The high radio frequency spectra and variability of southern flat-spectrum radio sources

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ABSTRACT

We have complemented observations of the millimeter spectra (90 and 230 GHz) of a complete sample of Southern flat spectrum AGNs. We discuss the overall shape of the radio spectrum of these sources, and identify two new gigahertz peaked spectrum (GPS) sources with unusually high peak frequencies (10–20 GHz). We also discuss the variability behaviour in the millimeter domain.

Subject headings: quasars: general – radio continuum

1. Introduction

In Tornikoski et al. (1993), hereafter Paper I, we published 2.3 to 230 GHz data for a complete sample of bright Southern BL Lacertae objects and quasars. The sources in the original sample were all the flat spectrum ($\alpha_{2.7GHz-5.0GHz} > -0.5$) bright ($S > 1$Jy at least once at frequencies $\nu \geq 10$GHz) sources in the Kühr 1 Jy catalog (Kühr et al. 1981), altogether 50 sources.

For Paper I we obtained 230 GHz data for only ca. 25% of the sources, due to the fact that the observations were made using a setup with a Schottky receiver and AOS as a backend, with a very compromised sensitivity in the higher frequency range. Since the original paper was published, we have obtained 230 GHz data for almost all of the sources as well as many additional 90 GHz data points, and this paper presents the updated results of the millimeter spectra and discusses the millimeter behavior of these sources.

Some of the source classifications have been revised since Paper I, for example PKS 0202−172 and PKS 0440−003 were previously listed as LPQs, but are now listed as HPQs (Impey and Tapia 1990; Wills et al. 1992). We have no 230 GHz data for three sources from the sample in Paper I, and they were thus excluded from this study (see section 3). Our current sample consists of 6 BL Lacertae objects (BLOs), 18 highly polarized quasars (HPQs), 20 low polarized quasars (LPQs) and 3 radio galaxies (RGs), altogether 47 sources. The sources and their classifications are listed in Table 1.

2. Observations

The low frequency observations at 2.3, 4.8 and 8.4 GHz were made at HartRAO in South Africa like described in Paper I. For some few sources no HartRAO data were available, and we used the 2.7 / 5.0 / 8.4 GHz data from the Parkes catalog (Wright and Otrupcek 1990) instead. All the HartRAO data points were taken between January 1991 and December 1992, so no conclusions about the long term variability can be made from these data.

All the 90 GHz and 230 GHz observations were made with the Swedish–ESO Submillimeter Telescope (SEST) at the European Southern Observatory (ESO) site of La Silla, Chile, latitude 29° South. Originally, the observations were made as described in Paper I. The new data points were initially observed as described in Tornikoski et al. (1994), but since June 1994 an SIS receiver was used for the 90 GHz observations instead of the Schottky receiver. The bolometer was used for the majority of the 230 GHz observations, resulting in improved sensitivity compared to the Schottky/AOS setup used for Paper I. All the SEST data were gathered between 1988 and 1999.

3. Results

We now have additional millimeter data to complete the study of the high frequency tail of the radio spectrum for this complete sample of Southern sources. Two of the sources included in the sample of Paper I, PKS 0539−537 and PKS 1148−001, were each observed at 230 GHz only once and with only a 1σ detection and were thus excluded from the current sample. A third source, PKS 1145−071, was not observed at 230 GHz at all and was also excluded from this sample. For all of the remaining sources we have obtained at least one significant ($> 4\sigma$) detection at 230 GHz. For most of the sources we have obtained several bolometer data points since 1992, for the HPQs and BLOs as many as 10–20 new data points, but for most of the LPQs only a few new data points.

The smallest flux observed at 230 GHz for any of the sources was 100 mJy, which is well above the bolometer detection limit of ca. 50–70 mJy (under normal observing conditions and when using integration times of 200–300 s, like our group normally does for the standard continuum monitoring of AGNs).

The minimum and average flux densities for each source at the frequencies 2.3, 4.8, 8.4, 90 and 230 GHz are given in Table 1. The number of data points taken for each source at 90 and 230 GHz is also given in Table 1.

3.1. The spectra

Many of the sources have a flat spectrum not only between 2.7 GHz and 5 GHz as originally defined when creating the sample, but in many cases all the way to 8.4 GHz or even higher. The medians of the spectral indices for all classes of sources are listed in Table 2. The “quiet” spectral index indicates the value obtained when using the minimum flux densities at each frequency, i.e. the flux density during the assumed quiescent state. The average index is obtained taking the average of all the fluxes. The median spectrum of all classes of sources between 2.3 and 8.4 GHz is very flat or slightly inverted. The median quiescent spectral indices between 8.4 and 90 GHz range from -0.30 to -0.50, and between 90 GHz and 230 GHz from -0.48 to -0.88. This indicates that the typical spectra steepen at around 100 GHz, but the sources remain bright enough to be detected at 230 GHz.

In Fig. 1 we have plotted the shape of the average spectrum of our sources. The plot was constructed using the median spectral indices from Table 2, both the quiescent and average values are plotted. Using this average spectrum we can estimate how faint sources should still be detected at the high radio frequencies, if we assume sources that have identical spectral shapes to our sample sources. For our current sample the lowest flux density at 230 GHz was 100 mJy, and the bolometer detection limit under normal observing conditions for the standard continuum monitoring observations would be 50–70 mJy. In Fig. 1 we have scaled the average spectrum so that the 230 GHz fluxes should be above the detection limit, the quiescent fluxes now ranging from 55 mJy for LPQs to 85 mJy for BLOs, and the average fluxes ranging from 80 mJy for LPQs to 143 mJy for BLOs. We can see that the 5 GHz flux density for these sources would be slightly less than 400 mJy, and the 2.3 GHz flux density 350 mJy.

Most of the high radio frequency studies have been made for sources which are known to be bright at the low radio frequencies, in many cases the flux limit being as high as 1 Jy at 5 GHz or 2.7 GHz, even though some higher frequency studies of sources brighter than 0.5 Jy at 2.7 GHz exist (Wright et al. 1991). From our scaled average spectrum we can see, however, that practically all flat-spectrum sources as faint as 350 mJy at 2.3 GHz should be detected at 230 GHz at SEST even during their quiescent state, and using the average flux densities we can estimate that if randomly observing a flat-spectrum source, we should be able to detect some sources as faint as 200 mJy at 2.3 GHz. Even though the spectra steepen between 90 and 230 GHz, no complete spectral breaks are observed in this frequency range. During a flaring state these sources have flat spectra up to 90 GHz, and also their flux densities at 230 GHz are considerably increased (see also section 3.3).

If we assume that also the fainter sources can in general have as flat spectra as the brighter ones, there should be a multitude of very little studied fainter sources which would still be detectable at the higher frequencies up to 230 GHz, and which could exhibit very interesting variability behavior also in the millimeter domain. The current "complete" samples, selected by flux density criteria using data obtained at the low frequencies (2 to 5 GHz) are in no way complete if one wants to get a full understanding of the high radio frequency behavior of AGNs. Many interesting source populations may get overlooked and excluded from such studies. Our group is in the process of conducting a study of such fainter sources (Tornikoski et al. 2000) that routinely get excluded from the flux-limited samples.

3.2. GPS sources

Even though the spectral shapes of the sample sources vary, most of the spectra are relatively flat up to 10–100 GHz, as can be expected from the bias in selecting bright sources with flat low frequency spectra for the study. There are, however, a handful of sources with inverted low frequency spectra and spectral peaks in the cm/mm-domain. Two of the sample sources, PKS 0238−084 and PKS 0743−006 have been identified as gigahertz peaked spectrum (GPS) sources in literature (de Vries et al. 1997; Stanghellini et al. 1998). Their radio spectra are plotted in Fig. 2 and Fig. 3.

Among the sources in our sample we have identified two new GPS candidates, PKS 1936−155 and PKS 2008−159. In Fig. 4 and Fig. 5 we have plotted the radio spectra of PKS 1936−155 and PKS 2008−159, respectively, together with the typical spectrum of a GPS source as described by de Vries et al. (1997), where the optically thick spectral index is $\alpha = +0.51 \pm 0.03$ (for $S \propto \nu^{\alpha}$), and after the turnover $\alpha = -0.36 \pm 0.05$ for the flat part $\nu_T < \nu \leq 2\nu_T$ and $\alpha = -0.73 \pm 0.06$ for $\nu > 2\nu_T$.

Both of the new GPS candidates have a spectrum that very much resembles the canonical GPS source spectrum of de Vries et al. (1997), especially when using the lowest flux density values for each frequency, i.e. when the sources assumingly have been in the quiescent state. They both have a rising spectrum up to 10–20 GHz, which makes them unusually high-peaked sources. Most known GPS sources peak at around 1 GHz (de Vries et al. 1995), and most of the sources in the sample in de Vries et al. (1997) had turnover frequencies in the range of 0.5–2 GHz. Only very few other GPS sources with extreme peak frequencies have been reported earlier: RXJ 0952.7+5151 and RXJ 1459.9+3337, which peak at 20 and 30 GHz, respectively (Edge et al. 1996).

PKS 1936−155 (z=1.657) has been observed with an optical polarization as high as p=12.2% (Fugmann and Meisenheimer 1988). PKS 2008−159 (z=1.181) has an optical polarization p=2.31% reported in literature (Wills et al. 1992), so it is classified as a low polarization quasar. The very high optical polarization of PKS 1936−155 is in disagreement with the suggestion that low polarization might be characteristic for GPS sources (O'Dea et al. 1991).

In the high radio frequency domain, 90 to 230 GHz, there is a lot of variability in the flux levels observed during the 8 years (1988–1996) of 90 GHz and 5 years (1991–1995) of 230 GHz observations in both sources. The turnover frequencies have been closer to 100 GHz when the sources have been in the flaring state. The flux density of PKS 1936−155 has varied between 0.55 and 1.49 Jy at 90 GHz (15 data points), and between 0.21 and 0.85 Jy at 230 GHz (10 data points). The flux density of PKS 2008−159 has varied between 0.32 and 1.60 Jy at 90 GHz (19 data points) and from 0.17 to 0.71 Jy at 230 GHz (7 data points). According to O'Dea et al. (1991), GPS sources tend to have low radio variability, but compared to the two bona fide GPS sources in our sample, PKS 0238−084 and PKS 0743−006, the variability behaviour is very similar in all four of them, and thus the relatively high mm-domain variability should not be taken as evidence against these two new candidate sources being actual GPS sources. We want to emphasize that most of the studies on GPS sources have been made at relatively low radio frequencies, and thus the millimeter domain variability of these sources in general is unknown, and the variability of especially the quasar-type GPS sources should be investigated further. The two extreme GPS sources reported by Edge et al. (1996) exhibit strong variability especially at 5 GHz, which is in agreement with our observations of the new candidates.

VLBI observations of GPS sources in general show that they are compact (de Vries et al. 1995, 1997; O'Dea et al. 1991), and VLBI observations reported in literature (Wehrle et al. 1984; Moellenbroek et al. 1996; Shen et al. 1998) have confirmed the compactness of PKS 1936−155 and PKS 2008−159.

The high peak frequencies and the strong variability of these two new GPS sources probably explain why they were not earlier recognised as GPS sources. We believe that many more GPS sources with extreme peak frequencies exist, but they are easily ignored because their low frequency data points may have been taken during a flaring state of their variability cycle, indicating flatter spectra than the typical inverted spectra of the canonical GPS sources, and especially because they are not being systematically searched for at the high radio frequencies.

3.3. Variability

The fractional variability index at 90 and 230 GHz for all sources, $\mathrm{Var}_{\Delta S} = (S_{max} - S_{min})/S_{min}$, is given in Table 1, together with the actual difference between the maxima and minima in Janskys, Var_S. The $\mathrm{Var}_{\Delta S}$ indices are larger than those shown in Paper I, which can be easily explained by the fact that we now have much longer data sets and better sampling for these sources, and for most of the well-observed BLOs and HPQs we have been able to detect the actual maxima and minima instead of observing just a few random data points. There is a clear trend that the variability increases with the number of observations, Fig. 6, which can be interpreted so that the peaks of rapid outbursts easily go unnoticed when the sampling is very sparse. As can be seen from Fig. 6, the lower $\mathrm{Var}_{\Delta S}$ of the LPQs than that of the HPQs could be explained by the smaller number of data points, which would imply that the given $\mathrm{Var}_{\Delta S}$ values for the LPQs underestimate the actual variability of LPQs.

Accurate estimates of the millimeter/submillimeter spectrum of AGNs are needed for many projects, e.g. the future Planck satellite mission, but source counts at high radio frequencies are nonexistent and most of the current studies are based on low frequency source counts and some additional information from very limited high frequency studies (e.g., Toffolatti et al. (1998)). If one wants to make use of the limited studies of certain types of sources, it is very important to understand the general millimeter domain variability behavior of these sources. Making conclusions on source behavior based on only one- or two-epoch observations can be very misleading, since sources like the ones in our sample easily vary in flux in the order of 300% in the 100–200 GHz range; the median $\mathrm{Var}_{\Delta S}$ for HPQs is 2.9 at 90 GHz and 3.0 at 230 GHz, the maxima being ca. $\mathrm{Var}_{\Delta S} \approx 12$ at both frequencies.

In an attempt to get a meaningful estimate of the high radio frequency variability behavior, we have divided the data for each source into three categories: the quiescent state, where the source flux stays within 1/3 of the maximum $\Delta S = S_{max} - S_{min}$, the intermediate state where the source stays above the quiescent level but within 2/3 of the ΔS, and the flaring state where the source flux is above this. Using this method, we analyzed the data taken for all those sources that had at least 15 data points, usually distributed over ca. 8 years, i.e. we can assume that during these relatively random observing epochs we have managed to observe many of the sources in the actual quiescent as well as flaring state. For some sources we had far more data points than 15 (see Table 1). In our sample we have 3 BLOs, 17 HPQs, 3 LPQs and 2 RGs with $\geq$ 15 data points at 90 GHz, and according to the forementioned division, the median result was that 37.3% of the data points are taken when the source is in the quiescent state, 36.8% in the intermediate state, and 21.7% in the flaring state. At 230 GHz we only have 3 BLOs and 10 HPQs with $\geq$ 15 data points, and the median result was 47.1% of data in the quiescent state, 40.0% in the intermediate state, and 11.8% in the flaring state.

Since we used a method where we have very discretely sampled data instead of continuous flux curves, the outcome is bound to be distorted. For the known bright and variable sources the selection effect is biased towards overestimating the time the source is observed in a flaring state, because in our monitoring program it is typical to prioritize sources that are known to have an outburst, either from earlier observations or data from other frequency bands. On the other hand, especially in the LPQ class there are probably several sources with slow changes in the flux levels and these sources were excluded from this analysis because there were less than 15 data points, simply because these sources have been considered "uninteresting" compared to the more rapidly variable sources, typically HPQs and BLOs.

The outcome that a variable source spends less time in the flaring state than in the intermediate or quiescent state is not surprising because we know from long term high radio frequency monitoring projects (Tornikoski et al. 1994, 1996) that the high radio frequency outbursts are relatively rapid, especially at 230 GHz. The result is also in accordance with the model of Valtaoja et al. (1999), where the 22 and 37 GHz total flux density curves were modeled by exponential flare components. However, this fact should also be taken into account when very accurate information about the high frequency tail of the radio spectrum is needed, for example when estimating the foreground contribution that AGNs have for the cosmic microwave background observations (e.g. for the MAP and Planck missions). Sources which are observed only a few times may be considered faint sources that are to be excluded when discussing the millimeter spectra of AGNs, but in reality their flux densities in the flaring state may far exceed the estimates drawn from the few-epoch observing campaigns.

4. Conclusions

We have complemented the data from Tornikoski et al. (1993) with new 90 and 230 GHz measurements, also for the sources for which no 230 GHz data was presented earlier. Many of the sources have flat spectra up to 90 GHz, but even at 230 GHz they remain bright enough to be detected at >100 mJy flux levels, many of them considerably brighter than that. When we construct an average spectrum using the spectral shape from the sample sources, we find that sources as faint as 350 mJy at 2.3 GHz should be detected at 230 GHz with the current SEST setup, indicating that a large number of sources fainter at the lower frequencies that get excluded from the "complete" samples should be easily detectable in the millimeter domain. Many of these sources probably exhibit interesting high radio frequency variability behavior and studying them more closely could offer us new information about the millimeter tail of the radio spectrum.

In our current sample we have identified two new GPS sources, PKS 1936−155 and PKS 2008−159, both peaking at unusually high frequencies, ca. 10–20 GHz in the observer's frame. We suggest that there are many more GPS sources peaking at high frequencies but they have not been recognised as being GPS sources due to lack of data.

We have analyzed the millimeter-domain variability of our sample sources, finding that with random data sampling, only 1/5 of the observations at 90 GHz and 1/10 at 230 GHz detect BLOs and HPQs in the flaring state. The variability behaviour should be taken into account when estimating the source behavior based on only few data points, likely to have been observed during the intermediate or quiescent state.

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Fig. 1.— The scaled average spectrum of the sample sources, assuming a flux density at 2.3 GHz S(2.3GHz)=350mJy. For each class of sources (BLOs, HPQs and LPQs) both the minimum (i.e. the assumed quiescent level) and average values are shown.

Fig. 2.— The cm–mm spectrum of PKS 0238−084. The data are from this paper; Kühr et al. (1981); Wright and Otrupcek (1990); Tornikoski et al. (1993), Tornikoski et al. (1996); Teräsranta et al. (1998) and Kovalev et al. (1999).

Fig. 3.— The cm–mm spectrum of PKS 0743−006. The data are like listed in the caption of Fig 2.

Fig. 4.— The cm–mm spectrum of PKS 1936−155. The data are from this paper; Kühr et al. (1981); Wright and Otrupcek (1990); Tornikoski et al. (1993), Tornikoski et al. (1996) and Kovalev et al. (1999).

Fig. 5.— The cm–mm spectrum of PKS 2008−159. The data are like listed in the caption of Fig 4.

Fig. 6.— The 90 GHz variability index $\mathrm{Var}_{\Delta S}$ vs. the number of data points taken at 90 GHz.

Table 1. The flux density and variability data for each source. All the flux densities are given in Janskys.

Source	Class	S(2.3GHz)		S(4.8GHz)		S(8.4GHz)		S(90GHz)			S(230GHz)			Var(90GHz)		Var(230GHz)	
		Ave	Min	Ave	Min	Ave	Min	Ave	Min	N_{obs}	Ave	Min	N_{obs}	$Var_{\Delta S}$	Var_S [Jy]	$Var_{\Delta S}$	Var_S [Jy]
0003-066	BLO	2.26	2.11	2.49	2.29	3.30	2.64	1.65	0.83	22	0.92	0.61	15	2.43	2.02	1.03	0.63
0048-097	BLO	1.02	0.92	1.49	1.09	1.57	1.22	1.45	0.61	26	0.81	0.25	17	3.11	1.90	5.56	1.39
0138-097	BLO	0.79	0.79	0.81	0.65	0.65	0.58	0.49	0.38	6	0.20	0.12	3	0.50	0.19	1.25	0.15
1514-241	BLO	1.79	1.58	1.84	1.20	1.95	1.55	1.72	0.76	45	1.25	0.48	22	2.91	2.21	3.02	1.45
2131-021	BLO	1.26	1.05	1.74	1.34	2.35	2.17	0.96	0.69	12	0.51	0.32	12	1.12	0.77	2.03	0.65
2155-152	BLO	2.88	2.72	2.67	2.47	2.49	2.31	1.46	1.22	13	0.66	0.46	13	0.45	0.55	0.89	0.41
0202-172	HPQ	1.15	1.15	1.34	1.20	1.20	1.14	0.57	0.30	19	0.23	0.10	11	3.23	0.97	2.60	0.26
0336-019	HPQ	2.44	2.30	3.02	2.63	2.97	2.78	1.94	1.08	23	1.08	0.59	13	1.82	1.97	1.29	0.76
0403-132	HPQ	3.52	3.17	2.96	2.51	2.63	2.52	1.05	0.64	12	0.38	0.17	10	1.25	0.80	2.35	0.40
0420-014	HPQ	3.64	3.45	4.27	3.60	4.01	3.28	4.85	1.39	82	2.36	1.04	39	5.50	7.65	4.13	4.30
0440-003	HPQ	1.85	1.85	1.35	1.35	1.62	1.62	0.72	0.43	22	0.40	0.16	12	1.87	0.80	3.88	0.62
0454-234	HPQ	2.13	2.06	2.25	1.95	2.40	2.09	1.07	0.56	35	0.54	0.28	17	2.98	1.67	2.96	0.83
0458-020	HPQ	2.79	2.47	3.10	2.72	2.89	1.36	1.55	0.49	24	0.70	0.16	19	4.32	2.10	7.75	1.24
0605-085	HPQ	2.41	2.29	2.24	2.08	2.09	1.91	1.90	1.12	31	1.03	0.62	20	1.33	1.50	1.16	0.72
1253-055	HPQ	10.54	9.96	11.81	11.11	12.82	11.15	17.47	8.16	98	9.84	3.55	68	2.78	22.69	4.68	16.62
1334-127	HPQ	2.01	2.01	4.99	4.85	6.13	5.89	6.41	2.04	51	3.94	1.76	19	3.50	7.15	2.78	4.90
1504-167	HPQ	2.89	2.57	2.48	1.93	2.52	2.02	1.00	0.54	19	0.36	0.23	10	1.41	0.76	1.09	0.25
1510-089	HPQ	3.34	2.75	3.52	2.60	3.80	2.58	2.50	0.74	51	1.14	0.35	25	5.04	3.75	5.91	2.07
1741-038	HPQ	2.27	1.95	2.57	2.12	3.10	2.48	3.13	1.33	47	1.40	0.79	22	3.72	4.95	2.41	1.90
1936-155	HPQ	0.66	0.52	1.05	0.96	1.51	1.32	1.03	0.55	15	0.39	0.21	10	1.70	0.94	3.05	0.64
2223-052	HPQ	4.70	4.70	4.31	4.31	6.31	5.52	3.68	2.11	64	2.00	1.08	29	3.54	7.46	4.19	4.53
2227-088	HPQ	1.51	1.31	1.36	0.80	1.10	0.73	1.39	0.23	17	0.85	0.13	14	12.52	2.88	12.08	1.57
2243-123	HPQ	2.07	2.00	2.63	2.54	3.06	2.87	1.99	1.30	19	0.91	0.45	15	1.43	1.86	3.73	1.68

Table 1—Continued

Source	Class	S(2.3GHz)		S(4.8GHz)		S(8.4GHz)		S(90GHz)			S(230GHz)			Var(90GHz)		Var(230GHz)	
		Ave	Min	Ave	Min	Ave	Min	Ave	Min	N_{obs}	Ave	Min	N_{obs}	$Var_{\Delta S}$	Var_S [Jy]	$Var_{\Delta S}$	Var_S [Jy]
2345-167	HPQ	2.72	2.48	2.38	1.93	2.21	1.88	1.70	0.82	15	1.38	0.51	13	2.10	1.72	2.65	1.35
0112-017	LPQ	1.35	1.35	1.54	1.45	1.21	1.19	0.63	0.52	4	0.22	0.22	1	0.38	0.20		
0122-003	LPQ	1.56	1.56	1.31	1.15	1.31	1.28	0.77	0.51	10	0.29	0.19	8	2.10	1.07	1.16	0.22
0135-247	LPQ	1.23	1.00	0.90	0.82	1.02	0.85	0.87	0.56	11	0.40	0.16	9	0.96	0.54	2.44	0.39
0414-189	LPQ	1.18	1.18	1.20	1.09	1.22	0.92	0.61	0.42	3	0.28	0.23	2	1.10	0.46		
0511-220	LPQ	1.21	1.21	0.92	0.90	1.11	1.05	0.37	0.26	3	0.22	0.19	4	0.73	0.19	0.26	0.05
0743-006	LPQ	1.28	0.94	2.11	1.95	2.03	1.75	0.49	0.37	8	0.15	0.15	1	1.05	0.39		
0834-201	LPQ	4.15	4.15	1.53	1.46	1.33	1.24	0.67	0.36	5	0.42	0.39	3	2.47	0.89	0.18	0.07
1032-199	LPQ	1.26	1.26	1.22	1.19	1.12	1.08	0.61	0.44	4	0.29	0.27	2	0.80	0.35	0.15	0.04
1045-188	LPQ	0.78	0.74	0.96	0.87	1.26	1.11	1.20	0.69	13	0.79	0.47	14	1.55	1.06	1.79	0.84
1127-145	LPQ	4.55	3.63	3.82	3.50	3.09	2.81	1.33	0.66	13	0.85	0.62	11	2.26	1.49	1.10	0.68
1243-072	LPQ	0.59	0.54	0.69	0.61	0.66	0.66	0.60	0.56	3	0.39	0.36	3	0.20	0.11	0.14	0.05
1302-102	LPQ	1.07	0.84	0.96	0.90	1.03	0.77	0.74	0.42	14	0.27	0.21	6	2.86	1.20	0.76	0.16
1354-152	LPQ	0.87	0.85	1.06	0.99	1.48	1.39	0.67	0.35	5	0.16	0.15	2	1.74	0.61	0.07	0.01
1406-076	LPQ	0.63	0.54	0.71	0.62	0.58	0.58	0.74	0.42	23	0.41	0.27	12	2.31	0.97	1.81	0.49
2008-159	LPQ	0.74	0.62	1.20	1.04	1.71	1.62	1.10	0.32	19	0.46	0.17	7	3.94	1.28	3.18	0.54
2126-158	LPQ	1.06	0.97	1.18	1.09	1.07	0.94	0.29	0.29	1	0.15	0.15	1				
2128-123	LPQ	2.02	1.92	2.66	2.28	2.60	2.38	1.26	0.62	20	0.52	0.38	11	2.05	1.27	0.66	0.25
2203-188	LPQ	5.38	5.33	4.37	4.25	3.61	3.53	0.66	0.56	7	0.27	0.22	4	0.39	0.22	0.64	0.14
2216-038	LPQ	2.39	2.18	2.74	2.61	2.70	2.42	0.89	0.71	9	0.33	0.29	9	0.85	0.60	0.34	0.10
2354-117	LPQ	1.83	1.74	1.59	1.56	1.43	1.43	0.44	0.44	1	0.15	0.15	1				
0238-084	RG	1.16	0.89	2.89	2.56	3.94	3.18	1.53	1.00	23	0.64	0.19	12	1.32	1.32	3.68	0.70
1213-172	RG	1.34	1.21	1.48	1.38	1.45	1.30	1.20	0.47	22	0.69	0.30	14	3.23	1.52	2.10	0.63

Table 1—Continued

Source	Class	S(2.3GHz)		S(4.8GHz)		S(8.4GHz)		S(90GHz)			S(230GHz)			Var(90GHz)		Var(230GHz)	
		Ave	Min	Ave	Min	Ave	Min	Ave	Min	N_{obs}	Ave	Min	N_{obs}	$Var_{\Delta S}$	Var_S [Jy]	$Var_{\Delta S}$	Var_S [Jy]
2331-240	RG	0.94	0.92	1.11	1.05	1.27	1.21	1.12	0.66	13	0.68	0.57	5	1.42	0.94	0.60	0.34

Table 2. The median spectral indices for the different classes of sources.

Spectral index	BLOs	HPQs	LPQs	RGs	ALL
$\alpha_{2.3-4.8}$,ave	0.08	0.11	0.09	0.23	0.14
$\alpha_{2.3-4.8}$,quiet	-0.01	-0.01	0.10	0.18	0.09
$\alpha_{4.8-8.4}$,ave	0.10	0.07	-0.05	0.24	0.00
$\alpha_{4.8-8.4}$,quiet	0.23	0.04	-0.15	0.25	0.01
$\alpha_{2.3-8.4}$,ave	0.18	0.08	-0.05	0.23	0.06
$\alpha_{2.3-8.4}$,quiet	0.08	-0.02	-0.05	0.21	-0.01
$\alpha_{8.4-90}$,ave	-0.17	-0.18	-0.29	-0.08	-0.23
$\alpha_{8.4-90}$,quiet	-0.30	-0.42	-0.50	-0.43	-0.43
α_{90-230},ave	-0.65	-0.74	-0.88	-0.59	-0.79
α_{90-230},quiet	-0.88	-0.77	-0.69	-0.48	-0.74