Low-Frequency Data Reduction at the VLA: A Tutorial for New Users

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We would not have been able to write this document were it not for the assistance of Eric Greisen. He wrote `FLGIT` and gave `IMAGR` the capability of properly compensating for the non-coplanar nature of the VLA.

Bill Cotton wrote `VLAFM` (and `VLALB`).

We have benefited from discussions with many individuals. An almost certainly incomplete listing includes M. Bietenholz, C. Brogan, A. Cohen, K. Dyer, T. Enßlin, C. Lacey, W. Lane, and W. Tschager.

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Chapter 1

Introduction

The completion of the 27-antenna, 74-MHz system at the VLA in 1998 January heralds the world's first instrument to break the "ionospheric barrier" and bring sub-arcminute resolution imaging to the sky below 100 MHz. Because of source confusion this angular resolution brings unprecedented levels of sensitivity, despite the modest collecting area. There are also differences—some slight, some substantial—between the reduction of centimeter- and meter-wavelength VLA data. It has become apparent that many new or potential users of the system are intimidated by the perceived complexity of the data reduction procedures. The situation is not too different at 330 MHz, and so, to some extent, both low-frequency systems are underutilized as a result.

In order to correct this situation, we present here some general notes on reducing "4-band" data (i.e., 74 MHz or 4 m wavelength). Some of the same general prescriptions should work for 330 MHz observations, though in many cases 330 MHz observations can be reduced in a manner similar to that of higher frequency observations. Where there are differences between 330 MHz observations and those at higher frequencies, we have called attention to them. One key difference is the nature of the RFI. At both frequencies, RFI is often narrow band, but the internally generated 74 MHz interference is stronger and more predictable (harmonics always in the same channels) while RFI at 330 MHz is externally generated and occurs randomly.

One particularly important consideration in reducing 74 and 330 MHz VLA data as compared to centimeter wavelength data is that a straightforward two-dimensional Fourier inversion of the measured visibility data is inadequate because of the non-coplanar array geometry. The errors that are introduced by a 2-D inversion increase with distance from the field center and are enhanced at high resolution (long baselines). The large primary beam of the VLA at 74 MHz (field of view $\sim 10^\circ$) and 330 MHz (FoV $\sim 2\overset{\circ}{.}5$) introduces severe errors if only a 2-D inversion is used. Such large fields typically have tens to hundreds of sources scattered across the FoV, which must be properly deconvolved to approach classical-confusion or thermal-noise–limited sensitivities. Another key consideration that will come up is the heavy dependence on self-calibration to compensate for the ionospheric effects on visibility phases. Since ionospheric effects may dominate over tropospheric effects up to L band, some of the procedures outlined here will apply to L-band data reduction as well.

We hope this tutorial will be enough to get the novice (and not-so novice!) user started.

In addition to the material presented here, one may want to consult The $\mathcal{AIPS}$ Cookbook[1] and *Synthesis Imaging in Radio Astronomy II* [Taylor et al. 1999].

[1] http://www.aoc.nrao.edu/aips/cook.html

Chapter 2

Overview

A quick reference:

2.1 Initial Calibration

1. Load the data—`FILLM`. Make sure to set `DOUVCOMP=-1` and `DOWEIGHT=1` to retain the weighting information. Delete the "Channel 0" data set.

2. Summarize the observing run—`LISTR` and `PRTAN`.

3. Establish channels/time ranges of significant RFI—`POSSM`.

4. Calibrate the bandpass—`BPASS`. (Cygnus A was observed, right?!) Eventually, there may be a repository of bandpass calibrations (i.e., BP tables) available. For now, this must be done for each run.

2.2 Traditional Imaging Strategy

1. Determine antenna gains (accurately) and phases (crudely)—`CALIB`. Obtain a model for Cygnus A (or other strong source, see Appendix A) from one of the authors. The best procedure is to identify a few (5–10) RFI-free channels in the spectral-line data base and use these to determine the gains. Use `CLCAL` to apply the gain solutions to the data.

2. Re-scrutinize the data for RFI and flag—`SPFLG` and `FLGIT`. Typical flagging settings for `FLGIT` are `APARM=20000, 5, 400, 5, 5` for a run that includes Cygnus A, `APARM(1)=3000` if doing a subset of sources that does not include Cygnus A. Aim for 15–30% of the data to be flagged.

3. Average in frequency, if desired—`SPLIT` or `SPLAT`. Using `TVFLG` on the frequency-averaged data is recommended as `FLGIT` can occasionally miss RFI spikes.

4. Hybrid mapping—`IMAGR` and `CALIB`. Make sure to set `DO3DIMAG=1` and `OVERLAP=2`. One will probably want to use `SETFC` to set the coordinate shifts for the large number of fields required.

5. Flattening the sky—`FLATN`. If one desires a single, wide-field image of the entire field of view, one needs to "glue" together the multiple `IMAGR` fields.

2.3 Ionospheric Imaging Strategy

1. Determine antenna gains and phases—`CALIB`. Obtain a model for Cygnus A (or other strong source, see Appendix A) from one of the authors. The best procedure is to identify a few (5–10) RFI-free channels in the spectral-line data base and use these to determine the gains.

2. Filter the gain phases to isolate the instrumental phases—`SNFLT`. Hope that the ionospheric phases are either small and random or large and random over the entire time of observation.

3. Excise RFI and flag—`SPFLG` and `FLGIT`. This step can be considered optional, because it can also be done automagically in the next step.

4. Wide-field imaging—`VLAFM`. This is a special-purpose, wide-field imaging task developed by B. Cotton, building on much of the work by E. Greisen.

2.4 330 MHz Imaging

Reduction of 330 MHz data appears to be evolving into a "hybrid" technique, with aspects drawn from both 74 MHz and higher frequency reduction techniques. In this scheme, Cygnus A is observed but used *only* as a bandpass calibrator. The reason for this is that Cygnus A is sufficiently strong to increase the system temperature. Thus, one does not want to use it as a flux density and/or phase calibrator, *unless* one is sufficiently confident that the Van Vleck corrections applied with `FILLM` are correct. For flux density and phase calibrators, one chooses sources in a manner identical to that at higher frequency observations, i.e., 3C 48, 3C 147, or 3C 286 for the flux density calibrator and a source from the VLA Calibrator Manual[1].

1. Load the data—`FILLM`. Make sure to set `DOUVCOMP=-1` and `DOWEIGHT=1` to retain the weighting information. Delete the "Channel 0" data set.

2. Summarize the observing run—`LISTR` and `PRTAN`.

3. Establish channels/time ranges of significant RFI—`POSSM`.

[1] http://www.aoc.nrao.edu/~gtaylor/calib.html

4. Calibrate the bandpass—`BPASS`. (Cygnus A was observed, right?!) Eventually, there may be a repository of bandpass calibrations (i.e., BP tables) available. For now, this must be done for each run.

5. Determine antenna gains and phases—`CALIB`. Identify a few (5–10) RFI-free channels in the spectral-line data base and use these to determine the gains. Use `CLCAL` to apply the gain solutions to the data.

6. Re-scrutinize the data for RFI and flag—`SPFLG` and `FLGIT`. Expect 15–30% of the data to be flagged.

7. Average in frequency, if desired—`SPLIT` or `SPLAT`. Make sure to set `DOCALIB=2`! Using `TVFLG` on the frequency-averaged data is recommended as `FLGIT` can occasionally miss RFI spikes.

8. Hybrid mapping—`IMAGR` and `CALIB`. Make sure to set `DO3DIMAG=1` and `OVERLAP=2`. One will probably want to use `SETFC` to set the coordinate shifts for the large number of fields required.

9. Flattening the sky—`FLATN`. If one desires a single, wide-field image of the entire field of view, one needs to "glue" together the multiple `IMAGR` fields. Alternately, one may use `VLALB` which can do the imaging, self-calibration, and sky flattening in one fell swoop.

Chapter 3

Preparing for A Low-Frequency Observing Run

The typical phase calibration techniques employed at higher frequencies (i.e., looking at some compact source a few degrees away from a target source every 30 min. or so) is useful only at 330 MHz. Even at this frequency, this technique may be of limited utility as there is so much flux in any target field (as the FOV is large, 10° FWHM at 74 MHz) that, as long as the visibility phases are roughly calibrated, the first map will generate a model sufficient to drive self-calibration and bring the rest of the phases into line. The reason this is so is that the sky is coherent across the array for the short (< 5 km) spacings, and so even a phase calibration based on a bright source tens of degrees from one's target source will be enough to generate the first model. Thus, this is one of those rare cases in which one should be thankful that even the A configuration has lots of relatively short spacings.

The key is picking bright calibrators and observing them briefly, perhaps every hour or so for 5 min. By far the best of all sources to use is Cygnus A, with a flux of approximately 17 *kJy*. It is slightly resolved in even the B- and C configuration, but we have excellent models on hand which can compensate for this. Cygnus A is so bright that it makes bandpass and gain calibration trivial, especially since it is so strong that it is stronger than most RFI, so that these calibration steps can be done *before* the RFI excision steps. *We strongly advise that 5 min. observations of Cygnus A (3C 405) be inserted every hour or so.* In configurations other than A, Cas A (3C 274), the Crab (3C 144), or Virgo A (3C 274) should work as well, and we are compiling a list of other sources that may be suitable. The stronger (preferably > 100 Jy) VLA flux density calibrators (e.g., 3C 123 with a flux of 400 Jy at 74 MHz) could be used in a pinch.

In fact, Cygnus A is so strong that it can be problematic at 330 MHz for the purposes of flux density and phase calibration. Cygnus A makes a measurable, possibly even a dominant, contribution to the system temperature. As such, one needs to apply the Van Vleck correction when reading in the data, but the robustness of the Van Vleck correction algorithm within `FILLM` has not been determined. Thus, the traditional phase-calibration technique should be used, but the number and reliability of phase calibrators at 330 MHz is generally lower than at the higher frequencies. For bandpass calibration, Cygnus A is still a good source to use. Thus, a 330 MHz observing run can be prepared in a manner identical to that for a higher frequency one, but with the addition of a few scans on Cygnus A in order to determine the bandpass.

Also in preparing the observing file, use a consistent equinox! The VLA will quite happily observe sources for which a subset are in the B1950 equinox and a subset in the J2000 equinox. However, scheduling such an observing run increases the "bookkeeping" requirements considerably and provides no benefits (with plenty of possibilities for error). Before submitting the OBSERVE file, look through it. The J2000 equinox is indicated by a `C` just at the end of the declination; the B1950 equinox is indicated by the *lack* of a `C`. Make sure that the presence or absence of a `C` is consistent.

As mentioned later, antenna amplitudes (SN tables) and bandpass solutions (BP tables) probably are good for an entire configuration, barring significant hardware changes at the front end. We realize a list of suitably strong calibrators (with models) is needed and are working on generating such a list. We also hope to generate standard gain and bandpass solutions at the beginning of each configuration, using Cygnus A, which users can tap into should they fail to get the appropriate solutions from their own runs.

Finally, stay away from the Sun! A Galactic center observing run, conducted by one of the authors, was done while the Sun was "only" 25° away from the Galactic center. It appears that scattering from the solar wind affected the run significantly. Especially near solar maximum, we recommend making sure that the Sun is at least 40°–50° away from the target source, if possible. One may get good data considerably closer, but it's risky and we don't really know the odds at this point.

3.1 Special Observing Notes for A (and B?) Configuration

Ionospheric wander in the A configuration (arcminute scales over tens of minutes) make the initial self-calibration of A-configuration data difficult. (Depending upon the state of the ionosphere, ionospheric wander may become problematic in the B configuration also.) The limited ionospheric isoplanatic patch will restrict the field of view probably to no more than 3° vs. 10° for the other configurations. One will likely need to "freeze out" ionospheric refraction. This can be accomplished by using `FACES` or `VLAFM`.

One can use `FACES` to familiarize oneself with the sky around one's target source. In an "ideal" situation, one would be at a declination north of +30°, so that one can use the WENSS. If there is no bright source nearby, one's target source is below +30°, or one is observing near the Galactic plane, then one seriously should consider observing simultaneously at 330 MHz. This is because you can fix up your phases using the simultaneously obtained data 330 MHz data. (We call this phase transfer.) So to be absolutely safe you should observe in "4P" mode. In most cases the

330 MHz data are scientifically complimentary to your 74 MHz data, and so it actually enriches one's data set.

Initial data indicate things get difficult low elevations as well. So falling back on traditional phase calibration (looking at the nearest bright 3C source every hour or so) is probably a good idea.

3.2 Predicting and Monitoring Ionospheric Weather

The ionosphere imposes phase fluctuations on low-frequency radio waves on a variety of timescales. The shorter the timescale and the larger the fluctuation, the more difficult it can be to obtain an image. This problem is bad for the A- and B configurations, but severe impacts on D configuration observations have been seen under conditions of particularly brutal ionospheric weather.

In an ideal world, we would employ some means of "dynamic scheduling" so that 74 MHz observations would be scheduled only when the ionosphere was quiescent. Unfortunately, we do not yet have a good, *fast* diagnostic for assessing ionospheric conditions that would enable us to begin dynamic scheduling. We have developed some general rules, though:

- Avoid sunrise and sunset. As the ionosphere is ionized and recombines, respectively, maintaining phase coherence can be impossible.
- Prefer nighttime observations. However, observing at night does not guarantee quiescent ionospheric conditions nor does observing during the day guarantee violent ionospheric conditions.

If one has some frequency flexibility (e.g., using only 327 MHz instead of both 74 and 327 MHz would be worthwhile), one can monitor various Web sites for possible indications of bad ionospheric weather.

- Space Weather Now[1] is a NOAA site that provides details about geomagnetic storms, radio blackouts, and the like.
- ARRL Propagation Bulletins[2] are distributed by the American Radio Relay League. If good long-distance propagation conditions exist (e.g., Florida to Tahiti at 6 m wavelength), it is a good bet that the ionosphere will be nearly opaque at 4 m.

[1] http://www.sel.noaa.gov/SWN/
[2] http://www.arrl.org/w1aw/prop/

Chapter 4

Initial Steps

Throughout the rest of this document, we describe various $\mathcal{AIPS}$ tasks. The lists of adverbs for each task were appropriate at the time this document was written. However, various slight changes do occur. Do not be alarmed if there are minor differences in the list of adverbs presented here and those one sees in one's version of $\mathcal{AIPS}$. Also, one may want to refer to the $\mathcal{AIPS}$ Cookbook[1] to see the similarities and differences between centimeter- and meter-wavelength data reduction for the VLA.

4.1 Obtaining Your Data

Remote observers are shipped one or more data tapes. If you are at the AOC, search the VLA archives[2] to find your observations. Use either one's program code (e.g., AK461) or the name of one's source. Then go to the archive tape room and, from the date and program code, figure out the proper tape to use in `FILLM`. (The archive listing may give the tape, too.)

4.2 Loading Your Data

Use the verb `MOUNT`, usually with `DENSITY=22500` (for 8 mm a.k.a Exabyte tapes), to mount the tape.

The data are loaded using `FILLM`. Important adverbs to set include

`VLAOBS` Use one's program code (e.g., AZ001) or observing date to point `FILLM` to one's data. In general, the program code is easier to use, and if one is reading from an archive tape, other people's data may be on the tape also.

[1] http://www.cv.nrao.edu/aips/cook.html
[2] http://www.aoc.nrao.edu/vla/vladb/VLADB.html

`DOUVCOMP=-1` Preserve weight information. In compressing the visibility data, only a single weight is kept for all spectral channels, IFs, and polarizations of the sample time and baseline. At low frequencies, the weights can be (are!) substantially different and without retaining that informatin, a serious loss of sensitivity in imaging will result.

`DOACOR=1` All low-frequency data are (should be!) acquired in spectral-line mode. This adverb specifies that the autocorrelation data should also be loaded, which may help in identifying particularly noisy antennas, ones being blasted by RFI, etc.

`DOWEIGHT=1` Use the nominal sensitivity to set data weights, thereby allowing poorer receivers to be downweighted which can make a considerable difference in the sensitvity of the final images. Weights set in this way must be calibrated along with the visibilities (`DOCAL=2` does this in all calibration tasks).

`CPARM(2)=1` **and** `CPARM(3)=16` These override the use of the on-line system's flagging information. Experience has shown that the on-line system may flag more, *far more* of one's data than is justified, at least at low frequencies. The burden of flagging the data is increased only slightly by overriding the on-line flags and doing so increases greatly the chances that one will have data to flag.

`CPARM(8)` **and** `CPARM(9)` These adverbs specify the CL and TY table increments. In general these should be the same and equal to the sampling time. We used to use 10 s, but more recently we've been able to use 6.667 s with no problems. Particularly in the A (and B?) configuration, one wants the shortest possible sampling time so as to follow ionospheric phase variations. For C and D configuration observations, one might be able to average the data to 30 s. If you have a fast machine, stay with the shortest possible time (and you'll probably need a fast machine for the later imaging steps!).

`BPARM=0` Use the default gain curves for the VLA antennas. (At low frequencies, the gain probably doesn't change much anyway!)

Two to four basic files should load: A "channel 0" file and a line data file. The number (2 vs. 4) will depend upon whether one is observing at only 74 or 330 MHz or at both. Use `IMHEAD` to confirm which are which.

For bookkeeping purposes, it may be helpful to `RENAME` them. For example below one author had Galactic center data taken in C configuration and renamed them as follows:

```
>pcat
AIPS 1: Catalog on disk  2
AIPS 1:  Cat Usid Mapname      Class   Seq  Pt     Last access      Stat
AIPS 1:    1 1372 GC-4C       .CH 0  .    1 UV 04-MAR-1999 10:24:39
AIPS 1:    2 1372 GC-4C       .LINE  .    1 UV 06-MAR-1999 11:13:43
```

```
AIPS 1:    3 1372 GC-PC       .CH 0  .     1 UV 04-MAR-1999 10:25:16
AIPS 1:    4 1372 GC-PC       .LINE  .     1 UV 04-MAR-1999 10:25:20
```

The "Channel 0" data sets are afflicted with varying degrees of RFI. A prudent (and disk space-saving) step is to delete them at this stage. (Moreover, if one should want to recreate them for some reason, `AVSPC` can be used to do so.)

4.3 `LISTR` and `PRTAN`—Summarizing your observing run

Run `LISTR` with `OPTYPE = 'SCAN'` to print out a summary of your basic data sets. Actually if you are working with the 74 MHz data just do it on the LINE data base, that's all you'll need. Also run `PRTAN` and keep the end part which tells you where the antennas were. This will be useful throughout.

4.4 `POSSM`—Scrutinizing the Data for RFI

Next run `POSSM` on a few of your sources to see what the RFI (spikes) looks like. Look at various sources. You'll find strong sources show the least RFI and that the RFI is strongest on the shortest baselines.

The example below shows the input for looking at the cross power spectra for the Crab (3C 144) in the polarization LL for the baseline 3-4. Do not apply any calibration (`DOCALIB=-1`) or bandpass corrections (`DOBAND=-1`) at this stage since neither has been determined yet.

```
AIPS 1: POSSM     Task to plot total and cross-power spectra.
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    '3C144          '      Source list
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                   Source qualifier -1=>all
AIPS 1: CALCODE    '    '                 Calibrator code '    '=>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: UVRANG        0           0       UV range to be plotted
AIPS 1: TIMERANG   *all 0                 Time range to be plotted
AIPS 1: STOKES     'LL  '                 Stokes type to select.
AIPS 1: BIF           1                   Lowest IF number 0=>all
AIPS 1: EIF           0                   Highest IF number 0=>all
```

```
AIPS 1: BCHAN          1                    Lowest channel number 0=>all
AIPS 1: ECHAN          0                    Highest channel number 0=>all
AIPS 1: SUBARRAY       0                    Subarray, 0=>1
AIPS 1: ANTENNAS       3          *rest 0   Antennas to select
AIPS 1: BASELINE       4          *rest 0   Baselines with ANTENNAS
AIPS 1: DOCALIB       -1                    If >0 calibrate data
AIPS 1: GAINUSE        2                    CL (or SN) table to apply
AIPS 1: DOPOL         -1                    If >0 correct polarization.
AIPS 1: FLAGVER        1                    Flag table version
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: SMOOTH       *all 0                 Smoothing function. See
AIPS 1:                                     HELP SMOOTH for details.
AIPS 1: SHIFT          0            0       Position shift:
AIPS 1:                                     RA, Dec (arcsec)
AIPS 1:                                     0 => no shift
AIPS 1: APARM        *all 0                 Control information:
AIPS 1:                                     1: = 0 => scalar average
AIPS 1:                                        > 0 => vector average
AIPS 1:                                     2: = 0 => self-scale
AIPS 1:                                        > 0 => fixed scale
AIPS 1:                                         (use APARM(3-6))
AIPS 1:
AIPS 1:                                         (use APARM(3-6))
AIPS 1:                                     3: min. amplitude
AIPS 1:                                     4: max. amplitude
AIPS 1:                                     5: min. phase (degrees)
AIPS 1:                                     6: max. phase
AIPS 1:                                     7: x-axis labelling
AIPS 1:                                        = 0 = > in channels.
AIPS 1:                                        = 1 = > in Hz (or secs
AIPS 1:                                            if corr. fn)
AIPS 1:                                        = 2 = > in m/s
AIPS 1:                                     8: = 0 => plot cross power
AIPS 1:                                        = 1 => plot total power
AIPS 1:                                        = 2 => plot BP table
AIPS 1:                                        = 3 => plot ACF
AIPS 1:                                        = 4 => plot XCF
```

```
AIPS 1:                                       = 5 => plot cross power of
AIPS 1:                                              individual antennas
AIPS 1:                                              for cross polaris.
AIPS 1:                                              (STOKES=RL, or LR)
AIPS 1:                                    9: > 0 => plot several IF's
AIPS 1:                                       together as though one
AIPS 1:                                       long spectrum (see HELP)
AIPS 1:                                    10: > 0 => reverse direction
AIPS 1:                                       of plotted spectrum, so
AIPS 1:                                       velocity increases to
AIPS 1:                                       right.
AIPS 1: CODETYPE   '    '                  'A&P ', 'AMP ', 'PHAS',
AIPS 1:                                    'R&I ', 'REAL', 'IMAG'
AIPS 1:                                    other => 'A&P '
AIPS 1: POLPLOT    '        '              Option to display various
AIPS 1:                                    combinations of polzns to
AIPS 1:                                    plot: 'RL/RR', 'RL/LL',
AIPS 1:                                    'LR/RR', 'LR/LL', 'RR/LL'
AIPS 1:                                    'LL/RR'; other = don't use
AIPS 1:                                    this option.
AIPS 1: SOLINT        -1                   If SOLINT > 0 then it enables
AIPS 1:                                    the user to make multiple
AIPS 1:                                    plots per pass of POSSM.
AIPS 1:                                    It defines the averaging time
AIPS 1:                                    for each individual plot.
AIPS 1:                                    Task will start at TIMERANG
AIPS 1:                                    and make a plot for every
AIPS 1:                                    SOLINT minutes. If SOLINT
AIPS 1:                                    = -1 will do the same but
AIPS 1:                                    will do scan averages if NX
AIPS 1:                                    table is present.
AIPS 1: NCOUNT         0                   Number of plots per page
AIPS 1: BPARM      *all 0                  More control information:
AIPS 1:                                    1: If = 1 divide by 'channel
AIPS 1:                                       0' before plotting data.
AIPS 1:                                       0 => do not divide.
AIPS 1:                                    2: Start chn. of 'channel 0'
AIPS 1:                                       (0 => determined by POSSM)
AIPS 1:                                    3: Stop chn. of 'channel 0'
AIPS 1:                                       (0 => determined by POSSM)
```

```
AIPS 1:                                     4: ignore spectrum when ampl.
AIPS 1:                                        channel 0 < BPARM(4) Jy
AIPS 1:                                     5-9: unused
AIPS 1:                                     10: =1 => don't write header
AIPS 1:                                     info when writing to outfile
AIPS 1:                                     useful for appending several
AIPS 1:                                     spectra into a single outfile
AIPS 1:                                     [see EXPLAIN POSSM]
AIPS 1: OUTFILE    '                                                 '
AIPS 1:                                     Filename in which to write
AIPS 1:                                     spectrum. Default = ' ' =
AIPS 1:                                     do not write spectrum. The
AIPS 1:                                     file is written only if
AIPS 1:                                     NCOUNT = 0
AIPS 1: LTYPE        -3                     Type of labeling: 1 border,
AIPS 1:                                     2 no ticks, 3 - 6 standard,
AIPS 1:                                     7 - 10 only tick labels
AIPS 1:                                     <0 -> no date/time
AIPS 1: BADDISK    *all 0                   Disks to avoid for scratch
AIPS 1: DOTV         -1                     > 0 Do plot on the TV, else
AIPS 1:                                     make a plot file
AIPS 1: GRCHAN        0                     Graphics channel 0 => 1.
```

Figure 4.1 shows an example of a `POSSM` plot showing RFI at 74 MHz (from a different experiment than the sample inputs above). At 74 MHz, the RFI is (exclusively?) is internal and due to the VLA electronics. As such, it appears as a regular "comb." At 330 MHz, the RFI is (almost exclusively?) due to external sources and will be so much more random in frequency.

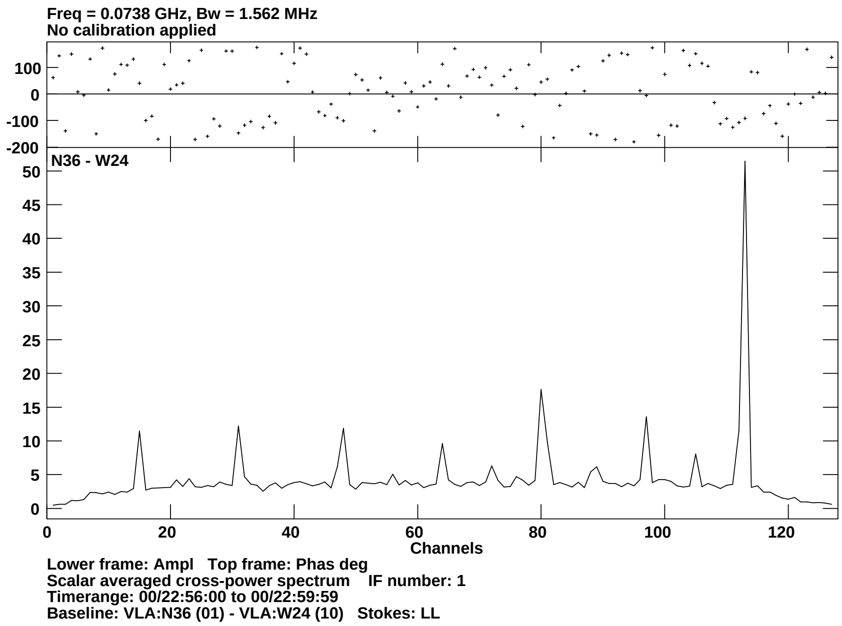

Figure 4.1: An example of a `POSSM` plot showing RFI at 74 MHz. Clearly evident is the "comb" of VLA-generated RFI. This plot is from a different experiment than the sample input shown in the text.

Chapter 5

Data Calibration

5.1 QUACK—Some Initial Flagging

As at higher frequencies, it may be necessary to eliminate data at the beginning and/or end of scans. One way to determine if one's data are affected by any potential problems is to view a short segment of data, e.g., three or four scans, using `TVFLG`. If data at the beginning and/or end of scans are consistently offset with respect to the rest of the scan, it is worthwhile running `QUACK`.

One can always run `QUACK` just to be safe. For typical "long" observing scans (i.e., 5 min. or longer), `QUACK` eliminates an extremely small amount of data.

The crucial adverbs are

`OPCODE` This is used to indicate whether the beginning (`OPCODE='BEG'`) or end (`OPCODE='END'`) of scans are to be flagged.

`APARM` This is used to indicate the amount of time to flag from the end (`APARM(1)`) and beginning (`APARM(2)`) of the scan. A typical value is the first 0.5 minutes of each scan.

5.2 BPASS—Calibrating the Bandpass

A strong source is needed for bandpass calibration. Cygnus A is by far the preferred choice, but one will need a good model as the fractional bandwidth is great enough that its intrinsic visibility changes across the pass band.

A rough estimate shows that the effect of resolution can be ignored if

$$\pi\frac{\Delta\nu}{\nu}\frac{\theta_{\mathrm{src}}}{\theta_{\mathrm{HPBW}}} \ll 1, \tag{5.1}$$

where $\Delta\nu/\nu$ is the fractional bandwidth and $\theta_{\mathrm{src}}/\theta_{\mathrm{HPBW}}$ is the source size expressed in units of the *synthesized* beam. Consider two examples:

Cyg A at 74 MHz in the A configuration The quantity on the left hand-side of equation (5.1) is 0.3. This means there is a 30% change (worst case) in visibility across the 1.6 MHz bandpass, on the longest baseline, due to the resolution of Cyg A. As the solution will be dominated by shorter spacings (and the use of `UVRANGE` will help!), this error can probably be tolerated.

Cyg A at 325 MHz with 6 MHz bandwidth in the A configuration The left-hand side of equation (5.1) is 1.4. This is bad. A model must be used.

Even though $\mathcal{AIPS}$ can use a model source to permit proper calculation of bandpasses for resolved objects, there are still some residual issues of normalization.

Use of the "Channel 0" mode in `BPASS` (enabled by filling in `IN3NAME`, `IN3CLASS`, `IN3SEQ`, and `IN3DISK`) will bypass these normalization problems, but will not allow proper accounting for resolution of the object. The difficulty is that a resolved object's visibility is a function of frequency—if the source is large or the bandwidth is large, the change in visibility across the bandpass can be significant. This change is not accounted for by "division by channel 0."

FITS images of Cygnus A, with attached CLEAN component tables, are now available online (other sources are also available, see Appendix A). These models are applicable to observations in all VLA configurations at 74 MHz[1] and 330 MHz[2]. In order to use either one of these models, download the appropriate file. Place the downloaded file someplace where AIPS can see it, e.g., the `FITS` directory. Use `FITLD` or `IMLOD`, with `INFILE` set appropriately, to load the model image into AIPS. Then, when setting up the inputs for `CALIB` and `BPASS`, set `IN2NAME`, `IN2CLASS`, `IN2SEQ`, and `IN2DISK` to refer to this model image and set `NMAPS=1`.

Check the equinox of the model. If the equinox of the model is not the same as one's data set, use `EPOSWITCH` before using the model! (Presumably one did not schedule the observing run with mixed equinoxes for the sources! [§3])

The advantage of Cygnus A is that you can make the `BPASS` run without having to edit out any of the RFI. For configurations other than A (if Cygnus A is not available), Cas A (3C 274), 3C 144 (the Crab), and 3C 274 (Virgo A) can be used (with models, see Appendix A).

Below is an example of a `BPASS` run on Cygnus A. Important adverbs include

`REFANT` Use `PRTAN` output to choose a reference antenna. Contrary to standard practice at higher frequencies, it may be helpful to use a `REFANT` located far from the array center, as this reduces the relative number of short spacings used for the in finding the bandpasses, i.e., mitigates the effects of RFI.

One can also set *u*-*v* ranges (via `UVRANGE`) again to remove the shortest spacings from the `BPASS` solutions. For Cygnus A it doesn't matter too much, it blows through the RFI in most cases without any problem.

`DOCAL=-1` As the data are not yet calibrated, one does not want to try to apply a calibration.

[1] http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/Cyg_A-4.model.FITS
[2] http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/Cyg_A-P.model.FITS

`SMOOTH=1 0` It may be necessary or desirable to apply additional spectral smoothing in order to give less weight to channels affected by RFI. The specified setting uses Hanning smoothing with a 4-channel width and 1-channel convolving function.

`SOLINT` Different values of this adverb may be useful. `SOLINT=-1` makes a single bandpass solution for the entire observing run, thereby giving less weight to any particular scan with bad RFI in it. `SOLINT=0` makes a bandpass solution per scan, which can be useful for identifying scans for which flagging by hand may be necessary.

`CMETHOD='DFT'` It is vital that `CMETHOD` is set and not left at the default (`CMETHOD=' '`) or set to `CMETHOD='GRID'`. The CCs in the model may not have been (probably were not) made from *u*-*v* data gridded in the same manner that would make sense for one's database. With `CMETHOD='DFT'` one calculates the effect of each CC at the *u*-*v* coordinates for each visibility datum.

`BPASSPRM(5)=2` Do not normalize by an external "Channel 0." As the external "Channel 0" can contain considerable RFI, normalizing by it would have the effect of corrupting the bandpass solution amplitudes.

`BPASSPRM(8)=0` Use vector averaging (default).

`BPASSPRM(9)=1` Because of on-line flagging (or flagging already done by experts or would-be experts), one may have channels that have been flagged. This option makes `BPASS` interpolate or attempt to interpolate over the flagged channels.

`BPASSPRM(10)=3` One does not want to normalize using the default "Channel 0" file provided by `FILLM` because that file contains considerable quantities of RFI. Setting this adverb allows one to specify a region of the spectrum free from RFI and use that, combined with the source model, to normalize the bandpass solutions.

`BPASSPRM(11)=1` Set the weights given to be independent of channel. The converse is to scale the weights by the square of the amplitude, which has the effect of giving more weight to baselines with lots of RFI (higher amplitudes) and the short baselines (which are most often affected by RFI).

`ICHANSEL` Specify the RFI-free region(s) of the spectrum. These region(s) can be determined from the `POSSM` plots produced above (§4.4).

```
AIPS 1: BPASS     Task to generate a "Bandpass" (BP) table.
AIPS 1: Adverbs     Values                    Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: [...]
AIPS 1:                                       Data Selection
```

```
AIPS 1: CALSOUR    '3C405           '      Bandpass calibrator sources.
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                    Calibrator qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>all
AIPS 1: UVRANG        0            0       UV range to select
AIPS 1: TIMERANG   *all 0                  Time range to select
AIPS 1: SELBAND      -1                    Bandwidth to select (kHz)
AIPS 1: SELFREQ      -1                    Frequency to select (MHz)
AIPS 1: FREQID        0                    Freq. ID to select.
AIPS 1: BIF           1                    Lowest IF number 0=>all
AIPS 1: EIF           0                    Highest IF number 0=>all
AIPS 1: SUBARRAY      0                    Subarray, 0=>all
AIPS 1: ANTENNAS   *all 0                  Antennas to select
AIPS 1:
AIPS 1:                                    CLEAN map (optional)
AIPS 2: IN2NAME    'Cyg A 333MHz'          Cleaned map name (name)
AIPS 2: IN2CLASS   'MODEL '                Cleaned map name (class)
AIPS 2: IN2SEQ        1                    Cleaned map name (seq. #)
AIPS 1: IN2DISK       0                    Cleaned map disk unit #
AIPS 1: INVERS        0                    CC file version #.
AIPS 1: NCOMP      *all 0                  # comps to use for model.
AIPS 1:                                    1 value per field
AIPS 1: FLUX          0                    Lowest CC component used.
AIPS 1: NMAPS         1                    No. Clean map files
AIPS 1: CMETHOD    'DFT '                  Modeling method:
AIPS 1:                                    'DFT','GRID','    '
AIPS 1: SMODEL     *all 0                  Source model, 1=flux,2=x,3=y
AIPS 1:                                    See HELP SMODEL for details.
AIPS 1:
AIPS 1:                                    Control options
AIPS 1: DOCALIB       0                    If >0 calibrate data
AIPS 1:                                    = 2 calibrate weights
AIPS 1: GAINUSE       0                    CL table to apply (SN table
AIPS 1:                                    to apply to single-source)
AIPS 1: DOPOL        -1                    If >0 correct polarization.
AIPS 1: FLAGVER       1                    Flag table version
AIPS 1: SOLINT        0                    Solution interval (mins)
AIPS 1:                                    -1 => do whole time range
AIPS 1: REFANT        8                    Reference antenna
AIPS 1: BPVER         0                    BP table version to write
```

```
AIPS 1:                                           0 => a new table to be
AIPS 1:                                                generated.
AIPS 1: SMOOTH        *all 0                      Smoothing function. See
AIPS 1:                                           HELP SMOOTH for details.
AIPS 1: ANTWT      *all 0                         Ant. wts (0 => 1.)
AIPS 1: MINAMPER      0                           Amplitude closure error
AIPS 1:                                           regarded as excessive in %
AIPS 1: MINPHSER      0                           Phase closure error regarded
AIPS 1:                                           as excessive in degrees
AIPS 1: BPASSPRM      0           0               Control information:
AIPS 1:               0           0               1: if > 0 use only the
AIPS 1:               2           0                  autocorrelation data.
AIPS 1:               0           0               2: print level - see help
AIPS 1:               1           3               3: If > 0 do not divide data
AIPS 1:               1                              by source model
AIPS 1:                                           4: If > 0 store phases only
AIPS 1:                                              in the BP table.
AIPS 1:                                           5: If <= 0 divide by 'channel
AIPS 1:                                              0' before determining BP.
AIPS 1:                                              If > 0 switch off the
AIPS 1:                                              channel 0 divide option.
AIPS 1:                                           6: amp closure error limit -
AIPS 1:                                              print channels averaging
AIPS 1:                                              over this if (2) > 0
AIPS 1:                                           7: phase closure error limit
AIPS 1:                                              print channels averaging
AIPS 1:                                              over this if (2) > 0
AIPS 1:                                           8: > 0 => scalar average
AIPS 1:                                           9: > 0 => interpolate over
AIPS 1:                                              flagged channels if poss.
AIPS 1:                                           10:1 => normalize amplitudes
AIPS 1:                                                using all channels
AIPS 1:                                              2 => normalize amplitudes
AIPS 1:                                                using ICHANSEL channels
AIPS 1:                                              3 => normalize amplitudes
AIPS 1:                                                and zero average phase
AIPS 1:                                                using ICHANSEL channels
AIPS 1:                                              0 => no deliberate norm.
AIPS 1:                                           11: > 0 solution weights are
AIPS 1:                                              independent of channel
```

```
AIPS 1:                                          <=0, > -1.5 weights scaled
AIPS 1:                                            by amplitude**2
AIPS 1:                                          < -1.5 weights scaled by
AIPS 1:                                            1 / amplitude**2
AIPS 1: ICHANSEL     55          65           Array of start and stop chan
AIPS 1:               1           1           numbers, plus a channel
AIPS 1:             *rest 0                   increment and IF to be used
AIPS 1:                                       to select channels to sum to
AIPS 1:                                       find a 'channel 0'.  If all
AIPS 1:                                       0, range set to inner 75% of
AIPS 1:                                       observing band.
AIPS 1:
AIPS 1:                                       'Channel 0' uv-data
AIPS 1: IN3NAME    '            '             Channel 0 uv name (name)
AIPS 1:                                       must be '' to suppress option
AIPS 1: IN3CLASS   '      '                   Channel 0 uv name (class)
AIPS 1:                                       must be '' to suppress option
AIPS 1: IN3SEQ        0                       Channel 0 uv name (seq. #)
AIPS 1: IN3DISK       0                       Channel 0 uv disk unit #
```

It may be useful to make use of two runs of BPASS. On the first pass, use SOLINT=0. Then evaluate how the bandpass solutions as a function of time using BPLOT. Some flagging or restricting of the data (via TIMERANG or UVRANG) can be done. This process is repeated until the bandpass solutions are smooth in time. Once this situation has been achieved, a final pass of BPASS with SOLINT=-1 is done in order to obtain one set of solutions.

Good BPASS tables should be useful for the entire configuration unless significant hardware (filters) changes are made at the front end. Eventually we plan to make good BP tables from Cygnus A at the start of each new configuration, and keep these tables in a repository for observers to use should they not have obtained good solutions from their own runs.

It is important to examine the bandpass solutions to ensure that they are not influenced by RFI. One method is to use POSSM with APARM(8)=2 and NPLOT=9 (9 plots per page so one obtains only 3 pages). Figure 5.1 shows an example of good bandpass solutions. A key aspect of good solutions is that they are smooth.

If the bandpass solutions are not smooth, but contain spikes, one can try setting a UVRANGE (something like UVRANGE=0.3 50 for C configuration, UVRANGE=0.8 10 for B configuration), again since the internally generated RFI is worse on the shortest spacings. Thus, setting an inner UVRANGE keeps the short spacings out of the BPASS solutions, at the cost of lowering the signal-to-noise. In general, this is not a problem because Cygnus A is so strong.

An alternate strategy would be to re-do BPASS with SOLINT=0 to obtain a bandpass solution for each scan. One can then use BPLOT, with CODETYPE='AMP' and SORT='AT', to plot the bandpass

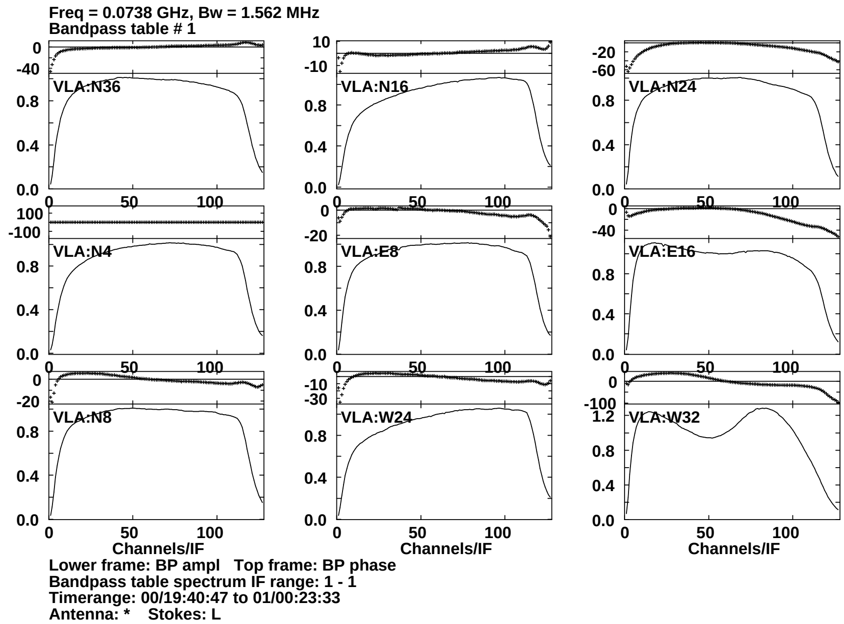

Figure 5.1: An example of a set of bandpass solutions, plotted using `POSSM`.

solutions from the various antennas as a function of time. It may be then possible to identify a bad scan(s) that could be flagged by hand or excluded from the `BPASS` run, by setting `TIMERANG`.

As a final resort, if there are still some ripples in the BP table, one can utilize the `SMOOTH` option in `BPASS` (`SMOOTH=1 4 4` or `SMOOTH=1 8 8`, actually `SMOOTH = 1 0` is fine since this defaults to `SMOOTH=1,4,5` which is Hanning smoothing) to smooth these out. The objective is to retain the basic shape of the BP spectrum but get rid of the little spikes and dips. Use `SMOOTH` only if absolutely necessary. *If* one smooths at this stage, make sure to smooth the data in exactly the same fashion when forming the continuum data base (§5.6).

5.3 `CALIB`—Setting Antenna Gains and Phases

This section is intended mainly for observers with 74 MHz data. Setting the gains and phases for 330 MHz observations can be approached in the normal way as at higher frequencies, i.e., run `SETJY` on your primary flux calibrator, then run `CALIB` on both phase and flux calibrators (with appropriate u-v restrictions), and then `GETJY` to fix the flux of your phase (secondary) calibrators. If one has a nice model of Cygnus A (at the proper P-band frequency, with a correct flux density, and at a resolution at least as good as one's data, see below) *and* one believes that the Van Vleck corrections applied within `FILLM` are accurate, then 330 MHz data can be calibrated in the same manner as described here.

The objective of this pass of calibration is to set the antenna gains correctly and provide an initial, crude calibration of the antenna phases. Only a crude calibration of the phases is necessary as self-calibration will improve them substantially later. Furthermore, the gains of the system are highly stable and should be good for long periods of time (configuration lengths).

Cygnus A is the best choice as a calibrator, but because it is resolved, one needs a model to start the calibration procedure correctly. FITS images of Cygnus A, with attached CLEAN component tables, are available online (other sources are also available, see Appendix A). These models are applicable to observations in all VLA configurations at 74 MHz[3] and 330 MHz[4]. (Of course, one should already have one or both of these models as they are recommended for bandpass calibration as well, §5.2.)

As one will be running `CALIB` on a spectral line data base, one first must run `POSSM` (looking at cross power spectra, not the BP tables) on a few baselines (but apply the BP table, so `DOBAND=1` and `BPVER=1` or whatever is the BP version that was the smoothest). Use a short baseline to look at a worst case scenario, and find 5–10 RFI-free channels, ones that are in between the "comb." These channels will be used to set `BCHAN` and `ECHAN` in `CALIB`. In the example below a clean spot was found between channels 20 and 25.

Should you encounter a model that looks like it was made from only one polarization, use `PUTHEAD` to make it look like a model made in Stokes I:

`GETNAME` the model, then

```
> KEYWORD 'CRVAL4'; KEYVALUE 1 0; PUTHEAD
```

This sets the Stokes parameter to be "I" for the model.

Important adverbs include

`BCHAN` and `ECHAN` These should be set to 5 or 10 channels that are free of RFI. If using Cyg A, usually just about any 5–10 channels in the center of the bandpass.

`UVRANGE` One may consider excluding the shorter baselines (though it is not done in the example below).

`IN2NAME`, `IN2CLASS`, and `IN2SEQ` These should be set to the model, usually Cyg A.

`CMETHOD='DFT'` It is vital that `CMETHOD` is set and not left at the default (`CMETHOD=' '`) or set to `CMETHOD='GRID'`. The CCs in the model may not have been (probably were not) made from *u*-*v* data gridded in the same manner that would make sense for one's database. With `CMETHOD='DFT'` one calculates the effect of each CC at the *u*-*v* coordinates for each visibility datum.

[3]http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/Cyg_A-4.model.FITS

[4]http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/Cyg_A-P.model.FITS

```
AIPS 1: CALIB:  Task to determine calibration for data.
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1:                                    Data selection (multisource):
AIPS 1: CALSOUR    'CYGA            '      Calibrator sources
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                    Calibrator qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>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: TIMERANG   *all 0                  Time range to use.
AIPS 1: BCHAN        20                    Lowest channel number 0=>all
AIPS 1: ECHAN        25                    Highest channel number
AIPS 1: ANTENNAS   *all 0                  Antennas to select. 0=all
AIPS 1: DOFIT      *all 0                  Subset of ANTENNAS list
AIPS 1:                                    for which solns are desired.
AIPS 1:                                    0 => solve for all antennas
AIPS 1:                                    implied by ANTENNAS list
AIPS 1:                                    [except of course, REFANT]
AIPS 1: SUBARRAY      0                    Subarray, 0=>all
AIPS 1: UVRANGE       0          0         Range of uv distance for full
AIPS 1:                                    weight
AIPS 1: WTUV          0                    Weight outside UVRANGE 0=0.
AIPS 1:
AIPS 1:                                    Cal. info for input:
AIPS 1: DOCALIB      -1                    If >0 calibrate data
AIPS 1: GAINUSE       0                    CL table to apply.
AIPS 1: FLAGVER       0                    Flag table version
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: SMOOTH     *all 0                  Smoothing function. See
AIPS 1:                                    HELP SMOOTH for details.
AIPS 1:
AIPS 1:                                    CLEAN map. See HELP.
AIPS 1: IN2NAME    '4-CYG-MODEL '             Cleaned map name (name)
AIPS 1: IN2CLASS   'ICLN20'                   Cleaned map name (class)
```

```
AIPS 1: IN2SEQ        1                           Cleaned map name (seq. #)
AIPS 1: IN2DISK       3                           Cleaned map disk unit #
AIPS 1: INVERS        2                        CC file version #.
AIPS 1: NCOMP      *all 0                      # comps to use for model.
AIPS 1:                                        1 value per field
AIPS 1: NMAPS         0                        No. Clean map files
AIPS 1: CMETHOD    'DFT '                      Modeling method:
AIPS 1:                                        'DFT','GRID','    '
AIPS 1: CMODEL     'COMP'                      Model type: 'COMP','IMAG'
AIPS 1: SMODEL     *all 0                      Source model, 1=flux,2=x,3=y
AIPS 1:                                        See HELP SMODEL for models.
AIPS 1:
AIPS 1:                                        Output uv data file.
AIPS 1: OUTNAME    '            '                 UV file name (name)
AIPS 1: OUTCLASS   '      '                       UV file name (class)
AIPS 1: OUTSEQ        0                           UV file name (seq. #)
AIPS 1: OUTDISK       3                           UV file disk drive #
AIPS 1:
AIPS 1:                                        Solution control adverbs:
AIPS 1: REFANT        7                        Reference antenna
AIPS 1: SOLINT        1                        Solution interval (min)
AIPS 1: APARM      *all 0                      General parameters
AIPS 1:                                           1=min. no. antennas
AIPS 1:                                           2 > 0 => data divided
AIPS 1:                                           3 > 0 => avg. RR,LL
AIPS 1:                                           5 > 0 => avg. IFs.
AIPS 1:                                           6=print level, 1=good,
AIPS 1:                                             2 closure, 3 SNR
AIPS 1:                                           7=SNR cutoff (0=>5)
AIPS 1:                                           8=max. ant. # (no AN)
AIPS 1:                                           9 > 0 => pass failed soln
AIPS 1:
AIPS 1:                                        Phase-amplitude Parameters:
AIPS 1: SOLTYPE    '    '                      Soln type,'  ','L1','GCON'
AIPS 1: SOLMODE    'A&P '                      Soln. mode: 'A&P','P','P!A',
AIPS 1:                                        'GCON'
AIPS 1: SOLCON        0                        Gain constraint factor.
AIPS 1: MINAMPER      0                        Amplitude closure error
AIPS 1:                                        regarded as excessive in %
AIPS 1: MINPHSER      0                        Phase closure error regarded
```

```
AIPS 1:                                          as excessive in degrees
AIPS 1: CPARM      *all 0                        Phase-amp. parameters
AIPS 1:                                             2 >0 => normalize gain
AIPS 1:                                             3 avg. amp. closure err
AIPS 1:                                             4 avg. ph. closure err
AIPS 1:                                             5 >0 => scalar average
AIPS 1:
AIPS 1: SNVER         0                          Output SN table, 0=>new table
AIPS 1: ANTWT      *all 0                        Ant. weights (0=>1.0)
AIPS 1: GAINERR    *all 0                        Std. Dev. of antenna gains.
```

CALIB should produce a large number of good solutions (= number of antennas × number of scans × number of polarizations). If not, try using a longer SOLINT, lower the signal-to-noise ratio (APARM(7)=3 sets the signal-to-noise ratio to 3), or use SOLTYPE = 'L1' which is more tolerant of errors. Usually Cygnus A is so strong that one obtains all good solutions the first time.

Examine the solutions using LISTR or SNPLT (for a more graphical experience). The gains should be smooth and solid. For LISTR set OPTYPE='GAIN', INEXT='SN', and INVERS to examine the solutions. Use FACTOR=0.1 to get more significant figures. Afterwards, set FACTOR=1 and DPARM=5 1 0 so that you can see the phases as well. The amplitudes should be rock solid on the shortest spacings (i.e., antennas closest to the REFANT) where the signal-to-noise ratio is highest (the source is least resolved) and the ionosphere is the least nuisance. The phases should also remain fairly constant, though slow drifts over many hours are not unusual.

For SNPLT set OPTYPE='PHAS', INEXT='SN', and INVERS to examine the solutions. Figure 5.2 shows a typical example from SNPLT (at least during times when the ionosphere is "calm") of the gain phase solutions produced.

5.4 CLCAL—Applying the Calibration

In this step you apply the calibration from Cygnus A, presumably contained in SN 1 table, to create a CL table that will be used calibrate all the other sources. (This will be CL 2, CL 1 is a default one with all gain amplitudes set to unity and all phases set to 0.)

The example below uses INTERPOL='SIMP', but RAP often prefers INTERPOL='BOX' with a 96 hr box car (INTPARM=96 96 0) so that that only a single phase and amplitude are transferred from Cygnus A. Otherwise you might impose a modest phase slope on our data. For "good" data it hardly seems to matter.

```
AIPS 1: CLCAL     Task to manage SN and CL calibration tables
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
```

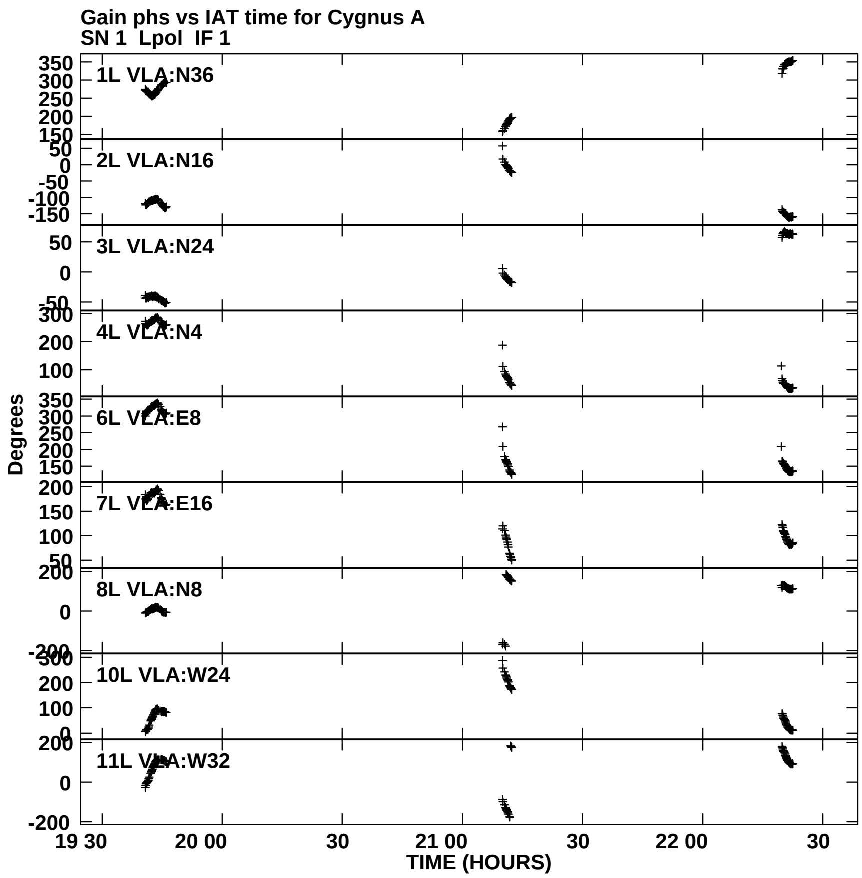

Figure 5.2: The gain phase solutions from Cygnus A as a function of time, plotted using `SNPLT`.

```
AIPS 1: SOURCES    *all ' '                    Source list to calibrate
AIPS 1: SOUCODE    '    '                      Source "Cal codes"
AIPS 1: CALSOUR    'CYGA            '          Cal sources for calibration
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                        Source qualifier -1=>all
AIPS 1: CALCODE    '    '                      Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                      Time range to calibrate
AIPS 1: SUBARRAY      0                        Subarray, 0=>all,
AIPS 1: ANTENNAS   *all 0                      Antennas selected, 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: OPCODE     '    '                      Operation 'MERG','CALI',
```

```
AIPS 1:                                     'SMOO','CALP'; ' ' => 'CALI'
AIPS 1: INTERPOL   'SIMP'                   Interpolation function,
AIPS 1:                                     choices are:
AIPS 1:                                     '2PT','SIMP','AMBG','CUBE',
AIPS 1:                                     'SELF','POLY','MWF','BOX'
AIPS 1:                                     see HELP for more details.
AIPS 1: INTPARM    *all 0                   Interpolation parameters
AIPS 1: CUTOFF        0                     Interpolation limit in
AIPS 1:                                     time (min); 0=> no limit.
AIPS 1: SMOTYPE    '    '                   Data to smooth
AIPS 1: SNVER         0                     Input SN table, 0=>all.
AIPS 1: GAINVER       0                     Input Cal table 0=>1
AIPS 1: GAINUSE       0                     Output CAL table 0=>2
AIPS 1: REFANT        7                     Reference antenna 0=>pick.
```

5.5 RFI and Your Data

The next step is to edit out RFI. There are two conflicting approaches to doing so.

(Prior to doing so, one may employ an additional round of calibration. This technique is particularly useful if one has included other calibration sources, such as Virgo A or 3C 123, in the observing run. In this case, one applies the calibration as in §5.4, then runs `CALIB` again solving for Cygnus A and all other calibrators. In this case, the gain phases for all sources should be slowly changing with time and, at least for Cygnus A, near zero.)

Below we describe using either `SPFLG` or `TVFLG` to edit the data. In general when doing so, flag on amplitude or amplitude difference, not the amplitude vector difference if the data are uncalibrated (because the phases are meaningless unless calibrated). Examine RR and LL seperately. Sometimes they look quite different, a clear indication of bad data. Also examine the Stokes V polarization (RR-LL), if it is not noise-like then it is also indicating interference.

Looking ahead to the imaging, some RFI can be coherent. This is indicated in the image by stripes. If this occurs, particularly from a spectral line data set, produce a continuum data set (averaging over all channels) and use that to isolate bad data.

5.5.1 `FLGIT`—Automagic Flagging

First, you should get a feel for what flagging levels to set in `FLGIT`. You could run `POSSM` a bunch of times (this time applying both BP and CL table, i.e., `DOCALIB=2` and `DOBAND=1`) but `SPFLG` lets you see it visually. However, depending upon the speed of one's machine, `SPFLG` can be *slow*. One way of making `SPFLG` run faster is to use `UVCOP` to extract a small subset of the original data set. (Make sure to include some short spacings to see the worst case RFI.) Then run `SPFLG`.

Important adverbs include

`DOBAND=1` **and** `DOCALIB=2` In order to apply the calibration determined above. `DOCALIB=2` is required in order to calibrate the weights.

`DOCAT=1` This has the effect of leaving a (potentially large) file in one's catalog containing the data gridded in such a way as to make them easy to visualize. In general, this file is useful only if one plans to restart the editing *with all other adverbs set to exactly the same values.*

```
AIPS 2: SPFLG:  edit line UV data using the TV display and cursor
AIPS 2: Adverbs     Values                 Comments
AIPS 2: ----------------------------------------------------------------
[...]
AIPS 2: DOCAT        -1                    Catalog work file ?
AIPS 2: IN2SEQ        0                    Sequence number of work file
AIPS 2: IN2DISK       0                    Disk number of work file
AIPS 2: DOHIST       -1                    Record flags in history file
AIPS 2: SOURCES     'G21             '     Source list
AIPS 2:             *rest ' '
AIPS 2: CALCODE     '    '                 Calibrator code '    '=>all
AIPS 2: TIMERANG    *all 0                 Time range to include
AIPS 2: STOKES      '    '                 Stokes type to display
AIPS 2: SELBAND      -1                    Bandwidth to select (kHz)
AIPS 2: SELFREQ      -1                    Frequency to select (MHz)
AIPS 2: FREQID        0                    Freq. ID to select.
AIPS 2: BIF           1                    Lowest IF number 0=1
AIPS 2: EIF           0                    Highest IF number
AIPS 2: BCHAN         1                    Lowest channel number 0=>1
AIPS 2: ECHAN         0                    Highest channel number
AIPS 2: ANTENNAS    *all 0                 Antennas to include
AIPS 2: BASELINE    *all 0                 Baselines with ANTENNAS
AIPS 2: UVRANGE       0          0         UV range in kilolambda
AIPS 2: SUBARRAY      0                    Subarray,   0 => 1
AIPS 2:                                    Cal. info for input:
AIPS 2: DOCALIB       2                   If >0 calibrate data
AIPS 2:                                    = 2 calibrate weights
AIPS 2: GAINUSE       2                    CAL (CL or SN) table to apply
AIPS 2: BLVER        -1                    BL table to apply.
AIPS 2: FLAGVER       1                    Flag table version 0 => 1
AIPS 2:                                       < 0 no flagging on input
AIPS 2:                                       Used w single-source too
AIPS 2: DOBAND        1                    If >0 apply bandpass cal.
```

```
AIPS 2:                                   Method used depends on value
AIPS 2:                                   of DOBAND (see HELP file).
AIPS 2: BPVER        1                    Bandpass table version
AIPS 2: SMOOTH     *all 0                 Smoothing function. See
AIPS 2:                                   HELP SMOOTH for details.
AIPS 2: DPARM      *all 0                 Control info:
AIPS 2:                                   (1) 0=amp, 1=phase, 2=rms,
AIPS 2:                                       3=rms/mean for initial
AIPS 2:                                       display, can choose any
AIPS 2:                                       interactively later
AIPS 2:                                   (2) >0 include total-power
AIPS 2:                                       <2 include cross-power
AIPS 2:                                          [see HELP file]
AIPS 2:                                   (3)
AIPS 2:                                   (4) >0 => divide by source
AIPS 2:                                       IPOL flux
AIPS 2:                                   (5) Expand time ranges by
AIPS 2:                                       DPARM(5) in sec
AIPS 2:                                   (6) y-axis interval: give the
AIPS 2:                                       sample time in seconds.
AIPS 2:                                       default = 10 seconds.
AIPS 2:                                   (7)
AIPS 2:                                   (8) initial relative baseline
AIPS 2:                                       # displayed; 0 => 1, can
AIPS 2:                                       choose interactively
AIPS 2:                                   (9,10) pixrange for initial
AIPS 2:                                       TV load - can reset later
AIPS 2:                                       interactively
```

One should see a "comb" of regularly spaced stripes which come and go at different levels on different baselines. (This is the case at 74 MHz; at 330 MHz the RFI will not be so regularly spaced in general.) These are the internally generated RFI. Using "Flag Pixel," read cursor values and get a feel for the values in RFI-free areas and in RFI channels. Check a fair number of baselines. In one 10 s pixel in `SPFLG`, the noise is usually 50–150 Jy and will depend on T_{sys} which in turn depends on where you pointed (with the Galactic center being worst case and the Galactic poles being much better.) Make sure to check for bad channels outside the "comb," "comb" features that spill into nearby channels, time variable RFI, etc.

`FLGIT` is sophisticated, and we're just now learning how to use all the power Eric has built into it. Key to using `FLGIT` is to run `SPFLG` on a relatively weak source, where the RFI is obvious. With `SPFLG` work one's way across the spectrum (and across several baselines) and define some RFI-free

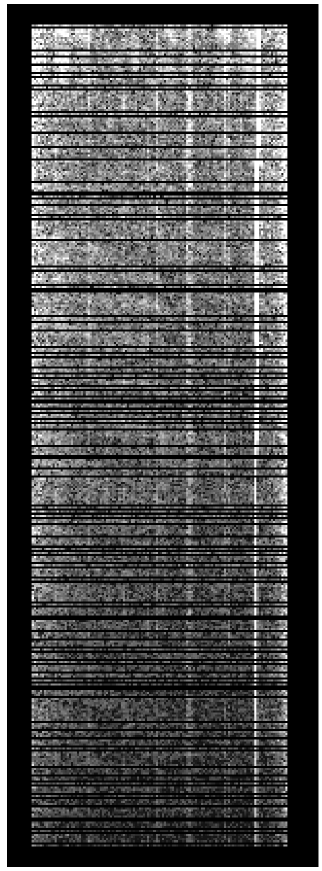

Figure 5.3: An example of the SPFLG display for a 74 MHz observing run. The vertical lines are the "comb" of internal RFI.

areas, which one will then use to define a clean mask within `FLGIT`. Again, this is best defined on a weaker source where the RFI is prominent.

Important adverbs include

`APARM(1)` This should be set to be higher than the flux of the brightest source. If Cygnus A is in one's run, and one is running `FLGIT` on everything at once, `APARM(1)=20000`. For most other sources (e.g., if one sets `SOURCES` or one is running `FLGIT` after having `SPLAT`'ed off data for a target source with more normal flux levels) it can be 2000–3000 or so. This clips the really bad stuff right off, so subsequent least-squares fits within `FLGIT` won't be totally thrown off.

`APARM(2)` After flagging the truly horrendous RFI, `FLGIT` then fits the spectrum across the bandpass, using the mask of RFI-free channels defined in `ICHANSEL` (which is obtained from `SPFLG`). `FLGIT` applies two tests. Weighted visibilities *inside* the clean mask of channels are flagged if they exceed `APARM(2)`.

`APARM(3)` After flagging the truly horrendous RFI, `FLGIT` then fits the spectrum across the bandpass, using the mask of RFI-free channels defined in `ICHANSEL` (which is obtained from `SPFLG`). `FLGIT` applies two tests. Unweighted visibilities *outside* the clean mask of channels are flagged if they exceed `APARM(3)`.

`APARM(4)` **and** `APARM(5)` These provide additional flagging after the tests specified by `APARM(2)` and `APARM(3)`. In comparison to `APARM(2)` and `APARM(3)`, which are tests in terms of a specified level (i.e., Jy), `APARM(4)` and `APARM(5)` are tests in terms of rms levels (i.e., "number of sigma"). `APARM(4)` tests the flux level while `APARM(5)` tests the ratio of the real to imaginary.

`APARM(6)` This adverb may also prove useful in excising RFI, though we do not have much experience with it yet. If `APARM(6)` is set, `FLGIT` also checks the circular polarization of the data. Various observers have noted that RFI can often be strongly circularly polarized. One could use `UVPLT`, `SPFLG`, or `TVFLG` with `STOKES='V'` to assess at what level to set `APARM(6)`.

For a recent observing run at 74 MHz in the B configuration, the final values used for `APARM` were `APARM=750,4,500,3,3,0`. Expect 15–30% of the data to be flagged. The amount will depend not only on the settings of `APARM`, but also upon the number of channels and bandwidth.

```
AIPS 1: FLGIT     Flags data based on the rms of uv-data spectra
AIPS 1: Adverbs     Values                  Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    '1800+726        '      Source list
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                    Source qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                  Time range to purge
AIPS 1: SELBAND      -1                    Bandwidth to select (kHz)
AIPS 1: SELFREQ      -1                    Frequency to select (MHz)
AIPS 1: FREQID        0                    Freq. ID to select.
AIPS 1: BCHAN         0                    First channel selected.
AIPS 1: ECHAN         0                    Last channel selected.
AIPS 1: BIF           0                    Lowest IF number 0=>all
AIPS 1: EIF           0                    Highest IF number 0=>all
AIPS 1: SUBARRAY      0                    Subarray, 0=>all
AIPS 1: DOCALIB       2                    If >0 calibrate data
AIPS 1:                                    = 2 calibrate weights
AIPS 1: GAINUSE       3                    CL (or SN) table to apply
```

```
AIPS 1: FLAGVER        1                   Flag table version
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: OPCODE       '    '                'MWFL' median window
AIPS 1:                                    else fit linear function
AIPS 1: APARM        750           4       Cutoff parameters: 1. Clip
AIPS 1:              500           3       2. Flag in BL regions
AIPS 1:                3      *rest 0      3. Flag in signal regions
AIPS 1:                                    4. Flag flux > A(4) * RMS
AIPS 1:                                    5. Flag Re/Im > A(5)*RMS
AIPS 1:                                    6. VPOL clip level
AIPS 1:                                    7. Width of median window
AIPS 1:                                    8. Number median pts averaged
AIPS 1:                                    9. Flag all samples with
AIPS 1:                                        |u| < APARM(9) lambda
AIPS 1: ICHANSEL       8          14       Select channels to fit: NOTE
AIPS 1:                1           1       this is start,end,increment
AIPS 1:               16          20       and IF for each region
AIPS 1:                1           1         24          30
AIPS 1:                1           1         33          38
AIPS 1:                1           1         41          46
AIPS 1:                1           1         49          54
AIPS 1:                1           1         61          63
AIPS 1:                1           1         65          71
AIPS 1:                1           1         74          77
AIPS 1:                1           1         82          87
AIPS 1:                1           1         90          93
AIPS 1:                1           1         95          96
AIPS 1:                1           1        101         104
AIPS 1:                1           1        106         109
AIPS 1:                1           1        111         112
AIPS 1:                1           1       *rest 0
AIPS 1: ORDER          1                   Order of fit line (0 -> DC)
```

FLGIT will produce a single source data base, if you specified a source. This may be the way you want to run if you have just one or two target sources. If you don't specify a source, it will spit out a multi source data base, which is perhaps the way you want to go if your run involved many target sources, such as for cycling snapshot observations.

As it may be necessary to run FLGIT numerous times to figure out what the appropriate values for APARM are, using the small UVCOP'ed data base will make FLGIT run much faster.

```
thuban> FLGIT1: Flagged     15620 full spectra
thuban> FLGIT1: Flagged   5387016 channels for input flux > clip level 7.500E+02
thuban> FLGIT1: Flagged         0 channels for VPOL flux > clip level  0.000E+00
thuban> FLGIT1: Flagged       118 channels for residual fit flux >     4.000E+00
thuban> FLGIT1: Flagged   2518677 channels for residual signal flux >  5.000E+02
thuban> FLGIT1: Flagged      1494 channels for residual flux >  3.00*RMS(f)
thuban> FLGIT1: Flagged     71371 channels for residual Re/Im >  3.00*RMS(R/I)
thuban> FLGIT1: Flagged   1982852 channels previously or in calibration
thuban> FLGIT1: 0.1948 of the channels are now flagged
```

At the end of FLGIT is a crucial number: The total number of channels flagged. We've found you want this number to be in the 15–30% range—higher and you have flagged out too much data, lower and you have not done anything.

From your SPFLG (and/or POSSM) runs, you should get a feel for how many channels at the edge of the bandpass need to be cut out. In the case below I had a total of 63 channels. I decided to use only channels 3–61, so I set BCHAN=3 and ECHAN=61 as well as BOX. Take a look at the FLGIT EXPLAIN file and experiment. There are median window filters, and other options that may be useful as well.

You might try carrying two data bases through, one with a severe FLGIT run that may cut out up to 30% of the data, and one that cuts out only 10%. Then the proof is in the maps, see what difference it makes. This is how we will build up intuition as to how best to run FLGIT.

5.5.2 Pattern Recognition—The Human Eye-Brain Combination

One of the emerging difficulties that has been found is that FLGIT may flag data that do not contain RFI and fail to flag data containing RFI. There are a number of reasons, though perhaps no hard-and-fast rules, for this. For instance, it has been observed that the noise level can vary as a function of distance from the origin of the u-v plane, the noise level could change if a bright source rises or passes through a sidelobe during the observing run, occasional episodes of broad-band RFI, etc.

There may be other ways to attack this problem, but the human eye-brain combination is the best known pattern recognition "computer." Unfortunately, this can be a bit tedious as it involves looking at *all* baselines (for both polarizations). This technique uses SPFLG, possibly in combination with UVPLT, UVFND, and UVFLG.

One may want to start by looking through all of the data first, using SPFLG, to remove the clearly obvious miscreant data. By averaging the data (§5.6) to a single channel, one can identify times and baselines (UVPLT and UVFND). One this involves looping, plotting the visibilities, restricting the u-v range to where possible bad data exist, using UVFND to identify which baseline(s) at what time(s) is bad, and flagging it.

Do not clip interactively! i.e., "CLIP INTERACTIVE." Flag the data by channel, time, or area in order to flag the data completely. This is true of both SPFLG and TVFLG. Cutting off the brightest RFI may leave low-level RFI underneath. Often it is helpful to repeat the mantra attributed to B. Clark: "Bad data are worse than no data."[5]

We are interested in any ideas people might have of ways to get a computer to do this! Something like 90% of this step should be automated, as the bad data have such an obvious signature.

5.6 Spectral Averaging

When one is satisfied with a FLGIT run, the spectral line data base can be spectrally averaged. Many tasks can do this: AVSPC, SPLIT, and SPLAT (for multisource data bases). In general, if FLGIT produced a single-source data base use AVSPC while if FLGIT produced a multi-source data base use SPLAT or SPLIT.

The amount of frequency averaging required is a science- and computational-resource–driven decision. In general, do as little averaging as required. The more averaging done, the more bandwidth smearing will affect sources in the outer parts of the primary beam. At low frequencies there are always strong sources in the outer parts of the primary beam. Of course, the more averaging that is done, the faster later processing steps can be accomplished. If you are looking at a bright source in the middle of your map, you can probably tolerate more bandwidth smearing. If you are trying to see as many point sources as possible in your full field of view, then bandwidth smearing should be minimized.

In the example below the multisource data base has two sources in it; these were designated by SOURCES when FLGIT was run. These two sources were near each other in the sky so that the T_{sys} was similar and thus the same APARM settings could be used for both sources. In this example, SPLAT starts with a spectral-line, multi-source data base and create a continuum data base. In this case bandwidth smearing was not a concern.

Other important adverbs include

APARM(1) This adverb specifies how to perform the spectral averaging. If APARM(1)=1, then the frequency channels selected by ICHANSEL, *in each IF* will be averaged together. The result will be a multi-IF, single-channel file(s). If APARM(1)=2, then all IFs will be averaged also. The result will be a single-IF, single-channel file(s). If APARM(1)=3, then every CHANNEL channels will be averaged together. The result will be a multi-IF, multi-channel file(s).

ICHANSEL **and** CHANNEL These adverbs control, in conjunction with APARM(1), which frequency channels are to be averaged together.

[5]Historians of astronomy may recall that the human eye-brain combination is extremely capable of finding patterns, particularly linear patterns, even in data where no patterns exist. This capability is thought to be the explanation for why Lowell (and others) saw canals on Mars where none existed. If this worries the reader, repeat the mantra.

SMOOTH If smoothing was used in forming the bandpass (§5.2), it should also be applied here, with the same value.

```
AIPS 1: SPLAT     Split/assemble the sources in single/multi source file
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    *all '           '      Source list
AIPS 1:
AIPS 1: QUAL         -1                    Source qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                  Time range to copy
AIPS 1: STOKES     '    '                  Stokes type to pass.
AIPS 1:                                    Look HELP.
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: BIF           1                    Lowest IF number 0=>all
AIPS 1: EIF           0                    Highest IF number 0=>all
AIPS 1: BCHAN         4                    Lowest channel number 0=>all
AIPS 1: ECHAN         27                   Highest channel number
AIPS 1: SUBARRAY      0                    Subarray, 0=>all
AIPS 1: DOCALIB       2                    If >0 calibrate data
AIPS 1: GAINUSE       2                    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:                                    0 => highest numbered table
AIPS 1:                                    <0 => no flagging
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: SMOOTH     *all 0                  Smoothing function. See
AIPS 1:                                    HELP SMOOTH for details.
AIPS 1: OUTNAME    '            '          Output UV file name (name)
AIPS 1: OUTCLASS   '      '                Output UV file name (class)
AIPS 1: OUTSEQ        0                    Output UV file name (seq. #)
AIPS 1: OUTDISK       2                    Output UV file disk unit #.
AIPS 1: DOUVCOMP     -1                    1 (T) => compressed data
```

```
AIPS 1: APARM         1        *rest 0     Control information:
AIPS 1:                                      1 = 1 => avg. freq. in IF
AIPS 1:                                        = 2 => avg IF's also
AIPS 1:                                        = 3 => average each
AIPS 1:                                          N channels. N is given
AIPS 1:                                          by CHANNEL
AIPS 1:                                      2 = Input avg. time (sec)
AIPS 1:                                      3 > 0 => Drop subarrays
AIPS 1:                                      4 > 0 => calibrate weights
AIPS 1:                                      5 = 0 pass only xc data
AIPS 1:                                        = 1 pass xc and ac data
AIPS 1:                                        = 2 pass only ac data
AIPS 1:                                      6 > 0 add full source name
AIPS 1:                                            to header
AIPS 1:                                      7 = 0 assemble all selected
AIPS 1:                                            sources in one
AIPS 1:                                            multiple source file.
AIPS 1:                                        > 0 split for single
AIPS 1:                                            source files.
AIPS 1: CHANSEL    *all 0                  Array of channel start, stop,
AIPS 1:                                    and increment numbers to give
AIPS 1:                                    channels to be used when
AIPS 1:                                    averaging in frequency.
AIPS 1:                                    These are absolute channel
AIPS 1:                                    numbers, i.e. not relative
AIPS 1:                                    to BCHAN.
AIPS 1: CHANNEL       0                    Number of chans to average
AIPS 1:                                    together; if APARM(1) = 3
AIPS 1: SOLINT        0                    Time of averaging in sec.
AIPS 1:                                    0 => no averaging
```

Here's an example of SPLAT that was run on a spectral-line data base which was originally 128 channels. The user has decided to use only channels 2 to 121, or 120 channels. He has set APARM(1)=3 and CHANNEL=12 which will result in a spectral line data base of 10 "smoothed" channels. So he has reduced his bandwidth smearing by a factor of 10 over what would have happened if it had all be folded into one continuum data set. Of course, the resulting data set is still fairly formidable, and IMAGR and CALIB will run slow. Let science drive this decision.

```
AIPS 2: SPLAT     Split/assemble the sources in single/multi source file
AIPS 2: Adverbs         Values              Comments
```

```
AIPS 2: ---------------------------------------------------------------
[...]
AIPS 2: SOURCES    *all ' '                  Source list
AIPS 2: QUAL         -1                      Source qualifier -1=>all
AIPS 2: CALCODE    '    '                    Calibrator code '    '=>all
AIPS 2: TIMERANG   *all 0                    Time range to copy
AIPS 2: STOKES     '    '                    Stokes type to pass.
AIPS 2:                                      Look HELP.
AIPS 2: SELBAND      -1                      Bandwidth to select (kHz)
AIPS 2: SELFREQ      -1                      Frequency to select (MHz)
AIPS 2: FREQID       -1                      Freq. ID to select.
AIPS 2: BIF           0                      Lowest IF number 0=>all
AIPS 2: EIF           0                      Highest IF number 0=>all
AIPS 2: BCHAN         2                      Lowest channel number 0=>all
AIPS 2: ECHAN       121                      Highest channel number
AIPS 2: SUBARRAY      0                      Subarray, 0=>all
AIPS 2: DOCALIB       0                      If >0 calibrate data
AIPS 2: GAINUSE       0                      CL (or SN) table to apply
AIPS 2: DOPOL        -1                      If >0 correct polarization.
AIPS 2: BLVER        -1                      BL table to apply.
AIPS 2: FLAGVER       0                      Flag table version.
AIPS 2:                                      0 => highest numbered table
AIPS 2:                                      <0 => no flagging
AIPS 2: DOBAND        0                      If >0 apply bandpass cal.
AIPS 2:                                      Method used depends on value
AIPS 2:                                      of DOBAND (see HELP file).
AIPS 2: BPVER         1                      Bandpass table version
AIPS 2: SMOOTH     *all 0                    Smoothing function. See
AIPS 2:                                      HELP SMOOTH for details.
AIPS 2: OUTNAME    '            '            Output UV file name (name)
AIPS 2: OUTCLASS   '      '                  Output UV file name (class)
AIPS 2: OUTSEQ        0                      Output UV file name (seq. #)
AIPS 2: OUTDISK       5                      Output UV file disk unit #.
AIPS 2: DOUVCOMP      1                      1 (T) => compressed data
AIPS 2: APARM         3         *rest 0      Control information:
AIPS 2:                                        1 = 1 => avg. freq. in IF
AIPS 2:                                          = 2 => avg IF's also
AIPS 2:                                          = 3 => average each
AIPS 2:                                            N channels. N is given
AIPS 2:                                            by CHANNEL
```

```
AIPS 2:                                           2 = Input avg. time (sec)
AIPS 2:                                           3 > 0 => Drop subarrays
AIPS 2:                                           4 > 0 => calibrate weights
AIPS 2:                                           5 = 0 pass only xc data
AIPS 2:                                             = 1 pass xc and ac data
AIPS 2:                                             = 2 pass only ac data
AIPS 2:                                           6 > 0 add full source name
AIPS 2:                                                 to header
AIPS 2:                                           7 = 0 assemble all selected
AIPS 2:                                                 sources in one
AIPS 2:                                                 multiple source file.
AIPS 2:                                             > 0 split for single
AIPS 2:                                                 source files.
AIPS 2: CHANSEL    *all 0                       Array of channel start, stop,
AIPS 2:                                         and increment numbers to give
AIPS 2:                                         channels to be used when
AIPS 2:                                         averaging in frequency.
AIPS 2:                                         These are absolute channel
AIPS 2:                                         numbers, i.e. not relative
AIPS 2:                                         to BCHAN.
AIPS 2: CHANNEL      12                         Number of chans to average
AIPS 2:                                         together; if APARM(1) = 3
AIPS 2: SOLINT        0                         Time of averaging in sec.
AIPS 2:                                         0 => no averaging
```

The essential inputs for `AVSPC` are similar as to `SPLAT`, with `ICHANSEL` and `CHANNEL` controlling which channels are to be averaged together. Presumably the only option of `AVSPC` that will useful is `AVOPTION='SUBS'`, which is equivalent to `APARM(1)=3` within `SPLAT`.

5.7 A Final Edit

As a final step, run `TVFLG` on the data before imaging. This step is required because `FLGIT` may have trouble producing a good fit to the bandpass in spots of particularly bad RFI and thereby fail to flag some RFI. Set `DOCALIB=-1` and `DOBAND=-1` because the data have been calibrated already (with `FLGIT`).

Within `TVFLG` a fruitful way to display the data is with “AMP V DIFF” or “Amplitude Vector Differencing.” If there are apparent “hot spots” in the data, use “CLIP INTERACTIVE” to remove them until the remaining data look “random.” Make sure to edit the RR and LL polarizations separately and to switch the Stokes flags after switching the polarization displayed. Also, if the data are loaded and smoothed to 40 s say, use “SETWIN” and “LOAD” to cut it into 4 pieces, setting "SMOOTH TIME" to 10 s so all of the data can be seen. Unfortunately, this does mean having to do the editing in 4 steps (8 steps actually). The first quarter of the data are examined at 10 s smoothing (i.e., no smoothing), and RR then LL are flagged. Then the second quarter are examined, etc.

An alternate approach is simply to load the data at 10 s resolution (set `DPARM(6)=10`). The data are then loaded on the TV so that only the middle section of it can be seen; the top and bottom sections roll off the screen. However, even though all of the data cannot be seen, the "CLIP INTERACTIVE" mode does (or should) clip all of the data.

One probably wants to "SORT BY LENGTH" in the display. This reorganizes the display so that the shortest baselines are on the left and the longest baselines are on the right. Often the remaining RFI will appear at the shortest baselines.

In many cases, one will be examining a multi-channel data base. `TVFLG`'s "CLIP BY FORM" can be extremely useful because it applies the same flagging criterion from one channel to all other channels. In order to use it, load only one polarization and flag one channel, say, using "AMP V DIFF" and "CLIP INTERACTIVE." Then, specify "CLIP BY FORM"; one will have to answer questions about which channels to apply the flagging criterion. If everything is working properly, `TVFLG` will then (before one's eyes!) load each specified channel, apply the flagging criterion, show the result, and loop.

As a last step, reverse the transfer function and look for anomalously low points near zero amplitude. With the transfer function reversed, these will show up as "hot spots." The presence of any such points is apparently due to a software error in the on-line system, and they can cause havoc in the self-calibration. These points seem to occur especially at 330 MHz.

When `TVFLG`'ing a single source data base, you should specify `FLAGVER=1`, otherwise the data are flagged directly (instead of a FG table being produced). Thus mistakes cannot be easily corrected.

When done load the whole thing back on the TV again (using the default smoothing) and do a general "AMP V DIFF" clip again.

You should play with `TVFLG`, it has many ways to clip data, everyone needs to develop their own intuition.

A plot of the data using `UVPLT` (amplitude vs. baseline) should show the data being less affected by RFI after having run `TVFLG`. A "before" and "after" plot of the data at this step, for one's records, is useful to assure oneself that something useful was in fact done to the data.

5.8 Yet More Editing Possibilities

Despite one's best efforts, low-level RFI may remain in the data. Sometimes this will not be manifest until after the imaging. This section presents a "catch-all" collection of additional strategies to try.

5.8.1 Even More Spectral Averaging

In previous sections, we have suggested averaging the data spectrally, including the use of `TVFLG`. Some low-level RFI may be visible only after averaging down to single channel. Thus, one can use `SPLIT` or `AVSPC` to average all of the spectral channels together. Then `TVFLG` or a combination of `UVPLT` and `UVFND` can be used to identify bad antennas, baselines, and/or timeranges.

5.8.2 `UVPLT`

M. Bietenholz suggests that `UVPLT` combined with the TV display can be used to isolate RFI.

`BPARM(3)=1` Specify that a fixed scale be used so that the data can be compared on the same scale.

`BPARM(4)`—`BPARM(7)` These specify the abscissa and ordinate. For the usual display, correlated flux density as a function of projected baseline length, `BPARM(4)` and `BPARM(5)` should be specified in kilowavelengths while `BPARM(6)` and `BPARM(7)` should be in Janskys.

`DOTV=1` **and** `GRCHAN` Specify these to use the TV display. One can then display four different spectral channels or baselines or . . . via `GRCHAN`.

5.8.3 `KILRF`—u-v–based Editing (*Contributed by M. Bietenholz*)

`KILRF` is an program that can be run from within $\mathcal{AIPS}$ and is designed to edit data automatically, mostly for consistency in the u-v plane. It edits calibrated data! It was designed to try and edit out data from broad-band RFI which often cannot be edited out by `SPFLG`. The underlying assumption it uses is that the true correlated flux is a relatively smooth function of u and v. This is true for small, simple distributions of flux in the image plane, and becomes less so as the image flux becomes more extended and complex. It is not true for RFI.

`KILRF` edits out any visibilities that are discrepant with the other visibilities nearby in the u-v plane. It does this by first binning all the visibilities in u and v (with a selectable bin size) and then examining the discrepancy of each visibility with the average value in the relevant u-v bin. This procedure only works if the u-v bins are large enough to have several visibilities, yet not so large that the source's structure causes significant changes in the visibility within the bin. This is more likely to be true near the center of the u-v plane where coverage is denser.

Please contact M. Bietenholz to obtain `KILRF`.

Chapter 6

"Traditional" Imaging Strategy

6.1 SETFC and CHKFC—Determining the Field of View

One of the key issues in wide-field imaging is setting the number and dimensions of the regions on the sky to be imaged. One usually does not attempt to image the entire primary beam in one large $N \times N$ pixel image, rather the sky is tessellated into smaller subregions, which may later be re-assembled into a single, wide-field image. The number of facets will be dictated by the *spatial* dynamic range of one's observations, i.e., the ratio of the primary beam diameter or the isoplanatic patch size to the CELLSIZE one is using. For C-configuration observations at 74 MHz, one probably needs no more than approximately 50 facets. For A-configuration observations at 330 MHz, more than 500 facets may be required.

Another crucial aspect of low-frequency imaging is the need to image sources far from the phase center. At low frequencies, sources 30° or more away from the phase center can be bright enough to cause an unacceptably high level of sidelobe confusion, if these sources are not imaged and CLEANed (particularly troubling can be Cygnus A, Cas A, and Virgo A.) These degradations manifest themselves as ripples and stripes. One way to combat this is to use a portion of one's facets to map "outlier" sources, those bright sources whose sidelobes will degrade the image of the target source. This procedure takes advantage of the fact that the sky is mainly dark to do "targeted faceting." In this procedure one maps only the target source at the full A-configuration resolution, and the rest of the boxes can be spread around just on the bright sources.

There are two issues to address in making this decision about the number, dimension, and location of the subregions. First, is an image of the entire primary beam required or will selected sub-regions of the primary beam suffice? If, for example, one is studying a bright source near the phase center of the field, it may be sufficient just to image other bright sources in the primary beam. Alternately, if one is searching for a new source(s), then it may be necessary to make an image of the entire primary beam. (An image of the entire primary beam also often produces a more valuable educational/public outreach image.) Second, where are the bright sources *outside* the primary beam?

Much of the decision-making has been automated by a new task, `SETFC`. This task has three modes of operation. It can produce a "fly's eye" set of overlapping contiguous *facets* for the primary beam, it can place outlying facets on "nearby" NVSS sources, or do both.

In order to find bright sources, `SETFC` relies on an external catalog. As such, external text files containing subsets of the NVSS and WENSS catalog should accompany `SETFC`. The default location for these catalogs is specified by the Unix environment variable `AIPSTARS`. Check with one's local AIPS manager if the catalogs cannot be located. In general, if one is north of declination $+30°$, one should use the WENSS; otherwise make use of the NVSS.

Important adverbs include

`CELLSIZE` and `IMSIZE` These specify the pixel spacing and size of the facets, respectively. An important default is that if both of these are set to 0, then `SETFC` will determine appropriate values based on the longest baseline in the visibility data.

`FLUX` This adverb sets the flux that an NVSS (or WENSS) source has to have in order to be placed in an outlier field, *taking into account the primary beam.* This can reduce the number of outliers tremendously.

`BPARM(1)` This specifies the portion to be covered by the "fly's eye" and would commonly be the primary beam.

`BPARM(2)` This specifies the amount of overlap between facets. In order to make sure that one does not miss sources in between facets, this value should be larger than 0. Near the equatorial north pole, this value may have to become much larger (say, 20 or 25) due to the way that *AIPS* treats the spherical geometry of the sky.

`BPARM(3)` This adverb is a scaling factor for the flux densities of the sources in the external catalog. In general this value would be the ratio of the observation frequency and the catalog reference frequency, with the appropriate spectral index.

`BPARM(4)` If `BPARM(4)` > `BPARM(1)`, then an additional region outside the region specified by `BPARM(1)` is searched for bright sources.

`BPARM(5)` The flux density limit (Jy) in the external catalog search.

```
AIPS 2: SETFC:  Task to make a BOXFILE for input to IMAGR
AIPS 2: Adverbs     Values                 Comments
AIPS 2: ----------------------------------------------------------------
[...]
AIPS 2: SOURCES    *all ' '                Source selected
AIPS 2: BCOUNT        1                    First field number to use
```

```
AIPS 2: BOXFILE    'FITS:G11-4AB-BOX3                                  '
AIPS 2:                                   disk file to write to (the
AIPS 2:                                   input BOXFILE for IMAGR)
AIPS 2: CELLSIZE      7           7       (X,Y) size of grid in asec
AIPS 2: IMSIZE      512         512       field size
AIPS 2: SHIFT         0           0       Position shift (RA,Dec) asec
AIPS 2:                                   for all fields
AIPS 2: FLUX          1                   Minimum component flux =
AIPS 2:                                   (source * beam)
AIPS 2: BPARM         6           5       (1) Inner region radius (deg)
AIPS 2:               0          20       (2) Field overlap (pixels)
AIPS 2:               2         256       (3) Factor to scale NVSS
AIPS 2:            *rest 0                    fluxes, 0 -> 1
AIPS 2:                                   (4) Radius NVSS search (deg)
AIPS 2:                                   (5) Flux limit in NVSS (Jy)
AIPS 2:                                   (6) IMSIZE for NVSS fields
AIPS 2:                                   (7) IMSIZE for Sun fields
AIPS 2:                                   (8) Write Clean boxes for
AIPS 2:                                       NVSS fields
AIPS 2: PBPARM     *all 0                 Beam parameters:
AIPS 2:                                   (1) Cutoff; (2) Use (3)-(7)
AIPS 2:                                   (3)-(7) Beam shape parms
AIPS 2: INFILE     '                                                   '
AIPS 2:                                   NVSS input file name
AIPS 2:                                   ' ' => AIPS provided.
```

One may also want to use `CHKFC` to verify that the facets are where you think they are and that you have covered a sufficiently large portion of the sky.

6.2 `FACES` and `CALIB`—Improving the Phase Calibration

At this point, the phases are presumably only poorly calibrated. They may be so poorly calibrated that an image will show few sources, too few sources to drive any hybrid imaging loops. If one had an initial model of the sky, one could use it to improve the phase calibration. Remember that, in contrast to the case in VLBI or at higher frequencies, the field of view is so large at low frequencies that one requires a model not only of the source at or near the phase center, but of all sources within a few or several degrees.

One does not need excessive accuracy for the sky model. Numerous examples in the literature attest to the robustness of self-calibration; for instance, one can produce an excellent image of a double source even if one starts with a point-source model.

Fortunately, reasonable sky models do exist in the form of the NVSS and WENSS. `FACES` searches these catalogs to find sources within a specified region of the sky. It then constructs model images, with pseudo-CLEAN component files attached.

The important adverbs for `FACES` are similar to those of `SETFC` (§6.1).

With the model images forming the sky model, one then uses `CALIB` on one's single-source data base to improve the phases. Important adverbs are

`NMAPS` This specifies the number of images forming the sky model. It should be set to whatever number of images `FACES` produced.

`CMETHOD='DFT'` It is vital that `CMETHOD` is set and not left at the default (`CMETHOD=' '`) or set to `CMETHOD='GRID'`. The sources found in the external catalog search may not (probably do not) lie exactly on pixels in the images. If one attempts to grid these images, phase errors will be introduced. At best, the result will be considerably less success in improving the phases than one would have had otherwise.

`SOLINT=3` Value of 1–3 min. are reasonable, depending upon the amount of flux in the model.

`APARM(1)=4` The default number of antennas to be required for a solution is 6. As `CALIB` is being run for phase-only calibration, a lower number of required antennas can be used. Setting `APARM(1)` to a value below the default can be useful in reducing the number of failed solutions or the amount of data discarded because of an insufficient number of antennas.

`APARM(7)=3` The default signal-to-noise ratio cutoff is 5. Choosing lower values is often acceptable.

`SOLTYPE='L1'` The default value of `SOLTYPE` is a least-squares fit. This method of fitting is well-known to be sensitive to outlier points. The "L1" mode, which uses an absolute value, is often less sensitive to outliers, so will produce more acceptable solutions.

`SOLMODE='P'` One needs to specify that phase-only calibration is to be performed.

```
AIPS 3: CALIB:  Task to determine calibration for data.
AIPS 3: Adverbs     Values                Comments
AIPS 3: ----------------------------------------------------------------
[...]
AIPS 3:                                   Data selection (multisource):
AIPS 3: CALSOUR    *all ' '               Calibrator sources
AIPS 3: QUAL         -1                   Calibrator qualifier -1=>all
AIPS 3: CALCODE    '    '                 Calibrator code '    '=>all
AIPS 3: SELBAND      -1                   Bandwidth to select (kHz)
AIPS 3: SELFREQ      -1                   Frequency to select (MHz)
AIPS 3: FREQID        1                   Freq. ID to select.
```

```
AIPS 3: TIMERANG   *all 0                       Time range to use.
AIPS 3: BCHAN        1                          Lowest channel number 0=>all
AIPS 3: ECHAN        0                          Highest channel number
AIPS 3: ANTENNAS   *all 0                       Antennas to select. 0=all
AIPS 3: DOFIT      *all 0                       Subset of ANTENNAS list for
AIPS 3:                                         which solns are desired.  0
AIPS 3:                                         => all in ANTENNAS, < 0 all
AIPS 3:                                         but those in DOFIT
AIPS 3: ANTUSE     *all 0                       Mean gain is calculated
AIPS 3:                                         (CPARM(2)>0) using only the
AIPS 3:                                         listed antennas. See explain.
AIPS 3: SUBARRAY     0                          Subarray, 0=>all
AIPS 3: UVRANGE      0            0             Range of uv distance for full
AIPS 3:                                         weight
AIPS 3: WTUV         0                          Weight outside UVRANGE 0=0.
AIPS 3:
AIPS 3:                                         Cal. info for input:
AIPS 3: DOCALIB     -1                          If >0 calibrate data
AIPS 3:                                         = 2 calibrate weights
AIPS 3: GAINUSE      2                          CL table to apply.
AIPS 3: FLAGVER      1                          Flag table version
AIPS 3: DOBAND      -1                          If >0 apply bandpass cal.
AIPS 3:                                         Method used depends on value
AIPS 3:                                         of DOBAND (see HELP file).
AIPS 3: BPVER        1                          Bandpass table version
AIPS 3: SMOOTH     *all 0                       Smoothing function. See
AIPS 3:                                         HELP SMOOTH for details.
AIPS 3:
AIPS 3:                                         CLEAN map. See HELP.
AIPS 3: IN2NAME    '3C 48       '                  Cleaned map name (name)
AIPS 3: IN2CLASS   'IM0001'                        Cleaned map name (class)
AIPS 3: IN2SEQ       1                             Cleaned map name (seq. #)
AIPS 3: IN2DISK      3                             Cleaned map disk unit #
AIPS 3: INVERS       1                          CC file version #.
AIPS 3: NCOMP      *all 0                       # comps to use for model.
AIPS 3:                                         1 value per field
AIPS 3: FLUX         0                          Lowest CC component used.
AIPS 3: NMAPS       36                          No. Clean map files
AIPS 3: CMETHOD    'DFT '                       Modeling method:
AIPS 3:                                         'DFT','GRID','    '
```

```
AIPS 3: CMODEL     'COMP'                      Model type: 'COMP','IMAG'
AIPS 3: SMODEL     *all 0                      Source model, 1=flux,2=x,3=y
AIPS 3:                                        See HELP SMODEL for models.
AIPS 3:
AIPS 3:                                        Output uv data file.
AIPS 3: OUTNAME    '            '                 UV file name (name)
AIPS 3: OUTCLASS   '      '                       UV file name (class)
AIPS 3: OUTSEQ        0                           UV file name (seq. #)
AIPS 3: OUTDISK       3                           UV file disk drive #
AIPS 3:
AIPS 3:                                        Solution control adverbs:
AIPS 3: REFANT       27                        Reference antenna
AIPS 3: SOLINT        3                        Solution interval (min)
AIPS 3: APARM         4           0            General parameters
AIPS 3:               0           0               1=min. no. antennas
AIPS 3:               0           0               2 > 0 => data divided
AIPS 3:               3        *rest 0            3 > 0 => avg. RR,LL
AIPS 3:                                           5 > 0 => avg. IFs.
AIPS 3:                                           6=print level, 1=good,
AIPS 3:                                             2 closure, 3 SNR
AIPS 3:                                           7=SNR cutoff (0=>5)
AIPS 3:                                           8=max. ant. # (no AN)
AIPS 3:                                           9 > 0 => pass failed soln
AIPS 3:                                        Phase-amplitude Parameters:
AIPS 3: SOLTYPE    'L1  '                      Soln type,'  ','L1','GCON'
AIPS 3: SOLMODE    'P   '                      Soln. mode: 'A&P','P','P!A',
AIPS 3:                                        'GCON'
AIPS 3: SOLCON        0                        Gain constraint factor.
AIPS 3: MINAMPER      0                        Amplitude closure error
AIPS 3:                                        regarded as excessive in %
AIPS 3: MINPHSER      0                        Phase closure error regarded
AIPS 3:                                        as excessive in degrees
AIPS 3: CPARM         0           1            Phase-amp. parameters
AIPS 3:            *rest 0                        1 = Min el for gain
AIPS 3:                                                normalization (deg)
AIPS 3:                                           2 >0 => normalize gain
AIPS 3:                                           3 avg. amp. closure err
AIPS 3:                                           4 avg. ph. closure err
AIPS 3:                                           5 >0 => scalar average
AIPS 3:
```

```
AIPS 3: SNVER         0                     Output SN table, 0=>new table
AIPS 3: ANTWT      *all 0                   Ant. weights (0=>1.0)
```

One can examine the solutions using `LISTR` or `SNPLT` (for a more graphical experience). The phases should be smoothly varying. For `LISTR` set `OPTYPE='GAIN'`, `INEXT='SN'`, `INVERS`, and `DPARM=5 1 0` to examine the phase solutions. For `SNPLT` set `OPTYPE='PHAS'`, `INEXT='SN'`, and `INVERS` to examine the solutions.

6.3 `IMAGR`—Making an Image

Below are some examples of `IMAGR` runs. One may also want to refer to §8 if one has difficulty with the initial imaging.

For technical reasons, `IMAGR` handles different numbers of subregions or facets differently. For 64 or fewer facets, one can use `RASHIFT` and `DECSHIFT` within AIPS. If one needs more than 64 facets, one has to specify them within an external text file. This external text file is given in `BOXFILE`, and its format is described in the `HELP` file for `IMAGR`. A maximum of 512 facets can be specified in this external file. (If one so desires, the external file can be used to set the number and location of the facets even if one is using fewer than 64 facets.)

Important adverbs to set or consider include

`MINPATCH=121` The default is too low.

`UVBOX` This adverb controls the size of the region in the *u*-*v* plane that is averaged to the *u*-*v* grid points. Increasing `UVBOX` increases the size of the region over which *u*-*v* data are averaged onto the grid. This has two effects. The first is to produce "superresolution." The second is that, if there is any RFI remaining in the data, it is "diluted" by virtue of the increased averaging. The recommended value if one is worried about any remaining, low-level RFI is `UVBOX=1`.

`OBOXFILE=BOXFILE` When run interactively, `IMAGR` will write the boxes into the `BOXFILE` for subsequent runs.

`IMAGRPRM(20)=1.05` When `IMAGR` tries to find another field to CLEAN, it may wander aimlessly before finding a facet whose levels match the strict criteria required to CLEAN it. Increasing `IMAGRPRM(20)` relaxes that test and speeds things up.

`MAXPIXEL` The adverb `MAXPIXEL` limits the number of map points that are loaded to AP memory during CLEANing cycles. With the dramatic increase in available memory, the default value (20 000!) is often not appropriate for low-frequency imaging. `IMAGR` now can put an entire subfield into memory, and, because of some bad tuning, it will use up thousands of components CLEANing out sidelobes and noise, rather than go to the next subfield. Recommended values are 100–200. Such small values can *really* helps the quality of the imaging, as well as the speed. It can also make self-calibrations much better, as the CC components are now nearly all on real objects, rather than noise peaks spread all over the place. However, for runs with many facets (> 200), setting it low can be incredibly slow. One might also experiment with setting it to 40 000.

`DOTV` One probably wants to start with the TV display enabled in order to verify the CLEAN boxes. The TV display can be turned off interactively from the menu. It is worth watching it work—often one will see `IMAGR` CLEANing empty fields. Use "FORCE A FIELD" to send it to a field with known flux. One can also use "TVBOX" to set *no* boxes in a particular field, though, in doing so, it is necessary to tell `IMAGR` to "REMAKE IMAGES" later, in order to see if weaker sources have appeared. If so, one would need to set boxes again.

```
AIPS 1: IMAGR: Wide field imaging/Clean task
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 2: SOURCES    *all ' '                Source name
AIPS 2: QUAL         -1                    Calibrator qualifier -1=>all
AIPS 2: CALCODE    '    '                  Calibrator code '    '=>all
AIPS 2: TIMERANG   *all 0                  Time range to use
AIPS 2: SELBAND      -1                    Bandwidth to select (kHz)
AIPS 2: SELFREQ      -1
AIPS 2: FREQID       -1                    Freq. ID to select.
AIPS 2: SUBARRAY      0                    Sub-array, 0=>all
AIPS 2: DOCALIB      -1                    If >0 calibrate data
AIPS 2:                                    = 2 calibrate weights
AIPS 2: GAINUSE       0                    CL (or SN) table to apply
AIPS 2: DOPOL        -1                    If >0.5 correct polarization.
AIPS 2: BLVER        -1                    BL table to apply.
AIPS 2: FLAGVER       1                    Flag table version
AIPS 2: DOBAND       -1                    If >0.5 apply bandpass cal.
AIPS 2:                                    Method used depends on value
AIPS 2:                                    of DOBAND (see HELP file).
AIPS 2: BPVER        -1                    Bandpass table version
AIPS 2: SMOOTH     *all 0                  Smoothing function. See
AIPS 2:                                    HELP SMOOTH for details.
AIPS 2: STOKES     '    '                  Stokes parameters (see HELP)
AIPS 2: BCHAN         1                    Low freq. channel 0 for cont.
AIPS 2: ECHAN         0                    Highest freq channel
```

```
AIPS 2: CHANNEL       0                        Restart channel number
AIPS 2: NPOINTS      14                        Number of chan. to average.
AIPS 2: CHINC         1
AIPS 2: BIF           0                        First IF in average.
AIPS 2: EIF           0                        Last IF in average.
AIPS 2: OUTNAME    '            '              Output image name (name)
AIPS 2: OUTDISK       1                        Output image disk drive #
AIPS 2: OUTSEQ        0                        Output seq. no.
AIPS 2: OUTVER        0                        CC ver. no (Continuum only)
AIPS 2:                                        *** SET OUTVER ON RESTARTS
AIPS 2: IN2NAME    '            '              UV work file name
AIPS 2: IN2CLASS   '      '                    UV work file class
AIPS 2: IN2SEQ        0                        UV work file seq
AIPS 2:                                        *** SET TO KEEP WORK FILE
AIPS 2: IN2DISK       0                        UV work file disk
AIPS 2: CELLSIZE      7            7           (X,Y) size of grid in asec
AIPS 2: IMSIZE      512          512           Minimum image size
AIPS 2: NFIELD      230                        Number of fields (max. 512)
AIPS 2: DO3DIMAG      1                        > 0 => use different tangent
AIPS 2:                                        points for each field
AIPS 2: FLDSIZE    *all 0                      Clean size of each field.
AIPS 2: RASHIFT    *all 0                      RA shift per field (asec)
AIPS 2: DECSHIFT   *all 0                      DEC shift per field (asec)
AIPS 2: UVTAPER       0            0           (U,V) Gaussian taper
AIPS 2:                                          units are kilo-lambda
AIPS 2: UVRANGE       0            0           Min & max baseline (klambda)
AIPS 2: GUARD         0            0           x,y guard band fractional
AIPS 2:                                        radius
AIPS 2: ROTATE        0                        Rotate image CCW from N by
AIPS 2:                                        ROTATE degrees
AIPS 2: ZEROSP     *all 0                      0-spacing fluxes and weights
AIPS 2:                                        SEE HELP!!
AIPS 2: UVWTFN     '  '                        UV dist. weight function
AIPS 2:                                          blank => uniform
AIPS 2: UVSIZE        0            0           Array size for doing uniform
AIPS 2:                                        weights.  0 -> actual field
AIPS 2:                                        size.
AIPS 2: ROBUST        0                        Robustness power: -5 -> pure
AIPS 2:                                        uniform weights, 5 => natural
AIPS 2: UVBOX         0                        Additional rows and columns
```

```
AIPS 2:                                   used in weighting.
AIPS 2: UVBXFN        1                   Box function type when UVBOX
AIPS 2:                                   > 0.  0 -> 1 round pill box.
AIPS 2: XTYPE         5                   Conv. function type in x
AIPS 2:                                     default spheroidal
AIPS 2: YTYPE         5                   Conv. function type in y
AIPS 2:                                     default spheroidal
AIPS 2: XPARM      *all 0                 Conv. function parms for x
AIPS 2: YPARM      *all 0                 Conv. function parms for y
AIPS 2: NITER      20000                  Maximum # of Clean components
AIPS 2: BCOMP      *all 0                 Begin at BCOMP component
AIPS 2:                                   Specify for each field.
AIPS 2: ALLOKAY       0                   For restart: > 0 => beams
AIPS 2:                                   okay, > 1 => work file too
AIPS 2: NBOXES        0                   Number of boxes for Clean
AIPS 2:                                   NB: field 1 only.
AIPS 2: CLBOX      *all 0                 Four coordinates for each box
AIPS 2: BOXFILE    'FITS:G11-4AB-BOX3     Input file of field params
AIPS 2:
AIPS 2:               '
AIPS 2:                                   and Clean boxes; ' ' => use
AIPS 2:                                   FLDSIZE, RASHIFT, DECSHIFT,
AIPS 2:                                   NBOXES, CLBOX only.
AIPS 2: OBOXFILE   'FITS:G11-4AB-BOX3'    Output file for final Clean
AIPS 2:                                   boxes
AIPS 2: GAIN          0.1                 Clean loop gain
AIPS 2: FLUX          0.45                Minimum Clean component (Jy)
AIPS 2: MINPATCH    121                   Min. BEAM half-width in AP.
AIPS 2: BMAJ          0                   FWHM(asec) major axis Clean
AIPS 2:                                   restoring beam.
AIPS 2: BMIN          0                   FWHM(asec) minor axis Clean
AIPS 2:                                   restoring beam.
AIPS 2: BPA           0                   Clean beam position angle
AIPS 2: OVERLAP       2                   1 => restore components to
AIPS 2:                                   overlapped fields, >=2=>
AIPS 2:                                   expect overlaps in Cleaning
AIPS 2: PHAT          0                   Prussian hat height.
AIPS 2: FACTOR        0                   Speedup factor see HELP
AIPS 2: CMETHOD    '    '                 Modeling method:
AIPS 2:                                   'DFT','GRID','    '
```

```
AIPS 2: IMAGRPRM      0           0        Task enrichment parameters
AIPS 2:               0           0        (1) Antenna diameter (m)
AIPS 2:               0           0        (2) Source Spectral index
AIPS 2:               0           0        (3) Frequency scaling factor
AIPS 2:               0           0        (4) > 0 -> SDI Clean factor
AIPS 2:               0           0        (5) >0 => scale residuals
AIPS 2:               0           0        (6) Half-width in x of box
AIPS 2:               0           0        (7) Half-width in y of box
AIPS 2:               0           0        (8) Filter components whose
AIPS 2:               0           1.05     neighborhood is weaker than
AIPS 2:                                    IMAGRPRM(8) Jy.  0 -> don't
AIPS 2:                                    (9) Radius in pixels for the
AIPS 2:                                    IMAGRPRM(8) test.
AIPS 2:                                    (10) multiplier of image size
AIPS 2:                                    to get beam size: 0 => 2;
AIPS 2:                                    2, 1, 0.5 0.25 supported
AIPS 2:                                    (11-15) Multi-resolution
AIPS 2:                                    added controls
AIPS 2:                                    (20) Retry factor (see help)
AIPS 2:                                    (20) Retry factor (see help)
AIPS 2: NGAUSS        0                    Number of resolutions to use
AIPS 2: WGAUSS     *all 0                  Resolutions in arc sec >= 0
AIPS 2: FGAUSS     *all 0                  Minimum flux for each resol.
AIPS 2: MAXPIXEL   40000                   Maximum pixels searched in
AIPS 2:                                    each major cycle.
AIPS 2: DOTV          1                    Display residuals on TV ?
AIPS 2:                                    Start with field = DOTV
```

`IMAGR` produces a large number of maps. `GETNAME` the first one, and put them back together again with `FLATN` (§6.5).

If one has a large list of outlier fields, they can be specified in an external text file using `BOXFILE`. However, after producing an external `BOXFILE`, it is good to examine the outlier fields. Oftentimes one will discover that not all outlier fields contain sources. The lack of a source in an outlier field may be because bandwidth smearing has reduced its flux, it is resolved out, or both. In this case, the list of outlier fields needs to be revised. The following script can be used to renumber an outlier list after pruning it:

```
#!/usr/bin/awk -f
#
# Replace first line with appropriate path to awk, nawk, or gawk.
```

```
#
# RENUMBER
# renumbers IMAGR fields after some have been deleted
# based on code by K. Dyer
#
#
$1 ~ /^[fFcC]/ {
 printf "%s  %d  ", $1, NR;
 for (i=3; i<=NF; i++) { printf "%s  ", $i; }; printf "\n";
}
#
$1 !~ /^[fFcC]/
#
```

With these large `IMAGR` runs one probably wants to run with `DOTV=-1`. When it is done, one can "glue" the maps together with `FLATN`. If there is some flux in the map (i.e., recognizable sources) then you've done something right!

6.4 Self-calibration—`CALIB` Again

Like the situation at higher frequencies, the initial calibration may provide a hint of the source of interest, but the dynamic range is well below the theoretical value. The dynamic range of one's image can be improved by self-calibration. `CALIB` is run on the same u-v data base from which the last set of `IMAGR` images were produced. These images form the model which drive self-calibration. This procedure is iterative, with many imaging–self-calibration rounds potentially being necessary.

If `NCOMP=0`, as in the example below, all CLEAN components will be used in constructing the model to drive self-calibration. If `NCOMP=-10000` (or some other large negative number), `CALIB` will use all the CCs up to the first negative. One can run `CCMRG` on the CC files (all 49 of them!) to condense more flux into the first set of positive components. (Also, `IMAGR` can do this automatically now, set `OVERLAP=2`.)

The example below is a phase only self-calibration, which is usually all one needs since the gains were set by such a strong source such as Cygnus A. `SOLTYPE='L1'` is more tolerant of bad data than the default least-squares algorithm, use this if `CALIB` has trouble finding solutions. If convergence still seems difficult to obtain, try setting `APARM(7)=3` which lowers the acceptable signal-to-noise ratio to 3 (from the default of 5) and typically shifts insufficient data solutions to the good category. `SOLINT=1` (1 min. solution intervals) is typical, but one can try increasing it if one is getting many bad solutions.

In the initial iteration or two, it is also recommended to set `UVRANGE`, thus limiting the range of baselines. A recommended value is `UVRANGE=0 1.5`. Over this range of baselines the ionosphere is reasonably coherent, and good phase solutions should be found. However, one also does not want to discard the longer baseline data entirely, so also set `WTUV=0.1`.

One runs `CALIB` iteratively, gradually making the model better. Always run it on the original *u-v* data base, to keep as much data as possible. This works ok since this is a linear process. Each time one runs `CALIB`, an SN table gets tacked on to the *u-v* data base. Use `SNPLT` to see what kind of phase corrections one is making. The disadvantage of running `CALIB` on the original *u-v* data base each time instead of on each new *u-v* data base produced by `CALIB` is that one does not get to see the incremental difference that each successive `CALIB` run has via `SNPLT`. One should see the number of good solutions increasing with successive `CALIB` runs, and the `IMAGR` runs should CLEAN more and more flux each time, and of course the maps should look better, i.e., peaks higher, rms lower, more sources, etc ...

If one is desperate to decrease the size of one's data sets (e.g., the computer is overloaded), one may time average your data sets *after* one's first successful phase self-calibration. B- and C-configuration data sets can be time average down to 20 and 45 s, respectively. A-configuration needs to be kept at 10 s sampling.

Here is a `CALIB` run following the `IMAGR` run from above:

```
AIPS 1: CALIB:  Task to determine calibration for data.
AIPS 1: Adverbs         Values           Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1:                                   Data selection (multisource):
AIPS 1: CALSOUR    *all ' '               Calibrator sources
AIPS 1: QUAL         -1                   Calibrator qualifier -1=>all
AIPS 1: CALCODE    '    '                 Calibrator code '    '=>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: TIMERANG   *all 0                 Time range to use.
AIPS 1: BCHAN         0                   Lowest channel number 0=>all
AIPS 1: ECHAN         0                   Highest channel number
AIPS 1: ANTENNAS   *all 0                 Antennas to select. 0=all
AIPS 1: DOFIT      *all 0                 Subset of ANTENNAS list
AIPS 1:                                   for which solns are desired.
AIPS 1:                                   0 => solve for all antennas
AIPS 1:                                   implied by ANTENNAS list
AIPS 1:                                   [except of course, REFANT]
AIPS 1: SUBARRAY      0                   Subarray, 0=>all
AIPS 1: UVRANGE       0          0        Range of uv distance for full
AIPS 1:                                   weight
```

```
AIPS 1: WTUV          0                        Weight outside UVRANGE 0=0.
AIPS 1:
AIPS 1:                                        Cal. info for input:
AIPS 1: DOCALIB      -1                        If >0 calibrate data
AIPS 1: GAINUSE       0                        CL table to apply.
AIPS 1: FLAGVER       0                        Flag table version
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: SMOOTH     *all 0                      Smoothing function. See
AIPS 1:                                        HELP SMOOTH for details.
AIPS 1:
AIPS 1:                                        CLEAN map. See HELP.
AIPS 1: IN2NAME    'GC-4BC-P1I  '                 Cleaned map name (name)
AIPS 1: IN2CLASS   'ICLN  '                       Cleaned map name (class)
AIPS 1: IN2SEQ        1                           Cleaned map name (seq. #)
AIPS 1: IN2DISK       5                           Cleaned map disk unit #
AIPS 1: INVERS        0                        CC file version #.
AIPS 1: NCOMP      *all 0                      # comps to use for model.
AIPS 1:                                        1 value per field
AIPS 1: NMAPS        49                        No. Clean map files
AIPS 1: CMETHOD    '    '                      Modeling method:
AIPS 1:                                        'DFT','GRID','    '
AIPS 1: CMODEL     '    '                      Model type: 'COMP','IMAG'
AIPS 1: SMODEL     *all 0                      Source model, 1=flux,2=x,3=y
AIPS 1:                                        See HELP SMODEL for models.
AIPS 1:
AIPS 1:                                        Output uv data file.
AIPS 1: OUTNAME    '            '                 UV file name (name)
AIPS 1: OUTCLASS   'P1    '                       UV file name (class)
AIPS 1: OUTSEQ        0                           UV file name (seq. #)
AIPS 1: OUTDISK       2                           UV file disk drive #
AIPS 1:
AIPS 1:                                        Solution control adverbs:
AIPS 1: REFANT        7                        Reference antenna
AIPS 1: SOLINT        1                        Solution interval (min)
AIPS 1: APARM         0            0           General parameters
AIPS 1:               0            0              1=min. no. antennas
AIPS 1:               0            0              2 > 0 => data divided
```

```
AIPS 1:                3        *rest 0        3 > 0 => avg. RR,LL
AIPS 1:                                        5 > 0 => avg. IFs.
AIPS 1:                                        6=print level, 1=good,
AIPS 1:                                          2 closure, 3 SNR
AIPS 1:                                        7=SNR cutoff (0=>5)
AIPS 1:                                        8=max. ant. # (no AN)
AIPS 1:                                        9 > 0 => pass failed soln
AIPS 1:
AIPS 1:                                     Phase-amplitude Parameters:
AIPS 1: SOLTYPE    'L1  '                   Soln type,'  ','L1','GCON'
AIPS 1: SOLMODE    'P   '                   Soln. mode: 'A&P','P','P!A',
AIPS 1:                                     'GCON'
AIPS 1: SOLCON         0                    Gain constraint factor.
AIPS 1: MINAMPER       0                    Amplitude closure error
AIPS 1:                                     regarded as excessive in %
AIPS 1: MINPHSER       0                    Phase closure error regarded
AIPS 1:                                     as excessive in degrees
AIPS 1: CPARM      *all 0                   Phase-amp. parameters
AIPS 1:                                        2 >0 => normalize gain
AIPS 1:                                        3 avg. amp. closure err
AIPS 1:                                        4 avg. ph. closure err
AIPS 1:                                        5 >0 => scalar average
AIPS 1:
AIPS 1: SNVER          0                    Output SN table, 0=>new table
AIPS 1: ANTWT      *all 0                   Ant. weights (0=>1.0)
AIPS 1: GAINERR    *all 0                   Std. Dev. of antenna gains.
```

6.5 FLATN—Making a Single Image from Multiple Images

If one's objective is to produce a single wide-field image of the sky, there has to be a way to "glue" back together the multiple fields that IMAGR has produced. Making a single wide-field image is not an issue if one is imaging in a "targeted faceting" mode (§6.3), as one might use for A-configuration observations at 330 MHz. In targeted faceting, only a small section of sky around each identified source is imaged. Gluing these images together would produce a large image with considerable blank space. However, at lower resolutions, e.g., C-configuration observations at 74 MHz, one might wish to image the entire primary beam.

In order to "glue" the multiple IMAGR fields together, FLATN is the task of choice. It is fairly straightforward, and an example input listing is shown below. The key adverbs are NMAPS and IMSIZE. NMAPS may have to be set differently from the value used in IMAGR. If one has imaged not only the primary beam, but a small number of strong sources outside the primary beam, then `NMAPS` should be set to use only the number of images required to reconstruct the primary beam. `IMSIZE` should be set to the size desired for the *final* image, not the individual `IMAGR` fields.

An important implication of using `FLATN`, however, is its impact on the brightnesses of sources in the resulting image. In order to produce a flat image from a series of tangent planes, which themselves are an approximation of a curved surface, involves projecting the sources from the series of tangent planes to the flat image. As a consequence, *brightness is not preserved*, though flux density is. Thus, if one is attempting to construct a source catalog from one's data, the proper way to do so is to search for sources in the `IMAGR` facets; save the flattened image for an illustration of the field of view or for a public release.

Important adverbs include

`NFIELD` This adverb is the number of facets used in the imaging.

`NMAP=1` This adverb is the number of *pointings*. This will always be 1, because during the typical 74 MHz observation of a source the VLA remains pointed at only a single point in the sky. (One should not confuse multiple sources with multiple pointings. One may observe multiple sources during an observation, but each source will have only one pointing.) The only time this adverb should be set to a value larger than 1 is if one is creating a mosaic, which is generally done only at higher frequencies.

`IMSIZE` This is the number of pixels in the *output* image. Thus, to take a simple example of a field imaged with 9 facets (3×3), with each facet being 512 pixels $\times$ 512 pixels, one would set `IMSIZE=1534`.

`APARM(1)=0` The 3-D correction here applies only to *snapshots* which is almost never the case with 74 MHz observations.

```
AIPS 1: FLATN: Re-grid multiple fields to one image
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME     'GC-4BC-P1I  '            Image name (name)
AIPS 1: INCLASS    'ICL001'                  Image name (class)
AIPS 1: INSEQ         1                      Image name (seq. #)
AIPS 2: NFIELD      313                   Max number of fields per
AIPS 2:                                      pointing
AIPS 2: NMAPS         1                   Number of pointings
AIPS 2:                                   Output image
AIPS 2: OUTNAME    '            '            Image name (name)
AIPS 2: OUTCLASS   '      '                  Image name (class)
AIPS 2: OUTSEQ        0                      Image name (seq. #)
```

```
AIPS 2: OUTDISK       2                          Image disk drive #
AIPS 2: IMSIZE     9400        9400           Output image size in pixels
AIPS 2: COORDINA   *all 0                     Central pixel coordinate
AIPS 2:                                       all 0 => use observed
AIPS 2: REWEIGHT      0           0           (1) Interpolation halfwidth
AIPS 2:                                       (2) Minimum fraction of good
AIPS 2:                                           pixels required (0->1/3)
AIPS 2: DOWEIGHT      1                       Weight image down by DOWEIGHT
AIPS 2:                                       time radius from center
AIPS 2: EDGSKP        0                       Skip pixels around the edges
AIPS 2: APARM         *all 0                  (1) >0 => do 3-D corr.
AIPS 2:                                          ONLY for snapshots
AIPS 2:                                       (2) Parallactic angle (deg)
AIPS 2:                                       (3) Zenith angle (deg)
AIPS 2:                                       (4-8) radial scaling parms
AIPS 2:                                       (9) Linear scaling
AIPS 2: PBPARM     *all 0                     Beam parameters:
AIPS 2:                                       (1) Cutoff; (2) Use (3)-(7)
AIPS 2:                                       (3)-(7) Beam shape
AIPS 2: NOISE      *all 0                     Relative uncertainties by
AIPS 2:                                       pointing
```

Chapter 7

Ionospheric Imaging Strategy

In this strategy, one does *not* rely upon self-calibration. Rather one counts on being able to determine and remove the two major sources of phase distortions, the instrument and the ionosphere. The essential assumption in this strategy is that the visibility phase at any time is the combination of four terms,

$$\phi_{\mathrm{vis}} = \phi_{\mathrm{src}} + \phi_{\mathrm{ant}} + \phi_{\mathrm{ion,low}} + \phi_{\mathrm{pec}}, \tag{7.1}$$

where ϕ_{src} is the contribution from the sources in the sky, ϕ_{ant} is an instrumental term, and $\phi_{\mathrm{ion,low}}$ and ϕ_{pec} are ionospheric terms. The ionosphere over the array is modelled as "slowly varying" and "rapidly varying." The slowly-varying term is described by low-order Zernike polynomials, in practice the first- and second-order polynomials. (An interferometer is insensitive to the zero-order polynomial.) All other ionospheric phase effects are lumped into the rapidly-varying term, also called "peculiar phases."

The tasks described here have all been written by B. Cotton; they are not available in the standard $\mathcal{AIPS}$ distribution. One should contact TJWL or B. Cotton to obtain copies.

7.1 `CALIB`—Setting Antenna Gains and Phases

This step can be done in the same manner as in §5.3. The only change would be make the solution interval `SOLINT` as short as possible, possibly as short as a single integration time (e.g., 6.66 or 10 s). One may want to leave `TIMERANG` set to its default and run `CALIB` on all of the Cygnus A (or other calibrater) data.

7.2 `SNFLT`—Isolating the Instrumental Phases

This step is intermediate between the initial gain calibration (§7.1 and §5.3) and applying this calibration to all sources (§5.4). The gains phases are assumed to have contributions from both the ionosphere and the instrument. Assuming (hoping?) that the ionosphere phases "average out" in some sense, over a suitably long time, `SNFLT` can filter the gain phases to produce the instrumental phases.

Key to this method is that one have a sufficient number of observations of a calibrator (i.e., Cygnus A). In practice, hourly observations of 2–5-min. duration often seem to work. One will probably also want to limit the time range to a single "good" scan. Good scans can be identified by at least one of two methods:

- One can use `SNPLT` to look at the phase solutions from `CALIB`. Good scans will have "well-behaved" phases, changing smoothly as a function of time. In bad scans, the phases will appear random or nearly so.
- One can apply the phase solutions of Cyg A back to itself and image it. Good scans will show Cyg A to have the structure of the model with a flux density close to that expected. In bad scans the structure of Cyg A will be distorted and its flux density will be considerably lower than expected.

Important adverbs are

`TIMERANG` Set this to a "good" scan (see above).

`DOGREY=-1` In general, one only wants to solve for the instrumental phases.

`X` There may be scans on the calibrator when the rms phase is so large as to be unbelievable. Setting `X` can ignore these times. `SNPLT` can be used to identify these times.

The filtered SN table is then applied to all sources as in §5.4.

7.3 `VLAFM`—Automagic Ionospheric Calibration and Imaging

The task `VLAFM` performs "wide-field imaging" after correcting for the low-order ionospheric terms. Its steps include

1. Filters RFI from the visibility data.
2. Establishes a grid of NVSS sources around the pointing position. The positions of the NVSS sources are known to much better than a 74 MHz beamwidth, and these positions serve as a means for estimating the low-order ionospheric distortions.
3. At each `SOLINT` interval in the visibility data, image and attempt to CLEAN the NVSS grid. Determine the offsets of the apparent positions of the NVSS sources from their expected positions.

4. Apply various "quality control" checks to the fitted offsets. Among the various tests performed are
   (a) Exclude sources whose offsets appear to be random in time; and
   (b) Exclude intervals for which an insufficient number of offsets could be determined.
5. Use the time series of fitted offsets to model the low-order ionospheric distortions using Zernike polynomials.
6. Remove these modelled ionospheric distortions ($\phi_{\rm ion,low}$).
7. CLEAN the resulting visibilities.

Important adverbs include

`IONPRM(1)` Specify whether or not to use the ionospheric calibration mode. (`VLAFM` also has a more "traditional" imaging mode.)

`IONPRM(2)` Specify the maximum acceptable residual ionospheric seeing. A plausible value is one-quarter of the synthesized beam size ($20''$ for B configuration). This value will increase the beam area by 35% with a comparable reduction in peak flux density. The default is $100''$.

`IONPRM(6)` The NVSS contains a "quality code," which is little more than a code for how extended the source is. One would like to use only compact sources (codes 0 or 1) in constructing the NVSS grid but based on signal-to-noise ratios and desperation, higher codes (more extended sources) may have to be considered acceptable.

`RFIFILT` `VLAFM` also has the capability to do flagging, if one does not want to use `FLGIT`. This adverb is similar to `APARM` in `FLGIT` (§5.5). If one wants to make use of `RFIFILT`, `ICHANSEL` must also be used.

`FOV` This is the radius of the desired field of view. In conjunction with `NFIELD=0`, this adverb will produce a fly's eye pattern of facets covering this distance from the phase center. This adverb is similar to `BPARM(1)` in `SETFC`.

`ADDFIELD` This adverb controls whether or not, and to what extent, outlier fields are used in the imaging. Its values are similar to those of `BPARM` in `SETFC`.

`CELLSIZE` **and** `IMSIZE` While these adverbs have their traditional meanings as in `IMAGR`, it is recommended that both be set to 0 and `VLAFM` allowed to determine their values from the data.

`DOTV` If this is set to 1, it is **essential** that the TV be used only for watching what `VLAFM` is doing. Attempting to use the TV functions (other than "CONTINUE CLEAN" and "STOP CLEANING") while `VLAFM` is running, particularly while it is attempting to establish the initial grid of sources, can be disastrous! In severe cases, it may be necessary to reboot the machine.

`VLAFM` is a powerful task (with capabilities not understood fully by the authors of this document). The above list should be sufficient to get one started, though.

B. Cotton has also written a task `VLALB` which is similar in spirit to `VLAFM` but does not do the ionospheric calibration and so is more useful at 1400 MHz and probably 330 MHz.

Chapter 8

Special Considerations in Imaging

8.1 Pathologically Bright Sources near the Field of View (*Contributed by M. Bietenholz*)

A handful of very bright sources (the brightest being Cas A with a 74 MHz flux density of 23 000 Jy!) can generate undesirable levels of sidelobe confusion. As the 74 MHz primary beam is approximately 11° in diameter, even sources 20°–30° away can result in noticable sidelobe levels. There have been a number of people who have tried different attacks on this problem. This section has benefitted from their comments.

The first thing to try is putting a box on the bright source and CLEANing normally. The resulting image of the confusing source probably will not look a lot like what it should, but this procedure will often remove the sidelobes. Using the resulting CLEAN model for the source and subtracting the source from the u-v data may or may not help improve the image.

A secondary complication is that the array may not be quite focussed. The result is that point sources tend to be approximately 1.4 times larger than the nominal diameter. (Of course, the HST lived with that problem for a couple of years!) The cause of this is not well established, but it may mean that the resolution at 74 MHz is not actually given by the dirty beam, because the phases cannot be quite that well aligned. One might use `PUTHEAD` to change the nominal Convolving size in the image header to reflect this, keeping in mind that the effective resolution is likely position dependent, and probably not nicely Gaussian either. One or more of suggestions listed below (particularly the first two) may provide some improvement:

1. Set CLEAN boxes around actual sources, using the TV capabilities of `IMAGR`, as opposed to CLEANing the whole field blindly. These boxes can be reused on future runs of `IMAGR` if `OBOXFILE` is set.

2. Include as much flux as possible in one's model for self-calibration. For B-configuration imaging, one can make an image of the entire field of view using fields on a regular grid. For

the A-configuration imaging, try making a low-resolution image with a resolution comparable to that obtained by a B-configuration observation, then hand-pick a managable number of fields so as to include as much flux as possible.

3. Set `FACTOR=-0.2` in `IMAGR`. This will make `IMAGR` run slower, but otherwise it often seems to do substantial CLEANing on fields with strong sources and ignores the rest. (One could easily find that 20 000 CLEAN components were found, *none* of which are on the program source!) One can also set `MAXPIXEL` in order to limit the number of map points that are loaded to AP memory during CLEANing cycles. Recommended values are 100–200. Such small values can *really* helps the quality of the imaging, as well as the speed. It can also make self-calibrations much better, as the CC components are now nearly all on real objects, rather than noise peaks spread all over the place.

4. Stick to doing phase-only self-calibration, `SOLMODE='P'` in `CALIB`. Accurate amplitude self-calibration may not be possible because it depends upon being able to subtract accurately the distant, confusing source(s). Also, use only positive CLEAN components, at least for confusing source fields where there are only point sources and noise. If a bright source or one's program source have considerable exended emission, one may need to include negative CLEAN components in order to obtain a reasonable amount of the flux in the model.

5. Try using L1 minimization in self-calibration, `SOLTYPE='L1'` in `CALIB`.

6. Often times, one will find (much) better results if the distant source(s) is ignored during self-calibration, i.e., the distant source is not included in the model. However, it may also be necessary to lower the signal-to-noise threshold in `CALIB`, `APARM(7)`. The default value is a signal-to-noise threshold of 5; a threshold as low as 2–3 may be necessary. This lower threshold can be necessary because the presence of the distant source will lower artificially the signal-to-noise ratio of the solutions. If the threshold is lowered, then examining the SN table for consistency with `LISTR` or `SNPLT` becomes advisable. If one's gain solutions look like random numbers, they likely are!

7. It may be possible to average the R and L circular polarization (assuming both were recorded), thereby improving the signal-to-noise ratio and possibly obtaining better distant source rejection. Set `APARM(3)=1)`.

8. Distant source rejection in `CALIB` will also be aided by setting long `SOLINT`s.

8.2 Possible Other Avenues to Explore

Thus far, it has been a common assumption that the antenna phase is not a function of frequency. This assumption could be relaxed by running `FRING` or `KRING`. Both tasks allow one to search for slopes of the antenna phase with frequency or delay; `KRING` may be slightly preferable because it allows one to specify that only a delay search be done (i.e., `CPARM(5)=-1` so that no rate search is performed).

8.3 The Fight Against Large-Scale Undulations *Written by T. Enßlin*

This section describes the removal of large-scale undulations in low frequency radio maps from RFI and confusing sources. It essentially forms a separate tutorial in and of itself. For that reason, it is contained separately as both an HTML and PostScript document.

8.4 The Galactic Plane

We have come to realize that data reduction for observations in the Galactic plane is quite different then in the extragalactic sky. Most of these lessons apply both to 74 and 330 MHz.

8.4.1 Gain Calibration

For the compact configurations (C and D configurations), it may be difficult to obtain good solutions. One may have to average the data spectrally, flag it (`TVFLG`), then calibrate as best as possible—`SETJY-CALIB-GETJY-CLCAL` on regular calibrators for 330 MHz or `CALIB` on Cyg A for 74 MHz. Then copy the resulting CL table to the original line data base and begin the flagging process.

8.4.2 RFI Excision

The biggest issue is *flagging* of bad data. `FLGIT` breaks down in the plane, especially for C and D configurations. Often there is so much rolling broad-band junk that `FLGIT` gets confused and cannot find bad data. Also, it cuts off the of the rolling broad-band junk and makes it harder to find later.

Thus, manual flagging of all 351 baselines with `SPFLG` (to get narrow band RFI), followed by `TVFLG` (to get broad band RFI, possibly after spectral averaging to a small number of channels), followed by loops of `UVPLT`, `UVFND`, and `UVFLG` on the Stokes I and V polarizations (to get individual baselines in certain limited times), are required to excise it. Later, after imaging, one can subtract the CCs (`UVSUB`) from the data and plot the residuals (`UVPLT`). Residual visibility data that "stand out" can be flagged. The example below shows how to isolate bad data using the Stokes V polarization.

```
AIPS 2: UVFND:  Task to print selected source data from a UV disk file
AIPS 2: Adverbs     Values                    Comments
```

```
AIPS 2: ----------------------------------------------------------------
[...]
AIPS 2: CHANNEL       0                     Frequency channel number.
AIPS 2: BIF           2                     IF number to test.
AIPS 2: NITER      1000                     Max # lines printed.
AIPS 2:                                         0 => 10 pages
AIPS 2: UVRANGE       2.6          3.4      UV range in kilolambda
AIPS 2: STOKES     'IV  '                   Stokes parameters: ' ' => 'I'
AIPS 2:                                        'CORR' for correlators
AIPS 2: SOURCES    *all ' '                 Source list
AIPS 2: TIMERANG   *all 0                   Time range
AIPS 2: SELBAND      -1                     Bandwidth to select (kHz)
AIPS 2: SELFREQ      -1                     Frequency to select (MHz)
AIPS 2: FREQID        0                     Freq. ID to select.
AIPS 2:                                     None selected => 1.
AIPS 2: DOCALIB      -1                     If >0 calibrate data
AIPS 2:                                     = 2 calibrate weights
AIPS 2: GAINUSE       0                     CAL (CL or SN) table to apply
AIPS 2: FLAGVER       0                     Flag table version
AIPS 2: OPCODE     'VCLP'                   'CLIP' print excess fluxes
AIPS 2:                                     'FRNG' print all in annulus
AIPS 2:                                     'UVBX' print points in uv box
AIPS 2:                                     'VCLP' print excess (RR-LL)/2
AIPS 2: APARM         5            5        CLIP:(1) peak ok flux IPOL
AIPS 2:               5            5             (2) peak ok pol. flux
AIPS 2:               5            5             (3) min. ok flux IPOL
AIPS 2:               5            5             (4) min. ok pol flux
AIPS 2:               5            5        FRNG:(1) fringe spacing arsec
AIPS 2:                                          (2) range fringe spacing
AIPS 2:                                          (3) baseline pos. angle
AIPS 2:                                          (4) range of pos. angle
AIPS 2:                                     UVBX:(1) U in kilolambda
AIPS 2:                                          (2) range of U
AIPS 2:                                          (3) V in kilolambda
AIPS 2:                                          (4) range of V
AIPS 2:                                          (5) >0 => Hermitian too
AIPS 2:                                     VCLP:(1) peak ok VPOL flux
AIPS 2: WTUV          0                     Maximum "reasonable" weight
AIPS 2:                                     0 => infinity
AIPS 2: DOCRT         1                     > 0 -> use CRT, else printer
```

```
AIPS 2:                                    > 72 => CRT width in chars
AIPS 2: OUTPRINT   '                                              '
AIPS 2:                                    Printer disk file to save
```

Do not clip interactively. Flag the data by area or some other means to flag the data completely. This is true of both SPFLG and TVFLG. Cutting off the brightest RFI may leave low-level RFI underneath.

After TVFLG, run SPLAT again in order to make a "diagnostic" data set in which all of the channels are averaged. RFI ofen shows up easier in the latter. One will have to flag the line and the continuum data in succession, iterating (including making a new continuum data set) in order to convince oneself that in the nightmare of doing all this one didn't forget to zap something.

8.4.3 Imaging

The key is that IMAGR has to be run interactively, as there is so much complex extended structure in the field. Make sure to set DOWAIT=1 before one starts it otherwise IMAGR will not let one set boxes for each field in succession. Set OBOXFILE=BOXFILE so that CLEAN boxes are saved, making future runs easier. Also take a look at 11 cm maps [Reich et al. 1990a, Furst et al. 1990a, Furst et al. 1990b, Reich et al. 1990b] or another relevant Galactic plane survey to get a feel for the sources that will be encountered. Some fields may not need boxes initially, but one can "FORCE A FIELD" later to check those fields.

Appendix A

Source Models

For both bandpass (§5.2) and initial gain amplitude and phase calibration (§5.3), it is recommended that one use Cygnus A. Cygnus A is recommended because it is much brighter than the radio frequency interference commonly encountered at 74 MHz. However, one will need a good model as the fractional bandwidth is great enough that its intrinsic visibility changes across the pass band.

FITS images of Cygnus A, with attached CLEAN component tables, are now available online; these models are applicable to observations in all VLA configurations at 74 MHz[1] and 330 MHz[2].

Alternately, one can examine the list of all available models[3].

In order to use either one of these models, download the appropriate file. Place the downloaded file someplace where AIPS can see it, e.g., the `FITS` directory. Use `FITLD` or `IMLOD`, with `INFILE` set appropriately, to load the model image into AIPS. Then, when setting up the inputs for `CALIB`, set `INNAME`, `INCLASS`, `INSEQ`, and `INDISK` to refer to this model image and set `NMAPS=1`.

Check the epoch of the models! If necessary, make sure to use `EPOSWITCH` *before calibration!*

[1] http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/Cyg_A-4.model.FITS
[2] http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/Cyg_A-P.model.FITS
[3] http://lwa.nrl.navy.mil/pubs/tutorial/VLAmodels/models.html

Appendix B

Phase Transfer

Start with the multi-source P-band data which comes out of FILLM. In the example below we started with the CH0 multisource data from a C-configuration observation of the Galactic center.

Use SETJY in this case on 3C 286 which, for C-configuration at 74 MHz, has a UVRANGE restriction of 0 to 18 kλ, bigger than the C configuration itself:

```
AIPS 1: SETJY     Task to enter source info into source (SU) table.
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
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
AIPS 1: SYSVEL        0                   Velocity of source (km/s)
AIPS 1: RESTFREQ      0           0       Line rest frequency (Hz)
AIPS 1: VELTYP     '        '             Velocity type 'LSR,'HELIO'
AIPS 1: VELDEF     '        '             Velocity definition 'RADIO',
AIPS 1:                                   'OPTICAL'
AIPS 1: FREQID       -1                   FQ table entry to use for
AIPS 1:                                   velocity information and
AIPS 1:                                   'CALC' option
AIPS 1: APARM      *all 0                 (1): Pixel to which SYSVEL
AIPS 1:                                        refers ( 0=>1)
AIPS 1:                                   (2): Only for 'CALC' option:
AIPS 1:                                     <= 0 => use latest VLA
AIPS 1:                                         values (1995.2) or,
AIPS 1:                                         for 1934-638, the
AIPS 1:                                         ATCA value of 30Jul94.
AIPS 1:                                        1 => use Baars values
AIPS 1:                                         or old ATCA/PKS values
AIPS 1:                                         for 1934-638
AIPS 1:                                     >= 2 => use previous VLA
AIPS 1:                                         values (1990) or,
AIPS 1:                                         for 1934-638, the
AIPS 1:                                         ATCA value of 30Jul94.
```

Calibrate the 330 MHz data as usual, maybe after `TVFLG`ing the calibrators for good measure. Our phase calibrator 1830−360 also did not have any *u*-*v* restrictions, so we could do it together with 3C 286 in `CALIB`:

```
AIPS 1: CALIB:  Task to determine calibration for data.
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1:                                   Data selection (multisource):
AIPS 1: CALSOUR    '1331+305        '     Calibrator sources
AIPS 1:            '1830-360        '  *rest ' '
AIPS 1: QUAL         -1                   Calibrator qualifier -1=>all
AIPS 1: CALCODE    '    '                 Calibrator code '    '=>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: TIMERANG   *all 0                    Time range to use.
AIPS 1: BCHAN         0                      Lowest channel number 0=>all
AIPS 1: ECHAN         0                      Highest channel number
AIPS 1: ANTENNAS   *all 0                    Antennas to select. 0=all
AIPS 1: DOFIT      *all 0                    Subset of ANTENNAS list
AIPS 1:                                      for which solns are desired.
AIPS 1:                                      0 => solve for all antennas
AIPS 1:                                      implied by ANTENNAS list
AIPS 1:                                      [except of course, REFANT]
AIPS 1: SUBARRAY      0                      Subarray, 0=>all
AIPS 1: UVRANGE       0           0          Range of uv distance for full
AIPS 1:                                      weight
AIPS 1: WTUV          0                      Weight outside UVRANGE 0=0.
AIPS 1:
AIPS 1:                                      Cal. info for input:
AIPS 1: DOCALIB      -1                      If >0 calibrate data
AIPS 1: GAINUSE       0                      CL table to apply.
AIPS 1: FLAGVER       0                      Flag table version
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: SMOOTH     *all 0                    Smoothing function. See
AIPS 1:                                      HELP SMOOTH for details.
AIPS 1:
AIPS 1:                                      CLEAN map. See HELP.
AIPS 1: IN2NAME    '            '               Cleaned map name (name)
AIPS 1: IN2CLASS   '      '                     Cleaned map name (class)
AIPS 1: IN2SEQ        0                         Cleaned map name (seq. #)
AIPS 1: IN2DISK       0                         Cleaned map disk unit #
AIPS 1: INVERS        0                      CC file version #.
AIPS 1: NCOMP      *all 0                    # comps to use for model.
AIPS 1:                                      1 value per field
AIPS 1: NMAPS         0                      No. Clean map files
AIPS 1: CMETHOD    '    '                    Modeling method:
AIPS 1:                                      'DFT','GRID','    '
AIPS 1: CMODEL     '    '                    Model type: 'COMP','IMAG'
AIPS 1: SMODEL     *all 0                    Source model, 1=flux,2=x,3=y
AIPS 1:                                      See HELP SMODEL for models.
AIPS 1:
```

```
AIPS 1:                                   Output uv data file.
AIPS 1: OUTNAME    '            '            UV file name (name)
AIPS 1: OUTCLASS   '      '                  UV file name (class)
AIPS 1: OUTSEQ        0                      UV file name (seq. #)
AIPS 1: OUTDISK       6                      UV file disk drive #
AIPS 1:
AIPS 1:                                   Solution control adverbs:
AIPS 1: REFANT        7                   Reference antenna
AIPS 1: SOLINT        0                   Solution interval (min)
AIPS 1: APARM      *all 0                 General parameters
AIPS 1:                                      1=min. no. antennas
AIPS 1:                                      2 > 0 => data divided
AIPS 1:                                      3 > 0 => avg. RR,LL
AIPS 1:                                      5 > 0 => avg. IFs.
AIPS 1:                                      6=print level, 1=good,
AIPS 1:                                        2 closure, 3 SNR
AIPS 1:                                      7=SNR cutoff (0=>5)
AIPS 1:                                      8=max. ant. # (no AN)
AIPS 1:                                      9 > 0 => pass failed soln
AIPS 1:
AIPS 1:                                   Phase-amplitude Parameters:
AIPS 1: SOLTYPE    '    '                 Soln type,'  ','L1','GCON'
AIPS 1: SOLMODE    'A&P '                 Soln. mode: 'A&P','P','P!A',
AIPS 1:                                   'GCON'
AIPS 1: SOLCON        0                   Gain constraint factor.
AIPS 1: MINAMPER      0                   Amplitude closure error
AIPS 1:                                   regarded as excessive in %
AIPS 1: MINPHSER      0                   Phase closure error regarded
AIPS 1:                                   as excessive in degrees
AIPS 1: CPARM      *all 0                 Phase-amp. parameters
AIPS 1:                                      2 >0 => normalize gain
AIPS 1:                                      3 avg. amp. closure err
AIPS 1:                                      4 avg. ph. closure err
AIPS 1:                                      5 >0 => scalar average
AIPS 1:
AIPS 1: SNVER         0                   Output SN table, 0=>new table
AIPS 1: ANTWT      *all 0                 Ant. weights (0=>1.0)
AIPS 1: GAINERR    *all 0                 Std. Dev. of antenna gains.
```

Set the flux scale of the phase calibrator with `GETJY`:

```
AIPS 1: GETJY     Task to determine source flux densities.
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    *all ' '                Source list to find fluxes
AIPS 1: SOUCODE    '    '                  Source "Cal codes"
AIPS 1: CALSOUR    '1331+305        '      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         0                    Input SN table, 0=>all.
```

Create your CL table from the SN table you just made using `CLCAL`. But you want to transfer only a single phase, so *boxcar* average over a length longer than your observing run. This takes out a single average phase and gain of the antennas, but preserves the time variations in the visibility phases due to the ionosphere.

```
AIPS 1: CLCAL     Task to manage SN and CL calibration tables
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    *all ' '                Source list to calibrate
AIPS 1: SOUCODE    '    '                  Source "Cal codes"
AIPS 1: CALSOUR    '1830-360        '      Cal sources for calibration
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                    Source qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                  Time range to calibrate
AIPS 1: SUBARRAY      0                    Subarray, 0=>all,
AIPS 1: ANTENNAS   *all 0                  Antennas selected, 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: OPCODE     '    '                     Operation 'MERG','CALI',
AIPS 1:                                       'SMOO','CALP'; ' ' => 'CALI'
AIPS 1: INTERPOL   'BOX '                     Interpolation function,
AIPS 1:                                       choices are:
AIPS 1:                                       '2PT','SIMP','AMBG','CUBE',
AIPS 1:                                       'SELF','POLY','MWF','BOX'
AIPS 1:                                       see HELP for more details.
AIPS 1: INTPARM      10          10           Interpolation parameters
AIPS 1:               0
AIPS 1: CUTOFF        0                       Interpolation limit in
AIPS 1:                                       time (min); 0=> no limit.
AIPS 1: SMOTYPE    '    '                     Data to smooth
AIPS 1: SNVER         0                       Input SN table, 0=>all.
AIPS 1: GAINVER       0                       Input Cal table 0=>1
AIPS 1: GAINUSE       0                       Output CAL table 0=>2
AIPS 1: REFANT        7                       Reference antenna 0=>pick.
```

SPLIT off the source of interest, applying the calibration:

```
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: SOURCES    'GC              '         Source list
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                       Source qualifier -1=>all
AIPS 1: CALCODE    '    '                     Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                     Time range to copy
AIPS 1: STOKES     '    '                     Stokes type to pass.
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: BIF           0                       Lowest IF number 0=>all
AIPS 1: EIF           0                       Highest IF number 0=>all
AIPS 1: BCHAN         0                       Lowest channel number 0=>all
AIPS 1: ECHAN         0                       Highest channel number
AIPS 1: SUBARRAY      0                       Subarray, 0=>all
AIPS 1: DOCALIB       1                       If >0 calibrate data
```

```
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       0                    Flag table version
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: SMOOTH     *all 0                  Smoothing function. See
AIPS 1:                                    HELP SMOOTH for details.
AIPS 1: OUTCLASS   'S-PC  '                Output UV file name (class)
AIPS 1: OUTSEQ        0                    Output UV file name (seq. #)
AIPS 1: OUTDISK       6                    Output UV file disk unit #.
AIPS 1: DOUVCOMP      1                    1 (T) => compressed data
AIPS 1: APARM      *all 0                  Control information:
AIPS 1:                                      1 = 1 => avg. freq. in IF
                                                      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
AIPS 1:                                      4 > 0 => calibrate weights
AIPS 1:                                      5 = 0 pass only xc data
AIPS 1:                                        = 1 pass xc and ac data
AIPS 1:                                        = 2 pass only ac data
AIPS 1:                                      6 > 0 add full source name
AIPS 1:                                            to header
AIPS 1: NPOINTS       4                    Number of chan. to average.
AIPS 1:                                    (used if APARM(1) = 1)
AIPS 1:                                    <= 0 -> ALL
AIPS 1: CHINC         1                    Channel incr. between output
AIPS 1:                                    channels (used if APARM(1)=1)
AIPS 1: CHANSEL    *all 0                  Array of channel start, stop,
AIPS 1:                                    and increment numbers to give
AIPS 1:                                    channels to be used when
AIPS 1:                                    averaging in frequency.
AIPS 1:                                    These are absolute channel
AIPS 1:                                    numbers, i.e. not relative
AIPS 1:                                    to BCHAN.
```

```
AIPS 1:                                      (used if APARM(1) = 2, 3)
```

You may now want to TVFLG this data base. For example load according to baseline length, flag based on some statistical test that does not flag based on amplitude alone (such as AMP-VECTOR-DIFF lest you lose your extended structure) and hack away any crap. See more tips on TVFLG in main text.

Use a good model of the source at P band to drive self-calibration on as short a time scale as your data allows. You could obtain the model by imaging the *u*-*v* data set from above (though you may have wanted to do this after a more normal run of CLCAL) and you can improve it with various traditional self-calibration passes, i.e., image the P-band field in the traditional way as best you can. When you have this really good model then use it to self-calibrate the *u*-*v* data base from above:

```
AIPS 1: CALIB:  Task to determine calibration for data.
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1:                                    Data selection (multisource):
AIPS 1: CALSOUR    *all ' '                Calibrator sources
AIPS 1: QUAL         -1                    Calibrator qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>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: TIMERANG   *all 0                  Time range to use.
AIPS 1: BCHAN         0                    Lowest channel number 0=>all
AIPS 1: ECHAN         0                    Highest channel number
AIPS 1: ANTENNAS   *all 0                  Antennas to select. 0=all
AIPS 1: DOFIT      *all 0                  Subset of ANTENNAS list
AIPS 1:                                    for which solns are desired.
AIPS 1:                                    0 => solve for all antennas
AIPS 1:                                    implied by ANTENNAS list
AIPS 1:                                    [except of course, REFANT]
AIPS 1: SUBARRAY      0                    Subarray, 0=>all
AIPS 1: UVRANGE       0           0        Range of uv distance for full
AIPS 1:                                    weight
AIPS 1: WTUV          0                    Weight outside UVRANGE 0=0.
AIPS 1:
AIPS 1:                                    Cal. info for input:
AIPS 1: DOCALIB      -1                    If >0 calibrate data
```

```
AIPS 1: GAINUSE       0                         CL table to apply.
AIPS 1: FLAGVER       0                         Flag table version
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: SMOOTH     *all 0                       Smoothing function. See
AIPS 1:                                         HELP SMOOTH for details.
AIPS 1:
AIPS 1:                                         CLEAN map. See HELP.
AIPS 1: IN2NAME    'SGRA,CD     '                 Cleaned map name (name)
AIPS 1: IN2CLASS   'ICLN  '                       Cleaned map name (class)
AIPS 1: IN2SEQ        1                           Cleaned map name (seq. #)
AIPS 1: IN2DISK       6                           Cleaned map disk unit #
AIPS 1: INVERS        0                         CC file version #.
AIPS 1: NCOMP      *all 0                       # comps to use for model.
AIPS 1:                                         1 value per field
AIPS 1: NMAPS         0                         No. Clean map files
AIPS 1: CMETHOD    '    '                       Modeling method:
AIPS 1:                                         'DFT','GRID','    '
AIPS 1: CMODEL     '    '                       Model type: 'COMP','IMAG'
AIPS 1: SMODEL     *all 0                       Source model, 1=flux,2=x,3=y
AIPS 1:                                         See HELP SMODEL for models.
AIPS 1:
AIPS 1:                                         Output uv data file.
AIPS 1: OUTNAME    '            '                 UV file name (name)
AIPS 1: OUTCLASS   'A&P1  '                       UV file name (class)
AIPS 1: OUTSEQ        0                           UV file name (seq. #)
AIPS 1: OUTDISK       6                           UV file disk drive #
AIPS 1:
AIPS 1:                                         Solution control adverbs:
AIPS 1: REFANT        7                         Reference antenna
AIPS 1: SOLINT        0.1667                    Solution interval (min)
AIPS 1: APARM      *all 0                       General parameters
AIPS 1:                                           1=min. no. antennas
AIPS 1:                                           2 > 0 => data divided
AIPS 1:                                           3 > 0 => avg. RR,LL
AIPS 1:                                           5 > 0 => avg. IFs.
AIPS 1:                                           6=print level, 1=good,
AIPS 1:                                             2 closure, 3 SNR
```

```
AIPS 1:                                      7=SNR cutoff (0=>5)
AIPS 1:                                      8=max. ant. # (no AN)
AIPS 1:                                      9 > 0 => pass failed soln
AIPS 1:
AIPS 1:                                   Phase-amplitude Parameters:
AIPS 1: SOLTYPE    '    '                 Soln type,'  ','L1','GCON'
AIPS 1: SOLMODE    'A&P '                 Soln. mode: 'A&P','P','P!A',
AIPS 1:                                   'GCON'
AIPS 1: SOLCON        0                   Gain constraint factor.
AIPS 1: MINAMPER      0                   Amplitude closure error
AIPS 1:                                   regarded as excessive in %
AIPS 1: MINPHSER      0                   Phase closure error regarded
AIPS 1:                                   as excessive in degrees
AIPS 1: CPARM      *all 0                 Phase-amp. parameters
AIPS 1:                                      2 >0 => normalize gain
AIPS 1:                                      3 avg. amp. closure err
AIPS 1:                                      4 avg. ph. closure err
AIPS 1:                                      5 >0 => scalar average
AIPS 1:
AIPS 1: SNVER         0                   Output SN table, 0=>new table
AIPS 1: ANTWT      *all 0                 Ant. weights (0=>1.0)
AIPS 1: GAINERR    *all 0                 Std. Dev. of antenna gains.
```

In this example I ran an A&P selfcal since my model was so good and the signal-to-noise so high that I decided I might as well tweak up my amplitudes based on my great model. However, if your gains from your first `CALIB` run were stable, it is probably safer in this step to run just a phase-only self-calibration, which is all you need. Especially with a 10-second `SOLINT`, since phases are less susceptible to poor signal-to-noise then A&P selfcal. So in general do the above step with phase-only self-calibration.

Set this aside. I call the SN table produced above PION because it is what the ionosphere is doing at P band. Move to your 74 MHz, line data base. I am going to assume that you have run `BPASS` on it, and it has a SN table with good gains that came from a `CALIB` run on Cyg A. (Make sure the model you used for the `CALIB` run has the same epoch of observation as the data you calibrated it with.) So this is all just as outlined above for normal 74 MHz calibration.

Now when you run `CLCAL`, do the same thing you did at 330 MHz, i.e., use a long *boxcar* to generate a CL table that has only one amplitude and one phase. Then proceed to run `FLGIT` as usual, applying this CL table and the BP table from `BPASS`. Average these data using `SPLAT` to whatever level you can tolerate for bandwidth smearing. In the example below I smear all the channels into a single continuum data base:

```
AIPS 1: SPLAT     Split/assemble the sources in single/multi source file
```

```
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    'GC              '      Source list
AIPS 1:            *rest ' '
AIPS 1: QUAL         -1                    Source qualifier -1=>all
AIPS 1: CALCODE    '    '                  Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                  Time range to copy
AIPS 1: STOKES     '    '                  Stokes type to pass.
AIPS 1:                                    Look HELP.
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: BIF           0                    Lowest IF number 0=>all
AIPS 1: EIF           0                    Highest IF number 0=>all
AIPS 1: BCHAN         3                    Lowest channel number 0=>all
AIPS 1: ECHAN        61                    Highest channel number
AIPS 1: SUBARRAY      0                    Subarray, 0=>all
AIPS 1: DOCALIB      -1                    If >0 calibrate data
AIPS 1: GAINUSE       3                    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       0                    Flag table version.
AIPS 1:                                    0 => highest numbered table
AIPS 1:                                    <0 => no flagging
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: SMOOTH     *all 0                  Smoothing function. See
AIPS 1:                                    HELP SMOOTH for details.
AIPS 1: OUTNAME    '            '          Output UV file name (name)
AIPS 1: OUTCLASS   '      '                Output UV file name (class)
AIPS 1: OUTSEQ        0                    Output UV file name (seq. #)
AIPS 1: OUTDISK       6                    Output UV file disk unit #.
AIPS 1: DOUVCOMP      1                    1 (T) => compressed data
AIPS 1: APARM         1        *rest 0     Control information:
AIPS 1:                                      1 = 1 => avg. freq. in IF
AIPS 1:                                        = 2 => avg IF's also
AIPS 1:                                        = 3 => average each
```

```
AIPS 1:                                         N channels. N is given
AIPS 1:                                         by CHANNEL
AIPS 1:                                     2 = Input avg. time (sec)
AIPS 1:                                     3 > 0 => Drop subarrays
AIPS 1:                                     4 > 0 => calibrate weights
AIPS 1:                                     5 = 0 pass only xc data
AIPS 1:                                       = 1 pass xc and ac data
AIPS 1:                                       = 2 pass only ac data
AIPS 1:                                     6 > 0 add full source name
AIPS 1:                                           to header
AIPS 1:                                     7 = 0 assemble all selected
AIPS 1:                                           sources in one
AIPS 1:                                           multiple source file.
AIPS 1:                                       > 0 split for single
AIPS 1:                                           source files.
AIPS 1: CHANSEL    *all 0                 Array of channel start, stop,
AIPS 1:                                   and increment numbers to give
AIPS 1:                                   channels to be used when
AIPS 1:                                   averaging in frequency.
AIPS 1:                                   These are absolute channel
AIPS 1:                                   numbers, i.e. not relative
AIPS 1:                                   to BCHAN.
AIPS 1: CHANNEL       0                   Number of chans to average
AIPS 1:                                   together; if APARM(1) = 3
AIPS 1: SOLINT        0                   Time of averaging in sec.
AIPS 1:                                   0 => no averaging
```

Now TACOP the SN table from the PION P-band u-v data set to this SPLAT data base:

```
AIPS 1: TACOP     task to copy tables
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME     'GC            '        Input image name (name)
AIPS 1: INCLASS    'S-PC  '                Input image name (class)
AIPS 1: INSEQ         1                    Input image name (seq. #)
AIPS 1: INDISK        6                    Input image disk unit #
AIPS 1: INEXT      'SN'                    Input table extension type
AIPS 1: INVERS        1                    Input table file version no.
AIPS 1: NCOUNT        1                    Number of tables to consider
AIPS 1: OUTNAME    'GC4CBX10    '          Output image name (name)
```

```
AIPS 1: OUTCLASS   'SPLAT '                Output image name (class)
AIPS 1: OUTSEQ        1                    Output image name (seq. #)
AIPS 1: OUTDISK       6                    Output image disk unit #.
AIPS 1: OUTVERS       1                    Output table file version.
AIPS 1: KEYWORD    '        '              Header keyword to test
AIPS 1: KEYVALUE      0           0        Min., max. keyword value
AIPS 1: KEYSTRNG   '                '      Character keyword value
```

Run SNCOR to "transfer" these phases to 74 MHz:

```
AIPS 1: SNCOR     Task which applies various corrections to SN tables.
AIPS 1: Adverbs         Values           Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    *all ' '                Source list ' '=>all.
AIPS 1: STOKES     '    '                  Stokes type to process
AIPS 1: SELBAND      -1                    Bandwidth to select (kHz)
AIPS 1: SELFREQ      -1                    Frequency to select (MHz)
AIPS 1: FREQID       -1                    Freq. ID to select, 0=>all
AIPS 1: BIF           0                    Lowest IF number 0=>all
AIPS 1: EIF           0                    Highest IF number 0=>all
AIPS 1: TIMERANG   *all 0                  Time range to use.
AIPS 1: ANTENNAS   *all 0                  Antennas to correct.
AIPS 1: SUBARRAY      0                    Subarray; 0 => 1.
AIPS 1: SNVER         1                    SN table version to update
AIPS 1: OPCODE     'XFER'                  Operation code.See HELP
AIPS 1: SNCORPRM      0           0        Parameters (see HELP SNCOR).
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           1
AIPS 1: PHASPRM       0           0        Parameters for OPCODE=XFER
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
AIPS 1:               0           0           0           0
```

```
AIPS 1:                 0            0            0            0
AIPS 1:                 0            0          327.5        73.8
```

Use SPLIT to apply this SN table to your source:

```
AIPS 1: SPLIT     Task to split multi-source uv data to single source
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
[...]
AIPS 1: SOURCES    *all ' '                   Source list
AIPS 1: QUAL         -1                       Source qualifier -1=>all
AIPS 1: CALCODE    '    '                     Calibrator code '    '=>all
AIPS 1: TIMERANG   *all 0                     Time range to copy
AIPS 1: STOKES     '    '                     Stokes type to pass.
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: BIF           0                       Lowest IF number 0=>all
AIPS 1: EIF           0                       Highest IF number 0=>all
AIPS 1: BCHAN         0                       Lowest channel number 0=>all
AIPS 1: ECHAN         0                       Highest channel number
AIPS 1: SUBARRAY      0                       Subarray, 0=>all
AIPS 1: DOCALIB       1                       If >0 calibrate data
AIPS 1: GAINUSE       1                       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       0                       Flag table version
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: SMOOTH     *all 0                     Smoothing function. See
AIPS 1:                                       HELP SMOOTH for details.
AIPS 1: OUTCLASS   'XFER  '                   Output UV file name (class)
AIPS 1: OUTSEQ        0                       Output UV file name (seq. #)
AIPS 1: OUTDISK       6                       Output UV file disk unit #.
AIPS 1: DOUVCOMP      1                       1 (T) => compressed data
AIPS 1: APARM      *all 0                     Control information:
AIPS 1:                                         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
AIPS 1:                                      4 > 0 => calibrate weights
AIPS 1:                                      5 = 0 pass only xc data
AIPS 1:                                        = 1 pass xc and ac data
AIPS 1:                                        = 2 pass only ac data
AIPS 1:                                      6 > 0 add full source name
AIPS 1:                                            to header
AIPS 1: NPOINTS       0                    Number of chan. to average.
AIPS 1:                                    (used if APARM(1) = 1)
AIPS 1:                                    <= 0 -> ALL
AIPS 1: CHINC         1                    Channel incr. between output
AIPS 1:                                    channels (used if APARM(1)=1)
AIPS 1: CHANSEL    *all 0                  Array of channel start, stop,
AIPS 1:                                    and increment numbers to give
AIPS 1:                                    channels to be used when
AIPS 1:                                    averaging in frequency.
AIPS 1:                                    These are absolute channel
AIPS 1:                                    numbers, i.e. not relative
AIPS 1:                                    to BCHAN.
AIPS 1:                                    (used if APARM(1) = 2, 3)
```

Congratulations! you are done. `IMAGR` this u-v data base and, in principle, the ionosphere has been removed.

Appendix C

The Isoplanatic Patch

Believed to be about 4°, mainly a problem for the A array. Sources start disappearing when more than 4° from the field center. This scatters power in the map, and along with the real effect of resolving out many sources, a robust model is much more difficult to develop. If there is no bright source in the central 4° things get tough. But the short spacings still see enough flux that your Cyg A phase calibration should let you get a hold of something.

`UBAVG` is a task I am not very familiar with, it will average *u*-*v* data to reduce overly large data bases. Here's an example of a run someone helped me set up at some point.

Need to BT sort first, the TB sort when done.

```
AIPS 1: UBAVG:  Baseline dependent time averaging of "BT" order uv data
AIPS 1: Adverbs         Values            Comments
AIPS 1: ----------------------------------------------------------------
AIPS 1: INNAME     'GF4-BW9C-P3 '          Input UV data (name)
AIPS 1: INCLASS    'BT    '                Input UV data (class)
AIPS 1: INSEQ         1                    Input UV data (seq. #)
AIPS 1: INDISK        4                    Input UV data disk #
AIPS 1: OUTNAME    'GF4-BW9C-P3 '          Output uvdata name (name)
AIPS 1: OUTCLASS   '      '                Output uv data class
AIPS 1: OUTDISK       4                    Output uvdata disk #
AIPS 1: OUTSEQ        0                    Output seq. no.
AIPS 1: APARM        60          100       (1) max. time (sec)
AIPS 1:            *rest 0                 (2) = fov (min)
```

Appendix D

UVIEW—A Procedure for Viewing u-v Data

Torsten Enßlin has developed a PROCEDURE for examining the u-v data visually with the resolution in which one is interested. It simply FFTs a very-wide-field dirty image and calculates the amplitude and phase maps. With a sufficient high resolution one can see the individual baseline-tracks in the u-v-plane. Comparing them with plots produced by UVPLT can be a big help in finding bad data. For additional information, see the comments in the PROCEDURE itself.

Save the following as UVIEW.hex in the RUNFIL area, where hex is your extended hexadecimal AIPS number. If your extended hexadecimal number is not known, at the Unix level use EHEX number. Then within AIPS:

- RUN UVIEW
- GETN datafile
- IMSIZE=2048; CELLSIZE=-1
- UVIEW

The above choice for CELLSIZE specifies 1 wavelength per pixel resolution in the u-v map, which is a good choise for 74 MHz C-configuration data. The amplitude map will be loaded into the TV in a few minutes. The PROCEDURE can be sped up by using data that are averaged in frequency.

```
$ UVIEW
$
$ written 3rd August 1999 by Torsten A. Ensslin
$
$ Gives a view into the UV-plane
```

```
$
*. Produces maps of the UV data in amplitude, phase, real and
*. imagrinary, which at the location of the antenna tracks. Is useful for
*. finding bad spots in the data. Should be used in combination
*. with UVPLT, and UVFND.
*.
*. Assumes INNAME, INCLASS, INSEQ, INDI to point to the
*. (TB-sorted) UV-database. It is recommended to apply this
*. procedure  to a frequency averaged database, since then it is
*. much faster and can be used nearly interactively (on a fast machine).
*.
*. FLAGVER, TIMERANG, UVRANG should be set, if required. Many other
*. data selection parameter of IMAGR can be set by the user, too.
*.
*. The user should supply IMSIZE (recommended is 2048 2048) and CELLSIZE.
*. These determine the resolution in the UV plane.
*. Alternatively, the final resolution in the UV-plane can be
*. specified by setting CELLSIZE to the negative required UV
*. pixel distance in units of lambda.
*.
*. I recommend to produce several maps with different resolutions:
*. High resolution in order to see the tracks, low resolution to
*. see which spikes do survive the averaging and which cause
*. large-scale rolling in the final map.
*.
*. The resulting amplitude map is loaded into the AIPS-TV.
*. Note that the U-axis is horizontal, and the V-axis vertical.
*.
*. amplitude map: 'UVAMPL'
*. phase map    : 'UVPHAS'
*. real map     : 'UVREAL'
*. imaginary map: 'UVIMAG'
*.
*.
*.

PROC UVIEW
  SCALAR K
```

```
type 'procedure UVIEW is running'
type ' '
type ' '
type ' '


* Set the parameter for IMAGR;

task 'imagr'


 OUTNAME    '          '
 OUTSEQ        0
 IN2NAME    '             '
 IN2CLASS   '      '
 IN2SEQ        0
 IN2DISK       0


 IF (CELLSIZE(1)*CELLSIZE(2) = 0) then
    CELLSIZE(1) =100;
    CELLSIZE(2) =100;
 end

 IF (CELLSIZE(1) <= 0) THEN
    CELLSIZE(1)= -3600*180/(IMSIZE(1)*CELLSIZE(1)*3.1415927);
 END

 IF (CELLSIZE(2) <= 0) THEN
    CELLSIZE(2)= -3600*180/(IMSIZE(2)*CELLSIZE(2)*3.1415927);
 END


 type 'The UV-plane will be plotted with a resolution of'

 k = 3600 * 180/(CELLSIZE(1)*IMSIZE(1)*3.1415927)
 type k
 type 'lambda per pixel in u-direction and'

 k = 3600 * 180/(CELLSIZE(2)*IMSIZE(2)*3.1415927)
```

```
 type k
 type 'lambda per pixel in v-direction.'
 type ' '

 NFIELD        1
 DO3DIMAG      0
 FLDSIZE       0
 RASHIFT       0
 DECSHIFT      0
 UVTAPER       0           0


 k =3600*180/(sqrt(cellsize(1)**2 + cellsize(2)**2)*3*3.1415927*1000)
 IF UVRANG(2) = 0 THEN UVRANG(2) = k; END
 IF UVRANG(2) >= k THEN UVRANG(2) = k; END

 GUARD         0           0
 ROTATE        90

 UVWTFN     '  '
 UVSIZE        0           0
 ROBUST        0
 UVBOX         0
 XTYPE         5
 YTYPE         5
 XPARM      0
 YPARM      0
 NITER      0
 BCOMP      0
 NBOXES        0
 CLBOX       0
 BOXFILE    ' '
 OBOXFILE   ' '
 OVERLAP       0
 CMETHOD    '    '
 DOTV         -1

go imagr
wait imagr
```

```
* Set the parameter for FFT

task 'fft'
indi outdi
inseq  0
incl 'IMAP'
clr2na
opcode ''

go fft
wait fft

* Set the parameter for COMB


task  'COMB'
incl  'UVREAL'
in2na inname
in2cl 'UVIMAG'
in2di indi

clr3na
clr4na
doalign 1
blc 0
trc 0
opcode 'pola'
aparm 1 0
bparm 0
outcl 'UVPHAS'
go comb
wait comb

opcode 'poli'
outcl  'UVAMPL'
go comb
wait comb

incl 'UVAMPL'
```

```
type ' '
type ' '
type 'The amplitude map will now be loaded to TV.'
tvlod
tvfid

FINISH
```

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