

EVLA Data Reduction Techniques: I



Emmanuel Momjian

NRAO

Atacama Large Millimeter/submillimeter Array

Expanded Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array



Outline

- The archive tool.
- Loading the data set.
- CASA
- Examining/Flagging the data set.
- Calibration
 - Including high and low frequency considerations.
- Imaging
 - Including spectral line, continuum, wide band, and wide field.
- Image analysis

I

II



Assumptions

This presentation assumes that you are familiar with **the basics of:**

- radio interferometry.
- flux density calibration, *antenna-based* calibration (gain, bandpass) and self-calibration.
- imaging and deconvolution.

For references on the above, please check:

- The lectures of the synthesis imaging workshop
<http://www.aoc.nrao.edu/events/synthesis/2010/>
- Synthesis Imaging for Radio Astronomy II (eds. Taylor, Carilli, and Perley).
- Interferometry and Synthesis in Radio Astronomy (by Thompson, Moran, and Swenson).



The archive tool

<https://archive.nrao.edu/>



National Radio Astronomy Observatory

[NRAO Home](#) > [Archive Home](#)

Archive login moved to query pages.

NRAO Archive:

[Archive Description](#)

[Archive Policy](#)

[Archive Status](#)

[Archive Tools](#)

[Future Goals](#)

NRAO Supported Catalogs/Surveys:

[VLA Pipeline Images](#)

[2cm Survey](#)

[4MASS](#)

[FIRST](#)

[GRB Project](#)

[MOJAVE](#)

[NVSS](#)

[SIRTF First Look](#)

Other Surveys:

[ADS](#)

[ICRF-Source List](#)

[MAST](#)

[NCSA-ADIL](#)

[NED](#)

[NSSDC](#)

The NRAO Data Archive System

Welcome to the NRAO Data Archive System. Complete instructions and documentation on the Data Archive System can be found to the left under NRAO Archive.

Log in to your NRAO User Account and your proprietary data in the archive will automatically be unlocked. This is true only for observations that were proposed using the new Proposal Tool. You may log in using the My NRAO Account banner at the top of the Basic and Advanced Search Pages.

Downloading Your Data.

You may use this tool to select and retrieve archived data from the EVLA, VLA and VLBA. Note that during the proprietary period, downloading will require an access key, obtained from the NRAO Data Analysts' office in Socorro, [analysts](#).

[Basic Data Retrieval Tool](#)

New Archive Search Tool

This tool provides more advanced query parameters for searching the EVLA, VLA and VLBA archives. Please see Archive Status for details on completeness of the archive contents and send feedback to the NRAO DAS contact.

[Advanced Query Tool](#)

Image Archive Tool

A collection of images produced by VLA and VLBA observations are available for browsing and downloads. The image collection consists of results from surveys and the VLA Imaging Pipeline Project. There are approximately 180,000 images in the archive.

[Image Archive Tool](#)

VLBA Observation List

The VLBA maintains a flat file listing of all radio sources that have been observed by the VLBA and some details of the observations. Click here to display the list.

[VLBA Obs. List](#)

The archive: Basic data retrieval tool

In order to unlock your proprietary data and have access to other archive tools, you must log in to your My.NRAO account.

NRAO Science Data Archive : Basic Search Tool

EVLA, VLA and VLBA Data Products

Instructions on how to download your data : [click here](#)

[Project \(Proposal\) Code](#)

The NRAO proposal or observing project id.

[Observer :](#)

The observer's name. Case sensitive, partial string searches best.

[Telescope](#)

You may restrict the search to a single telescope.

[Observe Start Date :](#)

Format : yyyy-MMM-dd or yyyy-MMM-dd hh:mm:ss

[Observe Stop Date :](#)

Format : yyyy-MMM-dd or yyyy-MMM-dd hh:mm:ss

Query Control Parameters :

[Enter Locked Project Access](#)

[Key :](#)

Unique keywords may be used to unlock proprietary data from individual observing projects. Contact the [NRAO Data Analysts](#) for project access keys.

[Query Returns :](#)

Select 'Download Archive Files' to proceed to the download page, the other options are for browsing.

Please direct feedback and/or questions concerning this page and its associated search engine to [NRAO DAS contact](#).

Version 5.8.6



The archive: Advanced query tool

Output Control Parameters :

Choose Query Return Type :

- ☒ Download Archive Data Files
- ☐ VLA Observations Summary
- ☐ List of Observation Scans
- ☐ List of Projects

[Output Tbl Format](#) HTML
 [Sort Order Column 1](#) Starttime
 Asc
 [Max Output Tbl Rows](#) NO LIMIT
 [Sort Order Column 2](#) Starttime
 Asc

General Search Parameters :

[Project Code](#)
[Project Segment](#)
[Dates From](#)

[Observer Name](#)
[Archive File ID](#) (partial strings allowed)
 [To](#) (format: 2002-jun-21 14:20:30)

Position Search :

[Target Name](#)
[Search Type](#) SIMBAD or NED
 [Min. Exposure Time](#) (secs)

[RA or Longitude](#) (12h34m56.78s or 187.606d)
 [DEC or Latitude](#) (15d30'30" or 15.5d)
 [Equinox](#) J2000

[Search Radius](#) 1.0' (1d00'00" or 0.2d)
 - OR -
 ☐ Check for automatic VLA field-of-view, freq. dependent.??

Observing Configurations Search :

[Telescope](#)
☒ All
 ☐ EVLA
 ☐ VLA
 ☐ VLBA
 [Telescope Config](#)
☒ All
 ☐ A
 ☐ AB
 ☐ BnA
 ☐ B
 ☐ BC
 ☐ CnB
 ☐ C
 ☐ CD
 ☐ DnC
 ☐ D
 ☐ DA
 ☐ DCR
 ☐ SP
 [Sub_array](#)
☒ All
 ☐ 1
 ☐ 2
 ☐ 3
 ☐ 4
 ☐ 5
 [Data Type](#) ALL

[Observing Bands](#)
☒ All
 ☐ 4
 ☐ P
 ☐ L
 ☐ S
 ☐ C
 ☐ X
 ☐ U
 ☐ K
 ☐ Ka
 ☐ Q
 ☐ W
 [Observing Mode](#) ALL
 [Correl Mode](#) ALL
 [Polarization](#) ALL
 [Frequency Range](#) (In MHz : 1665.401 - 1720.500)



The archive tool

- For each observing session, the archive tool allows the observer to view:
 - The logs
 - The scans
 - The SDM-BDF set (listing of the sdm and bdf files)
 - Any data quality issues.

Archive File	Status	Project	Seg	Project Data Starts	Project Data Stops	File Size	Telescope: config:sub"	Bands	Format	Type	DQ	View Scans	Logs etc.
<input type="checkbox"/> 11A-291.sb4911125.eb4924302.55782.00136674769	locked	11A-291	x	11-Aug-09 00:02:01	11-Aug-09 01:01:45	42.46GB	EVLA:A:0	L	SDMset	raw	OK	Scans	Logs
<input type="checkbox"/> 11A-291.sb4911125.eb4944094.55784.99251239583	locked	11A-291	x	11-Aug-11 23:50:07	11-Aug-13 02:14:44	30.29GB	EVLA:A:0	L	SDMset	raw	OK	Scans	Logs
<input type="checkbox"/> 11A-291.sb4910900.eb4947827.55787.6933925	locked	11A-291	x	11-Aug-14 16:39:27	11-Aug-14 18:39:07	78.96GB	EVLA:A:0	L	SDMset	raw	info	Scans	Logs



Checking the data in the archive tool

The scan listing:

Project	Scan :sub	Source	Cal Code	Start Time	Stop Time	Sys	TOS (sec)	Intrvl (sec)	Scan Intent	Spect Win	Obs_Freq (MHz)	Bandw (MHz)	Polar	Spect chans	Corr Mode	Tele:config :sub:nants	RA(J2000)	DEC(J2000)	Archive File
11A-291	1:1	J1120+1420		11-Aug-09 00:02:01	11-Aug-09 00:02:54	UTC	53.5	1	OBS	CD_0:SW_0 CD_0:SW_1 CD_0:SW_2 CD_0:SW_3 CD_0:SW_4 CD_0:SW_5 CD_0:SW_6 CD_0:SW_7 CD_0:SW_8 CD_0:SW_9 CD_0:SW_10 CD_0:SW_11 CD_0:SW_12 CD_0:SW_13 CD_0:SW_14 CD_0:SW_15	998.000000 1062.000000 1126.000000 1190.000000 1254.000000 1318.000000 1382.000000 1446.000000 1506.000000 1570.000000 1634.000000 1698.000000 1762.000000 1826.000000 1890.000000 1954.000000	64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000	RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL	128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128	WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR	EVLA:A:1:27	11h20m27.807s	+14d20'54.99"	11A-291.sb4911125.eb4924302.55782.00136674769 uid____evla_bdf_1312848123251.bdf
11A-291	2:1	J1120+1420		11-Aug-09 00:02:54	11-Aug-09 00:03:54	UTC	59.8	1	CAL	CD_0:SW_0 CD_0:SW_1 CD_0:SW_2 CD_0:SW_3 CD_0:SW_4 CD_0:SW_5 CD_0:SW_6 CD_0:SW_7 CD_0:SW_8 CD_0:SW_9 CD_0:SW_10 CD_0:SW_11 CD_0:SW_12 CD_0:SW_13 CD_0:SW_14 CD_0:SW_15	998.000000 1062.000000 1126.000000 1190.000000 1254.000000 1318.000000 1382.000000 1446.000000 1506.000000 1570.000000 1634.000000 1698.000000 1762.000000 1826.000000 1890.000000 1954.000000	64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000	RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL	128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128	WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR	EVLA:A:1:27	11h20m27.807s	+14d20'54.99"	11A-291.sb4911125.eb4924302.55782.00136674769 uid____evla_bdf_1312848123257.bdf
11A-291	3:1	J1120+1420		11-Aug-09 00:03:54	11-Aug-09 00:05:24	UTC	89.8	1	CAL	CD_0:SW_0 CD_0:SW_1 CD_0:SW_2 CD_0:SW_3 CD_0:SW_4 CD_0:SW_5 CD_0:SW_6 CD_0:SW_7 CD_0:SW_8 CD_0:SW_9 CD_0:SW_10 CD_0:SW_11 CD_0:SW_12 CD_0:SW_13 CD_0:SW_14 CD_0:SW_15	998.000000 1062.000000 1126.000000 1190.000000 1254.000000 1318.000000 1382.000000 1446.000000 1506.000000 1570.000000 1634.000000 1698.000000 1762.000000 1826.000000 1890.000000 1954.000000	64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000 64.000	RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL RR,LL	128 128 128 128 128 128 128 128 128 128 128 128 128 128 128 128	WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR WIDR	EVLA:A:1:27	11h20m27.807s	+14d20'54.99"	11A-291.sb4911125.eb4924302.55782.00136674769 uid____evla_bdf_1312848174961.bdf

Checking the data in the archive tool

The scan listing (reference pointing):

11A-258	42:1	0542+498=3C147		11-Jun-01 01:26:47	11-Jun-01 01:27:07	UTC	19.4	1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891607524.bdf
11A-258	42:2	0542+498=3C147		11-Jun-01 01:27:07	11-Jun-01 01:27:27	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891608043.bdf
11A-258	42:3	0542+498=3C147		11-Jun-01 01:27:27	11-Jun-01 01:27:47	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891627503.bdf
11A-258	42:4	0542+498=3C147		11-Jun-01 01:27:47	11-Jun-01 01:28:07	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891647507.bdf
11A-258	42:5	0542+498=3C147		11-Jun-01 01:28:07	11-Jun-01 01:28:27	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891667503.bdf
11A-258	42:6	0542+498=3C147		11-Jun-01 01:28:27	11-Jun-01 01:28:47	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891687511.bdf
11A-258	42:7	0542+498=3C147		11-Jun-01 01:28:47	11-Jun-01 01:29:07	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891707505.bdf
11A-258	42:8	0542+498=3C147		11-Jun-01 01:29:07	11-Jun-01 01:29:27	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891727505.bdf
11A-258	42:9	0542+498=3C147		11-Jun-01 01:29:27	11-Jun-01 01:29:47	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891747507.bdf
11A-258	42:10	0542+498=3C147		11-Jun-01 01:29:47	11-Jun-01 01:30:07	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891767505.bdf
11A-258	42:11	0542+498=3C147		11-Jun-01 01:30:07	11-Jun-01 01:30:27	UTC	20	1.1	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891787507.bdf
11A-258	42:12	0542+498=3C147		11-Jun-01 01:30:27	11-Jun-01 01:30:42	UTC	15.4	1.2	POINT	CD_1:SW_16 CD_1:SW_17	8332.000000 8460.000000	128.000 128.000	RR,RL,LR,LL RR,RL,LR,LL	64 64	WIDR WIDR	EVLA:BnA->A:1:25	05h42m36.138s	+49d51'07.23"	11A-258.sb4139176.eb4258095.55713.0339549537 uid____evla_bdf_1306891807506.bdf



Loading The Data: The archive tool

EVLA - WIDAR datasets

- Data formats:
 - **CASA MS**
 - **AIPS FITS**
 - **SDM-BDF (request through helpdesk)**

Choose download data format

☒ CASA MS
☐ AIPS FITS

: ☐ SDM-BDF dataset (all files)
☐ SDM tables only (no visibilities)

Create tar file: ☒ Create MS or SDM tar file

Apply telescope flags: ☒ Apply flags generated during observing

Choose online averaging for
CASA MS or AIPS FITS: Spectral Averaging (chans)
 Time Averaging (secs)

Select scans for MS or AIPS
FITS:

Auxiliary SDM Tables: ☐ Include verbatim SDM tables in MS

- If CASA MS is requested, the SDM-BDF is loaded to a staging area and converted to MS using CASA's *importevla* task.
- If AIPS FITS is requested, then the MS made above will be exported as a FITS file using CASA's *exportuvfits* task.



Loading The Data: The archive tool

EVLA - WIDAR datasets

Choose download data format

☒ CASA MS
☐ AIPS FITS
: ☐ SDM-BDF dataset (all files)
☐ SDM tables only (no visibilities)

Create tar file : ☒ Create MS or SDM tar file

Apply telescope flags : ☒ Apply flags generated during observing

Choose online averaging for
CASA MS or AIPS FITS : Spectral Averaging (chans)
 Time Averaging (secs)

Select scans for MS or AIPS
FITS :

Auxiliary SDM Tables : ☐ Include verbatim SDM tables in MS

- If the apply flags option is not checked, the flags are written to a FLAG_CMD MS table. They can later be applied by using the CASA task *flagcmd*.
- If checked, the flags are applied on the data.
- We recommend the application of the online flags. They can be un-applied in CASA if need be.
- For UVFITS, the flags need to be applied, as there will not be a FLAG_CMD table in the resulting file.



Loading The Data: The archive tool

EVLA - WIDAR datasets

☒ CASA MS

Choose download data format ☐ AIPS FITS

☐ SDM-BDF dataset (all files)

☐ SDM tables only (no visibilities)

Create tar file : ☒ Create MS or SDM tar file

Apply telescope flags : ☒ Apply flags generated during observing

Choose online averaging for
CASA MS or AIPS FITS : Spectral Averaging (chans)
 Time Averaging (secs)

Select scans for MS or AIPS
FITS :

Auxiliary SDM Tables : ☐ Include verbatim SDM tables in MS

- The tool allows the observer to average the data in time and/or in frequency.
- It also allows the selection of scans.
- For these, the archive tool uses the CASA task *split*.



Loading The Data: The archive tool

EVLA - WIDAR datasets

If applying online averaging:

1. Make sure to apply the flags.
2. Averaging in frequency is discouraged as delays can cause coherence loss. We recommend reviewing the data before frequency averaging.
3. Averaging in time should take into account the type of science you would like to do. See the EVLA Observational Status Summary for amplitude loss due to time averaging.

Choose download data format

☒ CASA MS
☐ AIPS FITS
: ☐ SDM-BDF dataset (all files)
☐ SDM tables only (no visibilities)

Create tar file : ☒ Create MS or SDM tar file

Apply telescope flags : ☒ Apply flags generated during observing

Choose online averaging for
CASA MS or AIPS FITS : Spectral Averaging (chans)
 Time Averaging (secs)

Select scans for MS or AIPS
FITS :

Auxiliary SDM Tables : ☐ Include verbatim SDM tables in MS



Loading The Data: The archive tool

EVLA - WIDAR datasets

☒ CASA MS
Choose download data format ☐ AIPS FITS
: ☐ SDM-BDF dataset (all files)
☐ SDM tables only (no visibilities)

Create tar file : ☒ Create MS or SDM tar file

Apply telescope flags : ☒ Apply flags generated during observing

Choose online averaging for Spectral Averaging (chans)
CASA MS or AIPS FITS : Time Averaging (secs)

Select scans for MS or AIPS FITS :

Auxiliary SDM Tables : ☐ Include verbatim SDM tables in MS

- A MS is a directory. For downloading through the net, make sure to ask for a tar file.



Loading The Data: The archive tool

Requesting the data on a hard disk

- NRAO offers a data shipping service using hard disks:
 - when the size of the data is large, or
 - when the user does not have fast enough internet connection.
- This disk-ordering process is done through the archive tool.
- The data will be saved on 1.8 TB disks and shipped to the observer.
- Disk shipment information and policies are posted at
 - <https://archive.nrao.edu/archive/hdshipInfo.html>
 - <https://science.nrao.edu/facilities/evla/data-shipment>



CASA



- Web site: <http://casa.nrao.edu/>
- Available for both Linux and Mac OS.
- Two versions of CASA, *Release* and *Stable* can be downloaded.
 - The *Stable* version has more functionality but has not been as rigorously tested as the *Release*.
 - The available documentation is only for the release, so *Stable* may behave somewhat differently than what is currently documented.
 - Make sure to subscribe to the CASA mailing list for announcements of new releases, workshops, etc... (casa-announce), or for critical bugs and code updates (casa-users) at: <http://casa.nrao.edu/> → Getting Help → Mailing lists



CASA

- Documentation is available at <http://casa.nrao.edu/> → ‘Using CASA’
- Training material is available at <http://casaguides.nrao.edu>
- For help, use the NRAO help desk at: <http://help.nrao.edu>
(Forward ALMA CASA questions to <https://alma-help.nrao.edu>)

CASA release 3.3.0 will be used at this workshop



CASA

- All CASA tasks can be listed by *tasklist*.
- The tasks are grouped as:
 - Import/export
 - Information
 - Editing
 - Manipulation
 - Calibration
 - Modeling
 - Imaging
 - Analysis
 - Visualization
 - Simulation
 - Single dish
 - Utility
- AIPS – CASA dictionary is available at <https://safe.nrao.edu/wiki/bin/view/Software/CASA-AIPSDictionary>
- (Historic) MIRIAD-CASA and CLIC-CASA dictionaries are available in the CASA cookbook.



Loading The Data: *impordevla*

If one chooses to download the SDM

- The task *impordevla* converts the SDM to MS.
- *impordevla* is an enhanced version of *importasdm* that allows the use of the EVLA online flags.
- It converts the data into a MS, and carries out various types of flagging (online flags, pure zeros, shadowing).

```
asdm           =      'archive_sdm_directory'
vis            =      'output MS name'
ocorr_mode     =      'co'      (or load ca, ao)
scans          =      ''
switchedpower  =      False or True
                  (process SW and Tsys)
```



Loading The Data: *importevla*

`switchedpower = True or False`

- If 'switchedpower' is True, the SysPower and CalDevice tables are processed, enabling support for switched power gain and Tsys corrections.
- The switched power is being commissioned for the EVLA.
- Its application is fully implemented in AIPS, and under development in CASA.
- Its application on the data will be covered on Friday by E. Greisen.
- For technical details on the switched power, see the EVLA memo #145 by R. Perley.



Loading The Data: *importevla*

Flags:

online	=	True
tbuff	=	1.0
flagzero	=	True
cliplevel	=	1e-08
flagpol	=	True
shadow	=	True
diameter	=	-1.0
applyflags	=	False

- If `applyflags` is false => flags are written to a `FLAG_CMD` MS table. They can later be applied by using the task *flagcmd*.
- If `applyflags` are true, the flags are applied.



Examining Your Data

- Observing summary (sources, scans, spectral windows, antennas, etc...): *listobs*
- Plotting the antennas: *plotants*
- Plotting/displaying data: *plotms* (unix command line *casaplotms*), and *msview*

Examine your data carefully before flagging



Observing Summary: *listobs*

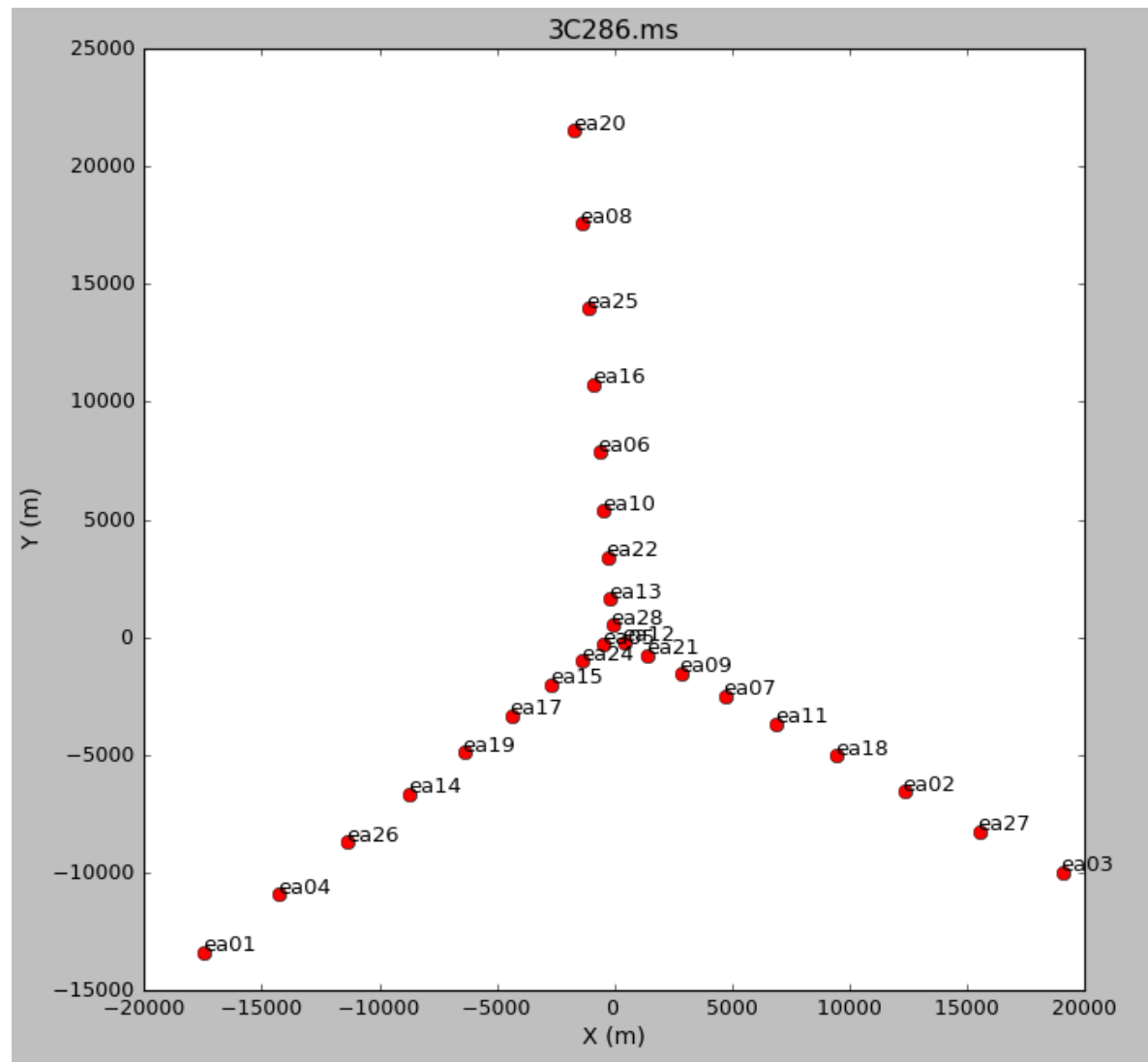
vis = 'MS file name'

verbose = True (or False)

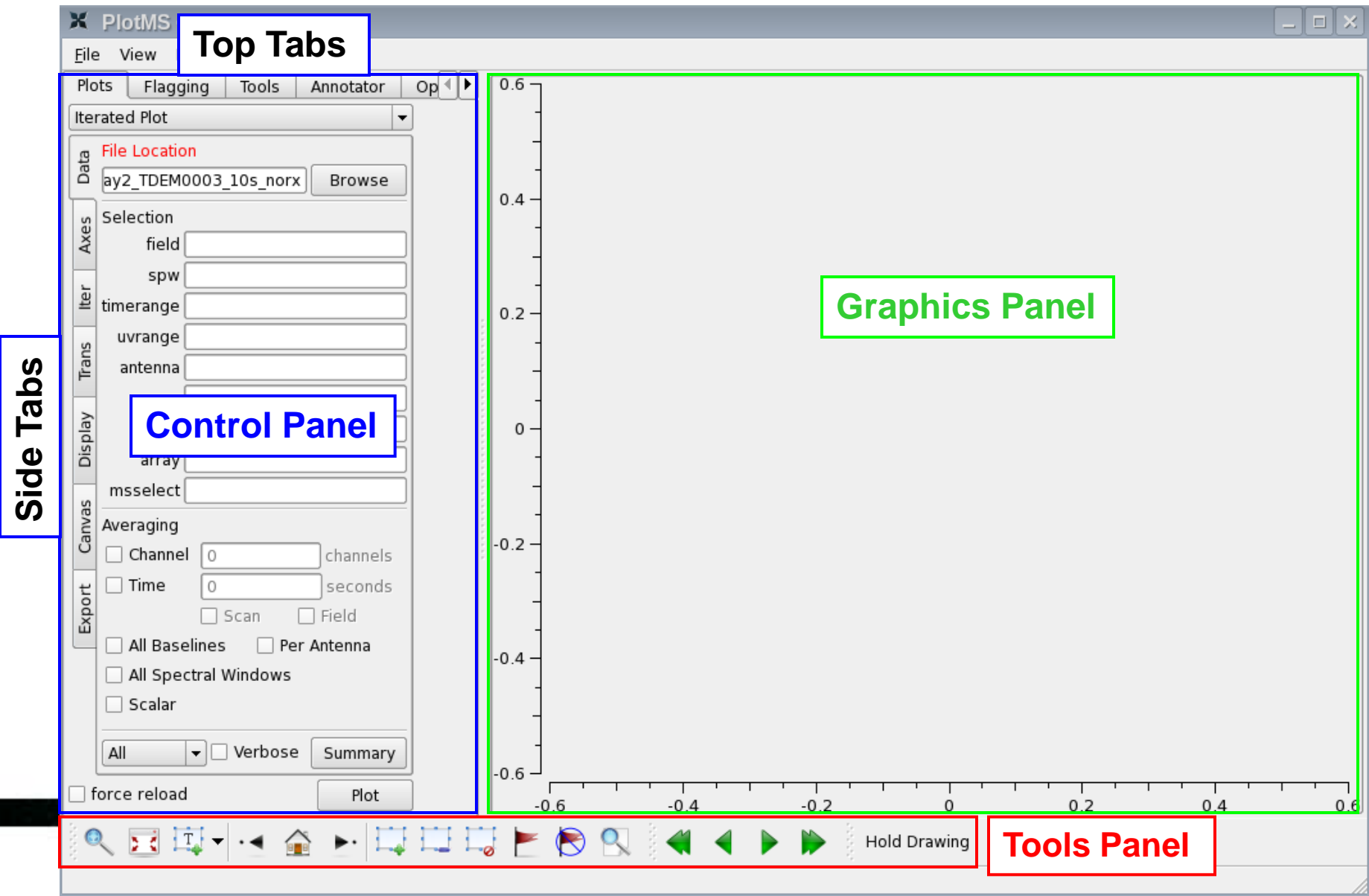
```
listobs:... =====
listobs:...           MeasurementSet Name: /lustre/aoc/users/emomjian/zeeman/StokesV_50Hz_
listobs:... =====
listobs:... Observer: Dr. Emmanuel Momjian      Project: T.B.D.
listobs:... Observation: EVLA(27 antennas)
listobs:... Data records: 1249911      Total integration time = 3586.94 seconds
listobs:... Observed from 12-Jul-2011/10:22:38.6 to 12-Jul-2011/11:22:25.5 (UTC)
listobs:... Fields: 3
listobs:...   ID   Code Name      RA              Decl              Epoch   SrcId
listobs:...   0    D    J1851+0035   18:51:46.7217 +00:35:32.4140 J2000    0
listobs:...   1   NONE G37.40+1.52* 18:54:14.2627 +04:41:41.4167 J2000    1
listobs:...   2    E    0137+331=3C* 01:37:41.2994 +33:09:35.1330 J2000    2
listobs:... (nVis = Total number of time/baseline visibilities per field)
listobs:... Spectral Windows: (1 unique spectral windows and 1 unique polarization setups)
listobs:... SpwID  #Chans Frame Ch1(MHz)   ChanWid(kHz) TotBW(kHz) Ref(MHz)   Corrs
listobs:...   0      256 TOPO  6667.85673   0.9765625   250          6667.85673 RR LL
listobs:... Sources: 3
listobs:...   ID   Name           SpwId RestFreq(MHz) SysVel(km/s)
listobs:...   0    J1851+0035     0     6668.518      41
listobs:...   1    G37.40+1.52*  0     6668.518      41
listobs:...   2    0137+331=3C*  0     6668.518      41
listobs:... Antennas: 27 'name'='station'
listobs:...   ID= 0-3: 'ea01'='W72', 'ea02'='E56', 'ea03'='E72', 'ea04'='W64',
listobs:...   ID= 4-7: 'ea05'='W08', 'ea06'='N40', 'ea07'='E32', 'ea08'='N64',
listobs:...   ID= 8-11: 'ea09'='E24', 'ea10'='N32', 'ea11'='E40', 'ea12'='E08',
listobs:...   ID= 12-15: 'ea13'='N16', 'ea14'='W48', 'ea15'='W24', 'ea16'='N48',
listobs:...   ID= 16-19: 'ea17'='W32', 'ea18'='E48', 'ea19'='W40', 'ea20'='N72',
listobs:...   ID= 20-23: 'ea22'='N24', 'ea23'='E16', 'ea24'='W16', 'ea25'='N56',
listobs:...   ID= 24-26: 'ea26'='W56', 'ea27'='E64', 'ea28'='N08'
```

Plotting the antennas: *plotants*

```
vis = 'MS file name'
```



Data Review: *plotms* (unix command line *casaplotms*)



Data Review: *plotms*

Control Panel: Data

Use the 'force reload' if the MS has been modified through another task.

The screenshot shows the PlotMS <3> control panel with the Data tab selected. The 'Data' section includes a 'File Location' field with the text 'ay2_TDEM0003_10s_norx' and a 'Browse' button. Below this is a 'Selection' section with input fields for 'field', 'spw', 'timerange', 'uvrange', 'antenna', 'scan', 'corr', 'array', and 'msselect'. The 'Averaging' section has checkboxes for 'Channel' (0 channels), 'Time' (0 seconds), 'Scan', and 'Field'. There are also checkboxes for 'All Baselines', 'Per Antenna', 'All Spectral Windows', and 'Scalar'. At the bottom, there is a dropdown menu set to 'All', a 'Verbose' checkbox, a 'Summary' button, and a 'force reload' checkbox which is circled in red. A 'Plot' button is also visible.



Data Review: *plotms*

MS Ids and other meta info:

'scan' (number)

'field' (index)

'time',

'interval'='timeint'='timeinterval'='time_interval'

'spw' (index)

'chan'='channel' (index)

'freq'='frequency' (GHz)

'vel'='velocity' (km/s)

'corr'='correlation' (index)

'ant1'='antenna1' (index)

'ant2'='antenna2' (index)

'baseline' (a baseline index)

'row' (absolute row Id from the MS)

Visibility values, flags:

'amp'='amplitude'

'phase' (deg)

'real'

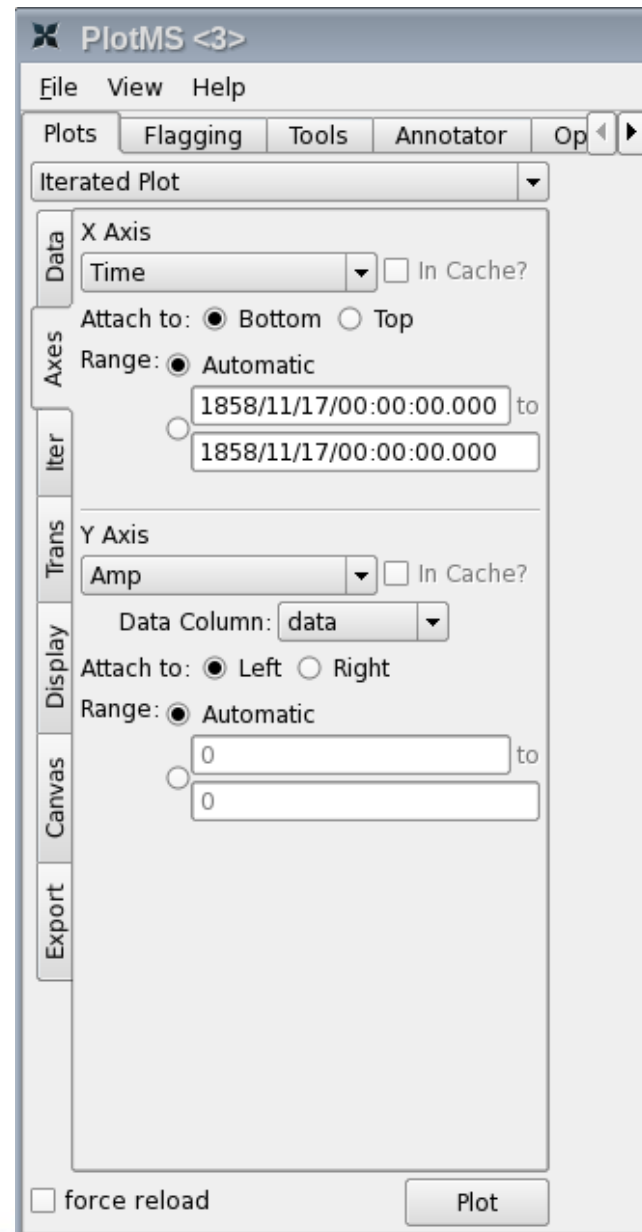
'imag'='imaginary'

'wt'='weight'

'flag'

'flagrow'

Axes



Data Review: *plotms*

Axes

Observational geometry:

'uvdist' (meters)

'uvwave'='uvdist'='uvdist_l' (wavelengths, per channel)

'u' (meters)

'v' (meters)

'w' (meters)

'azimuth' (at array reference; degrees)

'elevation' (at array reference; degrees)

'hourang'='hourangle' (at array reference; hours)

'parang'='parangle'='parallacticangle' (at array reference; degrees)

Antenna-based (only works vs. data lds):

'ant'='antenna'

'ant-azimuth'

'ant-elevation'

'ant-parang'='ant-parangle'

The screenshot shows the PlotMS <3> window with the following settings:

- File View Help** menu bar.
- Plots** tab selected, with **Flagging**, **Tools**, **Annotator**, and **Op** sub-tabs.
- Iterated Plot** dropdown menu.
- Data** section: X Axis is **Time**, **In Cache?** checkbox is unchecked.
- Axes** section: **Attach to:** **Bottom** (selected), **Top** (unselected).
- Range:** **Automatic** (selected), with input fields for **1858/11/17/00:00:00.000** to **1858/11/17/00:00:00.000**.
- Iter** section: **Y Axis** is **Amp**, **In Cache?** checkbox is unchecked.
- Trans** section: **Data Column:** **data** (selected).
- Display** section: **Attach to:** **Left** (selected), **Right** (unselected).
- Range:** **Automatic** (selected), with input fields for **0** to **0**.
- Canvas** section: **Export** button.
- force reload** checkbox and **Plot** button at the bottom.



Data Review: *plotms*

Iteration

Scan

Field

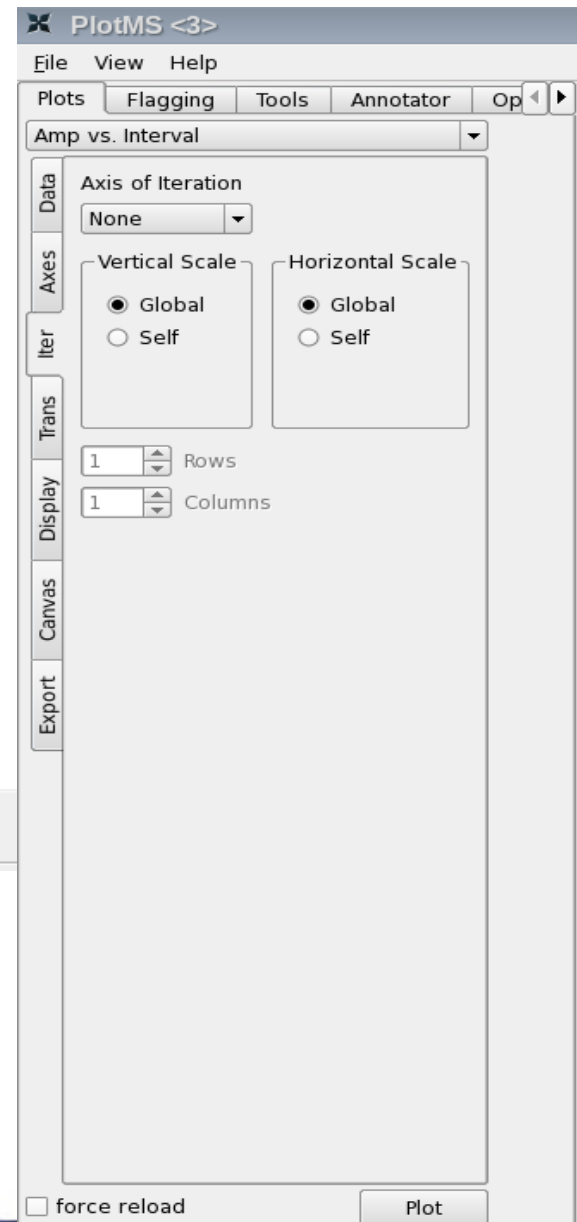
Spw

Baseline

antenna



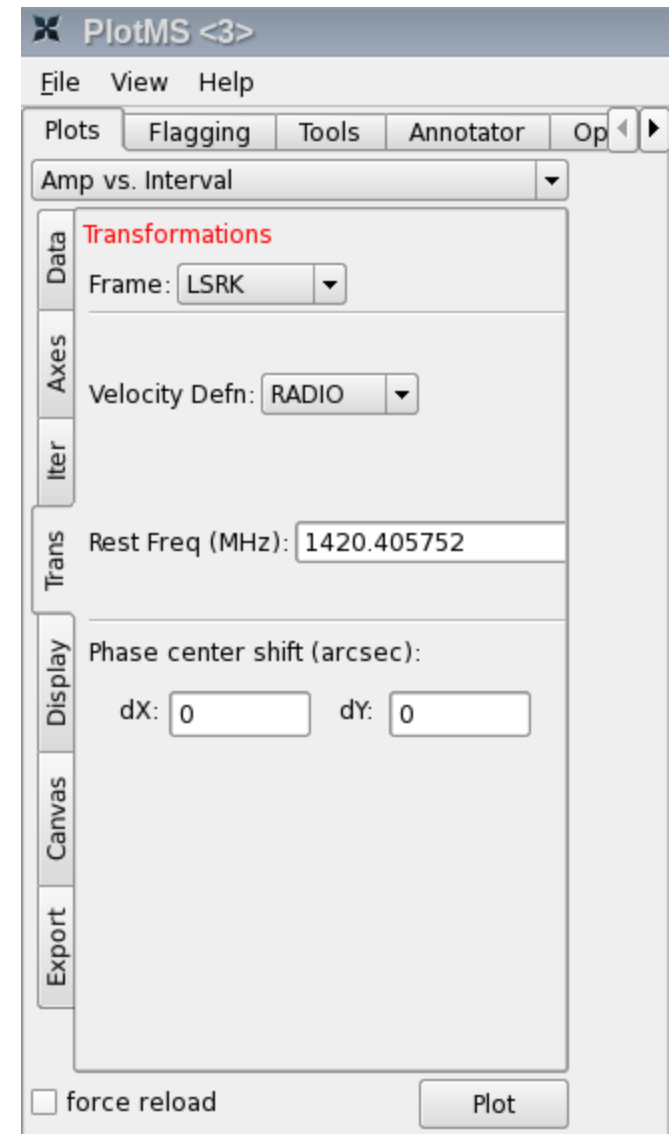
Tool panel



Data Review: *plotms*

Transformations

Frame: TOPO, GEO, BARY, LSRK, LSRD, etc..



The screenshot shows the PlotMS software interface. The title bar is "PlotMS <3>". The menu bar includes "File", "View", and "Help". The main window has several tabs: "Plots", "Flagging", "Tools", "Annotator", and "Op". The "Plots" tab is active, and a dropdown menu shows "Amp vs. Interval". On the left side, there is a vertical toolbar with buttons for "Data", "Axes", "Iter", "Trans", "Display", "Canvas", and "Export". The "Data" button is selected, and the "Transformations" panel is displayed. This panel contains the following settings:

- Frame:** LSRK (dropdown menu)
- Velocity Defn:** RADIO (dropdown menu)
- Rest Freq (MHz):** 1420.405752 (text input)
- Phase center shift (arcsec):**
 - dx:** 0 (text input)
 - dy:** 0 (text input)

At the bottom of the panel, there is a checkbox labeled "force reload" and a "Plot" button.



Data Review: *plotms*

Display

Colorize by:

Scan

Field

Spw

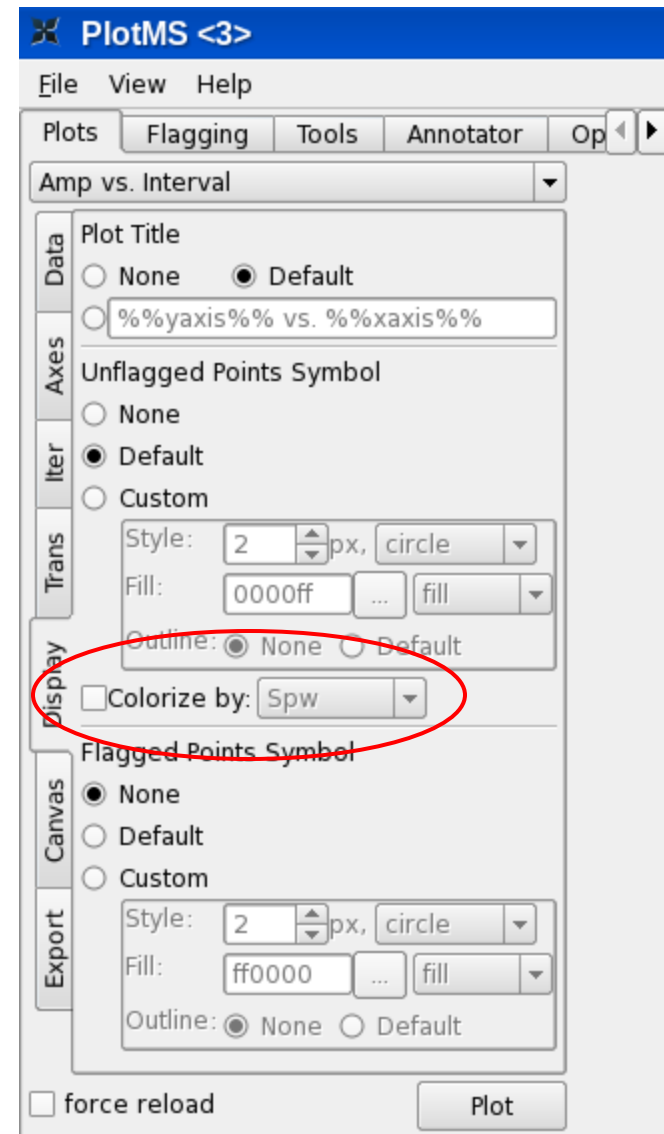
Antenna1

Antenna2

Baseline

Channel

Correlation



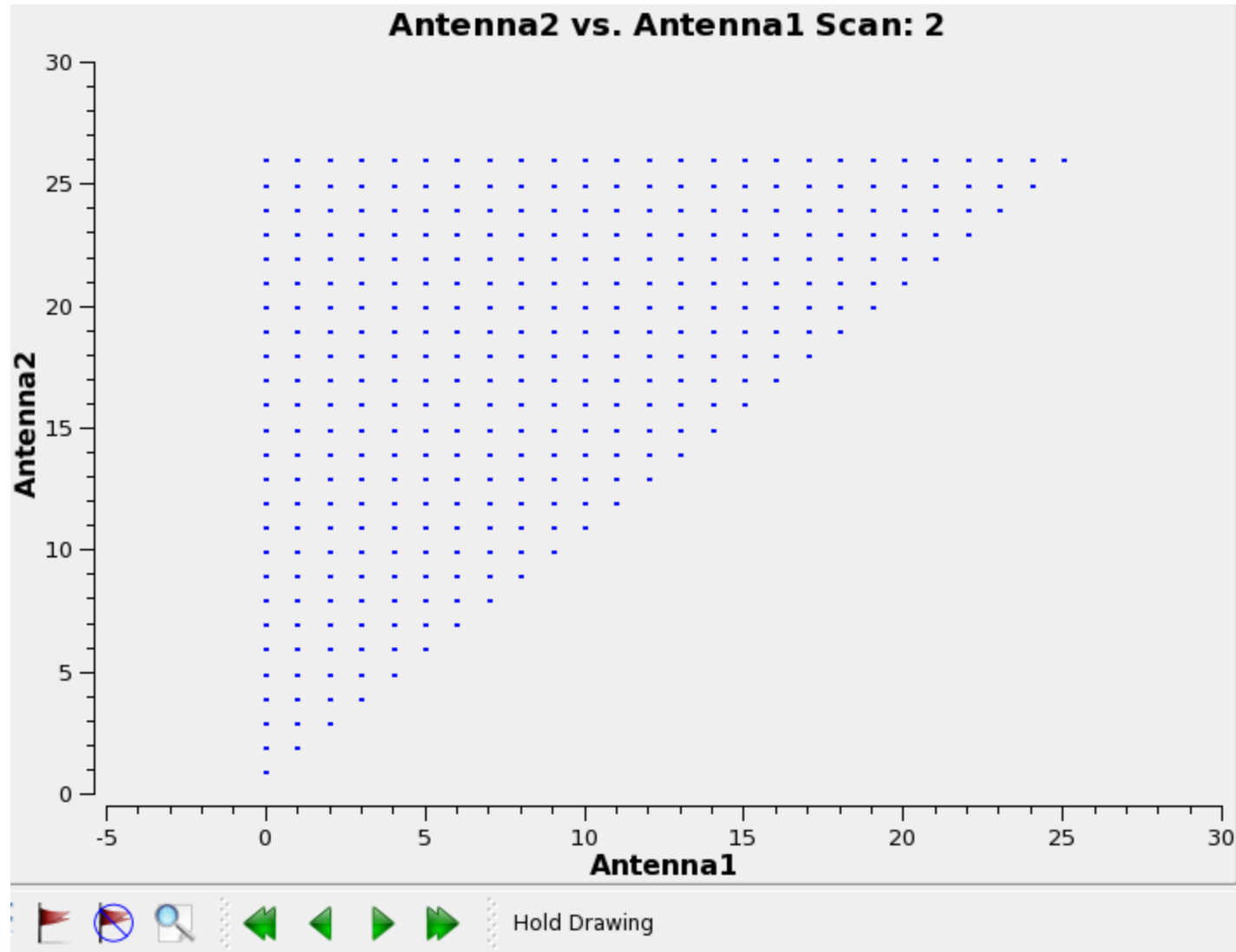
Data Review: *plotms*

Example:

x-axis: ant 1

y-axis: ant 2

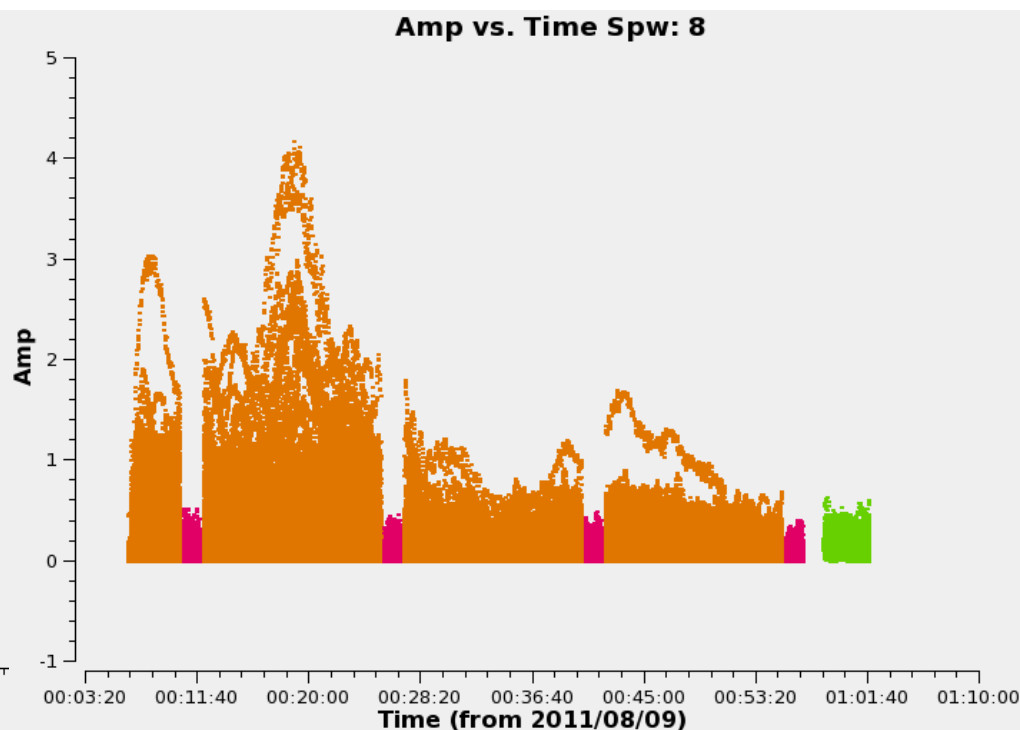
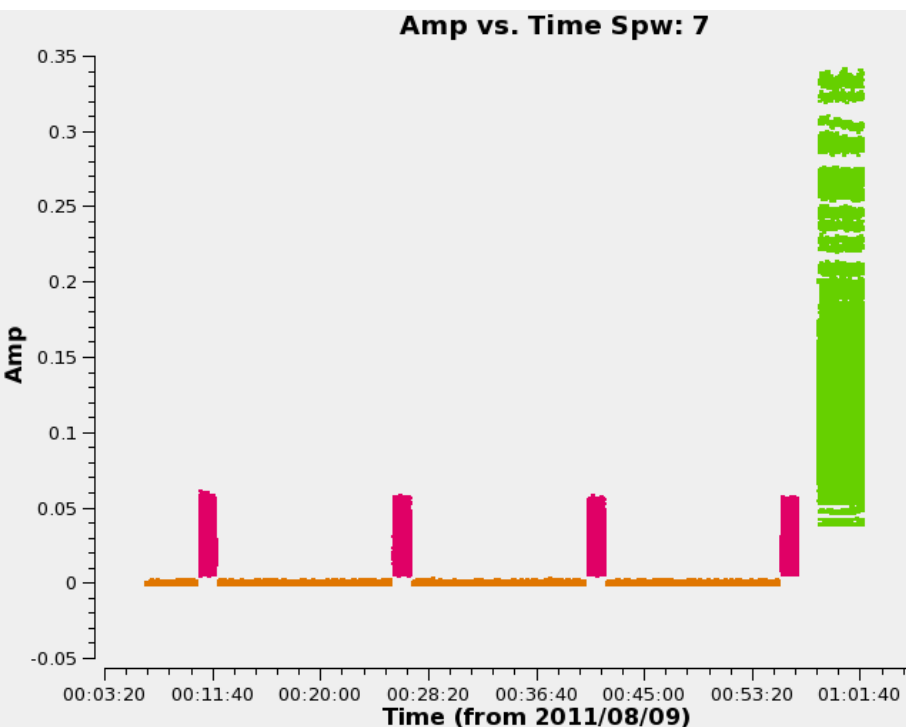
iter: scans



Data Review: *plotms*

Example: x-axis: time, y-axis: amp

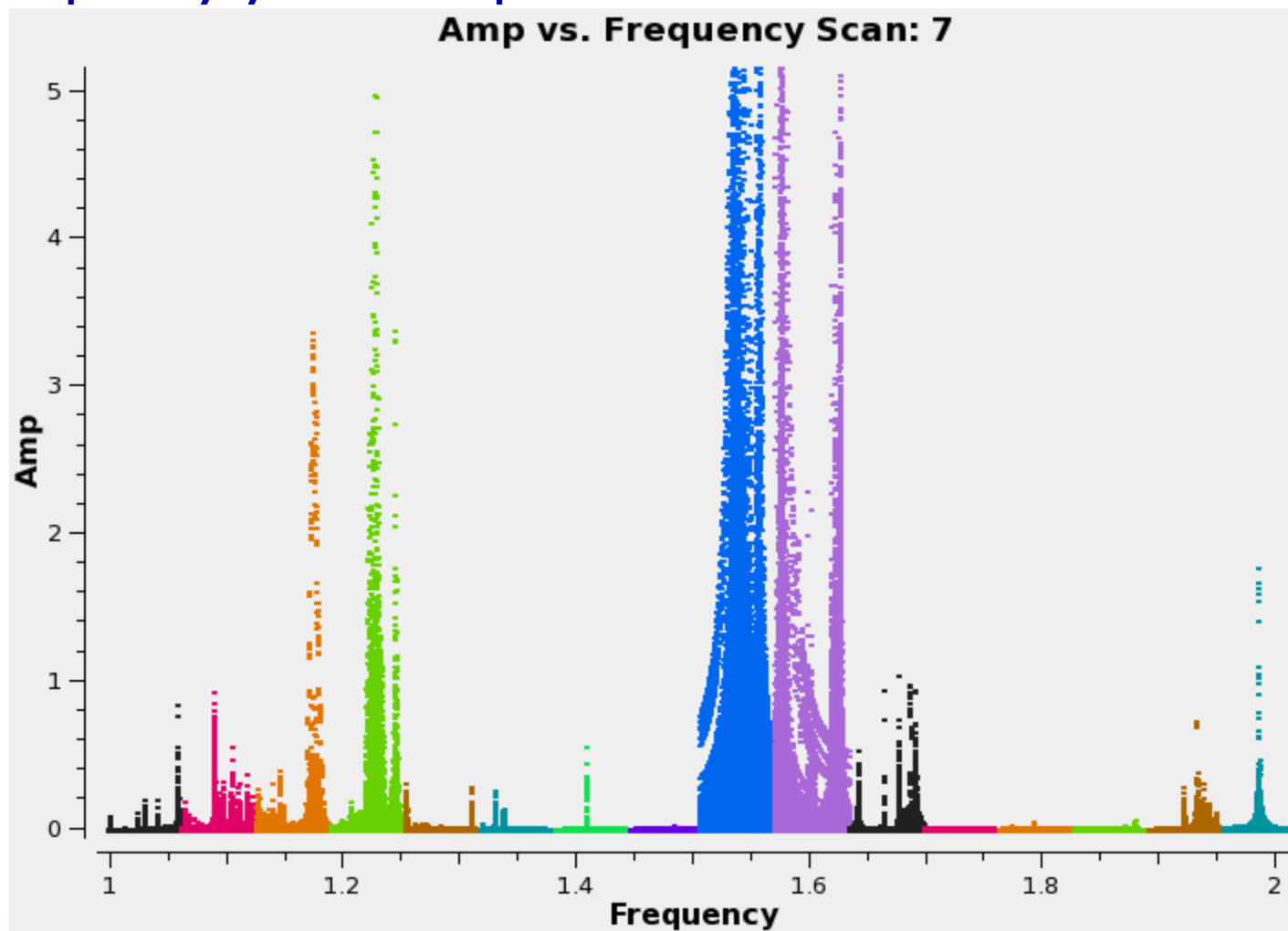
iter: spw (with all channels averaged)



Data Review: *plotms*

Example: x-axis: frequency, y-axis: amp

iteration: scan



Flagging (or unflagging) Data

1. *flagdata*: All purpose flagging task based on selection
2. *flagcmd*: All purpose flagging task based on commands (alternative to *flagdata*)
3. *plotms*: Interactive flagging
4. *msview*: Interactive flagging
5. *testautoflag*: For automatic identification and flagging of RFI (In the near future, the *RFLAG* task of AIPS will be implemented in CASA.)

**Review the EVLA operator's log carefully.
Certain issues (e.g., antennas without receivers), do not end up in the online flags, and need to be flagged manually.**



Flagging (or unflagging) Data

A few important notes

1. Data in CASA are either flagged or not flagged.
 - Every MS has a flag column.
 - Every bit of data has its own flag (set either to true or false).
 - Applying flags means setting the flag column entries of the selected bits of data to true.
2. Most flagging tasks have the option of creating a flag backup.
3. A flag backup is a MS that contains the state of the flags before running a flagging task.
4. Using *flagmanager*, backed-up flags can be restored.



Flagging Data: *flagdata*

Modes of flagging

- Manualflag
- Shadow
- Quack

Data selection:

- antenna
- timertange
- correlation
- scan
- intent
- array (i.e. subarray)
- uvrage

Every execution of *flagdata* means going through the whole MS and changing the flag state of the selected bits of data.



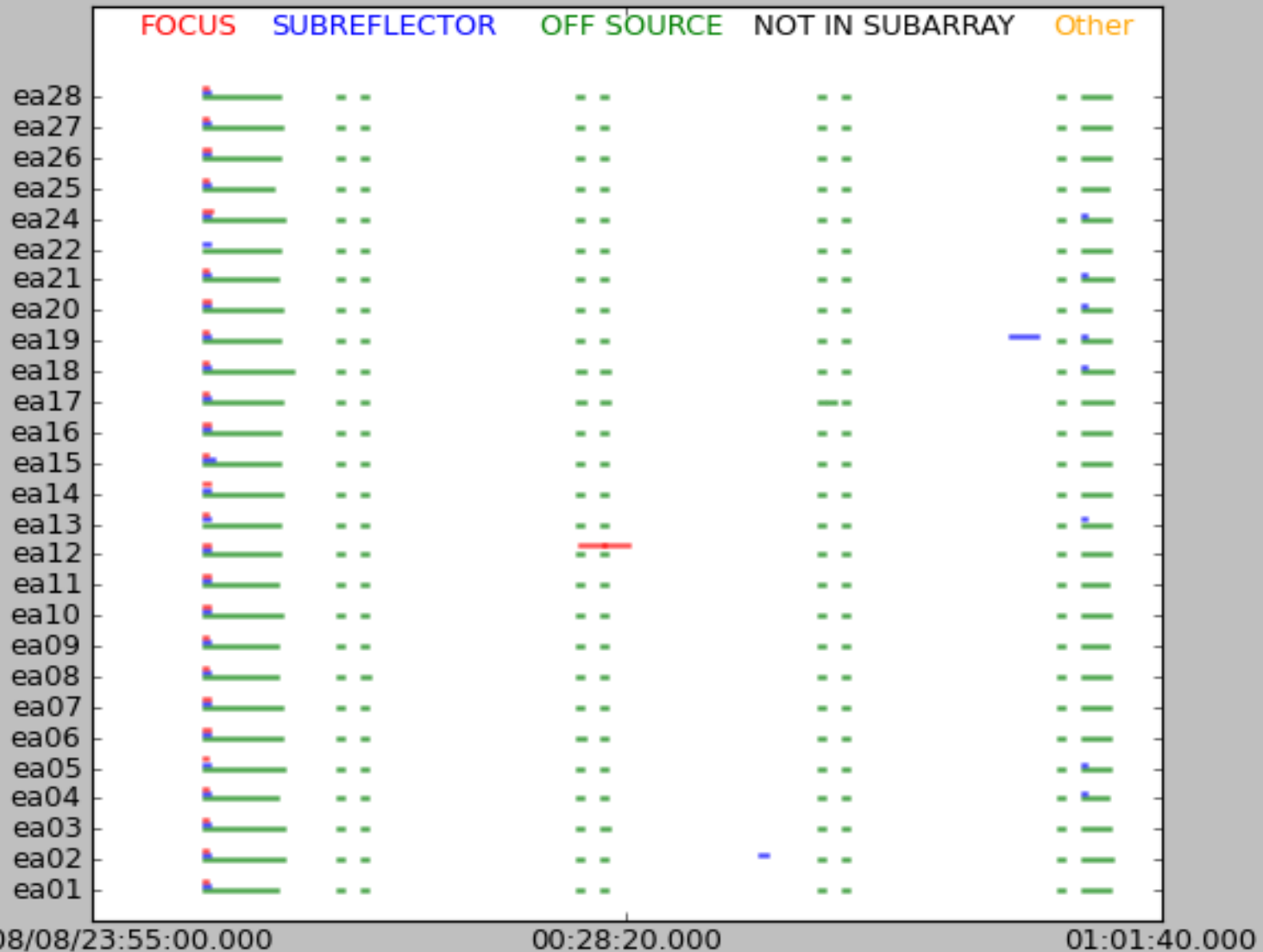
Flagging Data: *flagcmd*

- It allows listing, plotting, saving, applying, or un-applying flags.
- The user makes a set of command lines for flagging, and applies them later on the MS.
- Flagging modes (`flagmode`) are:
 - `table`: uses the FLAG_CMD MS table.
 - `file`: uses an ASCII file that contains a set of flagging commands.
 - `cmd`: uses a list of command strings.
 - `xml`: uses the online flags from Flag.xml in the MS.
- It allows the user to save the flag records in the FLAG_CMD MS table or a text file.



Examining the flags with *flagcmd*

plot



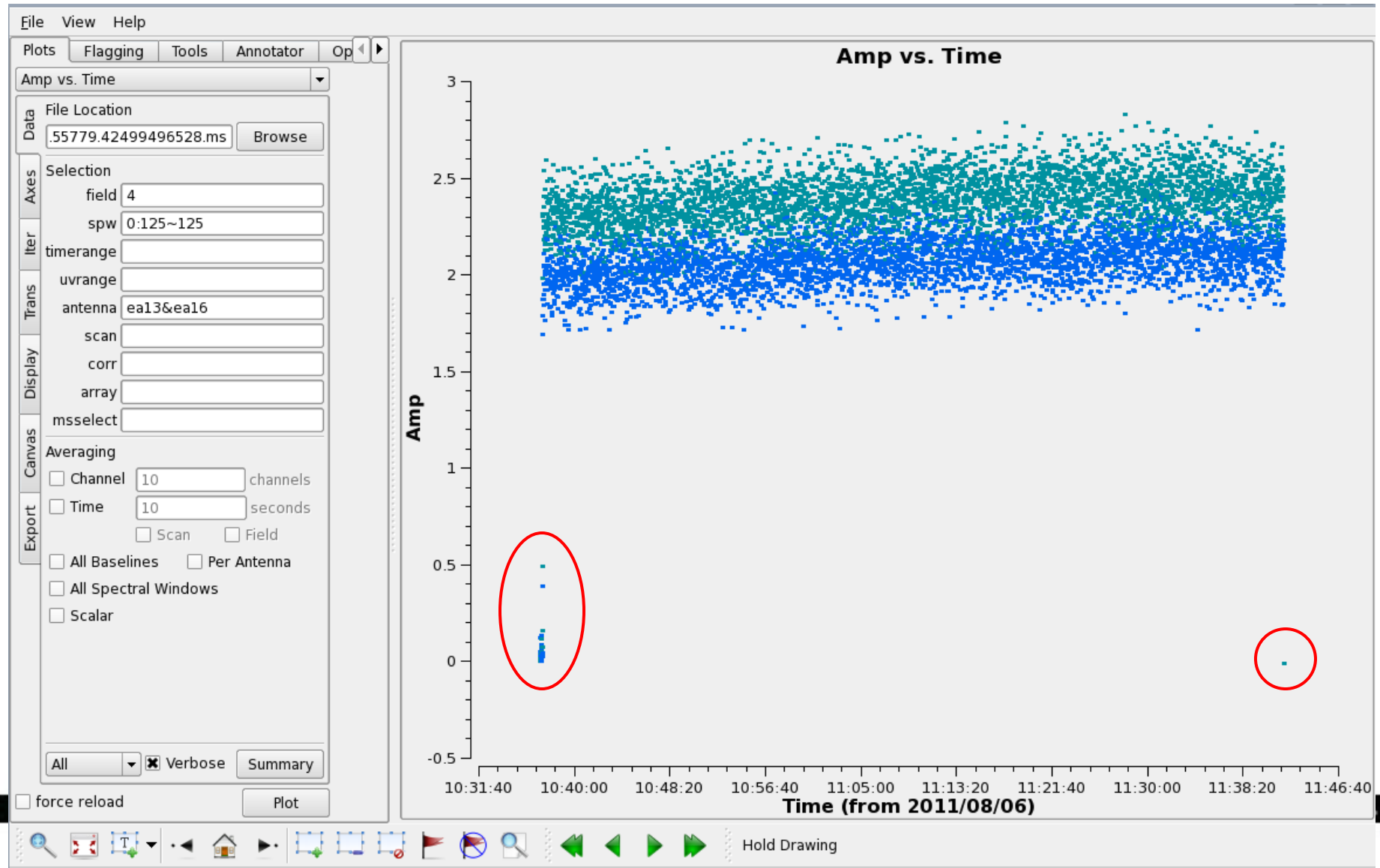
Examining the flags with *flagcmd*

list

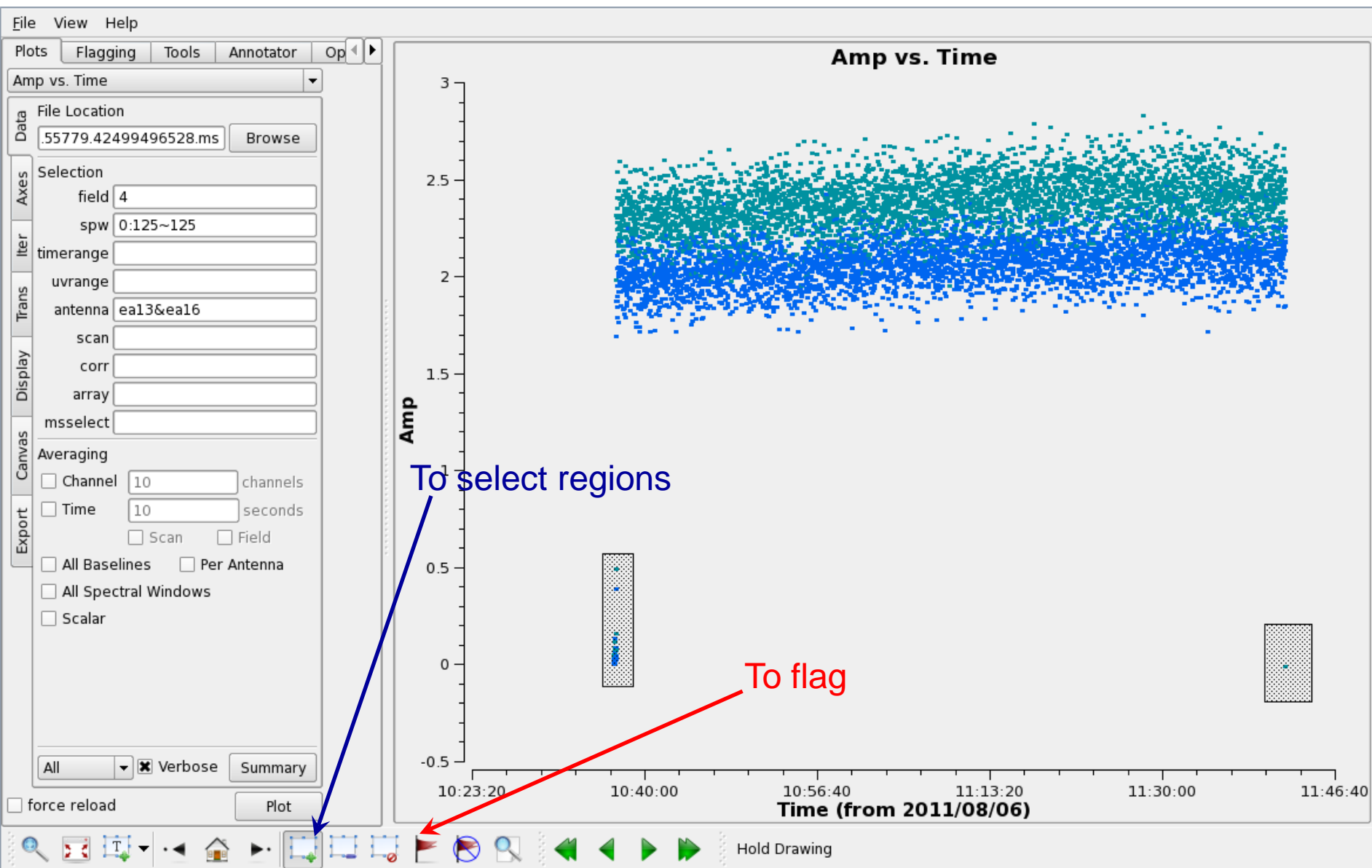
Key	FlagID	Antenna	Reason	Timerange
0	0	ea28	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.401~2011/08/09/00:02:15.300
1	1	ea26	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.435~2011/08/09/00:02:15.274
2	2	ea21	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.478~2011/08/09/00:02:15.093
3	3	ea08	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.478~2011/08/09/00:02:15.300
4	4	ea22	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.487~2011/08/09/00:02:14.946
5	5	ea27	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.487~2011/08/09/00:02:15.594
6	6	ea20	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.522~2011/08/09/00:02:15.343
7	7	ea03	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.548~2011/08/09/00:06:58.537
8	8	ea03	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.548~2011/08/09/00:02:15.551
9	9	ea18	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.573~2011/08/09/00:07:31.533
10	10	ea18	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.573~2011/08/09/00:02:15.084
11	11	ea04	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.573~2011/08/09/00:06:30.586
12	12	ea04	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.573~2011/08/09/00:02:15.179
13	13	ea19	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.591~2011/08/09/00:06:42.907
14	14	ea19	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.591~2011/08/09/00:02:16.069
15	15	ea28	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.599~2011/08/09/00:06:42.397
16	16	ea07	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.608~2011/08/09/00:06:46.907
17	17	ea16	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.591~2011/08/09/00:06:39.658
18	18	ea07	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.608~2011/08/09/00:02:15.663
19	19	ea16	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.591~2011/08/09/00:02:15.706
20	20	ea10	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.608~2011/08/09/00:06:45.810
21	21	ea01	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.591~2011/08/09/00:06:30.301
22	22	ea10	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.617~2011/08/09/00:02:15.706
23	23	ea01	SUBREFLECTOR_ERROR	2011/08/09/00:02:00.591~2011/08/09/00:02:15.430
24	24	ea02	ANTENNA_NOT_ON_SOURCE	2011/08/09/00:02:00.625~2011/08/09/00:06:59.098



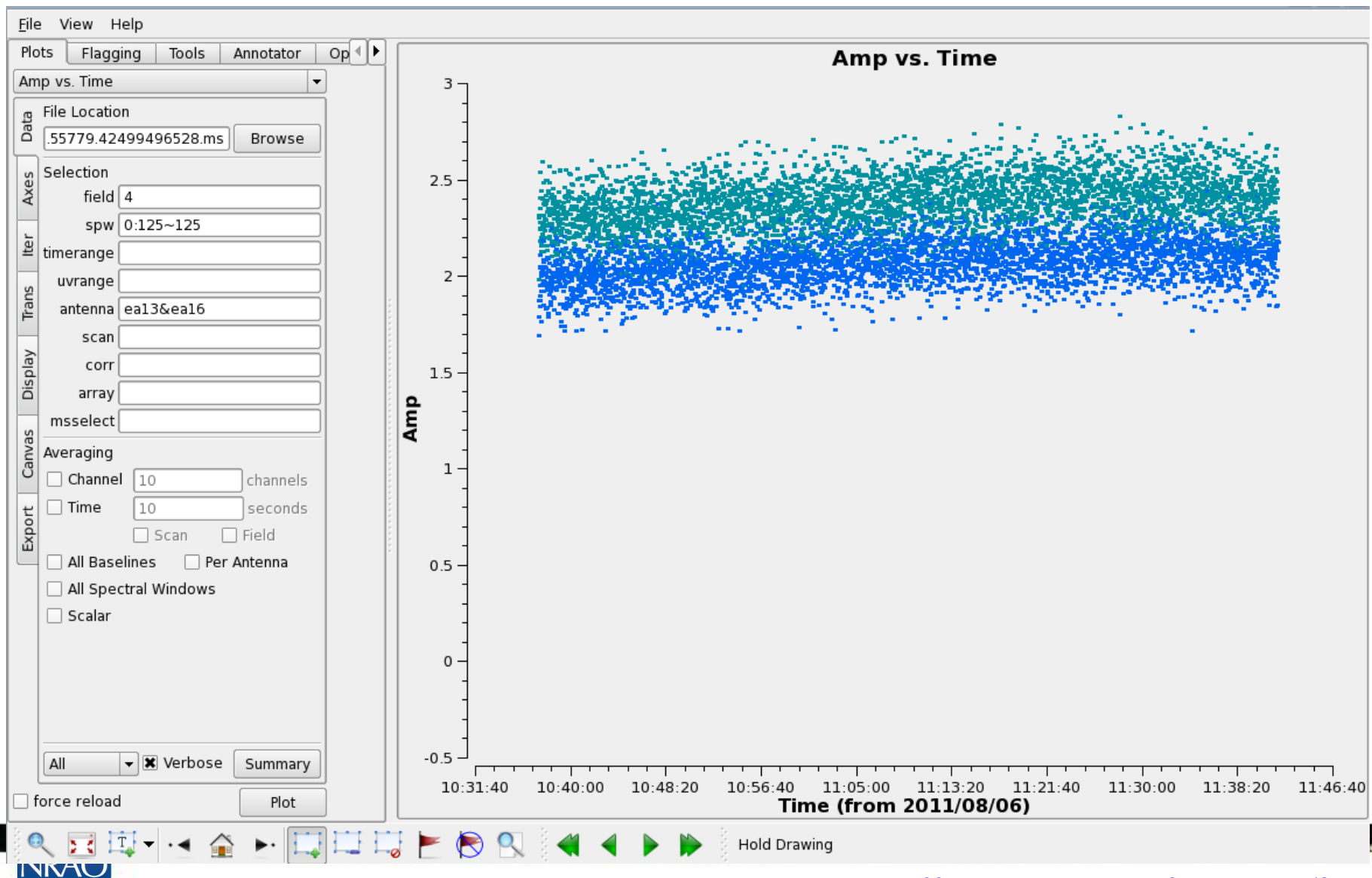
Flagging Data: *plotms*



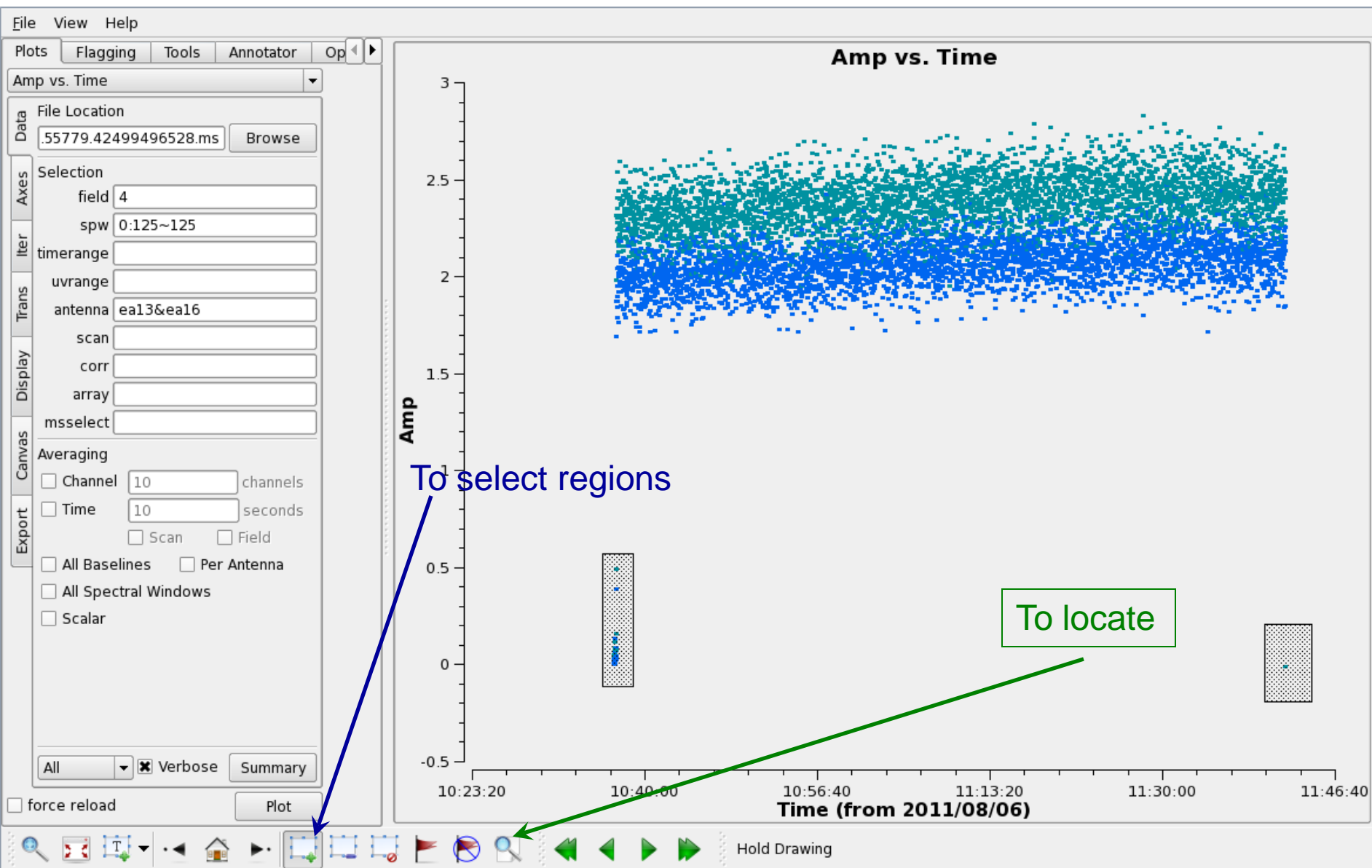
Flagging Data: *plotms*



Flagging Data: *plotms*



Flagging Data: *plotms*



Flagging Data: *plotms*

The output of `locate` in the `casalog`

```
-----  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:36:57.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:36:57.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:36:58.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:36:58.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:36:59.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:36:59.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:00.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:00.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:01.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:01.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:02.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:02.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:03.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:03.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:04.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:04.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:05.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:05.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=LL  
Scan=9 Field=W3IRS5 [4] Time=2011/08/06/10:37:06.3 BL=ea13&ea16 [11&14] Spw=0 Chan=125 Freq=22.2398 Corr=RR
```



Flagging Data: *plotms*

A few important notes

- Use *plotms* carefully for flagging data.
- Keep in mind that flagging data with *plotms* often requires extending the flags (through the Flagging tab).
- *plotms* does not produce a flag backup (*flagmanager* has to be used).
- Use *plotms* to identify bad data (through the locate option). Then flag the bad data using *flagcmd* or *flagdata*.

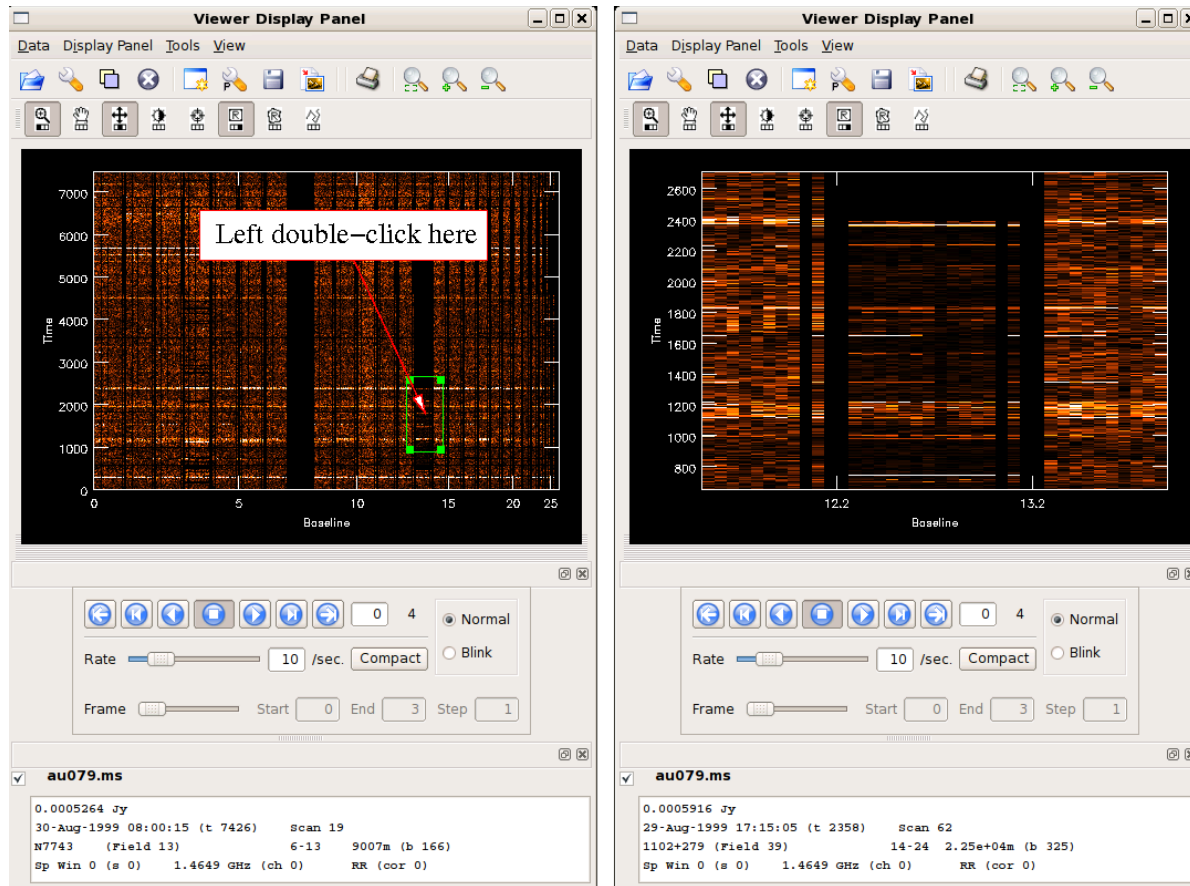


Flagging Data: *msview*

- Shows gray scale (or colored) waterfall, plots.
- Plots Time vs. Baseline, or Time vs. Channel for
 - Amplitude (or amplitude diff or amplitude rms)
 - Phase (or phase diff or phase rms)
 - Real
 - Imaginary
- Provides interactive flagging tools (comparable to TVFLG and SPFLG in AIPS).



Flagging Data: *msview*

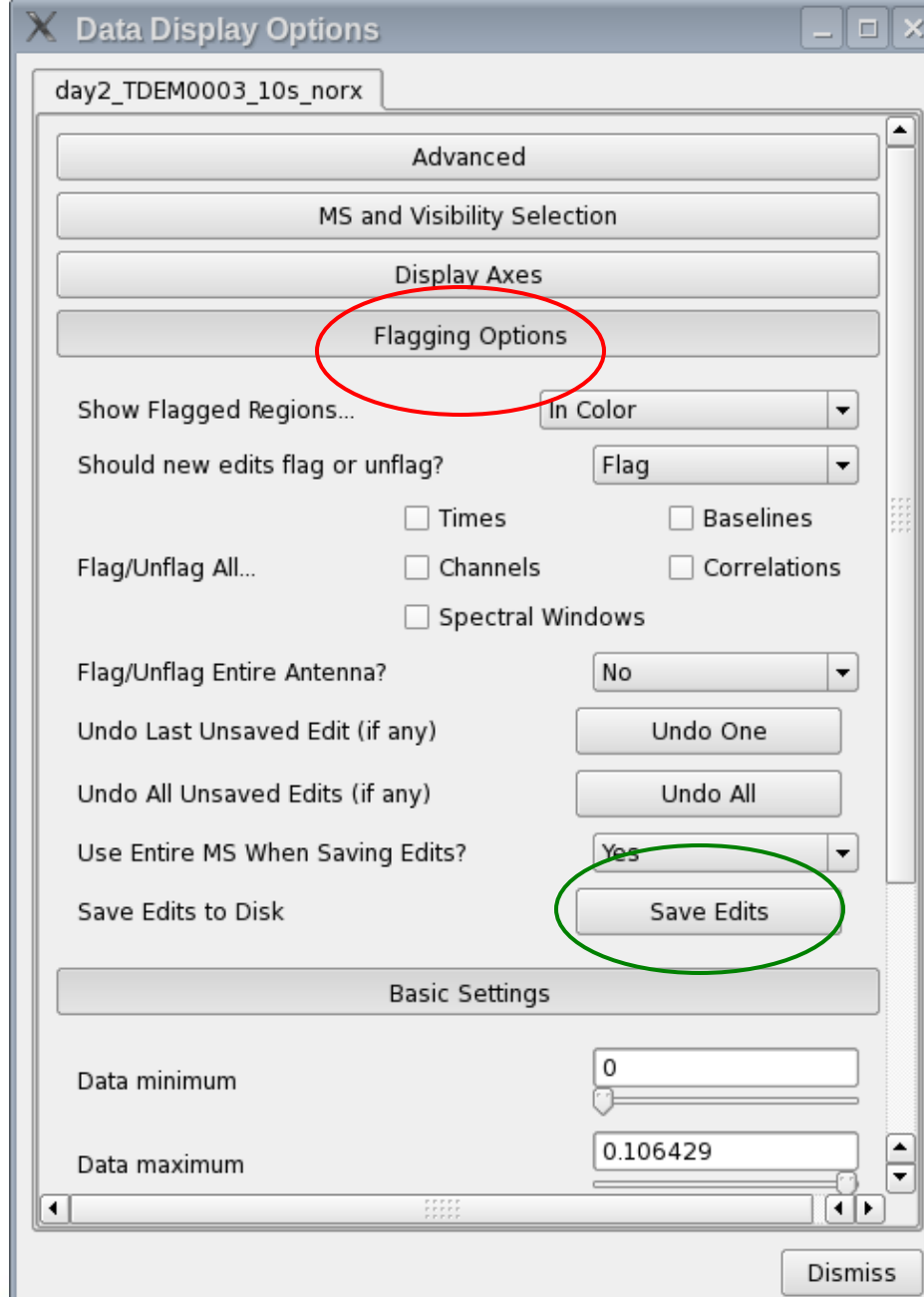


<http://casaguides.nrao.edu/> → Data flagging

Flagging Data: *msview*

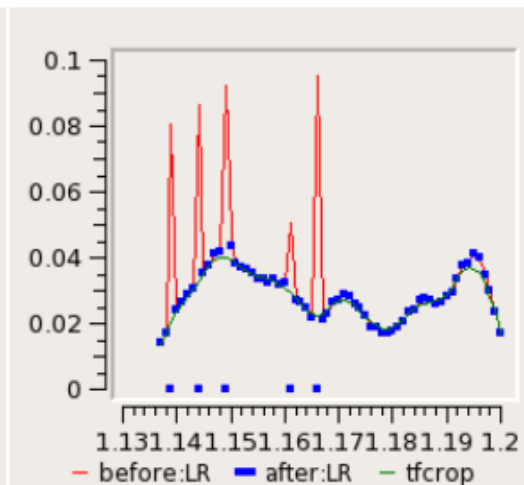
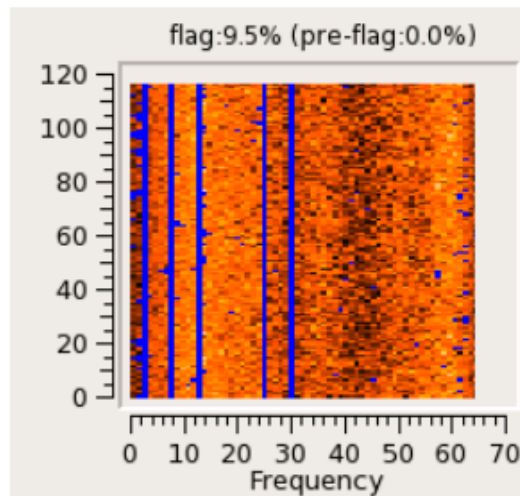
Use the Flagging Options

- to expand the flags.
- **to apply the flags.**



Flagging Data: *testautoflag*

1. For automatic identification and flagging of RFI.
2. Information is available at:
<http://casa.nrao.edu/> → Using CASA → Other Documentation
→ Description of the TFCrop autoflagging algorithm
3. Will be covered in detail on Friday by U. Rau.
4. Will be used in the EVLA Wide-Band Wide-Field Imaging tutorial.
5. New flagging infrastructure coming soon (in CASA 3.4).



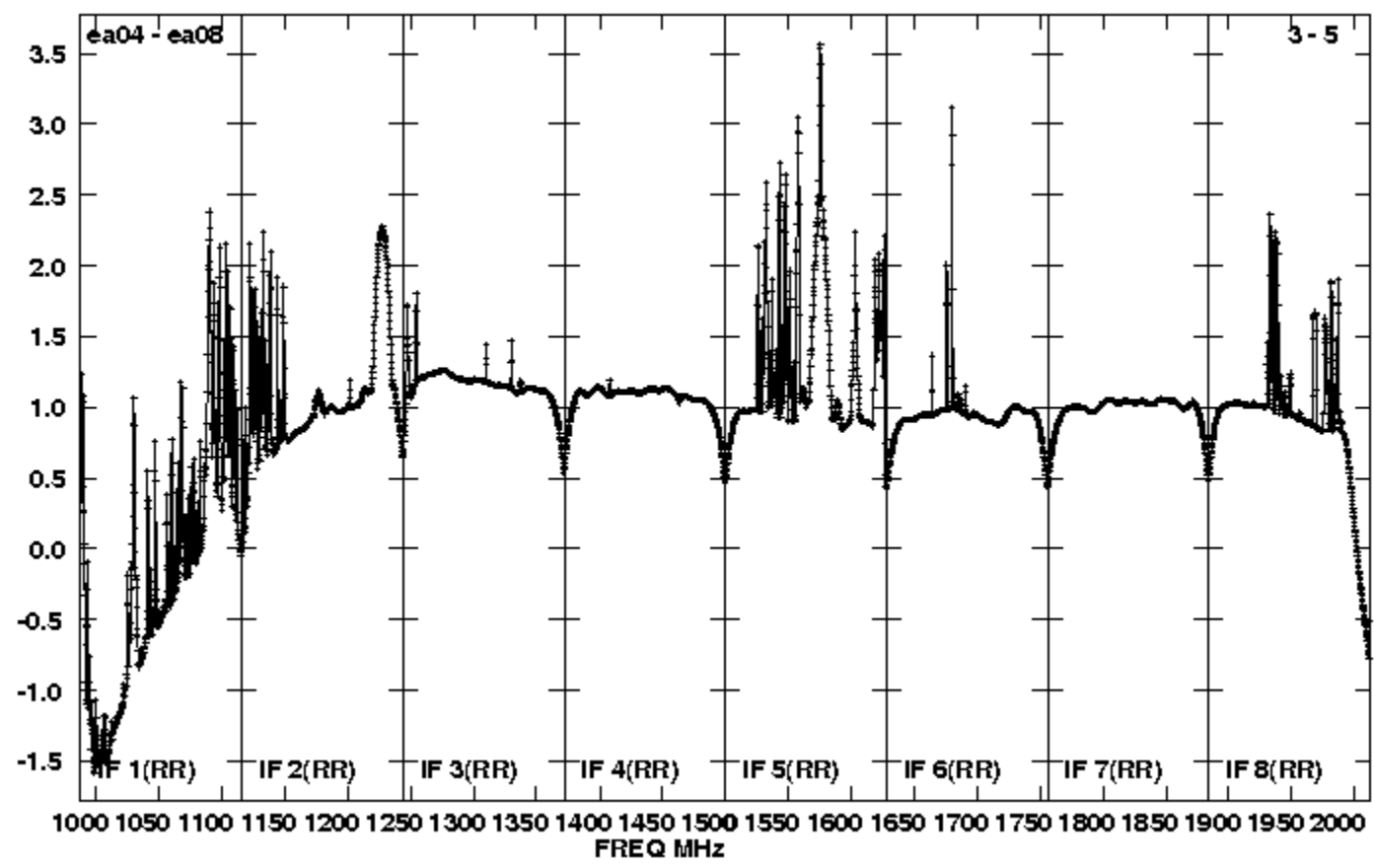
Radio Frequency Interference (RFI)

- 1. EVLA observations, particularly at the lower frequency bands, will be severely affected by RFI.
- 2. EVLA RFI information is available at:
<https://science.nrao.edu/> → EVLA → Observing → RFI
- 3. The RFI information has been tabulated by frequency, and the links provide listings and spectra.

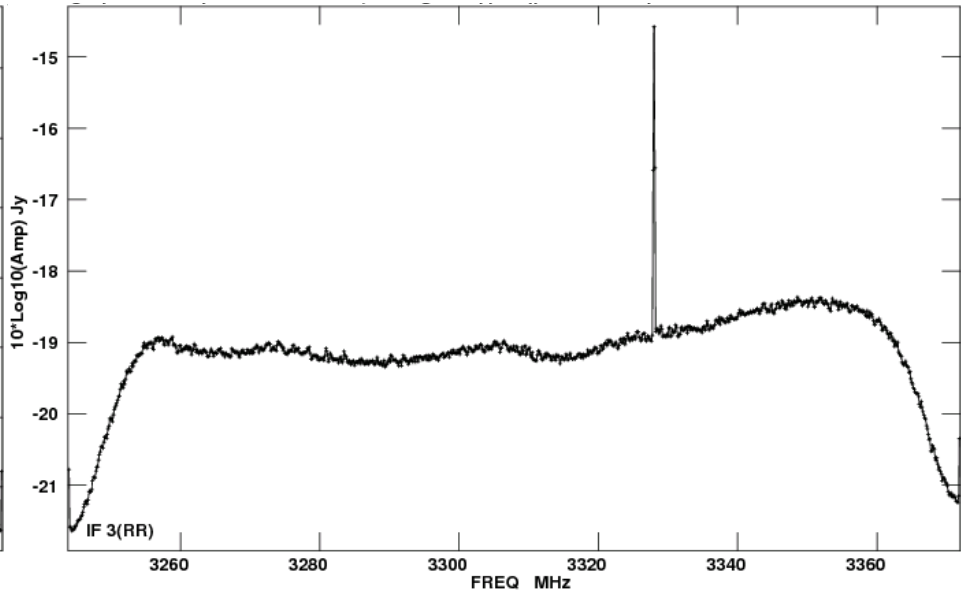
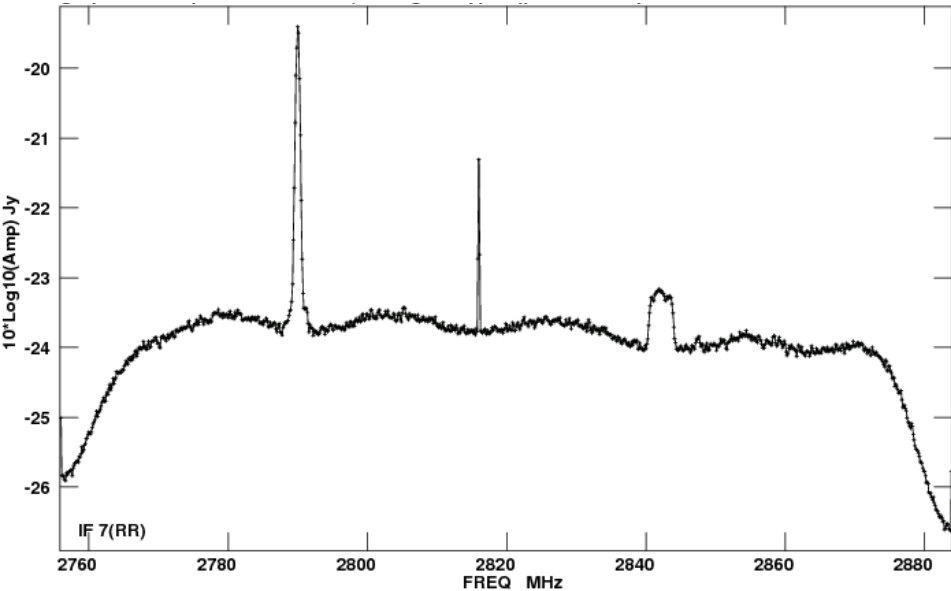
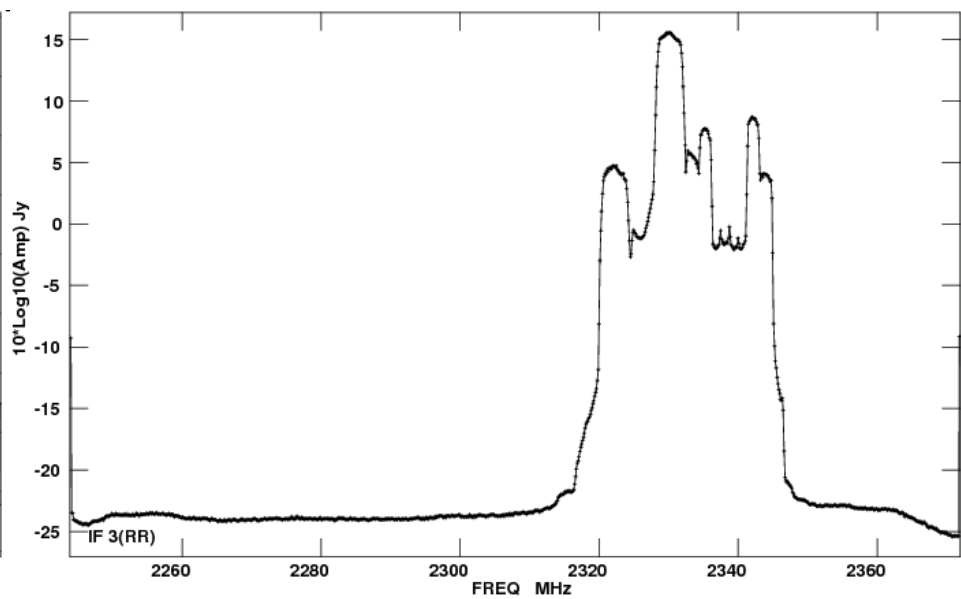
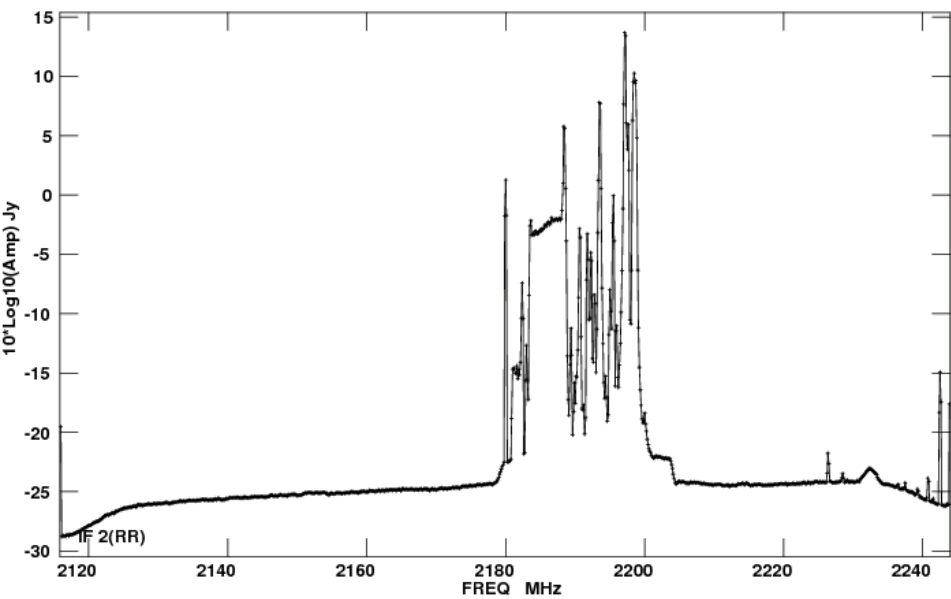
L-Band (1-2 GHz)	S-Band (2-4 GHz)	C-Band (4-8 GHz)	X-Band (8-12 GHz)	Ku-Band (12-18 GHz)	K-Band (18-26.5 GHz)	Ka-Band (26.5-40 GHz)	Q-Band (40-50 GHz)
List	List	List	List	List	List	List	N/A
Spectra	Spectra	Spectra	Spectra	Spectra	Spectra	Spectra	Spectra



RFI: L-band



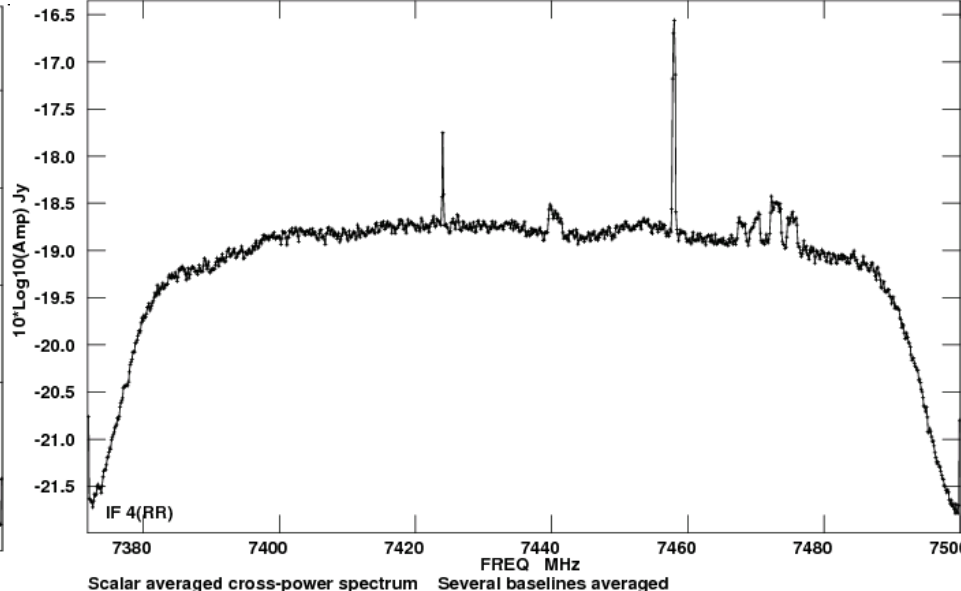
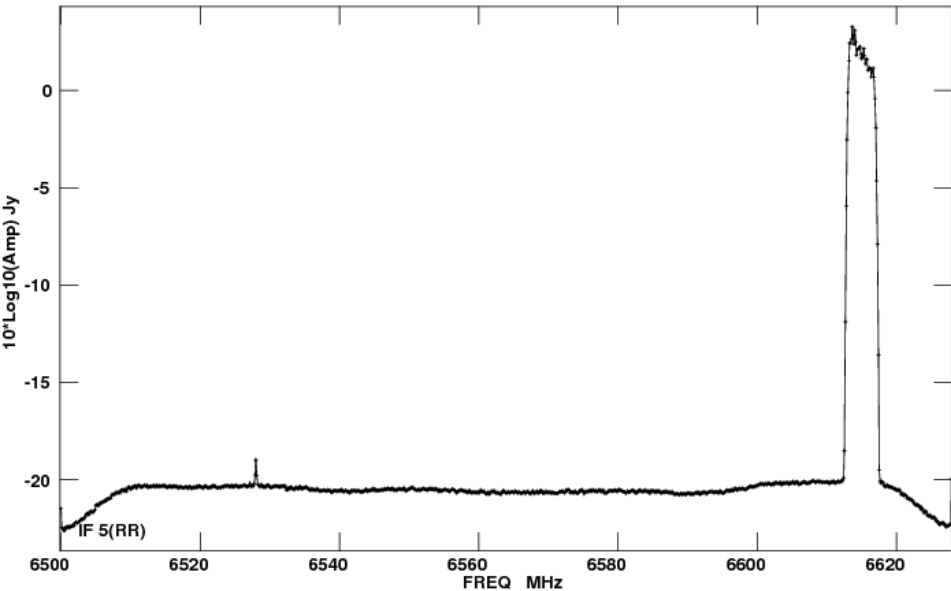
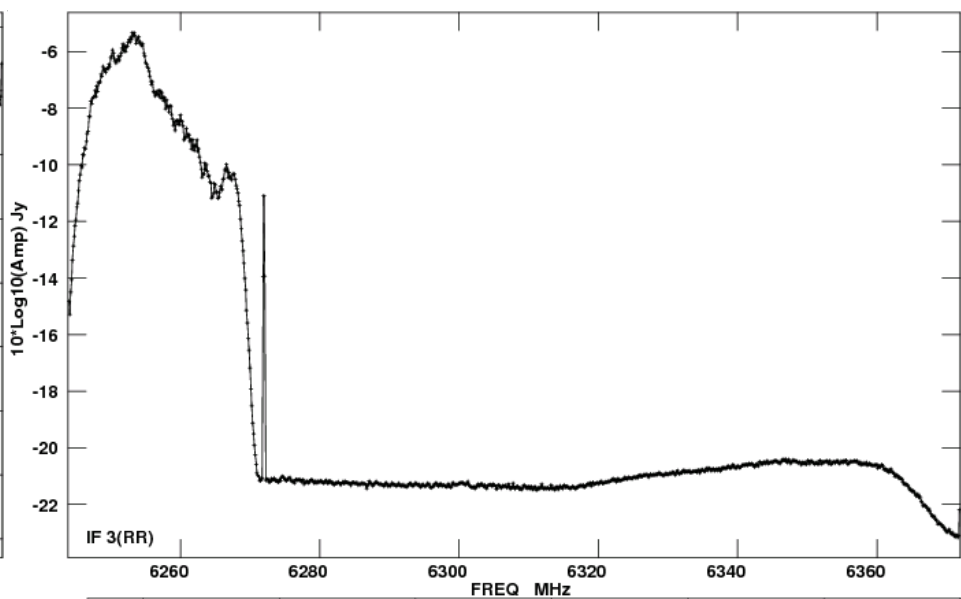
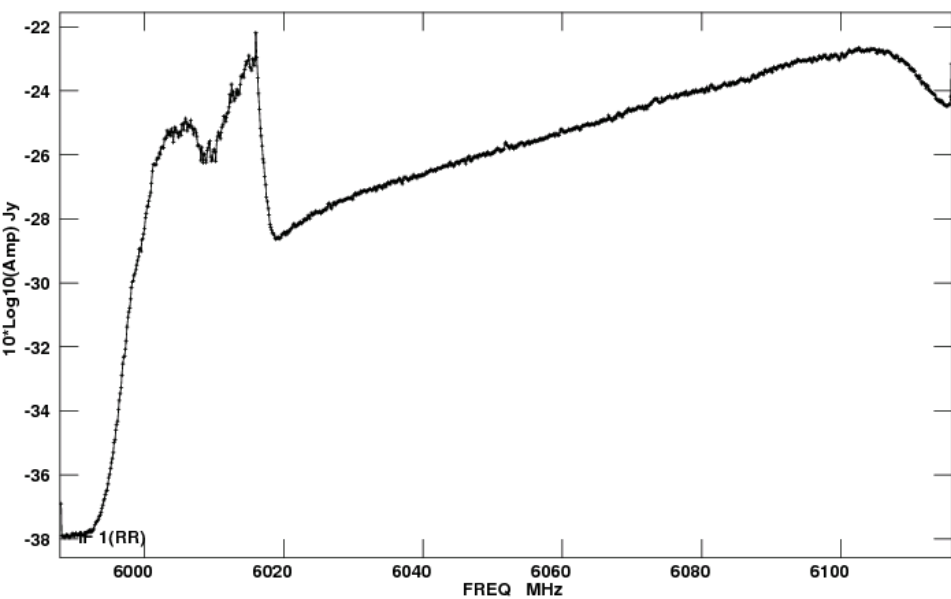
RFI: S-band



Scalar averaged cross-power spectrum Several baselines averaged

Scalar averaged cross-power spectrum Several baselines averaged

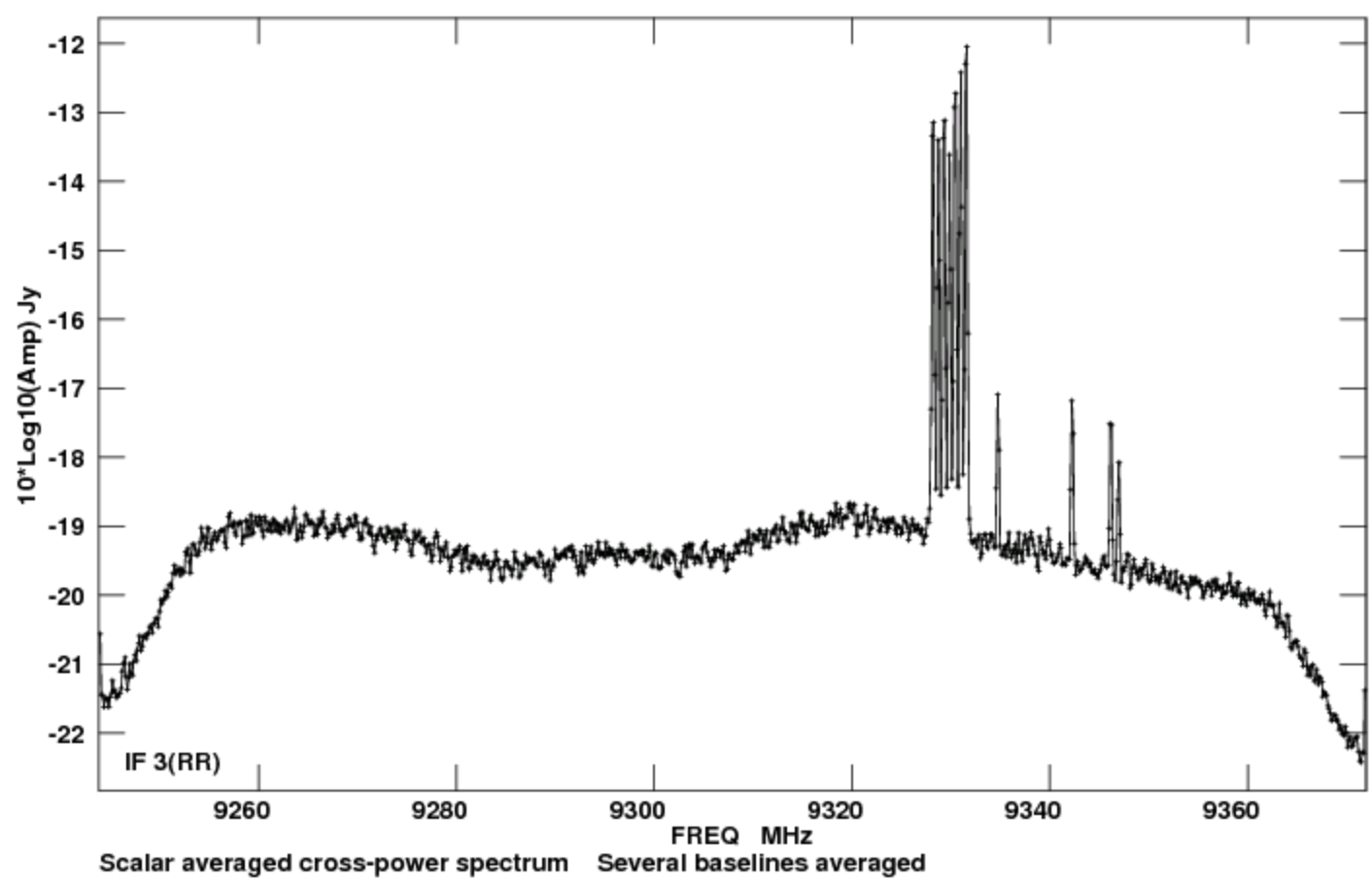
RFI: C-band



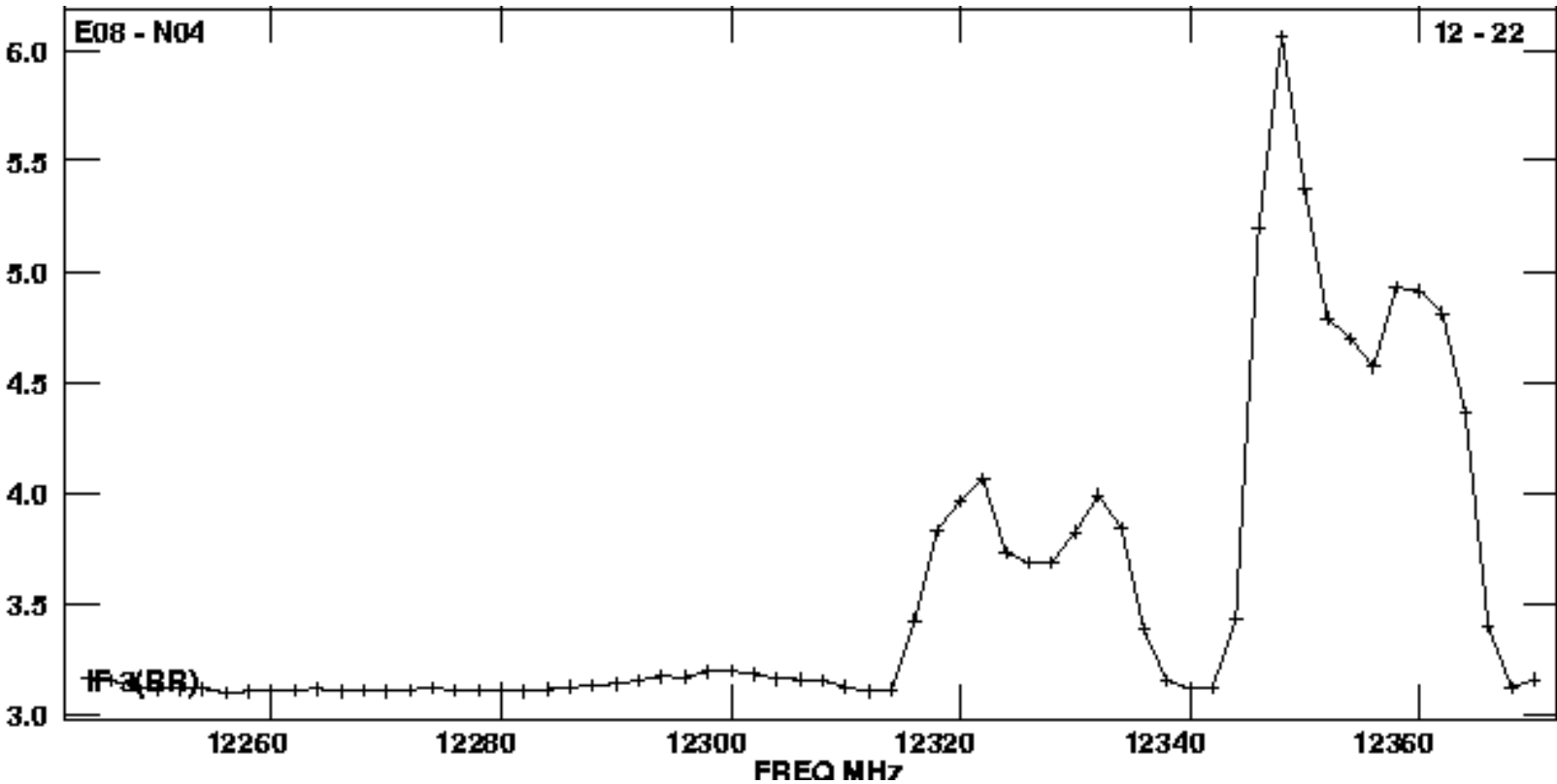
Scalar averaged cross-power spectrum Several baselines averaged

Scalar averaged cross-power spectrum Several baselines averaged

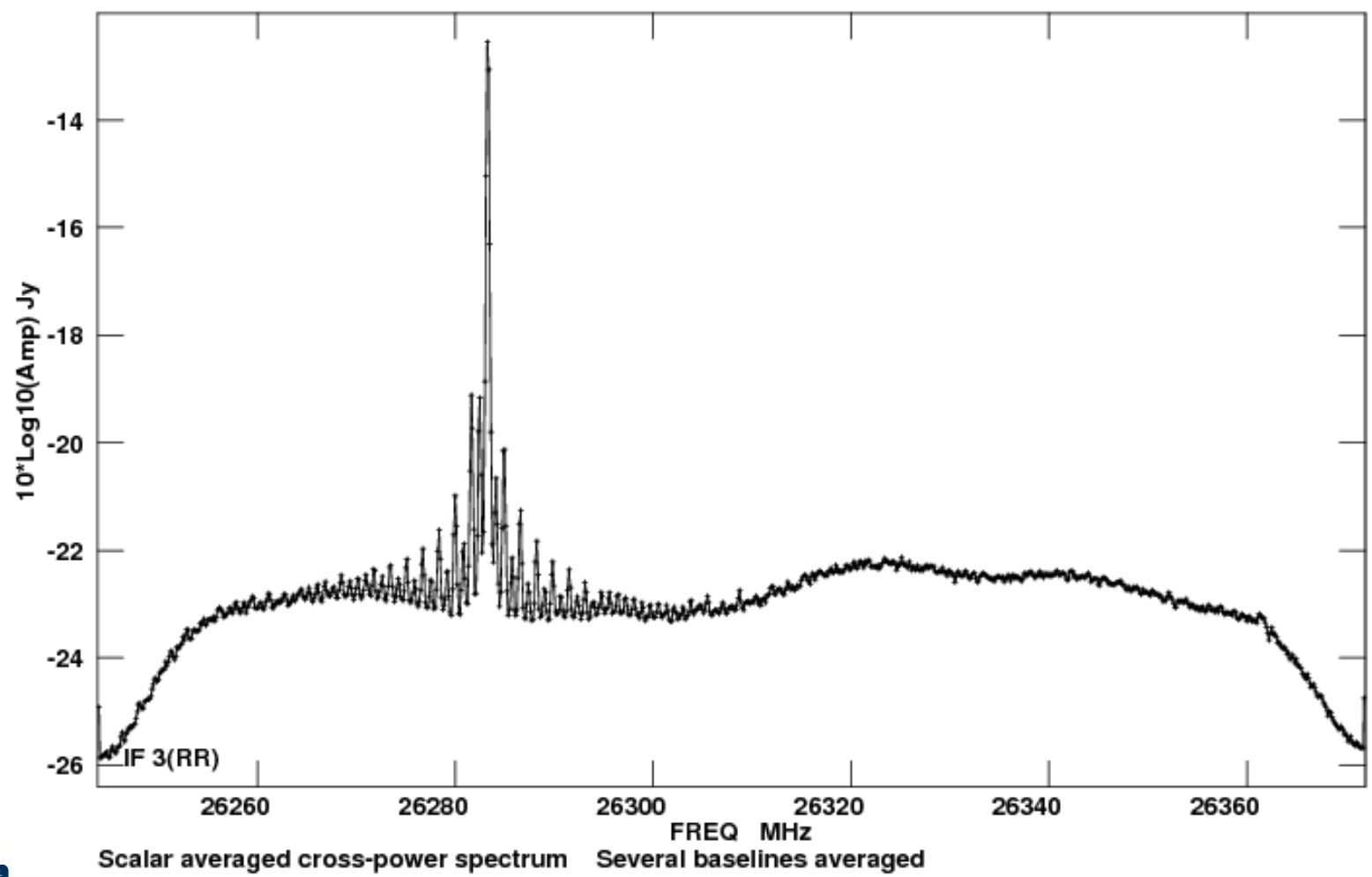
RFI: X-band



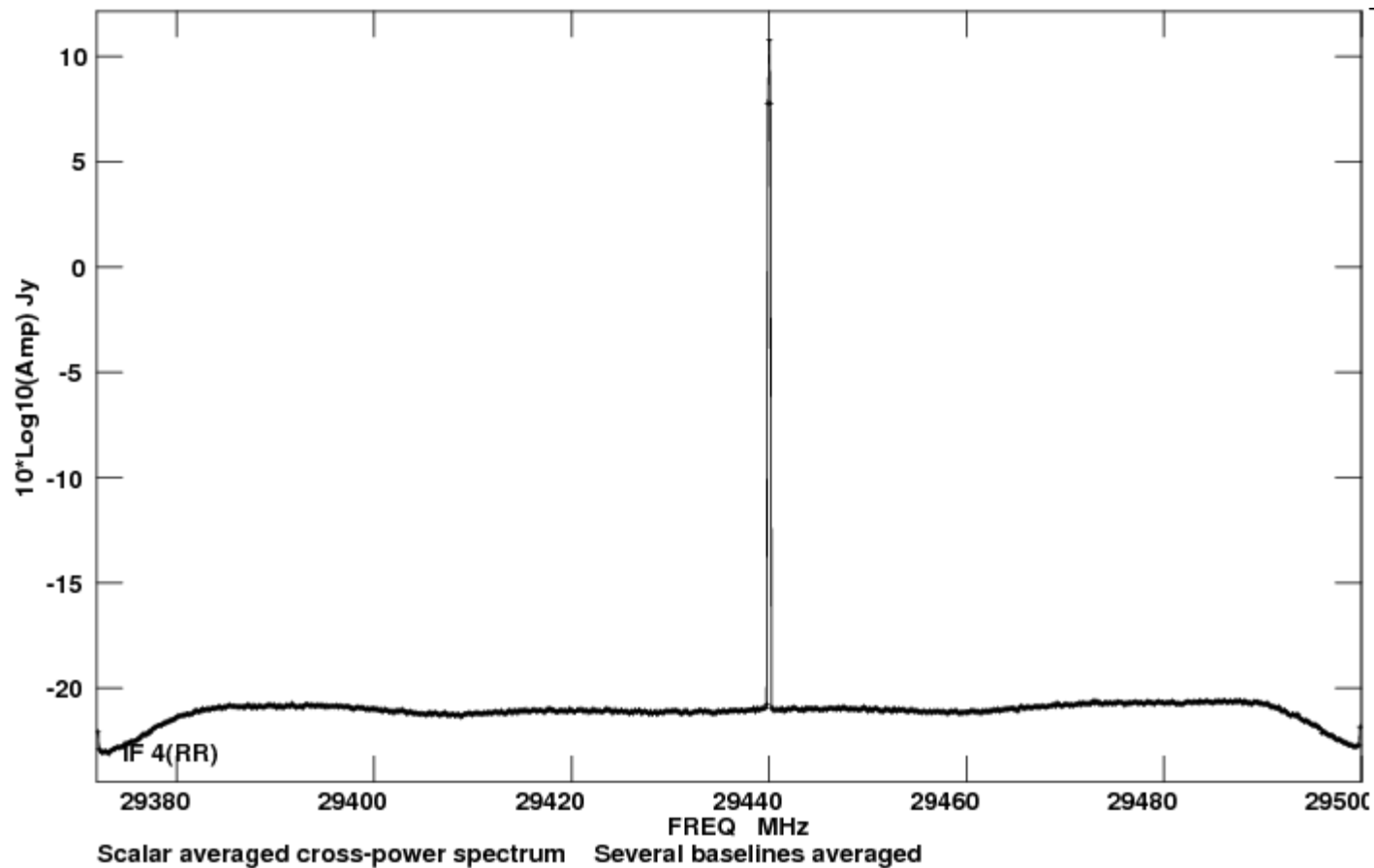
RFI: Ku-band



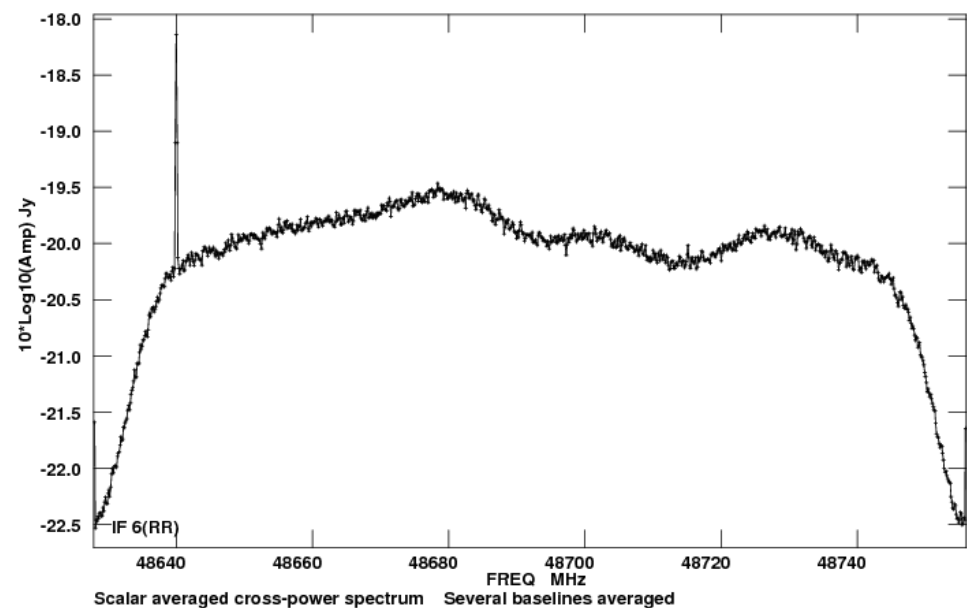
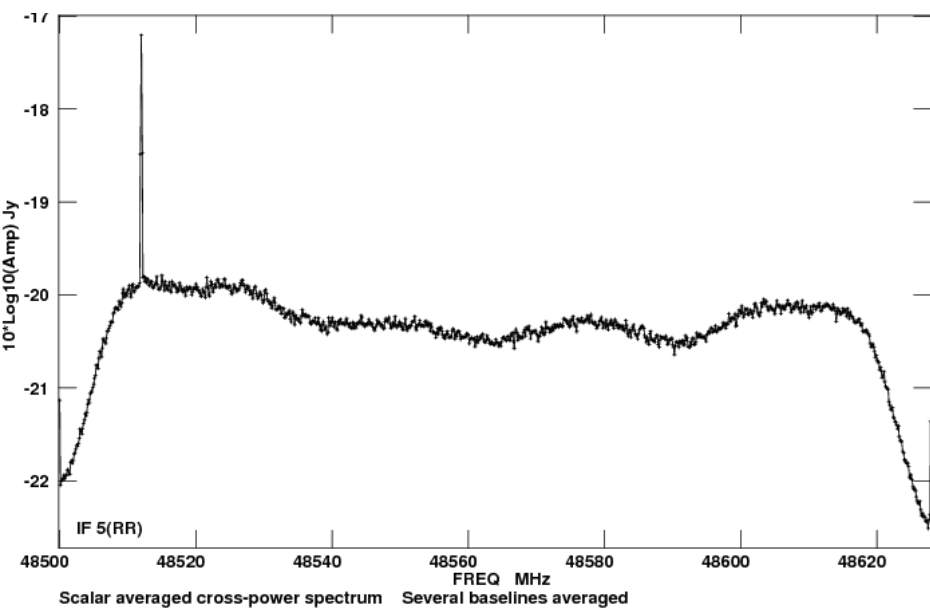
RFI: K-band



RFI: Ka-band



RFI: Q-band



RFI: feedback from observers

- The EVLA has opened the full 1 to 50 GHz frequency range.
- This exposed us to all types of RFI (including many that we didn't know).
- RFI is direction dependent.
- User feedback is critical to support our ongoing RFI identification and monitoring efforts.
- Observers are asked to email nrao-rfi@nrao.edu and provide:
 - Observation/project code
 - Frequency and Time of the observations
 - The characteristics of the RFI signal (e.g., continuous, intermittent)
 - A spectrum



RFI: spectral (Gibbs) ringing

- Strong RFI will introduce disturbing spectral ringing.
- This is a significant problem at the lower frequency bands of the EVLA (L, S, and C).
- Hanning-smoothing should be applied on such data sets before attempting any spectral flagging, or calibration (except for delay calibration; stay tuned).
- In CASA, the task to use is *hanningsmooth*.



EVLA Data Reduction Techniques: II



Emmanuel Momjian

NRAO

Atacama Large Millimeter/submillimeter Array

Expanded Very Large Array

Robert C. Byrd Green Bank Telescope

Very Long Baseline Array



Outline

- The archive tool.
- Loading the data set.
- CASA
- Examining/Flagging the data set.
- Calibration
 - Including high and low frequency considerations.
- Imaging
 - Including spectral line, continuum, wide band, and wide field.
- Image analysis

I

II



Calibration

- Correcting antenna positions
- Delay Calibration
- Hanning-Smoothing (for the lower frequency bands)
- Opacity (for high frequency) and Ionosphere (for low frequency) corrections
- Setting the flux density scale
- Initial Phase only calibration (for high frequency observations)
- Bandpass calibration
- Complex gain (phase, amplitude gain) calibration
- Polarization Calibration
- Setting the flux scale of the secondary calibrators
- Applying the calibration
- Splitting the target source
- Continuum subtraction (spectral line data)



□ The MS structure

- The MS has the following columns:
 - The 'data' column.
 - The 'corrected' column
 - The 'model' column
- When you load your data from the archive, your MS will only have the 'data' column.
- The other two columns can be created by various means.
- The creation of the other two columns → MS tripling in size.



Antenna Positions

- Check the operator's log to see if any antennas were recently moved.
- Obtained the correction values from:
<http://www.vla.nrao.edu/astro/archive/baselines/>
- Use the task *gencal* in CASA to produce a calibration table that includes the antenna position corrections.

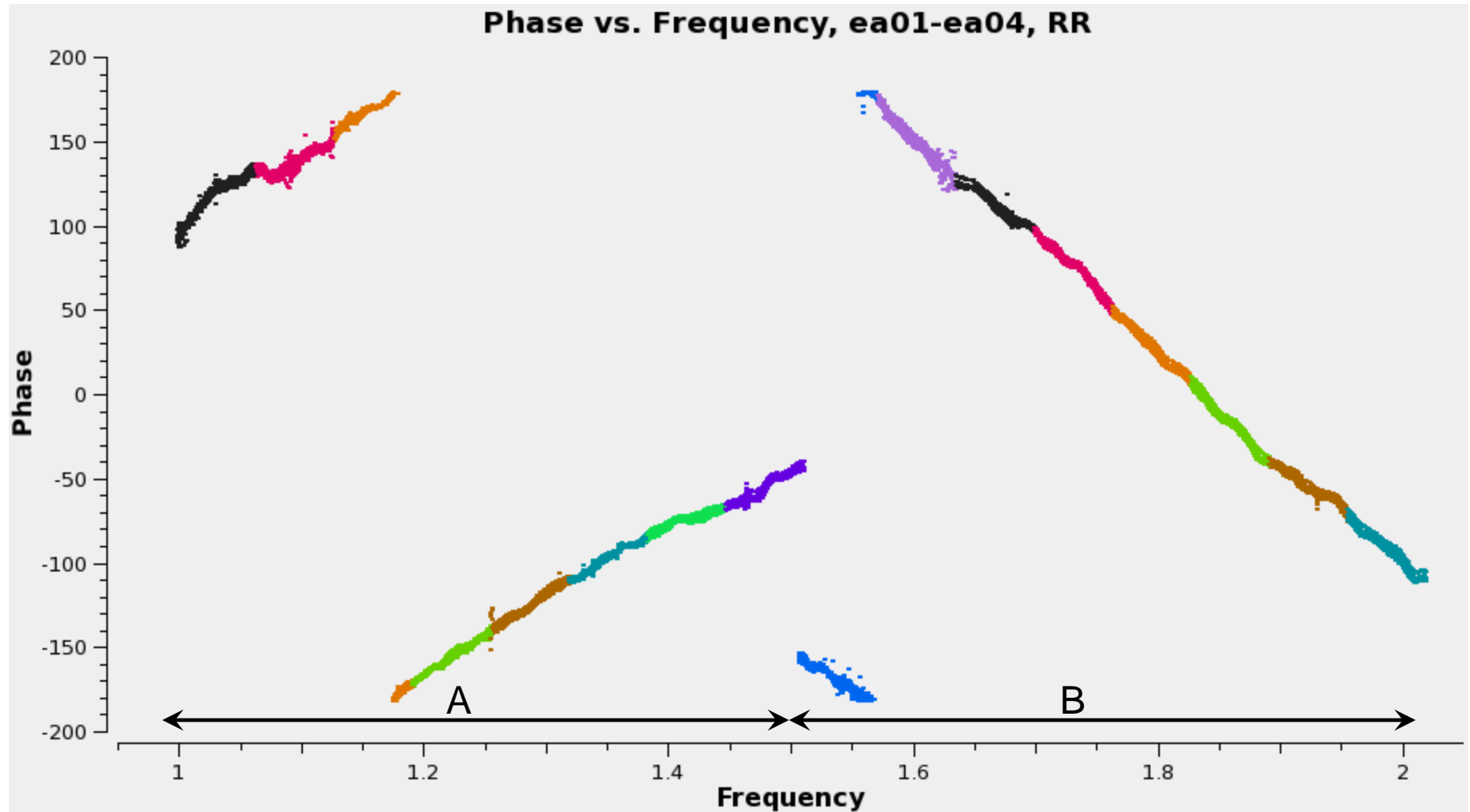


Delay Calibration and Hanning-smoothing:

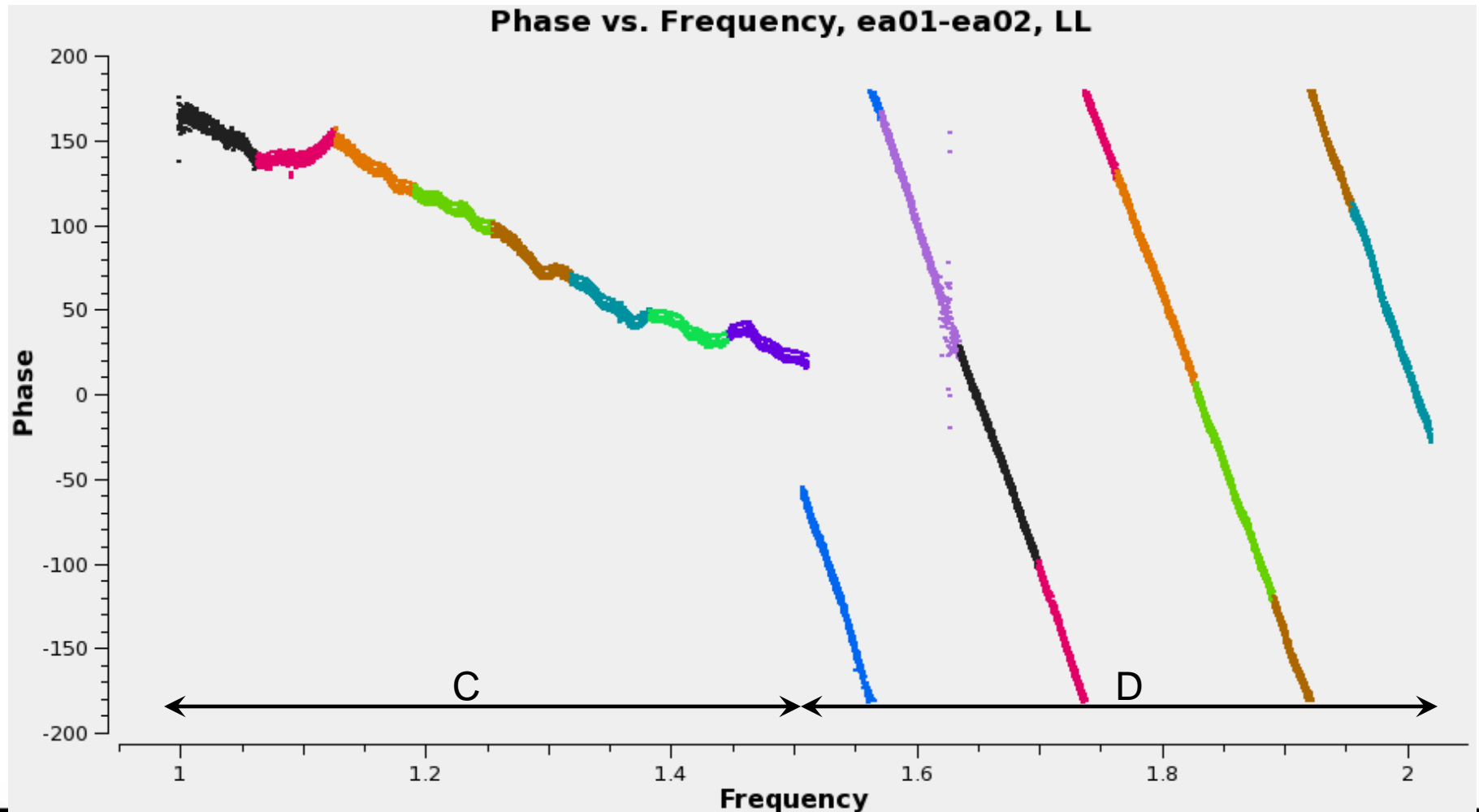
- We recommend performing the delay calibration prior to any spectral flagging and other calibration steps.
- For the lower frequency bands (L, S, C), this would be followed by Hanning-smoothing the data (strong RFI → Gibbs ringing).
- The steps are:
 - Calibrate the delays (*gaincal*)
 - Apply the calibration obtained so far (*applycal*).
 - *Hanningsmooth* the corrected column.
 - *Split* the corrected column.



Delays



Delays



Delay Calibration: *gaincal*

```
vis                =      'MS file name'
caltable           =      'delays.cal'
field              =      '?'
solint             =      '60s'
refant             =      'ea??'
gaintype          =      'K'
gaintable         =      'antenna positions'
```

- Choose 1 min of data on a strong source (through `selectdata` → `timerange`).
- Make sure the `refant` has baselines to all the antennas in the selected time range.
- May need to exclude spw's with significant spectral ringing.
- This is not a Global Fringe Fitting; it solves for antenna based single-band delays.



Applying the Delay Calibration:

- Run *applycal* to apply the delay calibration (and the antenna position corrections).

```
field                = ''
interp              = nearest
gaintable            = delay and antenna position tables
spwmap               = '?'
calwt                = False
```



Hanningsmooth:

- Hanning-smooth the corrected column of the MS using the task *hanningsmooth*

```
datacolumn          =      'corrected'
```

- You can set this task to overwrite the corrected column with the hanning-smoothed version of itself, or make a new MS.



Split:

- Split the hanning-smoothed corrected column into a new MS.

```
vis                =      'input MS'  
outputvis          =      'output MS'  
datacolumn         =      'corrected'
```

- The new MS will only have a data column which is the corrected column of the original MS.



Important Note:

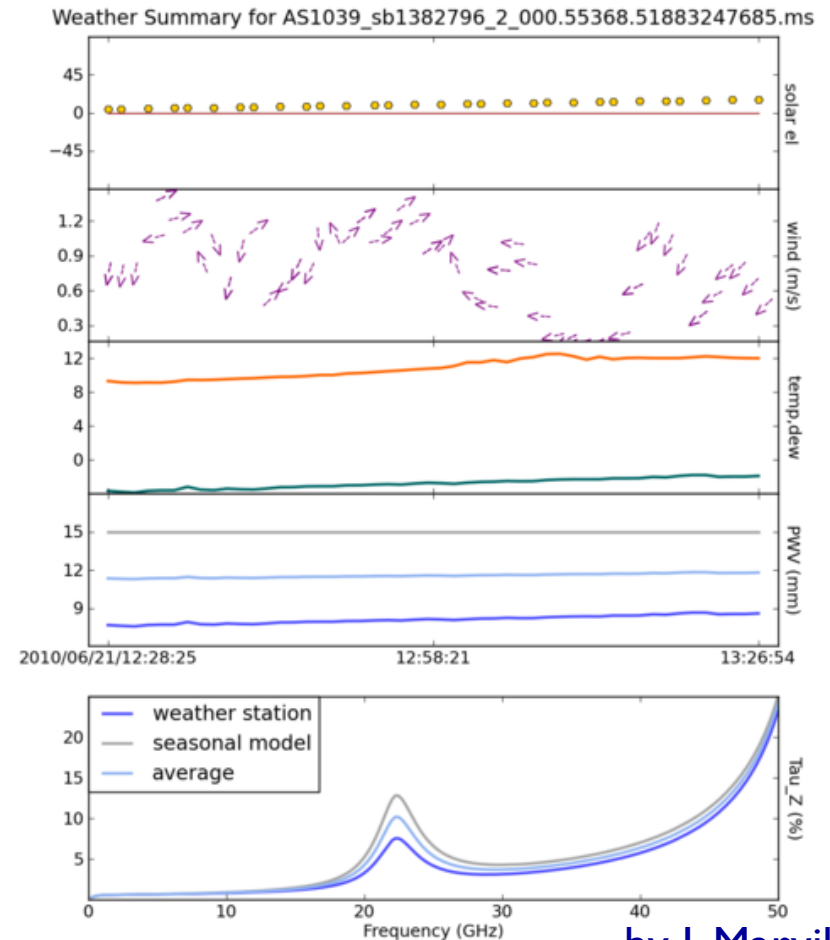
- If Hanning-smoothing is not required
 - No need to run *applycal*, *hanningsmooth* and *split*.
 - Make sure to apply the delay calibration and the antenna position corrections tables on-the-fly in all consequent calibration steps.

Ionosphere Correction

- Needed for lower frequency observations (L and S bands, and sometimes C band).
- Available in AIPS (task *TECOR*; derives corrections for ionospheric Faraday rotation and dispersive delay).
- Will be made available in CASA in the future.
- More details will be covered on Friday by E. Greisen.

Opacity Correction

- Needed for high frequency observations (K, Ka, Q bands).
- A contributed task will calculate the zenith opacities per spw using the weather information contained in the data and seasonal model.
- The values should be used in the *opacity* adverb in all calibration tasks for their on-the-fly application (spw based *opacity* is currently implemented in *stable*).
- Will be used in the EVLA high frequency Spectral Line tutorial.



by J. Marvil



Calibration: *setjy*

Calculates the absolute flux density of a known calibrator, and fills the model column of the MS with its visibilities

```
vis           =      'MS file name'  
field         =      '?'  
spw           =      ''  
modimage      =      '?'  
listmodimages =      False  
scalebychan   =      True  
fluxdensity   =      -1  
standard      =      'Perley-Butler 2010'
```



Calibration: *setjy*

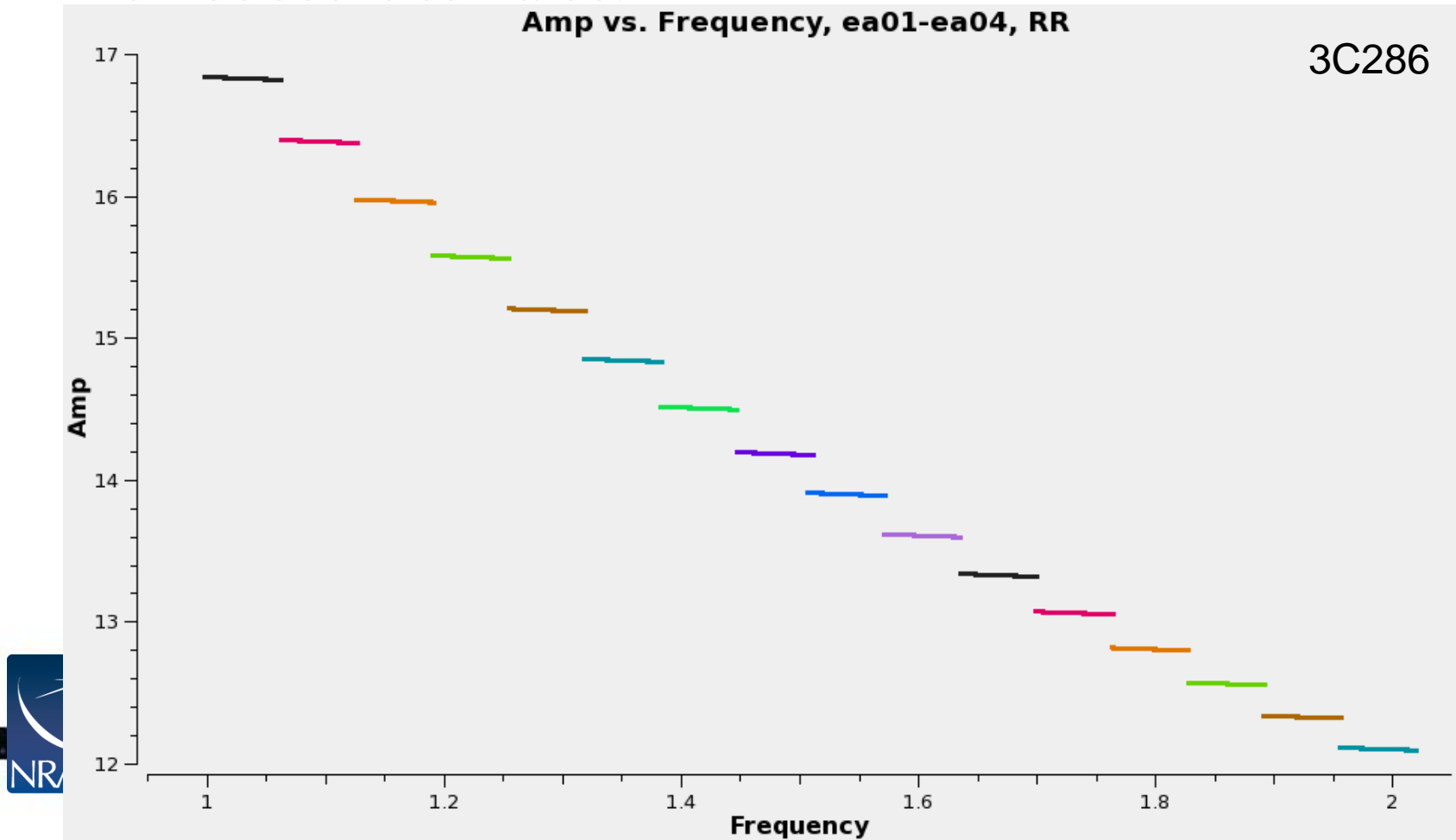
- If `listmodimages = True`, the task will only list the available primary calibrator models (3C138, 3C147, 3C286, 3C48; at L, C, X, U, K, Q bands).
- Models of these sources for the new EVLA bands (e.g., Ka-band) are available at: <https://science.nrao.edu/> → EVLA → Data Processing → Flux Calibrator Models for New EVLA Bands
- These will be added into both AIPS and CASA in the very near future.



Calibration: setjy

The scalebychan parameter

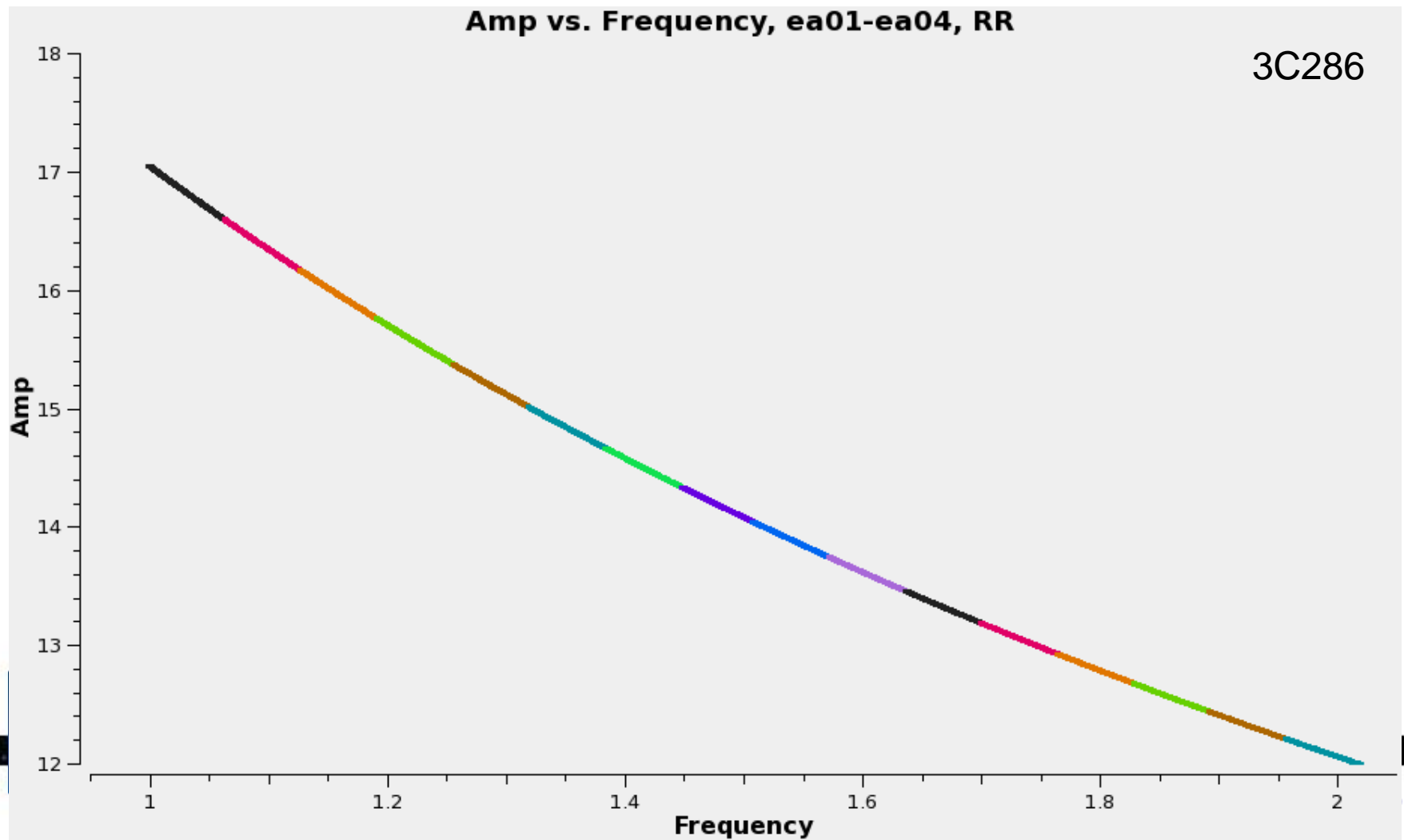
- If `False`: The values will be per spectral window.
- **Do not set it to `False`!**



Calibration: *setjy*

The `scalebychan` parameter

- If `True`: The values will be per spectral channel



Before Bandpass Calibration

- Bandpass calibration is not only needed for spectral-line observations, but also for continuum.
- Before calibrating the bandpass, do phase-only calibration on the bandpass calibrator (to be applied when calibrating the bandpass).
 - Prevents decorrelation when vector averaging.
 - Critical for high frequency observations.

Initial Phase only calibration: *gaincal*

- Run *gaincal* on the bandpass calibrator using:
 - a short solution interval, and
 - a few channels per spw (free of RFI).
- This table should only be used while calibrating the bandpass.
- In *gaincal*, set
 - `caltable` = `'bpphase.gcal'`
 - `calmode` = `'p'`
 - `gaintype` = `'G'`
 - `gaincurve` = `True`
 - `gaintable` = `'?'`
 - `opacity` = `[?,?,?....]`
 - `solint` = `'a short time interval'`



Initial Phase only calibration

Plotting the solutions: *plotcal*

- *plotcal* is a multi-purpose plotter for calibration results
- To plot the phase calibration results:

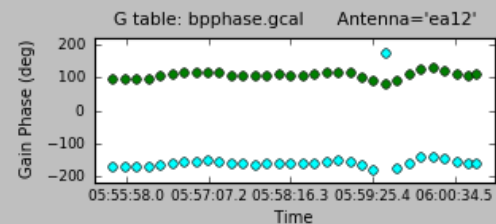
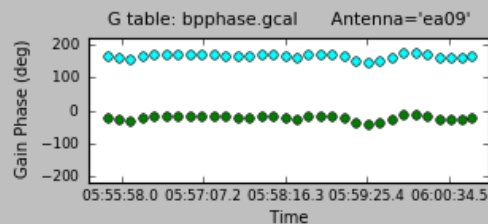
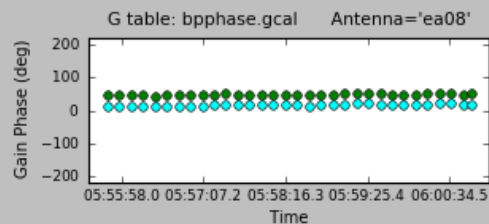
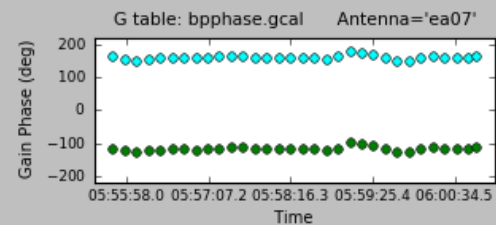
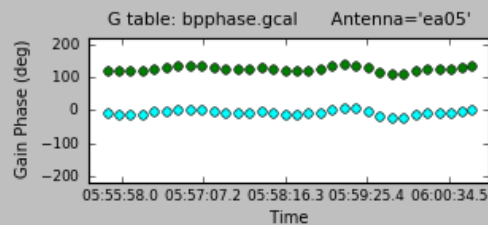
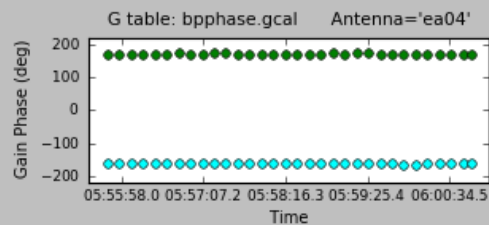
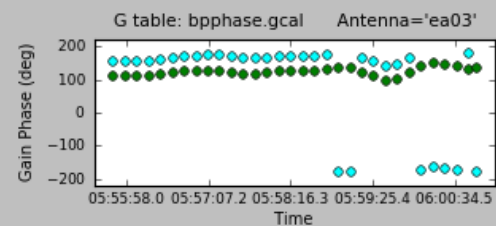
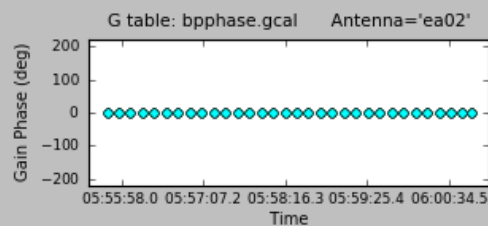
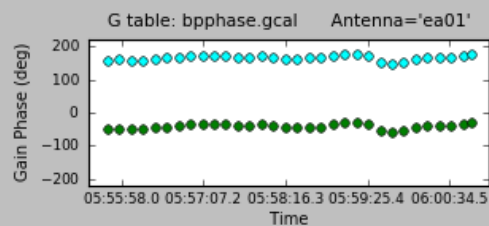
```
caltable      = 'bpphase.gcal'  
xaxis         = 'time'  
yaxis         = 'phase'  
spw           = '1'  
subplot       = 331  
iteration      = 'antenna'  
plotrange     = [0, 0, -200, 200]
```



Initial Phase only calibration

Plotting the solutions: *plotcal*

CASA Plotter <2>

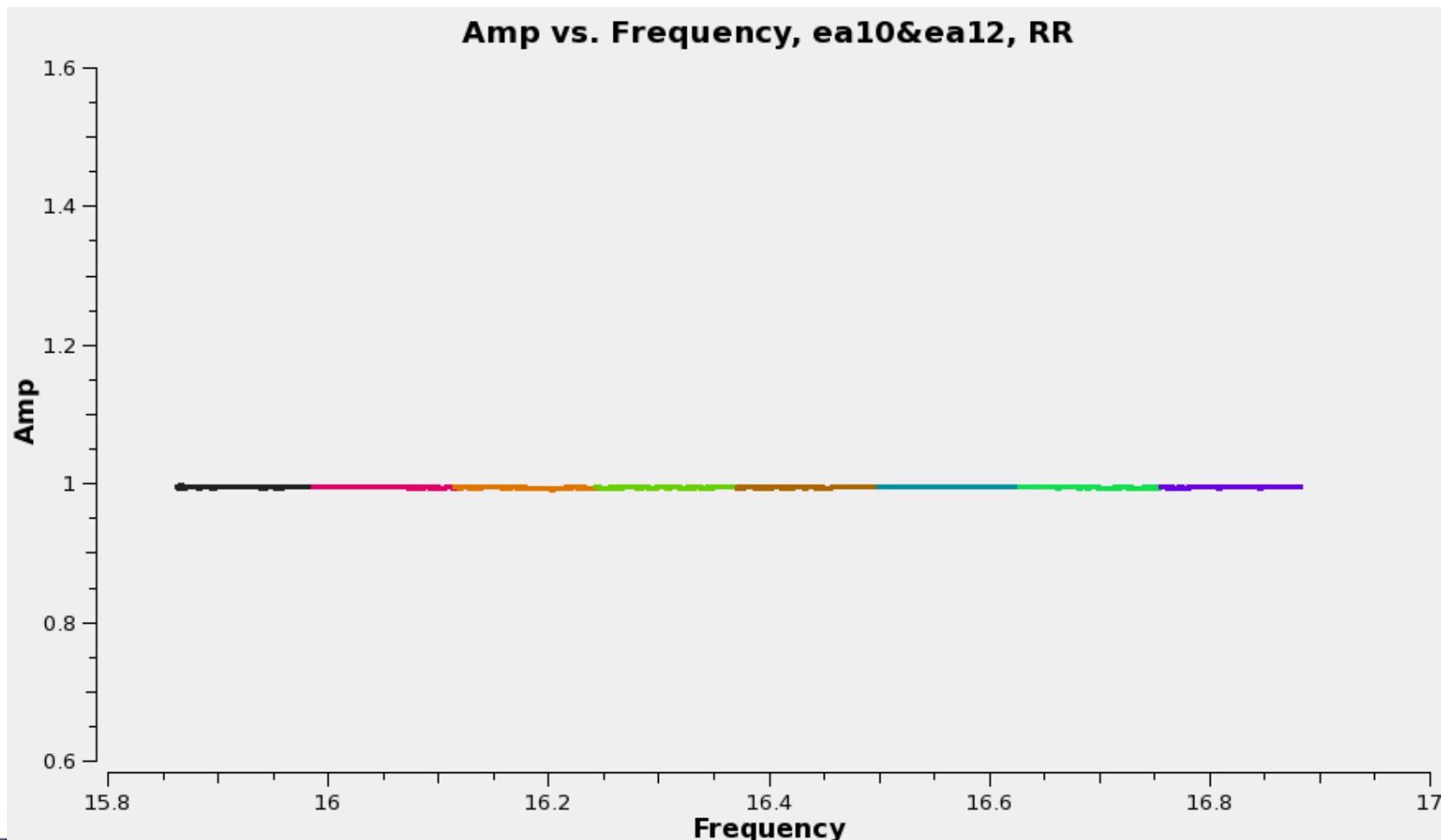


Mark Region Flag Unflag Locate Next Quit



Bandpass Calibration: *bandpass*

- Needed for continuum observations too.



Bandpass Calibration: *bandpass*

```
caltable      =      'bandpass.bcal'  
field         =      '?'  
solint        =      ''  
refant        =      'ea??'  
solnorm       =      False  
bandtype      =      B      or      BPOLY  
      fillgaps =      3      (for B bandtype)  
gaintable     =      various calibration tables  
gainfield     =      fields corresponding to the  
                      above tables
```

If using a source other than the flux calibrator, the spectral index (and the spectral curvature) should be accounted for. For this, use *setjy*.



Bandpass Calibration

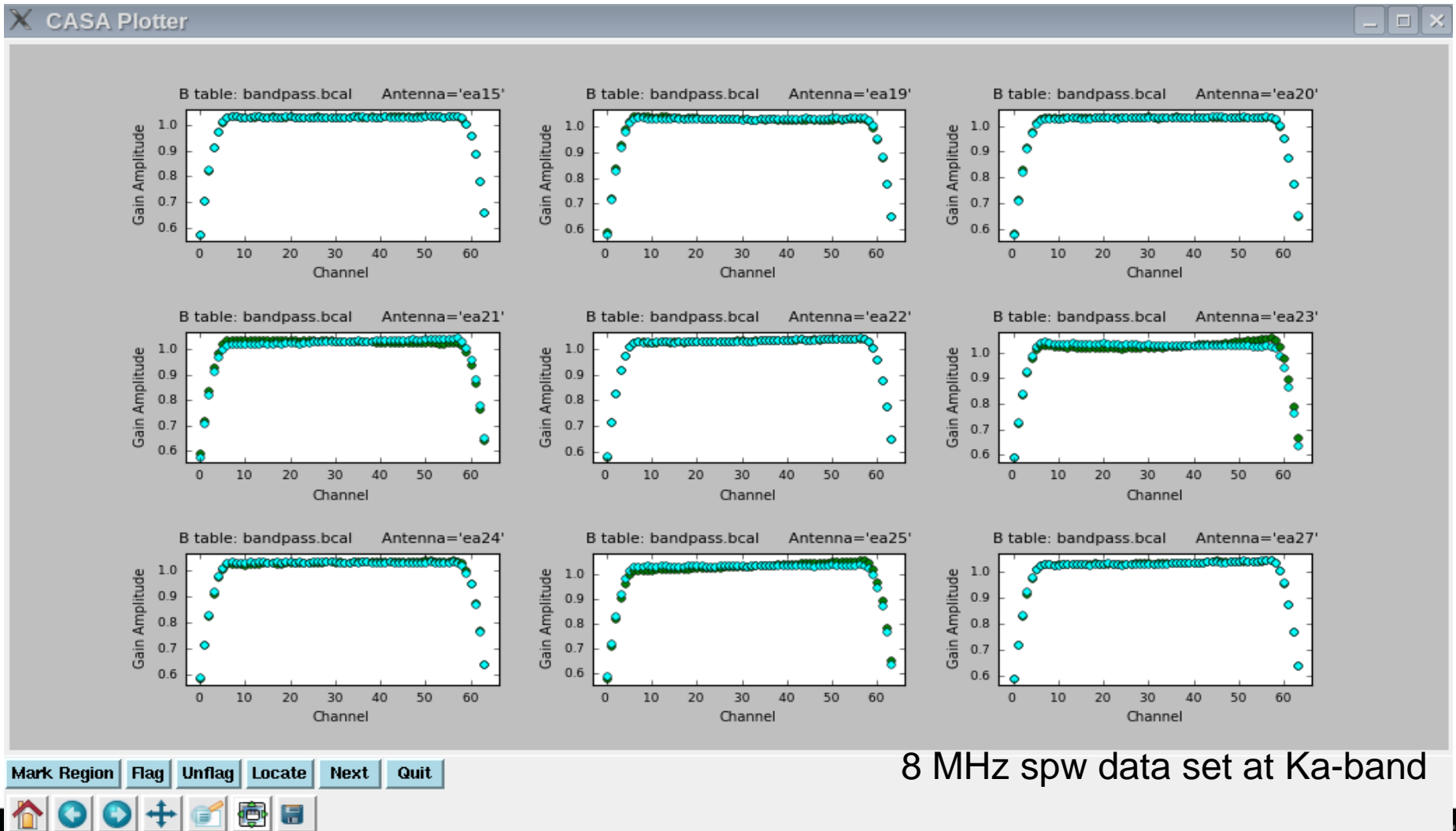
Plotting the solutions: *plotcal*

```
caltable      = 'bandpass.bcal'  
xaxis         = 'chan'  
yaxis         = 'amp'      or 'phase'  
spw           = '1'  
subplot       = 331  
iteration      = 'antenna'
```



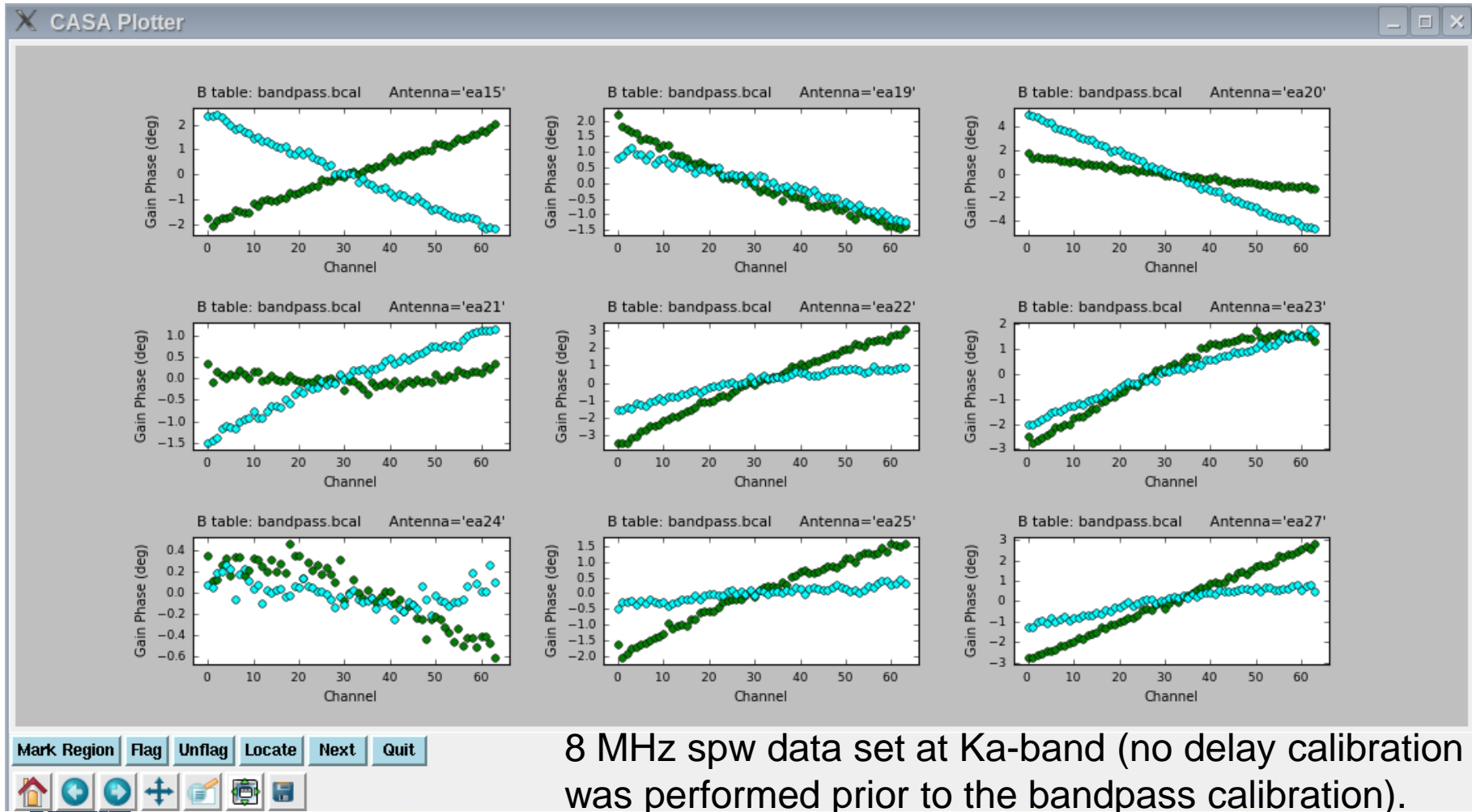
Bandpass Calibration

Plotting the solutions: *plotcal*



Bandpass Calibration

Plotting the solutions: *plotcal*



8 MHz spw data set at Ka-band (no delay calibration was performed prior to the bandpass calibration).

Complex Gain Calibration: *gaincal*

For high frequencies:

- i. Phase only with short solint on all calibrators.
- ii. Phase and amplitude (`calmode = 'ap'`) with a longer solint on all calibrators applying the phases of (i). This will be used to bootstrap the flux density scale of the secondary calibrators.
- iii. Phase only on the phase calibrator with one solution per scan. **This will only be applied to the target source.**

For low frequencies:

- i. Phase and amplitude (`calmode = 'ap'`) on all calibrators with one solution per scan. This will be used to bootstrap the flux density scale of the secondary calibrators.
- ii. If the phases show rapid variations (e.g., due to ionosphere), use the method outlined for high frequencies.



Polarization Calibration: *polcal*

- Solving for the cross-hand delays.
 - Solving for the leakage terms.
 - Solving for the R-L polarization position angle.
-
- For EVLA observations, and particularly for wide bandwidth observations, you should have channel based solutions for the leakage terms and for the R-L polarization position angle.
 - Both CASA and AIPS allow solving for these per spectral channel.



Polarization Calibration: *pre-polcal*

- For polarization calibration, you will typically observe
 - A source to calibrate the leakage terms (this can be a polarized or an unpolarized source), and
 - A source with very well known polarization characteristics to calibrate the polarization angle.
- Before running *polcal*, we recommend calibrating the cross hand delays:
 - Use of one of the polarized sources.
 - Run *gaincal* with `gaintype = 'KCROSS'`
 - Apply the resulting table in consequent steps.



Polarization Calibration: *polcal*

I. Solving for the leakage terms

1. For an unpolarized calibrator:

- Use `poltype = 'Df'` to solve for the leakage terms (D) on per channel (f) basis.

2. For a polarized calibrator:

- Use `poltype = 'Df+QU'` to solve for the leakage terms (D) on per channel (f) basis, and also for the apparent source polarization.
- This requires good parallactic angle coverage.



Polarization Calibration: *polcal*

2. Solving for the R-L polarization position angle

- With the total polarization has been corrected, the R-L phase needs to be calibrated to obtain an accurate polarization position angle.
- In *polcal*, use `poltype = 'Xf'` for a frequency dependent polarization position angle calibration.
- Requires the use of a source with known polarization angle (use *setjy* to set its Q and U values in the model column of the data).
- Visit the web page <http://www.vla.nrao.edu/astro/calib/polar/> for the VLA/EVLA polarization monitoring database.
- The EVLA Continuum Tutorial on 3C391 covers the polarization calibration aspects.



Scale flux density: *fluxscale*

- Bootstraps the flux density scale of the secondary calibrators.
- Uses the gain table that was made with `calmode= 'ap'`

<code>vis</code>	<code>= 'MS file name'</code>
<code>caltable</code>	<code>= 'input ap table'</code>
<code>fluxtable</code>	<code>= 'output ap table'</code>
<code>reference</code>	<code>= 'field # of the flux cal'</code>
- The flux density values will be reported, and the model column of the secondary calibrators will be adjusted accordingly.
- The output calibration table replaces the input (i.e., the input calibration table should be ignored after this stage).



Apply Calibration: *applycal*

field	=	' '
interp	=	nearest or linear
opacity	=	[?, ?, ?, ...]
gaincurve	=	True
gaintable	=	various calibration tables
gainfield	=	fields corresponding to the above tables
parang	=	False (True if polcal was run)
calwt	=	False

- One field at a time, but targets with the same calibrator can be grouped together.
- Use the appropriate tables for each source.
- Make sure to match the gainfield entries with the gaintables.



Examine the calibrated data
(the corrected column)
with *plotms*.

Flag, if needed, and re-calibrate.

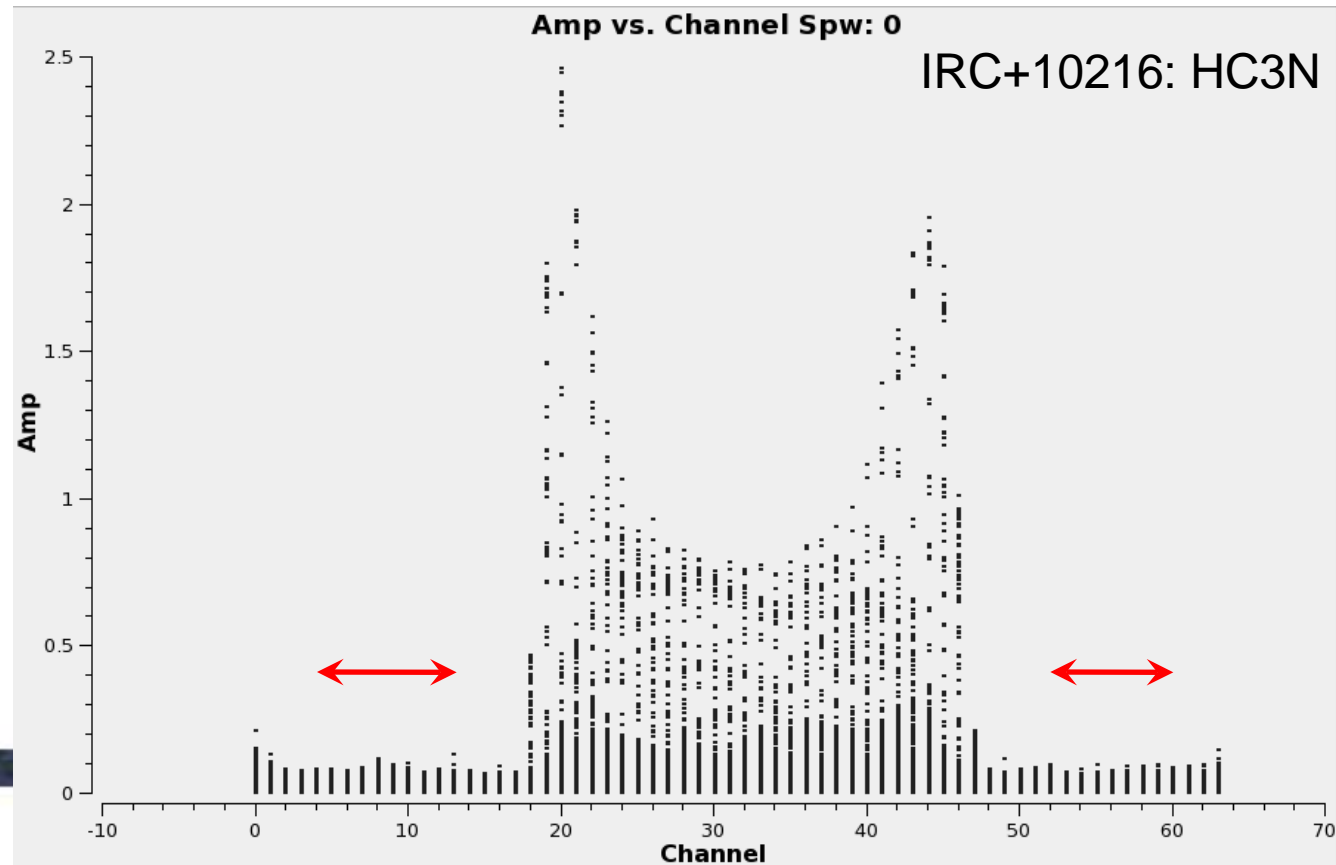
Split the target(s): *split*

- Split the target source(s) using the corrected column.
- Optionally:
 - apply time averaging
 - apply frequency averaging
 - choose spectral windows
 - choose certain antennas
 - choose a certain UV range
 - choose particular scans
 - choose polarization
- The *split*-ed data will occupy the ‘data column’ in the resulting MS.
- Run *clearcal* on the resulting MS to create its own scratch (corrected and model) columns (if self calibration to be done).



Continuum Subtraction: *uvcontsub*

```
vis           = 'MS file name'
fitspw        = '0:4~13;52~60'      can choose multiple spw's
want_cont     = False
```



Doppler Correction: *cvel*

- The EVLA (currently) does not offer Doppler Tracking, but only Doppler setting.
- The line of interest may shift over one or more channels during the observations.
- If adding different observing blocks, one can choose to first Doppler correct (*cvel*) each block, concatenate (*concat*) and then image (*clean*). However, stay tuned.....
- *cvel* should be run if one needs/wants to do self-calibration using the line.
- *cvel* can also be used if several spw's need to be combined (to make a single spw).



Imaging: *clean*

The imaging/cleaning task in CASA provides various options:

- Make 'dirty' image and 'dirty' beam (psf).
- Multi-frequency-continuum images or spectral channel imaging
- Full Stokes imaging
- Mosaicking
- Multi-scale cleaning
- Widefield cleaning
- Interactive clean boxing
- Use starting model (e.g., from single dish)



Imaging: *clean*

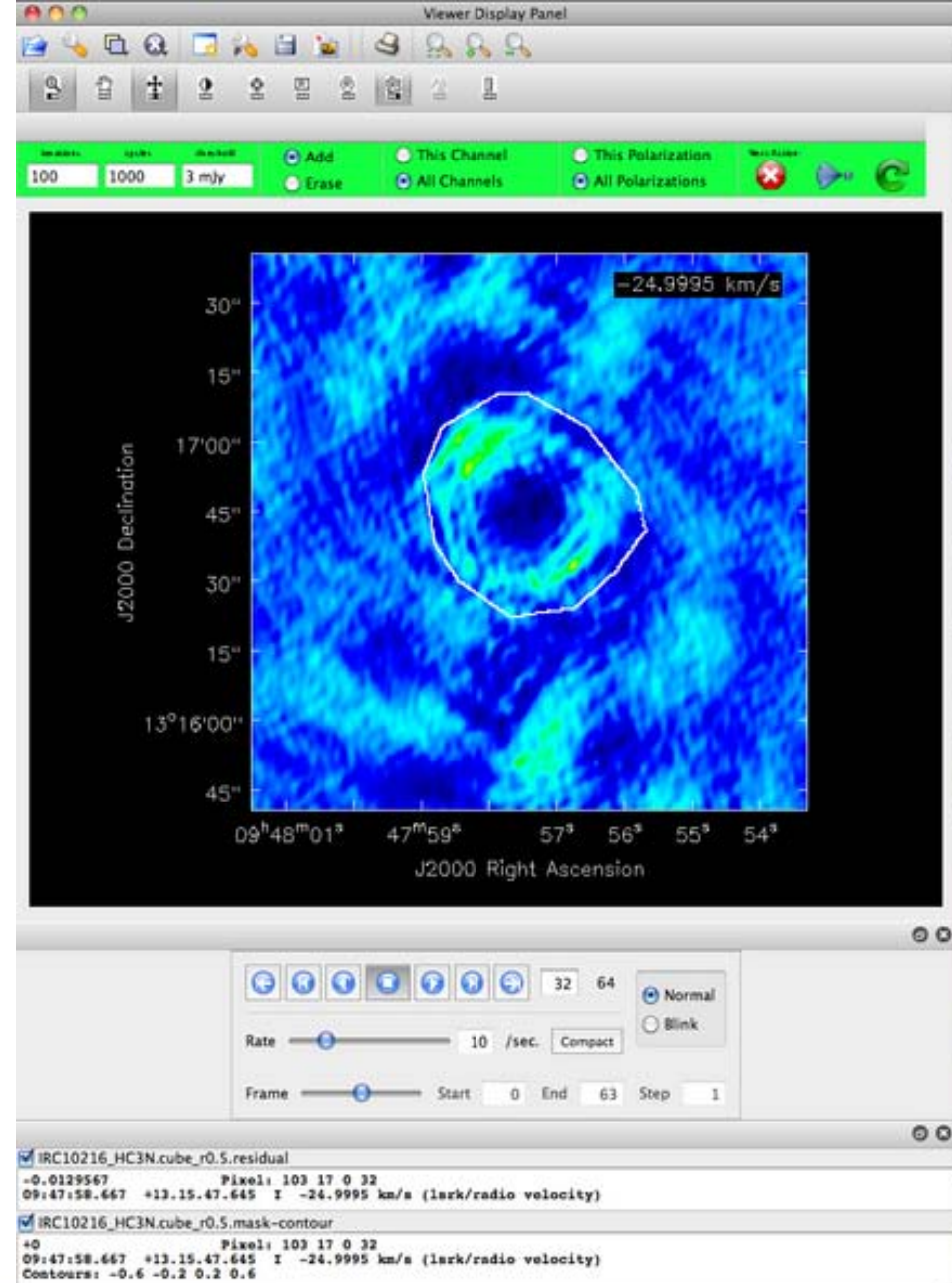
Interactive cleaning:

- Invokes the viewer.
- Cleaning regions (masks) can be made for each spectral channel if needed.
- If no mask is specified, cleaning is not performed (only in interactive mode).

Channel 28 of the HC3N cube of IRC+10216.

The white contour is showing the mask that has been drawn with the polygon tool.

Rectangular or ellipsoidal masks can also be made.



Imaging: *clean*

- If redoing, rename the output (`imagename`).
- Always check the CASA log while imaging.
- Don't do $\wedge c$ while imaging \rightarrow it might disturb your UV data.
- Can use mask files from previous clean iterations.
- If dirty image is desired, set `niter = 0`.
- If self-calibration to be performed, set
`calready = True`

This will create the scratch columns and will write the model column using the clean components.



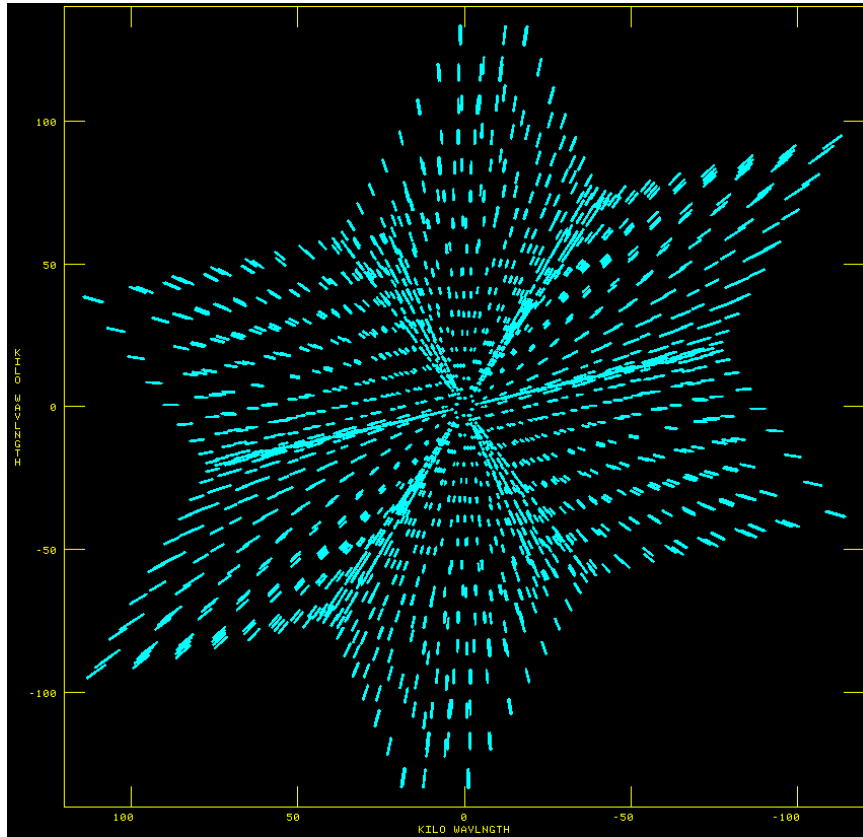
Spectral Line Imaging: *clean*

- Allows for imaging in the following modes:
 - Channel
 - Frequency
 - Velocity
- If the data are not Doppler corrected (*cvel*-ed), *clean* can perform the correction on the fly with the velocity (or frequency) mode.
- *clean* can also image multiple MS files, Doppler-correcting them on-the fly. This results in a single (concatenated) image cube.

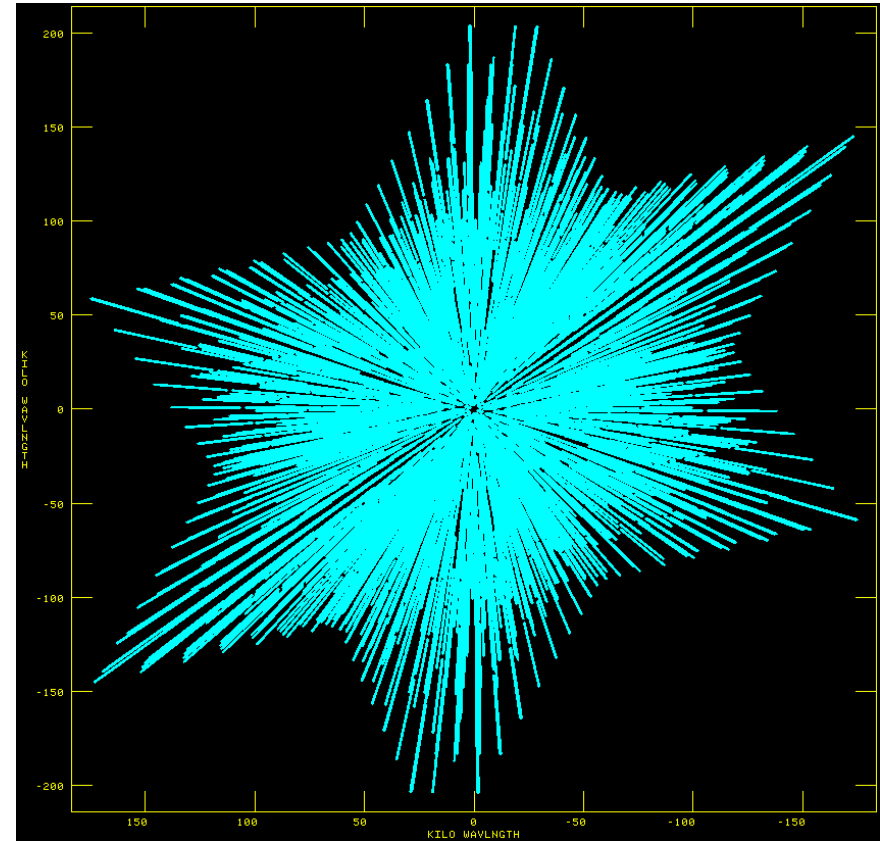


Continuum Imaging: clean

Wide-band narrow-field imaging



1 x 64 MHz spw



16 x 64 MHz spw

Continuum Imaging: clean

Wide-band narrow-field imaging

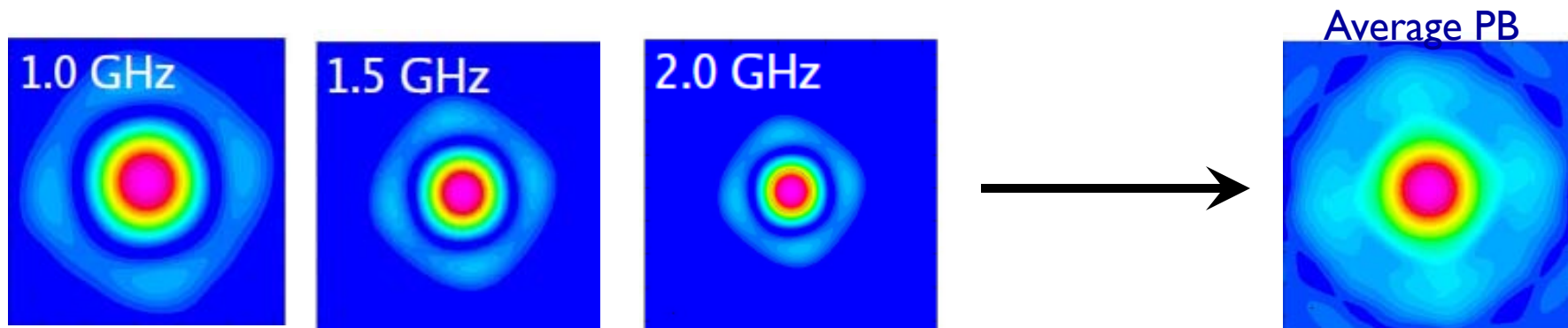
- Wide bandwidths:
 - Better UV coverage → cleaner dirty beam → better image fidelity.
 - More data → better SNR.
- In *clean*, `mode = 'mfs'` ; multi-frequency synthesis.
 - Combines all channels during imaging.
 - With `nterms=2`, get both average intensity and spectral slope image (intensity x spectral index). It also gives a spectral index image.
- If imaging sources that have complicated spatial structure, also use the parameter `multiscale` in *clean* => MS-MFS.
- This subject will be covered in detail on Friday by U. Rau.



Continuum Imaging: *clean*

Wide-band wide-field imaging

- Wide field imaging is required because:
 - The EVLA provides wide bandwidths, which in turn
 - greatly improves the continuum sensitivity, and
 - makes it sensitive for emission from a larger area.



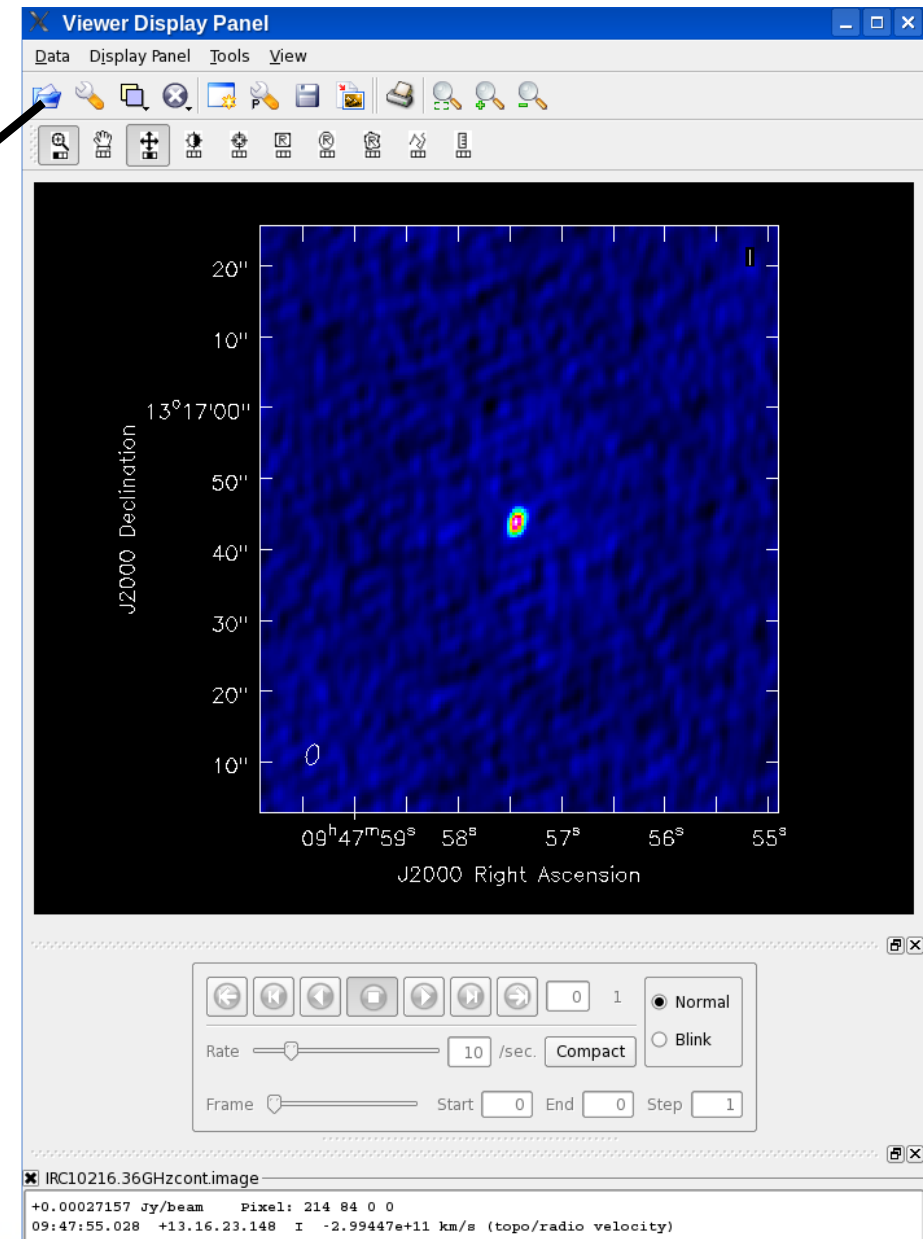
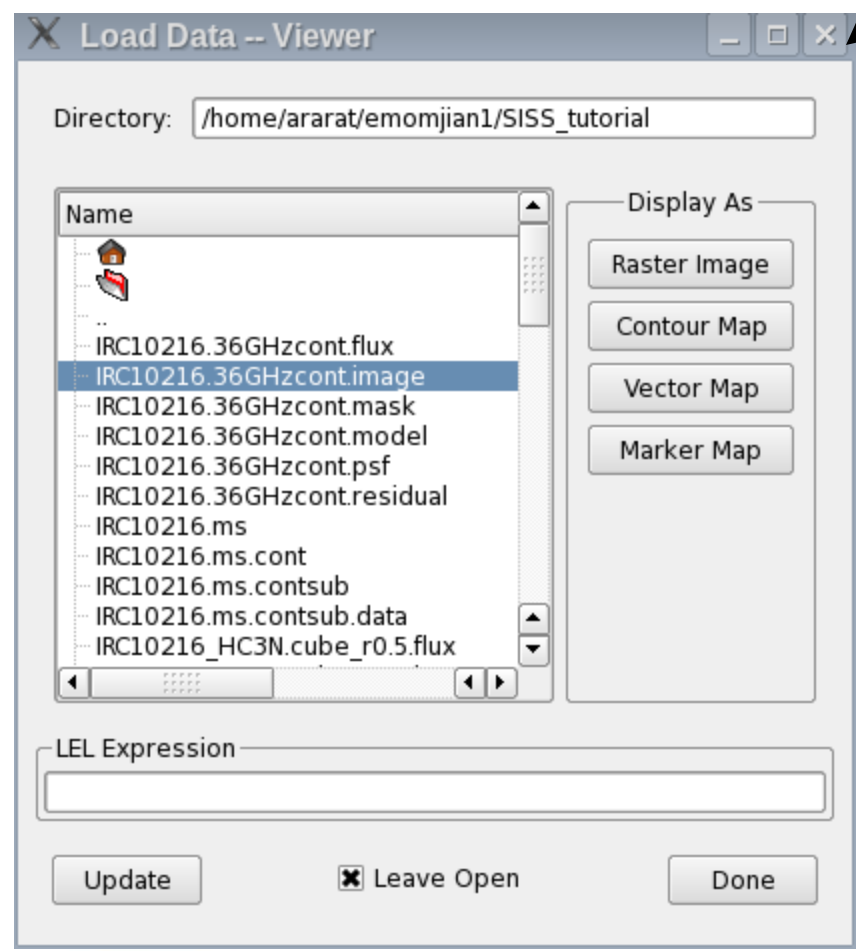
Continuum Imaging: *clean*

Wide-band wide-field imaging

- Set `gridmode = 'widefield'` in *clean*.
- Applies corrections for non-coplanar effects during imaging by using:
 - The WV-projection algorithm, and/or
 - Multi-faceting
- The tutorial on imaging the SNR G55.7+3.4 is about wide-band wide-field imaging.
- This subject will be covered in detail on Friday by S. Bhatnagar.



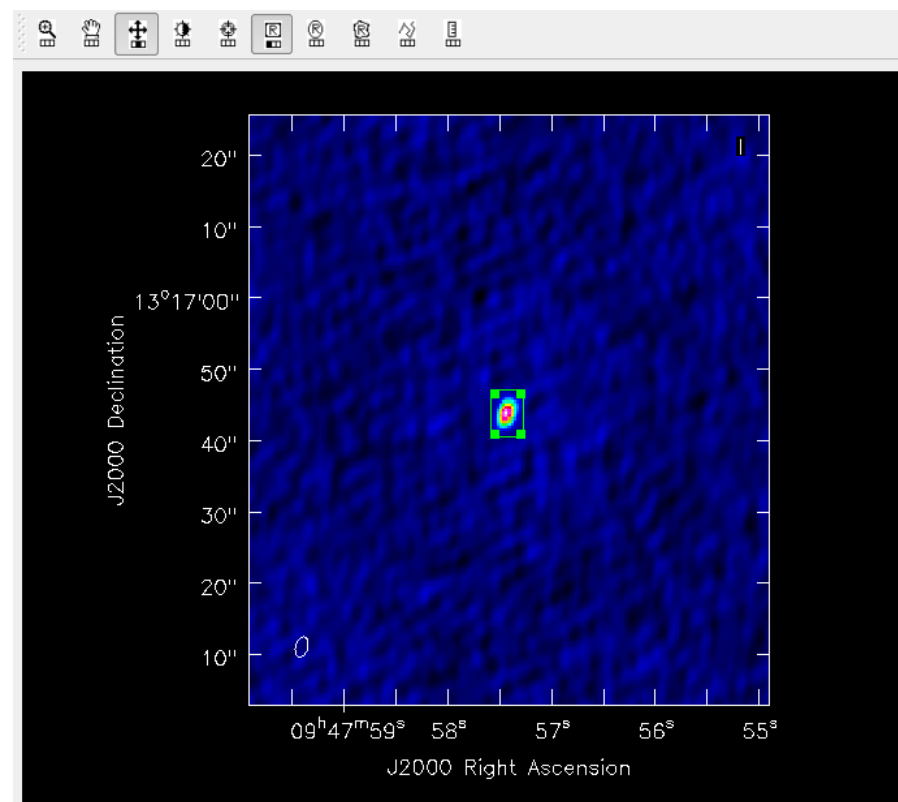
Examine Images: viewer



Examine Images: *viewer*

Obtain statistics by selecting a region and double-clicking:

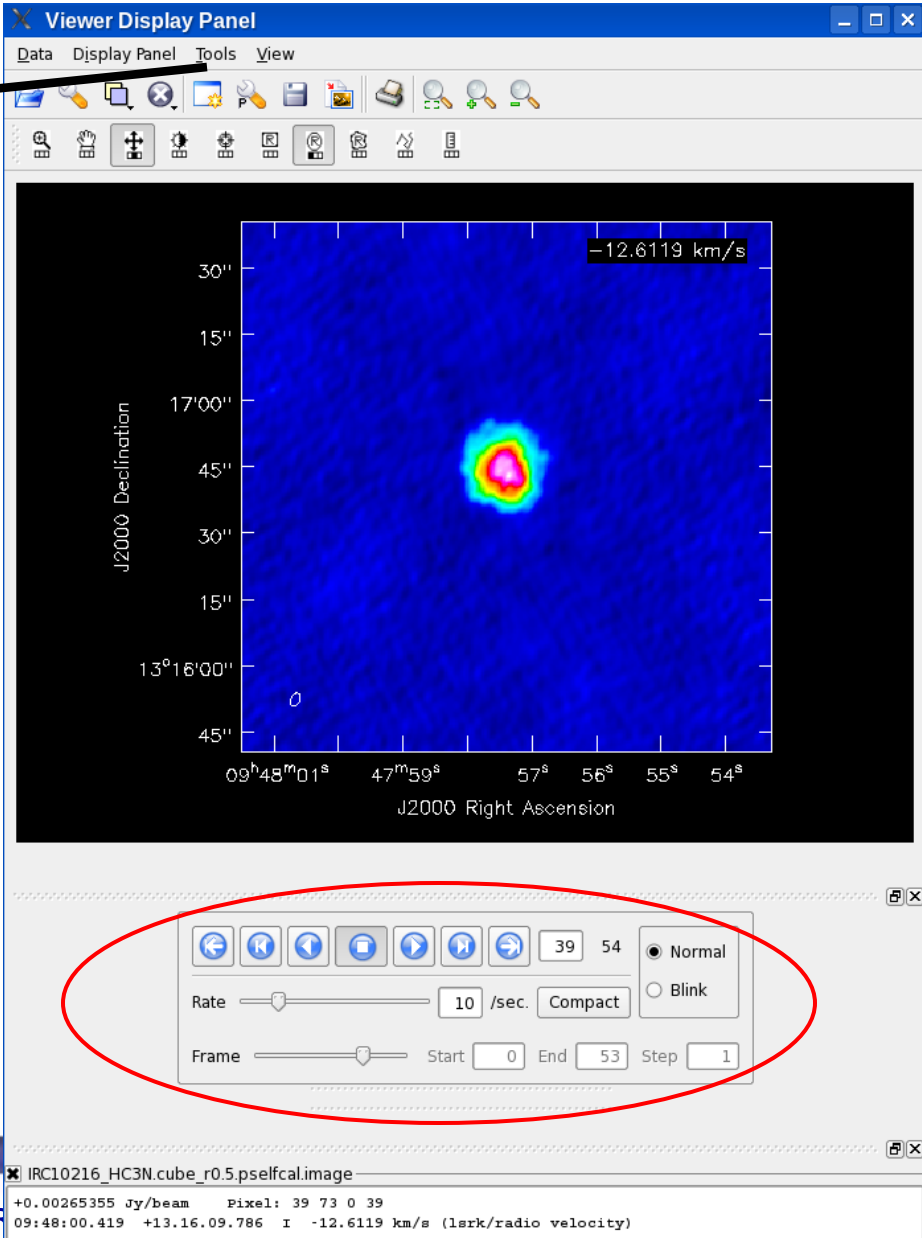
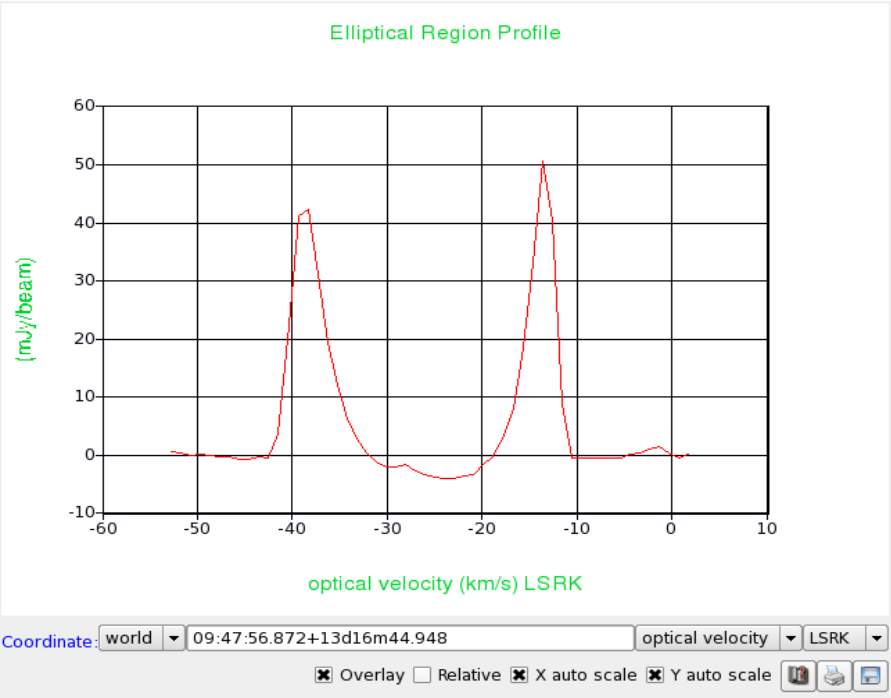
Npts	Sum	Flux (Jy)	Mean	Rms	Std dev	Minimum	Maximum
204	4.282397e-01	1.215614e-02	2.099214e-03	3.196456e-03	2.416455e-03	7.724831e-05	1.029828e-02



Examine Image cubes: viewer

select Spectral Profile

choose a point or a region on the image



Continuum subtraction in the image plane:

imcontsub

- Alternative to uvcontsub

```
imagename      = 'an image cube, line+continuum'
linefile       = '?'
contfile       = '?'
fitorder       = 0
region         = 'region file'      or use
box            = 'blc_x, blc_y, trc_x, trc_y'
chans          = 'x1~y1;x2~y2'
stokes         = 'I'
```



Moment Maps: *immoments*

```
imagename      = 'Input image-cube name'
moments        =          [0]      or [0,1] etc...
axis           = 'spectral'
region         = ''
box            = ''
chans          = '11~40'
stokes         = 'I'
includepix     = [x,y]
excludepix     = [x,y]
```



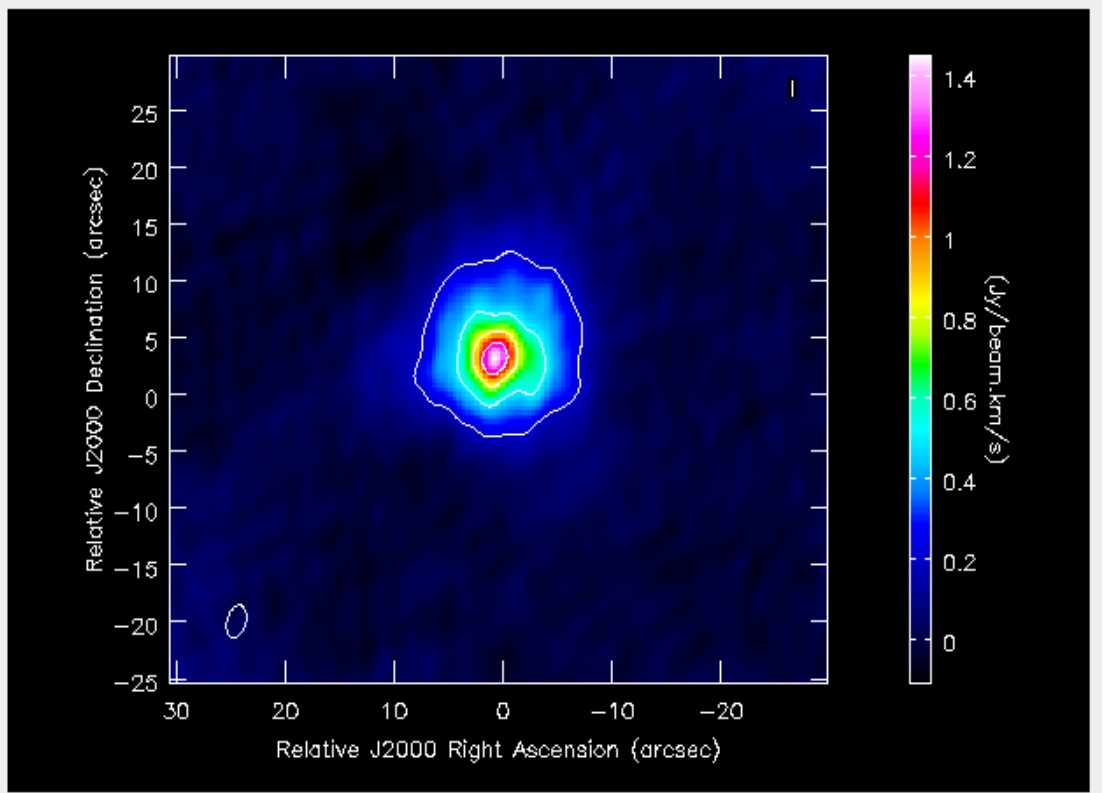
Moment Maps: *immoments*

- moments=-1 - mean value of the spectrum
- moments=0 - integrated value of the spectrum
- moments=1 - intensity weighted coordinate; traditionally used to get 'velocity fields'
- moments=2 - intensity weighted dispersion of the coordinate; traditionally used to get "velocity dispersion"
- moments=3 - median of I
- moments=4 - median coordinate
- moments=5 - standard deviation about the mean of the spectrum
- moments=6 - root mean square of the spectrum
- moments=7 - absolute mean deviation of the spectrum
- moments=8 - maximum value of the spectrum
- moments=9 - coordinate of the maximum value of the spectrum
- moments=10 - minimum value of the spectrum
- moments=11 - coordinate of the minimum value of the spectrum



Moment Maps: *immoments*

IRC+10216 SiS
Total intensity:
Moment 0



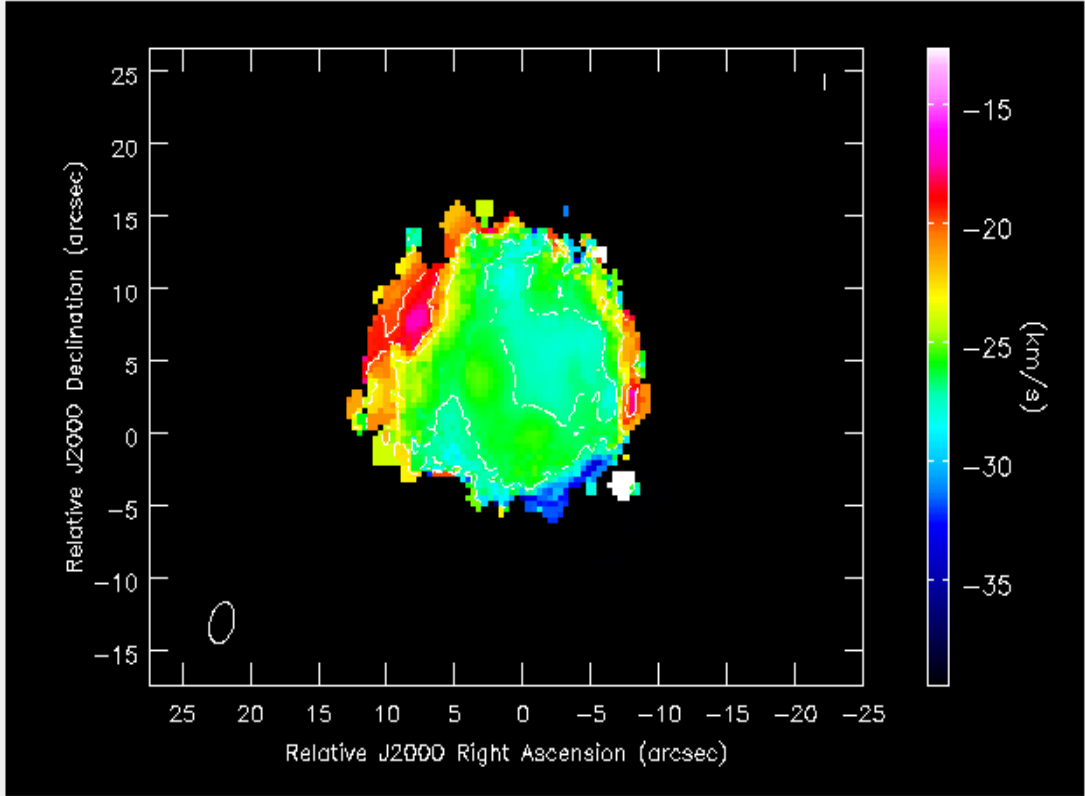
```
IRC10216_SiS.cube_r0.5.image.mom0
-0.0156549 Jy/beam.km/s      Pixel: 167 221 0 0
09:47:56.918 +13.17.09.012 I -41.4861 km/s (lsrk/radio velocity)

IRC10216_SiS.cube_r0.5.image.mom0-contour
-0.0156549 Jy/beam.km/s      Pixel: 167 221 0 0
09:47:56.918 +13.17.09.012 I -41.4861 km/s (lsrk/radio velocity)
contours: 0.2032 0.5154 0.8276 1.14
```



Moment Maps: *immoments*

IRC+10216 SiS
Velocity field:
Moment 1



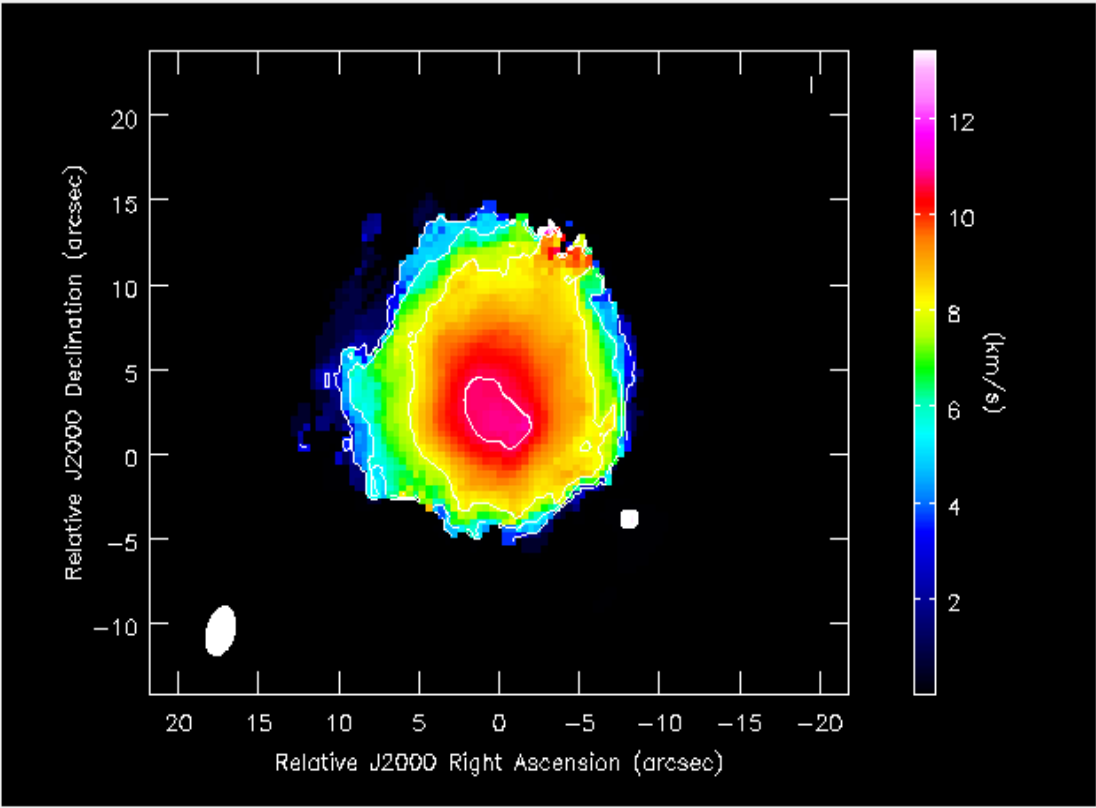
```
IRC10216_SiS.cube_r0.5.image.mom1
masked Pixel: 191 203 0 0
09:47:56.259 +13.17.01.872 I -41.4861 km/s (lsrk/radio velocity)

IRC10216_SiS.cube_r0.5.image.mom1-contour
masked Pixel: 191 203 0 0
09:47:56.259 +13.17.01.872 I -41.4861 km/s (lsrk/radio velocity)
Contours: -26.8 -23.2 -19.7 -16.1
```



Moment Maps: *immoments*

IRC+10216 SiS
Velocity dispersion:
Moment 2



```
IRC10216_SiS.cube_r0.5.image.mom2
masked Pixel: 193 207 0 0
09:47:56.199 +13.17.03.574 I -41.4861 km/s (lsrk/radio velocity)

IRC10216_SiS.cube_r0.5.image.mom2-contour
masked Pixel: 193 207 0 0
09:47:56.199 +13.17.03.574 I -41.4861 km/s (lsrk/radio velocity)
contours: 2.662 5.324 7.986 10.65
```



Image analysis

- *specfit*: to fit 1-dimensional gaussians and/or polynomial models to an image or image region.
- *imfit*: fit one or more elliptical Gaussian components on an image region(s).
- Contributed scripts can be used (can be submitted by you).
- Contributed scripts are currently available at:
<http://casaguides.nrao.edu/> → Data Reduction Guides
→ EVLA Guides → Contributed EVLA CASA Scripts and Tasks



The End

