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6 December 1971; revised 19 January 1972 ■

3C279: Evidence for a Non-Superrelativistic Model

Abstract. *Measurements of the variation of the total flux density of the quasi-stellar radio source 3C279 provide evidence for an alternate model to explain the recently reported apparent source expansion rate of ten times the speed of light.*

In a recent report, Knight *et al.* (*1*) presented some very-long-baseline interferometry (VLBI) observations which showed that the quasi-stellar source 3C279 had a complex angular structure on a scale of 10^{-3} arc second. In a subsequent report by the same group, Whitney *et al.* (*2*) showed that the null of the interferometric fringe amplitude function was displaced from the position they had observed 4 months earlier. The above authors interpreted their observed fringe amplitude curves as having been produced by two nearly point sources, which must be of nearly equal flux density, since a deep null exists in the fringe amplitude curve. In terms of this model the observed displacement of the null was interpreted as being the result of an increase in the angular separation of the two components which, when converted to a velocity of separation (with the assumption of a cosmological distance for 3C279), gave an apparent speed of 10 ± 3 times the speed of light (*3*).

It is the purpose of this report to present some measurements of the variations in the flux density of 3C279 at the same frequency as the interferometric observations and to show that these measurements are consistent with a model for 3C279 that does not involve an apparent expansion at super-relativistic speeds.

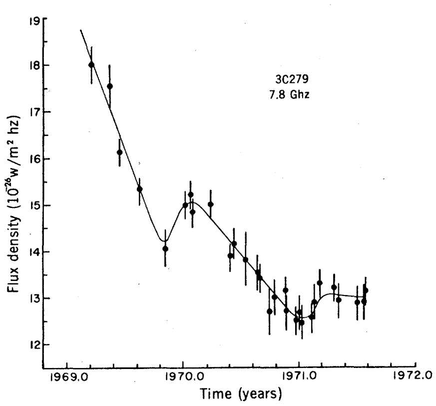

Fig. 1. The measured variations of the flux density of 3C279 at 7.8 Ghz.

Figure 1 is a plot of the flux density of 3C279 measured at a frequency of 7.8 Ghz between 1969.0 and 1971.5 with a maser radiometer on the 120-foot Haystack antenna (1 foot = 0.3 m). These data were taken as part of an extensive program of monitoring variable sources that is being conducted at the Haystack Observatory (*4*). The errors associated with each flux density measurement have been conservatively estimated and can be considered to represent a 90 percent confidence limit.

It can be seen in Fig. 1 that the flux density of 3C279 has been generally decreasing since 1969.0 with a temporary minor increase in late 1969. This general decline is the remnant of a major radio outburst in 3C279 that began at this frequency in early 1966 (*5*). In 1965, before the outburst, the flux density was about 12 flux density units (10^{-26} watt m^{-2} hz^{-1}), and it can be seen from Fig. 1 that 3C279 again reached this minimum in early 1971.

The first set of VLBI observations (*1*) were made in mid-October 1970 (1970.79), when the flux density of 3C279 was 13.12 ± 0.05 units. This value was obtained from a least-squares linear curve fit to the measurements made between 1970.2 and 1971.0.

Between October 1970 and mid-February 1971, when the second set of VLBI observations were made, the flux density decreased to a minimum and then increased slightly to a value of 12.7 ± 0.10 units in mid-February (1971.13). The latter value was obtained from a fourth-order polynomial fit to the data taken after 1970.9. Thus, the total flux density of 3C279 had changed by 0.42 ± 0.12 unit over the same period that the fringe amplitude null was seen to move. Can the apparent null displacement have been caused by this observed change in flux density?

Since the fringe nulls are so deep, any source model must be very nearly symmetric during both interferometric observations. The simplest such model is one in which the source structure at 7.8 Ghz consists of an unresolved variable component situated midway between two static nonvarying components of equal amplitude (*6*). Figure 2 shows the computed location of the first fringe null in such a symmetric three-point-source model as a function of the ratio of the flux density of the central component to the sum of the flux densities of the two outer components (S_c/S_o). The computed null position is specified in terms of the corresponding projected interferometer spacing rela-

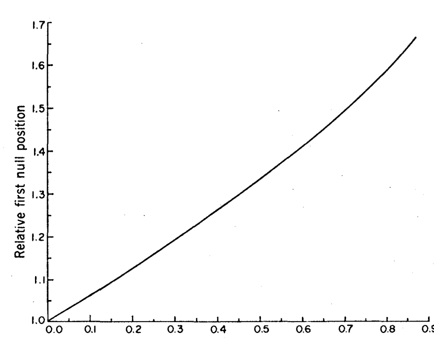

Fig. 2. The computed first null position as a function of the ratio of the flux density of the central component to the flux density of the two outer components (S_c/S_o) in the three-point-source model. The interferometer spacing (d) corresponding to the null has been normalized to the spacing (d_0) for which S_c would be 0.

tive to wavelength (d/λ) normalized to the spacing for zero contribution from the central component (d_0/λ). It can be seen that if the relative amplitude of the central component decreases the fringe nulls will appear at progressively lower values of d/λ, in qualitative agreement with both the VLBI data and the observed change in total flux density.

It will now be argued that this three-component model also gives reasonable quantitative results as well. From the measurements of Whitney *et al.* (*2*) the observed relative change in the null position is equivalent to a 9 ± 3 percent displacement in d between mid-October 1970 (d_1) and mid-February (d_2) (that is, $d_1/d_2 = 1.09$). With this condition and the assumption that the net change in the central component (ΔS_c) is −0.42 unit, a knowledge of the total flux of the two outer components (S_o) would permit us to locate the null positions d_1/d_0 and d_2/d_0 in Fig. 2. This flux density S_o is an unknown parameter of the model, but it must be less than the total source flux density of about 13 units, which includes contributions from other more extended components seen by the Haystack beam (4 arc minutes) but resolved out by the interferometer. From the above information and the slope of the curve in Fig. 2, it can be shown that S_o must satisfy the condition: $\Delta S_c/S_o \approx 0.14\,(d_2/d_0)$. Since the model requires that d_2/d_0 must be greater than 1 (because S_c is greater than 0) and that ΔS_c is -0.42 ± 0.12, the flux density S_o of the two outer components must be approximately 3.0 ± 0.9 units, a value that is in good agreement with the total correlated flux density measured by the interferometer in February 1971 (*2*).

Thus, a model for 3C279 in which a variable component is centrally located between two stationary nonvarying components equally sharing a flux density of about 3.0 ± 0.9 units is consistent with both the observed time variations of the total flux density and the interferometric results. Because the model is very sensitive to the uncertainty in the net change in flux density (ΔS_c), precise values of the flux density of the central component [$S_c(t)$] cannot be obtained. However, in order to account for the observed correlated flux density seen by the interferometer it is necessary to require that S_c contribute less than a few tenths of a unit in February 1971. A model in which the flux density of the central component declined from about 0.6 unit in October 1970 to near 0 at the end of 1970 (as suggested by the minimum in Fig. 1) and then flared up slightly to about 0.2 unit in February 1971, reaching a level of about 0.5 unit later in 1971, would be plausible within the uncertainties of the data. In such a model the corresponding values of d_1/d_0 and d_2/d_0 in Fig. 2 would be 1.13 and 1.04, respectively.

The parameters of the simple model suggested here can, of course, be further refined by considering components that are not point sources and by fitting the model to the numerical data defining the observed fringe amplitude curves. In addition there are other, less simple variable-source models that can be made consistent with the data. For example, a model could be considered in which two components are separating at apparent superrelativistic speeds but with their flux densities decreasing in unison. Such a possibility seems less likely, however. It might also be argued that the observed variations in flux density are taking place in a component whose linear size is greater than about 20 parsecs and hence is resolved out by the interferometer. It is evident from the minimum in late 1969 that the variable component under consideration in 3C279 is probably only about 1 year old, and it is certainly less than 5 years old, as evidenced by the 1965 minimum. Thus, its linear diameter must be no more than a parsec or two, and hence the variable component must have affected the observed VLBI fringe amplitude curves, even if not as suggested in this report.

The model for 3C279 presented here can be readily tested by a third set of VLBI observations made after 1971.2. If the central component did indeed increase by about 0.5 flux density unit in 1971, as suggested by Fig. 1, then this model would predict that the null in the fringe amplitude curve should appear back near its original position in October of 1970.

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3. In addition to the interpretations of this result given in (*2*), A. Cavaliere, P. Morrison, and L. Sartori (*ibid.*, p. 525) have suggested that such superrelativistic speeds are due to changing radio images resulting from relativistic illusions.
4. The details of the observational procedures, calibrations, and numerical tabulations are being prepared for publication (W. A. Dent and G. Kojoian).
5. See, for example, observations at 8 Ghz by W. A. Dent in a review paper by K. I. Kellermann and I. I. K. Pauliny-Toth [*Annu. Rev. Astron. Astrophys.* **6**, 417 (1968)] or the data of H. D. Aller and E. T. Olsen (*Astron. J.*, in press).
6. This model was briefly mentioned in (*2*) but was not considered seriously.
7. I am indebted to the staff of the Haystack Observatory for their continuing and patient support. I wish to thank G. Kojoian and J. Kapitzky for their contributions in obtaining and processing the data. I would also like to acknowledge helpful conversations with T. A. Clark, K. I. Kellermann, and S. H. Zisk. Supported by NSF grant GP-14690. Research programs are conducted at the Northeast Radio Observatory Corporation Haystack Observatory with support from NSF grant GP-25865 and from NASA grant NGR 22-174-003 and contract NAS9-7830. Contribution No. 125 of the Five College Observatories.

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Preceramic Sequences in the El Abra Rock-Shelters, Colombia

Abstract. *A series of crude stone artifacts, characterized by a trimming mainly of the working edge of a single face of a chert flake or a fragment of a nodule, was excavated in the El Abra rock-shelters, north of Bogotá, Colombia. The tools indicate a cultural complex distinct from others that have been described for the Paleo-Indian of South America.*

Recent excavations in the preceramic levels of the El Abra rock-shelters, Sabana de Bogotá, have revealed a series of chert stone tools distinguishable from others that have been described for South America. Although new types were added over a time range estimated to be from 10,500 B.C. to A.D. 1000, nearly all the tools were characterized by an alteration of only the working edge of a single face by percussion-flaking of the raw material. In function they appear to have been useful for butchering, hide-working, and wood-cutting (Fig. 1). Chert does not occur in the vicinity of the rock-shelters but can be found in outcrops of the sabana (an extinct lake bed) exposed in small