THE SIZE OF NGC 1068 AT 10 MICRONS

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Received 1973 September 4

ABSTRACT

Scans of the Seyfert galaxy NGC 1068 show that most of its 10-μ radiation arises from an area approximately 60 pc (1") in diameter. This is interpreted as evidence that the infrared emission is not synchrotron radiation.

Subject headings: Seyfert galaxies — infrared sources

I. INTRODUCTION

Most of the energy of the Seyfert galaxy NGC 1068 is emitted in the infrared wavelengths (see, e.g., Rieke and Low 1972a) from a nucleus small compared with the size of the galaxy. In the visual wavelengths, there is evidence that the nuclear core has dimensions on the order of 100 pc (de Vaucouleurs and de Vaucouleurs 1968). Rieke and Low (1972b) have, however, presented evidence of 30 percent variations in the 10-μ flux on the time scale of 2 months, which would limit the core emitting the infrared radiation to a diameter of a few parsecs. The conclusion that NGC 1068 varies at 10 μ has recently been contradicted by Stein, Gillett, and Merrill (1973), who find no variability during the same time period. The size of the infrared region is of interest since a small core would preclude the emission being thermal radiation from heated dust while a large core would preclude a single source arising from self-absorbed synchrotron radiation.

In this paper, data are presented which are interpreted as showing that a majority of the 10-μ emission from NGC 1068 does in fact come from an area on the order of 60 pc in diameter.

II. OBSERVATIONS

The measurements described here were made at 10 μ (8 μ < λ < 13 μ) on two nights at the 200-inch (5-m) Hale telescope. On the first of these, 1972 September 30, the visual seeing was on the order of 0’’5 and data were obtained at the f/16 Cassegrain focus. The focal-plane aperture was a 1’’8 × 5’’0 slit, and sky cancellation was effected by a focal-plane chopper such that two areas of the sky separated by 3’’8 center to center were alternatively viewed.

The second set of data was obtained on 1973 August 13 using an f/72 oscillating secondary mirror such that two areas of sky separated by 5’’ were observed. The focal plane aperture was again a slit but was only 0’’7 × 3’’5. The visible seeing on this night was under 1’’ but somewhat variable, especially at the end of the observations.

On both nights, data were taken by scanning the telescope in declination and normal to the slits at a rate of 0’’34 per second. The September observations consisted of four scans of α Ceti ([10 μ] = -2.00), followed by seven scans of NGC 1068 ([10 μ] = +0.8), followed by four more scans of α Cet; the latter object is approximately 6° from NGC 1068. The August observations consisted of three scans of

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α Cet, five scans of NGC 1068, three scans of α Cet, and finally, three scans of IRC+00036 (= GC 3547); the latter source, which is almost certainly point-like, has a 10-μ magnitude similar to that of NGC 1068 and is ~ 4° from that object. Averaged normalized scans of α Cet and NGC 1068 are shown in figure 1.

III. REDUCTION

A visual inspection of figure 1 shows that NGC 1068 is clearly extended relative to α Cet. The scans have been normalized to have equal areas in the signals, and the

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![Graphs showing normalized deflection vs. declination](image)

**Fig. 1**—(a) Traces of declination scans over α Cet and NGC 1068 made in 1973 August with a 0.7 (N-S) by 3.75 (E-W) slit are shown. The positive and negative signals result from synchronous demodulation of a signal which has been optically chopped between two beams separated by 5". The traces shown are averages of all the declination scans over α Cet and NGC 1068 and have been normalized to have equal areas. The finite width of NGC 1068 is evident from the decreased peak amplitude and broadening of its profile. (b) Traces of declination scans over α Cet and NGC 1068 made in 1972 September with a 1.8 (N-S) by 5.0 (E-W) slit are shown.
extended nature of NGC 1068 is seen by the decreased peak deflection and broadening of NGC 1068 relative to α Cet. The shape of the α Cet scan is determined by a combination of the seeing, the system time constant, diffraction, and inefficiency in the chopper.

The approximate extent of the NGC 1068 infrared source was determined from the data by convolving the response profile of the unresolved source α Cet with assumed models for the intensity distribution of the source and then minimizing, in a least-squares sense, the point-by-point difference between the convoluted response and the data as a function of a size parameter of the model. With this fitting procedure, the two sets of data gave qualitatively the same results, although the 1973 August fits defined the values of the parameters for a given model with higher accuracy. For example, if the model is taken to follow a Gaussian profile, the full widths at half-maximum which minimize the square residuals are 0''94 ± 0''04 for the 1972 September data and 0''90 ± 0''02 for the 1973 August data. The uncertainties are based on an intercomparison of the results from each scan; the individual widths obtained are 1''01, 0''92, 0''92, 1''04, 0''71, 1''01, and 0''97 for 1972 September and 0''90, 0''85, 0''90, 0''88, 0''95 for 1973 August. In contrast, the best fits to the scans of IRC+00036 were consistent with a source less than 0''2.

It is difficult to make a realistic assessment of the quality of the fits because the seeing noise when on the source varied from scan to scan and even within a scan. Given the uncertainty in the noise, the quality of the fit was found to be satisfactory for a Gaussian model of the appropriate width. For the 1972 September data the fit to a Gaussian was no better than when the model was assumed to consist of a uniform disk of diameter ∼ 1''5; for the 1973 August data the former was significantly better. In marked contrast, for both sets of data the fit to a single central unresolved core was unacceptably poor.

A more complicated set of models consisting of a uniform disk of variable diameter plus a central unresolved core containing a variable fraction of the 10-μ energy was also tried to allow for short-term variability. With this model, the quality of the best fits was as good as for the Gaussian profile as long as the central source did not contribute more than about one-third of the total energy. The quality degraded significantly when larger fractions were included in the central core. Because radio sources often show a double-cored structure, a model consisting of two unresolved cores was also tried. For both nights, such models gave significantly poorer fits to the data than did a simple Gaussian profile.

In view of relatively low signal-to-noise ratios obtained in 1972 September and the variable seeing in 1973 August, we do not feel that more elaborate model fitting is appropriate for these data.

IV. DISCUSSION

The immediate conclusion derived from the data of figure 1 is that a significant fraction of the 10-μ radiation of NGC 1068 comes from an extended source. The data do not have a sufficiently high signal-to-noise ratio to be able to distinguish the shape of the model source. It is clear, however, that an extended source of dimension ∼ 1'' must exist. If a distance of 13 Mpc is accepted for NGC 1068, this corresponds to a diameter of about 60 pc.

It is important to realize that the 10-μ radiation described above is not an extension of the stellar radiation making up the outer portion of NGC 1068. Specifically, the observed 10-μ radiation exceeds by almost three orders of magnitude a reasonable extrapolation of the 2.2- and 1.6-μ flux coming from the appropriate area (Neugebauer et al. 1971).

The core derived above at 10 μ is comparable with the size of the visual core in NGC 1068 observed by de Vaucouleurs and de Vaucouleurs (1968), although the
emission processes at infrared and visible wavelengths are probably quite different. It is interesting that the diameter of NGC 1068 is comparable to that of the infrared sources in the centers of NGC 253 (Becklin, Fomalont, and Neugebauer 1973) and M82 (Kleinmann and Low 1970). These sources have similar infrared energy distributions, although the 10-μ luminosity of NGC 1068 is an order of magnitude higher than the others. The infrared emission from the nuclei of NGC 253 and M82 has been conjectured to arise from thermal emission from dust, and it is the most natural conclusion from the present data on NGC 1068 that the mechanism for producing its infrared radiation is also thermal in nature. Certainly, it is impossible to have magnetic fields sufficiently high to sustain synchrotron emission over the entire extended source at the level of the observed infrared flux, although it is possible that the radiation originates from a number of localized nonthermal sources.

In order to reconcile the present data with the variability observed by Rieke and Low (1972b) it is necessary to postulate that 30 percent of the energy comes from an unresolved core, a possible fit to our data. At this point in time, however, our data seem to favor those of Stein et al. (1973). It is clear that further, higher-quality spatial scans and a more complete time history are required to define the spatial structure and emission mechanism of NGC 1068.

We thank our night assistant G. Tuton for help in taking these data and Ms. J. Bennett for her help with the reduction. This work was partially supported by National Aeronautics and Space Administration grant NGL 05-002-207 and National Science Foundation grant GP 35545X.

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