

Starting Out With AIPS Tutorial

James M Anderson

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 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 = 'VLAI FS ' 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
```

```
v1b054    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)		

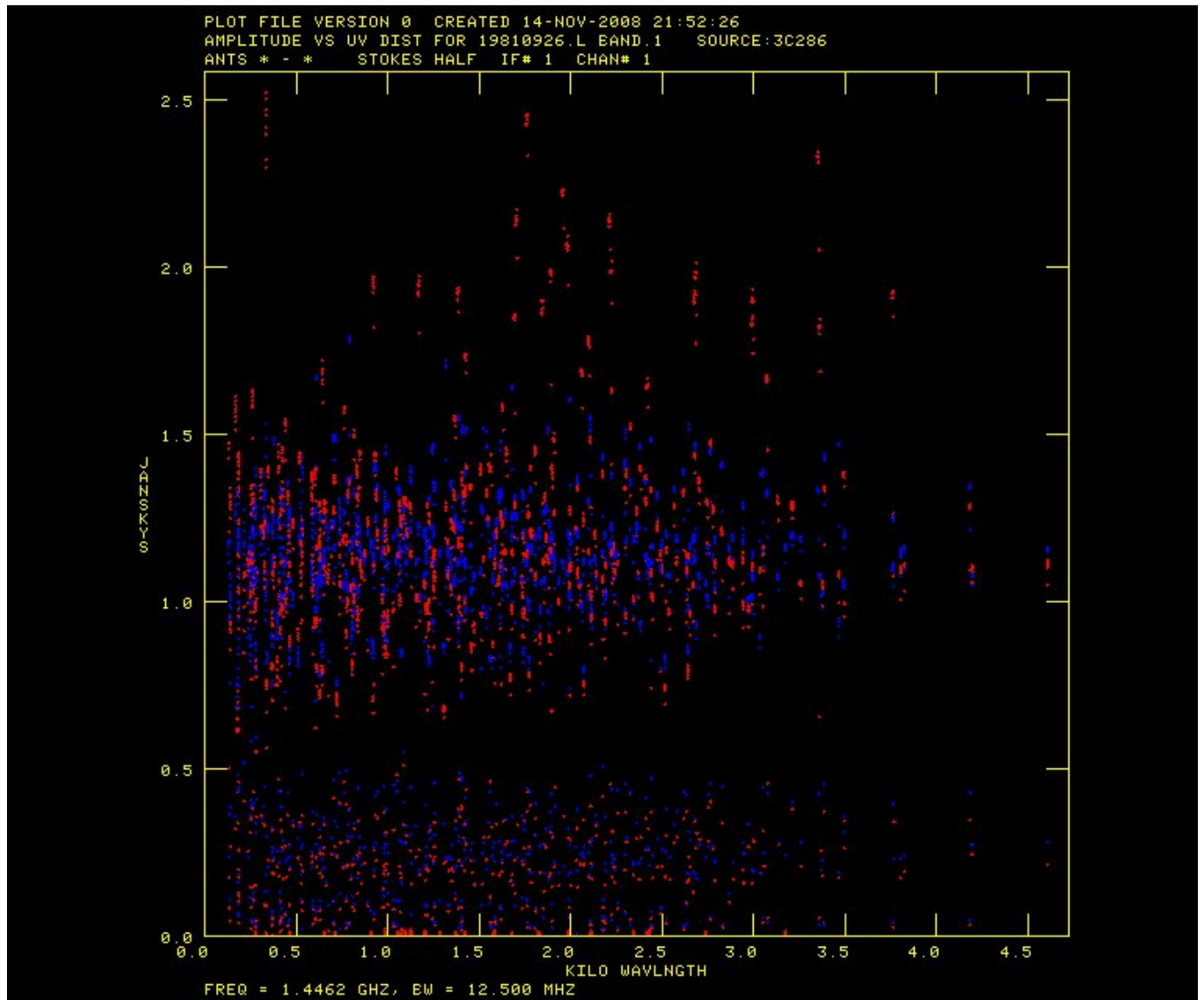
AIPS 1: Resumes

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.

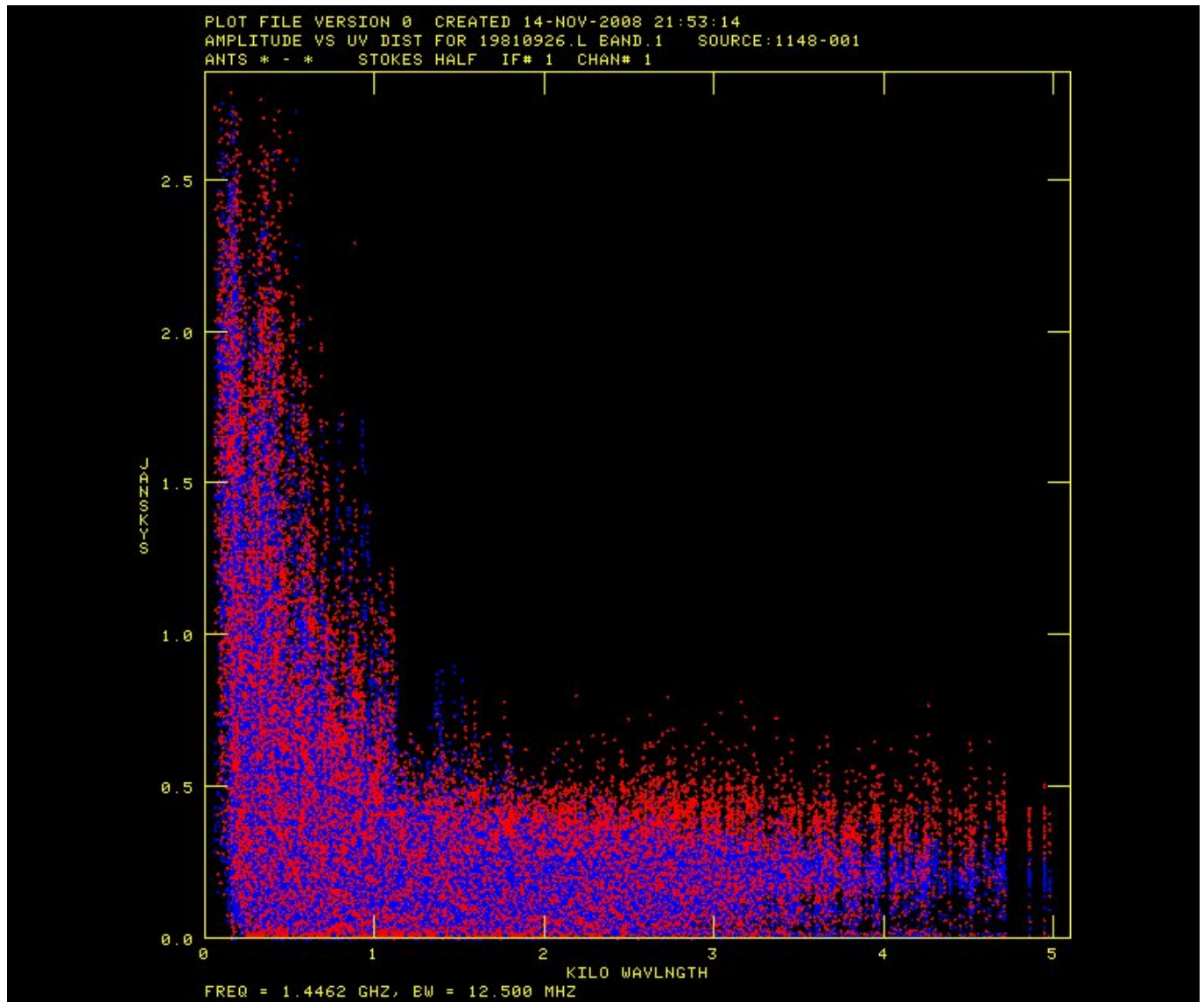
UVPLT

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
```

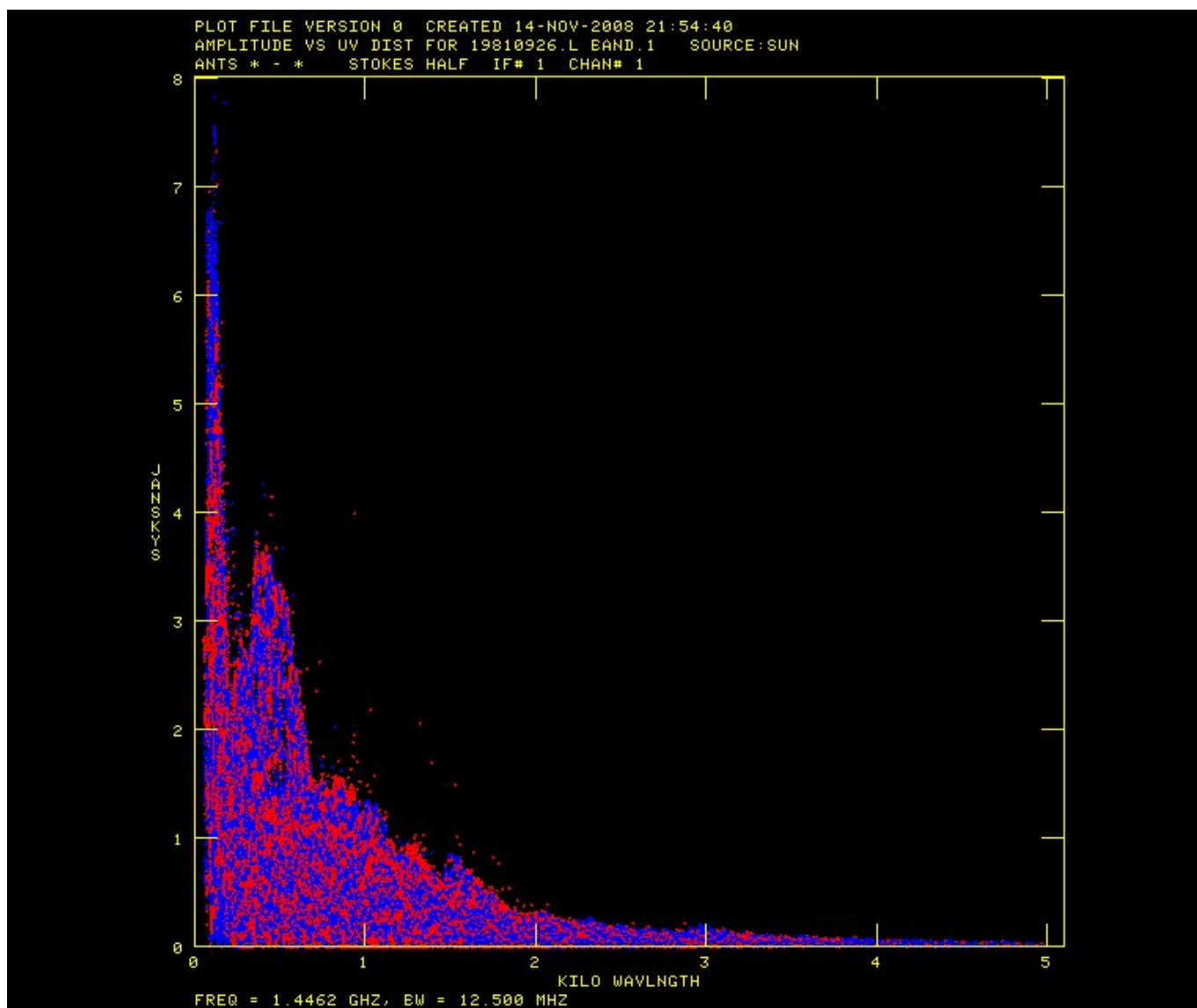


source '1148-001', ' '
go

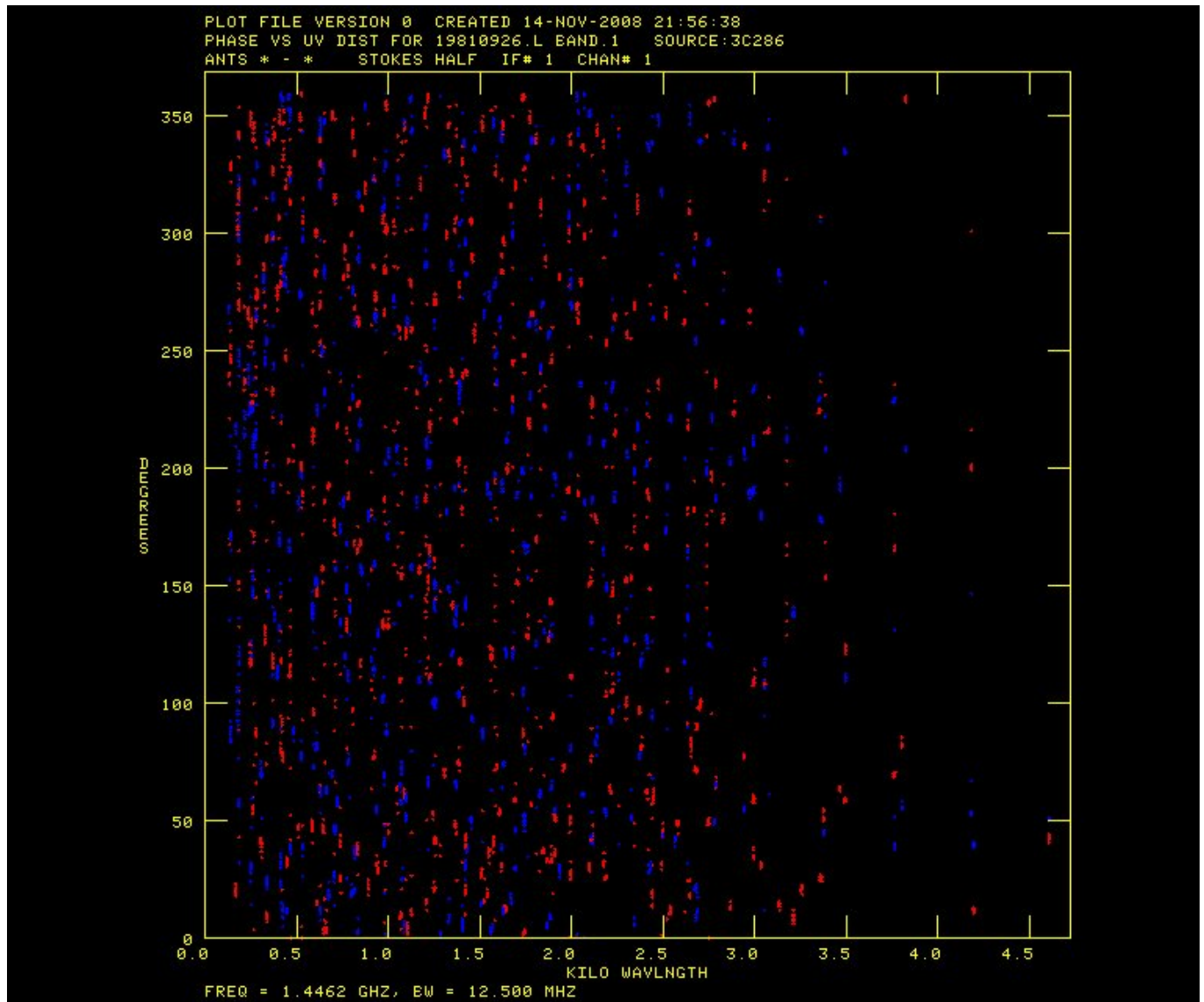


Warning: the next step will take a long time. You are free to skip this, and just look at the picture.

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

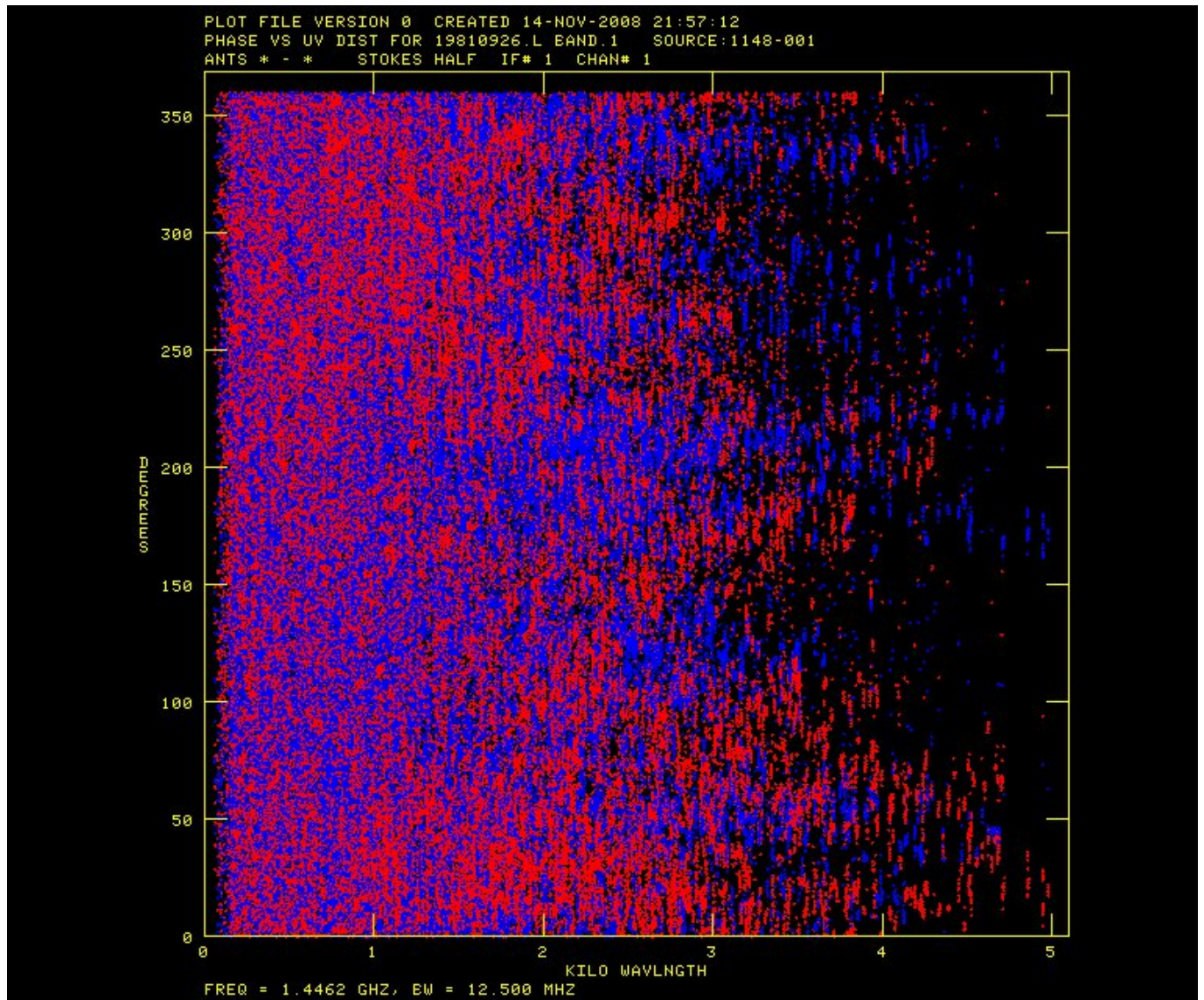


```
source '3c286', ' '  
bparm 0 2  
go
```

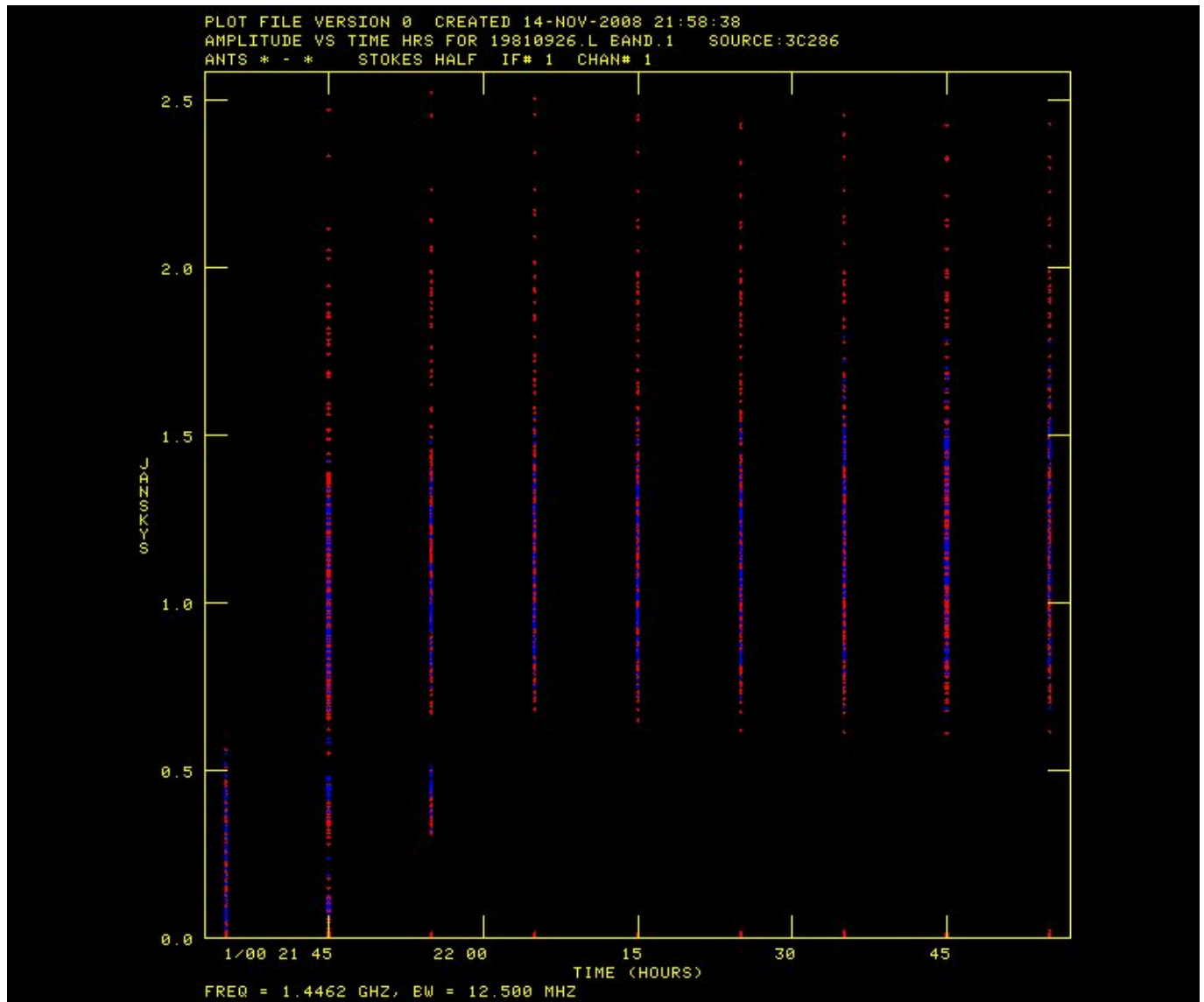


source '1148-001', ' '

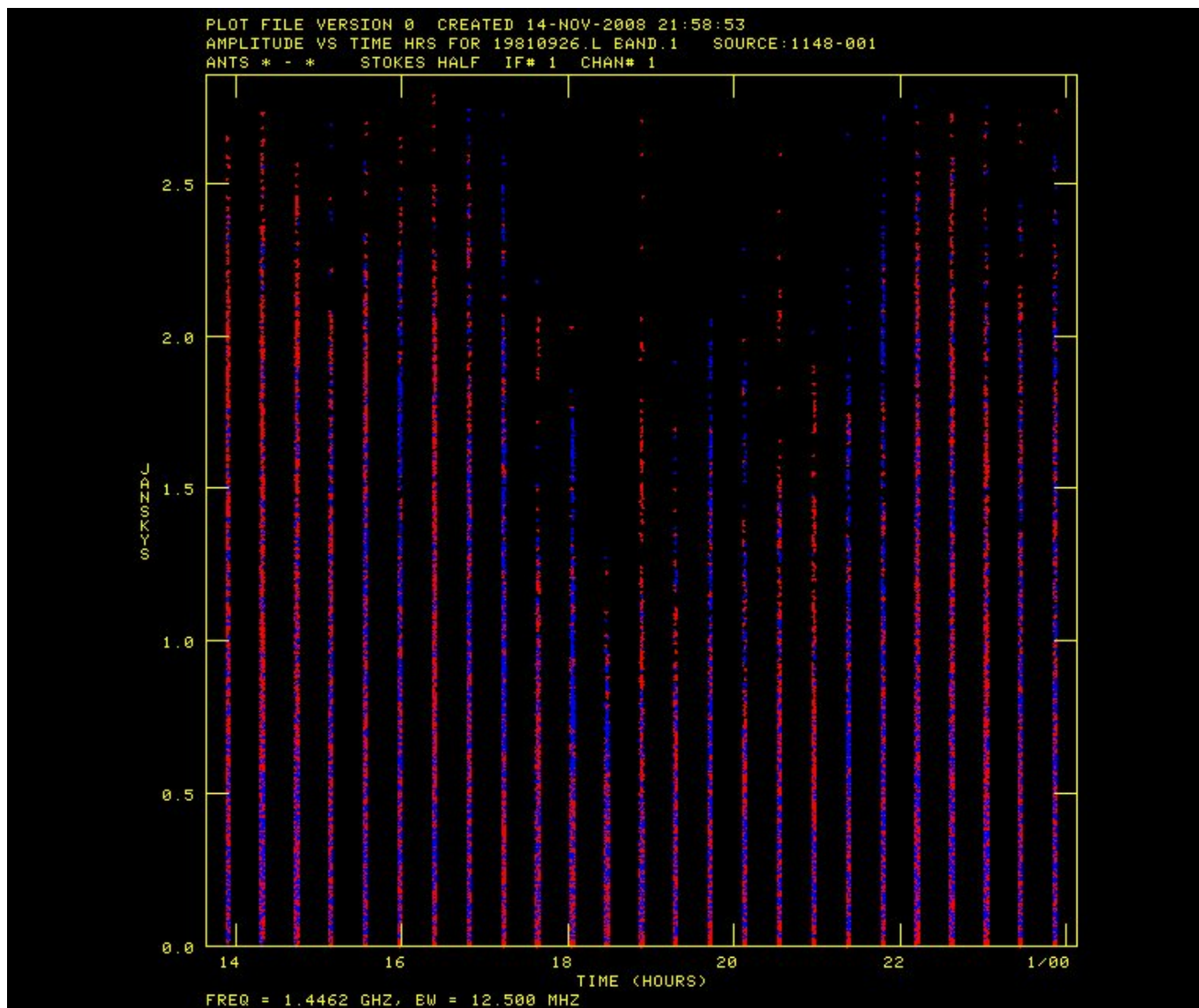
go



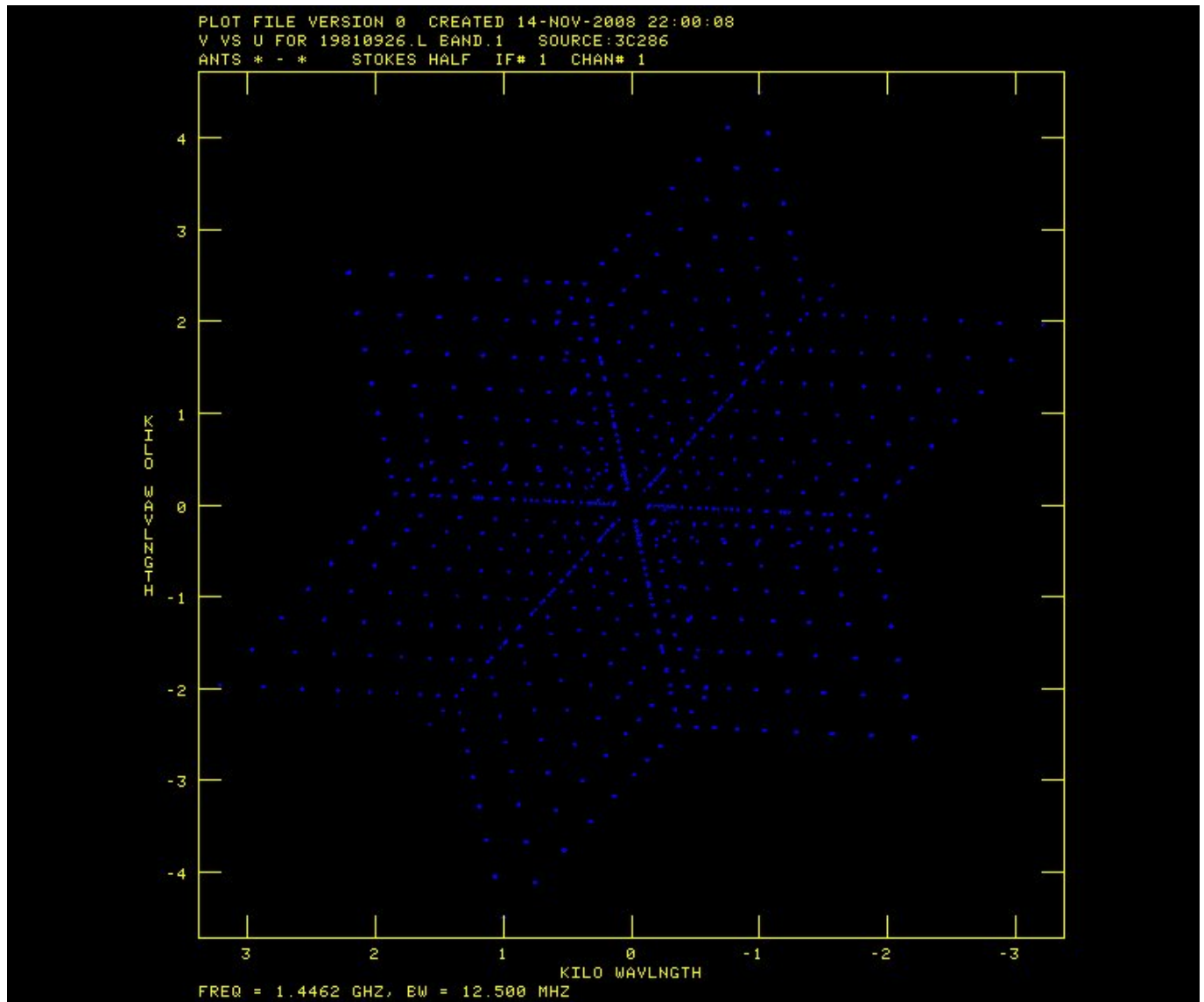
```
source '3c286', ' '  
bparm 11 1  
go
```



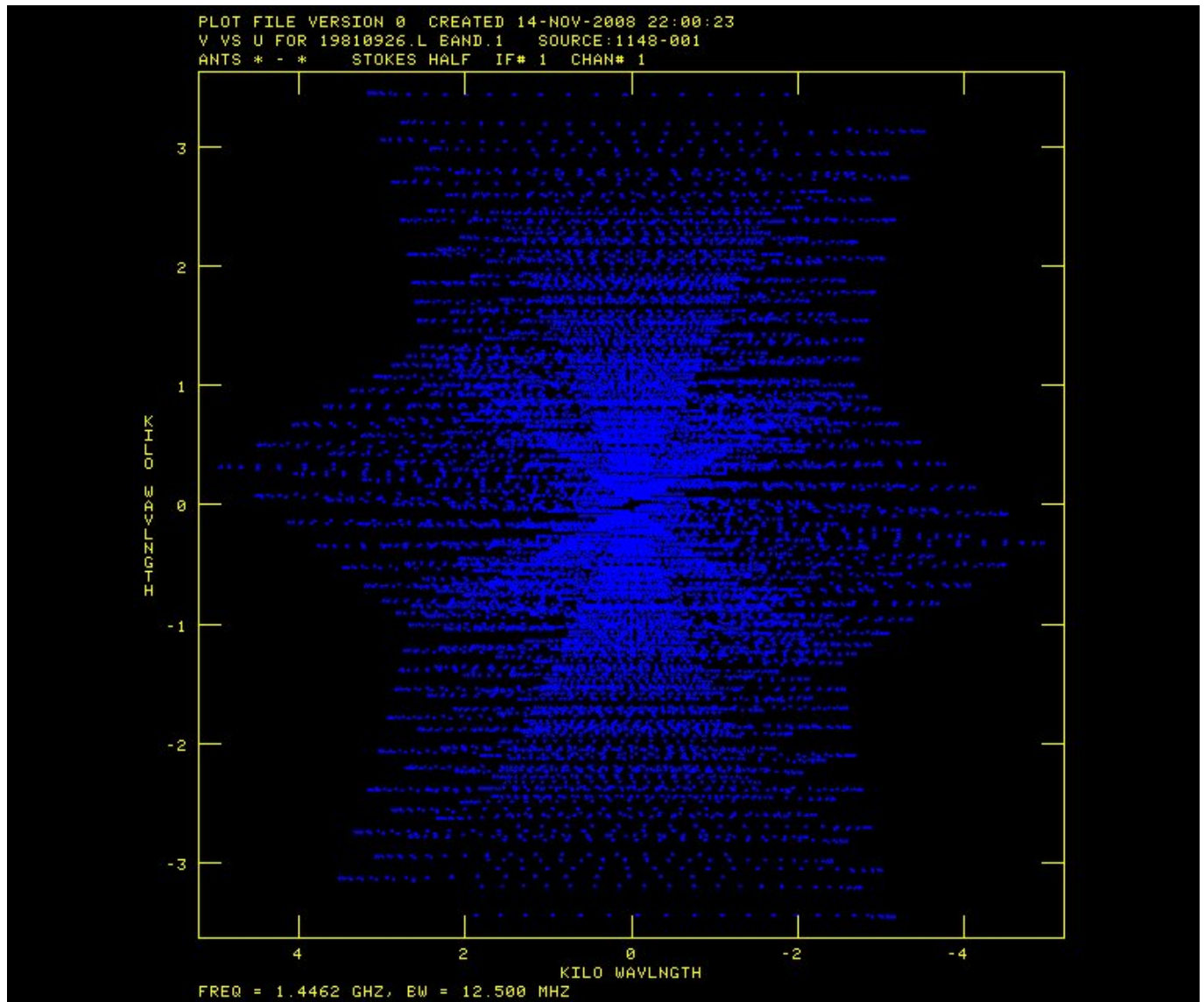
source '1148-001', ' '
 go



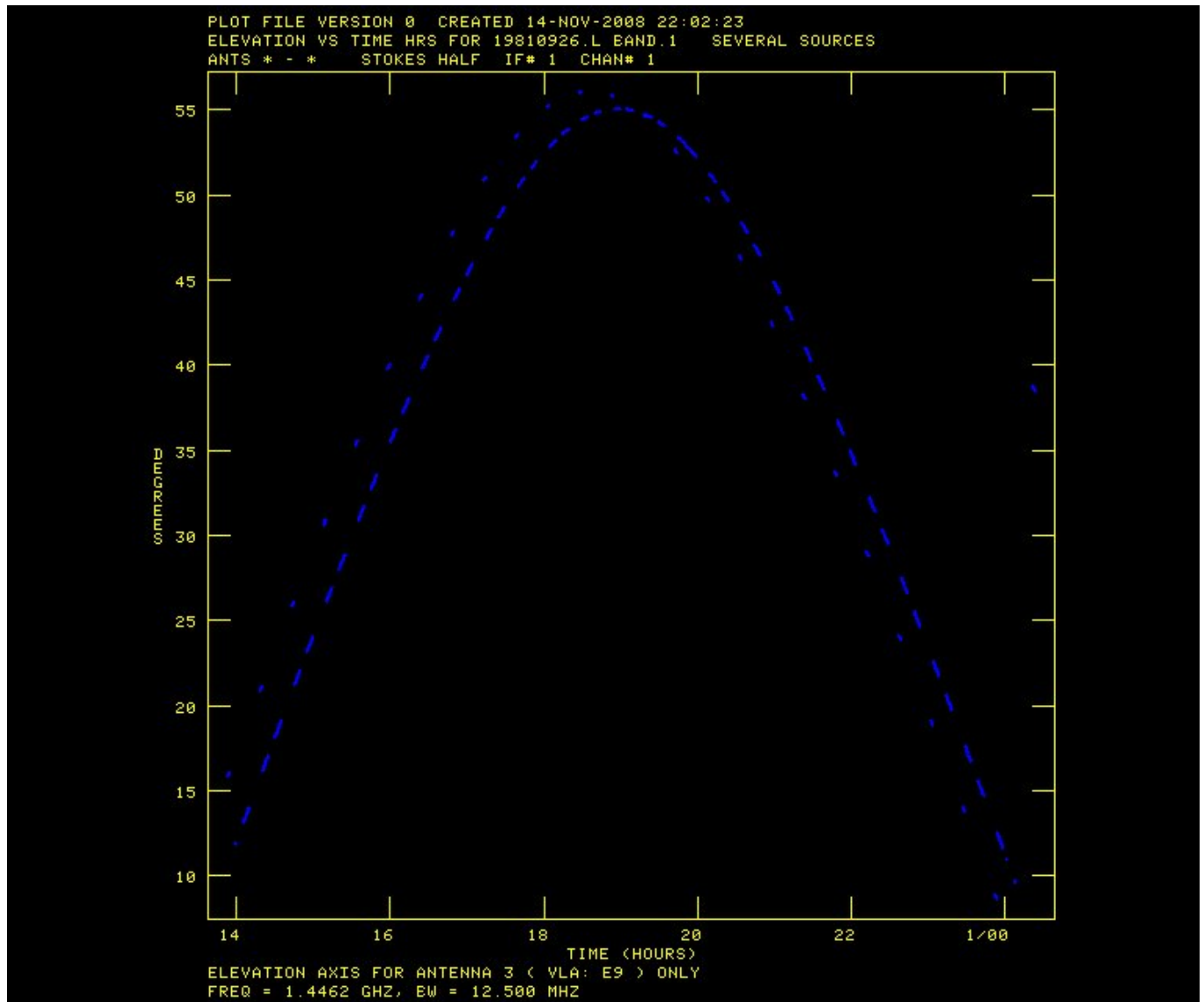
source '3c286', ' '
bparm 6 7
go



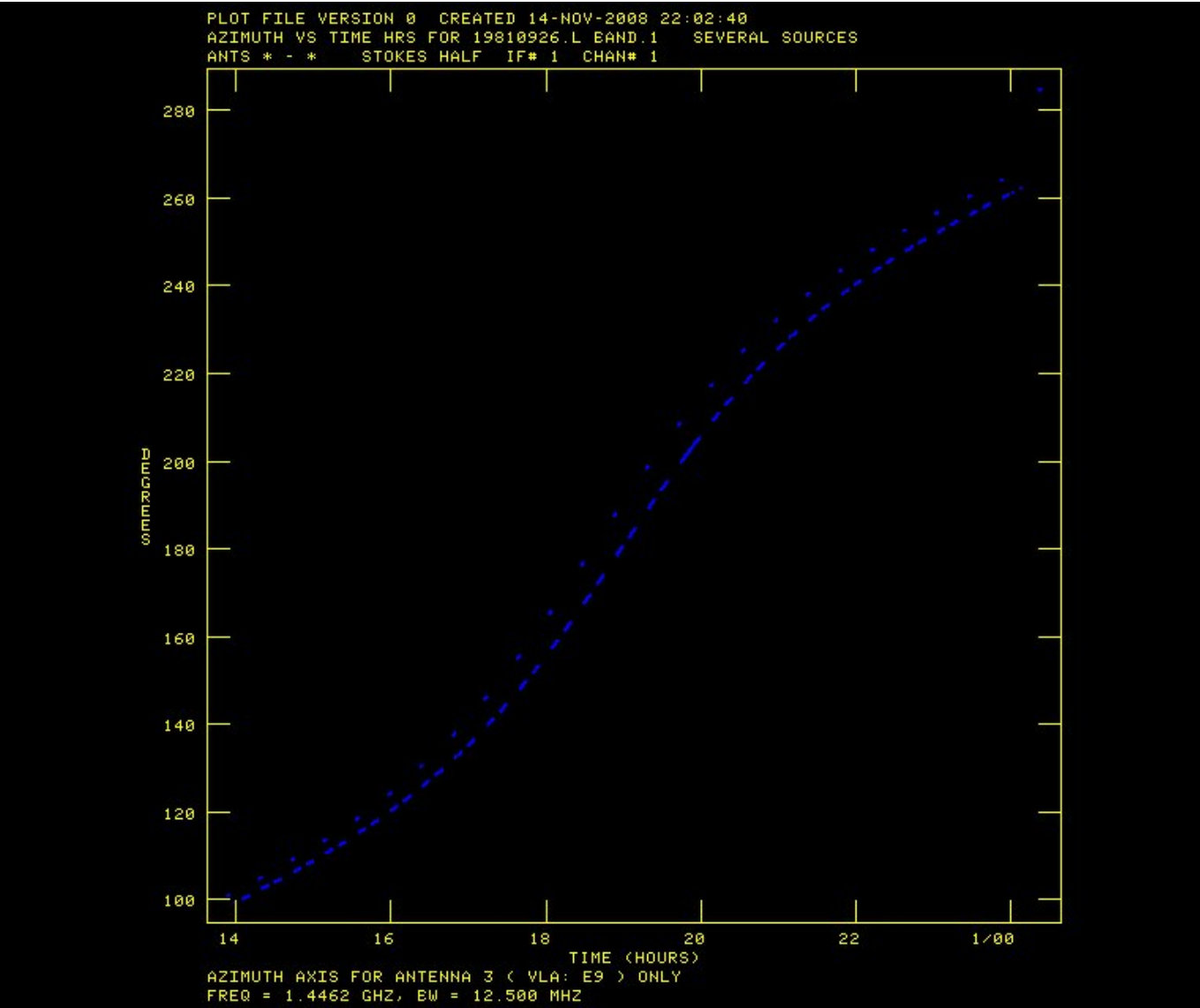
source '1148-001', ' '
 go



```
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

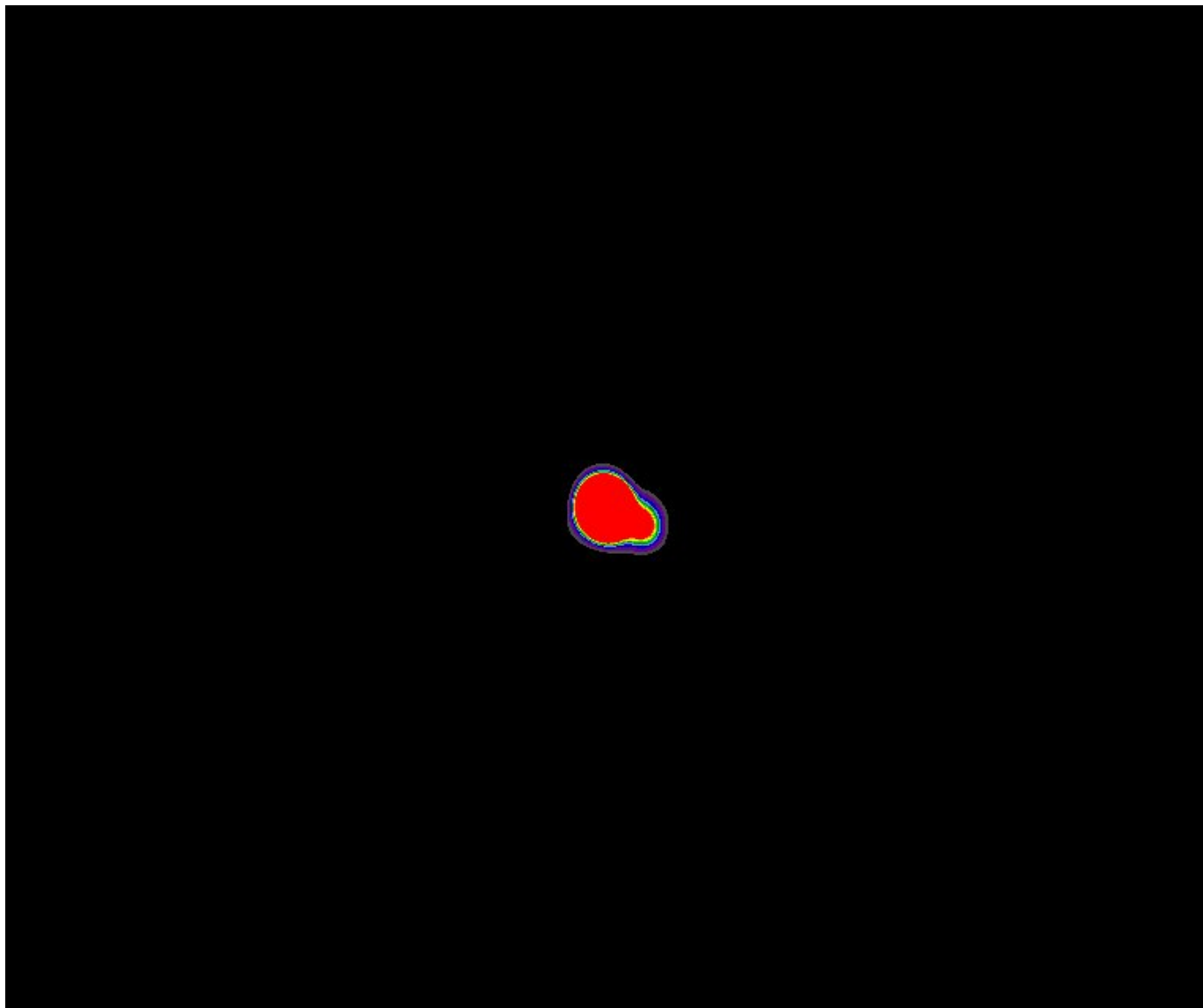
```
task 'calrd'  
object '3c286'  
band 'l'  
go
```

```
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

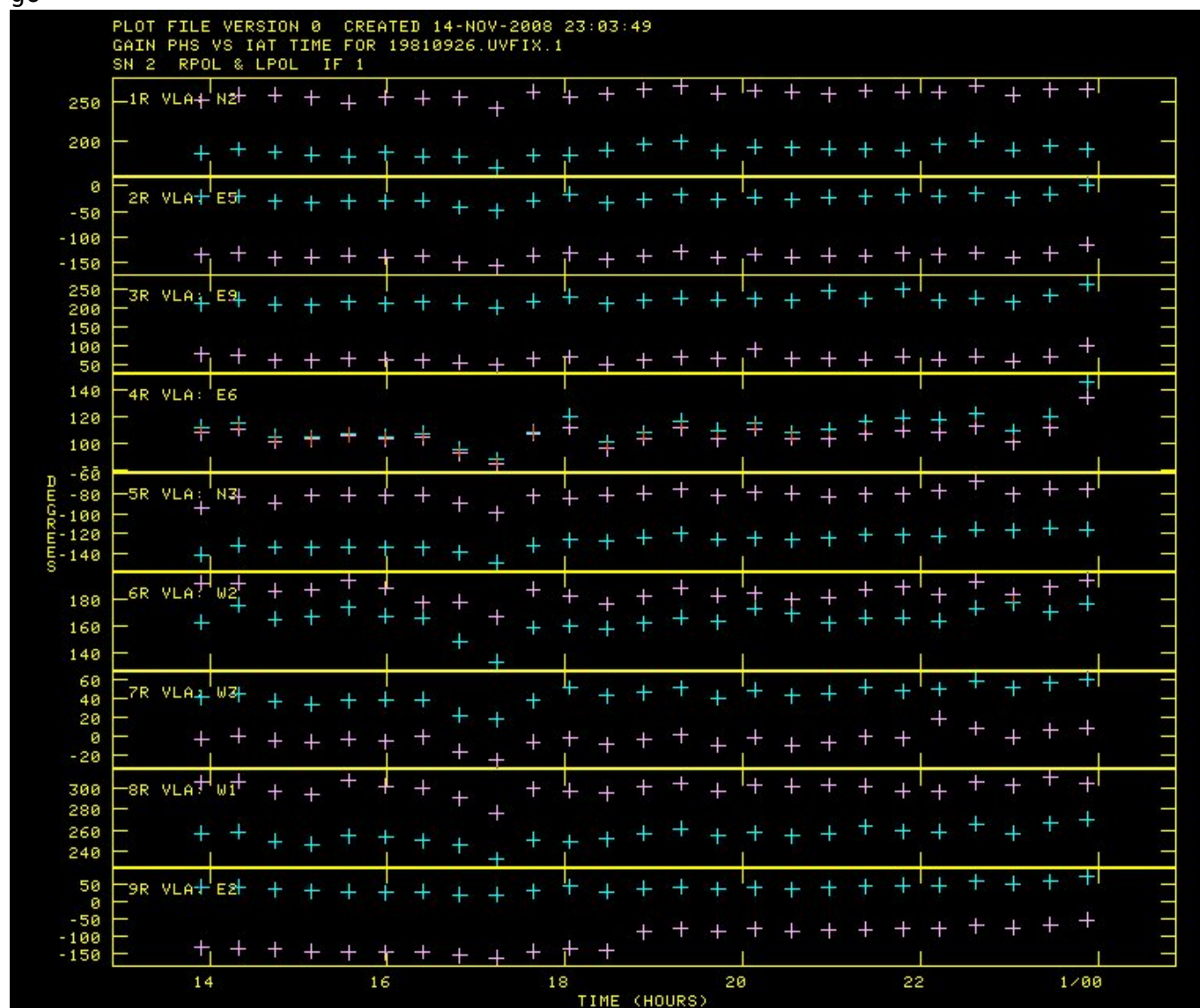
Look at the amplitude calibrator results.

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

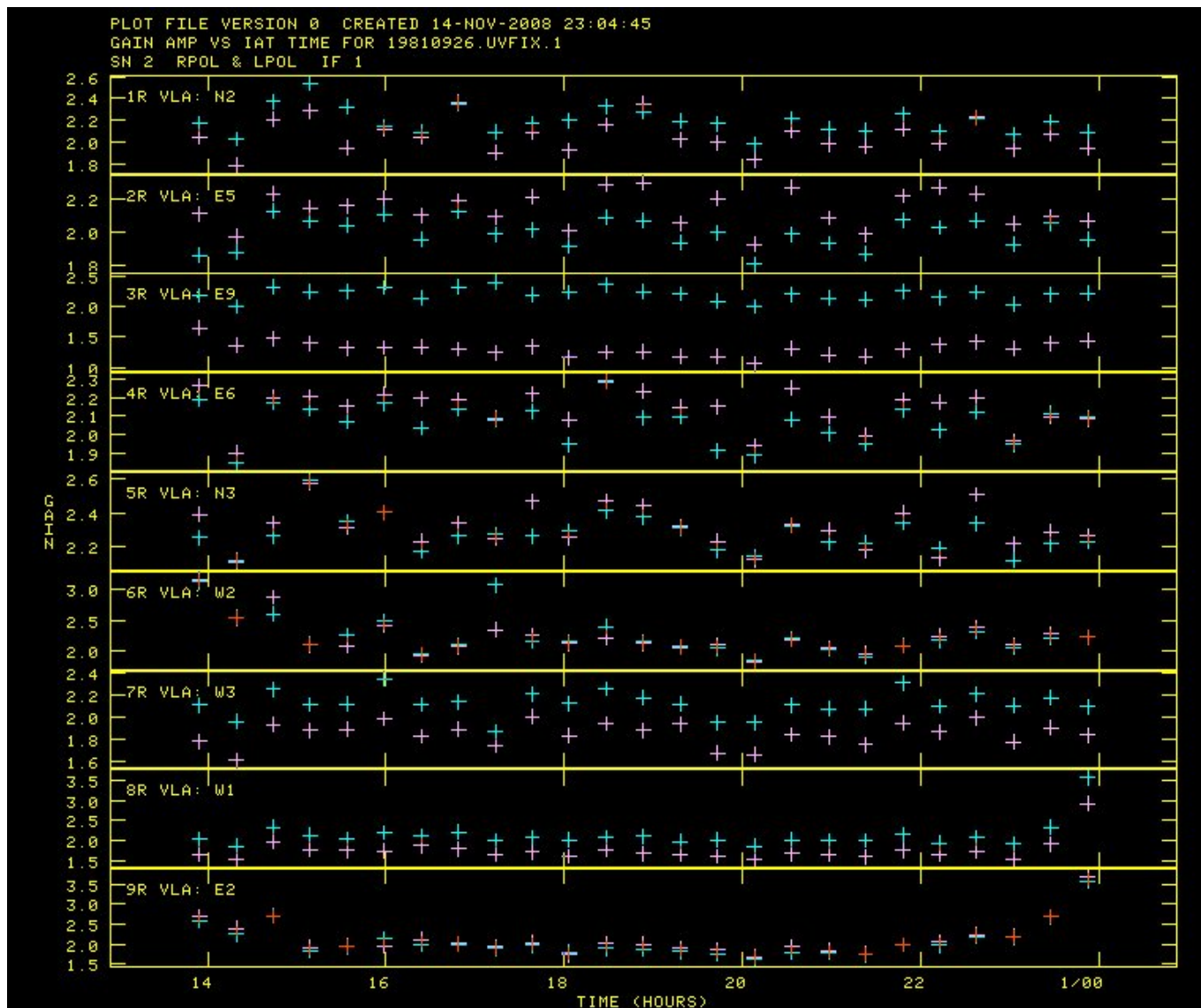
```
timer 0
tvinit
dotv 1
go
optype 'amp'
go
```

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

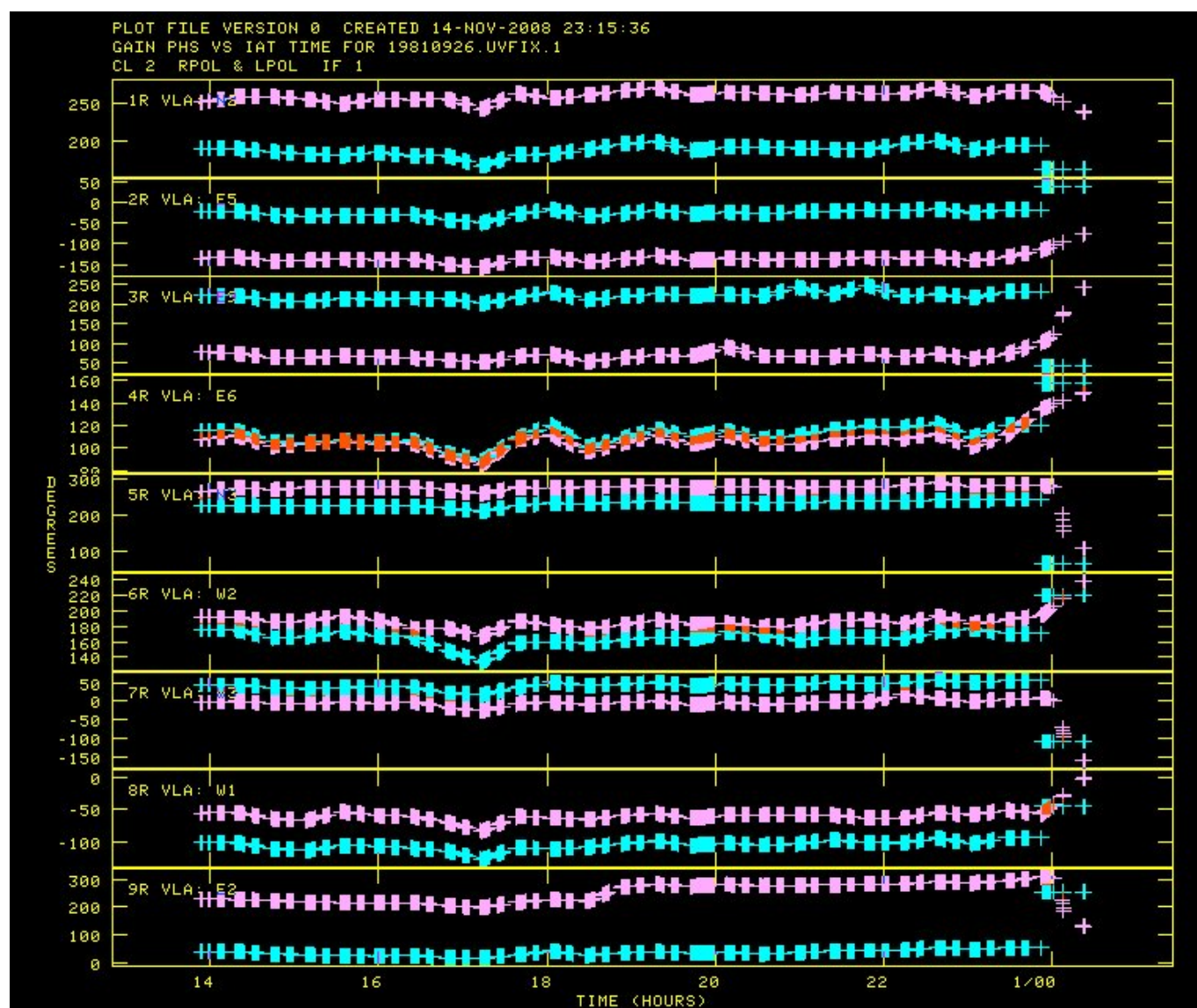
```
inext 'sn'
inver 2
extdest
tget calib
go
clrmsg
```

Apply the calibration to all sources, both amplitude and phase

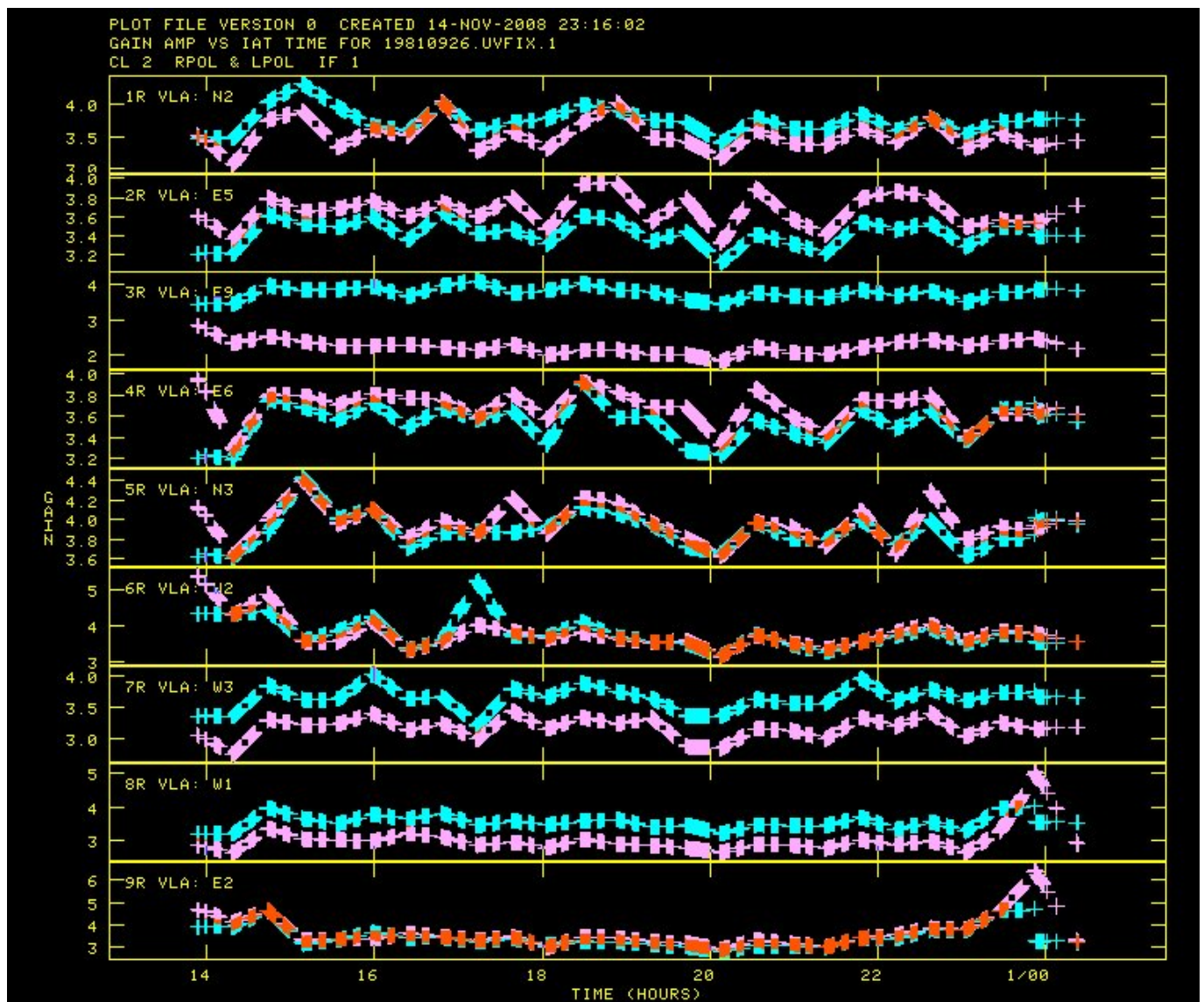
```
task 'clcal'
getn 3
sources ' '
calsour '3c286','1148-001',' '
calcode ' '
opcode 'cali'
gainver 1
gainuse 2
refant 24
bparm 0
interpol '2pt'
timer 0
antenna 0
doblank 1
go
```

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

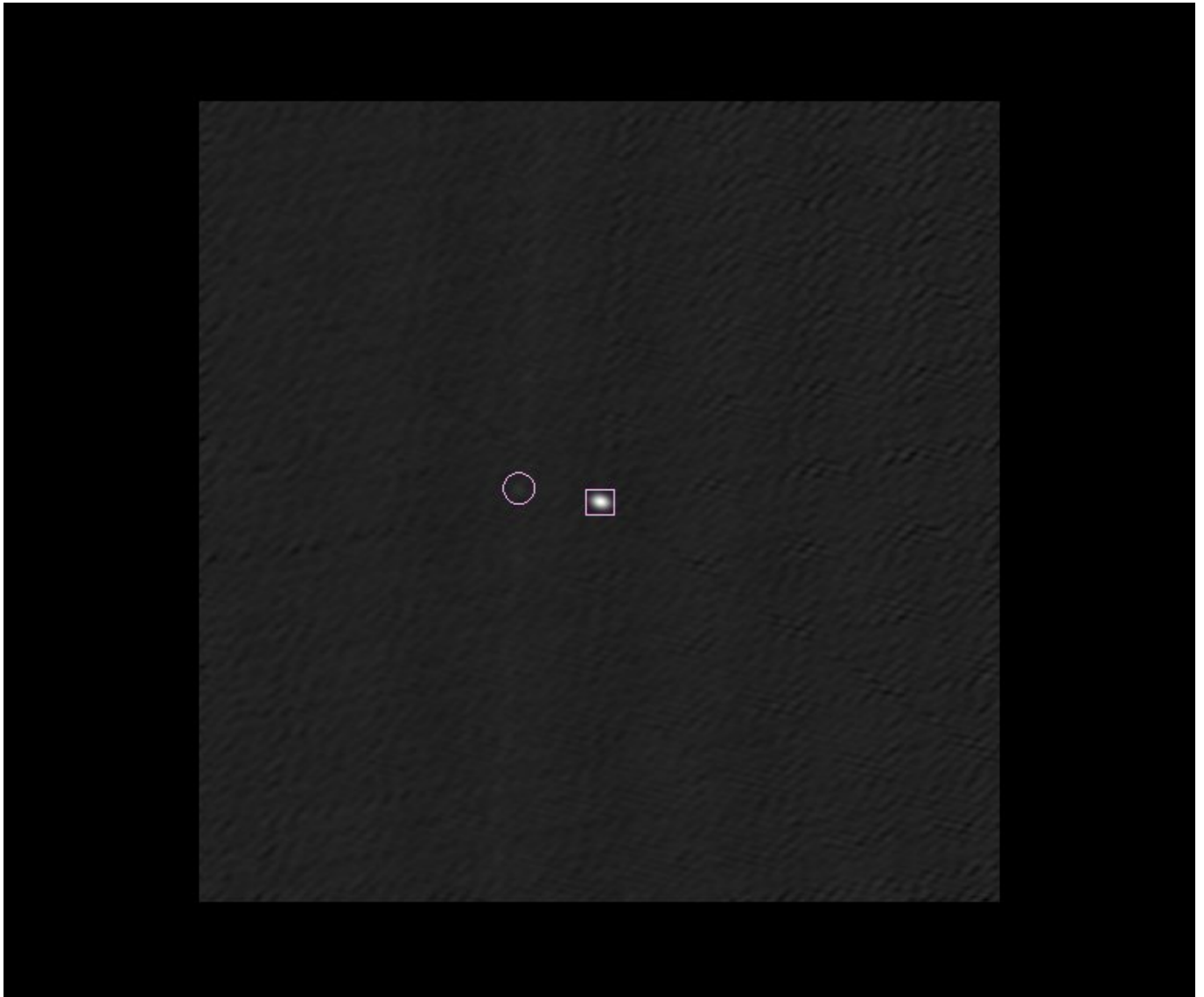
Amplitude Calibrator

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
```

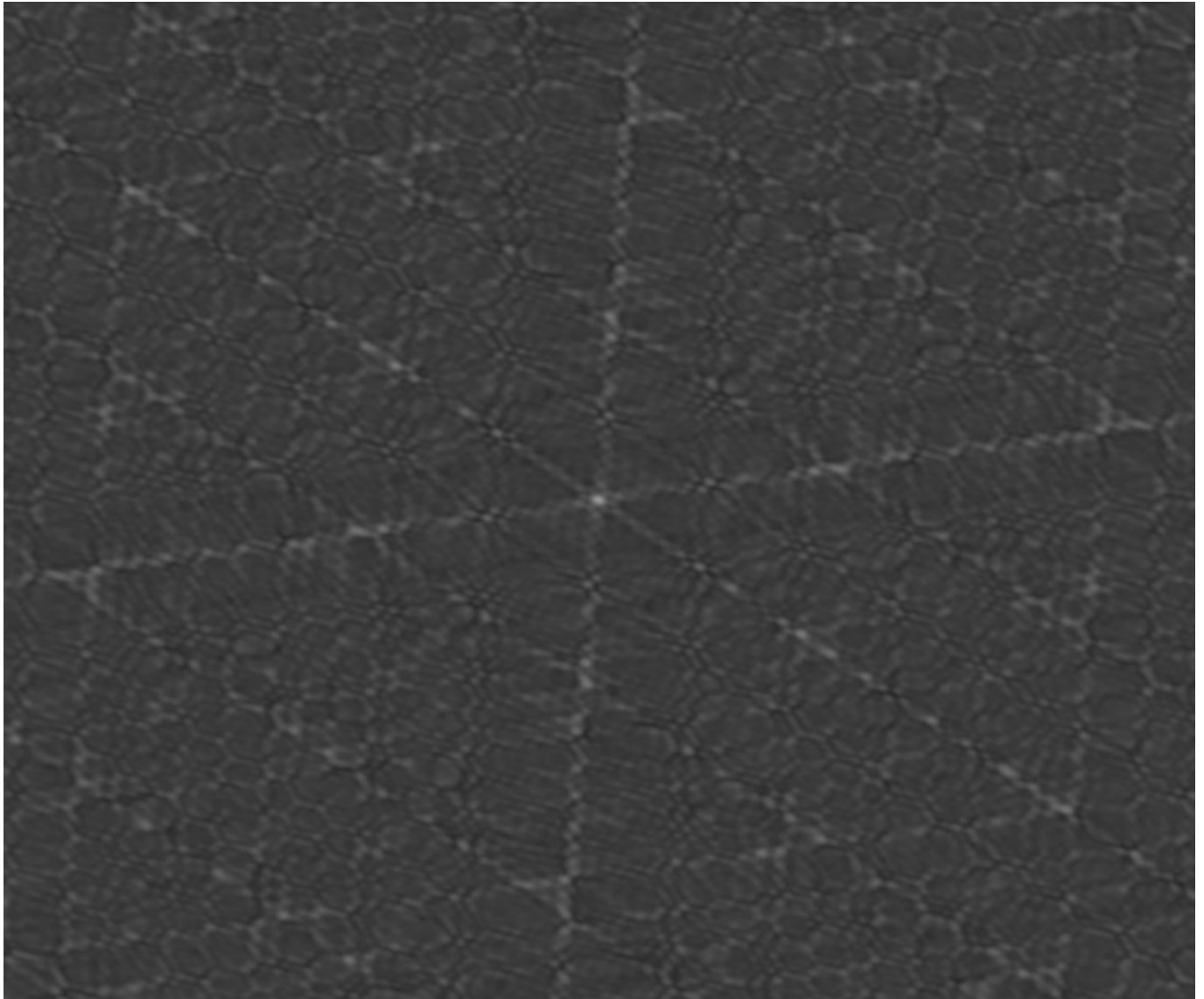
```
antenna 0  
niter 10000  
overlap 1  
D03DIMAG 1  
rashift 1800.00,0  
decshift -920.00,0  
go  
clrmsg
```

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
```



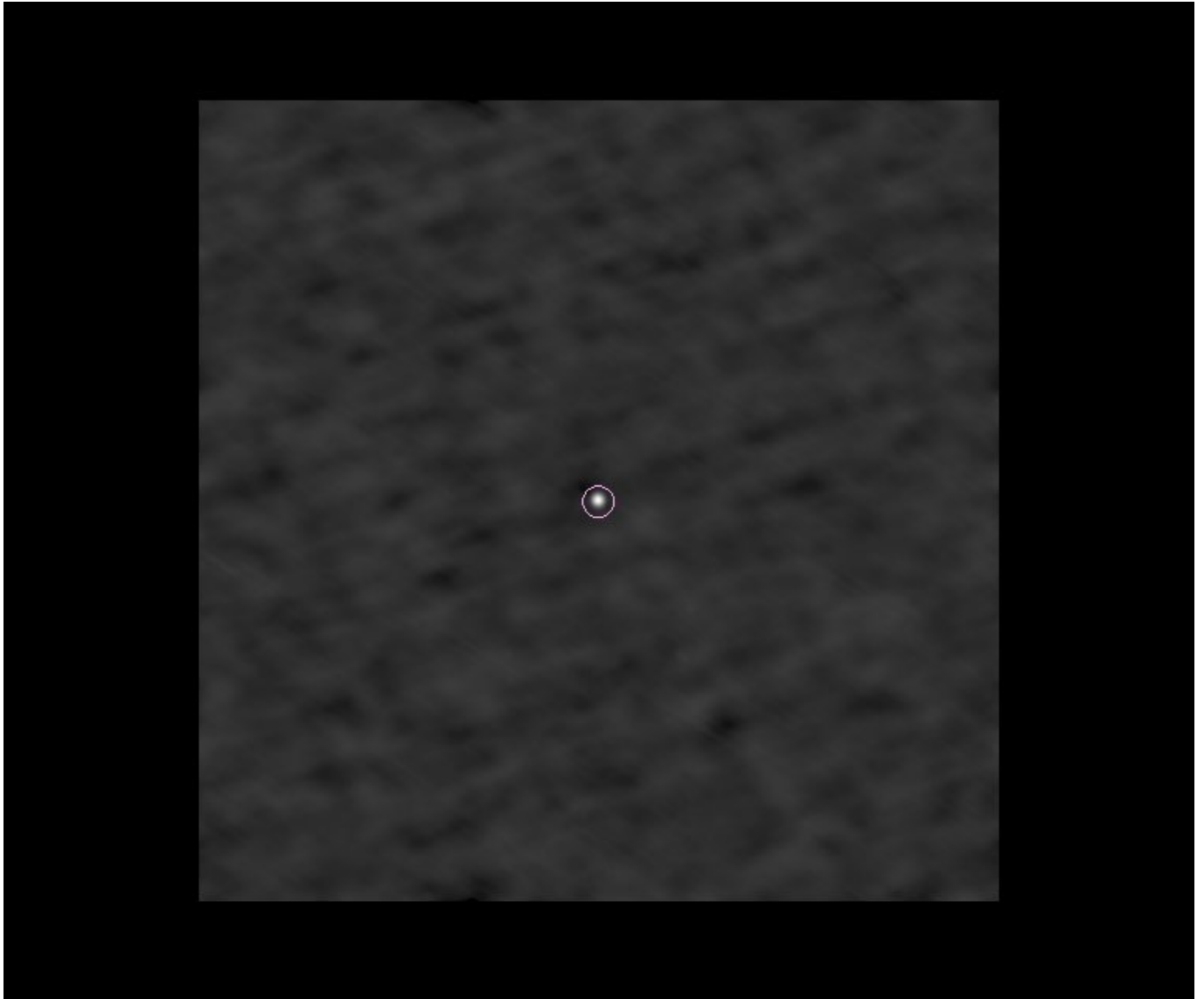
Phase Calibrator

Ok, clean up after ourselves

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

Now do the imaging and light cleaning

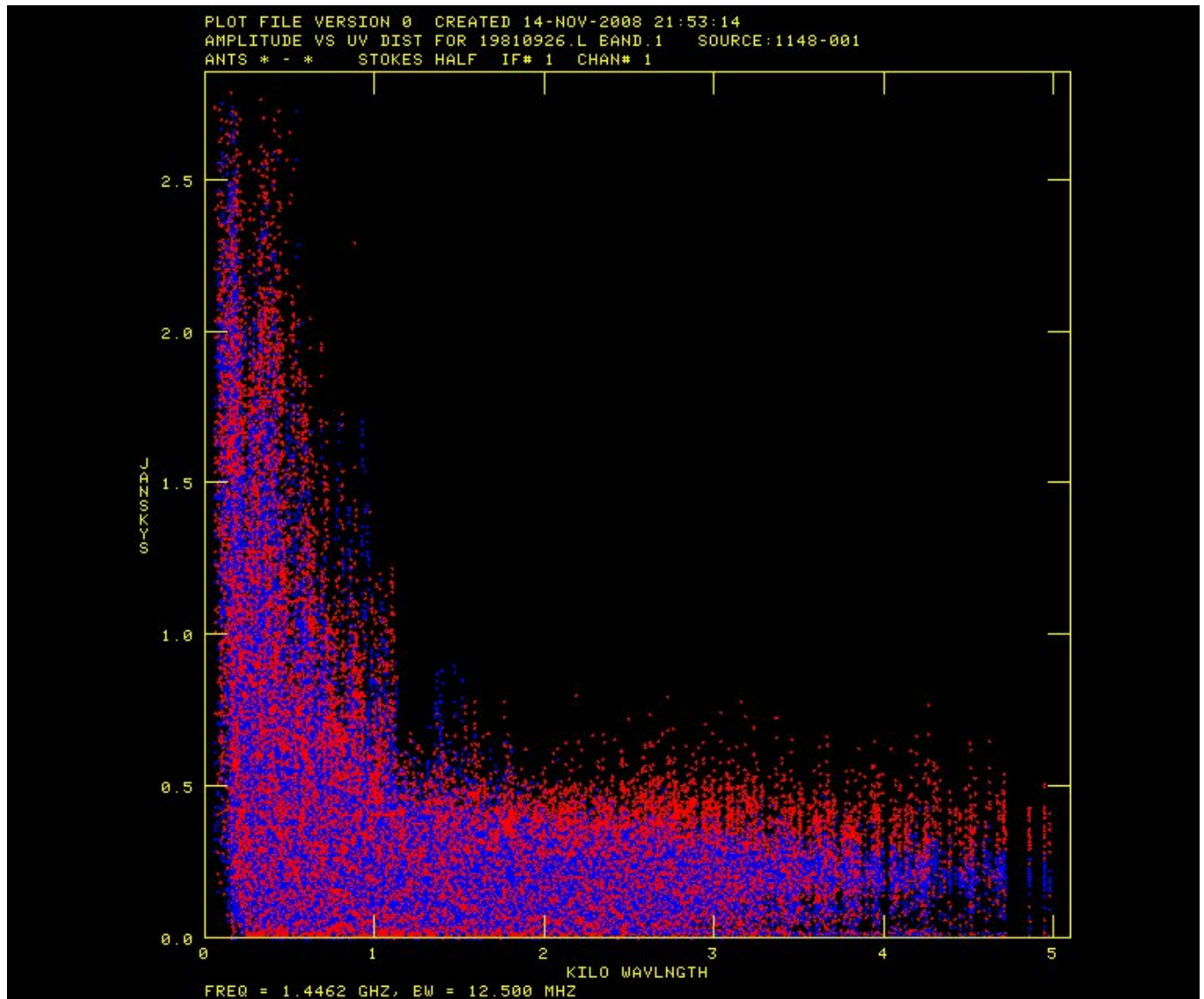
```
tget imagr  
source '1148-001',' '  
rashift 0  
decshift 0  
go
```



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 ' '
```

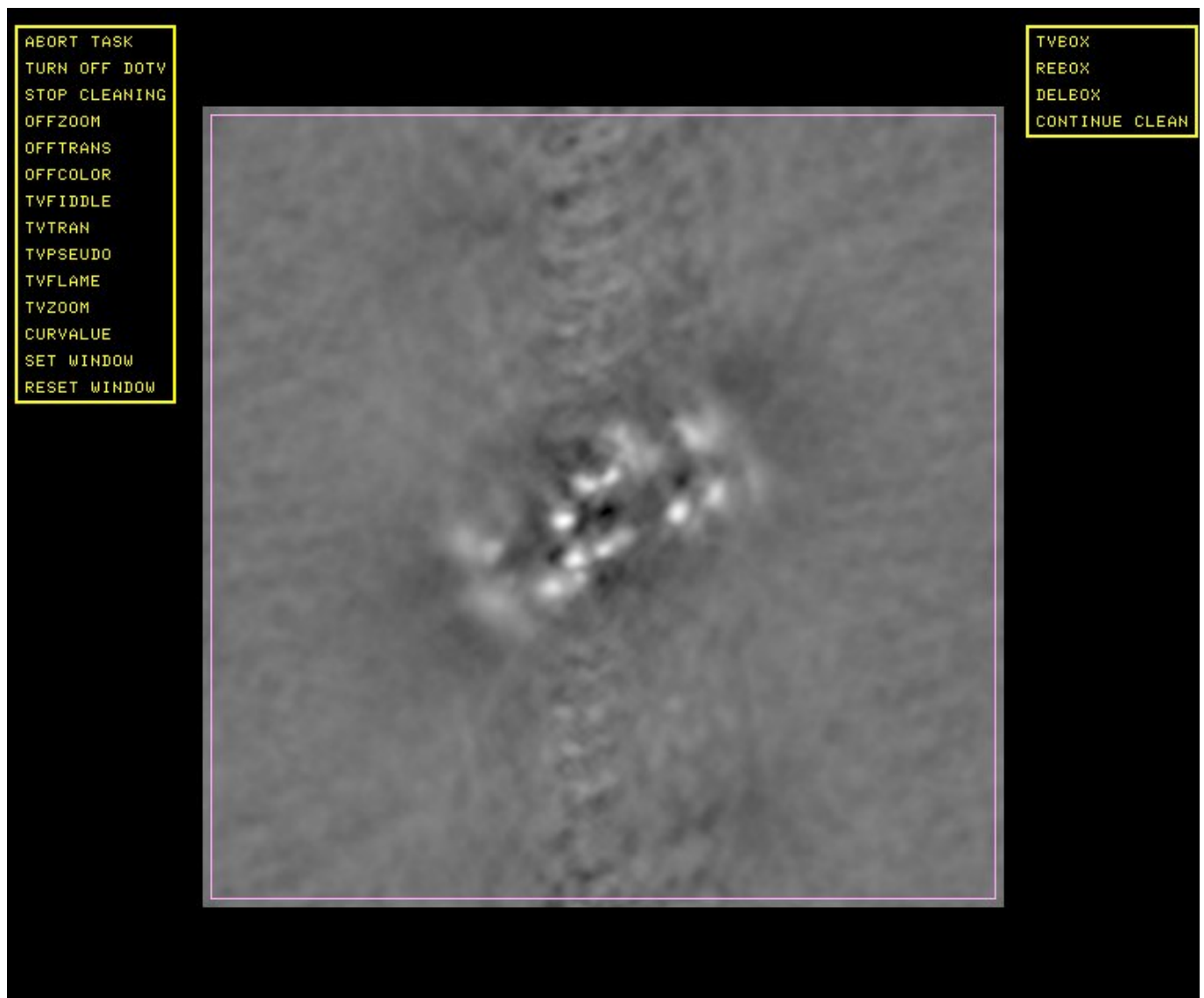
```
aparm 0  
go
```

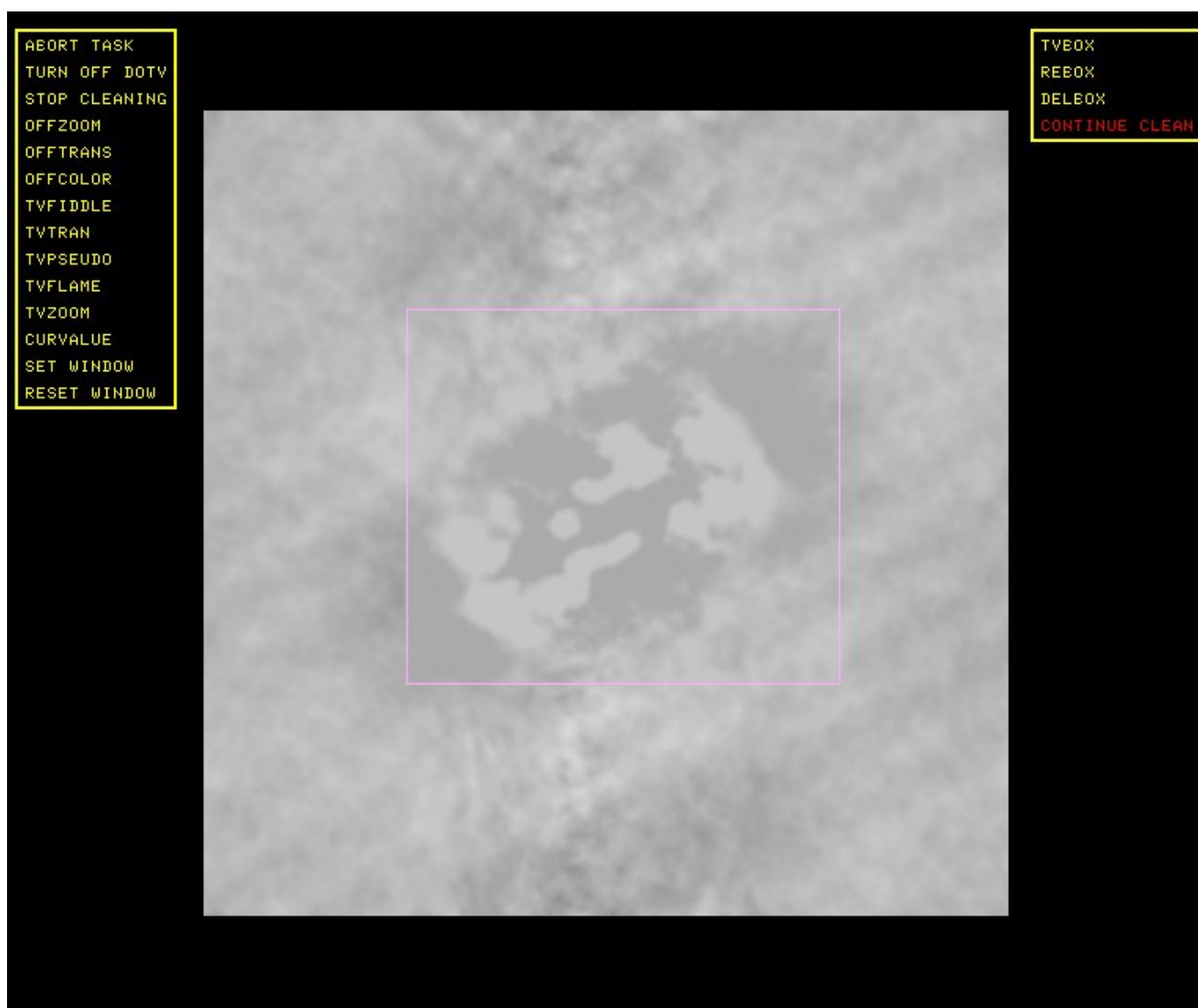
IMAGR

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.

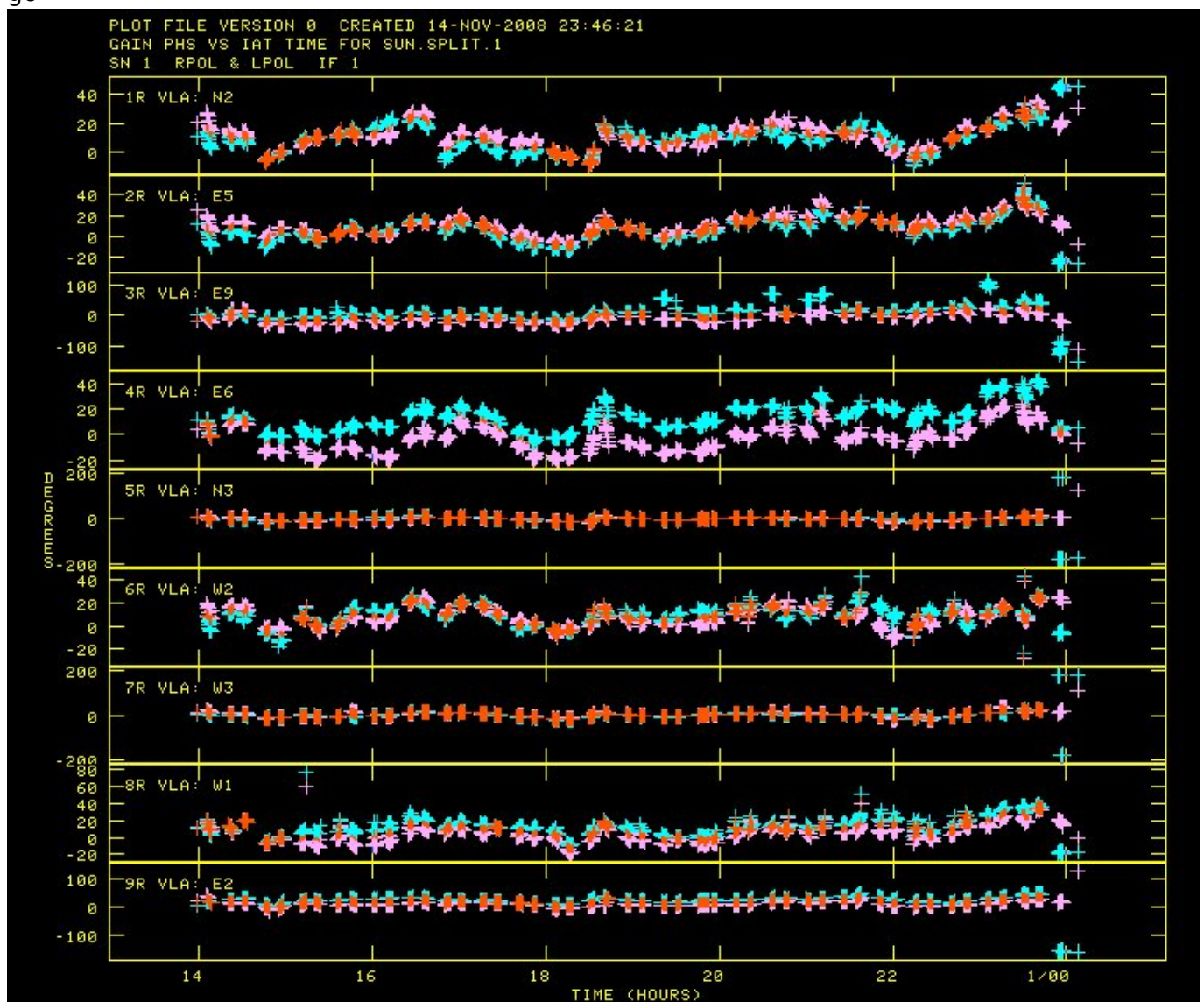
We run exactly the same calibration software, in exactly the same manner. Because the phase calibrator was resolved at short spacings, and because it is quite difficult for us to clean the extended emission, I limit the (u,v) coverage. Note that this also is only doing phase calibration, not amplitude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

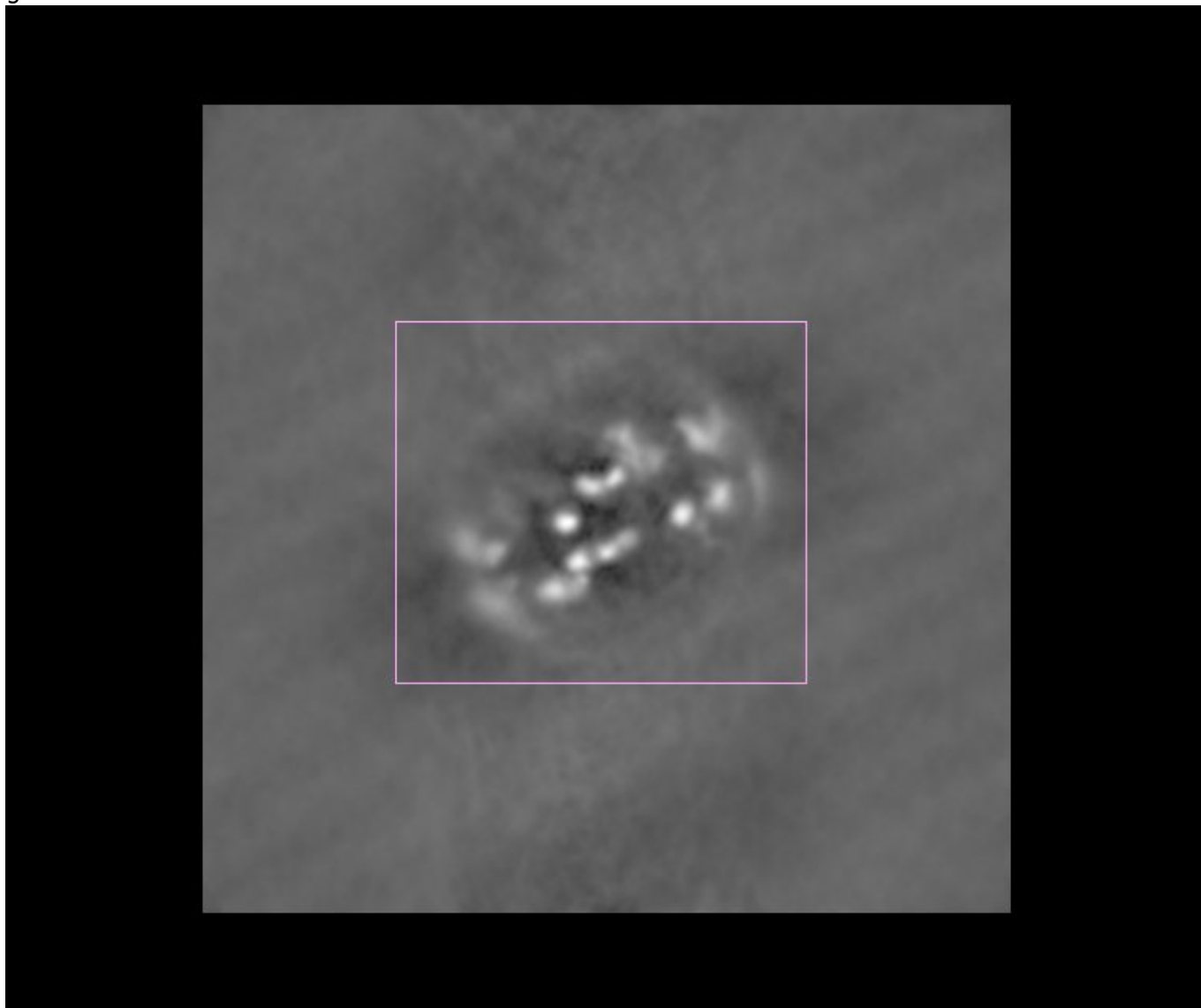
```
task 'snplt'
inext 'sn'
inver 1
stokes ' '
optype 'phas'
tvinit
go
```



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  
optype 'amp'  
go
```

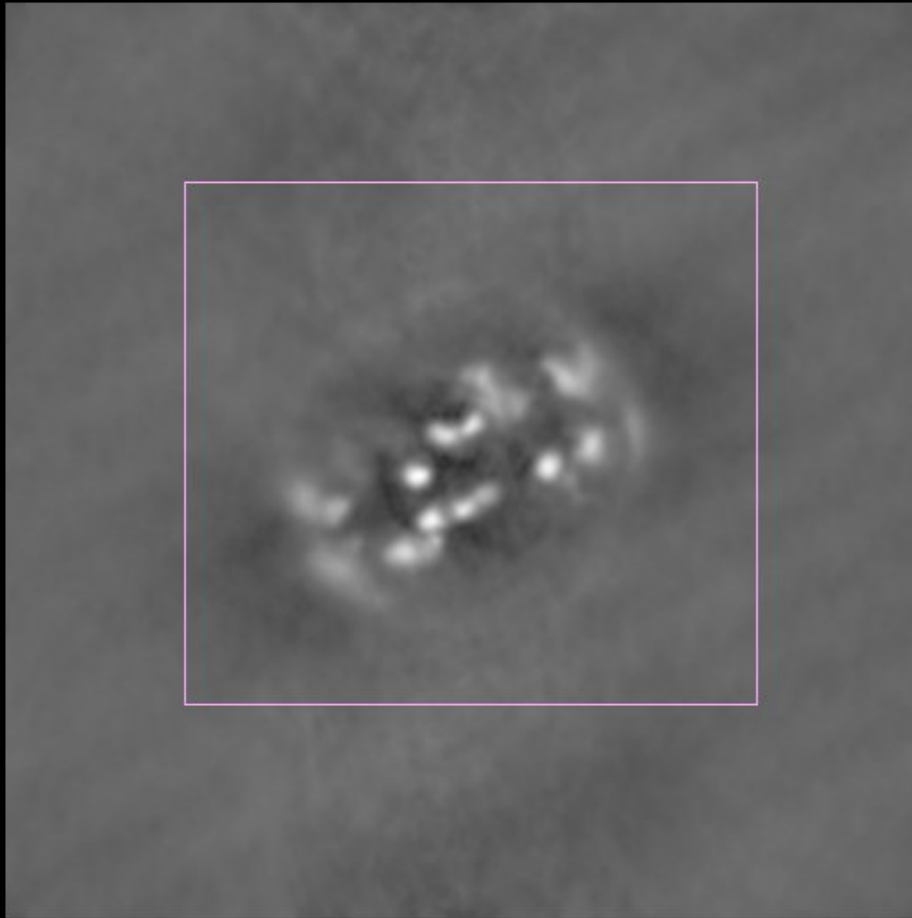
Cleanup

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?

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