Radio Sources in the Vicinity of Source M 31

Abstract. *The region α (right ascension) equal to 23h 50m to 01h 30m, δ (declination) 39°20′ to 40°40′ has been observed at 195 and 430 megahertz with the 1000-foot (300 m) telescope of the Arecibo Ionospheric Observatory. Eighteen sources from the Ohio Catalogue and source 3C 13 are contained in this region. We conclude that the sources have straight-line spectra with indices between −0.4 and −0.9 and that they are probably not associated with M 31, except those within the optical limit of the nebula.*

The region of the sky containing M 31 has been surveyed by radio astronomers at various frequencies in the continuum and at the frequency of the hydrogen line. The continuum surveys, whether aimed specifically at the region of M 31, or covering this region as part of a survey over a large area of the sky, have revealed a fairly high number of radio sources in the vicinity of the Andromeda Nebula. According to some authors (*1*) there appears to be an excess of sources in this area and some indication of clustering. In addition, from the data on fluxes published by Scott *et al.* (*2*), Kraus (*3*), Kraus *et al.* (*1*), and Sholomitsky *et al.* (*4*) it also seemed that the sources had very peculiar spectral indices, with extremely large negative values for frequencies above 600 Mhz, and positive values at lower frequencies.

The presence of an unusual number of radio sources clustered around M 31, all having very peculiar spectra, would certainly provide food for thought. Therefore, it was decided to look at this problem again in an attempt to establish if indeed there is an excess of sources, and what is the true shape of their spectra. With regard to the latter problem, we measured at two frequencies the fluxes of 19 sources listed by Kraus, one frequency very close to that used by Scott *et al.* and the other at a value that would allow discrimination between straight-line or strongly curved spectra. We now report statistics on the number of sources and consider their possible maximum size.

The data were gathered with the 1000-foot (300-m) telescope of the Arecibo Ionospheric Observatory during the months of January and February 1967. The telescope is fixed, and different points in the sky can be reached by moving the feeds in azimuth and elevation. Since the telescope is located at 18°21′14″N and the feed mount was designed to move only 20° in elevation, M 31 cannot be observed with the normal feeds. To overcome this limitation a boom was attached to the carriage house which transports the radio astronomy feeds, and additional feeds were placed on the boom. With this construction δ (declination) equal to 40°40′ can be reached comfortably and the southern part of M 31 can be mapped.

The frequencies used for this work were 195 and 430 Mhz. Since we had to work very close to the edge of the dish, the feeds were designed to illuminate only about one-third of the total area [the equivalent of a 600-foot dish (180 m)] to minimize the effects of vignetting. The resulting beam is slightly elliptical, 16′ × 18′ (minutes of arc) at 430 Mhz and 34′ × 38′ at 195 Mhz.

The observations consisted of scans at constant declination. The region covered extended 50 minutes in right ascension on either side of M 31, for 39°20′ ≤ δ ≤ 40°40′. The source 3C 13 was also observed. A minimum of four, and as many as twelve, measurements of the flux were made for each source.

Spectra. All the spectral data known to us about the 19 sources included in our program are presented on Table 1. At 195 and 430 Mhz we give the standard deviations for the different measurements on the same source and, between brackets, the number of independent measurements. When the value of the flux was below one unit, the error involved was so large that the value was meaningless; therefore, such fluxes were not quoted.

From the table, it is apparent that the fluxes measured by Kraus (*3*) at 600 Mhz are systematically too high, in some cases by as much as a factor of 3. We should point out, however, that Kraus gives standard errors of ±75 percent for all the sources, except 3C 13, and only two of the six measured sources have fluxes greater than twice

Table 1. Radio fluxes in units of 10^{-26} watt m^{-2} $(cycle/sec)^{-1}$. The numbers in square brackets represent the number of independent measurements. References are given in parentheses.

Source	Fluxes at frequency (Mhz) indicated								
	178 (*2*)	195 (this paper)	430 (this paper)	600 (*3*)	610 (*5*)	750 (*11*)	920 (*4*)	1415 (*1*)	2680 (*8*)
OA 8		3.6 ± 1.4 [12]	1.5 ± 0.4 [11]	3.6			0.96	0.7	
17		2.0 ± 0.5 [4]	2.0 ± 0.4 [3]					.6	
18	5.4	6.0 ± 1.4 [11]	3.9 ± 0.7 [10]	3.6	3.5			2.6	
25		< 1	< 1					.5	
28		< 1	< 1					.2	
29		< 1	< 1					.3	
35.1		1.0 ± 0.8 [5]	< 1					.2	0.1 *
36	4 (*6*)	3.7 ± 0.7[6]	2.7 ± 0.6 [5]		1.6 (*10*)			.7	.4
37	3.5	3.5 ± 0.8 [8]	1.6 ± 1.0 [8]	5.4	1.3		1.25	.8	.4
38	3.5	4.5 ± 0.4 [8]	2.4 ± 0.2 [7]	3.6	2.0	1.50		.67 (*11*)	
38.1		2.9 ± 0.5 [4]	2.1 ± 0.2 [5]					.8	
43		< 1	< 1					.5	
46		1.0 ± 0.7 [6]	1.0 ± 0.8 [6]					.2	
52		} confused	} confused		0.7			.4	
53								.6	
54	2.5	1.9 ± 0.8 [5]	1.3 ± 0.6 [5]	2.7	1.1		0.9	1.2	
59	3.0	1.9 ± 0.8 [6]	1.6 ± 0.8 [4]		1.4			.5	
61		2.3 ± 0.4 [7]	1.0 ± 0.8 [5]					.7	
3C 13	12.2(*12*)	11.8 ± 2.1 [9]	6.0 ± 1.7 [8] †5.8 (*13*)	8.1	3.31 (*12*)	3.46	4.0	.4 2.3 2.42 (*12*) 1.83 (*11*)	

* Identification uncertain. † At 408 Mhz.

his quoted minimum flux. For the seven sources for which the information is more complete we calculated their spectral indices by fitting by least-squares a straight line through the available points. All measurements were given equal weight, and Kraus's values at 600 Mhz were omitted (Fig. 1). No spectral peculiarities are apparent; there are no indications of curvature, and the slopes are average for extragalactic sources, with only OA 18 being somewhat flatter.

Distribution. First we can verify whether surveys over a large area of the sky reveal an excess of sources in the region of M 31. To this effect we can examine the surveys of Scott *et al.* (*2*) and of MacLeod *et al.* (*5*). Scott *et al.* have observed the region α (right ascension) from $20^h\ 40^m$ to $19^h\ 15^m$ and δ from 40° to 44° at 178 with a beam $25' \times 35'$, and they found a total of 175 sources to a limiting flux of two units. They found no significant excess in the vicinity of M 31, in agreement with previous work (*6*).

MacLeod *et al.* have observed the region α equal to 21^h to 19^h and δ 40° to 44° at 610, with a pencil beam 16′ in diameter and found a total of 239 sources to a limiting flux of 0.8 units. They do not make any particular statement with regard to the sources found in the vicinity of M 31, but it can be easily seen from the histogram shown on Fig. 2 that there is no excess of sources in this region.

However, Kraus *et al.* point out that some of the sources show clustering. They suggest that two clusters exist, one 30^m preceding and the other 30^m following M 31, each consisting of seven sources. They add that no clustering is seen north or south of M 31, although in a previous paper (*7*) it is stated that there is a southern cluster, also composed of seven sources.

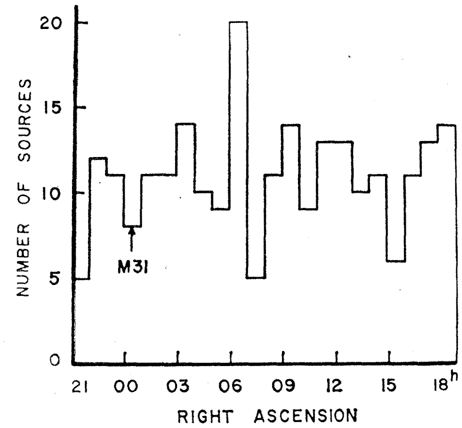

Fig. 2. Distribution of sources in right ascension according to MacLeod *et al.* (see *5*).

Examining Fig. 3 of Kraus *et al.* one sees a certain suggestion of clustering at the places indicated by the authors, but similar "clustering" is apparent in the region α equal to $23^h\ 30^m$ to $23^h\ 50^m$ and again at α equal to $01^h\ 30^m$ to $01^h\ 50^m$. The sample is too small for significant statistical analysis, and the clustering effect could very well be due to random fluctuations.

Sizes. According to Kraus *et al.* (*1*), fifteen of the sources included in our program are extended, with typical dimensions of 10′ to 15′. A source 15′ in diameter should widen our 16′ beam to 20′. Very careful measurements of OA 18, 37, and 38 failed to show any widening of the beam; hence we believe that the sizes given by Kraus *et al.* may be overestimated. This conclusion is further strengthened by inspection of the map published by Cooley *et al.* (*8*). They worked with the 140-foot (42 m) telescope of the National Radio Astronomy Observatory which, at 2680 Mhz, gives an 11′ beam. A source 15′ in diameter—for example, OA 37—should have widened their beam by 70 percent. No such effect is noticeable; OA 37 does not appear, on their map, to be any more extended than OA 33, for which Kraus *et al.* give a diameter $d < 6'$.

Thus, the sources found in the vicinity of M 31 have average nonthermal spectra and sizes definitely smaller than 10′. From statistical considerations, there is no reason to believe that the sources outside the optical limit of M 31 are physically associated with the nebula, at least to the limit $S600 \geq 0.8 \times 10^{-26}$ watt m^{-2} $(cycle/sec)^{-1}$. The maps of MacLeod (*9*), Dickel *et al.* (*10*), Kraus *et al.* (*1*), Cooley *et al.* (*8*), and our own observations reveal a complex

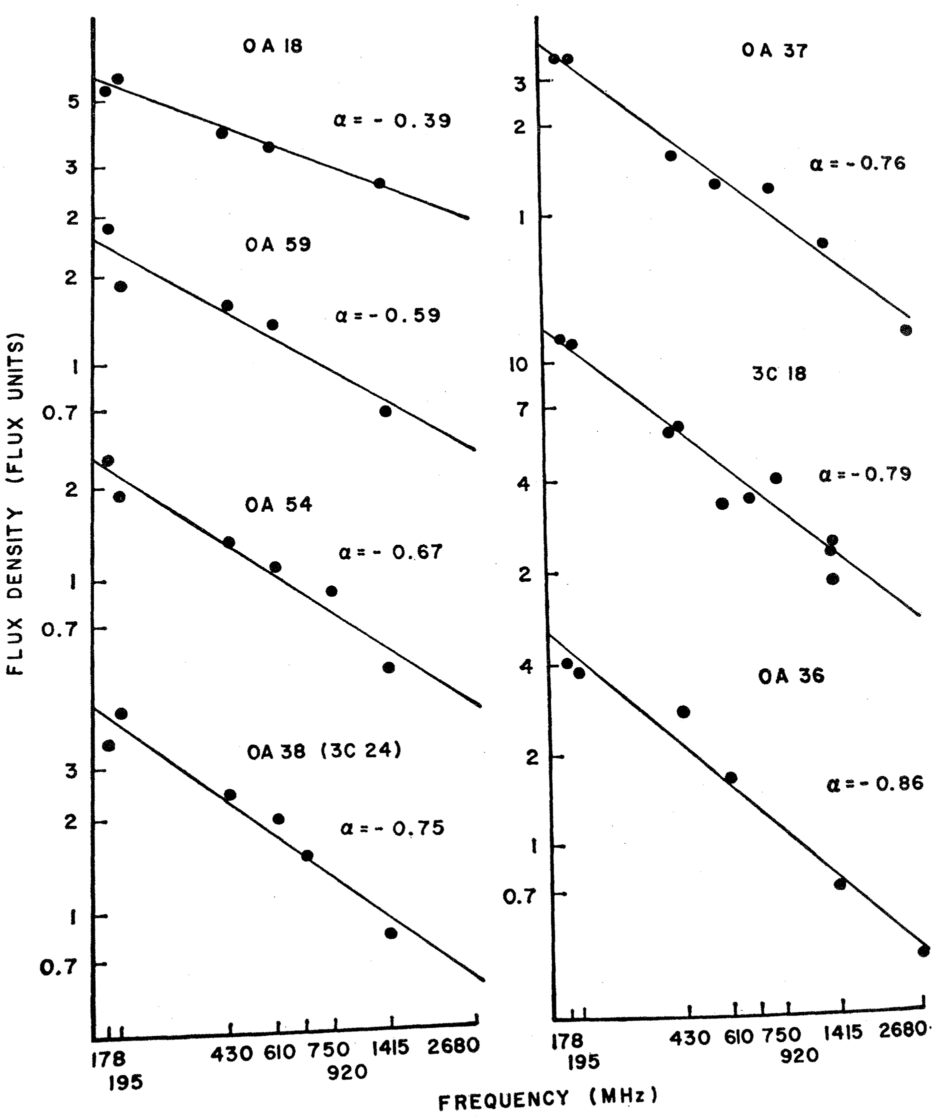

Fig. 1. The spectra of seven sources in the vicinity of M 31. Spectra are arbitrarily displaced for clarity.

structure over the optical disk of the nebula, which suggests that the nebular halo may be composed of a large number of unsolved discrete sources.

The possibility that some of the sources in this region are indeed associated with the nebula—say material ejected from the nebula in the past—cannot be excluded. A careful examination of this area at optical wavelengths seems warranted.

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References and Notes

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Optical Environment about the OGO-III Satellite

Abstract. *An upper limit to the brightness of the daytime sky near a large unmanned satellite has been obtained; it is some 30 times less than the darkest daytime sky yet reported by an astronaut. However, there still remains the danger that this background light (less than 5×10^{-13} as bright as the sun) will interfere with observations of the solar corona and zodiacal light.*

Astronauts find it difficult to see stars from an orbiting spacecraft in the daytime (*1, 2*). Both Dunkelman (*3*) and Ney and Huch (*2*) suggested that this can be explained by scattering, in the viewing window, of light coming from the sun and from the daylight half of the earth. Schmidt (*4*) investigated scattering of light within the eye itself and absorption due to the window. With proper shielding from direct illumination by bright sources, these interferences can be greatly reduced. However, speculation has also centered on another possibility, namely, that a cloud of solid particles surrounds an orbiting vehicle and scatters a high background of light in all directions when illuminated by direct sunlight (*2*). From his study of the dynamics of dust grains that leave the surface of the spacecraft or condense from fluids emitted by the spacecraft, Newkirk (*5*) concluded that, under some conditions, a serious problem may exist in observing faint sources such as the solar corona and zodiacal light from a manned spacecraft. He predicts a background brightness (in the vicinity of the Gemini spacecraft) of 3×10^{-11} that of the sun. This is consistent with the best visual observations from Gemini (*3*) that no star with a visual magnitude dimmer than 4.5 was observed in the daytime.

I now report on photometric measurements from an Orbiting Geophysical Observatory (OGO-III) which set a much smaller limit on the brightness of any cloud that might surround this large, unmanned vehicle.

The OGO-III satellite was a mechanically complex vehicle that weighed about 500 kg and contained 20 different experiments to study the near-earth environment. The photometric data was obtained from an experiment designed to monitor the brightness of the gegenschein by taking pictures (similar to those of television) of the antisolar region of the sky. Of necessity, the equipment was quite reproducible from day to day and sensitive, because the gegenschein is only 10^{-13} as bright as the sun. The optical portion of the apparatus consisted of an $f/1.5$ lens of quartz and CaF_2 which formed an image on the cathode of an image dissector, and a rotating wheel that contained filters to determine the spectral response of the system as either 3000, 5000, or 7000 Å with a pass band of ± 500 Å. The stable response of such an optical system over a 1-year period in orbit has been reported (*6*).

Figure 1 is an overall view showing the conical light shield in front of the lens and an opaque flap. The purpose of this flap is to prevent most of the sunlight, singly scattered from other parts of the spacecraft, from entering the light shield. The geometry of the spacecraft and the weight available for the design of the flap prevents complete protection against light from one

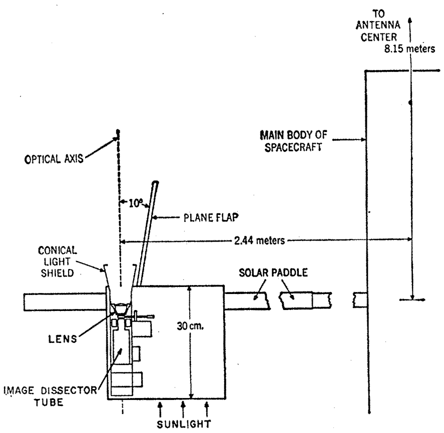

Fig. 1. Location of antenna relative to photoelectric camera.

very long radio antenna. This antenna is a torus (2.9 m in diameter) located 8.15 m from the axis (horizontal on Fig. 1) about which it rotates relative to the camera in the course of each orbit. As a result, a large amount of scattered light reaches the phototube for many positions of the antenna. The photometer response as a function of antenna position is shown by the experimental points on Fig. 2, which gives data obtained during a 5-week period beginning 9 June 1966. All three colors are included, and at all times the photometer was aimed in the antisolar direction. The unit, B⊙, is the brightness of the sun averaged over its apparent disk.

When the satellite goes into the earth's shadow, all local sources of light disappear, and only the brightness of the distant sky background is recorded, as shown by the zone labeled "night-

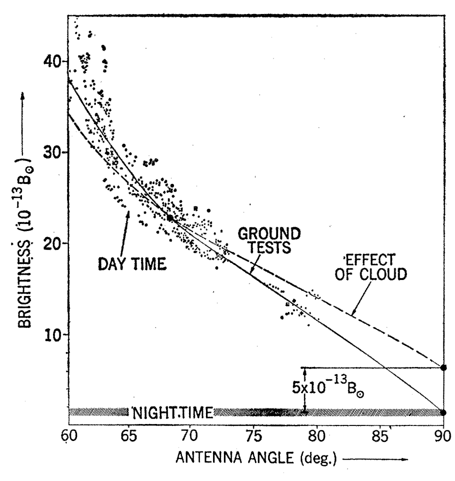

Fig. 2. Camera response as angle of antenna from optical axis is increased (dots); normalized ground simulation (solid curve); effect of hypothetical cloud (dashed curve). Antenna angle, angle subtended at the lens between the center of the antenna and the optical axis of the photometer. Large dot, point to which data were normalized.