CARMA

Combined Array for Research in Millimeter-Wave Astronomy

CARMA Memorandum Series #61

CARMA 2011 VLBI Calibration

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ABSTRACT

In March/April 2011 CARMA participated in a 1mm VLBI experiment organized under the auspices of the Event Horizon Telescope. Other stations participating were the Arizona Radio Observatory Submillimeter Telescope on Mt Graham, Arizona; and the Submillimeter Array, the James Clerk Maxwell Telescope, and the Caltech Submillimeter Observatory, all on Mauna Kea, Hawaii.

Left circularly polarized signals in two 480 MHz wide bands, centered at 229.089 and 229.601 GHz, were recorded at all sites. During this experiment CARMA was treated as a 'double' VLBI station – signals were recorded on separate VLBI recorders for 2 separate CARMA telescopes, which then were treated as independent VLBI stations. In this way, the flux densities measured on the CARMA-CARMA VLBI baseline could be compared with flux densities measured with the local CARMA correlator. For some of the observations, the signals from 7 CARMA telescopes were phased together in a beamformer and sent to one of the VLBI recorders.

This document describes the calibration of the CARMA data for this experiment, including the absolute flux calibrations, computation of the system equivalent flux densities for single telescopes and the subarray of phased telescopes, and estimates of the phasing efficiency.

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<tr><td rowspan="2">Revision</td><td>Date</td><td>Author</td><td>Sections/Pages Affected</td></tr>
<tr><td colspan="3">Remarks</td></tr>
<tr><td rowspan="2">1.0</td><td>2011-Dec-22</td><td>R. Plambeck</td><td>all</td></tr>
<tr><td colspan="3">Memo completed, sent to collaborators.</td></tr>
<tr><td rowspan="2">2.0</td><td>April 1, 2013</td><td>R. Plambeck</td><td>Abstract</td></tr>
<tr><td colspan="3">Added Abstract, submitted to CARMA memo series for future reference.</td></tr>
</table>

1. Flux Calibration

The absolute flux calibrator was Uranus, which was observed following the VLBI scans on day90 (31mar), day91 (01apr), and day92 (02apr). Figure 1 shows the Uranus visibilities vs baseline length for day90 and day91 after amplitude selfcalibration; day92 data were useless because of high atmospheric turbulence. Miriad program `bootflux` was used to transfer the Uranus gains to the other sources. For SgrA, only baselines longer than 20 klambda were used to avoid confusion from extended emission. The measured source flux densities were as follows:

source	S-31mar (Jy)	S-01apr (Jy)	avg (Jy)
0854+201	4.39		4.39
3C273	5.98	6.38	6.18
M87	1.64	1.69	1.66
3C279	13.34	14.33	13.83
1633+382		3.09	3.09
3C345		2.14	2.14
NRAO530	3.34	3.29	3.32
SGRA	3.18	2.93	3.06
1749+096		3.98	3.98
1921-293	5.19	5.63	5.41
MWC349	1.97	2.11	2.04
BLLAC		3.19	3.19
3C454.3	11.42		11.42

MWC349 was included as a secondary flux standard. It was observed at high elevation, before sunrise, whereas the Uranus calibration was done at about 30 degrees elevation, after sunrise. The flux density we obtained for MWC349, 2.04 Jy at 225 GHz, is higher than the value ~ 1.9 Jy that is commonly assumed, but it is the typical value measured by CARMA.

2. SEFD calculation

The goal of the calibration procedure is to compute the system equivalent flux density (SEFD) time-averaged for each scan. The SEFD is the system noise power expressed in Jy:

$$\frac{S}{SEFD} = \left\langle \frac{T_A}{T_S} \right\rangle, \tag{1}$$

where S is the source flux density and T_S is the (single sideband) system temperature scaled to outside the atmosphere.

For a phased array of telescopes, the source antenna temperature T_A is obtained by adding the signal voltage

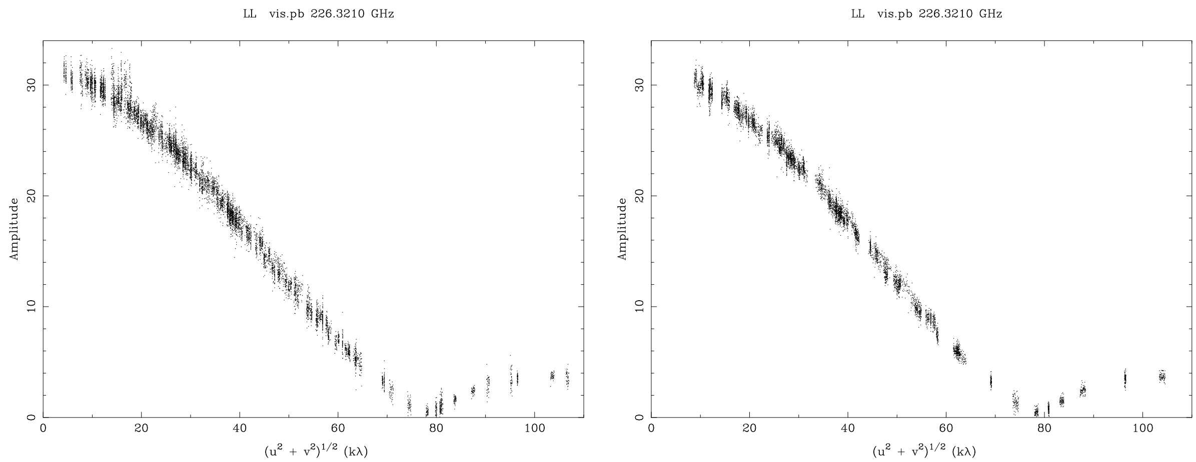

Fig. 1.— Visibility amplitudes (Jy) vs. baseline length (klambda) measured on Uranus after selfcalibration, for 31Mar (left) and 01Apr (right).

vectors, then squaring the result. The signal voltage vector from antenna i (expressed in units of $\sqrt{K}$) is

$$\mathbf{V}_{Si} = \frac{\sqrt{S}}{g_i\sqrt{C_i}} \tag{2}$$

where C_i is the nominal Jy/K conversion factor, and g_i is the (complex) voltage correction coefficient obtained from an amplitude selfcal solution. C_i is 65 Jy/K for the 10.4-m telescopes and 145.3 Jy/K for the 6.1-m telescopes, corresponding to nominal aperture efficiencies of 0.50 and 0.65 respectively. For VLBI data, g_i are computed on a record-by-record basis, every 10 seconds, assuming that the true source fluxes are the average values in table 1. Then, for N phased telescopes,

$$\left\langle \frac{T_A}{T_S} \right\rangle = \left\langle \frac{|\sum_N w_i \mathbf{V}_{Si}|^2}{\sum_N w_i^2 T_{Si}} \right\rangle \tag{3}$$

where w_i is the voltage weighting factor. Note that the voltage correction factor g_i hidden inside $\mathbf{V}_{Si}$ takes into account imperfect phasing of the antennas. For the CARMA beamformer the voltages were given equal weight, so that $w_i = 1/\sqrt{T_{Si}}$ (see Thompson, Moran, & Swenson, 2nd Edition, page 372). Combining equations 1-3,

$$SEFD_{phased} = N\left\langle \left(\sum_N \frac{1}{g_i\sqrt{C_i}\sqrt{T_{Si}}} \right)^{-2} \right\rangle \tag{4}$$

In the case where N=1, this reduces to $SEFD = |g_i|^2 C_i T_{Si}$.

System temperatures are measured at the beginning of each scan using the chopper wheel method, then are updated continuously during the scan under the assumption that the receiver gain is constant. In the Miriad data, system temperatures are reported separately for each of the 16 spectral windows (LSB and USB for each of 8 correlator bands). In computing the SEFDs, we used the value of T_S appropriate for the 500 MHz window sent to the VLBI recorder (lo-band = band 5 USB = window 13, hi-band = band 7 USB = window 15); gain correction factors g_i were, however, derived from the vector averaged visibilities across all 16 correlator windows, after applying a passband correction.

Gain corrections g_i are available for the 'comparison' antenna C1 and the 'passthrough' antenna C4 only in pre- or post-scan data. Phase switching and lobe rotation were disabled for these two antennas during the VLBI scans, so no CARMA correlator data are available for them during the scans.

3. Explanation of tables

The SEFDs for each scan are given in Appendix A. Columns 1-5 are self-explanatory.

- (col 6) *tau* is the 230 GHz opacity reported by a tipper
- (col 7) *path* is the rms atmospheric path variation, in microns, from the CARMA phasemonitor
- (cols 8,9) *C1-lo* and *C1-hi* are the lo- and hi-band SEFDs for the 'comparison' antenna, C1; note that all these SEFDs were derived from pre-scan or post-scan data; asterisks indicate that no pre- or post-scan data were available, so the nominal antenna gain was assumed
- (col 10) *C4-lo* is the lo-band SEFD for the 'passthrough' antenna C4, except for a few scans on day90, when the beamformer output was used
- (col 11) *CP-hi* is the hi-band SEFD for either the 'passthrough' antenna C4 (days 88,90), or for the beamformer output CP (most scans on days 91,92,94). Antennas C2,C3,C5,C10,C11,C12,C13 were phased for days 91 and 92; C9 replaced C10 on day94.
- (col 12) *ph-eff* is the phasing efficiency calculated relative to the hypothetical case where the antennas were perfectly phased (all vectors in a line); note that this limit is not the ideal case where the voltage weighting factors w_i are chosen to be proportional to $\sqrt{gain}/T_S$; -1 indicates a passthrough scan where the signal from C4 was sent to the recorder
- (col 13) *CD amp* is the predicted lo-band amplitude $10^4\,S/\sqrt{SEFD_{C1-lo}\,SEFD_{C4-lo}}$ for comparison with Haystack results
- (col 14) *FD amp* is the predicted hi-band amplitude $10^4\,S/\sqrt{SEFD_{C1-hi}\,SEFD_{CP-hi}}$ for comparison with Haystack results

4. Phasing efficiency

Figure 2 shows the cumulative phasing efficiency for days 91,92,94. As in the tables, the phasing efficiencies are relative to the case where the phasing was perfect, but the voltage weights for all telescopes were equal.

The SEFD corresponding to 100% phasing efficiency, for three 10-m and four 6-m telescopes, is 4.6 times smaller (better) than the SEFD for a single 10-m telescope, shown by the vertical dashed line. On day 92 the phasing efficiencies are abysmal because of high atmospheric turbulence. For the other two days the median phasing efficiency was 70%, better than a factor of 3 improvement over a single 10-m telescope.

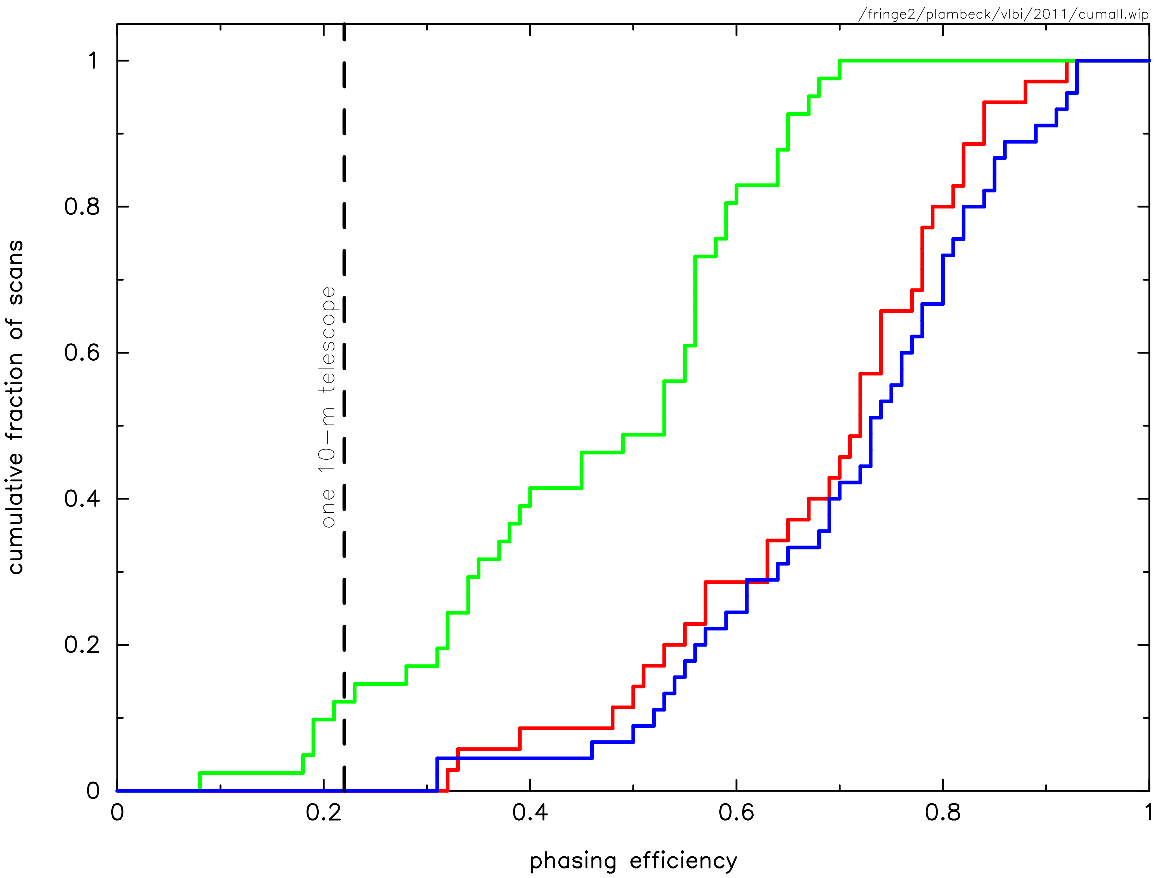

Fig. 2.— Cumulative distribution of phasing efficiencies for day90 (red), day92 (green), and day94 (blue). Each curve shows the fraction of scans with phasing efficiency less than or equal to the abscissa.

5. Comparison with VLBI amplitudes

The histograms in Figure 3 compare the amplitudes derived from the CARMA SEFDs (columns 13 and 14 in `CARMA-cal.dat`) with those obtained at Haystack from VLBI cross-correlations. The agreement is reasonable, although there is a disturbing tendency for the VLBI amplitudes to exceed the CARMA amplitudes.

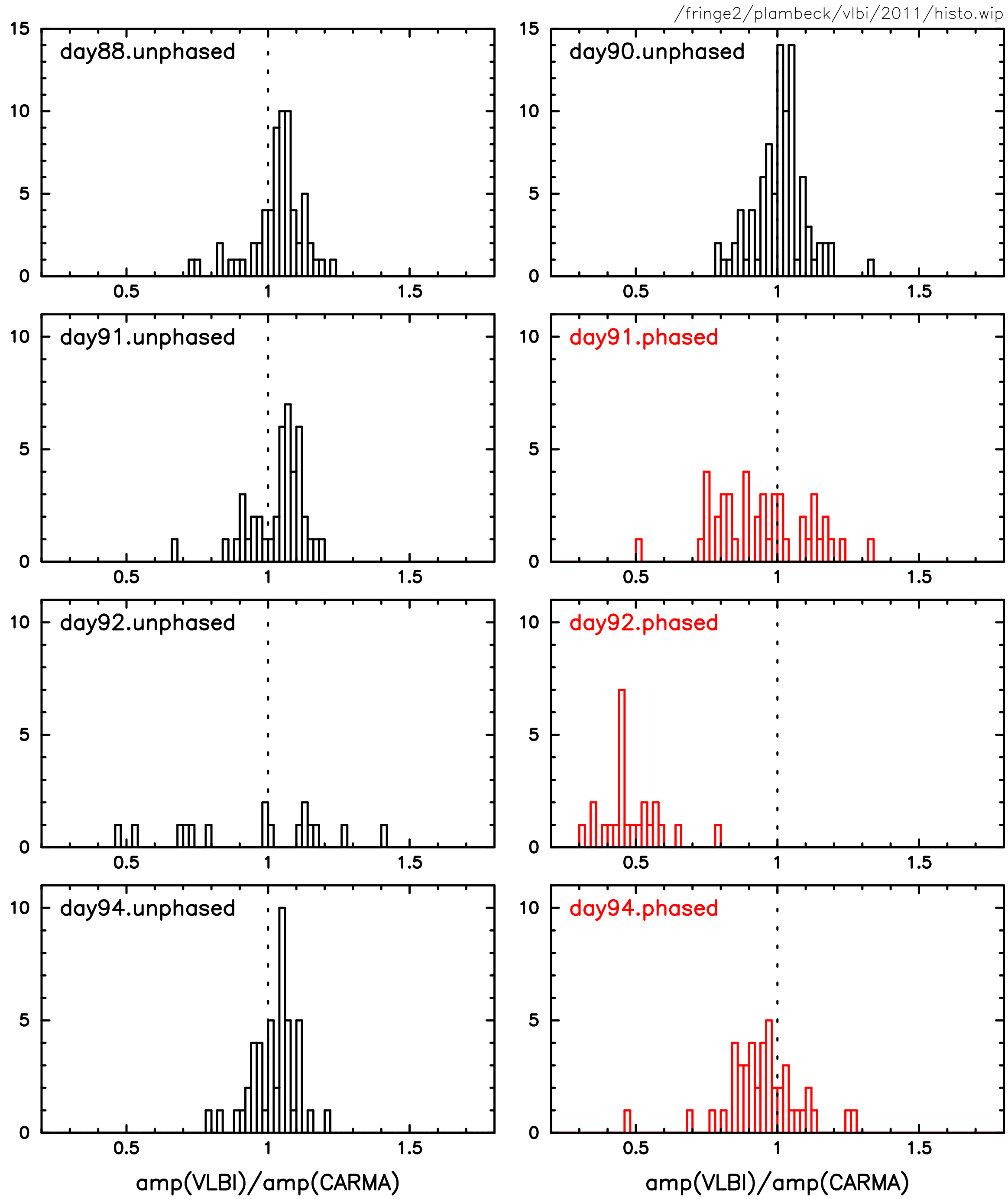

Fig. 3.— Histogram of VLBI/CARMA amplitudes. Single antenna results are in black, phased array results in red.

6. Appendix A

```
#
# day88 (29mar) - no phasing; CP-hi = C4 in passthrough mode
#
#   scan        src     UTstart   UTstop    el  tau  path    C1-lo     C1-hi     C4-lo     CP-hi  ph-eff    CD     FD
#                                          deg        um   SEFD-Jy   SEFD-Jy   SEFD-Jy   SEFD-Jy          amp    amp
 088-050000    missed  05:00:00  05:07:00   71  0.00    0        0*        0*        0*        0*   -1    0.000  0.000
 088-051655    missed  05:16:55  05:25:00   46  0.00    0        0*        0*        0*        0*   -1    0.000  0.000
 088-052955    missed  05:29:55  05:34:00   41  0.25  133        0*        0*        0*        0*   -1    0.000  0.000
 088-054355    missed  05:43:55  05:54:00   51  0.24  160        0*        0*        0*        0*   -1    0.000  0.000
 088-055955    missed  05:59:55  06:04:00   46  0.25  133        0*        0*        0*        0*   -1    0.000  0.000
 088-061355    missed  06:13:55  06:24:00   56  0.24  177        0*        0*        0*        0*   -1    0.000  0.000
 088-062855    missed  06:28:55  06:33:00   39  0.25  143        0*        0*        0*        0*   -1    0.000  0.000
 088-064255    missed  06:42:55  06:53:00   60  0.25  114        0*        0*        0*        0*   -1    0.000  0.000
 088-065755    missed  06:57:55  07:02:00   52  0.24  104        0*        0*        0*        0*   -1    0.000  0.000
 088-071155    missed  07:11:55  07:22:00   63  0.24  114        0*        0*        0*        0*   -1    0.000  0.000
 088-072655     3C279  07:26:55  07:31:00   45  0.24  111    31004     34361     33138     37169     -1    4.318  3.873
 088-074055       M87  07:40:55  07:51:00   65  0.25   82    23178     25886     27595     31309     -1    0.656  0.583
 088-075555     3C273  07:55:55  08:00:00   55  0.25   63    27685     30931     30697     34471     -1    2.120  1.893
 088-081955       M87  08:19:55  08:30:00   65  0.27  123    25952     28778     29705     33286     -1    0.598  0.536
 088-083455     3C279  08:34:55  08:39:00   47  0.26  152    34025     37380     37676     41910     -1    3.865  3.497
 088-084855       M87  08:48:55  08:59:00   63  0.26  134    24836     27484     28405     31820     -1    0.625  0.561
 088-090355     3C273  09:03:55  09:08:00   52  0.27  127    27677     30628     34270     38380     -1    2.007  1.803
 088-091755       M87  09:17:55  09:28:00   59  0.27  132    26364     29286     30499     33981     -1    0.585  0.526
 088-093255     3C279  09:32:55  09:37:00   44  0.28  108    31902     34980     39658     44117     -1    3.891  3.523
 088-094655       M87  09:46:55  09:57:00   55  0.27  112    26852     29885     31993     35902     -1    0.566  0.507
 088-100155     3C279  10:01:55  10:06:00   41  0.28  133    37207     40886     44400     49436     -1    3.405  3.078
 088-101555       M87  10:15:55  10:26:00   50  0.28  154    30317     33458     34817     38961     -1    0.511  0.460
 088-105455    missed  10:54:55  11:02:00   16  0.28  151        0*        0*        0*        0*   -1    0.000  0.000
 088-110455  1749+096  11:04:55  11:10:00   49  0.28  153    32191*    35529*    34664*    38612*   -1    1.191  1.075
 088-111255      SGRA  11:12:55  11:20:00   18  0.29  155    91434*    97594*    98205*   106162*   -1    0.336  0.312
 088-112255  1749+096  11:22:55  11:28:00   52  0.28  722    30608*    33864*    33456*    37557*   -1    1.244  1.116
 088-113255      SGRA  11:32:55  11:40:00   20  0.28  349    80236*    85846*    83448*    91698*   -1    0.389  0.358
 088-114455  1749+096  11:44:55  11:50:00   55  0.28   72    35089     38829     36238     40380     -1    1.116  1.005
 088-115455      SGRA  11:54:55  12:03:00   21  0.29  130   106599    113887    120547    131099     -1    0.281  0.260
 088-120755   NRAO530  12:07:55  12:13:00   38  0.29   86    48774     53360     50349     55826     -1    0.670  0.608
 088-121755      SGRA  12:17:55  12:26:00   23  0.29   70    83344     89746     94948    104462     -1    0.357  0.328
 088-123055   NRAO530  12:30:55  12:36:00   39  0.30   91    45269     49160     47787     53001     -1    0.714  0.650
 088-124055      SGRA  12:40:55  12:49:00   23  0.29   94    68487*    73810*    73969*    80973*   -1    0.447  0.411
 088-125355   NRAO530  12:53:55  12:59:00   40  0.30   97    37989     41495     43571     48793     -1    0.816  0.738
 088-130355      SGRA  13:03:55  13:12:00   24  0.30   77    68424     73333     79204     86988     -1    0.432  0.398
 088-131655   NRAO530  13:16:55  13:22:00   40  0.31   79    40006     43744     47912     53310     -1    0.758  0.688
 088-132655      SGRA  13:26:55  13:35:00   24  0.31   80    74570     80616     86643     95455     -1    0.396  0.363
 088-133955   NRAO530  13:39:55  13:45:00   39  0.31   87    39152     42567     48609     54151     -1    0.761  0.692
 088-141955      SGRA  14:19:55  14:28:00   22  0.32   72    89628     96027     98484    107703     -1    0.338  0.313
 088-142955  1921-293  14:29:55  14:35:00   23  0.33   67    79128*    85916*    83486*    91170*   -1    0.666  0.611
 088-143955      SGRA  14:39:55  14:47:00   21  0.33   73   112906    121471    109814    119190     -1    0.286  0.264
 088-145155  1921-293  14:51:55  14:57:00   24  0.33   73    70572     75738     79596     87602     -1    0.722  0.664
 088-150155      SGRA  15:01:55  15:09:00   19  0.35   82   143943    153576    156687    171016     -1    0.212  0.196
 088-151355  1921-293  15:13:55  15:19:00   23  0.34   74    73945     79689     77784     85610     -1    0.713  0.655
 088-152355      SGRA  15:23:55  15:31:00   17  0.35   87   275327*   296617*   292460*   316932*   -1    0.112  0.104
 088-153555  1921-293  15:35:55  15:41:00   23  0.35  130   103111    111041     96553    105601     -1    0.542  0.500
 088-154555      SGRA  15:45:55  15:53:00   15  0.37  304   406994    443693    515696    567180     -1    0.069  0.063
 088-155755  1921-293  15:57:55  16:03:00   22  0.39  374   133524    141969    129441    141745     -1    0.412  0.381
 088-160755      SGRA  16:07:55  16:14:00   12  0.39  343        0*        0*        0*        0*   -1    0.000  0.000
```

```
 088-161855  1921-293  16:18:55  16:24:00   20  0.00    0       0*       0*       0*       0*   -1     0.000  0.000
#
# day90 (31mar) - no phasing; CP-hi = C4 in passthrough mode
#
#   scan        src     UTstart   UTstop    el  tau  path    C1-lo     C1-hi     C4-lo     CP-hi  ph-eff     CD     FD
#                                          deg        um    SEFD-Jy   SEFD-Jy   SEFD-Jy   SEFD-Jy          amp    amp
 090-050000     3C273  05:00:00  05:07:00   38  0.52  155    86195     91245    107046    114448    -1     0.643  0.605
 090-051700       M87  05:17:00  05:25:00   48  0.51  126    60057     64001     66617     71135    -1     0.262  0.246
 090-053000     3C273  05:30:00  05:34:00   42  0.50  152    67923     72077     75758     80367    -1     0.862  0.812
 090-054400       M87  05:44:00  05:54:00   52  0.50  172    54824     58395     60951     65034    -1     0.287  0.269
 090-060000     3C273  06:00:00  06:04:00   47  0.50  232    58203*    61669*    63095*    67174*   -1     1.020  0.960
 090-061200       M87  06:12:00  06:22:00   57  0.49  201    49713     53324     59702     63712    -1     0.305  0.285
 090-062600     3C273  06:26:00  06:30:00   50  0.48  219    51148     54720     61256     65214    -1     1.104  1.035
 090-063800       M87  06:38:00  06:48:00   60  0.49  181    41116     44037     58644     62769    -1     0.338  0.316
 090-065200     3C273  06:52:00  06:56:00   52  0.49  171    52000     55469     58877     62755    -1     1.117  1.047
 090-070400       M87  07:04:00  07:14:00   63  0.48  224    38820     41360     55601     59597    -1     0.357  0.334
 090-071800     3C273  07:18:00  07:22:00   54  0.48  192    44256     47100     57743     61825    -1     1.223  1.145
 090-073000       M87  07:30:00  07:40:00   65  0.47  219    42823     45752     50397     54214    -1     0.357  0.333
 090-074400     3C273  07:44:00  07:48:00   55  0.46  255    43224     46021     52180     56102    -1     1.301  1.216
 090-080800       M87  08:08:00  08:18:00   65  0.43  256    38413     41237     45140     49317    -1     0.399  0.368
 090-082200     3C279  08:22:00  08:26:00   47  0.43  229    53172     57079     59627     64285    -1     2.458  2.285
 090-083400       M87  08:34:00  08:44:00   63  0.44  178    40122     43089     42852     46577    -1     0.400  0.371
 090-084800     3C279  08:48:00  08:52:00   46  0.45  321    59857     63929     70017     75684    -1     2.138  1.990
 090-090000       M87  09:00:00  09:10:00   61  0.44  296    47111     50520     46768     50817    -1     0.354  0.328
 090-091400     3C279  09:14:00  09:18:00   45  0.44  273    60363     64130     65489     70326    -1     2.201  2.061
 090-092600       M87  09:26:00  09:36:00   57  0.43  179    41185     44023     49279     53253    -1     0.368  0.343
 090-094000     3C279  09:40:00  09:44:00   43  0.42  204    62106     66063     67875     72749    -1     2.132  1.996
 090-095600       M87  09:56:00  10:06:00   52  0.42  127    47498     50578     52904     56678    -1     0.331  0.310
 090-101000     3C279  10:10:00  10:14:00   39  0.43  123    63364     67505     77491     82399    -1     1.975  1.856
 090-102200       M87  10:22:00  10:32:00   48  0.43  125    47660     51066     59149     63374    -1     0.313  0.292
 090-103600     3C279  10:36:00  10:40:00   36  0.42  104    68515     72926     86751     92684    -1     1.795  1.683
 090-104800       M87  10:48:00  10:58:00   43  0.43   94    54935     58774     66924     71269    -1     0.274  0.256
 090-110200     3C279  11:02:00  11:06:00   32  0.43  101    83275     87716    108347    114109    -1     1.457  1.383
 090-111400       M87  11:14:00  11:24:00   38  0.43  131    69332     73656     80654     85163    -1     0.222  0.210
 090-115500   NRAO530  11:55:00  12:00:00   38  0.42   77    65897     70298     81423     86719    -1     0.453  0.425
 090-120400      SGRA  12:04:00  12:11:00   22  0.43   80   123061    129018    170601    179139    -1     0.219  0.209
 090-121500   NRAO530  12:15:00  12:20:00   39  0.41  107    57899     61798     73751     78931    -1     0.508  0.475
 090-122700      SGRA  12:27:00  12:35:00   23  0.42  135   130453    137506    143365    151168    -1     0.233  0.221
 090-123900   NRAO530  12:39:00  12:44:00   40  0.43  135    63165     67262     70709     75187    -1     0.497  0.467
 090-124800      SGRA  12:48:00  12:56:00   24  0.43  101   115604    122048    141130    148254    -1     0.249  0.236
 090-131200      SGRA  13:12:00  13:20:00   24  0.43  106   126211    132818    154594    164472    -1     0.228  0.215
 090-132400   NRAO530  13:24:00  13:29:00   39  0.43  119    56220     60054     69952     74986    -1     0.529  0.495
 090-133600      SGRA  13:36:00  13:44:00   23  0.41   83   118740    124023    132171    139852    -1     0.254  0.241
 090-134800   NRAO530  13:48:00  13:53:00   38  0.41  136    59720     63957     66425     71435    -1     0.527  0.491
 090-135700      SGRA  13:57:00  14:05:00   23  0.41  142   118392    124647    132410    140354    -1     0.254  0.240
 090-142500      SGRA  14:25:00  14:31:00   21  0.40  151   153803    160458    142933    149895    -1     0.214  0.205
 090-143500  1921-293  14:35:00  14:40:00   23  0.39  139   136671    143804    101732    107101    -1     0.459  0.436
 090-144500      SGRA  14:45:00  14:52:00   20  0.38  148   280245    292670    142524    150390    -1     0.159  0.152
 090-145700  1921-293  14:57:00  15:02:00   23  0.37  150   174951    185516    103186    109875    -1     0.403  0.379
 090-150700      SGRA  15:07:00  15:14:00   18  0.37  154   360370    377872    152706    162080    -1     0.136  0.128
 090-151900  1921-293  15:19:00  15:24:00   23  0.36  377   193108    205389    102811    109635    -1     0.384  0.361
 090-154400   3C454.3  15:44:00  15:49:00   51  0.36  314    39751     42900     41184     44594    -1     2.822  2.611
 090-155400   3C454.3  15:54:00  15:59:00   53  0.36  163    39751     42900     41184     44594    -1     2.822  2.611
#
# day91 (01apr) - CP-hi = C4 in passthrough mode through 091-0730; [C2,C3,C5,C10,C11,C12,C13] phased thereafter
#
#   scan        src     UTstart   UTstop    el  tau  path    C1-lo     C1-hi     C4-lo     CP-hi  ph-eff     CD     FD
#                                          deg        um    SEFD-Jy   SEFD-Jy   SEFD-Jy   SEFD-Jy          amp    amp
```

```
 091-050000    missed  05:00:00  05:07:00   38  0.00    0        0*       0*       0*       0*   -1     0.000  0.000
 091-051500    missed  05:15:00  05:23:00   48  0.00    0        0*       0*       0*       0*   -1     0.000  0.000
 091-053000     3C273  05:30:00  05:37:00   43  0.37  218    43358*   46802*   47296*   50588*   -1     1.365  1.270
 091-054500       M87  05:45:00  05:53:00   53  0.37  170    40403    43560    47101    50632    -1     0.381  0.353
 091-060000     3C273  06:00:00  06:04:00   47  0.34  164    36685    39814    49968    53607    -1     1.443  1.338
 091-061200       M87  06:12:00  06:22:00   57  0.34  147    32061    34955    41573    45186    -1     0.455  0.418
 091-062600     3C273  06:26:00  06:30:00   50  0.34  154    35067    38094    42309    45494    -1     1.604  1.485
 091-063800       M87  06:38:00  06:48:00   61  0.32  176    29551    32124    43465    47330    -1     0.463  0.426
 091-065200     3C273  06:52:00  06:56:00   53  0.31  136    36384*   39623*   40633*   43941*   -1     1.607  1.481
 091-070400       M87  07:04:00  07:14:00   63  0.31  117    27638    30019    39005    42326    -1     0.506  0.466
 091-071800     3C273  07:18:00  07:22:00   54  0.31  146    35011    38097    38088    41117    -1     1.692  1.561
 091-073000       M87  07:30:00  07:40:00   65  0.30  152    29686    32365    34414    37226    -1     0.519  0.478
 091-080000     3C279  08:00:00  08:05:00   47  0.31   98    36877    40018    41124    11293   0.82    3.554  6.510
 091-081300       M87  08:13:00  08:23:00   64  0.30   95    27938    30401    31609    10853   0.74    0.559  0.914
 091-082700     3C279  08:27:00  08:32:00   47  0.30   93    40379    43705    41526    14204   0.67    3.380  5.555
 091-084000  1633+382  08:40:00  08:50:00   53  0.30   76    30820    33517    36815     9680   0.88    0.917  1.716
 091-090000     3C345  09:00:00  09:10:00   55  0.31  132    31560    34263    37850    11237   0.84    0.619  1.091
 091-092000     3C279  09:20:00  09:25:00   44  0.31  132    40898    44047    45954    14119   0.79    3.192  5.550
 091-092900       M87  09:29:00  09:36:00   56  0.32  126    34738    37787    39518    16014   0.57    0.448  0.675
 091-094000       M87  09:40:00  09:50:00   54  0.32  136    36434    39664    40409    12497   0.78    0.433  0.746
 091-100000     3C345  10:00:00  10:10:00   67  0.32  171    29733    32324    35583    10464   0.84    0.658  1.164
 091-102000  1633+382  10:20:00  10:30:00   72  0.32  143    27657    30304    32703     8935   0.92    1.027  1.878
 091-104000  1749+096  10:40:00  10:45:00   47  0.31  124    38210    41604    49076    18288   0.57    0.919  1.443
 091-104900      SGRA  10:49:00  10:56:00   17  0.31  124   121742*  127762*  136721*   46857   0.63    0.246  0.411
 091-110000  1749+096  11:00:00  11:05:00   50  0.31  116    38110*   41451*   42519*   12045   0.82    0.989  1.781
 091-110900      SGRA  11:09:00  11:16:00   19  0.32  121   109585*  114367*  119459*   52657   0.51    0.278  0.410
 091-112000  1749+096  11:20:00  11:25:00   53  0.32  127    36307*   39534*   38302*   15117   0.63    1.067  1.628
 091-112900      SGRA  11:29:00  11:36:00   20  0.33  206    95497*  100150*  105726*   53107   0.39    0.316  0.436
 091-114300   NRAO530  11:43:00  11:48:00   37  0.32  162    48083    51536    63347    15977   0.69    0.602  1.157
 091-115200      SGRA  11:52:00  12:00:00   22  0.33  140    87043    91419   135778    25375   0.65    0.293  0.660
 091-120700   NRAO530  12:07:00  12:12:00   39  0.33   96    45906    49535    67325    14100   0.78    0.597  1.256
 091-121600      SGRA  12:16:00  12:24:00   23  0.33   90    81395*   85996*   89621*   25534   0.72    0.372  0.679
 091-123100   NRAO530  12:31:00  12:36:00   40  0.33   85    47730    51473    62517    14345   0.77    0.608  1.222
 091-124000      SGRA  12:40:00  12:48:00   24  0.33  189   101092   107732   142018    27463   0.70    0.265  0.585
 091-125500   NRAO530  12:55:00  13:00:00   40  0.35  151    53817    57967    66228    17031   0.71    0.556  1.057
 091-130400      SGRA  13:04:00  13:12:00   24  0.35  142   100618   105532   127870    40718   0.48    0.280  0.485
 091-131900   NRAO530  13:19:00  13:24:00   39  0.35  130    50306    54131    66625    15140   0.81    0.573  1.160
 091-132800      SGRA  13:28:00  13:36:00   23  0.35  198   100912   106757   126890    37268   0.55    0.281  0.504
 091-135600   NRAO530  13:56:00  14:01:00   37  0.38  143    50975*   54300*   55535*   16723   0.74    0.624  1.102
 091-140500      SGRA  14:05:00  14:13:00   22  0.37  101   111126   117572   156177    45494   0.53    0.241  0.435
 091-142000   NRAO530  14:20:00  14:25:00   35  0.36  138    58787    62632    72491    18963   0.78    0.509  0.963
 091-142900      SGRA  14:29:00  14:37:00   21  0.36  137   115868   122842   146947    38909   0.74    0.244  0.460
 091-144400  1921-293  14:44:00  14:49:00   24  0.36  135   143222   151653   101368    39731   0.72    0.449  0.697
 091-145300      SGRA  14:53:00  15:01:00   19  0.35  447   189665   200514   137070   122471   0.33    0.197  0.203
 091-150500  1921-293  15:05:00  15:10:00   23  0.35  447   174626   184435   113429    42064   0.72    0.384  0.614
 091-152500     BLLAC  15:25:00  15:35:00   68  0.35  313    24751    26955    28768    35879   0.32    1.195  1.026
 091-154000     BLLAC  15:40:00  15:50:00   71  0.36  210    25593    27884    29577    26004   0.50    1.159  1.185
#
# day92 (02apr) - CP-hi = [C2,C3,C5,C10,C11,C12,C13]; CP-lo also phased until 092-0800
#
#   scan        src     UTstart    UTstop    el  tau  path     C1-lo    C1-hi    C4-lo    CP-hi  ph-eff     CD     FD
#                                            deg        um   SEFD-Jy  SEFD-Jy  SEFD-Jy  SEFD-Jy           amp    amp
 092-050000    missed  05:00:00  05:07:00   39  0.00    0        0*       0*       0*       0*  0.00    0.000  0.000
 092-051500    missed  05:15:00  05:23:00   49  0.00    0        0*       0*       0*       0*  0.00    0.000  0.000
 092-053000    missed  05:30:00  05:37:00   44  0.00    0        0*       0*       0*       0*  0.00    0.000  0.000
 092-054500    missed  05:45:00  05:53:00   54  0.00    0        0*       0*       0*       0*  0.00    0.000  0.000
 092-060000    missed  06:00:00  06:04:00   48  0.00    0        0*       0*       0*       0*  0.00    0.000  0.000
 092-061200    missed  06:12:00  06:22:00   58  0.35  288        0*       0*       0*       0*  0.00    0.000  0.000
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 092-062600    missed  06:26:00  06:30:00   51  0.35  302        0*        0*        0*        0*  0.00    0.000  0.000
 092-063800       M87  06:38:00  06:48:00   61  0.32  407     45535     49542     12917     14082  0.68    0.684  0.628
 092-065200     3C273  06:52:00  06:56:00   53  0.34  371     50743     55031     14904     16189  0.70    2.247  2.070
 092-070400       M87  07:04:00  07:14:00   64  0.34  402     33061     36091     14795     16145  0.60    0.751  0.688
 092-071800     3C273  07:18:00  07:22:00   54  0.34  362     43433     47292     15075     16099  0.64    2.415  2.240
 092-073000       M87  07:30:00  07:40:00   65  0.33  352     39942     43493     13394     14754  0.64    0.718  0.655
 092-074400     3C273  07:44:00  07:48:00   55  0.32  337     38760     42094     15309     16794  0.59    2.537  2.324
 092-080000     3C279  08:00:00  08:05:00   47  0.36  405     53085     57685     15400     16618  0.59    4.841  4.470
 092-081300       M87  08:13:00  08:23:00   64  0.31  426     31295     34300     15023     16543  0.56    0.766  0.697
 092-082700     3C279  08:27:00  08:32:00   47  0.28  484    39524*    42977*    43463*     22026  0.55    3.339  4.498
 092-084000  1749+096  08:40:00  08:50:00   25  0.29  611     84426     90799    106319     81740  0.28    0.420  0.462
 092-090000  1749+096  09:00:00  09:10:00   29  0.34  239     83702     90041    109339     26504  0.65    0.416  0.815
 092-092000     3C279  09:20:00  09:25:00   44  0.37  208     45805     49400     54255     22929  0.56    2.776  4.112
 092-092900       M87  09:29:00  09:36:00   56  0.32  248     44317     48432     55786     25289  0.49    0.334  0.474
 092-094000       M87  09:40:00  09:50:00   54  0.31  439     45314     49634     53745     16974  0.67    0.336  0.572
 092-100000  1633+382  10:00:00  10:10:00   69  0.33  443     40163     44112     36291     23738  0.45    0.809  0.955
 092-102000  1633+382  10:20:00  10:30:00   73  0.35  360     43355     47600     37516     20503  0.56    0.766  0.989
 092-104000  1749+096  10:40:00  10:45:00   48  0.35  396     66823     72548     52810     21717  0.65    0.670  1.003
 092-104900      SGRA  10:49:00  10:56:00   17  0.35  392   130602*   137316*   146002*    105073  0.45    0.230  0.265
 092-110000  1749+096  11:00:00  11:05:00   51  0.37  444    37222*    40461*    40028*     26117  0.53    1.031  1.224
 092-110900      SGRA  11:09:00  11:16:00   19  0.35  471    95994*   101617*   107958*     63918  0.53    0.312  0.395
 092-112000  1749+096  11:20:00  11:25:00   54  0.32  471    35769*    38968*    38547*     28141  0.53    1.072  1.202
 092-112900      SGRA  11:29:00  11:36:00   21  0.35  527    79586*    84065*    89407*    106836  0.32    0.377  0.336
 092-114300   NRAO530  11:43:00  11:48:00   38  0.36  716    42763*    46364*    46294*     60906  0.40    0.746  0.625
 092-115200      SGRA  11:52:00  12:00:00   22  0.35  759    74294*    79483*    83365*     93742  0.34    0.404  0.368
 092-120700   NRAO530  12:07:00  12:12:00   39  0.35  468    118512    127885     77373     31548  0.56    0.347  0.523
 092-121600      SGRA  12:16:00  12:24:00   23  0.37  535    214474    228252    132695     75606  0.38    0.189  0.242
 092-123100   NRAO530  12:31:00  12:36:00   40  0.39  425    111628    119584     71879     28061  0.58    0.371  0.573
 092-124000      SGRA  12:40:00  12:48:00   24  0.39  424    401499    428543    158705    110657  0.31    0.126  0.146
 092-125500   NRAO530  12:55:00  13:00:00   40  0.39  470    44987*    48585*    48466*     74821  0.23    0.711  0.551
 092-130400      SGRA  13:04:00  13:12:00   24  0.39  560    179526    191395    123536     87076  0.37    0.214  0.246
 092-131900   NRAO530  13:19:00  13:24:00   39  0.38  550    103320    111650     76315     55591  0.34    0.374  0.421
 092-132800      SGRA  13:28:00  13:36:00   23  0.38  573    163300    173235    150905     87886  0.35    0.203  0.258
 092-135600  1921-293  13:56:00  14:01:00   23  0.40  465    259959    277892    191998     94386  0.39    0.242  0.334
 092-140500      SGRA  14:05:00  14:13:00   22  0.41  468    316156    333806    198974    241166  0.19    0.127  0.112
 092-142000  1921-293  14:20:00  14:25:00   23  0.40  502    86854*    91729*    94004*    237822  0.18    0.599  0.366
 092-142900      SGRA  14:29:00  14:37:00   20  0.39  494    642947    685187    184213    151232  0.32    0.092  0.099
 092-144400  1921-293  14:44:00  14:49:00   23  0.39  410    325476    348235    179810    206883  0.19    0.224  0.202
 092-145300      SGRA  14:53:00  15:01:00   18  0.39  372   1118688   1186920    208560    432121  0.21    0.066  0.044
 092-150500  1921-293  15:05:00  15:10:00   23  0.37  360    333725    353591    237343    443219  0.08    0.192  0.137
 092-152500     BLLAC  15:25:00  15:35:00   69  0.40  386     32281     35094     31230     18505  0.56    1.005  1.252
 092-154000     BLLAC  15:40:00  15:50:00   71  0.41  450     29730     32405     30633     19393  0.55    1.057  1.272
#
# day94 (04apr) - CP-hi = [C2,C3,C5,C9,C11,C12,C13] phased, all scans
#
#   scan        src     UTstart   UTstop    el  tau  path     C1-lo     C1-hi     C4-lo     CP-hi  ph-eff     CD     FD
#                                           deg        um   SEFD-Jy   SEFD-Jy   SEFD-Jy   SEFD-Jy           amp    amp
 094-050000     3C273  05:00:00  05:03:00   40  0.00    0        0*        0*        0*        0*  0.00    0.000  0.000
 094-051000       M87  05:10:00  05:22:00   49  0.23  139     30580     34159     38307     23539  0.31    0.485  0.585
 094-052600     3C273  05:26:00  05:29:00   44  0.23  138     33413     37135     41300     10265  0.73    1.664  3.165
 094-053600       M87  05:36:00  05:48:00   54  0.22  161     29974     33527     35896      8432  0.80    0.506  0.987
 094-055200     3C273  05:52:00  05:55:00   48  0.22  135     30015     33579     37647      9638  0.73    1.838  3.435
 094-060200       M87  06:02:00  06:14:00   58  0.21  120     26883     30156     34987      6945  0.89    0.541  1.147
 094-061800     3C273  06:18:00  06:21:00   51  0.21  105     27679     30918     33568      9495  0.70    2.027  3.607
 094-062800       M87  06:28:00  06:40:00   61  0.21  155     23473     26301     34869      6548  0.91    0.580  1.265
 094-064400     3C273  06:44:00  06:47:00   53  0.21  152     26341     29493     31785      7140  0.86    2.136  4.259
 094-065400       M87  06:54:00  07:06:00   64  0.21  142     22112     24904     30881      6406  0.92    0.635  1.314
 094-072100     3C279  07:21:00  07:24:00   46  0.22  103     29350     32680     38196      9038  0.80    4.134  8.053
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094-073100	M87	07:31:00	07:43:00	65	0.23	129	23999	26874	28411	8485	0.78	0.636	1.099
094-074700	3C279	07:47:00	07:50:00	47	0.23	150	28556*	31817*	31806*	8918	0.81	4.592	8.216
094-075700	M87	07:57:00	08:09:00	65	0.23	182	22877	25665	29138	8350	0.82	0.643	1.134
094-081300	3C279	08:13:00	08:16:00	47	0.23	131	32252	35976	40223	9279	0.80	3.843	7.575
094-082300	M87	08:23:00	08:35:00	63	0.24	187	24298	27144	29230	6804	0.93	0.623	1.221
094-083900	3C279	08:39:00	08:42:00	46	0.24	118	30305	33783	38495	8769	0.85	4.052	8.041
094-084900	M87	08:49:00	09:01:00	60	0.23	223	26042	29203	30676	9397	0.72	0.587	1.002
094-090500	3C279	09:05:00	09:08:00	44	0.23	265	35095	39173	42985	13924	0.61	3.563	5.926
094-091500	M87	09:15:00	09:27:00	57	0.23	303	28966	32499	35504	7970	0.82	0.518	1.031
094-093100	3C279	09:31:00	09:34:00	42	0.24	371	36296	40330	44436	8559	0.93	3.446	7.449
094-094100	M87	09:41:00	09:53:00	52	0.23	156	30836	34525	33691	8638	0.77	0.515	0.961
094-095700	3C279	09:57:00	10:00:00	39	0.23	160	43476	47824	49490	10530	0.85	2.984	6.167
094-100700	M87	10:07:00	10:19:00	48	0.24	109	32907	36503	39334	10136	0.75	0.461	0.863
094-102300	3C279	10:23:00	10:26:00	36	0.24	114	51602	56672	59932	15829	0.64	2.489	4.621
094-103300	M87	10:33:00	10:45:00	43	0.25	151	40215	44599	45521	16464	0.52	0.388	0.613
094-104900	3C279	10:49:00	10:52:00	32	0.25	190	63962	69990	75998	16029	0.74	1.985	4.132
094-105900	M87	10:59:00	11:11:00	38	0.25	228	51320	56533	59819	13626	0.76	0.300	0.598
094-113100	NRAO530	11:31:00	11:34:00	37	0.28	153	47053	51496	57553	18299	0.53	0.638	1.082
094-113900	SGRA	11:39:00	11:54:00	22	0.30	143	74818	80938	112888	24405	0.59	0.346	0.716
094-115800	NRAO530	11:58:00	12:01:00	39	0.30	196	46057	50665	56572	15515	0.65	0.650	1.184
094-120500	SGRA	12:05:00	12:20:00	23	0.31	173	67119	72303	99177	17358	0.73	0.390	0.898
094-122200	SGRA	12:22:00	12:37:00	23	0.32	131	62875*	68113*	69331*	16695	0.78	0.482	0.943
094-124100	NRAO530	12:41:00	12:44:00	40	0.33	134	43421	47552	56505	14068	0.76	0.670	1.284
094-124800	SGRA	12:48:00	13:03:00	24	0.34	110	65911	71309	85590	19276	0.69	0.423	0.858
094-130500	SGRA	13:05:00	13:20:00	24	0.36	117	73989*	79291*	84705*	22764	0.68	0.402	0.748
094-132400	NRAO530	13:24:00	13:27:00	38	0.36	127	53643	58609	69802	15501	0.84	0.543	1.101
094-133300	1921-293	13:33:00	13:36:00	22	0.37	126	107746	116327	138084	36217	0.57	0.444	0.833
094-134000	SGRA	13:40:00	13:55:00	23	0.37	99	86002	92876	98299	26295	0.69	0.346	0.643
094-135700	SGRA	13:57:00	14:12:00	22	0.38	106	88445*	95150*	102972*	36743	0.54	0.333	0.538
094-141600	1921-293	14:16:00	14:19:00	23	0.38	134	93277	100817	102241	36324	0.56	0.554	0.894
094-142300	SGRA	14:23:00	14:38:00	20	0.37	111	103618	111498	104991	45522	0.50	0.305	0.446
094-144000	SGRA	14:40:00	14:55:00	19	0.37	160	119280*	128791*	135597*	50766	0.55	0.250	0.393
094-145900	1921-293	14:59:00	15:02:00	23	0.36	158	105573	112979	103770	52702	0.46	0.517	0.701
094-150600	SGRA	15:06:00	15:16:00	16	0.36	121	179749	192109	123248	139623	0.31	0.214	0.194
094-152000	1921-293	15:20:00	15:25:00	22	0.36	114	130071	138693	104137	45909	0.61	0.465	0.678
094-155500	MWC349A	15:55:00	16:07:00	85	0.00	0	0*	0*	0*	0*	0.00	0.000	0.000
094-160900	MWC349A	16:09:00	16:21:00	83	0.00	0	0*	0*	0*	0*	0.00	0.000	0.000
094-162500	2015+371	16:25:00	16:30:00	77	0.00	0	0*	0*	0*	0*	0.00	0.000	0.000
094-163400	MWC349A	16:34:00	16:46:00	78	0.00	0	0*	0*	0*	0*	0.00	0.000	0.000
094-164800	MWC349A	16:48:00	17:00:00	75	0.00	0	0*	0*	0*	0*	0.00	0.000	0.000