ALMA Visibility Calibration

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The delivered ALMA data consist of the amplitudes and phases for the combined signals from pairs of antennas. These are called visibility data.

The goal of visibility calibration is to make the following corrections to the visibility data:

- Correct phase variations versus frequency
- Correct amplitude variations versus frequency
- Correct phase variations versus time
- Correct amplitude variations versus time

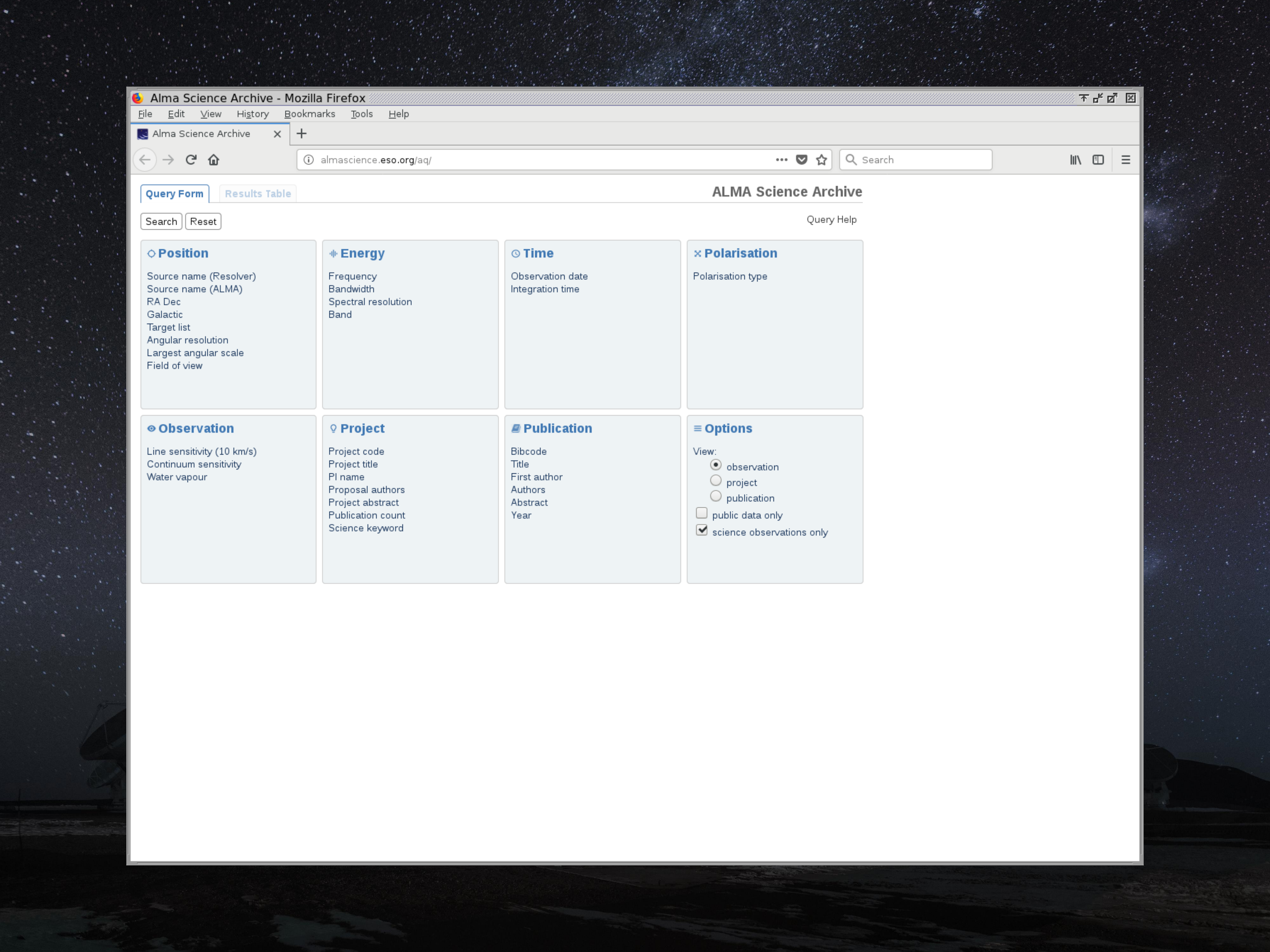
These corrections are derived from up to three different calibration sources.

The archive is accessible at http://almascience.eso.org/aq/ .

The web interface allows for multiple types of searches that will be shown in the next slide.

Data can be selected by individual Scheduling Blocks (SBs), which are observations with an individual array that achieve individual Science Goals.

The downloads come in tar format. The processed data as well as quality control and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Query Form
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Search
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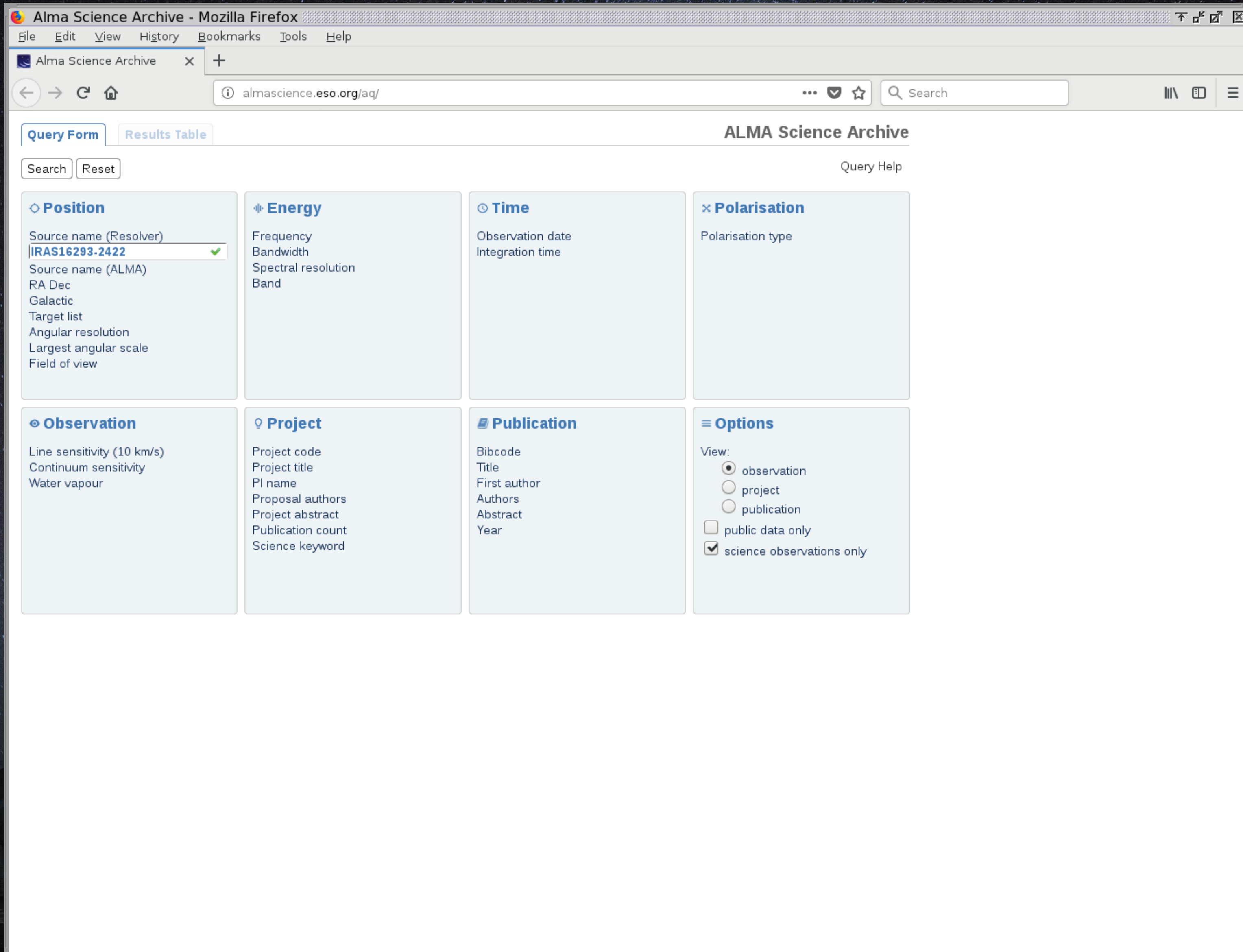
Query Help
Position
Source name (Resolver)
Source name (ALMA)
RA Dec
Galactic
Target list
Angular resolution
Largest angular scale
Field of view
Energy
Frequency
Bandwidth
Spectral resolution
Band
Time
Observation date
Integration time
Polarisation
Polarisation type
Observation
Line sensitivity (10 km/s)
Continuum sensitivity
Water vapour
Project
Project code
Project title
PI name
Proposal authors
Project abstract
Publication count
Science keyword
Publication
Bibcode
Title
First author
Authors
Abstract
Year
Options
View:
observation
project
publication
public data only
science observations only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Search
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Search
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Position
Source name (Resolver)
IRAS16293-2422
Source name (ALMA)
RA Dec
Galactic
Target list
Angular resolution
Largest angular scale
Field of view
Energy
Frequency
Bandwidth
Spectral resolution
Band
Time
Observation date
Integration time
Polarisation
Polarisation type
Observation
Line sensitivity (10 km/s)
Continuum sensitivity
Water vapour
Project
Project code
Project title
PI name
Proposal authors
Project abstract
Publication count
Science keyword
Publication
Bibcode
Title
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Year
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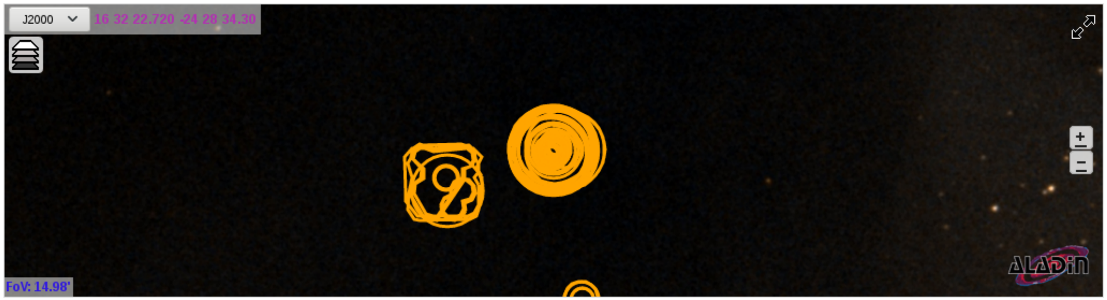

More columns Showing 104 of 104 rows.

	Project code	Source name	RA	Dec	Band	Integration	*Release date*	Velocity resolution	Frequency support	Pub
Filter:										
	2012.1.00712.S	IRAS_16293-2422	16:32:22.72	-24:28:34.3	6	2963.520	2015-06-12	291.90	231.03..250.74GHz	4
	2012.1.00712.S	IRAS_16293-2422	16:32:22.72	-24:28:34.3	6	2903.040	2015-07-10	304.14	221.77..240.65GHz	4
	2013.1.00061.S	IRAS16293_AB	16:32:22.75	-24:28:34.4	7	604.800	2015-07-25	230.73	303.88..319.00GHz	1
	2013.1.00061.S	IRAS16293_AB	16:32:22.75	-24:28:34.4	7	786.240	2015-07-29	226.90	310.48..324.04GHz	1
	2012.1.00712.S	IRAS_16293-2422	16:32:22.72	-24:28:34.3	3	1663.200	2015-07-30	353.87	89.49..103.41GHz	4
	2013.1.00061.S	IRAS16293-AB	16:32:22.75	-24:28:34.4	6	393.120	2015-11-13	302.43	225.82..243.13GHz	1
	2012.1.00178.S	L1689N	16:32:29.32	-24:28:59.3	7	847.198	2015-12-25	27.27	332.64..347.45GHz	1
	2012.1.00178.S	L1689N	16:32:29.32	-24:28:59.2	7	1450.414	2015-12-27	29.51	307.06..310.88GHz	1
	2013.1.00278.S	IRAS16293-2422	16:32:22.72	-24:28:34.3	7	2842.560	2016-02-05	411.82	353.51..355.46GHz	10
	2013.1.00352.S	IRAS16293-2422	16:32:22.72	-24:28:34.3	4	1874.880	2016-02-25	130.78	138.61..140.61GHz	1
	2013.1.00018.S	IRAS_16293-2422	16:32:22.78	-24:28:35.3	7	3749.760	2016-02-28	211.63	330.51..345.85GHz	0
	2013.1.00187.S	163223-24284	16:32:22.90	-24:28:37.1	3	60.480	2016-03-30	317.30	99.75..115.33GHz	1
	2013.1.00187.S	163229-24291	16:32:29.10	-24:29:07.2	3	60.480	2016-03-30	317.30	99.75..115.33GHz	1
	2013.1.00278.S	IRAS16293-2422	16:32:22.72	-24:28:34.3	7	1512.000	2016-04-16	432.35	336.67..338.58GHz	10
	2013.1.00278.S	IRAS16293-2422	16:32:22.72	-24:28:34.3	7	1179.360	2016-04-17	414.02	351.69..353.56GHz	10
	2013.1.00278.S	IRAS16293-2422	16:32:22.72	-24:28:34.3	7	786.240	2016-04-28	418.46	347.94..349.81GHz	10

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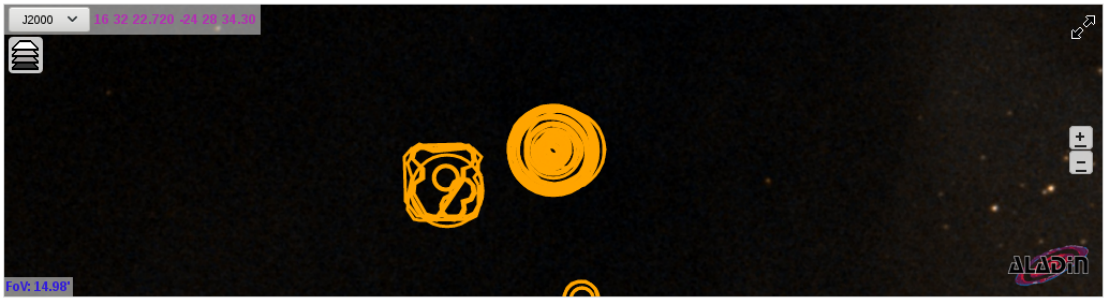
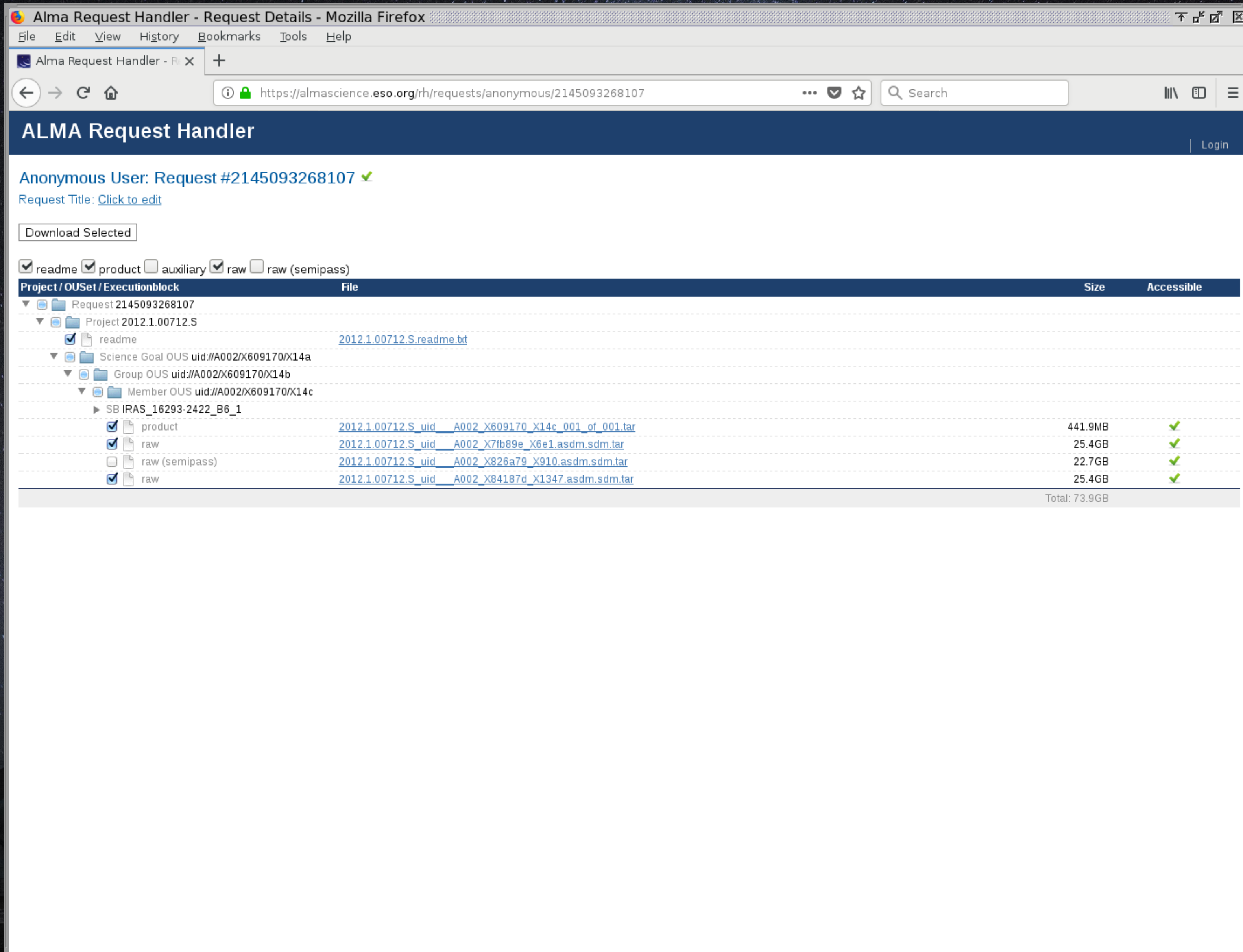


More columns Showing 104 of 104 rows.

	Project code	Source name	RA	Dec	Band	Integration	Release date	Velocity resolution	Frequency support	Pub
Filter:										
	2011.0.00007.SV	IRAS16293-2422	16:32:22.74	-24:28:32.5	4	3659.040	In Progress	248.55	145.11..159.16GHz	8
	2011.0.00007.SV	IRAS16293-2422-a	16:32:22.74	-24:28:32.5	9	2104.574	In Progress	415.16	686.56..705.19GHz	8
☐	2012.1.00178.S	L1689N	16:32:29.32	-24:28:59.3	7	847.198	2015-12-25	27.27	332.64..347.45GHz	1
☐	2012.1.00178.S	L1689N	16:32:29.32	-24:28:59.2	7	1450.414	2015-12-27	29.51	307.06..310.88GHz	1
☐	2012.1.00178.S	L1689N	16:32:29.32	-24:29:00.3	7	264.838	2016-07-14	54.53	332.77..347.42GHz	1
☐	2012.1.00178.S	L1689N	16:32:29.32	-24:29:01.1	7	160.701	2016-09-22	29.52	307.12..310.81GHz	1
☐	2012.1.00178.S	L1689N	16:32:29.17	-24:28:56.6	7	23218.560	2016-12-18	29.52	307.03..310.85GHz	1
☐	2012.1.00178.S	L1689N	16:32:29.17	-24:28:56.6	7	15553.728	2017-04-01	54.53	332.74..347.42GHz	1
☐	2012.1.00712.S	IRAS_16293-2422	16:32:22.72	-24:28:34.3	3	1663.200	2015-07-30	353.87	89.49..103.41GHz	4
☐	2012.1.00712.S	IRAS_16293-2422	16:32:22.72	-24:28:34.3	6	2963.520	2015-06-12	291.90	231.03..250.74GHz	4
☑	2012.1.00712.S	IRAS_16293-2422	16:32:22.72	-24:28:34.3	6	2903.040	2015-07-10	304.14	221.77..240.65GHz	4
☐	2013.1.00018.S	IRAS_16293-2422	16:32:22.78	-24:28:35.3	7	3749.760	2016-02-28	211.63	330.51..345.85GHz	0
☐	2013.1.00018.S	IRAS_16293-2422	16:32:22.78	-24:28:35.3	7	967.680	2016-05-04	210.67	334.53..350.03GHz	0
☐	2013.1.00018.S	IRAS_16293-2422	16:32:22.78	-24:28:35.3	7	937.440	2016-05-11	211.60	330.56..345.89GHz	0
☐	2013.1.00018.S	IRAS_16293-2422	16:32:22.78	-24:28:35.3	7	1905.120	2016-10-22	210.71	334.47..349.97GHz	0
☐	2013.1.00018.S	IRAS_16293-2422	16:32:22.78	-24:28:35.3	7	3749.760	2016-10-30	211.63	330.51..345.85GHz	0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https://almascience.eso.org/rh/requests/anonymous/2145093268107
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ALMA Request Handler
Login
Anonymous User: Request #2145093268107
Request Title: Click to edit
Download Selected
readme product auxiliary raw raw (semipass)
Project / OUSet / Executionblock File Size Accessible
Request 2145093268107
Project 2012.1.00712.S
readme 2012.1.00712.S.readme.txt
Science Goal OUS uid://A002/X609170/X14a
Group OUS uid://A002/X609170/X14b
Member OUS uid://A002/X609170/X14c
SB IRAS_16293-2422_B6_1
product 2012.1.00712.S_uid___A002_X609170_X14c_001_of_001.tar 441.9MB
raw 2012.1.00712.S_uid___A002_X7fb89e_X6e1.asdm.sdm.tar 25.4GB
raw (semipass) 2012.1.00712.S_uid___A002_X826a79_X910.asdm.sdm.tar 22.7GB
raw 2012.1.00712.S_uid___A002_X84187d_X1347.asdm.sdm.tar 25.4GB
Total: 73.9GB

The SB that contain the example dataset come in three files:

```
2012.1.00712.S_uid___A002_X609170_X14c_001_of_001.tar
2012.1.00712.S_uid___A002_X7fb89e_X6e1.asdm.sdm.tar
2012.1.00712.S_uid___A002_X84187d_X1347.asdm.sdm.tar
```

The first file contains the results from data processing and supporting files, including final images, logs, and quality assurance results.

The second and third files contain the raw data from individual Execution Blocks (EBs), which are self-contained observations.

This observations has two EBs (and a third semipass EB that did not pass quality assurance). For this tutorial, we will use the one ending in X6e1.

Directory structure after untarring files:

```
2012.1.00712.s
    science_goal.uid___A002_X609170_X14a
        group.uid___A002_X609170_X14b
            member.uid___A002_X609170_X14c
                calibration
                log
                product
                qa
                raw
                README
                script
```

Directory contents:

- `calibration`: Calibration plots and tables.
- `log`: Log files.
- `product`: Fully processed images.
- `qa`: Quality assurance data.
- `raw`: Raw data (ASDM format).
- `README`: Information from calibration and imaging as well as general file information.
- `script`: Data processing scripts.

Data downloaded from the archive can be reprocessed using the following command:

```
execfile(‘scriptForPI.py')
```

If the data were manually calibrated and imaged, these scripts will be available and can also be applied (after renaming some files).

If the data were pipeline-calibrated, executing `scriptForPI.py` is the fastest way to produce calibrated measurement sets.

If the data were pipeline-imaged, images are expected to be produced using `scriptForPI.py`.

ALMA and CASA data are stored in object oriented file systems, where a "file" is a directory that actually contains a series of ascii and binary files (some in subdirectories).

The scientific data in these datasets are the phases and amplitudes produced by the signals from pairs of antennas. These data are referred to as visibility data.

The raw ALMA data is in a format called ASDM.

To apply manual calibration scripts to data from the ALMA archive, it is usually necessary to rename the ASDM files to remove the ".asdm.sdm" suffix.

Contents of the example ASDM file:

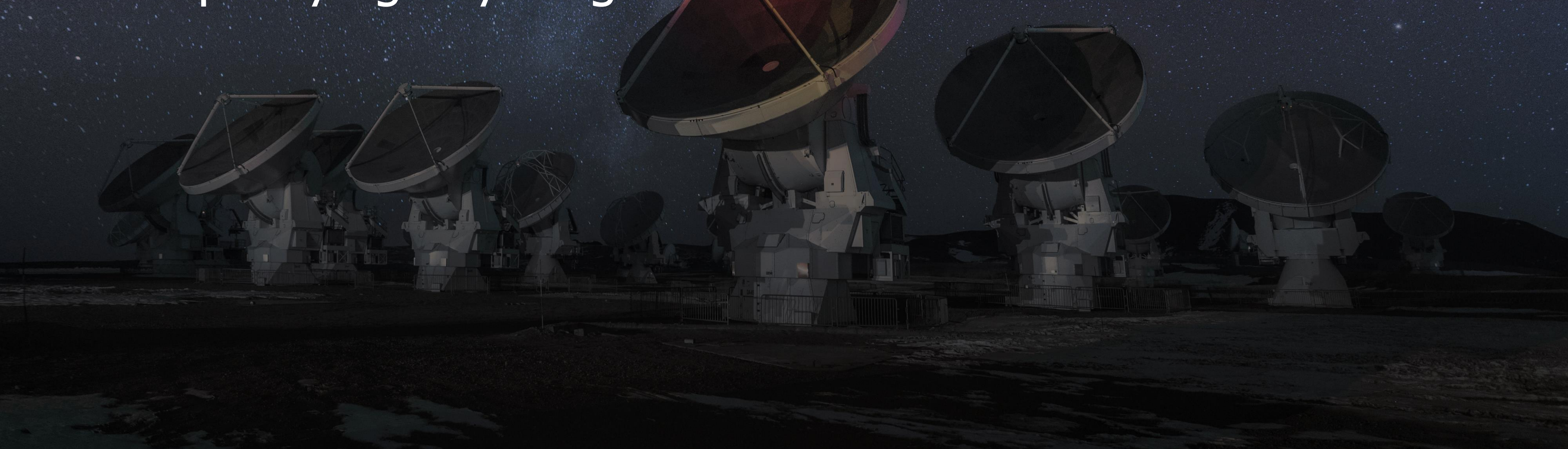
AlmaRadiometer.xml
Antenna.xml
ASDMBinary/
ASDM.xml
CalAmpli.xml
CalAtmosphere.bin
CalAtmosphere.xml
CalCurve.xml
CalData.xml
CalDevice.xml
CalFlux.xml
CalPhase.xml
CalPointing.xml
CalReduction.xml
CalSeeing.xml
CalWVR.xml
ConfigDescription.xml
CorrelatorMode.xml
DataDescription.xml
ExecBlock.xml
Feed.xml
Field.xml
Flag.xml
FocusModel.xml
Focus.xml
Main.xml
Pointing.bin
PointingModel.xml
Pointing.xml
Polarization.xml
Processor.xml
Receiver.xml
SBSummary.xml
Scan.xml
Source.xml
SpectralWindow.xml
State.xml
Station.xml
Subscan.xml
SwitchCycle.xml
SysCal.xml
Weather.xml

The calibration scripts we are using contain a series of steps. To execute individual step "N", enter the following commands into CASA:

```
mysteps=[N]
execfile('uid___A002_X7fb89e_X6e1.ms.scriptForCalibration.py')
```

Multiple commands can be executed at once.

Not specifying anything will execute all of the commands.



The rest of this presentation describes each calibration step in more detail.

The data processing steps can be divided into three broad groups:

0-1: Data import
2-8: A priori calibration
9-19: Calibration

Step 0: Import of the ASDM

The purpose of this step is to convert the data from its native ALMA format (the ASDM format) into a CASA measurement set format.

Contents of the example measurement set:

```
ANTENNA/                 OBSERVATION/       table.f14            table.f22_TSM1
ASDM_ANTENNA/            POINTING/          table.f15            table.f22_TSM2
ASDM_CALATMOSPHERE/      POLARIZATION/      table.f16            table.f23
ASDM_CALWVR/             PROCESSOR/         table.f17asdmindex   table.f23_TSM1
ASDM_CORRELATORMODE/     SOURCE/            table.f18            table.f23_TSM2
ASDM_RECEIVER/           SPECTRAL_WINDOW/   table.f19            table.f3
ASDM_SBSUMMARY/          STATE/             table.f2             table.f4
ASDM_SOURCE/             SYSCAL/            table.f20            table.f5
ASDM_STATION/            SYSPOWER/          table.f20_TSM0       table.f6
CALDEVICE/               table.dat          table.f21            table.f7
DATA_DESCRIPTION/        table.f1           table.f21_TSM1       table.f8
FEED/                    table.f10          table.f21_TSM2       table.f9
FIELD/                   table.f11          table.f21_TSM3       table.info
FLAG_CMD/                table.f12          table.f21_TSM4       table.lock
HISTORY/                 table.f13          table.f22            WEATHER/
```

Step 1: Fix SYSCAL table times

The system temperature (Tsys) measurements may include recording errors. Occasionally, multiple measurements have the same timestamp. This step corrects these errors.

Step 2: Listobs

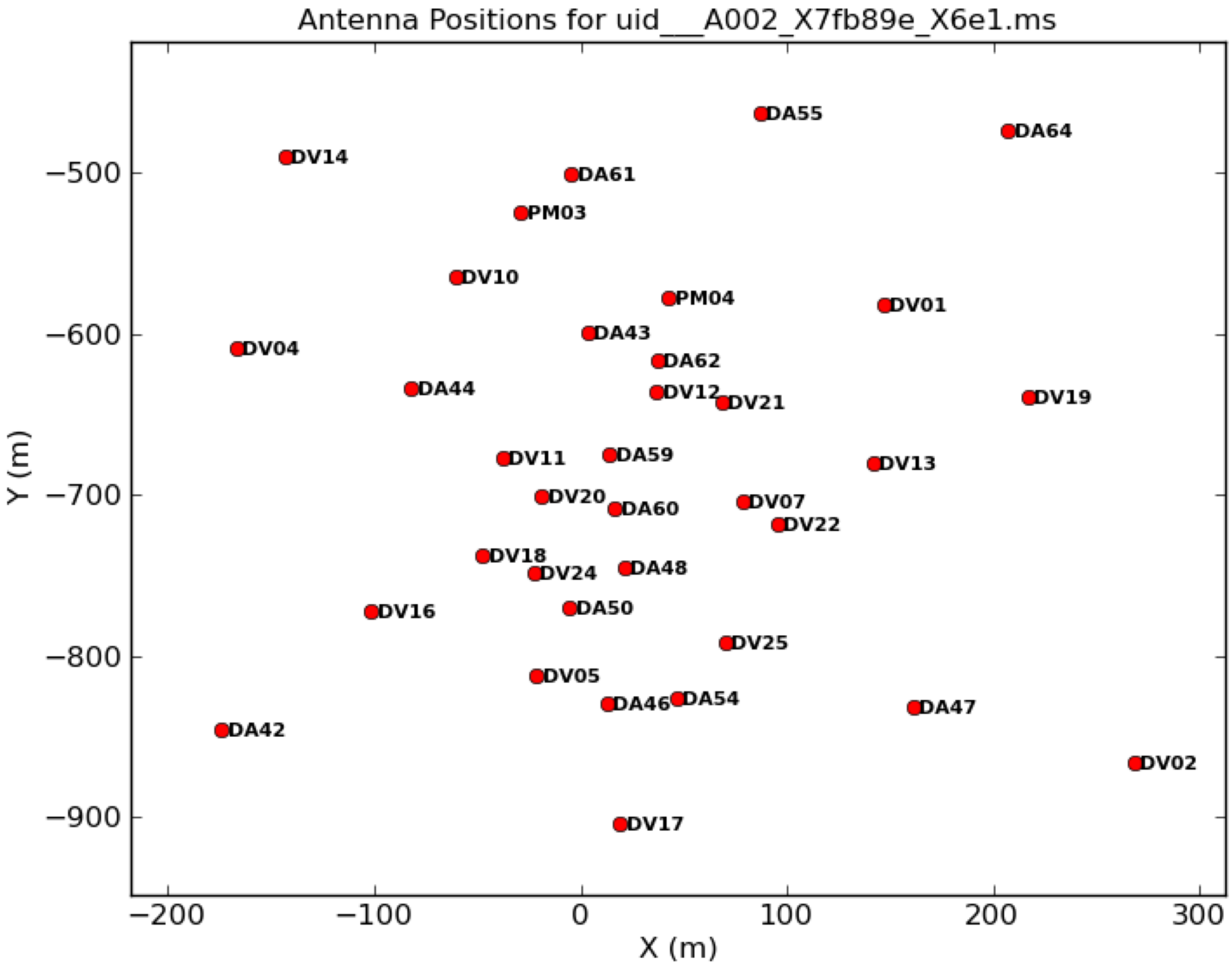
The listobs command will list a large amount of information about the observations. We run this step again later in step 9, so we will look at the listobs file in more detail then.

At this point in time, it would be useful to use plotants to produces a plot showing the locations of antennas in the array.

This is not included in standard calibration scripts, but it should be.

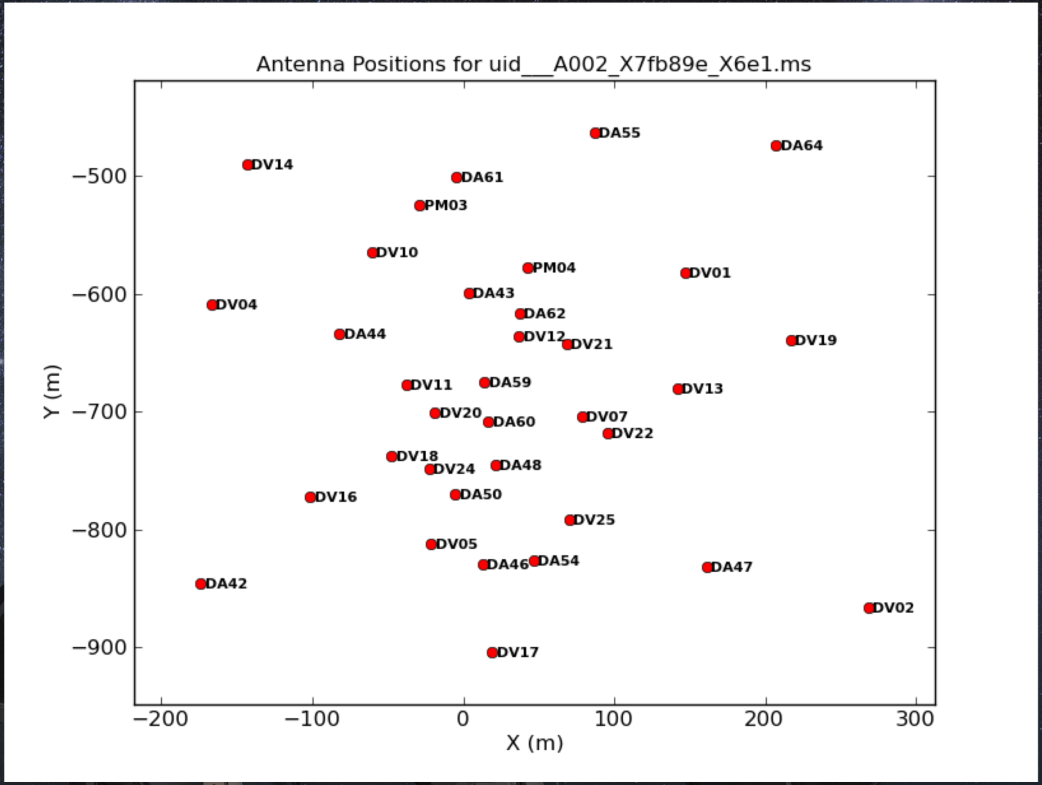
To execute this command, type the following:

```
plotants(vis='uid___A002_X7fb89e_X6e1.ms')
```


Antenna Positions for uid___A002_X7fb89e_X6e1.ms
Y (m)
X (m)
−500
−600
−700
−800
−900
−200
−100
0
100
200
300
DA55
DA64
DV14
DA61
PM03
DV10
PM04
DV01
DA43
DV04
DA62
DA44
DV12
DV21
DV19
DV11
DA59
DV13
DV20
DA60
DV07
DV22
DV18
DV24
DA48
DV16
DA50
DV25
DV05
DA46
DA54
DA47
DA42
DV02
DV17

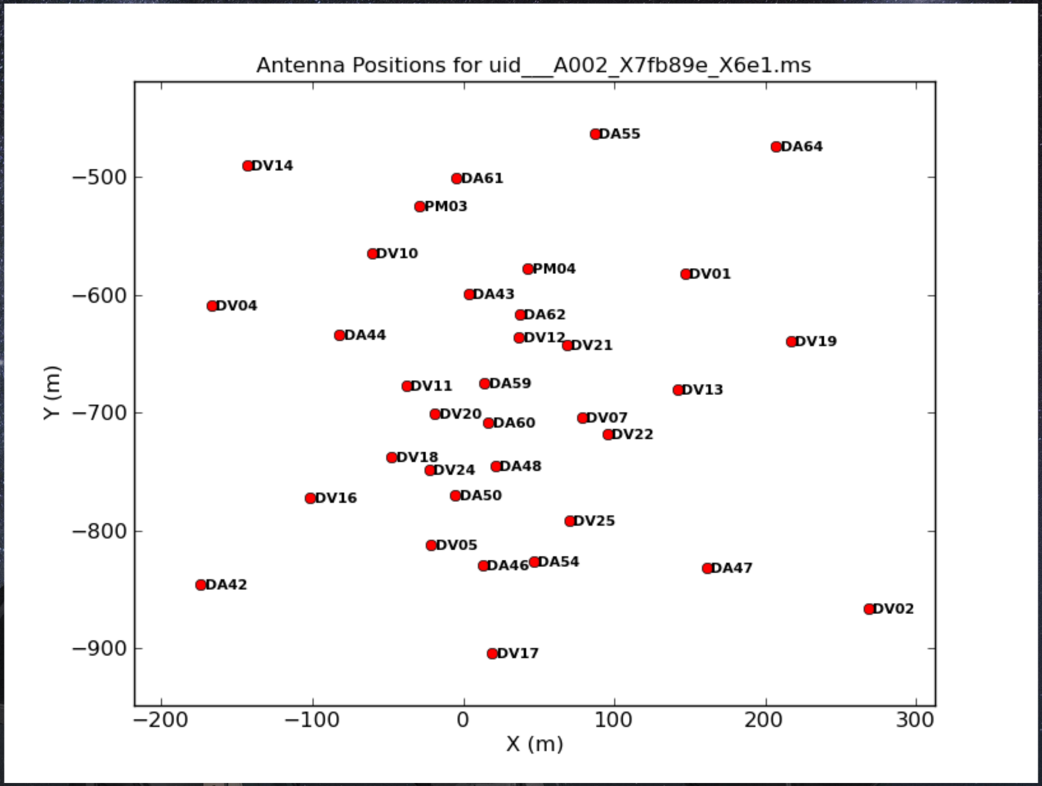
This plot can be used to select the reference antenna, which is used in many of the data processing steps.

The antenna needs to be from the centre of the array.



Antennas on long baselines will tend to produce noisier data than antennas on short baselines.

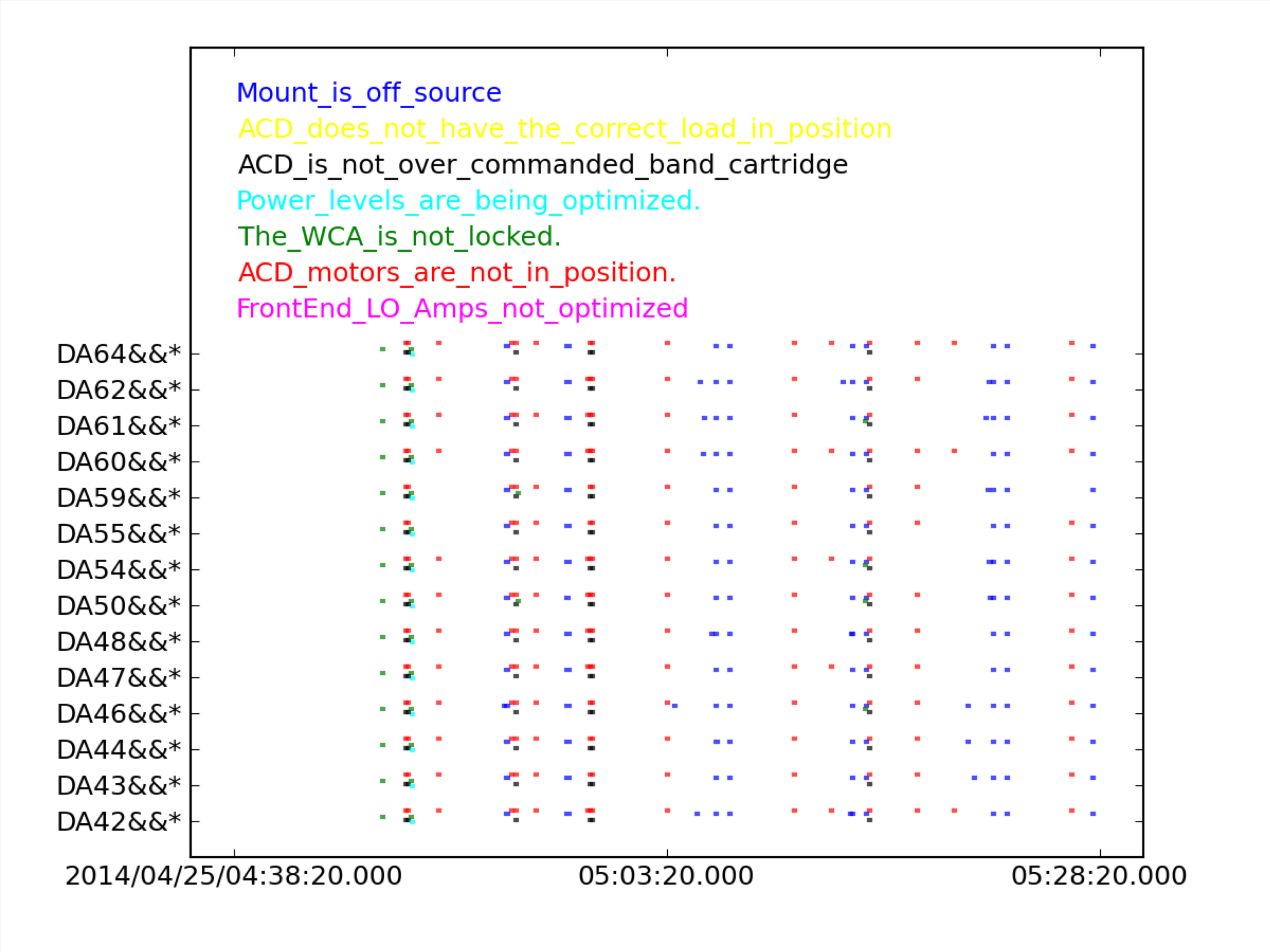
This figure can be used to diagnose these types of issues.



Step 3: A priori flagging

Some of the data are either not useful or not needed for the rest of the calibration and can be discarded. This includes the following:

- Autocorrelated data
- Pointing and atmosphere measurements
- Data taken when the telescope is not ready for observing (for example, the telescope is slewing, etc)

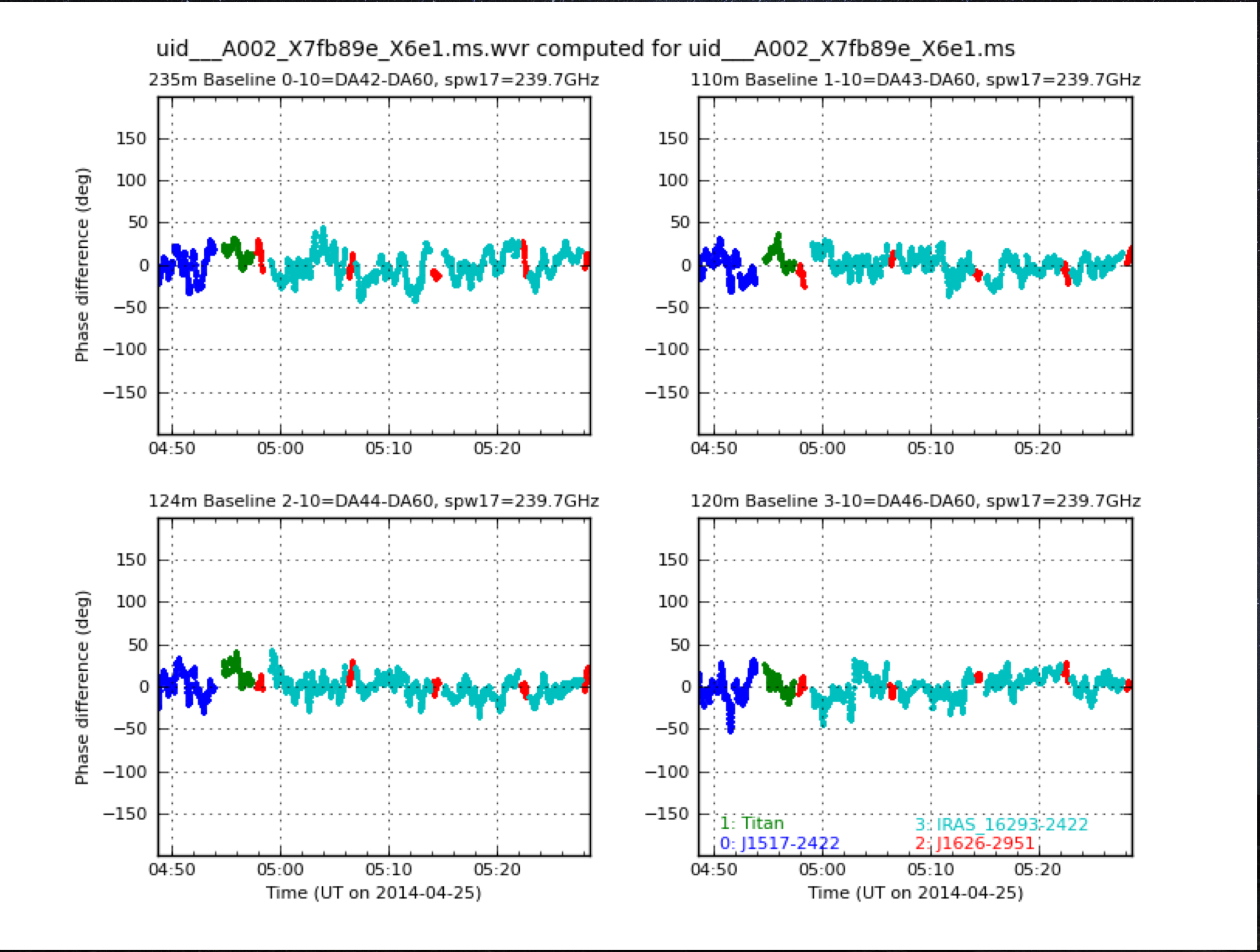


Mount_is_off_source
ACD_does_not_have_the_correct_load_in_position
ACD_is_not_over_commanded_band_cartridge
Power_levels_are_being_optimized.
The_WCA_is_not_locked.
ACD_motors_are_not_in_position.
FrontEnd_LO_Amps_not_optimized
DA64&&*
DA62&&*
DA61&&*
DA60&&*
DA59&&*
DA55&&*
DA54&&*
DA50&&*
DA48&&*
DA47&&*
DA46&&*
DA44&&*
DA43&&*
DA42&&*
2014/04/25/04:38:20.000
05:03:20.000
05:28:20.000

Step 4: Generation of the WVR calibration table

The water vapour radiometers (WVRs) produce measurements of the water vapour content of the atmosphere that can be used to correct for phase variations related to this.

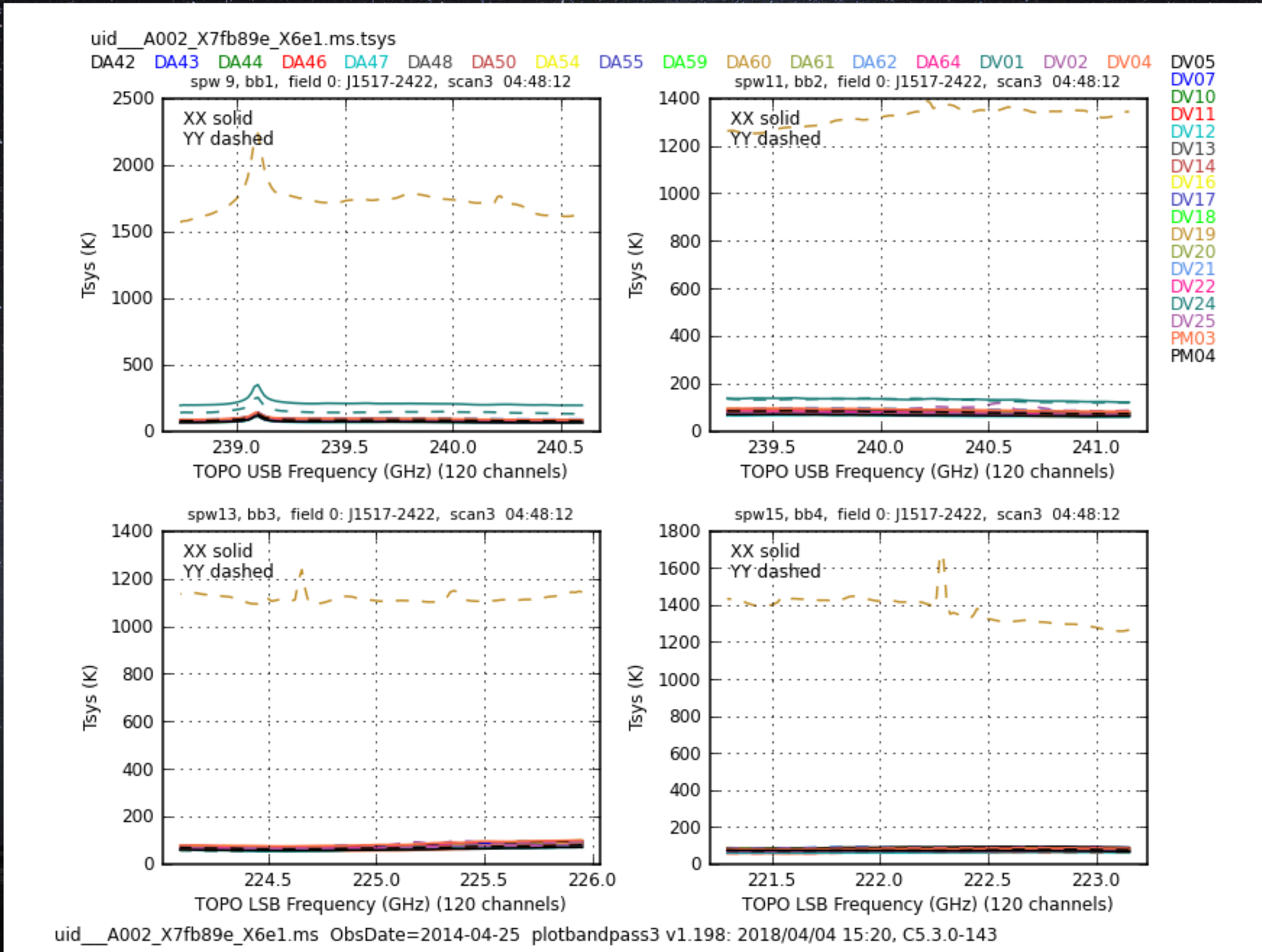
This steps generates calibration tables that correct the phases. The corrections are applied in step 7.

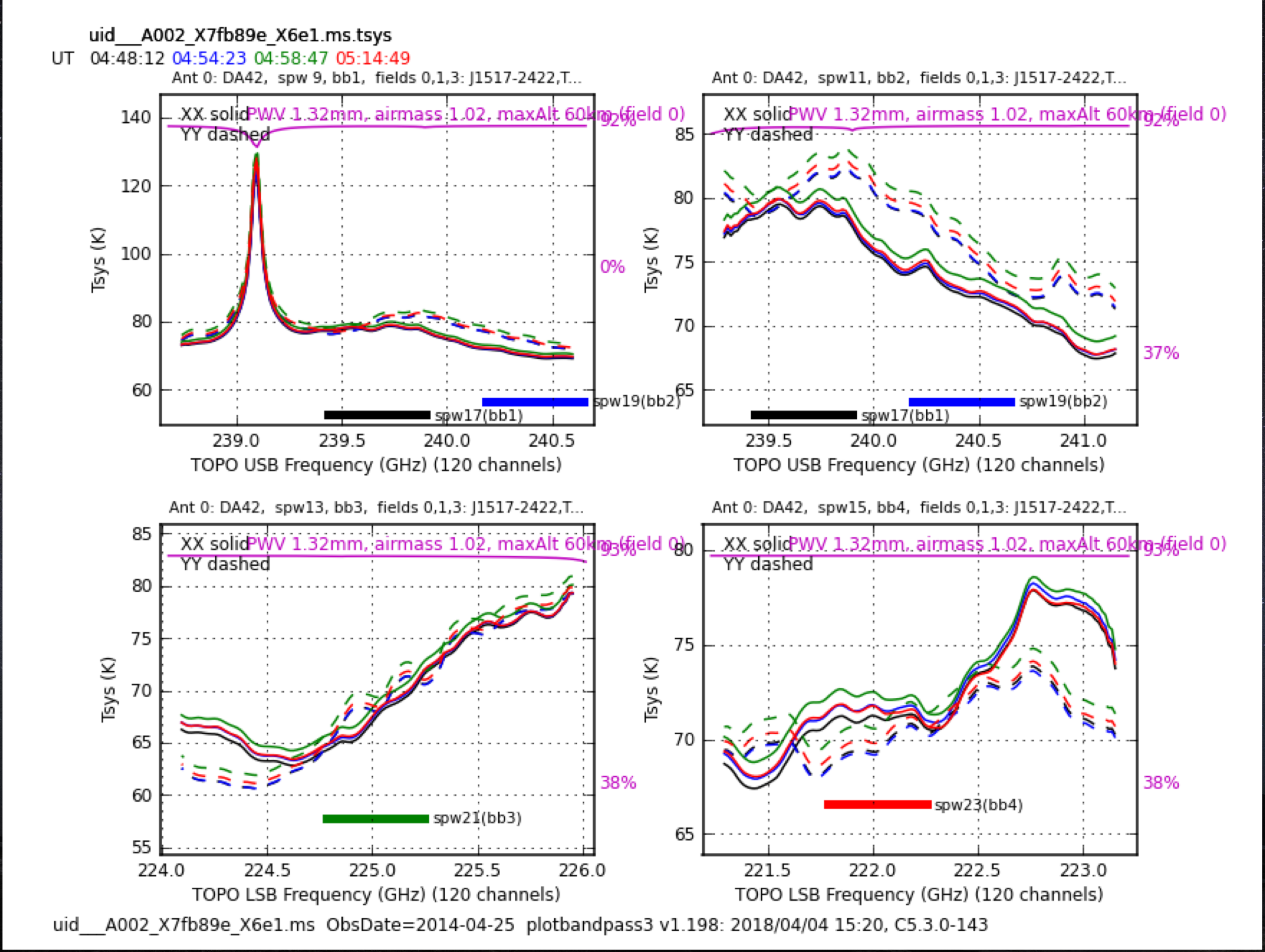

uid___A002_X7fb89e_X6e1.ms.wvr computed for uid___A002_X7fb89e_X6e1.ms
235m Baseline 0-10=DA42-DA60, spw17=239.7GHz
110m Baseline 1-10=DA43-DA60, spw17=239.7GHz
124m Baseline 2-10=DA44-DA60, spw17=239.7GHz
120m Baseline 3-10=DA46-DA60, spw17=239.7GHz
Phase difference (deg)
150
100
50
0
−50
−100
−150
04:50
05:00
05:10
05:20
Time (UT on 2014-04-25)
1: Titan
0: J1517-2422
3: IRAS_16293-2422
2: J1626-2951

Step 5: Generation of the Tsys calibration table

The system temperature (Tsys) measurements include measurements of the emission from the atmosphere and telescope.

This steps generates calibration tables that correct the amplitudes based on the Tsys data. The corrections are applied in step 7.


uid___A002_X7fb89e_X6e1.ms.tsys
DA42 DA43 DA44 DA46 DA47 DA48 DA50 DA54 DA55 DA59 DA60 DA61 DA62 DA64 DV01 DV02 DV04
DV05 DV07 DV10 DV11 DV12 DV13 DV14 DV16 DV17 DV18 DV19 DV20 DV21 DV22 DV24 DV25 PM03 PM04
spw 9, bb1, field 0: J1517-2422, scan3 04:48:12
spw11, bb2, field 0: J1517-2422, scan3 04:48:12
spw13, bb3, field 0: J1517-2422, scan3 04:48:12
spw15, bb4, field 0: J1517-2422, scan3 04:48:12
XX solid
YY dashed
Tsys (K)
TOPO USB Frequency (GHz) (120 channels)
TOPO LSB Frequency (GHz) (120 channels)
uid___A002_X7fb89e_X6e1.ms ObsDate=2014-04-25 plotbandpass3 v1.198: 2018/04/04 15:20, C5.3.0-143


uid___A002_X7fb89e_X6e1.ms.tsys
UT 04:48:12 04:54:23 04:58:47 05:14:49
Ant 0: DA42, spw 9, bb1, fields 0,1,3: J1517-2422,T...
XX solid
YY dashed
PWV 1.32mm, airmass 1.02, maxAlt 60km (field 0)
92%
0%
spw19(bb2)
spw17(bb1)
Tsys (K)
TOPO USB Frequency (GHz) (120 channels)
Ant 0: DA42, spw11, bb2, fields 0,1,3: J1517-2422,T...
XX solid
YY dashed
PWV 1.32mm, airmass 1.02, maxAlt 60km (field 0)
92%
37%
spw19(bb2)
spw17(bb1)
Tsys (K)
TOPO USB Frequency (GHz) (120 channels)
Ant 0: DA42, spw13, bb3, fields 0,1,3: J1517-2422,T...
XX solid
YY dashed
PWV 1.32mm, airmass 1.02, maxAlt 60km (field 0)
93%
38%
spw21(bb3)
Tsys (K)
TOPO LSB Frequency (GHz) (120 channels)
Ant 0: DA42, spw15, bb4, fields 0,1,3: J1517-2422,T...
XX solid
YY dashed
PWV 1.32mm, airmass 1.02, maxAlt 60km (field 0)
93%
38%
spw23(bb4)
Tsys (K)
TOPO LSB Frequency (GHz) (120 channels)
uid___A002_X7fb89e_X6e1.ms ObsDate=2014-04-25 plotbandpass3 v1.198: 2018/04/04 15:20, C5.3.0-143

Step 6: Generation of the antenna position calibration table

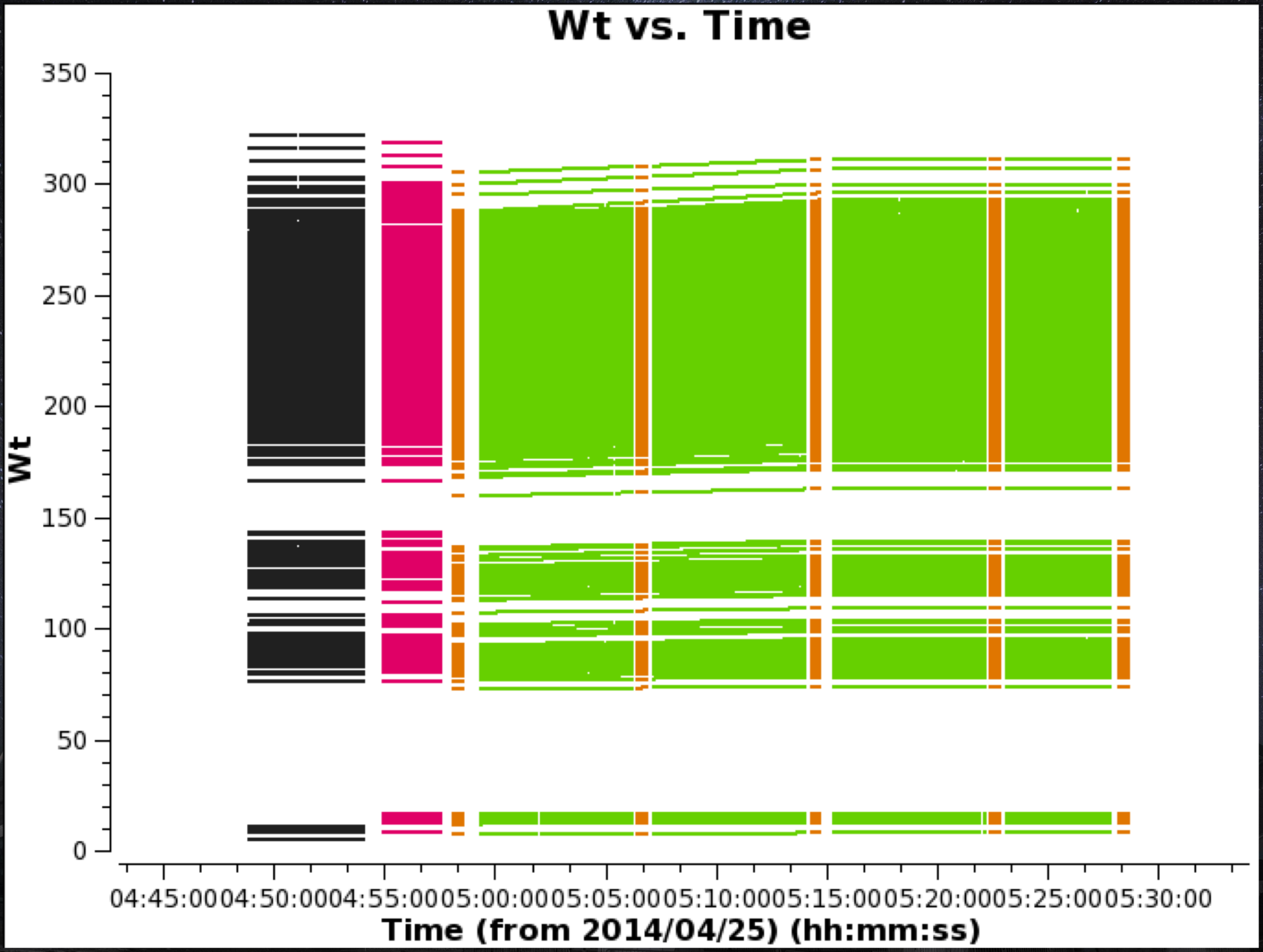
Corrections to antenna positions can be very important if the antennas are on long baselines. This step generates a calibration table that corrects the positions.

Sometimes, the corrections may be unnecessary. In this situation, a table filled with zeroes is created.

Step 7: Application of the WVR, Tsys, and antenna position calibration tables

The tables generated in steps 4, 5, and 6 are applied in this step.

This step also generates a plot of the weights for the data (which are applied when final images are created).



Wt vs. Time
Wt
350
300
250
200
150
100
50
0
04:45:00
04:50:00
04:55:00
05:00:00
05:05:00
05:10:00
05:15:00
05:20:00
05:25:00
05:30:00
Time (from 2014/04/25) (hh:mm:ss)

Step 8: Split out science spws

In this step, the data for the science and calibration sources is separated from the other data.

For the example dataset, the original measurement set included 25 spectral windows (spws), while the output from this step has only 4 spws.

This is the end of the a priori calibration.

Step 9: Listobs and save initial flags

The listobs command will list a large amount of information about the observations, including the following:

- Basic observation information (PI, project ID, dates, etc)
- List of the sequence of observations performed
- List of the fields
- List of the spectral windows
- List of the sources (the spectral windows for each field)
- List of the antennas

The other part of this step saves data related to flagging. This is done several times throughout the script.

Step 10: Initial flagging

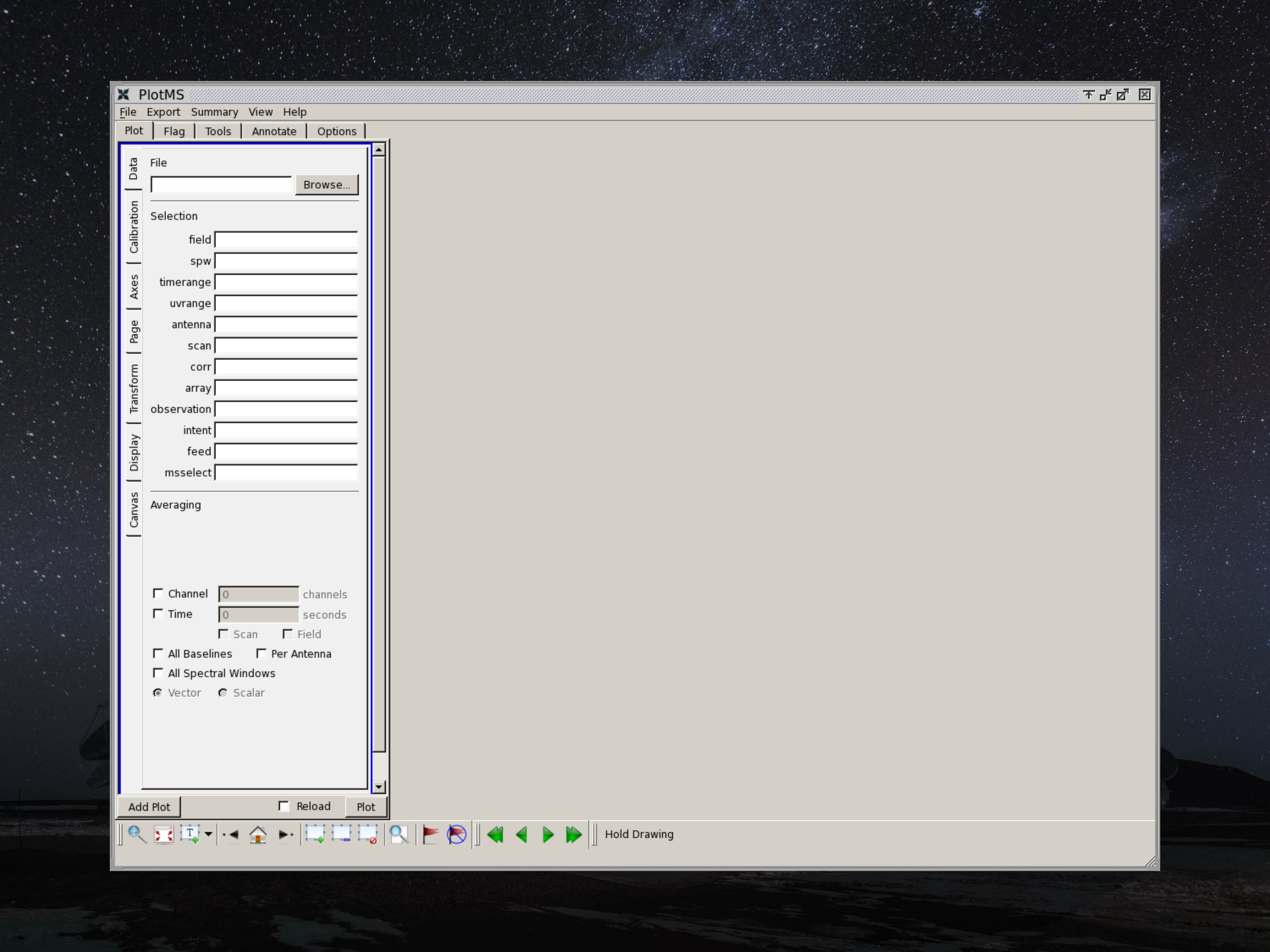
Any data that look abnormally noisy or are that are otherwise unusable are flagged (identified as bad) in this step and not used in any subsequent steps.

Standard scripts include flagdata commands to flag shadowed antennas (antennas that are blocked by other antennas). Additional commands to flag end channels for time domain data (data with 2 GHz spws and 128 channels) are also typically included when needed.

At this point, it is good to check the quality of the data with plotms, which can be run by typing this at the CASA command prompt.

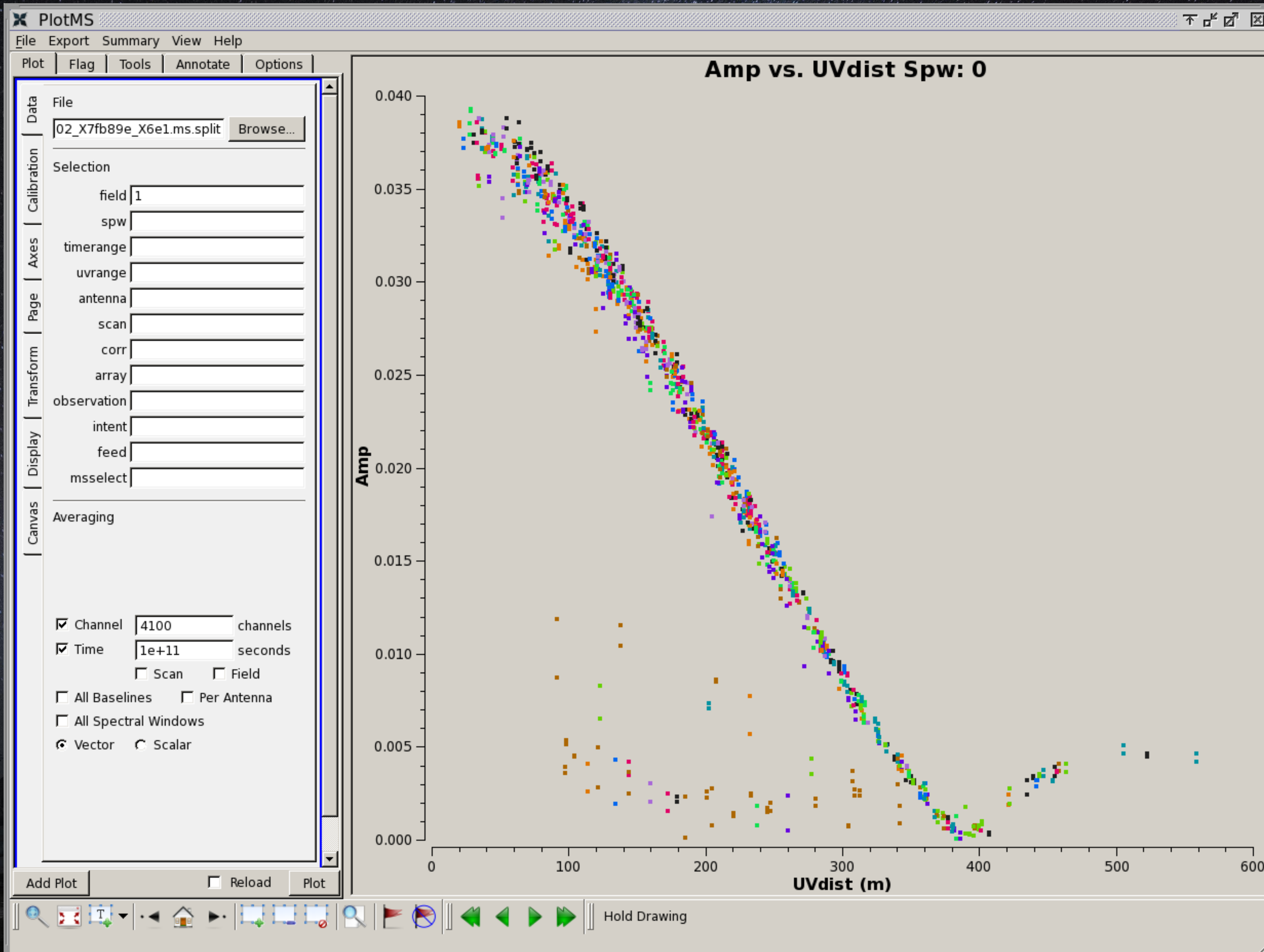
I recommend performing the following checks in the following order:

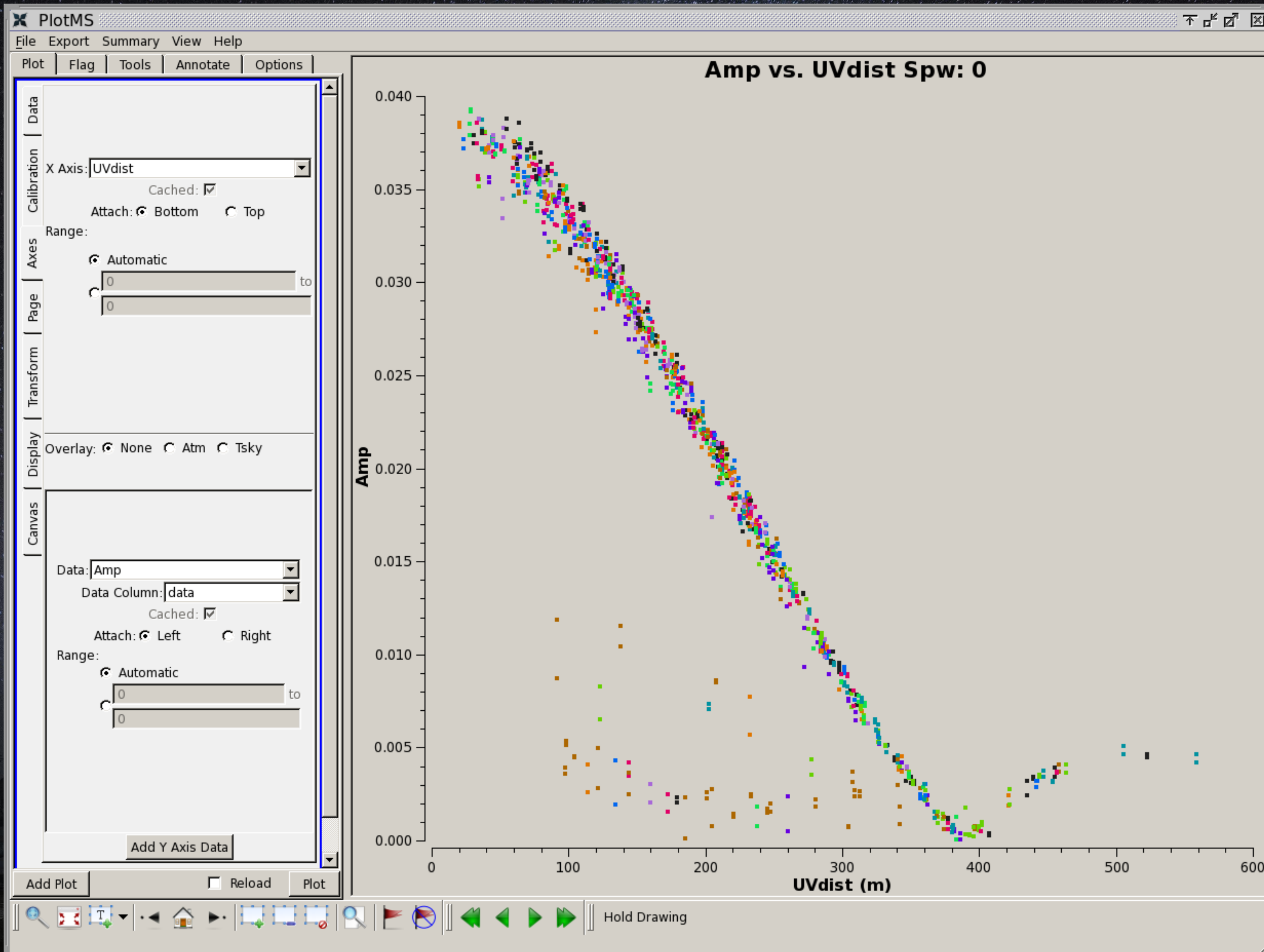
- Check amplitude versus uv distance for the amplitude or bandpass calibrator
- Check amplitude versus channel for the bandpass calibrator
- Check phase versus scan for the phase calibrator

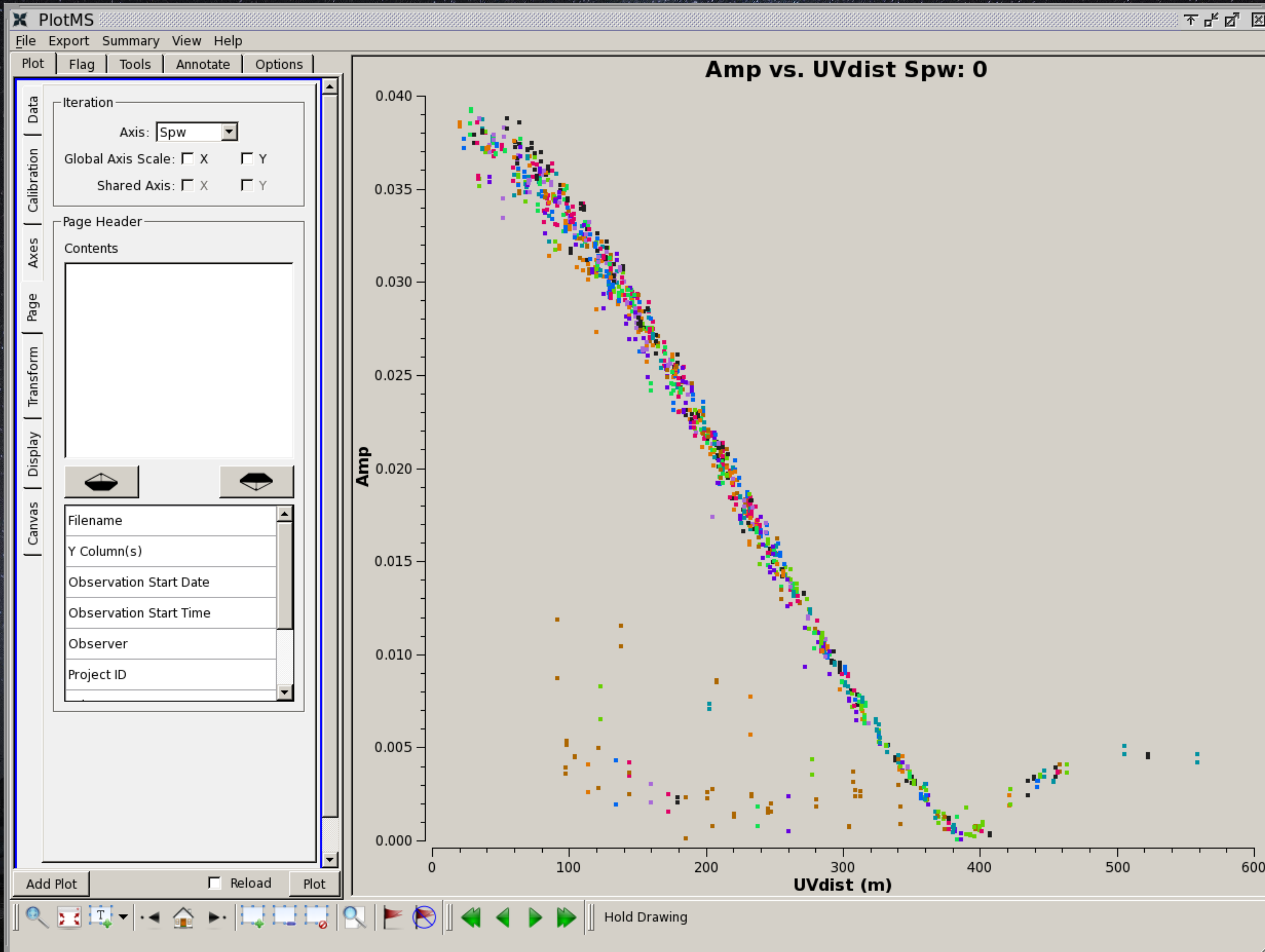

PlotMS
File
Export
Summary
View
Help
Plot
Flag
Tools
Annotate
Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
File
Browse...
Selection
field
spw
timerange
uvrange
antenna
scan
corr
array
observation
intent
feed
msselect
Averaging
Channel
0
channels
Time
0
seconds
Scan
Field
All Baselines
Per Antenna
All Spectral Windows
Vector
Scalar
Add Plot
Reload
Plot
Hold Drawing

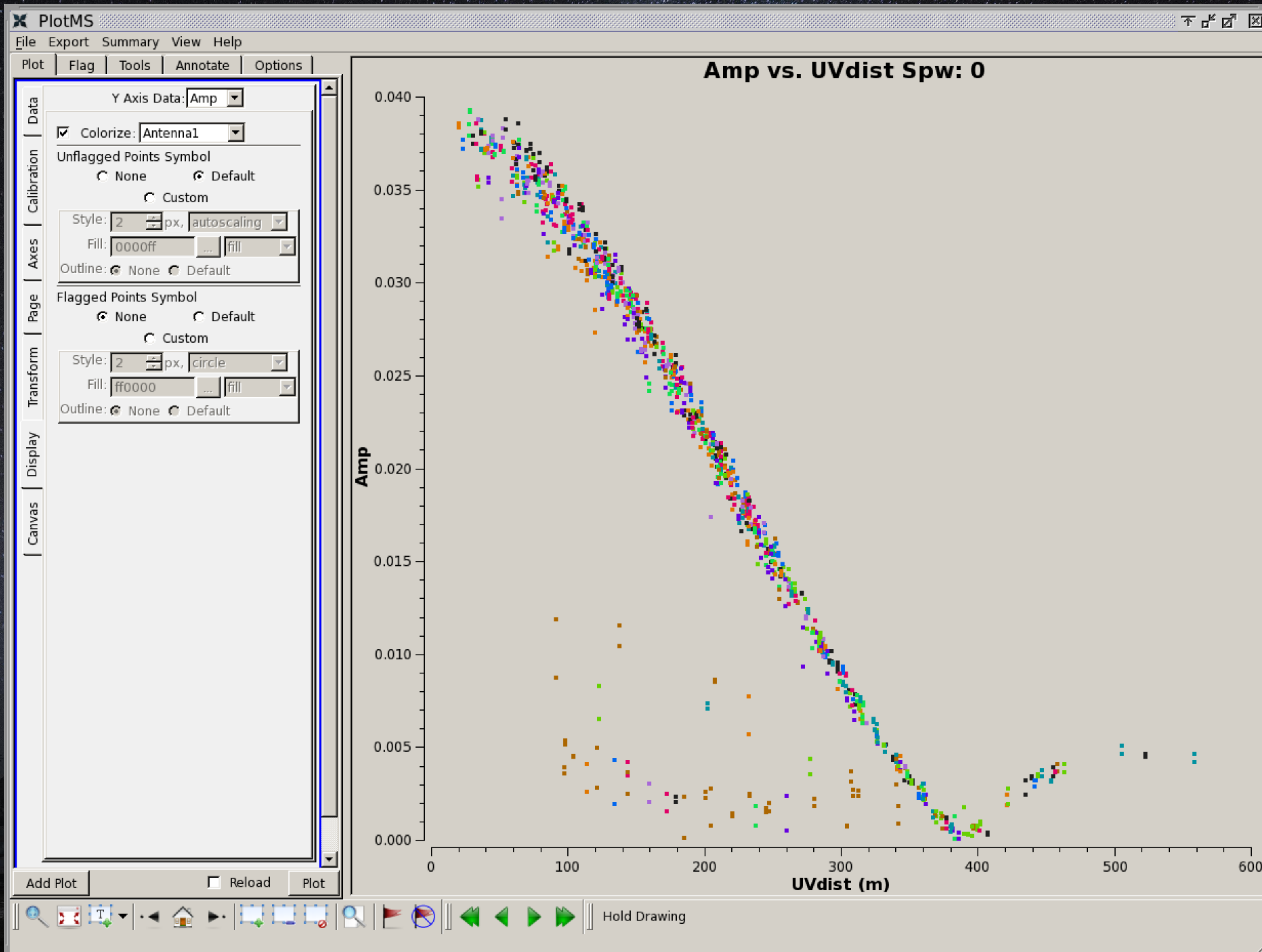
To check *amplitude versus uv distance*, set the following:

- Under the Data tab:
  - Set the file to the ms.split file created in step 8
  - Set the field to the number of the amplitude calibrator
  - Set channel averaging to 4100
  - Set time averaging to 1e11
- Under the Axes tab:
  - Set the x-axis to UVdist
  - Set the y-axis to Amp
- Under the Page tab:
  - Set axis to Spw
- Under the Display tab:
  - Set Colorize to Antenna1


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
File
02_X7fb89e_X6e1.ms.split
Browse...
Selection
field 1
spw
timerange
uvrange
antenna
scan
corr
array
observation
intent
feed
msselect
Averaging
Channel 4100 channels
Time 1e+11 seconds
Scan
Field
All Baselines
Per Antenna
All Spectral Windows
Vector
Scalar
Add Plot
Reload
Plot
Amp vs. UVdist Spw: 0
Amp
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
100
200
300
400
500
600
UVdist (m)
Hold Drawing


PlotMS
File
Export
Summary
View
Help
Plot
Flag
Tools
Annotate
Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
X Axis:
UVdist
Cached:
Attach:
Bottom
Top
Range:
Automatic
0
to
0
Overlay:
None
Atm
Tsky
Data:
Amp
Data Column:
data
Cached:
Attach:
Left
Right
Range:
Automatic
0
to
0
Add Y Axis Data
Add Plot
Reload
Plot
Hold Drawing
Amp vs. UVdist Spw: 0
Amp
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
100
200
300
400
500
600
UVdist (m)

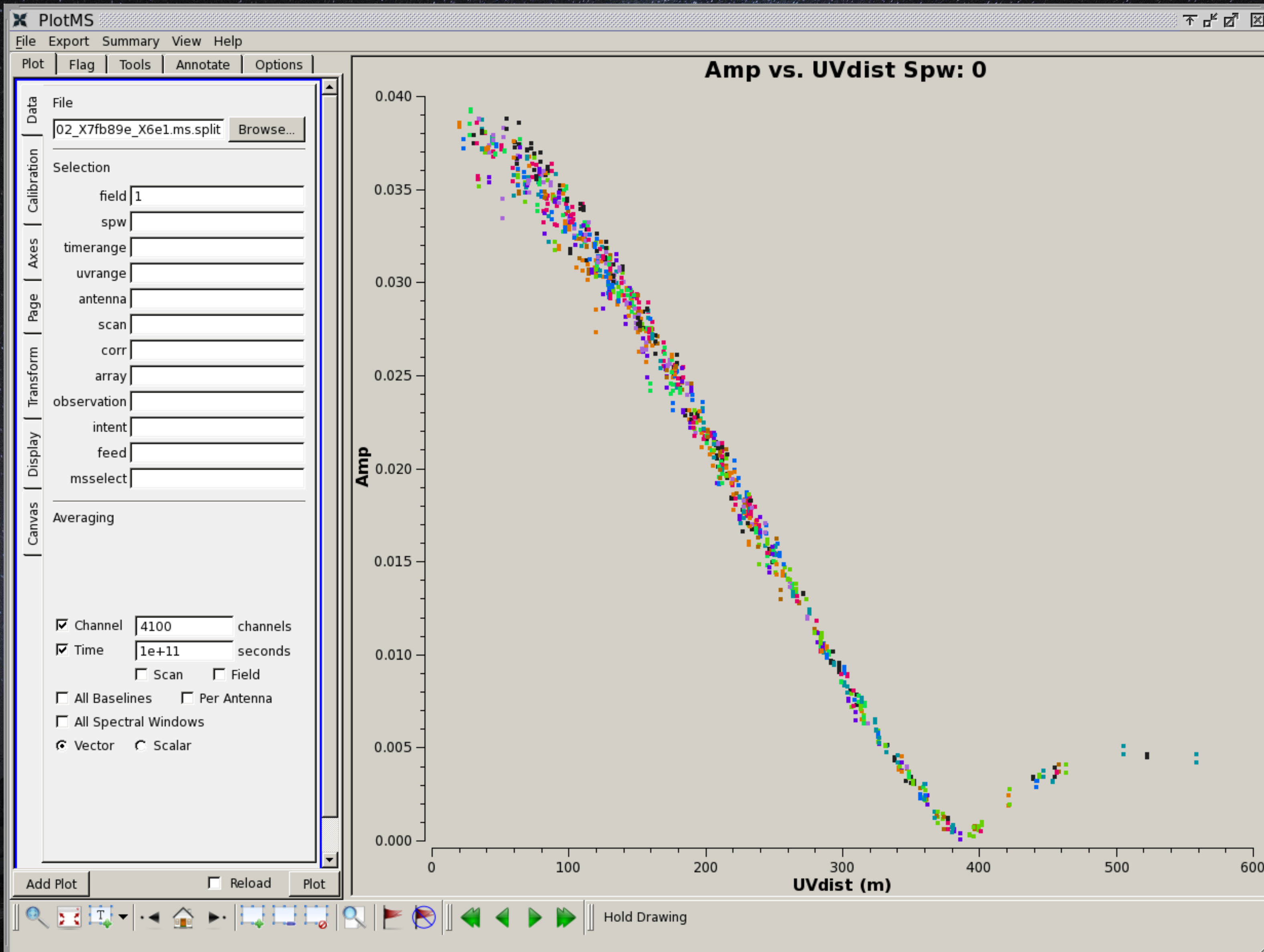

PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
Iteration
Axis: Spw
Global Axis Scale: X Y
Shared Axis: X Y
Page Header
Contents
Filename
Y Column(s)
Observation Start Date
Observation Start Time
Observer
Project ID
Add Plot
Reload
Plot
Amp vs. UVdist Spw: 0
Amp
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
100
200
300
400
500
600
UVdist (m)
Hold Drawing



PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
Y Axis Data: Amp
Colorize: Antenna1
Unflagged Points Symbol
None Default
Custom
Style: 2 px, autoscaling
Fill: 0000ff ... fill
Outline: None Default
Flagged Points Symbol
None Default
Custom
Style: 2 px, circle
Fill: ff0000 ... fill
Outline: None Default
Add Plot
Reload
Plot
Amp vs. UVdist Spw: 0
Amp
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
100
200
300
400
500
600
UVdist (m)
Hold Drawing

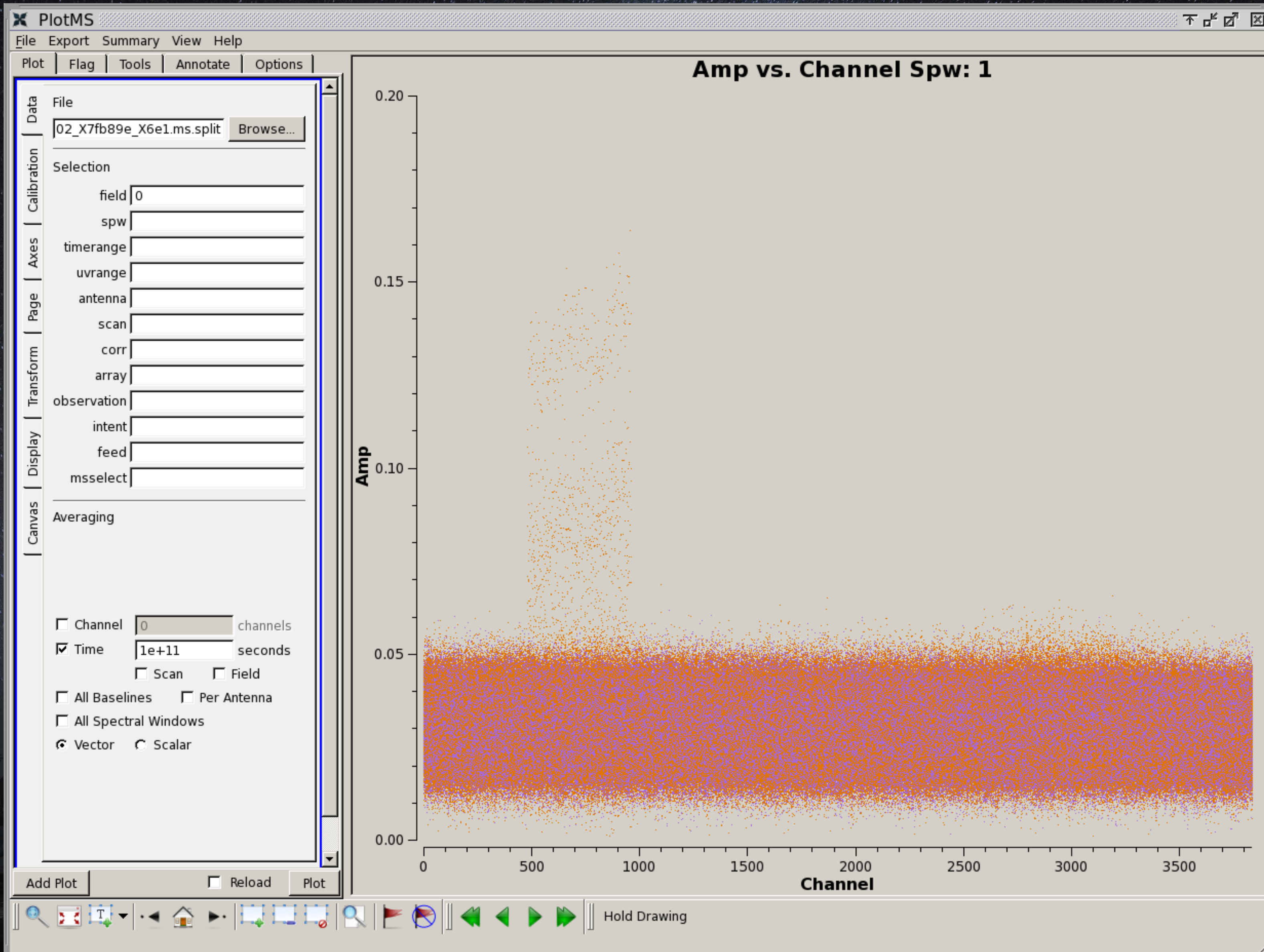
In the amplitude versus uv distance plots, most of the data should fall along a straight line (for unresolved or marginally resolved sources) or should follow something similar to a $sinc^2$ function (for resolved objects line Solar System objects).

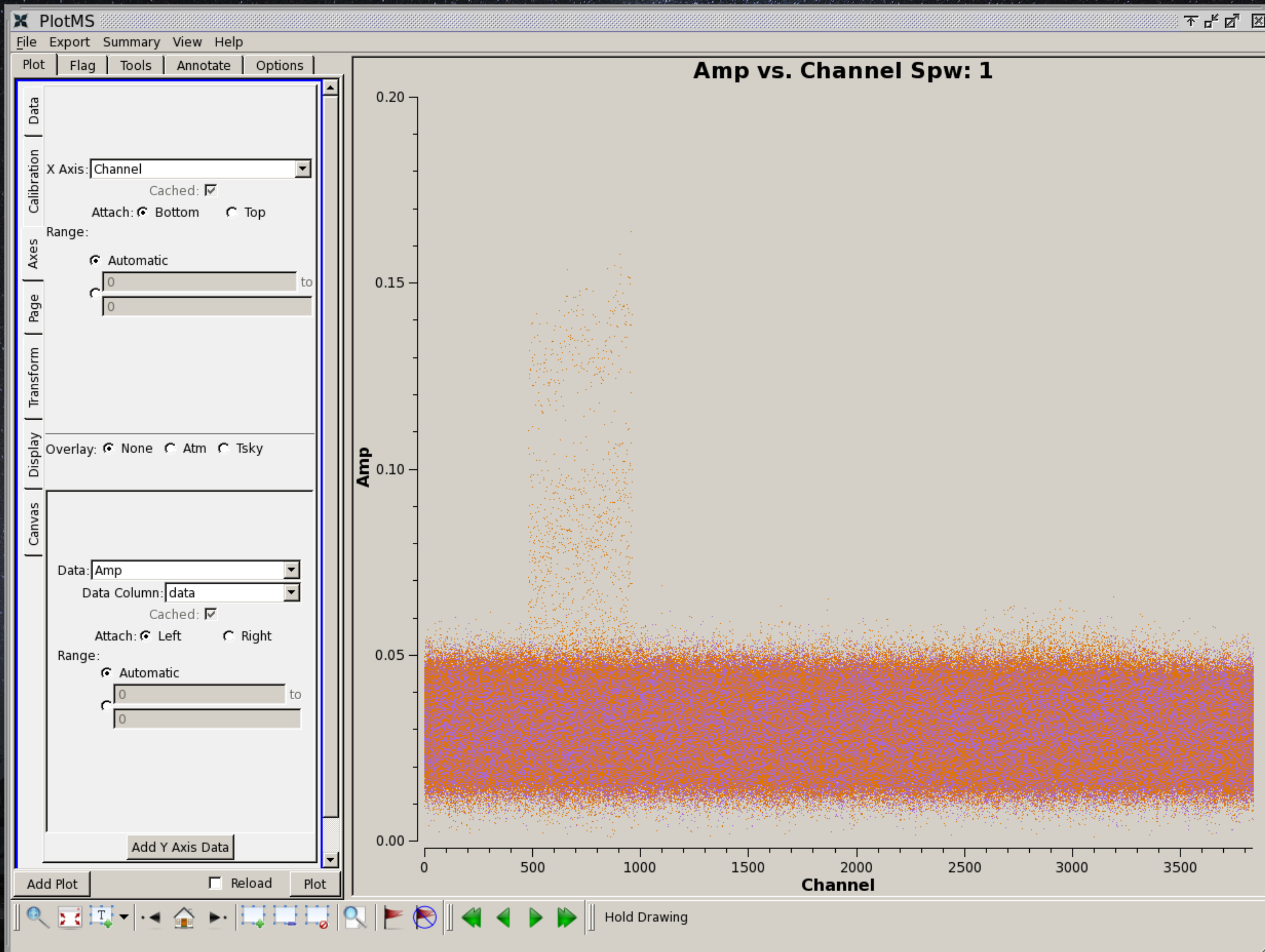
Data from bad antennas or baselines will appear as outliers from these trends.

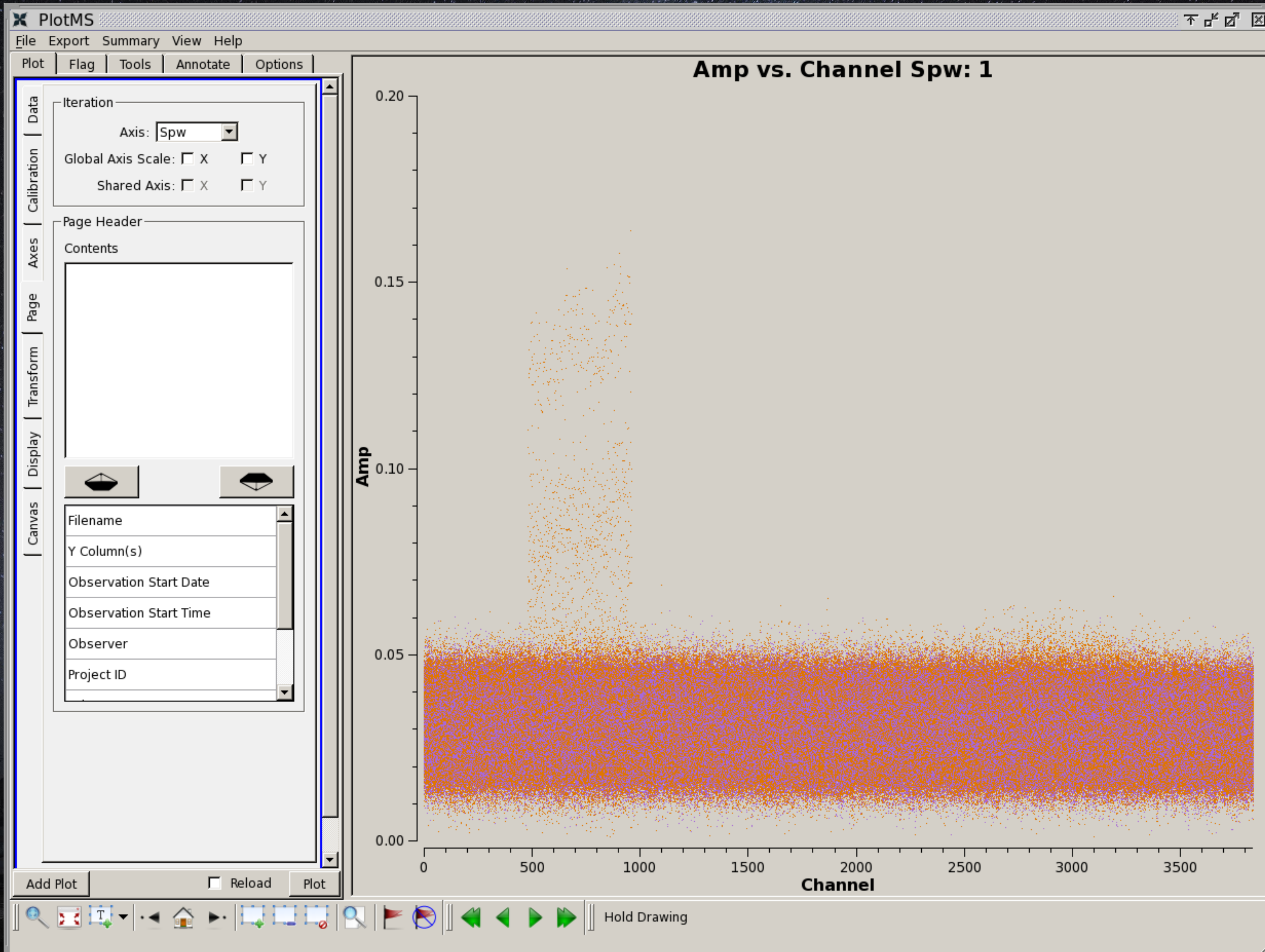

PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
File
02_X7fb89e_X6e1.ms.split
Browse...
Selection
field 1
spw
timerange
uvrange
antenna
scan
corr
array
observation
intent
feed
msselect
Averaging
Channel 4100 channels
Time 1e+11 seconds
Scan
Field
All Baselines
Per Antenna
All Spectral Windows
Vector
Scalar
Add Plot
Reload
Plot
Amp vs. UVdist Spw: 0
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Amp
0
100
200
300
400
500
600
UVdist (m)
Hold Drawing

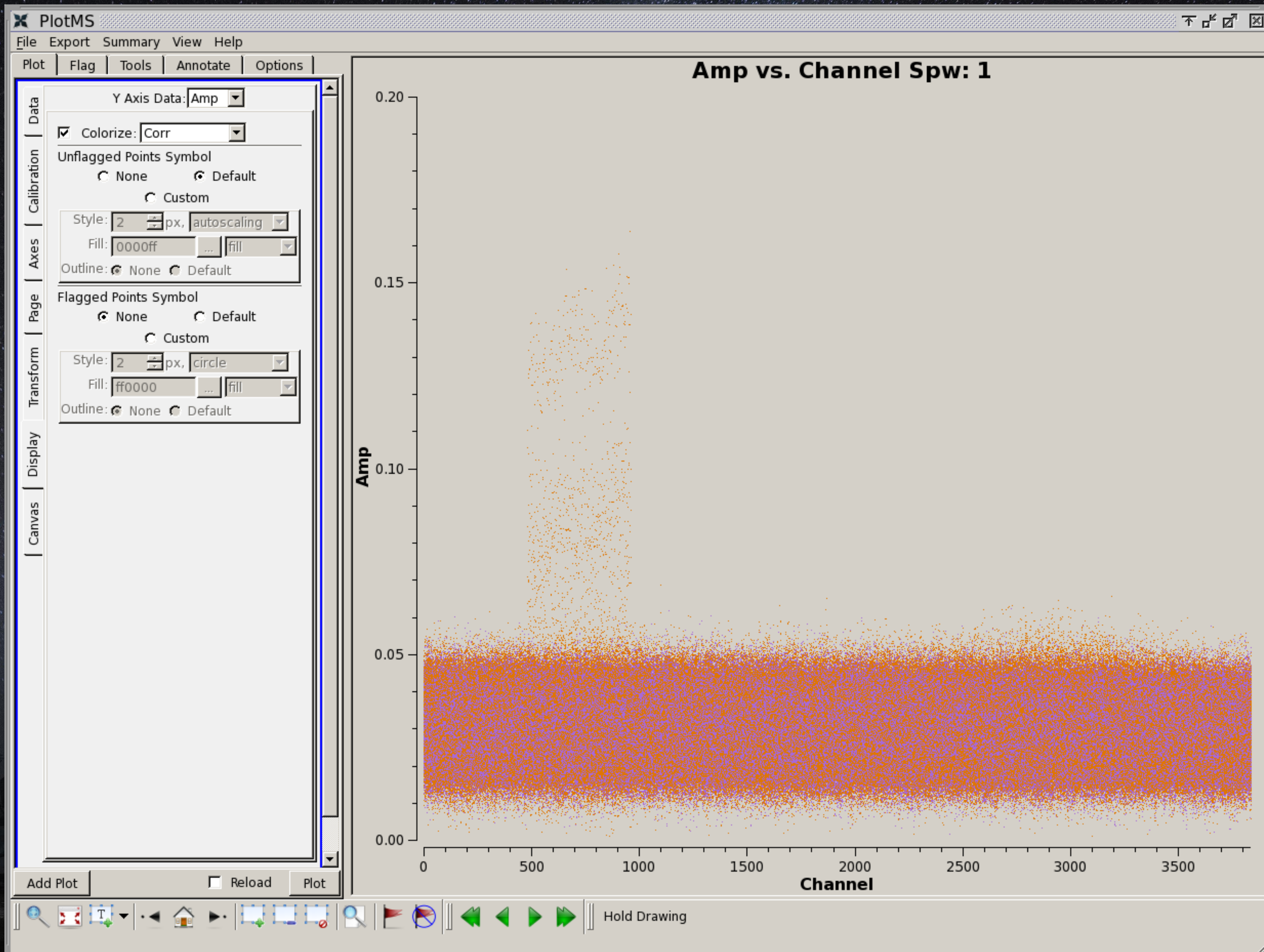
To check *amplitude versus channel*, set the following:

- Under the Data tab:
  - Set the file to the ms.split file created in step 8
  - Set the field to the number of the bandpass calibrator
  - Set time averaging to 1e11
- Under the Axes tab:
  - Set the x-axis to Channel
  - Set the y-axis to Amp
- Under the Page tab:
  - Set axis to Spw
- Under the Display tab:
  - Set Colorize to Corr (which will produce different colours for the XX and YY data)


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
File
02_X7fb89e_X6e1.ms.split
Browse...
Selection
field 0
spw
timerange
uvrange
antenna
scan
corr
array
observation
intent
feed
msselect
Averaging
Channel 0 channels
Time 1e+11 seconds
Scan Field
All Baselines Per Antenna
All Spectral Windows
Vector Scalar
Add Plot
Reload
Plot
Hold Drawing
Amp vs. Channel Spw: 1
Amp
0.00
0.05
0.10
0.15
0.20
Channel
0
500
1000
1500
2000
2500
3000
3500


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
X Axis: Channel
Cached:
Attach: Bottom Top
Range:
Automatic
0 to
0
Overlay: None Atm Tsky
Data: Amp
Data Column: data
Cached:
Attach: Left Right
Range:
Automatic
0 to
0
Add Y Axis Data
Add Plot
Reload
Plot
Hold Drawing
Amp vs. Channel Spw: 1
Amp
0.20
0.15
0.10
0.05
0.00
0 500 1000 1500 2000 2500 3000 3500
Channel

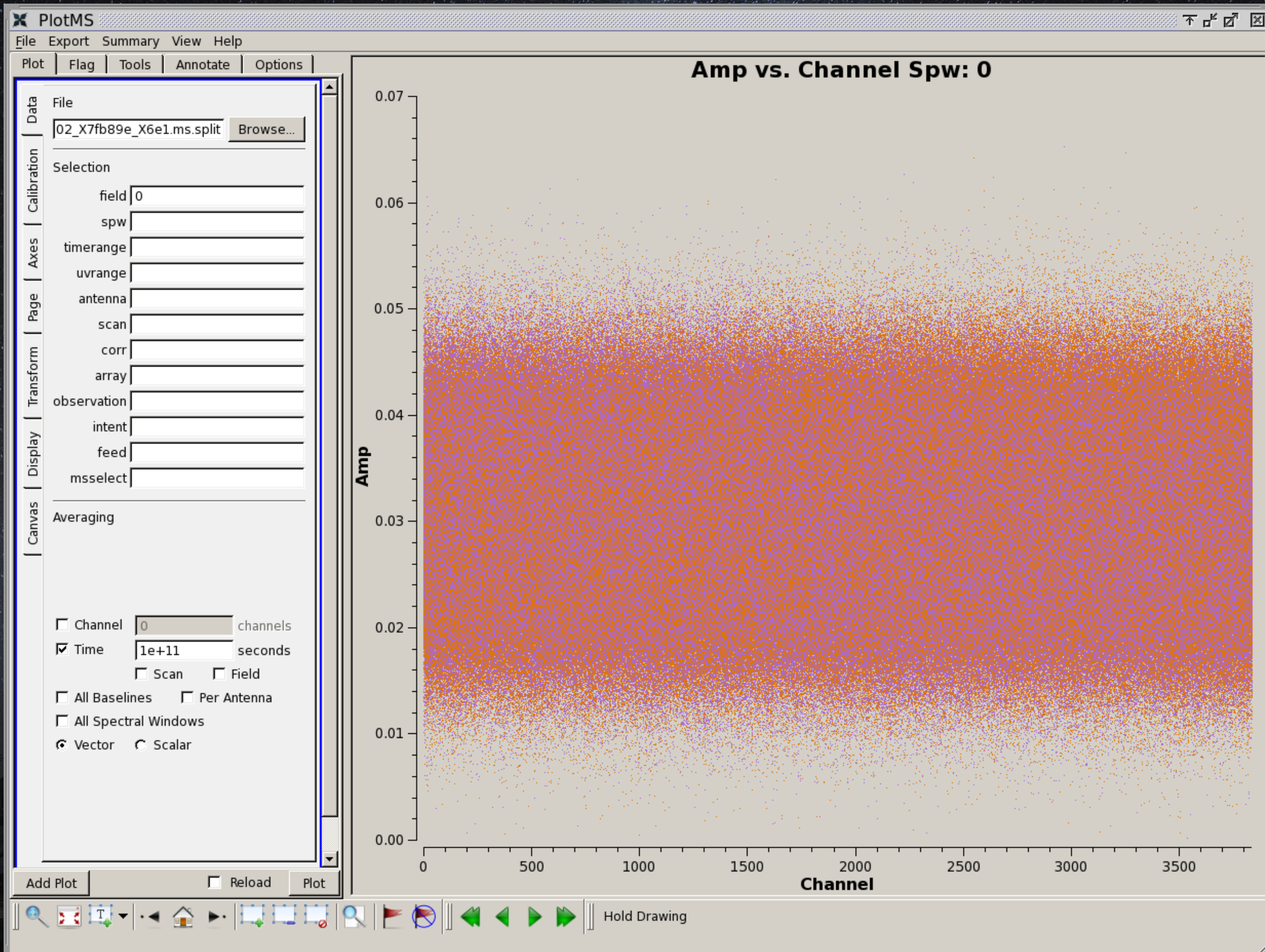

PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
Iteration
Axis: Spw
Global Axis Scale: X Y
Shared Axis: X Y
Page Header
Contents
Filename
Y Column(s)
Observation Start Date
Observation Start Time
Observer
Project ID
Add Plot
Reload
Plot
Hold Drawing
Amp vs. Channel Spw: 1
Amp
0.20
0.15
0.10
0.05
0.00
0
500
1000
1500
2000
2500
3000
3500
Channel


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
Y Axis Data: Amp
Colorize: Corr
Unflagged Points Symbol
None
Default
Custom
Style: 2 px, autoscaling
Fill: 0000ff fill
Outline: None Default
Flagged Points Symbol
None
Default
Custom
Style: 2 px, circle
Fill: ff0000 fill
Outline: None Default
Add Plot
Reload
Plot
Hold Drawing
Amp vs. Channel Spw: 1
Amp
0.20
0.15
0.10
0.05
0.00
0 500 1000 1500 2000 2500 3000 3500
Channel

In the amplitude versus channel plots, most of the data should fall along a relatively straight line or should at least look smooth.

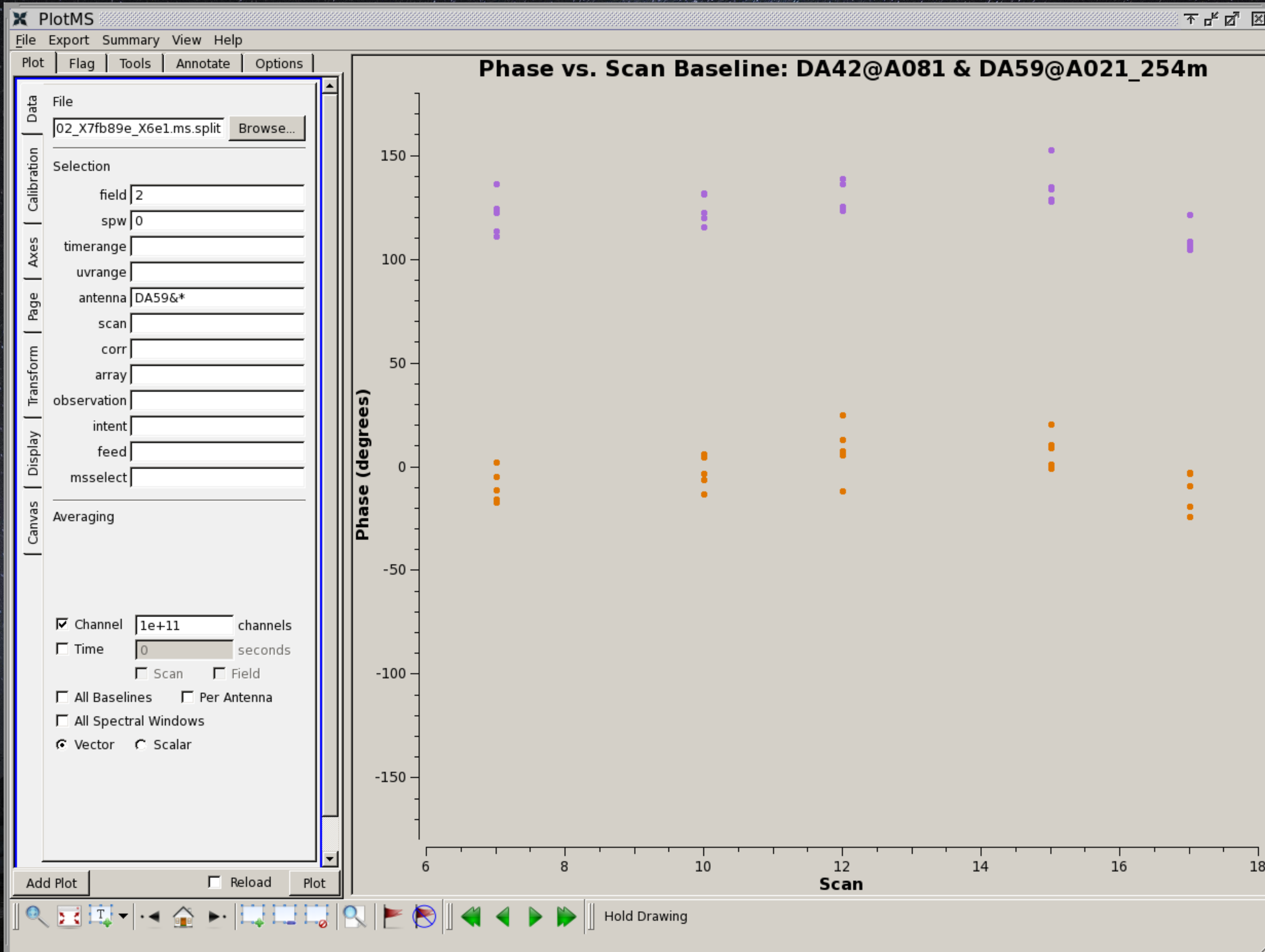
Data from the end channels will often appear either abnormally high or low. So will data from bad channels.

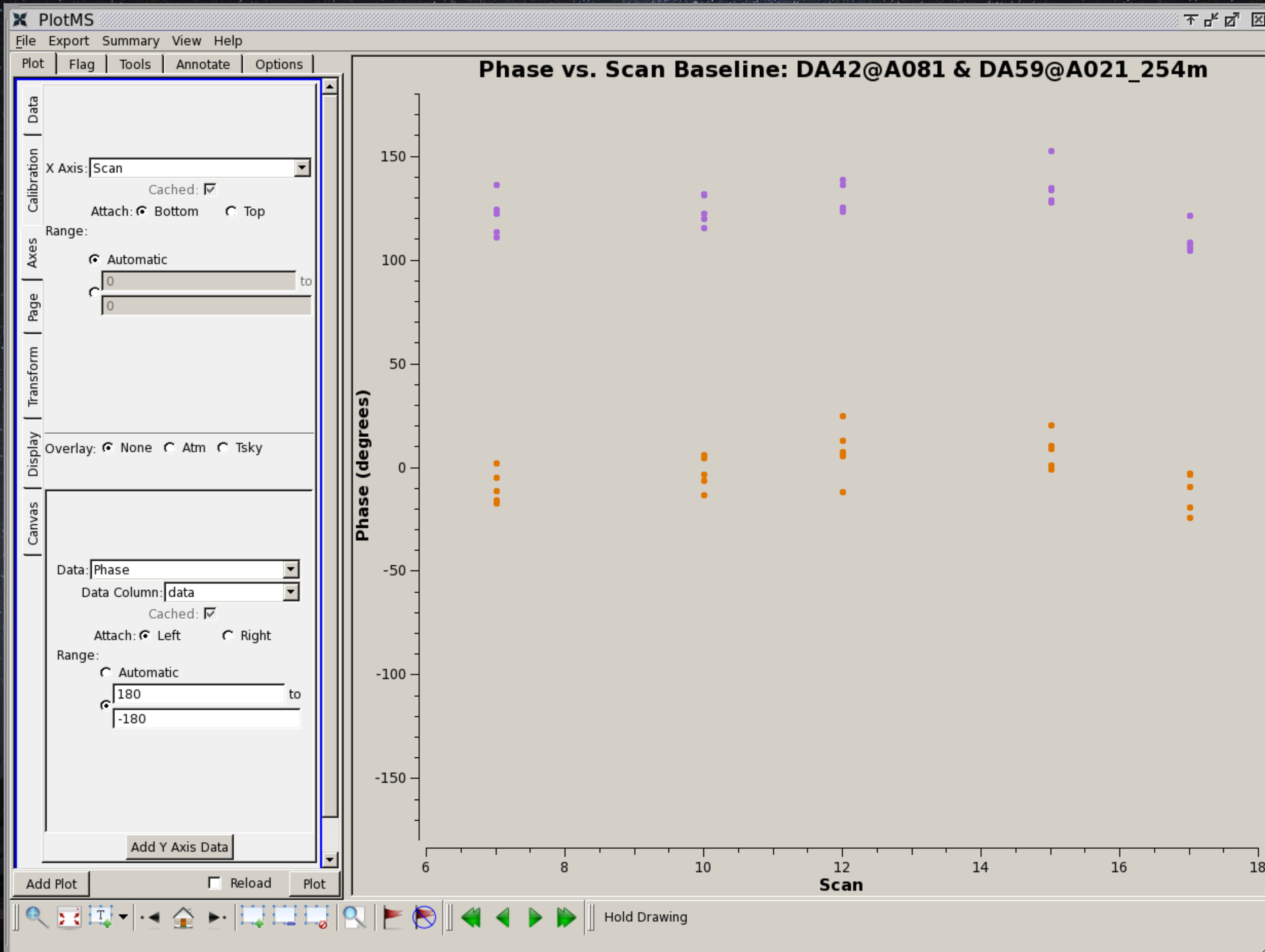
Additionally, atmospheric absorption features can be identified using these plots.

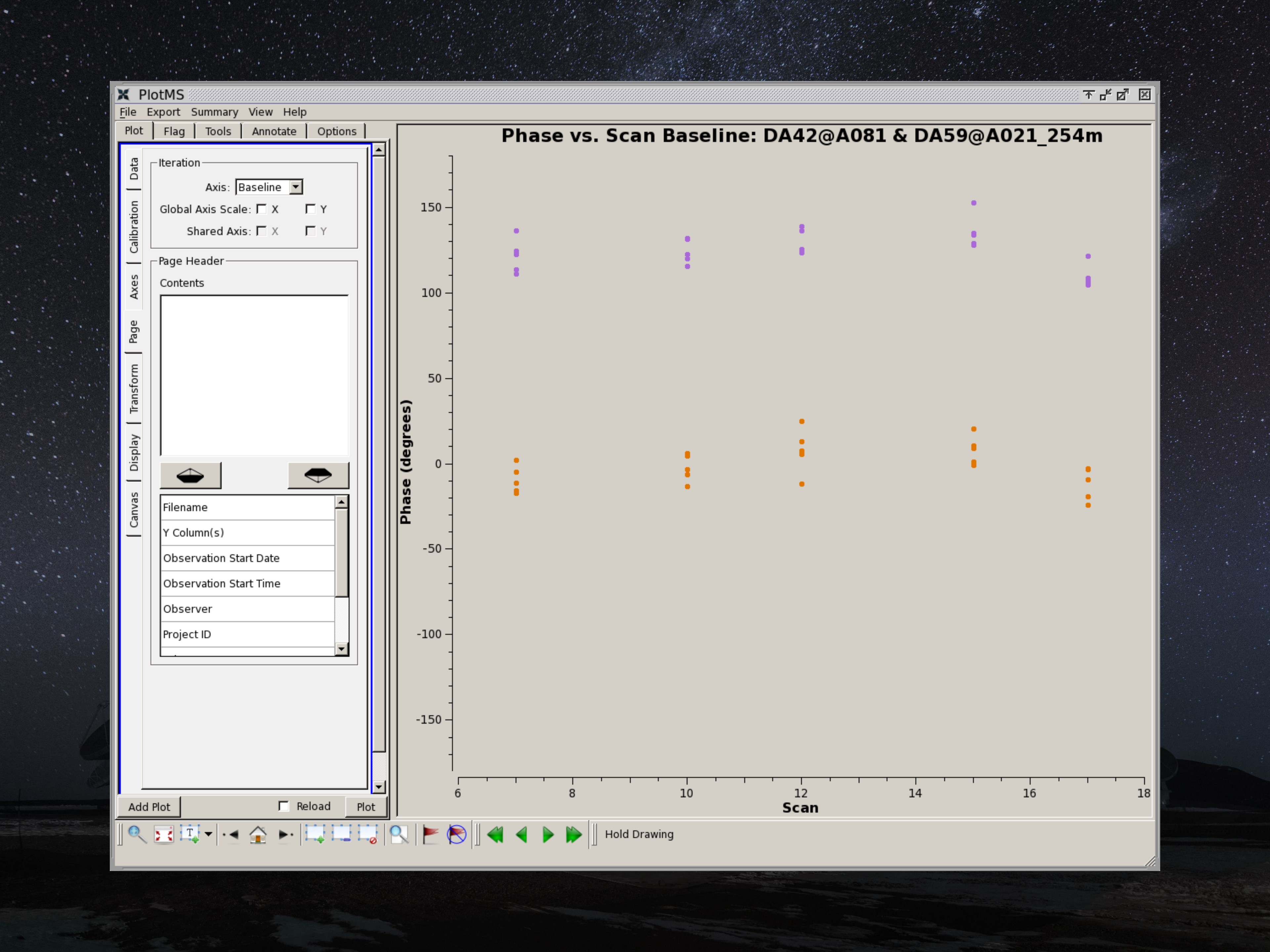

PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
File
02_X7fb89e_X6e1.ms.split
Browse...
Selection
field 0
spw
timerange
uvrange
antenna
scan
corr
array
observation
intent
feed
msselect
Averaging
Channel 0 channels
Time 1e+11 seconds
Scan
Field
All Baselines
Per Antenna
All Spectral Windows
Vector
Scalar
Add Plot
Reload
Plot
Hold Drawing
Amp vs. Channel Spw: 0
Amp
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Channel
0
500
1000
1500
2000
2500
3000
3500

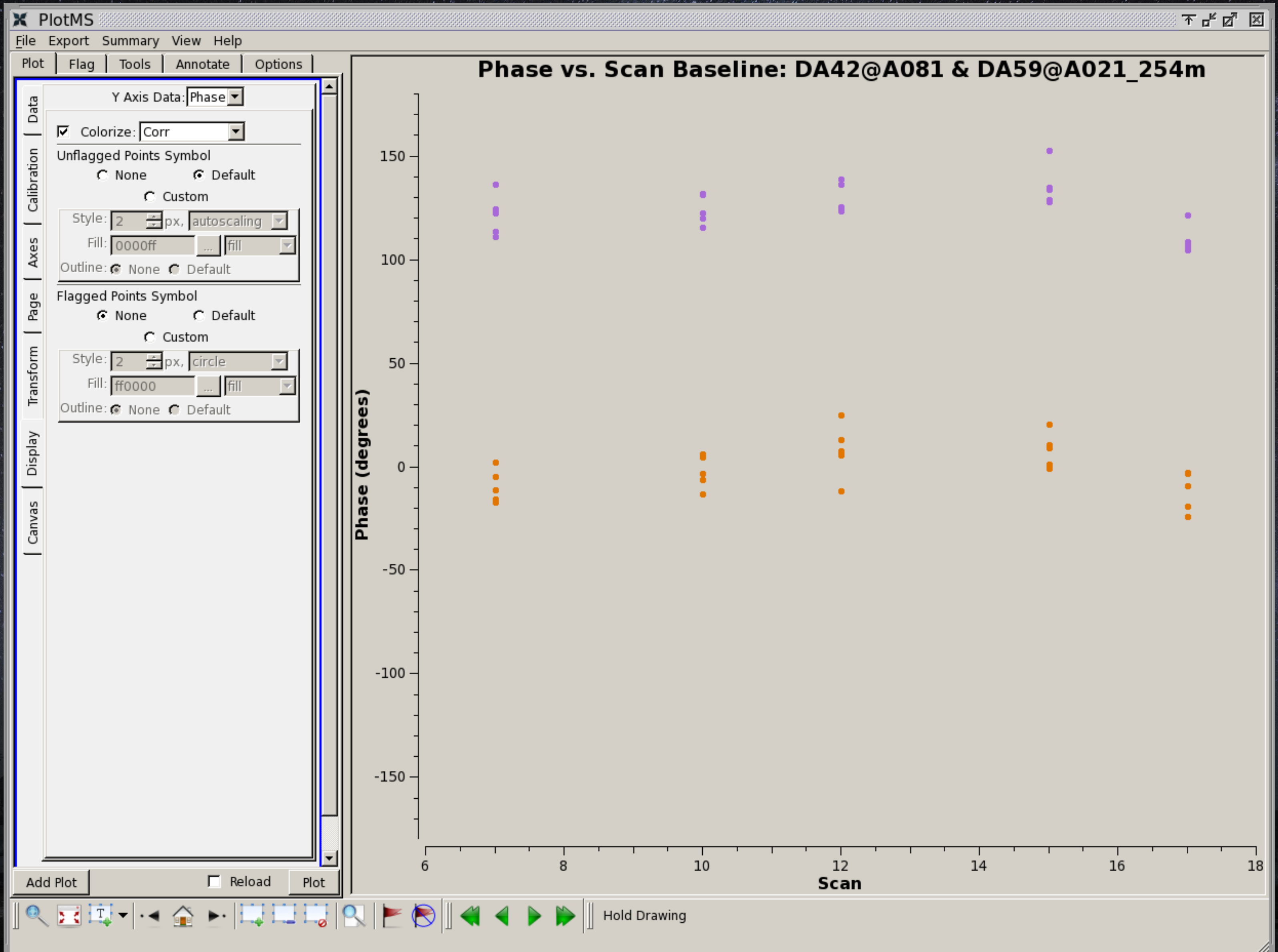
To check *phase versus scan*, set the following:

- Under the Data tab:
  - Set the file to the ms.split file created in step 8
  - Set the field to the number of the phase calibrator
  - Set the spw to one of the spw numbers (each one should be checked separately
  - Set the antenna to the reference antenna followed by "&*"
  - Set channel averaging to 4100
- Under the Axes tab:
  - Set the x-axis to Scan
  - Set the y-axis to Phase and set the range to 180 to -180
- Under the Page tab:
  - Set axis to Baseline
- Under the Display tab:
  - Set Colorize to Corr (which will produce different colours for the XX and YY data)


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
File
02_X7fb89e_X6e1.ms.split
Browse...
Selection
field 2
spw 0
timerange
uvrange
antenna DA59&*
scan
corr
array
observation
intent
feed
msselect
Averaging
Channel 1e+11 channels
Time 0 seconds
Scan
Field
All Baselines
Per Antenna
All Spectral Windows
Vector
Scalar
Add Plot
Reload
Plot
Hold Drawing
Phase vs. Scan Baseline: DA42@A081 & DA59@A021_254m
Phase (degrees)
Scan
150
100
50
0
-50
-100
-150
6
8
10
12
14
16
18


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
X Axis: Scan
Cached:
Attach: Bottom Top
Range:
Automatic
0 to
0
Overlay: None Atm Tsky
Data: Phase
Data Column: data
Cached:
Attach: Left Right
Range:
Automatic
180 to
-180
Add Y Axis Data
Add Plot
Reload
Plot
Hold Drawing
Phase vs. Scan Baseline: DA42@A081 & DA59@A021_254m
Phase (degrees)
150
100
50
0
-50
-100
-150
Scan
6
8
10
12
14
16
18


PlotMS
File
Export
Summary
View
Help
Plot
Flag
Tools
Annotate
Options
Data
Calibration
Axes
Page
Transform
Display
Canvas
Iteration
Axis:
Baseline
Global Axis Scale:
X
Y
Shared Axis:
X
Y
Page Header
Contents
Filename
Y Column(s)
Observation Start Date
Observation Start Time
Observer
Project ID
Add Plot
Reload
Plot
Hold Drawing
Phase vs. Scan Baseline: DA42@A081 & DA59@A021_254m
Phase (degrees)
Scan
150
100
50
0
-50
-100
-150
6
8
10
12
14
16
18


PlotMS
File Export Summary View Help
Plot Flag Tools Annotate Options
Data Calibration Axes Page Transform Display Canvas
Y Axis Data: Phase
Colorize: Corr
Unflagged Points Symbol
None Default
Custom
Style: 2 px, autoscaling
Fill: 0000ff fill
Outline: None Default
Flagged Points Symbol
None Default
Custom
Style: 2 px, circle
Fill: ff0000 fill
Outline: None Default
Add Plot Reload Plot
Hold Drawing
Phase vs. Scan Baseline: DA42@A081 & DA59@A021_254m
Phase (degrees)
Scan

In the phase versus scan plots, the phase data should look smooth enough that it appears possible to interpolate between the phase calibration observations.

Data from bad scans will show abnormal scatter. (The data will also appear to have a high scatter if you forget to set the range for the y-axis).

Gradual changes in phases are acceptable, but if the phases change significantly (for example more than ~120 degrees) between phase calibrator observations, it may be necessary to flag the data from the antenna or baseline.

Step 11: Put a model for the flux calibrator into the measurement set

This step adds information indicating the flux density of one of the sources in the data (typically the amplitude calibrator, although a different source can be used if necessary).

Either a Solar System object or a quasar is used in this step.

The flux densities for Solar System objects are based on well-calibrated models (although the Ceres and Pallas models are suspect).

The quasar flux densities are based on a catalog of periodic measurements calibrated against Solar System objects.

Step 12: Save flags

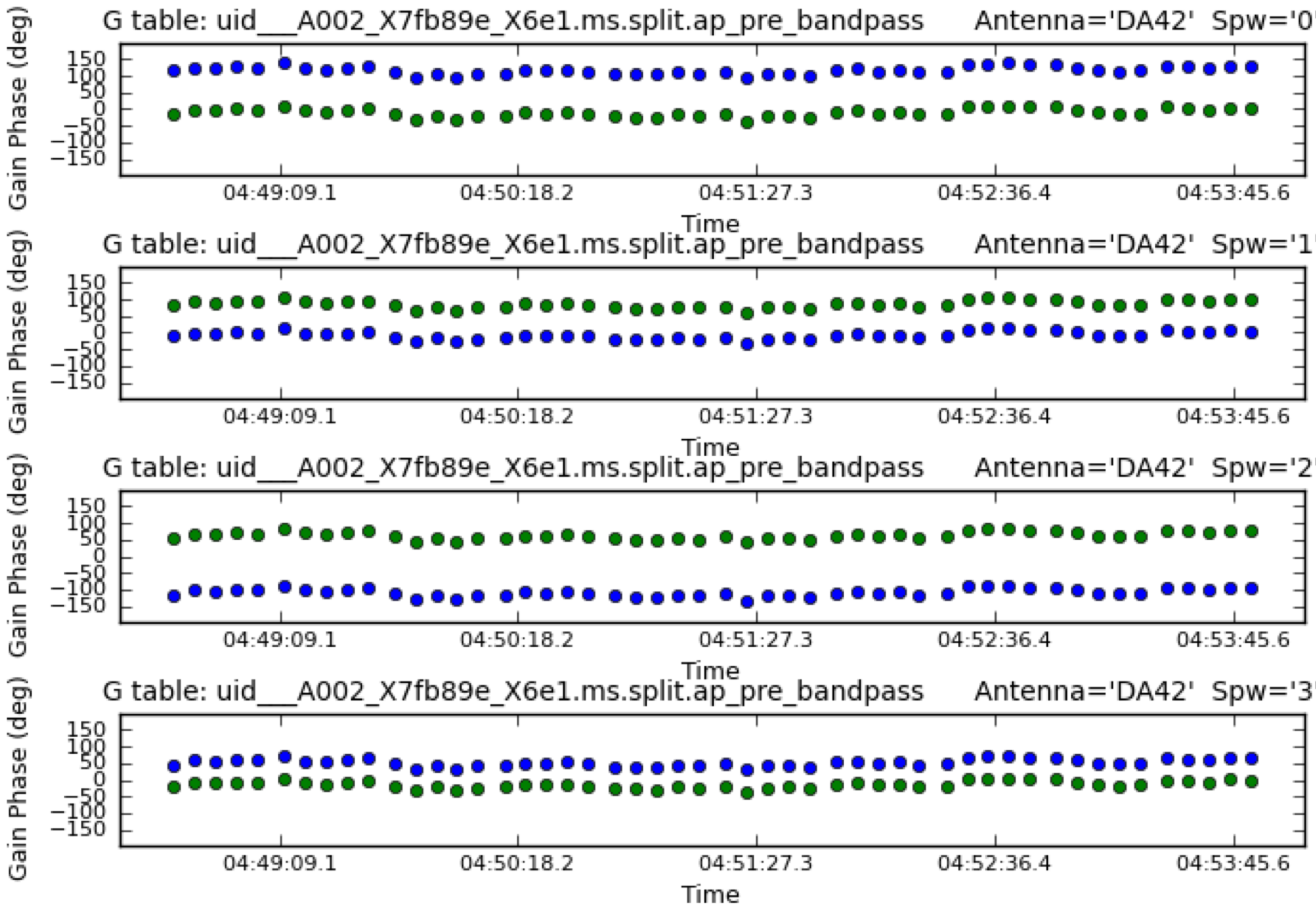
This is one of several steps where the flagging information is saved.

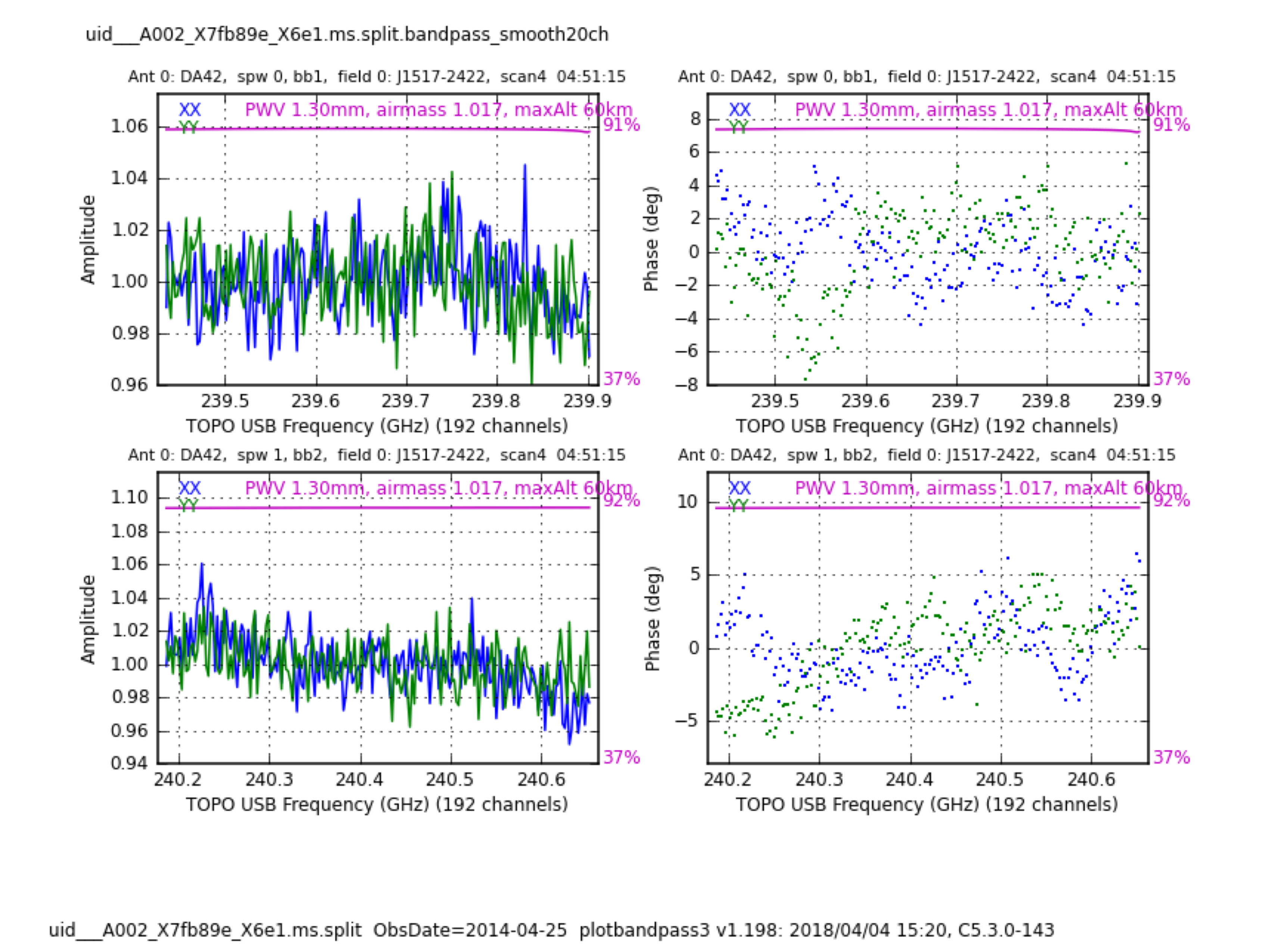
Step 13: Bandpass calibration

In this step, variations in phase and amplitude versus channel are measured and stored in a bandpass calibration table.

The calibration source used for this is typically a very bright quasar with a featureless spectrum.

Before deriving the bandpass calibration, the phase variations versus time are measured in the bandpass calibration data.


G table: uid___A002_X7fb89e_X6e1.ms.split.ap_pre_bandpass Antenna='DA42' Spw='0'
G table: uid___A002_X7fb89e_X6e1.ms.split.ap_pre_bandpass Antenna='DA42' Spw='1'
G table: uid___A002_X7fb89e_X6e1.ms.split.ap_pre_bandpass Antenna='DA42' Spw='2'
G table: uid___A002_X7fb89e_X6e1.ms.split.ap_pre_bandpass Antenna='DA42' Spw='3'
Gain Phase (deg)
150
100
50
0
−50
−100
−150
04:49:09.1
04:50:18.2
04:51:27.3
04:52:36.4
04:53:45.6
Time


uid___A002_X7fb89e_X6e1.ms.split.bandpass_smooth20ch
Ant 0: DA42, spw 0, bb1, field 0: J1517-2422, scan4 04:51:15
XX
YY
PWV 1.30mm, airmass 1.017, maxAlt 60km
91%
37%
Amplitude
Phase (deg)
TOPO USB Frequency (GHz) (192 channels)
Ant 0: DA42, spw 1, bb2, field 0: J1517-2422, scan4 04:51:15
92%
uid___A002_X7fb89e_X6e1.ms.split ObsDate=2014-04-25 plotbandpass3 v1.198: 2018/04/04 15:20, C5.3.0-143

Step 14: Save flags

This is one of several steps where the flagging information is saved.

Step 15: Gain calibration

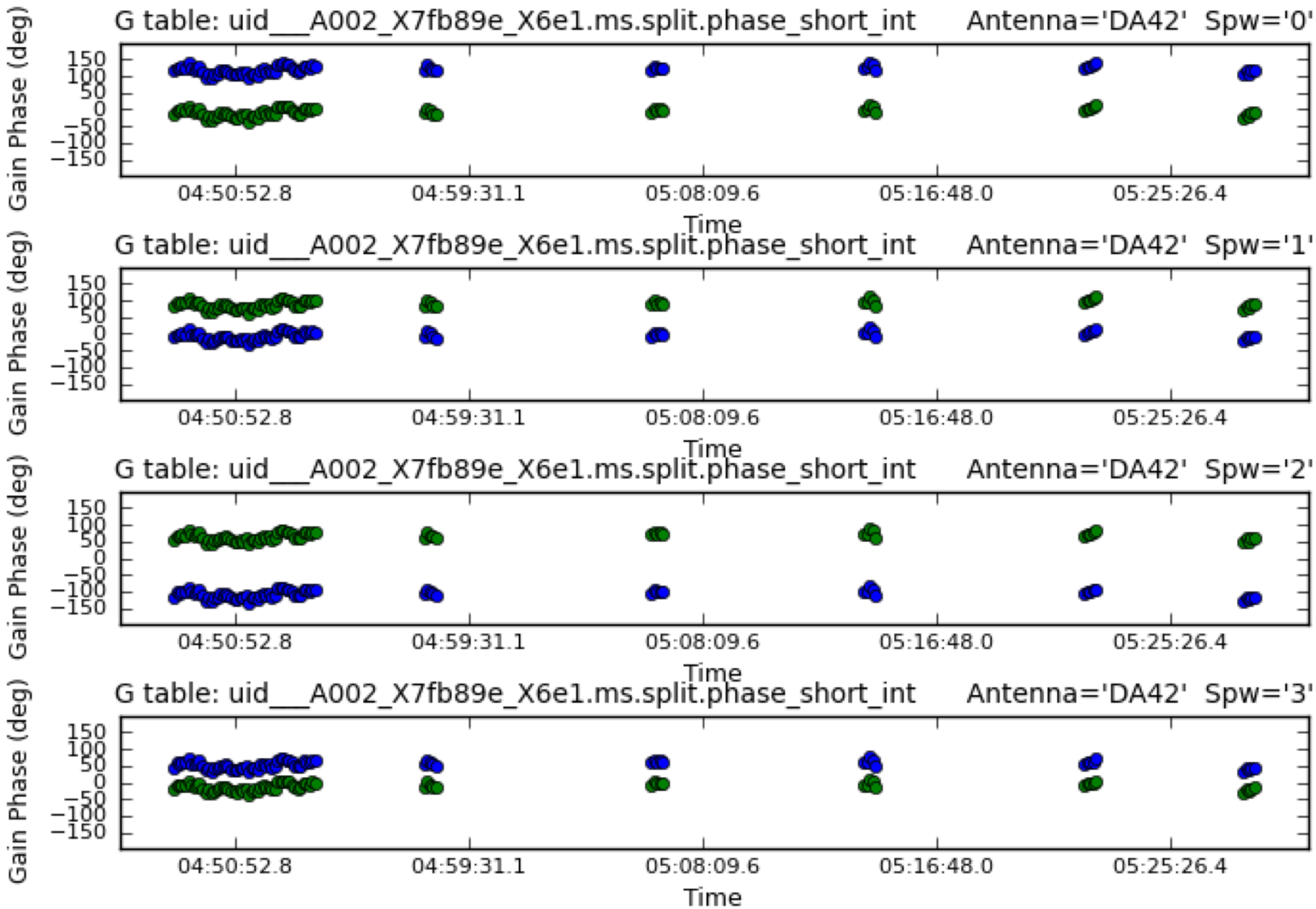
In this step, variations in phase and amplitude versus time are measured and stored in multiple calibration tables.

This step is complicated by the use of a resolved object as a flux calibrator. The Solar System object has more reliably-modelled fluxes, but the signal is not detected on some of the longer baselines.

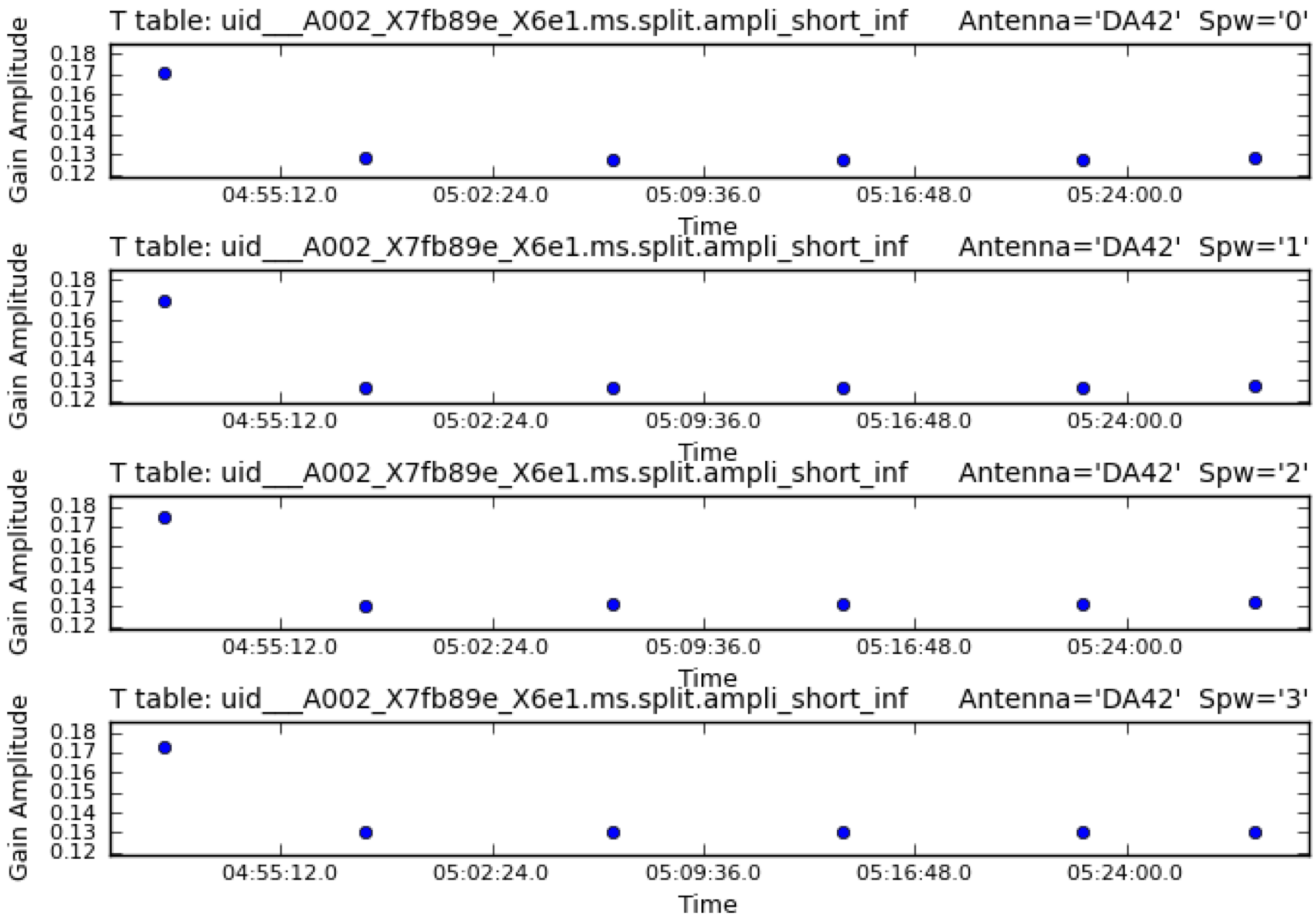
To properly calibrate the data, the flux calibration for the phase calibrator needs to be derived using the short baselines data for the flux calibrator. After that, the phase and amplitude calibration versus time can be derived for the science fields.

The first half of the steps used in this script are as follows:

- The phase variations versus time are measured for every integration on short baselines
- The amplitude variations versus time are measured on short baselines
- The fluxes for the phase calibrator are rescaled using the amplitudes for the flux calibrator

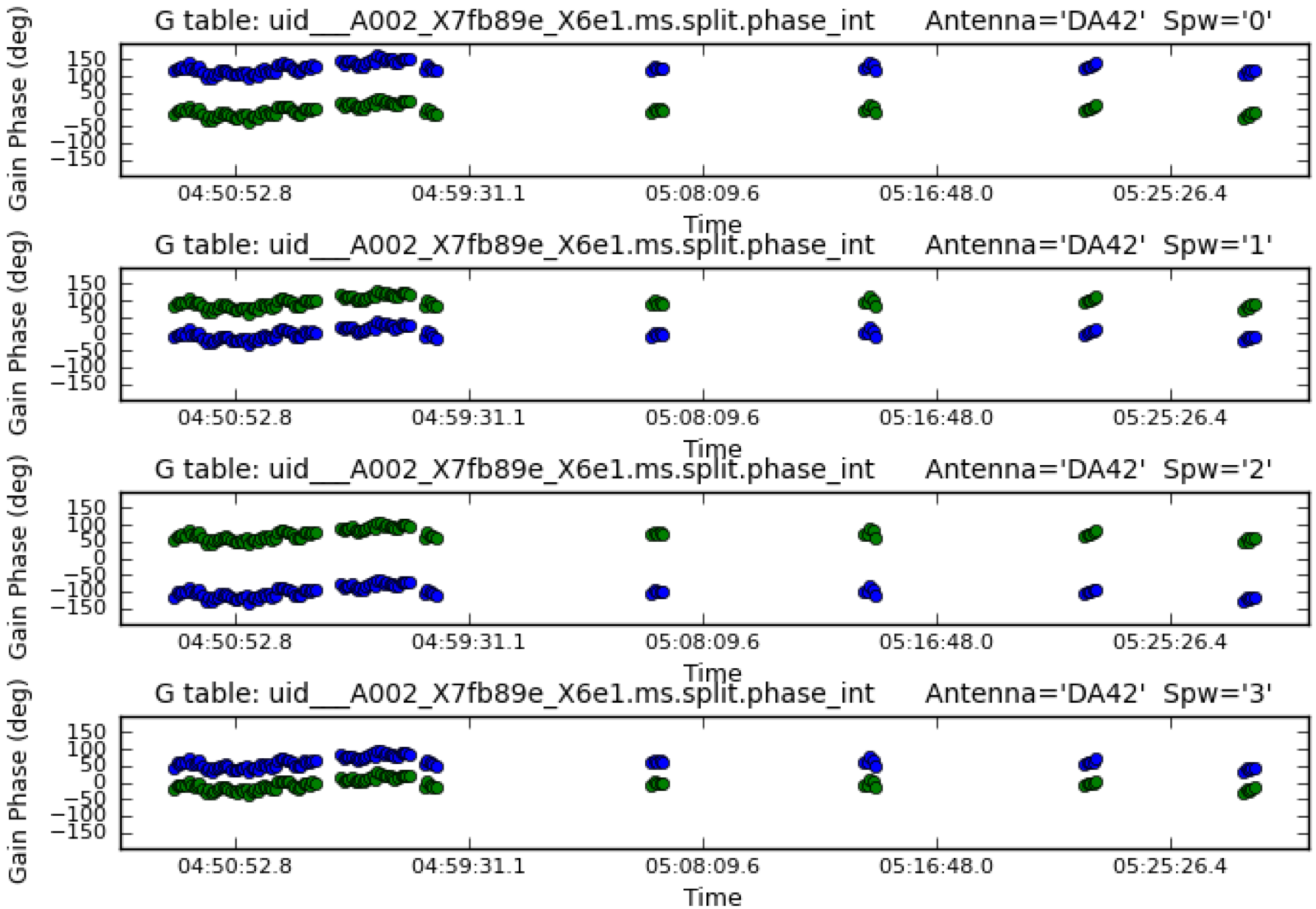


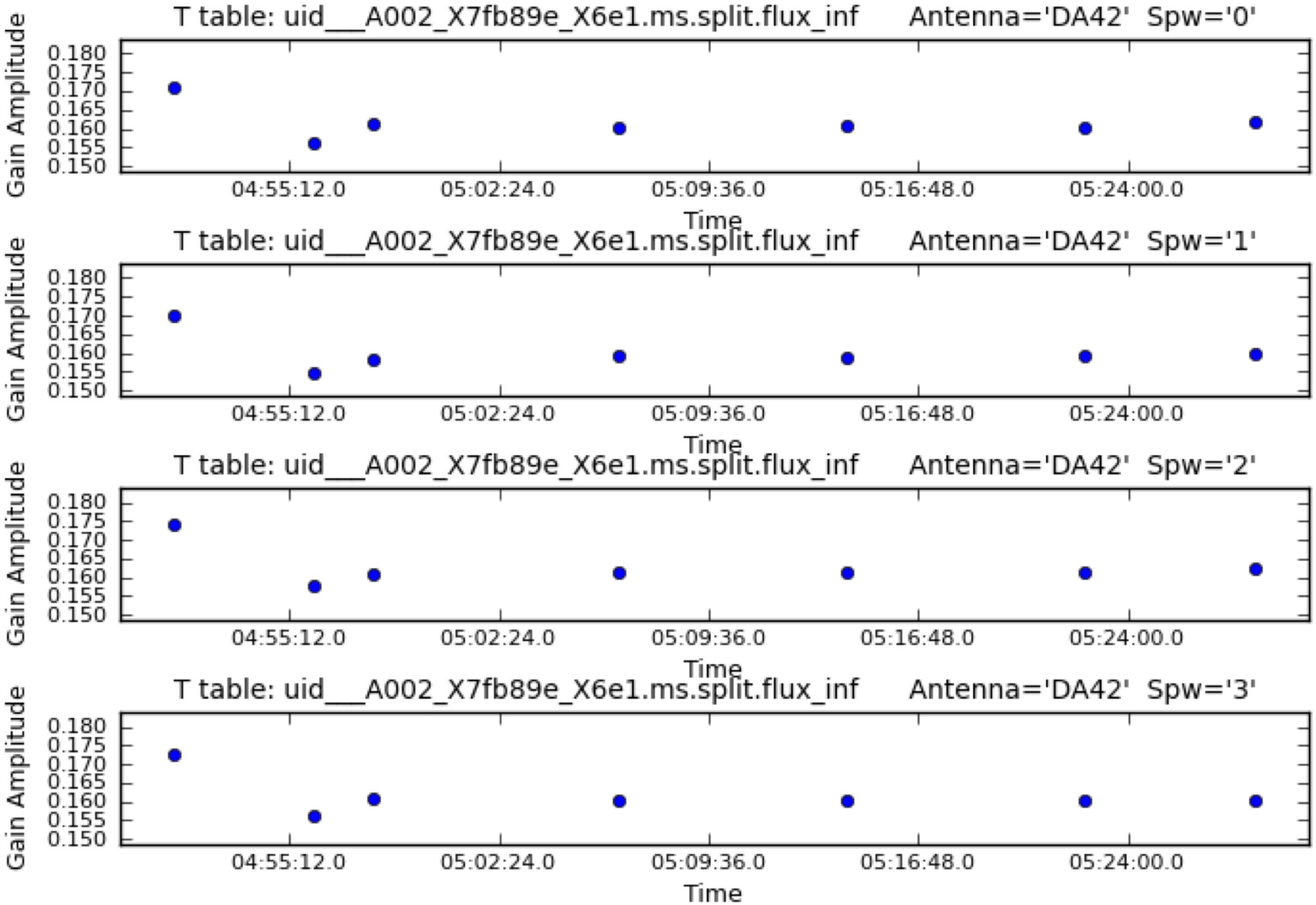
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_short_int Antenna='DA42' Spw='0'
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_short_int Antenna='DA42' Spw='1'
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_short_int Antenna='DA42' Spw='2'
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_short_int Antenna='DA42' Spw='3'
Gain Phase (deg)
150
100
50
0
−50
−100
−150
04:50:52.8
04:59:31.1
05:08:09.6
05:16:48.0
05:25:26.4
Time

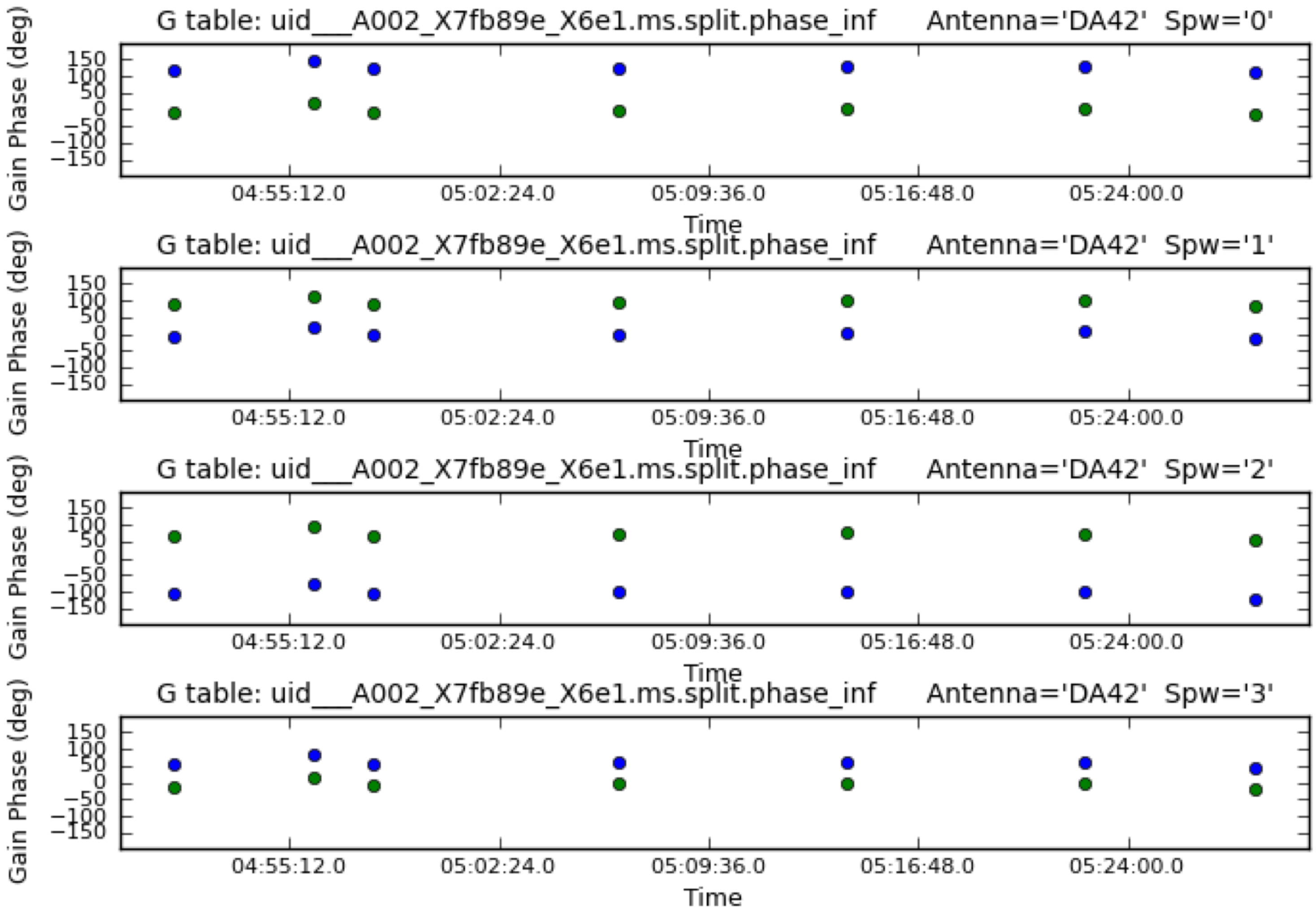

T table: uid___A002_X7fb89e_X6e1.ms.split.ampli_short_inf Antenna='DA42' Spw='0'
Gain Amplitude
0.18
0.17
0.16
0.15
0.14
0.13
0.12
04:55:12.0
05:02:24.0
05:09:36.0
05:16:48.0
05:24:00.0
Time
T table: uid___A002_X7fb89e_X6e1.ms.split.ampli_short_inf Antenna='DA42' Spw='1'
T table: uid___A002_X7fb89e_X6e1.ms.split.ampli_short_inf Antenna='DA42' Spw='2'
T table: uid___A002_X7fb89e_X6e1.ms.split.ampli_short_inf Antenna='DA42' Spw='3'

The second half of the steps used in this script are as follows:

- The phase variations versus time are measured for every integration
- The amplitude variations versus time are measured
- The phase variations versus time are measured by averaging over each scan


G table: uid___A002_X7fb89e_X6e1.ms.split.phase_int Antenna='DA42' Spw='0'
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_int Antenna='DA42' Spw='1'
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_int Antenna='DA42' Spw='2'
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_int Antenna='DA42' Spw='3'
Gain Phase (deg)
150
100
50
0
−50
−100
−150
04:50:52.8
04:59:31.1
05:08:09.6
05:16:48.0
05:25:26.4
Time


T table: uid___A002_X7fb89e_X6e1.ms.split.flux_inf Antenna='DA42' Spw='0'
T table: uid___A002_X7fb89e_X6e1.ms.split.flux_inf Antenna='DA42' Spw='1'
T table: uid___A002_X7fb89e_X6e1.ms.split.flux_inf Antenna='DA42' Spw='2'
T table: uid___A002_X7fb89e_X6e1.ms.split.flux_inf Antenna='DA42' Spw='3'
Gain Amplitude
0.180
0.175
0.170
0.165
0.160
0.155
0.150
04:55:12.0
05:02:24.0
05:09:36.0
05:16:48.0
05:24:00.0
Time


G table: uid___A002_X7fb89e_X6e1.ms.split.phase_inf Antenna='DA42' Spw='0'
Gain Phase (deg)
150
100
50
0
−50
−100
−150
04:55:12.0
05:02:24.0
05:09:36.0
05:16:48.0
05:24:00.0
Time
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_inf Antenna='DA42' Spw='1'
Gain Phase (deg)
Time
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_inf Antenna='DA42' Spw='2'
Gain Phase (deg)
Time
G table: uid___A002_X7fb89e_X6e1.ms.split.phase_inf Antenna='DA42' Spw='3'
Gain Phase (deg)
Time

Step 16: Save flags

This is one of several steps where the flagging information is saved.

Step 17: Application of the bandpass and gain calibration tables

The tables generated in steps 13 and 15 are applied to the data.

Step 18: Split out the corrected column

The fully corrected data are separated from the rest of the data and put into a new measurement set.

Step 19: Save flags

This is one of several steps where the flagging information is saved.