TABLE I.

Picture number	Sign	Mass
7049	+	211 ± 20
7811	+	207 ± 27
7821	+	222 ± 26
8818	+	240 ± 28
9860	can be identified as positive but the picture in the upper cloud chamber is too faint to be measured.	
7362	−	240 ± 31

would be difficult to find, and one might expect the experimental value to be lower than the calculated probability. Thus, the data are not inconsistent with the assumption of a decay electron of approximately 50 Mev from positive mesotrons.

The suggestion has been made by Valley and Rossi[3] and discussed by Piccioni[4] that perhaps negative mesotrons are not captured by nuclei but that their decay is accelerated. If this were true for lead, in the present experiment one would expect to see the tracks of decay electrons from 10 of the 27 negative mesotrons which stop in the lower cloud chamber. Only one picture gives evidence for the decay of a negative mesotron.

* This work was supported in part by the Office of Naval Research.

[1] To be published soon.

[2] Rossi and Greisen, Rev. Mod. Phys. 13, 240 (1941), see Fig. 9.

[3] Valley and Rossi, Phys. Rev. 73, 177 (1948).

[4] O. Piccioni, Phys. Rev. 73, 411 (1948).

A Note on the Paper "On the Possibility of Observing Beat Frequencies between Lines in the Visible Spectrum!"

L. R. GRIFFIN
University College, Swansea, Wales
January 5, 1948

IN a recent communication[1] the authors proposed an experiment to demonstrate the occurrence of beats with light radiations of slightly different frequencies.

Now, the variation of the intensity of the electric vector associated with either line at any point in space may be represented by a sine wave whose amplitude and phase vary continuously and discontinuously with time. The Fourier integral analysis of this variation gives the line spectrum and would be carried out automatically by a spectroscope. A Fourier integral analysis of a non-linear detector's response at this point will have no predominant frequency present as we may assume that the frequency equal to twice the incident frequency is so high that the detector is unable to respond. When there are two lines present there will be large fluctuations of amplitude and of phase of their combined electric vector. In this case the Fourier integral analysis of the detector's response gives a predominant frequency equal to the frequency difference Δ of the two lines, and this beat frequency could be detected by a suitable resonant circuit. It is interesting to note that there is no need to place any restriction upon the rapidity of the phase variations, except so far as it affects the sharpness of the response at the beat frequency. These conclusions are in general agreement with those of the authors.

However, we have so far restricted our discussion to one point in space, whereas in practice the detector must have dimensions large compared with the wave-length of the radiations present, in order that sufficient energy may be received. Therefore our analysis must be extended into three dimensions. Now obviously, at each point of our three-dimensional space, we shall have a predominant beat of frequency Δ, but the question of greatest interest is whether the beats will be in phase throughout the detector medium. If there is a phase variation, then it at once follows that the beat frequency will not be detected. There will be fluctuations of the detector's total response but these will be very irregular and have no relation to the beat frequency. A Fourier integral analysis of this response fluctuation would have a small predominant maximum at the frequency Δ, but this is not the beat in the sense implied in the paper, and in any case it would seem likely that its amplitude would be so small as to make it undetectable.

There would be well defined beats if the spatial beats were in phase, but this would mean that if at any time we construct the surfaces of equal phase for the two lines, they must be members of the same family of surfaces. This would seem to be impossible to attain in practice because the finite width of the slit alone is a prohibitive factor.

It thus appears unlikely that the proposed experiment will be successful in the detection of beats between light radiations.

[1] Forrester, Parkins, and Gerjuoy, Phys. Rev. 72, 728 (1947).

Signal-to-Noise Ratio in Photoelectrically Observed Beats

EDWARD GERJUOY, A. THEODORE FORRESTER
AND WILLIAM E. PARKINS
University of Southern California, Los Angeles, California
January 24, 1948

THE discussion by Griffin[1] of the effect of phase variations on the possibility of observing beats between lines in the visible spectrum is, in our opinion, not wholly correct. Calculations made by us prior to our previous communication,[2] but omitted because of the space limitations, show that phase variations do reduce the beat frequency signal relative to what would be obtained for the same light intensity if the beats at all points on the cathode were in phase. However, the beat frequency signal is by no means extinguished merely because phase variations occur.

The electric current per unit area $i(r,t)$ from any point r on the cathode is proportional to the square of the electric vector at that point, provided the assumptions discussed in reference 2 are valid. Fourier analysis of $i(r,t)$ yields terms $i_f(r)$ representing the components of the beat frequency f in the photo-current. We now note that the photoelectrons originate so close to the surface of the cathode that the phase of $i_f(r)$ does not vary with depth, so that the cathode can be considered two dimensional. Thus if the cathode is so small that the phase of $i_f(r)$ is practically constant everywhere on its surface, the amplitude of the beat frequency component of the total current I_f from the cathode is proportional to the area of the cathode, and the power activating the resonant cavity (Fig. 1, reference 2) is proportional to the square of the area. If the cathode is large, its surface can be subdivided into small regions of area $\sim\lambda^2/\Omega$ (defined below), in each of which the phase of i_f is constant, while the resultant currents I_f from separate regions are random in phase. In this case the total power activating the cavity is proportional to the number of subdivisions, i.e., to the area of the cathode.

These qualitative results are borne out by a more rigorous evaluation, using the exact phases at various points on the cathode. It should be emphasized that the received signal at the cavity increases with increasing cathode area. The limitation on the experiment is provided not by phase variations over the cathode, but by a phenomenon inherent in the emission process, namely, shot effect. The exact formula for the signal-to-noise ratio P is

$$P=2.11\cdot 10^{-3}\frac{Rg^2W^2\lambda^2S\Omega/\delta}{(RegWS\Omega/4\pi)+kT}, \tag{1}$$

where W is the power radiated per unit area of the source into both lines, whose mean wave-length is λ. δ is the width of each line in cycles/sec., g the photoelectric efficiency, S the area of the cathode, Ω the solid angle included in the incident bundle of waves falling on the cathode, and R the shunt resistance of the resonant cavity. The first term in the denominator is the energy in the resonant cavity caused by shot noise in the photo-current, and the second term is the thermal noise in the cavity. Except for very small cathodes, the kT term is negligible. For larger cathodes the signal-to-noise ratio is independent of cathode area or of Ω.

A scheme developed by Dicke,[3] who measured signals only 0.0015 of noise, is applicable to this problem; in making estimates we assumed a signal-to-noise ratio of 0.01 could be detected. Using $g=0.04$ ampere/watt at $\lambda=4000$A (commercial S-4 photo-surface) makes the required value of W one watt/cm². This is a larger value than is ordinarily obtainable, but may be feasible because the source need be operated only for intervals longer than the response time of the detecting equipment (~1 second). Where the average heat dissipation is the factor limiting the power output of the source, continuous operation for an interval no longer than one second should permit using a peak power considerably larger than is possible with steady operation. An experimental program is now under way here to determine the spectral intensity obtainable in a source so operated.

It is expected that the details of the derivation of Eq. (1) will be presented in a paper to be submitted to this journal.

---

[1] L. R. Griffin, Phys. Rev. **73**, 922 (1948).

[2] A. T. Forrester, W. E. Parkins, and E. Gerjuoy, Phys. Rev. **72**, 728 (1947).

[3] R. H. Dicke, Rev. Sci. Inst. **17**, 268 (1946).

On the Presence of Neutrons in the Extensive Cosmic-Ray Showers*

VANNA TONGIORGI
Laboratory of Nuclear Studies, Cornell University, Ithaca, New York

March 2, 1948

An experiment has been performed in order to find out whether or not neutrons are present in the extensive showers of the cosmic radiation.

For studying neutrons associated with showers one has to record the coincidences between some Geiger counters struck by the electrons of the showers and a neutron detector: a BF_3 proportional counter surrounded by paraffin seems to be the simplest and most reliable one. However, a serious difficulty arises from the fact that, when an extensive shower falls on the recording system, the neutron counter is struck by such a large number of electrons that a pulse may occur as large as the pulse due to the α-particles produced in the BF_3 by the neutrons; also stars and slow protons associated with the showers may give rise to confusing records. By experimenting with and without cadmium screens on the BF_3 counter, one is able to select only the neutrons, but one has to deal with a small effect superimposed on a large background.

We attempted to face the problem by taking advantage of the fact that neutrons have a quite long mean lifetime in paraffin (~200 μsec.). If one records the coincidences between the pulses of the neutron counter and the pulses of the electron counters delayed by several microseconds, all particles but neutrons are cut off; the number of neutrons lost, however, is very small (<5 percent for delays smaller than 10 μsec.).

The experimental arrangement used is drawn in Fig. 1. The extensive showers were detected by the counter trays, a, b, and c, each consisting of four G-M counters in parallel (area of each tray 2000 cm²). They were placed in a horizontal plane at the vertices of an equilateral triangle of 4-m sides.

Two identical neutron detectors N_1 and N_2 were used, each consisting of a paraffin box (45×45×50 cm³) in which four BF_3 proportional counters connected in parallel were embedded. Boxes N_1 and N_2 were placed 1.3 meters apart. The experiment was performed under a deck of few g/cm² of light material, practically at sea level.

All neutron counters (surface 2.5×45 cm²) were provided with Kovar guard ring seals and were filled to 100 cm Hg with enriched BF_3 (96 percent B^{10}), plus argon to 20 cm Hg. For all of them the operating voltage was about 5000 volts. Their calculated efficiency[1] was about 30 percent.

Figure 2 is the schematic diagram of the recording circuit. Pulses from N_1 and N_2, through cathode followers placed inside the paraffin boxes, were fed into Mod. 100 amplifiers, pulse discriminators, and blocking oscillator outputs (pulse width, 1.5 μsec.). Both N_1 and N_2 were put in coincidence with the coincidences $(a+b+c)$ delayed by 7 μsec. and shaped in a square pulse of 150-μsec. duration. Delayed coincidences $abc+N_1$, $abc+N_2$, and $abc+N_1+N_2$ were recorded.

Thus far have been recorded, in 482 hours, 25,901 extensive showers (~53 showers/hour) and 117 coinci-