prominences behind the limb, whereas scattered light should increase that light. Also, the double limb is visible on filtergrams and spectroheliograms. The inner limb is so bright that it likewise could not be scattered light.

The weight of evidence from these spectroheliograms indicates that the second limb, which may be identified with the upper chromosphere, is the confluence, due to foreshortening, of many bushes or clumps of spicules.

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THE STRUCTURE OF CYGNUS A

We wish to report direct resolution of Cygnus A at a frequency of 3292 Mc/s using the 52″-fan beam of the compound interferometer at Stanford,[1] and, on the basis of a firm determination of the actual peak-to-peak distance, we have re-examined the existing data and find that the reported dependence of separation on frequency (Maltby and Moffet 1962) is simply an appearance produced by the existence of a third component whose spectrum differs from that of the main components.

The compound interferometer was designed by Picken and Swarup (1963) for studying fine structure and polarization of solar centers of activity. It consists of an array of sixteen equatorially mounted 10-foot paraboloids spaced at 25-foot intervals in an east-west line (Bracewell and Swarup 1961) plus two extra 10-foot paraboloids in the same east-west line, one at the west end and the other 325 feet farther to the west. During the present observations, all antennas were polarized with their electric vector east-west. The sixteen-element array produces a series of fan-beams of half-power width 2.′3, separated by 41′. When the voltage from the array is multiplied with that from the two extra elements, the half-power width of the individual beams is reduced to 52″. The power response has the form

$$\frac{\sin 16\pi x}{\sin \pi x} \cos 29\pi x \cos 13\pi x ,$$

which exhibits alternate positive and negative lobes. In this expression $x = (d/\lambda) \sin \theta$, where d/λ (= 83.68) is the spacing in wavelengths between adjacent elements of the array and θ is measured from the plane perpendicular to the line of the interferometer.

As the over-all collecting area of the compound interferometer, including losses in transmission lines, is approximately equivalent to that of a 20-foot paraboloid, a number of scans must be summed to obtain a satisfactory record of Cygnus A. The passage of the source through approximately twelve beams near the meridian was observed each

[1] T. Krishnan informs us that Cygnus A has been scanned in Sydney with a 1.′5 beam and that the results are being prepared for publication.

day, the receiver output was integrated for 2-second periods and was then recorded digitally. Figure 1, the final record obtained from 12 days of observations, contains 148 scans of the source. In constructing this record, a number of points near the two peaks of the source were interpolated numerically. The asymmetry of the baseline in Figure 1 is attributed to an unidentified inequality in the electrical path lengths to the antennas of the order of 6 mm (in about 100 m).

The origin of the scale of angle in Figure 1 is at the centroid of the source distribution. The measured right ascension was $19^{h}58^{m}07^{s}.3$, subject to an undetermined correction estimated to be of the order of 2^{s}. The observations were made between December 11 and December 30, 1962.

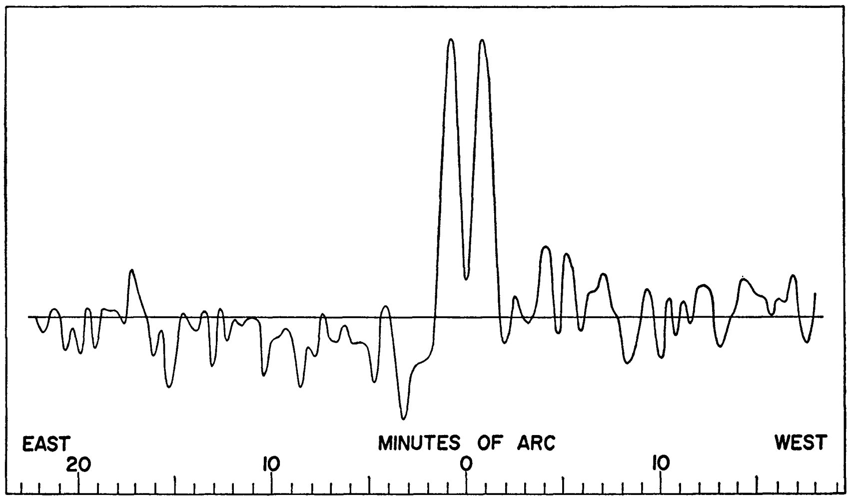

FIG. 1.—Composite record of Cygnus A based on 148 drift scans with the 52″ beam

The east-west spacing of the two peaks is 98″ ± 4″ r.m.s. error. The r.m.s. error was determined by theoretical considerations based on the signal-to-noise ratio of the record. By replotting the two peaks several times with the addition of noise samples taken from the skirts of the record, we confirmed that the r.m.s. error does not exceed this estimate. The ratio of peak signal to r.m.s. noise is 11. In terms of a two-component model we can say that the flux density ratio of the components is unity within 20 per cent estimated error.

The directly measured peak separation agrees with Rowson's (1959) value at 96″ obtained from 2800 Mc/s interferometry. However, the most detailed observations of the source are those by Lequeux (1962) at 1420 Mc/s, which extend to east-west spacings of 6950 wavelengths. From these data Lequeux derives a rather complicated profile of the source, which shows two components with centroids spaced 100″ and some intervening concentrations described as a bridge of emission or a common halo. This further agreement in the spacing raises the question whether the data at lower frequencies are compatible with the existence of two sources spaced about 98″. We now describe a study of the interferometer data based on a *simple mathematical model* in which we can readily vary the parameters of the components to fit the interferometer data at different frequencies. A study of Lequeux's data confirms that two components alone do not suffice, and our model therefore consists of three Gaussian components, as shown in Figure 2. In accordance with the 52″-beam observations, the fluxes of the outer components were made equal, and the spacing between them taken as 101″. (The spacing is slightly greater than the value directly observed, to take account of the effect of the central component.) The remaining parameters of the model were determined by straightforward manipulation of the complex visibility diagram to obtain a good fit with Lequeux's 1420 Mc/s data. The resulting model is specified in Table 1.

Let V be the visibility of interference fringes observed with an interferometer and σ their phase referred to the centroid of component 1. The complex fringe visibility is

$$\mathfrak{V}(s) = V \exp i\sigma = 0.375 \exp(-1.86 \times 10^{-8} s^2) + 0.375 \exp(-4.65 \times 10^{-8} s^2) \exp(-i3.07 \times 10^{-3} s) + 0.25 \exp(-5.08 \times 10^{-7} s^2) \exp(-i1.31 \times 10^{-3} s),$$

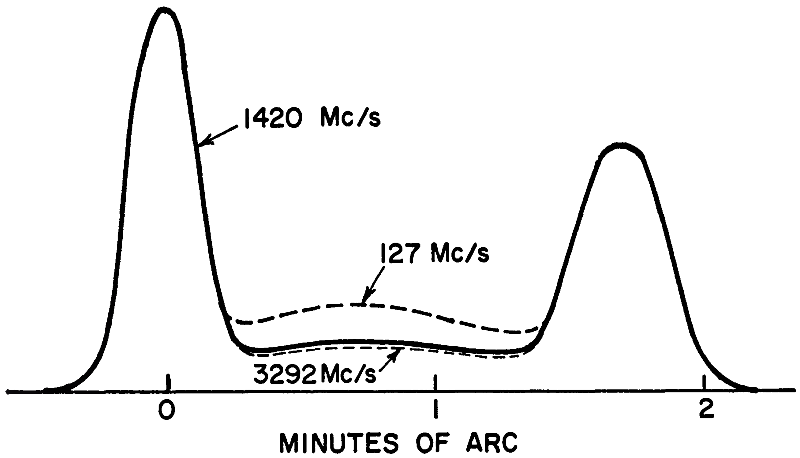

FIG. 2.—Model of Cygnus A involving a wide central component. Based on a frequency-independent spacing of 101″ and interferometry of Lequeux and Jennison and Latham

TABLE 1

DERIVED MODEL FOR CYGNUS A

Component	Relative Flux Density	Width to Half-Power	Abscissa
1	0 375	15″	0
2	375	23″	101″
3	0 25	78″	43″

where s is the antenna spacing in wavelengths. In the upper part of Figure 3, we represent $\mathfrak{V}(s)$ by means of the finite phase rotation complex visibility locus (Bracewell 1961), together with the conventional graph of V versus s. It will be seen that there is a good fit with the observational data; the discrepancies represent faint fine structure and would not affect the main features of the source. We are now in a position to understand how the third component gave rise to the conclusion that the spacing depended on frequency. The first minimum in Figure 3 occurs when the vectors OP and QR representing the contributions of the main components are approximately in opposition. If there were only two components, one could assume that the two vectors were precisely in opposition and deduce the source spacing. However, when the two main vectors are in opposition, the vector PQ associated with the central source is approximately in quadrature, and so the minimum shifts to a larger antenna spacing where the quadrature vector is approximately canceled by the resultant of the two main vectors. Thus, by simply increasing the strength of the third component from 25 to 38 per cent without changing its location or width, we can account for both the *location of the first minimum* and the *height of the second maximum* in the visibility-curve observed by Jennison and Latham (1959) at a frequency of 127 Mc/s, as shown in the lower part of Figure 3.

Rowson (1959), Twiss, Carter, and Little (1960), Lequeux, and Maltby and Moffet (1962) have all commented on the changing appearance of Cygnus A with frequency. Maltby and Moffet have summarized the observational evidence for the increase in

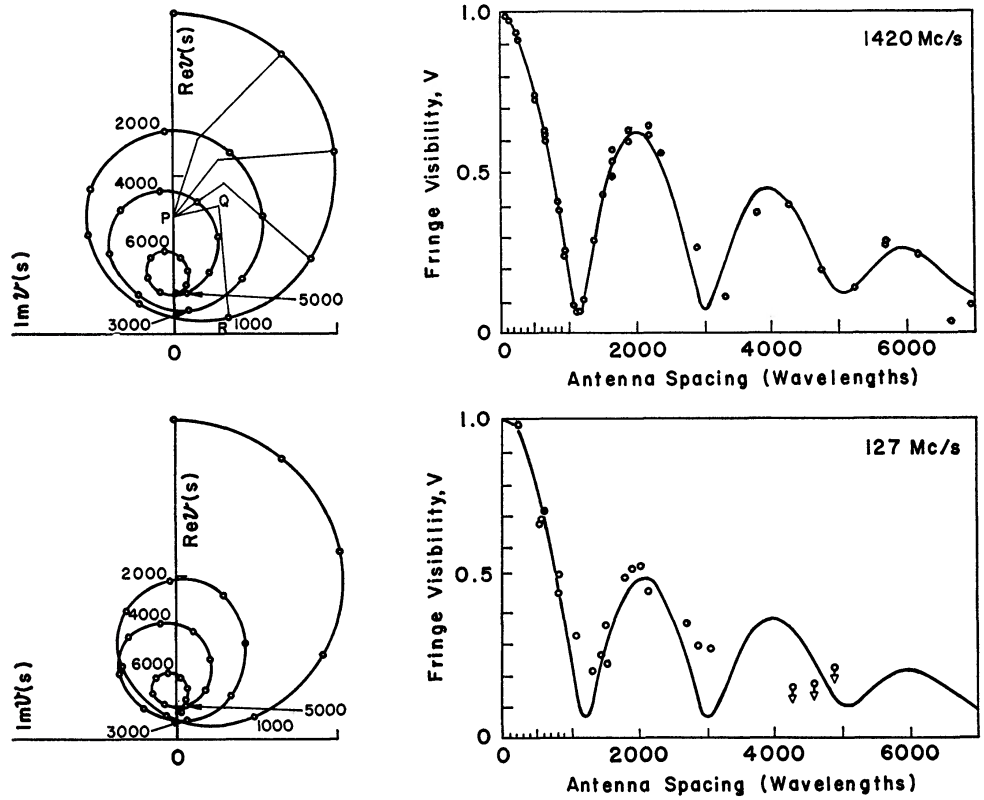

FIG. 3.—Observational data taken at 1420 Mc/s by Lequeux (*above*) and at 127 Mc/s by Jennison *et al.* (*below*), together with visibility-curves calculated from the model.

spacing with frequency, and Lequeux says that the diameter of the components decreases and that the inner margin of the components and connecting bridge becomes weaker. According to the present analysis, a simple change in the strength of the third bridging component suffices to explain both the 127 and the 1420 Mc/s data without requiring any change in the separation or the diameter of the main components.

We conclude that Cygnus A is describable by two main components whose spacing of approximately 100″ is not required to vary with frequency, joined by an extended central component amounting to 0.38 of the total flux density at 127 Mc/s and 0.25 at 1420 Mc/s. The central component thus has a markedly different spectrum from that of the outer components. This would cause a bend in the *over-all* spectrum of Cygnus A but not in the direction of the knee that is observed (Whitfield 1957). One or both of the main components must therefore have a knee, and the third component may also exhibit a knee, but at a lower frequency. If this is so, it could be shown by special interferometric observations of the first minimum and the following maximum of fringe visibility, which are sensitive to the third component. At present we cannot say what the strength of the third component is at 3292 Mc/s, but, if there is no knee, it would be about as indicated in Figure 2. Discussion of the separate spectra of the various components rather than of the integrated spectrum of the whole source will be very helpful in interpreting the spectral features involving age and magnetic-field strength.

The present contribution and a previous one by Little (1963) show that it is possible for the grating interferometer to resolve directly radio sources whose structure has previously been painstakingly built up from observations over a period of time with variable spacing interferometers. With an instrument of adequate collecting area, fan-beam or pencil-beam resolution of the order of tens of seconds of arc as reported here could be obtained on a wide range of extragalactic sources in a single scan.

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