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SEST observations of southern flat–spectrum radio sources

A.J. Beasley[1], J.E. Conway[2], R.S. Booth[2], L.-Å. Nyman[3], and M. Holdaway[4]

[1] National Radio Astronomy Observatory, P.O. Box 0, Socorro NM 87801, U.S.A.*
[2] Onsala Space Observatory, S-439 92 Onsala, Sweden
[3] Swedish–ESO Submillimetre Telescope, European Southern Observatory, Casilla 16001, Santiago 19, Chile
[4] National Radio Astronomy Observatory, 949 North Cherry Ave., Campus Building 65, Tucson AZ 85721, U.S.A.

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Abstract. We present the results of a 2 & 3 mm Swedish–ESO Submillimetre Telescope continuum survey of bright southern flat–spectrum radio sources. Our sample consists of all sources in the PKSCAT90 catalog south of declination $-40°$ with accurate positions ($< 2''$), and predicted 3 mm flux (based on published low–frequency spectral indices) greater than 300 mJy (47 sources). In addition, 32 bright radio sources from the USNO Radio-Optical Reference Frame catalog have been observed. Our overall detection rate for the combined sample is 66% above typical 5σ limits of $300 - 500$ mJy. This survey has identified many new sources suitable for use as phase and pointing calibrators for southern millimeter interferometers. A number of individual sources are discussed.

Key words: galaxies: active — BL Lacertae objects: general — quasars: general — radio continuum: general; galaxies

1. Introduction

The subset of compact extragalactic radio sources which exhibit bright mm-wavelength ($30 - 300$ GHz) emission includes many of the most active and interesting objects in the radio sky. These sources usually exhibit flat or inverted spectra ($\alpha \geq -0.5, S \propto \nu^{\alpha}$), which are modeled in the context of nuclear jets as a cone of partially optically-thick synchrotron emission with the number density of relativistic particles and magnetic field strength increasing inwards towards an active galactic nucleus (Blandford & Koñigl 1979). High-frequency single–dish monitoring studies (e.g. Brown et al. 1989; Valtaoja et al. 1992a; Tornikoski et al. 1993; Tornikoski et al. 1996) and ground-based VLBI observations (now routinely available with the Coordinated Millimeter VLBI Array) are providing important information to constrain models of the physical conditions and shock–emission mechanisms in these sources (Marscher & Gear 1985; Valtaoja et al. 1992b).

Bright compact mm radio sources can also be used as phase calibrators for interferometer arrays. Planned "fast-switching" schemes involve regular scans of a nearby calibrator source to derive antenna-based phase corrections to reduce or remove the effects of the wet and dry troposphere, and geometric/electronic delays (Holdaway et al. 1995). These schemes require dense grids of bright sources with accurate positions, as residual phase errors increase rapidly with source-calibrator separation and slew time. A survey of 418 northern and equatorial flat and steep–spectrum calibrator candidates was made by Holdaway et al. (1994) using the NRAO 12 m telescope; in this paper we present the results of a 2 & 3 mm continuum survey of 79 southern radio sources, made using the Swedish–ESO Submillimetre Telescope (SEST). The primary goals of this experiment were to catalog bright mm radio sources in the southern sky suitable for use as pointing and/or phase calibrators, and to identify interesting sources for follow-up radio and optical observations.

2. The sample

Our observing sample has two main components. Firstly, we selected the 47 radio sources in the Parkes PKSCAT90 Catalog (Wright & Otrupcek 1990) which met the following criteria: (1) south of declination $-40°$; (2) possessing both 5 & 8 GHz flux density measurements in PKSCAT90; (3) accurate positions (i.e. quoted errors $< 2''$); and (4) expected 3 mm flux density greater than 300 mJy (based on a spectral index derived from 5 & 8 GHz fluxes). The compact (milliarcsecond-scale) structures of most of these sources are not known. Secondly, we selected all sources south of declination $-40°$ from the US Naval Observatory (USNO) Radio–Optical Reference Frame (Johnston et al.

Send offprint requests to: A.J. Beasley

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1995). These are compact flat-spectrum radio sources with highly–accurate positions (typically better than 3 milliarcseconds), and typically have 8.4 GHz flux densities greater than $100-200$ mJy. Of the 60 sources identified this way, 28 were already selected as part of the Parkes sample, leaving 32 new sources. A declination cut-off of -40° was used to select regions of the sky inaccessible to northern mm telescopes. We note that the spectral indices based on non-contemporaneous PKSCAT90 5 & 8 GHz flux densities may be significantly in error. We also note that it is possible that a population of radio sources with curved spectra, i.e., which flatten in spectral index or are inverted above 8 GHz, could be missed by our criteria.

3. Observations & results

The observations were made during the period 1996 May 21 to May 26 using the 15 m diameter SEST telescope, situated at the European Southern Observatory Cerro La Silla site (altitude 2300 m). A review of the SEST and its capabilities can be found in Booth et al. (1989). We observed using the 2 mm and 3 mm SIS receivers simultaneously (single sideband), each coupled to an acousto–optical spectrometer (LR1 and LR2 respectively). A description of these spectrometers can be found in Schieder et al. (1989). The 2 mm/LR1 configuration produced 1440 channels (694 kHz separation), centered on 146.969 GHz (the rest frequency of the CS$(3-2)$ transition). The 3 mm/LR2 configuration produced 1600 channels (681 kHz spacing), centered on 89.188 GHz (rest frequency of HCO+$(1-0)$ transition). These frequencies were chosen to allow us to search for Galactic CS or HCO+ absorption towards any strongly–detected sources. The receiver temperatures were typically $120-130$ K. The primary beam of the SEST telescope has a full-width at half-maximum (FWHM) of $33''$ and $55''$ at 2 and 3 mm respectively.

Calibration of the system was performed using the chopper–wheel method (Ulich 1980), which automatically corrects for atmospheric opacity effects. To convert the measured antenna temperatures into flux densities, standard sensitivities of 30 Jy/K (2 mm) and 25 Jy/K (3 mm) were assumed; these values agreed to within 20% and 10% (respectively) with values determined from a single low–elevation observation of Saturn during the run. One 30 minute observation of each source was performed, consisting of 30 cycles of a dual beam-switch mode, where the target is first placed in a signal beam from which a reference beam is subtracted at 6 Hz, then in the reference beam (to remove any residuals due to differences in gain between the beams). The sky separation of the signal and reference beams was $\sim 2.5'$. Each half of the cycle produces a spectrum which is the sum of 10 s of integration on source; these are averaged to produce a flat baseline, and the spectral channels averaged (channels $100-1300$ for LR1, $100-1500$ LR2). The resultant observing bandwidths were 834 (2 mm) and 953 MHz (3 mm). The 30 beamswitch cycles (consisting of approximately 10 min integration on source) were then averaged; a $1\,\sigma$ error was estimated as the standard error of the mean of the individual cycle results. One source ($0454-810$) was observed on five separate occasions, with consistent results; the value given in Table 1 is the observation with the lowest noise. The zenith opacities at 2 mm ranged from 0.2 to < 0.02, with a median value of ~ 0.05. The majority of sources were observed at elevations greater than 30°, therefore the small corrections for variations in the telescope gain with elevation at 2 and 3 mm have not been applied.

In Tables 1 and 2, the results of our observations for the Parkes and USNO samples are presented. In Col. 1, the J2000 source name is given (B1950 names are used in Table 2). Columns 2 and 3 are the source type and redshift (where known) from the NASA/IPAC Extragalactic Database (Q = quasar, G = galaxy, B = BL Lac), Cols. 4 and 5 are the observed J2000 coordinates, Cols. 6 and 7 are the 2 mm flux density and error ($1\,\sigma$), and Cols. 8 and 9 are the 3 mm flux density and error ($1\,\sigma$); all flux densities are given in Jy. Column 10 contains character codes indicating cross-references between the Parkes (P), USNO (U) and (T) Tornikoski et al. (1996) samples. Flux densities preceded by < indicate non-detections at a $5\,\sigma$ level. Our overall detection rate for the combined sample is 66% above typical $5\,\sigma$ limits of $300-500$ mJy; 37 of 47 sources in the Parkes sample were detected at at least one frequency, and 15 of 32 sources in the USNO sample. We have chosen 5σ as a conservative detection limit for these observations, although given the variations in the noise level due to changing atmospheric conditions, it is likely we actually detected sources at lower significance levels, e.g. 4σ. Inspection of the final summed spectra for each detected source showed no unambiguous examples of Galactic CS or HCO+ absorption.

The expected theoretical thermal noise for our observations was of order $5-10$ mJy, while in practice the observed $1\,\sigma$ noise varied from about 40 mJy to 200 mJy, and was roughly correlated with the zenith opacity during the integrations. This discrepancy is most likely due to slight systematic differences in gain between the target and reference beams, combined with temporal and spatial variations in the atmosphere on timescales of the beam switching. The planned replacement of the present chopper wheel system with a rapidly–nutating subreflector with a variable target–reference beam separation may improve the performance of the telescope for continuum surveys.

4. Individual sources

Our observations were primarily a finding survey for strong southern millimeter sources, however we now briefly discuss the nature of our detected sources and examine those of special astrophysical interest.

Table 1. Parkes sample. $<$ indicates non-detection at 5σ level. S & σ in Jy

Source	Type	z	RA(J2000)	Dec(J2000)	$S_{2\mathrm{mm}}$	$\sigma_{2\mathrm{mm}}$	$S_{3\mathrm{mm}}$	$\sigma_{3\mathrm{mm}}$	ID
J0004−4736	Q		0 4 35.65	−47 36 19.6	< 0.93	0.22	1.40	0.21	P
J0051−4226	Q	1.74	0 51 9.50	−42 26 33.2	< 0.18	0.07	0.38	0.06	P
J0106−4034	Q	0.58	1 6 45.10	−40 34 19.9	2.06	0.14	3.63	0.10	PU
J0210−5101	Q	1.00	2 10 46.38	−51 1 1.0	2.65	0.13	3.53	0.07	PTU
J0245−4459	Q	0.28	2 45 54.12	−44 59 39.7	0.49	0.09	0.45	0.05	P
J0246−4651	Q		2 46 0.00	−46 51 16.0	< 0.23	0.13	0.62	0.06	P
J0253−5441	Q	0.53	2 53 29.15	−54 41 51.3	0.63	0.12	0.94	0.07	PU
J0303−6211	Q		3 3 50.58	−62 11 25.0	0.60	0.09	0.83	0.10	PU
J0309−6058	Q		3 9 56.03	−60 58 38.6	< 0.46	0.13	0.88	0.08	PU
J0311−7651	Q	0.22	3 11 55.50	−76 51 50.1	< 0.29	0.13	< 0.37	0.12	PU
J0455−4616	Q	0.85	4 55 51.11	−46 16 4.0	0.79	0.07	1.32	0.06	PT
J0506−6109	Q	1.09	5 6 43.90	−61 9 41.1	0.81	0.13	1.19	0.10	PTU
J0515−4556	Q	0.19	5 15 45.27	−45 56 42.8	< 0.36	0.09	0.32	0.05	P
J0522−6107	Q	1.40	5 22 34.27	−61 7 58.5	< 0.43	0.10	0.84	0.11	PU
J0525−4557	Q	1.47	5 25 31.40	−45 57 54.7	< 0.20	0.12	0.31	0.06	P
J0538−4405	Q	0.89	5 38 50.36	−44 5 8.9	3.19	0.12	4.58	0.05	PTU
J0635−7516	Q	0.15	6 35 46.54	−75 16 16.8	1.01	0.10	1.76	0.16	PTU
J0743−6726	Q	1.51	7 43 31.52	−67 26 26.0	<-0.13	0.09	< 0.31	0.08	PTU
J0757−7353			7 57 14.13	−73 53 9.5	< 0.03	0.11	<-0.01	0.13	P
J0904−5735	Q	0.69	9 4 53.21	−57 35 3.6	< 0.30	0.10	< 0.20	0.10	P
J1041−4739			10 41 44.66	−47 39 59.6	< 0.22	0.10	0.32	0.06	
J1058−8003	Q		10 58 43.69	−80 3 54.3	0.41	0.07	1.05	0.10	PU
J1103−5356	Q		11 3 52.27	−53 56 59.8	0.47	0.07	1.01	0.09	PU
J1107−4449	Q	1.59	11 7 8.69	−44 49 7.6	0.79	0.10	1.58	0.07	PU
J1118−4634	Q	0.71	11 18 26.92	−46 34 15.0	< 0.29	0.09	< 0.30	0.11	PU
J1147−6753	Q		11 47 33.69	−67 53 41.8	1.67	0.06	2.62	0.07	P
J1224−8313			12 24 54.49	−83 13 10.4	< 0.49	0.12	0.62	0.10	P
J1255−7138	Q		12 54 59.99	−71 38 20.5	< 0.15	0.08	0.45	0.08	PU
J1424−6807	Q		14 24 55.65	−68 7 59.2	0.48	0.07	0.75	0.09	P
J1427−4206	Q	1.52	14 27 56.28	−42 6 18.5	3.34	0.09	4.83	0.12	PTU
J1454−4012	Q	1.81	14 54 32.89	−40 12 31.7	0.49	0.08	0.70	0.14	PU
J1624−6809	Q	1.36	16 24 18.56	−68 9 12.8	< 0.05	0.07	< 0.08	0.12	PU
J1723−6500	G	0.01	17 23 40.92	−65 0 35.9	< 0.34	0.10	0.61	0.06	PU
J1744−5144	G		17 44 25.41	−51 44 43.9	< 0.10	0.20	< 0.20	0.04	P
J1803−6507	G		18 3 23.86	−65 7 39.4	<-0.13	0.09	0.50	0.05	PU
J1809−4552			18 9 57.80	−45 52 41.0	< 0.94	0.20	1.67	0.18	P
J1819−5521	Q		18 19 45.44	−55 21 21.4	< 0.26	0.05	0.32	0.06	PU
J1837−7108	Q	1.35	18 37 28.78	−71 8 41.4	0.73	0.07	1.17	0.10	PU
J1932−4536	Q	0.65	19 32 44.90	−45 36 37.8	< 0.24	0.07	0.42	0.04	P
J1937−3958	Q	0.96	19 37 16.21	−39 58 1.5	0.77	0.06	< 0.39	0.17	PT
J2009−4849	Q	0.07	20 9 25.40	−48 49 53.7	< 0.41	0.10	0.52	0.10	PTU
J2207−5346	Q	1.20	22 7 43.73	−53 46 33.8	<-0.04	0.21	< 0.21	0.18	PTU
J2229−4051	Q	0.44	22 29 18.61	−40 51 31.7	< 0.02	0.18	<-0.22	0.17	P
J2235−4835	Q	0.51	22 35 13.24	−48 35 58.5	0.73	0.14	1.20	0.10	PU
J2329−4730	Q	1.29	23 29 17.71	−47 30 19.2	0.49	0.06	0.86	0.06	PTU
J2336−5236	Q		23 36 11.88	−52 36 12.9	< 0.15	0.07	0.37	0.07	P
J2357−5311	Q	1.00	23 57 53.18	−53 11 13.8	< 0.58	0.18	< 0.48	0.24	PTU

The majority of the detected sources are flat–spectrum core–dominated blazars (either quasars or BL Lac objects) at high redshift (roughly between $z \sim 0.5$ and 2.5). These objects are prime targets for future multi-epoch, multi-frequency monitoring to further constrain the properties of the highly beamed jet emission (Tornikoski et al. 1993). Many of the detected sources are strong at X-ray and gamma-ray wavelengths, and several mechanisms have been proposed for production of this high–energy emission via the inverse–Compton process (Ghisellini & Madau 1996). These various models predict different relationships between variability in the millimeter and X-ray/gamma-ray, and joint monitoring

Table 2. USNO sample. < indicates non-detection at 5σ level. S & σ in Jy

Source	Type	z	RA(J2000)	Dec(J2000)	S_{2mm}	σ_{2mm}	S_{3mm}	σ_{3mm}	ID
B0047−579	Q	1.79	0 49 59.47	−57 38 27.3	< 0.34	0.10	0.60	0.06	U
B0056−572	Q	0.01	0 58 46.58	−56 59 11.4	< 0.45	0.15	0.56	0.08	U
B0131−522	Q	0.01	1 33 5.76	−52 0 3.9	< 0.28	0.06	< 0.23	0.08	U
B0230−790	Q	1.07	2 29 34.94	−78 47 45.6	< 0.03	0.10	< 0.08	0.09	U
B0332−403	Q	1.44	3 34 13.65	−40 8 25.3	0.73	0.12	1.21	0.07	UT
B0437−454			4 39 0.85	−45 22 22.5	< 0.29	0.07	< 0.58	0.15	U
B0438−436	Q	2.85	4 40 17.17	−43 33 8.6	< 0.49	0.11	1.49	0.08	UT
B0454−810	Q	0.44	4 50 5.44	−81 1 2.2	0.72	0.06	1.63	0.05	U
B0516−621	Q		5 16 44.92	−62 7 5.3	< 0.28	0.29	< 0.50	0.45	U
B0530−727			5 29 30.04	−72 45 28.5	< 0.13	0.15	< 0.24	0.07	U
B0629−418	Q	1.41	6 31 11.99	−41 54 26.9	< 0.20	0.10	0.33	0.04	U
B0738−674	Q	1.66	7 38 56.49	−67 35 50.8	< 0.11	0.08	< 0.40	0.10	U
B0823−500			8 25 26.86	−50 10 38.4	<−0.13	0.08	< 0.12	0.04	U
B1105−680	Q	0.58	11 7 12.69	−68 20 50.7	< 0.19	0.08	0.53	0.06	U
B1148−671	Q		11 51 13.42	−67 28 11.0	<−0.02	0.06	< 0.08	0.09	U
B1236−684	Q		12 39 46.65	−68 45 30.8	< 0.16	0.09	<−0.05	0.10	U
B1349−439	B	0.05	13 52 56.53	−44 12 40.3	0.50	0.07	0.42	0.07	UT
B1549−790	G	0.15	15 56 58.86	−79 14 4.2	< 0.23	0.09	0.63	0.08	UT
B1610−771	Q	1.71	16 17 49.27	−77 17 18.4	0.60	0.09	1.10	0.11	UT
B1903−802	Q	0.50	19 12 40.01	−80 10 5.9	< 0.05	0.12	0.51	0.09	U
B1925−610	Q		19 30 6.15	−60 56 9.1	< 0.28	0.08	< 0.23	0.07	U
B1935−692	Q	3.15	19 40 25.52	−69 7 56.9	< 0.26	0.08	<−0.20	0.07	U
B1950−613	Q		19 55 10.77	−61 15 19.1	< 0.24	0.08	<−0.05	0.08	U
B2052−474	Q	1.48	20 56 16.35	−47 14 47.6	0.63	0.09	1.19	0.12	UT
B2059−786	Q		21 5 44.96	−78 25 34.5	< 0.11	0.10	< 0.20	0.06	U
B2106−413	Q	1.05	21 9 33.18	−41 10 20.6	1.03	0.09	1.55	0.06	U
B2109−811	G		21 16 30.84	−80 53 55.2	< 0.07	0.14	0.33	0.06	U
B2142−758	Q	1.13	21 47 12.73	−75 36 13.2	< 0.11	0.10	< 0.06	0.08	U
B2146−783	Q		21 52 3.15	−78 7 6.6	< 0.08	0.08	< 0.08	0.05	U
B2152−699	G	0.02	21 57 5.98	−69 41 23.6	0.65	0.09	1.07	0.04	U
B2311−452	Q	2.88	23 14 9.38	−44 55 49.2	<−0.18	0.14	< 0.00	0.07	U
B2353−686	Q	1.71	23 56 0.68	−68 20 3.4	< 0.64	0.16	< 0.08	0.14	U

observations in the different wavebands may distinguish between these mechanisms (e.g. Grandi et al. 1996).

Although inverse-Compton models are generally successful in explaining the spectral energy distributions of blazars, there are sources in which the νF_ν spectra peak strongly in the X-ray region; two of these "MeV blazars" are detected in our survey. One is $J0210-5101$ (Blom et al. 1995), and the other is $J0506-6109$ or $J0522-6107$ (Bloeman et al. 1995) (both mm-detected sources are within the COMPTEL error box, although the former is thought more likely as the source of gamma rays). These MeV–peaking sources can be explained by exotic proton–initiated cascade or electron/positron annihilation mechanisms (e.g. Roland & Hermsen 1995). These authors stress the importance of obtaining VLBI proper motion velocities for these sources which in combination with data on the MeV peak may strongly constrain the jet physical parameters.

A number of the detected blazars have unusual properties which suggest that it would be worth searching for spectral absorption along the line of sight (e.g., Wiklind & Combes 1996a). The source B0438−436 at $z = 2.85$ is one of the highest luminosity sources in the centimeter band (having a flux density of over 7 Jy at 8 GHz), and shows evidence for strong X-ray absorption (Elvis et al. 1992; Serlemitos et al. 1994), implying a significant foreground column density. Fugmann (1988) noted the extremely high apparent luminosity of this object and the fact that it has many more nearby companion galaxies than would be expected by chance, and argued that gravitational lens amplification might be occurring. It is notable that a number of detected mm–absorption systems have been found toward gravitational lenses (Wiklind & Combes 1995, 1997). Three blazar objects ($J0051-4226$, $J2329-4730$, and possibly $J0635-7516$) show evidence for optical/uv absorption lines along the line of sight (Junkkarinen et al. 1991), and these might also be searched for molecular absorption, although searches of such systems have proved unsuccessful to date (Wilkind & Combes 1996a).

Three of our detected sources are classified as galaxies, with their optical continuum luminosity being dominated by starlight. The $z = 0.15$ source B1549 − 790 contains a strong compact radio source and has an optical spectrum showing high ionization emission lines and stellar absorption lines characteristic of an evolved stellar population (Tadhunter et al. 1993). The source J1723 − 6500 is identified with the nearby (approximately 80 Mpc) galaxy NGC 6328, described as high-luminosity elliptical with weak spiral structure (Veron-Cetty et al. 1995); this galaxy is known to be very gas rich, containing over 10^{10} solar masses of HI. Australia Telescope images of this gas have been made by Veron-Cetty et al., who speculate that this galaxy is a recent merger product. Given our detection of a strong millimeter continuum source it will be interesting to probe the gas chemistry by looking for millimeter absorption and emission lines. The central continuum source is interesting in its own right, as both the VLBI morphology and the radio spectrum (which peaks in the gigahertz region) are characteristic of so–called Compact Symmetric Objects (Wilkinson et al. 1994), which are thought to be very young radio sources. The detected 3 mm flux density lies on a smooth extrapolation of the centimeter spectrum and implies a spectral index of −0.7 between 8 GHz and 90 GHz. One detection in our sample (J2336 − 5236) is a known gigahertz-peaked spectrum source (Cersosimo et al. 1994).

The final non-blazar that we have detected is the lobe-dominated FRII source B2152 − 699 at $z = 0.028$. This is one of the brightest objects in the southern sky at centimeter wavelengths, and consists of a compact core straddled by much brighter radio lobes (Fosbury et al. 1990; Norris et al. 1990). The pointing position used was that of the compact core as given by astrometric VLBI observations (Johnston et al. 1995), and at 2 mm in particular most of the extended emission should lie outside of the SEST primary beam. The core has a total flux of 0.82 Jy at 8.4 GHz (Tingay et al. 1996) and hence our 2 and 3 mm flux densities are consistent with a detection of this flat spectrum core. Optical observations of B2152 − 699 show blue optical emission from a patch of gas oriented almost along the initial radio axis (Tadhunter et al. 1987). It has been argued, based on the high optical polarization of this emission (di Serego Alighieri et al. 1988), that this is evidence for reflected non-isotropic optical emission along the radio axis, and that this object is misdirected quasar (although Tingay et al. investigate the alternative explanation of jet/cloud interactions). Optical spectroscopy of the nucleus (Tadhunter et al. 1993) shows only evidence for a stellar continuum with no nonthermal continuum emission, consistent with blocking of the putative quasar nucleus by a dense torus as proposed by the quasar/radio-galaxy unified scheme. There is, however, some weak broad line emission which may indicate that the source orientation and torus geometry is such that part of the broad-line region can be seen. Given our detection of the nucleus at millimeter wavelengths it will be interesting to perform cm and mm spectroscopy to search for absorption from molecular gas in a circumnuclear torus.

5. Conclusions

We have described SEST observations to search for mm-bright southern radio sources. Combined with source samples in the southern equatorial region (Tornikoski et al. 1996), this sample provides a useful first list of sources for making southern hemisphere pointing observations for single dish telescopes. As noted earlier, the noise level appears to be dominated by spatial and temporal atmospheric fluctuations; the planned replacement of the present SEST chopper wheel system with a nutating subreflector may improve the sensitivity of the telescope for continuum observations.

In the longer term, a large sample of calibration sources with mean separations of only a few degrees will be important for phase-calibration of the proposed southern millimeter interferometers (Woody et al. 1995; Holdaway et al. 1994). At present four southern mm interferometers are under development: the NRAO Millimeter Array[1], the European Large Southern Array LSA (Booth 1992, 1996), the Japanese LMSA (Ishiguro et al. 1994), and the mm upgrade of the Australia Telescope Compact Array. Site-testing of various locations in the Chilean Atacama Desert is underway for the first three (latitude −23° S). We note that our survey has identified one pair of bright (approximately 1 Jy at 3 mm) sources with separation of only 2°, i.e. J0506 − 6109/J0522 − 6107. This pair could be used for making further on-site test observations of phase-calibration methods over angular separations of a few degrees using a single–baseline interferometer with relatively small antennas.

From an astrophysical point of view our sample adds to the list of blazars with detected strong millimeter emission. These sources can be added to existing monitoring programs to improve statistics about flux and spectral variability amongst different classes of beamed sources (Tornikoski et al. 1993). We have identified a number of sources which are circumpolar from southern sites and can be observed continuously in search of intra-day variability (Wagner & Witzel 1995) at millimeter wavelengths. As described in Sect. 4, a number of the detected sources show evidence for significant foreground column densities either within the host galaxies or elsewhere along the line of sight; these should be searched for centimeter and millimeter absorption lines. Additionally four of our detected sources lie within 10 degrees of the galactic plane (J1041 − 473, J1145 − 676, J1255 − 714 and J1424 − 681) and can be used to search for cold molecular gas within our galaxy (Liszt 1994).

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[1] http://www.tuc.nrao.edu/mma/mma.html

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References

Blandford R.D., Koñigl A., 1979, ApJ 232, 34

Bloeman H., Bennett K., Collmar W., et al., 1995, A&A 293, L1

Blom J.J., Bennett K., Bloeman H., et al., 1995, A&A 298, L33

Booth R.S., et al., 1989, A&A 216, 315

Booth R.S., 1994, in IAU Colloq. 140 “Astronomy with Millimeter and Submillimetre Interferometry”, Ishiguro M. and Welch J. (eds.) ASP Conf. Ser. 59, 413

Booth R.S., 1996, in “High Sensitivity Radio Astronomy”, Davis R., Jackson N. (eds.). Publ. CUP, 194

Brown L.M.J., et al., 1989, ApJ 340, 129

Cersosimo J.C., Santos M., Cintron S.I., Quiniento Z.M., 1994, ApJS 95, 157

di Serego Alighieri S., Binette L., Courvoisier T.J-L., Fosbury R.A.E., Tadhunter C.N., 1988, Nat 334, 591

Elvis M., Fiore F., Wilkes B., McDowell J., 1994, ApJ 422, 60

Fugmann W., 1988, A&A 204, 73

Fosbury R.A.E., di Serego Alighieri S., Courvoisier T.J-L., et al., 1990, “Evolution in Astrophysics: IUE Astronomy in the Era of Space Missions”, ESA SP 310, 513

Ghisellini G., Madau P., 1996, MNRAS 280, 67

Grandi P., et al., 1996, ApJ 459, 73

Holdaway M.A., Owen F.N., Rupen M.P., 1994, Millimeter Array Memo No. 123, NRAO

Holdaway M.A., Radford S.J.E, Owen F.N., Foster S.M., 1995, Millimeter Array Memo No. 139, NRAO

Ishiguro M., et al., 1994, in IAU Colloq. 140 “Astronomy with Millimeter and Submillimetre Interferometry”, Ishiguro M. and Welch J. (eds.). ASP Conf. Ser. 59

Johnston K.J., et al., 1995, AJ 110, 880

Junkkarinen V., Hewitt A., Burbidge G., 1991, ApJS 77, 203

Liszt H., 1994, ApJ 429, 638

Marscher A.P., Gear W.K., 1985, ApJ 298, 114

Norris R.P., et al., 1990, Proc ASA 8(3), 252

Roland J., Hersen W., 1995, A&A 297, L9

Schieder R., Tolls V., Winnewisser G., 1989, Exper. Astron. 1, 101

Serlemitos P., Yaoob T., Ricker G., Woo J., Kunieda H., 1994, PASJ 46, L43

Tadhunter C.N., Fosbury R.A.E., Binette L., Danzuger I.J., Robinson A., 1987, Nat 325, 504

Tadhunter C.H., Morganti R., di Serego Alighieri S., Fosbury R.A.E., Danziger I.J., 1993, MNRAS 263, 999

Tingay S.J., et al., 1996, AJ 111, 718

Tornikoski M., et al., 1993, AJ 105, 1680

Tornikoski M., et al., 1996, A&AS 116, 157

Ulich B.L., 1980, Astrophys. Lett. 21, 21

Valtaoja E., et al., 1992a, A&A 254, 80

Valtaoja E., et al., 1992b, A&A 254, 71

Veron-Cetty M.-P., Woltjer L., Ekers R.D., Stavely-Smith L., 1995, A&A 297, L79

Wagner S.J., Witzel A., 1995, ARA&A 33, 163

Wiklind T.T., Combes F., 1995, A&A 299, 382

Wiklind T.T., Combes F., 1996a, Nat 379, 139

Wiklind T.T., Combes F., 1997, A&A (in press)

Wilkinson P.N., Polatadis A., Readhead A.C.S., Xu W., Pearson T.J., 1994, ApJ 432, L87

Woody D., Holdaway M., Lay O., Masson C., Owen F., Plambeck D., Radford S., Sutton E., 1995, Millimeter Array Memo No. 144, NRAO

Wright A.E., Otrupcek R., 1990, PKSCAT90 Parkes Radio Sources Catalogue, Version 1.01, Australia Telescope National Facility