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.

Step 4 --- Initial look at data

FILLM

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

```
dowait=true
dohist=1
docrt=132
dotv=1
task 'fillm'
default
datain = 'PWD:GD_
nfiles=0
ncount=2
vlamode='S '
doweight=10
doconcat=true
douvcomp=0
cparm(2)=16
cparm(4)=28
cparm(8)=10./60
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 2
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

```
default listr
task 'listr'
indi 1
getn 2
optype 'scan'
docrt=132
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.

SETJY

```
task 'setjy'
```

```
source '3c286',' '
optype 'calc'
aparm(2)=3
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    5
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 5.

CALIB

```
task 'calib'
getn 2
calsour '3c286',' '
uvrange 0
antennas 0
refant 24
weightit 1
in2di 1
get2n 5
ncomp 0
solmode 'A&P'
aparm(6) 2
minamper 10
```

```
minphser 10
docalib 1
solint 1
solsub 2
cparm(3) 10
cparm(4) 10
```