Does practical calibration scare you?

(Not to mention the theory of calibration.....)

Daniele Dallacasa et al.

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Disclaimer(s):

1. In order to minimize impact on natural resources, please to not print this document
2. This document is going to be revised soon (only minor changes and a few additions); there are a couple of slides that will be added (for completeness, but will not be relevant for the actions during the tutorial); the final document is expected to be ready a few seconds before the tutorial starts (then consider 1.)
3. The level of this tutorial is very basic (many of you already familiar with interferometric data will be bored of many parts of it!)

AIPS Polarization images in a relatively small number of steps

What AIPS is in a page

Login in and then import your data

Exploration of the visibilities: IMH, PRTAN, PRTAB, LISTR, UVPLT, PRTUV, VPLOT,...

Is flagging needed? Then ... WIPER, TVFLG, SPFLG, FLGIT, UVFLG, ...

A-priori calibration:

Preamble (primary, secondary, SETJY)

Running procedures

VLACALIB (primary) & MSGSRV

VLACALIB (secondary) & MSGSRV

Compare solutions for primary and secondary calibrators: GETJY & SNPLOT (SN table)

Apply solutions to get calibration table (CL): CLCAL

Test your calibration: UVPLT (DOCALI 1), phases and amplitudes for calibrators and target

Polarization impurities: what is this

Solve for polarization leakage (D-terms): PCAL & MSGSRV (& AN table)

Absolute orientation of the electric vector (either LISTR-RLDIF & CLCOR)

SPLIT your data

Map your sources: IMAGR

Final imaging: stokes' I,U,Q & V and then PPOL, FPOL & PANG

Hints of map analysis (display TVALL, TVLOD, KNTR, ... ; image statistics: TVSTAT, IMSTAT, JMFIT ...)

What is AIPS in a page:

AIPS stands for Astronomical Image Processing System. It's a freely distributed software package developed by the National Radio Astronomy Observatory (NRAO, USA). Originally (very late '70s) intended for VLA data analysis, it has grown in the years and now can handle both interferometric and single dish radio data (and also optical, X-ray,... image analysis)
It has it's own jargon, imports the data in its environment (catalogue: `UCAT, MCAT, PCAT`) and performs variour operations via `TASKS` (heavy duties) and `VERBS` (light duties). Both use `ADVERBS`, i.e. parameters to specify what operation is intended to be done by the verb/task. All the alphabetical inputs given by the user (within quotes) are converted into upper case letters, unless a trick is used (omit the second quote).
For each task, most of the defaults parameters are ok, and there will be indications on which parameter(s) change, and its (their) meaning. Once a task is run, the last set of parameters are saved in a “save&get” area and they can be recovered.
For each `TASK, VERB` and parameters, there is an on-line help available, just typing the command `HELP 'TASKNAME'`; often a more extensive information is available with `EXPLAIN 'TASKNAME`'. An AIPS COOKBOOK is available (both on the web, but there is a copy in the subdirectory TEXT/PUB of the AIPS ROOT) installation where the main steps of the data handling are well explained.

on-line AIPS cookbook at the url: http://www.aips.nrao.edu/CookHTML/CookBook.html

Login in and then import your data

Once you start aips, you will get:

```
./START_AIPS
START_AIPS: Your initial AIPS printer is the
START_AIPS:  - system name , AIPS type

START_AIPS: User data area assignments:
  (Using private file /home/ddallaca/.dadevs for DADEVS.PL)
   Disk 1 (1) is /home/daniele/DATA/LOCALHOST_1
   Disk 2 (2) is /home/daniele/DATA/LOCALHOST_2        Your data will be stored into 2 disk areas. (from AIPS confguration)

Tape assignments:
   Tape 1 is REMOTE
   Tape\ 2 is REMOTE

START_AIPS: I am GUESSING you are at a workstation called daniele-laptop
START_AIPS: Starting TV servers on daniele-laptop asynchronously
START_AIPS:  - with Internet Sockets...
START_AIPS: Starting TPMON daemons on DANIELE-LAPTOP asynchronously...
Starting up 31DEC08 AIPS with normal priority
STARTPMON: [DANIELE-LAPTOP] Starting TPMON1 with output SUPPRESSED
XASERVERS: Start TV LOCK daemon TVSERV on daniele-laptop
XASERVERS: Start XAS on daniele-laptop, DISPLAY :0
XASERVERS: Start graphics server TEKSRV on daniele-laptop, DISPLAY :0
XASERVERS: Start message server MSGSRV on daniele-laptop, DISPLAY :0
TVSERVER: Starting AIPS TV locking, Inet domain
XAS: ** TrueColor FOUND!!!
XAS: ***  Using shared memory option for speed ***
XAS: Using screen width height 1430 800, max grey level 255 Begin the one true AIPS number 1 (release of 31DEC08) at priority =   0
AIPS 1: You are assigned TV device/server   2
AIPS 1: You are assigned graphics device/server   2
AIPS 1: Enter user ID number
?   _ENTER YOU NUMBER HERE ( avoid 1) . ALL YOUR DATA WILL BE ACCESSED ONLY ENTERING AIPS WITH THIS NUMBER
```

Loggin in and then import your data (2)

```
AIPS 1: Enter user ID number
? 11
AIPS 1:                    31DEC08 AIPS:
AIPS 1:     Copyright (C) 1995-2008 Associated Universities, Inc.
AIPS 1:          AIPS comes with ABSOLUTELY NO WARRANTY;
AIPS 1:              for details, type HELP GNUGPL
AIPS 1: This is free software, and you are welcome to redistribute it
AIPS 1: under certain conditions; type EXPLAIN GNUGPL for details.
AIPS 1: Previous session command-line history recovered.
AIPS 1: TAB-key completions enabled, type HELP READLINE for details.
AIPS 1: Loading a brand new POPS vocabulary
>
```

In this example, USER 11 has logged in, and got the '>' prompt. This is a quite old release.... get a more recent one!
Three other windows pop up:
`AIPS98-INET`: the TV SERVER, the graphic interface. Actions on this windows are done with the A,B, C and D (exit) buttons
`MSGSRV`: the message server. It is very important. You get information on how tasks perform!
`TEKSRV`: the server for visualization of plots
PAY ATTENTION TO THE `MSGSRV`.

Let's start loading the data. Let us assume that the data are located in: /home/ddallaca/ERIS/ERIS_C.CBAND
They are in FITS format. They were earlier downloaded from the VLA archive in their own format, then loaded into AIPS and then written out on a disk are in FITS format (AIPS task FITTP).
The task to load fits data is FITLD. Most of the defaults are ok. The parameters relevant to any task/verb can be inspected with the command **`> inp taskname`**
Some brief information on the meaning of the task is also provided.
An example of the first page of the input of `FITLD` is provided in next page

Loggin in and then import your data (3)

```
> inp fitld
AIPS 1: FITLD:  Task to store an image or UV data from a FITS tape
AIPS 1: Adverbs     Values              Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INTAPE        1                 Input tape drive # (0 => 1)
AIPS 1: NFILES        0                 # of files to advance on tape
AIPS 1: DATAIN     *all ' '              Disk file name
AIPS 1: OUTNAME     ' '                 File name (name)
AIPS 1: OUTCLASS    ' '                 File name (class)
AIPS 1: OUTSEQ        0                 File name (seq. #)
AIPS 1:                                 0 => highest unique number
AIPS 1:                                   => matching (on VLBA)
AIPS 1:                                 -1 => FITS tape value
AIPS 1: OUTDISK       1                 Disk drive # (0 => any)
AIPS 1: OPTYPE      ' '                 Type of data to load,
AIPS 1:                                  '  ' => all types
AIPS 1:                                  'UV' => UV data
AIPS 1:                                  'IM' => images
AIPS 1: NCOUNT        0                 Number of files to load.
AIPS 1: DOTABLE       1                 True (1.0) means load tables
AIPS 1:                                  for images.
AIPS 1: DOUVCOMP      1                  >0 => compressed data (FITS)
AIPS 1: ** press RETURN for more, enter Q or next line to quit print **
#   ----- omissis   -------
#
AIPS 1: NPIECE        0                 Maximum uv table piece to
AIPS 1:                                  load (ignored for tape unless
AIPS 1:                                 NCOUNT = 1)
AIPS 1: ERROR        -1                 >= 2 -> do not use AIPS
AIPS 1:                                 history in the FITS file
> datain 'home/ddallaca/ERIS/ERIS_C.CBAND
> go fitld
```

User commands are highlighted in red.

```
daniel> FITLD1: Task FITLD  (release of 31DEC08) begins
daniel> FITLD1: Found MULTI    observed on 03-JAN-1999
daniel> FITLD1: UV data will be written in compressed format
daniel> FITLD1: Create ERIS_C      .C BAND.   1 (UV)  on disk  1  cno    1
daniel> FITLD1: Image=MULTI     (UV)           Filename=ERIS_C      .C BAND.   1
daniel> FITLD1: Telescope=VLA                  Receiver=VLA
daniel> FITLD1: Observer=AB881                 User #=    11
daniel> FITLD1: Observ. date=03-JAN-1999       Map date=07-SEP-2011
daniel> FITLD1: # visibilities    530178       Sort order  TB
daniel> FITLD1: Rand axes: UU-L-SIN  VV-L-SIN  WW-L-SIN  BASELINE  TIME1
daniel> FITLD1:           SOURCE  FREQSEL  WEIGHT  SCALE
daniel> FITLD1: ----------------------------------------------------------------
daniel> FITLD1: Type    Pixels   Coord value     at Pixel     Coord incr   Rotat
daniel> FITLD1: COMPLEX      1   1.0000000E+00       1.00  1.0000000E+00    0.00
daniel> FITLD1: STOKES       4  -1.0000000E+00       1.00 -1.0000000E+00    0.00
daniel> FITLD1: FREQ         1   4.8851000E+09       1.00  5.0000000E+07    0.00
daniel> FITLD1: IF           2   1.0000000E+00       1.00  1.0000000E+00    0.00
daniel> FITLD1: RA           1    00 00 00.000       1.00      3600.000     0.00
daniel> FITLD1: DEC          1    00 00 00.000       1.00      3600.000     0.00
daniel> FITLD1: ----------------------------------------------------------------
daniel> FITLD1: Coordinate equinox 1950.00
daniel> FITLD1: Maximum version number of extension files of type HI is   1
daniel> FITLD1: Maximum version number of extension files of type AN is   1
daniel> FITLD1: Maximum version number of extension files of type NX is   1
daniel> FITLD1: Maximum version number of extension files of type SU is   1
daniel> FITLD1: Maximum version number of extension files of type FQ is   1
daniel> FITLD1: Maximum version number of extension files of type CL is   1
daniel> FITLD1: Maximum version number of extension files of type TY is   1
daniel> FITLD1: Maximum version number of extension files of type WX is   1
daniel> FITLD1: Maximum version number of extension files of type OF is   1
daniel> FITLD1: Appears to have ended successfully
daniel> FITLD1: daniele- 31DEC08 TST: Cpu=      1.4  Real=      2  IO=       44
```

MSGSRV output has pale yellow background

Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR, UVPLT, PRTUV, VPLOT (1)`

The file is in the user catalogue which is organized into two types of files: UV for visibilities, MA for images.
They can be checked with the verbs `UCAT` and `MCAT` respectively, while `PCAT` shows the whole catalogue.

```
> ucat
AIPS 1: Catalog on disk  1
AIPS 1:  Cat Usid Mapname      Class   Seq  Pt          Last access      Stat
AIPS 1:     1    11  ERIS_C       .C BAND.    1 UV   07-SEP-2011 15:27:30
```

The `MSGSRV` already provided some information.
The same basic information can be obtained in the command window just picking up the file and typing the verb `imhead`, or simply `imh`

```
> getn 1
AIPS 1: Got(1)   disk= 1  user=  11   type=UV   ERIS_C.C BAND.1
> imh     (eventually look at the inputs with inp imh)
```

You will be returned with the same information aside. Note the summary of information available and that this file contains the whole experiment (i.e. many sources, position is not determined).
Ancillary information is in the tables related to the file. The relevant ones are

`HI` is the history file where relevant AIPS parms are reported by any task capable to modify the file

`AN` contains info on the antennas of the interferometer

`SU` is for the sources in the file

`CL` is the native calibration table. It is very important and has 1 for amplitudes and 0 for phases

```
daniel> FITLD1: Task FITLD  (release of 31DEC08) begins
daniel> FITLD1: Found MULTI    observed on 03-JAN-1999
daniel> FITLD1: UV data will be written in compressed format
daniel> FITLD1: Create ERIS_C      .C BAND.   1 (UV)  on disk  1  cno    1
daniel> FITLD1: Image=MULTI     (UV)            Filename=ERIS_C      .C BAND.   1
daniel> FITLD1: Telescope=VLA                   Receiver=VLA
daniel> FITLD1: Observer=AB881                  User #=   11
daniel> FITLD1: Observ. date=03-JAN-1999        Map date=07-SEP-2011
daniel> FITLD1: # visibilities     530178       Sort order  TB
daniel> FITLD1: Rand axes: UU-L-SIN  VV-L-SIN  WW-L-SIN  BASELINE  TIME1
daniel> FITLD1:            SOURCE  FREQSEL  WEIGHT  SCALE
daniel> FITLD1: ----------------------------------------------------------------
daniel> FITLD1: Type    Pixels   Coord value    at Pixel     Coord incr   Rotat
daniel> FITLD1: COMPLEX      1   1.0000000E+00       1.00  1.0000000E+00    0.00
daniel> FITLD1: STOKES       4  -1.0000000E+00       1.00 -1.0000000E+00    0.00
daniel> FITLD1: FREQ         1   4.8851000E+09       1.00  5.0000000E+07    0.00
daniel> FITLD1: IF           2   1.0000000E+00       1.00  1.0000000E+00    0.00
daniel> FITLD1: RA           1    00 00 00.000       1.00       3600.000    0.00
daniel> FITLD1: DEC          1    00 00 00.000       1.00       3600.000    0.00
daniel> FITLD1: ----------------------------------------------------------------
daniel> FITLD1: Coordinate equinox 1950.00
daniel> FITLD1: Maximum version number of extension files of type HI is   1
daniel> FITLD1: Maximum version number of extension files of type AN is   1
daniel> FITLD1: Maximum version number of extension files of type NX is   1
daniel> FITLD1: Maximum version number of extension files of type SU is   1
daniel> FITLD1: Maximum version number of extension files of type FQ is   1
daniel> FITLD1: Maximum version number of extension files of type CL is   1
daniel> FITLD1: Maximum version number of extension files of type TY is   1
daniel> FITLD1: Maximum version number of extension files of type WX is   1
daniel> FITLD1: Maximum version number of extension files of type OF is   1
daniel> FITLD1: Appears to have ended successfully
daniel> FITLD1: daniele- 31DEC08 TST: Cpu=      1.4  Real=      2  IO=        44
```

User commands are highlighted in red.

Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR, UVPLT, PRTUV, VPLOT (2)`

To inspect the antenna table we can use the task PRTAN: check the inputs (defaults should be ok). Make sure that the parameter DOCRT is positive, so that the output will show up on the terminal, rather than on the line printer!

```
> inp prtan
AIPS 1: PRTAN:  Task to print the Antenna (AN) extension of a uv file.
AIPS 1: Adverbs     Values                  Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: USERID       0                   Image owner ID number
AIPS 1: INNAME     'ERIS_C'              Image name (name)
AIPS 1: INCLASS    'C BAND'              Image name (class)
AIPS 1: INSEQ        1                   Image name (seq. #)
AIPS 1: INDISK       1                   Disk drive #
AIPS 1: INVERS       0                   AN file ver. #
AIPS 1: NPRINT       0                   No. records to print 0 => all
AIPS 1: DOCRT      132                   > 0 => use terminal instead
AIPS 1:                                  > 72 => terminal width
AIPS 1: OUTPRINT   ' '
AIPS 1:                                  Printer disk file to save
>
```

```
> go prtan
 daniele-  PRTAN(31DEC08)     11     07-SEP-2011  16:54:31    Page    1
File=ERIS_C      .C BAND.   1     An.ver=   1      Vol= 1      User=   11
Array= VLA         Freq=  4885.100000 MHz      Ref.date= 03-JAN-1999

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 =  360.9856449750 degrees / IAT day
GST at UT=0 =  102.1774813374 degrees
UT1-UTC=      0.0000000   Data time(IAT     )-UTC=      0.0000000 seconds
Solutions not yet determined for a particular FREQID

Ant    1 = VLA:_W16 BX=      499.8608 BY=     -1317.9838 BZ=      -735.2016
Mount=ALAZ  Axis offset=  0.0004 meters     IFA               IFB
Feed polarization type =                      R                 L

Ant    2 = VLA:_N16 BX=     -801.3711 BY=      -124.9709 BZ=      1182.1331
Mount=ALAZ  Axis offset=  0.0000 meters     IFA               IFB
Feed polarization type =                      R                 L
Type Q to stop, just hit RETURN to continue
      ----------------- go to the next page ---------------------
```

There is information about the interferometer and antenna coordinates, along with some incomplete parametrization of the instrumental polarization

Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR, UVPLT, PRTUV, VPLOT (3)`

After hitting the return button for a number of times at the very end the antenna number (1 through 28) are associated to a VLA pad in each arm (North, East and West). In this example antenna 18 was out (maintenance!). Among the 27 operating antennas note those in a central position: #7, 24 and 25. They are important since they form short-medium size baselines to all the others. One of them will be used as reference for determining phase solutions.

```
> ---------------- from the previous page --------------
AIPS 1: PRTAN:  Task to print the Antenna (AN) extension of a uv file.

                 Location Of VLA Antennas

                             N18 (27)
                             N16 ( 2)
                             N14 (15)
                             N12 ( 3)
                             N8  ( 8)
                             N6  (11)
                             N4  (19)
                             N2  ( 5)
                             N1  (24)
                        (25) W2   E2  ( 7)
                     (10) W4        E4  (14)
                   (23) W6            E6  (28)
                 ( 4) W8                E8  ( 9)
              (17) W10                    E10 ( 6)
            (22) W12                        E12 (21)
          (16) W14                            E14 (26)
        ( 1) W16                                E16 (12)
      (13) W18                                    E18 (20)
                  VLA:_OUT (18)
                  VPT:_OUT (29)
AIPS 1: Resumes
>
```

Also the source table could be of interest. The task to display the content of the `SU` table is `PRTAB`

Explore the visibilities: IMH, PRTAN, **PRTAB**, LISTR, UVPLT, PRTUV, VPLOT (4)

```
> inp prtab
AIPS 1: PRTAB:  Task to print any table-format extension file
AIPS 1: Adverbs     Values              Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: USERID       0                  Image owner ID number
AIPS 1: INNAME      'ERIS_C'            Image name (name)
AIPS 1: INCLASS     'C BAND'            Image name (class)
AIPS 1: INSEQ        1                  Image name (seq. #)
AIPS 1: INDISK       1                  Disk drive #
AIPS 1: INEXT       ' '                 Extension type
AIPS 1: INVERS       0                  Extension file version #
AIPS 1: BPRINT       1                  First row number to print
AIPS 1: EPRINT       0                  Last row number to print
AIPS 1: XINC         1                  Increment between rows
AIPS 1: NDIG         0                  > 3 => extended precision
AIPS 1: DOCRT      132                  If > 0, write to CRT
AIPS 1:                                 > 72 => CRT line width
AIPS 1: OUTPRINT   ' '
AIPS 1:                                 Printer disk file to save
AIPS 1: DOHMS        1                  If > 0 print times with
AIPS 1:                                 hh:mm:ss.s format
AIPS 1: NCOUNT       0                  Print the first NCOUNT values
AIPS 1:                                 in a cell plus
AIPS 1: BDROP        0                  values BDROP through
AIPS 1: EDROP        0                  EDROP (if appropriate)
AIPS 1: BOX        *all 0               List of columns to be printed
AIPS 1:                                 0 -> all.
AIPS 1: DOFLAG       0                  > 0 => list flagged rows too
> inext'su'
>
```

```
> go prtab
 daniele-  PRTAB(31DEC08)    11    07-SEP-2011  17:24:46    Page    1
ERIS_C     .C BAND.   1  Disk= 1    SU Table version    1
Title: AIPS SU
Created by      FITLD on 07-SEP-2011 15:27:30
Last written by FITLD on 07-SEP-2011 15:27:30
Ncol  19  Nrow      3    Sort cols:
    Table has     4 keyword-value pairs:
   NO_IF    =          2
   VELTYP   =
   VELDEF   =
   FREQID   =         -1
   Table format incompatable with FITS ASCII tables

COL. NO.     1       2          3         4            5          6           7
     ROW  ID. NO.  SOURCE QUALCALCODE  IFLUX      QFLUX      UFLUX
  NUMBER                                              JY         JY          JY
      1        1    3C219       0              0.000E+00  0.000E+00  0.000E+00
      1                                        0.000E+00  0.000E+00  0.000E+00
      2        2    1035+564    0       A      0.000E+00  0.000E+00  0.000E+00
      2                                        0.000E+00  0.000E+00  0.000E+00
      3        3    1331+305    0       C      0.000E+00  0.000E+00  0.000E+00
      3                                        0.000E+00  0.000E+00  0.000E+00
Type Q to stop, just hit RETURN to continue

---------- more information will be displayed on the screen --------------
```

There are 3 sources in this file. A primary calibration source (1331+305), a secondary calibrator (1035+564) and the target (3C219). Hitting return the source coordinates will be displayed, along with other obscure info.

Explore the visibilities: `IMH`, `PRTAN`, `PRTAB`, **`LISTR`**, `UVPLT`, `PRTUV`, `VPLOT` (5)

```
> inp listr
> AIPS 1: LISTR:  Task to print UV data and calibration tables.
AIPS 1: Adverbs     Values                Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: USERID       0                    User number.
AIPS 1: INNAME     'ERIS_C'               UV data (name).
AIPS 1: INCLASS    'C BAND'               UV data (class).
AIPS 1: INSEQ        1                    UV data (seq. #).  0 => high
AIPS 1: INDISK       1                    Disk unit #.       0 => any
AIPS 1: OPTYPE     ' '                    List type:
AIPS 1:                                   'MATX','LIST','GAIN','SCAN'
AIPS 1: INEXT      'SU'                   CL, SN or TY table for 'GAIN'
AIPS 1: INVER        0                    CL, Sn or TY table version
    [ omissis ]  there is a large number of parms ....
> inext ' '
> optype 'scan'
>
```

The table to be used is the `CL` (calibration table) and the proper value should be set. Either `' '` (a blank value) or `'CL'` are appropriate. Select the `'SCAN'` option to have a scan listing of the experiment, which is shown aside. There are 32 scans with info on source name, start & stop times, and there is a summary on the (3) sources (position and total number of visibilities) in this file and on the frequency table (`FQ`) as well.

The 2 IFs are at 4.8851 and 4.8351 GHz, with 50 MHz bandwidth each.

```
> go prtab
 daniele-  LISTR(31DEC08)     11     07-SEP-2011  17:42:30    Page     1
File = ERIS_C      .C BAND.   1 Vol = 1  Userid =    11
Freq =  4.885100000 GHz   Ncor =  4   No. vis =     530178
Scan summary listing

Scan   Source       Qual  Calcode Sub        Timerange           FrqID   START
  1 3C219          : 0000              1  0/05:24:55 -   0/05:41:25     1         1
  2 1035+564       : 0000   A          1  0/05:53:25 -   0/05:55:25     1   34101
  3 3C219          : 0000              1  0/05:56:15 -   0/06:09:35     1   37962
  4 1035+564       : 0000   A          1  0/06:21:45 -   0/06:23:55     1   66393
  5 3C219          : 0000              1  0/06:24:45 -   0/06:38:15     1   70608
                                   [omissis]
 27 3C219          : 0000              1  0/11:54:15  -  0/12:07:45     1  430325
 28 1035+564       : 0000   A          1  0/12:08:55  -  0/12:11:05     1  458389
 29 3C219          : 0000              1  0/12:23:15  -  0/12:36:45     1  463303
Type Q to stop, just hit RETURN to continue
                                   [omissis]
 30 1035+564       : 0000   A          1  0/12:37:45 -   0/12:39:55     1  491393
 31 3C219          : 0000              1  0/12:55:35 -   0/13:09:05     1  496307
 32 1331+305       : 0000   C          1  0/13:13:55 -   0/13:16:45     1  524397
                                   [omissis]
 ID Source          Qual  Calcode   RA(2000.0)     Dec(2000.0)   No. vis
  1 3C219          : 0000           09:17:50.6000  45:51:44.000  456689
  2 1035+564       : 0000   A       10:35:07.0399  56:28:46.792   67707
  3 1331+305       : 0000   C       13:31:08.2873  30:30:32.959    5782
                                   [omissis]
Frequency Table summary
FQID IF#      Freq(GHz)      BW(kHz)    Ch.Sep(kHz)   Sideband
  1   1       4.88510000  50000.0039  50000.0039      1
      2       4.83510000  50000.0039  50000.0039      1
AIPS 1: Resumes
>
```

Explore the visibilities: IMH, PRTAN, PRTAB, LISTR, UVPLT, PRTUV, VPLOT (6)

```
> inp uvplt
AIPS 1: UVPLT     Plots data from a u,v data base: multi-channel version
AIPS 1: Adverbs     Values               Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: USERID       0                Data base owner number
AIPS 1: INNAME     'ERIS_C'           Input UV file name (name)
AIPS 1: INCLASS    'C BAND'           Input UV file name (class)
AIPS 1: INSEQ          1              Input UV file name (seq. #)
AIPS 1: INDISK         1              Input UV file disk unit #
AIPS 1: SOURCES    *all ' '           Sources to plot, ' '=>all.
                 [omissis]
AIPS 1: STOKES       ' '              Stokes type to select.
                 [omissis]
AIPS 1: XINC        1                 Plot every XINC'th visibility
AIPS 1:                               0 => 1.
AIPS 1: BPARM      *all 0             Control parameters
AIPS 1:                               1 : X-axis type 0=>UV dist
AIPS 1:                               2 : Y-axis type 0=>Ampl
AIPS 1:                                   1=> amplitude (Jy)
AIPS 1:                                   2=> phase (degrees)
AIPS 1:                                   3=> uv dist. (klambda)
AIPS 1:                                   4=> uv p.a. (deg N->E)
AIPS 1:                                   5=> time (IAT days)
AIPS 1:                                   6=> u (klambda)
AIPS 1:                                   7=> v (klambda)
AIPS 1:                                   8=> w (klambda)
AIPS 1:                                   9=> Re(Vis) (Jy)
AIPS 1:                                   10=> Im(Vis) (Jy)
AIPS 1:                                   11=> time (IAT hours)
AIPS 1:                                   12=> log(ampl)
AIPS 1:                                   13=> weight
AIPS 1:                                   14=> HA (hours)
AIPS 1:                                   15=> elevation (deg)
```

```
---------- more information will be displayed on the screen -------------
AIPS 1:                                   16=> parallactic angle
AIPS 1:                                   17=> uv dist. (klambda)
AIPS 1:                                        along p.a.
AIPS 1:                                   18=> azimuth (deg)
AIPS 1:                               3 : > 0.0 => fixed scale
AIPS 1:                                   < 0.0 => fixed range
AIPS 1:                               4 : Xmin (fixed scale)
AIPS 1:                               5 : Xmax (fixed scale)
AIPS 1:                               6 : Ymin (fixed scale)
AIPS 1:                               7 : Ymax (fixed scale)
AIPS 1:                               8 : Number of bins to plot
AIPS 1:                               9 : > 0 => list bin values.
AIPS 1:                               10: > 0 => plot auto-corr too
AIPS 1:                               BPARM=6,7,2,0 generates
AIPS 1:                               square UV coverage plots
                          [omissis]
AIPS 1: DOTV        -1                > 0 Do plot on the TV, else
AIPS 1:                               make a plot file
                          [omissis]
>
> stokes 'half'            parallel hand data only (cross are not used)
> bparm 6,7,2 0            uv coverage, using the same scale in X and Y
> source '1035+564' '      the secondary calibrator only is considered
> dotv 1                   the plot  will appear on the TV screen
> go uvplt
```

BPARM (s) select what to plot!

Then have a look to the TV screen!

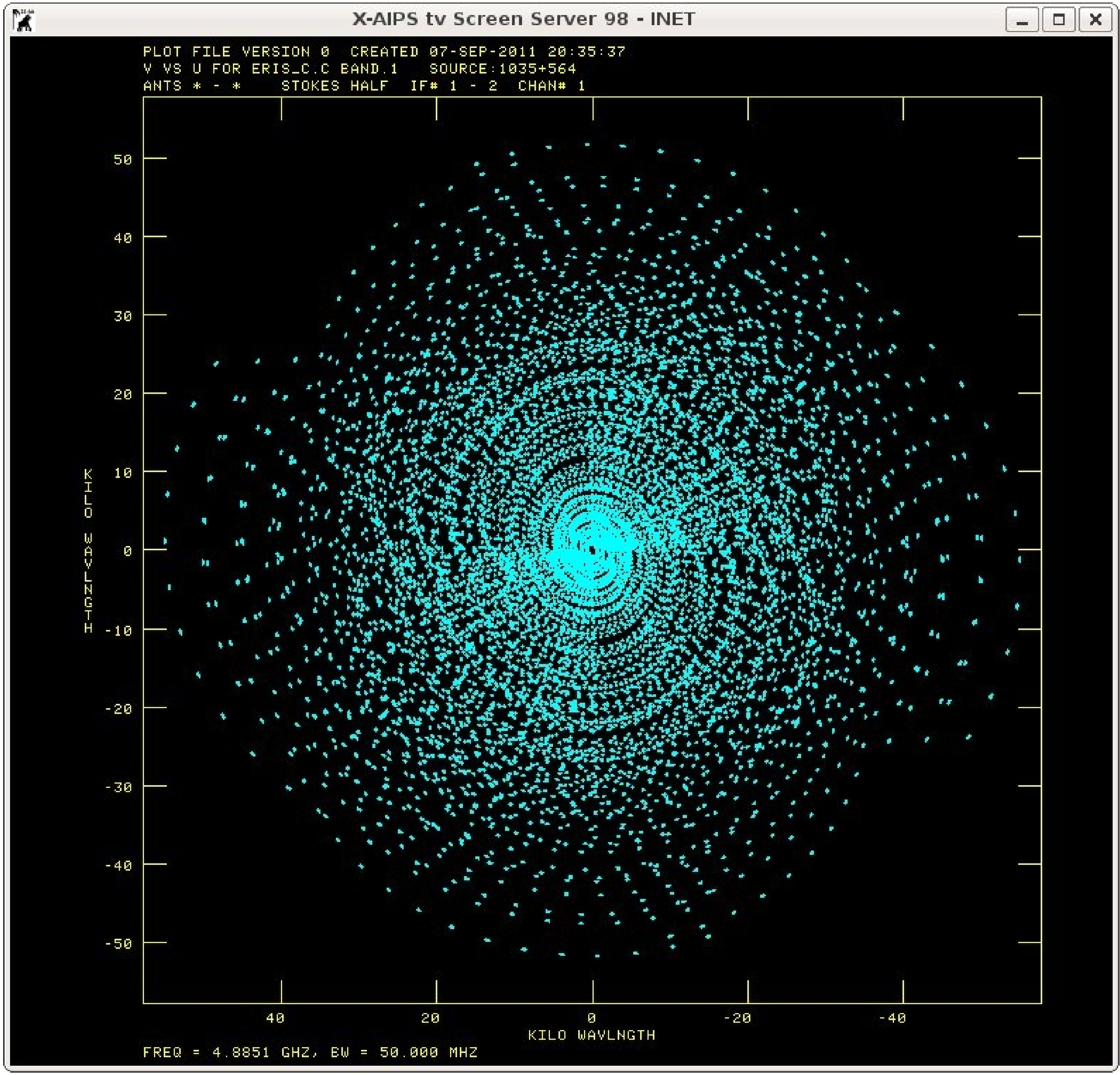
Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR,` **`UVPLT`**`, PRTUV, VPLOT (7-1)`

```
UVPLT
BPARM 6, 7, 2, 0
```

The UV coverage. Note that

- scan calibrators are short and repeated several times
- each (long) baseline describes an elliptical track created by the earth rotation.
- the uv-plane is more densely sampled in the inner part, while the sampling becomes more sparse as baseline length increase
- the maximum baseline length is about 50 kλ

Question:
which is the predicted HPBW?



Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR,` **`UVPLT`**`, PRTUV, VPLOT (7-2)`

```
UVPLT
BPARM 0
```

Baseline length (X) – Amplitudes (Y

Note that

- raw amplitudes are flat, as expected for point-like sources

- there are a few points in the low part of the plot; they are likely bad.

Here, both RR and LL, IF1 and IF2 correlations have been shown.

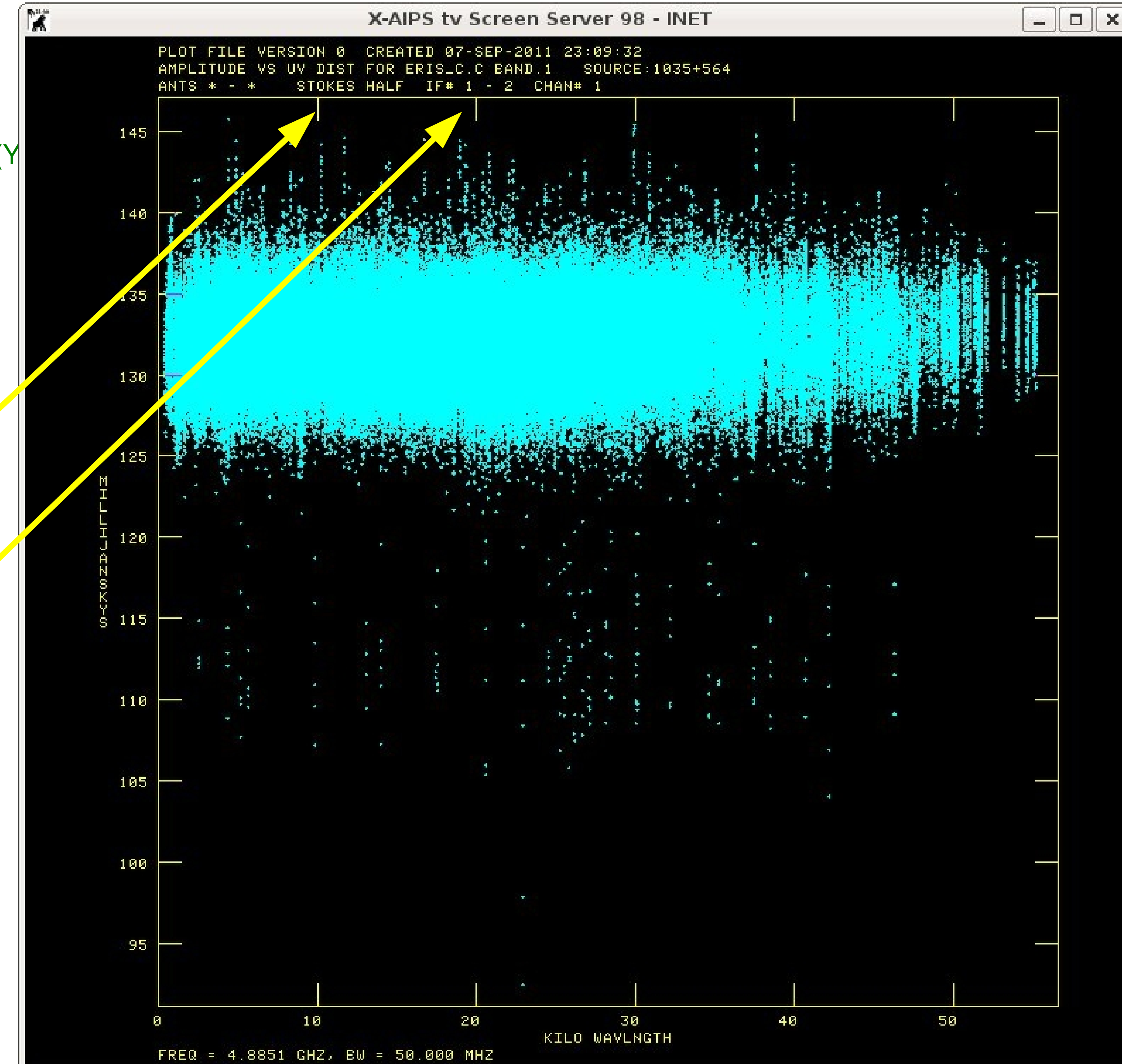
They can be selected by typing

`stokes 'RR'` (plots RR)

`stokes 'LL'` (plots LL)

`BIF=1; EIF= 1` (plots IF1)

`BIF=2; EIF= 2` (plots IF2)



Explore the visibilities: IMH, PRTAN, PRTAB, LISTR, **UVPLT**, PRTUV, VPLOT (7-3)

```
UVPLT
BPARM 11,0
```

Time (X) & Amplitudes (Y)

Note that

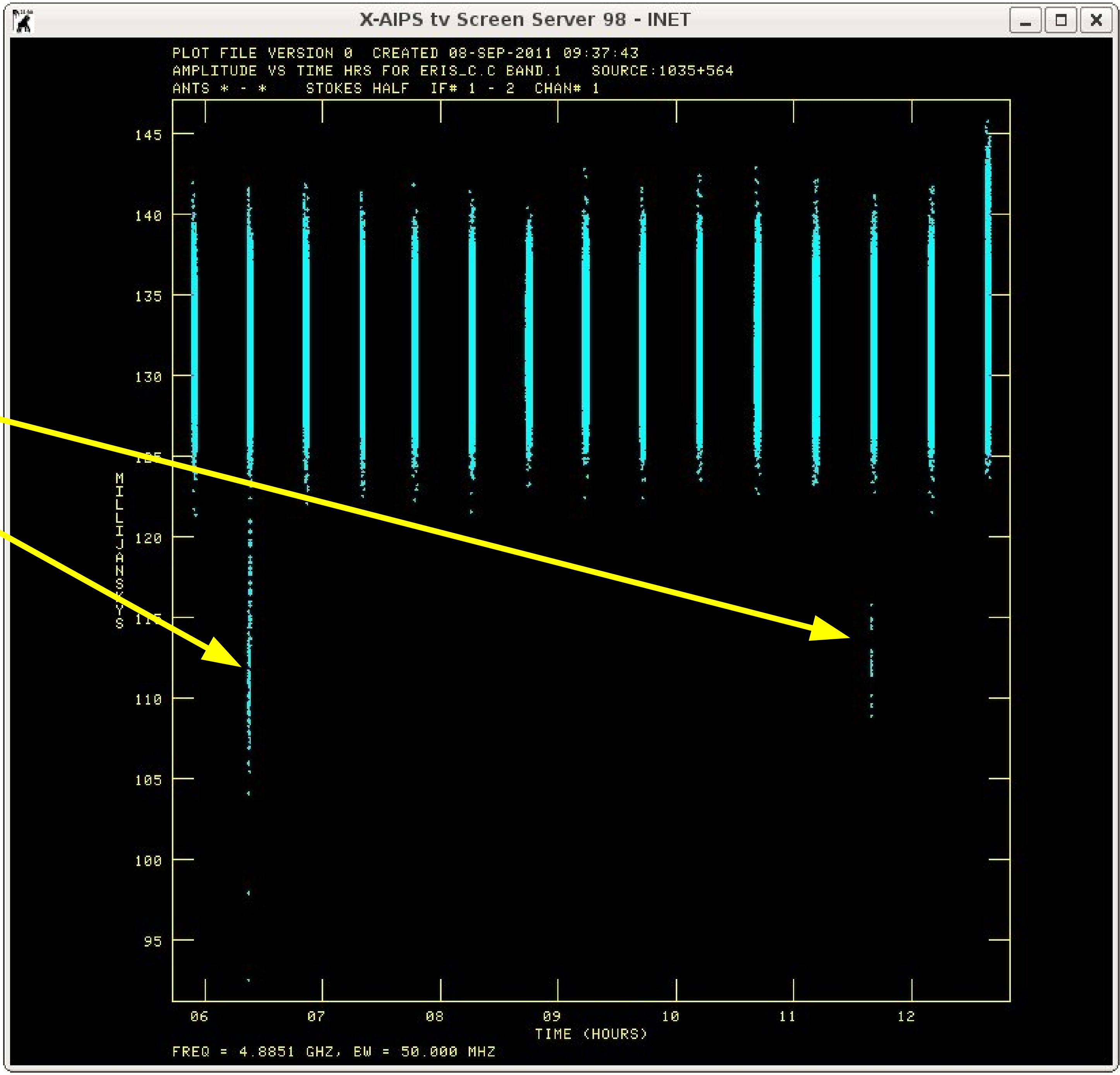
- raw amplitudes show problems (at the very beginning) in two scans.
- the last scan have slightly higher amplitudes

Again, RR and LL, IF1 and IF2 correlations can be displayed separately. Bad data can come from a single IF / polarization only

pay attention that

```
stokes 'half'
bif 1; eif 0
```

have been used for this plot



Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR, UVPLT,` **`PRTUV`**`, VPLOT (8)`

```
> inp prtuv
AIPS 1: PRTUV:  Task to print UV data stored on disk
AIPS 1: Adverbs       Values                  Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: USERID          0                     User number.
AIPS 1: INNAME     'ERIS_C'                   UV data (name).
AIPS 1: INCLASS    'C BAND'                   UV data (class).
AIPS 1: INSEQ           1                     UV data (seq. #).  0 => high
AIPS 1: INDISK          1                     Disk unit #.       0 => any
AIPS 1: SOURCES     '1035+564'                Source list
AIPS 1:                *rest ' '
AIPS 1: CHANNEL         0                     Frequency channel number.
AIPS 1: BIF             0                     IF number
AIPS 1: BPRINT          1                     # of first data sample.
AIPS 1: NPRINT          0                     # of samples. 0 => 1 page.
                    [omissis]
AIPS 1: DOCRT         132                     > 0 -> use the terminal,
AIPS 1:                                       else use the line printer
                    [omissis]
> go prtuv
>
```

```
 daniele-  PRTUV(31DEC08)     11     08-SEP-2011  09:55:27    Page    1
ERIS_C      .C BAND.   1  Vol= 1  User=   11  Channels=    1 to     1
Source= 1035+564    RA   =  10 35  7.04    DEC  =  56 28 46.8 IF =  1
Freq=  4.885099862 GHz   Ncor=  4   No. vis=    530178   Sort order= TB
Weights have been multiplied by  1.0E-04

1035+564  4.885099862 TB       1 RR          1 LL           1 RL             1 LR
 Vis #     IAT      Ant   Amp  Phas Wt  Amp  Phas Wt  Amp  Phas Wt  Amp  Phas Wt

 34101  0/05:53:45 10-22  0.134  21 21  0.132  13 21  0.006-176 21  0.003-100 21
 34102  0/05:53:45  4-22  0.136  10 19  0.135   4 19  0.007   97 19  0.005  22 19
 34103  0/05:53:45 16-22  0.136  -9  20  0.133   0 20  0.008 116 20  0.002 119 20
 34104  0/05:53:45 22-23  0.134  -1  21  0.135   1 21  0.004-110 21  0.004 -60 21
 34105  0/05:53:45   1-22  0.131   9 15  0.137  -4 15  0.004   81 15  0.000  15 15
 34106  0/05:53:45 17-22  0.133  12 19  0.133   2 19  0.008  96 19  0.001 173 19
 34107  0/05:53:45 22-25  0.134 -16 19  0.130  -3 19  0.002-129 19  0.003 -88 19
 34108  0/05:53:45 13-22  0.136  15 18  0.136   6 18  0.001  111 18  0.003 155 18
 34109  0/05:53:45 14-22  0.136  16 19  0.132  16 19  0.003  135 19  0.005 137 19
                             [omissis]
 34114  0/05:53:45 22-26  0.135  38 18  0.135-153 18  0.001-160 18  0.005 -55 18
 34115  0/05:53:45 22-28  0.133 -16 19  0.134  -4  19  0.001  -10 19  0.003 -15 19
 34116  0/05:53:45  6-22  0.134   6  14  0.131  -4 14  0.011  124 14  0.004  18 14
 34117  0/05:53:45 21-22  0.134  14  16  0.133   7 16  0.005  57 16  0.003 126 16
 34118  0/05:53:45   3-22  0.134   5  19  0.138   0 19  0.005  111 19  0.004  59 19
                             [omissis]
34126  0/05:53:45  5-22  0.132  13 18  0.135  -3 18  0.002  94 18  0.002 178 18
Type Q to stop, just hit RETURN to continue
```

The visibilities of the secondary calibrator (1035+564) are displayed on the terminal. In general, data for IF1 are shown. To display data of IF 2, BIF 2 needs to be specified.

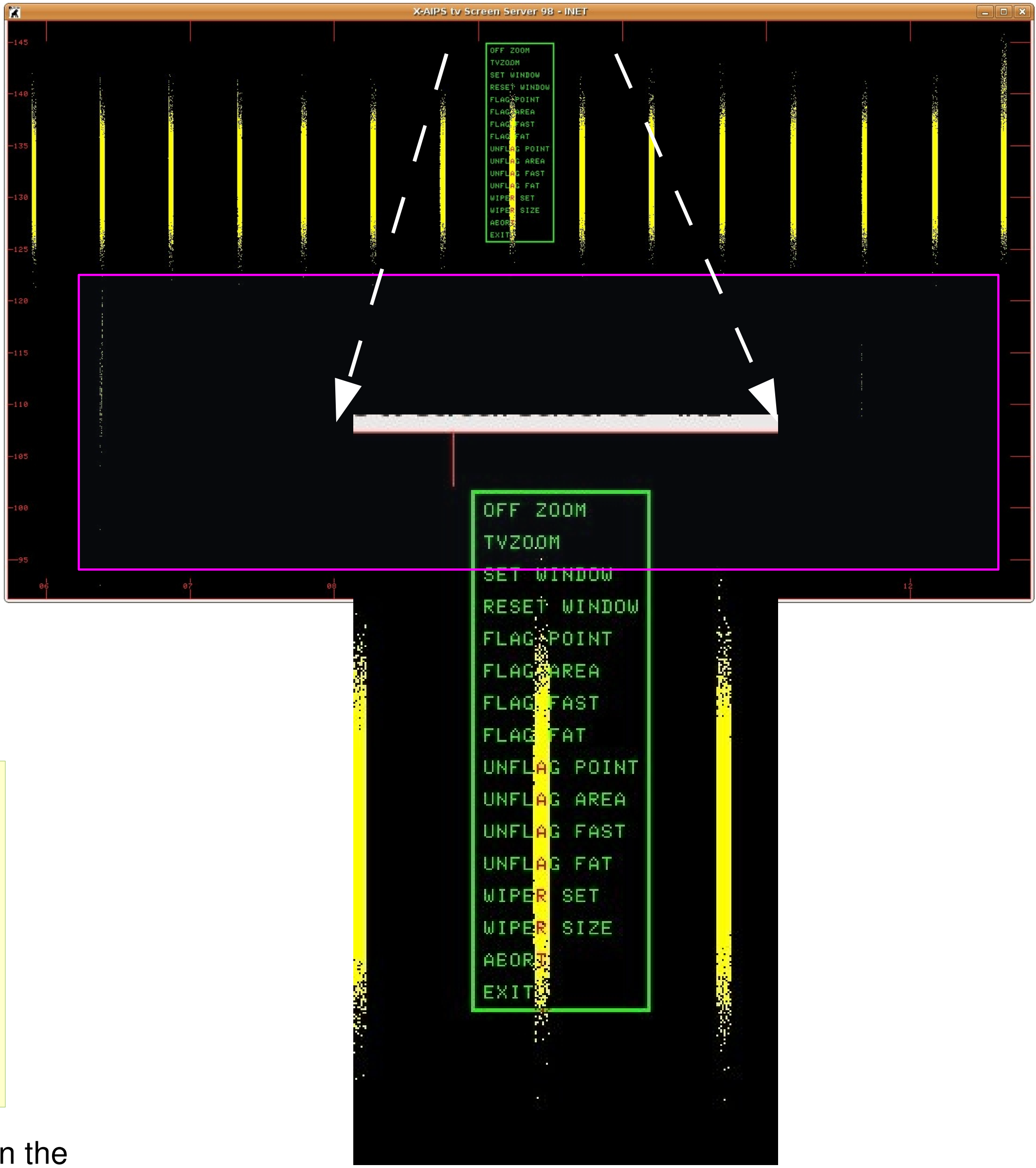
Amplitudes are very similar in both RR and LL (around 0.13 Jy but remember these are 'engineer units' at the moment), while for cross hands (RL and LR) they are much smaller.

Phases are not 0, since no contribution to phase corruption (atmosphere and electronics) has been removed.

The aim of calibration is to change the 'engineer units' to real Jy, and phases from apparently random values to zero (phases to 0 applies for calibration source only!)

Is flagging needed? Then ... **WIPER**, `TVFLG`, `SPFLG`, `FLGIT`, `UVFLG`, ...

For single channel data flagging can be performed with `TVFLG` (TV screen based editing) and `WIPER`, that shows a uvplot-like plot on the TV screen in which the user can define areas containing visibilities to be removed. It is possible to use the last `UVPLT` inputs (i.e. `BPARM 11 0`) and perform the editing



> **inp wiper**
AIPS 1: WIPER Plots and edits data from a u,v data base using TV
AIPS 1: Adverbs Values Comments
AIPS 1: --
[omissis]
> **flagver 1** **use FG table 1 (if present)**
>**outfgver 1** **write on FG table 1 (update flags!)**
> **bparm 11 0** **plot time (X) .vs. amplitudes (Y)**
> **go wiper**

daniel> WIPER1: Task WIPER (release of 31DEC08) begins
daniel> WIPER1: Doing no flagging this time
daniel> WIPER1: PLOTUV: X axis in IAT hrs 5.727E+00 1.283E+01
daniel> WIPER1: PLOTUV: Y axis in Janskys 9.114E-02 1.471E-01
daniel> WIPER1: PLOTUV: 270806 Points put in array
daniel> WIPER1: SOME PARTS OF LABEL DID NOT FIT ON THE SCREEN
daniel> WIPER1: Press buttons A, B, or C to choose an operation
daniel> WIPER1: Press button D for on-line help

How to perform the editing is summarized in the `MSGSRV`: Click on the '`FLAG AREA`' option in green, and then hit button A. The green rectangle will disappear and pink lines will allow you to set the `BLC` (bottom left corner of the rectangle). Click on the desired position and then hit button A. Then you will have to set the `TRC` (top right corner). When done, hit button C: will execute the flag (yellow points become cyan) and return to the green menu. Click on '`EXIT`' and hit button A. **A `FG` table has been produced**. Now try again `UVPLT` with `FGVER 1` to see the effect of `WIPER`

Explore the visibilities: `IMH, PRTAN, PRTAB, LISTR,` **`UVPLT`**`, PRTUV, VPLOT (7-4)`

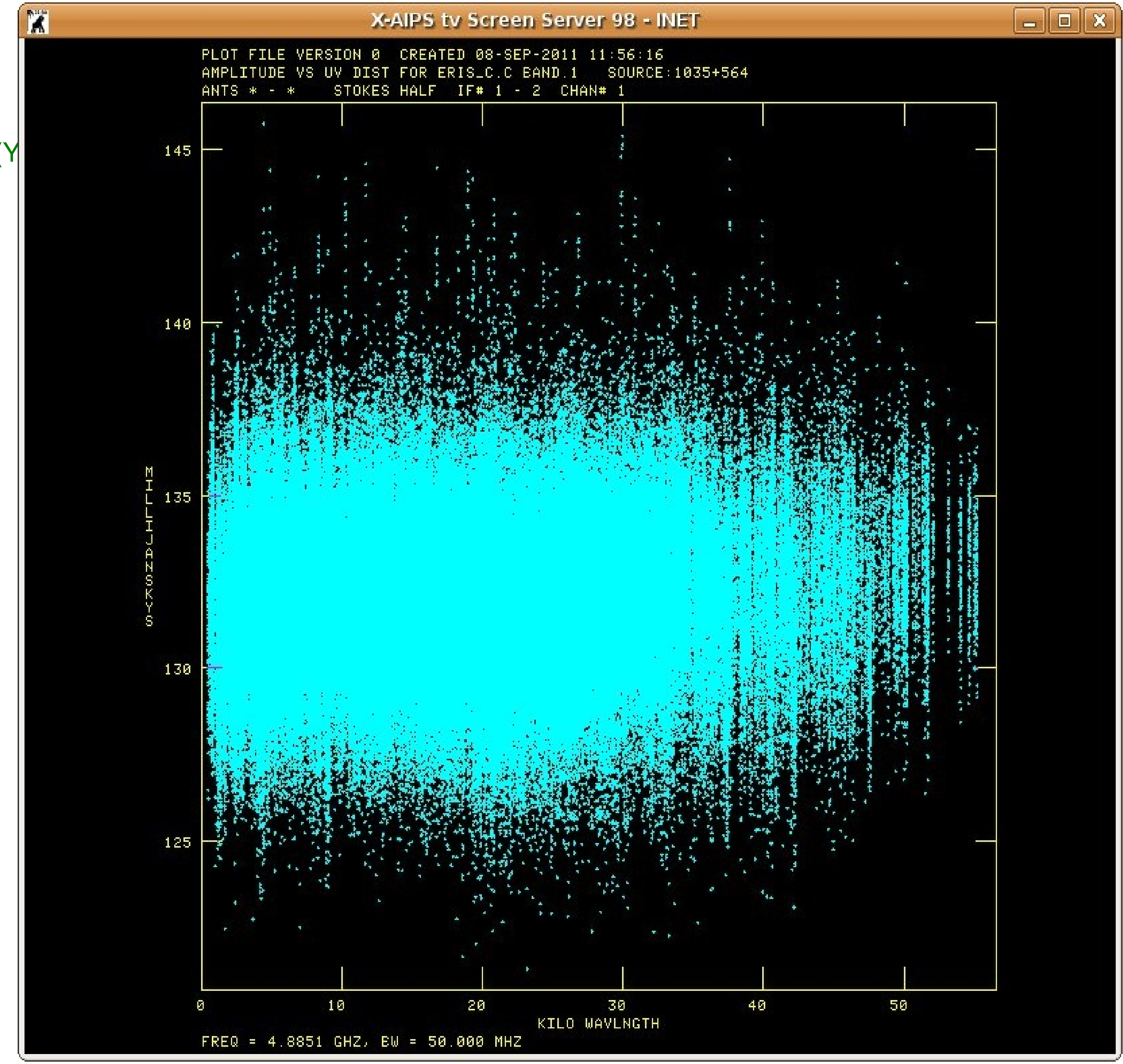
```
UVPLT
BPARM 0
FGVER 1
```

Baseline length (X) – Amplitudes (Y

- the `FG` table drops the bad data

It is necessary to look at the primary calibration source 1331+305 (shown later!)

Let's plot the phases, changing `BPARM`

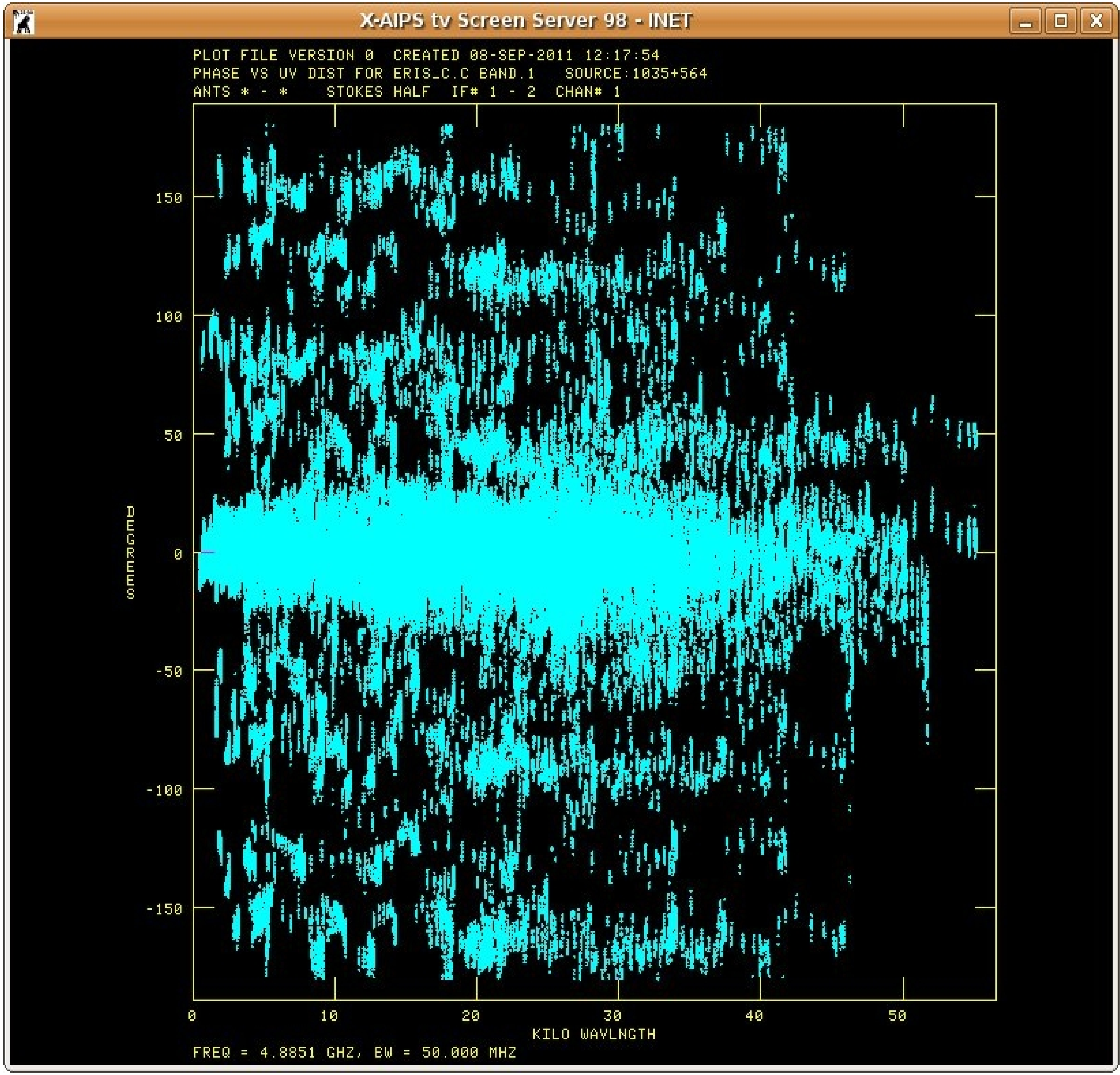


Explore the visibilities: IMH, PRTAN, PRTAB, LISTR, **UVPLT**, PRTUV, VPLOT (7-5)

UVPLT
BPARM 0 2 0
FGVER 1
Baseline length (X) – Phases (Y)

- the FG table drops the bad data

The phases are distributed between -180 and + 180 deg. This is due to the atmospheric and electronic corruption that will be corrected by the calibration



A-priori calibration: Preamble (primary, secondary, **SETJY**)

We have to provide the information on the flux density of the primary calibration source. This is done by the task `SETJY`. Make sure to use `SOURCE'1331+305''` (an alias of 3C286) and look at the `MSGSRV`

```
> inp setjy
AIPS 1: SETJY     Task to enter source info into source (SU) table.
AIPS 1: Adverbs     Values               Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME     'ERIS_C'              Input image name (name)
AIPS 1: INCLASS    'C BAND'              Input image name (class)
AIPS 1: INSEQ        1                   Input image name (seq. #)
AIPS 1: INDISK       1                   Input image disk unit #
AIPS 1: SOURCES    '1331+305'            Sources to modify.
AIPS 1:            *rest ' '
AIPS 1: QUAL        -1                   Source qualifier -1=>all
AIPS 1: BIF          0                   Low IF # for flux density
AIPS 1: EIF          0                   High IF # for flux density
AIPS 1: ZEROSP     *all 0                I,Q,U,V flux density (Jy)
AIPS 1: OPTYPE     'CALC'                '    ' => use other adverbs
AIPS 1:                                  for required operation
AIPS 1:                                  'CALC' => determine
AIPS 1:                                  3C286/3C48/1934 fluxes from
AIPS 1:                                  standard formulae
AIPS 1:                                  'REJY' => reset source
AIPS 1:                                  fluxes to zero.
AIPS 1:                                  'REVL' => reset velocity
AIPS 1:                                  to zero
AIPS 1:                                  'RESE' => reset fluxes &
AIPS 1:                                  velocities to zero.
AIPS 1: CALCODE     ' '                  New calibrator code:
AIPS 1:                                  '----' => change to blank
                        [omissis]
> optype 'calc'    SETJY will determine the flux density from built a in function
> go setjy
```

```
daniel> SETJY1: Task SETJY  (release of 31DEC08) begins
daniel> SETJY1: **WARNING: OPCODE=CALC AND FREQID =   -1
daniel> SETJY1: FREQID will be reset to 1, CHECK YOUR RESULTS CAREFULLY
daniel> SETJY1: A source model for this calibrator may be available
daniel> SETJY1: Use the verb CALDIR to see if there is one
daniel> SETJY1: A source model for this calibrator may be available
daniel> SETJY1: Use the verb CALDIR to see if there is one
daniel> SETJY1: / Flux calculated using known spectrum
daniel> SETJY1: BIF =  1 EIF =  2 /Range of IFs
daniel> SETJY1: '1331+305        ' IF =  1 FLUX = 7.4620 (Jy calcd)
daniel> SETJY1: '1331+305        ' IF =  2 FLUX = 7.5100 (Jy calcd)
daniel> SETJY1: / Using (1999.2) VLA or Reynolds (1934-638) coefficients
daniel> SETJY1: Appears to have ended successfully
daniel> SETJY1: daniele-lapt 31DEC08 TST: Cpu=       0.0  Real=       0
```

Among the messages you will learn that the the flux density of 1331+305 is 7.46 and 7.51 Jy for IF1 and 2 respectively. You can re-run `PRTAB` for the `SU` table. You will see that now such info appears in the I total flux density (column 5, raw 3).

Inspection of band-pass (POSSM) response and its calibration (BPASS) and verification (POSSM) goes here

A-priori calibration: Running procedures (1)

For VLA data a number of specific procedures have been developed to help the user to fucus on a small number of task parameters (most of them are governed by the procedures themselves!)
To activate these procedures, it is necessary to type `run vlaprocs` on the terminal window.
After that, a **large** number of instruction are activated and rapidly scroll in the window.

```
> run vlaprocs
                    [omissis]
AIPS 1:   default tecor; vget vlatecr; task 'TECOR'
AIPS 1: *    nfiles=vba_nfil; infi=vba_inf; runwait('TECOR')
AIPS 1:    nfiles=vba_nfil; infi=vba_inf; go tecor
AIPS 1:   type 'NUMBER OF FILES DOWNLOADED = '!!char(nfiles)
AIPS 1:   type 'There are jplg* (IONEX) files in your /tmp directory.
AIPS 1:   type 'CL #'!!char(maxtab('CL'))!!' CONTAINS IONOSPHERIC CORREC
      TIONS'
AIPS 1: end
AIPS 1: if(vba_ok=-6) then
AIPS 1:   type 'You must have a NX table to use this procedure.
AIPS 1:   type 'Run INDXR and try again.
AIPS 1: end
AIPS 1: tget vlatecr
AIPS 1: return;finish
>
```

For our purposes, we will use the procedure/task `VLACALIB`, which needs to be run on both the primary and secondary calibration sources.

These two sources needs to be dealt separately for a number of reasons. In fact, for 1331+305 at 6 cm there are UV-range restrictions.

In fact it could be considered point-like on a subset of the spacings sampled by the C array data.

Consult the AIPS Cookbook, chapter 4, section 4.3.3.2 and you will learn that modern versions of AIPS will use models for the brightness distribution of primary sources, while older ones require to restrict the uv-range to be considered in the calibration.
We will follow this second option. The only difference will be the number of data points that will be considered for determining the solution.

A-priori calibration: Running procedures (2)

To examine the input of VLACALIB should be easy!

Parameters to change:

`CALSOUR'1331+305''`

Selects data for the primary cal source only

`UVRANGE 0 25`

Selects baselines shorter than 25 kl, where the source is supposed to be point-like. This is also visible in the amplitude plot in the next page!

`REFANT 24`

Selects this central antenna for phase reference. All the phases (both IFs and both Pols)

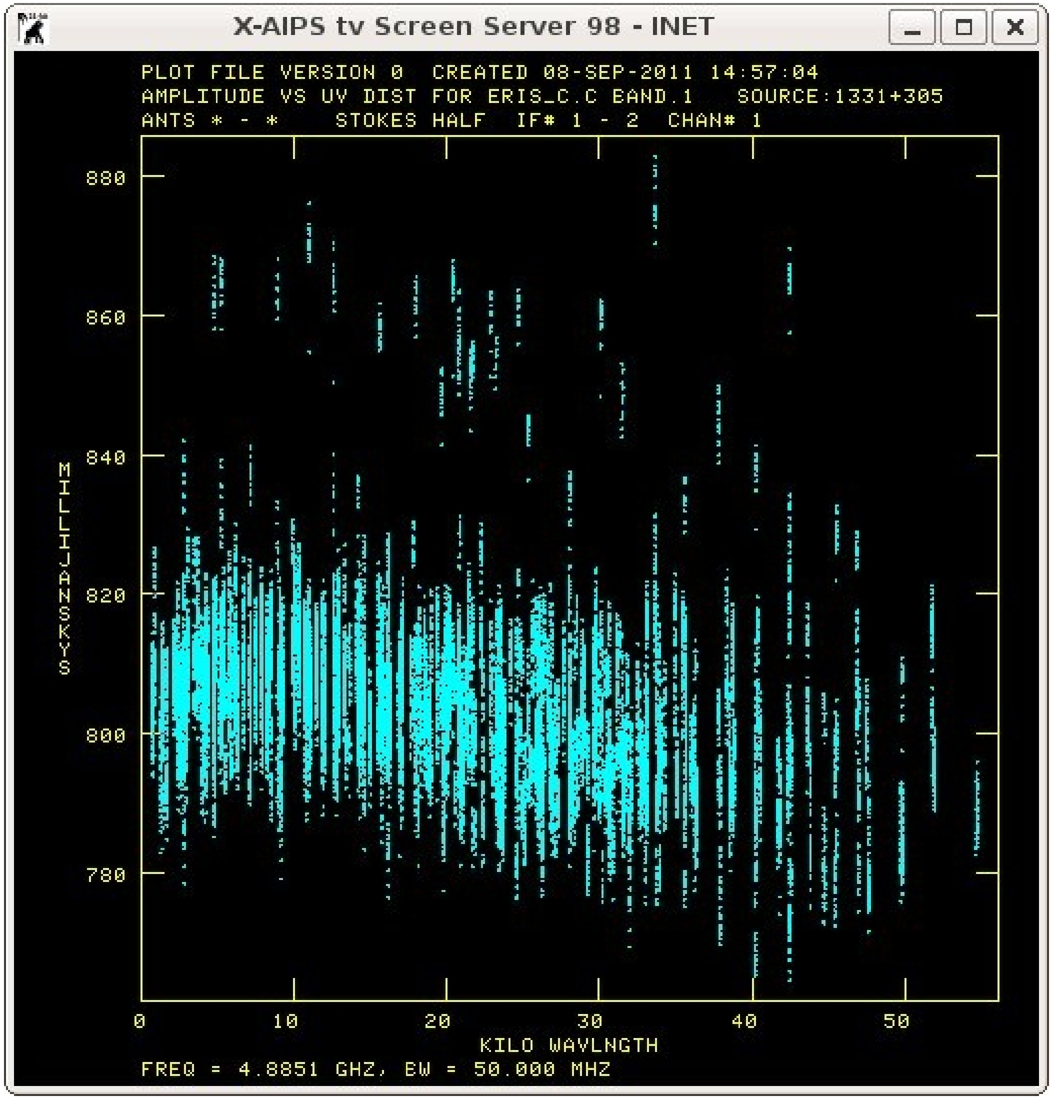
`SNVER 1`

Explicit this. All the solutions will be written in SN table 1

Moreover, we will skip the printing of results on the line printer (or file) with `DOPRINT -1`;
also type `DOLISTR -1` to avoid listings of solutions.
Solutions will be inspected later on

```
> inp vlacalib
AIPS 1: VLACALIB:  Procedure to run CALIB and LISTR for VLA calibration.
AIPS 1: Adverbs     Values                   Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1:                                      Use RUN VLAPROCS first!!!
AIPS 1: INNAME     'ERIS_C'                  UV file name (name)
AIPS 1: INCLASS    'C BAND'                  UV file name (class)
AIPS 1: INSEQ           1                    UV file name (seq. #)
AIPS 1: INDISK          1                    UV file disk drive #
AIPS 1:                                      Data selection (multisource):
AIPS 1: CALSOUR       *all ' '               Calibrator sources
AIPS 1: CALCODE    ' '                       Calibrator code '*'=>all cal.
AIPS 1: QUAL            -1                   Calibrator qualifier -1=>all
AIPS 1: TIMERANG   *all 0                    Time range to use.
AIPS 1: ANTENNAS   *all 0                    Antennas to solve for. 0=all
AIPS 1: UVRANGE       0          0           Range of uv distance for full
AIPS 1:                                      weight, 0 outside.
AIPS 1: REFANT          0                    Reference antenna
AIPS 1: DOCALIB        -1                    If >0 calibrate data
AIPS 1:                                      = 2 calibrate weights
AIPS 1: GAINUSE         0                    CL table to apply, 0=> latest
AIPS 1: FLAGVER         0                    Flagtable version 0=> highest
AIPS 1: ** press RETURN for more, enter Q or next line to quit print **
#
AIPS 1: DOBAND         -1                    If >0 apply bandpass cal.
AIPS 1:                                      Method used depends on value
AIPS 1:                                      of DOBAND (see HELP file).
AIPS 1: BPVER          -1                    Bandpass table version
AIPS 1: SNVER           0                    SN table to write, 0=> create
AIPS 1:                                      new table
AIPS 1: MINAMPER       10                    Min. amplitude closure error
AIPS 1: MINPHSER       10                    Min. phase closure error
AIPS 1: FREQID         -1                    Unique frequency code
AIPS 1: DOPRINT         1                    >0 Print messages to a file
AIPS 1:                                      or to the printer.
AIPS 1: OUTPRINT      *all ' '               Printer disk file to save
>
```

A-priori calibration: Running procedures (3): **VLACALIB** on primary calibrator



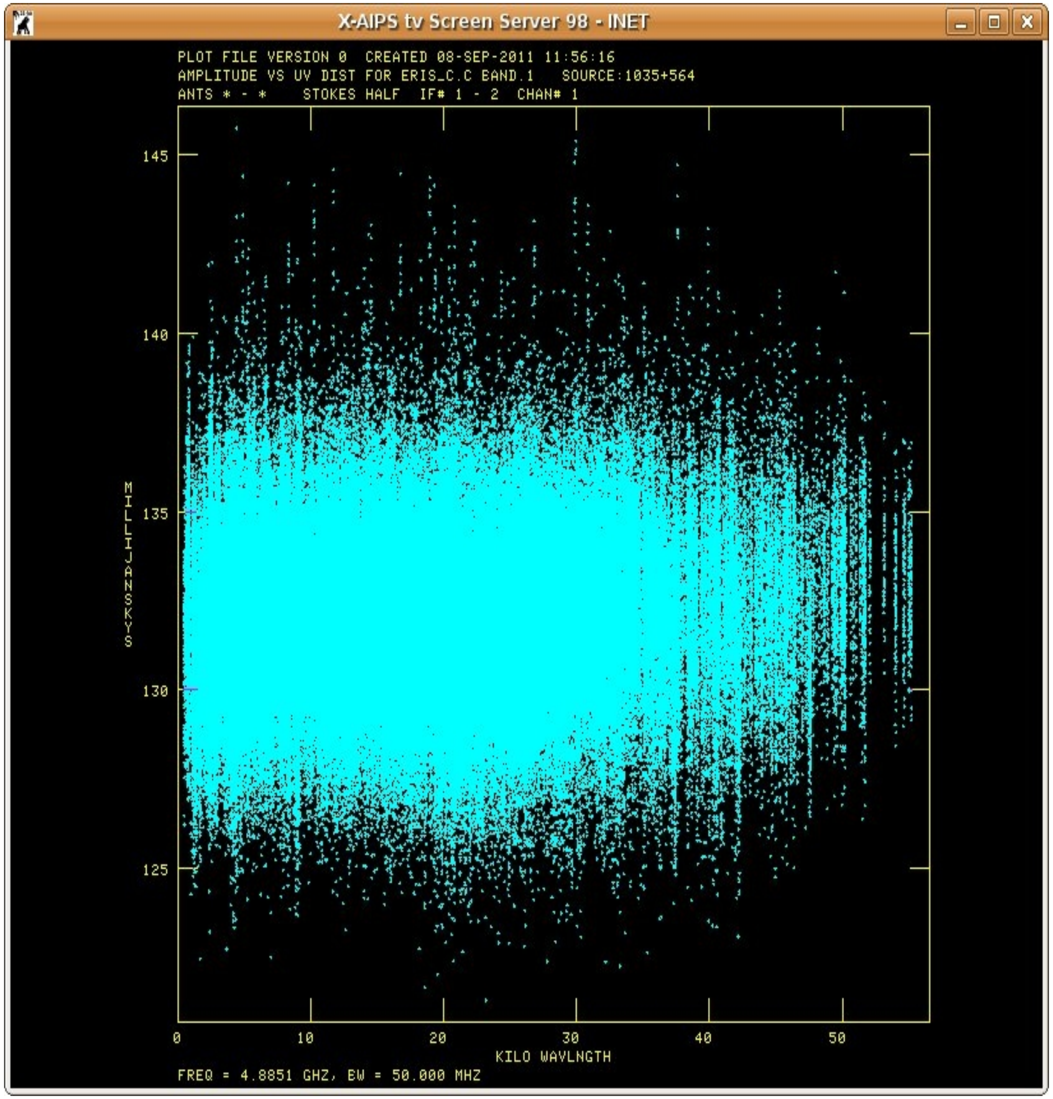

```
> calsour'1331+305' '
> uvra 0  25
> refant 24
> snver 1
> doprint -1
> dolistr -1
> go vlacalib
>
```

Eventually hit return in case everything stops !
otherwise, look at the MSGSRV

```
daniel> CALIB1: Task CALIB  (release of 31DEC08) begins
daniel> CALIB1: CALIB USING ERIS_C      . C BAND .   1 DISK=  1 USID=  11
daniel> CALIB1: UVGET: Using flag table version    1 to edit data
daniel> CALIB1: Selecting and editing the data
daniel> CALIB1: Doing cal transfer mode with point model for each source
daniel> CALIB1: This is not self-calibration
daniel> CALIB1: Dividing data by source flux densities
daniel> CALIB1: Determining solutions using amp-scalar averaging
daniel> CALIB1: Writing SN table    1
daniel> CALIB1: RPOL, IF= 1 The average gain over these antennas is  3.042E+00
daniel> CALIB1: RPOL, IF= 2 The average gain over these antennas is  3.046E+00
daniel> CALIB1: LPOL,  IF= 1 The average gain over these antennas is  3.047E+00
daniel> CALIB1: LPOL,  IF= 2 The average gain over these antennas is  3.048E+00
daniel> CALIB1: Found          108 good solutions
daniel> CALIB1: Average closure rms =  0.0009 +-  0.0001
daniel> CALIB1: No data were found > 99.0 rms from solution
daniel> CALIB1: Appears to have ended successfully
daniel> CALIB1: daniele- 31DEC08 TST: Cpu=      0.1  Real=      0  IO=        2
```

All antennas/IF/POL got good solutions (27x2x2=108). The average gain correction was about 3 and therefore to change from engineering units to physical ones, we will multiply amplitudes by about 9.
Also phase solutions have been computed, but they are not relevant for the target source (1331+305 is too far away from 3C219 to calibrate the atmospheric contribution). Solutions have been written into `SN` table 1

A-priori calibration: Running procedures (4): **VLACALIB** on secondary calibrator



> **calsour'1035+564' '**
> **uvra 0**
> **refant 24**
> **snver 1**
> **doprint -1**
> **dolistr -1**
> **go vlacalib**
> **Eventually hit return in case everything stops !**
otherwise, look at the MSGSRV

```
daniel> CALIB1: Task CALIB  (release of 31DEC08) begins
daniel> CALIB1: CALIB USING ERIS_C     . C BAND .   1 DISK=  1 USID=  11
daniel> CALIB1: UVGET: Using flag table version   1 to edit data
daniel> CALIB1: Selecting and editing the data
daniel> CALIB1: Doing cal transfer mode with point model for each source
daniel> CALIB1: This is not self-calibration
daniel> CALIB1: Dividing data by source flux densities
daniel> CALIB1: Determining solutions using amp-scalar averaging
daniel> CALIB1: Writing SN table    1
daniel> CALIB1: RPOL, IF= 1 The average gain over these antennas is  2.755E+00
daniel> CALIB1: RPOL, IF= 2 The average gain over these antennas is  2.748E+00
daniel> CALIB1: LPOL,  IF= 1 The average gain over these antennas is  2.755E+00
daniel> CALIB1: LPOL,  IF= 2 The average gain over these antennas is  2.750E+00
daniel> CALIB1: Found        1620 good solutions
daniel> CALIB1: Average closure rms =  0.0013 +-  0.0001
daniel> CALIB1: No data were found > 99.0 rms from solution
daniel> CALIB1: Appears to have ended successfully
daniel> CALIB1: daniele- 31DEC08 TST: Cpu=     0.3  Real=     1  IO=      23
```

All antennas/IF/POL got good solutions (27x2x2x number of scans). The average gain correction was ~ 2.75. In this case, since no information on the flux density was available, a reference value of 1 Jy has been used. The average value will be compared with that of the primary to get the flux density of the secondary cal as well.

Solutions have been written into `SN` table 1. Phases are relevant since the line of sight is close to that of 3C219. All the solutions of this source will be used (via interpolation) to derive corrections for the target (3C219).

In general, there could be some warning about non-closing errors at this stage. In that case some more editing may be required.

Compare solutions for primary and secondary calibrators: GETJY

Solutions for both primary and secondary are available in the same SN table. The task GETJY will compare gains and rescale solutions for the secondary aiming at obtaining also the same average gain as for 1331+305. An estimate of the secondary flux density will be given in the MSGSRV.

```
> inp getjy
AIPS 1: GETJY     Task to determine source flux densities.
AIPS 1: Adverbs     Values                    Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME      'ERIS_C'              Input UV file name (name)
AIPS 1: INCLASS     'C BAND'              Input UV file name (class)
AIPS 1: INSEQ               1             Input UV file name (seq. #)
AIPS 1: INDISK              1             Input UV file disk unit #
AIPS 1: SOURCES     '1331+305'            Source list to find fluxes
AIPS 1:           *rest ' '
AIPS 1: SOUCODE     ' '                   Source "Cal codes"
AIPS 1: CALSOUR     '1035+564'            Cal sources for calibration
AIPS 1:           *rest ' '
AIPS 1: QUAL               -1             Source qualifier -1=>all
AIPS 1: CALCODE         ' '               Calibrator code '    '=>all
AIPS 1: BIF                 0             Lowest IF number 0=1
AIPS 1: EIF                 0             Highest IF number
AIPS 1: TIMERANG    *all 0                Time range of solutions.
AIPS 1: ANTENNAS    *all 0                Antennas to use
AIPS 1: SUBARRAY            0             Subarray, 0=>all
AIPS 1: SELBAND            -1             Bandwidth to select (kHz)
AIPS 1: SELFREQ            -1             Frequency to select (MHz)
AIPS 1: FREQID             -1             Freq. ID to select.
AIPS 1: SNVER               1             Input SN table, 0=>all.
> source '1035+564''        secondary calibration source
> calsour'1331+305''        primary calibration source
> go getjy
```

```
daniel> GETJY1: Task GETJY  (release of 31DEC08) begins
daniel> GETJY1:    Source:         Qual   CALCODE IF  Flux (Jy)
daniel> GETJY1: 1035+564          :  0          A     1   1.22154 +/-   0.00099
daniel> GETJY1:                                       2   1.22815 +/-   0.00261
daniel> GETJY1: Appears to have ended successfully
daniel> GETJY1: daniele-lapt 31DEC08 TST: Cpu=       0.0  Real=      0
```

In this example, the secondary calibrator is 1.22 and 1.23 Jy in IF 1 and 2 respectively. GETJY rescaled GAIN solutions in the SN table 1.

Comparison between solutions for primary and secondary calibrators: **SNPLT**

To show solutions use `SNPLT`.

optype 'amp'

With these inputs, in one page will be provided all the solutions for each antenna.
Go through all of them and pay attention to the scatter in the amplitude values.
There should be no clear difference in the solutions for the secondary source and the primary calibrator (the very last scan).
There is a jump in the two last scans in `ANT#26, IF2, RPOL`

optype 'phas'

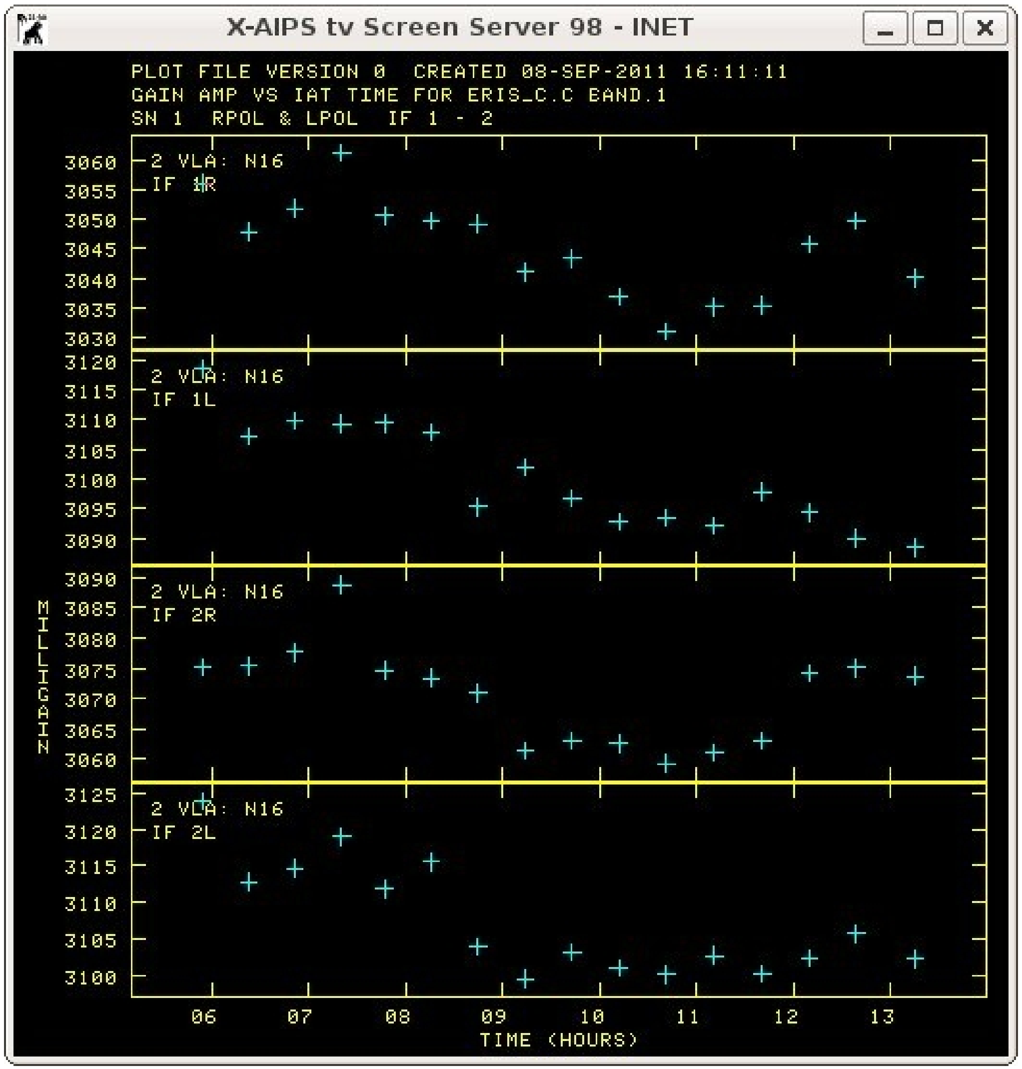
Again look at the phases. In this case, the solutions for 1331+305 may be slightly different from those of 1035+564 since they have rather different atmosphere. Since such difference is not really large, this means that at 5 GHz (for this experiment, at least!) the atmospheric contribution to the phase is quite small.
All the phases for antenna 24 are 0, since it has been chosen as reference.

Examples are given in the next page.

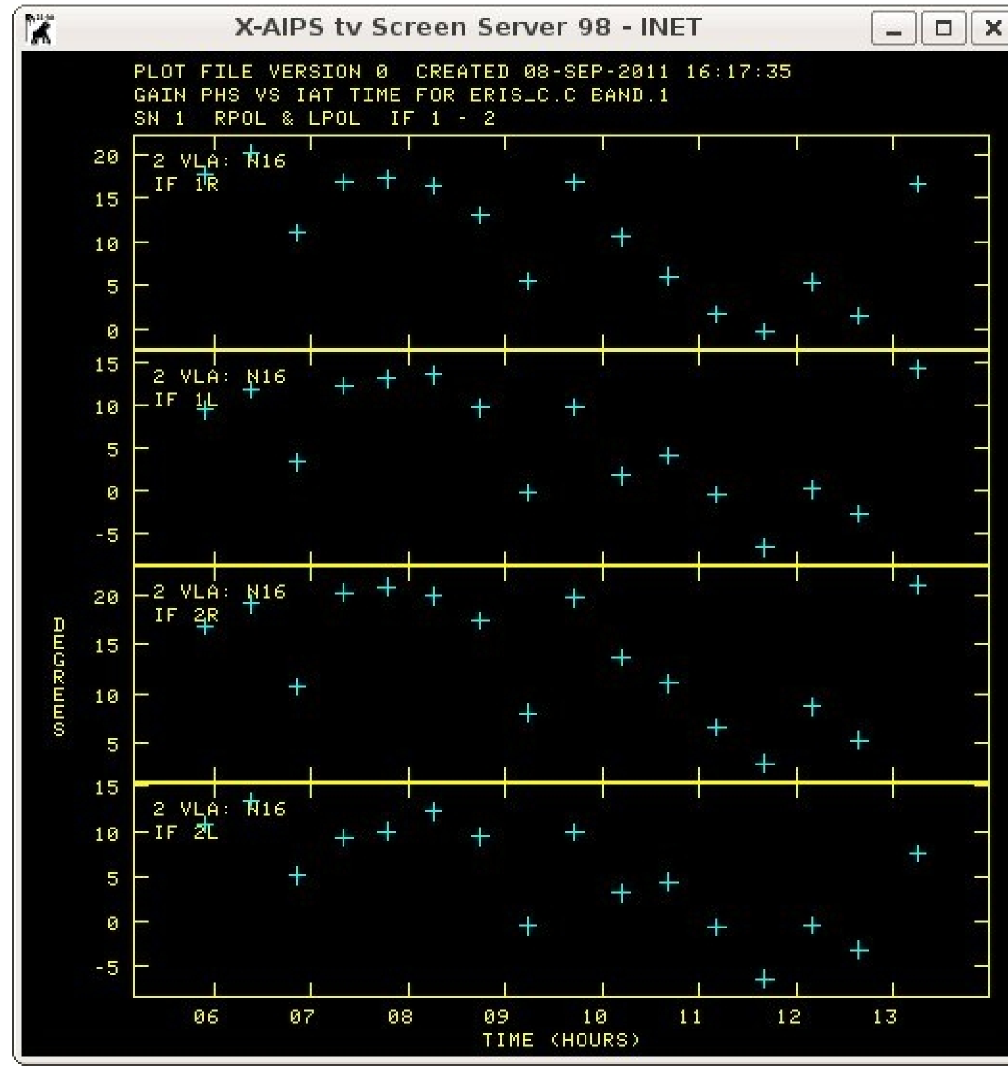
```
> inp snplt
AIPS 1: SNPLT:  Task to plot selected contents of SN, TY, PC or CL file.
AIPS 1: Adverbs     Values              Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME     'ERIS_C'             UV data (name).
AIPS 1: INCLASS    'C BAND'             UV data (class).
AIPS 1: INSEQ           1               UV data (seq. #).  0 => high
AIPS 1: INDISK          1               Disk unit #.  0 => any
AIPS 1: INEXT         'SU'              Input 'SN','TY','PC', 'CL'
AIPS 1: INVERS          0               Input table file version no.
AIPS 1: SOURCES    '1035+564'           Source list
AIPS 1:         *rest ' '
                          [omissis]
AIPS 1: STOKES     'HALF'               Stokes type to plot: R, L,
AIPS 1:                                 RR, LL, RRLL, DIFF, RATO
                          [omissis]
AIPS 1: NPLOTS          1               Number of plots per page
AIPS 1: XINC            1               Plot every XINC'th point
AIPS 1: OPTYPE     'CALC'               Data to be plotted:
AIPS 1:                                 'PHAS','AMP ','DELA','MDEL',
AIPS 1:                                 'RATE','TSYS','TANT','ATM ',
AIPS 1:                                 'GEO ','DOPL','SNR ','SUM ',
AIPS 1:                                 'CCAL','DDLY','REAL','IMAG',
AIPS 1:                                 'IFR '     ' '=phas.
                          [omissis]
AIPS 1: DOTV            1               > 0 Do plot on the TV, else
AIPS 1:                                 make a plot file
                          [omissis]
> inext'sn'         consider the SN table
> source ''         consider all sources in the SN table
> stokes''          consider both stokes (R & L)
> optype'amp'       show gain/amplitude solutions
> nplots 4          arrange 4 plots per page (1 antenna 2 Ifs 2 POLs)
> go snplt
```

Comparison between solutions for primary and secondary calibrators: **SNPLT** (2)

optyp'amp'



optyp'phas'



Amplitude solutions have % level scatter. In general phase solutions have variations of a few (a few tens of) degrees during the whole experiment. In case of very discrepant measurements some more editing may be required.

Apply solutions to get calibration table (CL): **CLCAL**

Calibration can be applied to the data via a CL table only. Therefore a new CL table must be created, where the solutions found by VLACALIB are transferred. This is done by either the procedure VLACLCAL or simply the task CLCAL.
The latter option will be illustrated.

The task mus be run twice:

The primary calibrator calibrates its own data

> **calsour'1331+305"** Source for which there are solution in the SN table
> **source '1331+305"** Source to enter calibration in the CL table (# 2)

The secondary calibrator will calibrate both its own data and the target source as well

> **calsour'1035+564"** Source for which there are solution in the SN table
> **source '1035+564"3C219'** Source to enter calibration in the CL table (# 2)

```
daniel> CLCAL1: Task CLCAL  (release of 31DEC08) begins
daniel> CLCAL1: Using interpolation mode 2PT
daniel> CLCAL1: Processing SN table    1
daniel> CLCAL1: SNMRG: Merging SN table
daniel> CLCAL1: SNMRG: Write     432 merged records from     432 input records
daniel> CLCAL1: SN2CL: Applying SN tables to CL table   1, writing CL table  2
daniel> CLCAL1: Appears to have ended successfully
daniel> CLCAL1: daniele- 31DEC08 TST: Cpu=      0.1  Real=      0  IO=        6
```

```
> inp clcal
AIPS 1: CLCAL     Task to manage SN and CL calibration tables
AIPS 1: Adverbs     Values               Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME      'ERIS_C'             Input UV file name (name)
AIPS 1: INCLASS     'C BAND'             Input UV file name (class)
AIPS 1: INSEQ             1              Input UV file name (seq. #)
AIPS 1: INDISK            1              Input UV file disk unit #
AIPS 1: SOURCES       *all ' '           Source list to calibrate
AIPS 1: SOUCODE        ' '               Source "Cal codes"
AIPS 1: CALSOUR    '1331+305'            Cal sources for calibration
AIPS 1:           *rest ' '
                        [omissis]
AIPS 1: OPCODE         ' '               Operation 'MERG','CALI',
AIPS 1:                                  'CALP'; ' ' => 'CALI'
AIPS 1: INTERPOL       ' '               Interpolation function,
AIPS 1:                                  choices are: '2PT','SIMP',
AIPS 1:                                  'AMBG','CUBE','SELF','POLY',
AIPS 1:                                  'SELN'; see HELP for details
AIPS 1: CUTOFF        0                  Interpolation limit in
AIPS 1:                                  time (min); 0=> no limit.
AIPS 1: SAMPTYPE  ' '                    Smoothing function
AIPS 1: BPARM        *all 0              Smoothing parameters
                        [omissis]
AIPS 1: SNVER             1              Input SN table, 0=>all.
AIPS 1: INVERS            0              Upper SN table vers in a
AIPS 1:                                  range.  0=>SNVER
AIPS 1: GAINVER           0              Input Cal table 0=>high
AIPS 1: GAINUSE           0              Output CAL table 0=>high+1
AIPS 1: REFANT           24              Reference antenna 0=>pick.
                        [omissis]
```

> **calsour'1331+305"** Source for which there are solution in the SN table
> **source '1331+305"** Source to enter calibration in the CL table (# 2)
> **gainver 1** Input CL table (# 1)
> **gainuse 2** Output CL table (# 2)
> **go clcal**

and look at the messages in the MSGSRV window

Apply solutions to get calibration table (CL): **CLCAL** (2)

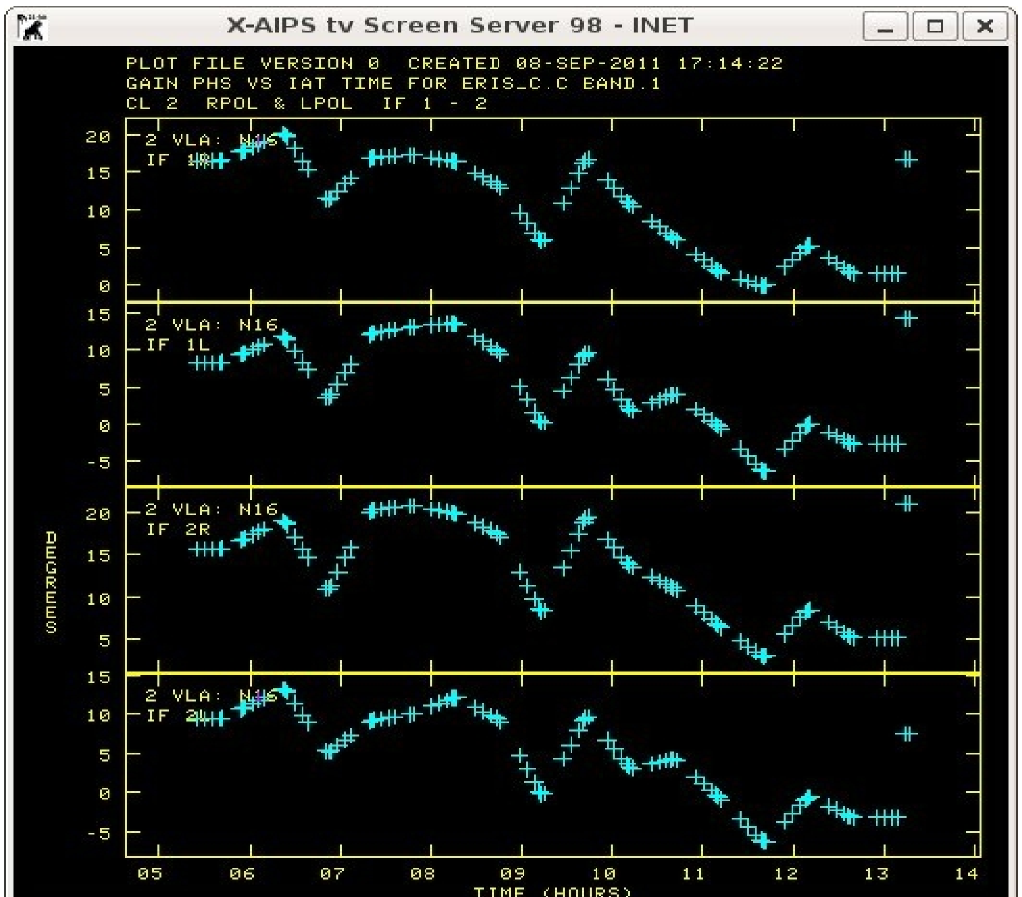
Now CL # 2 contains the calibration information for all the sources in the experiments.

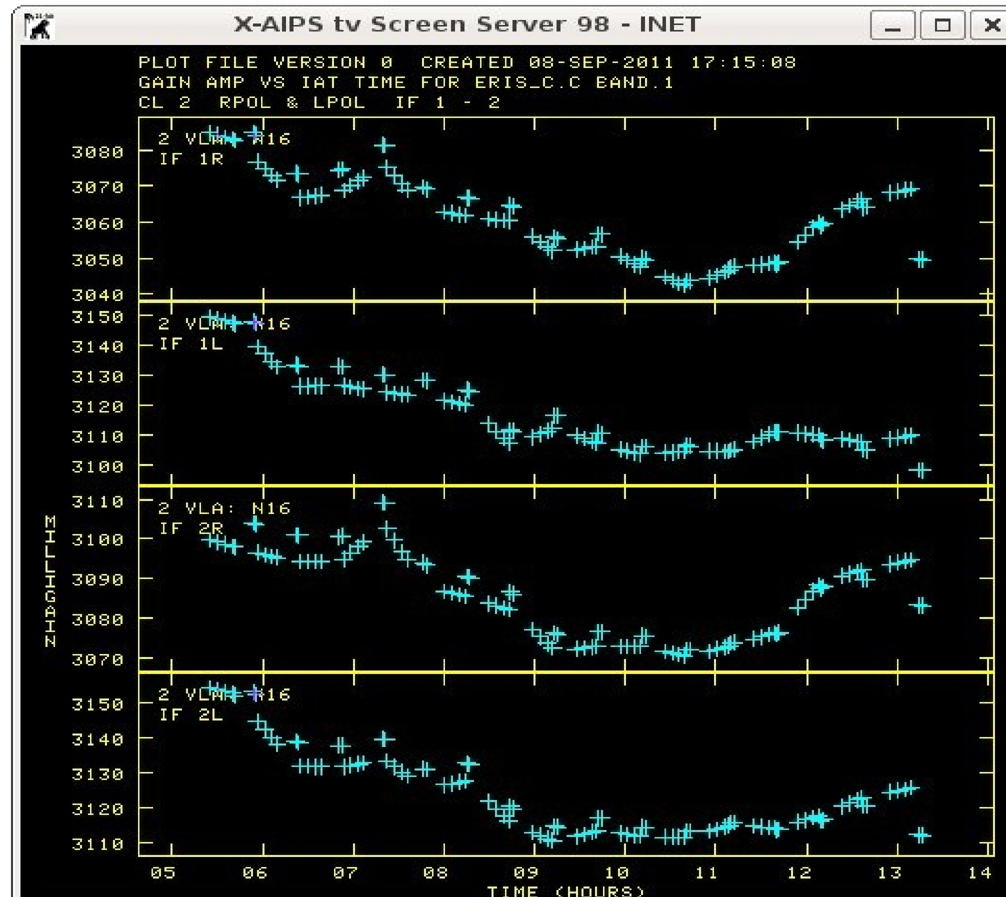
It can be inspected with SNPLT again, but with inext 'CL' instead of 'SN'

> **calsour'1035+564''** Source for which there are solution in the SN table
> **source '1035+564''3c219'** Sources to enter calibration in the CL table (# 2)
> **gainver 1** Input CL table (# 1) [already set do not change it!]
> **gainuse 2** Output CL table (# 2) [already set do not change it!]
> **go clcal**
and look at the messages in the MSGSRV window

```
daniel> CLCAL1: Task CLCAL  (release of 31DEC08) begins
daniel> CLCAL1: Using interpolation mode 2PT
daniel> CLCAL1: Processing SN table    1
daniel> CLCAL1: WARNING: SN table    1 has already been applied
daniel> CLCAL1: SNMRG: Merging SN table
daniel> CLCAL1: SNMRG: Write      432 merged records from      432 input records
daniel> CLCAL1: SN2CL: Applying SN tables to CL table   1, writing CL table  2
daniel> CLCAL1: Appears to have ended successfully
daniel> CLCAL1: daniele- 31DEC08 TST: Cpu=       0.1  Real=       0  IO=         6
```

Sample plots are given for the same antenna as before

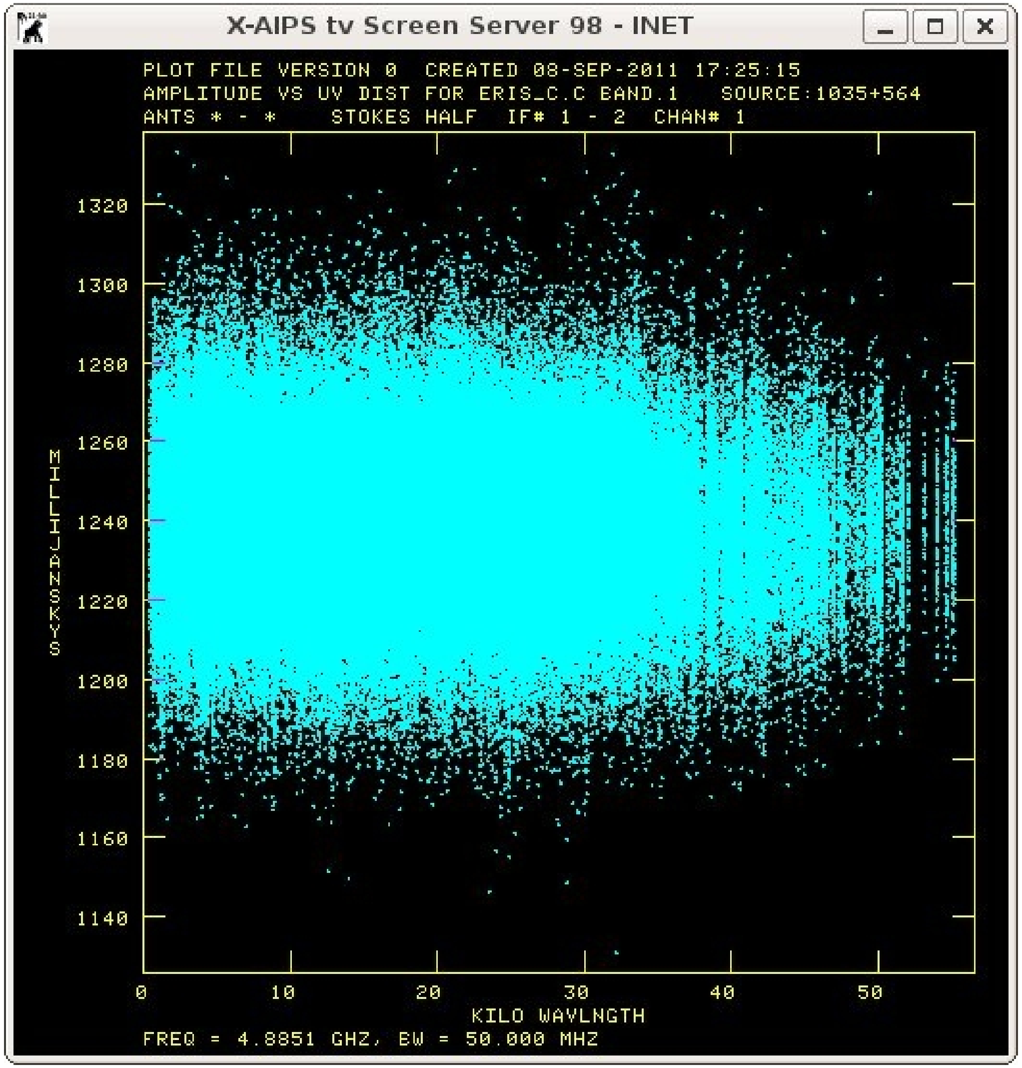


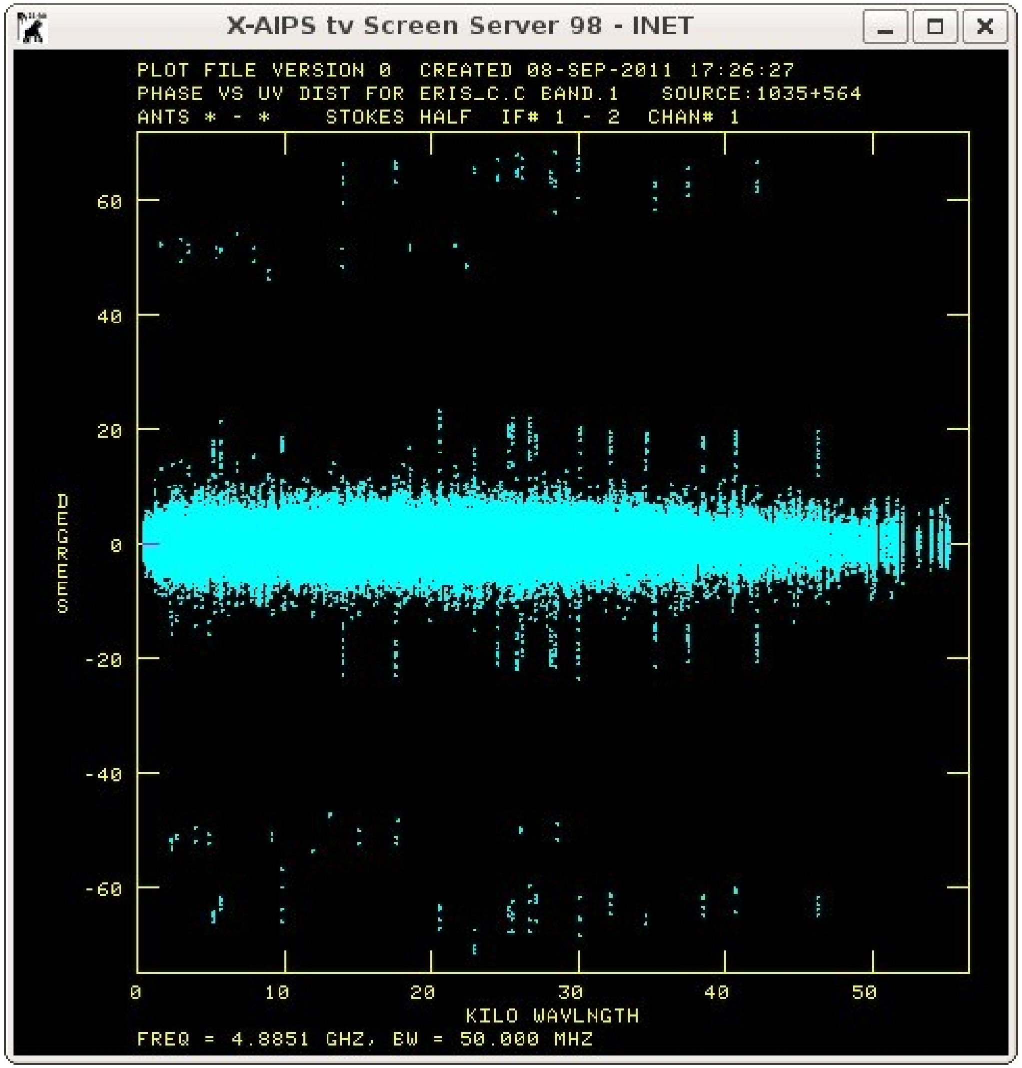


Test your calibration: **UVPLT (DOCALI 1)**, phases and amplitudes for **calibrators** and target

The same plots for the secondary calibration source that have been shown earlier, are obtained. Now CL # 2 is applied.
We must explicit DOCALI 1; GAINUSE 0 for this purpose.

BPARM 0 | **BPARM 0 2 0**



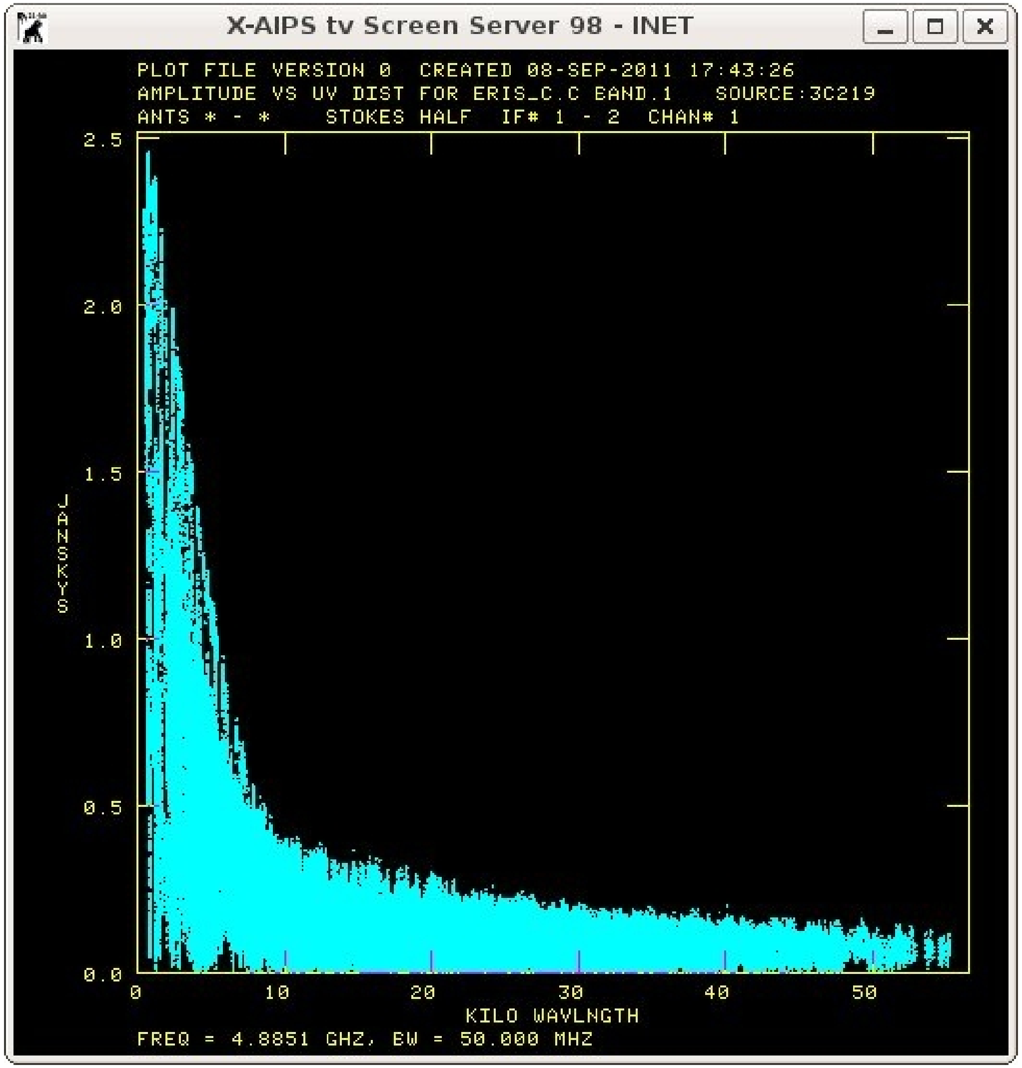


NB. Amplitudes (left) are very well behaved with a small scatter around the 1.22 average flux density given by **GETJY**. Phases (right) have some residual problem. Most of the data are OK, crowded around 0. Some editing would be required, but we will skip it, in this tutorial. These jumps are likely to be present in the target data. They will be cured by self-calibration.

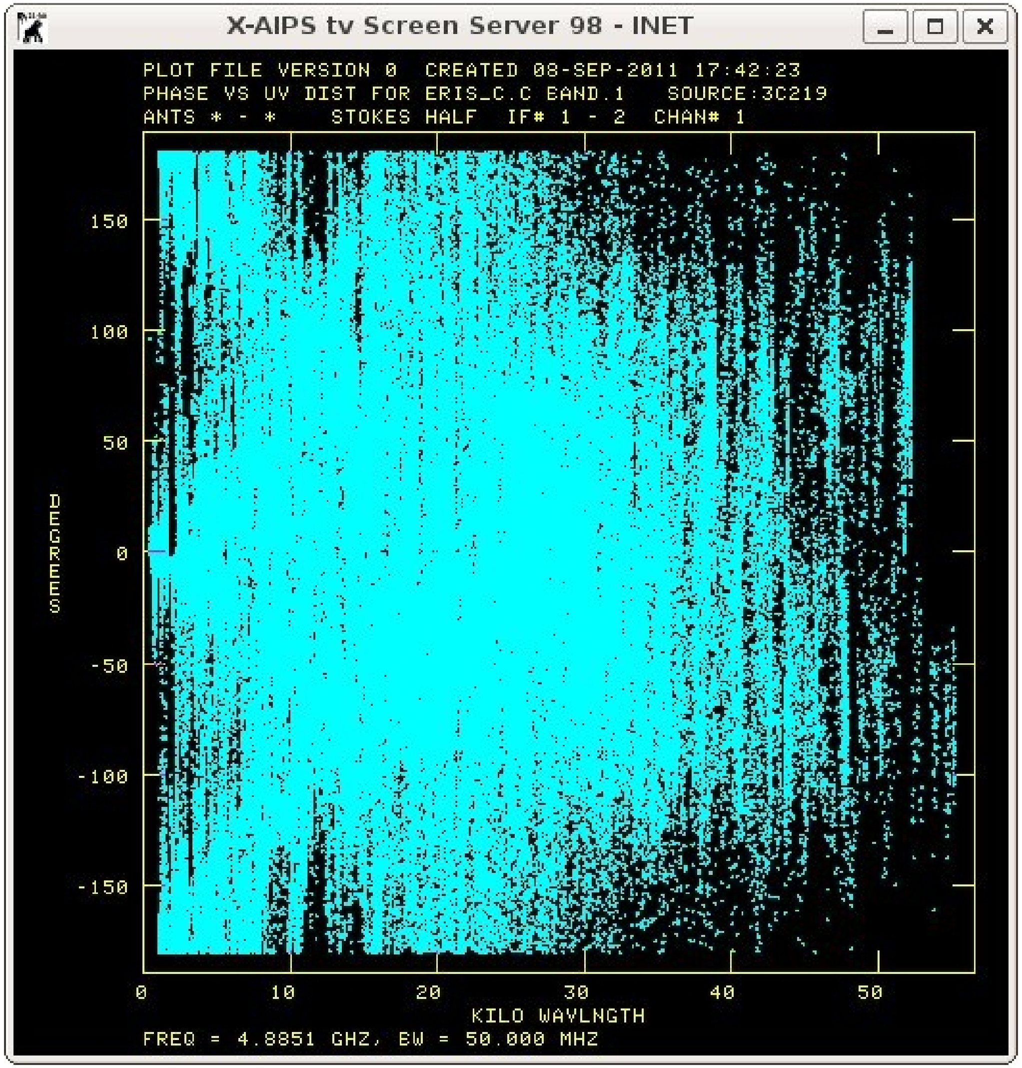
Test your calibration: **UVPLT (DOCALI 1)**, phases and amplitudes for calibrators and **target**

The same plots for the target source.

BPARM 0



BPARM 0 2 0



NB. Amplitudes (left) are very well behaved with a lot of structure. There are about 2.5 Jy on the shortest spacings, while the longest one have about 0.2 Jy only. Phases (right) confirm this! We expect a complex radio morphology, nothing to do with a point-like source!!!!

Polarization impurities: what is this?

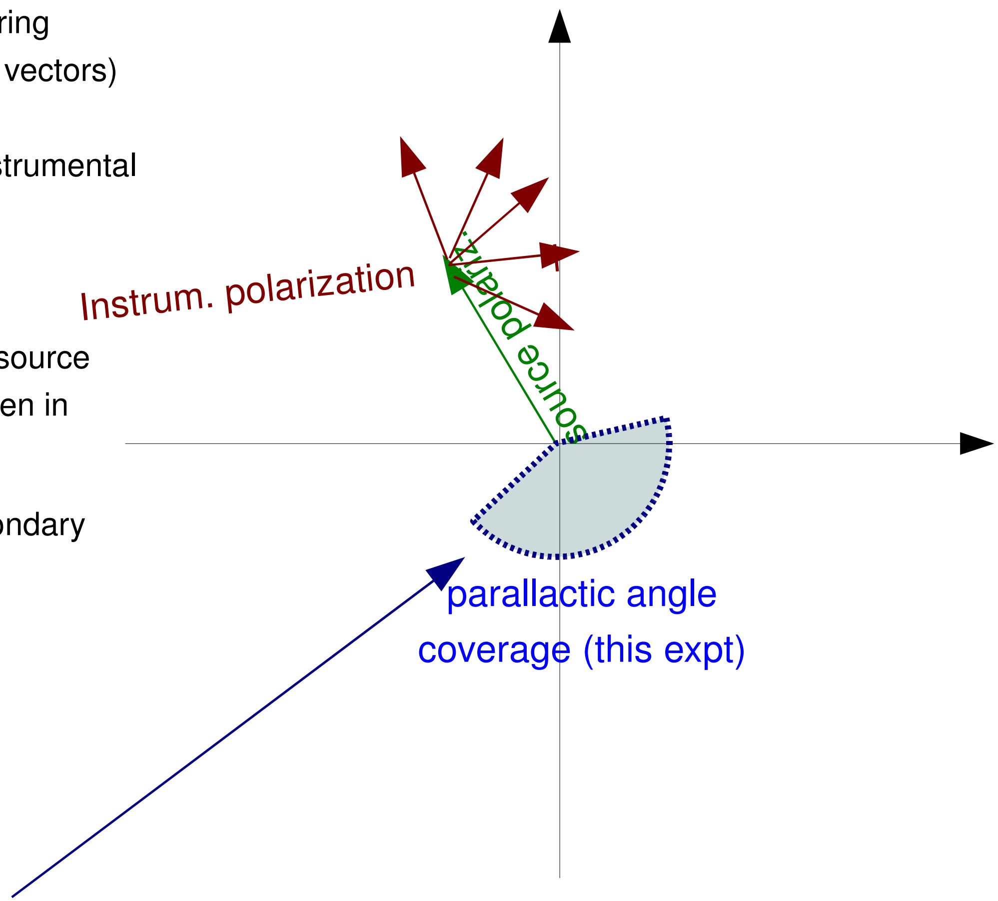
The VLA data are acquired using circular feeds. RCP and LCP however are partially contaminated by the orthogonal mode as a consequence of imperfections. These terms, known as D-terms or leakage terms can be treated as a feed characteristic which is also frequency dependent. In general these terms are of the order of 1-2 % and therefore are comparable to polarized emission which is generally a small fraction of the total intensity. They have to be removed before any polarization imaging is done. Furthermore, the present a-priori calibration, sets to 0 the phases on the reference antenna for both R and L polarizations. In this way the absolute (sky) orientation of the polarization vector is lost. It may be recovered by observing a source with known polarization angle, possibly strong!!!!

The source contribution is in the sky has a fix orientation (green vector). The instrumental polarization instead changes with time since the feed rotates (the azimuth makes the antenna rotate during the observation) and therefore the instrumental contribution (red vectors) changes with time, describing the “polarization circle”. Its centre measures the source polarization, while its radius defines the instrumental polarization term.

The orientation of the feed is known as “**parallactic angle**”

To solve this problem, ideally we would need to observe a point source over a wide range of parallactic angles (at least 120 deg. as written in the AIPS cookbook)

It is possible to look at the parallactic angle coverage of our secondary calibrator with these inputs




```
> task 'listr'
> source '1035+564'        Source(s) to consider
> inext 'cl'               Consider the  CL table
> optype 'gain'
> dparm 9 0                Show parallactic angle
> go listr
```

and look at the messages in the same input window

The parallactic angle (the same for all VLA antennas!) is very well sampled from -80 to + 130 deg, and therefore the polarization circle is very well sampled

Solve for polarization leakage (D-terms): PCAL & MSGSRV (& AN table)

Data on the secondary calibrator span a wide range of parallactic angles: on each baseline the polarization circle is well sampled. This fit and then the solution for the instrumental polarization is carried out by the task PCAL. A set of inputs is as follows:

```
> inp pcal
AIPS 1: PCAL    Task to compute polarization corrections
AIPS 1: Adverbs         Values              Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME      'ERIS_C'            Input UV file name (name)
AIPS 1: INCLASS     'C BAND'            Input UV file name (class)
AIPS 1: INSEQ              1            Input UV file name (seq. #)
AIPS 1: INDISK             1            Input UV file disk unit #
AIPS 1:                                 Data selection (multisource):
AIPS 1: CALSOUR     '1035+564'          Sources to calibrate with
AIPS 1:             *rest ' '
                        [omissis]
AIPS 1: TIMERANG     *all 0             Time range to use.
AIPS 1: DOCALIB            1            > 0 calibrate data & weights
AIPS 1:                                 > 99 do NOT calibrate weights
AIPS 1: GAINUSE     0                   CAL table to apply.
                        [omissis]
AIPS 1: PMODEL       *all 0             Source poln. model
AIPS 1: SOLINT             0            Soln. interval (min) 0=>10.
AIPS 1: SOLTYPE          ' '            Solution type:
AIPS 1:                                 'ORI-', 'APPR', 'RAPR'
AIPS 1: PRTLEV            0             Print statistics 0=>none
AIPS 1:                                 1 = some, 2 = lots. Use 1.
AIPS 1: REFANT            0             Reference antenna, 0->pick
AIPS 1: BPARM        *all 0             Task enrichment parameters
AIPS 1:                                 for SOLTYPE 'ORI-' only:
                        [omissis]
> gainuse 2          with DOCALI 1, applies CL table 2
> soltyp'appr'       linear approximation is selected
> prtlev 1           some feedback in the MSGSRV
> refant 24          reference antenna
> go pcal                and look at the messages in the same input window
```

```
daniel> PCAL 1: Task PCAL   (release of 31DEC08) begins
daniel> PCAL 1: Processing IF number    1
daniel> PCAL 1: UVGET: Using flag table version   1 to edit data
daniel> PCAL 1: RMS residual =   4.499E-05 DOF =10198.88
daniel> PCAL 1: Interferometer Element   1
daniel> PCAL 1:   R: Amp =  0.00854+/- 0.00040 Phase(deg) =  172.16+/-   1.92
daniel> PCAL 1:   L: Amp =   0.00788+/- 0.00040 Phase(deg) =  -29.26+/-   2.07
daniel> PCAL 1: Interferometer Element   2
daniel> PCAL 1:   R: Amp =  0.00282+/- 0.00040 Phase(deg) =    3.27+/-   5.74
daniel> PCAL 1:   L: Amp  =  0.00512+/- 0.00040 Phase(deg) = -170.13+/-   3.16
daniel> PCAL 1: Interferometer Element   3
                              [omissis]
daniel> PCAL 1: Interferometer Element  29
daniel> PCAL 1:   R: Amp =  0.00000+/- 0.00024 Phase(deg) =    0.00+/-   0.00
daniel> PCAL 1:   L: Amp =   0.00000+/- 0.00024 Phase(deg) =    0.00+/-   0.00
daniel> PCAL 1: Calibration source    1
daniel> PCAL 1:   Q+iU=(  -0.00015,  -0.00037) +/- (  0.000046,  0.000046) Jy
daniel> PCAL 1:   Pol. inten. =   0.00040 +/-  0.000065 Jy, angle = -56.31 +/-  3.286 deg
daniel> PCAL 1: 1035+564       I,Q,U,V =    1.2215 -0.00015 -0.00037  0.00000 Jy
daniel> PCAL 1: Processing IF number    2
daniel> PCAL 1: RMS residual =   4.610E-05 DOF =10186.82
daniel> PCAL 1: Interferometer Element   1
daniel> PCAL 1:   R: Amp =  0.00307+/- 0.00041 Phase(deg) =  171.35+/-   5.46
daniel> PCAL 1:   L: Amp =   0.00930+/- 0.00041 Phase(deg) =   20.56+/-   1.79
                              [omissis]
daniel> PCAL 1: Calibration source    1
daniel> PCAL 1:   Q+iU=(  -0.00007,  -0.00019) +/- (  0.000047,  0.000047) Jy
daniel> PCAL 1:   Pol. inten. =   0.00020 +/-  0.000066 Jy, angle = -55.27 +/- 6.649 deg
daniel> PCAL 1: 1035+564        I,Q,U,V =    1.2281 -0.00007 -0.00019  0.00000 Jy
daniel> PCAL 1: Appears to have ended successfully
daniel> PCAL 1: daniele- 31DEC08 TST: Cpu=      0.4  Real=      0  IO=        31
```

Solve for polarization leakage (D-terms): **PCAL** & **MSGSRV** (& AN table) (2)

A few comments on the PCAL. output.
There is info on:

- fit residuals (the smallest the best!)
- feed polarization parametrization. Such info is written onto the AN table. Leakage terms have amplitudes around 1%.
- also source polarization parameters have been derived. The secondary calibrator is roughly unpolarized
- information has been derived for both IF1 and IF2 individually
- instrumental polarization can be removed with the parameter DOPOL 1
- at the moment the absolute orientation of the electric vector is undetermined

Now we are looking after this last bit of calibration.

There is a procedure, RLDIF, that does the work for you!

```
daniel> PCAL 1: Task PCAL   (release of 31DEC08) begins
daniel> PCAL 1: Processing IF number    1
daniel> PCAL 1: UVGET: Using flag table version   1 to edit data
daniel> PCAL 1: RMS residual =   4.499E-05 DOF =10198.88
daniel> PCAL 1: Interferometer Element   1
daniel> PCAL 1:   R: Amp =  0.00854+/- 0.00040 Phase(deg) =  172.16+/-   1.92
daniel> PCAL 1:   L: Amp =   0.00788+/- 0.00040 Phase(deg) =  -29.26+/-   2.07
daniel> PCAL 1: Interferometer Element   2
daniel> PCAL 1:   R: Amp =  0.00282+/- 0.00040 Phase(deg) =    3.27+/-   5.74
daniel> PCAL 1:   L: Amp  =  0.00512+/- 0.00040 Phase(deg) = -170.13+/-   3.16
daniel> PCAL 1: Interferometer Element   3
                              [omissis]
daniel> PCAL 1: Interferometer Element  29
daniel> PCAL 1:   R: Amp =  0.00000+/- 0.00024 Phase(deg) =    0.00+/-   0.00
daniel> PCAL 1:   L: Amp =   0.00000+/- 0.00024 Phase(deg) =    0.00+/-   0.00
daniel> PCAL 1: Calibration source   1
daniel> PCAL 1:   Q+iU=(  -0.00015,  -0.00037) +/- (  0.000046,  0.000046) Jy
daniel> PCAL 1:   Pol. inten. =   0.00040 +/-  0.000065 Jy, angle = -56.31 +/-  3.286 deg
daniel> PCAL 1: 1035+564       I,Q,U,V =   1.2215 -0.00015 -0.00037  0.00000 Jy
daniel> PCAL 1: Processing IF number    2
daniel> PCAL 1: RMS residual =   4.610E-05 DOF =10186.82
daniel> PCAL 1: Interferometer Element   1
daniel> PCAL 1:   R: Amp =  0.00307+/- 0.00041 Phase(deg) =  171.35+/-   5.46
daniel> PCAL 1:   L: Amp =   0.00930+/- 0.00041 Phase(deg) =   20.56+/-   1.79
                              [omissis]
daniel> PCAL 1: Calibration source   1
daniel> PCAL 1:   Q+iU=(  -0.00007,  -0.00019) +/- (  0.000047,  0.000047) Jy
daniel> PCAL 1:   Pol. inten. =   0.00020 +/-  0.000066 Jy, angle = -55.27 +/- 6.649 deg
daniel> PCAL 1: 1035+564        I,Q,U,V =   1.2281 -0.00007 -0.00019  0.00000 Jy
daniel> PCAL 1: Appears to have ended successfully
daniel> PCAL 1: daniele- 31DEC08 TST: Cpu=      0.4  Real=      0  IO=       31
```

Absolute orientation of the electric vector (either `LISTR-RLDIF` & `CLCOR`)

The important numbers are the vector matrix averages. they measure the L – R systems phase difference for 1331+305, which is unresolved in the uv-range 0 25 kλ. Ideally all these numbers should be the same in the same IF. In this example the average is 156.31 and 54.09 deg for IF1 and 2 respectively. This phase measures twice the intrinsic polarization angle of the source. 1331+305 (3C286) is about 10% polarized with a position angle of 33 deg (at all cm/dm wavelengths). It corresponds to a value of 66 deg in this output.

```
> source'1331+305'' ; dopol 1
> uvra 0 25       the source is unresolved in this uv-range
> inp rldif
AIPS 1: RLDIF:  Task to return Right - Left phase difference
AIPS 1: Adverbs        Values              Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: USERID            0               User number.
AIPS 1: INNAME      'ERIS_C'              UV data (name).
AIPS 1: INCLASS    'C BAND'               UV data (class).
AIPS 1: INSEQ             1               UV data (seq. #).  0 => high
AIPS 1: INDISK            1               Disk unit #.      0 => any
AIPS 1: SOURCES     '1331+305'            Source list
AIPS 1:          *rest ' '
                       [omissis]
AIPS 1: UVRANGE      0        25       UV range in kilolambda
                       [omissis]
> go rldif                    and look at the messages in the same input window
 daniele-  RLDIF(31DEC08)    11    09-SEP-2011  00:27:54    Page    1
ERIS_C      .C BAND.   1  Vol= 1  User=   11  Channel=   1  IF=   1
Freq=  4.885100000 GHz   Ncor=  4   No. vis=      5782
Stokes = FULL Subarray =    1
Applying calibration table   2              Applying polarization corrections
Applying flag table   1
                        [omissis]
   follows next column
```

```
 Flux =  7.4620 Jy, Calcode = C   , Freq =  4.885100000 GHz, IF =  1
Phases in degrees, averaging type = Vector
RL in upper right, conjg(LR) in lower left

Ant -- 1-- 2-- 3-- 4-- 5-- 6-- 7-- 8-- 9--10--11--12--13--14--15--16--17--18
  1|           154                  156        158        156 156
  2|       156      156     157 156     157 156         156 156
  3|     155      156 158 157 156 156 156 157 157          157 156      157
  4|  156       156      155 155 156 155 156 156 156      156 157 154 157 157
                                [omissis]
28| 157      156 156 157 156 156 155
Ampscalar average of matrix  =    156.31(  0.037) sigma =  0.784
Vector average of upper data =    156.34          sigma =  2.722
Vector average of lower data =    156.27          sigma =  2.646

Time =    0/13:13:55 to   0/13:16:45   Source = 1331+305        : 0000
Flux =  7.5100 Jy, Calcode = C   , Freq =  4.835100000 GHz, IF =  2
Phases in degrees, averaging type = Vector
RL in upper right, conjg(LR) in lower left

Ant -- 1-- 2-- 3-- 4-- 5-- 6-- 7-- 8-- 9--10--11--12--13--14--15--16--17--18
  1|              52                    52         53          53  53
  2|          55        54      55  56      56  56          54  56
  3|      56        56  54  56  55  57  55  56  56          55  56      56
  4|  54        53      53  53  54  54  53  54  53       54  54  53  55  54
                                [omissis]
 28|  56       55   54  53  54  53  53
Ampscalar average of matrix  =    54.09(  0.035) sigma =  0.752
Vector average of upper data =    54.18          sigma =  2.286
Vector average of lower data =    53.96          sigma =  2.215
AIPS 1: Resumes
>
```

Absolute orientation of the electric vector (either LISTR-RLDIF & CLCOR) (2)

156.31 requires -90.31 to be set to 66 deg for IF1, while 54.09 needs +11.91 for IF2. These corrections measure the R – L phase difference on the reference antenna. After this correction is entered in the CL table and also all the corrections of the antenna table are consequently updated, the polarization calibration is over, and the dataset has the a-priori calibration fully exploited. Such corrections are applied by the task CLCOR:

```
> source''           the correction will be applied to all sources
> stokes 'l'
> opco 'polr'
> clcorprm -90.3067 11.9146
> gainver 2
> gainuse 3
> inp clcor
AIPS 1: CLCOR     Task which applies various corrections to CL tables.
AIPS 1: Adverbs     Values               Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME     'ERIS_C'            Input UV file name (name)
AIPS 1: INCLASS    'C BAND'            Input UV file name (class)
AIPS 1: INSEQ        1                 Input UV file name (seq. #)
AIPS 1: INDISK       1                 Input UV file disk unit #
AIPS 1: SOURCES     *all ' '           Source list ' '=>all.
AIPS 1: STOKES      'L'                Stokes type to process

AIPS 1: GAINVER      2                 Input CL table 0=>high
AIPS 1: GAINUSE      3                 Output CL table: not =
AIPS 1:                            GAINVER -> high+1
AIPS 1: OPCODE     'POLR '             Operation code.
AIPS 1: CLCORPRM    -90.3067     11.9146  Parameters (see HELP CLCOR).
AIPS 1:          *rest 0
> go clcor
   next column shows the summary of rldif
```

```
> tget rldif
> gainu 0
> go rldif
                          [omissis]
  28|  67     65  66  67  66  66  64
Ampscalar average of matrix  =    66.00(  0.016) sigma =  0.349
Vector average of upper data =    66.04        sigma =  2.714
Vector average of lower data =    65.96        sigma =  2.639
                          [omissis]
 28|  67     67  66  65  66  65  64
Ampscalar average of matrix  =    66.00(  0.024) sigma =  0.522
Vector average of upper data =    66.09        sigma =  2.472
Vector average of lower data =    65.87        sigma =  2.400
AIPS 1: Resumes
>
>    IF1 and 2 appear perfectly calibrated
```

SPLIT your data

The multi-source dataset is now fully calibrated. Calibration is in the `CL` and `AN` tables. It is time to `SPLIT` the data into single source files, applying the calibration parameters derived so far.

```
> inp split
AIPS 1: SPLIT     Task to split multi-source uv data to single source
AIPS 1: Adverbs           Values              Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1:                                        also works on single files.
AIPS 1: INNAME       'ERIS_C'                  Input UV file name (name)
AIPS 1: INCLASS      'C BAND'                  Input UV file name (class)
                        [omissis]
AIPS 1: SOURCES      '1331+305'                Source list
AIPS 1:              *rest ' '
                        [omissis]
AIPS 1: STOKES          'L'                    Stokes type to pass.
                        [omissis]
AIPS 1: DOCALIB          1                     > 0 calibrate data & weights
AIPS 1:                                        > 99 do NOT calibrate weights
AIPS 1: GAINUSE          0                     CL (or SN) table to apply
AIPS 1: DOPOL            1                     If >0 correct polarization.
AIPS 1: BLVER           -1                     BL table to apply.
AIPS 1: FLAGVER          1                     Flag table version
AIPS 1: DOBAND          -1                     If >0 apply bandpass cal.
AIPS 1: APARM          0        10             Control information:
AIPS 1:              *rest 0                   1 = 1 => avg. freq. in IF
AIPS 1:                                        multi-channel out
AIPS 1:                                        = 2 => avg. freq. in IF
AIPS 1:                                        single channel out
AIPS 1:                                        = 3 => avg IF's also
AIPS 1:                                        2 = Input avg. time (sec)
AIPS 1:                                        3 > 0 => Drop subarrays
                        [omissis]
> source ' '        all sources will be extracted
> stokes ' '        full polarization data will be extracted
> docalib 1         apply the CL table
```

go to next column

```
> gainuse 3         apply the CL table # 3
> dopol 1           apply instrumental polarization calibration
> flagver 1         apply the flags in FG table # 1
> aparm 0  10 0     data have 10 sec integrations and will not be
                    averaged (either time or freq)
> go split
```

```
daniel> SPLIT1: Task SPLIT  (release of 31DEC08) begins
daniel> SPLIT1: You are using a non-standard program
daniel> SPLIT1: Doing subarray  1
daniel> SPLIT1: UVGET: Using flag table version   1 to edit data
daniel> SPLIT1: Create 3C219       .SPLIT .   1 (UV)  on disk  1  cno    2
daniel> SPLIT1: Applying CL Table version    3
daniel> SPLIT1:            Previously flagged   flagged by gain       kept
daniel> SPLIT1: Partially            184               0                 184
daniel> SPLIT1: Fully                  0               0              456505
daniel> SPLIT1: Copied AN file from vol/cno/vers  1    1   1 to  1    2   1
daniel> SPLIT1: Copied WX file from vol/cno/vers  1    1   1 to  1    2   1
daniel> SPLIT1: Copied OF file from vol/cno/vers  1    1   1 to  1    2   1
daniel> SPLIT1: Create 1035+564    .SPLIT .   1 (UV)  on disk  1  cno    3
daniel> SPLIT1:            Previously flagged   flagged by gain       kept
daniel> SPLIT1: Partially             87               0                  87
daniel> SPLIT1: Fully                  0               0               67615
daniel> SPLIT1: Copied AN file from vol/cno/vers  1    1   1 to  1    3   1
daniel> SPLIT1: Copied WX file from vol/cno/vers  1    1   1 to  1    3   1
daniel> SPLIT1: Copied OF file from vol/cno/vers  1    1   1 to  1    3   1
daniel> SPLIT1: Create 1331+305    .SPLIT .   1 (UV)  on disk  1  cno    4
daniel> SPLIT1:            Previously flagged   flagged by gain       kept
daniel> SPLIT1: Partially              0               0                   0
daniel> SPLIT1: Fully                  0               0                5782
daniel> SPLIT1: Copied AN file from vol/cno/vers  1    1   1 to  1    4   1
daniel> SPLIT1: Copied WX file from vol/cno/vers  1    1   1 to  1    4   1
daniel> SPLIT1: Copied OF file from vol/cno/vers  1    1   1 to  1    4   1
daniel> SPLIT1: Appears to have ended successfully
```

SPLIT your data (2)

Now there are 3 new files in your catalogue. They have extension 'SPLIT' from the task which generated them. They can be inspected with UVPLT, for example. Remember to switch off calibration now (DOCALI -1 ; DOPOL -1).

```
> uc
AIPS 1: Catalog on disk  1
AIPS 1:  Cat Usid Mapname      Class   Seq  Pt     Last access      Stat
AIPS 1:    1   11 ERIS_C       .C BAND.     1 UV 09-SEP-2011 09:49:29
AIPS 1:    2   11 3C219        .SPLIT .     1 UV 09-SEP-2011 09:49:28
AIPS 1:    3   11 1035+564     .SPLIT .     1 UV 09-SEP-2011 09:49:29
AIPS 1:    4   11 1331+305     .SPLIT .     1 UV 09-SEP-2011 09:49:29
>
```

The MSGSRV info from split (previous page), informed us that the primary calibration source has a relatively small number of visibilities (5782), since was observed in a single snapshot at the end of the experiment. The secondary calibration source has 67615 visibilities (87 were flagged by us!), while the target source, 3C219, has 456505 visibilities. For each visibility there are 8 complex entries (phase and amplitude for IF1 and IF2, RR, LL, RL and LR).

The reader/user is invited to try UVPLOT of any of these, selected just with STOKES 'RL'; STOKES'LR'; STOKES 'Q' ; ...
In case amplitudes are considered:

- STOKES 'RL' & STOKES 'LR' will be just noise for the secondary, while there will be signal for the primary (and the target!)

- STOKES 'U' & STOKES 'Q' will be just noise for the secondary, while there will be signal for the primary (and the target!)

- STOKES 'V' will be noise for all sources!

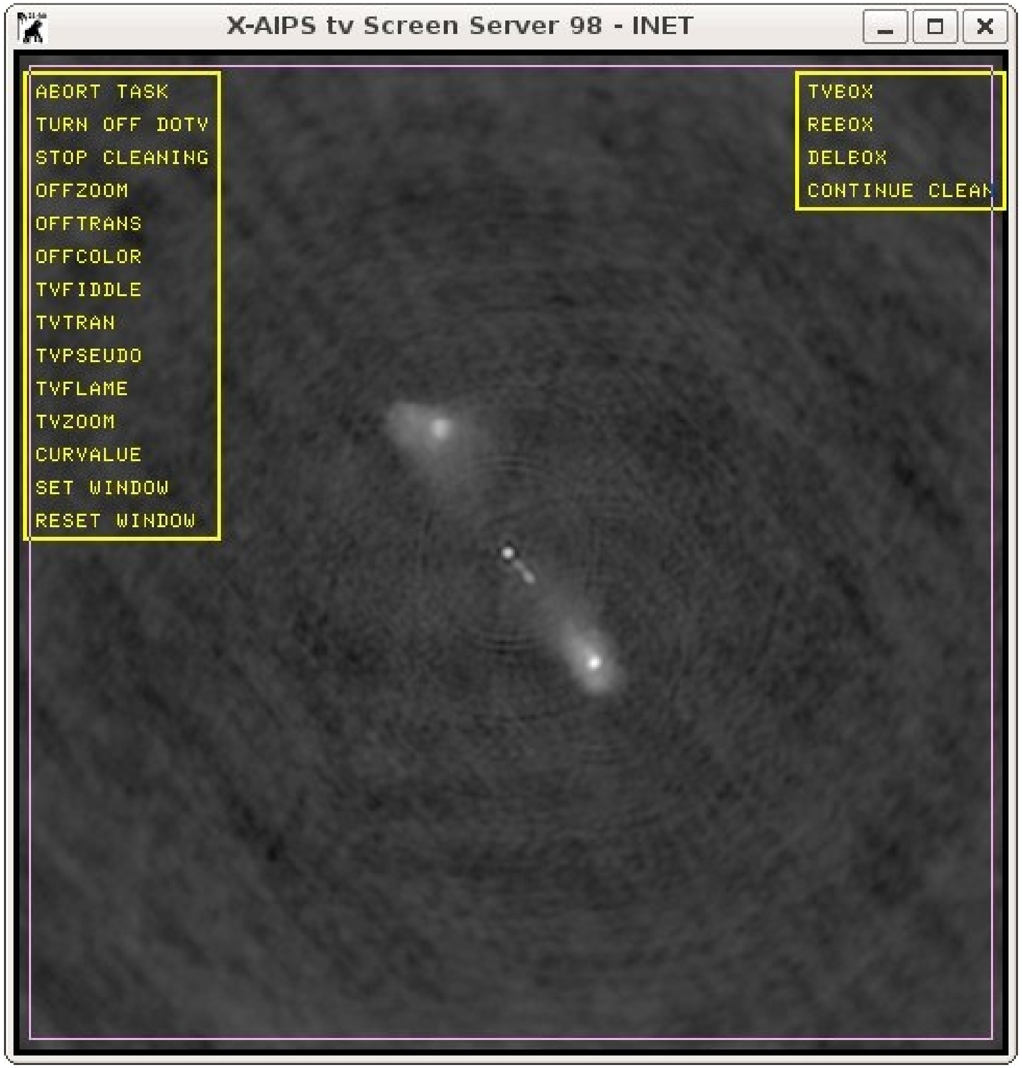
This tutorial ends here, but......

if you can't wait for the next tutorial on imaging, here you are a few, basic hints on how to make your sky image.....

Map your primary calibration source; map your secondary calibration source: IMAGR (1)

imaging is carried out by the task IMAGR, which has a large amount of parameters. The meaning of some of them is left to the reader to find out their meaning for most of them. The imaging of calibration sources will be just skipped but it may be done in the same way as the target source.

> **docali -1**	switch off calibration
> **dopol -1**	switch of pol calibr
> **minpatch 127**	patch of the beam to be used in the first coarse subtraction
> **factor -1**	size of 1” (expected HPBW of about 4”)
> **cellsi 1 1**	pixelsize of 1” (expected HPBW of about 4”)
> **imsize 512 512**	image size of 512 pixles (adequate for FoV and source size)
> **niter 30000**	maximum number of clean components CC to be found
> **getn 2**	
AIPS 1: Got(1) disk= 1 user= 11 type=UV 3C219.SPLIT.1	
> **inp imagr**	
> **go imagr**	and then have a look to the AIPS TV screen and to the MSGSRV

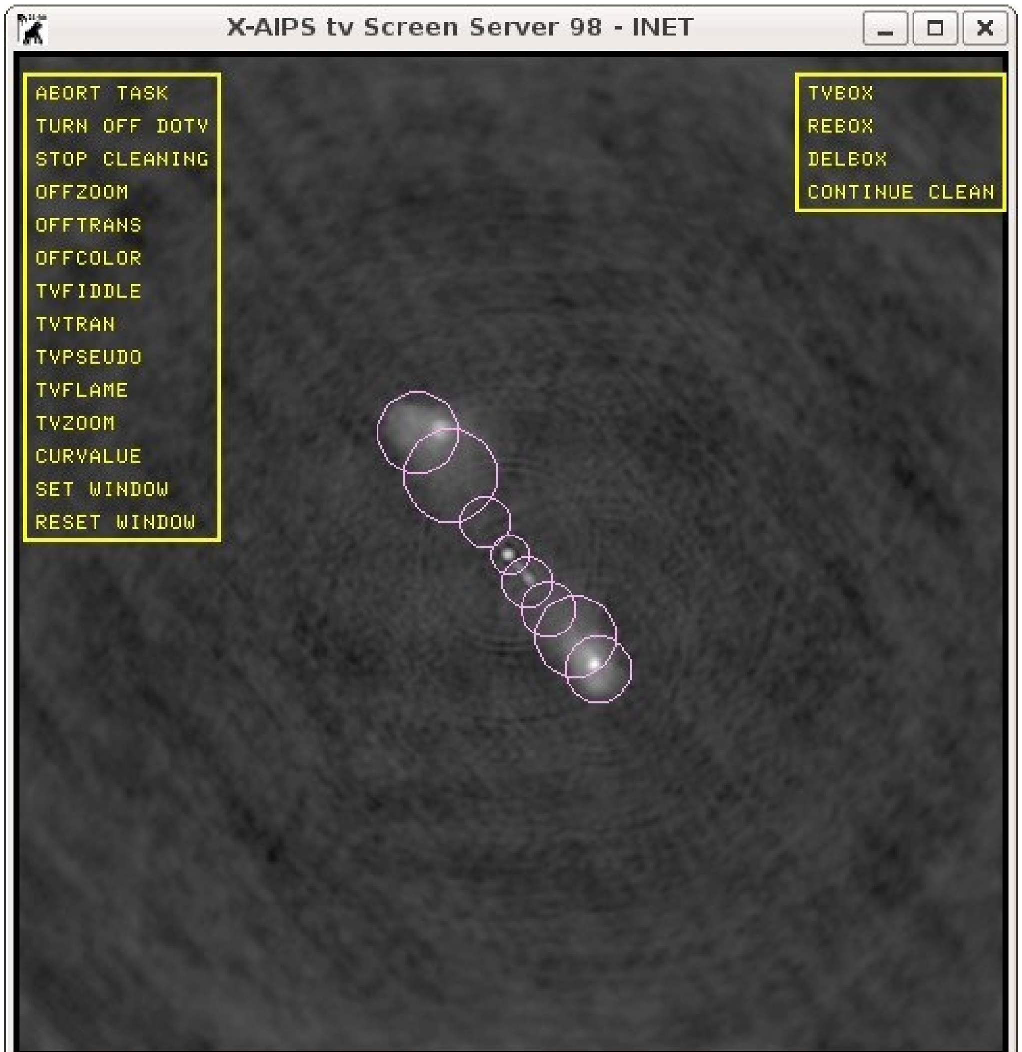


The dirty image of the target source is shown, along with a menu of possible clean actions that can be activated by clicking on any of them and then hitting button A, B or C.

In this example we will use clean boxes. The default clean area is delimited by the pink square in the image. It will be removed by clicking the `TVBOX` option and then a sequence of C and A buttons to set the round boxes visible in the next figure.

Map your primary calibration source; map your secondary calibration source: IMAGR (2)

The MSGSRV tells us that the dirty beam and clean image have been created (catalogue entries 5 and 6 respectively). A Gaussian fit to the beam provided a FWHM= 3.954 x 3.749 arcsec, PA= 85.2 ° with Beam min = -40.8 MilliJy, max = 1.0 Jy (it is normalized!) and the dirty image has a minimum/maximum peak of -3.6 / 93.1 MilliJy respectively.



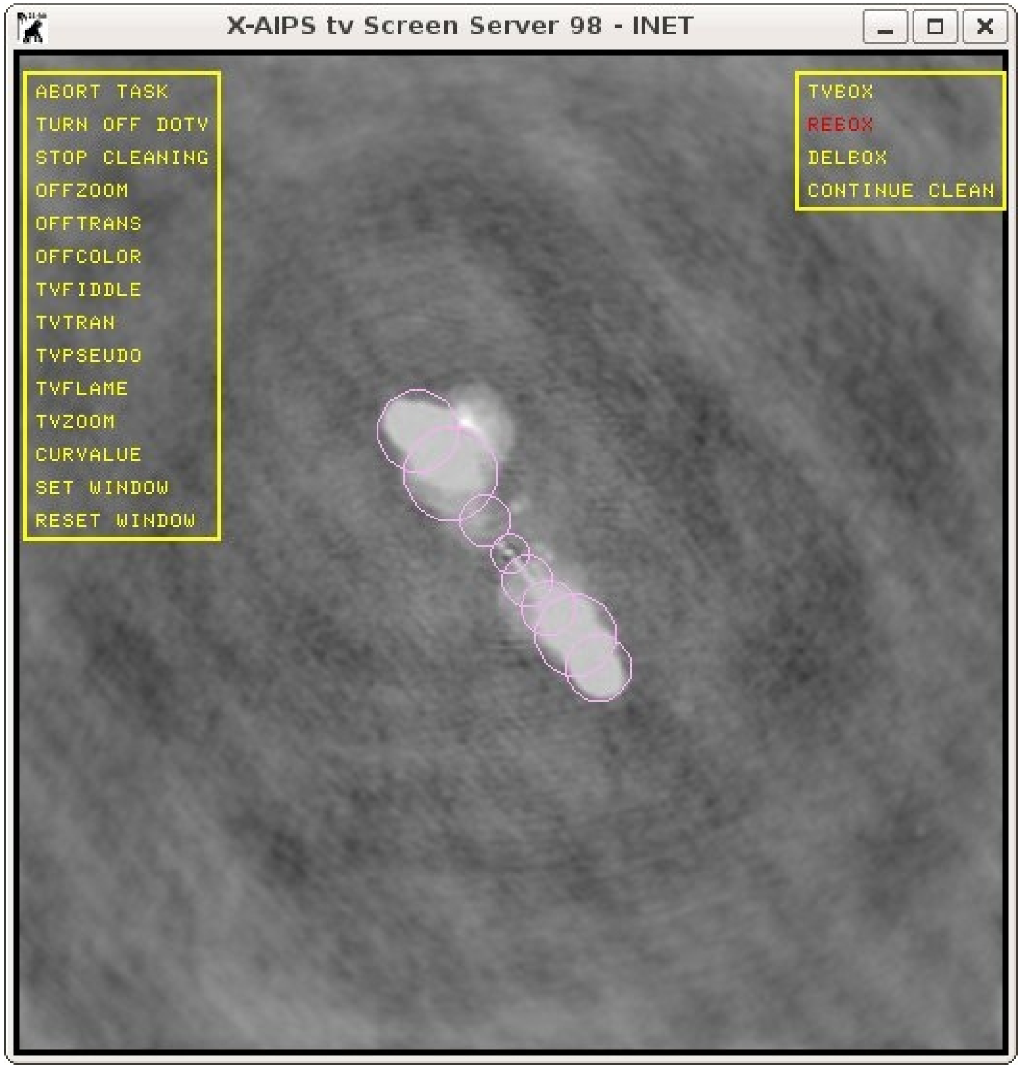

```
daniel> IMAGR1: Task IMAGR  (release of 31DEC08) begins
daniel> IMAGR1: Doing no flagging this time
daniel> IMAGR1: Create 3C219      .IMAGR .   1 (UV)  on disk  4  cno    1
daniel> IMAGR1: Beginning channel    1 through    1 with  2 IFs
daniel> IMAGR1: IMACPY: Copied   456647 visibilities to be imaged
daniel> IMAGR1: QINIT: did a GET  of    5120 Kwords, OFF      -348299341
daniel> IMAGR1: UVWAIT: begin finding uniform weights
daniel> IMAGR1: UVWAIT: Average grid weight  9.336E+05
daniel> IMAGR1: UVWAIT: Adding temperance S  1.867E+05
daniel> IMAGR1: UVWAIT: begin applying uniform or other weights
daniel> IMAGR1: UVWAIT: Sum of weights in  3.855E+09 and out  7.190E+09
daniel> IMAGR1: UVWAIT: Noise is increased by a factor 1.201 due to weighting
daniel> IMAGR1: UVWAIT: Average summed weight  9.336E+05 over     913234 vis
daniel> IMAGR1: Create 3C219      .IBM001.   1 (MA)  on disk  1  cno    5
daniel> IMAGR1: Create 3C219      .ICL001.   1 (MA)  on disk  1  cno    6
daniel> IMAGR1: GRDFLT: X and Y convolution type = SPHEROIDAL
daniel> IMAGR1: GRDFLT: X and Y parms =  3.0000  1.0000
daniel> IMAGR1: GRDFLT: convolution function sampled every 1/100 of a cell
daniel> IMAGR1: GRDMEM: Ave    2 Channels; 4.885100E+09 to 4.835100E+09 Hz
daniel> IMAGR1: Field    1 Sum of gridding weights =  7.63293E+10
daniel> IMAGR1: Field    1 Beam min =  -40.8 MilliJy, max =    1.0      Jy
daniel> IMAGR1: Field    1 fit FWHM=    3.954 x    3.749      arcsec, PA=   85.2
daniel> IMAGR1: CLBHIS: minimum component 0.076 of current peak
daniel> IMAGR1: Field    1 min =   -3.6 MilliJy,max =   93.1 MilliJy
daniel> IMAGR1: Loading field    1 to TV from -3.586E-03 to  9.310E-02
daniel> IMAGR1: You have   600 seconds to select a menu item by:
daniel> IMAGR1: Press buttons A, B, or C to choose an operation
daniel> IMAGR1: Press button D for on-line help
```

After this IMAGR will wait for 600 sec for instructions. The operations to be carried out are the determination of a new set of clean boxes, i.e. force the clean to consider only a subset of the image pixels where to find clean components.

Map your primary calibration source; map your secondary calibration source: **IMAGR** (3)

As IMAGR goes on, it provides useful messages: as it goes deeper and deeper, the min/max residual should get progressively smaller in abs value, as well as the minimum clean component flux, while the total cleaned flux density is expected to increase.

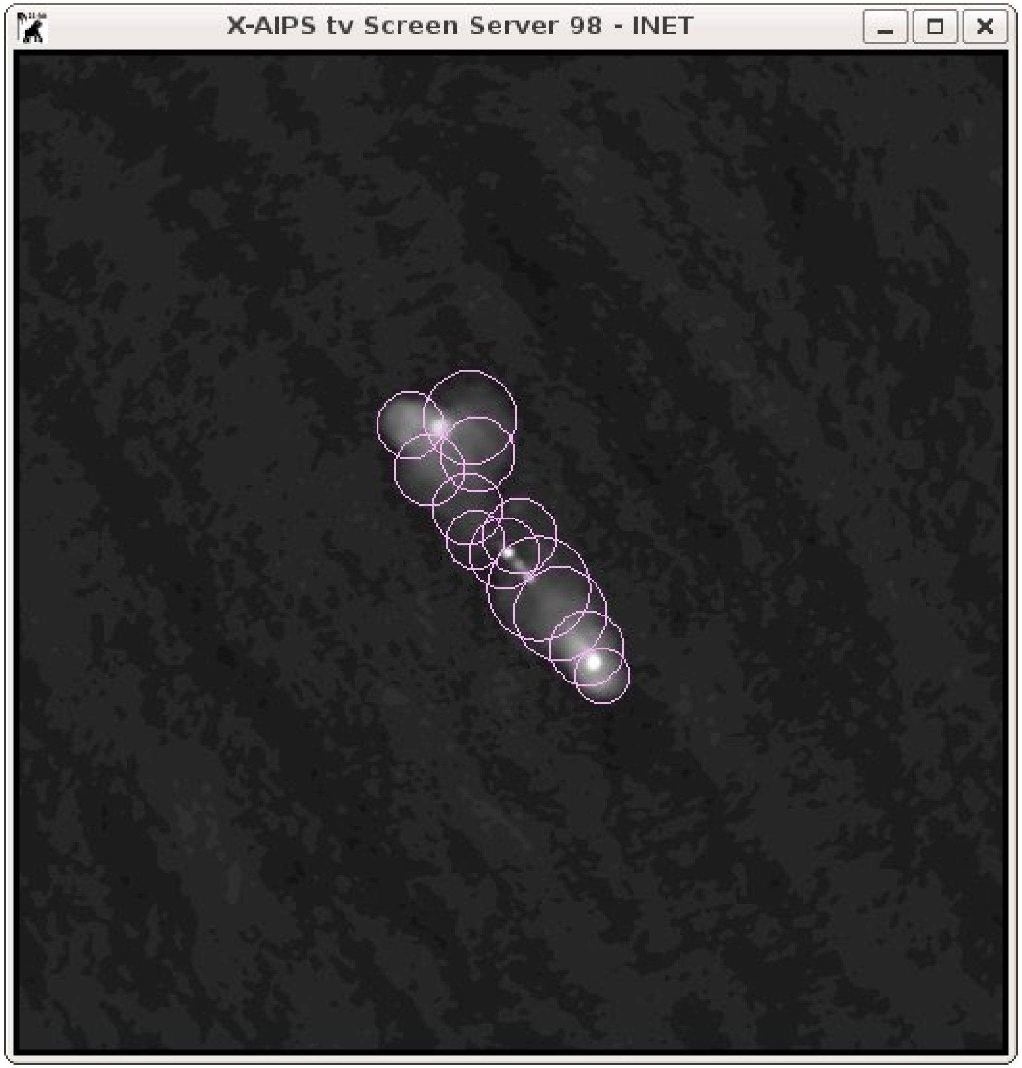
```
daniel> IMAGR1: BGC Clean: using 1019 cell beam + residuals >   980.25 MicroJy
daniel> IMAGR1:     6480 Residual map points loaded
daniel> IMAGR1: Reached minimum algorithm flux =   83.788 MilliJy iter=        2
daniel> IMAGR1: Total Cleaned flux density     =   17.689 MilliJy        2 comps
daniel> IMAGR1: VISDFT: Begin DFT component subtraction
daniel> IMAGR1: VISDFT: Model components of type Point
daniel> IMAGR1: I Polarization model processed
daniel> IMAGR1: Field     1 min =    -3.5 MilliJy,max =    75.4 MilliJy
daniel> IMAGR1: Loading field     1 to TV from -3.586E-03 to  9.310E-02
daniel> IMAGR1: You have     30 seconds to select a menu item by:
daniel> IMAGR1: Press buttons A, B, or C to choose an operation
daniel> IMAGR1: Press button D for on-line help
daniel> IMAGR1: Clean continuing
daniel> IMAGR1: BGC Clean: using 1019 cell beam + residuals >   794.00 MicroJy
daniel> IMAGR1:     6651 Residual map points loaded
daniel> IMAGR1: Reached minimum algorithm flux =   61.660 MilliJy iter=        6
daniel> IMAGR1: Total Cleaned flux density     =   44.506 MilliJy        6 comps
daniel> IMAGR1: VISDFT: Begin DFT component subtraction
daniel> IMAGR1: I Polarization model processed
daniel> IMAGR1: Field     1 min =    -3.3 MilliJy,max =    56.9 MilliJy
daniel> IMAGR1: Loading field     1 to TV from -3.586E-03 to  9.310E-02
daniel> IMAGR1: You have     30 seconds to select a menu item by:
```



At a certain point, the source structure will show up on regions out of the clean boxes. They have to be reset or other can be added with the option `REBOX`.

Map your primary calibration source; map your secondary calibration source: IMAGR (4)

When IMAGR stops (either when all NITER have been found, or just after the STOP CLEANING option has been selected) the CC are restored onto the residual image (the one progressively shown as the cleaning proceeds).
The figure shows the fully restored image, representing the total intensity distribution of 3C219.




```
daniel> IMAGR1: Clean continuing
daniel> IMAGR1: BGC Clean: using 1019 cell beam + residuals >   211.95 Nano Jy
daniel> IMAGR1:    14487 Residual map points loaded
daniel> IMAGR1: Reached Iter. limit, Max resid =   17.012 MicroJy iter=    30000
daniel> IMAGR1: Total Cleaned flux density    =    2.395      Jy    30000 comps
daniel> IMAGR1: ALGSTB: All   285 Rows In AP (Max     523)
daniel> IMAGR1: ALGSTB: Ipol gridded model subtraction, chans     1 through    2
daniel> IMAGR1: ALGSTB: Pass    1;  274-    0 Cells, with    456647 Pts
daniel> IMAGR1: Field     1 min = -686.3 MicroJy,max =  625.6 MicroJy
daniel> IMAGR1: Total Clean components    30000 reaches limit   30000
daniel> IMAGR1: Loading field     1 to TV from -7.633E-04 to  1.235E-03
daniel> IMAGR1: Field     1 min = -686.3 MicroJy,max =  625.6 MicroJy
daniel> IMAGR1: Restoring Clean components
daniel> IMAGR1: Checking image max/min
daniel> IMAGR1: Loading field     1 to TV from -7.633E-04 to  9.473E-02
daniel> IMAGR1: Field     1 final Clean flux     2.395      Jy
daniel> IMAGR1: Deleting UV work file:
daniel> IMAGR1: Destroyed  1 extension files of type AN
daniel> IMAGR1: Destroyed  1 extension files of type FQ
daniel> IMAGR1: Destroyed UV image file: catno=      1 disk= 4
daniel> IMAGR1: Appears to have ended successfully
daniel> IMAGR1: daniele- 31DEC08 TST: Cpu=      27.6  Real=      62  IO=       1499
```

The total cleaned flux density is about 2.4 Jy (check the amplitudes on the short spacings with UVPLT in an earlier plot)
Each clean component has been written into a CC file appended to the clean image. It can be inspected with the task PRTCC.

An interlude: self calibration (1)

The a-priori calibration samples phase variations every 15-20 min. It is clear that there could be small phase variations on shorter time scales, that can be taken care of with self-calibration, i.e. take the brightness distribution (i.e. clean components) of the target source to calibrate its own visibilities (phases). This operation is done by the task `CALIB` (the same of the a-priori calibration!) in which we have to provide an input file (the visibilities to be corrected), an input model (the image - we have to decide how many `CC` can be used to calculate the model, only positive components are generally used), a solution time interval (`SOLINT`) depending on the signal-to-noise-ratio of the data (we can use `SOLINT 1/6.` namely 10 sec, the source is strong on all baselines). There are a number of solution modes. We will correct for phases only, and therefore `SOLMODE 'p'` is appropriate.

```
daniel> CALIB1: Task CALIB  (release of 31DEC08) begins
daniel> CALIB1: CALIB USING 3C219        . SPLIT  .   1 DISK=  1 USID=  11
daniel> CALIB1: Create 3C219       .CALIB .   1 (UV)  on disk  1  cno     7
daniel> CALIB1: Doing no flagging this time
daniel> CALIB1: Selecting the data
daniel> CALIB1: Doing self-cal mode with CC model
daniel> CALIB1: FACSET: 2.093770 Jy found from 6700 components
daniel> CALIB1: Divide data by model - first compute model by summing
                          [omissis]
daniel> CALIB1: Field    1 used    6700 CCs
daniel> CALIB1: Determining solutions
daniel> CALIB1: Writing SN table    1
daniel> CALIB1: Found       140532 good solutions
daniel> CALIB1: Failed on       136 solutions
daniel> CALIB1: Average closure rms =  0.0530 +-  0.0058
daniel> CALIB1: Fraction of times having data >  2.5 rms from solution
daniel> CALIB1: 0.00019 of the times had 20 - 22 percent outside  2.5 times rms
daniel> CALIB1: 0.00019 of the times had 22 - 24 percent outside  2.5 times rms
                          [omissis]
daniel> CALIB1: 0.00038 of the times had 44 - 46 percent outside  2.5 times rms
daniel> CALIB1: Adjusting solutions to a common reference antenna
daniel> CALIB1: Applying solutions to data
daniel> CALIB1:          Previously flagged   Flagged by gain        Kept
daniel> CALIB1: Partially              142              78        78
daniel> CALIB1: Fully                    0              71    456498
daniel> CALIB1: Copied AN file from vol/cno/vers  1    2   1 to  1    7   1
daniel> CALIB1: Copied WX file from vol/cno/vers  1    2   1 to  1    7   1
daniel> CALIB1: Copied OF file from vol/cno/vers  1    2   1 to  1    7   1
daniel> CALIB1: Appears to have ended successfully
daniel> CALIB1: daniele- 31DEC08 TST: Cpu=      8.4  Real=     18  IO=       605
```

```
> task 'calib'
> getn 2
AIPS 1: Got(1)   disk= 1  user=  11   type=UV   3C219.SPLIT.1
> get2n 6
AIPS 1: Got(2)   disk= 1  user=  11   type=MA   3C219.ICL001.1
> ncomp 6700 0          use the first 6700 clean components in the model
> solint 1/6.           compute solutions every 10 sec
> solmode 'P'           compute phase solutions only
> solty ''
> aparm 0
                  check the inputs and then run it!
> go calib              and then have a look to the MSGSRV
```

A SN table has been appended to the file #2, while a new file has been created (3C219.CALIB) which already contains the corrections. The number of failed solutions is negligible! It will be used for the final imaging.

An interlude: self calibration (2)

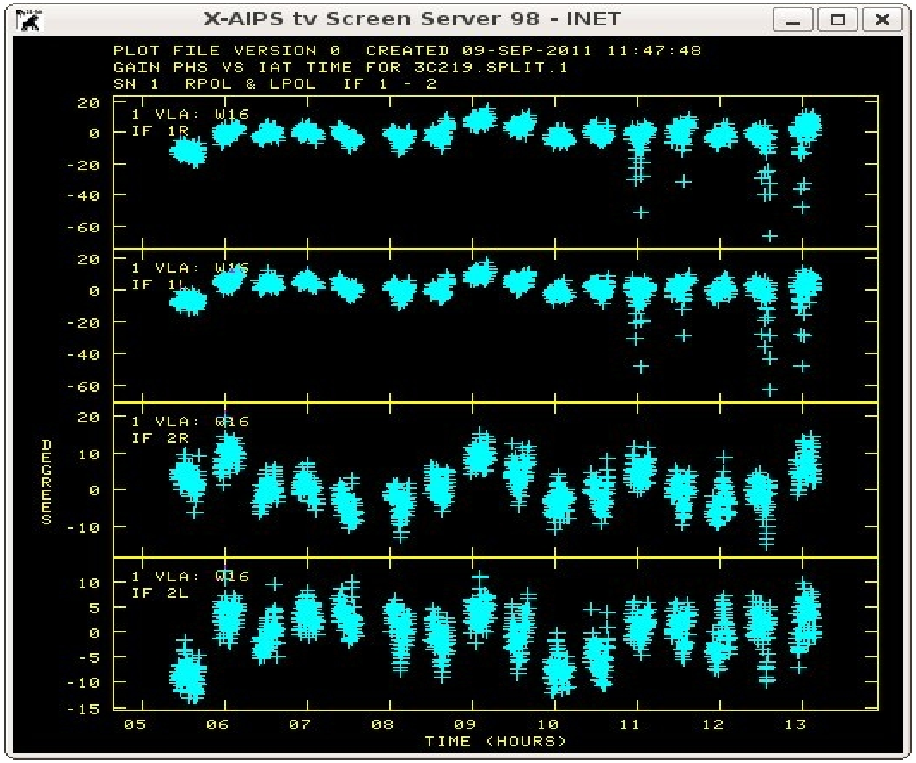
The phase solutions should be inspected by using SNPLT of the SN table of file #2 (3C219.SPLIT)

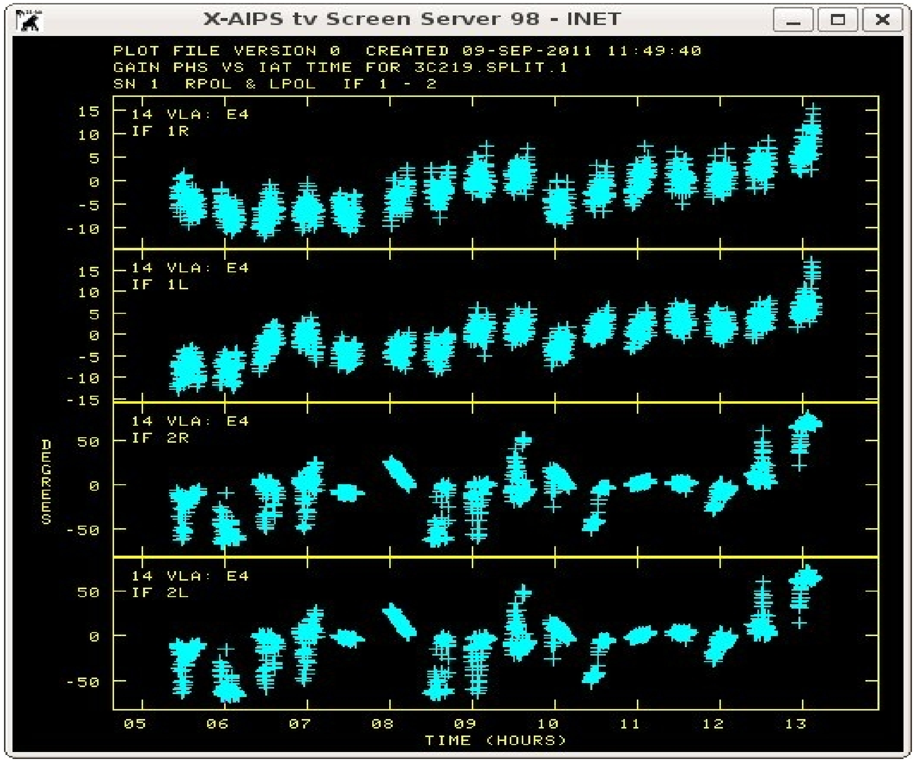
> task 'snplt'
> getn 2
AIPS 1: Got(1)   disk= 1 user= 11   type=UV   3C219.SPLIT.1
> inext 'sn'   consider the SN table
> opty 'phas'   coshow phases
> inver 0

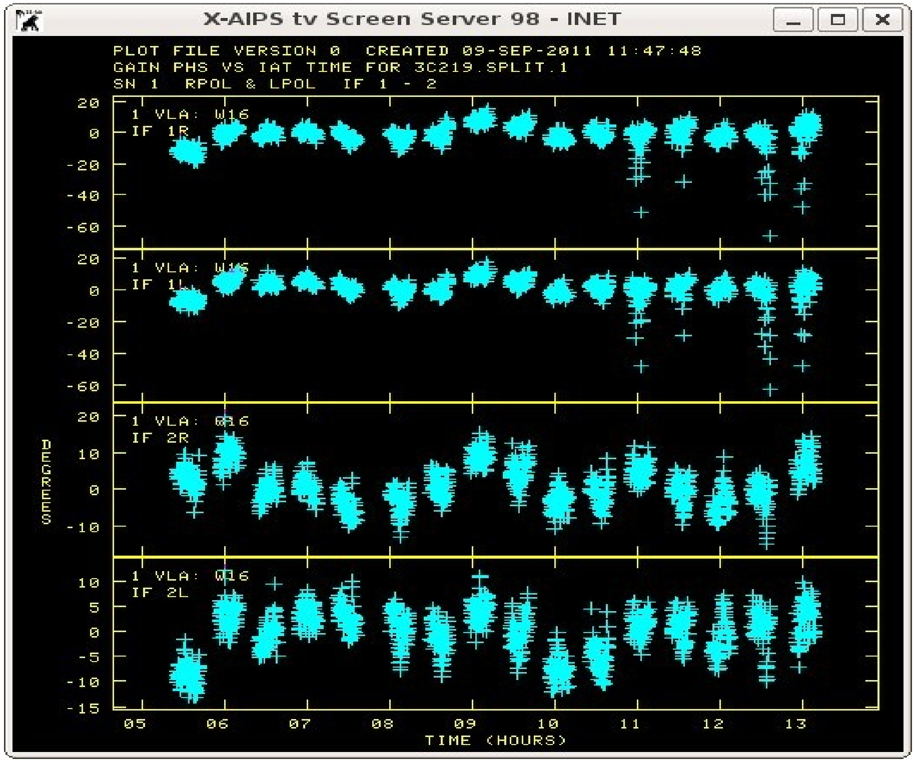
check the inputs and then run it!

> go snplt   and then have a look to the AIPS TV screen

Most of the corrections are within a few degrees, with some larger phase corrections on some antennas/times



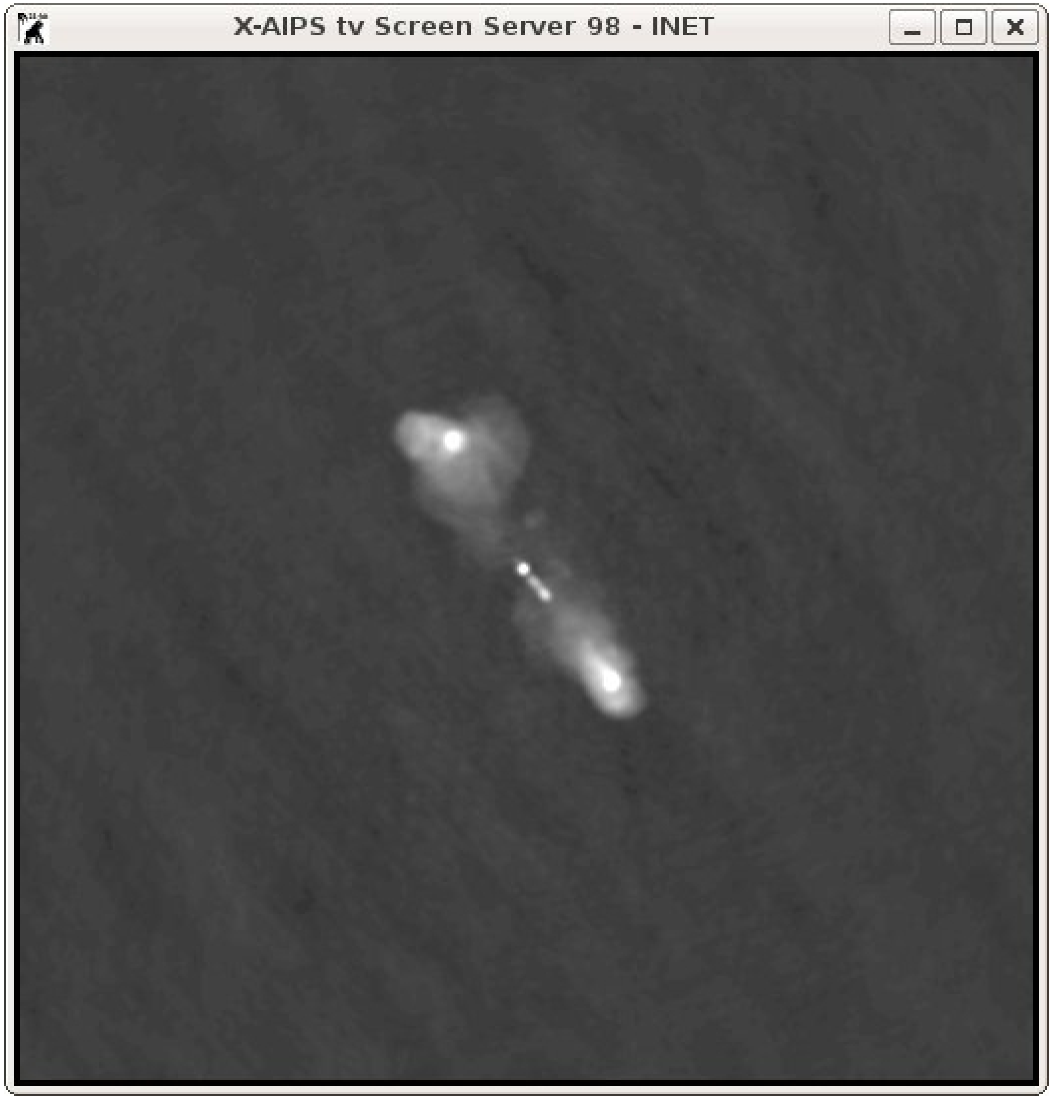




Final imaging: stokes' I,U,Q & V and then PPOL, FPOL & PANG (1)

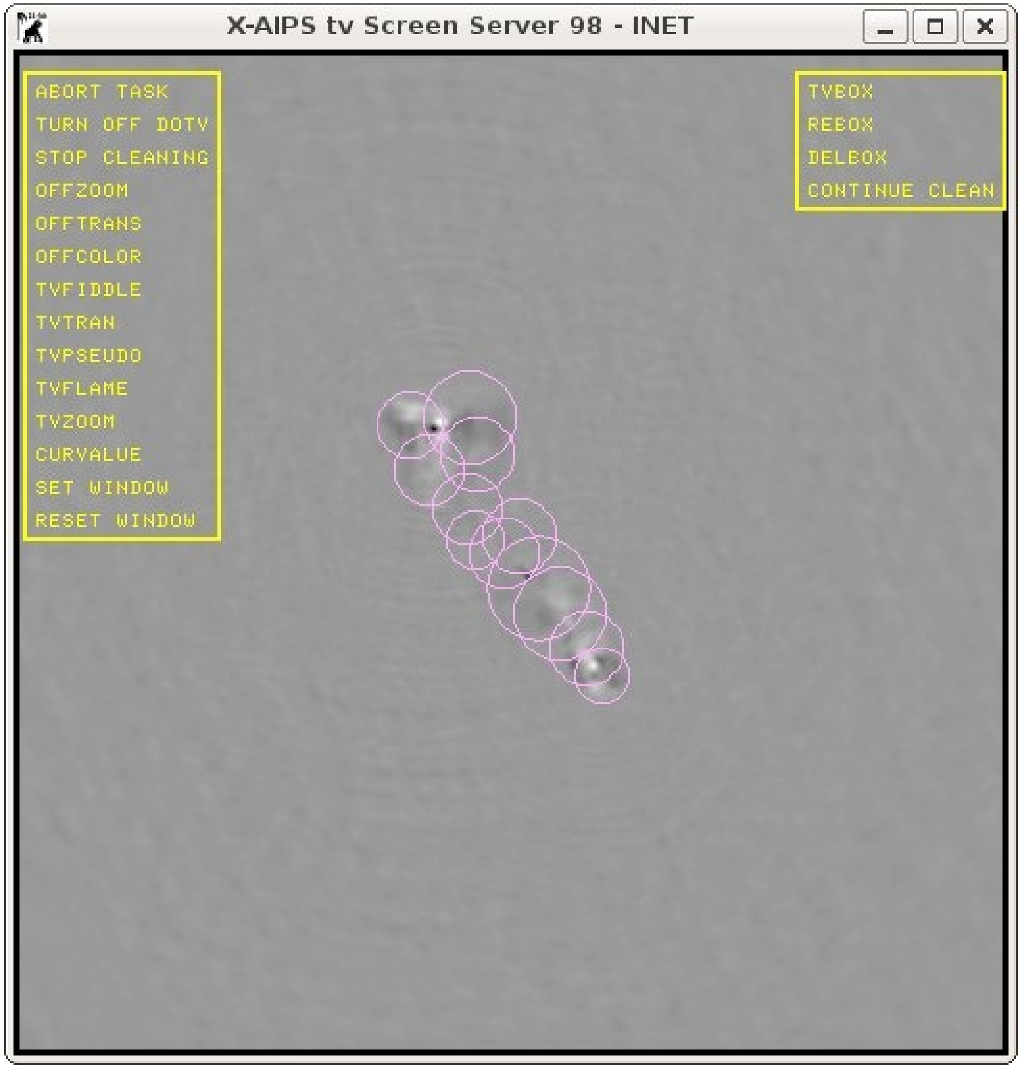
To get the final image, the 3C219.CALIB file should be picked up. The number of clean components to be considered should be rather large (100000 or even 200000), but for this example we will keep it a bit low (NITER 50000).
The clean will be guided with boxes for about 20000 components and then it should work on the whole field (except about 10 pix from the borders). To avoid confusion, I decided to remove the earlier beam and image (**getn 5; zap** and **getn 6; zap**).
Then type **tget imagr; getn 7; go imagr** and you will obtain – at the end - again two maps, the dirty beam (cat #5 and the clean image #6)

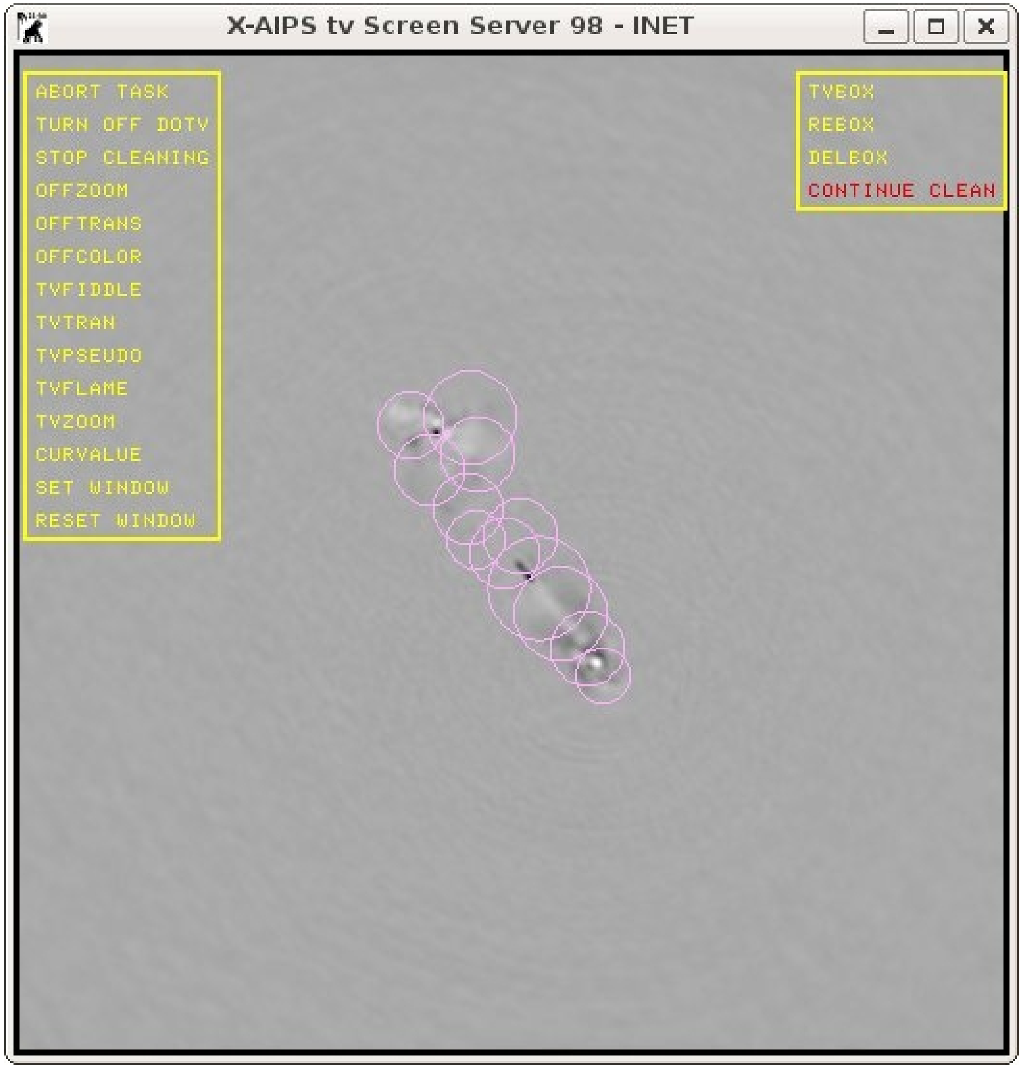
```
> getn 6
>AIPS 1: Got(1)   disk= 1  user=  11   type=MA   3C219.ICL001.1
> imh                    show the header
>AIPS 1: Image=3C219     (MA)       Filename=3C219      .ICL001.   1
AIPS 1: Telescope=VLA              Receiver=VLA
AIPS 1: Observer=AB881             User #=   11
AIPS 1: Observ. date=03-JAN-1999     Map date=09-SEP-2011
AIPS 1: Minimum=-7.02092017E-04      Maximum= 9.47528183E-02 JY/BEAM
AIPS 1: ----------------------------------------------------------------
AIPS 1: Type    Pixels   Coord value     at Pixel     Coord incr   Rotat
AIPS 1: RA---SIN   512    09 17 50.600     256.00        -1.000    0.00
AIPS 1: DEC--SIN   512    45 51 44.000     257.00         1.000    0.00
AIPS 1: FREQ        1   4.8601000E+09      1.00  1.0000000E+08    0.00
AIPS 1: STOKES       1   1.0000000E+00      1.00  1.0000000E+00    0.00
AIPS 1: ----------------------------------------------------------------
AIPS 1: Coordinate equinox 1950.00
AIPS 1: Map type=NORMAL            Number of iterations=   50000
AIPS 1: Conv size=   3.95 X   3.75   Position angle=  85.24
AIPS 1: Rest freq      0.000        Vel type: OPTICAL wrt YOU
AIPS 1: Alt ref. value  0.00000E+00  wrt pixel    1.00
AIPS 1: Maximum version number of extension files of type CC is    1
AIPS 1: Maximum version number of extension files of type HI is    1
AIPS 1: Keyword = 'WTNOISE '  value =  1.201096E+00
AIPS 1: Keyword = 'CCFLUX  '  value =  2.351095E+00
AIPS 1: Keyword = 'CCTOTAL '  value =  2.351095E+00
AIPS 1: Keyword = 'PARANGLE'  value = -1.537415E+02
AIPS 1: Keyword = 'ZENANGLE'  value =  1.285867E+01
```



Final imaging: stokes' I,**U**,**Q** & V and then PPOL, FPOL & PANG (2)

Polarization images are just obtained simply by specifying STOKES 'Q' and then STOKES'U' before running IMAGR. The number of clean component can be smaller than for total intensity (e.g. NITER 30000).
The two dirty images in Q and U are shown here. Clean boxes are shown to help to remind from where the total intensity emission comes from. A lot of polarized emission is present.

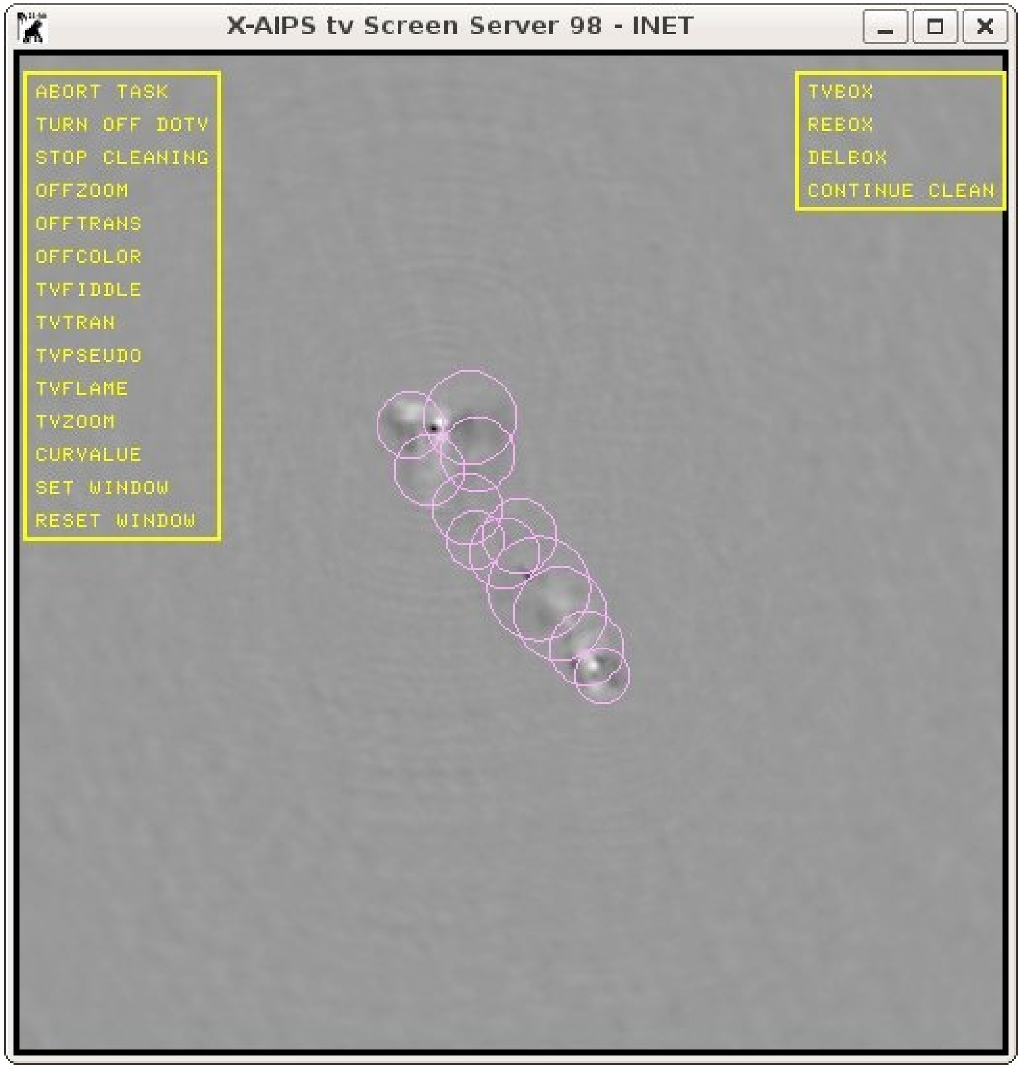


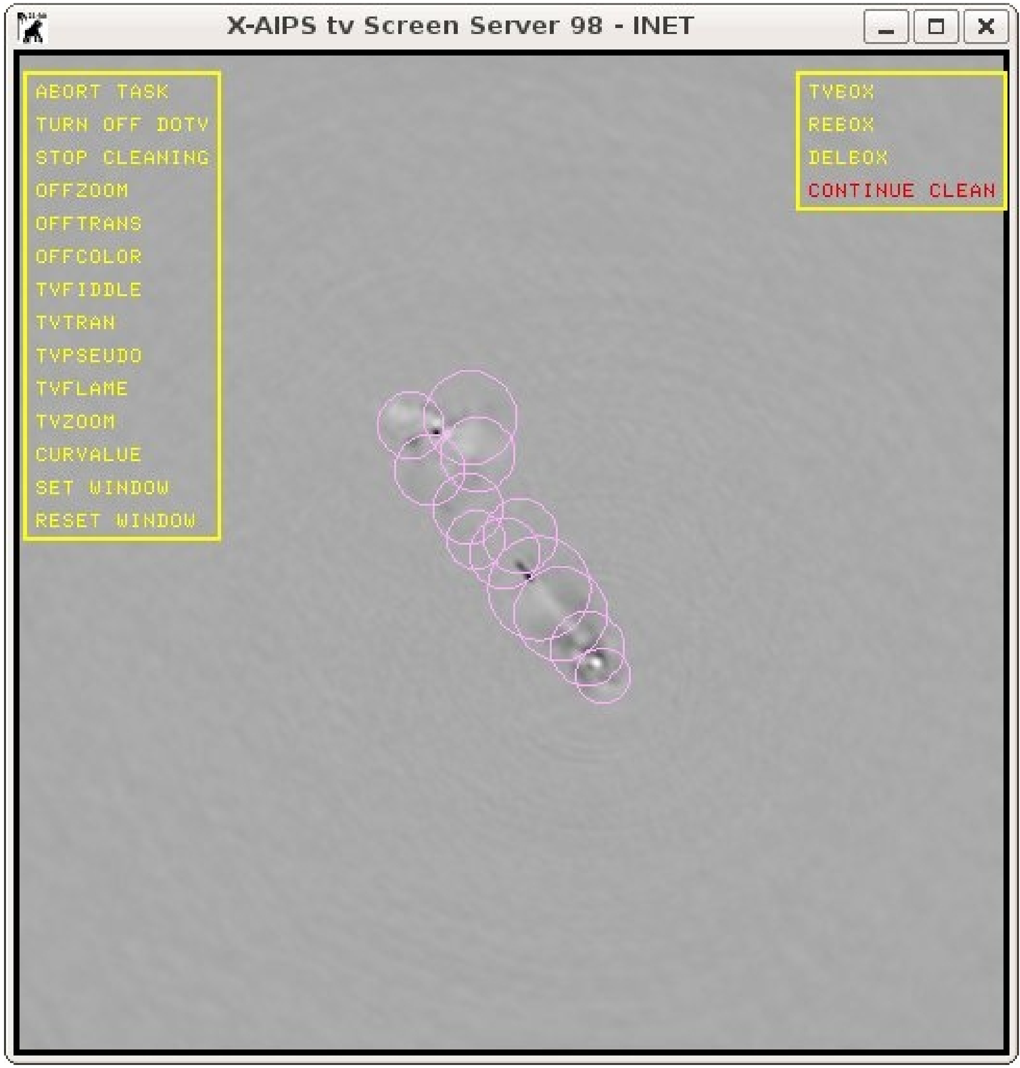


Final imaging: stokes' I,U,Q & V and then PPOL, FPOL & PANG (3)

Polarization images are just obtained simply by specifying STOKES 'Q' and then STOKES'U' before running IMAGR. The number of clean component can be smaller than for total intensity (e.g. NITER 30000).

The two dirty images in Q and U are shown here. Clean boxes are shown to define the total intensity emission. A lot of polarized emission is present.





Final imaging: stokes' `I`,**U**,**Q** `&` `V` and then `PPOL`, `FPOL` `&` `PANG` `(4)`

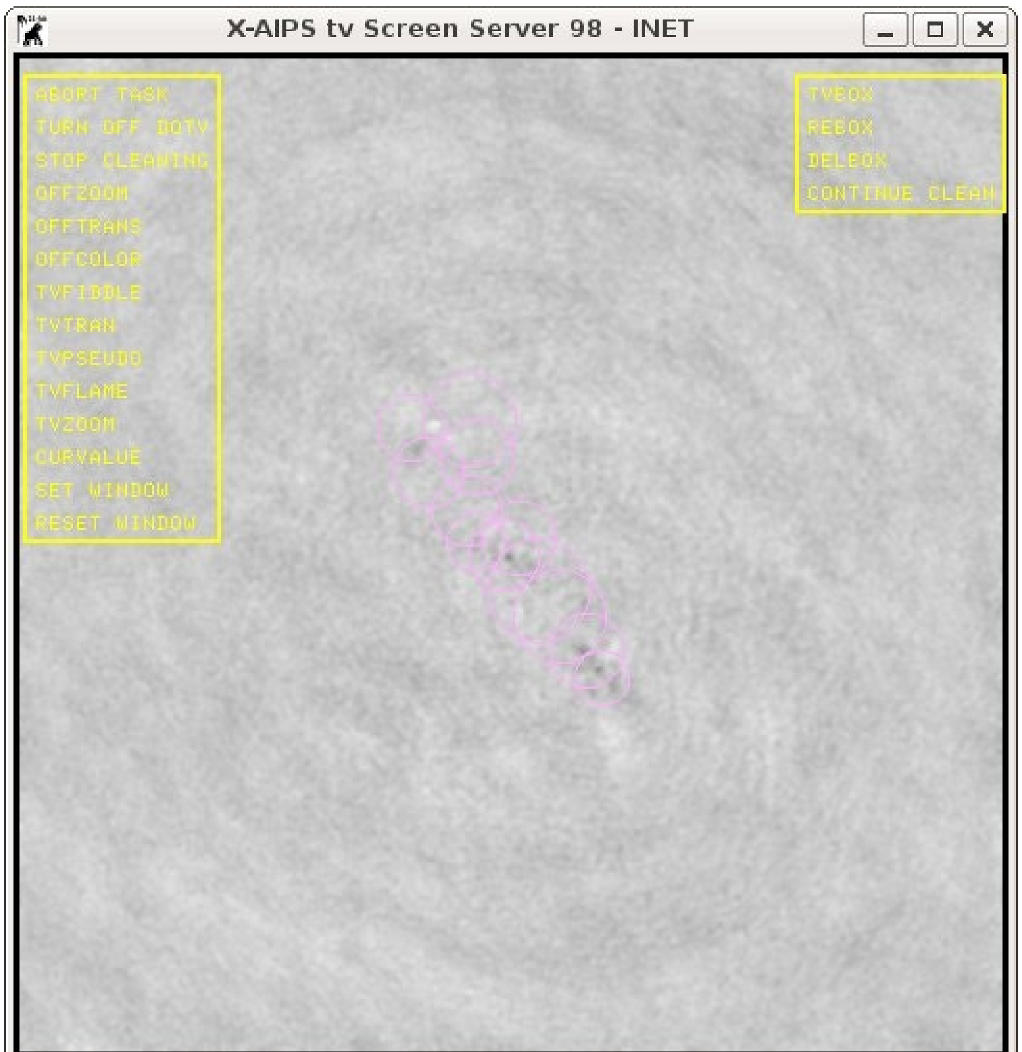
The final images in Q and U are shown. The total flux density cleaned in both images is quite low (0.024 and -0.076 Jy for Q and U respectively). This is what would have measured a single dish, which is not able to resolve all the structure in the polarized emission, causing a *beam depolarization, i.e. originated by limitation of the resolving power which mixes regions with positive and negative emission (and the sum is close to 0).*

The peaks in these images are about -/+ 7 mJy/beam. The r.m.s. noise is 0.022 mJy/beam in both images

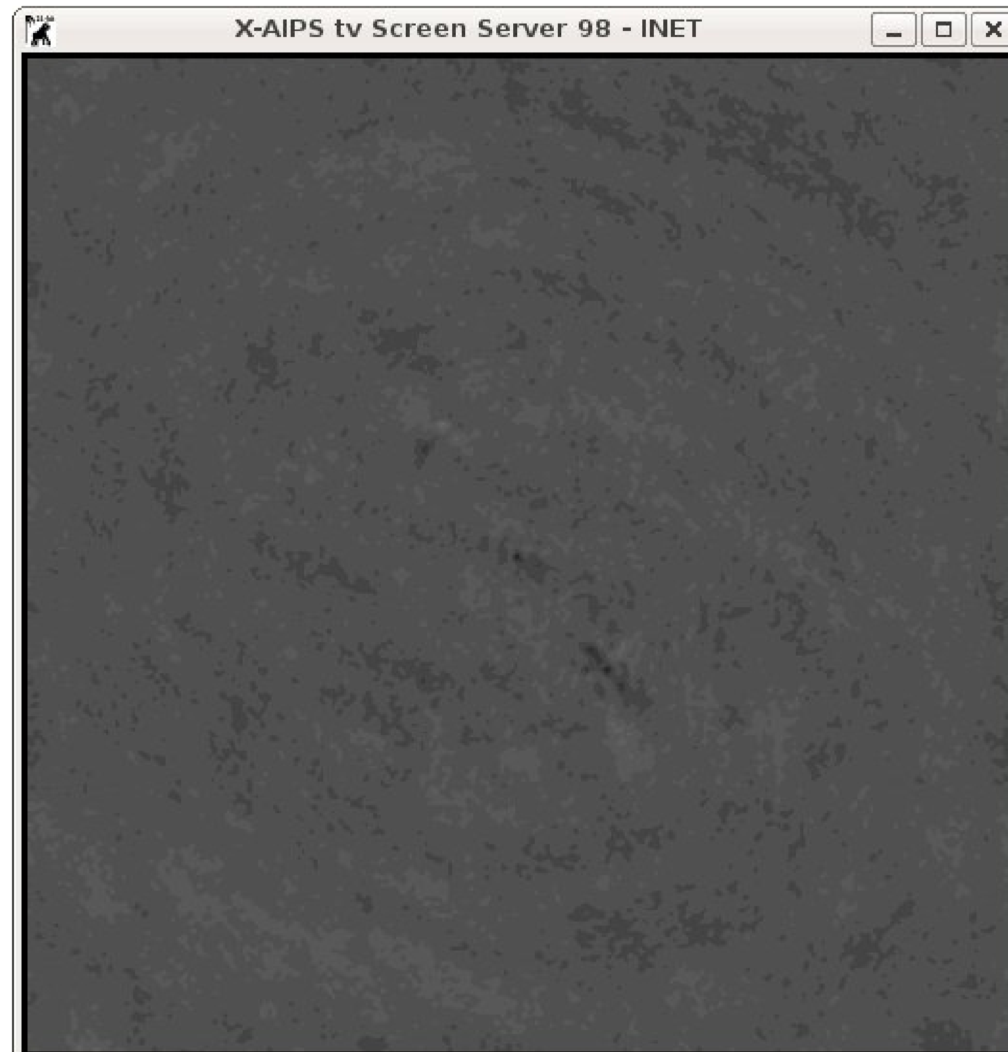
Final imaging: stokes' `I,U,Q & V` and then `PPOL, FPOL & PANG` (5)

Circular polarization (STOKES 'V') should show noise only. Indeed a sort of footprint of the source core and southern jet/hot spot are visible in circular polarization. The peak in the `VCLN` image is -0.24/0.21 mJy/beam and therefore the circular polarization from this source can be considered negligible. The r.m.s. noise is about 0.025 mJy/beam

'V' Dirty image



'V' Clean image

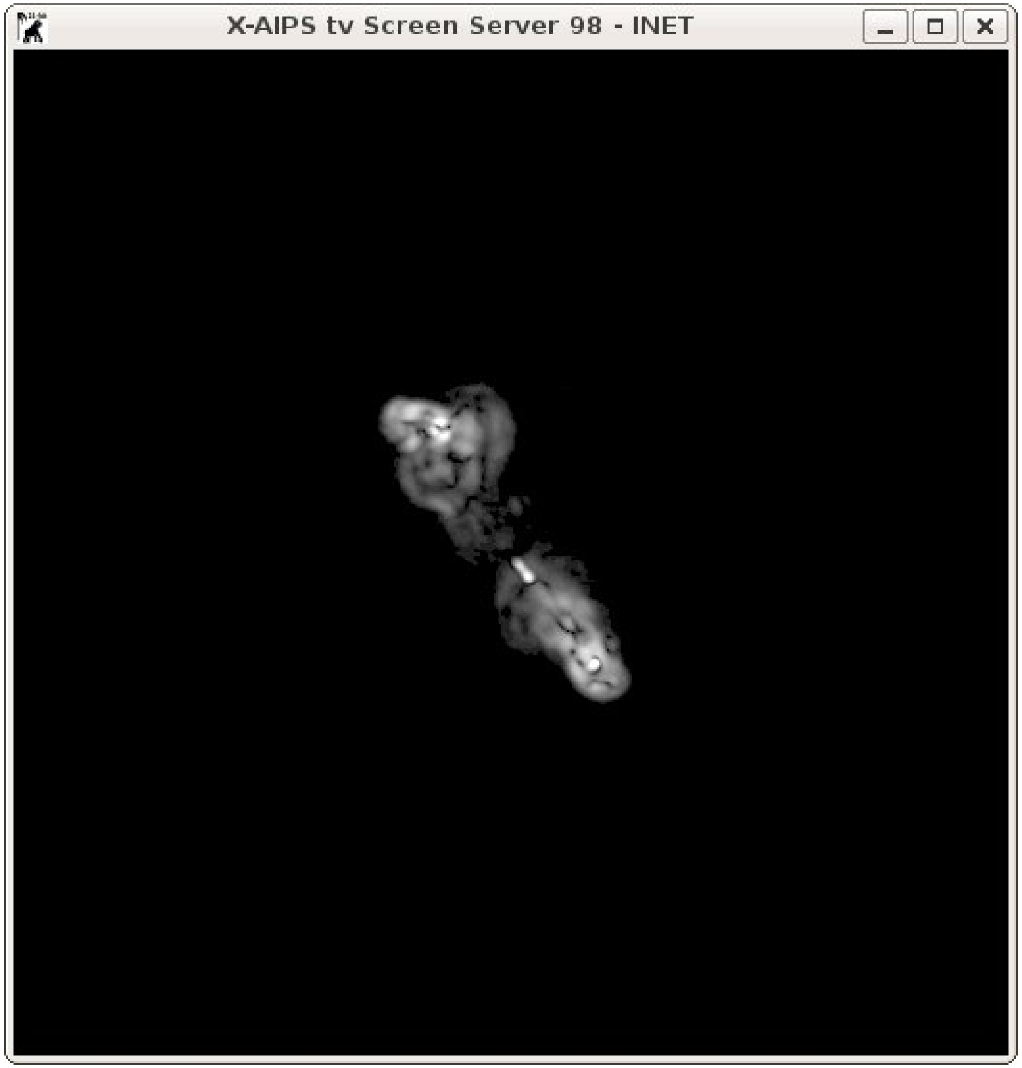


Final imaging: stokes' I,U,Q & V and then **PPOL**, FPOL & **PANG** (6)

The total polarization can be obtained from the task COMB which performs operation on images.

```
> task 'comb'
> getn 9
AIPS 1: Got(1)   disk= 1  user=  11   type=MA   3C219.QCL001.1
> get2n 11
AIPS 1: Got(2)   disk= 1  user=  11   type=MA   3C219.UCL001.1
>  opco 'polc'                      determine PPOL and remove ricean bias
>  bparms 2.2e-5 2.2e-5 0 2 5   only pixels with output SNR > 5 will be considered
> go comb
```

```
daniel> COMB 1: Task COMB   (release of 31DEC08) begins
daniel> COMB 1: Create 3C219       .PPOLC .   1 (MA)  on disk  1  cno   14
daniel> COMB 1: Poli corr:  1.000E+00*Sqrt(Map(1)**2 + Map(2)**2) +  0.000E+00
daniel> COMB 1: Magic blanking used for clipped & illegal values
daniel> COMB 1: Blanking done if output S/N is less than  5.0000
daniel> COMB 1: Using MAP(1) noise level  2.200E-05
daniel> COMB 1: Using MAP(2) noise level  2.200E-05
daniel> COMB 1: History file created and written for IMAGE file
daniel> COMB 1: Appears to have ended successfully
daniel> COMB 1: daniele- 31DEC08 TST: Cpu=       0.1  Real=       0  IO=         3
```



The final image (PPOLC) is shown aside. The total flux density is about 398 mJy, much in excess from what can obtain from the U and Q images.

```
> tget comb
>  opco 'pola'                      determine Pol angle
>  bparms 2.2e-5 2.2e-5 0        onoise control parms
> go comb
```

The polarization angle image has been created. It has values between -180 and 180 deg (not shown here).

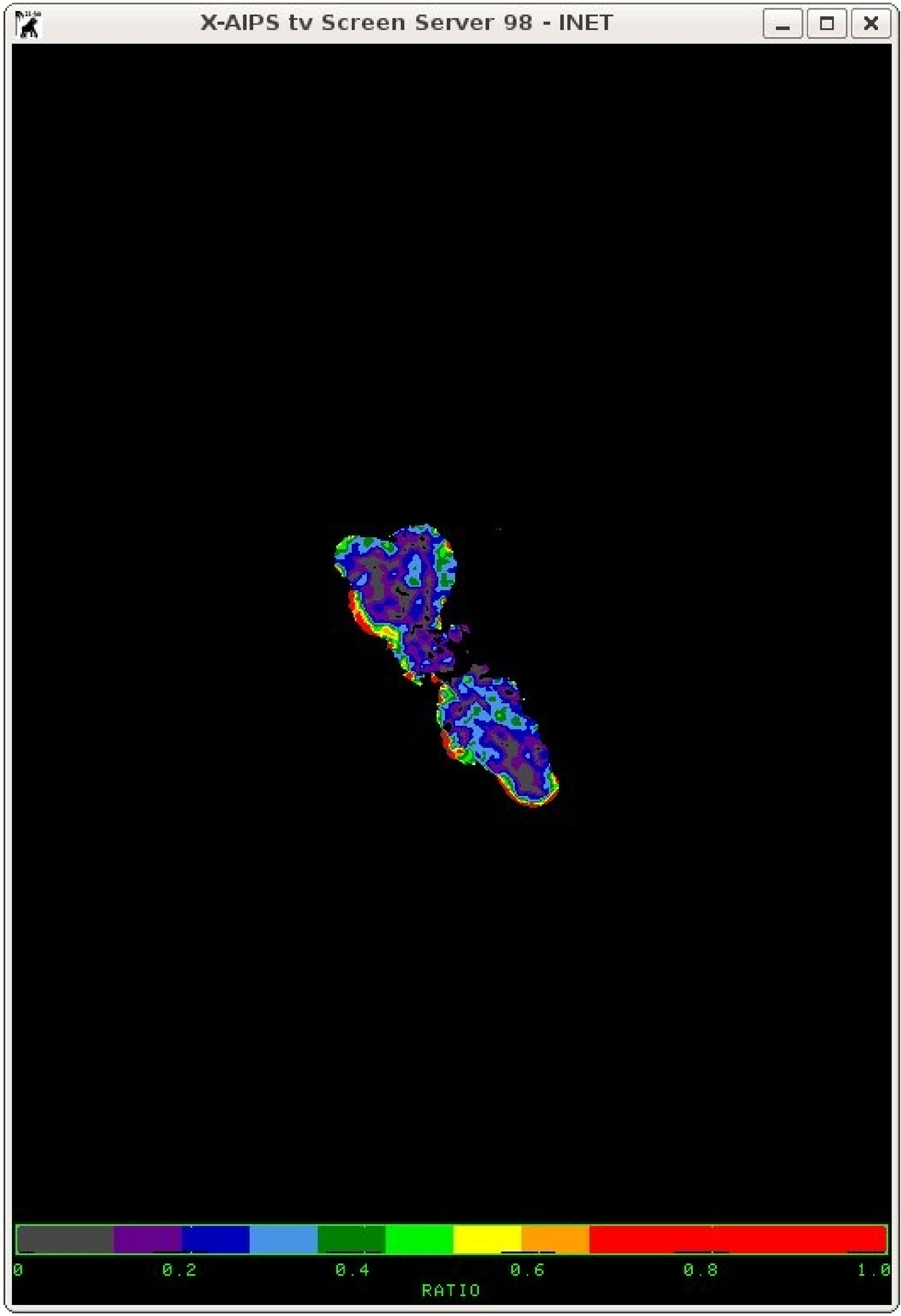
Final imaging: stokes' `I,U,Q & V` and then `PPOL`, **`FPOL`** `& PANG (7)`

The fractional polarization is obtained from the task COMB by dividing the polarized emission by the total intensity.

```
> tget comb
> getn 14
AIPS 1: Got(1)   disk= 1  user=  11   type=MA   3C219.PPOLC.1
> getn 6
AIPS 1: Got(1)   disk= 1  user=  11   type=MA   3C219.ICL001.1
> opco 'div'
> bparm 0
> go comb
```

```
daniel> COMB 1: Task COMB   (release of 31DEC08) begins
daniel> COMB 1: Create 3C219       .FPOL  .   1 (MA)  on disk  1  cno   15
daniel> COMB 1: Division:  1.000E+00*Map(1)/Map(2) +  0.000E+00
daniel> COMB 1: Magic blanking used for clipped & illegal values
daniel> COMB 1: History file created and written for IMAGE file
daniel> COMB 1: Appears to have ended successfully
daniel> COMB 1: daniele- 31DEC08 TST: Cpu=      0.0  Real=      0  IO=        3
```

The final image of fractional polarization is shown aside. Note that the fractional polarization increases at the source boundaries.



Hints of map analysis (display TVALL, TVLOD, KNTR, ... ; image statistics: IMSTAT, IMEAN, TVSTAT, JMFIT ...)

At the end of the whole process we have obtained a number of UV and MA files. Some basic experience on how to inspect and show UV files should be already in hands. Images can be loaded on the TV screen with a number of VERBS ('go' is not necessary) like

- TVALL loads the the image and provides you a number of fiddling options (grey scale/colour; zoom in and out)

- TVLOD just load the image and returns the prompt on the command window

- TVFIDDLE provides options on what is on the screen already

- TVPS (similar to TVFIDDLE)

Many other verbs are available (TVINI resets the display) .....

You can try to load either a (dirty) beam or an image from the list aside. Various images have their own scales. The range of values for saturation can be set with the parameter
PIXRANGE min max (2 numbers)

In case you have not the prompt in the command window, just go to the TV screen and hit button D (always quits TV operations)

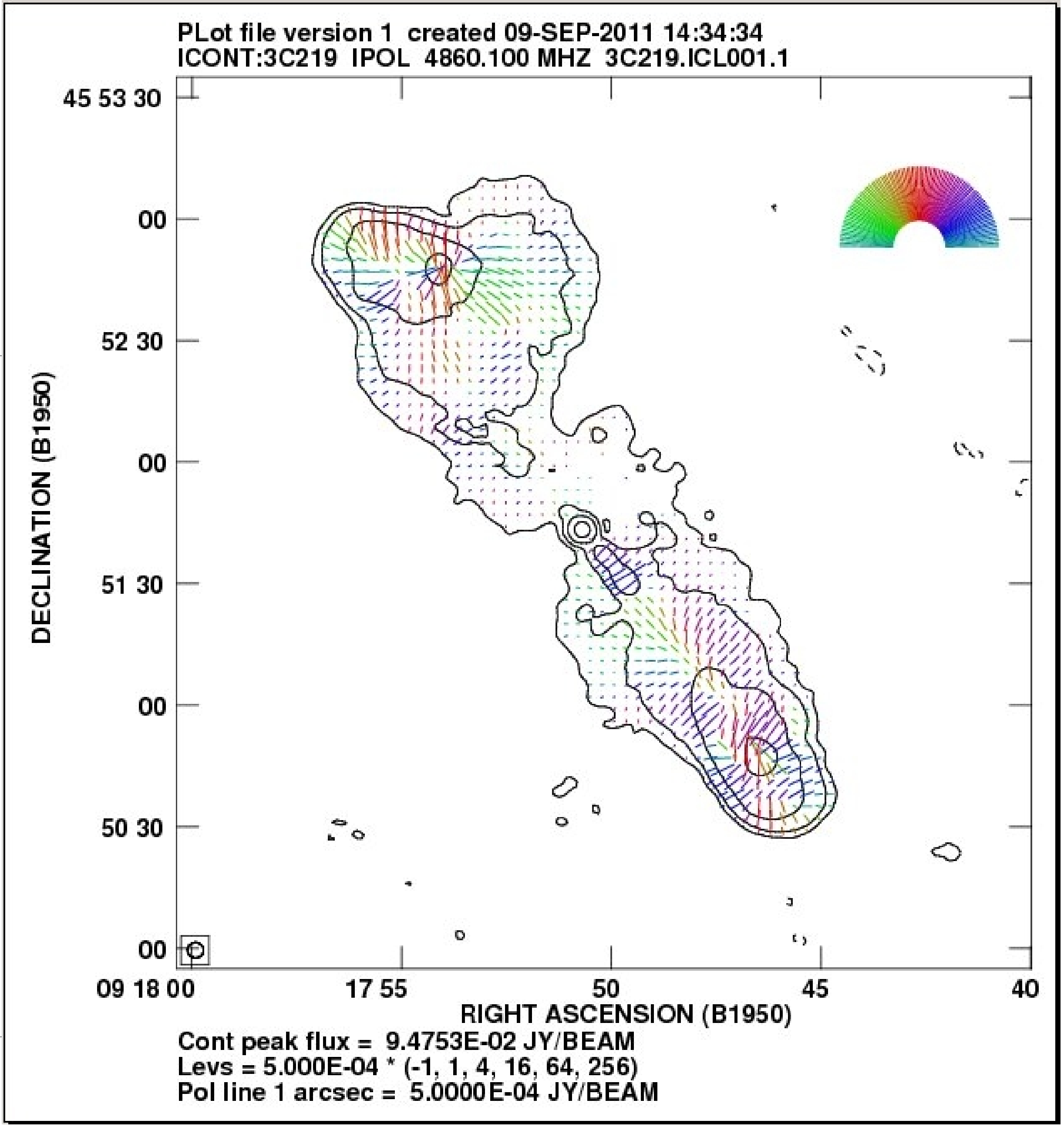
```
> ucat
AIPS 1: Catalog on disk  1
AIPS 1:  Cat Usid Mapname      Class   Seq  Pt     Last access      Stat
AIPS 1:    1   11 ERIS_C      .C BAND.    1 UV 09-SEP-2011 09:49:29
AIPS 1:    2   11 3C219       .SPLIT .    1 UV 09-SEP-2011 12:30:51
AIPS 1:    3   11 1035+564    .SPLIT .    1 UV 09-SEP-2011 09:49:29
AIPS 1:    4   11 1331+305    .SPLIT .    1 UV 09-SEP-2011 09:49:29
AIPS 1:    7   11 3C219       .CALIB .    1 UV 09-SEP-2011 11:36:11
> mcat
AIPS 1: Catalog on disk  1
AIPS 1:  Cat Usid Mapname      Class   Seq  Pt     Last access      Stat
AIPS 1:    5   11 3C219       .IBM001.    1 MA 09-SEP-2011 11:59:12
AIPS 1:    6   11 3C219       .ICL001.    1 MA 09-SEP-2011 14:07:13
AIPS 1:    8   11 3C219       .QBM001.    1 MA 09-SEP-2011 12:16:46
AIPS 1:    9   11 3C219       .QCL001.    1 MA 09-SEP-2011 14:10:59
AIPS 1:   10   11 3C219       .UBM001.    1 MA 09-SEP-2011 12:18:21
AIPS 1:   11   11 3C219       .UCL001.    1 MA 09-SEP-2011 14:10:59
AIPS 1:   12   11 3C219       .VBM001.    1 MA 09-SEP-2011 12:30:51
AIPS 1:   13   11 3C219       .VCL001.    1 MA 09-SEP-2011 12:40:22
AIPS 1:   14   11 3C219       .PPOLC .    1 MA 09-SEP-2011 14:10:59
AIPS 1:   15   11 3C219       .PANG  .    1 MA 09-SEP-2011 14:10:08
AIPS 1:   16   11 3C219       .FPOL  .    1 MA 09-SEP-2011 14:07:13
```

Hints of map analysis (display TVALL, TVLOD, **KNTR**, ... ; image statistics: TVSTAT, IMSTAT, JMFIT ...) (2)

A way to show in a summarized way the polarization images makes use of the task KNTR. A suitable set of parameters to obtain this plot (DOTV -1, and then exported to a postscript file) with LWPLA). This example reports contours for the total intensity, vector length is proportional to the polarized intensity while the orientation is from the 'PANG' image

You can try this set of inputs

> getn 6
> get3n 14
> get4n 15
> **task 'kntr'**
> **blc 150 150**
> **trc 365 365**
> **facto 1000**
> **xin 3**
> **yin 3**
> **dotv 1**
> **clev 0.0005**
> **levs -1,1,4,16,64,256**
> **docont 1**
> **dogrey -1**
> **dovec 1**
> **pol3co 1**
> **dotv -1**
> **go kntr**



The DOTV -1 option will create a PL file attached to file #6, which can be sent to the printer (or to a file with the task (LWPLA – check inputs!)

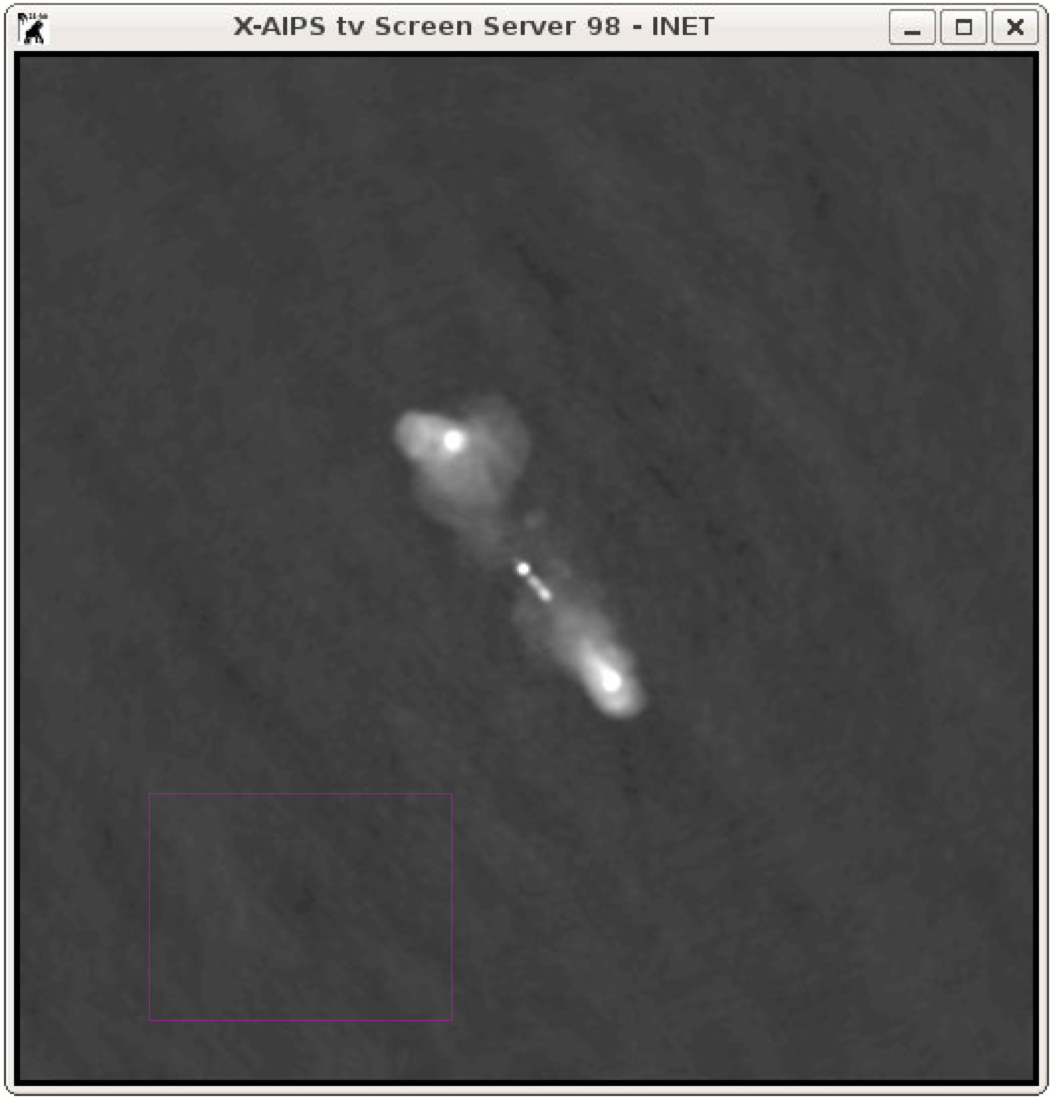
Hints of map analysis (display TVALL, TVLOD, KNTR, ... ; image statistics: IMSTAT, IMEAN, TVSTAT, JMFIT ...) (3)

Once an image is loaded on the TV screen, there are a number of tools to perform the analysis. The r.m.s. noise can be determined selecting areas on the screen:

TVWIN selects a rectangular region (BLC and TRC are set on the TV) like in the picture aside. Then

IMSTAT performs the statistics of such area.

Alternatively, (go) IMEAN is a task which allows a more detailed statistcs (see below)



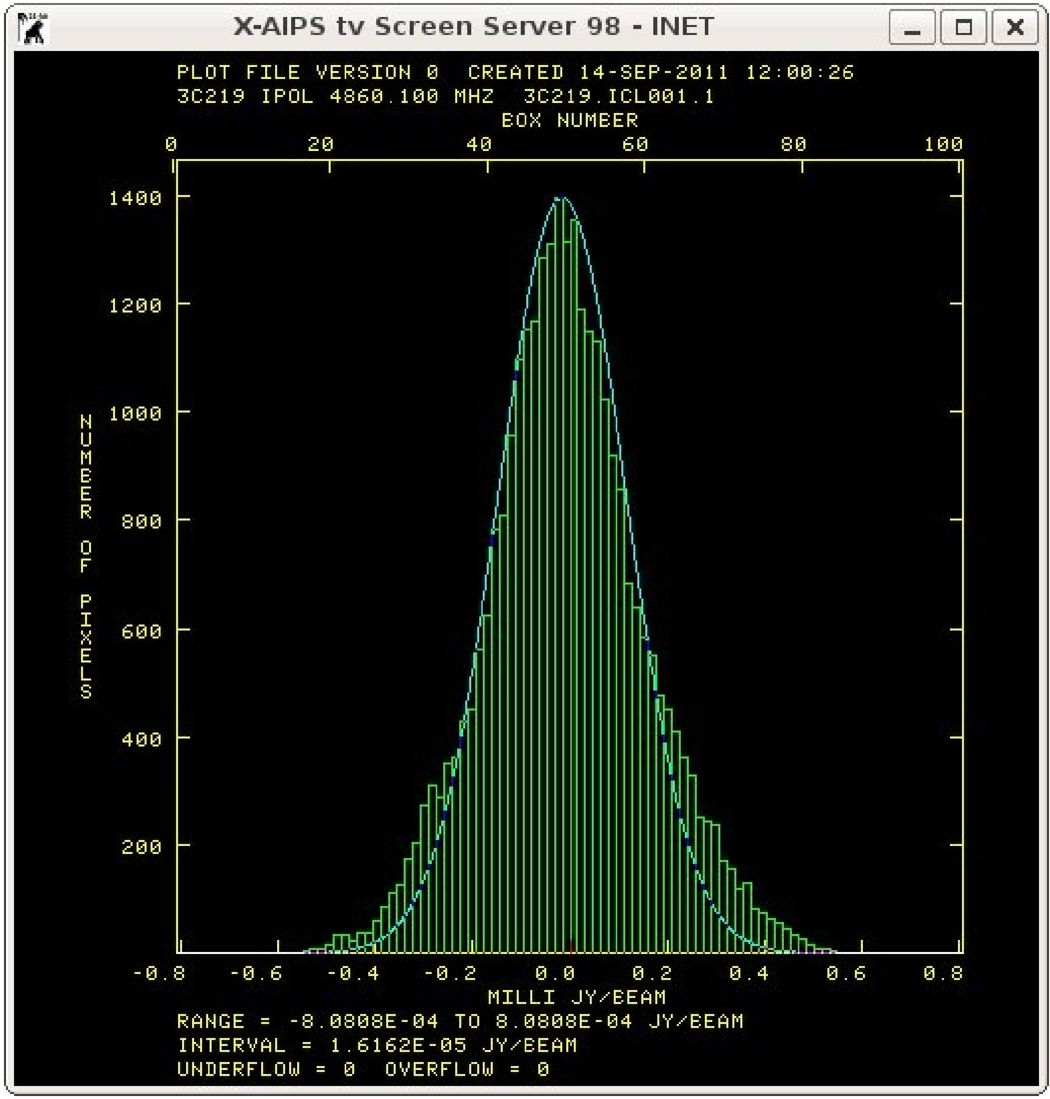

```
---------------      try these inputs  -->-:
 > task 'imean'; inp
AIPS 1: IMEAN:  Task to print the mean, rms and extrema in an image
AIPS 1: Adverbs       Values               Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: DOHIST          2                  True (1.0) do histogram plot.
AIPS 1:                                    = 2 => flux on x axis
                          [omissis]
AIPS 1: INNAME     '3C219'                 Image name (name)
AIPS 1: INCLASS    'ICL001'                Image name (class)
                          [omissis]
AIPS 1: BLC           56         64        Bottom left corner of image
AIPS 1:                1          1        0=>entire image
AIPS 1: TRC          235        228        Top right corner of image
AIPS 1:                1          1        0=>entire image
AIPS 1: DOINVERS      -1                   > 0 => histogram outside
AIPS 1:                                    <=0 => inside BLC/TRC
AIPS 1: NBOXES       100                   No. of ranges for histogram.
AIPS 1: PIXRANGE   -8.00E-04   8.000E-04   Min and max range for hist.
                          [omissis]
AIPS 1: DOTV          1               > 0 Do plot on the TV, else
                          [omissis]
> go imean
```

Hints of map analysis (display `TVALL`, `TVLOD`, `KNTR`, ... ; image statistics: **`IMSTAT`**, **`IMEAN`**, `TVSTAT`, `JMFIT` ...) (4)

With the inputs shown on the previous page, `(go) IMEAN` delivers the diagram shown aside on the TV screen. The r.m.s. noise distribution in this case is not exactly Gaussian, since some more self-calibration would be required as well as a deeper cleaning (`NITER 60000` could be better suited).

On the MSGSRV window there is the following relevant info:

```
daniel> IMEAN1: Task IMEAN  (release of 31DEC08) begins
daniel> IMEAN1: Draw gaussian fit
daniel> IMEAN1: Image= 3C219      .ICL001.   1 1   xywind=   56   64  235  228
daniel> IMEAN1: Mean and rms found by fitting peak in histogram:
daniel> IMEAN1: Mean=-1.6029E-05 Rms= 1.3174E-04  **** from histogram
daniel> IMEAN1: Mean and rms found by including all data:
daniel> IMEAN1: Mean=-7.5997E-06 Rms= 1.6127E-04 JY/BEAM  over     29700 pixels
daniel> IMEAN1: Flux density = -1.3437E-02 Jy.   beam area =  16.80 pixels
daniel> IMEAN1: Minimum=-5.3709E-04 at  142   87    1    1
daniel> IMEAN1: Skypos: RA 09 18 01.50423  DEC 45 48 53.9675
daniel> IMEAN1: Maximum= 5.4860E-04 at  199  181    1    1
daniel> IMEAN1: Skypos: RA 09 17 56.05467  DEC 45 50 27.9919
daniel> IMEAN1: Skypos: IPOL  4860.100 MHZ
daniel> IMEAN1: returns adverbs to AIPS
daniel> IMEAN1: Appears to have ended successfully
daniel> IMEAN1: daniele-lapt 31DEC08 TST: Cpu=       0.0  Real=       0
```



Positive/negative peak values as well as positions are shown, together with the mean pixel value, the r.m.s. and the total flux density in the rectangular area.

N.B. The `DOTV -1` option will create a `PL` file attached to file #6, which can be sent to the printer (or to a file with the task (`LWPLA` – check inputs!)

Hints of map analysis (display TVALL, TVLOD, KNTR, ... ; image statistics: **IMSTAT, IMEAN, TVSTAT**, JMFIT ...) (5)

Extended radio sources are distributed over a number of pixels exceeding the beam area (in pixels). The target source 3C219 in this observation is very well resolved into various components like the (unresolved) core, a jet with a number of knots, two hot-spots and two very large lobes.

A proper way to measure the total source flux density can be obtained with the verb TVSTAT

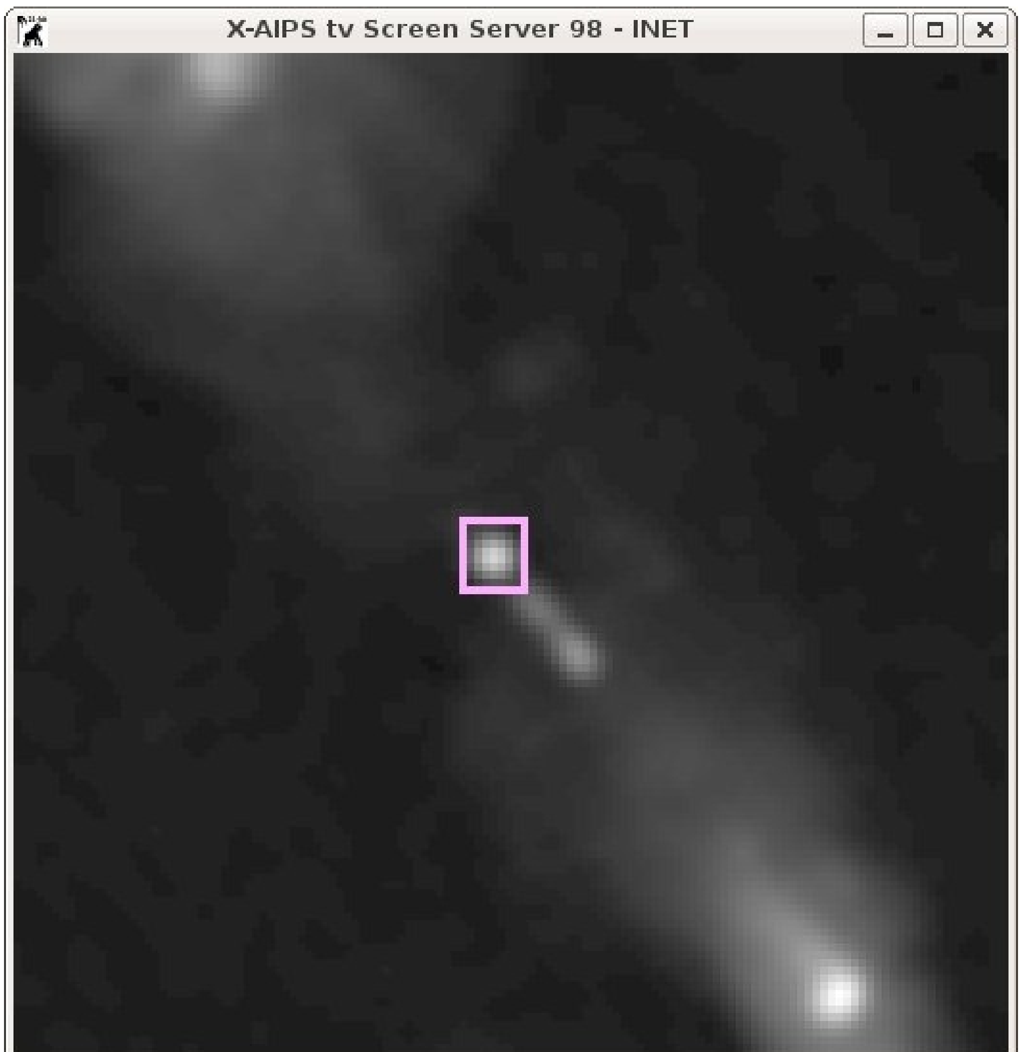
TVSTAT selects a polygonal area over which the statistics is done. This verb can be used also to determine image statistics like the mean and r.m.s. noise value (an off-source region must be selected in this case).

In the example aside, a polygonal region can be selected by hitting button 'B' to set intermediate vertices and button 'D' to set the final vertex and exit. When exiting the messages are returned to the terminal window


```
> tvstat
AIPS 1: Begin setting region number  1
AIPS 1: Press button A to set intermediate vertex
AIPS 1: Press buttons B, C, or D to set final vertex
AIPS 1: C => then reset a vertex,  D => then exit
AIPS 1: Mean= 3.6890E-03 rms= 6.5256E-03 JY/BEAM   over   10901. pixels
AIPS 1: Maximum= 9.4753E-02 at   300   200    1    1    1    1    1
AIPS 1: Skypos: RA 09 17 46.38898  DEC 45 50 46.9952
AIPS 1: Skypos: IPOL  4860.100 MHZ
AIPS 1: Minimum=-4.1670E-04 at  206  279    1    1    1    1    1
AIPS 1: Skypos: RA 09 17 55.38714  DEC 45 52 05.9938
AIPS 1: Skypos: IPOL  4860.100 MHZ
AIPS 1: Flux density =  2.3939E+00 Jy.   Beam area =  16.80 pixels
```

Hints of map analysis (display `TVALL`, `TVLOD`, `KNTR`, ... ; image statistics: `IMSTAT`, `IMEAN`, `TVSTAT`, **`JMFIT`** ...) (5)

When there is a compact component a 2D Gaussian fit can be performed with the task JMFIT, which operates over a small rectangular area. In this example the core component is suitable for running such task. To properly select the area, it could be convenient to zoom the image before setting the window. Then just run `JMFIT` (`niter` 1000) and look at the `MSGSRV` window. The interpretation of the output parameters is straightforward.




```
daniel>daniel> JMFIT1: ********* Solution from JMFIT ********************************
daniel> JMFIT1:
daniel> JMFIT1: Component   1-Gaussian
daniel> JMFIT1:   Peak intensity    = 6.1839E-02 +/-  1.32E-04 JY/BEAM
daniel> JMFIT1:   Integral intensity= 6.7573E-02 +/-  2.42E-04 JANSKYS
daniel> JMFIT1:   X-position       =    255.008 +/-   0.0037 pixels
daniel> JMFIT1:   Y-position       =    256.286 +/-   0.0036 pixels
daniel> JMFIT1:                      RA 09 17 50.69492    +/-  0.0003542
daniel> JMFIT1:                      DEC 45 51 43.2861    +/-   0.003591
daniel> JMFIT1:   Major axis       =   4.168 +/-  0.0089 pixels
daniel> JMFIT1:   Minor axis       =   3.887 +/-  0.0083 pixels
daniel> JMFIT1:   Position angle    =  57.670 +/-  1.234 degrees
daniel> JMFIT1:   Major axis       =  4.16798 +/-  0.00888 asec
daniel> JMFIT1:   Minor axis       =  3.88673 +/-  0.00828 asec
daniel> JMFIT1:   Position angle    =  57.670 +/-  1.234 degrees
daniel> JMFIT1:   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
daniel> JMFIT1:                 Deconvolution of component in pixels
daniel> JMFIT1:                      Nominal     minimum      maximum
daniel> JMFIT1:     Major ax            1.528        1.492        1.562
daniel> JMFIT1:     Minor ax            0.673        0.594        0.743
daniel> JMFIT1:     Pos ang            35.829       33.299       38.359
daniel> JMFIT1:                 Deconvolution of component in asec
daniel> JMFIT1:                      Nominal     minimum      maximum
daniel> JMFIT1:     Major ax         1.527655     1.492408     1.562119
daniel> JMFIT1:     Minor ax         0.672743     0.594467     0.743121
daniel> JMFIT1:     Pos ang         35.828659    33.300186    38.359177
daniel> JMFIT1:   - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
daniel> JMFIT1: returns adverbs to AIPS
daniel> JMFIT1: Appears to have ended successfully
```