The Astrophysical Journal, Vol. 152, April 1968

RADIO SOURCES WITH PEAKED SPECTRA

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Received February 19, 1968

In a sky survey being made with the Ohio State University (OSU) 260-foot radio telescope, a number of sources have been found which have a peak in their spectrum at a frequency above 0.5 GHz. The survey is being conducted at three frequencies: 612, 1415, and 2650 MHz with 1415 MHz as the principal frequency. Measurements at these frequencies have been supplemented by ones at 3.2, 6.5, and 10.7 GHz with the 150-foot Algonquin Park radio telescope of the National Research Council (NRC), Canada.

Data on the sources are presented in Table 1. Most of the sources are new (from lists to be published separately by Dixon and Fitch). Preliminary data on OL 318, OL 333, ON 343, OQ 208, and OQ 323 were reported earlier (Scheer and Kraus 1967; Kraus and Scheer 1967). One source, OA 33, was found in a survey of the Andromeda region (Kraus 1964, 1966) and another, OA 129, in a survey at the celestial equator (Nash 1965). Several well-known sources, CTD 93, NRAO 140, and NRAO 190, are also included in Table 1 with new flux densities measured at Algonquin Park. The source OX 057 was detected late in 1967. Subsequently, it was learned that this source had been discovered several months earlier by Shimmins using the 210-foot radio telescope at Parkes, Australia (Shimmins *et al.* 1968). This source, PKS 2134+004 (OX 057) was recorded in July 1964 during a survey with the OSU 260-foot telescope but was not included in the list of published sources (Nash 1965). It was also observed with the Dominion Radio Astrophysical Observatory telescope, Penticton, Canada, in October 1964 (Galt and Kennedy 1968). Although time variations might be suspected for a source of this type, these prediscovery observations indicate flux densities at 612 and 1415 MHz in 1964, which are not significantly different from the measurements obtained in 1967.

The sources with peaked spectra (Table 1) constitute about 1 per cent of the sources found in the OSU survey at 1415 MHz to a limit of 0.3 flux units. However, since nearly all these peaked spectra sources have 1415 MHz flux densities of 1 flux unit or more, they constitute approximately 5–10 per cent of all of the sources found at or above this flux level. The apparent deficiency of weaker sources with peaked spectra is due at least in part to their being unresolved at lower frequencies, and/or below the detection limit at higher frequencies so that the spectral information needed to identify them is unavailable.

Surveys at frequencies above 1 GHz are essential for finding sources with peaked spectra, since many reach a flux-density maximum in this part of the spectrum. The observations reported herein represent a comprehensive attempt to find as many of these sources as possible and to provide an estimate of their abundance.

The spectra of the sources of Table 1 are presented in Figure 1. Spectra with steeper slopes are displayed at the left. The spectra of CTA 21, CTA 102 (Harris and Roberts 1960; Kellermann 1964), and PKS 1934−63 (Kellermann 1966) are also included at the lower left for comparison. The flux densities shown in Figure 1 are from Table 1, with some additional values as follows: for OA 33 at 0.61 and 2.7 GHz (Cooley, Roberts, and Swenson 1967), for NRAO 140 and 190 at 0.75 and 1.4 GHz (Pauliny-Toth, Wade,

1968ApJ...152L..35K

TABLE 1*

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Source	Position (1950.0)		Flux Density						Peak Freq.	Remarks
			OSU			NRC				
	R.A.	Decl.	0.612	1.415	2.65	3.2	6.5	10.7		
OA 33	$00^h35^m41^s$	+41°20′	...	0.4	...	...	0.50	0.60	>11	
OA 129	04 20 40	−01 30	...	2.2	2.4	2.20	2.50	2.50	>11	PKS 0420−01
OB 338	00 24 03	+34 52	2.3	1.0	...	...	0.65	0.60	0.5}	Close pair
OB 343	00 26 28	+34 40	2.6	1.5	...	1.20	1.00	1.00	0.5}	
OC 328	01 16 49	+31 55	3.5	2.8	...	1.55	1.10	0.95	0.55	4C 31.4
OD 058	02 34 59	+09 02	<0.7	1.0	1.4	...	0.35	<0.3	2.3	
OE 355	03 33 25	+32 07	3.9	3.1	...	2.70	2.25	2.05	0.53	NRAO 140, 4C 32.14
NRAO 190	04 40 04	−00 25	...	...	...	3.10	2.95	2.50	3.0	PKS 0440−00
OI 255	07 33 10	+24 00	1.1	1.2	...	...	0.55	<0.3	1.5	
OI 318	07 11 06	+35 40	1.4	1.7	...	1.40	1.10	0.65	1.6	1.0 at 5 GHz (GB)
OI 363	07 38 01	+31 19	1.2	1.9	...	2.40	2.20	2.05	3.2	See †
OJ 287	08 52 00	+20 09	1.2	1.5	...	0.95	1.40	1.90	>11	VRO 20.08.01?
OK 290	09 54 13	+25 33	0.7	0.7	...	1.10	1.30	1.40	>11	
OL 318	10 10 59	+35 03	...	0.6	0.8(GB)	...	...	0.60	Flat	See ‡
OL 333	10 19 41	+30 58	...	1.0	0.7(GB)	...	...	0.30	1.5	See §
OM 133	11 19 51	+18 16	...	1.0	...	...	0.80	0.70	3.3	BH 1119+18
ON 343	12 25 43	+36 54	2.6	2.6	1.6(GB)	...	0.55	...	1.2	0.8 at 5 GHz (GB)
OP 114	13 08 36	+14 37	0.7	1.4	0.8	0.90	0.50	0.20	1.4	
OQ 208	14 04 48	+28 42	0.3	0.9	1.8(GB)	1.95	2.95	2.10	5.3	3.4 at 5 GHz (GB)
OQ 323	14 13 59	+35 01	2.0	1.6	1.8(GB)	...	...	0.95	1.4	
CTD 93	16 07 12	+26 53	...	...	...	2.10	1.35	0.65	1.2	
OV 080	19 47 38	+07 59	1.4	1.2	2.0	...	1.35	0.95	3.3	
OX 057	21 34 03	+00 26	1.3	2.7	7.5	...	12.7±3%	11.8±3%	5.0	PKS 2134+004, DA 553
OX 074	21 44 41	+09 17	0.6	1.5	1.9	1.15	1.15	1.20	2.5	
OX 131	21 18 33	+18 52	...	0.8	...	...	0.40	<0.3	2.0	BH 2118+18
OX 161	21 36 36	+14 10	<1.0	1.1	...	...	1.15	1.00	3.7	

* Flux density in flux units (f.u.), frequency in GHz. NRC flux densities are the average of two perpendicular linear polarizations; OSU values are of a single linear polarization parallel to the meridian. Source positions nominally ±3 sec R.A., ±3′ decl. NRC flux densities ±0.2 f.u. at 3.2 GHz and ±0.1 f.u. at 6.5 and 10.7 GHz, except where otherwise indicated; OSU flux densities nominally ±15 per cent or ±0.1 f.u. at 1.415 GHz and ±20 per cent or ±0.2 f.u. at 0.612 and 2.65 GHz, whichever is greater, with larger errors in some cases as indicated by the error bars in Fig. 1. Point sources are assumed for all flux densities. All flux-density values in the table were measured at OSU or NRC, except for some designated (GB), which were measured by us or W. Altenhoff at Green Bank (National Radio Astronomy Observatory). BH = Höglund (1967), DA = Dominion list A (Galt and Kennedy 1968); VRO = Dickel *et al.* (1967). The approximate peak-flux frequency as listed under "Peak Freq." was determined from the spectral graphs of Fig. 1.

† OI 363: 1.6 at 0.75 and 1.4 GHz; 2.4 at 5 GHz (GB).

‡ OL 318: 0.7 at 0.75; 0.6 at 1.4; and 0.8 at 5 GHz (GB).

§ OL 333: 0.4 at 0.75; 0.6 at 5 GHz (GB).

and Heeschen 1966), for OM 133 and OX 131 at 0.75 and 1.4 GHz (Höglund 1967), for PKS 2134+004 at several frequencies (Shimmins *et al.* 1968; Galt and Kennedy 1968), for OC 328 and OE 355 at 178 MHz (Pilkington and Scott 1965), for OA 129 and NRAO 190 at 0.4, 1.4, and 2.65 GHz (Shimmins *et al.* 1966), for CTD 93 at 1.4 GHz (Kellermann and Read 1965), for OQ 208 and ON 343 at 1.43 GHz with the California Institute of Technology interferometer (private communication from G. J. Stanley), and for OQ 208 and OQ 323 at 8 GHz with University of Michigan telescope (private communication from W. A. Dent). It is assumed for several sources that the flux density is less than 2 flux units at 178 MHz if the sources are not included in the 4C catalogue (Pilkington and Scott 1965) or less than 0.8 flux units at 610 MHz if they are not included in the VRO catalogue (Dickel *et al.* 1967).

In preparing Figure 1, the simplest spectra have been drawn which are consistent with the flux densities and their estimated errors. In many cases the true spectra may be more complex, but further measurements would be required to establish this fact. Even with the spectra presented in their simplest form there is a wide variety of shape. Some spectra have very steep slopes, while others are much flatter. OQ 208, with its steeply

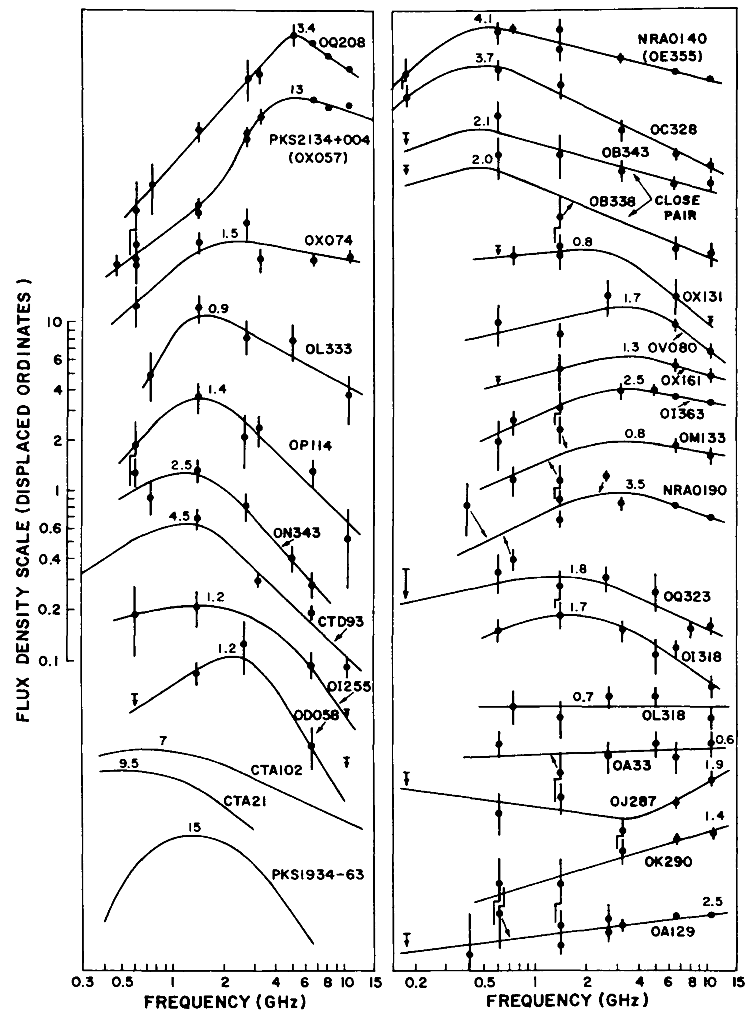

FIG. 1.—Spectra of radio sources. The ordinates are displaced to avoid overlap. Approximate maximum flux density (in flux units) is indicated on each spectrum at its highest point.

sloped spectrum approximated by two straight lines and high-peak frequency of 5.3 GHz, may be regarded as an example of one extreme. At the other extreme are sources with spectra which are flat or which have small positive slopes such as OL 318, OA 33, and OA 129. Two sources, OB 338 and OB 343, of intermediate spectral slope are of interest because they form a close pair. Their separation is about $0\overset{\circ}{.}5$, and their spectra are of similar shape and magnitude. All the sources in Table 1 have spectra with peaks between 0.5 and 11 GHz except for OL 318, which has a flat spectrum, and OA 33, OJ 287, OK 290, and OA 129, which presumably have peaks above 11 GHz. The spectrum for OJ 287 suggests the possibility of a low-frequency component such as exists for 3C 273.

Thompson (1967) has identified OQ 208 with a composite object which appears to consist of a principal object of 13 mag and two fainter objects, one stellar and one nebulous, both of which are in contact with the principal object on the *Palomar Sky Survey* print. The principal object is slightly elliptical (axial ratio 1.2) and is presumed to be a galaxy. The source PKS 2134+004 has been identified with a QSO of about 18 mag and redshift $z = 1.93$ (Shimmins *et al.* 1968). Further identifications will be of great interest and importance in attempting to establish correlations between the radio spectra and optical types.

The work at the Ohio State University was supported in part by the National Science Foundation and the Mershon and Development Funds of the Ohio State University.

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