VLBA Scientific Memo 42

On P-band Observations with the VLBA

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Abstract

The VLBA has a little-used mode of observation that produces 3 or more spectral windows at 90cm and, optionally, one at 50cm wavelength. For this Memo, three science projects and two data quality observations were examined. The results suggest that, while the VLBA is not particularly sensitive in this mode, useful results can be obtained with some effort.

1 Introduction

In two of the science data sets, the P-band system of the VLBA produced 4 spectral windows, 3 at about 90cm wavelength (0.315, 0.323, 0.331 GHz) and one at about 50cm wavelength (0.607 GHz). Each spectral window is rather narrow (8 MHz total). The outer channels at 50cm have very little amplitude, so the usable bandwidth at 600 MHz is only about 5 MHz. One data set from project BS309 (PI Carlo Stanghellini) was an attempt to observe a "young" radio galaxy with both diffuse and mas-scale emission. It was observed 02 August, 2022 with 16 spectral channels per SPW. The other data set, BG279B at P band, had Neeraj Gupta as PI and sought to map a powerful FRI-type quasar at z=2.1 embedded in an HI halo. It was observed 29 July 2022 with 64 spectral channels per SPW. (Note that the majority of BG279 was observed at C band and not considered here.)

The third science data set produced 4 SPWs all at 90cm (0.31225, 0.32025, 0.32825, 0.33625 GHz). Each has 64 spectral channels separated by 0.125 MHz. Project BM486A (PI Emmanuel Momjian) was an attempt toq resolve an extremely powerful radio-loud quasar at z 5.1. There are two P-band correlation files in the archive, the slightly larger one has "calib" added to the name. Both were examined for this study. The P-band data were observed on 18 February 2019.

The two Data Quality runs used different setups. DQ2318 used 4 MHz bandwidth spectral windows at 320.8, 324.8, 328.8, and 608.8 MHz and only 8 spectral channels per SPW. It was observed on 28 May 2023. The second DQ data set, DQ2229 used two different setups and was observed 4 August 2022. The first data set was similar to BS309, but at frequencies 0.32075, 0.32475, 0.32875, and 0.60875 GHz with 8 spectral channels each 0.5 MHz wide and all 4 polarizations. The second DQ2229 data set had 8 SPWs each with 16 spectral channels 0.5 MHz in width and only the LL correlation. The SPWs ranged from 0.29275 to 0.34875 GHz.

2 DQ2318

The data of DQ2318 consists of a single 6-minute scan on J1642+3948. BR was flagged for sub-reflector focus error for the whole run. Tsys was well behaved for most antennas including BR, but SPWs 3R and 4R at KP, 4R and 4L at LA, 3R at MK, all SPWs at OV are in the kilo or mega Kelvin range. The Tsys at NL appears rather low compared to the others and PT 2R is probably 2 to 3 times too high. The first Tsys value in the

Ant	IF	S	Max	Min	Avg	Rms	Median	Madrms	Station
1	1	1	568.700	427.570	447.719	38.710	436.190	6.627	BR
1	1	2	768.180	360.460	404.492	115.154	368.980	8.836	BR
1	2	1	845.740	388.700	438.342	128.904	397.400	5.515	BR
1	2	2	775.080	354.660	398.332	119.181	360.620	4.181	BR
1	3	1	930.120	438.420	488.756	139.619	445.150	3.543	BR
1	3	2	748.840	348.700	394.030	112.285	360.070	5.234	BR
2	1	1	198.820	155.900	160.163	12.228	156.310	0.489	FD
2	1	2	333.680	165.360	182.007	47.967	167.060	0.489	FD
2	2	1	229.620	144.370	152.518	24.383	144.800	0.385	FD
2	2	2	321.070	154.820	170.817	47.516	156.120	0.371	FD
2	3	1	221.320	140.120	148.133	23.146	140.880	0.356	FD
2	3	2	336.190	158.140	175.111	50.940	159.050	0.415	FD
3	1	1	327.980	253.010	262.195	20.826	255.910	0.756	HN
3	1	2	262.460	161.550	172.675	28.410	163.520	0.904	HN
3	2	1	321.210	198.250	212.689	34.669	200.200	1.735	HN
3	2	2	274.120	167.590	182.088	29.418	171.430	3.202	HN
3	3	1	315.600	191.680	205.334	34.938	194.140	3.321	HN
3	3	2	323.560	195.070	211.628	35.549	200.300	3.721	HN
4	1	1	315.020	300.840	306.398	3.849	306.610	3.173	KP
4	1	2	215.630	177.950	187.335	9.496	185.570	4.566	KP
4	2	1	293.560	281.110	288.189	3.581	288.800	4.285	KP
4	2	2	211.180	171.880	179.264	10.221	175.930	0.652	KP
4	3	1	16835.551	-12107.420	1721.965	6441.223	706.700	209.862	KP
4	3	2	502.380	242.990	323.515	83.424	276.690	49.964	KP
5	1	1	173.860	149.650	157.419	7.062	155.140	4.700	LA
5	1	2	232.190	164.940	182.452	18.411	177.500	12.869	LA
5	2	1	163.780	149.300	153.927	3.689	152.770	2.135	LA
5	2	2	190.550	165.780	174.249	6.913	172.160	7.265	LA
5	3	1	153.690	143.530	147.404	2.452	146.860	1.156	LA
5	3	2	160.010	154.650	156.797	1.449	156.680	1.557	LA
6	1	1	188.750	184.490	186.662	1.353	186.470	1.853	MK
6	1	2	181.360	164.720	178.045	4.525	179.860	1.957	MK
6	2	1	180.030	171.570	174.798	2.062	174.510	1.497	MK
6	2	2	168.790	159.050	166.380	2.479	166.980	1.186	MK
6	3	1	1015.250	-24024.250	-2711.075	7206.197	149.280	102.863	MK
6	3	2	579.520	128.480	261.925	146.817	181.060	77.955	MK
7	1	1	53.340	52.250	52.517	0.337	52.360	0.133	NL
7	1	2	62.820	60.910	61.355	0.547	61.270	0.519	NL
7	2	1	58.410	57.360	57.754	0.278	57.670	0.208	NL
7	2	2	50.790	49.580	49.905	0.339	49.780	0.119	NL
7	3	1	79.720	66.470	71.269	4.630	68.660	3.247	NL
7	3	2	50.610	47.830	49.075	1.042	48.730	1.201	NL
8	1	1	4.661E+06	-2.132E+05	7.810E+05	1.508E+06	-8.716E+04	1.868E+05	OV
8	1	2	2.677E+06	-5.652E+05	1.607E+05	8.126E+05	-5.513E+04	4.964E+04	OV
8	2	1	2.120E+05	-6.668E+05	-7.491E+03	2.238E+05	4.853E+04	5.269E+04	OV
8	2	2	57963.398	5941.480	11303.144	14769.761	6356.990	437.056	OV
8	3	1	5.909E+04	-1.351E+06	-1.237E+05	3.899E+05	-1.213E+04	5.378E+04	OV
8	3	2	5277.320	1453.700	2056.893	1031.776	1761.030	195.184	OV
9	1	1	521.780	488.650	505.247	10.120	508.380	7.976	PT
9	1	2	152.640	141.820	144.613	2.748	143.680	1.023	PT
9	2	1	933.840	859.060	891.015	21.627	891.770	22.684	PT
9	2	2	168.530	159.460	161.752	2.294	161.340	1.171	PT
9	3	1	467.160	432.940	445.140	8.544	444.270	4.804	PT
9	3	2	147.360	139.450	141.235	2.043	140.800	0.726	PT
10	1	1	318.800	203.240	214.802	32.892	204.520	0.608	SC
10	1	2	439.280	267.850	289.149	47.530	275.100	1.927	SC
10	2	1	394.830	258.200	272.390	38.728	260.190	0.979	SC
10	2	2	373.190	230.680	246.168	40.180	233.420	1.156	SC
10	3	1	557.260	363.990	386.746	53.962	370.420	1.023	SC
10	3	2	316.300	198.450	210.234	33.548	199.910	0.979	SC

Table 1: `SNRMS` output for `TY` table from DQ2318 90cm

Ant	IF	S	Max	Min	Avg	Rms	Median	Madrms	Station
1	4	1	517.790	356.590	377.753	46.219	359.880	2.728	BR
1	4	2	338.880	212.800	228.135	35.296	215.950	1.231	BR
2	4	1	171.670	145.210	149.670	8.689	145.860	0.237	FD
2	4	2	290.720	190.470	201.344	28.584	190.950	0.178	FD
3	4	1	200.040	176.670	180.993	6.105	179.580	0.549	HN
3	4	2	303.800	283.840	287.307	5.437	285.680	1.527	HN
4	4	1	3303.100	2201.040	2919.975	282.383	2949.030	268.099	KP
4	4	2	270.420	235.340	245.305	11.915	240.400	6.123	KP
5	4	1	73068.609	4039.070	19837.856	19883.385	10080.440	6922.290	LA
5	4	2	92872.391	8227.940	29050.471	25655.782	17613.340	12113.643	LA
6	4	1	234.650	159.340	167.745	21.204	161.580	2.239	MK
6	4	2	205.940	174.040	180.062	8.503	176.920	2.268	MK
7	4	1	159.820	69.340	110.214	27.955	106.180	32.395	NL
7	4	2	129.070	63.180	92.764	20.246	88.230	25.619	NL
8	4	1	1.269E+05	-2.807E+05	-7.286E+03	9.944E+04	2.657E+04	6.640E+04	OV
8	4	2	-2453.920	-5757.320	-3810.953	804.721	-3839.210	536.360	OV
9	4	1	180.320	162.100	165.164	5.444	162.690	0.860	PT
9	4	2	223.610	203.170	211.504	5.048	211.170	2.950	PT
10	4	1	306.560	295.000	298.484	3.201	298.390	2.224	SC
10	4	2	339.540	296.920	304.431	11.348	301.530	3.573	SC

Table 2: `SNRMS` output for `TY` table from DQ2318 50cm

scan was quite a bit higher than the others for several antennas. The Tsys values are summarized using `SNRMS` in Table 1 and Table 2.

Examining autocorrelation data for evidence of RFI we find spikes at KP SPW 3 R and L channel 7 (0.3318), MK SPW 3 R and L channel 4 (0.3303), NL SPW 3 R and L channel 8 (0.3323), and PT SPW 1 L channels 2 and 3 (0.321.3, 0.321.8). BR was flagged, SC had no valid autocorrelations, and OV lost all of R and SPW 1 L also. OV SPW 2 L may have RFI in channels 7 and 8 (0.3278, 0.328.3). No spikes were seen in the 50cm data. The autocorrelation signals are quite variable over time for KP SPW 3 and moderately variable for MK SPW 3 and OV SPW 1.

The target source was well detected on all baselines with those to OV being rather noisy and with considerable evidence of resolution by the longest baselines. Delay and bandpass calibration did not seem to be called for. After standard VLBI calibration (with an edited `TY` table) and `SPLIT`, `CALIB` run with a point source at the origin converged on almost all solutions. Self-cal started with Clean flux density of 4.1 Jy, rose to 4.7 and, with amplitude and phase, dropped to 3.34 Jy. The image rms began at 0.110 Jy/beam and dropped to 0.017 Jy/beam.

3 DQ2229a

The first of the DQ2229 data sets consists of a single 6-minute scan on J2148+0657 with three SPWs at about 90cm and one at 50 cm. BR is flagged over the full time for sub-reflector focus error and KP is missing. The source is well detected on all baselines with evidence of resolution on baselines to MK and SC at 90cm. Autocorrelations at 90 cm show RFI at 330 MHz at MK in both polarizations, at the highest frequency at NL both polarizations, and a weaker signal above 320 MHz at PT in L polarization. No obvious RFI is found in the limited 50cm data.

Tsys is relatively normal except LA at 50cm (Mega K) and PT SPW 2R (kilo K). MK is high at SPW 3 and NL oddly low except SPW 3L and 50cm. Without fixing any Tsys, the data responded to the normal calibration sequence as one would hope. After `SPLIT`, `CALIB` was run with a point source at the origin to obtain an initial phase calibration. Imaging at 90 cm then produced a Clean flux density of 3.93 Jy with image noise of 0.017 Jy/beam reduced to 0.008 Jy/beam with amplitude and phase self-cal. At 50 cm, self-cal raised the

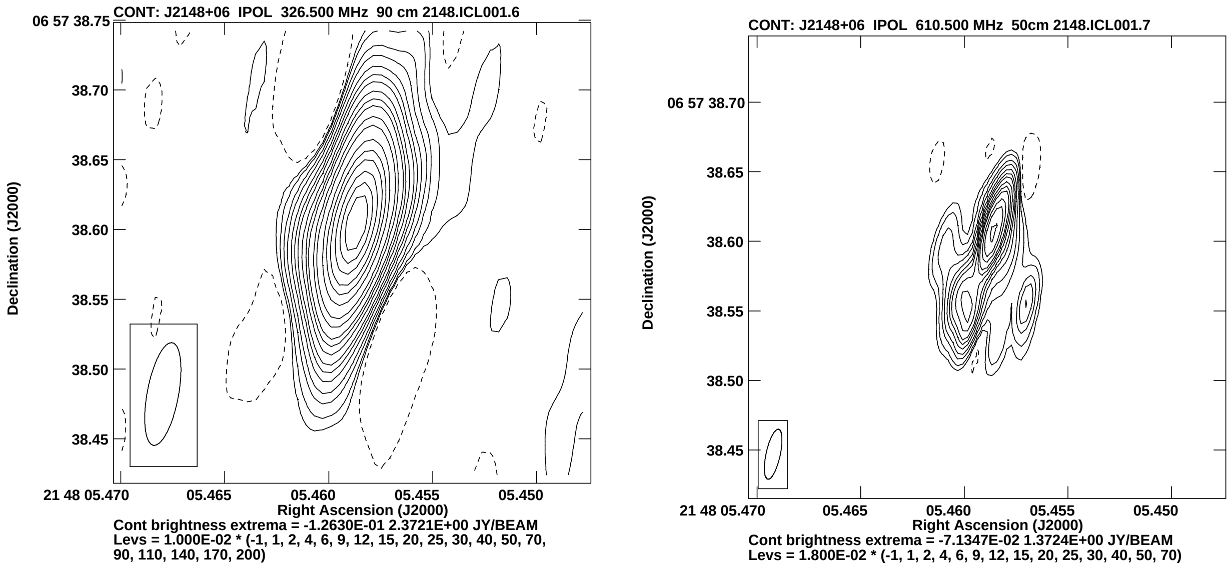

Figure 1: J2148+0657 self-cal images at 90cm (left) and 50cm (right). Note that self-cal forces the brightest point in the source to the center of the image. The apparent alignment of the two images should therefore not be believed.

total flux density slightly to 3.83 Jy while reducing the noise from 0.011 Jy/beam to 0.006 Jy/beam. The resulting images are shown in Figure 1.

4 DQ2229b

The second of the DQ2229 data sets consists of two 3-minute scans on J2253+1608 with eight SPWs at about 90cm spanning 64 MHz in LL polarization. The response is weak in SPW 1 and the last 6 channels in SPW 8, making the useful bandwidth 53 MHz. BR has useful data in this data set and KP is still missing. RFI makes a mess of SPWs 6 and 7, centered on 340 MHz, at LA. SPW 5 around 330 MHz is bad at MK, NL has an RFI spike just above 330 MHz, OV has RFI spikes throughout, and PT has an RFI spike at 300 MHz. The other antennas' autocorrelations are relatively clean. OV is relatively clean in the first data set and a terrible mess in this immediately following data set.

Tsys in SPW 1 is very high (kilo K) on all antennas. SPW 8 tends to be higher than the other SPWs on all antennas. PT has high and quite variable Tsys and OV has mega K of both signs. SPW 7 at LA has a bad point (-49 kilo K). `UVFLG` was used to flag all of SPW 1, the highest 6 channels in SPW 8, and all of OV. `SNEDT` was used to flag bad Tsys values before they were used in calibration. Standard calibration was done except that `FRING` was told to get a single solution covering all SPWs at the `VLBAMPCL` step. The data were `SPLIT` and then made phase coherent with a point source at the origin by `CALIB`. Self-cal imaging changed the total flux density from 9.8 Jy to 10.6 Jy, with the noise going from 0.085 Jy/beam to 0.025 Jy/beam. The source is somewhat extended to the northwest as seen in Figure 2.

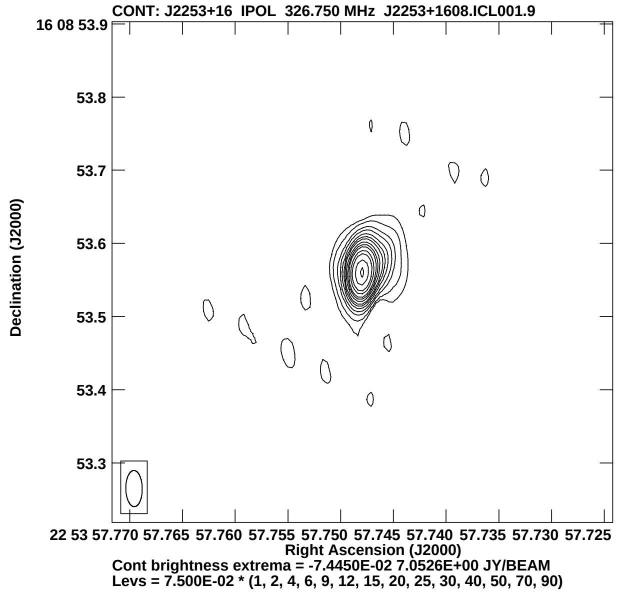

Figure 2: J2253+1608 self-cal images at 90cm.

5 BS309

BS309 was observed on August 2, 2022. Primary calibration sources were 4C39.25, 3C273, J1331+3030 (3C286), 3C345, and 1358+624. The phase reference source J1408+2831 was observed with 2 different source numbers while the target source was OQ208. The standard frequency setup was used with 16 0.5-MHz spectral channels per SPW. Antenna 2 was Effelsberg and did not have Tsys values. It was ignored.

Examining the Tsys tables at 90cm, seriously corrupt values are found for BR SPW 1 R and L, all SPWs for MK and OV, and all R SPWs and 3L for PT. `SNEDT` may be used to flag out the bad values leaving generally reasonable Tsys. Serious time-dependent disturbances in Tsys are seen for MK SPW 2 R and L, NL, PT, and SC after the editing. At 50cm, LA and OV have bad values in R and L, NL has bad values only in R. `SNEDT` leaves almost no values for LA and flags the last several hours of OV. The Tsys values *after flagging* are summarized using `SNRMS` in Table 3 and Table 4.

`VBRFI` is a task designed to examine autocorrelation spectra for evidence of RFI. It determines the mean and rms as a function of spectral channel in each scan and polarization. It then sums across scans and polarizations to determine the mean autocorrelation, rms, and rms/mean spectra. A sample from the 90cm data set is plotted in Figure 3. Note the RFI signal in both the autocorrelation and the time variability at 319.25 and 328.25 MHz. SPW 3 is poorly behaved and apparently variable in time. BR, LA, and OV show clear RFI signals as well. There seems to be little RFI in the 50cm data. A possible signal is seen at 610 MHz at OV. Note that spectral channels 1 - 3, and 14-16 in the 50cm data set have essentially zero amplitude and have been flagged at the start.

I then attempted to calibrate these data. Using one scan on 3C286, `VLBAMPCL` converged on all antennas and polarizations except HN L polarization which failed at both 50cm and 90cm. The bandpass computation failed for 50cm HN L polarization. `FRING` was then run separately for each source. At 50 cm, it failed about 88% of the time on 4C39.25, J1408+2831, and OQ208. 50% on 1358+624, 39% on 3C345, 29% on 3C286, and 7% on 3C273. At 90cm, `FRING` converged for most of the possible solutions for 3C273, 3C345, J1331+3030 and 1358+624, but failed for 88% or more for J1408+2831 and OQ208. `CALIB` with a simple point source at the origin was tried for J1408+2831 but the solutions failed 90% of the time. 4C39.25 is normally a good VLB calibrator, but it was the first scan (only) in this data set and a total failure for calibration.

Ant	IF	S	Ngood	Max	Min	Avg	Rms	Median	Madrms	Nblank	Station
1	1	1	786	250.340	198.870	211.542	7.634	209.480	4.033	4	BR
1	1	2	784	200.240	162.190	172.622	8.558	168.800	3.692	6	BR
1	2	1	790	214.930	164.980	181.849	3.933	181.410	2.298	0	BR
1	2	2	778	164.630	145.950	156.426	2.464	156.180	2.402	12	BR
1	3	1	784	216.050	184.220	200.477	3.730	200.060	2.906	6	BR
1	3	2	790	189.300	150.390	165.530	3.705	165.080	2.921	0	BR
3	1	1	785	184.750	161.060	173.139	2.499	173.060	1.646	0	FD
3	1	2	785	207.660	175.710	191.504	3.335	192.000	3.054	0	FD
3	2	1	774	165.300	143.710	157.392	2.414	157.390	2.135	11	FD
3	2	2	785	236.520	160.370	174.871	3.897	174.890	1.957	0	FD
3	3	1	770	177.780	151.450	163.473	2.589	163.310	2.135	15	FD
3	3	2	773	204.770	171.300	187.401	3.445	187.900	2.506	12	FD
4	1	1	784	313.870	283.930	293.998	3.587	293.500	2.817	6	HN
4	1	2	775	194.560	158.980	165.312	3.086	164.770	2.001	15	HN
4	2	1	783	224.380	195.470	205.990	3.820	205.470	3.039	7	HN
4	2	2	769	193.130	147.870	172.055	4.315	171.160	3.321	21	HN
4	3	1	786	243.750	188.090	202.415	6.287	201.090	4.789	4	HN
4	3	2	769	221.480	179.000	194.064	6.031	193.230	5.397	21	HN
5	1	1	788	251.110	131.450	173.021	14.497	171.100	10.601	0	LA
5	1	2	788	290.780	138.910	182.291	17.347	179.820	11.535	0	LA
5	2	1	788	205.540	130.180	164.232	9.200	163.350	6.642	0	LA
5	2	2	788	262.830	139.620	182.975	11.675	181.850	8.125	0	LA
5	3	1	788	204.050	122.690	159.914	12.233	158.010	11.342	0	LA
5	3	2	788	313.120	135.740	186.720	20.594	182.880	18.088	0	LA
6	1	1	543	228.860	129.400	169.502	6.709	169.960	4.166	5	MK
6	1	2	537	180.670	113.780	158.710	6.014	158.660	3.929	11	MK
6	2	1	477	295.840	126.980	177.024	34.139	166.150	26.657	71	MK
6	2	2	417	286.690	123.400	175.748	36.278	164.910	27.250	131	MK
6	3	1	536	145.260	116.190	129.763	4.697	129.090	3.366	12	MK
6	3	2	539	173.110	126.790	144.395	6.379	143.500	4.804	9	MK
7	1	1	762	56.530	51.350	53.209	0.928	53.050	0.875	28	NL
7	1	2	749	56.730	52.280	53.644	0.769	53.580	0.845	41	NL
7	2	1	775	69.890	56.400	58.849	2.342	58.050	1.334	15	NL
7	2	2	767	65.150	52.950	55.416	2.104	54.810	1.231	23	NL
7	3	1	744	134.580	54.380	72.099	18.518	63.720	8.718	46	NL
7	3	2	747	103.920	45.230	60.436	14.118	54.390	8.377	43	NL
8	1	1	521	197.400	147.580	162.768	8.161	162.460	9.207	265	OV
8	1	2	528	198.200	146.580	158.319	8.617	156.160	6.271	258	OV
8	2	1	541	207.110	130.340	141.055	8.049	139.710	6.583	245	OV
8	2	2	542	257.870	137.210	150.508	13.287	148.510	6.701	244	OV
8	3	1	546	201.790	130.990	140.194	7.741	139.160	5.841	240	OV
8	3	2	546	261.520	144.160	158.544	11.024	157.550	7.962	240	OV
9	1	1	720	510.330	152.350	373.727	52.852	374.550	45.768	51	PT
9	1	2	752	260.450	118.670	196.214	17.939	197.510	15.241	19	PT
9	2	1	754	848.800	225.740	520.489	105.413	490.900	94.249	17	PT
9	2	2	746	220.480	96.560	166.429	15.106	164.540	13.195	25	PT
9	3	1	736	355.980	150.220	218.959	44.614	202.780	30.897	35	PT
9	3	2	752	325.370	120.300	197.509	27.540	191.330	22.906	19	PT
10	1	1	785	255.900	216.060	230.101	6.554	227.940	2.891	5	SC
10	1	2	785	359.780	259.090	324.044	9.056	322.110	4.136	5	SC
10	2	1	784	218.480	188.040	201.143	4.689	199.970	2.387	6	SC
10	2	2	787	255.420	222.080	236.833	4.898	236.370	5.056	3	SC
10	3	1	782	239.240	214.640	222.305	4.482	220.700	1.156	8	SC
10	3	2	787	218.420	182.310	191.832	6.324	189.430	1.142	3	SC

Table 3: `SNRMS` output for `TY` table from BS309 90cm

Ant	IF	S	Ngood	Max	Min	Avg	Rms	Median	Madrms	Nblank	Station
1	4	1	790	274.400	239.230	255.741	5.100	255.970	5.323	0	BR
1	4	2	790	167.730	147.810	157.802	2.371	157.520	2.209	0	BR
3	4	1	785	173.530	159.560	165.449	1.447	165.560	1.112	0	FD
3	4	2	785	234.660	212.090	221.655	1.969	221.790	1.349	0	FD
4	4	1	790	220.510	192.890	206.460	2.648	206.450	2.506	0	HN
4	4	2	775	374.270	324.010	339.685	4.561	339.820	3.914	15	HN
5	4	1	247	670.230	164.090	332.664	147.725	302.870	171.285	541	LA
5	4	2	135	402.830	150.460	251.269	67.387	227.410	67.162	653	LA
6	4	1	548	182.100	161.240	170.622	4.369	170.600	4.685	0	MK
6	4	2	548	198.540	173.010	183.039	4.670	183.130	4.878	0	MK
7	4	1	732	257.070	99.670	170.598	29.223	165.550	26.464	58	NL
7	4	2	789	301.730	43.690	102.631	27.860	94.910	22.120	1	NL
8	4	1	546	190.350	117.740	128.312	5.897	127.270	3.988	240	OV
8	4	2	544	174.330	111.820	122.230	5.421	120.960	4.789	242	OV
9	4	1	771	336.400	143.950	207.646	16.216	207.400	7.917	0	PT
9	4	2	771	417.200	127.260	196.524	19.848	193.830	8.139	0	PT
10	4	1	789	464.180	263.350	293.674	36.320	280.890	5.471	1	SC
10	4	2	790	653.170	318.950	372.167	65.852	347.590	17.865	0	SC

Table 4: `SNRMS` output for `TY` table from BS309 50cm

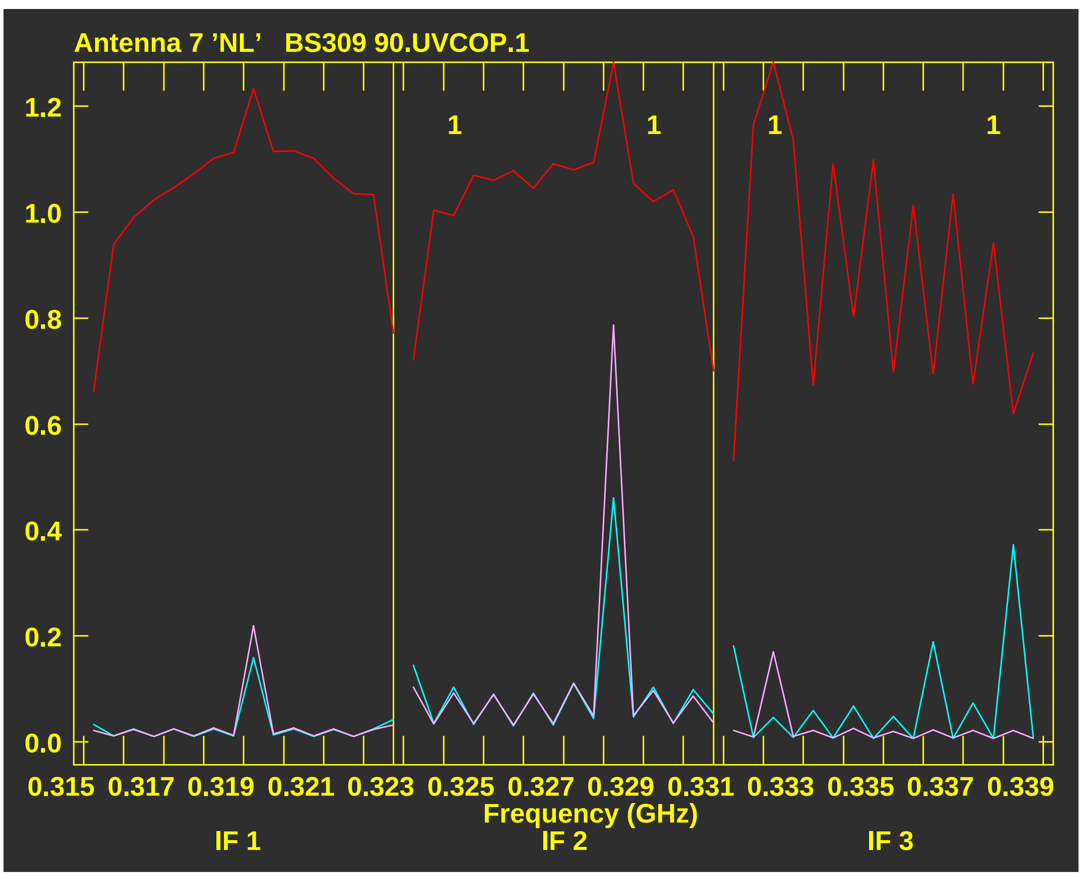

Figure 3: `VBRFI` plot for antenna NL SPWs 1 through 3. The mean autocorrelation is in red, mean rms in pink, and mean rms/mean in cyan. Data are from primary calibration sources only.

Source	flux 90cm init	flux 90cm selfcal	rms 90cm init	rms 90cm selfcal	flux 50cm init	flux 50cm selfcal	rms 50cm init	rms 50cm selfcal
J1331+3030	15.7	17.6	0.24	0.045	8.3	13.0	0.239	0.048
3C273	12.7	12.6	0.34	0.041	18.2	29.0	0.838	0.094
3C345	3.2	3.6	0.044	0.020	4.37	4.83	0.040	0.015
1358+624	4.9	5.8	0.038	0.007	6.09	6.20	0.029	0.0075

Table 5: Clean flux densities and rmses initially and after self-cal

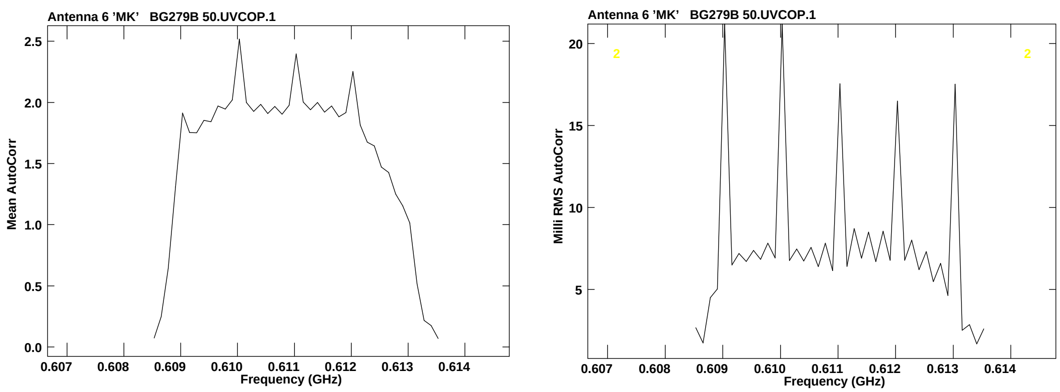

Figure 4: `VBRFI` plot for antenna MK at 50cm in BG279B. The average autocorrelation spectrum is plotted at left and the rms spectrum is plotted at right.

The four primary calibrators were `SPLIT`, producing data sets with only half to two thirds as many visibility samples as in the input data set. They were then imaged and run through several rounds of self-cal. The Cleaned flux densities and rms for each are summarized in Table 5. Two methods were tried to deal with the bad Tsys values. In one, the bad values were flagged causing the associated data to be flagged. In the other, the bad values were replaced by apparently good values from nearby times. Imaging with the latter produced lower flux densities, suggesting that the data are bad when the Tsys are bad.

6 BG279B

The BG279B data set had the same 4 SPWs as BS309, but each SPW had 64 spectral channels each 0.125 MHz wide. Nine VLBA antennas were used, KP was missing. The source list was 3C273 as a primary calibrator, J1512-0905 as the phase reference calibrator, and J1538-1510 as the target source. At 50cm, the edge channels have little or no signal. Channels 1 through 14 and 56 through 64 were flagged at the beginning. At 50cm, the delays were apparently quite small. At 50cm, Tsys values reached Mega K for LA and IV, Kilo K for NL, and were quite time variable for SC. `SNEDT` was used to flag the bad values. RFI was seen in all 50cm autocorrelations except NL. The spikes were every MHz and are due to the pulse cal presumably. They are illustrated in Figure 4. This "RFI" is not seen in the cross-correlation data.

At 90cm, the Tsys are sensible except for MK SPW 3, PT SPW 2R and all of OV. The Tsys values *after flagging* are summarized using `SNRMS` in Table 6 and Table 7. The autocorrelation spectra at 90cm show a variety of spikes some of which are not due to the pulse cal. They are illustrated in Figure 5, where SC is omitted since it had no serious RFI spikes. SPW 3 L had some serious oscillations in some antennas. To illustrate this more clearly in Figure 6, the rms spectra from the autocorrelation data do show affects of the pulse cal but also significant time variability of actual RFI.

Ant	IF	S	Ngood	Max	Min	Avg	Rms	Median	Madrms	Nblank	Station
1	1	1	496	274.460	206.600	251.430	7.268	250.130	4.729	9	BR
1	1	2	488	220.280	192.670	205.462	4.354	204.740	3.529	17	BR
1	2	1	505	238.370	213.550	228.949	3.848	229.150	2.802	0	BR
1	2	2	505	198.700	175.290	191.275	3.355	191.460	3.099	0	BR
1	3	1	505	237.260	210.660	224.423	4.300	225.010	3.959	0	BR
1	3	2	505	194.680	175.540	188.180	3.440	188.530	2.417	0	BR
2	1	1	504	199.130	177.470	188.591	2.851	188.450	2.550	4	FD
2	1	2	503	231.830	201.270	211.361	3.953	210.890	3.736	5	FD
2	2	1	507	186.710	169.720	178.156	2.843	177.990	2.684	1	FD
2	2	2	507	206.160	186.460	194.508	3.065	194.080	2.876	1	FD
2	3	1	507	181.850	165.310	172.838	2.637	172.340	1.957	1	FD
2	3	2	507	208.480	190.110	198.396	3.016	197.790	2.861	1	FD
3	1	1	521	385.700	304.080	324.351	11.410	322.040	7.354	0	HN
3	1	2	509	233.900	168.890	186.402	9.605	184.540	6.212	12	HN
3	2	1	521	295.590	231.290	242.744	10.466	239.520	4.685	0	HN
3	2	2	509	232.520	167.760	182.449	10.434	178.790	4.003	12	HN
3	3	1	521	293.030	210.690	230.501	13.145	226.950	8.036	0	HN
3	3	2	509	275.020	192.650	215.071	13.338	212.070	8.065	12	HN
5	1	1	493	239.630	142.440	189.546	15.152	189.280	12.498	15	LA
5	1	2	508	278.310	146.470	190.274	14.403	188.220	9.741	0	LA
5	2	1	508	276.960	134.820	181.392	14.164	179.430	9.237	0	LA
5	2	2	508	310.880	158.740	206.414	21.291	203.490	13.862	0	LA
5	3	1	508	395.160	130.090	190.814	36.991	180.470	21.572	0	LA
5	3	2	508	308.310	155.390	202.403	24.910	197.800	23.840	0	LA
6	1	1	482	219.190	178.110	194.898	4.449	194.950	2.328	0	MK
6	1	2	482	212.640	174.620	187.912	4.882	187.500	2.906	0	MK
6	2	1	482	207.860	160.640	176.983	4.305	176.770	2.209	0	MK
6	2	2	482	199.890	154.460	170.352	4.042	170.380	1.913	0	MK
6	3	1	413	297.830	129.870	170.571	37.448	156.240	23.588	69	MK
6	3	2	372	317.250	117.720	175.093	37.521	161.550	19.392	110	MK
7	1	1	516	115.140	50.840	60.453	4.555	59.370	0.608	0	NL
7	1	2	516	107.710	38.480	54.461	4.112	53.620	1.053	0	NL
7	2	1	516	78.920	60.520	63.633	2.290	63.080	0.667	0	NL
7	2	2	516	101.350	60.770	65.276	4.997	63.760	0.845	0	NL
7	3	1	516	85.860	60.910	65.865	4.893	63.660	2.921	0	NL
7	3	2	516	146.460	49.170	63.070	16.843	55.820	8.021	0	NL
8	1	1	457	228.100	175.670	201.795	7.080	200.610	5.026	49	OV
8	1	2	458	213.770	179.760	194.066	4.318	194.480	3.944	48	OV
8	2	1	455	199.730	154.890	174.746	6.484	174.430	5.456	51	OV
8	2	2	454	189.760	163.650	179.631	3.678	179.870	2.654	52	OV
8	3	1	458	181.010	149.580	162.632	4.745	161.640	3.573	48	OV
8	3	2	455	196.700	165.220	177.452	3.902	177.750	3.410	51	OV
9	1	1	506	347.160	279.190	318.500	14.808	314.710	13.699	0	PT
9	1	2	506	274.880	223.050	250.106	7.073	250.040	3.558	0	PT
9	2	1	493	528.880	341.380	421.197	38.023	411.440	31.164	13	PT
9	2	2	506	206.250	162.240	179.480	8.252	180.850	8.555	0	PT
9	3	1	506	267.400	206.980	236.793	12.078	240.210	10.289	0	PT
9	3	2	506	175.660	149.010	158.750	4.251	159.590	2.980	0	PT
10	1	1	477	287.170	225.540	259.522	10.598	257.800	12.128	31	SC
10	1	2	508	503.240	334.560	376.278	29.798	366.670	21.038	0	SC
10	2	1	508	330.870	214.630	240.865	12.869	238.800	10.438	0	SC
10	2	2	508	395.090	261.270	288.331	17.383	284.910	13.418	0	SC
10	3	1	508	301.480	211.030	225.068	9.980	223.200	7.517	0	SC
10	3	2	508	346.590	194.010	216.287	16.998	211.930	15.730	0	SC

Table 6: `SNRMS` output for `TY` table from BG279B 90cm

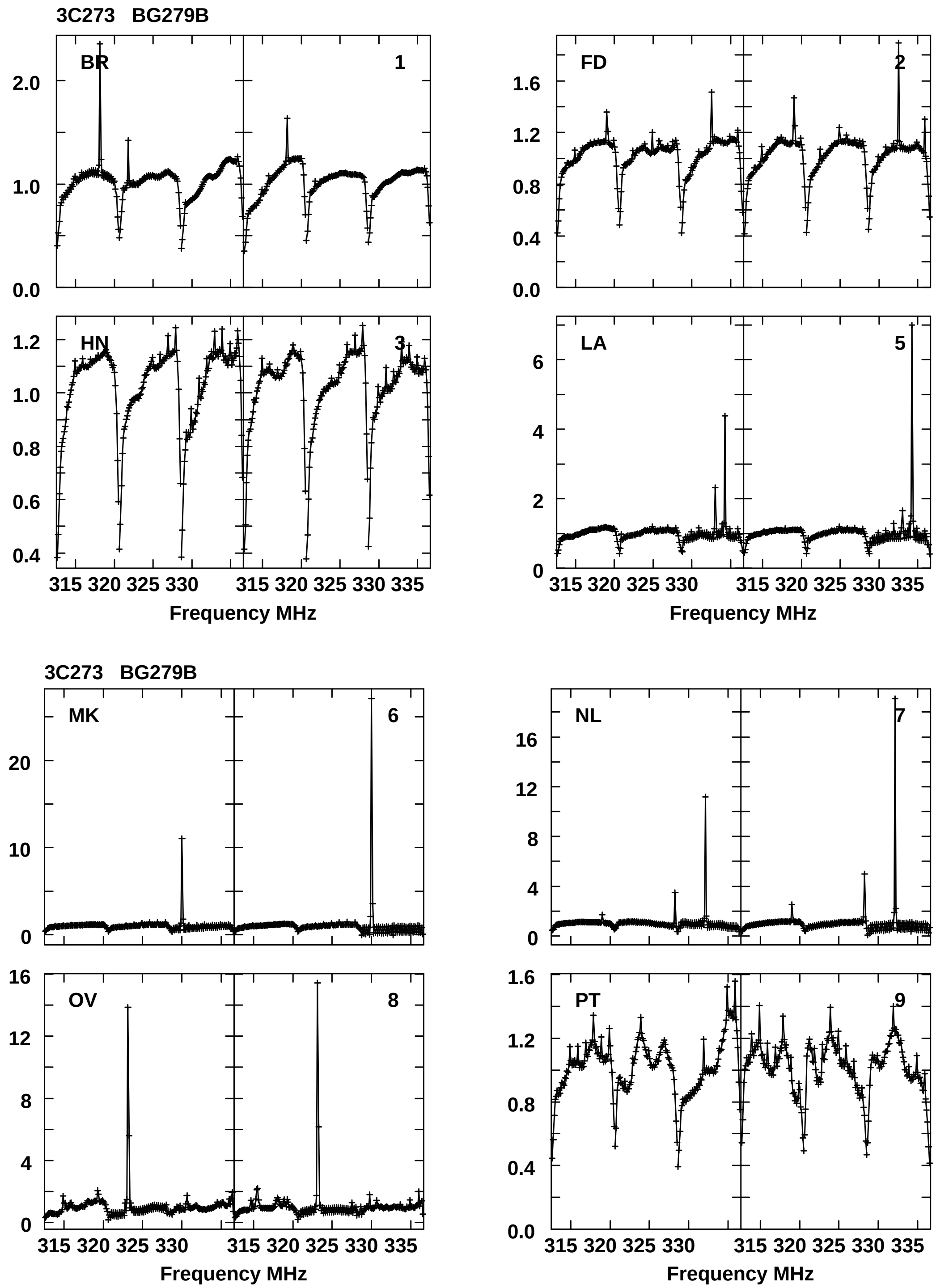

Figure 5: `POSSM` autocorrelation spectra for 3C273 at 90cm in BG279B for all antennas except SC.

Ant	IF	S	Ngood	Max	Min	Avg	Rms	Median	Madrms	Nblank	Station
1	1	1	505	288.320	262.490	273.049	4.988	272.110	3.884	0	BR
1	1	2	505	180.500	163.990	171.368	2.744	171.420	2.965	0	BR
2	1	1	508	171.050	156.170	161.728	2.574	161.170	2.698	0	FD
2	1	2	508	227.190	204.750	213.288	3.931	212.200	4.166	0	FD
3	1	1	517	284.710	207.720	228.088	9.851	224.780	5.930	4	HN
3	1	2	501	427.250	352.260	371.594	14.175	366.650	9.207	20	HN
5	1	1	253	721.200	155.180	290.950	139.956	239.270	91.165	255	LA
5	1	2	119	500.590	165.410	301.653	97.305	278.190	113.730	389	LA
6	1	1	482	198.410	169.910	179.666	5.452	178.530	4.893	0	MK
6	1	2	482	204.170	175.120	186.356	5.384	185.310	4.655	0	MK
7	1	1	490	184.740	142.140	153.514	7.685	150.410	3.202	26	NL
7	1	2	483	154.810	74.220	85.793	14.251	79.630	4.196	33	NL
8	1	1	458	141.170	128.900	135.380	2.676	135.130	3.380	48	OV
8	1	2	459	136.540	123.340	128.238	2.737	127.810	3.277	47	OV
9	1	1	506	218.490	201.860	207.464	2.672	206.880	1.898	0	PT
9	1	2	506	200.970	177.080	184.904	4.748	183.110	3.143	0	PT
10	1	1	508	472.430	263.720	301.737	38.776	287.550	14.633	0	SC
10	1	2	508	629.560	304.130	381.012	64.166	358.450	40.356	0	SC

Table 7: `SNRMS` output for `TY` table from BG279B 50cm

Calibration of BG279B proceeded more or less normally. At 90cm, `FRING` had 143 good solutions on 3C273 with 7 failures. J1512-0905 had 1143 good solutions with 69 failures. The target source J1538-1510 even succeeded two thirds of the time. At 90 cm, imaging of 3C273 started with a Clean flux density of 11.5 Jy which became 12.6 Jy after a number of rounds of self-cal in agreement with the flux density found in BS309. The image rmses went from 0.153 Jy/beam to 0.032 Jy/beam after self-cal. J1512-0905 had 1.25 to 1.32 Jy Cleaned flux density with rms 0.008 to 0.002 Jy/beam. Applying the `FRING` solutions of J1512-0905 to the target did not allow the target to be detected. Applying `CALIB` to the target source with simply a point at the center got phase solutions for all but 0.1% of the samples. Imaging from there found two sources in the field with total flux density that went from 0.37 Jy to 0.49 but then dropped with amplitude/phase self-cal to 0.34 Jy. The image rms went 0.0019 to 0.00026 Jy/beam. It is shown in Figure 7.

At 50cm, `FRING` essentially failed completely and normal "calibrated" output files had no visible sources. Using `CALIB` with phase only on the two calibration sources, about 90% of the possible solutions succeeded. Running `SPLIT` with this calibration, imaging of 3C273 worked rather well. The Cleaned flux density started as 19.9 Jy and was reduced to 17.6 Jy by 2 rounds of amplitude and phase self-cal. This is quite different from the flux density at 50 cm found in BS3909. The image rms started at 0.564 Jy/beam and dropped to 0.104 in the last round. Calibrator J1512-0905 had cleaned flux density of 1.27 Jy, rising to 1.40 Jy with self-cal. The image rms was 0.016 Jy/beam which dropped to 0.0068 Jy/beam with the amplitude self-cal. The target source was not detected in the `SPLIT` output file and `CALIB` was not able to get a solution for a point source at the origin (87% of the solutions failed).

7 BM486A

BM486A was observed on 18 February 2019 with primary calibrator 3C273, phase calibrator J1258-2219, and target source J1314-2020. Four SPWs were observed, all at roughly 90cm wavelength. Tsys values were mostly reasonable except for SPWs 3 and 4 at KP and LA. Examining the Tsys statistics in Table 8 and Table 9 suggests that the noise tube calibration at P band is suspect. NL is way too low for all SPWs while at PT the scales of the two polarizations differ by more than a factor of 2. For most antennas, the plots of Tsys versus time are rather similar in all SPWs and polarizations, but the quoted scales are often rather different. This problem may also be seen in the other data sets examined here.

The initial calibration of BM486 went normally with an edited Tsys table and 3C273 as the calibration source.

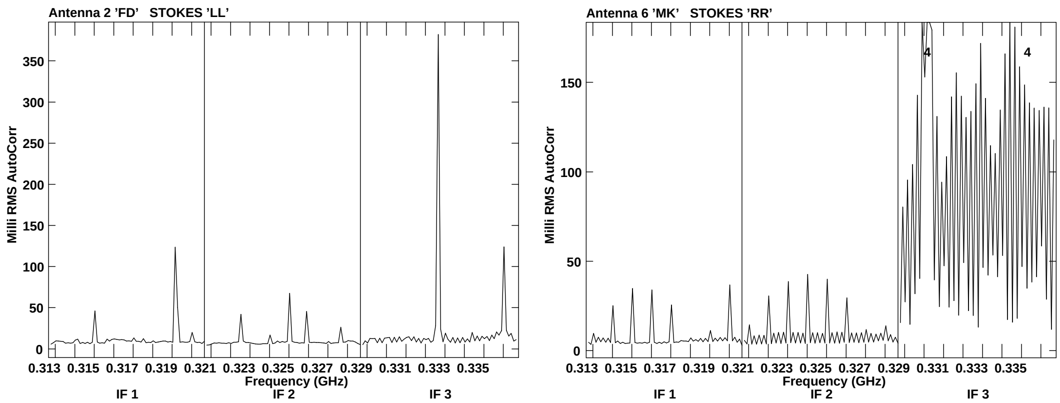

Figure 6: `VLBRF` autocorrelation rms spectrum at 90cm in BG279B for 2 antennas. The left plot shows the full range of values in LL polarization while the right plot shows a limited range of values in RR polarization. The rmses in LL on MK were similar with higher values. The actual peak rms at MK exceeds 14 in SPW 3!

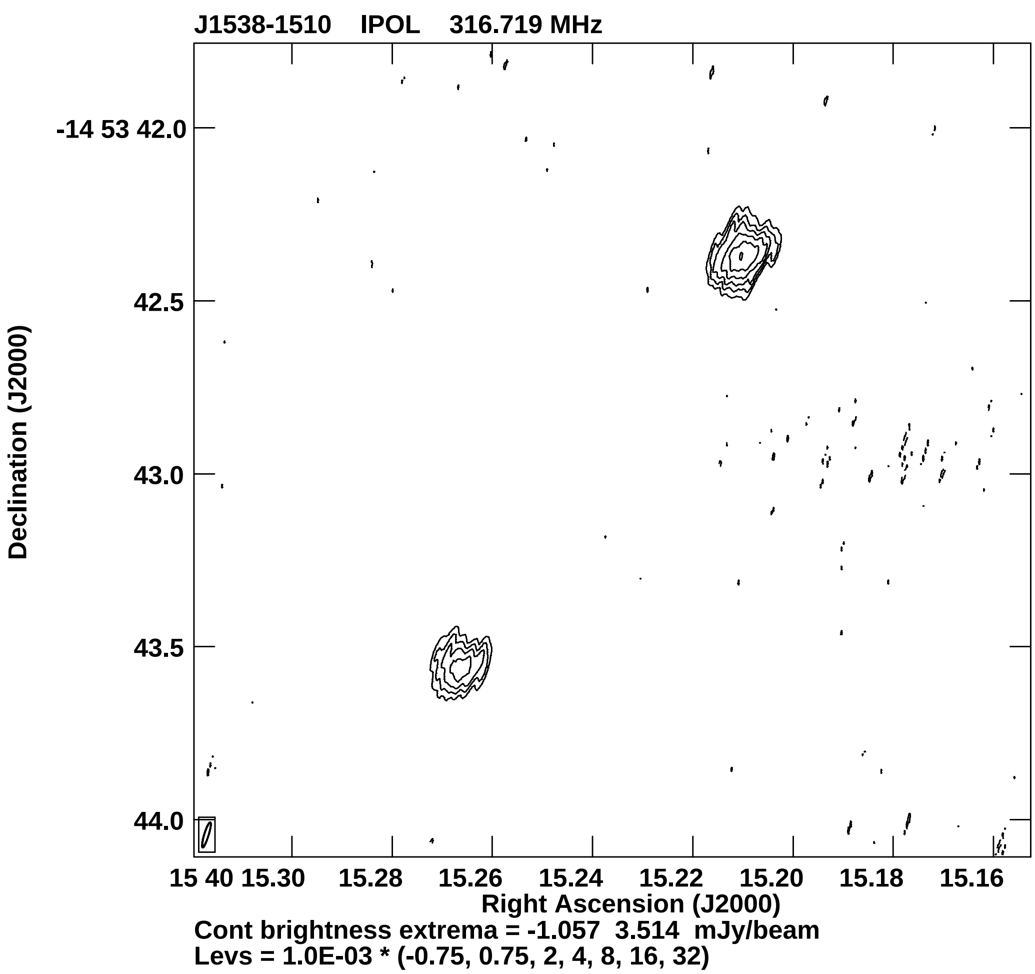

Figure 7: J1538-1510 image after multiple self-calibration steps with `CALIB`.

Ant	IF	S	Ngood	Max	Min	Avg	Rms	Median	Madrms	Station
1	1	1	525	230.040	209.250	220.346	3.384	219.980	3.707	BR
1	1	2	521	151.160	137.550	143.948	2.323	143.650	2.565	BR
1	2	1	525	225.070	189.980	202.082	6.513	202.550	7.680	BR
1	2	2	521	177.100	146.380	149.330	2.076	148.890	1.112	BR
1	3	1	525	152.110	134.370	142.641	4.073	142.890	4.818	BR
1	3	2	521	165.660	151.460	157.144	2.108	156.860	1.646	BR
1	4	1	525	126.630	119.310	121.448	1.103	121.120	0.741	BR
1	4	2	521	154.520	139.230	145.825	3.324	145.240	3.588	BR
2	1	1	527	235.420	154.120	159.717	5.808	158.690	3.321	FD
2	1	2	521	263.290	171.250	176.297	4.748	175.370	2.491	FD
2	2	1	527	155.100	142.960	147.784	2.748	146.940	2.684	FD
2	2	2	521	161.410	150.360	154.896	1.792	154.620	1.927	FD
2	3	1	527	145.530	134.520	139.134	2.424	138.410	2.609	FD
2	3	2	521	163.040	151.590	156.204	1.787	156.140	1.749	FD
2	4	1	527	140.300	130.570	134.305	2.127	133.650	2.031	FD
2	4	2	521	154.540	145.390	149.485	1.618	149.470	1.616	FD
3	1	1	497	345.140	266.530	298.056	11.127	296.360	9.059	HN
3	1	2	491	207.090	161.950	177.999	6.776	177.650	6.271	HN
3	2	1	497	260.520	215.340	234.070	6.451	232.680	5.441	HN
3	2	2	491	193.880	159.570	172.771	6.407	172.170	7.398	HN
3	3	1	497	241.810	181.150	205.962	11.196	206.410	11.890	HN
3	3	2	491	260.790	179.310	199.412	11.234	197.620	9.933	HN
3	4	1	497	298.600	196.760	216.797	13.462	213.440	10.838	HN
3	4	2	491	244.970	168.440	184.451	11.680	181.090	10.008	HN
4	1	1	524	413.960	320.400	364.179	28.297	378.750	32.677	KP
4	1	2	524	228.450	177.580	202.427	16.161	211.630	15.152	KP
4	2	1	524	413.450	295.990	363.118	35.144	377.190	35.923	KP
4	2	2	524	231.920	168.000	200.213	22.099	207.500	22.536	KP
4	3	1	524	1.177E+06	-1.441E+04	2.601E+03	5.137E+04	4.078E+02	8.076E+01	KP
4	3	2	524	16886.311	-14480.670	235.897	1678.211	235.600	43.944	KP
4	4	1	524	3073.600	281.700	362.509	201.511	333.450	44.107	KP
4	4	2	524	1036.480	138.990	175.262	59.234	169.510	24.493	KP
5	1	1	527	221.900	156.270	164.151	5.454	162.980	3.351	LA
5	1	2	522	206.290	160.400	172.509	4.659	171.930	4.151	LA
5	2	1	527	271.710	141.520	150.645	9.349	149.180	1.764	LA
5	2	2	522	232.230	153.060	159.229	5.469	158.270	1.913	LA
5	3	1	527	1834.280	129.150	198.884	153.316	161.120	31.431	LA
5	3	2	522	1928.970	-13835.120	173.129	647.112	166.760	30.378	LA
5	4	1	527	196.450	127.100	131.839	4.767	131.090	1.186	LA
5	4	2	522	195.750	145.640	150.063	3.826	149.330	1.260	LA
7	1	1	527	49.990	44.980	46.342	0.703	46.170	0.623	NL
7	1	2	523	34.190	32.460	32.995	0.282	32.920	0.252	NL
7	2	1	527	71.520	44.250	46.042	2.638	45.430	0.593	NL
7	2	2	523	83.910	51.080	53.453	4.044	52.390	0.756	NL
7	3	1	527	266.710	48.630	58.395	23.985	50.180	1.349	NL
7	3	2	523	156.030	45.880	52.327	13.784	47.440	1.408	NL
7	4	1	527	53.500	51.150	52.015	0.397	51.980	0.445	NL
7	4	2	523	51.180	48.320	49.477	0.532	49.380	0.504	NL

Table 8: `SNRMS` output for `TY` table from BM486A 90cm with no editing.

Ant	IF	S	Ngood	Max	Min	Avg	Rms	Median	Madrms	Station
8	1	1	525	147.070	134.940	138.954	2.591	138.100	2.239	OV
8	1	2	521	160.150	148.170	152.952	2.558	151.940	2.076	OV
8	2	1	525	132.910	125.130	128.050	1.206	127.900	1.364	OV
8	2	2	521	134.990	128.200	131.173	1.294	131.090	1.453	OV
8	3	1	525	128.320	121.420	124.407	1.512	124.150	1.690	OV
8	3	2	521	136.670	130.320	132.977	1.259	132.750	1.260	OV
8	4	1	525	132.740	125.760	128.777	1.336	128.590	1.527	OV
8	4	2	521	142.640	134.330	137.455	1.649	137.270	1.868	OV
9	1	1	526	112.890	105.490	107.976	1.109	107.910	0.993	PT
9	1	2	526	274.310	220.000	245.841	5.359	245.510	4.388	PT
9	2	1	526	111.860	99.660	102.997	2.380	102.230	1.749	PT
9	2	2	526	211.610	177.270	190.650	5.704	189.140	3.973	PT
9	3	1	526	87.930	80.620	83.112	1.429	82.640	1.097	PT
9	3	2	526	243.130	174.530	217.110	14.504	223.400	9.074	PT
9	4	1	526	93.230	84.480	88.715	1.706	88.930	1.764	PT
9	4	2	526	263.430	228.020	242.973	7.986	242.670	7.472	PT
10	1	1	525	464.170	189.320	225.537	20.124	219.830	5.812	SC
10	1	2	525	725.980	249.260	311.608	28.711	303.890	7.413	SC
10	2	1	525	313.680	197.210	209.395	17.337	205.360	4.374	SC
10	2	2	525	324.210	226.050	236.789	14.489	233.580	3.603	SC
10	3	1	525	276.920	187.920	196.219	13.440	193.550	3.899	SC
10	3	2	525	262.460	169.430	178.053	14.632	174.710	3.884	SC
10	4	1	525	337.420	238.090	247.561	15.043	243.700	3.262	SC
10	4	2	525	349.730	216.650	228.401	20.790	223.150	4.611	SC

Table 9: `SNRMS` output for `TY` table from BM486A 90cm with no editing.

However, the final `FRING` step failed more or less completely on the phase calibrator and target source. Both sources were clearly detected well on short spacings and, especially the target, were not detected on long spacings. The phase calibrator was `SPLIT` without the final `FRING` and was self-calibrated with `CALIB`. That model was then used to run `CALIB`, phase only, on the main uv data set with only 5% failures. This calibration was then applied to the target source. After a `SPLIT`, the target source was self-calibrated. Its total Clean flux density started at 127 mJy, rose to 830 mJy with phase-only self-cal, but then dropped a lot with amplitude and phase self-cal even with gain normalization turned on. The final image contained only 119 mJy but with a very low rms 0.046 mJy/beam. The image rms before `'A& P'` was about 7 mJy/beam. The image shows an extended double source (see Figure 8), but its amplitude is clearly not to be believed.

Self-cal on 3C273 started and ended with Cleaned flux density 8.6 Jy with the image rms dropping from 173 mJy/beam to 43 mJy/beam. Phase-only self-cal did raise the Cleaned flux density to 9.88 Jy but this is still rather less than found in the previous two data sets. J1258-2219 started with a Clean flux density of 395 mJy which increased slightly with phase-only self-cal and then dropped to 295 mJy with `A& P`. The image rms started at 6.2 mJy/beam and dropped to 2.1 mJy/beam.

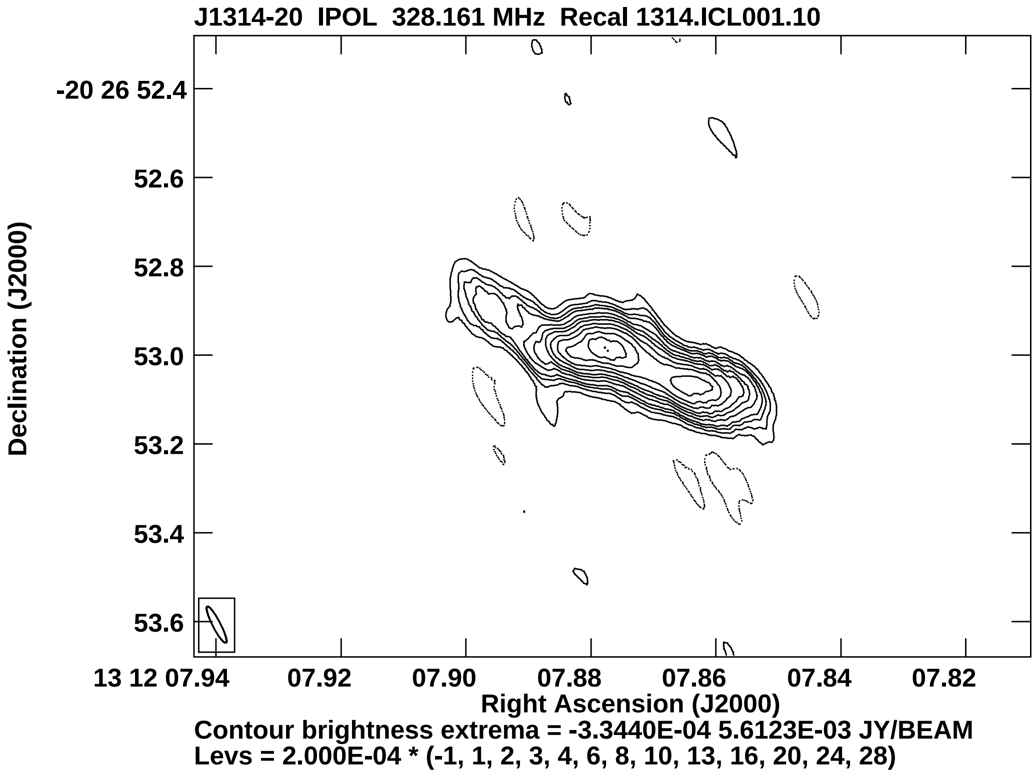

Figure 8: Contour plot of final J1314-2029 image.

8 Conclusion

Unlike S-band, the 50cm and 90cm data from the VLBA appear to be usable with caution. The total bandwidth is small, limiting the sensitivity. Three science experiments were examined and one of the three failed to detect the phase calibrator and target sources while the second had quite reasonable results including a usable image of the target source at 90cm (but not at 50cm). The third data set produced, with some difficulty, reasonable images of all 3 sources observed although the amplitude of the images is not well calibrated. The DQ runs examined detected each source observed quite well. It is clear that RFI is a problem at these wavelengths, but judicious editing of the data when the Tsys values are unreasonable should eliminate the data affected. RFI spikes due to pulse cals and to external sources are seen in the autocorrelation spectra but do not seem to cause spectral effects in the cross-correlation data except when the data are rendered unusable. Amplitude calibration particularly at 50cm may be affected by unflagged RFI and poor calibration of the noise tubes. The source of the poor and variable amplitude calibration of BM468 is not known.