# Difmap Roadmap

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## Contents

There are three parts to the Caltech VLBI Analysis programs, and DIFMAP is one of them.
Difmap (Shepherd 1997) provides editing, imaging, self-calibration, and pipelining capabilities in an interactive package, link.
This file records my Difmap learning process including the Concept, Installation processes and Using Difmap to processing various data.

# 1 Introduction

DIFMAP is an interactive mapping program that replaces many of the Caltech VLBI analysis programs. It is written in ANSI C, and runs on Sun, IBM, and HP workstations and possibly other UNIX workstations with X-window graphics. For a description, see DIFMAP: an interactive program for synthesis imaging by M. C. Shepherd, T. J. Pearson, and G. B. Taylor [Bull. Amer. Astron. Soc., 26, 987-989 (1994); Bull. Amer. Astron. Soc., 27, 903 (1995).]; and DIFMAP: an interactive program for synthesis imaging***** by M. C. Shepherd [ASP Conference Series, vol.125, "Astronomical Data Analysis Software and Systems VI"].

DIFMAP is obtainable by anonymous ftp from ftp://ftp.astro.caltech.edu/pub/difmap/. An introductory users' guide is available in the Cookbook.

Other useful links: Difmap Tutorial

# 2 Install Difmap (and PGPLOT)

DIFMAP is obtainable by anonymous ftp from ftp://ftp.astro.caltech.edu/pub/difmap/.
So first using lftp command to download the file.

```
lftp ftp.astro.caltech.edu:/pub> lcd .
lcd ok, local cwd=/home/anything/.DIFMAP
lftp ftp.astro.caltech.edu:/pub> mirror difmap/
New: 9 files, 0 symlinks
4868240 bytes transferred in 13 seconds (374.4 KiB/s)
lftp ftp.astro.caltech.edu:/pub> exit

# anything @ anything-China in ~/.DIFMAP [17:51:23]
$ ls
difmap

# anything @ anything-China in ~/.DIFMAP [17:51:24]
$ ls difmap
automap             cookbook.ps.gz     difmap2.5e.tar.gz  help.pdf  README
change_details.txt  difmap2.5d.tar.gz  difmap.html        muppet
```

里面的help.pdf - A manual of Difmap help pages - 共277页， 2018年11月出的。
cookbook.ps 共 36 页
按照difmap.html的提示安装。

To successfully install difmap you will need the following items:

1. An ANSI-C compiler (eg. gcc). You can get the gcc distribution via anonymous ftp from prep.ai.mit.edu in directory /pub/gnu/.

2. A FORTRAN-77 compiler.
   sudo apt install gfortran

3. PGPLOT at version 5.0.2 or above. This may be obtained via anonymous ftp from ftp.astro.caltech.edu in directory /pub/pgplot/. Older versions of PGPLOT will not work with this version of Difmap.
   mkdir /.PGPLOT && cd /.PGPLOT
   LFTP FTP.ASTRO.CALTECH.EDU/PUB
   lcd .
   mirror pgplot

```
# anything @ anything-China in ~/.PGPLOT [18:12:26]
$ lftp ftp.astro.caltech.edu/pub
cd ok, cwd=/pub
lftp ftp.astro.caltech.edu:/pub> lcd .
lcd ok, local cwd=/home/anything/.PGPLOT
lftp ftp.astro.caltech.edu:/pub> mirror pgplot/
Total: 1 directory, 23 files, 1 symlink
New: 23 files, 1 symlink
4146226 bytes transferred in 26 seconds (153.9 KiB/s)
lftp ftp.astro.caltech.edu:/pub> exit

# anything @ anything-China in ~/.PGPLOT [18:13:33]
$ ls pgplot
copyright.notice  install-vms.txt  pgplot5.2.tar.gz  ver501.txt  ver511.txt
DOC               pgplot520.tar.gz README            ver502.txt  ver520.txt
install.txt       pgplot521.tar.gz sys_win.readme    ver503.txt  ver521.txt
install-unix.txt  pgplot522.tar.gz ver500.txt        ver510.txt  ver522.txt
```

Install PGPLOT in Ubuntu, original link

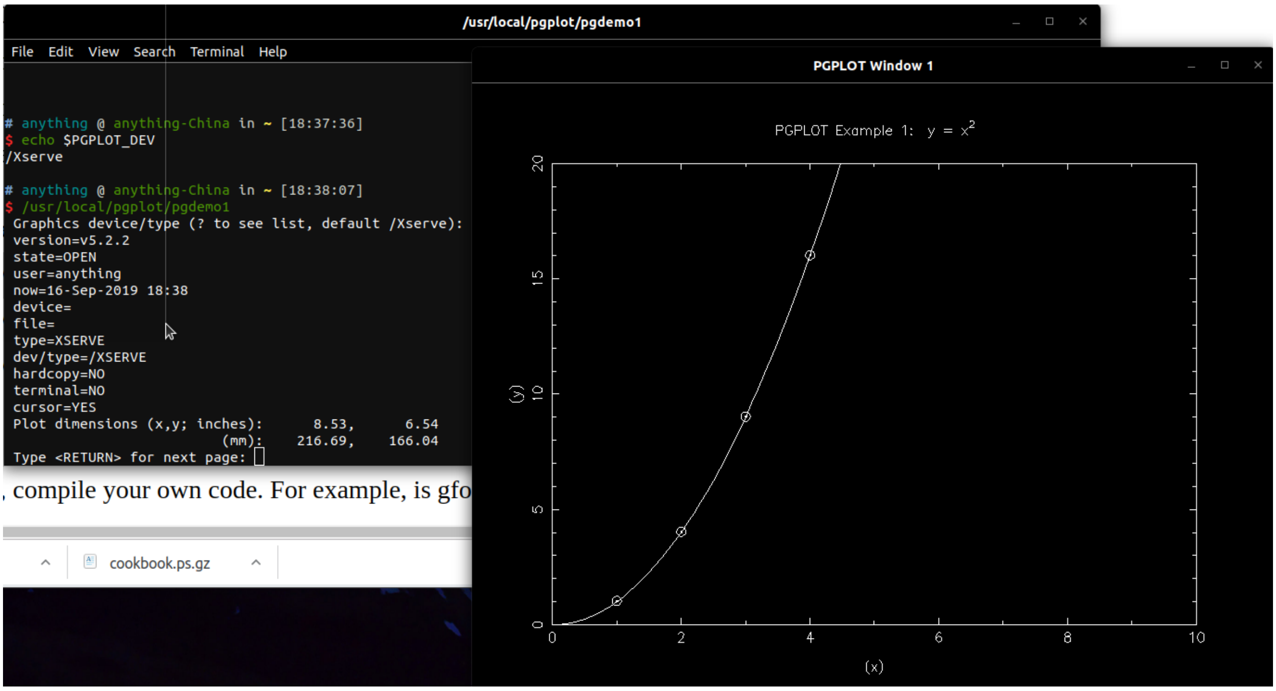
After sudo make:

```
*** Finished compilation of PGPLOT ***

Note that if you plan to install PGPLOT in a different
directory than the current one, the following files will be
needed.

        libpgplot.a
        grfont.dat
        rgb.txt
        pgxwin_server

Also note that subsequent usage of PGPLOT programs requires that
the full path of the chosen installation directory be named in
an environment variable named PGPLOT_DIR.
```

After sudo make cpg:

```
*** Finished compilation of the C PGPLOT wrapper library ***

Note that if you plan to install the library in a different
directory than the current one, both libcpgplot.a and cpgplot.h
will be needed.
```

After Successfully installed:




In uvf_difmap folder install difmap:
sudo ./configure linux-i486-gcc
sudo ./makeall
Error:
/usr/bin/ld: cannot find -lpgplot
/usr/bin/ld: cannot find -lncurses
collect2: error: ld returned 1 exit status
Using this link to solve
sudo ln -s /home/anything/.CASA/lib/libpgplot.so.5 libpgplot.so
sudo ln -s /home/anything/.CASA/lib/libncurses.so.5 libncurses.so

sudo cp /home/anything/.CASA/lib/libpng15.so.15 /usr/lib/x86_64-linux-gnu
sudo cp /home/anything/.CASA/lib/libgfortran.so.3 /usr/lib/x86_64-linux-gnu
sudo ln -s /home/anything/.CASA/lib/libgfortran.so.3 /usr/lib/x86_64-linux-gnu/libgfortran.so
Finally: sudo ./makeall finished:

```
Compiling the command parser library libsphere.a

make: Nothing to be done for 'default'.

Compiling difmap itself

gfortran -o difmap  startup.o f77main.o difmap.o slfcal.o wmapbeam.o maplot.o moddif.o vlbhead.o uvaver.o mapmem.o mapclean.o
 mapres.o costran.o uvinvert.o clphs.o clplot.o vlbhist.o enumpar.o symtab.o plbeam.o uvrotate.o stnstr.o uvtrans.o corplt.o
modplot.o uvradplt.o vedit.o vplot.o color.o uvplot.o timplt.o specplot.o markerlist.o uvf_read.o uvf_write.o obs.o subarray.
o obutil.o binan.o dpage.o if.o ifpage.o intrec.o obedit.o obhead.o uvpage.o chlist.o obpol.o telcor.o visaver.o utbin.o intl
ist.o obshift.o resoff.o winmod.o subamphs.o addamphs.o nextif.o wtscal.o units.o scans.o mapwin.o stokes.o visstat.o pb.o ma
pcor.o hms.o termstr.o visflags.o telspec.o ellips.o uvrange.o baselist.o spectra.o pollist.o freelist.o planet.o cksum.o fni
nt.o dnint.o frange.o imran.o minmax.o lmfit.o matinv.o newfft.o  model.o modvis.o besj.o addmod.o modfit.o modeltab.o -L/hom
e/anything/.DIFMAP/difmap/uvf_difmap/lib -lsphere -L/home/anything/.DIFMAP/difmap/uvf_difmap/lib -llogio -L/home/anything/.DI
FMAP/difmap/uvf_difmap/lib -lpager -L/home/anything/.DIFMAP/difmap/uvf_difmap/lib -lcpgplot -lpgplot -lX11 -L/home/anything/.
DIFMAP/difmap/uvf_difmap/lib -lfits -L/home/anything/.DIFMAP/difmap/uvf_difmap/lib -lrecio -L/home/anything/.DIFMAP/difmap/uv
f_difmap/lib -lscrfil -L/home/anything/.DIFMAP/difmap/uvf_difmap/lib -lslalib -ltecla -lncurses /usr/lib/gcc/x86_64-linux-gnu
/8/libgcc.a -lm
/usr/bin/ld: /home/anything/.DIFMAP/difmap/uvf_difmap/lib/libpager.a(pager.o): in function `new_Pager':
pager.c:(.text+0x2af): warning: the use of `tmpnam' is dangerous, better use `mkstemp'
/usr/bin/ld: warning: libgfortran.so.3, needed by /usr/lib/gcc/x86_64-linux-gnu/8/../../../x86_64-linux-gnu/libpgplot.so, may
 conflict with libgfortran.so.5
mv difmap /home/anything/.DIFMAP/difmap/uvf_difmap/difmap
chmod ugo+rx /home/anything/.DIFMAP/difmap/uvf_difmap/difmap
```

Then, run difmap and an error comes out:
./difmap
./difmap: error while loading shared libraries: libpgplot.so.5: cannot open shared object file: No such file or directory
After this command:
sudo cp /home/anything/.CASA/lib/libpgplot.so.5 /usr/lib/x86_64-linux-gnu/
it is fine:

```
# anything @ anything-China in ~/.DIFMAP/difmap/uvf_difmap [19:32:16]
$ ./difmap
Caltech difference mapping program - version 2.5e (30 May 2019)
Copyright (c) 1993-2019 California Institute of Technology. All Rights Reserved.
Type 'help difmap' to list difference mapping commands and help topics.
Started logfile: difmap.log on Mon Sep 16 19:32:19 2019
0>help difmap
The following is a list of difference mapping topics and commands on
which help documentation is available. Other information can be found
in the difmap cookbook. To see help for a given entry in the following
list, type

  help name

where name is the entry that you want to learn about.

General help topics:
-------------------
 antenna_names
   A description of the format of telescope specifications.
 editing
   General discussion of editing in difmap.
 models
   An overview of how models are used in difmap.
 multi_if
   An overview of multi-IF mapping.
 polarization
   Overview of Difmap polarization mapping.
 spectral_line
Press return to continue, Q [or command] to quit, or P to page.
#exit
Listing completed.
Exiting program
Log file difmap.log closed on Mon Sep 16 19:32:45 2019
```

Finally, add this line:
export PATH=/home/anything/.DIFMAP/difmap/uvf_difmap:$PATH
to ~/.zshrc file and source ~/.zshrc

# 3 Difmap: An Interactive Program for Synthesis Imaging, link

Difmap is a stand-alone program used by the radio-astronomy community to produce images from radio interferometers. It reads and writes the standard UV FITS file format produced by packages such as AIPS, and provides convenient ways to inspect, edit, and self-calibrate visibility data while incrementally building up a model of the sky. Some time will also be spent describing the general structure of Difmap, particularly how being contained within a single-process is exploited to achieve speed, portability, and a degree of interactivity that is hard to match in larger systems.

An integrated difference mapping environment in which all of the functionality of the Caltech VLBI package would be incorporated within a single program.

Three month the minimum quorum of commands needed to implement difference mapping, packaged under a scripting interface. The resulting program was called Difmap.

Difmap quickly spread throughout the VLBI community, and later, after Difmap had been upgraded to support multi-dimensional AIPS UV-FITS files, it became a popular alternative to more general packages, such as AIPS.

No significant development has taken place since the release of the FITS version of Difmap in April 1995, owing to a reduction in NSF funding. However, Difmap has retained a strong following and has required very little maintenance.

## 3.1 Interferometry in a Nutshell

The essential steps needed to construct an image from signals received by a radio interferometer are:

1. Point an array of telescopes at a radio source.

2. Measure the complex wavefronts that arrive at each telescope with radio receivers.

3. Insert artificial delays in the signal paths of each telescope so that the telescopes all appear to be at the same effective distance from the source.

4. Interfere signals from pairs of telescopes and record the resulting complex fringe visibilities as a function of time.

5. Note that the visibilities from a given pair of telescopes sample spatial frequencies on the sky in proportion to the projected separation of the telescopes. Also note that this separation changes as the Earth turns, so each pair of telescopes samples a locus of spatial frequencies as a function of time. This is called Earth rotation synthesis.

6. Use the observations of a bright source to calibrate the visibilities.

7. Interpolate the visibilities onto a 2-D spatial-frequency plane called the UV plane.

8. Calculate the FFT of the UV plane. The resulting image is called a dirty map, and constitutes an image of the source corrupted by the point-spread function of the interferometer.

9. Form a model of the source through CLEAN deconvolution of the dirty map, or by fitting a model to the visibilities.

10. Convolve the model by an elliptical Gaussian approximation of the point spread function of the interferometer, and add the result to the un-modeled residual noise in the dirty map. This is called a clean map.

11. Publish the map.

## 3.2 What Does Difmap Do?

### 3.2.1 Data Inspection and Editing

A significant fraction of Difmap is devoted to providing users with convenient tools for interactive data inspection and editing. A family of graphical commands displays observed and model visibilities from a variety of perspectives, and allows the user to flag or unflag visibilities directly with the mouse. Simple key-bindings are combined with mouse positioning to quickly navigate through telescopes, baselines, bands, and sub-arrays, to edit visibilities collectively or individually, to zoom in on parts of the data, and to perform many other command-specific operations. These facilities are important because:

- They allow users quickly to identify and excise corrupt data.
- They provide a direct comparison between the model and the data.
- They help to familiarize users with the peculiarities of their datasets.
- They provide beginners with visualization tools to learn how given visibility profiles produce given maps.
- They can be used to inspect dynamically changes made to the visibilities and the model during processing.

### 3.2.2 Difference Mapping

Difmap was named after a mapping technique called Difference Mapping.

Difmap was named after a mapping technique called **Difference Mapping**.

When a model of a source is subtracted from a dirty map, what remains is known as a difference or residual map. This is a key component in Difference Mapping.

The source model that is subtracted from the dirty map is built up in an iterative fashion, usually through **CLEAN** deconvolution of successive versions of the residual map. Alternatively a model can be fitted to the observed visibilities.

When CLEAN is used to build up the source model, each iteration of CLEAN not only adds a delta-function to the model, but also subtracts that delta-function and its PSF from the residual map. Thus CLEAN automatically keeps the residual map up to date with the changes that it makes to the model.

Conversely, when model fitting is used to build up the model, or when a user edits either the visibilities or the model between successive iterations of CLEAN, then the residual map becomes out of date. When this happens, Difmap automatically re-calculates the residual map by taking the 2-D FFT of the difference between the observed and the model visibilities.

At this point, if visibilities were edited by the user, then the current model may retain minor features that were deconvolved from those visibilities. With the offending visibilities removed from the data, these artifacts only remain in the model, so when the model is subtracted from the data, the revised residual map contains an inverted version of the artifacts. Subsequent iterations of CLEAN thus erase them from the model. This typically involves both positive and negative CLEAN components.

The ability to transparently continue deconvolution after modifying the model or the observed visibilities highlights a fundamental difference between difference mapping and traditional techniques. The traditional approach would require the user to restart deconvolution from scratch, whereas the difference mapping approach encourages the user to edit or re-calibrate the data on-the-fly as ever weaker artifacts appear in successive versions of the residual map. It also enables users to incrementally add clean windows. This is especially useful when features that were initially obscured by the point spread functions of brighter features, are revealed in the residual map.

### 3.3 Difmap Architecture

#### 3.3.1 The Observation Object

## 4 Difmap Cookbook, link

Using ps2pdf cookbook.ps cookbook.pdf command to convert ps file to pdf file.
If comes this error:
./base/gsicc_manage.c:1244: gsicc_open_search(): Could not find default_gray.icc
— ./base/gsicc_manage.c:2261: gsicc_init_iccmanager(): cannot find default icc profile
**** Unable to open the initial device, quitting. then follow this instruction,
Using following commands:
sudo rmdir /usr/share/ghostscript/9.26/iccprofiles
sudo apt-get install –reinstall libgs9-common Then ps file can be converted to pdf file using ps2pdf command.
cook_book.pdf 共36页。

The purpose of this cookbook is to instruct and demonstrate how to drive Difmap effectively. A general mapping technique is presented and demonstrated for a snapshot VLBI observation of a core-jet source. Sample outputs are produced from all the displays generated by Difmap.

Selected output lines are also written to the logfile, although they are prefixed with a ! sign so that the log file may later be executed as a command file from within Difmap by typing difmap .log_5

## 4.1 Reading Data

Difmap 载入数据 blog, difmap check and edit data
Astronomy software
VLBI_Imaging_Script

In cookbook, the data file called: "0749+540.cal" and I can not find it on internet.
Yet I find a .fits file at VLBI_Imaging_Script and can be read by difmap using observe command:

```
$ difmap
Caltech difference mapping program - version 2.5e (30 May 2019)
Copyright (c) 1993-2019 California Institute of Technology. All Rights Reserved.
Type 'help difmap' to list difference mapping commands and help topics.
Started logfile: difmap.log_2 on Tue Sep 17 12:52:12 2019
0>observe J0017+8135_S_1998_10_01_pus_vis.fits
Reading UV FITS file: J0017+8135_S_1998_10_01_pus_vis.fits
AN table 1: 1533 integrations on 136 of 136 possible baselines.
AN table 2: 810 integrations on 136 of 136 possible baselines.
AN table 3: 240 integrations on 136 of 136 possible baselines.
Apparent sampling: 0.29775 visibilities/baseline/integration-bin.
*** This seems a bit low - see "help observe" on the binwid argument.
Found source: J0017+8135

There are 4 IFs, and a total of 4 channels:

 IF  Channel    Frequency  Freq offset  Number of   Overall IF
      origin    at origin  per channel   channels    bandwidth
 ------------------------------------------------------------- (Hz)
 01        1  2.22298e+09       4e+06           1       4e+06
 02        2  2.24298e+09       4e+06           1       4e+06
 03        3  2.33298e+09       4e+06           1       4e+06
 04        4  2.36298e+09       4e+06           1       4e+06

Polarization(s): RR

Read 2 lines of history.

Reading 418384 visibilities.
0>
```

To get more information about your observation type header.

In order for editing and selfcalibration to work, visibilities from diferent baselines must be grouped with the same integration times.

### 4.2 Examing Data

At this point it is often useful to take a look at a plot of amplitude versus u-v radius.
This may be obtained by typing: 0¿ radplot

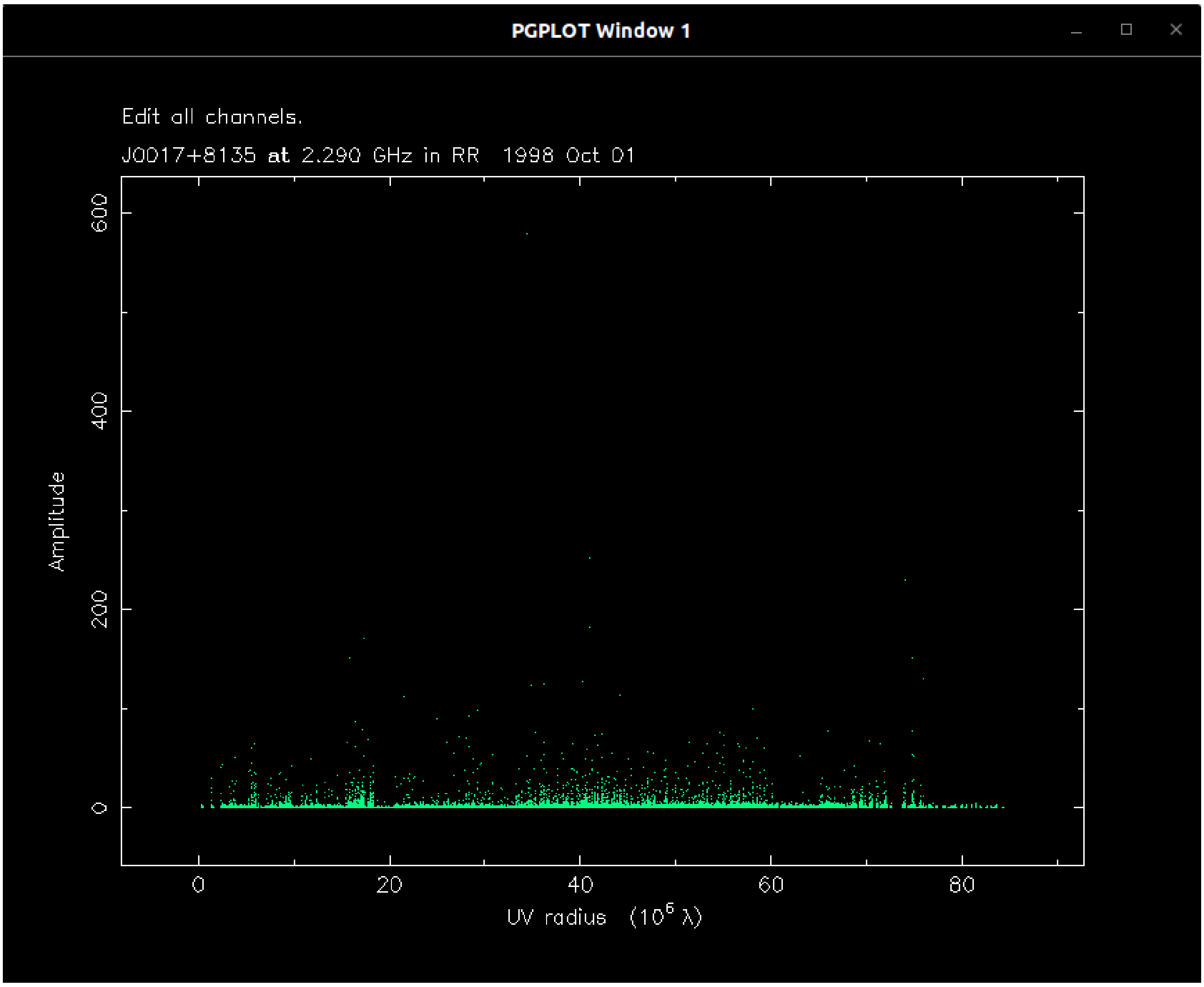
If your data consists of only a single polarization and spectral line channel (as in the example above), then Difmap will automatically select that polarization after it is read in. If you have more than one polarization then you'll need to to select a polarization and channel range for processing using the select command

```
0>select rl
Polarization RL is unavailable.
Selecting polarization: RR,  channels: 1..4
Reading IF 1 channels: 1..1
Reading IF 2 channels: 2..2
Reading IF 3 channels: 3..3
Reading IF 4 channels: 4..4
0>
```

Then use radplot command to plot amplitude versus u-v radius:

```
0>radplot
 Graphics device/type (? to see list, default /Xserve): ?
 PGPLOT v5.3.1 Copyright 1983-2005 California Institute of Technology
 Interactive devices:
    /XTERM      (XTERM Tek terminal emulator)
    /XWINDOW    (X window window@node:display.screen/xw)
    /XSERVE     (A /XWINDOW window that persists for re-use)
 Non-interactive file formats:
    /NULL       (Null device, no output)
    /PNG        (Portable Network Graphics file)
    /TPNG       (Portable Network Graphics file - transparent background)
    /PS         (PostScript file, landscape orientation)
    /VPS        (PostScript file, portrait orientation)
    /CPS        (Colour PostScript file, landscape orientation)
    /VCPS       (Colour PostScript file, portrait orientation)
    /EPS        (Encapsulated Postscript, colour)
 Graphics device/type (? to see list, default /Xserve): /xw

Using default options string "m1"
Move the cursor into the plot window and press 'H' for help
```

And the result figure comes out:

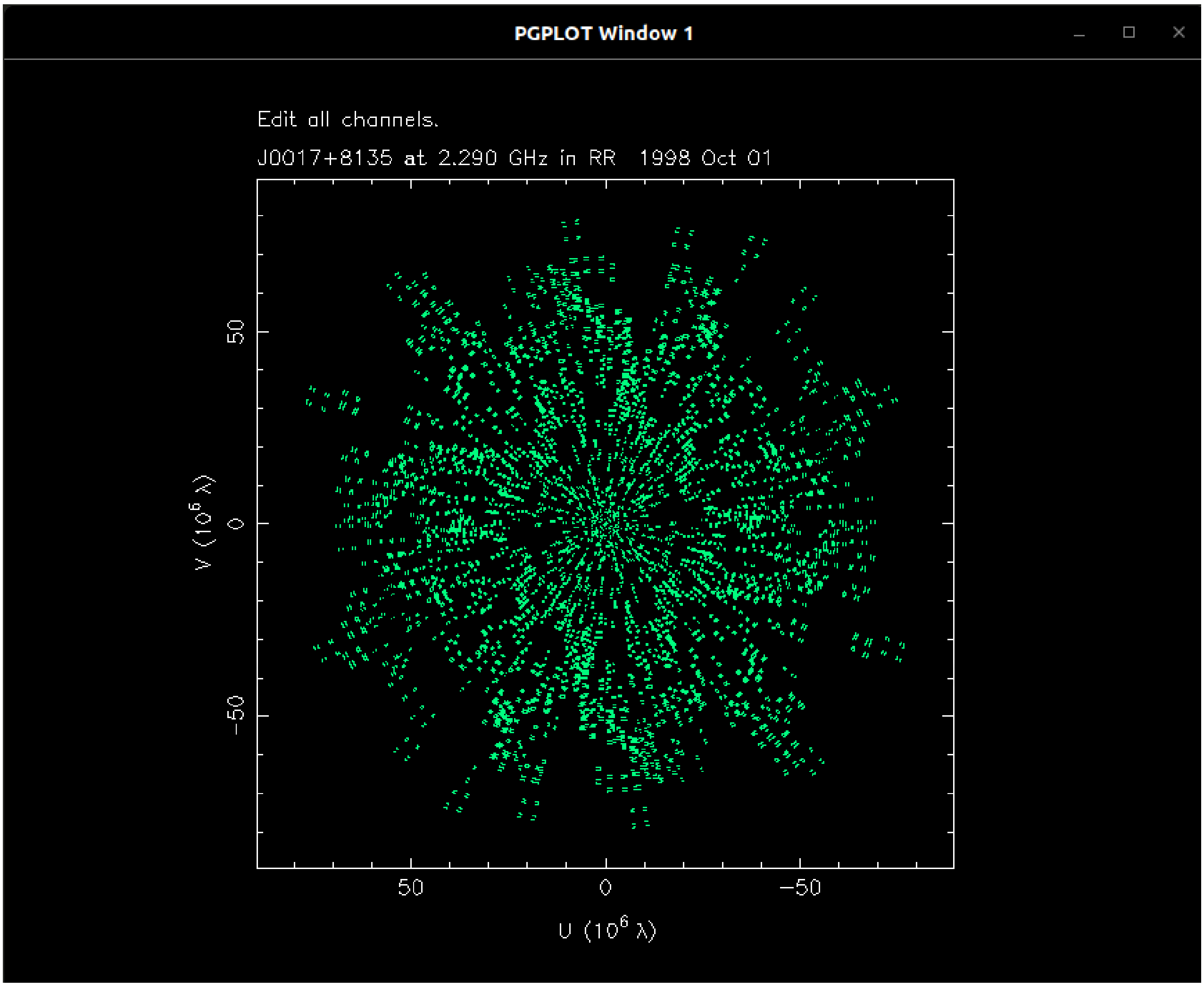



This display can be manipulated in a variety of ways. Move the cursor to the plot window. Now type n. This will highlight all visibilities involving the

rst antenna, and the name of that antenna will be displayed in the top right corner of the plot. Pressing n again will highlight visibilities of the next antenna, and so forth. If you're having trouble seeing your data points, try typing a period, ", to make each point bigger. Type h to obtain the following list of options.

Although it it often tempting to edit away bad points in radplot be aware that such edits are baseline-based edits, while systematic errors are more often antenna-based

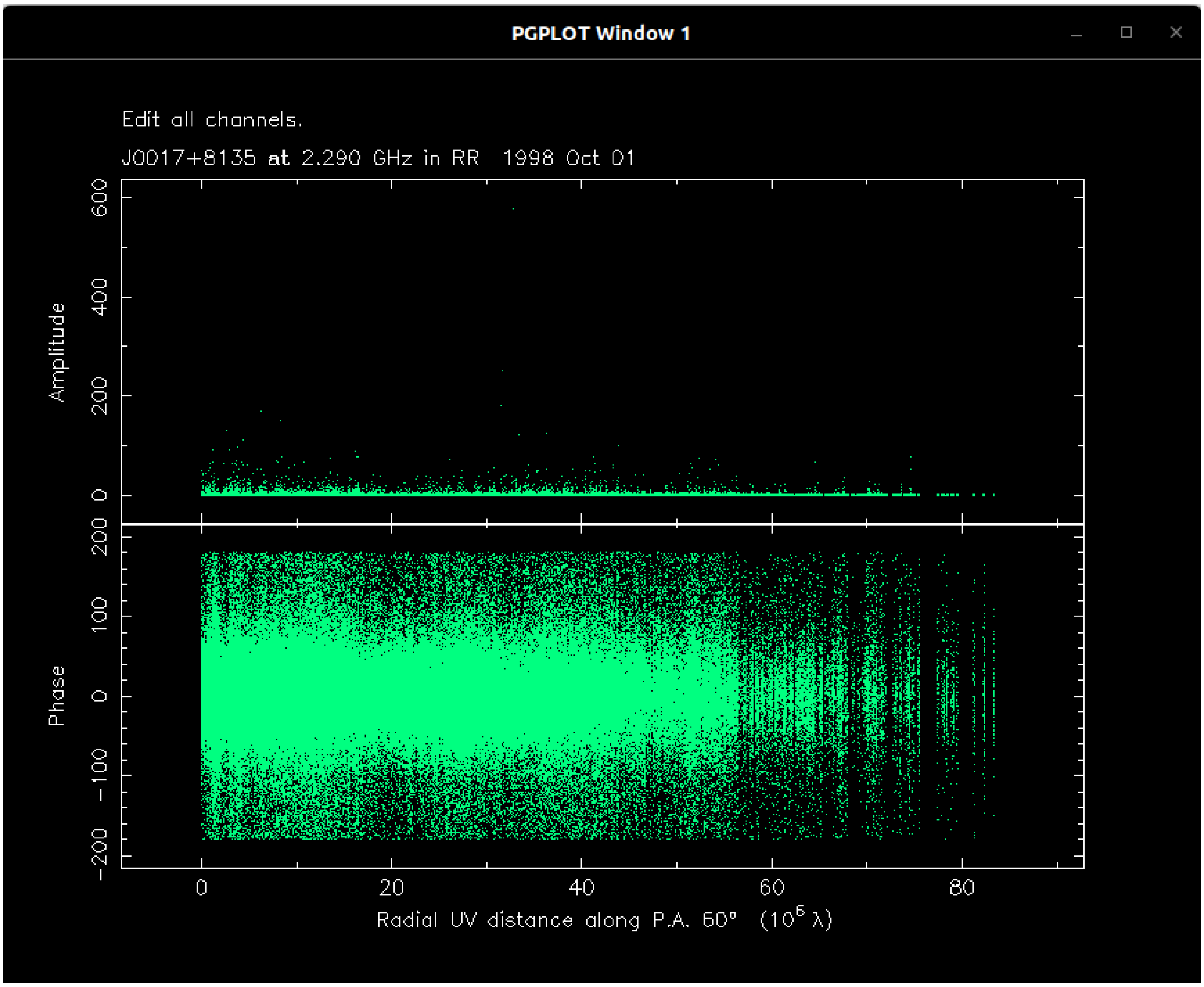
Another useful display is a plot of the u-v coverage. This may be obtained by typing:
uvplot




Visibilities common to each telescope can be highlighted by typing n with the cursor in the plot window. To zoom in on a region of the uvplot, type z followed by two opposite corners. Pressing the z key twice more will unzoom the plot. Other display options are similar to radplot except that editing of individual points is not allowed. Regions may be selected for editing with the c key, but such edits are generally not recommended. To exit, type X or push the third mouse button

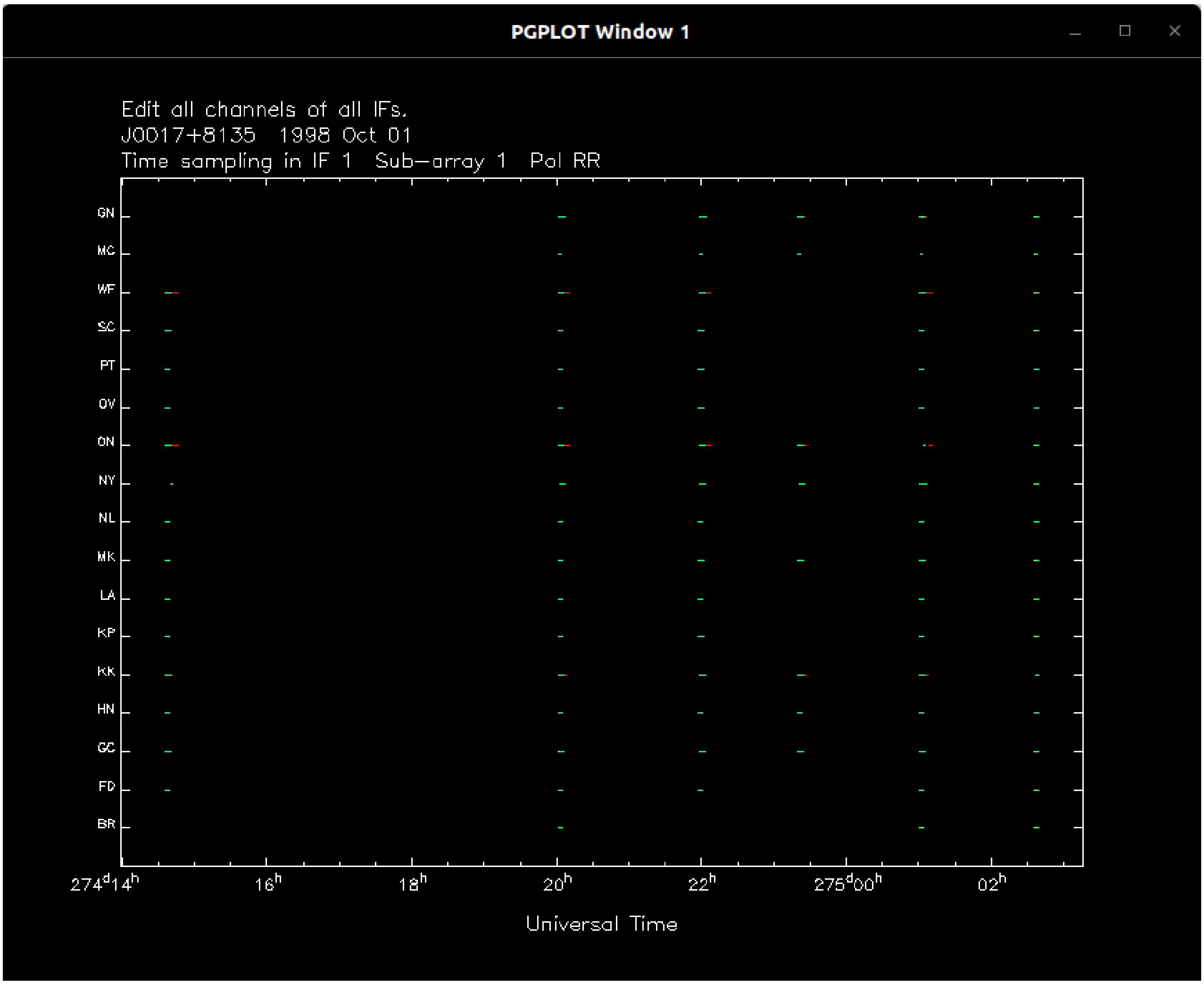
To look at a cut of amplitude and/or phase along any radial line in the UV plane use the command projplot. This is especially useful for double sources, or sources with straight jets.

projplot 60:




If you suspect that some of your data may be missing, or have gaps, you can verify this using tplot.

## tplot 60:



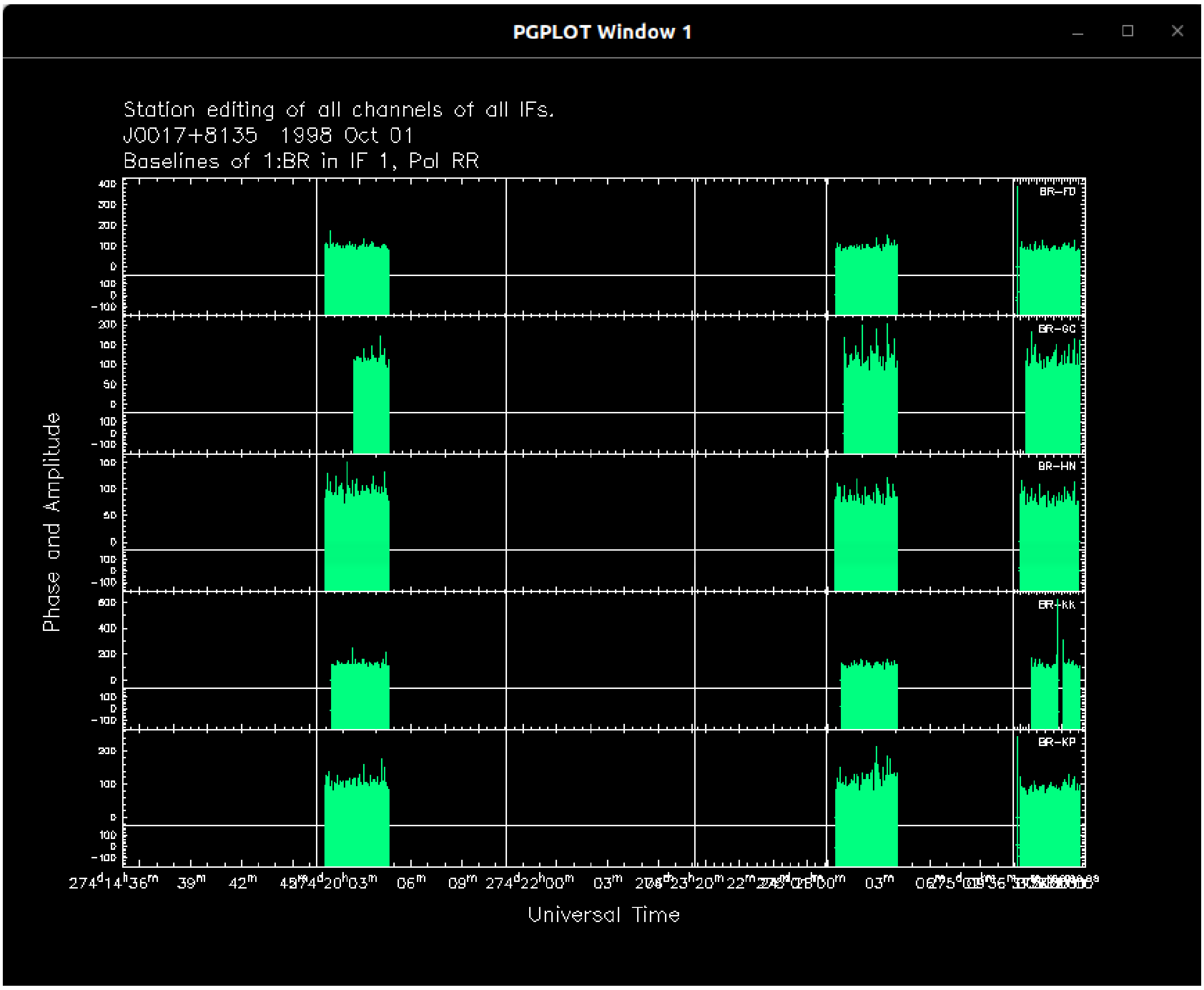

A dot is displayed for every time interval for which data exists for each telescope. Data are colored green if there are no edits, yellow if any data to an antenna are agged, blue if the antenna has been agged in selfcal or corplot, and red if all data to a given antenna are agged. tplot is also useful if you should want to ag all baselines to a selected antenna, or all antennas for a given time-range

## 4.3 Editing Data

It is a time honored tradition among scientists to get rid of bad data. With VLBI observations this should be done carefully yet thoroughly. While speaking about VLBI observations, a famous scientist once said, bad data is worse than no data at all." Difmap provides an interactive data editor, vplot. Before invoking vplot you may

nd it useful to set a few flags" which will effect how it runs. The setting of these ags for optimal performance depends on the dataset in question and your own personal preferences. A good choice for snapshot observations is:

```
0>vflags="ebm"                    e: plot error bars, b: remove time gaps
0>vplot 5                         plot 5 baselines on each page
Over-riding default options with user defined vflags="ebm"
NB. Keyboard input will only be accepted when the cursor
   is in the plot window
For HELP, hit the 'H' key on your keyboard
```




By default, this will plot both amplitudes and phases versus time for the first 5 baselines (see Figure 5). The default interscan gap is one hour, but this can be changed with the scangap command

If the error bars on your data don't look right, you may have to adjust them globally using the wtscale command. See the help
le for wtscale for the equation relating the weight scale factor to the bandwidth, integration time, correlator coecient, effective collecting area, and system temperature

At this point you may interactively edit the displayed data. Move the cursor (it should appear as a '+') to a bad datapoint (such as those evident at the beginning of each scan in Figure 5), and click the leftmost mouse button. If vplot is in "Station Editing" mode (look for these words in the upper left corner of the plot) then this action will flag all data points associated with antenna number 1 (Bonn in the example) for this one time.

To perform baseline-based lagging operations, hit the spacebar. The words "Baseline Editing" should now appear in the upper left corner of the plot. If you have multiple IFs and want the edits on the currently selected IF to be applied to all IFs then toggle this on with the I key. The W key will toggle editing between the selected channel and all channels. To see the agged data, type f and then press return. Flagged data will now be marked with a red cross. Clicking on a agged data point will un ag it. The full range of options can be listed by typing an h in the plot window.

It is often desirable to ag all points within a given region. To do this
first move the cursor into the plot window and type a c. Next, select a corner of the region of bad points by moving the cursor there and pushing the leftmost mouse button. Finally, move the cursor to the opposite corner of the region and push the leftmost mouse button again.

If you make a change in the way the plot is displayed, either by toggling one of the flags or selecting a number, you will need to follow that with a return key to see its effect. Move forward to the next screen of baselines by pressing n, and backwards with p. If you have multiple sub-arrays then a capital N will move to the next sub-array. Continue to edit and move through the baselines until you encounter the message:
*No plottable baselines in forward direction* At this point you will actually have seen every baseline twice. While this is redundant, it allows the user to work through the data antenna by antenna with all baselines plotted for each station

Once you have
finished editing the data, it is a good idea to write out a copy of it. First exit from the vplot window (far-right mouse button), then type:
0>wobs 0749+540.edt

You can enter and exit vplot any number of times and Difmap will remember your edits. If you quit from Difmap without
rst writing your data, then it is gone like the wind.

It is sometimes possible for the amplitudes and phases of a number of visibilities to look ok, even while there are serious problems with those data. One such example is when there is significant leakage of one polarization into another at the feeds of two or more antennas.

Closure phases are defined as the sum of visibility phases around a closed triangle of three antennas (Cornwell and Fomalont 1988). For a point source the closure phase should be zero. Closure phases are free of antenna-based errors such as those induced by atmospheric fluctuations and position shifts, and are used in self calibration. Under antenna-based self calibration the closure phases remain constant which also means that unlike some phase and amplitude errors that can be

fixed by self calibration, errors in the closure phase cannot. Examining the closure phases with cpplot may also be useful to determine whether self calibration is possible. To examine the closure phases type cpplot bonn,5. This example plots the closure phase for the

first 5 triangles involving the bonn telescope. Alternatively the command cpplot bonn-nrao,6 will display the

rst 6 triangles containing the bonn-nrao baseline. Lastly, cpplot bonn-nrao-noto will display this single triangle. If your data have multiple sub-arrays the number of the sub-array should go before the telescopes. So typing cpplot 3:bonn-nrao,5 will display the first 5 triangles in subarray 3 containing the bonn-nrao baseline. The scope of the editing is displayed on the top line of the plot and is dependent upon if cpplot was invoked with a station, baseline, or triangle. Triangle editing indicates that all baselines for the displayed closure triangle will be edited. As in vplot, the scope of the editing can be toggled with the spacebar, I, and W keys.

## 4.4 Difference Mapping

And now for the part which lends Difmap its name. In diverence mapping the observer converges on a model by progressively cleaning the residual map, and self calibrating using the latest model. At each selfcal-mapplot- clean iteration the model is subtracted from the data in the u-v plane, thus avoiding aliasing of side-lobes within the field of view. The model is retained in memory thereby saving considerable CPU time over programs that must recalculate it every time (such as in AIPS), and allows for easy comparisons between the model and the data. Upon convergence, the user obtains the self calibrated data, a model, and a map of the source.

Before starting diverence mapping the data should be amplitude calibrated (using the program CAL from the Caltech Package, or using the task ANCAL within AIPS) and edited.

So I need to calibrate first?

Aips on my ubuntu encounter a error:

```
$ aips notv tpok
START_AIPS: Your initial AIPS printer is the
START_AIPS:  - system name , AIPS type

START_AIPS: User data area assignments:
DADEVS.PL: This program is untested under Perl version 5.026
  (Using global default file /home/anything/.AIPS/DA00/DADEVS.LIST for DADEVS.PL)
                  ~/.AIPS/DATA/LOCALHOST_1 is currently unavailable.
   Disk 1 (1) is /home/anything/.AIPS/DATA/LOCALHOST_1

Tape assignments:
   Tape 1 is REMOTE
   Tape 2 is REMOTE

START_AIPS: Assuming TPMON daemons are running or not used (you said TPOK)
Starting up 31DEC18 AIPS with normal priority
Begin the one true AIPS number 1 (release of 31DEC18) at priority =   0
AIPS1: error while loading shared libraries: libtinfo.so.5: cannot open shared object file: No such file or directory
```

For sources with a very extended, diuse component, the user may also want to use modelt (see x8) to generate a starting model, as the clean algorithm has some difficulty with such structures. For most VLBI sources a point source model is a good starting place (Cornwell & Fomalont 1988). To start with the default 1 Jy point source model at the map center type:

```
0>startmod
Applying default point source starting model.
Performing phase self-cal
Adding 1 model components to the UV plane model.
The established model now contains 1 components and 1 Jy

Correcting IF 1.
 A total of 14922 telescope corrections were flagged in sub-array 1.
 A total of 9156 telescope corrections were flagged in sub-array 2.
 A total of 2135 telescope corrections were flagged in sub-array 3.

Correcting IF 2.
 A total of 14923 telescope corrections were flagged in sub-array 1.
 A total of 9156 telescope corrections were flagged in sub-array 2.
 A total of 2136 telescope corrections were flagged in sub-array 3.

Correcting IF 3.
 A total of 14925 telescope corrections were flagged in sub-array 1.
 A total of 9156 telescope corrections were flagged in sub-array 2.
 A total of 2136 telescope corrections were flagged in sub-array 3.

Correcting IF 4.
 A total of 14925 telescope corrections were flagged in sub-array 1.
 A total of 9288 telescope corrections were flagged in sub-array 2.
 A total of 2137 telescope corrections were flagged in sub-array 3.

Fit before self-cal, rms=1.810132Jy  sigma=0.004094
Fit after  self-cal, rms=1.808659Jy  sigma=0.004066
clrmod: Cleared the established, tentative and continuum models.
Redundant starting model cleared.
0>
```

Selfcal reports the rms difference between the model and the data and also sigma, which is the rms divided by the variances implied by the visibility weights (effectively sigma is the square root of the reduced $\chi^2$), Don't worry about the (potentially huge) value of sigma at this point since the starting model probably doesn't match the visibility amplitudes well. The effect of startmod is to fix up the phases so that you may begin mapping your source. If you want to begin with a more complicated model than a point source, supply the name of a le containing that model to startmod

```
0>selfcal
Performing phase self-cal

Correcting IF 1.

Correcting IF 2.

Correcting IF 3.

Correcting IF 4.

Fit before self-cal, rms=1.818014Jy  sigma=0.004445
Fit after  self-cal, rms=1.818014Jy  sigma=0.004445
0>
```

The default units for Difmap are milli-arcseconds in the map plane and mega wavelengths in the UV plane. If it is more convenient for you to work in units of arcseconds and kilo-wavelengths then type mapunits arcsec

Now, define the image size and cell size you wish to map. The image size (square or rectangular) must be an integer power-of-two, and since Difmap can only properly deconvolve the inner quarter of the image, it should be at least twice the maximum source dimension. The cell size should be small enough to allow for 3 or more pixels across the synthesized beam. For the 5 GHz snapshot data on 0749+540, a reasonable choice is

```
0>mapsize 256,0.2
Map grid = 256x256 pixels with 0.200x0.200 milli-arcsec cellsize.
0>
```

Difmap will complain if the cell size chosen is too coarse to allow at least 2.5 pixels across the synthesized beam. If a certain cell size is required, the UV range can be restricted by typing uvrange 0,51.6/cel l where cel l is the cell size.

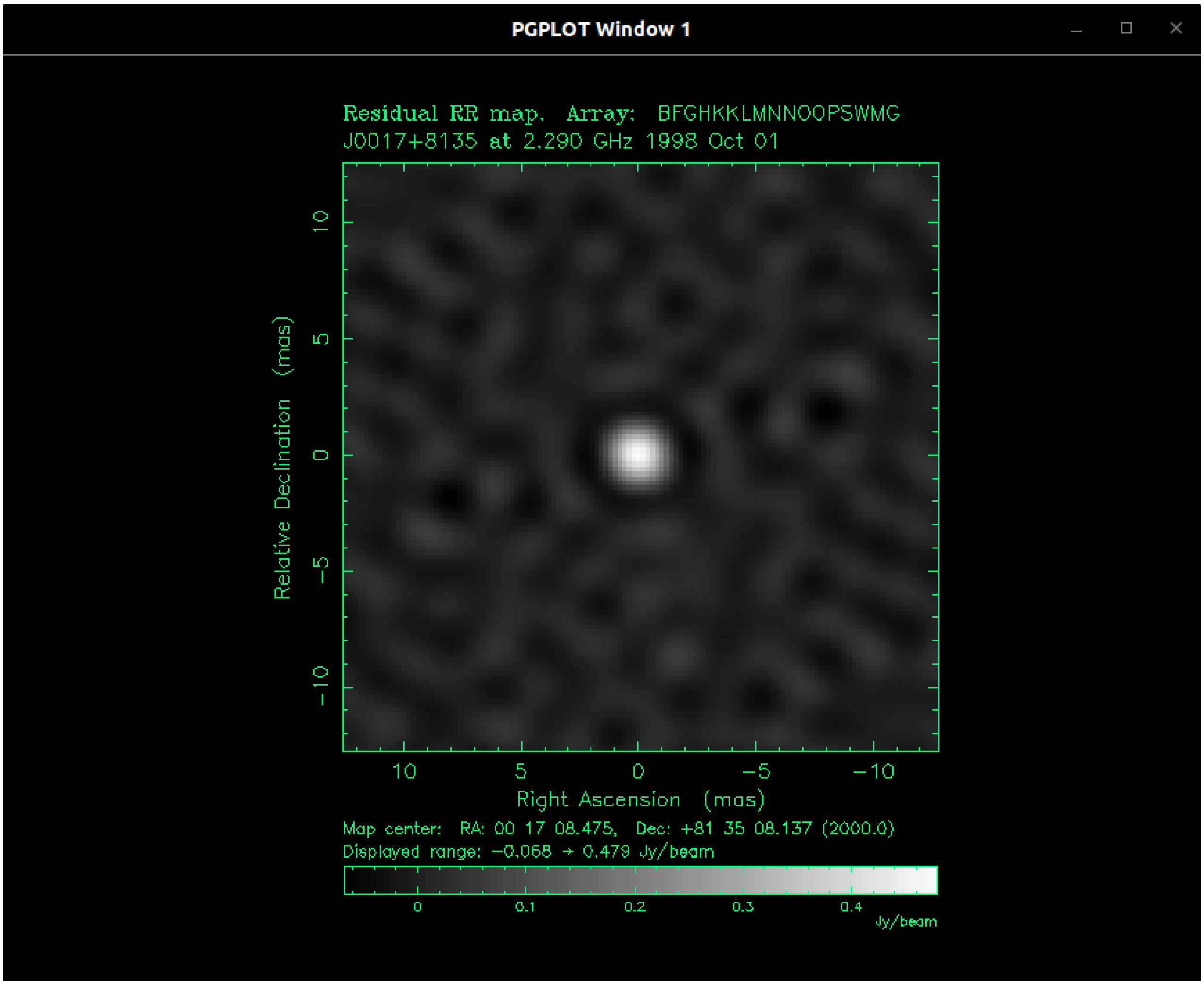
The default weighting scheme is uniform, with a binning size of 2 uv-grid pixels. With uniform weighting, the data are weighted inversely to the number of visibilities occurring within the bins. Equal weighting of all data points is called natural weighting, and provides higher sensitivity than uniform weighting, although uniform weighting provides higher resolution and in some cases may deconvolve more readily. Natural weighting is selected within Difmap by choosing a binning size of 0. At the same time the u-v weighting is set, the user should also select the appropriate weighting of the visibilities by the errors. If the errors have been meaningfully calculated then -1 is a good choice for the error power, otherwise use 0. Type help uvweight for more information and see Sramek & Schwab (1988). For our sample data we'll start with uniform weighting:

```
0>uvweight 2,-1
Uniform weighting binwidth: 2 (pixels).
Gridding weights will be scaled by errors raised to the power -1.
Radial weighting is not currently selected.
0>
```

Now you're ready to look at a rst map of the source via:

## mapplot

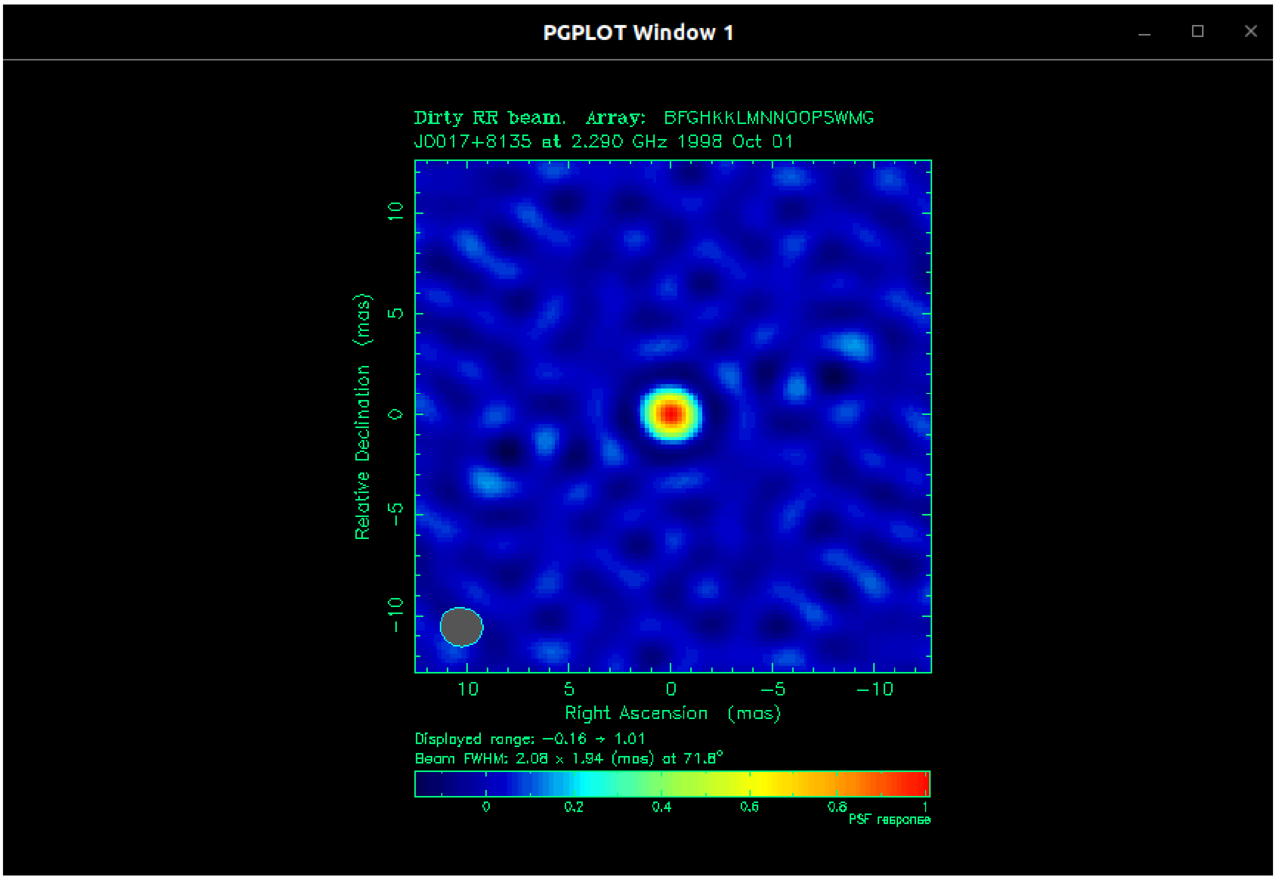
```
0>mapplot
Inverting map and beam
Estimated beam: bmin=1.936 mas, bmaj=2.084 mas, bpa=71.81 degrees
Estimated noise=479.161 mJy/beam.

Move the cursor into the plot window and press 'H' for help
```




This will generate a dirty map of the source (see Figure 6). The hexagonal sidelobes are due to the gaps in u-v coverage resulting from the three scans at widely spaced hour angles. With the cursor in the active window type c to change to a false-color transfer function. Hold down the f key and move the cursor within the graphics display window to interactively modify the transfer function. A capital F will reset the transfer function, and a c will switch to color. Other options can be explored by typing h.

Define a small window around the brightest component for cleaning. This is done by moving the cursor to a corner of the desired region, clicking the leftmost mouse button, and then moving to the opposite corner and clicking the leftmost mouse button again. Use the middle button, with the cursor at any corner, if you wish to delete a window. For a false-color representation type c, to get back to greyscale type g. When you are finished type x or click the rightmost mouse button. To look at the dirty beam, use mapplot beam. To look at the restored (clean) map, use mapplot cln. To zoom in on an interesting feature type z and then select the region of interest by selecting its opposite corners with the leftmost mouse button. To unzoom, type the z key twice.

## mapplot beam:




## mapplot cln:

An error:

```
0>mapplot cln
restore: Substituting estimate of restoring beam from last 'invert'.
Restoring with beam: 1.936 x 2.084 at 71.81 degrees (North through East)
No model to restore with.
Error occured in command: mapplot

0>
```

### 4.5 Cleaning

Choose a number of iterations and a loop gain for cleaning. Once entered, these will become the default values. You may also set a cutoff if you wish - type help clean for more details. A slow, gradual cleaning works well for Difmap since you will see the residuals at each step. For our example source we'll choose:

```
0>clean 100,0.05
clean: niter=100  gain=0.05  cutoff=0
Component: 050  -  total flux cleaned = 0.438209 Jy
Component: 100  -  total flux cleaned = 0.510445 Jy
Total flux subtracted in 100 components = 0.510445 Jy
Clean residual min=-0.006770 max=0.031501 Jy/beam
Clean residual mean=0.001331 rms=0.004069 Jy/beam
Combined flux in latest and established models = 0.510445 Jy
0>
```

### 4.6 Self-calibration

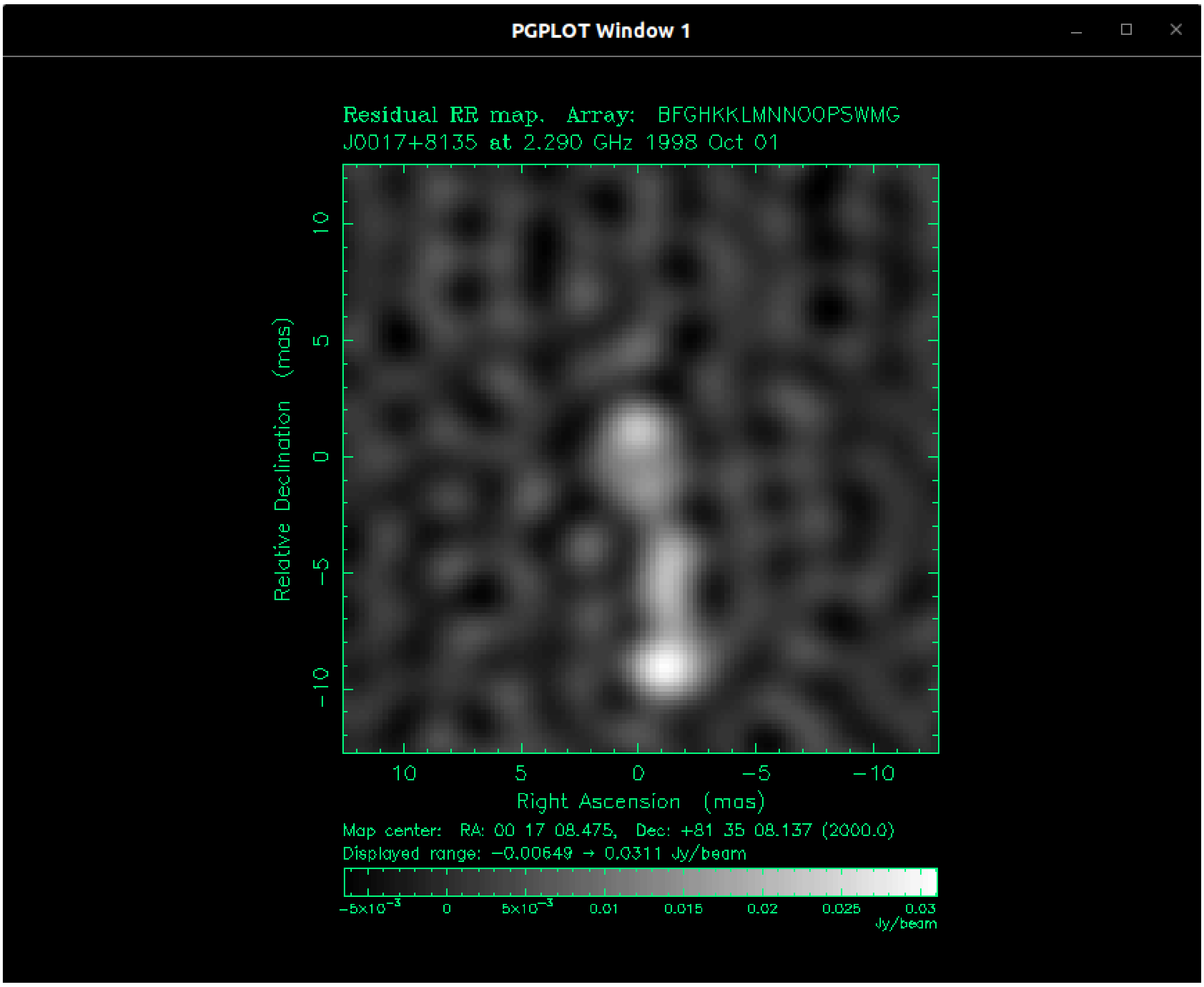
With the improved, but still basically point-like model just obtained, self-calibrate the phases by typing:
selfcal:

```
0>clean 100,0.05
clean: niter=100  gain=0.05  cutoff=0
Component: 050  -  total flux cleaned = 0.438209 Jy
Component: 100  -  total flux cleaned = 0.510445 Jy
Total flux subtracted in 100 components = 0.510445 Jy
Clean residual min=-0.006770 max=0.031501 Jy/beam
Clean residual mean=0.001331 rms=0.004069 Jy/beam
Combined flux in latest and established models = 0.510445 Jy
0>
```

```
0>selfcal
Performing phase self-cal
Adding 14 model components to the UV plane model.
The established model now contains 14 components and 0.510445 Jy

Correcting IF 1.

Correcting IF 2.

Correcting IF 3.

Correcting IF 4.

Fit before self-cal, rms=1.742457Jy  sigma=0.002496
Fit after  self-cal, rms=1.742354Jy  sigma=0.002495
0>
```

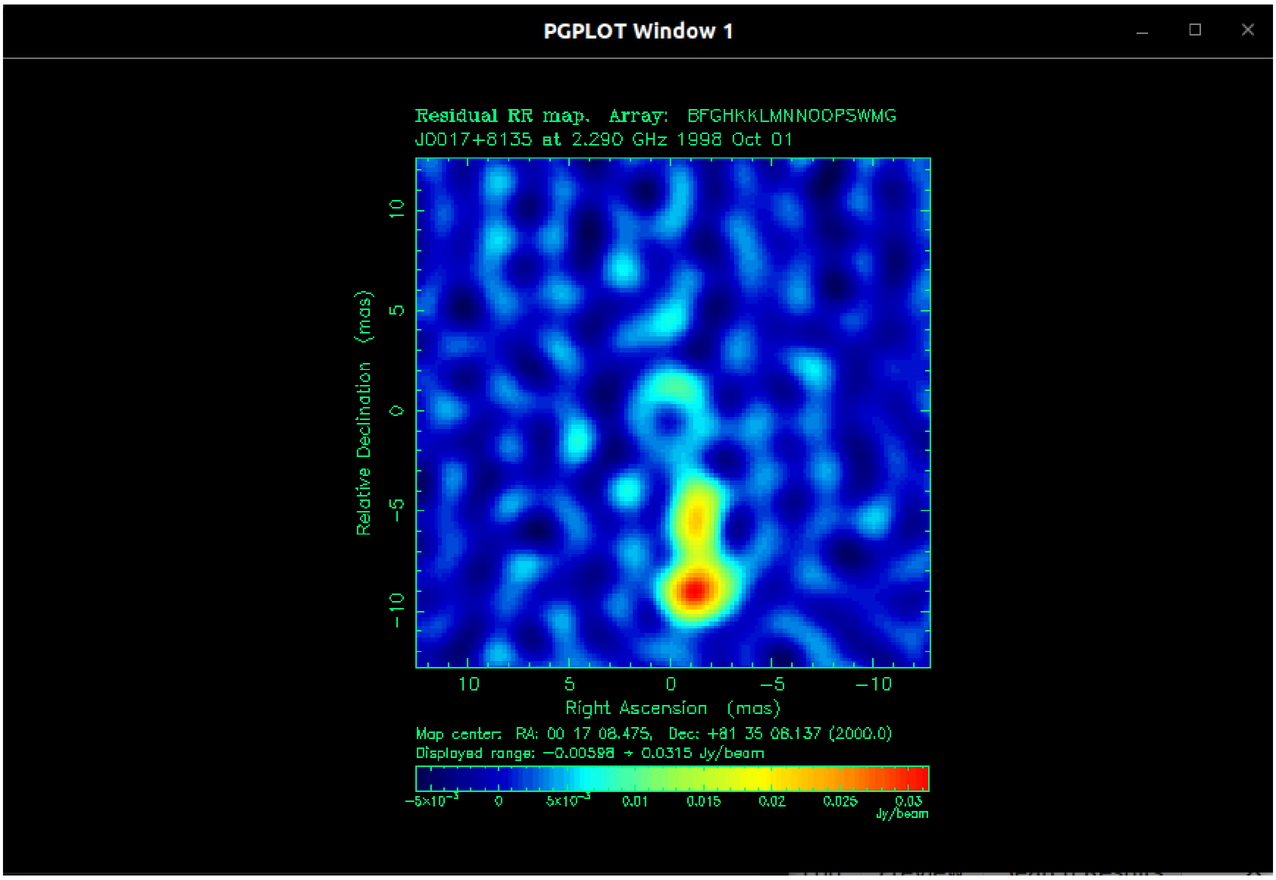
The last line (for cookbook) provides a warning concerning visibilities that are not part of closed arrays with a sufficient number of telescopes. A small number of such visibilities may result from vigorous baseline-based editing. The minimum, and also default, for phase only self calibration is 3 telescopes, and for amplitude self-calibration it is 4 telescopes. Correction ags applied by selfcal or in corplot are different from ordinary ags in that they can only be undone in corplot or with uncalib. In plot commands, visibilities that are agged due to self-calibration are displayed in blue to differentiate them from good visibilities (in green) and otherwise agged visibilities (in red). Type help selfflag for more details

To see the residual map type
mappl



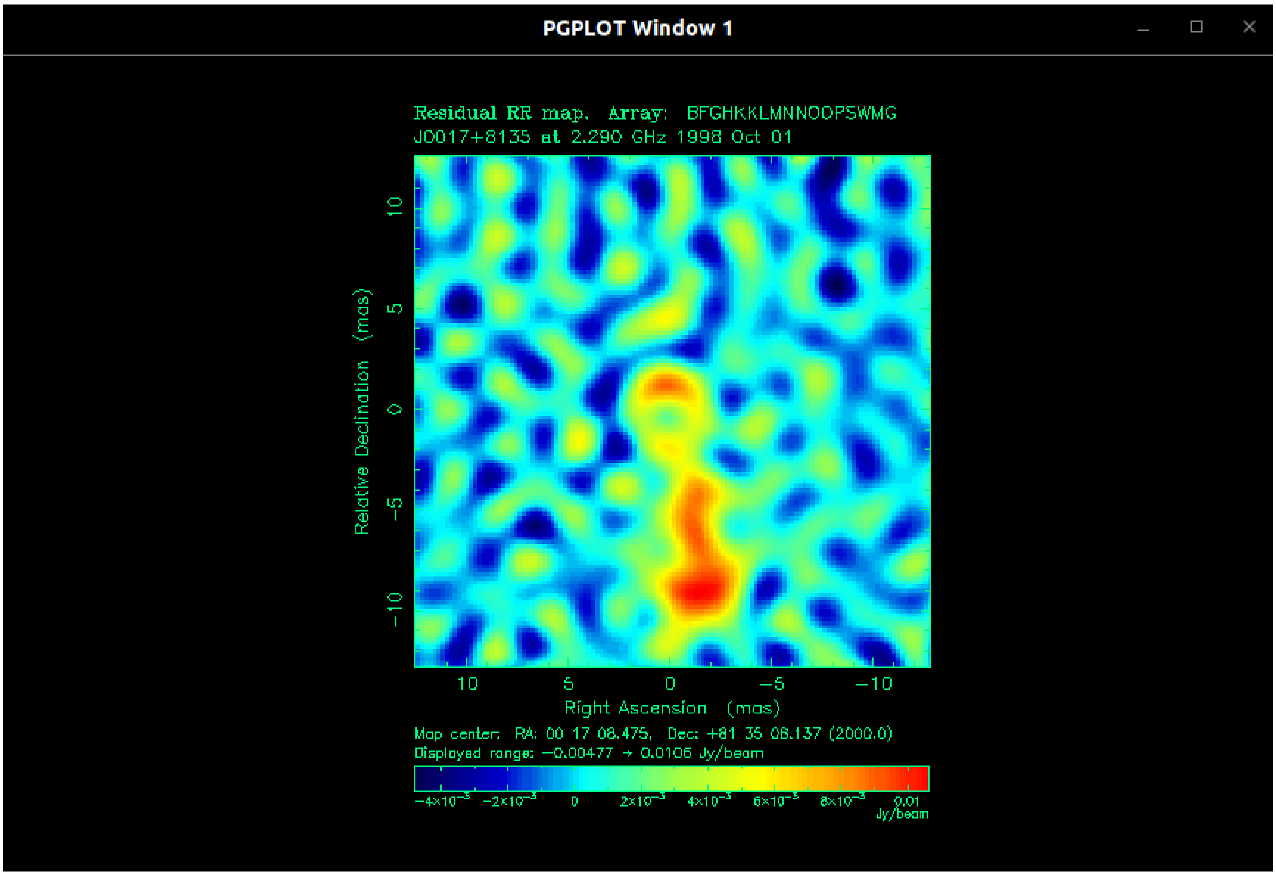

Be aware that some spurious symmetrization may have resulted from using a point source model. Find the brightest component in the residual map and place a window around it as described in x4. Use a small window, since the idea behind difference mapping is to progressively build a model for the source by cleaning from the residual map. Type clean to clean another 100 components from the windowed regions. Iterate with selfcal, mapplot and clean until sigma is no longer decreasing, the cleaned ux is no longer increasing, and the residual map is roughly smooth and featureless. You can view (and edit) the corrections to the antennas with corplot. Examine the goodness of fit of the model to the data in a general sense with radplot, and in more detail with vplot using the m ag to request a plot of the model as well as data. To see a map with the clean components restored type mapplot cln. To see where clean components are located type a m in mapplot, or start it up with mapplot cln,true. Positive clean components will be shown as green crosses, and negative components as red ones. Gaussian components will be displayed as ellipses (and see x8 on model fitting). You can get rid of clean components within a window by deleting that window within mapplot, and then typing winmod. Individual model components can be removed by typing R with the cursor placed on the offending component

```
0>clean
clean: niter=100  gain=0.05  cutoff=0
Component: 050  -  total flux cleaned = 0.0319912 Jy
Component: 100  -  total flux cleaned = 0.0501934 Jy
Total flux subtracted in 100 components = 0.0501934 Jy
Clean residual min=-0.006190 max=0.031661 Jy/beam
Clean residual mean=0.001046 rms=0.003534 Jy/beam
Combined flux in latest and established models = 0.560638 Jy
0>selfcal
Performing phase self-cal
Adding 26 model components to the UV plane model.
The established model now contains 39 components and 0.560638 Jy

Correcting IF 1.

Correcting IF 2.

Correcting IF 3.

Correcting IF 4.

Fit before self-cal, rms=1.741520Jy  sigma=0.002458
Fit after  self-cal, rms=1.741473Jy  sigma=0.002458
0>
```

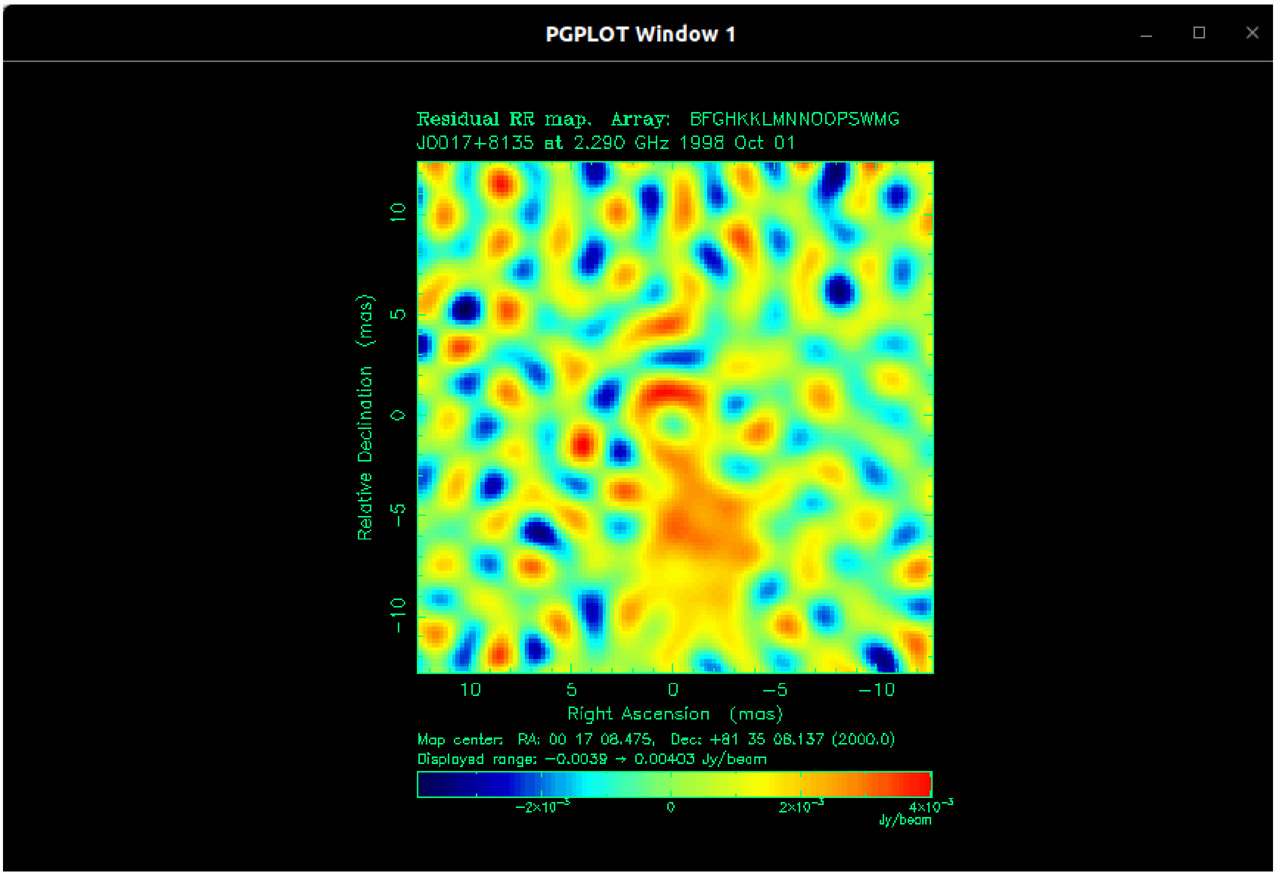



Another iteration of choosing window, clean, selfcal, mappl:

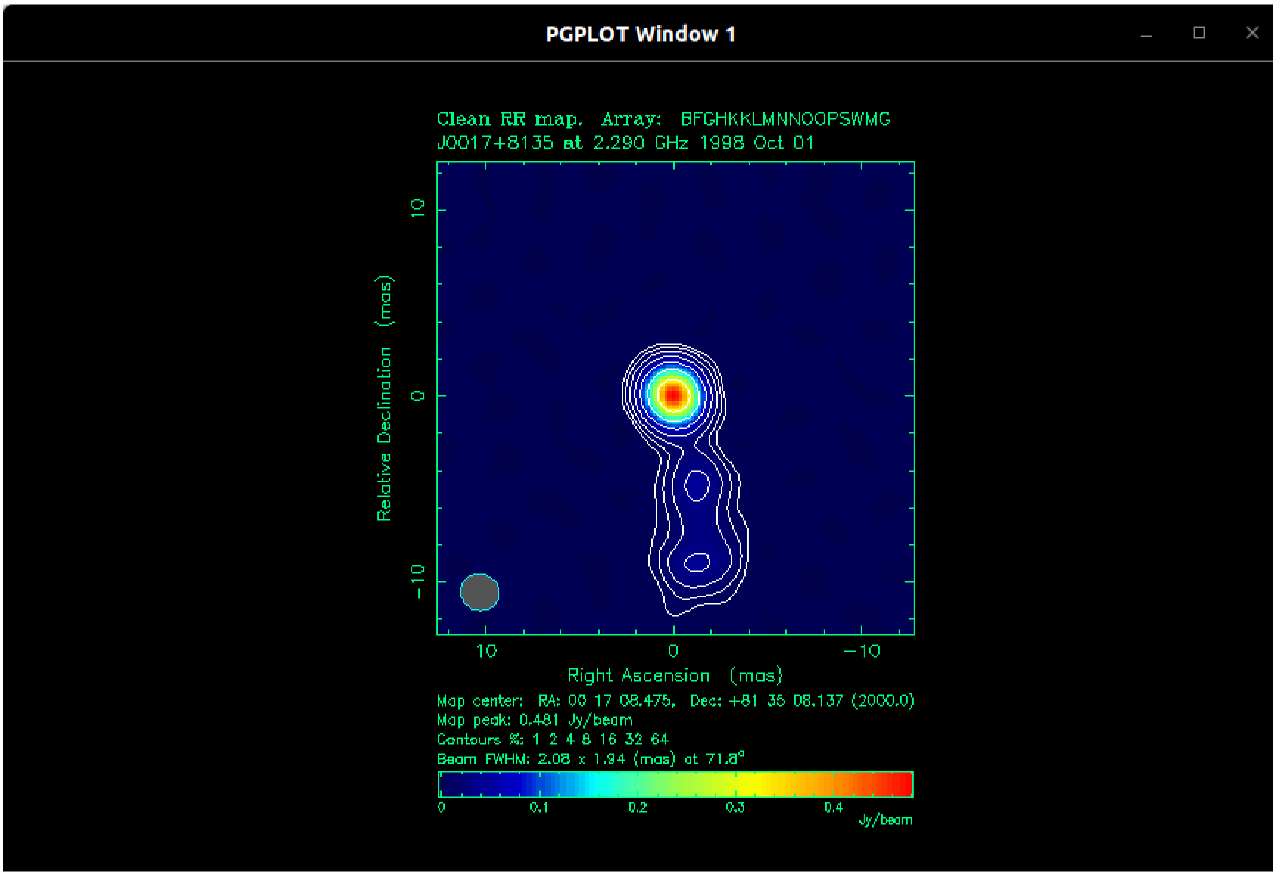
```
0>clean
clean: niter=100  gain=0.05  cutoff=0
Component: 050  -  total flux cleaned = 0.042291 Jy
Component: 100  -  total flux cleaned = 0.064779 Jy
Total flux subtracted in 100 components = 0.064779 Jy
Clean residual min=-0.004858 max=0.010837 Jy/beam
Clean residual mean=0.000705 rms=0.002159 Jy/beam
Combined flux in latest and established models = 0.625417 Jy
0>selfcal
Performing phase self-cal
Adding 29 model components to the UV plane model.
The established model now contains 65 components and 0.625417 Jy

Correcting IF 1.

Correcting IF 2.

Correcting IF 3.

Correcting IF 4.

Fit before self-cal, rms=1.740236Jy  sigma=0.002404
Fit after  self-cal, rms=1.740101Jy  sigma=0.002401
```



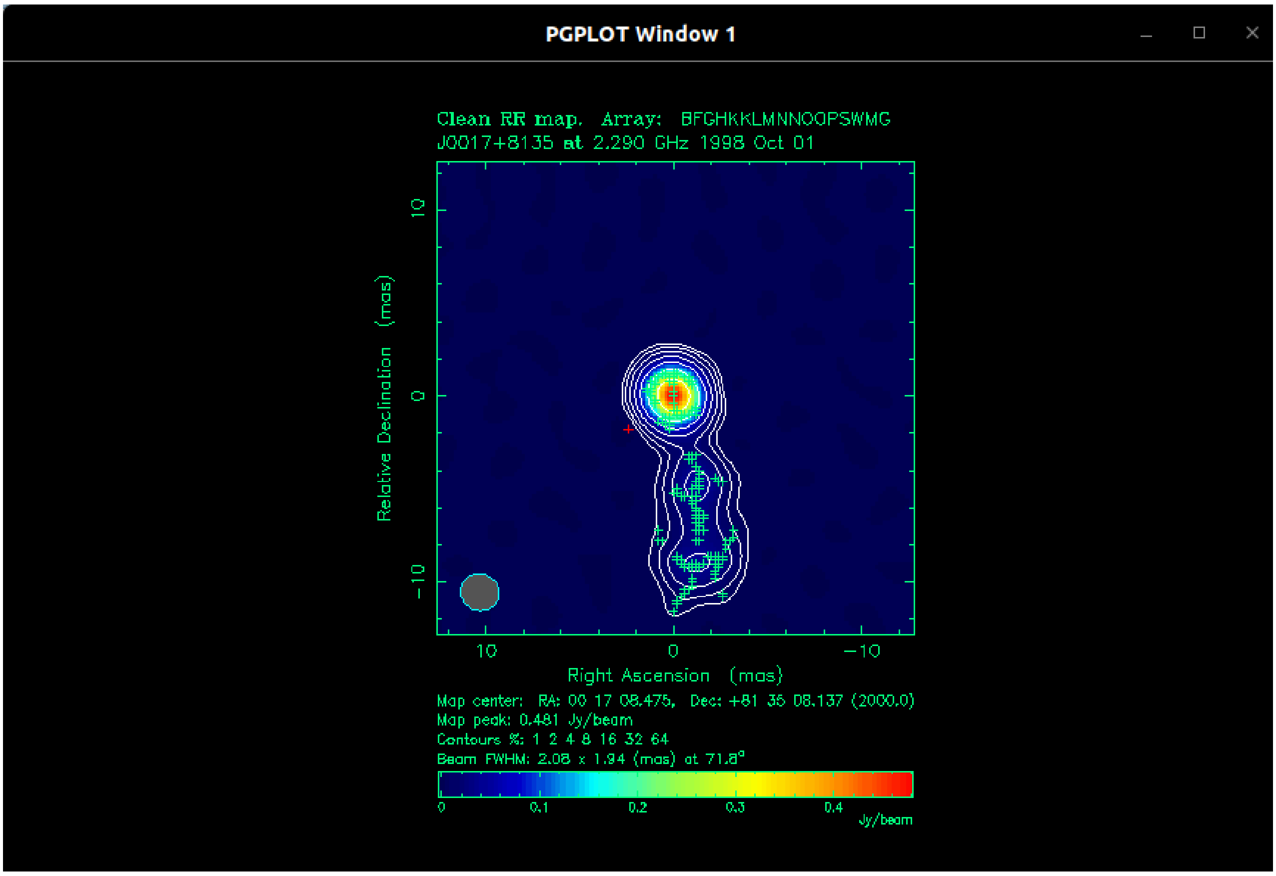

After several iterations, the residual map is roughly smooth and featureless




To see a map with the clean components restored type mapplot cln.




To see where clean components are located type a m in mapplot, or start it up with mapplot cln,true:




If your model fails to match up with the data on the short spacings, you may be missing some ux. If this is the case you may want to switch to natural weighting uvweight 0,-1, before you start in with amplitude self-calibration

If you have sufficient signal-to-noise in your data and a good model you may now consider amplitude self-calibration. As a first step, compute a single amplitude correction factor for each antenna:

gscale

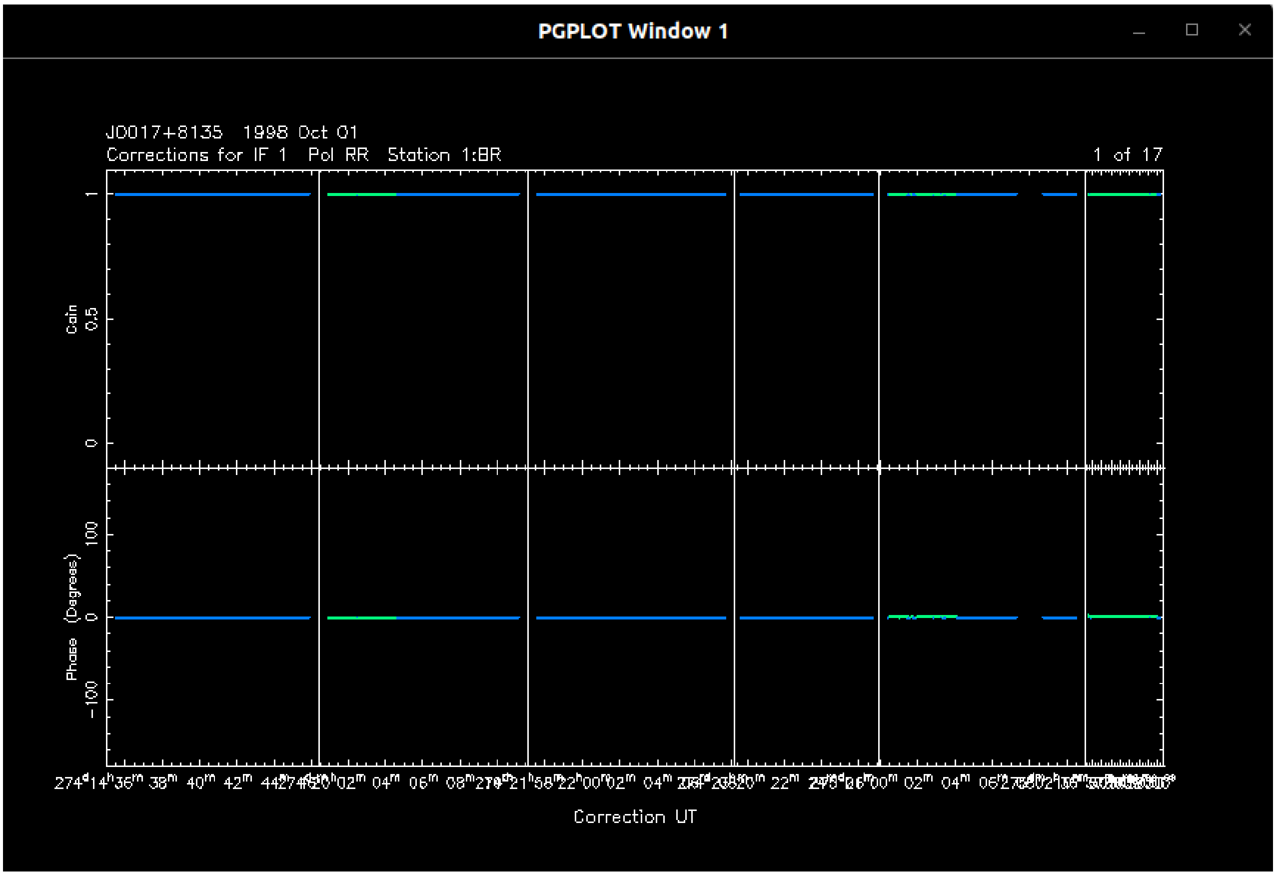
In this example the initial calibration was fairly good for all the antennas except Onsala. Use mapplot to see the effect of gscale. To allow the telescope amplitude factors to oat freely (which may alter the total ux) use gscale true. For further time dependent amplitude self calibration, it is best to start with long solution intervals (to insure a high enough signal-to-noise) and gradually shorten the solution interval as SNR permits. For example:

selfcal true,true,30

Be warned that an amplitude & phase self-calibration has the power to "make" the data fit the model, and can thereby "freeze" false components into the data. Be sure to use corplot to ensure that the solutions are reasonable. Figure 7 shows an example of the corplot solutions for the VLBA antenna at Pie Town with a 3 minute solution interval. corplot can also be used interactively to ag bad solutions or data. Or if you find that you don't trust the amplitude corrections, type

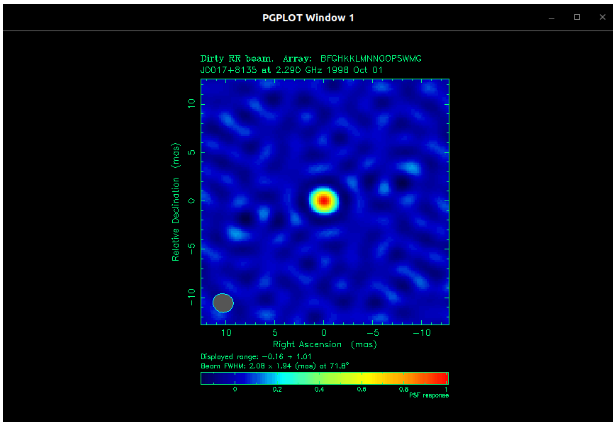
uncal false,true

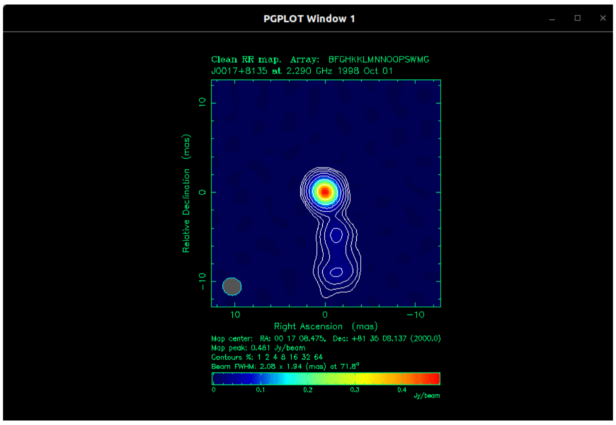
Using corplot:




When you think you have obtained a fairly good model for your source, you may want to remove all antenna gain corrections and start over with this as your initial model, instead of a point source. This will often lead to some improvements. Also, in the course of cleaning and self-calibrating, the map may become too deeply cleaned in some areas. This will be obvious if the clean components clearly follow the edges of the clean windows, and/or if there are almost as many negative as there are positive clean components. If you think this has happened, you may want to try clrmod true to throw away your current model, and then iteratively issue clean 200,0.03; keep; mapplot until you've cleaned away all source structure and regained your previous cleaned ux. You may find it useful to change your windows at this time as well. The keep command is necessary to force subtraction of the clean components from the visibility data as opposed to subtraction in the image plane. Difmap stores both an "established" and a "tentative" model. The established model has been subtracted from the visibility data, while the tentative model has not been. The function of the keep command is to move all tentative components to the established model

For contrast, put original beam with command mapplot beam and the beam after clean and self-calibration processes with command mapplot cln here:




## 4.7 Saving data, models and windows

At the final, or even at intermediate stages (depending on the time invested), you will want to write out your adjusted data, model, and windows. This can be done by typing
save Sourcename

```
0>save J0017+8135
Writing UV FITS file: J0017+8135.uvf
Writing 142 model components to file: J0017+8135.mod
Inverting map and beam
Estimated beam: bmin=1.936 mas, bmaj=2.084 mas, bpa=71.8 degrees
Estimated noise=479.187 mJy/beam.
restore: Substituting estimate of restoring beam from last 'invert'.
Restoring with beam: 1.936 x 2.084 at 71.8 degrees (North through East)
Clean map  min=-0.0037213  max=0.48084 Jy/beam
Writing clean map to FITS file: J0017+8135.fits
Writing difmap environment to: J0017+8135.par
0>
```

### 4.8 Some finer points on mapping

## 5 A New Guide to DIFMAP, link1, link2

DIFMAP is a powerful and expedient program for imaging multi-element arrays. Originally intended for use with continuum VLBI data, it serves just as well when being used on VLA data sets. DIFMAP uses the increasing amounts of RAM in modern computers to minimize time spent reloading data and regenerating models. This tutorial will walk you through the basic steps of using DIFMAP to clean and self-calibrate your data.

### 5.1 Starting DIFMAP

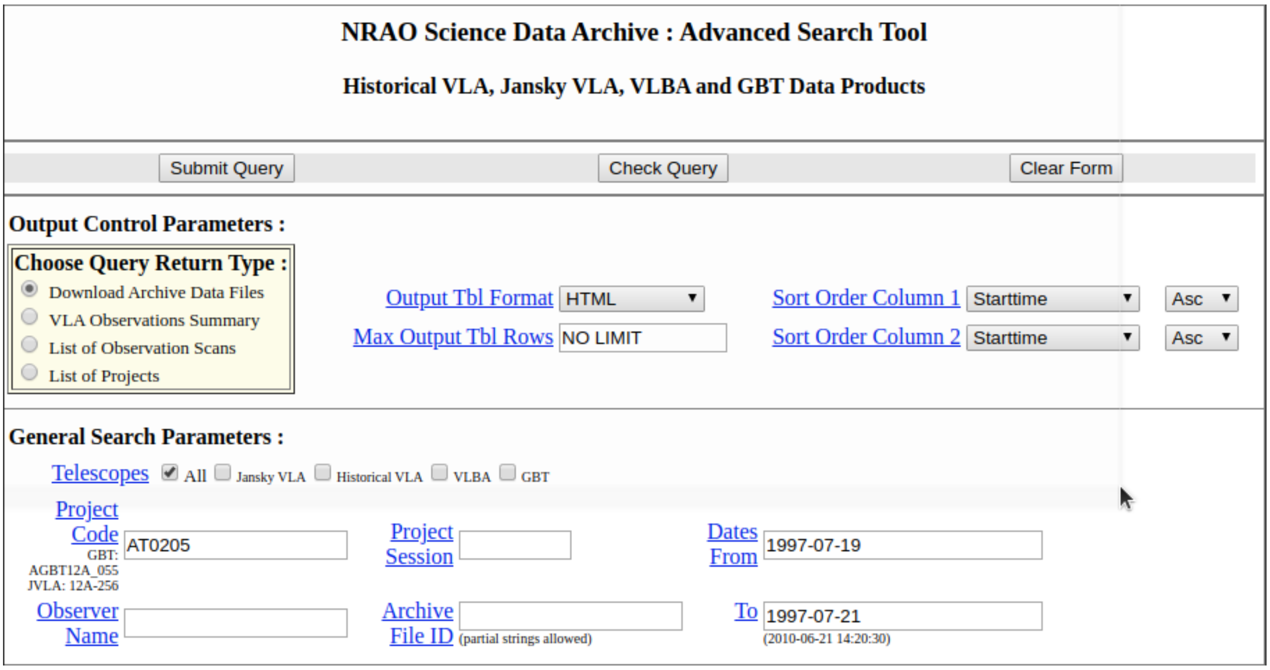
With DIFMAP installed, open a terminal and navigate to the directory in which your data resides. Because most of us use AIPS to perform the first round of data flagging/calibration, many people prefer to keep files in the /home/aips/FITS/ directory for convenience as this is where AIPS reads in and produces files.

Once you have navigated to the proper directory type "difmap" at the command prompt. This will initiate DIFMAP and we can begin loading data.

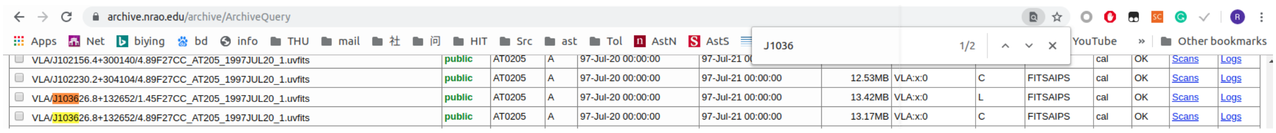
It should be noted that for this tutorial we will be using C Band C Array data for source J1036+1326. This is from Project AT0205, Seg A, source TEX1033+137, taken on 7/20/97 with 370 seconds TOS.

### 5.2 Downloading data from NARO

So first I need to download the data used in this tutorial. TEX1033+ at 4.860GHz in — 1997 Jul 20, VLA data
So, first I find the VLA data archive, and then this website: NRAO Science Data Archive : Advanced Search Tool
So first fill information I know currently like following image




and click the Submit button, I get a list of results, and using searching function of the web browser, I can find two files:




Choose both files, fill in my email and do some choices finally click Get My Data button, then I get this page:

## NRAO Archive - Data Delivery Options

### There are now two ways to deliver your archival NRAO data :

- by direct ftp as in the past
- or if your data set is very large, it may be shipped to you on a hard disk

You have selected (checked) these file sets for retrieval :

| Archive File | Status | File Type | File Size |
|---|---|---|---|
| VLA/J103626.8+132652/1.45F27CC_AT205_1997JUL20_1.uvfits | public | MS | 15.0304MB |
| VLA/J103626.8+132652/4.89F27CC_AT205_1997JUL20_1.uvfits | public | MS | 14.7504MB |

**Total file set size selected = 0.0297808 GBytes**

| Estimated Download Time | Network Transfer Rate |
|---|---|
| 1.2 hours | Transfer rate 56Kb/sec - Dial up modem |
| 0.1 hours | Transfer rate 1Mb/sec - low to mid-level broadband |
| 0.0 hours | Transfer rate 10Mb/sec - high-level broadband |
| 0.0 hours | Transfer rate 100Mb/sec - very high-level broadband |

You have selected public domain data for downloading. Public domain data is eligible for hard disk shipping, but you must pay for the hard disk and the shipping costs.

Retrieve over internet — If you choose to download your data to the archive ftp area or a local destination in the DSOC (AOC), hit this button. This is the same data retrieval option that has been used in the past. You may then download your data directly over the internet.

Send on Hard Disks — If you choose to have your data shipped to you on a hard disk, the full policy and instructions for data shipment can be accessed here : data shipping.

I choose Retrieve Over Internet:

## NRAO Data Archive - data download report

CGI program e2eftp.cgi version : 2.12.16
You submitted the following name/value pairs :

- `EMAILADDR = krk18@mails.tsinghua.edu.cn`
- `COPYFILEROOT = /home/e2earchive`
- `TIMEAVG = 0s`
- `SPECTAVG = x1`
- `CONVERT2FORMAT = MS`
- `FLAGGING = FLAG`
- `SCANS = ALL`
- `CASA_HOST = aocngas-master.aoc.nrao.edu`

---

Successfully test pinged your output directory. The archive download process has write permission there. Proceeding with downloads.

The download processes have been spawned. Your files should appear in the directory that you specified.
An email will be sent to : krk18@mails.tsinghua.edu.cn notifying you of the success or failure of the data transfer.

---

**Public Domain Data :**
The public domain files you selected are being written into the public ftp area (/e2earchive) at the NRAO AOC in Socorro, NM.
Your data files will be automatically deleted after two days.
The public ftp area may be accessed by amonomous ftp : **ftp://ftp.aoc.nrao.edu/e2earchive**
Before you attempt to download your data files, wait for the arrival of an email notifying you when the copy process is complete.

---

copy public project data : AT205 from this archive file : /home/archive_surveys/pipeline/position/J103626.8+132652/1.45F27CC_AT205_1997JUL20_1.uvfits
to this output file 4 x: /home/e2earchive/1.45F27CC_AT205_1997JUL20_1.uvfits

copy public project data : AT205 from this archive file : /home/archive_surveys/pipeline/position/J103626.8+132652/4.89F27CC_AT205_1997JUL20_1.uvfits
to this output file 4 x: /home/e2earchive/4.89F27CC_AT205_1997JUL20_1.uvfits

Then I received an email from NARO:

**Archive Data Copied** 发起会议

发件人： NRAO Arc... <archmgr@nrao.edu>
时 间： 2019年09月16日 21:48:06 (星期一)
收件人： krk18@mails.tsinghua.edu.cn

```
Data download results from the NRAO Data Archive System
--------------------------------------------------------------------------------
 If you directed your public file downloads to the default ftp directory,
/home/ftp/e2earchive, you may log into the ftp server at the AOC in New Mexico.
Connect to the ftp server ftp.aoc.nrao.edu, this is an anonymous/guest account.
After you login to the ftp area, change the default directory to
/pub/e2earchive. You should find your files there. The file names are in this
email.
 Files in the ftp area are automatically deleted after 2 days.
--------------------------------------------------------------------------------
 The VLA data files are provided in the VLA Export format, and are read into
 AIPS using the task FILLM. If you have an old version of AIPS (older than
 7APR2003) you will need to upgrade your AIPS to be able to read the data
 correctly.
 Upgrades can be obtained at the AIPS Home Page : http://www.nrao.edu/aips
--------------------------------------------------------------------------------
Public File available : ftp://ftp.aoc.nrao.edu/e2earchive/1.45F27CC_AT205_1997JUL20_1.uvfits
Public File available : ftp://ftp.aoc.nrao.edu/e2earchive/4.89F27CC_AT205_1997JUL20_1.uvfits
/bin/cp: cannot create regular file `/home/e2earchive/1.45F27CC_AT205_1997JUL20_1.uvfits': File exists
```

I use lftp command to access the data:
lftp ftp://ftp.aoc.nrao.edu/e2earchive/

There are lots of data files, which implies many people are accessing data from NARO! After following operation I finally download the data:

```
lftp ftp.aoc.nrao.edu:/e2earchive> lcd .
lcd ok, local cwd=/home/anything/THU/astro/astro_books/radio_astronomy/Softwares/difmap/data/J1036
lftp ftp.aoc.nrao.edu:/e2earchive> get 1.45F27CC_AT205_1997JUL20_1.uvfits
13720320 bytes transferred in 17 seconds (772.0 KiB/s)
lftp ftp.aoc.nrao.edu:/e2earchive> get 4.89F27CC_AT205_1997JUL20_1.uvfits
13461120 bytes transferred in 19 seconds (679.9 KiB/s)
lftp ftp.aoc.nrao.edu:/e2earchive> exit

# anything @ anything-China in ~/THU/astro/astro_books/radio_astronomy/Softwares/difmap/data/J1036 [22:01:38]
$ ls
1.45F27CC_AT205_1997JUL20_1.uvfits  4.89F27CC_AT205_1997JUL20_1.uvfits
```

## 5.3 Loading Data

Get Error:

```
$ difmap
Caltech difference mapping program - version 2.5e (30 May 2019)
Copyright (c) 1993-2019 California Institute of Technology. All Rights Reserved.
Type 'help difmap' to list difference mapping commands and help topics.
Started logfile: difmap.log_1 on Mon Sep 16 22:14:36 2019
0>observe 1.45F27CC_AT205_1997JUL20_1.uvfits
Reading UV FITS file: 1.45F27CC_AT205_1997JUL20_1.uvfits
get_fits: Error: Primary header does not contain random-groups.
Error occured in command: observe

0>
```

Maybe I need go to AIPS to export the correct data? → need to solve later

pyuvfits tutorial