LBWG memo 4

How many sources can we see?

Neal Jackson, 1.6.18
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Motivation. It is of crucial importance to know how many sources have significant signal on the long baselines – both scientifically, and because it affects the way in which pipelines are written and run.

Each LoTSS field has slightly more than 1000 sources visible in the main survey at 5-10 arcsecond resolution. We may expect an order of magnitude fewer at the highest international baseline resolutions, as experience with LBCS has shown that correlated flux declines steeply with baseline length.

Estimating the number of sources. The closure-based Fourier transform method of Memo 3 has been used for this experiment. 100 subbands (20 MHz) have been used to form 8-hour datasets around more than 40 sources in the surveys test field; the 5 bright sources described in the last memo, plus 35 further sources. These 35 sources surround the bright source 1349+5341, which has high S:N on all closure triangles to ST001 and RS208. They comprise a complete sample of sources in the southeast corner of the survey field with the following selection:

- Flux density in the main survey >10 mJy
- Right ascension >13h44m
- Declination $< 54°30'$

Delay and phase calibration has been performed on 1349+5341 as described in memo 2 (although for closure quantities the phase calibration is irrelevant, and for the closure phase dynamic spectrum method the delay calibration should not be critical). The method of memo 3 has been used, so we should not be sensitive to confusing flux leaking in from 1349+5341.

The results are shown in Table 1. Conclusions are as follows:

- If we define usable signal as S:N 3 or greater, then all but three sources above 25 mJy are detected to DE605, and approximately half of the sources with 10 mJy$<$ $S_{\rm int}$ $<$25 mJy.
- On the longer baselines, the proportion of sources with usable signal decreases drastically. If we require S:N of 3 on at least two of FR606, SE607 and UK608, then all (two) sources above 2 Jy are detected; 2 out of 7 of the sources between 100 mJy and 2 Jy; 3 out of 16 sources between 30 mJy and 100 mJy; and 3 out of 15 sources between 10 mJy and 30 mJy.
- The LOTSS pointing contains 342 sources above 20 mJy. Extrapolating from the above, there will probably be usable signal on 200-km baselines for about 300 of these. There are a further 200 sources between 10 and 20 mJy, of which usable signal should be seen on about half. I suspect that the incidence of correlated signal will drop drastically below this, so between 400 and 500 of the 1200 sources in the field will probably have usable signal and can be mapped at $2''$ resolution.

- There will probably be significant long-baseline signal on about 50–100 sources above 20 mJy. In most cases this will be from a couple of points in hotspots or cores. About 100 sources should therefore have detectable signal on 0.5-arcsecond resolution baselines, although this does not translate to being able to make good-quality maps at this resolution.
- It looks fairly clear that DE601 was producing much lower-quality data than DE605 during these observations. This is worrying, as we are in the regime where small differences in signal to noise make the differences between being able to map sources and not being able to map sources.
- The low S-N regime also means that it is easy to drive CLEAN/selfcal maps in the wrong direction.
- Note that this table was made from data with the gains applied properly during the superterp formation (updated 18.06.18).

To do (quite urgent): How many of the 50-100 sources with some signal can actually be mapped? Note that the closure-phase statistic is optimistic w.r.t. what can be mapped, because (i) it refers to the whole track rather than to the $\sim$5 minutes over which phase solutions need to be done (even after the fast phase winding has been taken out using the really bright sources) and (ii) it has the superterp as one of the corners of the closure triangle. (Should we build another superterp somewhere else?...).

Related question: How many sources similar to the two studied in Memo 2 would we need in order to build a phase screen model, and hence short-circuit the whole process and be able to calibrate everything?

Source	S_{peak}	S_{int}	**DE601**	**DE602**	**DE603**	**DE604**	**DE605**	**FR606**	**SE607**	**UK608**
ILTJ132737.2+550406.2	5420.7	5886.4	**143.5**	**58.9**	**145.3**	**129.6**	**286.0**	**48.0**	**64.4**	**38.3**
ILTJ134934.6+534117.9	2266.8	2634.5	**35.6**	**13.9**	**28.2**	**34.2**	**74.8**	**24.0**	**22.1**	**20.8**
ILTJ134136.6+534430.1	1646.4	2515.7	1.5	**4.8**	1.8	2.0	**4.5**	**3.2**	1.1	**5.1**
ILTJ133409.4+550149.0	1817.1	2334.8	**6.6**	2.7	**4.5**	1.9	**26.1**	1.2	1.7	1.3
ILTJ135146.8+551818.7	1728.5	1989.8	**8.7**	1.9	**3.6**	2.9	**27.3**	0.3	**3.7**	**3.0**
ILTJ133414.5+550053.4	1367.9	1738.8	**5.1**	2.7	**4.5**	**4.2**	**25.7**	1.5	2.6	1.3
ILTJ132703.1+543041.0	526.7	805.9	**7.7**	1.0	**3.1**	**3.2**	**25.0**	2.3	2.1	1.0
ILTJ134455.0+534829.2	443.8	488.4	**5.0**	1.8	**3.8**	0.8	**3.8**	2.0	1.8	1.7
ILTJ134744.5+533609.1	314.6	354.2	**6.3**	2.2	**3.7**	**8.1**	**11.6**	2.5	1.3	2.8
ILTJ135303.5+541026.9	218.7	252.7	1.0	1.4	**3.6**	2.7	**3.5**	0.0	2.0	2.9
ILTJ134911.1+535216.2	85.0	99.5	**5.5**	1.0	**4.5**	**5.7**	**15.4**	2.0	**3.4**	2.4
ILTJ134923.3+541905.0	64.8	97.1	**3.1**	**3.3**	**5.4**	1.6	**5.3**	1.7	**3.0**	1.5
ILTJ134911.9+533257.2	74.2	86.6	**10.7**	2.6	**11.8**	**11.1**	**37.3**	**4.7**	**3.6**	**9.2**
ILTJ134706.2+534003.6	57.6	80.8	**3.7**	**3.8**	**3.1**	**4.8**	**6.7**	**3.9**	0.0	2.0
ILTJ135252.7+541525.7	58.8	69.3	2.1	2.7	2.6	0.8	2.8	**3.1**	2.3	2.7
ILTJ134854.7+533151.1	51.4	62.2	**4.5**	**4.1**	**7.2**	**11.2**	**22.9**	**4.0**	**3.4**	**7.0**
ILTJ134156.9+534422.0	46.5	61.8	1.5	**4.8**	1.8	2.0	**4.5**	**3.2**	1.1	**5.1**
ILTJ134740.9+535610.3	42.7	57.5	1.7	0.9	2.3	2.3	**8.2**	**4.8**	1.6	1.2
ILTJ134759.8+540343.7	47.4	52.8	2.5	2.1	1.8	2.7	**4.6**	1.0	**3.1**	**3.5**
ILTJ134955.3+541259.0	33.7	43.5	2.5	1.7	**4.8**	0.8	**3.1**	**3.6**	1.6	2.1
ILTJ134518.8+541305.7	39.5	43.4	2.7	2.1	0.9	1.2	**4.6**	1.5	**3.5**	**3.7**
ILTJ134424.0+541003.9	36.8	41.0	2.0	0.0	2.6	**4.0**	**4.1**	0.0	2.3	1.8
ILTJ134546.5+535027.3	32.5	36.6	2.5	1.9	1.9	0.8	1.3	1.6	2.1	2.2
ILTJ134418.1+532922.8	30.8	36.3	2.8	2.4	2.0	1.4	2.6	2.3	**4.0**	1.6
ILTJ135030.4+534732.9	27.7	34.8	**3.3**	**3.1**	**3.5**	**3.8**	**13.3**	2.0	1.7	**3.1**
ILTJ134843.1+535310.3	22.6	33.5	1.9	2.2	**4.8**	**4.6**	**4.7**	2.8	1.4	**3.0**
ILTJ134545.5+534626.2	26.4	31.1	1.1	1.6	1.9	0.5	**3.3**	2.9	2.2	0.0
ILTJ135042.0+534351.5	21.7	30.8	**3.2**	2.0	2.1	1.7	**10.7**	1.2	**5.5**	1.3
ILTJ135009.6+541418.4	19.2	29.5	**3.1**	1.5	**5.8**	1.2	**5.2**	1.6	**4.5**	**3.1**
ILTJ134621.4+535445.8	25.4	28.4	2.6	**3.6**	**3.6**	2.3	**3.9**	3.0	2.9	1.7
ILTJ134454.2+531252.1	24.0	27.9	1.5	1.9	**3.1**	**3.3**	2.9	1.3	**4.7**	1.2
ILTJ134527.1+531734.0	21.4	24.4	1.8	2.7	2.1	0.6	**4.1**	1.4	**3.1**	1.4
ILTJ134439.2+535840.3	20.0	23.0	1.6	0.8	2.2	1.3	1.8	2.4	2.5	2.7
ILTJ135259.4+542046.2	18.3	22.8	0.6	**4.2**	**3.8**	2.5	**5.1**	0.9	**3.2**	2.4
ILTJ134500.4+541550.1	14.4	21.9	2.2	2.8	1.6	**3.6**	2.2	1.3	1.6	1.8
ILTJ134746.1+535700.9	14.6	21.2	**4.1**	**3.3**	**4.8**	**3.5**	**6.3**	**3.4**	0.3	2.7
ILTJ134850.4+540409.5	17.7	20.9	2.4	2.6	**3.6**	**5.5**	**9.4**	1.7	1.9	1.2
ILTJ134748.6+533241.6	15.2	19.8	**8.8**	**3.7**	**4.0**	**8.0**	**16.1**	**3.4**	**3.1**	**3.2**
ILTJ134628.6+535710.0	15.0	18.9	1.2	2.2	**5.2**	2.3	**5.0**	0.4	2.6	2.8
ILTJ134753.6+532647.4	11.6	15.9	**5.9**	2.3	**4.5**	**3.9**	**11.8**	1.8	0.0	**4.1**
ILTJ134700.2+534002.1	8.9	15.0	**3.7**	**3.8**	**3.1**	**4.8**	**6.7**	**3.9**	0.0	2.0
ILTJ134832.8+541143.8	12.5	14.5	**3.7**	**5.9**	2.0	2.0	2.0	2.0	**3.3**	1.9
ILTJ134510.4+534642.6	13.5	14.3	1.1	1.6	1.9	0.5	**3.3**	2.9	2.2	0.0
ILTJ135131.6+535855.8	11.8	13.5	**5.2**	1.8	**5.0**	2.8	**8.6**	0.0	1.5	0.1
ILTJ134929.7+542718.8	11.0	12.0	1.1	**3.2**	**3.3**	2.9	**5.6**	**3.0**	0.0	**3.5**
ILTJ135049.8+534757.1	7.1	11.8	**3.3**	**3.1**	**3.5**	**3.8**	**13.3**	2.0	1.7	**3.1**
ILTJ134441.9+532920.2	5.4	7.4	2.8	2.4	2.0	1.4	2.6	2.3	**4.0**	1.6
ILTJ134936.9+542716.1	2.8	4.7	1.1	**3.2**	**3.3**	2.9	**5.6**	**3.0**	0.0	**3.5**

All of the LBCS 'P' sources within 2.5 degrees of the field centre

L1324+5454	15.3	3.7	7.1	7.3	61.5	1.3	1.7	3.1
L1325+5540	6.4	3.4	0.5	3.3	34.4	0.0	2.4	3.3
L1326+5514	27.3	6.4	21.5	12.9	47.5	3.5	5.7	0.4
L1326+5637	1.1	0.0	2.3	2.0	2.8	3.3	2.3	3.3
L1327+5504	147.0	58.7	148.9	130.6	280.3	49.6	62.0	41.0
L1330+5546	3.1	3.2	3.3	3.3	28.9	1.6	0.0	1.7
L1334+5631	1.6	2.1	2.3	0.8	3.0	3.5	1.3	1.5
L1335+5631	3.2	0.3	1.6	2.8	4.9	1.4	2.1	2.0
L1337+5501	10.9	13.2	17.8	15.8	27.4	15.8	14.1	12.3
L1339+5257	1.5	1.4	1.3	1.3	4.8	3.9	3.2	3.2
L1339+5638	3.6	2.1	6.5	3.7	17.2	3.2	1.0	3.0
L1341+5415	5.4	2.7	7.1	9.7	13.6	4.5	2.0	7.8
L1342+5707	1.1	2.1	2.6	2.8	1.2	4.6	2.6	2.7
L1342+5717	3.0	2.1	0.9	1.5	3.2	1.1	0.8	0.9
L1343+5253	2.4	4.0	0.9	0.1	0.9	2.8	2.2	1.4
L1344+5233	0.0	3.0	0.0	1.5	0.7	0.2	2.3	1.4
L1344+5348	2.7	3.1	3.1	1.4	2.3	0.1	2.4	2.4
L1344+5503	4.2	8.9	17.8	17.9	19.1	3.9	2.5	3.8
L1344+5658	0.5	3.4	0.0	2.4	2.1	3.2	1.8	3.0
L1347+5647	3.7	1.3	2.0	2.9	1.3	3.6	1.1	2.0
L1349+5341	34.5	14.1	28.9	32.1	78.6	25.5	21.3	20.7
L1350+5447	1.4	2.9	3.7	4.0	3.0	4.7	2.8	1.8
L1351+5306	1.7	1.0	0.9	2.4	4.5	0.0	3.9	3.2
L1351+5518	10.2	2.4	4.0	3.0	29.4	0.8	2.7	2.0
L1352+5458	3.2	3.1	3.6	2.9	2.8	2.8	3.3	1.4
L1353+5610	0.5	2.1	4.4	1.9	4.5	0.9	3.0	3.6
L1353+5725	2.3	1.0	3.4	2.7	1.2	2.5	3.0	4.7
L1354+5520	2.9	1.0	0.9	4.2	3.9	2.9	2.1	2.2
L1354+5650	9.6	1.1	1.0	1.6	2.2	5.0	3.4	2.0
L1355+5540	2.7	0.0	3.1	3.2	4.4	0.0	4.1	1.7
L1355+5614	1.4	1.7	2.1	3.0	0.9	2.0	0.0	1.9
L1356+5339	1.3	1.1	4.9	1.3	1.0	3.2	2.0	1.9
L1356+5630	4.4	2.6	3.3	1.8	2.0	1.7	2.6	1.8