

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
```

You should be able to download them from [GD_1](#) and [GD_2](#).

While you are there, grab the new set of commands from [Sun.txt](#).

Step 3 --- Start up AIPS

aips

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

At first, most of the arcane 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
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 23 = VLA:_N5	BX=	-108.4301	BY=	-16.9862
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 24 = VLA:_N9	BX=	-298.3837	BY=	-46.5620
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 25 = VLA:_N6	BX=	-148.4545	BY=	-23.2162
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 26 = VLA:_N4	BX=	-74.8318	BY=	-11.7331
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 27 = VLA:_W6	BX=	93.5170	BY=	-245.0012
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 28 = VLA:_W4	BX=	46.9220	BY=	-122.0267
Mount=ALAZ	Axis offset=	0.0000 meters	IFA	IFB
Feed polarization type =			R	L
Ant 29 = VPT:_OUT	BX=	0.0000	BY=	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
                (27) W6
                (14) W7
                (17) W8
            (15) W9
                VLA:_OUT (10)
                VPT:_OUT (29)

```

```

E5 ( 2)
E6 ( 4)
E7 (13)
E8 (11)
E9 ( 3)

```

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.

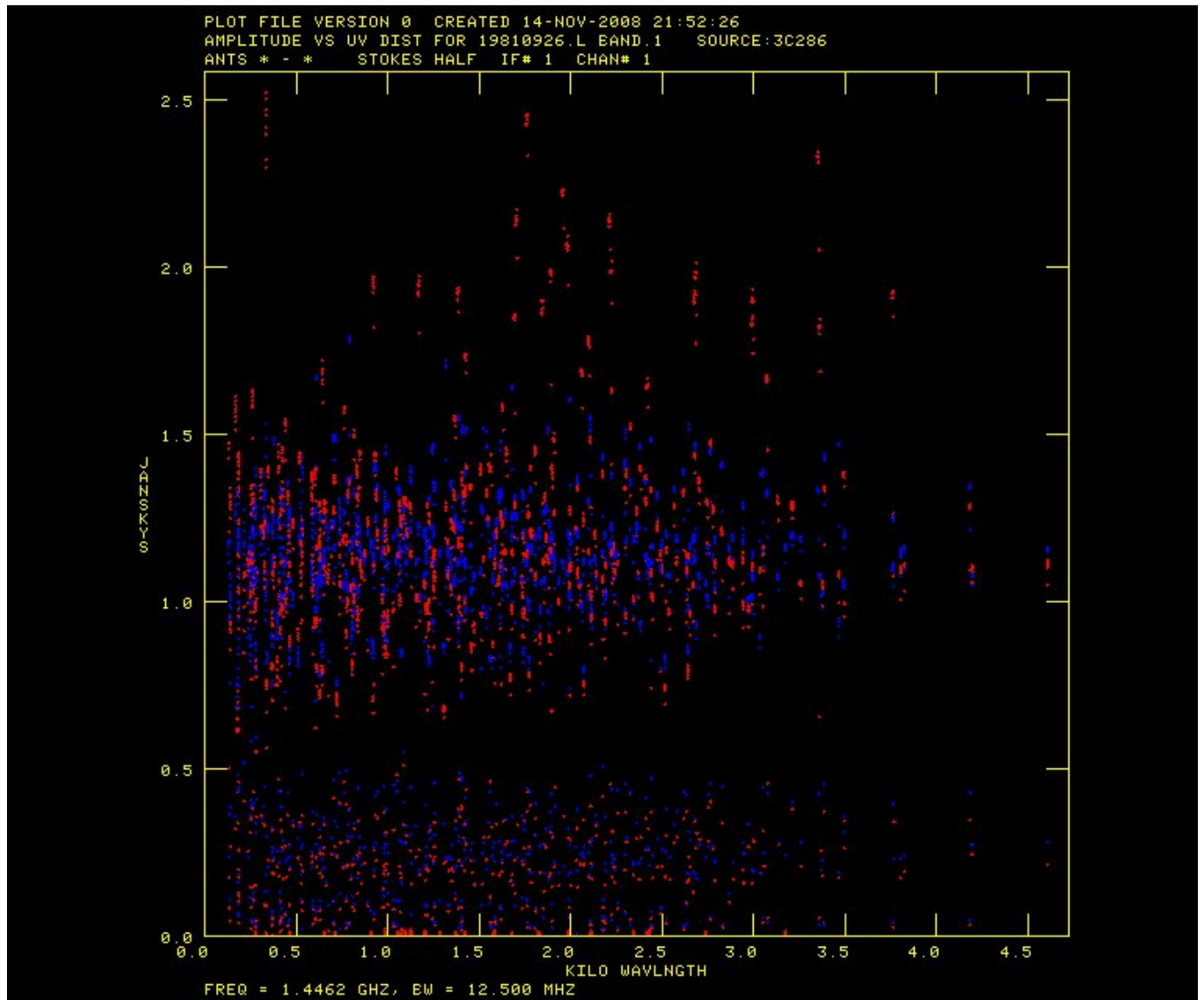
UVPLT

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

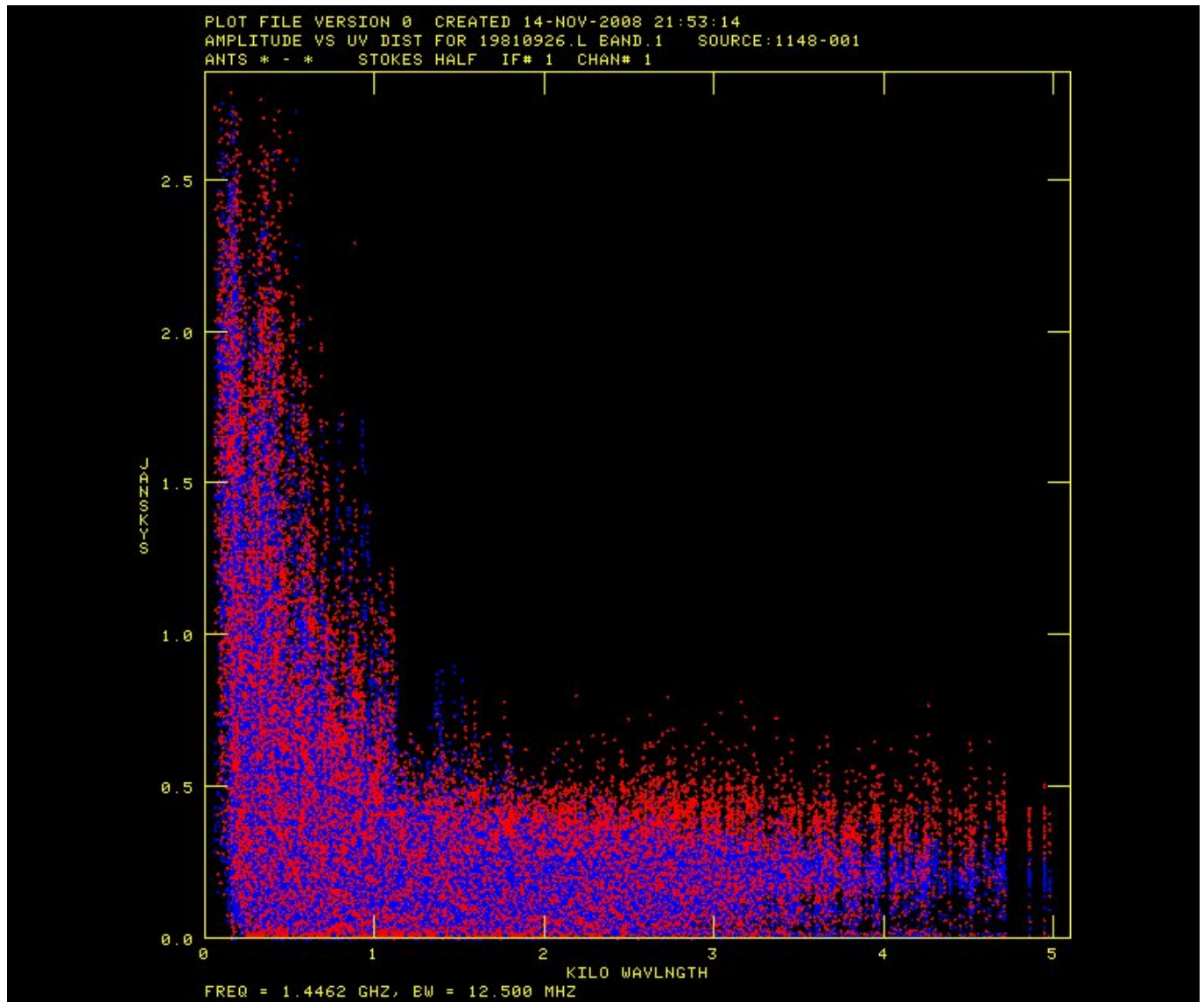
```

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

```

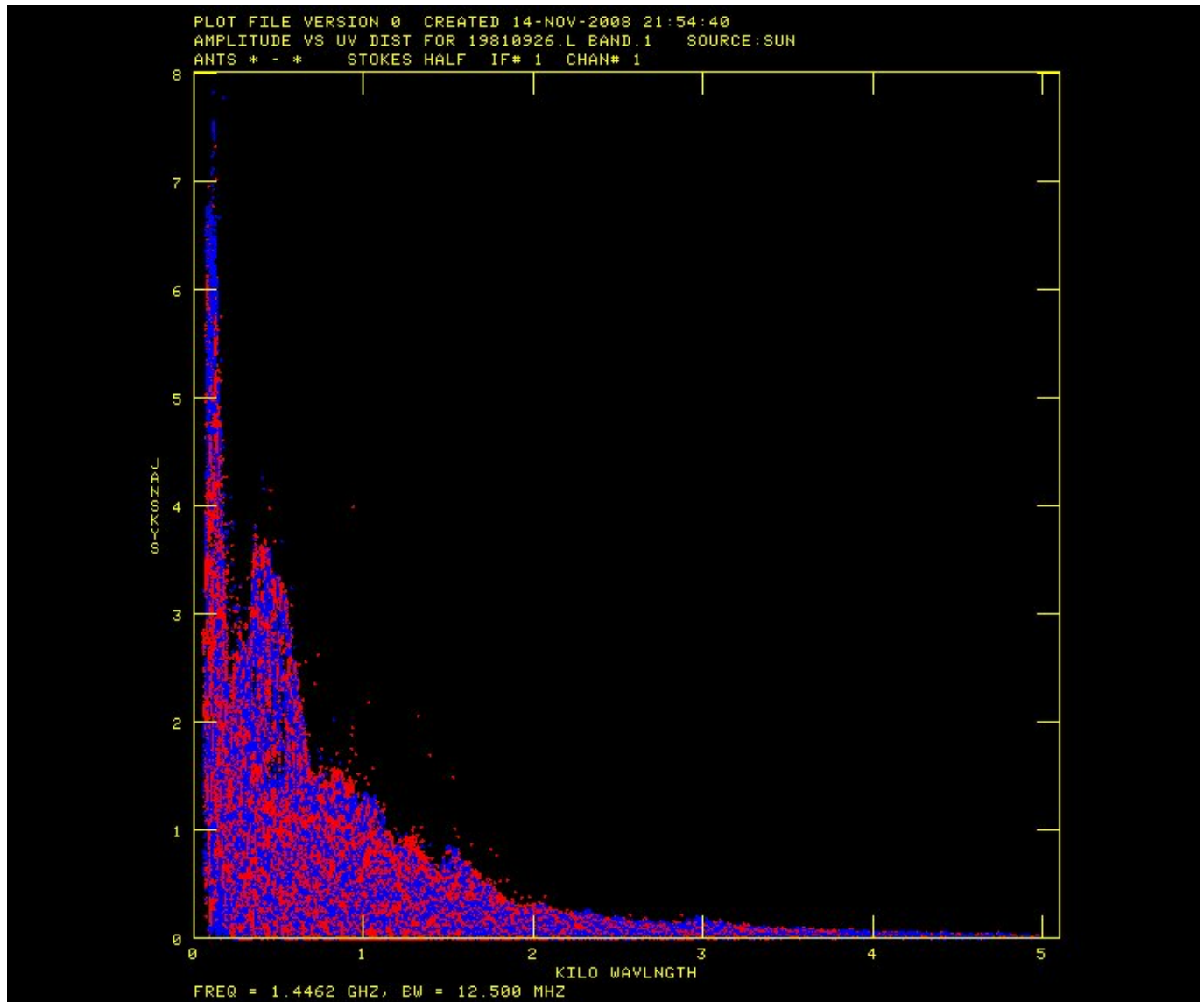


source '1148-001', ' '
go

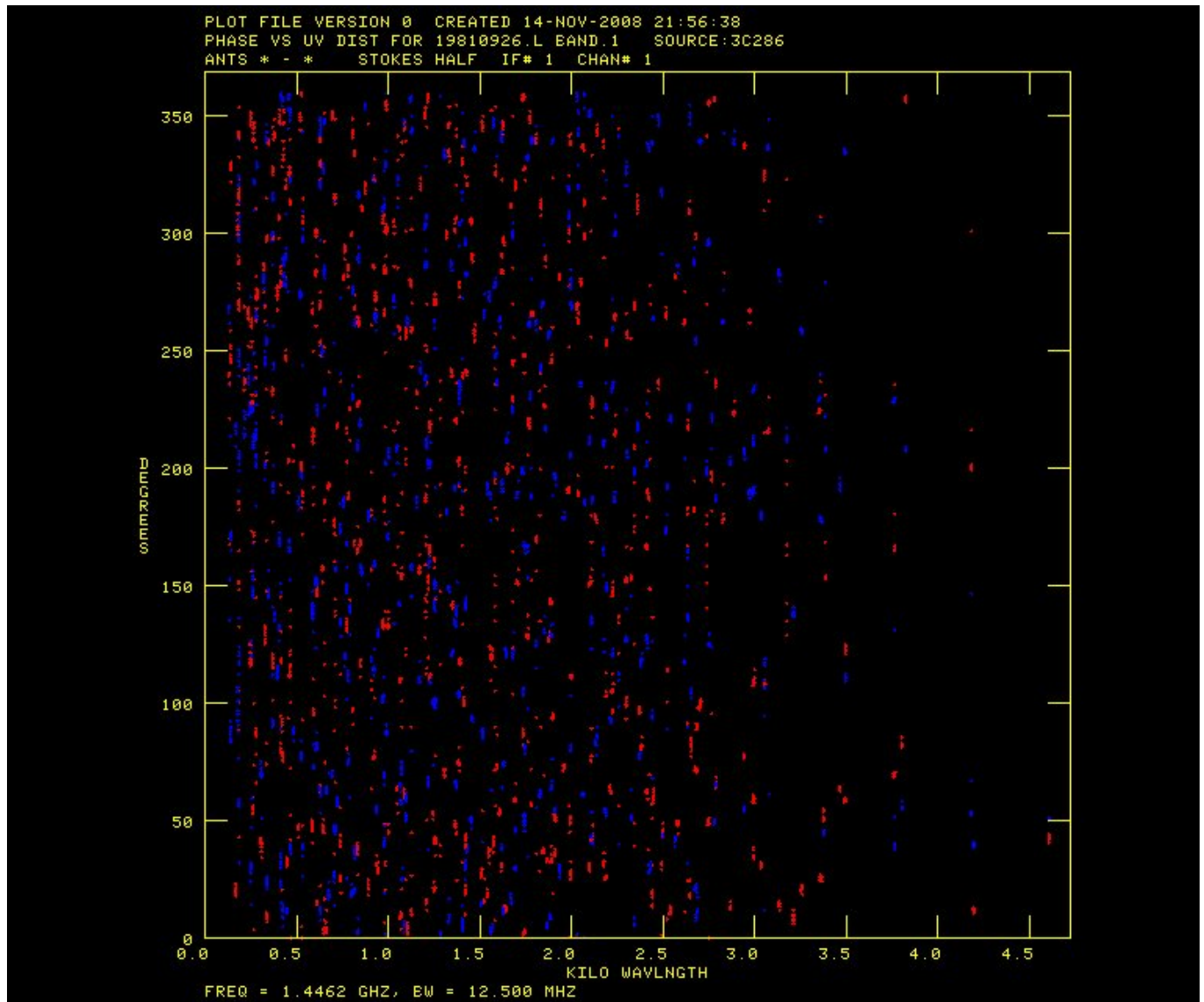


Warning: the next step will take a long time. You are free to skip this, and just look at the picture.

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

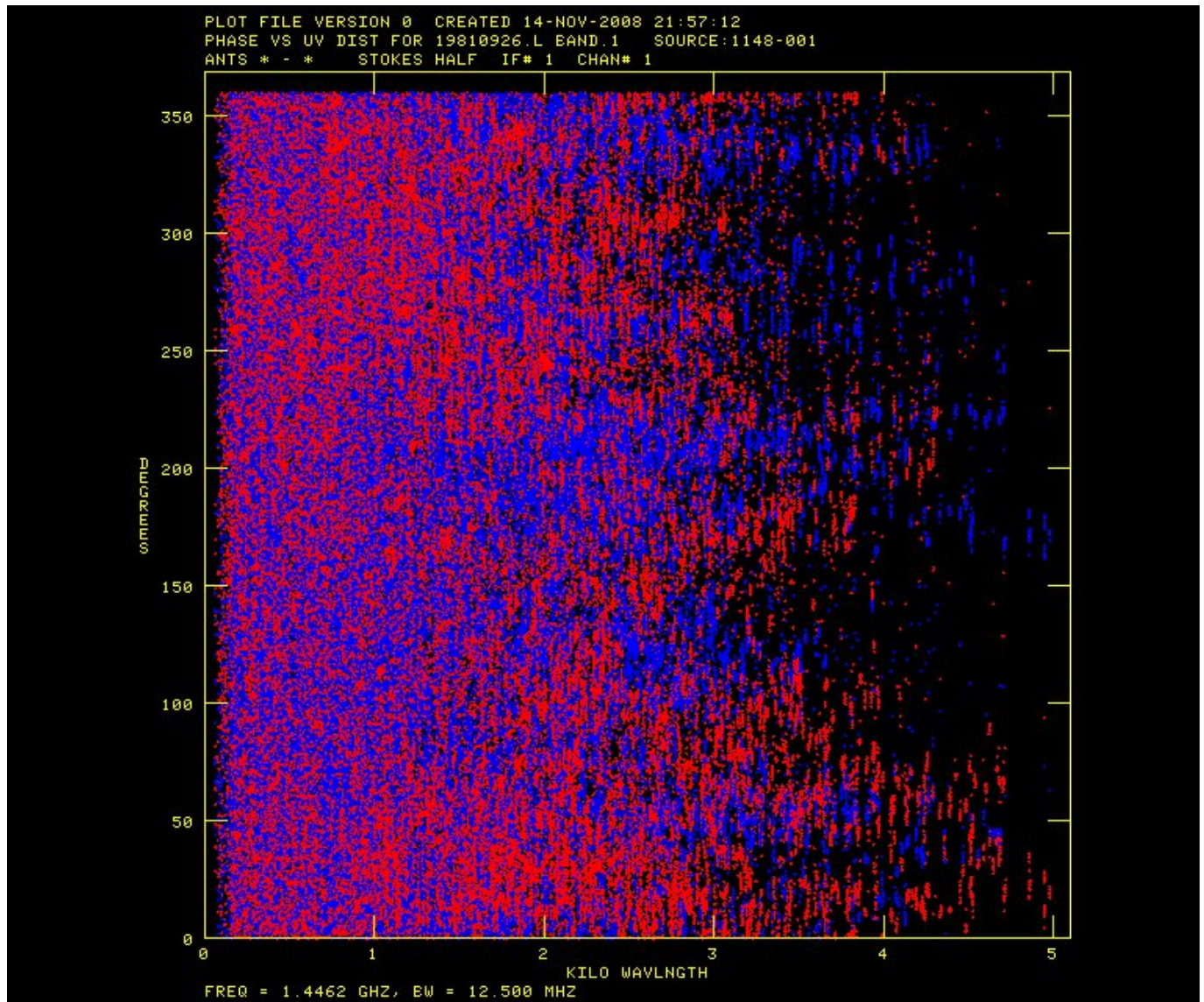


```
source '3c286', ' '  
bparm 0 2  
go
```

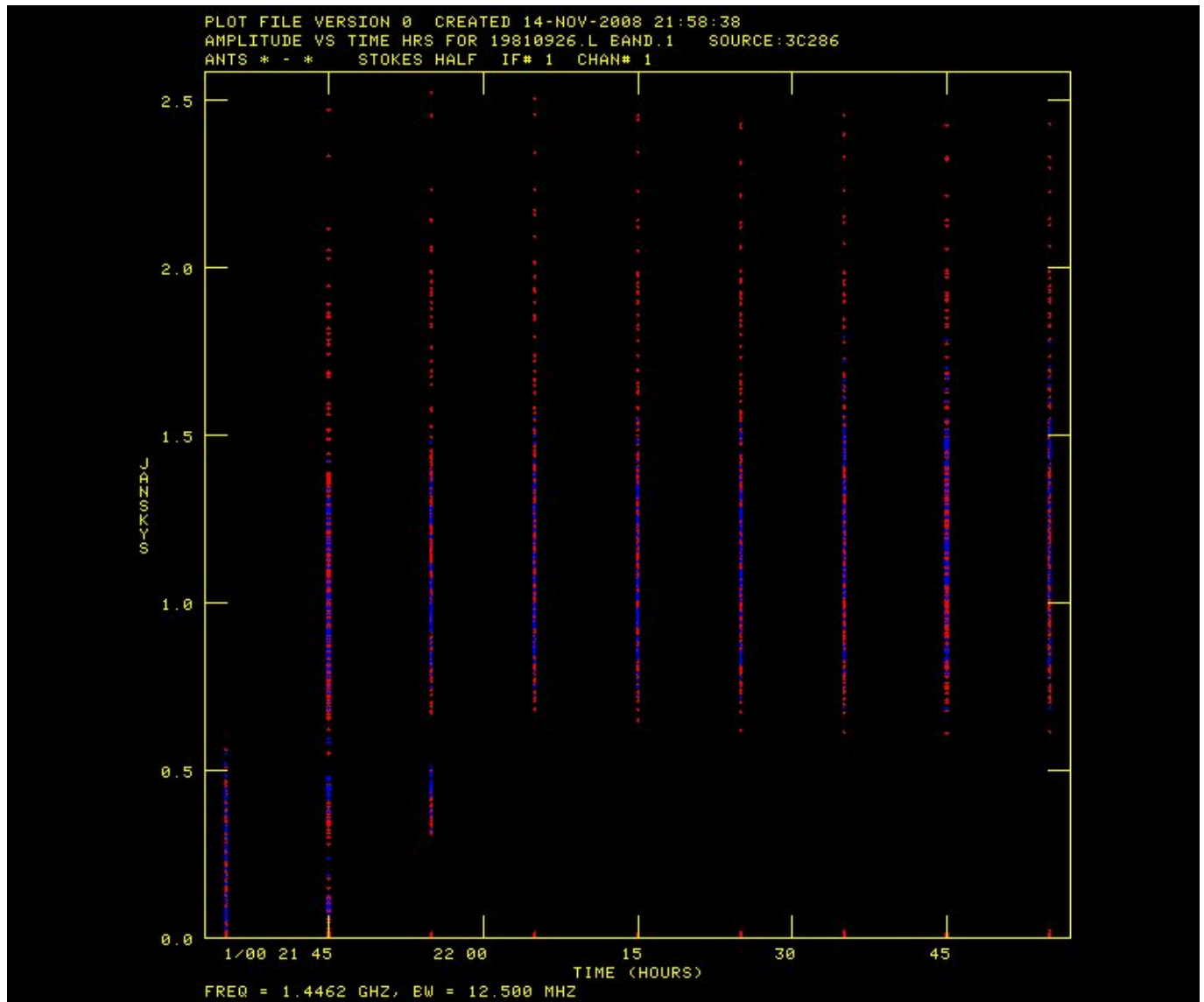


source '1148-001', ' '

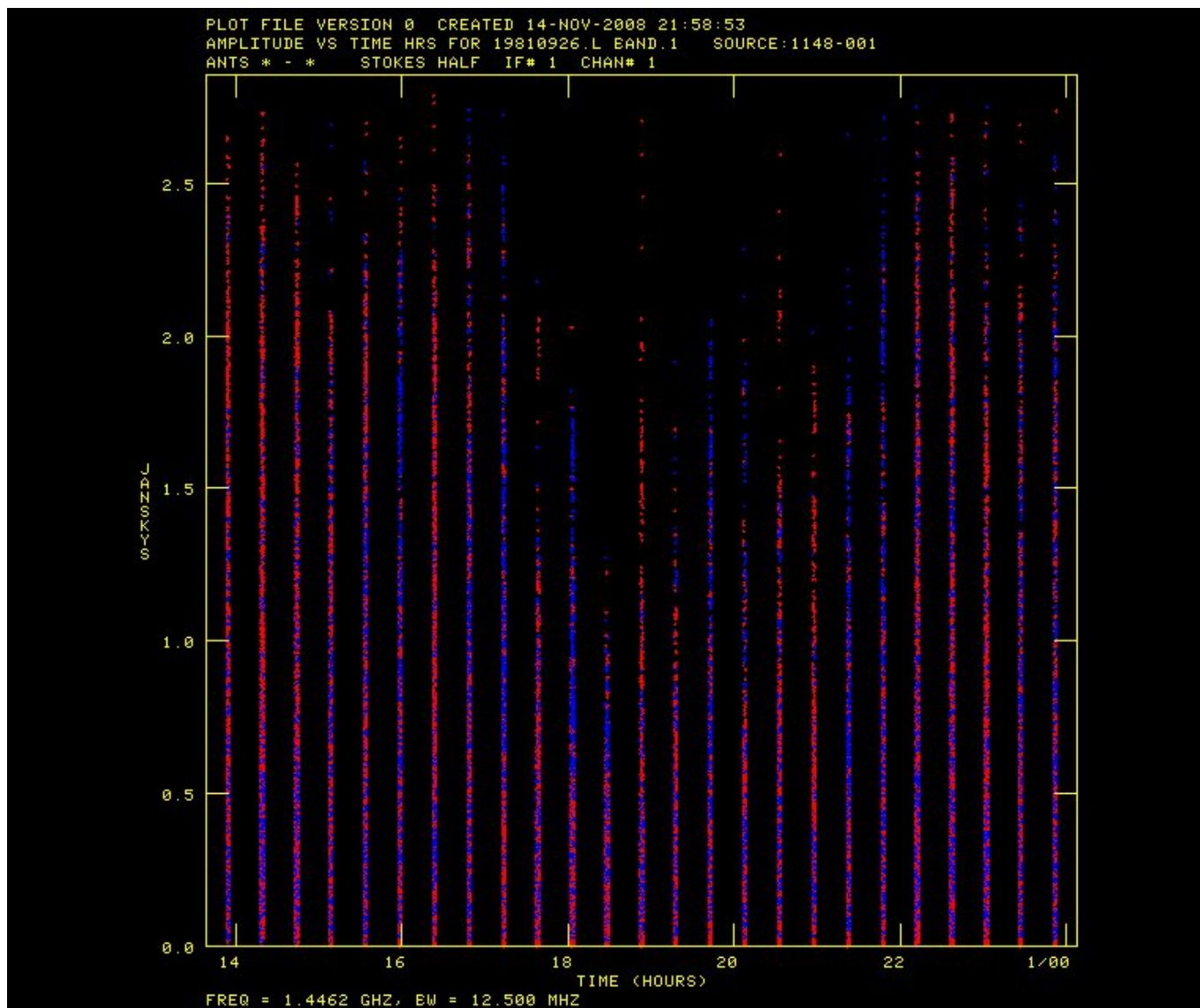
go



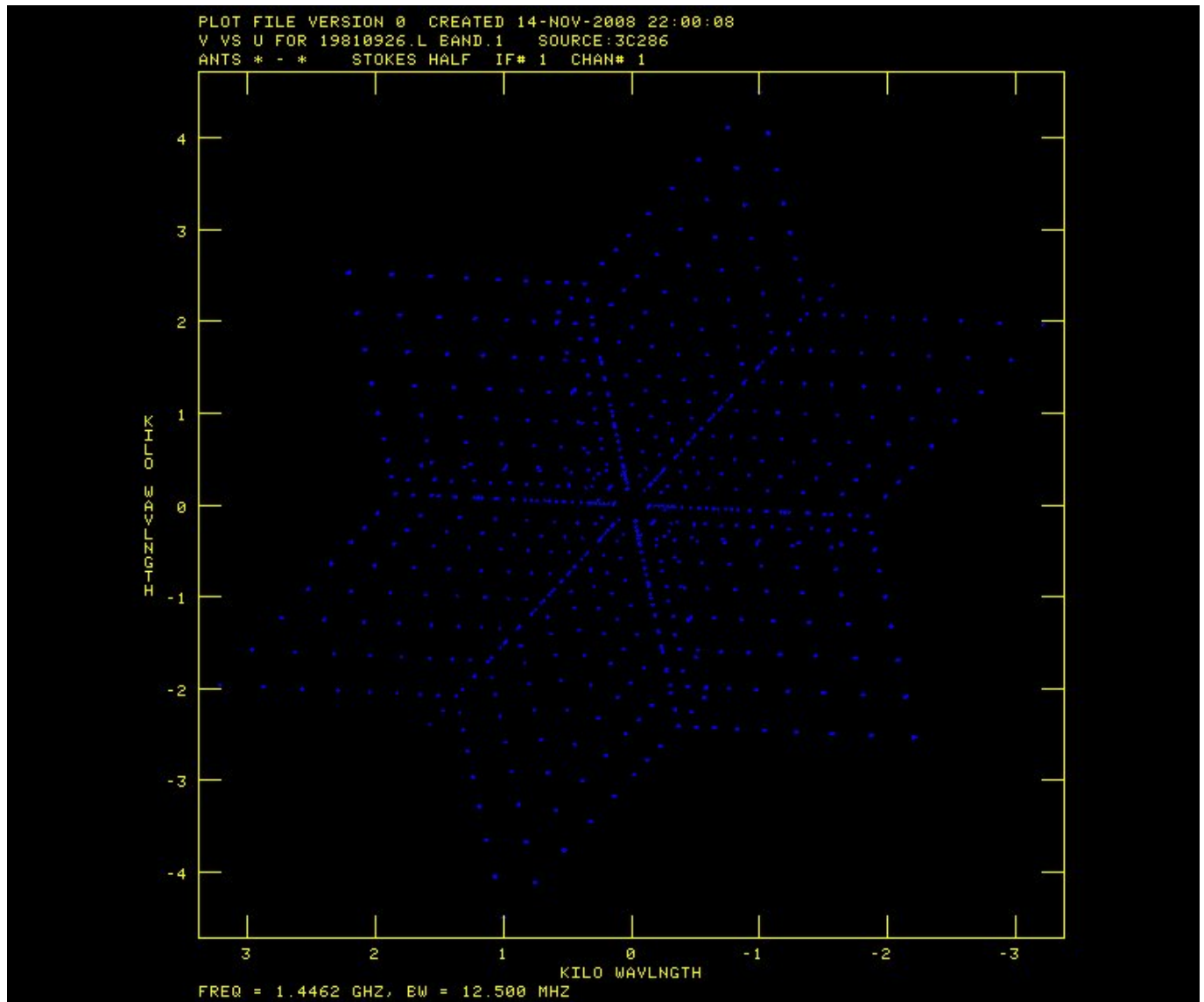
```
source '3c286', ' '  
bparm 11 1  
go
```



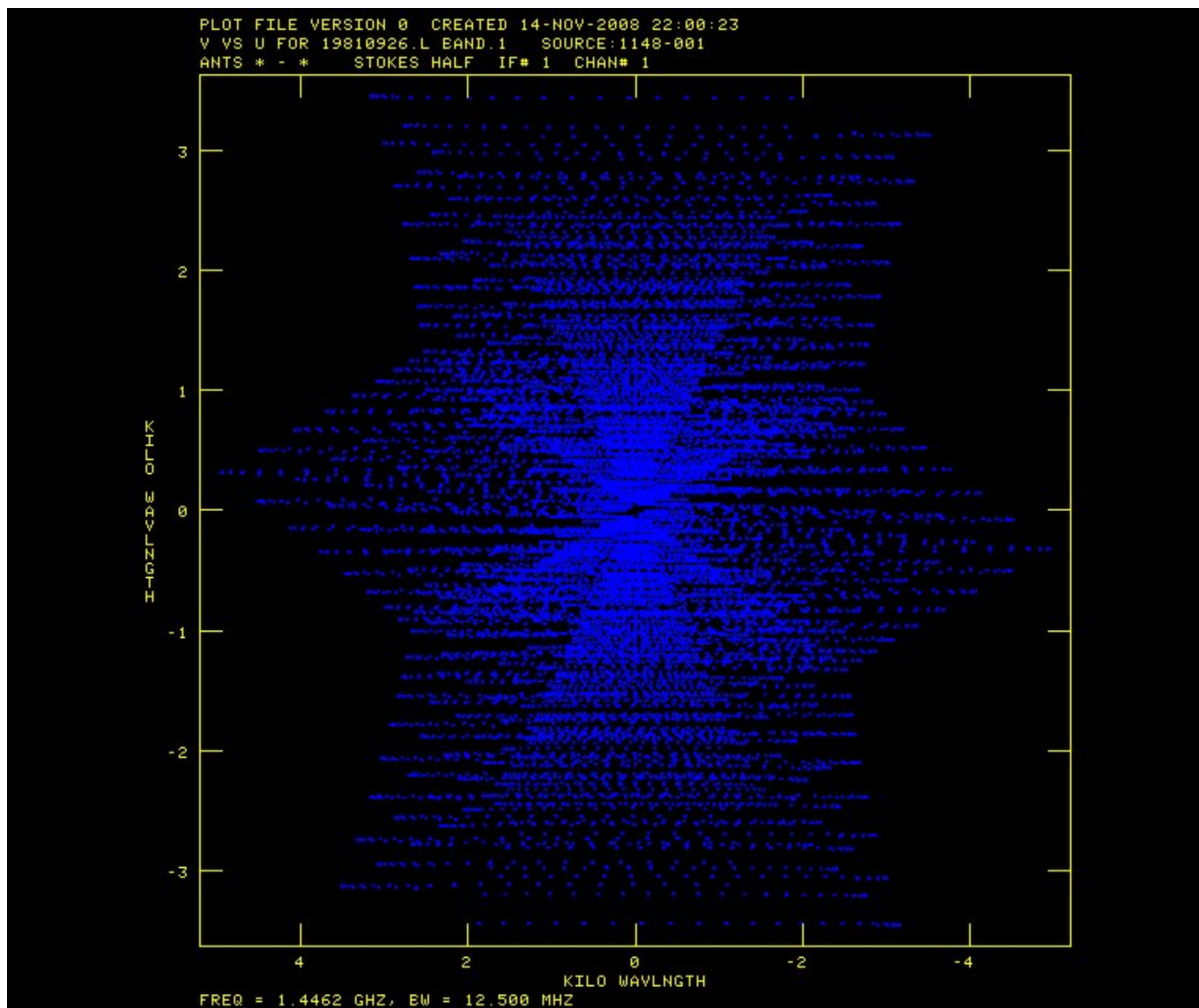
source '1148-001', ' '
 go



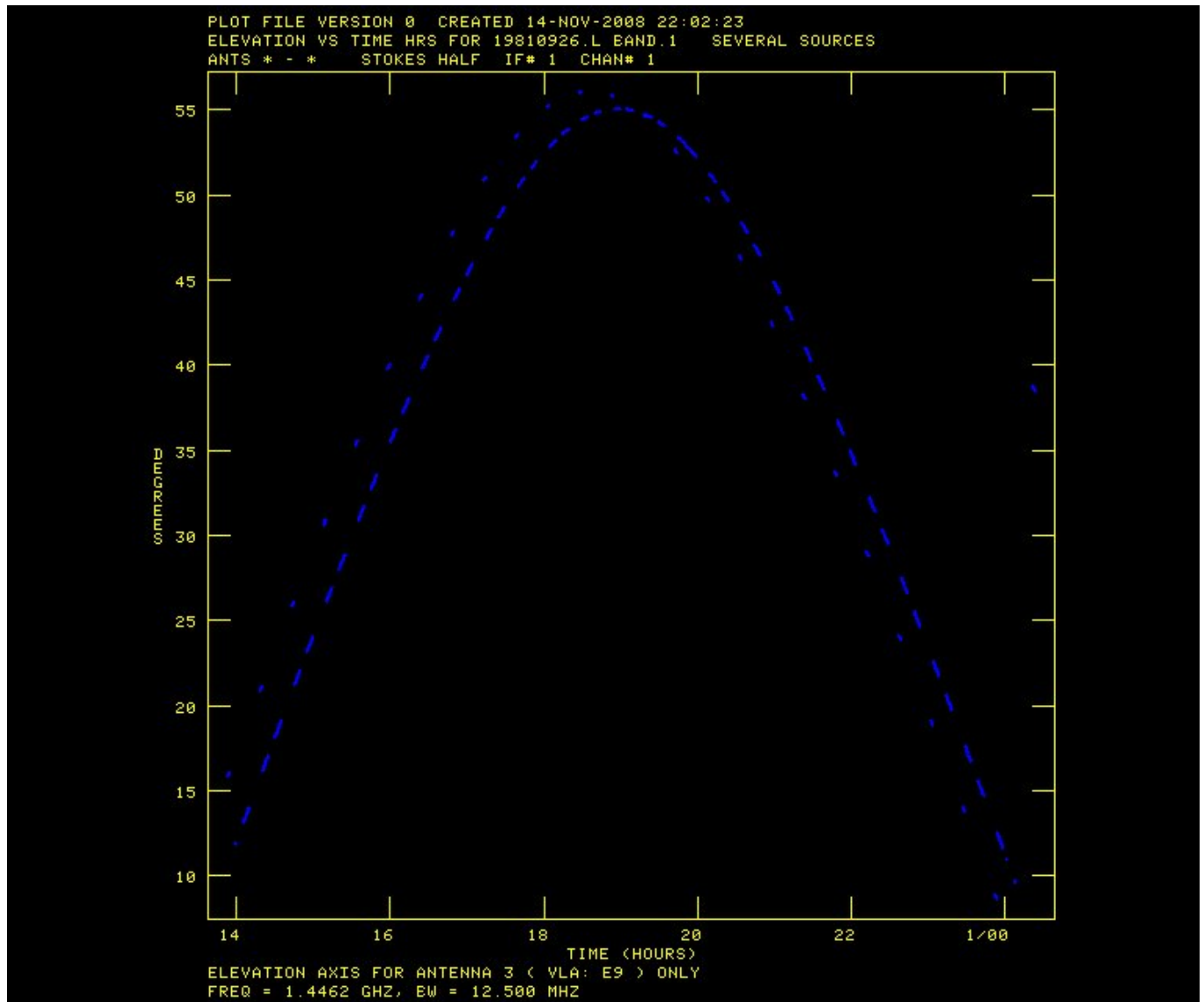
source '3c286', ' '
bparm 6 7
go



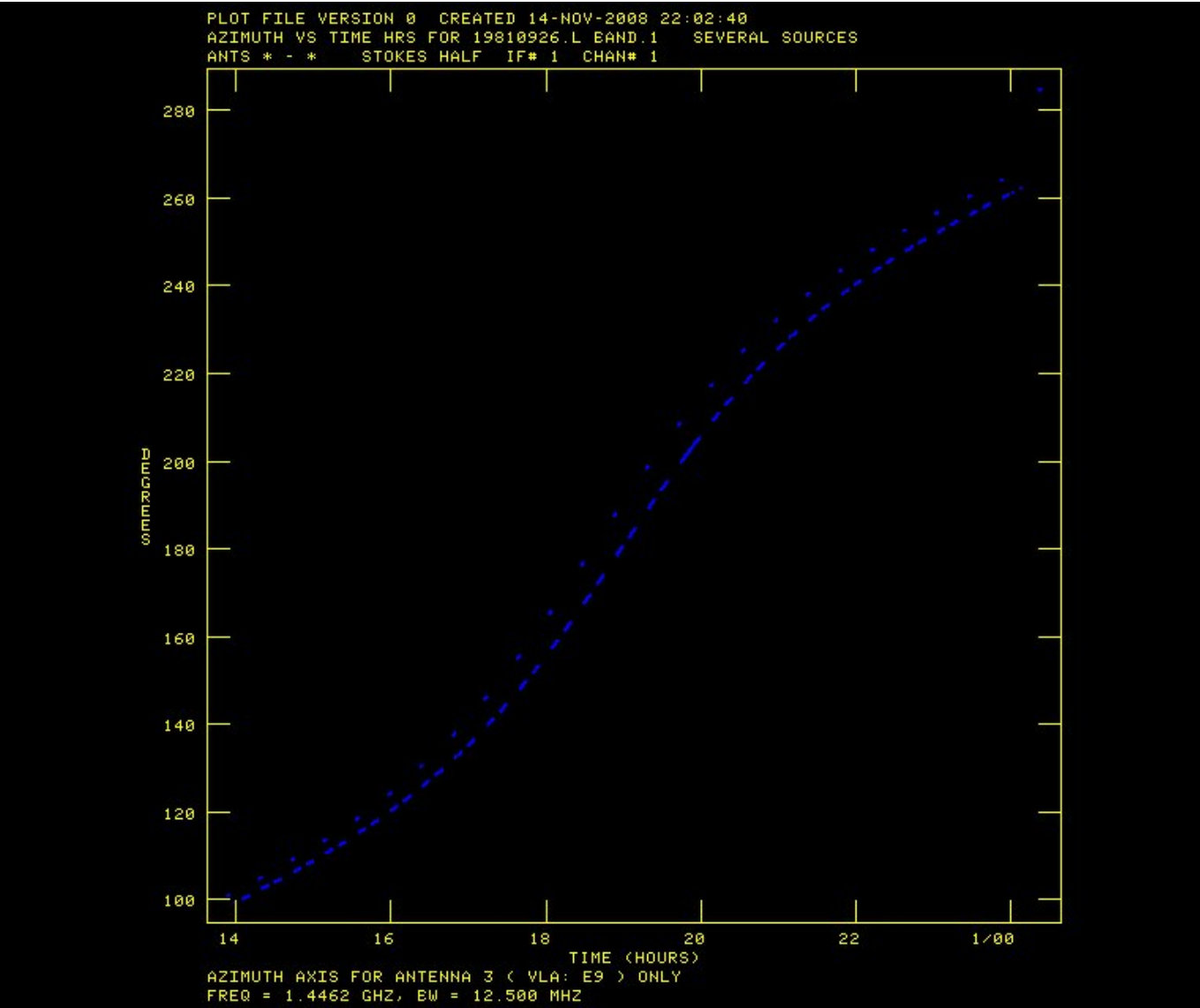
source '1148-001', ' '
 go



```
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
timer 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	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

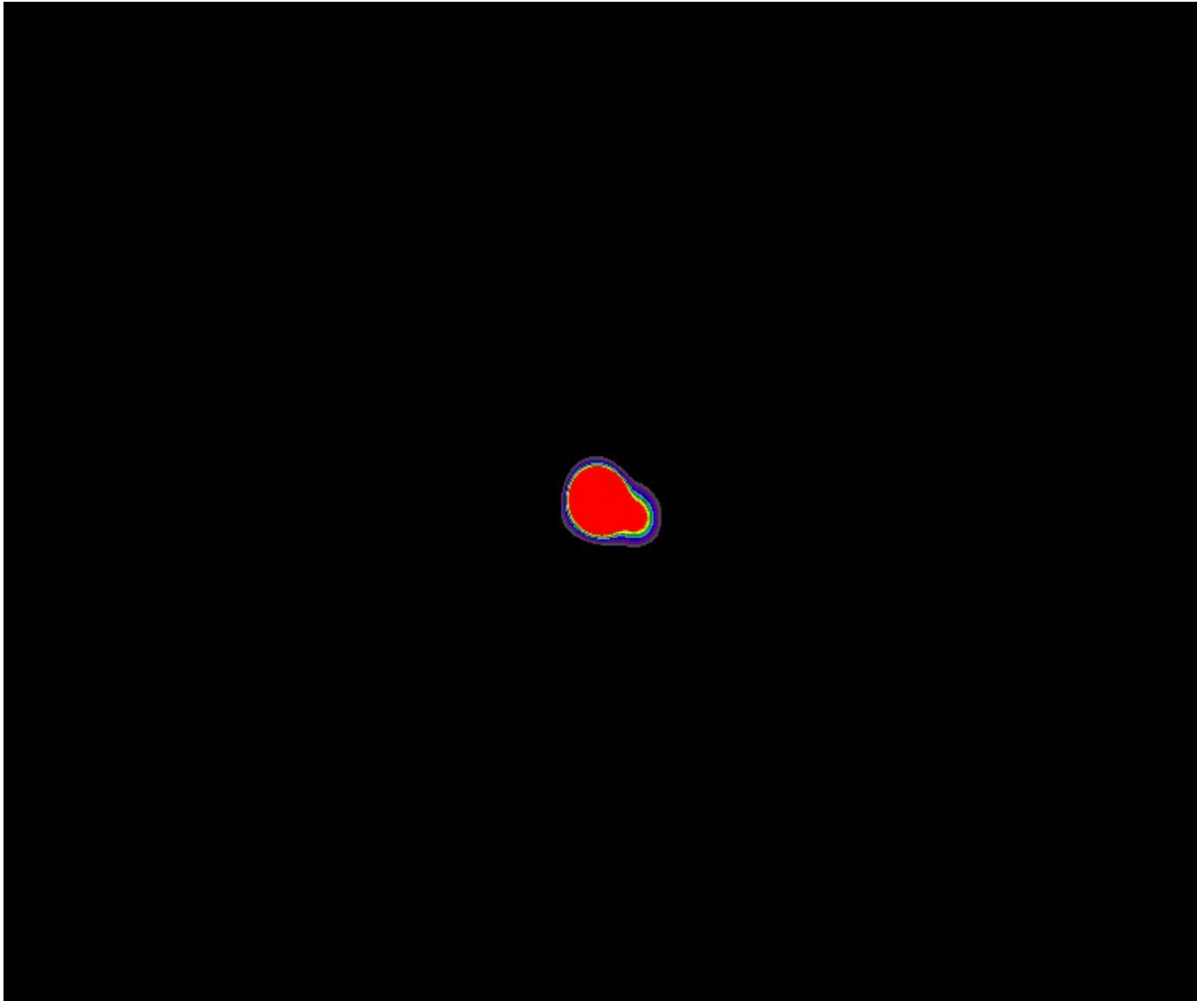
```
task 'calrd'  
object '3c286'  
band 'l'  
go
```

```
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

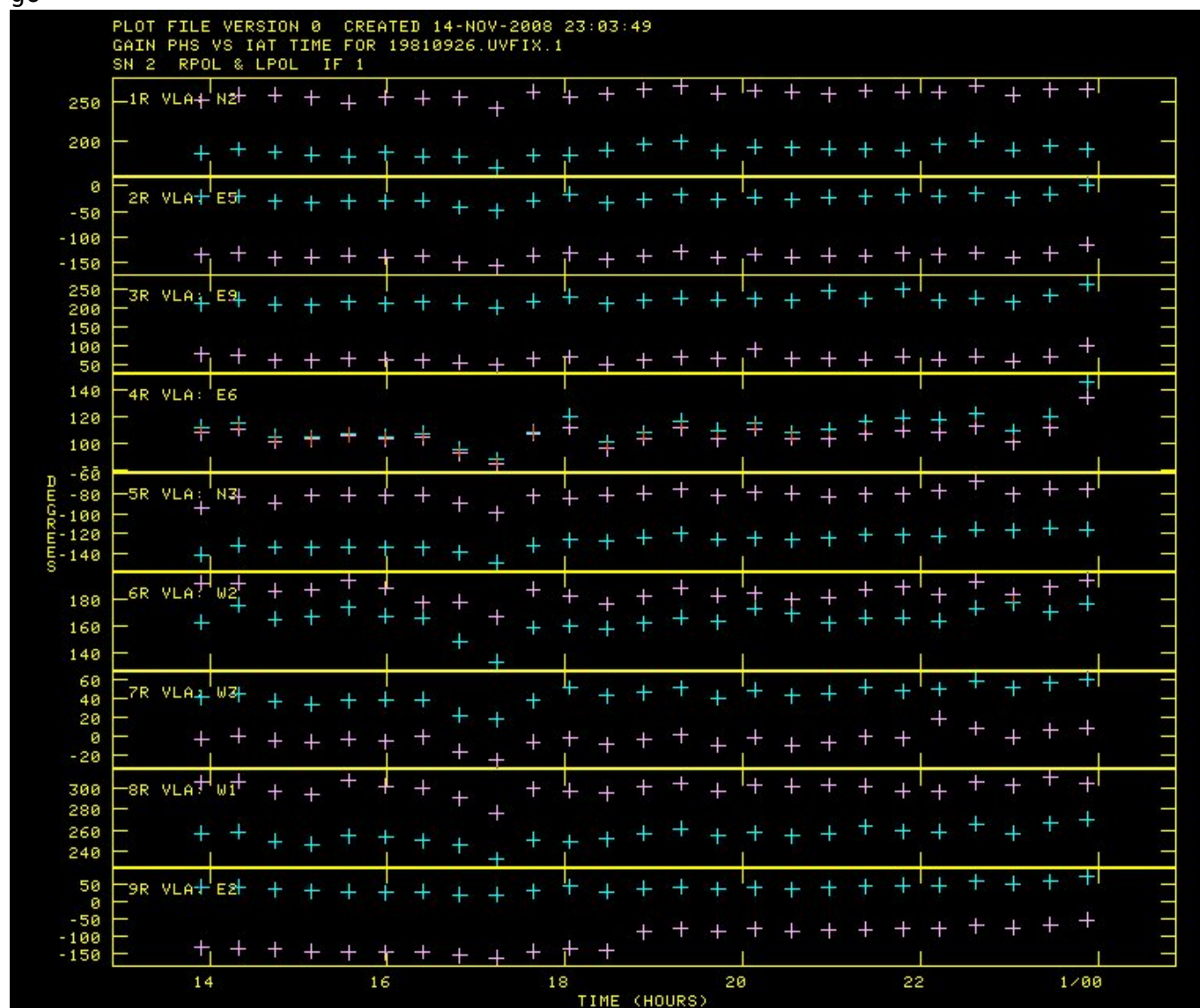
Look at the amplitude calibrator results.

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

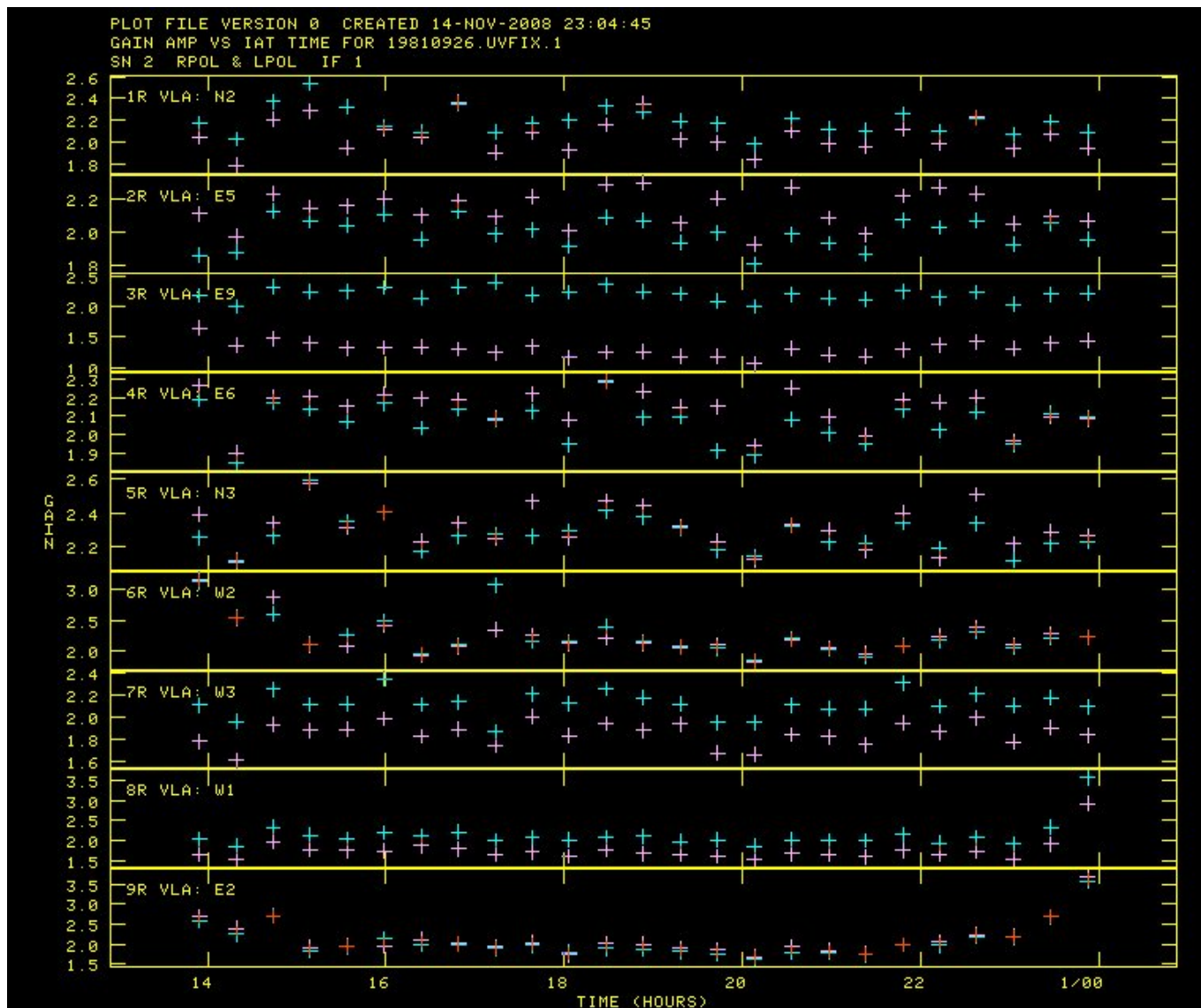
```
timer 0
tvinit
dotv 1
go
optype 'amp'
go
```

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

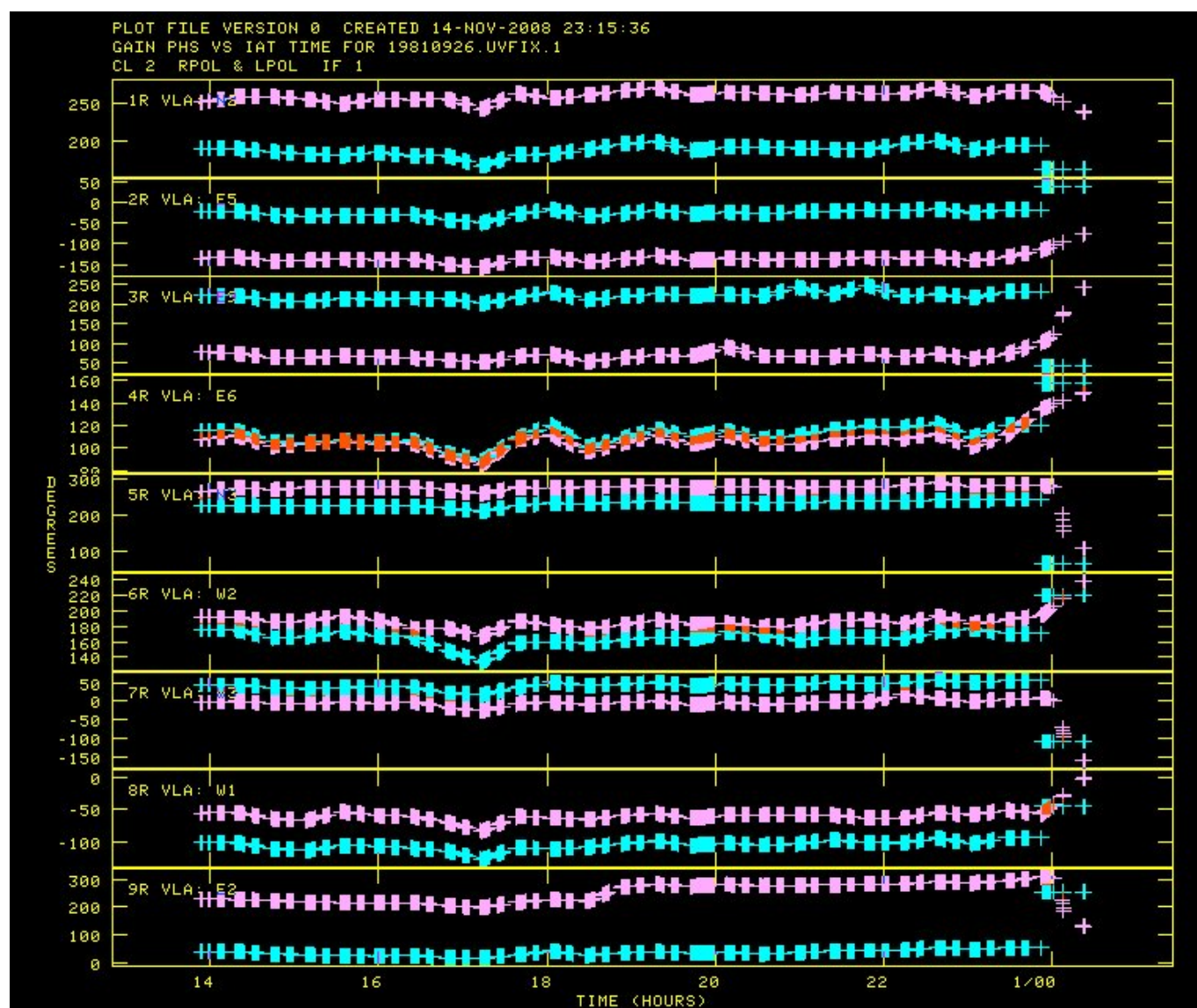
```
inext 'sn'
inver 2
extdest
tget calib
go
clrmsg
```

Apply the calibration to all sources, both amplitude and phase

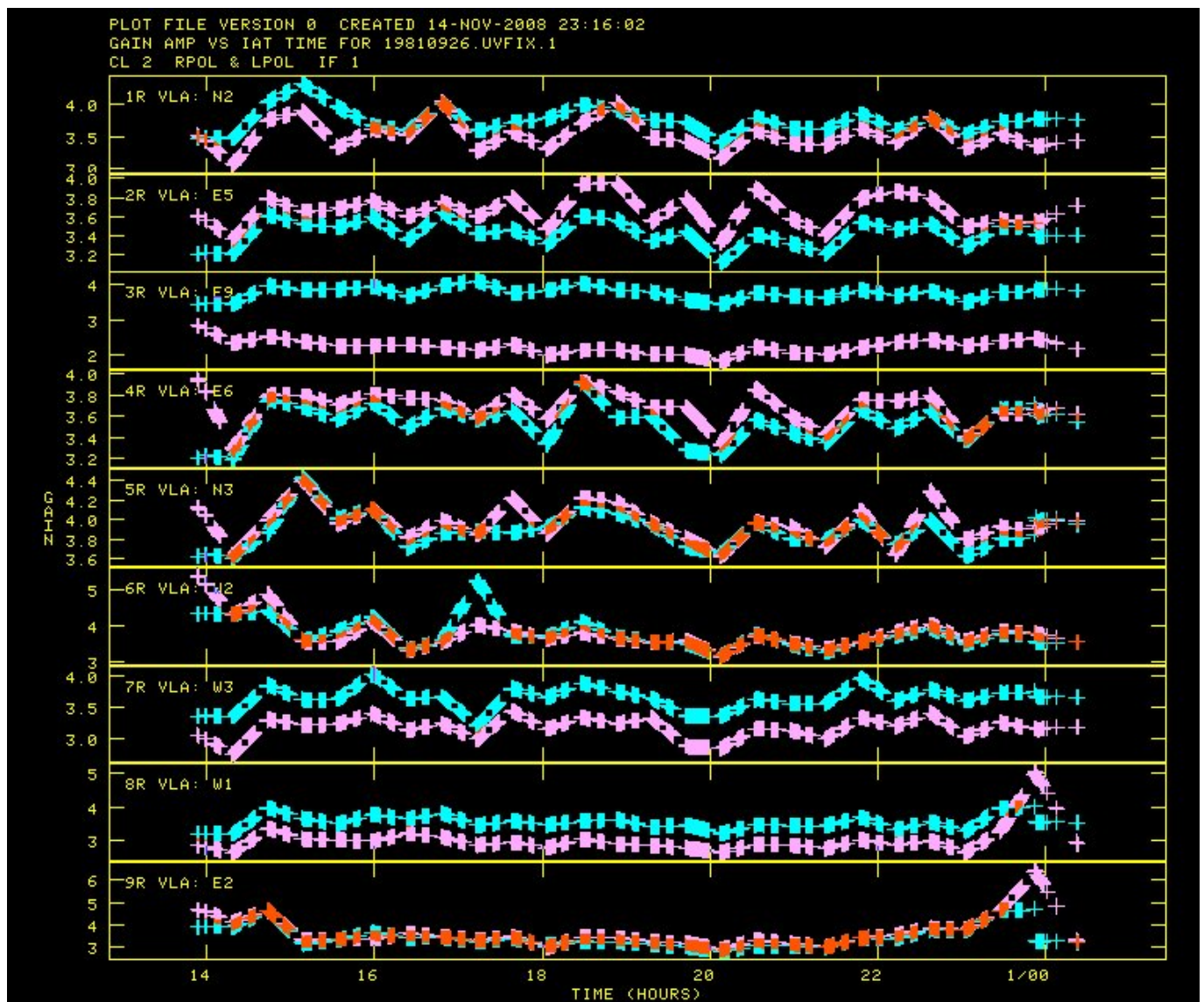
```
task 'clcal'
getn 3
sources ' '
calsour '3c286','1148-001',' '
calcode ' '
opcode 'cali'
gainver 1
gainuse 2
refant 24
bparm 0
interpol '2pt'
timer 0
antenna 0
doblank 1
go
```

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

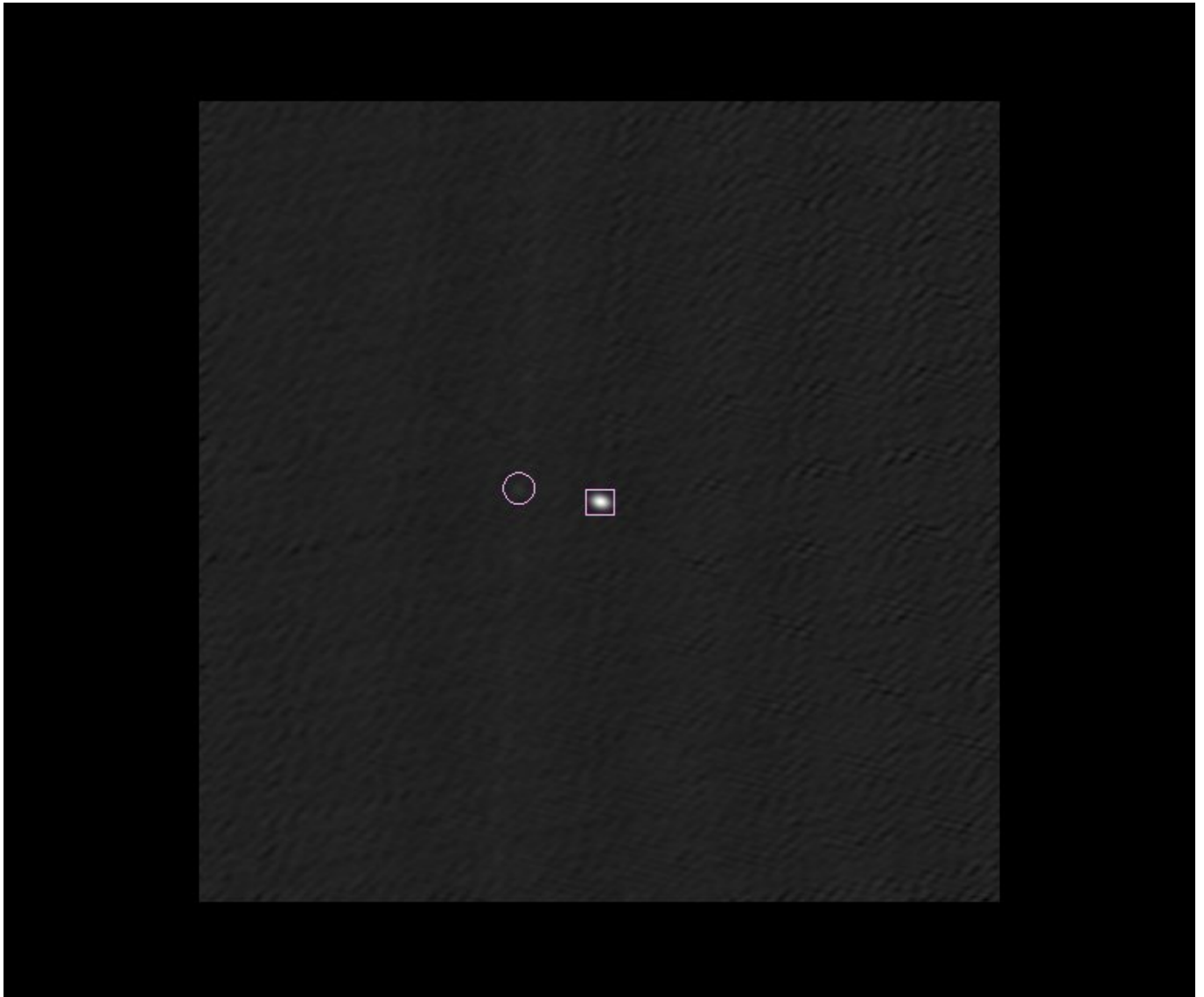
Amplitude Calibrator

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
```

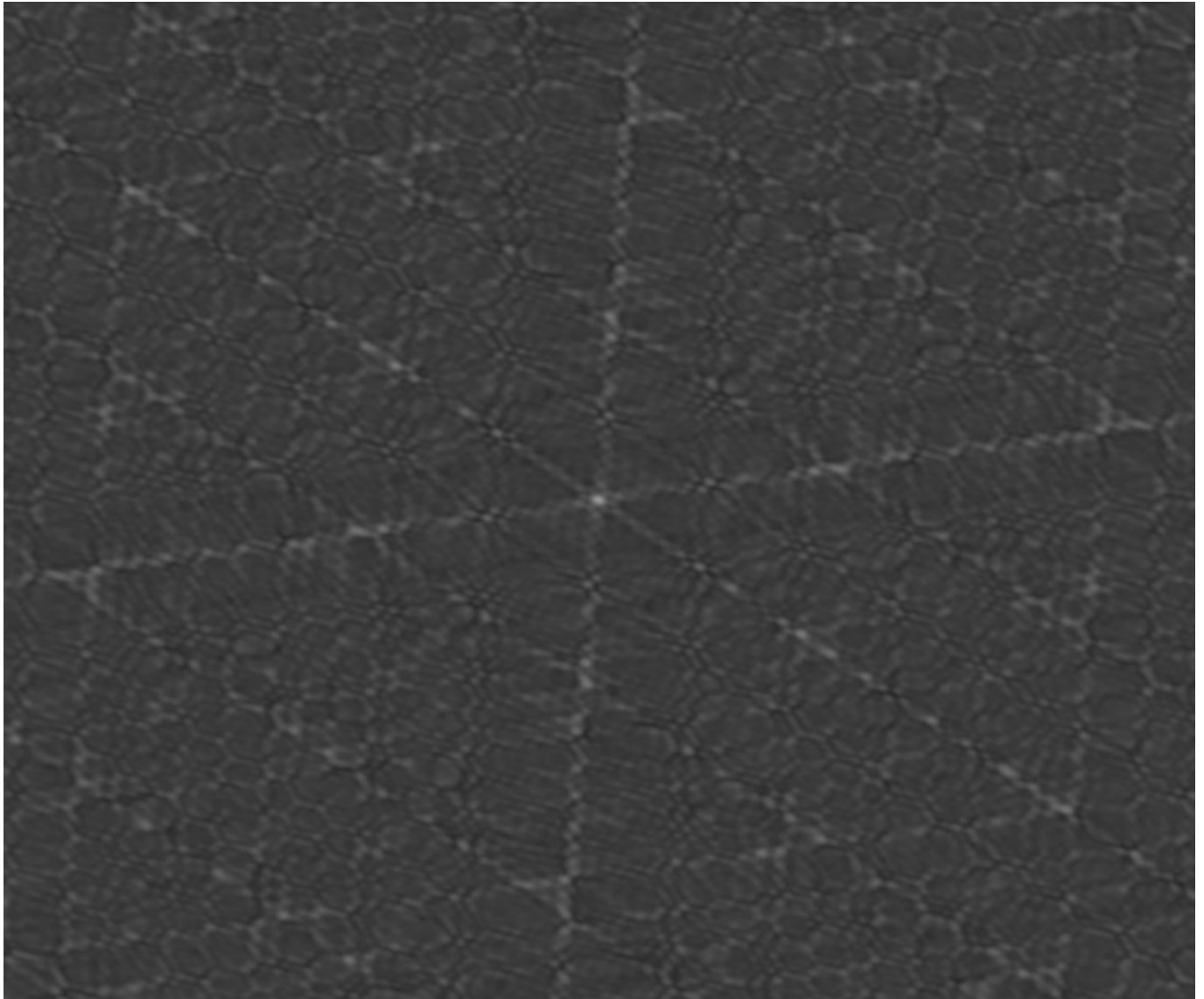
```
antenna 0
niter 10000
overlap 1
D03DIMAG 1
rashift 1800.00,0
decshift -920.00,0
go
clrmsg
```

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
```



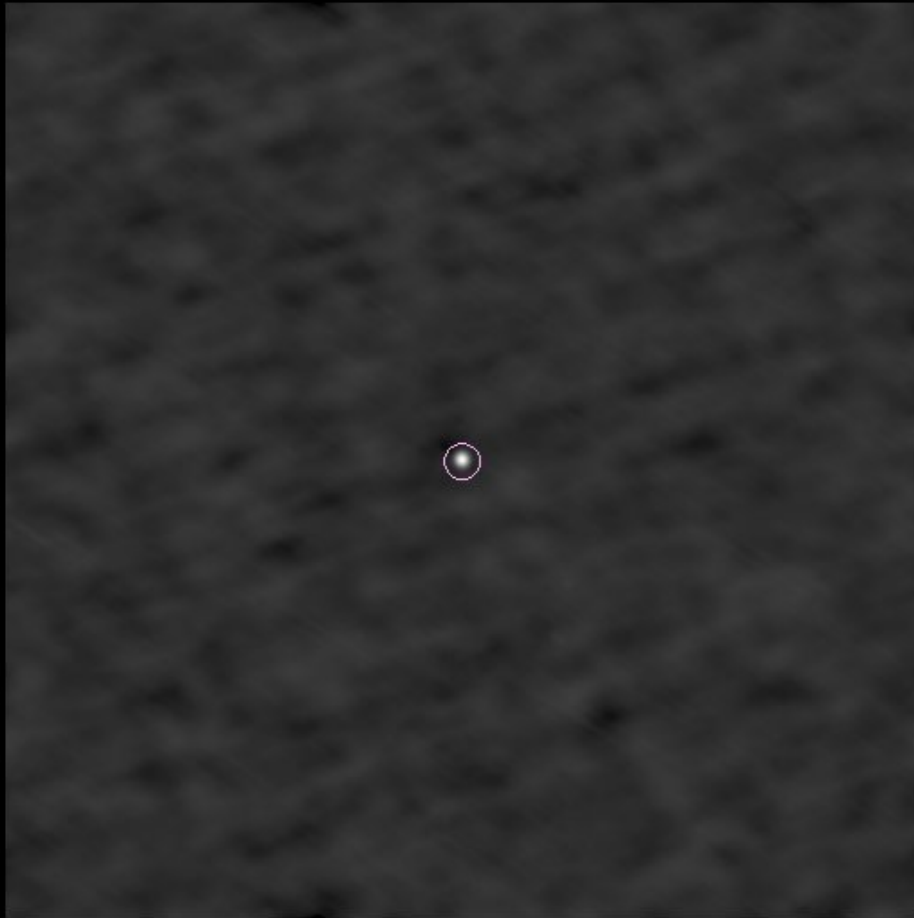
Phase Calibrator

Ok, clean up after ourselves

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

Now do the imaging and light cleaning

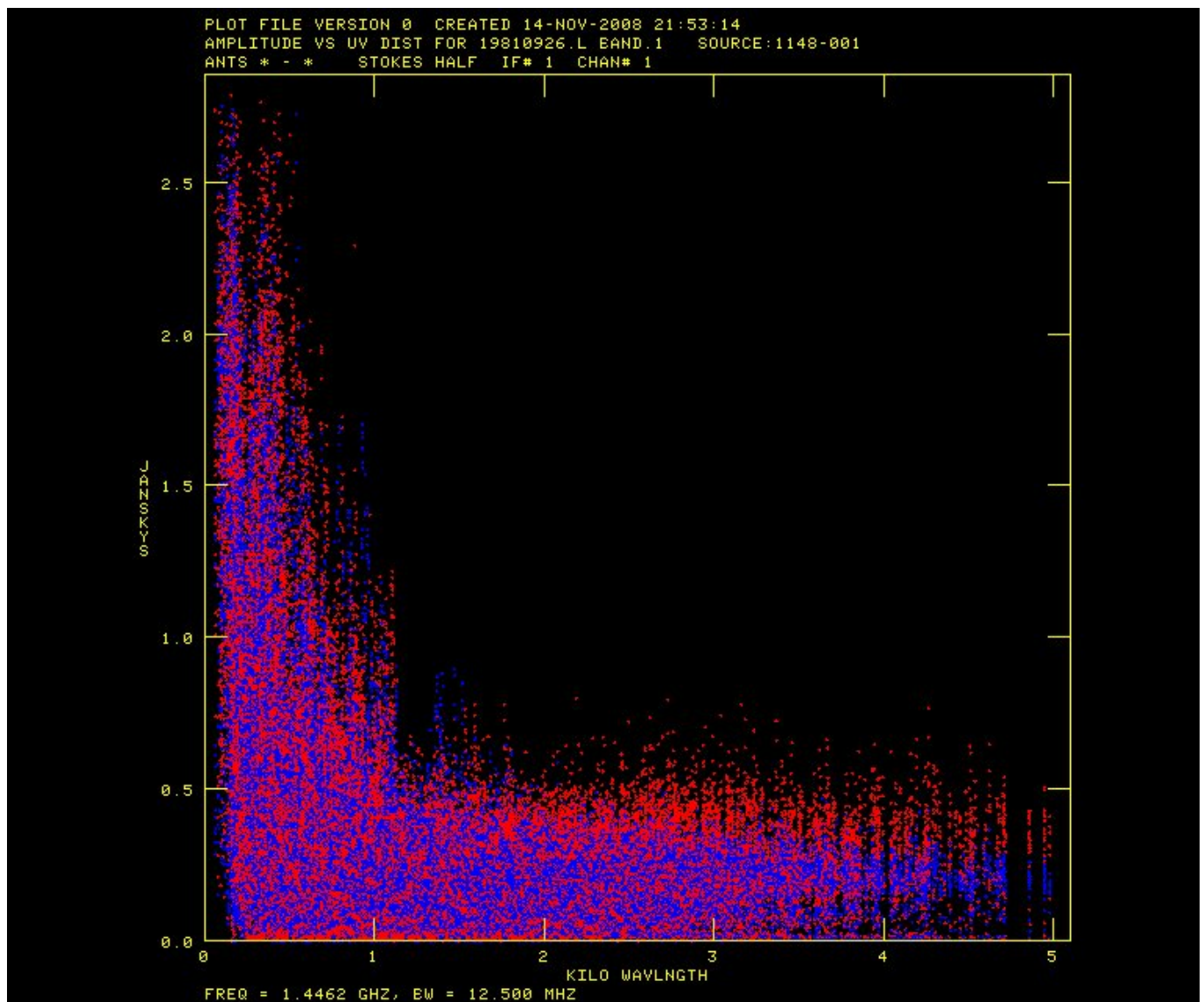
```
tget imagr  
source '1148-001',' '  
rashift 0  
decshift 0  
go
```



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 ' '
```

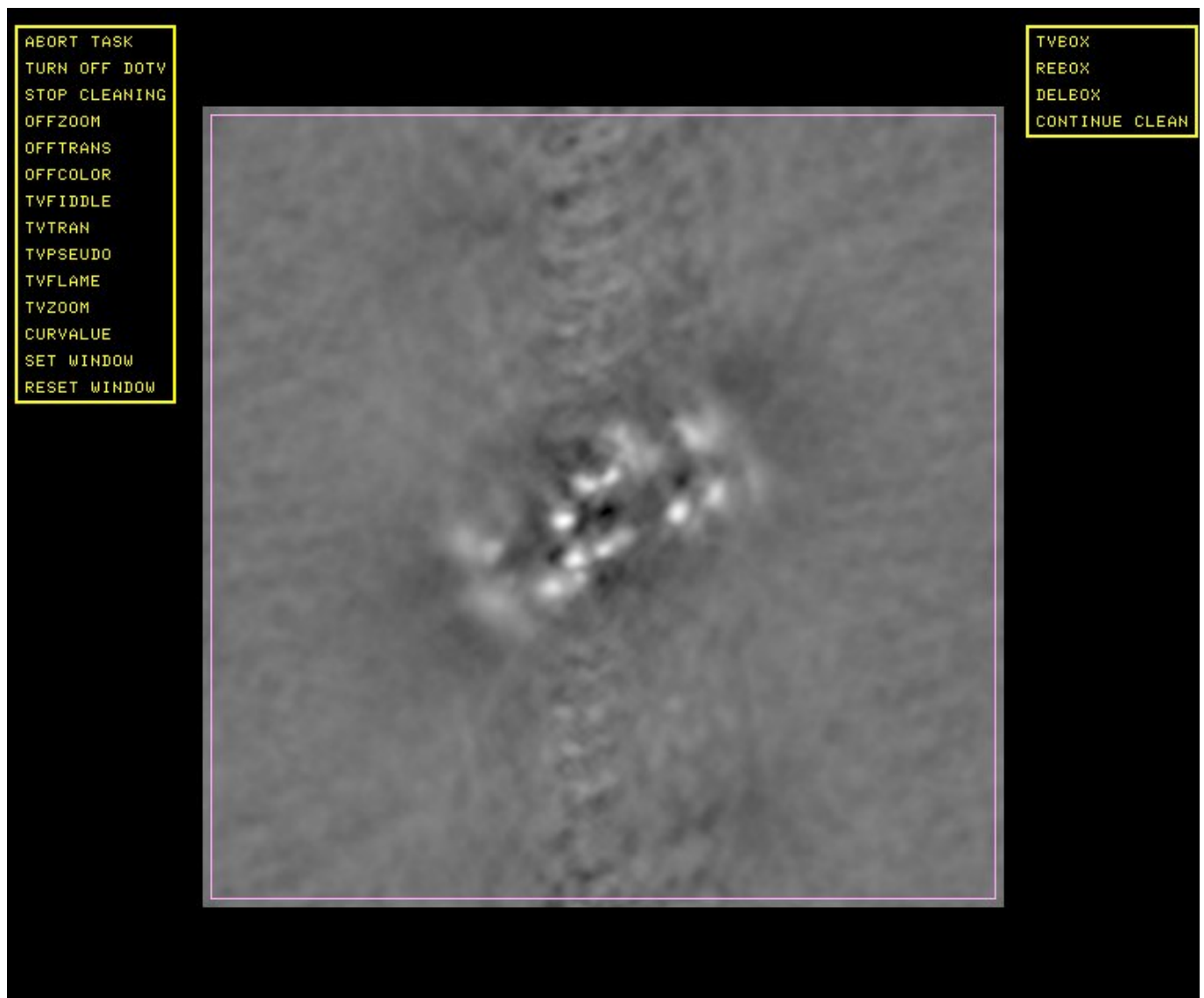
```
aparm 0  
go
```

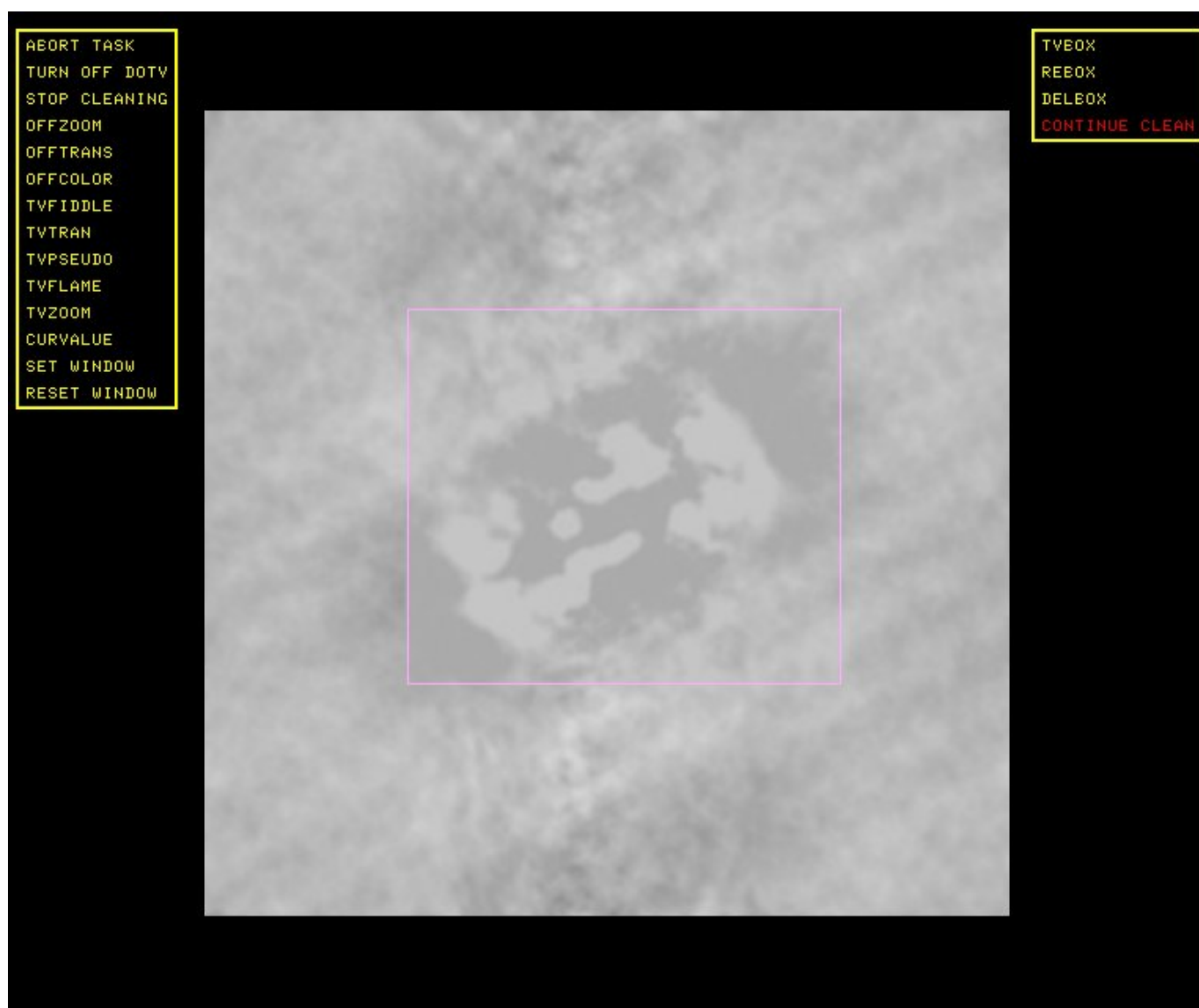
IMAGR

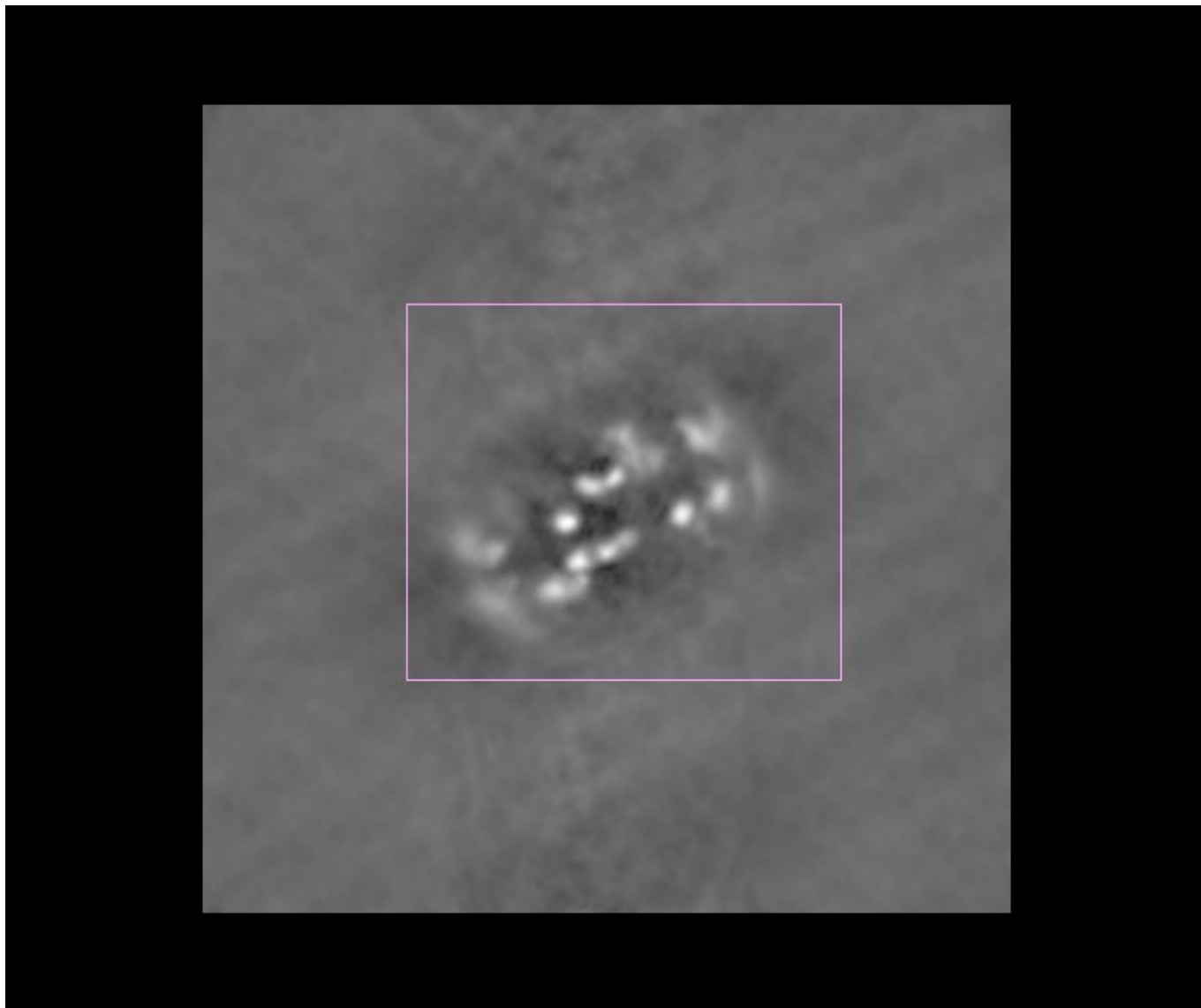
Now do an initial imaging and cleaning step.

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

Here are some of the stages of my cleaning.







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.

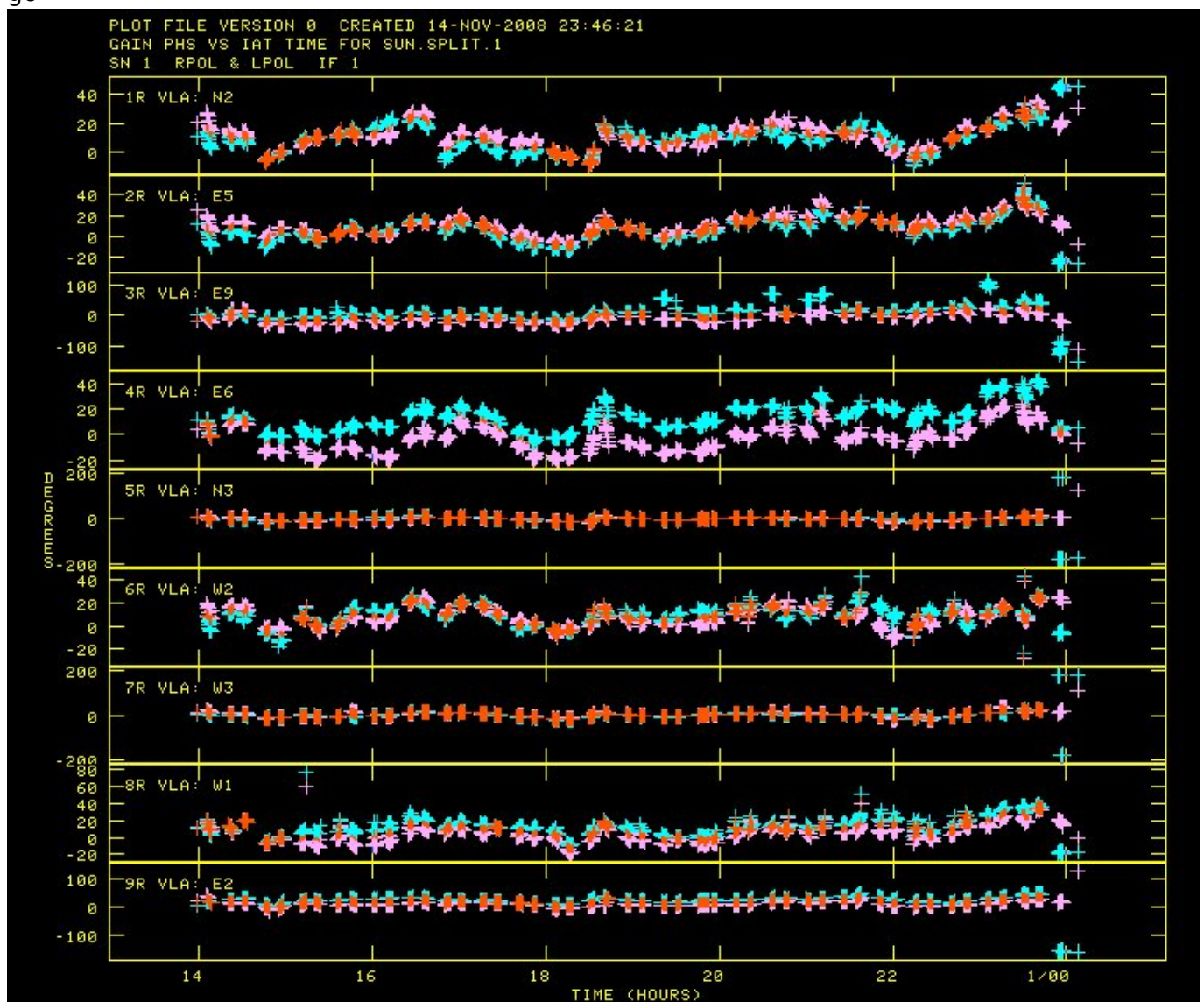
We run exactly the same calibration software, in exactly the same manner. Because the phase calibrator was resolved at short spacings, and because it is quite difficult for us to clean the extended emission, I limit the (u,v) coverage. Note that this also is only doing phase calibration, not amplitude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

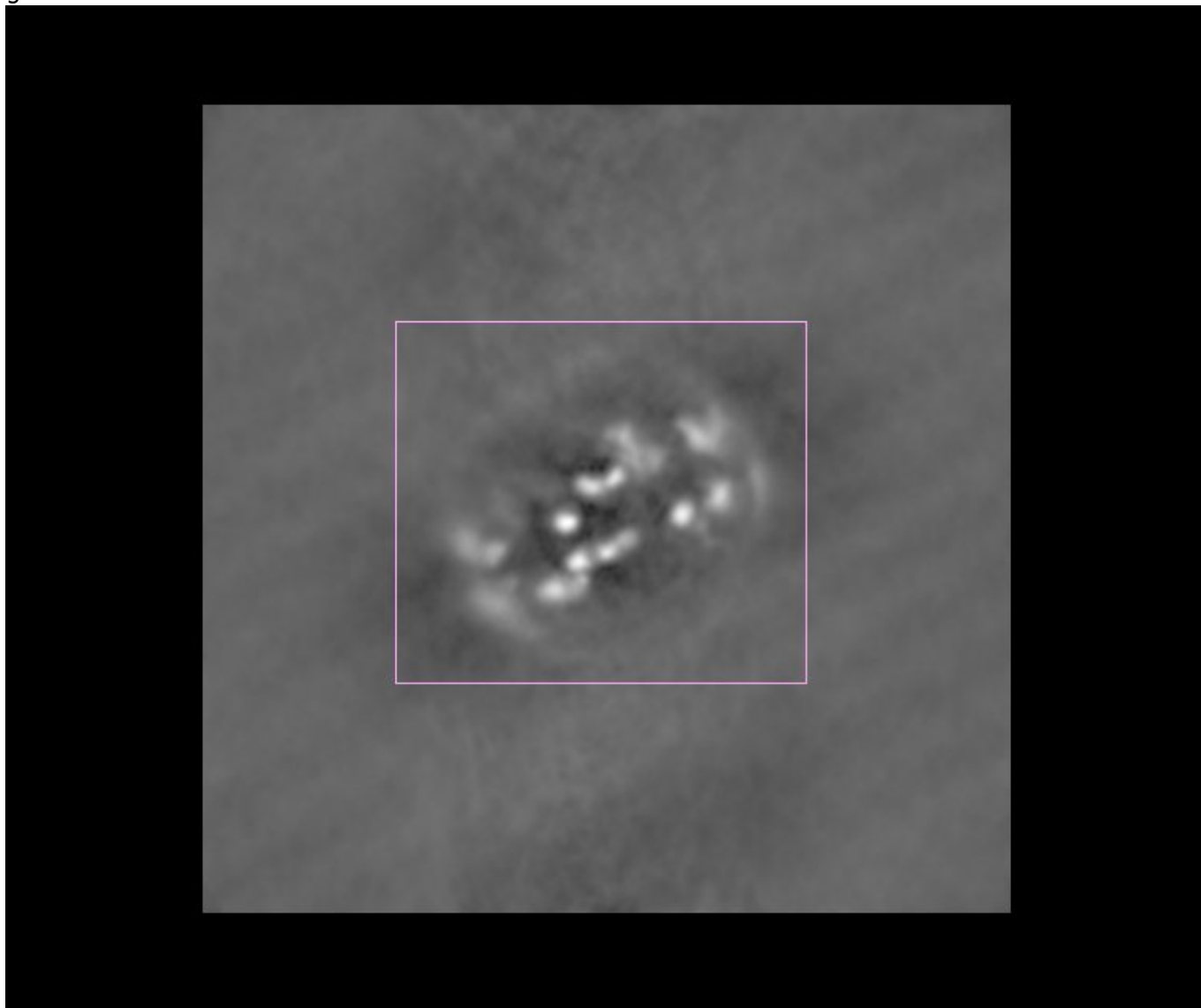
```
task 'snplt'
inext 'sn'
inver 1
stokes ' '
optype 'phas'
tvinit
go
```



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  
otype 'amp'  
go
```

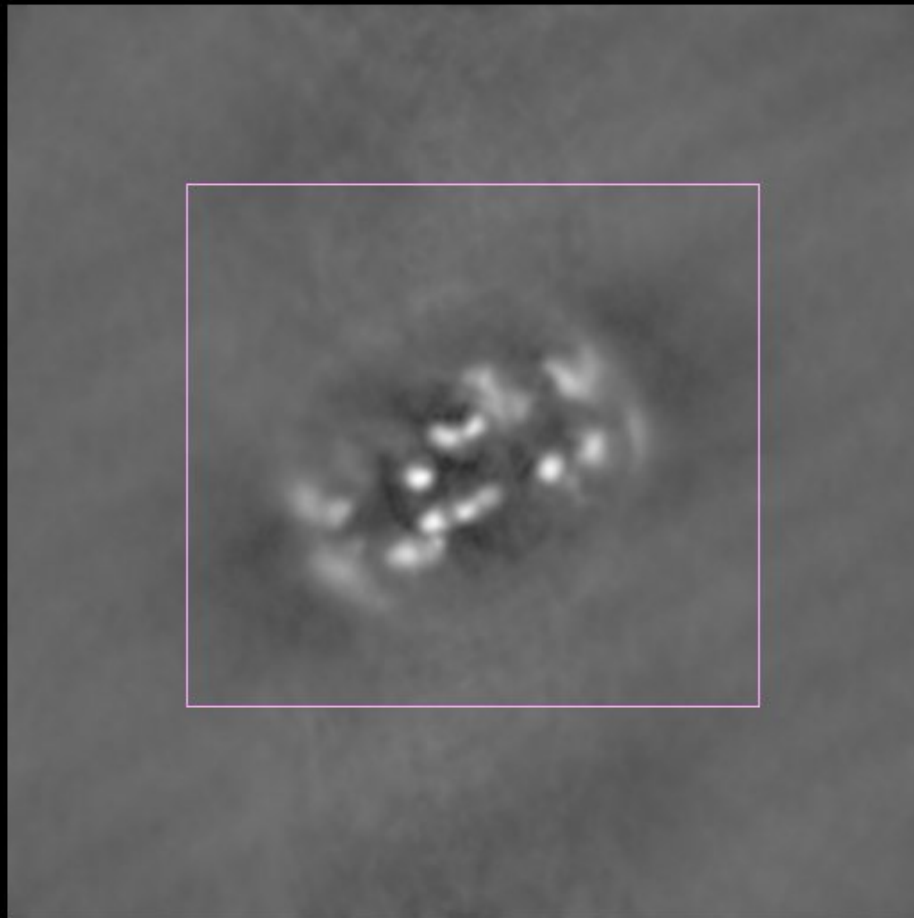
Cleanup

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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