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RAPID CHANGE IN THE VISIBILITY FUNCTION OF THE RADIO GALAXY 3C 120

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ABSTRACT

Second-epoch observations of the radio galaxy 3C 120 ($z = 0.033$) with the Goldstack interferometer show apparent rapid changes in structure similar to those observed for the quasars 3C 273 and 3C 279. The apparent transverse expansion velocity is 2 or 3 times the velocity of light. Our earlier observations of 3C 84 and VRO 42.22.01 are confirmed.

I. INTRODUCTION

In a recent paper (Cohen *et al.* 1971, hereafter referred to as Paper I), we reported observations of compact radio structure in a number of galaxies and quasars. We have repeated the observations for some of these objects and have found a large change in the visibility function of the Seyfert galaxy 3C 120. If we adopt the same interpretation as given to the quasars 3C 273 and 3C 279 (Whitney *et al.* 1971; Paper I), the new data suggest that 3C 120, a low-redshift object ($z = 0.033$), has a high-speed expansion similar to that observed for the two quasars.

II. THE OBSERVATIONS

The new observations were made on 1971 November 3 with the "Goldstack" interferometer: the 64-m telescope at Goldstone, California (NASA Deep Space Network) and the 37-m telescope at Tyngsboro, Massachusetts (Haystack Observatory).[1] The system was the same as described in Paper I, except that the local oscillator system at Goldstone was modified, changing the observing frequency from 7840 MHz to 7850 MHz ($\lambda = 3.8$ cm). The observation and reduction procedures were the same as described in Paper I.

Relative values of the total flux density for each source were measured at Goldstone during the observations, and the flux-density scale was calibrated from measurements made with the Haystack telescope three days later (Dent, private communication). The scale for the interferometer fringe amplitude was calibrated with OJ 287. The observa-

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tions of this source discussed in Paper I and other observations of ours at an even longer baseline ($d/\lambda = 2.8 \times 10^8$ at 3.5 cm in 1971 June, unpublished) indicate that it is essentially unresolved on the Goldstack baseline. We estimate that the systematic error in the fringe amplitude scale is less than ± 10 percent. The relative flux densities, however, are determined more accurately. The change in structure of 3C 120 is determined primarily by the variation of fringe amplitude with hour angle and does not depend on the absolute calibration.

III. 3C 120

Figure 1*a* shows the first-epoch data (1971 February) repeated from Paper I. The new data (1971 November) are shown in Figure 1*b*. The error bars include noise and the uncertainty in a correction for the effects of variable weather at Haystack (Paper I), but do not include any systematic scaling errors. The inset diagrams show the track of the observations in the (u, v)-plane: u and v are the east-west and north-south projections of the baseline as seen from the source.

Figure 1 shows that there was a change in the visibility function during the 0.68 year separating the two observations, suggesting changes similar to those inferred for 3C 273 and 3C 279 (Whitney *et al.* 1971; Paper I). The November data are rather limited and do not determine the structure, but they do allow an interpretation in terms of changes in the two models discussed in Paper I. In figures 1*a* and 1*b*, the solid line is the expected visibility function for an equal-double brightness distribution, and the dashed line is for a uniform circular ring distribution. The parameters of these models are given in table 1.

We emphasize that these are merely simple models which fit the data. For November (fig. 1*b*) our models predict minima as shown by the curves, but we have no data there. It is possible to find models which decrease monotonically from interferometer hour angle (IHA) = 0 past IHA = ± 4 and have minima at larger hour angles. However, these models have dimensions even larger than those given in table 1. The November models in table 1 are conservative in the sense of requiring the least change in size and no change in shape from the February models.

The two expanding models of table 1 fit the existing data equally well; it is obvious that more extensive data are required to determine the true structure of 3C 120. For the double model, the change in position angle is probably not significant; whereas the change in component diameters is significant, requiring peculiar dynamics for this model. The components are modeled with uniform disks whose diameters are poorly

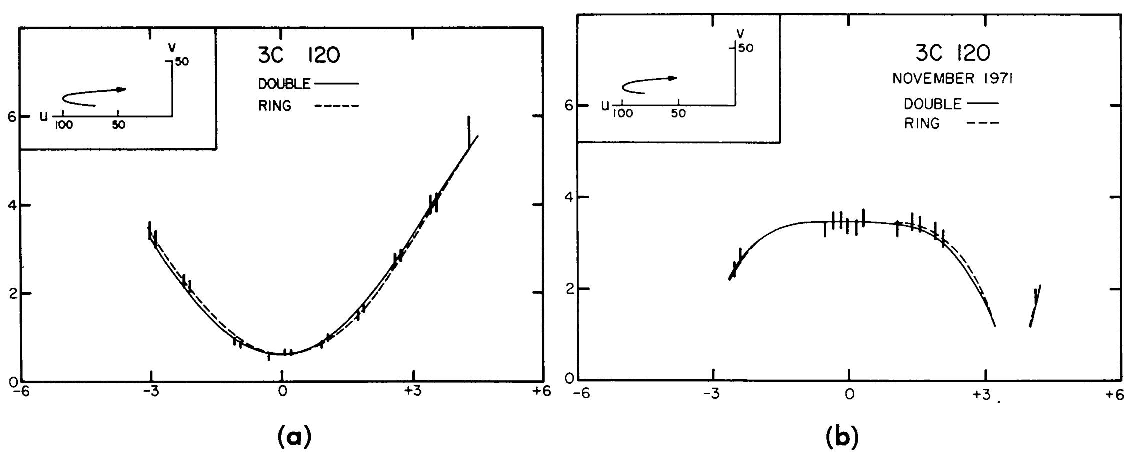

FIG. 1.—Fringe-amplitude data from the Goldstone-Haystack interferometer. Vertical scales are correlated flux density (in flux units); horizontal scales are hour angle from the interferometer meridian (in hours). Insets show the (u, v)-plane coverage for each source. Inset scales are in millions of wavelengths. (*a*) 1971 February 27; (*b*) 1971 November 3.

TABLE 1

MODELS FOR 3C 120

Parameter	1971 February 28	1971 November 3	Angular Rate (Rad yr^{-1})	v/c
Total flux (f.u.).......	9.2 ± 0.2	10.7 ± 0.5		
Uniform ring:				
Diameter (″).......	0.00144	0.00250	7.5×10^{-9}	3
Flux (f.u.)..........	7.4	8.6		
Equal double:				
Separation (″)......	0.00098	0.00170	5.1×10^{-9}	2
Diameters (″).......	<0.0005	0.0013		
Position angle.......	95°	85°		
Flux (f.u.)..........	6.5	7.0		

determined, both in February and November. Nevertheless, between February and November, the model components expanded by as much as or more than they separated. Prior to February they separated faster than they expanded, by a factor of 2 or more. If this model is correct, and if the two components continue to expand rapidly, they should soon interact, possibly producing sudden changes in apparent structure and flux density. The angular expansion rate shown in table 1 refers to the centers of the two components, and not their leading edges.

If the equal-double model of table 1 is approximately correct, then a simple explanation in terms of relativistic expansion of material is possible. The last column of table 1 shows v/c, the "apparent expansion velocity" (normalized to the velocity of light) obtained by multiplying the inferred angular rate by the distance, using $H_0 = 75$ km s^{-1} Mpc^{-1}. The value $v/c \approx 2$ could come from a relativistic explosion with motion nearly perpendicular to the line of sight.[2]

The alternatives to source expansion given in Paper I and by Whitney *et al.* (1971) may, of course, be applied to 3C 120 as well. One of those possibilities was that the redshifts of 3C 273 and 3C 279 may not be cosmological. 3C 120, however, is a well-established Seyfert galaxy, and the observation of apparent rapid expansion in a galaxy suggests that such evidence against the cosmological origin of quasar redshifts may not be relevant. On the other hand, the nature of the redshift in compact variable objects is not completely without question.

Another possible explanation involves secular flux variations in a model consisting of three stationary sources (Whitney *et al.* 1971; Paper I; Dent 1972). Dent has applied such a model to 3C 279. However, his model seems unlikely (Shaffer, in preparation) because it requires about 3 f.u. in the small components, whereas observations suggest 10 f.u. (Paper I). Such models do not seem likely for 3C 120, either. For 3C 120, any triple-component model that fits the November data gives systematic differences from the February data; the corresponding curve in figure 1*a* (not shown) is too broad and flat in the region between IHA $= \pm 2$. In addition, such secular variations should have an equal probability of producing apparent expansion or contraction, whereas all three sources with good evidence for change seem to be expanding.

[2] In Paper I, a factor $(1 + z)$ was omitted from the denominator of the formula for D on page 215. All quantities in table 3 were correctly calculated, however. Note also that in table 3 of Paper I, v/c referred to component velocities measured with respect to a hypothetical center. In the present paper, v/c is the separation velocity, equal to twice the velocities of Paper I. We have chosen the new definition (the same as that of Whitney *et al.* 1971) since it relates more nearly to the actual measurements, whereas the concept of component velocity is model-dependent.

IV. OTHER SOURCES

We also obtained further observations of the radio galaxy 3C 84 and the unusual object VRO 42.22.01 (BL Lac)—sources which were discussed in Paper I—and obtained first-epoch data for NRAO 150, an obscured, unidentified object. Although the data for 3C 84 and VRO 42.22.01 are incomplete, there is no evidence for large changes of the type seen for 3C 120, 3C 273, and 3C 279.

The new data for 3C 84 confirm the complex character of the visibility function for this source (fig. 1 of Paper I). In particular, the high values of correlated flux density for IHA ≈ -4, the sharp drop between IHA $= -2$ and -1, the maximum at IHA ≈ 0, and the low values at IHA $= +4$ are present in both the February and November data. This source is also complex at lower frequencies (Ryle and Windram 1968; Clarke *et al.* 1969; G. Purcell, private communication) and appears to consist of several widely separated emitting regions. The November data for VRO 42.22.01 are insufficient to do more than reaffirm the basic shape of the visibility function for IHA > 0 as given by the February observations. The new data for NRAO 150 show a systematic trend with hour angle, and can be fitted with an equal-point double model of separation $0\overset{''}{.}0006$ in position angle 60°, containing most of the total flux.

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