predominantly by high-energy primaries and their progeny. Low-energy protons (*i.e.*, close to the geomagnetic cutoff at $\lambda \cong 52°$N) yield a negligible contribution to the disintegration rate. This was demonstrated by the fact that, in 1950, the burst rate did not change between $\lambda = 52°$ and $\lambda = 69°$ (statistical uncertainty ±3%, atmospheric depths 7-70 g/cm^2) although the vertical primary intensity increased by 45%.[2]

However, it was not possible to deduce any quantitative information regarding the low-energy portion of the heavy primary spectrum because most particles of atomic number $Z>8$ in the band of energies admitted between $\lambda = 52°$ and $\lambda = 69°$ are absorbed as a result of energy loss by ionization in the residual atmosphere about the apparatus. This sharp atmospheric cutoff effect, somewhat surprising at that time, is now understandable in terms of the discrepancy between geomagnetic coordinates and directly measured minimum cutoff energies.[3] However, heavy nuclei having magnetic rigidities above the cutoff for Swarthmore, Pennsylvania, presumably reach atmospheric depths attainable by balloons.

If the burst rate at high altitudes were now lower than in 1950, this would be indicative of any or all of the following:

A. The heavy-nucleus flux is reduced at the low-energy end of the spectrum by the cutoff mechanism which is operative on the protons.[1]
B. The intensity of heavy nuclei is reduced throughout the energy spectrum.
C. The intensity of high-energy primary protons is reduced.

Although thus far data are available from only two pulsed-ionization chamber flights conducted during 1958, the results are sufficiently definitive to warrant certain conclusions. The justification for confidence in the validity of the data is illustrated in Fig. 1. It is seen here that the 1958 points are in excellent agreement with the intensity *vs* altitude curve obtained in 1950 (see Table I). It is unlikely that this agreement could be fortuitous. This result indicates that <u>none</u> of the possibilities A, B, or C has occurred.

The contribution to bursts >1 Po-α arising from nuclear disintegrations is significant down to a greater atmospheric depth than that from the heavy-nucleus component. Hence, the statistical uncertainty (±4%) in the comparison of the high-energy primary proton fluxes in 1950