# APPARENT INTENSITY VARIATIONS OF THE RADIO SOURCE HYDRA–A

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*Summary*

This paper describes the results of a detailed study of the flux density of the discrete radio source, Hydra-A. Over a period of 12 months, approximately 200 measurements of the Hydra-A intensity were compared with a similar number of observations on other strong sources. It was concluded that the observed flux density of Hydra-A is much more variable than that of these other sources, although no periodic changes have yet been detected. Possible mechanisms for the observed intensity changes are discussed.

## I. Introduction

In the course of a survey of cosmic radio noise in 1946 Hey, Parsons, and Phillips noticed that the intensity recorded from a region in Cygnus exhibited marked variability ; they suggested that this variable radiation originated in a source of small angular size. In 1947 Bolton and Stanley showed that such a discrete source of radiation did exist, and in addition were able to detect a few similar objects. Since these initial discoveries, several hundred discrete radio sources have been reported by different workers in both northern and southern hemispheres. It was soon demonstrated that the intensity fluctuations which led to the discovery of the Cygnus source were ionospheric in origin and that the emission of the source was constant to within the accuracy of measurement. However, the interest in the constancy of other discrete sources has remained because of the great astronomical significance of any variability which can be established.

From the results of a survey in which the intensities of about 100 sources with declinations between 10° and 80° were measured almost daily for 18 months, Ryle and Elsmore (1951) concluded that none showed any variation in intensity greater than 10 per cent. No such systematic survey has yet been undertaken by workers in the southern hemisphere, but from the many observations made at this laboratory on the stronger sources it was concluded that their intensities appeared to be constant within 10 per cent., a figure set by the errors of measurement. However, during the course of a discrete source survey (Bolton, Stanley, and Slee 1954), the author was impressed by apparent changes in the flux density of the source Hydra-A. The position given by Mills (1952) is R.A. 09 hr 15 min 46 sec, Dec. −11° 55′ (epoch 1950) and its I.A.U. number 09S1A. The intensities for two consecutive records differed by 30 per cent., although

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sources which appeared on the records at earlier and later rising times showed no significant change. In April 1954, the 110 Mc/s sea interferometer at Dover Heights, Sydney, became available for a systematic study of this source, which was recorded as often as possible until December 1954 when it was decided to transfer the observations to a meridian transit instrument on a site near Sydney ; by this means it was hoped to eliminate effects associated with very low angles of observation.

Since the measurement of absolute flux density is subject to factors which may vary in an unknown manner with time, the observed intensity of the Hydra source on any day was compared with that of one or more of the bright radio sources in Taurus, Virgo, Centaurus, and Fornax, all of which were observed within a few hours of each other. In this way, measurements of the intensity of the Hydra source were largely freed from the effects of calibration errors, and, in addition, a series of records was obtained of other sources for comparison with the suspected variable source.

The observations support the conclusion that the observed intensity of Hydra-A is more variable than that of the four comparison sources.

## II. The Observations

### (a) *Rising Measurements*

The equipment and techniques used in this series of observations have been described in detail elsewhere (Bolton and Slee 1953). The sensitivity of the equipment was monitored by frequent observations of one or more of the intense sources in Taurus, Virgo, Centaurus, and Fornax. Information concerning the five sources is given in Table 1. Two examples of records obtained

Table 1

DETAILS OF THE FIVE SOURCES OBSERVED

| Source | | Flux Density* at 100 Mc/s ($W\,m^{-2}\,(c/s)^{-1} \times 10^{24}$) | Approximate Position (1950) | | Rising Coordinates | | No. of Observations | |
|---|---|---|---|---|---|---|---|---|
| Constellation | I.A.U. No. | | R.A. (hr min) | Dec. | Sidereal Time (hr min) | Azimuth | Rising | Transit |
| Hydra .. | 09S1A | 2·5 | 09 16 | −11° 55′ | 02 45 | 105° | 108 | 91 |
| Taurus .. | 05N2A | 19·0 | 05 31 | 22° 00′ | 00 30 | 60° | 33 | 65 |
| Virgo .. | 12N1A | 12·0 | 12 28 | 12° 40′ | 07 00 | 75° | 25 | 95 |
| Centaurus | 13S4A | 17·0 | 13 22 | −42° 40′ | 04 45 | 140° | 20 | 57 |
| Fornax .. | 03S3A | 2·5 | 03 20 | −37° 18′ | 19 10 | 135° | 19 | — |

* The intensities quoted refer to interferometer measurements at 100 Mc/s.

in this series are shown in Figure 1, in which Hydra-A, rising at 02 hr 45 min, is in both cases calibrated by the Taurus source rising at 00 hr 30 min. These records illustrate a typical change of 20 per cent. in the Hydra-A flux density between the two observations, while no significant change is visible in the

Taurus source; it is also apparent that the difference in the intensities of Hydra-A was maintained for the period of observation lasting about 1 hr.

It is believed that scintillation effects, examples of which appear on the interference patterns of Figure 1, are the major source of error in reading the records. In order to ascertain if scintillations caused systematic errors in the recorded intensities of the sources, the scintillation indices for the records of

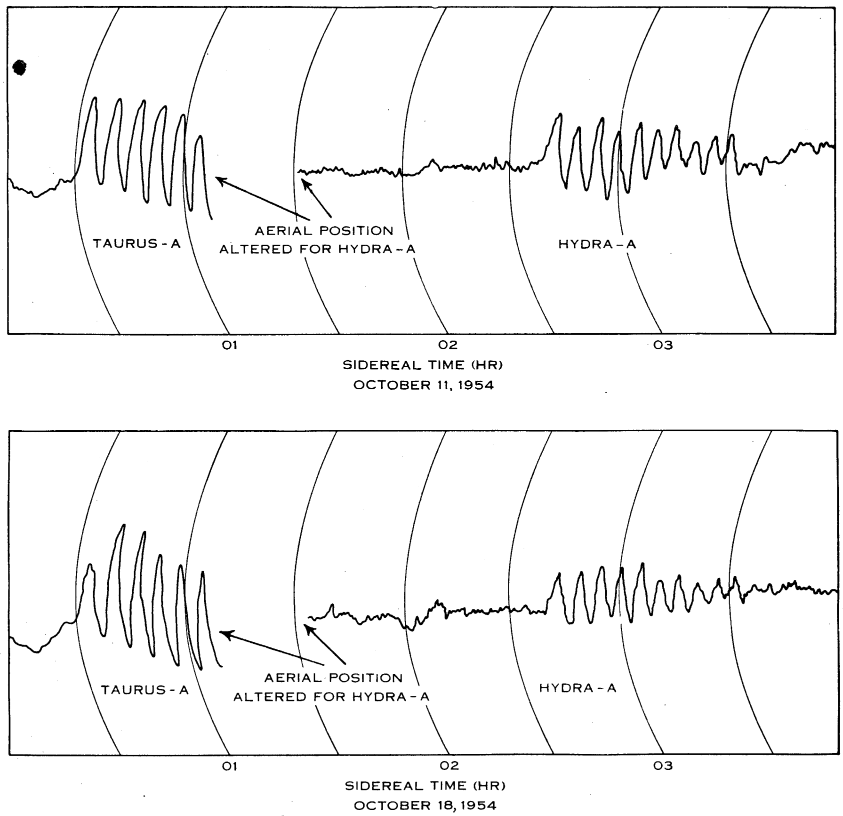


Fig. 1.—Typical records of Hydra-A and a comparison source obtained in the rising observations. The average deflection due to Hydra-A is 20 per cent. greater in the upper record than in the lower. Scintillations are visible on the interference fringes of both records.

the Hydra source were plotted against the estimated daily deviations from the mean intensity. The resulting plot, shown in Figure 2, indicates that there is no direct correlation between the apparent intensity of the source and the scintillation index.

*(b) Transit Observations*

From early December 1954 to July 1955, the Hydra source, together with the three comparison sources in Taurus, Virgo, and Centaurus, was recorded almost daily during meridian transit, using portion of the 85 Mc/s " cross " aerial, of which a description by Mills, Little, and Sheridan is in preparation.

The east-west arm of the aerial produces a fan-shaped response pattern, 0·6° east-west and 50° north-south, between half-power points. A large number of radio sources at different declinations therefore passes through the beam at meridian transit. By amplifying the output of the east-west arm and its associated receiver in a D.C. amplifier, Hydra-A and the three comparison sources were recorded at transit. Two sample records taken on successive nights

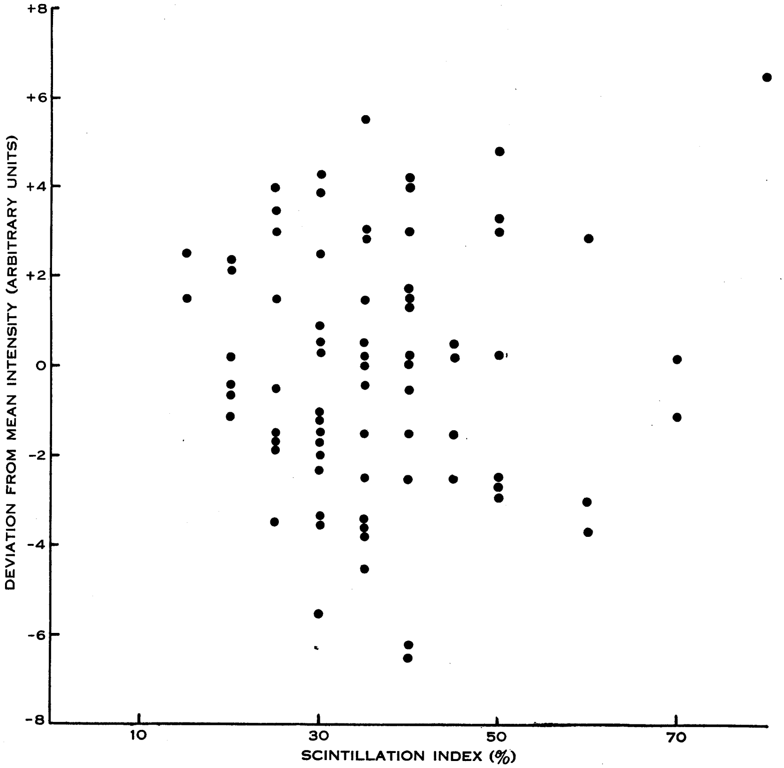


Fig. 2.—A correlation diagram of the scintillation indices and estimated deviations from the mean intensity for the rising series of observations on Hydra-A.

are shown in Figure 3, in which the deflection due to Hydra-A at 09 hr 16 min has changed by 30 per cent. ; other sources on the records show no appreciable alteration.

Any sensitivity changes which took place during the series were assumed to be very slow in character, and were measured by computing running intensity means of 10 consecutive records of each of the comparison sources ; in practice it was found that only small corrections were needed to bring the intensity measurements to a common scale for direct comparison with each other over long periods of time.

## III. Analysis of Results

The daily measured intensities for Hydra-A and a comparison source are plotted in Figure 4. The comparison source plotted for the rising measurements is a composite one, obtained by bringing the intensity measurements of the Taurus, Virgo, Fornax, and Centaurus sources to a common scale ; this procedure was necessary as normally only one comparison source was recorded at any particular time of the year. In the transit observations, Virgo-A has been shown for comparison, but similar plots are obtained for the Taurus and Centaurus sources.

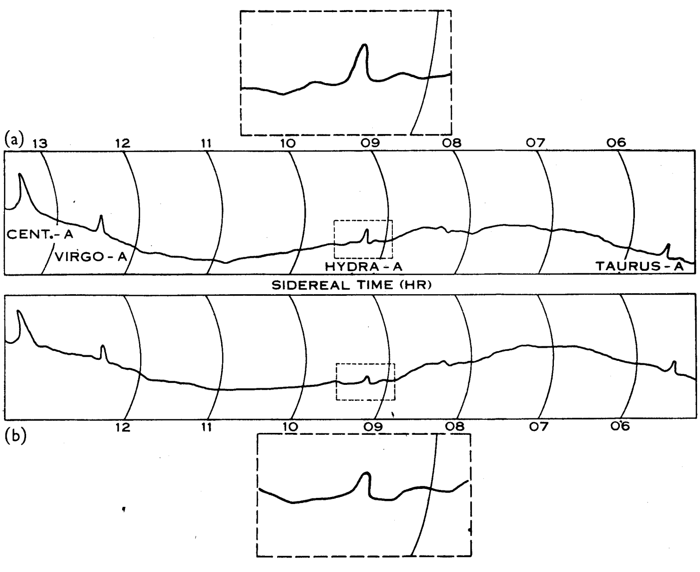


Fig. 3.—Typical records of Hydra-A and the three comparison sources in Taurus, Virgo, and Centaurus obtained during the transit observations. In the upper record of April 4, 1955, the intensity of Hydra-A is 10 per cent. above the mean and in the lower record of April 5, 1955, 30 per cent. below the mean.

It is obvious from Figure 4 that the observed intensity of Hydra-A possesses a greater range of values than the comparison sources. This difference is probably shown more effectively in Figures 5 (*a*) and 5 (*b*), which are histograms of the intensity distributions for the rising and transit observations respectively.

In interpreting the significance of the differences between Hydra-A and the comparison sources, it should be noticed that in both series of observations the suspected variable was compared with sources which were of higher signal-to-noise ratio at the receiver, except for the recordings of Fornax-A in the rising observations and Taurus-A in the transit series. One might therefore expect a larger scatter in the Hydra-A intensities. However, when the transit results were subjected to statistical analysis, details of which are given in Table 2, it was found that the standard deviations of the three comparison sources were very similar despite large differences in signal-to-receiver noise fluctuation ratios.

It may be concluded that the noise fluctuation level was not high enough to seriously affect the accuracy of intensity measurements for any of the sources.

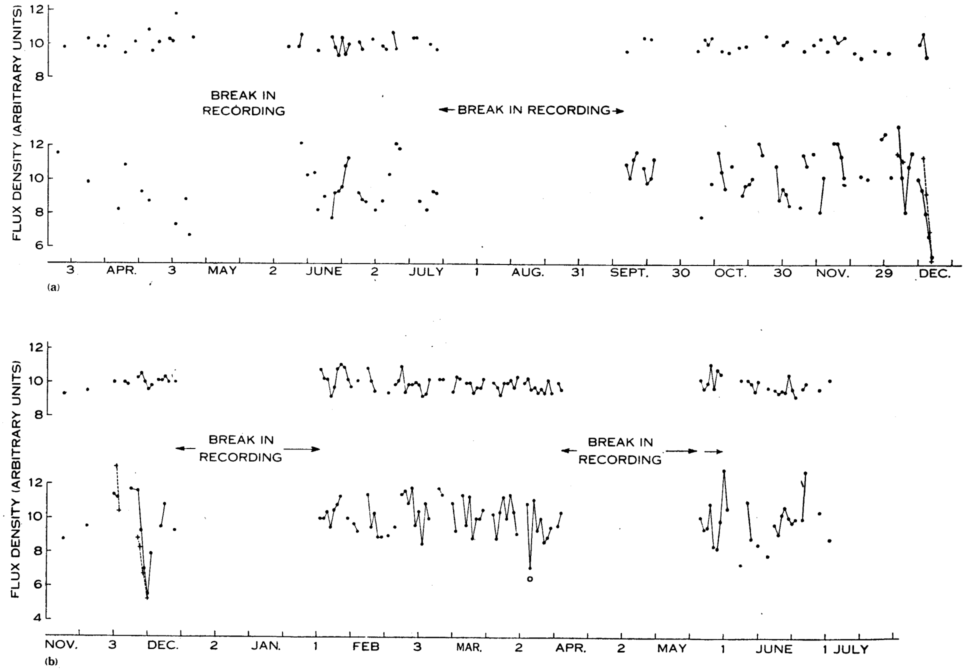


Fig. 4.—Plots of the daily observed intensities of Hydra-A and the comparison sources. All sources have been brought to a common arbitrary intensity scale of mean value 10 units. (*a*) and (*b*) refer to the rising and transit observations respectively. The upper diagram in each figure shows the results for the comparison source, and the lower for Hydra-A. The open circle of (*b*) refers to an interferometer measurement. The crosses plotted in December represent values transferred from the other series of measurements during the overlap of observations.

The above evidence is suggestive of a real variation in the apparent intensity of Hydra-A, but it is insufficient for a conclusive demonstration. Fortunately,

Table 2

RELATIONSHIP BETWEEN SIGNAL-TO-NOISE RATIO AND ACCURACY OF INTENSITY MEASUREMENTS

| Source | Signal-to-noise Ratio | % Standard Deviation |
|---|---|---|
| Hydra-A .. .. | 10 | 12·2 |
| Virgo-A .. .. | 15 | 5·3 |
| Taurus-A .. .. | 10 | 6·0 |
| Centaurus-A .. | 30 | 6·1 |

simultaneous or nearly simultaneous observations of the source with two different instruments are available. These serve to strengthen considerably the belief in a real variation.

Large intensity fluctuations of the Hydra source have, to some extent, been confirmed by Carter (1955), who observed the source at transit with an east-west interferometer operating at 101 Mc/s with a spacing of either 90 or 1000 wavelengths. The observations were made during April, May, June 1955, and on some of these days simultaneous records were obtained by the author with the east-west arm of the " cross ". A statistical comparison of the Hydra-A intensities measured on the two systems showed a significant correlation. Three very significant reductions in the Hydra-A flux density,

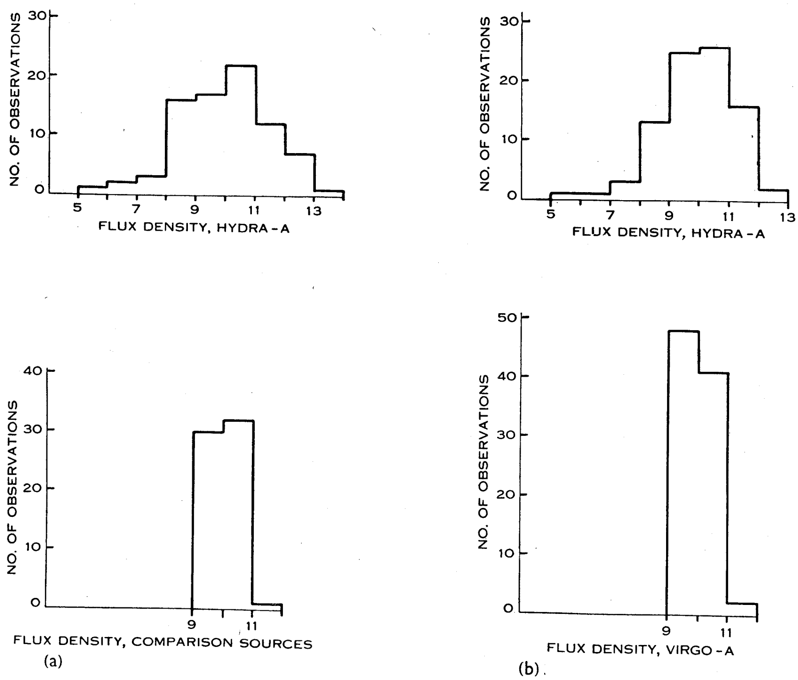


Fig. 5.—Histograms showing the distributions of intensities for Hydra-A and the comparison sources. (*a*) and (*b*) refer to the rising and transit observations respectively.

amounting to as much as 70 per cent. of the mean intensity, were measured with the interferometer during this period, and on one of these occasions, April 5, 1955, a simultaneous record was obtained by the author ; the two values of flux density, shown plotted in Figure 4, were well correlated with each other on this particular day. It should be pointed out that, on the three days concerned, the intensity of the source appeared constant during the interferometer observations lasting about 1 hr.

During the transition from rising to transit observations in December 1954, records were obtained of Hydra-A with both instruments on six days, the times of observation differing by approximately 6 hr. Both sets of intensity measurements for the days concerned have been superimposed in Figure 4, which shows a high correlation between the two series.

The flux density of Hydra-A does not appear to change in a periodic manner over an interval of a few days, as is the case for many variable stars, but rather varies randomly about the mean from day to day. This conclusion is supported by the results of an autocorrelation test of the transit measurements. Interferometer observations have shown that the source intensity is sensibly constant for periods approaching 6 hr ; the average " fading time " of the source therefore appears to lie between 6 and 24 hr.

## IV. Discussion

The observations support the conclusion that the observed flux density of the discrete radio source in Hydra is variable. Possible mechanisms for the production of the observed intensity variations may operate either in the source or during transmission of the radiation through space or the terrestrial atmosphere. No definite information is as yet available to fix the origin of the Hydra-A radiation, but obviously if this can be done, then possible mechanisms may be more clearly defined.

Using the full resolution of the 85 Mc/s " cross ", Mills (unpublished data) finds that the position of the Hydra source is R.A. 09 hr 15 min 40 sec $\pm 4$ sec, Dec. $-11^{\circ}\ 52\cdot5' \pm 2'$ (1950). The radio position is practically coincident with that of a faint galaxy which has been photographed by Baade, and its spectrum obtained by Minkowski using the 200 in. telescope (personal communication, Minkowski to Mills). It is found to display a double nucleus suggesting a very close approach of two galaxies, but there are no abnormalities in the spectrum to suggest that an actual collision may be in progress as in the case of the Cygnus radio source. It is not possible therefore to positively identify the radio source with the galaxy. However, if the optical object is responsible for the Hydra-A radiation, it is unlikely that the observed short-term variations in the radio flux density could be due to inherent changes in the radio emission of the galaxy unless the radio energy is emitted from only a small region. Measurements by Carter (1955) suggest that the half-brightness size of the Hydra source in the east-west direction is approximately $1\cdot5'$, a figure which is consistent with the dimensions of the galaxy.

Short-period fluctuations or scintillations in radio-source intensities are known to occur quite frequently, and have been studied extensively by several workers. Scintillation activity is believed due to the diffraction or focusing of the radiation by irregularities of about 5 km dimensions in the $F$ and $E$ regions of the ionosphere. However, very few cases of general absorption of the radiation at frequencies of the order of 100 Mc/s are known. Bolton, Slee, and Stanley (1953) reported that on three occasions out of about 1000 observations of the Cygnus source at rising, marked general absorption for periods up to 1 hr were noticed, but on these occasions fast and intense scintillations were also present. Since the flux density variations of Hydra-A show no correlation with scintillation activity, it is very unlikely that they are produced by the same mechanisms. The characteristics of the $E$ and $F$ regions of the ionosphere were examined at approximately the times of the observed intensity extremes shown by the Hydra source; the hourly values recorded at the Christchurch (New Zealand) ionospheric station were compared with the rising measurements, and the Canberra (Australia) hourly values used for the transit observations. No significant departures from normality were recorded in the critical frequencies of the ionospheric layers on these occasions. The daily magnetic variations recorded at Toolangi (Australia) for the same days were also examined with negative results. It must therefore be concluded that the large reductions in the Hydra-A intensity, which are believed to have special significance, cannot be explained by any well-known ionospheric effect. However, in view of the small angular size of the source compared with the comparison sources, it is possible that ionospheric effects may be more severe. One method of estimating the effect of the ionosphere on the radiation from sources of different angular sizes is to study their average scintillation indices. The radiation from the Hydra-A and Virgo-A sources at rising traverses equal path lengths through the ionosphere, and the sources differ in angular size by a factor of three. Since the average scintillation indices for the two sources over a period of 12 months are almost equal, it seems improbable that an ionospheric mechanism, selective to source size, produces the observed intensity changes in Hydra-A.

It has been suggested that a potential mechanism for the production of intensity variations in the Hydra source is the Faraday effect, that is, the rotation of the plane of polarization of a plane polarized wave during its passage through an ionized gas in the presence of a magnetic field. Murray and Hargreaves (1954) showed that such a mechanism was probably responsible for the slow fading of lunar echoes at a frequency of 120 Mc/s during transmission through the terrestrial ionosphere. However, in the case of the Hydra-A radiation, the ionized region responsible need not necessarily be located near the Earth, but could conceivably exist near the source or in interstellar space. In order to account for the observed intensity variations, the Hydra-A radiation would need to be plane polarized to the extent of at least 50 per cent. If present, polarization percentages of this order should be relatively easy to detect.

Finally, it is interesting to consider the implications of assuming that the variability of intensity is an intrinsic property of the source. It is clear that the physical dimensions of the source would be unlikely to exceed the distance an electromagnetic wave is propagated in a time of the order of the "fading time", that is, a distance of one "light-day". Taken in conjunction with the angular size of about $1 \cdot 5'$, this would suggest that the source must be within a few parsecs of the Sun. Such a distance, if correct, would seriously undermine some of the current ideas about the distribution of radio sources.

## V. Acknowledgments

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## VI. References

Bolton, J. G., and Slee, O. B. (1953).—*Aust. J. Phys.* **6**: 420.
Bolton, J. G., Slee, O. B., and Stanley, G. J. (1953).—*Aust. J. Phys.* **6**: 434.
Bolton, J. G., Stanley, G. J., and Slee, O. B. (1954).—*Aust. J. Phys.* **7**: 110.
Carter, A. W. L. (1955).—*Aust. J. Phys.* **8**: 564.
Mills, B. Y. (1952).—*Aust. J. Sci. Res.* A **5**: 266.
Murray, W. A. S., and Hargreaves, J. K. (1954).—*Nature* **173**: 944.
Ryle, M., and Elsmore, B. (1951).—*Nature* **168**: 555.