Letters to the Editor

PROMPT publication of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is the third of the month. Because of the late closing date for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not in general exceed 600 words in length.

Auger Transitions

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IN 1944, J. N. Cooper published a survey[1] of Auger transitions and the resultant doubly-ionized states. Through some oversight[2] he omitted the transition $L_{\text{I}} \rightarrow L_{\text{II}}M_{\text{IV,V}}$ which originates the $L\beta_1$ satellites in the x-ray spectrum. In all, he had some twenty-six transition groups. The final doubly-ionized state includes the same outer shell in each group, but not the same subshell. Including Cooper's omission, then, there should be twenty-seven transition groups. Of these, fifteen Auger transition groups obey the old x-ray selection rules: $\Delta_j = \pm 1$, 0; $\Delta k = \pm 1$; Δn is arbitrary. Coster[3] looked for radiation from the transitions $L_{\text{I}} \rightarrow L_{\text{II}}$ and $L_{\text{I}} \rightarrow L_{\text{III}}$ which he noted were permitted by selection rules. He later observed extremely faint radiation,[4] i.e., these are "radiationless" transitions. The present writer[5] remarked in 1942, that "selection rules point out where the radiationless transitions are sure to occur." Of these fifteen permissible transitions in Cooper's survey,[1] four groups yield x-ray satellites, in two cases of which it is for two x-ray diagram lines (see Table I). The question properly arises as to the meaning of these circumstances: the selection rules point out and control the occurrence of significant Auger transitions. Of the permitted transitions, relatively few result in the proper initial double (or triple) ionization which gives rise to x-ray satellite groups. This in no way contradicts the Franck-Condon principle: ${}_1E_2 \gtrsim h\nu_0$, where ${}_1E_2$ is the energy difference of the Auger transition, and $h\nu_0$ is the energy of ionization of the second (outer) shell in the Auger effect. Let $\nu_1 = RZ^2(1/n_1^2)$ and $\nu_2 = RZ^2(1/n_2^2)$, then ${}_1E_2 = h(\nu_1 - \nu_2) = hRZ^2(1/n_1^2 - 1/n_2^2)$; let $h\nu_0 = hRZ^2(1/n_3^2)$. Then for the Auger effect: $(1/n_1^2 - 1/n_2^2) \gtrsim 1/n_3^2$.[6] This last equation may easily be verified, if one remembers that the initial state of the Auger effect is one of ionization. Inspection of quantum numbers reveals the last equation is verified *only* for the old azimuthal quantum number k. Substituting in the last equation, for $L\alpha_1$, $L\beta_2$ and $L\beta_1$, we have

$$1/(1)^2 - 1/(2)^2 \gtrsim 1/(3)^2 \quad \text{or} \quad 1 - \tfrac{1}{4} \gtrsim \tfrac{1}{9}.$$

For $M\alpha_1$ and $M\zeta_{1,2}$,

$$1/(2)^2 - 1/(3)^2 \gtrsim 1/(3)^2.$$

However for $M\beta$,

$$1/(3)^2 - 1/(3)^2 = 0 \neq 1/(3)^2,$$

there is no verification. Thus for five of the six satellite groups, the azimuthal quantum number, k, verifies the Franck-Condon principle somewhat roughly.

TABLE I.

Auger transition	X-ray satellite group	Parent line transition
$L_{\text{I}} \rightarrow L_{\text{II}}M_{\text{IV,V}}$	$L\beta_1$	$L_{\text{II}}M_{\text{IV}}$
$\{L_{\text{I}} \rightarrow L_{\text{III}}M_{\text{IV,V}}$	$\{L\alpha_1$	$\{L_{\text{III}}M_{\text{V}}$
$\{L_{\text{I}} \rightarrow L_{\text{III}}M_{\text{IV,V}}$	$\{L\beta_2$	$\{L_{\text{III}}N_{\text{V}}$
$M_{\text{III}} \rightarrow M_{\text{IV}}N_{\text{IV,V}}$	$M\beta$	$M_{\text{IV}}N_{\text{VI}}$
$\{M_{\text{III}} \rightarrow M_{\text{V}}N_{\text{IV,V}}$	$\{M\alpha_1$	$\{M_{\text{V}}N_{\text{VII}}$
$\{M_{\text{III}} \rightarrow M_{\text{V}}N_{\text{IV,V}}$	$\{M\zeta_{1,2}$	$\{M_{\text{V}}N_{\text{II,III}}$

[1] J. N. Cooper, Phys. Rev. **65**, 155 (1944).
[2] My oversight as well as his, for I saw the paper in manuscript.
[3] D. Coster, Phil. Mag. **43**, 1089 (1922).
[4] D. Coster and R. DeL. Kronig, Physica **2**, 13 (1935).
[5] F. R. Hirsh, Jr., Phys. Rev. **62**, 137 (1942).
[6] Since ${}_1E_2 \gtrsim h\nu_0$, we may divide the close equality by hRZ^2, since for ${}_1E_2$, $Z \sim 50$ and for ν_0, $Z \sim 49.5$, the error in the approximation is 2 percent.

Meteoric Impact Ionization Observed on Radar Oscilloscopes

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THE short duration scattering of radio signals about 40,000 kc/sec. has been observed for fifteen years.[1] During 1940–41 it was observed and recorded by the author in frequency-modulation broadcast wave propagation tests.[2] This scattering was subsequently attributed to reflection from high density "*D*" and "*E*" region clouds ionized by high velocity meteoric impact.[3] This has been the basis of further study in the radio effects and the ionization dissipation of meteors. Of this, six objectives have been defined;

a. Determination of the virtual heights of the reflecting boundaries,
b. Application to the Maris theory of meteors to obtain accurate data for the astronomical study of masses and velocities,[3]
c. Transitions and dispersion of the ions produced by meteoric impact and the light of the night sky,
d. Correlation with the extended low frequency scattering of the Eckersley type,[4]
e. Determination of critical or limiting scatter radio-frequencies, and
f. Measurement of field-intensities and skip distances.

The first four objectives will be covered in a series of papers soon to be published by the author. The latter two represent new developments which have been brought somewhat closer to solution through wartime radio and radar operation.

The frequency of occurrence and the field-intensities[5] observed at 43,000 kc/sec. led to the supposition that the limiting or critical scattering frequency must lie above 100,000 kc/sec. This was substantiated when "echo-

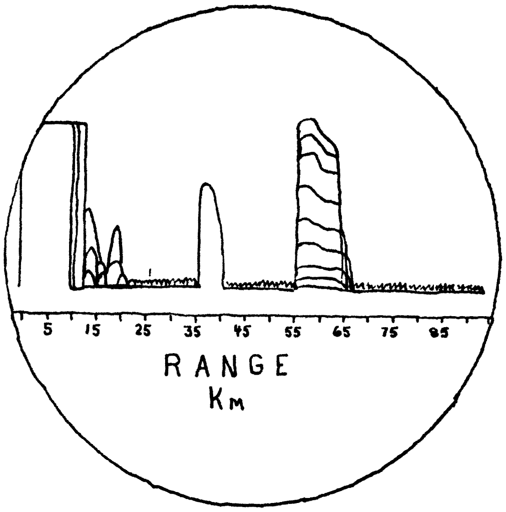

FIG. 1. Typical portion of the range oscilloscope traces on a radar unit showing three types of echo-returns. The rectangular wave form at the extreme left is the transmitter pulse with scattered reflections from hills, trees, large buildings, etc., extending to about 20 km. At 35 km is the echo-return of a single aircraft and at 55 km the multi-return from the ionized columnar meteor train. The sharp leading edge of both of the latter echoes is indicative of reflection from a well-defined boundary. The multi-returns from the meteor train are indicated by the numerous peaks within the echo envelope. The tails of the weaker echoes at about 65 km indicate the slight difference of range which would appear on a slightly different azimuth. The duration of these echoes is between ½ and 3 seconds with constant rapid fluctuations in field-intensity due to the high order of ion-recombination at these frequencies.

returns" coincident with the appearance of bright meteor trains were observed on the oscilloscopes of radar units operating in India. The author, while investigating these peculiar echoes in an unofficial capacity, noted several prominent features, which are reproduced in Fig. 1.

Operating the radar on a frequency of approximately 105,000 kc/sec., echoes were received lasting from ½ to 3 seconds on half-path lengths of 30 to 125 km. This is, naturally, relative to the radar, which for military purposes concentrates a considerable portion of its energy at very low radiation angles and probably, therefore, secures echo-returns from meteor trains passing far from the zenith. The echo rate of occurrence exhibited a random distribution during the early morning hours (0100–0700 hours local standard time) with a strong maximum about 0400 hours. No echoes were observed in the afternoons or early evenings (1300–2100 hours).

The particular character and the steep-sided leading edge of the echo, as illustrated in Fig. 1, are indicative of reflection from a sharply-defined boundary. Movement of the echoes is observed by the superimposition of numerous echoes within or above the original return. Variations in range of the echo radially to the radar, were small probably less than 3 km, although azimuth angles, which were difficult to obtain due to the fluttering signal and return, varied beginning to end points by about 10°.[6] These circumstances are the equivalent of specular reflection as proposed by Pierce for meteoric columnar ionization.[7]

The observation of meteoric impact ionization and the radio effects associated therewith will be greatly aided by the employment of a high angle radiational pattern radar unit operating on frequencies of about 50,000 kc/sec. Undoubtedly, valuable quantitative information on masses, velocities, and numbers of meteors may be obtained in this fashion.

[1] H. M. Beverage, H. O. Peterson, and C. W. Hansell, Proc. I. R. E. **19**, 1313 (1931).
[2] O. P. Ferrell, Radio **258**, 9 (1941).
[3] H. B. Maris, Terr. Mag. **34**, 309 (1929).
[4] T. L. Eckersley, J. I. E. E. **86**, 548 (1940).
[5] The author had observed intensities above 50 microvolts per meter over a path of 390 km (Paxton, Massachusetts to Atlantic City, New Jersey) and intended to expand his meteoric origin hypothesis in the second part of, "Notes on U.H.F. Propagation," (part 1), *Radio*, p. 267 (March, 1942), but was unable to do so before entering the U. S. Army Signal Corps.
[6] Many of these observations were made on SCR270B radar units which introduce considerable inaccuracy in the factor of human judgment and coordination. The exact determination of azimuth is therefore subject to gross extremes.
[7] J. A. Pierce, Proc. I. R. E. **26**, 892 (1938).

On the Nuclear Photo-Effect

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THE measurements of the thresholds and yields of the nuclear photo-effect indicate thresholds between 5 and 19 Mev,[1] and cross sections of the order of 10^{-26} cm^2.[2] Notwithstanding the experimental uncertainty of the latter value, one can easily recognize[3] how important this effect becomes at temperatures for which

$$kT \gtrsim 2\ mc^2 \sim 10^{10}\ \text{e-volts}.$$

Indeed, photons with $h\nu$ above the threshold produce excited nuclei which can undergo several types of processes, e.g., giving rise to a neutron or proton and a β-radioactive nucleus. This source of neutrons gives origin to a great concentration of neutrons at temperatures and nuclear densities indicated below. The neutrons absorbed by other nuclei produce the well-known transformations in which many $\pm\beta$-radioactive nuclei are generated. The emission of neutrinos and antineutrinos in the $\pm\beta$-processes increases very rapidly with temperature, according to formula (1), of this paper and becomes the dominant process above certain critical temperatures depending upon the threshold and the cross section for the photo-effect. These phenomena play an important role in the statistical processes which gave origin to the actual distribution of nuclei in the universe,[4] and possibly in the phenomenon of the stellar collapse.[5]

Let us consider the statistical equilibrium between nuclei, photons, and electrons at $kT \sim 2mc^2$, where m is the mass of an electron. Putting $x_0 = mc^2/kT$, $y = h\nu/kT$, $y_0 = h\nu_0/kT$, where $h\nu_0$ is the threshold for the kind of nuclei under consideration and assuming $y_0 \gg 1$, one obtains directly from the Plank's formula the following value for the number Ny_0, per unit volume, of photons having energy greater than the threshold:

$$Ny_0 = \frac{8\pi}{c^3}\int_{\nu_0}^{\infty}\frac{\nu^2 d\nu}{e^{h\nu/kT}-1} \sim 8\pi\left(\frac{mc}{h}\right)^3 x_0^{-3} y_0^2 e^{-y_0} \sim 1.8 \times 10^{30} \times x_0^{-1} \times \left(\frac{y_0}{x_0}\right)^2 \times e^{-y_0}. \quad (1)$$

Some values obtained from (1) for the mean life of a