THE EXTENDED COMPONENT OF CENTAURUS A*

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The strong southern radio source Centaurus A (IAU 13S4A) was one of the first to be identified with an optically observable object. Bolton, Stanley, and Slee (1949) suggested that the radio emission was associated with the peculiar galaxy NGC 5128, and this identification has been strengthened by more recent positional measurements (Mills 1952). NGC 5128 is a most unusual object, appearing to be a spheroidal galaxy transected by a heavy belt of obscuring matter (Baade and Minkowski 1954*a* ; Sérsic 1958). Its distance is uncertain, but it is likely to be about 1 megaparsec away (Baade, personal communication).

Early interferometric observations (Mills 1953 ; Bolton *et al.* 1954) indicated that the radio source comprises two distinct components : an intense source with an angular size of a few minutes of arc, coincident in position with NGC 5128 ; and a much fainter source of far greater size surrounding NGC 5128. This has been confirmed by subsequent pencil-beam observations at 19·7 Mc/s (Shain 1958), 85·5 Mc/s (Sheridan 1958), and 1400 Mc/s (Hindman and Wade 1959 ; Heeschen, personal communication). These show that the extended component covers a solid angle of more than 20 square degrees ; that it subtends about 8° of declination and 3° of Right Ascension ; and that NGC 5128 lies near its centre. The main features of the source remain much the same over the entire frequency range (more than 6 octaves).

Figures 1 and 2 reproduce the distributions found in the two surveys made with aerial beamwidths of less than 1°, at 85·5 Mc/s and at 1400 Mc/s (Heeschen, personal communication). Their close resemblance is quite striking in view of the great difference between the frequencies at which they were obtained. The two components of the source are shown clearly. Some structure is evident in the extended part, the most outstanding feature being a strong, broad maximum about 2° south of the central source associated with NGC 5128. Heeschen's observations (Fig. 2) also suggest complex structure in the northern part. The extended component has no known optical counterpart, although it accounts for 75 per cent. of the total flux at metre and decimetre wavelengths. While there is little doubt that the central source is physically associated with NGC 5128, there is a possibility that the larger source is a separate object accidentally aligned with it. The extended source is not likely to lie within our own galaxy, however, since it is some 20° from the Milky Way plane ; also, its centre is very close to NGC 5128. Thus it seems probable that the extended source is physically associated with NGC 5128.

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The extended component can be seen most clearly if the effects of the central source (which we shall call *Source a*) are removed from the observed distribution. We have done this with the 85·5 Mc/s observations shown in Figure 1. Since

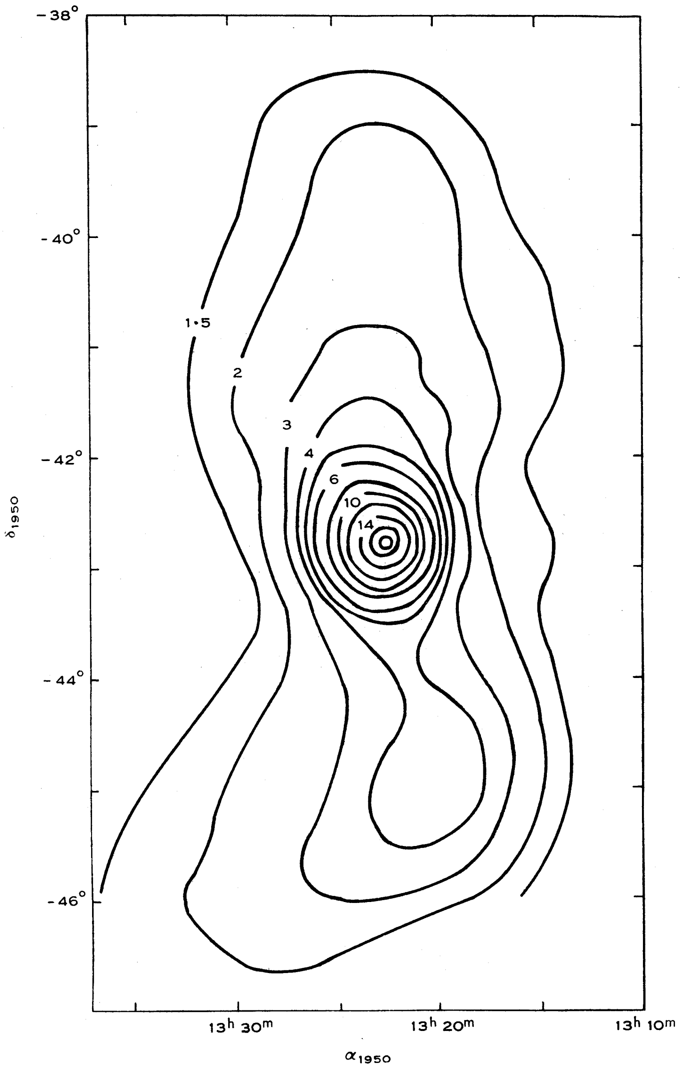

Fig. 1.—Centaurus A at 85·5 Mc/s ; aerial beamwidth 50 min of arc. Contour interval, 3000 °K. This chart is similar to one published by Sheridan (1958), but differs in minor details. It is based on Sheridan's observations but includes quantitative beam-asymmetry corrections.

Source *a* is much smaller than the 50 min of arc beamwidth, its contribution has the same shape as the aerial radiation pattern. Trial subtractions assuming various intensities for Source *a* show that its effects seem to be completely removed from the observed distribution if its flux density is equal to 25 per cent.

of the total. Upon removing Source *a* from the 85·5 Mc/s distribution, we are left with the picture shown in Figure 3. The new distribution has two broad, strong maxima: one is that previously noted, at $\alpha_{1950}=13^{h}\,21^{m}$, $\delta_{1950}=-44°\cdot7$;

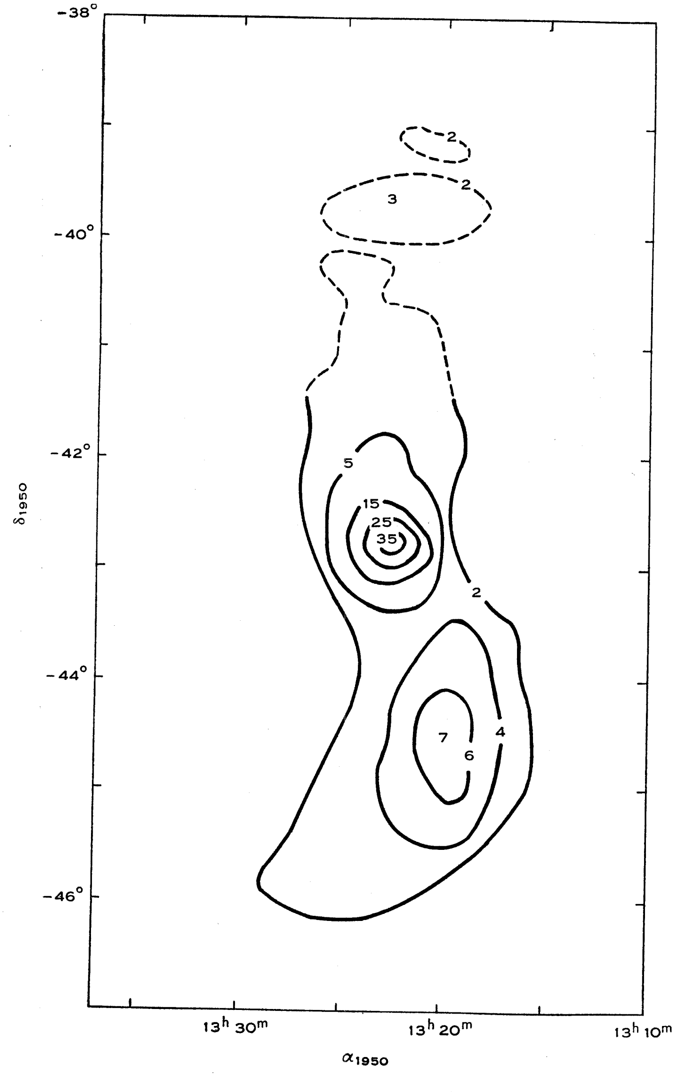

Fig. 2.—Centaurus A at 1400 Mc/s; aerial beamwidth 36 min of arc. Contours are marked in degrees of aerial temperature. These are preliminary observations made by D. S. Heeschen with the 85-ft radio telescope at the National Radio Astronomy Observatory (Green Bank, West Virginia), and they are reproduced here with his permission.

and the other is similar to it in size and intensity, at $\alpha_{1950}=13^{h}\,24^{m}$, $\delta_{1950}=-42°\cdot1$. We shall call these *Source b* and *Source c* respectively. Source *b* was resolved well in the original observations, but the beam-broadened radiation of Source *a* effectively masked Source *c*. One should not attach too much significance to the finer details in Figure 3, but the major features probably are shown with reasonable accuracy. The dimensions of Sources *b* and *c* are respectively about 1°·7 by 2°·6 and 1°·5 by 2°·4 between half-brightness points. The separation of their centres is 2°·7.

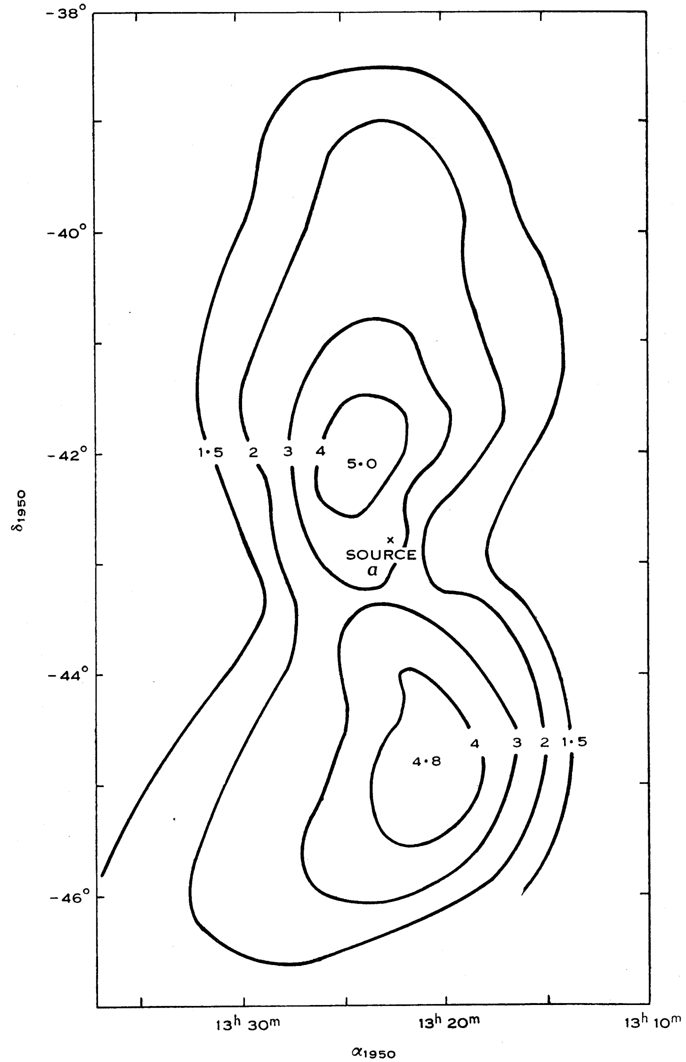

Fig. 3.—85·5 Mc/s contours of Centaurus A after subtraction of the radiation due to Source *a*. The position of Source *a* is indicated.

The fact that the central source accounts for some 25 per cent. of the total flux at both 85·5 and 1400 Mc/s (Hindman and Wade 1959) implies that Source *a* and the extended component both have similar spectral laws at metre and decimetre wavelengths. On the other hand, Source *a* contributes only 11 per cent. of the total at 19·7 Mc/s (Shain 1958). Shain (1959) suggests that the low value at 19·7 Mc/s is due to ionized hydrogen in NGC 5128 lying between Source *a* and the observer.

The dimensions of the extended component are enormous; assuming its distance is 1 megaparsec, we find that it has a linear size of roughly 50 kpc by 150 kpc. It fills a volume of at least 2×10^{14} cubic parsecs. This is about 500 times greater than the volume of the associated galaxy, NGC 5128. Hence the extended component is far too large to be a "galactic halo" in the usual sense. Another case of such a vast radio-emitting region outside the associated galaxy is Cygnus A (IAU 19N4A). It is of interest to compare these two sources.

Cygnus A is associated with a close pair of interacting galaxies (Baade and Minkowski 1954*b*). The system has a red-shift of 16,830 km/sec, which corresponds to a distance of about 150 megaparsecs if we assume that the Hubble constant is between 100 and 120 km sec^{-1} Mpc^{-1}. According to interferometric measurements by Jennison and Das Gupta (1956), the radio emission comes from two areas of nearly equal intensity separated by about 85 sec of arc, each having angular dimensions of about 35 by 45 sec of arc between half-brightness points. The radio positional data are not sufficiently precise to permit an accurate determination of the relative configuration of the galaxies and the radio areas, but the galaxies probably lie somewhere between the two radio centres. This is reminiscent of Centaurus A, where a peculiar galaxy is seen between two large radio-emitting regions (Sources *b* and *c*). Table 1 illustrates the good agreement between the linear separation and dimensions of the components of each source. There is no evidence of a central source in Cygnus A corresponding to Source *a* in Centaurus, but it should be remembered that most of the radiation from Centaurus A originates in the extended component; Source *a* is a relatively minor feature which presumably is due to local conditions in some part of NGC 5128 or the dark band. Thus Source *a* does not affect seriously the overall similarity in the apparent forms of the Centaurus and Cygnus sources. On the other hand, there are some marked differences between the two objects. Optically the associated galaxies appear to be dissimilar, although they are very unusual systems in each case. There is also a great disparity in the emitted radio fluxes, Cygnus A being intrinsically about 3×10^4 times more powerful than Centaurus A.

TABLE 1

COMPARISON OF CENTAURUS A AND CYGNUS A

Quantity	Centaurus A	Cygnus A
Distance	~1 Mpc	~150 Mpc
Linear separation of the radio components perpendicular to the line of sight	~50 kpc	~60 kpc
Linear dimensions of radio components to half-brightness	~30 kpc by 40 kpc	~25 kpc by 35 kpc

Although the similarities between Centaurus A and Cygnus A could well be fortuitous, it might be worth while to investigate the possibility that these objects represent a distinct class of very large binuclear extragalactic sources. This will require an adequate knowledge of the structure of a sufficient number of extragalactic sources. Criteria will be needed for distinguishing physical radio binaries from chance coincidences, and optical identifications would be desirable for any physical pairs found.

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References

BAADE, W., and MINKOWSKI, R. (1954*a*).—*Astrophys. J.* **119**: 215.
BAADE, W., and MINKOWSKI, R. (1954*b*).—*Astrophys. J.* **119**: 206.
BOLTON, J. G., STANLEY, G. J., and SLEE, O. B. (1949).—*Nature* **164**: 101.
BOLTON, J. G., WESTFOLD, K. C., STANLEY, G. J., and SLEE, O. B. (1954).—*Aust. J. Phys.* **7**: 96.
HINDMAN, J. V., and WADE, C. M. (1959).—*Aust. J. Phys.* **12**: 258.
JENNISON, R. C., and DAS GUPTA, M. K. (1956).—*Phil. Mag.* **1**: 65.
MILLS, B. Y. (1952).—*Aust. J. Sci. Res.* A **5**: 456.
MILLS, B. Y. (1953).—*Aust. J. Phys.* **6**: 452.
SÉRSIC, J. L. (1958).—*Observatory* **78**: 24.
SHAIN, C. A. (1958).—*Aust. J. Phys.* **11**: 517.
SHAIN, C. A. (1959).—I.A.U.-U.R.S.I. Symposium on Radio Astronomy, Paris 1958. p. 328. (Stanford Univ. Press.)
SHERIDAN, K. V. (1958).—*Aust. J. Phys.* **11**: 400.