THE ANGULAR SIZE OF THE VARIABLE RADIO SOURCE HYDRA–A*

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Slee (1955) has shown that the discrete cosmic radio source Hydra-A shows variations in intensity at metre wavelengths. This is the first variable radio source to be found, other than the Sun, although Ryle and Elsmore (1951) investigated about one hundred northerly sources and found no significant variations in their intensities over a period of 18 months. The observations to be described here were undertaken firstly to check the variability of the source, then suspected by Slee, and secondly to measure its angular size and see whether this might also be variable.

The measurements on any one day were made using either one or two radio interferometers chosen from three possible arrangements. It is well known that the brightness distribution across a radio source can be deduced from a number of interferometer observations at different angles and spacings (see, for example, Mills 1953). For the Hydra-A observations three aerials were available, each operating on a frequency of 101 Mc/s and spaced along an east-west line so that distances between pairs of about 90, 900, and 1000 wavelengths could be used.

The limited choice of spacings and angles used in the present observations does not allow the original brightness distribution to be reconstructed, so a simple model of the source has been assumed and the parameters of the model have been determined that best fit the observations. The model assumed has circular symmetry and a Gaussian distribution of radial intensity ; this is a reasonable approximation to the central parts of some known radio sources and has the advantage that the derivation of an angular size and central brightness temperature is fairly simple.

The first observations were made in September 1954 while testing the equipment, when the apparent intensity of the source was measured with the 90- and 900-wavelength interferometers on alternate days. These measurements suggested a ratio between the intensities of $0 \cdot 6$ corresponding to a diameter of about $1\frac{1}{2}$ min of arc between half-brightness points. The next observations were made in early April 1955 as part of a survey of the angular sizes of the sources of medium intensity ; they were also taken on different spacings on alternate days. Such observations, however, give unreliable angular sizes when made on a variable source, and so from the middle of May 1955 a systematic study of the Hydra-A source was begun, using one interferometer at a time for about 2 weeks continuously. Towards the end of June it became possible to use two interferometers at a time, and simultaneous observations with the 90-

* Manuscript received August 29, 1955.

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and 900-wavelength spacings were made until solar activity suspended this investigation in early July.

In all, 53 separate observations were made, many of which can be compared with simultaneous observations made by Slee. If the source is not resolved by the 90-wavelength interferometer, then the apparent intensity at this spacing should be directly comparable with Slee's intensities measured with the east-west arm of a Mills's cross aerial. Eleven such simultaneous observations showed positive correlation significant at the 5 per cent. level.

A similar comparison between the wide-spaced interferometer intensities and Slee's measurements can be used to test for variations in the angular size of the source. A group of 11 such observations with the 1000-wavelength interferometer showed negligible correlation. The fluctuations in intensities measured by each observer were much greater than the probable errors, so this lack of correlation suggests real variations in the apparent angular size. There is some suggestion that the major variations in the intensities were positively correlated.

More conclusive evidence for variations in the angular size is obtained from the final group of simultaneous observations with the 90- and 900-wavelength interferometers. These observations are considered the most reliable; the effect of ionospheric fluctuations was minimized by counting a large number of aerial lobes, and any changes in the properties of the aerial common to both interferometers do not influence the angular size measurements. The eight pairs of intensities measured by these two interferometers show positive correlation significant at the 10 per cent. level.

The intensities, angular sizes, and central brightness temperatures, derived from the last group of observations, are shown in Figure 1, and also the limits of error due to random effects of a single observation. The average angular size derived from these observations is $1\cdot6$ min of arc between half-brightness points and the average central brightness temperature is 6×10^5 °K. Any systematic error in the angular sizes is believed to be less than 10 per cent. The apparent negative correlation between the angular sizes and temperatures shown in the figure is a consequence of their functional relation and probably has little physical significance. The high value for the central brightness temperatures suggests that the radiation originates in a non-thermal process.

The temporal dependence and range of values of the variations in intensity and angular size derived from all the interferometer observations are of interest. The lowest total intensity measured is 30–40 per cent. of the mean value. The minima in total intensity are far more pronounced than the maxima, 20 per cent. above the average intensity being the largest value measured with the 90-wavelength interferometer. The minimum angular size measured is $1\cdot0$ min of arc and the maximum $2\cdot0$ min of arc, using Slee's measurements of the total intensities. There is no one-to-one correspondence between angular size and intensity but the major variations in these quantities appear to be positively correlated. No periodicity has been noticed in the variations of intensity or angular size.

On one occasion variations in total intensity were seen while the source was in the aerial beam. During this observation variations from about 75 to 35 per cent. of the average intensity were seen within 1 hr. No other observations on this source at the same time are available and no scintillations were seen. As ionospheric effects are a possible, but unlikely, cause of this variation, further observations will be needed before such rapid changes in intensity can be entirely accepted.

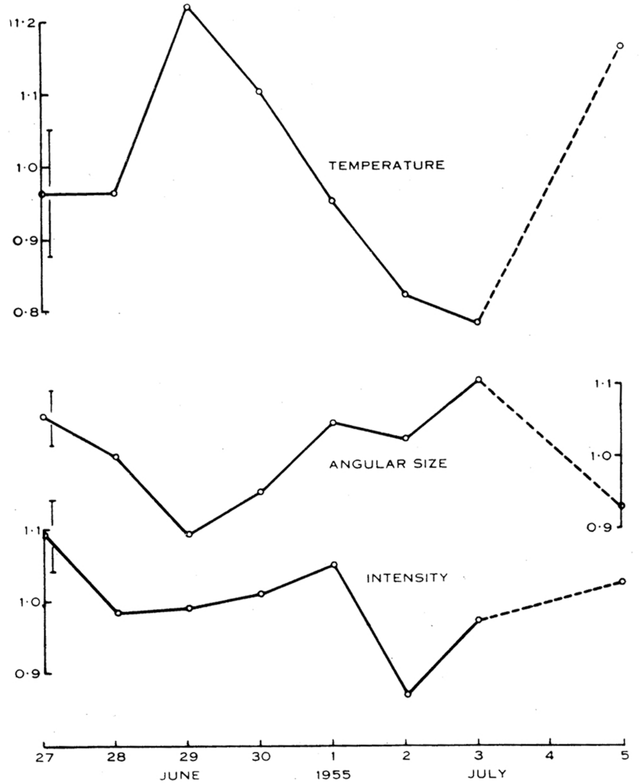

Fig. 1.—The intensity, apparent angular size, and central brightness temperature (normalized values) of the radio source Hydra-A from June 27 to July 5, 1955.

The variations of intensity and angular size may arise either in the source or in some intervening medium. Well-substantiated changes in intensity, from the mean value to a minimum, occur within a period of 1 day. This period, coupled with an overall apparent size of at least 1·6 min of arc, suggests that the variations, whatever the cause, must originate within about 2 parsecs from the solar system. It does not seem possible that some other brightness distribution, differing radically from the assumed model, could alter significantly this estimate of the maximum distance. For example, a distribution in which the variability is confined to a small, bright region of the source can be excluded, as such distributions would lead to a one-to-one correspondence between intensity and angular size. Further evidence against such distributions is provided by the absence of changes in the apparent position of the source ; no change in Right Ascension within the limits of detection, ± 2 min of arc, was detected. A small distant variable object, whose apparent size is increased by scattering in the intervening space, can also be excluded, as the apparent size of such an object would appear to remain constant. These considerations suggest that a considerable part of the apparent surface of the source must exhibit variations in brightness, and that the estimate of about 2 parsecs for the maximum distance from the Sun of the region in which the variations occur is unlikely to be seriously in error.

The present observations do not justify a more detailed analysis of possible mechanisms ; they can be reconciled with quite simple obscuration effects in which the angular size of the original source of radiation is unlikely to be larger than the measured value. A consideration of intrinsic source variations is handicapped by the present lack of knowledge of the more general problem of radio-frequency generation in cosmic bodies. Some light might be thrown on possible mechanisms by systematic optical observations of this region and by measurements of the radio-frequency spectrum of the source.

The author is indebted to Mr. O. B. Slee for communicating his results prior to publication.

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