Starting Out With AIPS Tutorial

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This tutorial session is intended to get people familiar with the basic concepts of radio interferometry. The student will be introduced to interferometry data, visibilities, the *(u,v)* plane, calibration, and imaging.

Step 1 --- Figure Out What to Observe (Reduce)

I decided to try to make an image of the Sun, as the Solar KSP is a significant part of GLOW. The NRAO image archive has a nice image of the Sun at 1400 MHz located at http://images.nrao.edu/8

Image courtesy of NRAO/AUI

Let's try to reduce the data ourselves.

Step 2 --- Download the Data From the Archive

Conveniently, the NRAO image archive gives details about the observations used to make the image, so I downloaded the data from the NRAO data archive, making sure to select the "AIPS friendly" filename option.

This has resulted in two files on my hard drive in my current directory:

```
ls -l
total 54164
-rw-r—— 1 anderson zeall 21002240 2008-11-11 14:40 GD_1
-rw-r—— 1 anderson zeall 34392064 2008-11-11 14:41 GD_2
```

Step 3 --- Start up AIPS

```
aips
```

I have chosen to use user ID 100, at semi-random selection.

At first, most of the archane syntax used to enter commands to AIPS will be difficult. As this is a tutorial session which intends to teach you about radio interferometry, and not how to use AIPS, we will gloss over the technical challenges of interacting with AIPS.

In AIPS you the user interact with something called POPS. You give POPS information by setting variables called ADVERBS to specific values. You can tell POPS which TASK you plan to run by setting a TASK ADVERB. If you want to check the values of ADVERBs for the current TASK, you ask for INPUTS. Because POPS will try to figure out what you mean if you only input the first few letters of an ADVERB or VERB, you can often abbreviate this to just INP. Also note that since AIPS is case-insensitive by default, you could also just type inp. If you want help on a specific topic, ask for HELP. If you want even more explanation for something, say EXPLAIN. If you don't know what it is you are trying to do, but you have some vague notion, say APROPOS SOMETHING. Note that apostrophes, and in certain locations, the lack of an apostrophe are significant.

```
dowait=true
dohist=1
docrt=132
dotv=1
```

Step 4 --- Initial look at data

FILLM

The AIPS task to read raw VLA data into AIPS is called FILLM.

```
task 'fillm'
datain = 'PWD:GD_
nfiles=0
ncount=2
vlamode='S '
band 'l'
doweight=10
doconcat=true
douvcomp=0
cparm(2)=16
cparm(4)=28
cparm(8)=10./60
dparm 0
bparm 0
timer 0
calcode ' '
clron
go
```

This sets us up to read the data, sets the VLA mode to Solar, tells AIPS not to change the source if the position appears to be moving (which the Sun does), sets the shadowing limit to 28 meters, and sets the CL table interval to 10 seconds.

Header information

```
pcat
```

```
AIPS 1: Catalog on disk  1
AIPS 1:  Cat Usid Mapname      Class   Seq  Pt     Last access      Stat
AIPS 1:    1  100 19810926    .L BAND.    1 UV 14-NOV-2008 21:35:31
```

```
getn 1
imhe
```

```
AIPS 1: Image=MULTI     (UV)         Filename=19810926    .L BAND.   1
AIPS 1: Telescope=VLA                Receiver=VLA
AIPS 1: Observer=GD                  User #=  100
AIPS 1: Observ. date=26-SEP-1981     Map date=14-NOV-2008
AIPS 1: # visibilities    556884     Sort order  TB
AIPS 1: Rand axes: UU-L-SIN  VV-L-SIN  WW-L-SIN  BASELINE  TIME1
AIPS 1:            SOURCE  FREQSEL
AIPS 1: ----------------------------------------------------------------
AIPS 1: Type    Pixels   Coord value     at Pixel     Coord incr   Rotat
AIPS 1: COMPLEX      3   1.0000000E+00       1.00  1.0000000E+00    0.00
AIPS 1: STOKES       4  -1.0000000E+00       1.00 -1.0000000E+00    0.00
AIPS 1: FREQ         1   1.4461500E+09       1.00  1.2500000E+07    0.00
AIPS 1: IF           1   1.0000000E+00       1.00  1.0000000E+00    0.00
AIPS 1: RA           1    00 00 00.000       1.00       3600.000    0.00
AIPS 1: DEC          1    00 00 00.000       1.00       3600.000    0.00
AIPS 1: ----------------------------------------------------------------
AIPS 1: Coordinate equinox    0.00
AIPS 1: Maximum version number of extension files of type HI is   1
AIPS 1: Maximum version number of extension files of type AN is   1
AIPS 1: Maximum version number of extension files of type NX is   1
AIPS 1: Maximum version number of extension files of type SU is   1
AIPS 1: Maximum version number of extension files of type FQ is   1
AIPS 1: Maximum version number of extension files of type CL is   1
AIPS 1: Maximum version number of extension files of type TY is   1
AIPS 1: Maximum version number of extension files of type WX is   1
AIPS 1: Maximum version number of extension files of type OF is   1
AIPS 1: Keyword = 'CORRMODE'  value = '        '
AIPS 1: Keyword = 'VLAIFS  '  value = 'AC      '
AIPS 1: Keyword = 'CORRCOEF'  value =           -1
```

LISTR --- scan listing

```
task 'listr'
indi 1
```

```
getn 1
optype 'scan'
docrt=132
flagver 0
sources ' '
stokes ' '
docalib 0
gainuse 1
dopol -1
dparm 0
go
```

```
 vlb054    LISTR(31DEC08)    100     14-NOV-2008  21:42:46    Page    1
File = 19810926    .L BAND.   1 Vol = 1  Userid =  100
Freq =  1.446150006 GHz   Ncor =  4   No. vis =    556884
Scan summary listing

Scan      Source      Qual  Calcode Sub        Timerange          FrqID
START VIS  END VIS
   1 1148-001        : 0000  C        1  0/13:53:25 -   0/13:53:25     1
1        351
   2 1148-001        : 0000  C        1  0/13:53:35 -   0/13:54:35     1
352       2808
   3 SUN             : 0000           1  0/13:59:05 -   0/13:59:35     1
2809       4212
   4 SUN             : 0000           1  0/14:05:15 -   0/14:09:35     1
4213      13689
   5 1148-001        : 0000  C        1  0/14:18:05 -   0/14:19:35     1
13690      17199
   6 SUN             : 0000           1  0/14:20:15 -   0/14:24:35     1
17200      26676
   7 SUN             : 0000           1  0/14:30:05 -   0/14:34:35     1
26677      36504
   8 1148-001        : 0000  C        1  0/14:43:05 -   0/14:44:35     1
36505      40014
   9 SUN             : 0000           1  0/14:45:15 -   0/14:49:35     1
40015      49491
  10 SUN             : 0000           1  0/14:55:05 -   0/14:59:25     1
49492      58968
  11 1148-001        : 0000  C        1  0/15:07:55 -   0/15:09:25     1
58969      62478
  12 SUN             : 0000           1  0/15:10:05 -   0/15:14:25     1
62479      71955
  13 SUN             : 0000           1  0/15:19:55 -   0/15:24:25     1
71956      81783
  14 1148-001        : 0000  C        1  0/15:32:55 -   0/15:34:25     1
81784      85293
  15 SUN             : 0000           1  0/15:35:05 -   0/15:39:25     1
85294      94770
  16 SUN             : 0000           1  0/15:44:55 -   0/15:49:25     1
```

```
94771     104598
  17 1148-001        : 0000  C        1  0/15:57:55 -   0/15:59:25     1
104599     108108
  18 SUN             : 0000           1  0/16:00:05 -   0/16:04:15     1
108109     117234
  19 SUN             : 0000           1  0/16:09:45 -   0/16:14:15     1
117235     127062
  20 1148-001        : 0000  C        1  0/16:22:45 -   0/16:24:15     1
127063     130572
  21 SUN             : 0000           1  0/16:24:55 -   0/16:29:15     1
130573     140049
  22 SUN             : 0000           1  0/16:34:45 -   0/16:39:15     1
140050     149877
  23 1148-001        : 0000  C        1  0/16:47:45 -   0/16:49:15     1
149878     153387
  24 SUN             : 0000           1  0/16:49:55 -   0/16:54:15     1
153388     162864
  25 SUN             : 0000           1  0/16:59:45 -   0/17:04:05     1
162865     172341
  26 1148-001        : 0000  C        1  0/17:12:35 -   0/17:14:05     1
172342     175851
  27 SUN             : 0000           1  0/17:14:45 -   0/17:19:05     1
175852     185328
  28 SUN             : 0000           1  0/17:24:35 -   0/17:29:05     1
185329     195156
  29 1148-001        : 0000  C        1  0/17:37:35 -   0/17:39:05     1
195157     198666
  30 SUN             : 0000           1  0/17:39:45 -   0/17:44:25     1
198667     208845
  31 SUN             : 0000           1  0/17:50:15 -   0/17:54:05     1
208846     217269
  32 1148-001        : 0000  C        1  0/18:02:25 -   0/18:03:55     1
217270     220779
  33 SUN             : 0000           1  0/18:04:35 -   0/18:08:55     1
220780     230256
  34 SUN             : 0000           1  0/18:14:25 -   0/18:18:55     1
230257     240084
  35 1148-001        : 0000  C        1  0/18:27:25 -   0/18:28:55     1
240085     243594
  36 SUN             : 0000           1  0/18:29:35 -   0/18:33:55     1
243595     253071
  37 SUN             : 0000           1  0/18:39:35 -   0/18:44:05     1
253072     262899
  38 1148-001        : 0000  C        1  0/18:52:35 -   0/18:53:55     1
262900     266058
  39 SUN             : 0000           1  0/18:54:45 -   0/18:59:05     1
266059     275535
  40 SUN             : 0000           1  0/19:04:25 -   0/19:08:45     1
275536     285012
  41 1148-001        : 0000  C        1  0/19:17:25 -   0/19:18:45     1
285013     288171
```

```
  42 SUN           : 0000        1  0/19:19:25 -   0/19:23:45     1
288172     297648
  43 SUN           : 0000        1  0/19:29:15 -   0/19:33:45     1
297649     307476
  44 1148-001      : 0000  C     1  0/19:42:15 -   0/19:43:45     1
307477     310986
  45 SUN           : 0000        1  0/19:44:25 -   0/19:53:05     1
310987     329589
  46 SUN           : 0000        1  0/19:54:25 -   0/19:58:45     1
329590     339066
  47 1148-001      : 0000  C     1  0/20:07:05 -   0/20:08:35     1
339067     342576
  48 SUN           : 0000        1  0/20:09:15 -   0/20:13:35     1
342577     352053
  49 SUN           : 0000        1  0/20:19:05 -   0/20:23:35     1
352054     361881
  50 1148-001      : 0000  C     1  0/20:32:05 -   0/20:33:35     1
361882     365391
  51 SUN           : 0000        1  0/20:34:15 -   0/20:38:35     1
365392     374868
  52 SUN           : 0000        1  0/20:44:05 -   0/20:48:35     1
374869     384696
  53 1148-001      : 0000  C     1  0/20:57:05 -   0/20:58:35     1
384697     388206
  54 SUN           : 0000        1  0/20:59:15 -   0/21:03:35     1
388207     397657
  55 SUN           : 0000        1  0/21:08:55 -   0/21:13:25     1
397658     407485
  56 1148-001      : 0000  C     1  0/21:21:55 -   0/21:23:25     1
407486     410969
  57 SUN           : 0000        1  0/21:24:05 -   0/21:28:25     1
410970     420446
  58 SUN           : 0000        1  0/21:33:55 -   0/21:38:25     1
420447     430274
  59 1148-001      : 0000  C     1  0/21:47:05 -   0/21:48:25     1
430275     433433
  60 SUN           : 0000        1  0/21:49:05 -   0/21:53:25     1
433434     442858
  61 SUN           : 0000        1  0/21:58:55 -   0/22:03:25     1
442859     452686
  62 1148-001      : 0000  C     1  0/22:11:45 -   0/22:13:15     1
452687     456196
  63 SUN           : 0000        1  0/22:13:55 -   0/22:18:15     1
456197     465647
  64 SUN           : 0000        1  0/22:23:55 -   0/22:28:15     1
465648     475124
  65 1148-001      : 0000  C     1  0/22:36:55 -   0/22:38:15     1
475125     478283
  66 SUN           : 0000        1  0/22:38:55 -   0/22:43:15     1
478284     487734
```

```
  67 SUN              : 0000           1  0/22:48:55 -   0/22:53:25     1
487735    497562
  68 1148-001         : 0000  C        1  0/23:01:55 -   0/23:03:15     1
497563    500721
  69 SUN              : 0000           1  0/23:03:55 -   0/23:08:05     1
500722    509847
  70 SUN              : 0000           1  0/23:13:45 -   0/23:18:05     1
509848    519324
  71 1148-001         : 0000  C        1  0/23:26:45 -   0/23:28:05     1
519325    522249
  72 SUN              : 0000           1  0/23:28:45 -   0/23:33:05     1
522250    531700
  73 SUN              : 0000           1  0/23:38:45 -   0/23:43:05     1
531701    540450
  74 1148-001         : 0000  C        1  0/23:51:45 -   0/23:53:05     1
540451    543350
  75 SUN              : 0000           1  0/23:53:45 -   0/23:58:05     1
543351    552125
  76 SUN              : 0000           1  1/00:01:15 -   1/00:01:15     1
552126    552450
  77 SUN              : 0000           1  1/00:07:25 -   1/00:07:55     1
552451    553725
  78 3C286            : 0000  B        1  1/00:21:35 -   1/00:22:55     1
553726    556884

Source summary
Velocity type = '        '    Definition = '        '

  ID Source           Qual  Calcode RA(   0.0)     Dec(   0.0)   IFlux
QFlux   UFlux   VFlux  No. vis
   1 1148-001         : 0000   C     11:48:10.1300 -00:07:13.300   0.000
0.000   0.000   0.000   84072
   2 SUN              : 0000         12:10:30.1272 -01:08:22.648   0.000
0.000   0.000   0.000  469653
   3 3C286            : 0000   B     13:28:49.6570  30:45:58.640   0.000
0.000   0.000   0.000    3159

  ID Source            Freq(GHz) Velocity(Km/s) Rest freq (GHz)
   1 All Sources          1.4462         0.0000          0.0000

Frequency Table summary
FQID IF#      Freq(GHz)      BW(kHz)   Ch.Sep(kHz)  Sideband
   1   1       1.44615001   12500.0010  12500.0010      1
AIPS 1: Resumes
```

PRTAN

Print the Antenna positions — useful for thinking about calibration.

go prtan

```
 vlb054    PRTAN(31DEC08)    100     14-NOV-2008  21:45:10    Page    1
File=19810926    .L BAND.   1     An.ver=   1     Vol= 1     User=  100
Array= VLA          Freq=  1446.150006 MHz     Ref.date= 26-SEP-1981

Array reference position in meters (Earth centered)
Array BX=  -1601185.36500    BY=  -5041977.54700    BZ=   3554875.87000
Polar X =   0.00000 Polar Y =   0.00000 arcsec
Earth rotation rate =  360.9856449713 degrees / IAT day
GST at UT=0 =  364.7139688925 degrees
UT1-UTC=      0.0000000   Data time(IAT     )-UTC=      0.0000000 seconds
Solutions not yet determined for a particular FREQID

Ant   1 = VLA:_N2  BX=      -30.0602 BY=       -4.7835 BZ=       45.7022
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   2 = VLA:_E5  BX=       51.8719 BY=      195.8466 BZ=      -75.1013
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   3 = VLA:_E9  BX=      139.6430 BY=      536.8956 BZ=     -207.7424
Mount=ALAZ  Axis offset= -0.0033 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   4 = VLA:_E6  BX=       70.6548 BY=      267.7575 BZ=     -102.8996
Mount=ALAZ  Axis offset=  0.0078 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   5 = VLA:_N3  BX=      -52.4373 BY=       -8.2629 BZ=       78.6643
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   6 = VLA:_W2  BX=       14.7735 BY=      -37.1404 BZ=      -20.2135
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   7 = VLA:_W3  BX=       28.9195 BY=      -74.4876 BZ=      -41.0524
Mount=ALAZ  Axis offset= -0.0036 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   8 = VLA:_W1  BX=       22.9920 BY=        3.4974 BZ=      -32.4864
Mount=ALAZ  Axis offset=  0.0084 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant   9 = VLA:_E2  BX=       11.3328 BY=       40.6638 BZ=      -15.1624
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L
```

```
Ant  10 = VLA:_OUT BX=       0.0000 BY=       0.0000 BZ=       0.0000
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  11 = VLA:_E8  BX=     114.4257 BY=     438.6941 BZ=    -169.4880
Mount=ALAZ  Axis offset=  0.0048 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  12 = VLA:_E3  BX=      21.9945 BY=      81.5250 BZ=     -30.9498
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  13 = VLA:_E7  BX=      91.5227 BY=     348.8871 BZ=    -134.4449
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  14 = VLA:_W7  BX=     121.6261 BY=    -319.1264 BZ=    -177.5842
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  15 = VLA:_W9  BX=     186.8061 BY=    -491.1158 BZ=    -273.5624
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  16 = VLA:_E4  BX=      35.6150 BY=     133.6310 BZ=     -51.1099
Mount=ALAZ  Axis offset= -0.0051 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  17 = VLA:_W8  BX=     152.7524 BY=    -401.2839 BZ=    -223.4146
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  18 = VLA:_E1  BX=      45.3386 BY=       7.0026 BZ=     -65.4888
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  19 = VLA:_N7  BX=    -193.6105 BY=     -30.2503 BZ=     286.4580
Mount=ALAZ  Axis offset= -0.0030 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  20 = VLA:_N1  BX=       0.6703 BY=       0.0144 BZ=       0.5135
Mount=ALAZ  Axis offset=  0.0045 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  21 = VLA:_N8  BX=    -243.6039 BY=     -38.0389 BZ=     360.0340
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L

Ant  22 = VLA:_W5  BX=      68.6012 BY=    -179.2282 BZ=     -99.5242
Mount=ALAZ  Axis offset=  0.0000 meters    IFA                 IFB
Feed polarization type =                    R                   L
```

```
Ant  23 = VLA:_N5  BX=     -108.4301 BY=      -16.9862 BZ=      161.0152
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  24 = VLA:_N9  BX=     -298.3837 BY=      -46.5620 BZ=      440.6260
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  25 = VLA:_N6  BX=     -148.4545 BY=      -23.2162 BZ=      219.9871
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  26 = VLA:_N4  BX=      -74.8318 BY=      -11.7331 BZ=      111.6208
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  27 = VLA:_W6  BX=       93.5170 BY=     -245.0012 BZ=     -136.2284
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  28 = VLA:_W4  BX=       46.9220 BY=     -122.0267 BZ=      -67.6047
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

Ant  29 = VPT:_OUT BX=        0.0000 BY=        0.0000 BZ=        0.0000
Mount=ALAZ  Axis offset=  0.0000 meters    IFA               IFB
Feed polarization type =                    R                 L

                      Location Of VLA Antennas

                               N9  (24)
                               N8  (21)
                               N7  (19)
                               N6  (25)
                               N5  (23)
                               N4  (26)
                               N3  ( 5)
                               N2  ( 1)
                               N1  (20)
                           ( 8) W1   E1  (18)
                         ( 6) W2       E2  ( 9)
                       ( 7) W3           E3  (12)
                     (28) W4               E4  (16)
                   (22) W5                   E5  ( 2)
                 (27) W6                       E6  ( 4)
               (14) W7                           E7  (13)
             (17) W8                               E8  (11)
           (15) W9                                   E9  ( 3)
                           VLA:_OUT (10)
                           VPT:_OUT (29)
```

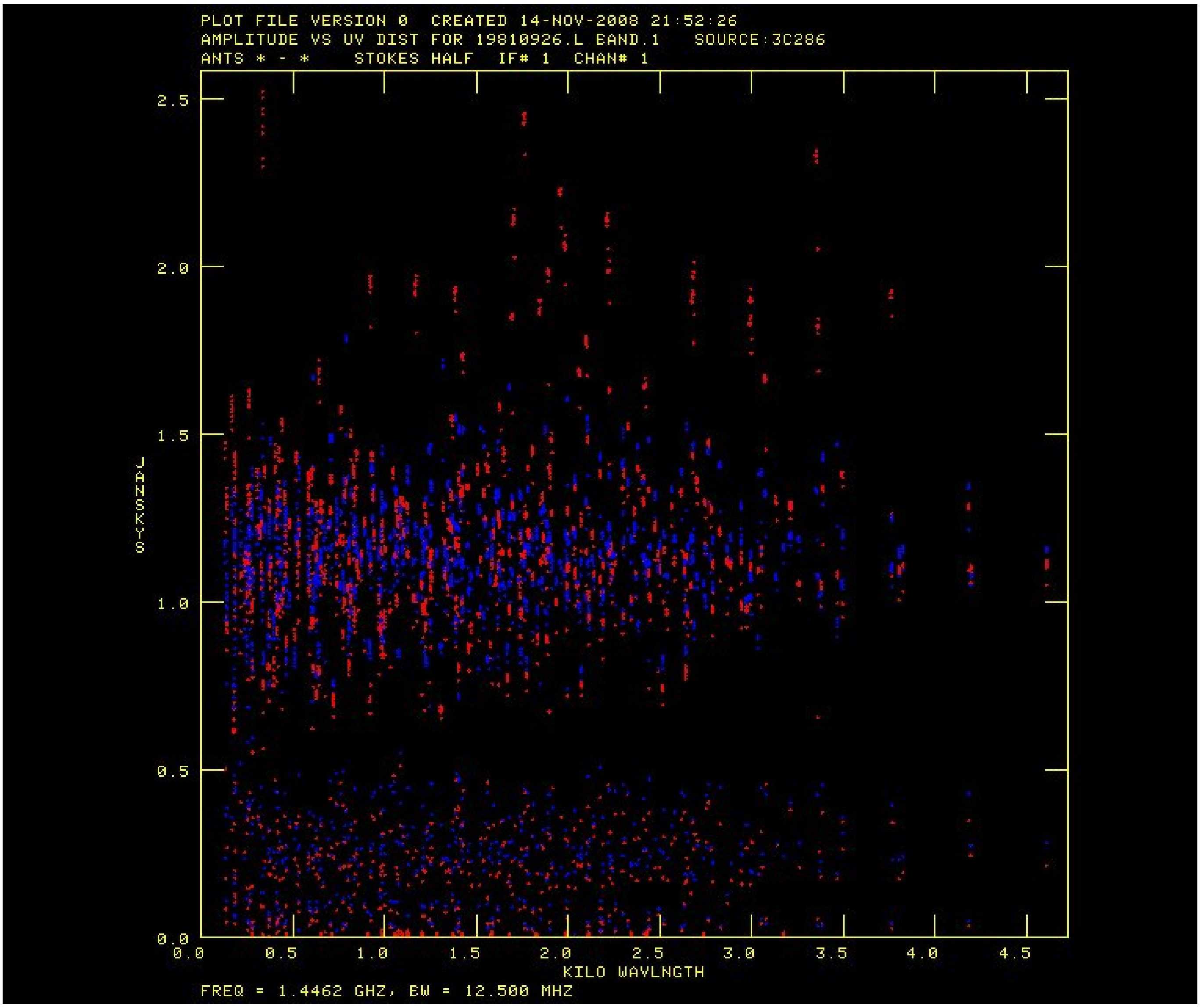
```
AIPS 1: Resumes
```

The really important part for you, the data reducer, is the antenna layout at the bottom. This tells you in a nice graphical form where each antenna is located. This helps you to figure out which baselines are small, and which baselines are long. This is also useful for figuring out other things related to antenna position and baseline direction.

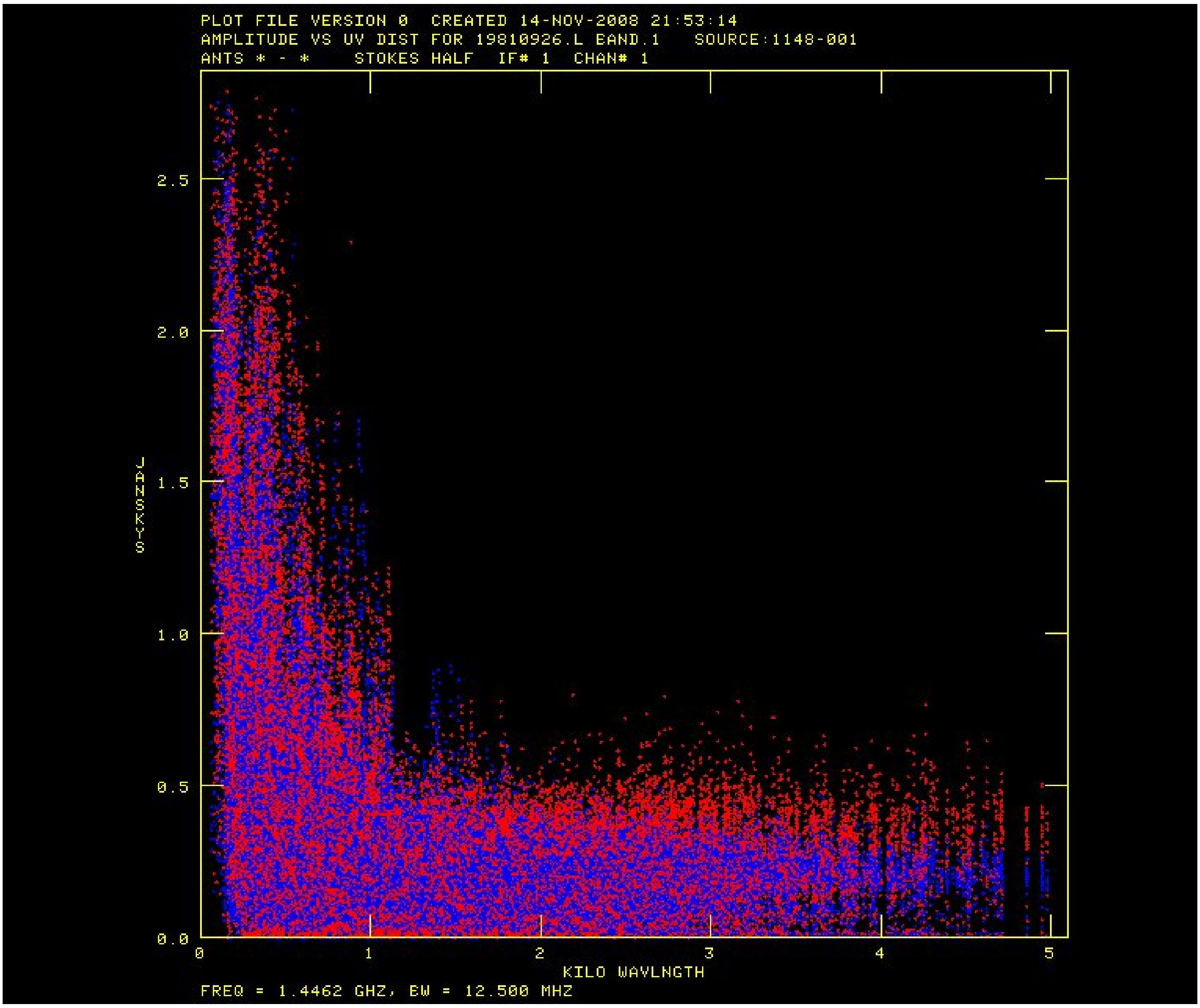
UVPLT

Let's have a look at the information about the visibilities.

```
task 'uvplt'
source '3c286',' '
stokes 'half'
calcode ' '
uvrange 0
antennas 0
basel 0
xinc 1
aparm 0
bparm 0
doweight 1
refant 3
do3col 1
dotv 1
tvinit
go
```

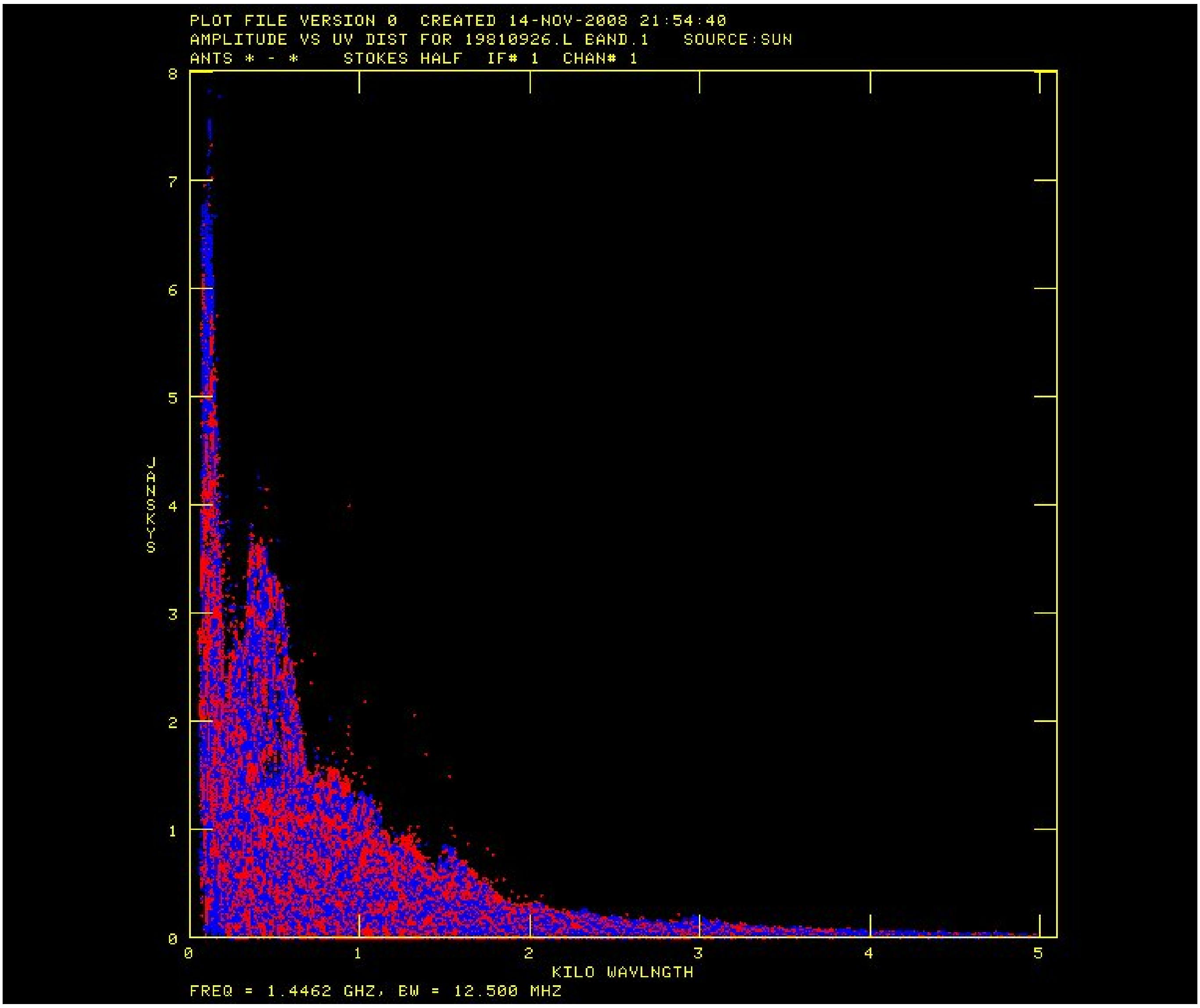



```
source '1148-001', ' '
go
```

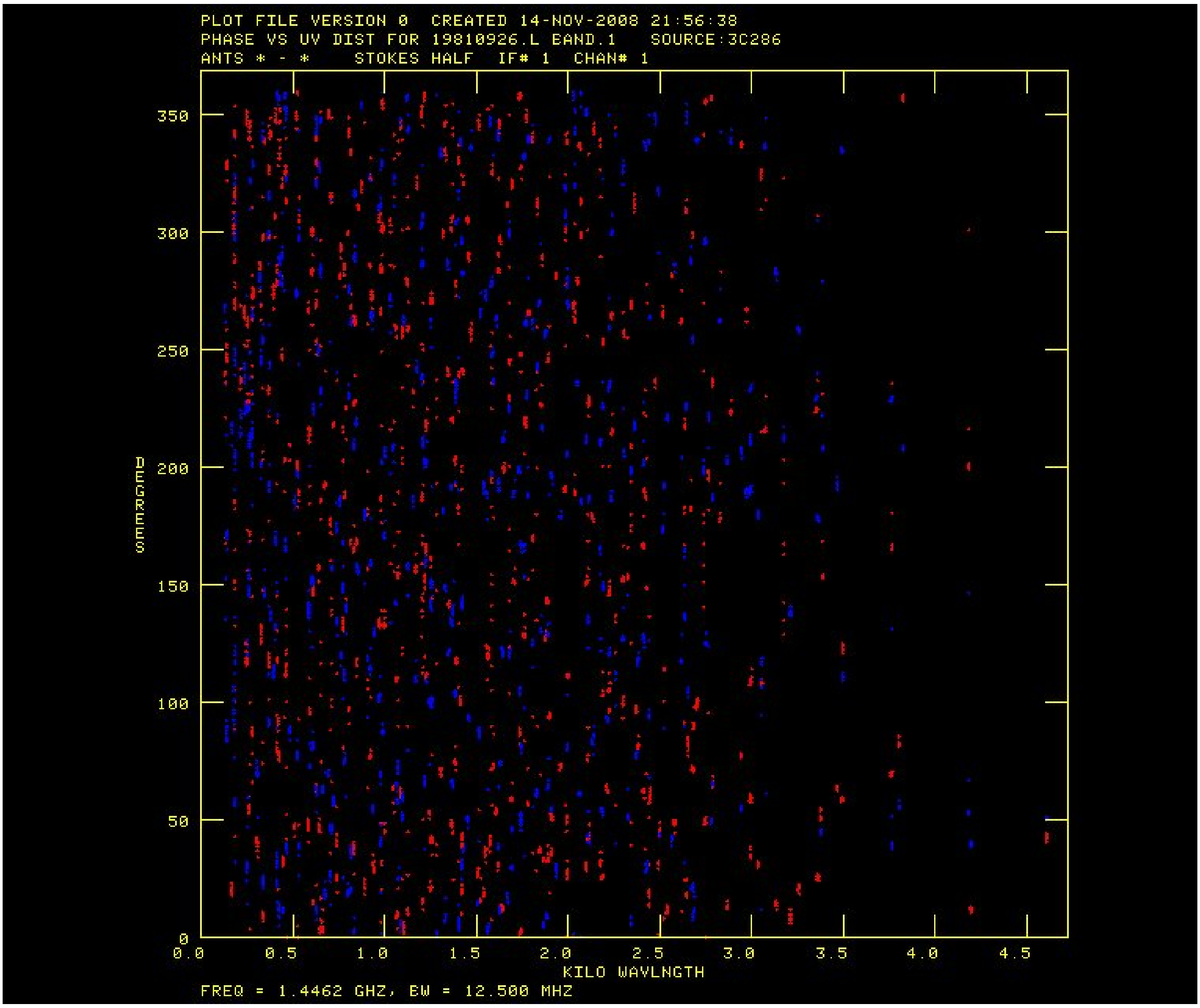


Warning: the next step will take a long time. You are free to skip this, and just look at the picture.

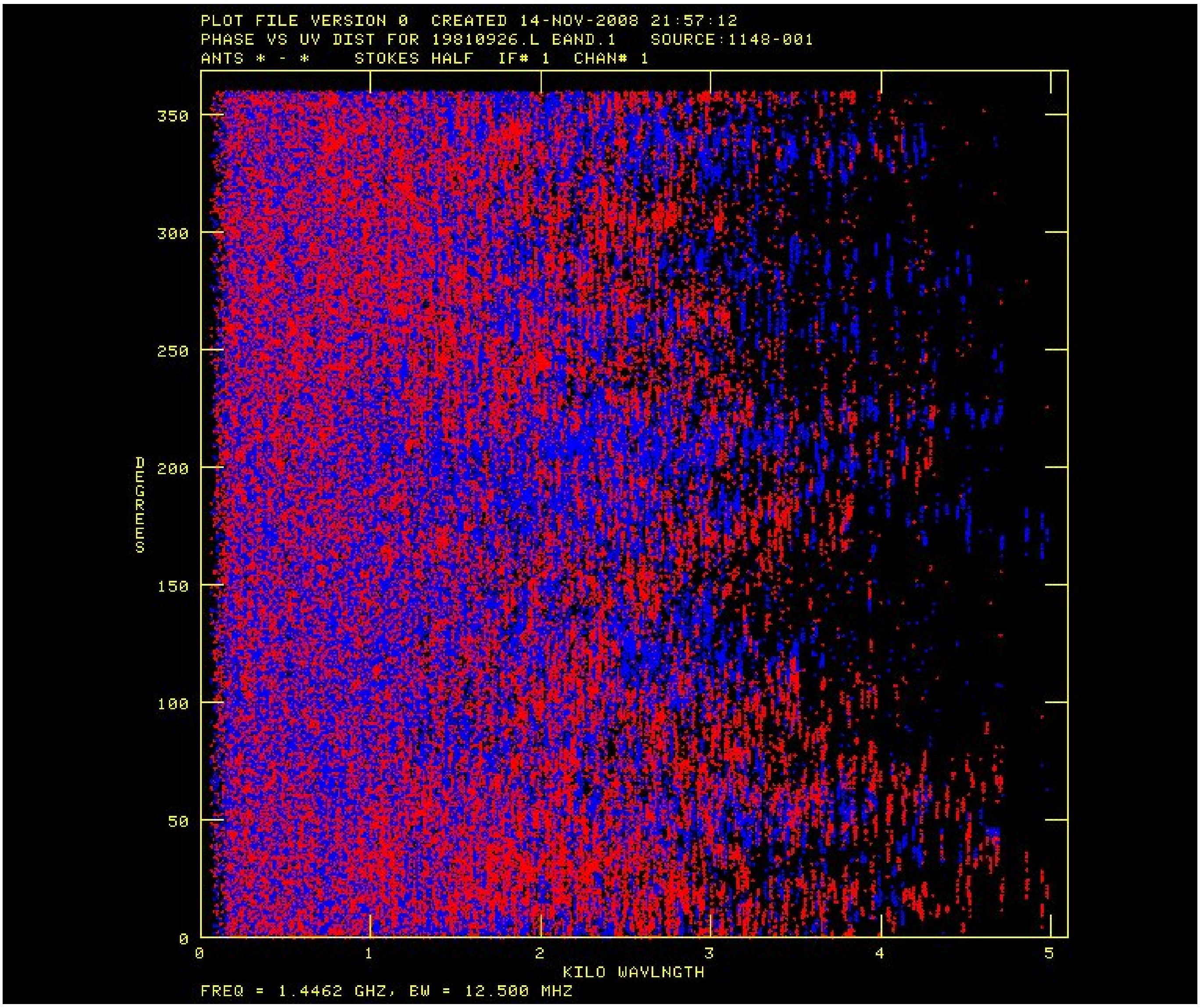
```
source 'sun',' '
go
```



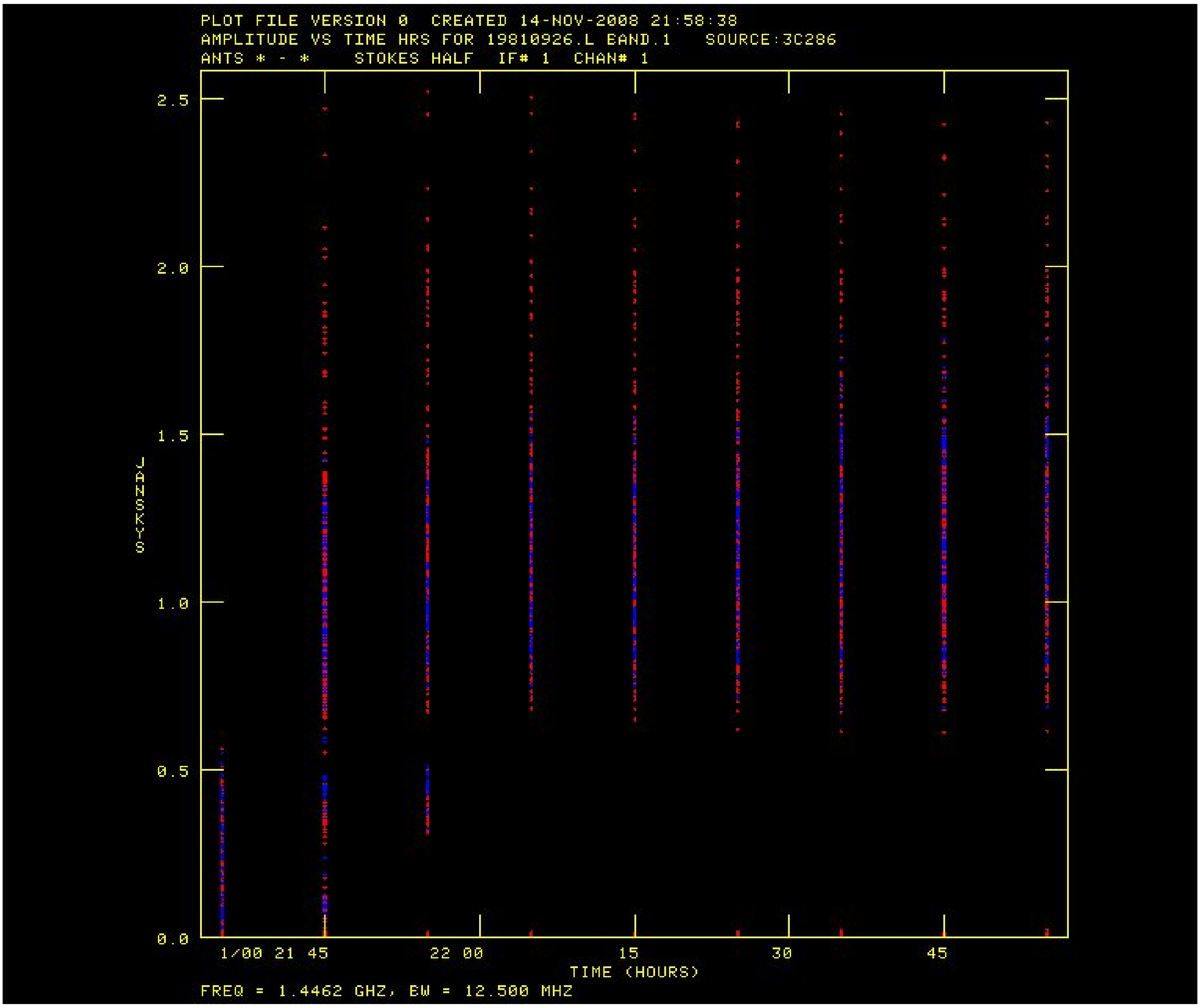

```
source '3c286',' '
bparm 0 2
go
```



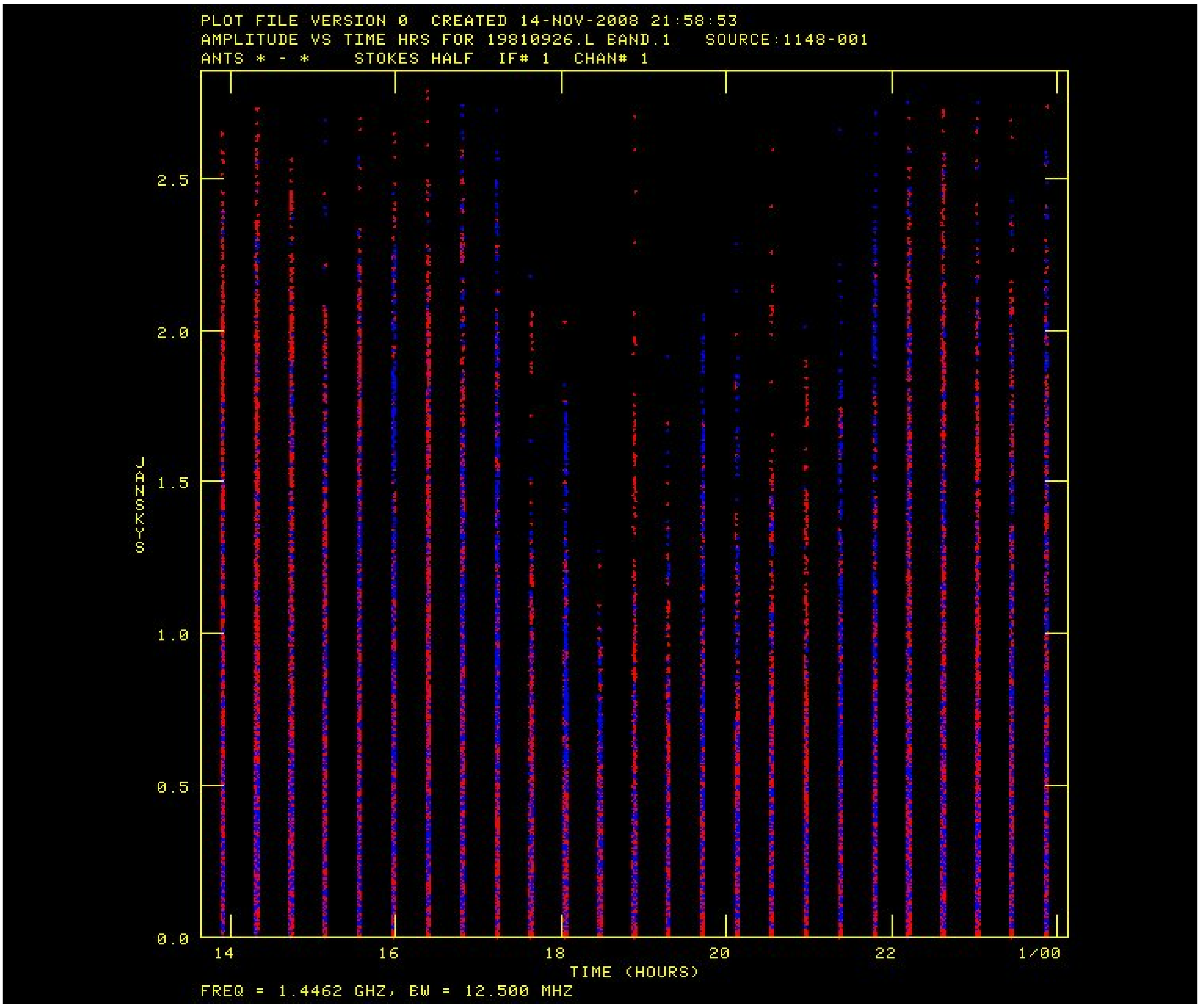

```
source '1148-001', ' '
go
```



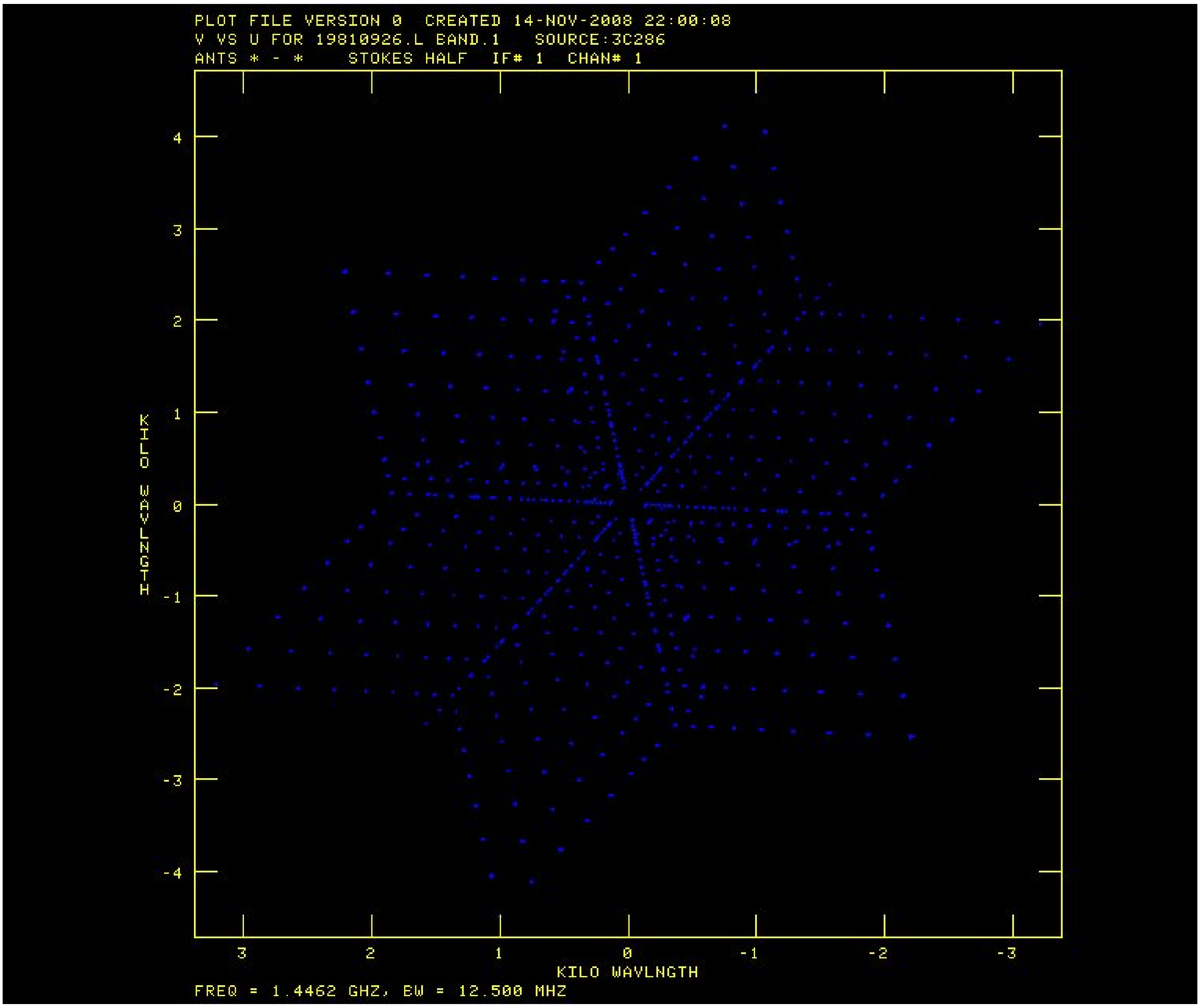

```
source '3c286',' '
bparm 11 1
go
```



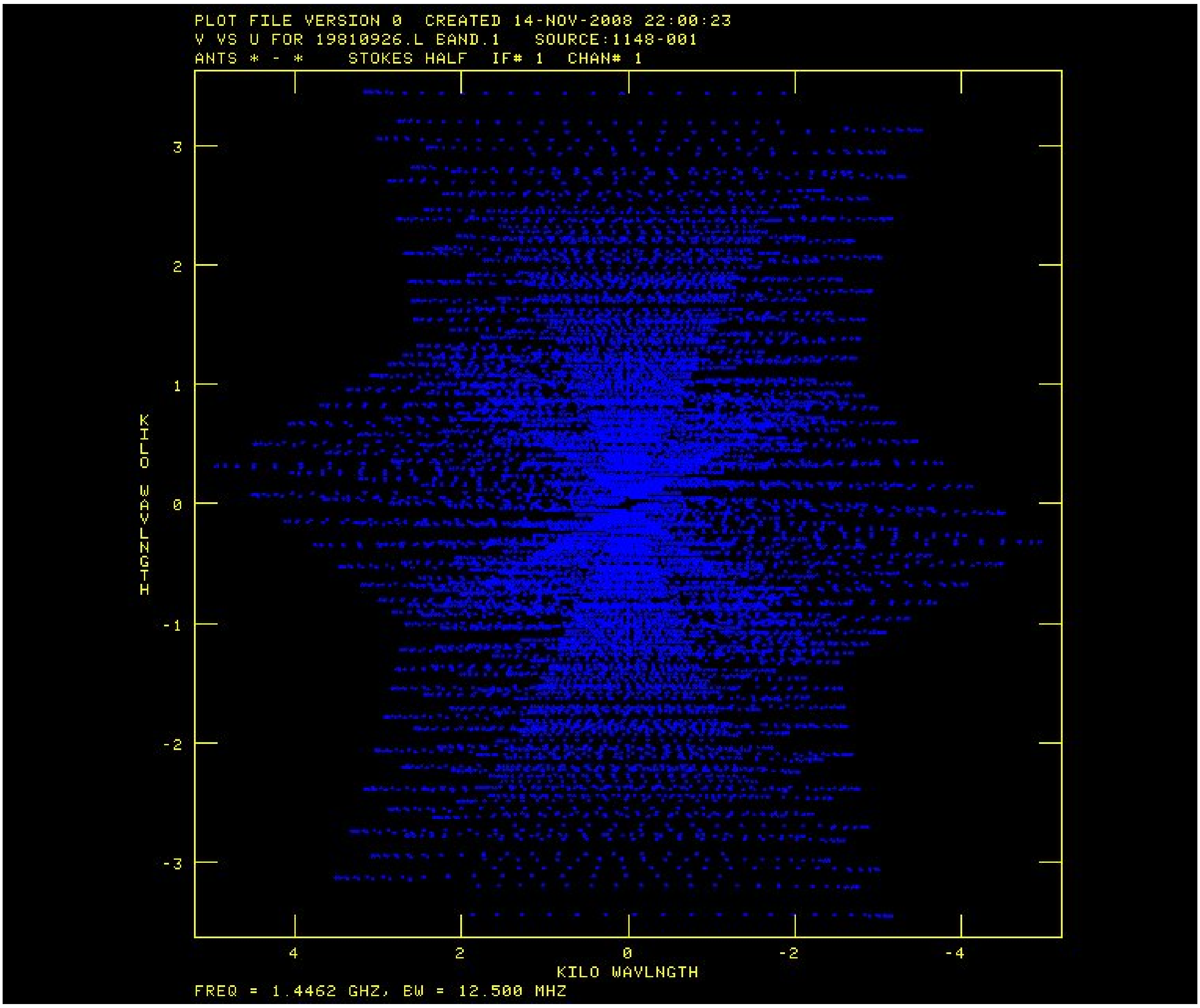

```
source '1148-001', ' '
go
```



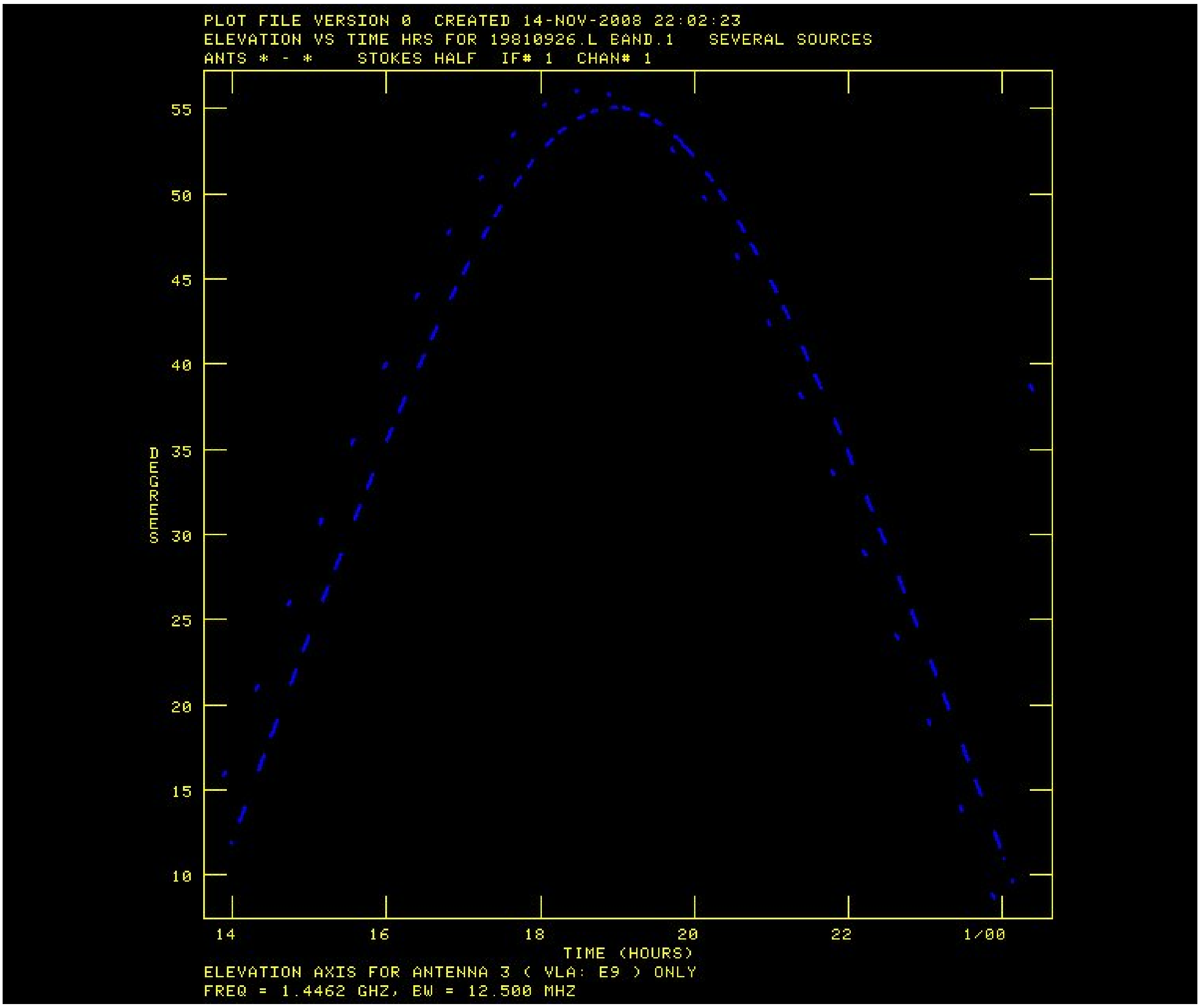

```
source '3c286',' '
bparm 6 7
go
```



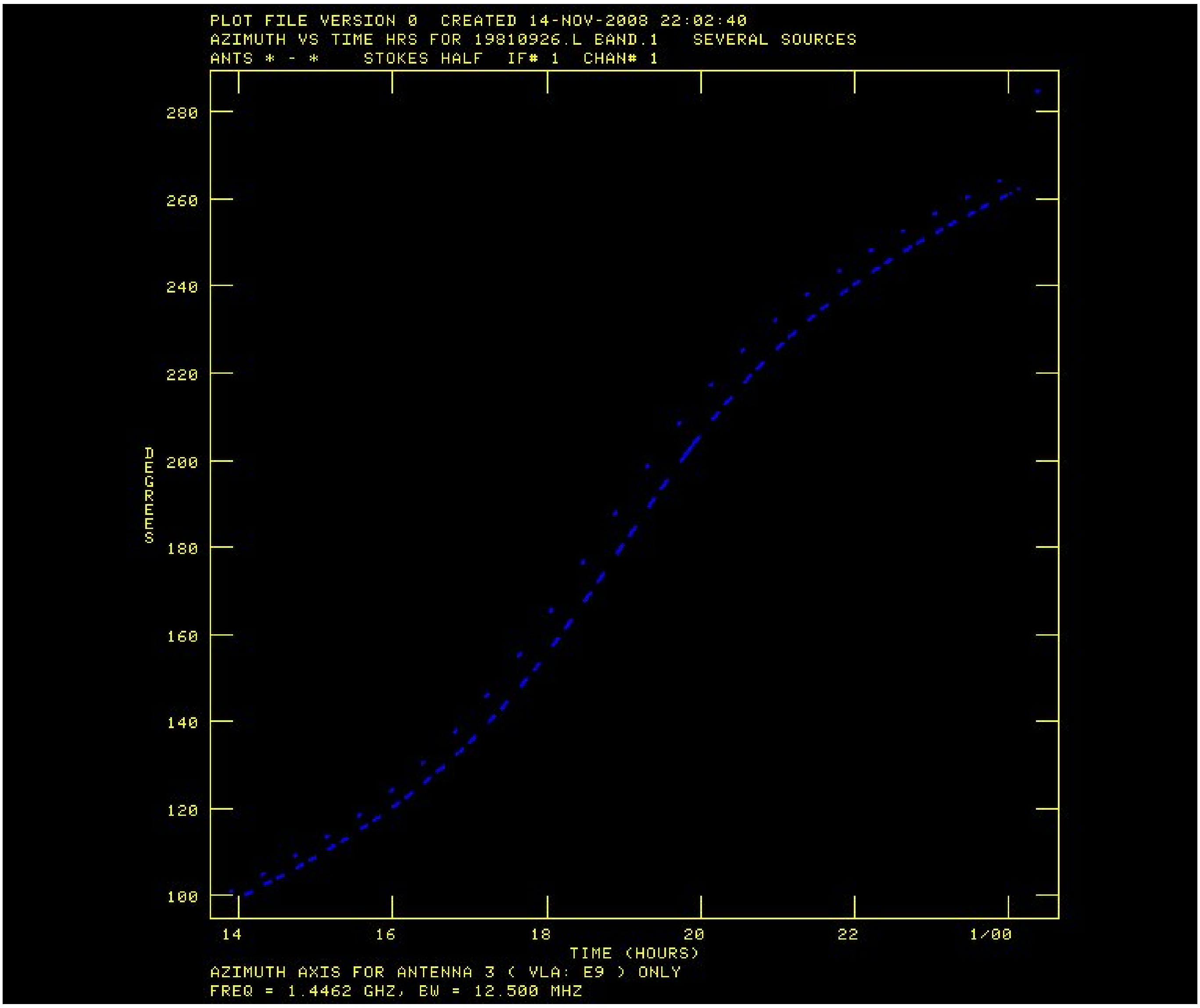

```
source '1148-001', ' '
go
```




```
source ' '
bparm 11 15
xinc 50
go
```




```
bparm 11 18
go
```



LISTR

Now let's look at the raw visibility numbers.

```
xinc 1
task 'listr'
optype 'list'
source '3c286', ' '
stokes ' '
bif 0
eif 0
flagver 0
dparm 0
antenna 3,0
go
```

```
 vlb054    LISTR(31DEC08)    100     14-NOV-2008  22:05:45    Page    1
File = 19810926    .L BAND.   1 Vol = 1  Userid =  100   Channels =  1-    1
```

```
IF = 1
Freq=  1.446150006 GHz   Ncor=  1   No. vis=      3159
Stokes = RR   Subarray =   1



Source=3C286           : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = B   , Freq =  1.446150006 GHz
Amplitudes, 1000 =   1.000 Jy, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   1/00:21:35  293 259 258 282  45 360 431 333     563 326 247 264 256 469
287 127 283  84  56 455  12 344 307 313 321 347
Amplitudes, 1000 =  10.000 Jy, averging type = Vector
   1/00:21:45  195 180 182 168  15 212 234 203     247 135 160 177 169 187
174 156 178 129  66 205   1 185 186 189 158 158
   1/00:21:55  206 196 194 176  67 223 246 214     252 139 169 192 183 193
183 185 190 188 205 214   1 192 199 199 165 168
   1/00:22:05  209 197 197 179 165 223 246 217     251 144 172 193 185 194
186 186 193 190 235 216   1 193 201 202 167 169
   1/00:22:15  205 194 196 178 198 223 244 214     246 140 170 189 182 193
183 186 190 190 235 212   0 193 198 199 164 169
   1/00:22:25  206 192 197 177 196 222 243 214     242 139 165 189 180 193
183 184 190 186 231 212   1 191 197 199 164 168
   1/00:22:35  207 195 196 178 198 223 246 215     240 140 166 192 182 192
184 185 190 190 233 214   0 192 199 199 165 168
   1/00:22:45  206 192 192 177 199 222 243 213     232 141 168 191 183 190
183 185 191 187 233 214   1 191 197 198 164 169
   1/00:22:55  206 193 195 179 199 223 243 213     230 140 170 190 182 193
183 185 190 186 233 215   1 191 197 199 164 169
AIPS 1: Resumes
```

Flagging

Just enter these commands. We can talk later about why they needed to be applied.

```
task 'quack'
sources ' '
stokes ' '
bif 0
eif 0
timer 0
antenna 0
basel 0
flagver 1
opcode 'beg'
reason 'bad start'
aparm 0
aparm(2) 15/60
```

```
go
antenna 6,0
aparm(2) 35/60
go
task 'uvflg'
antenna 23,0
basel 0
timer 0
aparm 0
opcode 'flag'
reason 'bad ant'
dohist 1
go
antenna 26,0
timer 0 18 29 0 0 20 7 20
go
timer 0 0 0 0 0 15 8 10
go
timer 0 21 48 30 0 22 37 10
go
antenna 25,0
timer 0 22 38 20 1 0 21 50
go
```

More LISTR, now on the phase calibrator

```
task 'listr'
optype 'list'
source '1148-001', ' '
stokes ' '
calcode ' '
bif 0
eif 0
flagver 0
dparm 0
antenna 3,0
go
```

```
 vlb054    LISTR(31DEC08)    100     14-NOV-2008  22:35:27    Page    1
File = 19810926    .L BAND.   1 Vol = 1  Userid =  100   Channels =  1-   1
IF = 1
Freq=  1.446150006 GHz   Ncor=  1   No. vis=     84072
Stokes = RR   Subarray =   1
Applying flag table   1


Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
```

```
Amplitudes, 1000 =  10.000 Jy, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/13:53:55   57 126  58  53      86 123  73     195  32  57  13  23  66
30  36  27  75  30  89      24  20  28  45 103
   0/13:54:05   67 134  66  24      65 155  47     213  26  66  28  28  92
30  53  35  60  26  63      28  33  55  77 103
   0/13:54:15   43 124  77  29  43  26 144  44     184  36  77  40  29  96
19  39  29  34  31  34      26  34  76  62 134
   0/13:54:25    6 104  91  62  40  68  96  73     177  59  93  30  30  87
35   4  26  41  45  78      32  31  74  14 139
   0/13:54:35   28  84  94  70  21  93  69  80     191  56 104  19  31  61
34  50  31  68  42  94      31  24  41  46  99

Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Amplitudes, 1000 =  10.000 Jy, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/14:18:25   37  65  58  31     101 107  83     230  68  57  35  34  81
33  90  40  56  18  32      32  45  69  32  47
   0/14:18:35    4  65  55  22      78  85  80     191  67  58  28  28  78
26  58  28  58  33  50      29  39  28  17  39
   0/14:18:45   36  62  56  30  17  32  45  47     128  48  57  28  32  61
32  48  24  31  44  48      34  26  18  29  17
   0/14:18:55   54  54  70  40  24  39  15  18     194  27  61  30  36  28
33  80  34   6  45  27      34  25  52  36  35
   0/14:19:05   48  27  87  54  30  90  70  24     176  21  56  29  47  14
39 114  42  29  50  42      43  44  63  24  47
   0/14:19:15   38   7 105  40  33 117 116  67     113  59  63  42  43  51
44 105  45  70  51  62      44  58  66  29  39
   0/14:19:25   23  48 112  35  30  75 117  92     198  80  50  46  44  84
46  57  38  74  59  63      47  48  21  50  30
   0/14:19:35   58  72  99  36  26  39  70  66     123  60  31  38  40  86
34  35  41  42  49  31      42  27  33  46  35

Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Amplitudes, 1000 =  10.000 Jy, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/14:43:25   32  32  95  40      47  27  55     237  14  83  30  33  58
31  33  38  40  20  35      34  35  13  28  35
   0/14:43:35   34  56  91  30      44  48  60     173  29  80  34  33  46
32  29  36  38  35  37      34  33  38  29  37
   0/14:43:45   27  59 103  14  27  21  51  54     130  51  66  25  25  72
24  23  22  14  27  26      21  23  48  23  26
   0/14:43:55   22  49 112  29  24  18  35  23     182  49  43  19  26  95
```

```
23  30  20   9  30  28       27  22  32  20  21
   0/14:44:05   39  59 141  41  28  42  36   2     163  35  32  32  33 112
31  32  37  35  41  35       34  35  29  30  30
   0/14:44:15   36  49 157  37  23  50  28  29     179  16  17  31  32  98
32  31  38  44  36  34       29  33  18  28  35
   0/14:44:25   27  28 159  25  22  37  38  54     200  17  17  30  29  71
28  26  27  38  33  31       27  28  36  28  31
   0/14:44:35   28   1 150  20  31  23  47  60     242  39  22  29  30  42
28  29  27  22  39  34       30  29  51  28  27

Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Amplitudes, 1000 =  10.000 Jy, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/15:08:15   17  35  52  25       33  42  35     148  14  29  28  29  49
29  31  30  27  15  38       29  32  35  25  33
   0/15:08:25   29  38  64  22       27  33  32     146  14  38  27  25  52
25  31  33  18  29  30       27  22  23  22  35
   0/15:08:35   33  25  70  27  23  25  27  25     135  25  35  21  25  49
21  29  26  17  30  25       24  19  18  18  29
   0/15:08:45   50  35  91  34  35  42  44  43     185  32  52  37  34  49
34  34  30  38  45  40       36  39  43  33  33
   0/15:08:55   30  28  84  30  32  37  43  34     188  26  53  32  33  26
32  26  29  42  37  40       32  36  41  27  26
   0/15:09:05   21  27  72  28  31  37  46  35     185  26  56  31  32   9
31  27  37  36  37  39       32  30  35  29  35
```

dparm 1,0
go

```
 vlb054    LISTR(31DEC08)    100     14-NOV-2008  22:36:24    Page    1
File = 19810926    .L BAND.   1 Vol = 1  Userid =  100   Channels =  1-   1
IF = 1
Freq=  1.446150006 GHz   Ncor=  1   No. vis=     84072
Stokes = RR   Subarray =   1
Applying flag table   1



Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Phase, 1000 = 1000.00 degrees, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/13:53:55 -154 176 177-145      82  59 -83     -35-118 -77 101  41   3
59  63 114  69 -97  80       76  88 -57  67 121
   0/13:54:05  163 138-130 -83     141 119 -21     -20 -30 -50  52  43  52
```

```
78  97 122 122-106 147      78  88  46 166-137
   0/13:54:15  127 100 -91  65-134-101 172  78    -173  44 -26  79  44  90
51 137 129-158-129 -79      72 102  95-124 -55
   0/13:54:25  118  61 -61 125 -91  13-128 145     172 105  -3  99  45 126
51-125 122 -51-119  21      73 111 140   2  12
   0/13:54:35 -125   9 -32 168 -49  68 -31-164     161 144  17  64  39 167
75  31 115  12-106  79      77  97-174 142  90

Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Phase, 1000 = 1000.00 degrees, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/14:18:25  135 174  69 167      66 121-173      51 109  26  75  39  58
61 136 118  27-117  30      73  88 140-157  -8
   0/14:18:35  -72 153 124 160     123 168-128      93 145  32  67  42  93
49-154 126  72-128  56      67 111-158 177  13
   0/14:18:45 -131 132 173 146-116-171-153 -91     147-177  42  68  36 129
50 -56 105 107-120  83      73 112  25 160 -43
   0/14:18:55 -165 103-132 149-123 -19  -9 -18       6-122  55  73  40 167
61  23 101-175-110  89      76  81  66-175 -41
   0/14:19:05  162  87 -88 160-120  46  81 143     -37  33  72  73  37  23
53  78 112  -3-118  46      73  83 112-159 -16
   0/14:19:15  141 -86 -66 164-116  89 113 174    -114  69  87  66  40  22
49 120 122  26-126  54      73  98 143 165  -7
   0/14:19:25 -137-143 -42 155-114 141 151-151     118 111  94  69  35  50
56 167 112  65-120  78      73 111 155 166 -18
   0/14:19:35 -139-164 -20 142-130 -91-161-118     166 144 107  72  37  79
55 -66  99 109-114  88      78  99  37-168 -38

Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Phase, 1000 = 1000.00 degrees, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/14:43:25 -174-121 103 162      65 109 166      41  37  70  66  32-169
49  86  97  42-121  64      64  91  89-178 -29
   0/14:43:35 -169-148 150 173      81 104-159     138  70  88  65  32 -85
48  76 109  66-129  60      67  92  71 178 -20
   0/14:43:45 -165-171-168 150-127  97 120-123     116 107 114  64  28 -20
54  69 109  87-132  61      56  94  90 170 -18
   0/14:43:55 -170 163-127 133-123  58 147 -84      90 142 139  68  35  32
53  74  91   6-133  61      58  85 121 175 -25
   0/14:44:05 -177 139 -92 148-112  53 149 -32      72 177 164  69  35  70
47  82  97  19-127  64      64  90 134-174 -30
   0/14:44:15  180 123 -62 162-122  68 116 147      62-116-143  65  32 105
54  81 109  35-124  64      66  90  87 175 -30
   0/14:44:25 -176 101 -37 168-136  85 105 177      51  15 -85  66  30 145
50  76 112  59-132  57      64  88  72 171 -20
```

```
   0/14:44:35 -162 105  -7 146-133  79 117-152      41  68 -46  68  30-163
47  71  96  67-132  61      59  87  97 173 -24

Source=1148-001        : 0000, Stokes=RR  , IF=  1, Chans=   1-   1
Flux =  0.0000 Jy, Calcode = C   , Freq =  1.446150006 GHz
Phase, 1000 = 1000.00 degrees, averging type = Vector

Baselines      1 3 2 3 3 4 3 5 3 6 3 7 3 8 3 9 310 311 312 313 314 315 316
317 318 319 320 321 322 323 324 325 326 327 328 329
   0/15:08:15 -152 172-105 148      73 125-161     -32 127 -46  69  28  39
48  65  87  38-129  62      62  93 108 179 -40
   0/15:08:25 -136 152 -86 139      76 126-157     -27  89 -36  66  28  63
53  80  95  41-139  66      61  96 114 175 -30
   0/15:08:35 -164 140 -63 149-130  64 135-148     -15 107 -11  67  22  87
50  78 114   9-134  60      67  80  93 177 -17
   0/15:08:45  178 144 -39 151-126  66 128-148      -3 119   9  68  28 106
51  90 108  12-127  58      65  82  91-177 -16
   0/15:08:55  167 150 -18 151-124  70 124-149       9 132  23  69  27 121
48  70  87  27-127  57      62  87 101-179 -33
   0/15:09:05 -160 162   3 151-129  72 126-157      21 135  33  65  28  74
51  48  93  40-134  67      61  96 111 177 -36
```

Calibration

SETJY

```
task 'setjy'
source '3c286',' '
optype 'calc'
aparm 0
aparm(2)=3
zerosp 0
go
```

```
vlb054> SETJY1: Task SETJY  (release of 31DEC08) begins
vlb054> SETJY1: **WARNING: OPCODE=CALC AND FREQID =   -1
vlb054> SETJY1:      FREQID WILL BE RESET TO 1, CHECK YOUR RESULTS CAREFULLY
vlb054> SETJY1: A source model for this calibrator may be available
vlb054> SETJY1: Use the verb CALDIR to see if there is one
vlb054> SETJY1: / Flux calculated using known spectrum
vlb054> SETJY1: BIF =  1 EIF =  1 /Range of IFs
vlb054> SETJY1: '3C286           ' IF =  1 FLUX =14.5979 (Jy calcd)
vlb054> SETJY1: / Using (1990) VLA or Reynolds (1934-638) coefficients
vlb054> SETJY1: Appears to have ended successfully
vlb054> SETJY1: vlb054       31DEC08 TST: Cpu=       0.0  Real=       0
```

CALRD

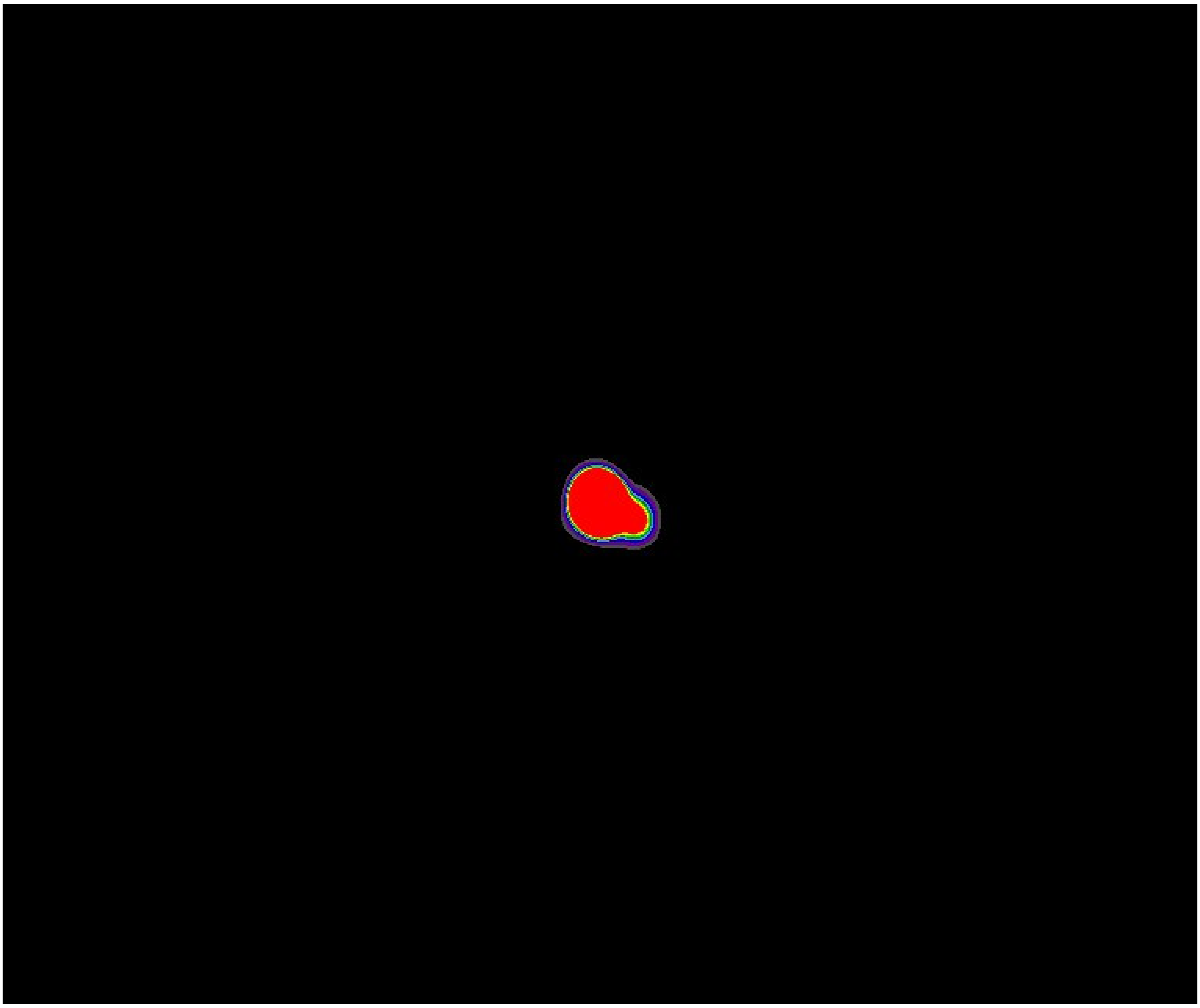
```
task 'calrd'
object '3c286'
band 'l'
go
```

```
vlb054> CALRD1: Task CALRD  (release of 31DEC08) begins
vlb054> CALRD1: Reading disk file AIPSTARS:3C286_L.MODEL
vlb054> CALRD1: Create 3C286_L     .MODEL .   1 (MA)  on disk  1  cno    2
vlb054> CALRD1: Appears to have ended successfully
vlb054> CALRD1: vlb054       31DEC08 TST: Cpu=       0.0  Real=       0
```

So it looks like the calibration data image was put into catalog entry number 2.

Let's have a look at it.

```
getn 2
tvinit
tvlod
tvfiddle
```



UVFIX

The sky positions (RA and Dec) were entered as coordinates of date, because the Sun is a moving object. However, they were entered in an odd fashion which means that the current software has trouble dealing with the calibration image for proper calibration. Run the fix program.

```
task 'uvfix'
getn 1
clron
shift 0
uvfixprm 0
go
```

CALIB

First, we do the amplitude calibrator.

```
task 'calib'
getn 3
calsour '3c286',' '
uvrange 0
antennas 0
refant 24
weightit 1
in2di 1
get2n 2
ncomp 0
solmode 'A&P'
aparm 0
aparm(6) 2
minamper 10
minphser 10
docalib 1
gainuse 1
solint 30
solsub 2
cparm 0
cparm(3) 10
cparm(4) 10
soltype ' '
clrmsg
go
clrmsg
```

Next, the phase calibrator.

```
calsour '1148-001',' '
clr2n
uvrange 1.5,0
solint 0
go
clrmsg
```

SNPLT

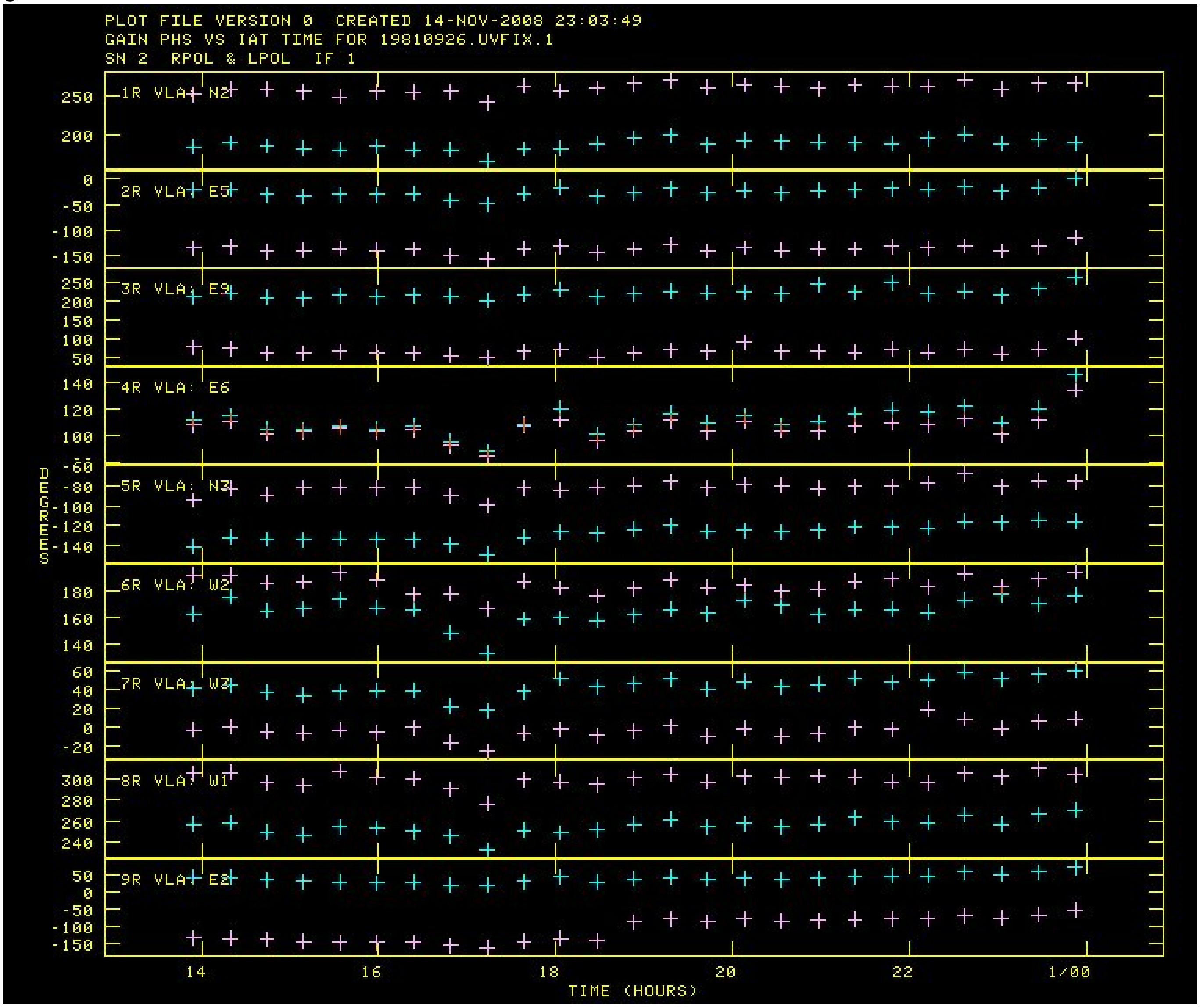
Look at the amplitude calibrator results.

```
task 'snplt'
source ' '
inver 1
inext 'sn'
stokes ' '
optype 'phas'
opcode 'alsi'
xinc 1
nplots 9
antenna 0
```

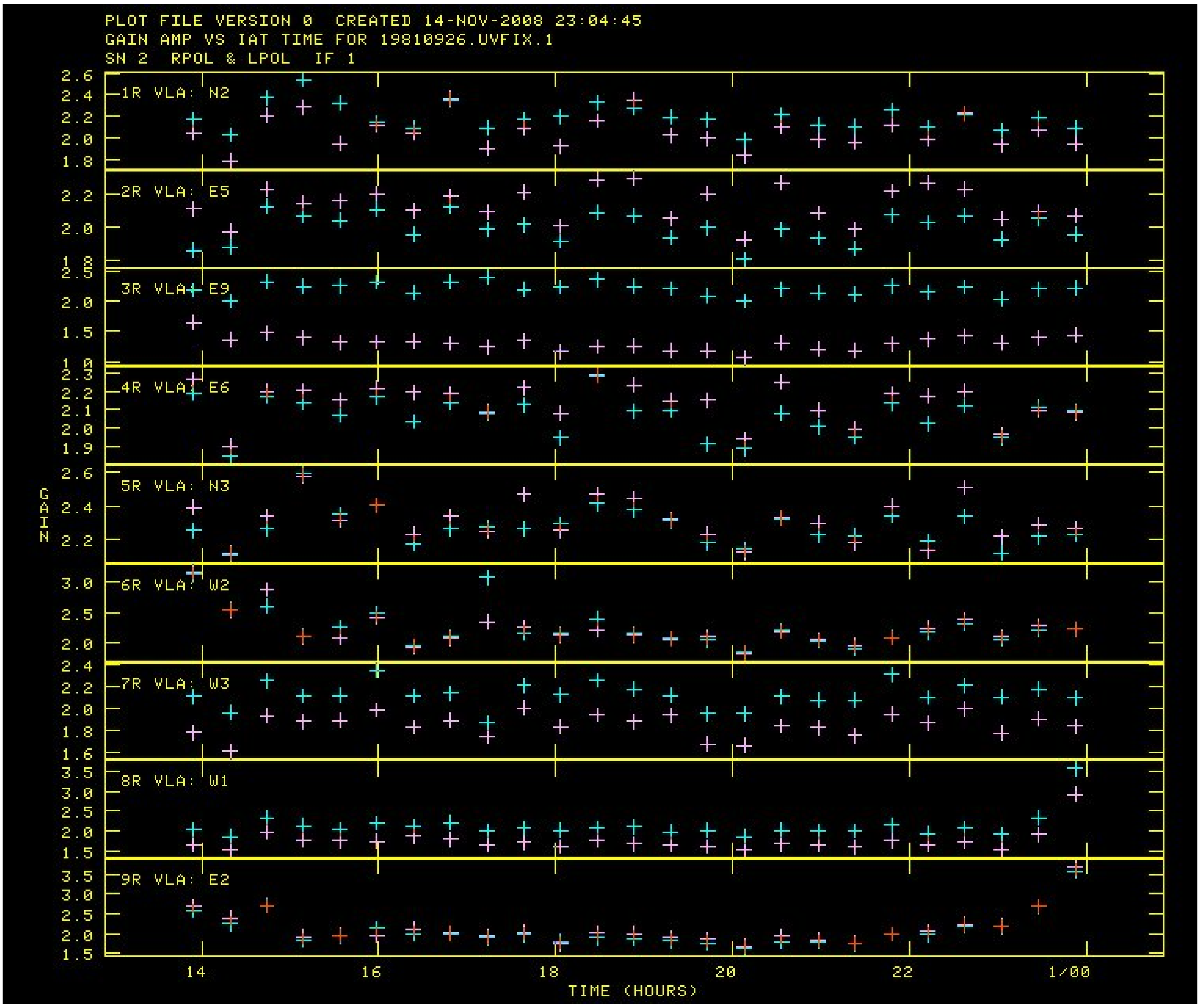
```
timer 0
tvinit
dotv 1
go
optype 'amp'
go
```

Look at the phase calibrator results.

```
inver 2
optype 'phas'
go
```




```
optype 'amp'
go
```



GETJY

Now we need to transfer the amplitude calibration information from the amplitude calibrator to the phase calibrator.

```
task 'getjy'
sources '1148-001',' '
calsour '3c286',' '
calcode ' '
bif 0
eif 0
antenna 0
timer 0
snver 0
go
```

```
vlb054> GETJY1: Task GETJY  (release of 31DEC08) begins
vlb054> GETJY1:    Source:Qual      CALCODE IF  Flux (Jy)
vlb054> GETJY1: 1148-001        :  0   C     1    2.90731 +/-   0.04192
```

```
vlb054> GETJY1: Appears to have ended successfully
vlb054> GETJY1: vlb054       31DEC08 TST: Cpu=       0.0  Real=       0
```

2.9 Jy agrees relatively well with the rough value given by the VLA calibrator list.

```
1150-003   J2000  A 11h50m43.870761s -00d23'54.204900"  Aug01
1148-001   B1950  A 11h48m10.124900s -00d07'13.164000"
-----------------------------------------------------
BAND        A B C D    FLUX(Jy)    UVMIN(kL)  UVMAX(kL)
=====================================================
 20cm    L  P P P P       2.80                       visplot
  6cm    C  P P P P       1.92
3.7cm    X  P P P P       1.25                       visplot
  2cm    U  P P P P       1.40
1.3cm    K  S S S S       0.63                       visplot
0.7cm    Q  W W W W       0.65''
```

Redo the CALIB calibration for the phase calibrator

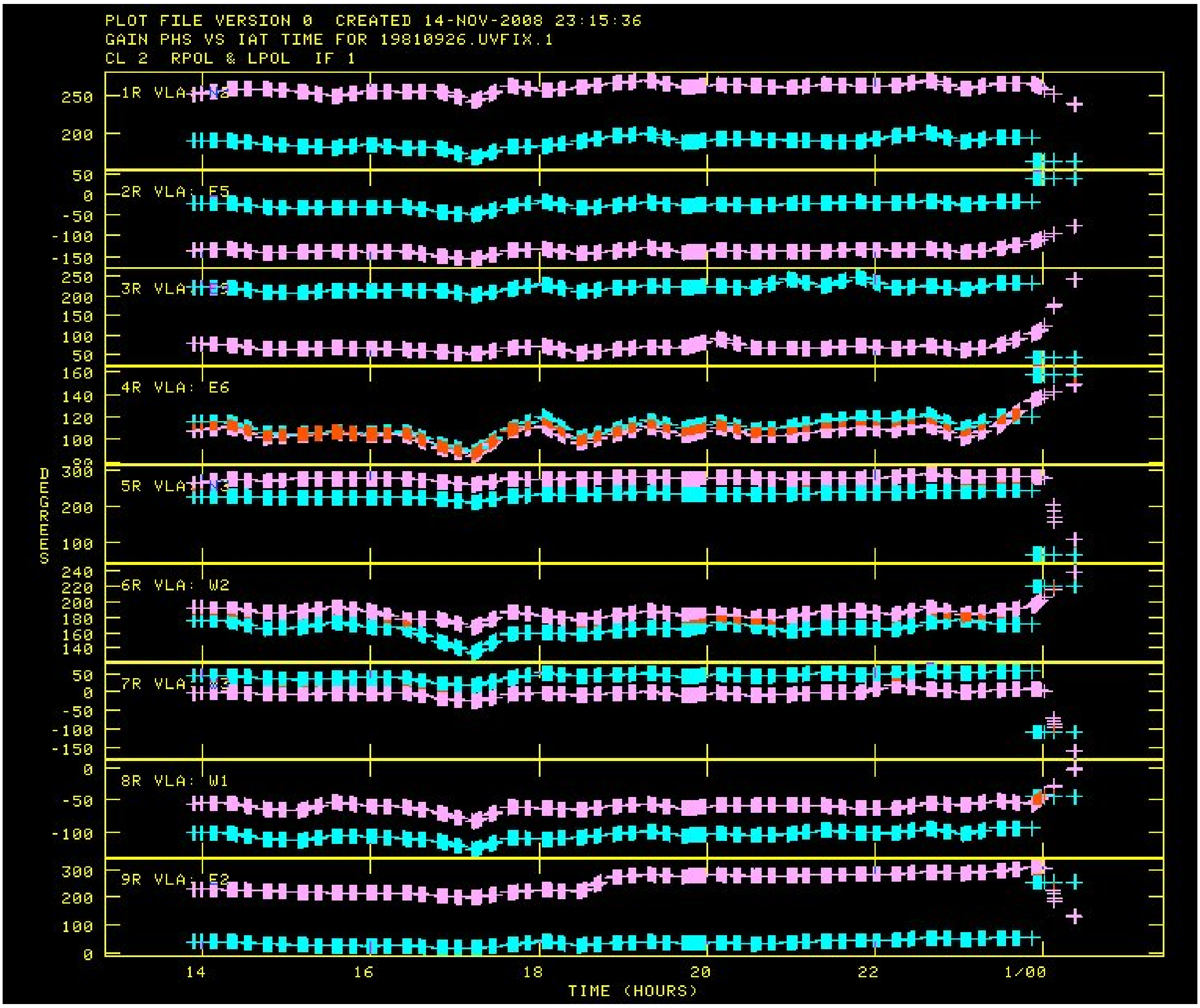
```
inext 'sn'
inver 2
extdest
tget calib
go
clrmsg
```

Apply the calibration to all sources, both amplitude and phase

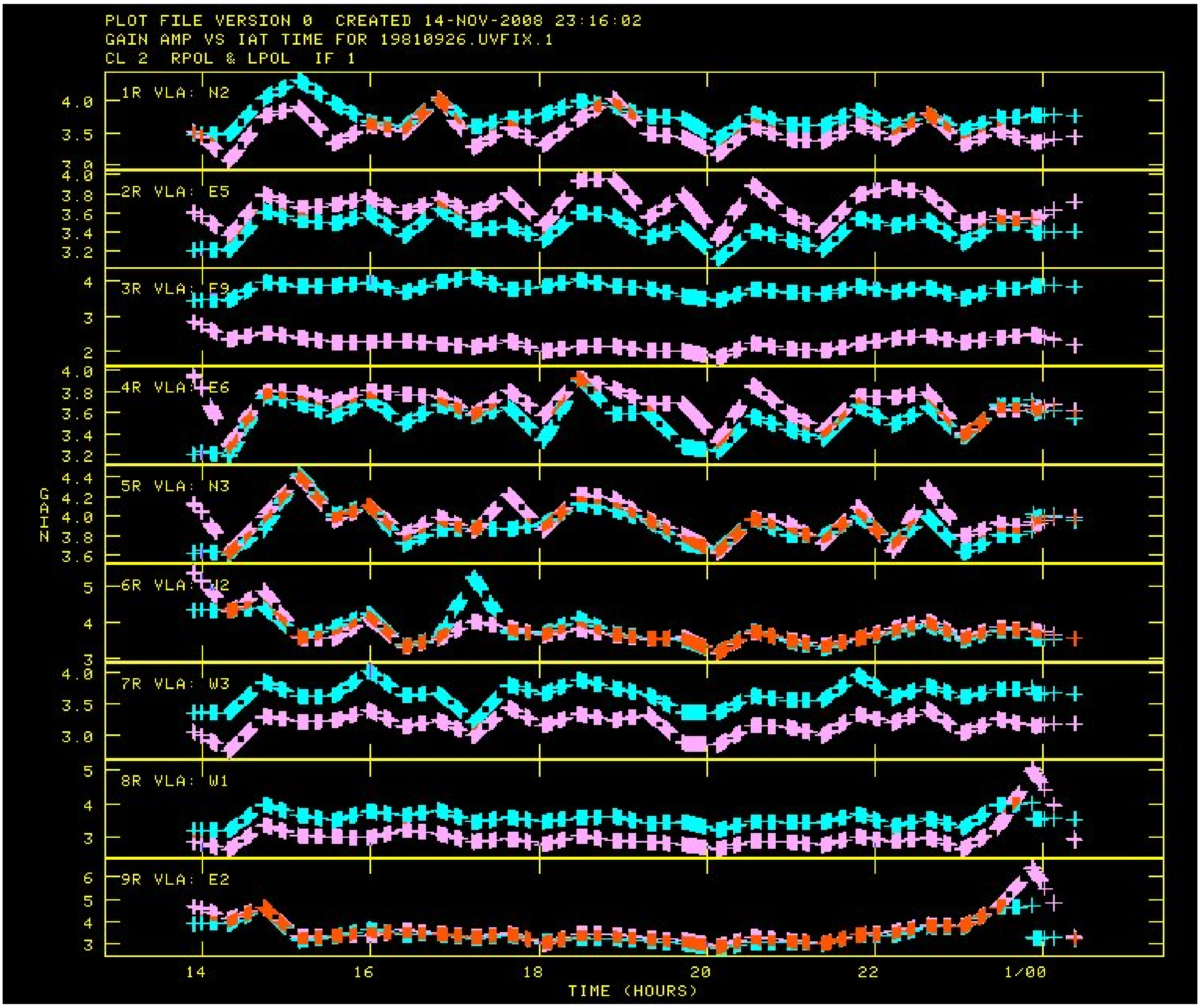
```
task 'clcal'
getn 3
sources ' '
calsour '3c286','1148-001',' '
calcode ' '
opcode 'cali'
gainver 1
gainuse 2
refant 24
bparm 0
interpol '2pt'
timer 0
antenna 0
doblank 1
go
```

Check the calibration results

```
task 'snplt'
source ' '
inver 2
inext 'cl'
stokes ' '
optype 'phas'
opcode 'alsi'
xinc 1
nplots 9
antenna 0
timer 0
tvinit
dotv 1
go
```




```
optype 'amp'
go
```



Test Imaging

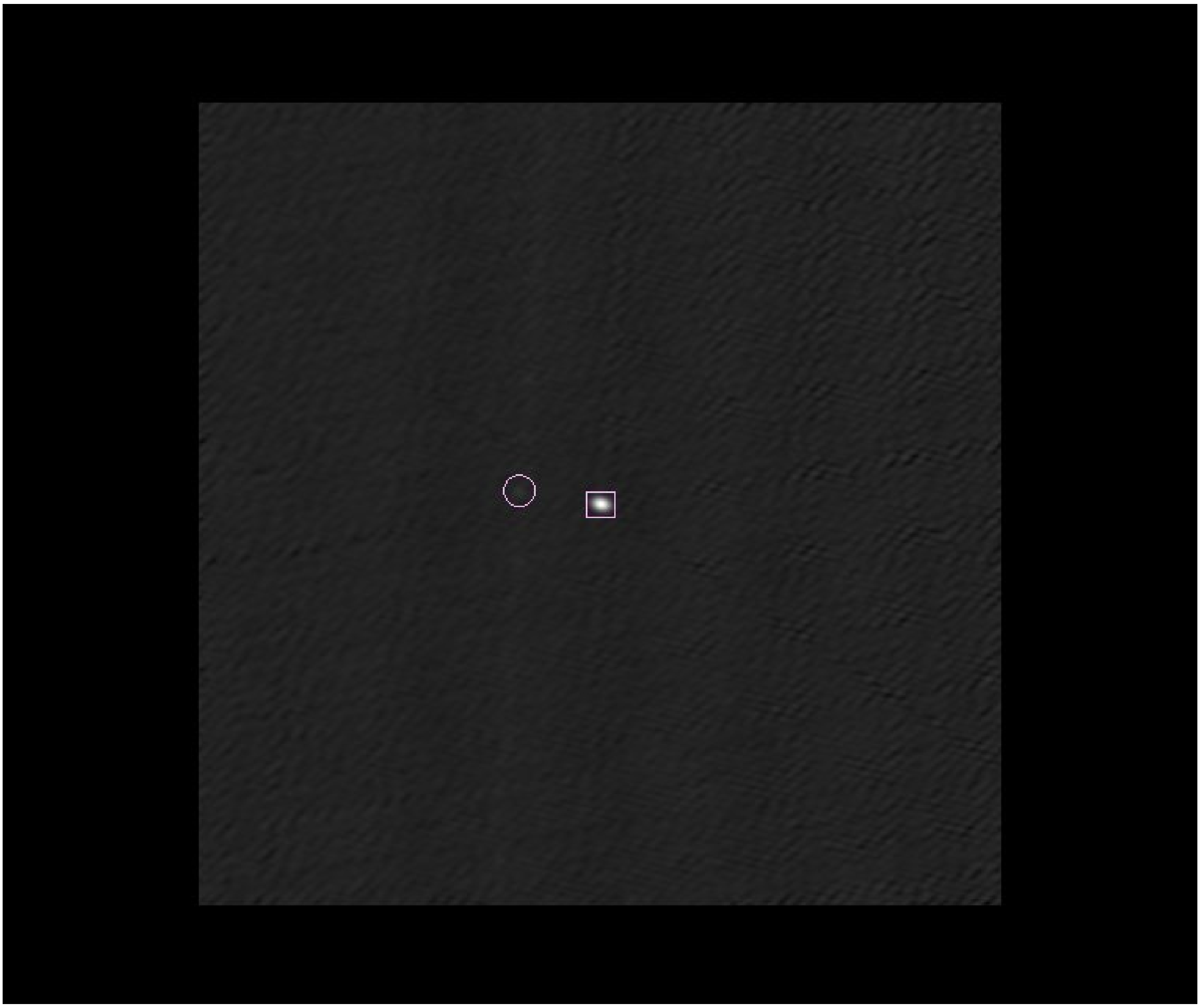
Amplitude Calibrator

Ok, let's start with a few test images. First, we will image the amplitude calibrator. Because of the funny epoch conversion stuff, it is not quite at the center where it is expected. This is not a problem.

```
task 'imagr'
getn 3
source '3c286',' '
uvrange 0
docalib 1
gainuse 2
stokes 'i'
cellsize 10,10
imsize 512,512
```

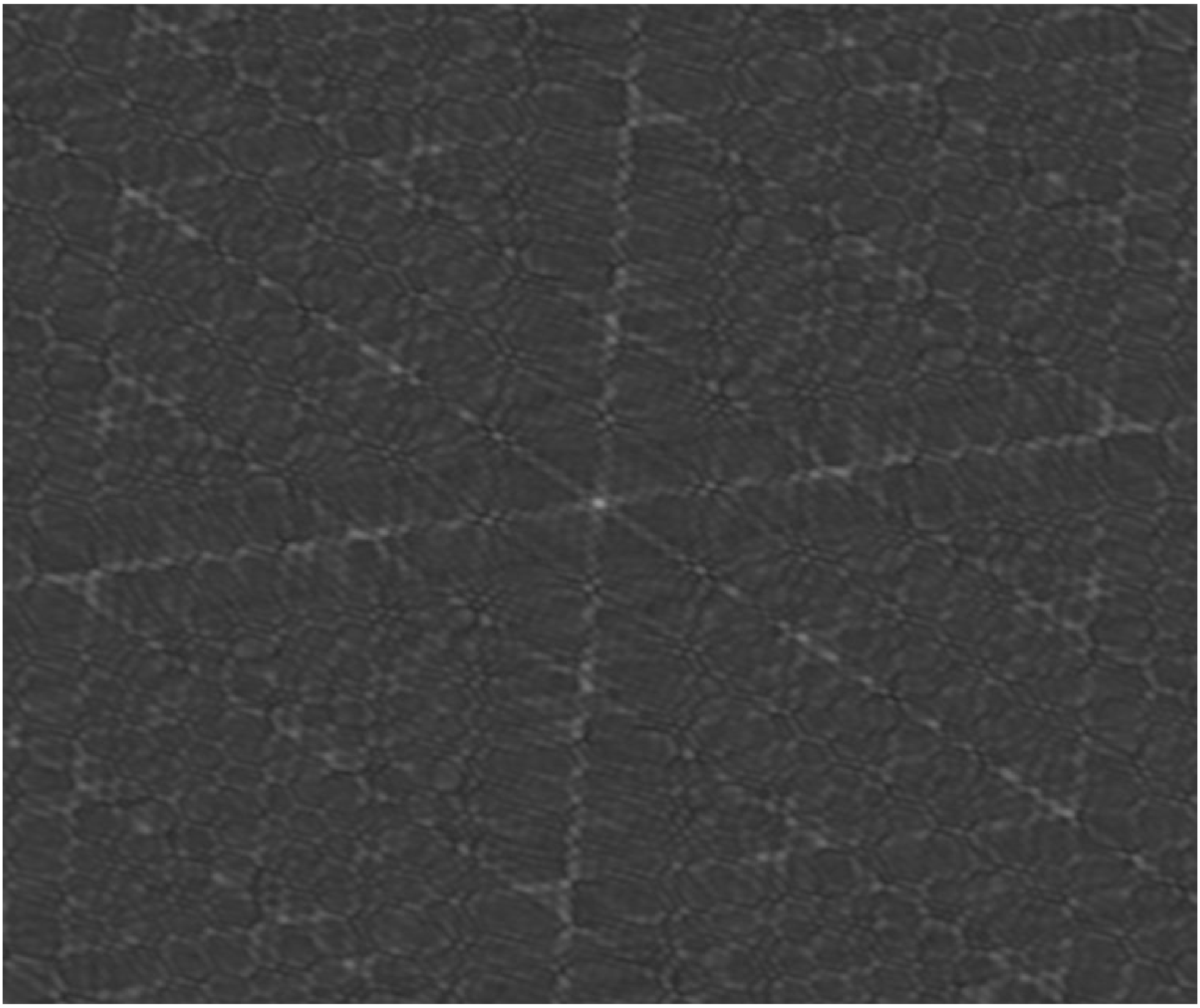
```
antenna 0
niter 10000
overlap 1
DO3DIMAG 1
rashift 1800.00,0
decshift -920.00,0
go
clrmsg
```

After you have cleaned it a bit, this is what it looks like.



And this is the point spread function of the actual observations (called the dirty beam). It looks like the amplitude calibrator image before you started cleaning. Why?

```
getn 5
tvinit
tvlod
tvfiddle
```



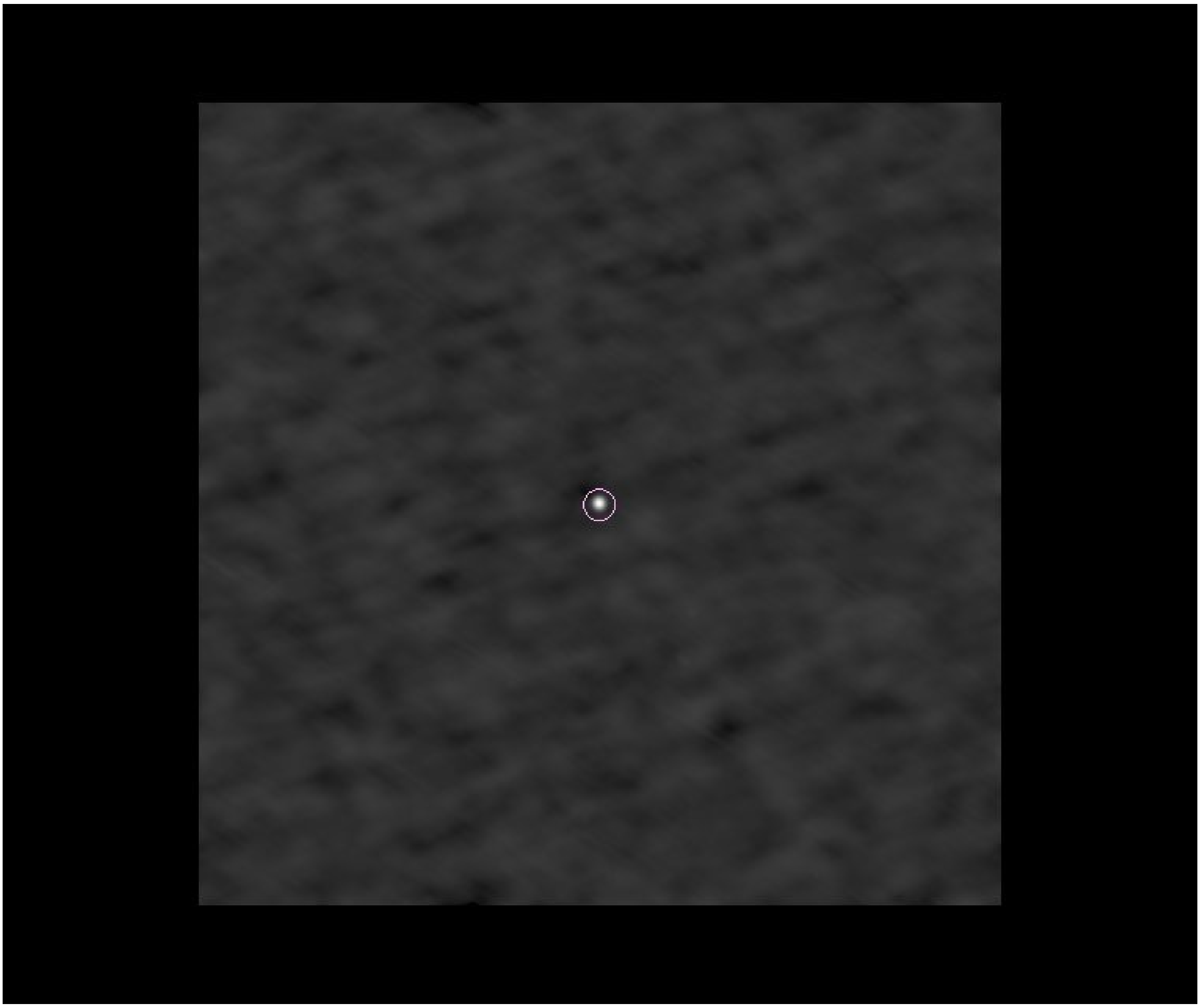
Phase Calibrator

Ok, clean up after ourselves

```
getn 5;zap
getn 6;zap
```

Now do the imaging and light cleaning

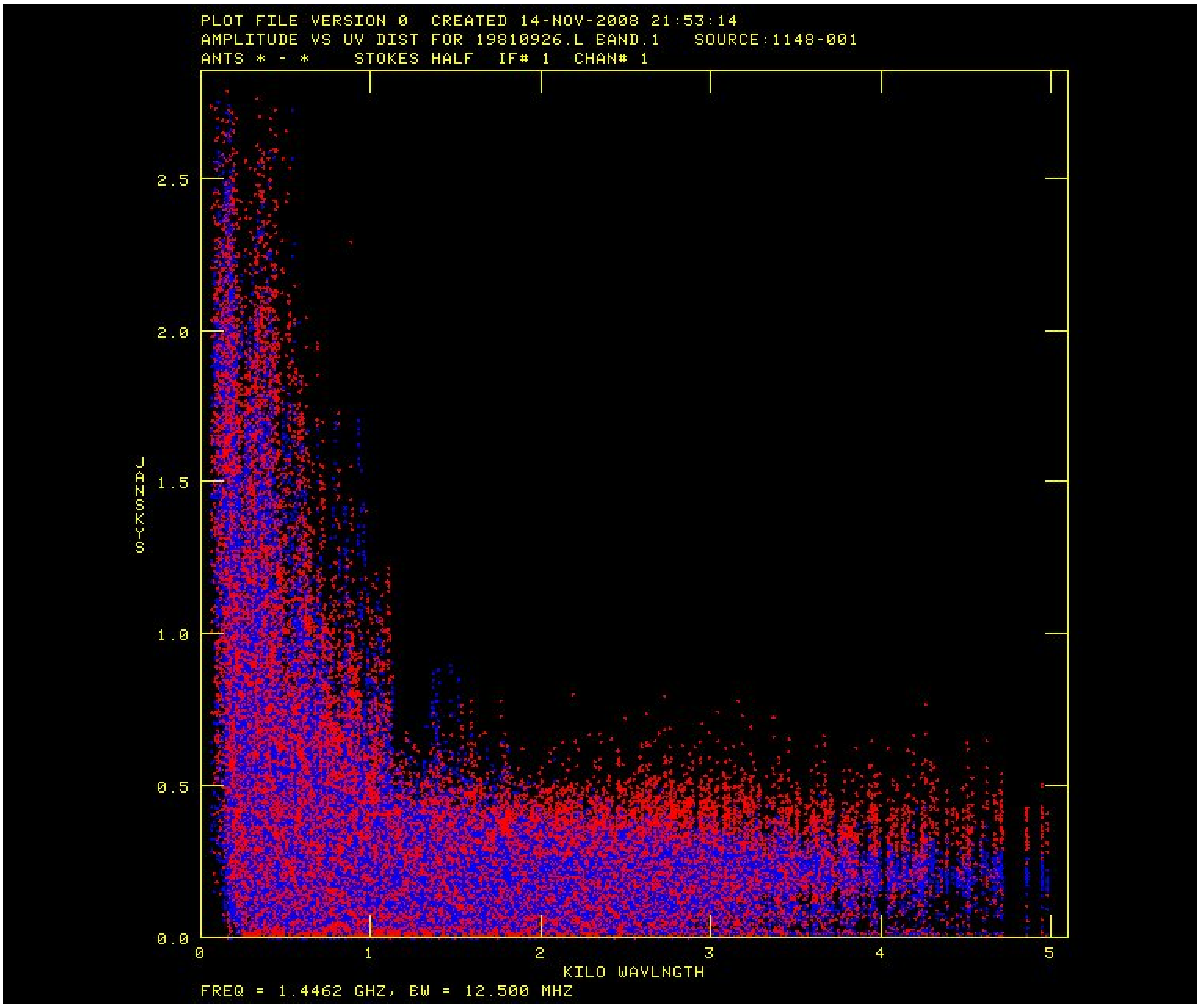
```
tget imagr
source '1148-001',' '
rashift 0
decshift 0
go
```



Note that in this image, there is a lot of large-scale junk. Why?

And here is the dirty beam. Notice how the dirty beam looks like the initial image of the phase calibrator before you began to clean it. Why?

```
getn 5
tvinit
tvlod
tvfiddle
```



Imaging the Sun

Ok, to do the best job, we need to separate the Sun data from the rest of the dataset. First, cleanup after the phase calibrator imaging.

```
getn 5;zap
getn 6;zap
```

SPLIT

```
task 'split'
getn 3
source 'sun',' '
timer 0
stokes ' '
```

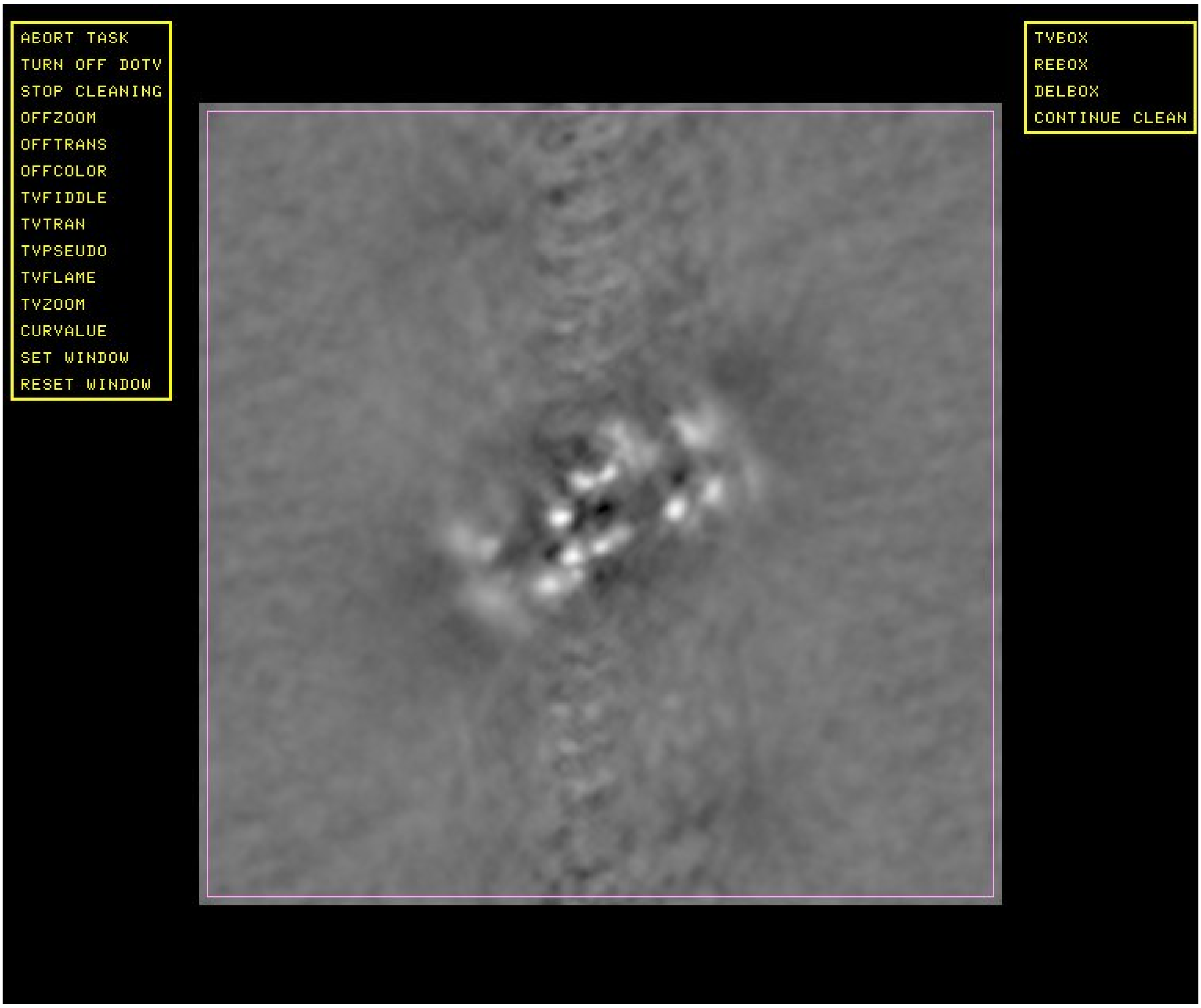
```
aparm 0
go
```

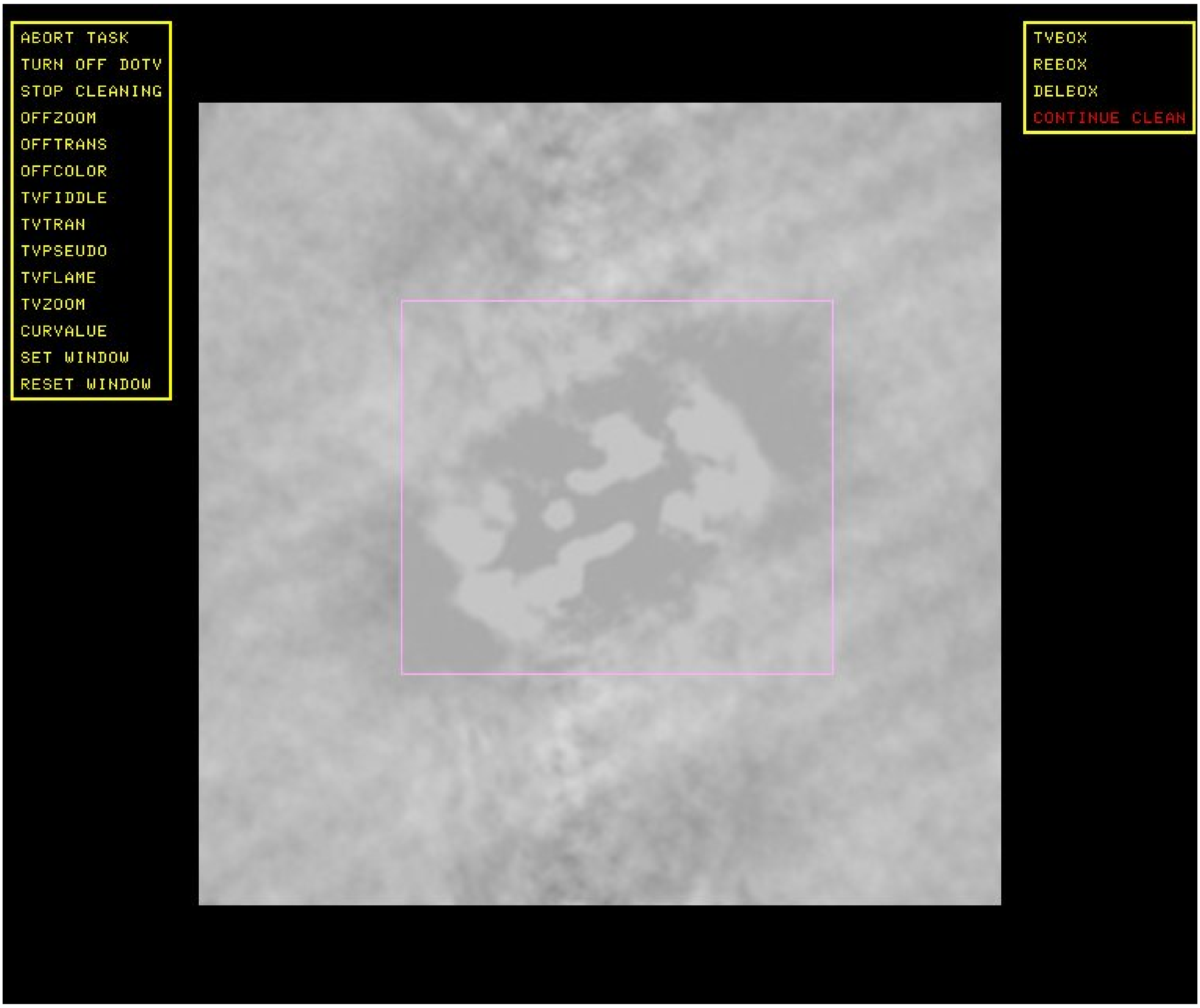
IMAGR

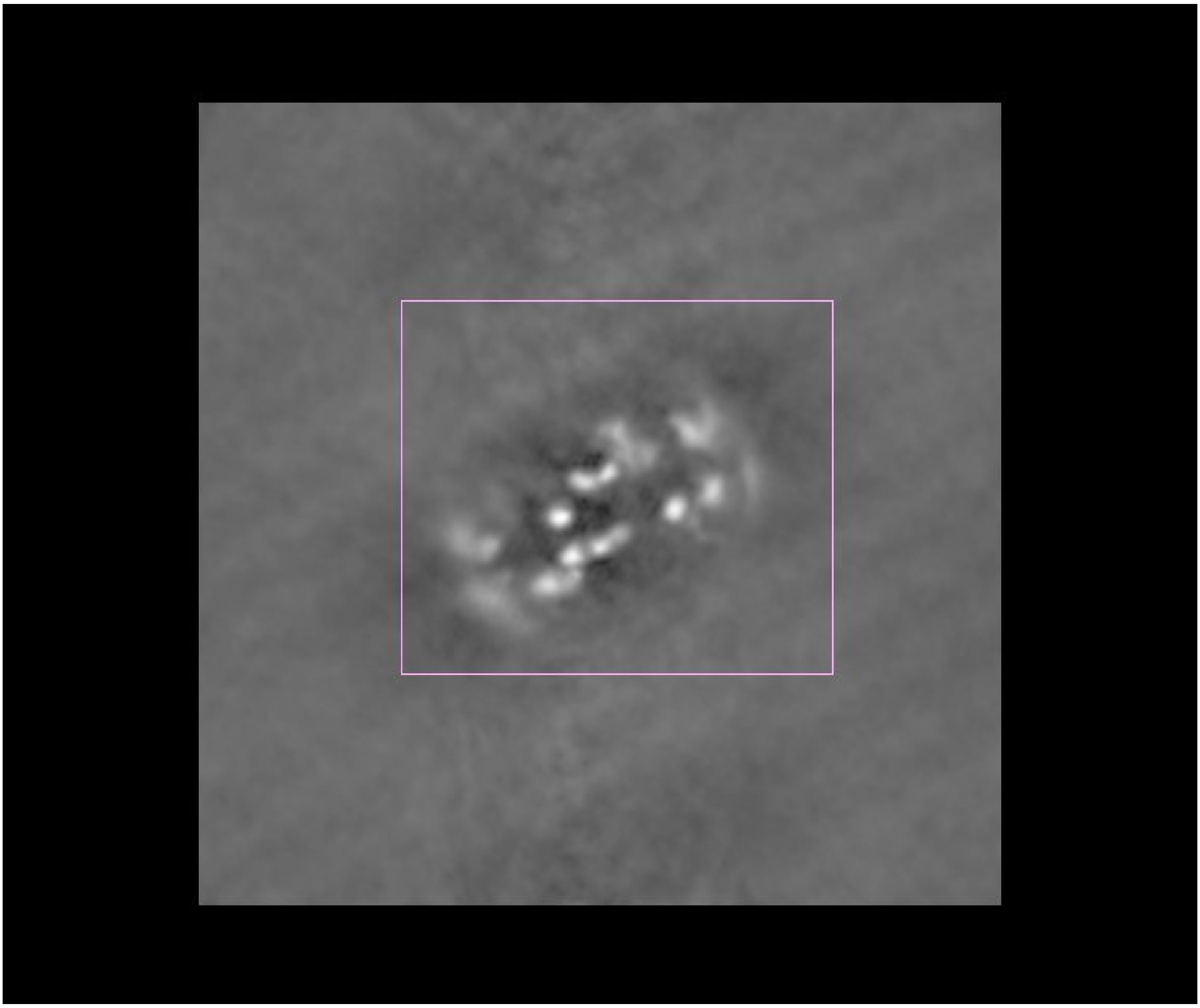
Now do an initial imaging and cleaning step.

```
tget imagr
getn 4
source ' '
docalib 0
gainuse 1
go
```

Here are some of the stages of my cleaning.




ABORT TASK
TURN OFF DOTV
STOP CLEANING
OFFZOOM
OFFTRANS
OFFCOLOR
TVFIDDLE
TVTRAN
TVPSEUDO
TVFLAME
TVZOOM
CURVALUE
SET WINDOW
RESET WINDOW
TVBOX
REBOX
DELBOX
CONTINUE CLEAN



Self-Calibration

Ok, let's do some self-calibration. This is just the same as “normal” calibration, except that you are saying to yourself that you are less confident that you know what the source is supposed to look like.

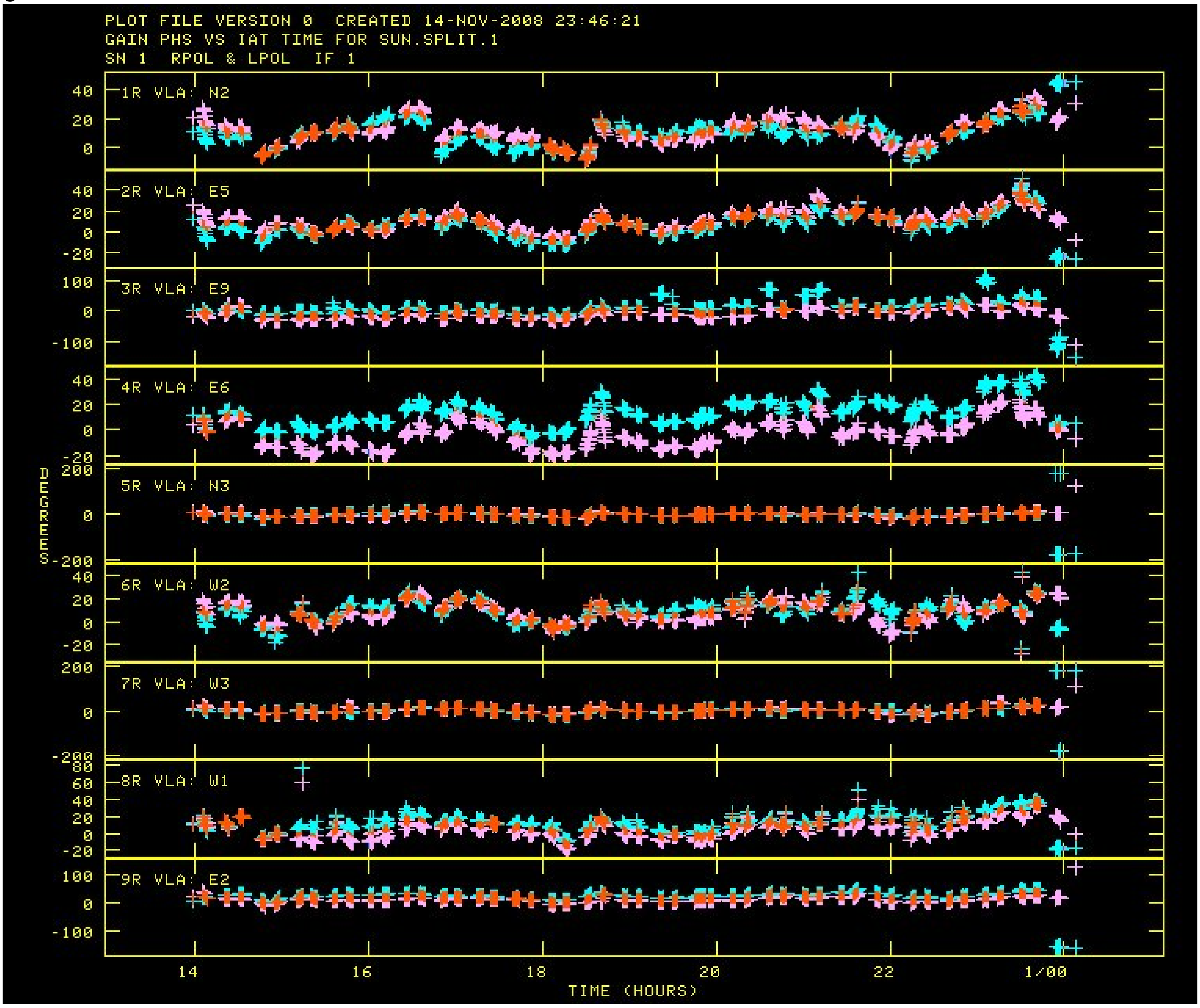
We run exactly the same calibration software, it exactly the same manner. Because the phase calibrator was resolved at short spacings, and because it is quite difficult for us to clean the extended emission, I limit the *(u,v)* coverage. Note that this also is only doing phase calibration, not amplitude calibration.

```
tget calib
getn 4
get2n 7
solint 30/60
solmode 'p!a'
docalib 0
uvrange 0.5,0
calsour ' '
inver 0
```

```
snver 0
go
clrmsg
```

Check the results

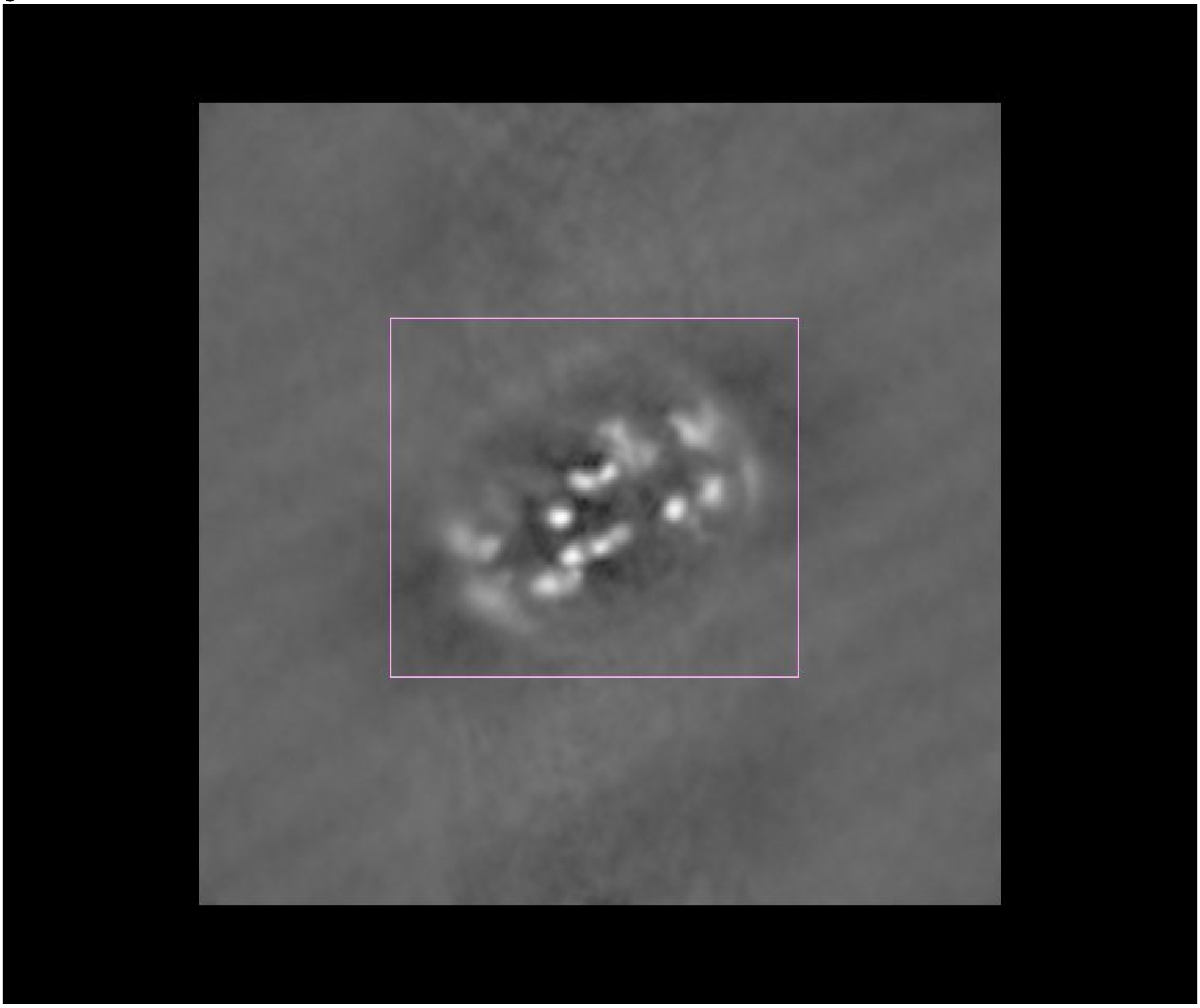
```
task 'snplt'
inext 'sn'
inver 1
stokes ' '
optype 'phas'
tvinit
go
```



Note some of the really large phase deviations! The phase calibration was not perfect.

Image again, using the new calibration

```
getn 5;zap
getn 6;zap
getn 7;zap
tget imagr
docalib 1
gainuse 1
go
```



This one is a bit better.

More Self-Calibration

But we can do more. Now let's do both amplitude and phase calibration. First, we do a phase-only self-calibration on short timescales, to get rid of the phase jitter.

Phase Self-Cal

```
tget calib
getn 4
get2n 7
solint 20/60
solmode 'p!a'
docalib 0
uvrange 0.5,0
calsour ' '
inver 0
snver 0
go
clrmsg
```

Check

```
task 'snplt'
inext 'sn'
inver 2
stokes ' '
optype 'phas'
tvinit
go
```

Amplitude Self-Cal

Doing both phase and amplitude calibration requires far more from the data S/N. It is best to have a longer time interval for amplitude calibration.

```
tget calib
getn 5
solint 20
solmode 'A&P'
cparm(2) 1
go
clrmsg
```

Check

```
task 'snplt'
inext 'sn'
inver 1
stokes ' '
optype 'phas'
```

```
tvinit
go
optype 'amp'
go
```

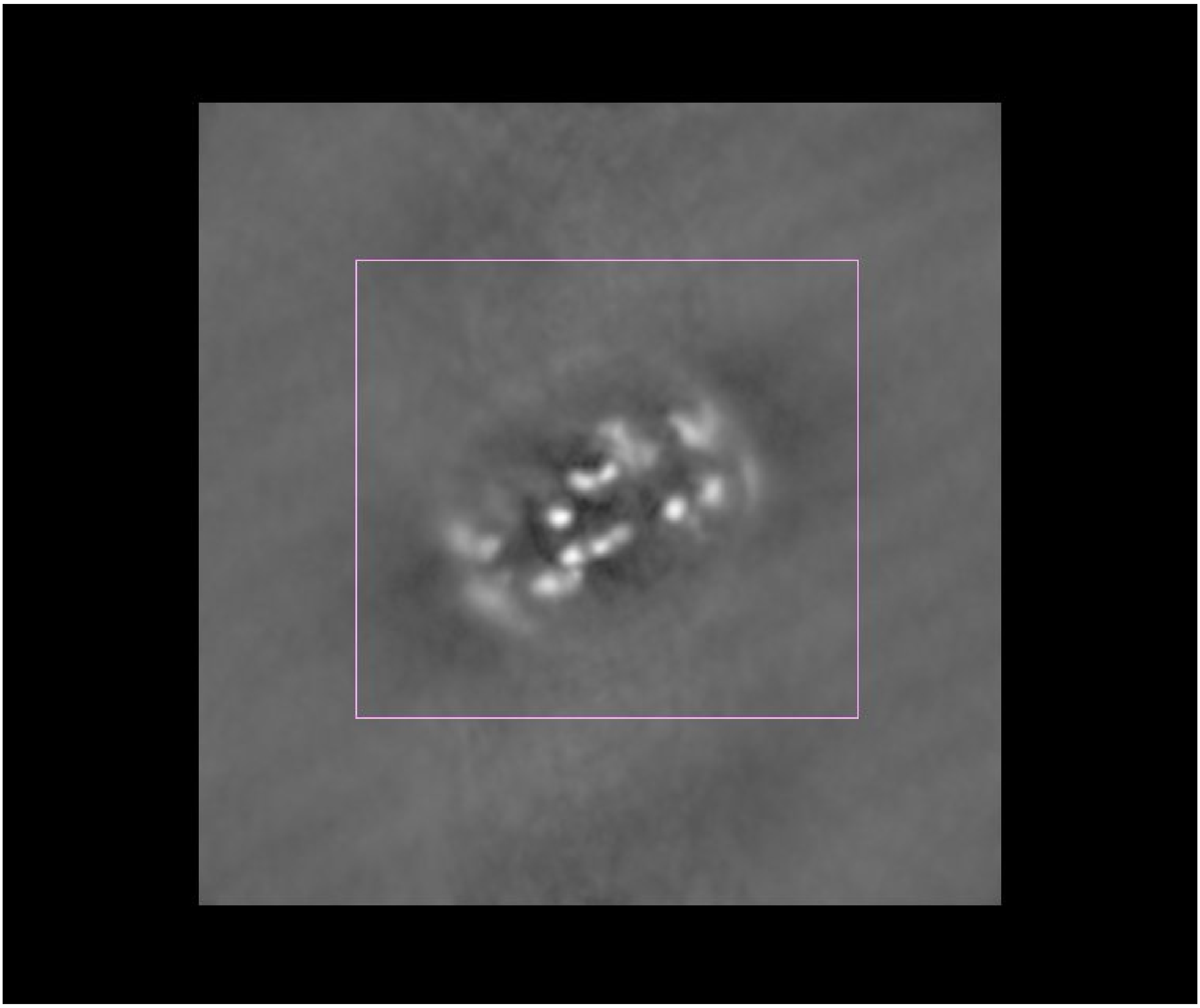
Cleanup

Clean up the files. But save the initial “CALIB” uv dataset! It is the one with the current amplitude calibration information.

```
getn 6;zap
getn 7;zap
getn 8;zap
```

Final Imaging

```
tget imagr
getn 5
docalib 1
gainuse 1
```



Discussion

What have you learned?

Does your image look like this image?

What is different?

Have a look at http://images.nrao.edu/8 and see what additional information was used to generate the NRAO web image. How would such additional information change your image?

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