3rd LOFAR Data Processing School
Tutorial 4

Data reduction of International LOFAR observations in *AIPS*

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The only fundamental step in the LOFAR Long Baseline calibration that requires *AIPS* is the fringe-fitting, which is performed with task 'FRING'. For completeness we will do the phase calibration, inspection of the solutions and the data, imaging, and self-calibration also in *AIPS*. This brief manual lists the main steps required to obtain an image from the data corresponding to observation id. L244445. Several steps have been conducted before generating the input FITS file. In particular we have flagged and averaged the data, calibrated the core and remote stations with the bright Dutch calibrator 3C196, we have form station TS001 by coherently adding the core stations, we have combined the 16 subbands in one single MS file, we have converted that file from linear to circular polarization, we have exported the data to a UVFITS file. We have removed the core stations (just to reduce the data volumn for this tutorial, we have fixed the data weights with `FIXWT`, and we have scaled the amplitudes of the international stations to a reasonable level.

It is important to remark that here we just present some hints to introduce the user to the *AIPS* work style, although further detailed and conscientious treatment would be required for a detailed data reduction. For a nearly complete explanation of the *AIPS* capabilities, the reader is referred to the *AIPS CookBook*. However, even the *CookBook* is not complete, and it has to be considered just as a guide or model, and to be completed with the specialized information detailed in the `explain` information of each task. The *AIPS* message (`MSG`) window should be checked for possible error messages

4.1 Accessing *AIPS*

Before entering *AIPS* it is useful to define an environment within the shell, before entering *AIPS*, that will be our working path, here we will use MYAREA, although it can be named elsehow:

```
> export MYAREA=$PWD
> export DATA='/data/dataschool2014/longbaseline'
> .  /opt/cep/aips/LOGIN.SH
```
Just needed once
```
> aips tpok tv=local
```

Your ID number is 6XX, where XX is your couple number. *AIPS* works with an internal data area for each user ID. To list the files loaded into *AIPS* you can write `PCAT` to see the whole file list of the current user (or `UCAT` for *uv*-files and `MCAT` for the images). The first time you access your ID number that list should be empty. The corresponding slot number of the file will be used hereafter to identify and apply any task to that file. We will use the input `GETN` followed by the slot number. In case we need to delete a file in the *AIPS* file system, we have to do:

`> GETN` *i*	to select the file to be removed
`> ZAP`	to definitely delete the file (forever!)

Some parameter names are used by different tasks. If you do not set the parameters, the current value will be used. It is recommended to use `DEFAULT` to set the parameters for the current task to the default values to avoid using parameters with values used for other task. You can access a task, for instance `FRING`, in three ways:

`> TASK 'FRING'`	Uses current parameters
`> TGET FRING`	Sets the paramenters from the last call to that task
`> DEFAULT FRING`	Loads the default parameters for that task

To review the list of parameters, read the documentation, or run a task, you can use, respectively:

`> INP FRING`	or simply INP
`> EXPLAIN FRING`	or simply EXPLAIN
`> GO FRING`	or simply GO

Finally, to exit *AIPS* and close all the windows use:

```
> KLEENEX
```

4.2 Loading and inspecting data

We are going to load the fits file L244445_J0834+5534.T4.UVDATA.FITS, located in the directory $D defined above before entering *AIPS*.

FITLD Loads data form UVFITS files into *AIPS*

`> TASK 'FITLD'; DEFAULT`	select the task with default parameters
`> DATAIN 'MYAREA:`*<filename>*`'`	Let the inverted commas opened to read lower-case
`> OUTNAME '`*L244445*`'`	name of the output file within *AIPS*
`> GO FITLD`	to run the program and load the data

✓ Where *filename* is L244445_J0834+5534.T4.UVDATA.FITS

✓ Check the message (`MSG`) window for additional information on how the task is executed, possible errors and warnings.

Once the data is loaded it will be assigned the first slot number. We can select the file and see its header by doing:

`> PCAT`	list the whole file list
`> GETN 1`	to specify the input file
`> IMHEADER`	show some file properties

```
AIPS 1: Image=MULTI      (UV)          Filename=L244445     .UVDATA.    1
AIPS 1: Telescope=LOFAR                Receiver=LOFAR
AIPS 1: Observer=unknown               User #=   500
AIPS 1: Observ. date=25-SEP-2014       Map date=19-NOV-2014
AIPS 1: # visibilities      829294     Sort order   TB
AIPS 1: Rand axes: UU-L  VV-L  WW-L   TIME1  BASELINE  SOURCE  INTTIM
AIPS 1: ----------------------------------------------------------------
AIPS 1: Type      Pixels    Coord value      at Pixel     Coord incr     Rotat
AIPS 1: COMPLEX        3    1.0000000E+00        1.00   1.0000000E+00     0.00
AIPS 1: STOKES         4   -1.0000000E+00        1.00  -1.0000000E+00     0.00
AIPS 1: FREQ          64    1.4284515E+08       32.00   4.8828125E+04     0.00
AIPS 1: IF             1    1.0000000E+00        1.00   1.0000000E+00     0.00
AIPS 1: RA             1     08 34 54.904        1.00        3600.000     0.00
AIPS 1: DEC            1     55 34 21.070        1.00        3600.000     0.00
AIPS 1: ----------------------------------------------------------------
AIPS 1: Coordinate equinox 2000.00
AIPS 1: Rest freq        0.000         Vel type: OPTICAL wrt YOU
AIPS 1: Alt ref. value   0.00000E+00   wrt pixel    32.00
AIPS 1: Maximum version number of extension files of type HI is     1
AIPS 1: Maximum version number of extension files of type FQ is     1
AIPS 1: Maximum version number of extension files of type AN is     1
```

```
AIPS 1: Maximum version number of extension files of type CL is    1
AIPS 1: Maximum version number of extension files of type SU is    1
AIPS 1: Maximum version number of extension files of type XX is    1
AIPS 1: Maximum version number of extension files of type NX is    1
```

✓ Check the number of stokes, frequency channels, IF (=subbands), source coordinates.
✓ The important tables: CL - calibration, SN - solution, FG - flags, AN - antenna list.

LISTR To adquire the list of scans and other general information as frequency, source names, scan structure, and times.

`> TASK 'LISTR'; DEFAULT`	load task with default values
`> GETN` *1*	to specify the input file
`> OPTY 'scan'`	to list the scan of the current file
`> GO LISTR`	to run the program and list the project scans

✓ How many scans are observed? What is their duration? And the total project time?
✓ Identify the source name (only one source, named BEAM_4)
✓ Search all the frequency subbands observed (only 1 in this case)

```
File = L244445      .UVDATA.   1 Vol = 1   Userid =   500
Freq =  0.142845154 GHz    Ncor =  4    No. vis =    829294
Scan summary listing

Scan       Source         Qual   Calcode Sub         Timerange            FrqID   START
   1 BEAM_4              : 0000             1  0/07:30:02 -   0/08:29:59      1        1
   2 BEAM_4              : 0000             1  0/08:30:03 -   0/09:30:00      1   206740
   3 BEAM_4              : 0000             1  0/09:30:04 -   0/10:30:01      1   414188
   4 BEAM_4              : 0000             1  0/10:30:05 -   0/11:29:58      1   621857

Source summary
Velocity type = '          '     Definition = '          '

  ID Source              Qual   Calcode RA(2000.0)      Dec(2000.0)    No. vis
   1 BEAM_4              : 0000           08:34:54.9040   55:34:21.070   829294

  ID Source                Freq(GHz)  Velocity(Km/s)  Rest freq (GHz)
   1 All Sources              0.1428          0.0000           0.0000

Frequency Table summary
FQID IF#        Freq(GHz)        BW(kHz)      Ch.Sep(kHz)    Sideband    Bandcode
   1   1        0.14284515      3125.0002       48.8281          1
```

PRTAN To print the `AN` table, in order to list the corresponding antenna numbers and information about their position we can use this task.

`> TASK 'PRTAN'; DEFAULT`	load task with default values
`> GETN` *1*	to specify the input file
`> INVER` *1*	number version of the table to copy
`> GO PRTAN`	to run the program and print the list of atennas

```
Ant   1 = RS106HBA  BX=  3827528.8700  BY=   473231.4485  BZ=  5064054.3288
Ant   2 = RS205HBA  BX=  3829802.9420  BY=   467576.4445  BZ=  5062863.2298
Ant   3 = RS208HBA  BX=  3846076.5820  BY=   471051.7245  BZ=  5050270.5708
Ant   4 = RS210HBA  BX=  3876150.8338  BY=   471625.5204  BZ=  5027318.9108
```

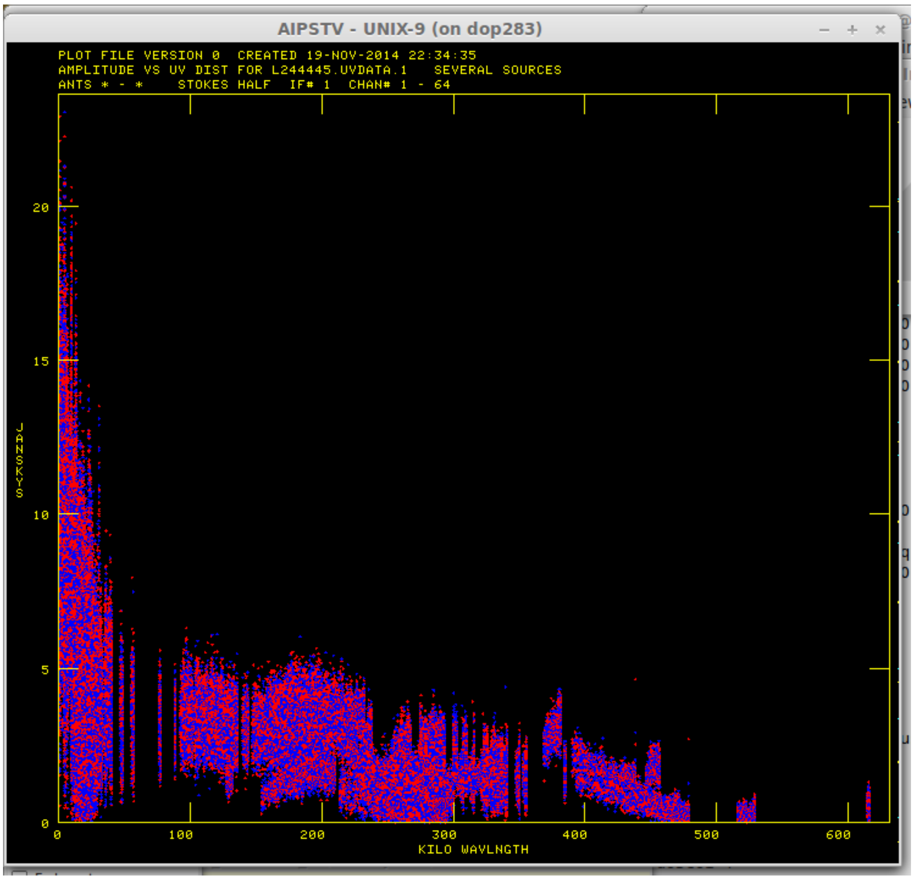
- ✓ Identify which antenna numbers correspond to Remote Stations (RS)
- ✓ Identify which antenna numbers correspond to International stations
- ✓ Identify which antenna numbers correspond to Core Stations (CS)
- ✓ Identify which antenna number correspond to the tied station (TS)
- ✓ Remember or annotate them

4.3 Tools for data examination

UVPLT We can use the AIPS_TV to plot the visibilities as a function of time or *uv*-distance.

> TASK 'UVPLT'; INP	to review the inputs
> GETN *1*	to specify the input file
> UVRANGE *0, 0*	to select the *uv*-range. Set 0 to whole range
> TIMER 0	corresponding time range. 8 values for initial and final time. 0 to use all the times
> STOKES 'HALF'	Can also select RR, LL, LR, LR, I
> BIF 0; EIF 0	first and last IF to plot. Set 0 to whole range
> BCHAN 0; ECHAN 0	first and last baseband channel to plot. Set 0 to all
> NCHAV 64	To average all channels together
> ANTEN *0*; BASEL *0*	list of antenna combination to plot
> DOCAL 2	to apply the CL calibration to the data
> GAINUSE *1*	CL version to apply
> XINC 5	XINC n will plot 1 visibility every n. Use 10 if the plot is too slow
> BPARM 0	X and Y axis. Set 11, 0 to amp vs time. Set 0 to amp vs *uv*-dist. Set 6, 7, 2, 0 to *uv*-coverage
> DO3COL 1	to activate multiple color plots for IF/Channels
> DOTV 1	plot on TV
> GO UVPLT	to run the program and plot the data

- ✓ What is the longest baseline?
- ✓ Can you identify the RS-RS baselines? Use `UVRANGE 0, 60` to see them better.
- ✓ Set `ANTEN 45 0` to see only baselines to the TS001 station.
- ✓ You can fix the scale by setting `BPARM 0, 0, 1, 0, 600, 0, 15, 0`.
- ✓ Now plot `ANTEN 1, 0` (a remote station). Can you see the difference in the dispersion with respect to TS001?
- ✓ Now plot only the international-international baselines by setting
  `ANTEN 15,16,17,18,19,20,21,22`, and
  `BASEL 15,16,17,18,19,20,21,22`
- ✓ How long is the shortest Int-Int baseline?
- ✓ Now plot only the RS-RS baselines by setting
  `ANTEN 1,2,3,4,5,6,7,8,9,10,11,12,13,14`, and
  `BASEL 1,2,3,4,5,6,7,8,9,10,11,12,13,14`
- ✓ How long is the longest RS-RS baseline?
- ✓ You can repeat all the previous steps but plotting phases vs uv-distances. Set: `BPARM 0, 2, 1, 0, 600, -180, 180, 0`. You can see that for the RS there is some structure. Are you convinced now that the phases look messy at long baselines?
- ✓ You can do a uvplot by setting `BPARM 6, 7, 2, 0` including all the stations. Can you see that the longest baselines are more scarce than the shorter ones?



VPLOT This task is very useful to plot the phases versus time for every baseline with the reference antenna. It can also plot the model of a CLEAN image.

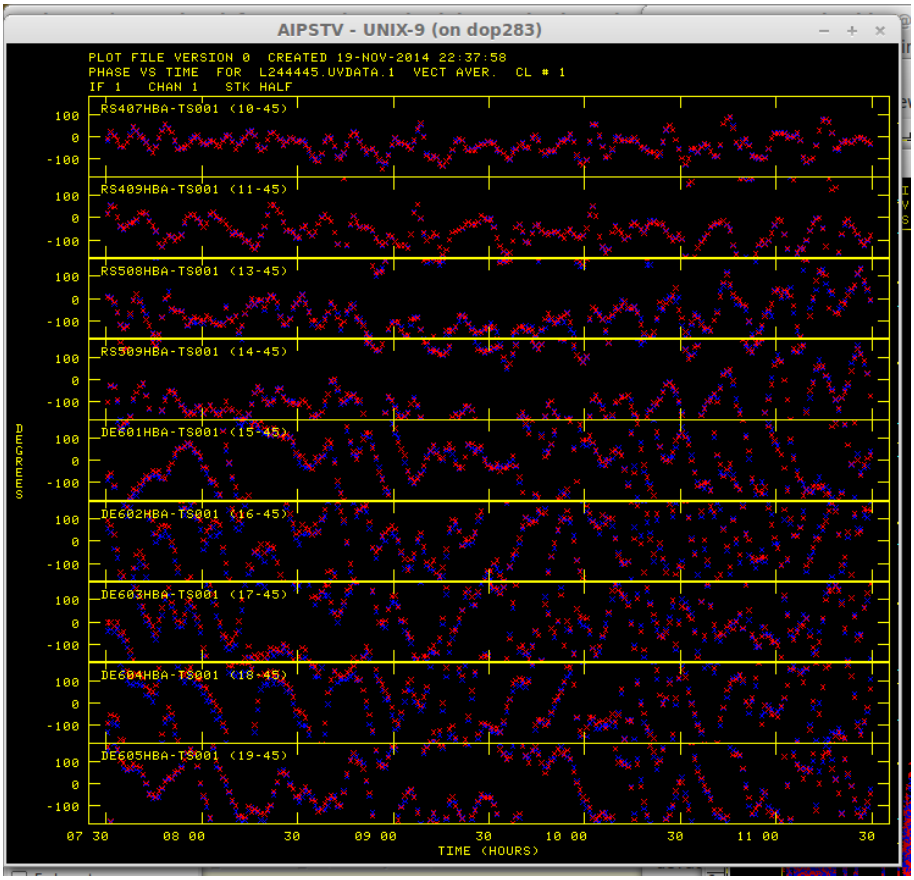
`> TASK 'VPLOT'; DEFAULT`	select the task with default parameters
`> GETN` *1*	to specify the input file
`> TIMER 0`	corresponding time range. 8 values for initial and final time. 0 to all the times
`> STOKES 'HALF'`	Can select `RR`, `LL`, `LR`, `LR`, `I`
`> ANTEN` *45*	usually set the reference antenna
`> BASEL` *0*	list of baselines to plot
`> DOCAL 2`	to apply the `CL` calibration to the data
`> GAINUSE` *1*	`CL` version to apply
`> SOLINT 1`	time interval to average in minutes.
`> APARM 0`	default. Can set list values to flag points
`> BPARM 0, 2, 1, 0, 0, -180, 180, 0`	plot parameters for phase plot vs time with fixed angle range. Set 0, 1, 0 for amplitude and 0, -1, 0 for both
`> NPLOTS 9`	maximum number of plots per page (one for each baseline)
`> DOTV 1`	plot on TV. Set -1 to make a `PL` plot
`> GRCHAN 1`	select the graphic channel, 0–8 (to superimpose plots)
`> DO3COL 1`	to activate multiple color plots for `IF`/Channels
`> TVINI`	to clean the TV server
`> GO VPLOT`	to run the program and plot the phases

✓ Look at the `MSG` server! To proceed with more baselines you have to press B or C. D to finish.

✓ You can change `SOLINT` to average less or more data in time.

✓ Note how fast the phases with International Baselines change with time. Specially at the end of the observation, after 10:00 UTC.

✓ You can zoom on a shorter time by using `TIMER 0, 8, 30, 00, 0, 9, 30, 00`. If you can follow the phases is because this source is bright.

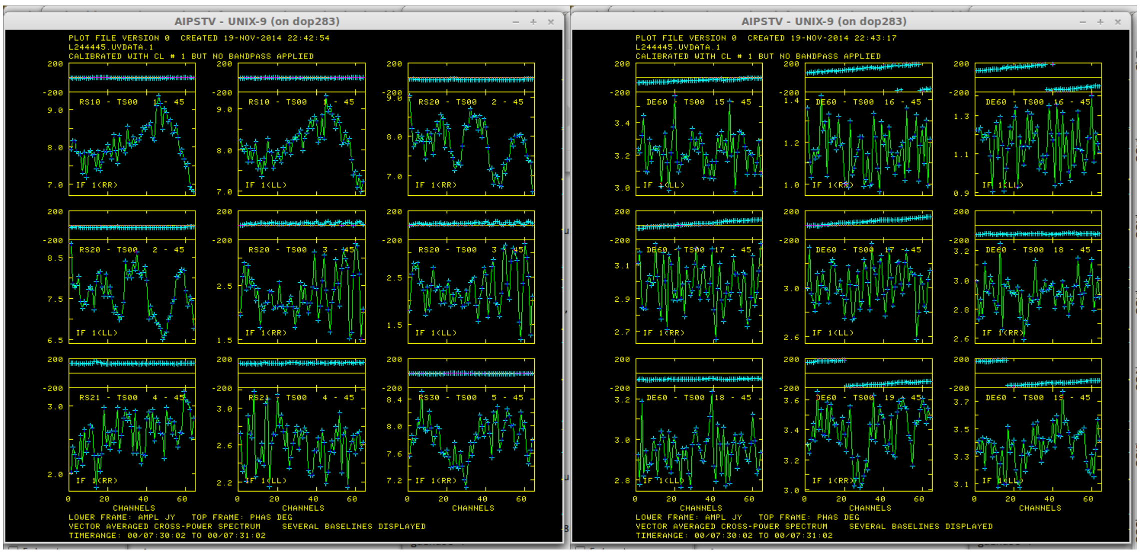


POSSM Now we can plot the amplitude and phases vs frequency.

`> TASK 'POSSM'; DEFAULT`	select the task with default parameters
`> GETN` *1*	to specify the input file
`> TIMER 0`	corresponding time range. 8 values for initial and final time. 0 to all the times
`> STOKES 'HALF'`	Can select `RR`, `LL`, `LR`, `LR`, `I`
`> BCHAN 0; ECHAN 0`	plotting whole range is recommended
`> ANTEN` *45*`, 0`	list of reference antennas to plot
`> BASEL 0`	combination of antennas to plot

`> DOCAL 2`	to apply the `CL` calibration to the data
`> GAINUSE 1`	CL version to apply
`> APARM 0, 1, 0, 0, -180, 180, 0, 0, 1, 0`	
	parameters to plot phase and amplitude. This sets the phase range between -180 and 180 degrees
`> CODETYPE 'A&P'`	to plot both amplitude and phase together
`> SOLINT 1`	time interval to average in minutes.
`> NPLOTS 9`	maximum number of plots per page
`> DOTV 1`	plot on TV
`> TVINI`	to clean the TV server
`> GO POSSM`	to run the program and plot phase & amp. vs frequency

- ✓ Look at the `MSG` server! To proceed with more baselines you have to press B or C. Press D to stop iterating through baselines/times.
- ✓ In each subplot, the top panel shows phase vs channel, and on bottom amplitude vs channel.
- ✓ Note That TS-RS show nice flat phases, because these stations were already calibrated using 3C196 as a model.
- ✓ Offsets from phase zero are caused by source structure, or due to other nearby sources affecting short baselines. As you go to longer baselines the offset is higher because of the source structure.
- ✓ The phase slope you see in the baselines with international stations is the delay!



4.4 Phase calibration

FRING Ready to start your first FRING experience? Now we have to calibrate the phase, delay, and rate of the data. We choose a solution interval of 4 minutes, we constrain the rate search to ±30 mHz, and the delay search to ±600 ns. We will not use baselines shorter than 10kλ because other sources in the field, or the source structure may affect the solutions.

`> TASK 'FRING'; DEFAULT`	select the task with default parameters
`> GETN` *1*	to specify the input file
`> BCHAN 0; ECHAN 0`	all the baseband channels
`> ANTEN 0`	fit all the stations
`> UVRANGE 10, 0`	uv-range to solve in kλ
`> DOCAL 2`	to apply the last calibration
`> GAINUSE` *1*	`CL` table to use
`> CMETHOD 'DFT'`	uses more accurate method, Direct Fourier Transform
`> REFANT` *45*	select the reference antenna. The most sensitive
`> SOLINT 1`	the solution interval
`> DPARM 0, 600, 30, 0`	search windows for `FRING`. Or individually:
`> DPARM(2) 600`	set delay window to search (in nanosec)
`> DPARM(3) 30`	set fringe-rate window to search (in mHz)
`> SNVER` *1*	output `SN` table containing solutions
`> GO FRING`	to run the program and fring the data

- ✓ You can see in the `MSG` window the result of the solution for every scan. It is also important to check the number of good/bad solutions found at the end.
- ✓ Use `IMH` to check that table SN is now in the dataset.
- ✓ That's it. It was not so hard.

```
DOP283> FRING1: Found      10912 good solutions
```

SNPLT Now we will plot de solution table SN. In particular the delays vs time.

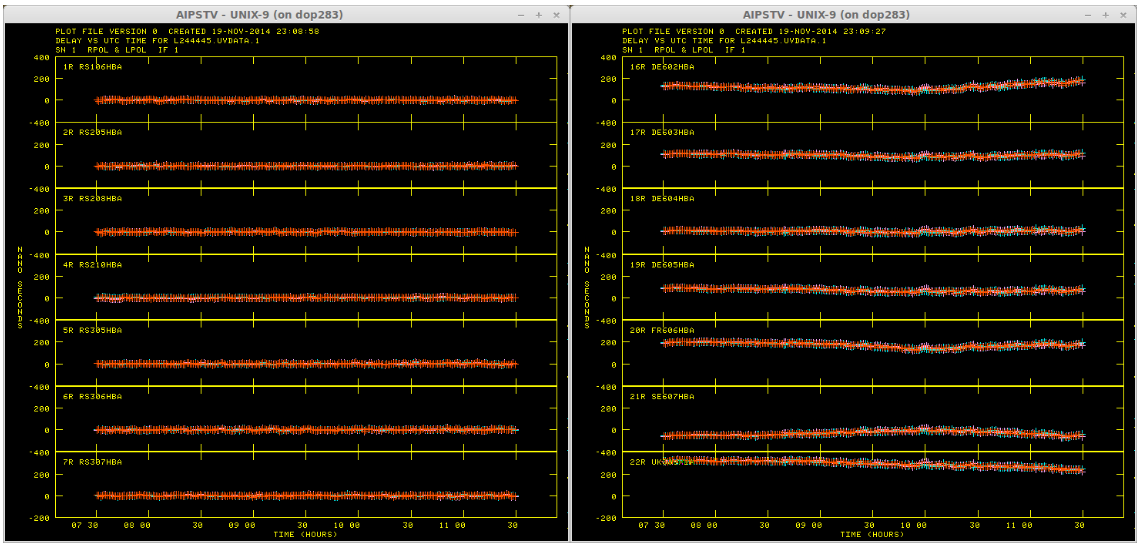
`> TASK 'SNPLT'; DEFAULT`	select the task with default parameters
`> GETN` *1*	to specify the input file
`> INEXT 'SN'`	the extension of the table. Tables `SN`, `TY`, `CL`, `PC`.
`> INVER 1`	number version of the table to plot

`> ANTEN 0`	list of antennas to plot
`> PIXRANGE -150e-9,350e-9`	set the range of the Y axis
`> NPLOTS 7`	number of plots per page
`> OPTYPE 'DELA'`	plots delays. Also possible: `AMP`, `DELA`, `MDEL`, `RATE`
`> OPCODE 'ALSI'`	to plot the two polarizations together
`> DOTV 1`	plot on TV
`> DO3COL 1`	to activate multiple color plots for `IF`/Channels
`> TVINI`	to clean the TV server
`> GO SNPLT`	to run the program and plot the table values

✓ In these plot we see the residual delays corrected by FRING.

✓ The RS have values of ±10 ns. The international stations have values up to 300 ns, with variability of about 30 ns per hour.

✓ You can use `PIXRANGE 0` to better see the small-scale variations of the differential delay at each station.



CLCAL The FRING solutions are in solution table `SN1`. To be applied the corrections to the data, the solutions have to be transferred to a `CL` table using task `CLCAL`. We combine the previous calibration `CL1` with the FRING solutions `SN1` to produce a new calibration table `CL` 2.

`> TASK 'CLCAL'; DEFAULT`	select the task with default parameters
`> GETN 1`	to specify the input file
`> OPCODE 'CALI'`	to calibrate the data
`> INTERPOL 'CUBE'`	fit third order polynomial to phases and rates
`> SNVER 1`	input `SN` table containing solutions to be interpolated

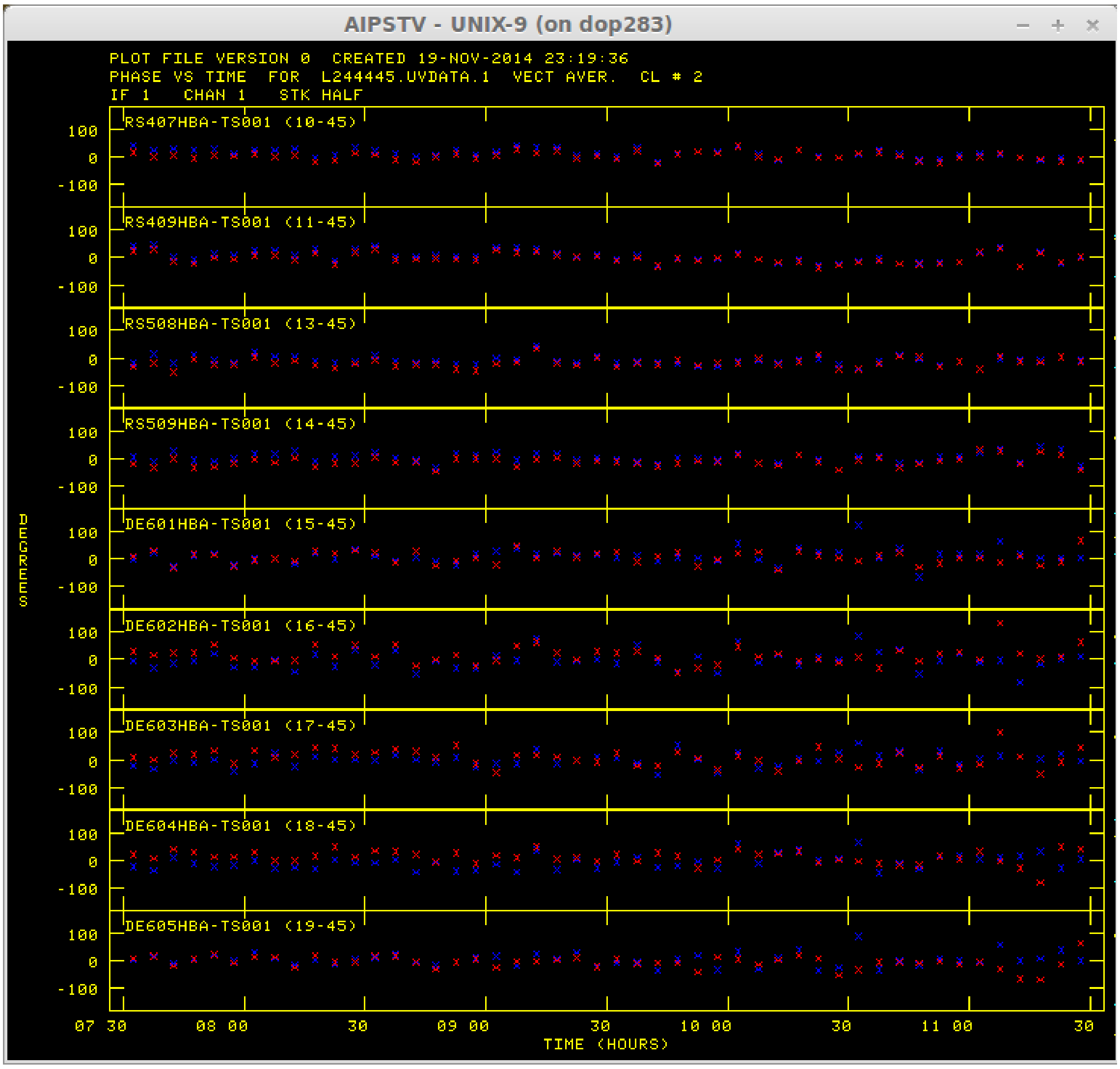
`> GAINVER` *1*	input `CL`version to which solutions are to be applied
`> GAINUSE` *2*	output `CL` version with updated calibration information
`> REFANT` *45*	select the number of the reference antenna
`> GO CLCAL`	to run the program and apply the `SN` solutions to the `CL`

✓ The warning is not important.
✓ Note the message: "Applying SN tables to CL table 1, writing CL table 2".

VPLOT Now let's check how the phases have improved. Against time:

`> TASK 'VPLOT'; DEFAULT`	select the task with default parameters
`> GETN` *1*	to specify the input file
`> STOKES 'HALF'`	Can select `RR`, `LL`, `LR`, `LR`, `I`
`> ANTEN` *45*	usually set the reference antenna
`> BASEL` *0*	list of baselines to plot
`> DOCAL 2`	to apply the `CL` calibration to the data
`> GAINUSE` *2*	`CL` version to apply
`> SOLINT 5`	time interval to average in minutes.
`> BPARM 0, 2, 1, 0, 0, -180, 180, 0`	plot parameters for phase plot vs time with fixed angle range. Set 0, 1, 0 for amplitude and 0, -1, 0 for both
`> NPLOTS 9`	maximum number of plots per page
`> DOTV 1`	plot on TV. Set -1 to make a `PL` plot
`> GRCHAN 1`	select the graphic channel, 0–8 (to superimpose plots)
`> DO3COL 1`	to activate multiple color plots for `IF`/Channels
`> TVINI`	to clean the TV server
`> GO VPLOT`	to run the program and plot the phases

- ✓ You can compare the phases before the calibration by setting `GAINUSE 1`.
- ✓ The phases are around 0, although there is still a high dispersion. That can be improved with self-calibration, where the source structure is also taken into account.
- ✓ You can also plot the phases vs *uv*-distance using `UVPLT`.



When you are happy with the calibration and editing of your multi-source file, the task `SPLIT` can be used to apply the `CL`, `FG`, `BP`, ... tables and to write an *uv*-file containing the data for only one source.

SPLIT When you are happy with the calibration and editing of your, you can apply the `CL`, `FG`, etc., tables to the data itself, and to obtain a data file ready to be imaged.

`> TASK 'SPLIT'; DEFAULT`	select the task with default parameters
`> GETN` *1*	to specify the input file

`> DOCAL 2`	to apply the last calibration
`> GAINUSE 2`	`CL` table to use
`> APARM 2, 0`	all channels will be averaged in the output.
`> GO SPLIT`	to run the program

✓ Run `PCAT` and check that the splitted file is created in catalog slot number 2. From now on, to select that file you will need to use `GETN 2`. Do also `IMH` on that file to see that the number of frequency channels is now 1, and the number of visibilities is much smaller.

FITTP We note that once the phase calibration has been conducted with `FRING`, the next steps can be conducted in any other imaging program, like CASA, Difmap, AWImager, Miriad, etc. You can export the split file as a FITS file to be used anywhere where.

`> TASK 'FITTP'; DEFAULT`	select the task with default parameters
`> GETN 2`	to specify the input *uv*-file
`> DATAOUT 'MYAREA:`<*filename*>	output file
`> GO FITTP`	to run the program and export the file

4.5 Imaging the data

The *uv*-data have to be Fourier-transformed to derive the brightness distribution of the source and obtain an image. The algorithm to deconvolve the dirty map iteratively subtracts the dirty beam pattern from the brightest points of the map, obtaining a residual dirty map. Each iteration subtracts one pattern at one position of the sky, and that position and flux density is stored temporarily in what we call clean component. This cleaning process is repeated until the residual dirty map is smooth and featureless (all noise, and no more sources). In a final step, the temporary map that contains the clean components has to be convolved with an idealized interferometer beam (equivalent to the diffraction pattern), which is a two-dimensional Gaussian function with the FWHM of the dirty beam. The combination of the residual map and the convolved clean components provides the final recovered flux density distribution, it is to say, the image. `IMAGR` is the task that performs all this process.

IMAGR This task applies the deconvolution algorithm (CLEAN). It will generate a dirty (`IBM`) and a clean (`ICLN`) image, which contains a Clean Component `CC` table.

`> TASK 'IMAGR'; DEFAULT`	select the task with default parameters
`> GETN 2`	to specify the input *uv*-file
`> CELLSIZE 0.04`	x,y pixel size, in arcsec.
`> IMSIZE 1024`	x,y size of the field to clean, in pixels. It must be 2^n
`> UVRANGE 20, 0`	*uv*-range to image. Set 0 for full range
`> UVTAPER 120, 120`	Gaussian taper (kilo-lambda) at 30% level
`> ROBUST 5`	weighting scheme parameter. Positive is natural weighting and negative is uniform weighting
`> NITER 1000`	max. number of CC. You can stop before reaching it. Choose more if the final map is not clean enough
`> GAIN 0.05`	loop gain parameter. Small is good for complex sources
`> FLUX 30e-3`	minimum flux to clean, in Jy
`> CMETHOD 'DFT'`	uses more accurate method, Direct Fourier Transform
`> DOTV 1`	to interactively clean the map using the `AIPS_TV`
`> GO IMAGR`	to run the program and obtain an image

- ✓ You can clean interactively in the AIPS_TV window. You can also run it automatically by setting DOTV -1
- ✓ Use Continue Cleaning to begin a new cycle. Left-click on it, and press A, B, C (the instructions are always displayed in the MSG server).
- ✓ You can use TVBOX to limit where to find clean components (CC).

In the MSG server search lines similar to these ones:

```
DOP283> IMAGR1: Total Cleaned flux density    =   3.029     Jy     1000 comps
DOP283> IMAGR1: Fit Gaussian FWHM =    1.462 x    0.984     arcsec , PA=   71.4
DOP283> IMAGR1: Reached minimum algorithm flux =   1.179     Jy iter=       17
```

- ✓ Do PCAT to check that the two new files are created. (CC). You can simply display the image in the AIPS_TV by doing:

> DEFAULT TVLOD	to clean the TV server
> TVINI	to clean the TV server
> GETN 4	to specify the input image
> GO TVLOD	load the image
> TVPS	uses color scale for better location of sources. Press D to exit

KNTR This task generates contour plots. It can also produce grey-scale images, or both together.

> TASK 'KNTR'; DEFAULT	select the task with default parameters
> GETN *4*	to specify the input image file
> DOCONT 1	plot contours
> DOGREY -1	not to plot grey-scale
> DOVECT -1	not to plot polarization vectors
> BLC 0	coordinates of the bottom left corner (in pixels)
> TRC 0	coordinates of the top right corner (in pixels)
> CLEV 10e-3	set the rms of the map as a reference flux to contour
> LEVS=-3 3 4.2, 6, 8.5, 12, 17, 24, 34, 48, 68, 96, 136, 192, 271	
>	contour levels to plot, in ascending order
> DOTV 1	plot on TV. Set -1 to make a PL plot
> GO KNTR	to run the program and plot the contour map

- ✓ Above the image, some information about the image is displayed. Below the image you will see some additional information.

4.6 Self-calibration

To improve the quality of the image of a source bright enough we can self-calibrate the *uv*-data. To do so, we use the `Clean Components` from a cleaned image as an initial model to determine the phase or amplitude calibration. The strategy consist of running the task `CALIB` over the `split` file, using as a model the `CCs` from the last image. This generates an `CALIB` file that can be cleaned again

CALIB Because the delays have already been calibrated with `FRING` the residual delays are small, and we can do a normal calibration. We first calibrate the phases.

`> TASK 'CALIB'; DEFAULT`	select the task with default parameters
`> GETN` *2*	to specify the input *uv* file to calibrate (`SPLIT`)
`> GET2N` *4*	to specify the input model from the best image. This can be different if you have produced several images! Use `PCAT` to know the catalog number of your image
`> UVRANGE 20, 0`	*uv*-range to image. Set 0 for full range
`> REFANT` *45*	select the number of the reference antenna
`> SOLINT 1`	time interval to average in minutes.
`> SOLMODE 'P'`	to calibrate only the phases. For amplitude and phase we will use '`A&P`'
`> SNVER 0`	version of output table to be attached to the *uv* file
`> GO CALIB`	to run the program

✓ The MSG window should be checked to see the number of good solutions found. If the bad solutions are above 20% we have to increase the time interval.

✓ This will create a new `calib` file, containing the calibrated *uv*-data, as well as a `SN` table in the `split` file.

Now we can repeat this process iteratively. We make a new image with the calibrated data. We run `CALIB` again over the previous *uv* file. Usually 1–2 phase self-calibrations followed by an `'A&P'` self-calibration works well. This process can be repeated iteratively. You can use the same parameters from previous executions, or define again all the parameters.

`> TGET 'IMAGR'; DEFAULT`	select the task with default parameters
`> GETN` *5*	to specify the input *uv*-file
`> GO IMAGR`	to run the program and obtain an image

`> TGET 'CALIB'; DEFAULT`	select the task with default parameters

`> GETN` *5*	to specify the input *uv* file to calibrate (`SPLIT`)
`> GET2N` *7*	to specify the input model from the best image.
`> SOLINT 0.5`	time interval to average in minutes.
`> SOLMODE 'P'`	to calibrate only the phases
`> GO CALIB`	to run the program

One more cycle, now calibrating also the amplitudes.

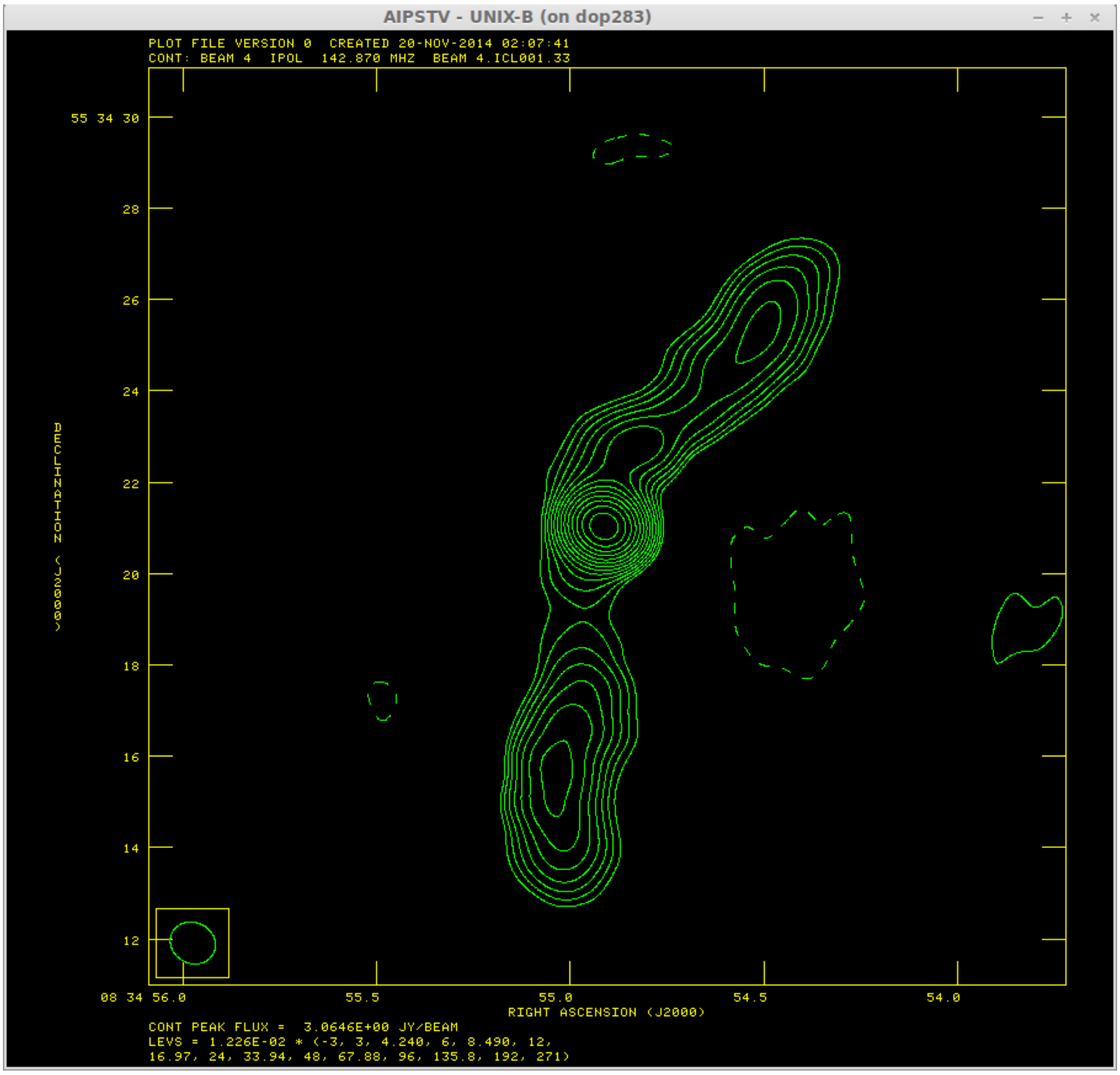
`> TGET 'IMAGR'; DEFAULT`	select the task with default parameters
`> GETN` *8*	to specify the input *uv*-file
`> GO IMAGR`	to run the program and obtain an image

`> TGET 'CALIB'; DEFAULT`	select the task with default parameters
`> GETN` *8*	to specify the input *uv* file to calibrate (`SPLIT`)
`> GET2N` *10*	to specify the input model from the best image.
`> SOLINT 5`	time interval to average in minutes.
`> SOLMODE 'A&P'`	to calibrate only the phases
`> GO CALIB`	to run the program

- ✓ When solving for phases the solution interval can be as short as the S/N of the fit allows.
- ✓ For `'A&P'` is better to start with long intervals (even the whole observation), and then do more cycles reducing the solution interval.
- ✓ You can check how the phases and amplitudes are improving by using `UVPLT`, `VPLOT`, or plot the SN table with `SNPLT`.

Once you are happy with your self-calibration. You are ready to produce your final image:

`> TGET 'IMAGR'; DEFAULT`	select the task with default parameters
`> GETN` *n*	to specify the input *uv*-file
`> GO IMAGR`	to run the program and obtain an image



AIPSTV - UNIX-B (on dop283)
PLOT FILE VERSION 0 CREATED 20-NOV-2014 02:07:41
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55 34 30
28
26
24
22
20
18
16
14
12
DECLINATION (J2000)
08 34 56.0
55.5
55.0
54.5
54.0
RIGHT ASCENSION (J2000)
CONT PEAK FLUX = 3.0646E+00 JY/BEAM
LEVS = 1.226E-02 * (-3, 3, 4.240, 6, 8.490, 12,
16.97, 24, 33.94, 48, 67.88, 96, 135.8, 192, 271)