LETTERS TO THE EDITORS

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Impulsive Radio Signals from the Planet Venus

RADIO signals of an impulsive or burst-like nature which appear to come from the planet Venus have been detected at the Ohio State University at a wave-length of 11 metres. The observations were made with an interferometer antenna consisting of two colinear arrays of six horizontal half-wave-length elements one-quarter wave-length above ground. Each array is backed up by a reflector element, which, with the ground, forms a corner reflector. The arrays are separated by 426 ft. along an east–west axis. The receiver operates a pen recorder with a time constant of about one-quarter second.

Twice on May 23 and once on May 30, 1956, intense signals were observed when Venus drifted through the main antenna beam. On each occasion the signals were recorded for a period of two to three hours. They appear on the recorder tape as a succession of randomly spaced sharp spikes each representing a burst of short duration (1 sec. or less). The appearance somewhat resembles records of signals received from Jupiter[1]. On each of the three records the envelope of the spikes shows an interferometer lobe pattern in close agreement with one to be expected for a radio source at the position of Venus. The likelihood of confusion with the Sun or other planets is remote, since these were well separated in angle from Venus. Radio sources such as Cygnus *A*, Cassiopeia *A* and Taurus *A* were also well removed. Furthermore, they exhibit a different appearance on the tape and have fixed, instead of changing, celestial co-ordinates.

On all the three records the bursts are observed to pass through peaks spaced about 90 min. apart, at which times they are most frequent and intense. The record of May 23 is of particular interest in this respect since a period of activity was observed between 1300 and 1500 E.S.T. and again between 1900 and 2100, both periods showing similar peaks of activity 90 min. apart. The Sun set at 1947 E.S.T. There is some indication of activity between 1500 and 1900, but Venus was near the edge of the main beam during this period.

In about three months of searching for signals from Venus since February 1, 1956 (no observations were made during April), the only periods of intense activity observed were on May 23 and 30. Possible indications of activity from Venus were noted on February 15 and March 6 but with less certainty. It may or may not be significant, but on May 17 and 26 there were large solar flares. These dates are six and four days, respectively, in advance of May 23 and 30, on which days signals from Venus were observed.

The peak power flux-density of the bursts of signals from Venus have often been recorded at several times the value of the Cygnus *A* radio source at the same frequency (26·7 Mc./sec.). Assuming that Cygnus *A* has a power spectrum proportional to the wave-length, the peak radiated radio-power flux-density of a burst from Venus is:

$$38 \times 10^{-24} \times 9{\cdot}4 \times 2{\cdot}5 \ = \ 8{\cdot}9 \times 10^{-22} \text{ W. m.}^{-2} \text{ (c./s.)}^{-1}$$

where 38×10^{-24} W. m.$^{-2}$(c./s.)$^{-1}$ is the value for Cygnus *A* observed[2] at 250 Mc./sec., 9·4 is the spectrum ratio, and 2·5 is taken as the Venus to Cygnus *A* ratio at 26·7 Mc./sec. on May 23. Actually, the Cygnus *A* spectrum may be flatter than assumed, but compensating this effect the peak burst of power may be higher than recorded since the receiver time constant is one-quarter second and the burst may be of considerably shorter duration. The distance of Venus on May 23 was 0·4 astronomical unit. Assuming that the Venus source radiates isotropically and neglecting the loss through any ionosphere which the planet may have, the peak power in a burst from Venus is about 40 watts per cycle per second of band-width. This is about 0·003 of the value observed for a burst from Jupiter.

If one assumes, in the absence of information about the spectrum of the signal, that the power is constant over a 10-Mc./sec. band-width, the integrated peak radiated radio power of a burst from Venus is 4×10^8 watts (or 400 megawatts). However, if the spectrum is more like that for terrestrial lightning, this may be too low by a factor of about 10, making the value 4×10^9 watts. The total peak power in a terrestrial lightning stroke has been estimated at 10^{13} watts or more[3]. Assuming a conversion efficiency to radiated radio power of 0·001 yields 10^{10} watts of radiated radio power for a terrestrial lightning stroke. This is somewhat larger than the probable value for Venus. Thus, it would appear that a lightning discharge phenomenon on Venus of the intensity of the terrestrial variety (or weaker) would have sufficient power to be the mechanism involved.

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1 Burke, B. F., and Franklin, K. L., *J. Geophys. Res.*, **60**, 213 (1955). Shain, C. S., *Nature*, **176**, 836 (1955). Kraus, J. D., *Sky and Telescope*, **15**, 358 (1956); *Astron. J.*, **61** (1956).

2 Kraus, J. D., Ko, H. C., and Matt, S., *Astronom. J.*, **59**, 439 (1954).

3 Loeb, L. B., *Scientific American*, **187**, 22 (Feb. 1949).

Interpretation of Ionospheric Measurements made during Solar Eclipses

Hunaerts and Nicolet[1] have pointed out that the interpretation of *E*-layer measurements made during solar eclipses is very sensitive to the value of the effective recombination coefficient ($\alpha \times 10^{-8}$ cm.^{3} s.$^{-1}$) in the range $\alpha = 1$–3. For the eclipse of February 25, 1952, at points in the belt of totality, a value of α near the lower end of this range implies, in general, that the west limb of the Sun must have been much brighter than the east limb, and also that there can have been no source of ionizing radiation outside the visible disk. Conversely, a higher value of α requires the existence, in the corona, of sources which remained unobscured during totality, and only a small difference between the brightness of the west and east limbs. At Khartoum, for example, the intensity of the coronal component (I_c) and the difference between the intensities of the sources near the west and east limbs ($I_w - I_e$), both expressed as a percentage of the total radiation, are given by $I_c = 12 - 18/\alpha$ and $I_w - I_e = 2 + 39/\alpha$. The arbitrary assumption that there was no coronal radiation thus leads to the result: $\alpha = 1{\cdot}5$.

Fortunately the interdependence of I and α suggests the possibility of using a method of finding α which makes no arbitrary assumptions about I. If